



# ANNUAL REPORT 2014-15



## National Institute of Solar Energy

(An Autonomous Institute of Ministry of New and Renewable Energy)

Gurgaon-Faridabad Road, Gwalpahari, Gurgaon - 122003 (Haryana)  
[www.nise.res.in](http://www.nise.res.in)

National Institute of Solar Energy



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A horizontal strip at the bottom of the page contains four small, square images. From left to right: a close-up of a solar panel's surface, a solar tower with a heliostat, a large solar panel array, and a close-up of a solar panel's electrical connections.

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## OVERVIEW

National Institute of Solar Energy was set up against the nucleus of Solar Energy Centre, as an autonomous Institute of Ministry of New and Renewable Energy in September, 2013 with the mandate to function as National Research Organization for undertaking and/or sponsoring Research & Development Projects on various aspects of Solar Energy Technologies. The Institute is to act as an Apex Organization for initiating and coordinating the R&D in the field of Solar Energy related areas. The Institute is to assist the Ministry in implementing the objectives of Jawaharlal Nehru National Solar Mission through appropriate mechanisms evolving S&T Programmes and projects, managing special projects and coordinating with all relevant stakeholder agencies in the pursuit of the assigned objectives.

The Institute is involved in the Solar Resource Assessment, Mapping, Technology Forecasting, Research and Development, Interactive Research, Testing/Standardization and Training, Skill Development of Solar Energy Systems and Technologies. The Institute is also working as an effective interface between the Government and institutions, industry & user organizations for development, promotion and widespread utilization of solar energy in the country. It is maintaining a data bank for use by all stake holders including industry and other Institutions. 115 Solar Radiation Resource Assessment Station (SRRA) have been set up in 28 States and 3 Union Territories in the country by the Ministry of New and Renewable Energy. This resource facility houses no. of high quality solar radiation sensors measuring various parameters with their traceability to World Radiometric Reference (WRR) and meteorological sensors measuring various meteorological parameters having their traceability to World metrological organization (WMO). These stations need calibrations for the accuracy of solar radiation and other meteorological data collected through various instruments. A Calibration laboratory for calibration of field solar radiation sensors is proposed to be set up at National Institute of Solar Energy (NISE) for calibrating the solar radiation sensors installed in north and east India.

The technical mandate also includes Research & Development in Solar Photovoltaic and thermal technologies Hybrid Systems and storage techniques/system; International Corporation; Bridging the gap between existing R&D Institutions and Industry, and get the Industry onboard, through partnership programmes and projects; keep track of latest Global Developments based on technology forecasting and fore-sighting relating to Solar Energy and related technologies including storage techniques, etc.

The Institute is maintaining a NABL accredited Solar Photovoltaic module testing laboratory, lighting system test laboratory, battery testing facility and a water pumping system test rig and outdoor test facilities. The centre has fully developed testing facility for small and large size solar thermal systems and Solar Resource Assessment. The Institute has been coordinating with Regional Test Centers (RTCs) and National and International Standards Organizations for development of Standards and protocols for solar photovoltaic and solar thermal systems. The indoor and outdoor test facilities conduct tests on efficiency, performance, reliability, life time, etc. on the solar photovoltaic modules and solar systems such as solar lanterns, task lights, home lighting systems, street lighting systems, solar water pumping systems, solar invertors (100W- 10 kW), batteries for solar systems, solar water heaters, solar air heaters, solar thermal air conditioners, and their components. These tests are conducted as per the specifications of the systems required under the National Solar Mission as well as the requirements of the Manufacturers. Batteries are

tested as per BIS/IEC Standards for its capacity, Ah efficiency, Wh efficiency, self-discharge, type, life cycle, and battery abuse. Failure analysis is also carried out to quantify long-term degradation of the systems and its components. Formalities were completed for setting up of the State-of-Art Test Facility for CSTs under UNDP-GEF CSH project on “Market Development and Promotion of solar Concentrated based process Heat Application in India” to develop performance measuring standards, test procedures & test protocols. The Institute has well established following Test Facilities for Solar Photovoltaic and Solar Thermal Technologies:

- Solar Cell Characterization Lab
- Advance Solar Lighting System Test Facility
- Solar Water Pump Test Facilities
- Solar Inverter Test Facilities
- Outdoor PV Module Characterization Test Facility
- Battery Testing facility
- Flat Plate Collector System Test Facility
- Evacuated Tube Collector System Test Facility
- Solar Cooker (i.e. Boxed Type & Paraboloid Cooker) Test Facility

The NISE has been involved in scrutinizing the R&D proposals submitted to the Ministry at the initial stage, getting the experts’ comments, arranging RDPAC and RDSPAC meetings and recommending proposals to the MNRE for sanction. Furthermore, it has also been responsible for monitoring the on-going R&D projects through expert visits, organising reviews, suggesting mid-course corrections, and monitoring and verifying claims as an independent, un-biased agency.

The Institute has been conducting research in Solar Photovoltaic, Solar Thermal and Hydrogen Technologies in collaboration with IIT’s, Other Universities, solar industry and foreign institutions through partnerships and direct support. Interactive research is being carried out on the high efficiency HIT solar cells, batteries, materials for solar photovoltaic and thermal systems, batteries and electronics. In Solar photovoltaic Systems, research and development is being carried out on performance, evaluation, and development of solar photovoltaic lighting system in India; development of white LED based PV Lighting systems; development of test procedure and test facilities for performance & reliability assurance of the LED based PV lighting systems for their trouble free and reliable operation in the field.

The NISE is also executing externally aided, large consortium projects funded by the DST and other Ministries in the area of solar photovoltaics and solar thermal energies. Joint research in specific areas of high efficiency solar cells, high performance inverters, PV systems, reliability tools etc. with industry and other institutes are also planned to be taken up at the Institute in Solar Energy Technologies.



The Institute has setup state-of-the-art Solar Thermal Technologies for different end use applications such as power generation, air-conditioning, cold storage, process heat, desalination, cooking, space heating, hot water, etc. A grid-interactive solar thermal power plant, with a capacity of 1 MWe at Direct Normal Irradiance (DNI) radiation of  $600 \text{ W/m}^2$ , has been designed developed and commissioned at National Institute of Solar Energy (NISE), in collaboration with IIT, Bombay and other consortium partner as a part of the project entitled “Development of a Megawatt-scale Solar Thermal Power Testing, Simulation and Research Facility”. A project is under implementation for design, development fabrication and testing of heliostat, central cavity receiver and thermal storage system in collaboration with to M/s Sun Borne Energy Technologies Pvt. Ltd. and other consortium partners for solar tower technology. Solar thermal cooling system, air conditioning, Stirling engine, solar-biomass hybrid system, water desalination system, poly generation system, phase change material for thermal storage, etc. have been set up at the NISE campus for performance evaluation and research purposes.

The Institute has set up a Solar based Hydrogen Generating Facility with a  $5\text{Nm}^3/\text{hr}$  capacity of Electrolyser for a Hydrogen Dispensing station. The Alkaline based Electrolyser uses the Ground water and with Electricity generated from Solar Power plant Hydrogen of 99.9999% purity [Fuel cell grade] can be generated. This is the first of its kind station with the state of the art infrastructure for the Hydrogen Facility in the country. The Institute proposes to establish a Fuel Cell Testing Laboratory for Research & Development, testing of various types of Fuel Cells, monitoring & evaluation to study the performance of the Fuel Cell Components & systems at different capacities, comparison of different kind of fuel cells in India and their techno-economic viability, development of test protocols for various type of Fuel Cells and development of standards for Indian conditions.

As a part of Skilling India Programme of Government of India, NISE has been given the responsibility of coordinating skill development of various levels in the country for the area of solar energy, technology development, system design, installation, commissioning, operation & maintenance and repair, etc. During 2014-15, the Institute organized 13 National Training Programs for the Indians in solar photovoltaic and solar thermal technologies. During the year 4 International Training Programs were organized for engineers, scientists, energy planners, government officials from developing and other countries. The International Training Programme includes 3 ITEC Program arranged by Ministry of External Affairs, Govt. of India. This was a three week program focused on latest renewable energy technologies. Apart from ITEC, NISE also conducted international program such as SAARC countries, Mangolia etc. on renewable energy technologies skill.

A new innovative skill development centre is established at NISE with young scientist for creating curriculum, content for various levels of skill development programs. During the year 2014-15, it has designed five new skill development programs for all India implantation i.e. Aryabhata, Konark, Bhaskar, Surya and Varun and released to select institutes across India.

The Institute has provided consultancy on projects on solar photovoltaics and solar thermal technologies to Ministry of Food Processing, Ministry of Defense, Kandla Port Trust, ISRO, Doordarshan, NLC, NEEPCO etc. The consultancy includes technical specifications, project management advisory,

techno-economic feasibility reports, clients engineers, EPC advisory services, etc.

The Institute plans to set up an Incubation Centre to nurture budding entrepreneurs in all walks of Solar space. Further NISE also aims to set up facilities programs to assist existing Solar companies to accelerate their market development to secure funding for later and global growth.

A New Office building and 30 room international guest house with Solar Passive Concept have been completed and are in use.

It is proposed to meet the entire electricity requirement of the campus through solar energy, solar thermal power plant and solar photovoltaic power plants comprising different SPV technologies and make it “net zero electricity consuming campus”.

The Institute has been set up with the long-term vision to develop it as a world-class Institute. The Institute has been re-orienting and organising its activities and manpower. Public-Private partnership with future investment coming from both Government and Private Sector is envisaged. During the year the Institute has embarked upon up-gradation of laboratories facilities. Towards re-orientation of activities the Institute has organized itself in the five technical verticals viz. Solar Photovoltaic Division, Solar Thermal Division, Resource Assessment & Information Technology Division, Hydrogen Division and Training & HRD Division.

Towards attracting Industrial participation in the pursuit for exploitation of solar energy as an alternative future clean energy, the Institute has planned several demonstration projects in the huge Campus available with the Institute. I feel privileged to present the first Annual Report of the Institute for the financial year 2014-15 along with the audited accounts.

Dr. O.S. Sastry

Director General



### Administration

National Institute of Solar Energy was set up in September, 2013 as autonomous Institute under the administrative control of Ministry of New and Renewable Energy against the nucleus of Solar Energy Centre. The Institute has been sanctioned 41 posts for the new Institute. With the setting up of the autonomous institution, the Solar Energy Centre staff was declared surplus and shifted to Ministry for their re-deployment. The Institute was allowed to continue its activities with the support from Ministry by deployment of five senior level officers to assist the Director General. In addition the Institute was allowed to recruit Consultants to run the Administration. The present Organisational Structure is given at Annexure – I. The details of the posts sanctioned are given as under:

Sl. No.	Name of the post	PB+GP	No. of posts		
			Technical	Admin	Total
1.	Director General	PB-4 +10000	1	0	1
2.	Deputy Director General	PB-4 +8900	3	0	3
3.	Director	PB-3+7600	2	1	3
4.	Deputy Director	PB-3+6600	6	2	8
5.	Assistant Director	PB-3+5400	7	2	9
6.	Administrative Officer	PB-3+6600	0	1	1
7.	Office Secretary	PB-2+5400	0	1	1
8.	Office Secretary-I	PB-2+4800	0	3	3
9.	Executive Officer	PB-2+4800	4	0	4
10.	Executive Assistant –I	PB-2+4600	8	0	8
	<b>Total</b>		<b>31</b>	<b>10</b>	<b>41</b>

The Recruitment Rules for the sanctioned 41 posts were in the process of framing during the period under reporting. These will be placed before the next meeting of the Governing Council before initiating action for filling up the posts. The Recruitment Rules for the post of Director General were approved by the Governing Council.

With the setting up of the Institute, the Governing Council considered its activities to be synchronously organised with the objectives of Jawarlal Nehru National Solar Mission and the following five Technical Verticals were established:

- Solar Photovoltaic Division
- Solar Thermal Division
- Resource Assessment and Information Technology Division
- Hydrogen Division
- Training and HRD Division

The Governing Council also approved the Delegation of Powers for Director General, NISE for creation of posts on consolidated salary for projects / self-supporting activities of the Institute.

The Governing Council considered the proposal for creation of equivalent technical posts for manning of the Laboratories to that of the erstwhile Solar Energy Centre for continuation of the activities of the Centre in the Institute. The recruitment for the following contractual posts was made during the year:

1.	Research Associates	10
2.	Senior Research Fellow/Project Fellow	9
3.	Junior Research Fellow	9
4.	Senior Technical Consultants	4
5.	Administrative Consultants	8

The new building under construction by National Building Construction Corporation for the Institute was in the last lag of completion and to be handed over to the Institute in due course. The Institute constituted Committee for review of the progress and takeover of the building. The new building of the NISE named as Surya Bhawan was inaugurated by Hon'ble Shri Piyush Goyal, Minister (Independent Charge) Coal, Power and Renewable Energy.

During the year, the Institute augmented the infrastructural facilities for different laboratories by renovation of buildings, procurement of equipment and machinery. The Laboratories are manned by Project Fellows recruited for the purpose.

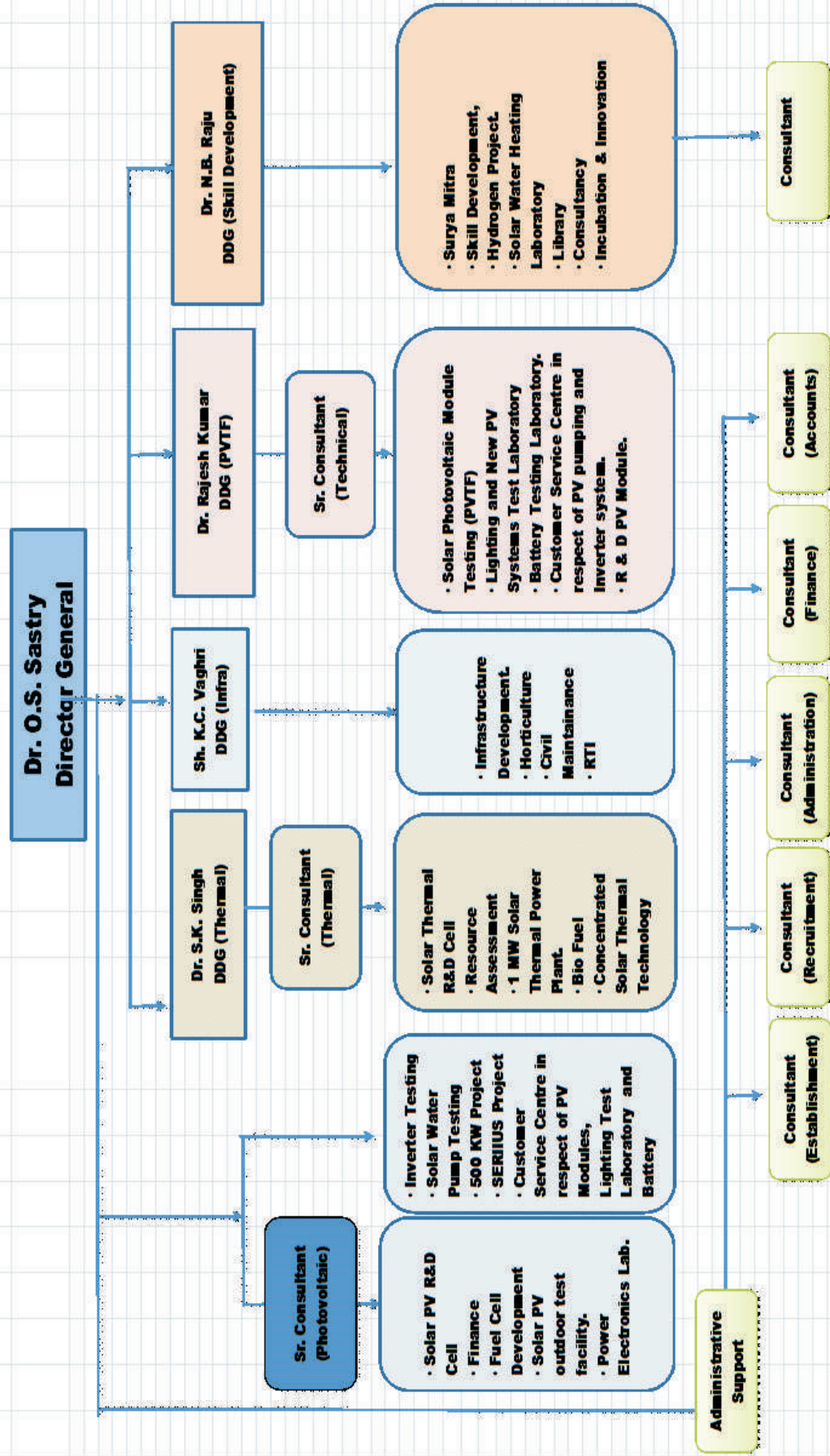
The Biometric Attendance System was introduced in the Institute in September, 2014.

The Institute convened the second meeting of the Governing Council during November, 2014. The first meeting of the Finance & Accounts Committee was also convened in January, 2015. The Executive Committee constituted by the Governing Council also met once to address the issues referred by Director General both for Technical and Financial matters.

The Institute was assigned the mandate to monitor the on-going solar R&D projects including organising of Advisory Committee meets. During the period under report, an R&D Cell was set up in the Institute for this purpose.



**National Institute of Solar Energy (NISE)**  
 Gandhinagar, Gurgaon, Haryana-122002  
 (Organisation Structure)



## **Surya Bhawan at NISE Inaugurated**

Shri Piyush Goyal, Union Minister of State (Independent Charge) for Power, Coal and New and Renewable Energy, inaugurated “Surya Bhawan” the new green building of the National Institute of Solar Energy (NISE) situated in Gwal Pahari, Gurgaon, Haryana. The NISE is the apex National Centre of Excellence in research and development in solar energy, an autonomous institute of Ministry of New & Renewable Energy, Government of India. It coordinates solar energy research & technology related work in the country and is aiming towards becoming a NET ZERO electricity centre.

Following the inauguration of the New Building, the Minister visited various solar projects in the Campus. The campus of National Institute of Solar Energy would soon meet all its electrical requirements from the Solar Power Projects setup in the campus with Solar Thermal and Solar Photovoltaic Technologies. Lauding the role and contribution of all officers and students of NISE in establishing this Institute, Shri Goyal said “in coming days, role of the NISE will take quantum growth particularly when energy security of the country is intrinsically linked with success of Renewable Energy mission.”

The Minister also announced establishment of International Solar Policy and Applications Agency which would be a coalition of solar resource rich countries for the development of solar energy and solar technology applications. This would help in addressing special energy needs of these countries and in the long run reduce reliance on fossil fuels by increasing the share of solar energy in the energy mix. Hon'ble Prime Minister Shri Narendra Modi, during his address in the RE-INVEST 2015 had given the idea to bring solar resource rich nations together to jointly address their challenges of energy security.

The Minister also announced preparation of establishing World Renewable Museum in the NISE campus.





*Hon'ble Minister inaugurating the building*



*Hon'ble Minister inaugurating the building*



*Hon'ble Minister addressing the gathering during the inauguration*

## Chapter 1

### Solar Radiation Resource Assessment (SRRA) Division

#### 1.1 Introduction

Solar Radiation Resource Assessment (SRRA) is a Ministry of New and Renewable Energy (MNRE) flagship program launched in the year 2010, setting up the world's largest network of ground measurement solar radiation resource assessment stations all over the country. The project aims to overcome the deficiencies in the availability of investor grade ground measured solar radiation data crucial for planning and implementation of solar power projects. The project is implemented by National Institute of Wind Energy (NIWE) Chennai in collaboration with NISE. In the first phase of the project, 51 SRRA stations were set up by October, 2011, in 11 States 1 Union Territory and in the second phase, 60 SRRA stations (in 28 states and 3 UTs) and 4 Advanced Measurement Stations (AMS) by June, 2014. All these stations automatically measures the data and send it to the central receiving station located at NIWE, Chennai. SRRA project in its wider scope envisages assessment and quantification of solar radiation, data processing, quality of data, modeling and making of solar atlas of the country, besides the collection and analysis of solar and meteorological data. Also in order to ensure high quality of Solar resource data to be continuously available from these stations, it is utmost required that the instruments along with their proper maintenance, to be recalibrated at the regular interval as per World Meteorological Organization (WMO) guidelines. To cater this need, two Calibration lab facilities in line with WMO standards, to calibrate all the instruments of wider SRRA network have been established at NISE, Gurgaon. National Institute of Solar Energy (NISE) being primer institute in the field of solar energy research is playing major role in this SRRA program with its Calibration facility for calibrating the SRRA field radiation sensors as per international standards and well equipped Advanced Solar radiation resource measurement facility.

#### 1.2 Solar Radiation Resource Assessment (SRRA) Facility at NISE

Solar Radiation Resource Assessment facility has been installed and commissioned in Oct 2011 at NISE under SRRA phase -1 project. The facility is further equipped with advanced measurement capability, commissioned in May 2014. Established in very sustainable environmental conditions, the facility automatically measures and logs the data pertaining to various solar radiation and meteorological parameters continuously. This resource facility houses number. of high quality solar radiation sensors measuring various parameters with their traceability to World Radiometric Reference (WRR) and meteorological sensors measuring various meteorological parameters having their traceability to World metrological organization (WMO).The complete SRRA facility is powered by solar panels. A trigger switch is also installed to track the cleaning status of the SRRA stations on a daily basis. Data is sampled for every second and averaged over a minute and transmitted to the Central Receiving Station through GPRS mode. The table below list these various sensors operating in the facility with their functionality.

Table 1.1 List of Instrumentation facility at SRRA Station, NISE

Sl.NO.	Instrument	Measurement Parameter
1.	Pyranometer	Global Horizontal Irradiance (W/m <sup>2</sup> )
2.	Shaded Pyranometer	Diffuse Horizontal Irradiance (W/m <sup>2</sup> )
3.	Pyrheliometer	Direct Normal Irradiance (W/m <sup>2</sup> )
4.	Solar Tracker	Mounted with Pyranometers with shading disc and Pyrheliometer
5.	Ultrasonic Wind Sensor	Wind Speed (m/s) & Wind Direction (Deg)
6.	Rain Gauge	Rain Accumulation (mm)
7.	Barometer	Atmospheric Pressure (mb)/ hpa
8.	a. Temperature sensor b. Relative Humidity sensor	a. Temperature (oC) b. Relative Humidity (%)
9.	GPS	To synchronize Sun Tracker with Sun movement
10.	Data Logger & Modem	For storing sensor data and transferring it Central Receiving Station(CRS) at NIWE, Chennai
11.	GPRS	To transmit data to CRS
12.	Solar PV panel	For charging battery for powering SRRA station
13.	External Battery	For Storage of SPV power
14.	Cleaning trigger switch	To track the cleaning status of the SRRA station



Fig. 1.1 Solar Radiation Resource assessment Station at NISE

### 1.3. Advanced Solar Radiation Resource Measurement Station (AMS)

The suspended particles matter in the atmosphere such as dust particles, water vapor and gases etc. attenuates the solar radiation to a great extent. The AMS is set up for quantification of attenuation of solar radiation due to the presence of aerosols in the atmosphere and for the measurement of the reflectivity of the earth (Albedo), incoming long wave radiation and atmospheric visibility for research and developmental activities. The station forms an integral part of an existing SRRA facility. The AMS was commissioned in the month of May 2014. The table below list the various instruments as part of advance solar radiation resource measurement station and their functionality.

Table 1.2 List of Instrumentation facility at AMS, NISE

Sl.No.	Instrument	Measurement Parameter
1.	Direct Beam filter spectrometer (Sun Photometer)	Direct solar spectral irradiance at discrete wave lengths, calculating Aerosol Optical Depth (AOD)
2.	Albedometer	Albedo (Reflectivity of earth surface)
3.	Pyrgeometer	Incoming long wave radiation
4.	Scatterometer	Atmospheric visibility
5.	Silicon Pyranometer (Horizontal & Inclined)	Global Solar Radiation. (on horizontal & inclined plane)



Fig. 1.2 Advanced Solar Radiation Resource Measurement Station at NISE

#### 1.4 Calibration Laboratory for Solar Radiation Measuring Instruments at NISE

In order to create reliable, high quality solar radiation resource database under SRRA program, a Calibration laboratory for calibration of field solar radiation sensors has been set up at National Institute of Solar Energy (NISE). This project has been implemented by Solar Energy Corporation of India (SECI) in collaboration with National Institute of Solar Energy (NISE) funded by MNRE. The project primarily aims to calibrate the solar radiation sensors operating at various SRRA stations as per the guidelines of World Meteorological Organization (WMO). It also offers the facility to calibrate the radiation sensors from private firms as per the availability (with calibration cost as applicable). The lab was commissioned during May 2015. The laboratory provides facility for calibration of solar radiation sensors such as Pyranometers (thermopile based) and Pyr heliometer. In process of calibration the output of field sensor under calibration is compared against the output of reference sensor under the same set of conditions as per the international standards. The reference sensors find their traceability to World Radiometric Reference (WRR) by calibrating them at regular intervals against primary standard such as Absolute cavity Radiometer (ACR). At a time the facility can calibrate six Pyranometers and three Pyr heliometer with calibration period varying depending on weather conditions at the site. Presently the facility is equipped to calibrate sensors from different make such as Eppley, Kipp & Zonen, Hukseflux. The International standards that are followed in

calibration process at the facility are ISO 9847, which specifies the procedure for Calibration of field Pyranometers by comparison to a reference Pyranometer and ISO 9059 which specifies the procedure for Calibration of field Pyr heliometers by comparison to a reference Pyr heliometer.

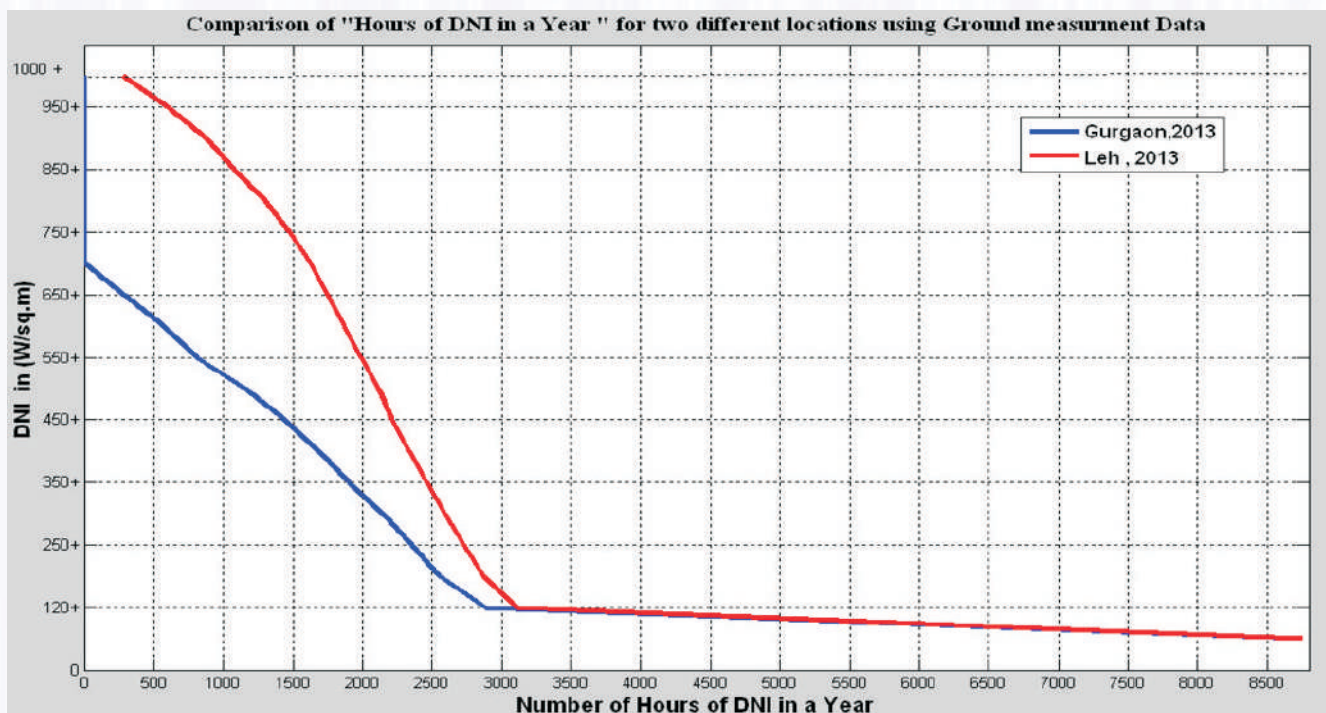


Figure 1.3 Calibration Facility for Solar Radiometers at NISE

## 1.5 R&D activities in the SRRA division

The focus of the SRRA division has been on the following major activities:

- Analysis of Radiation Data of various other SRRA locations in the country.
- Preparation of a solar map to identify feasible locations for various solar applications.
- Data monitoring and maintenance of SRRA station at NISE, Gurgaon.
- Solar radiation data extraction process from satellite images is under progress. The process of setting up a collaborative research with National Remote Sensing Centre, Hyderabad and ISRO is initiated.
- Experimentation to understand the effect of soiling on the radiation measurements, there by attempts to categorize the locations based on dust effect.
- A two day workshop on "Solar Resources: modeling and measurements" was conducted during Nov, 2014 in collaboration with NREL.



**Figure 1.4 A typical comparative chart of comparison of number of DNI hours for Gurgaon and Leh for the year 2013**

## 1.6 Solar Energy Potential Analysis of India

A study was carried out for calculating the state wise solar potential in the country based on census data (2011) and available waste land area. Assuming that 3% of total waste land of each state can be utilized for solar projects, total waste land area of our country can be differentiated in 12 types as give in the figure.







## CHAPTER - 2

### SOLAR PHOTOVOLTAIC DIVISION

#### 2.1 PHOTOVOLTAIC INDOOR TEST FACILITY

The Photovoltaic module testing facility (PVTf) at the National institute of Solar Energy is NABL (National accreditation board for testing & calibration laboratories) accredited laboratory as per IS 17025: 2005 standard. The laboratory is well-equipped and has well-trained, experienced and skilled personnel to conduct the tests as per the National (BIS) and International Standards (IEC/UL/ASTM). The lab offers wide range of services to the customers such as Quantitative and Qualitative analysis of PV modules by testing them according to the following Standards.

- â IEC 61215 :  
Crystalline silicon terrestrial photovoltaic (PV) modules and type Approval
- â IEC 61646 :  
Thin –film terrestrial photovoltaic (PV) modules and type Approval
- â IEC 61730:  
Photovoltaic module safety qualification

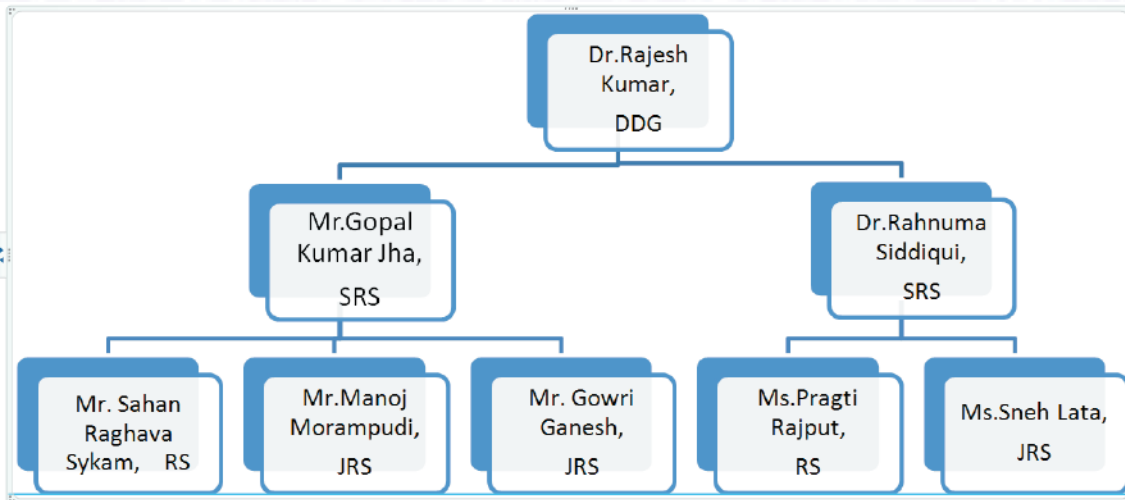
#### The Following Additional Services are also Available at the Laboratory:

- â Tests are conducted as per the user specific standards.
- â Infrared Image thermography.
- â Analysis of potential induced degradation (PID).
- â Calibration modules for manufacturing quality control.
- â There is a facility to test PV modules belonging to different technologies as per national and international standards and the Following PV technologies are tested at the PVTf lab at NISE.

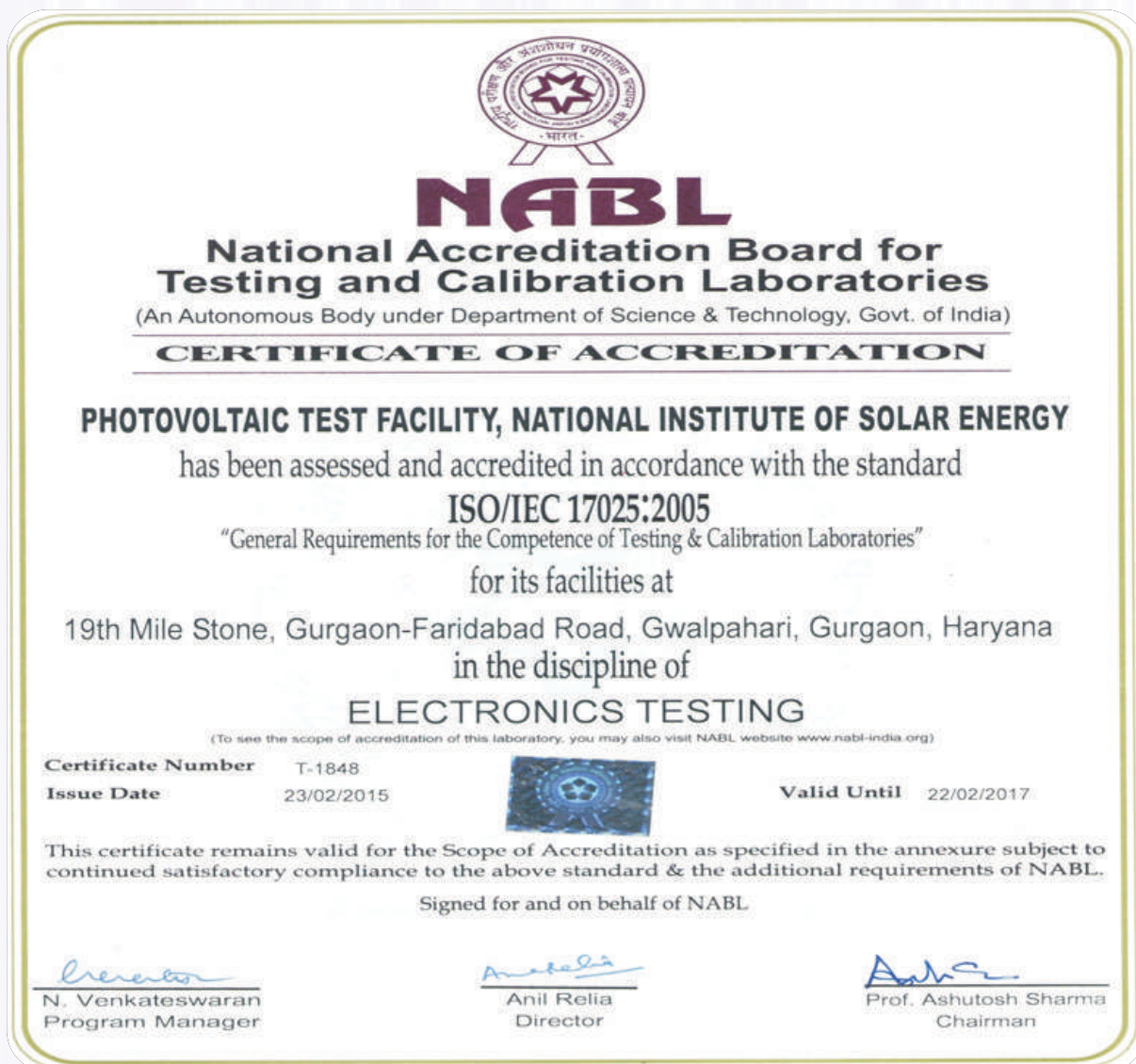
- |                             |              |                     |
|-----------------------------|--------------|---------------------|
| 1. Crystalline solar module | 2 Thin Film  | 3. Hybrid PV Module |
| a. Mono crystalline         | a. Amorphous | a. HIT              |
| b. Multi crystalline        | b. CdTe      |                     |
| c. IBC (SunPower)           | c. CIGs      |                     |



## About Group / Lab structure



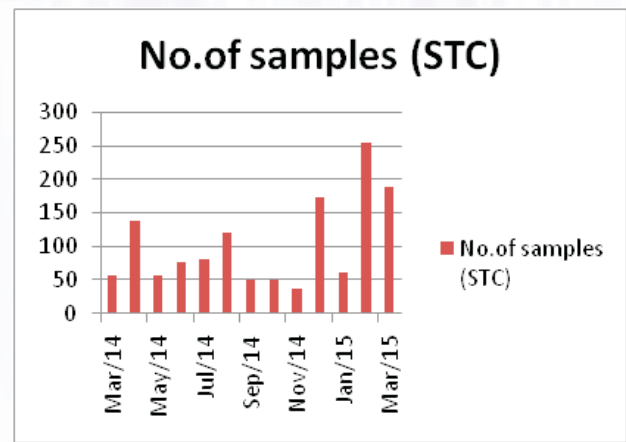
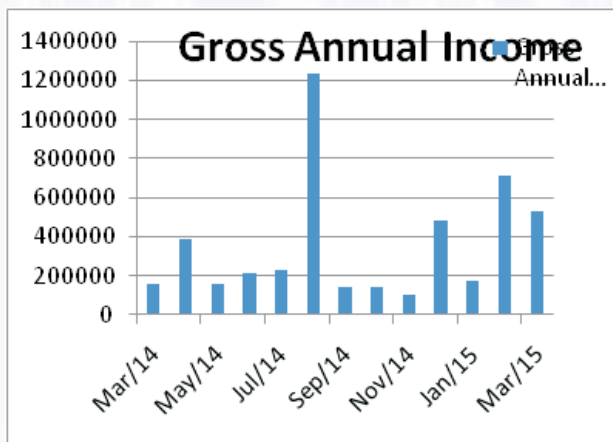
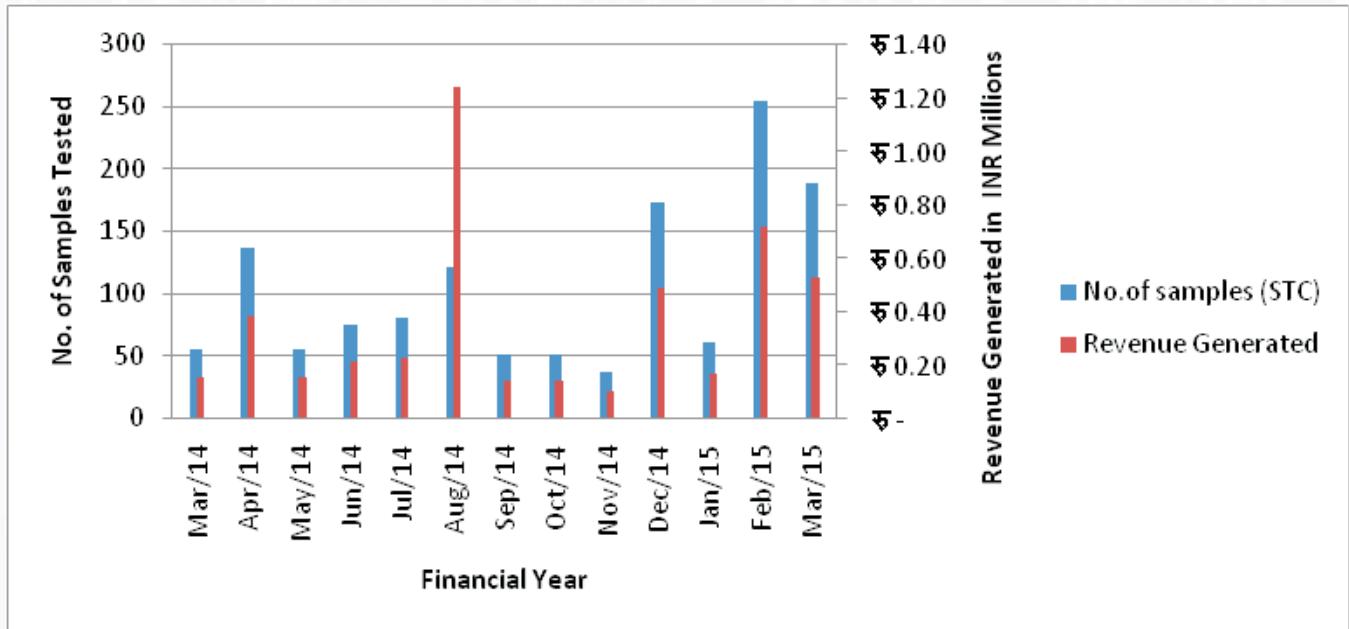
### NABL Accreditation Certificate:



## MONEY EARNED FOR NISE

â The Gross Annual Income in 2014-2015 was approximately. Rs. 4668558.00 - (Forty six lakh sixty eight thousand five hundred fifty eight)

â Sample tested at NISE during 2014-2015, 1342 for Performance testing & One Sample for Qualification testing



### Achievement:

- â Incorporated a safety qualification testing as per standard IEC 61730-2
- â NABL Certification for Design qualification and type Approval as per standard IEC 61215.

### Activity

- â Conducted internal audit as per NABL requirement IS 17025: 2005.
- â Started Digitalization of Lab Records/Registers.

## Research & Development

- â Prototype designed developed & demonstrated having a Project title of “Solar Wind Mill “ at NISE.
- â Developed a MATLAB Program to generate I-V & P-V Characteristics along with parameters in Excel Format from Data Repository to reproduce STC.
- â Developed a MATLAB Code for Evaluation and Comparison of Various module Parameters simultaneously in graphical format.
- â Performance Analysis of Various PV Technologies.
- â Dark I-V measurements.
- â Thermal imaging Analysis of PV module



## TRAINING COURSES ORGANISED

Students enrolled for Summer Training / Internships/ Final Year Projects are mentioned in the following list.

NAME	DURATION OF TRAINING	TOPIC OF TRAINING/PROJECT	COLLEGE NAME
Gayatri Nanda	1 year	Characterization of PV modules & predicting Maximum power with the help of simulation	KIIT University, Odisha.
Shreyank Dutt Dwivedi	45 days	Qualification testing of PV Modules	IMS Engineering College, Ghaziabad.
Shivanshu Rastogi	45 days	Qualification testing of PV Modules	IMS Engineering College, Ghaziabad.
Sidra Khatoon	2 Months	Indoor & Outdoor STC Performance Comparison of Solar Technology	University of Lucknow
Priyanka Verma	2 Months	Indoor & Outdoor STC Performance Comparison of Solar Technology	University of Lucknow
Stuti Tripathi	2 Months	Indoor & Outdoor STC Performance Comparison of Solar Technology	University of Lucknow
Atish Mehra	2 Months	Hotspot Investigation on Module Array	Green Hills Engineering College
Sahil Sharma	2 Months	Hotspot Investigation on Module Array	Green Hills Engineering College
Mayank Singh	45 days	Hotspot Investigation on Module Array	Institute of Enviromental studies(KUK)
Bharat Dubey	6 Months	Effect of Temperature over the different Technology of Module efficiency	Samrat Ashok Institute of Technology vidisha
Chaudhary Hiren	2 Months	Effect of Hotspot of Different Size of Modules	NIT Hamirpur
Satya Prakash	2 Months	Effect of Hotspot of Different Size of Modules	NIT Hamirpur
Shilpa Sharma	2 Months	Effect of Hotspot of Different Size of Modules	NIT Hamirpur
Raman Aggarwal	2 Months	Solar Wind mill	University of Urban state Illionois champaign, Chicago
Sidharth	1 Months		IIT Mandi

## PV Module Manufacturers List

PV MANUFACTURER DETAILS			
Serial no	ANDHRA PRADESH / TELAGANA	GUJARAT	West Bengal
1	ACCESS SOLAR ,	WAAREE ENERGIES PVT LTD	WEBSOL ENERGY SYSTEM,
2	ADITI SOLAR PVT LTD,	GREEN BRILLIANCE ENERGY PVT LTD,	VIKRAM SOLAR
3	AKSHAYA SOLAR POWER INDIA PVT LTD,	TOPSUN ENERGY ,	SOVA SOLAR
4	ESSENTECO SOLAR POER SOLUTIONS INDIA PVT LTD ,	SUN ENERGY,	SUN SHINE SOLAR
5	HBL POAWE SYSTEM LTD ,	NEETY EURO ASIA SOLAR ENERGY	SYNERGY RENEWABLE ENERGY (P) LTD,
6	HHV Solar	KOSOL HIRAMRUT ENERGIES LTD,	ENFIELD SOLAR ,
7	ICOMM, CHERLAPALLY,	SAHAJ SOLAR PVT LTD ,	HR SOLAR
8	J.J SOLAR ,	GOLDI GREEN ,	
9	JUNNA SOLAR ,	VIPSON SOLAR ENERGY PRIVATE LIMITED ,	
10	SUNFIELD ENERGY PVT. LTD,	POWER TRAC	
11	VEGA SOLAR ENERGY PVT LTD.	SHIVAM PHOTOVOLTAIC	
12	PHOTONIX SOLAR PVT LTD		
13	PHOTON ENERGY,		
14	SUNFIELD ENERGY ,		
15	ANDROMEDA ENERGY PVT LTD		
16	SHAN SOLAR PVT. LTD ,		
17	SOLAR SEMICONDUCTOR PVT LTD ,		

PV MANUFACTURER DETAILS				
Serial no	RAJASTHAN	KARNATAKA	MAHARASTRA	UTTAR PRADESH
1	AJIT SOLAR PVT LTD,	MICROSUN SOLAR TECH PVT LTD	M/S JAIN IRRIGATION SYSTEMS,	MAHARISHI SOLAR TECHNOLOGY PVT LTD,
2	TAPAN SOLAR ,	CONERGY ENERGY SYSTEM (INDIA) PVT LTD.	SCHOTT GLASS INDIA PVT LTD	RRG ENERGY PVT LTD,
3	REIL, JAIPUR ,	TATA POWER,	PV POWER TECHNOLOGIES PVT LTD.	MOSERBAER SOLAR INDIA LIMITED ,
4	MEDORS SOLAR	EMVEE SOLAR	URJA VIKAS SOLAR SYSTEMS,	CEL
5	RITIKA SOLAR	BHEL ,	ROLTA SOLAR	

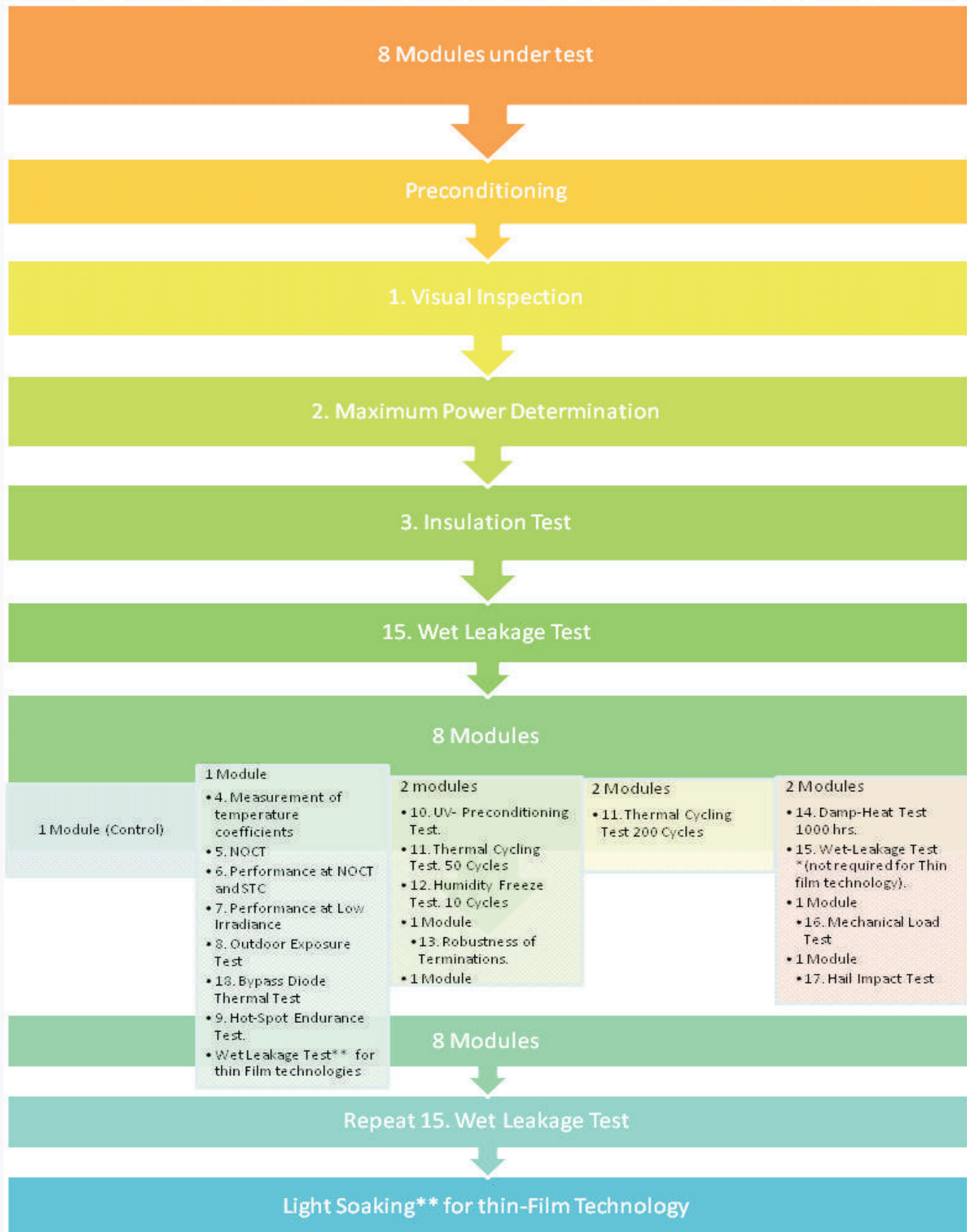
PV MANUFACTURER DETAILS				
Serial no	HIMACHAL PRADESH	TAMILNADU	MADHYA PRADESH	UTTRAKHAND
1	PLAZA POWER & INFRASTRUCTURE COMPANY,	NANO PV VOLTECH SOLAR PVT LTD ,	PRAGAT AKSHAY URJA LTD,	GAUTAM SOLAR PVT LTD,
2	ALPEX SOLAR ,	EVERGREEN SOLAR SYSTEMS INDIA PRIVATE LTD.		
3	VIPUL SOLAR ,			

**KERALA****CHATTISHGARH**

Serial no	PV Manufacturer Details
1	<b>SUN ENERGY SOLAR SOLUTIONS ,</b>

Serial no	PV Manufacturer Details
1	<b>LANCO SOLAR PVT LIMITED,</b>

## Flow Chart for Testing procedure of IEC 61215/61646 :



## PHOTOGRAPHS OF TEST SET-UP/EQUIPMENT

### a. The Quick Sun 700A Sun Simulator

This is a class A, simulator being used for performance evaluation of PV modules conforms to class A sun simulator specifications as per IEC 60904-9 and can measure the STC performance of PV modules of size up to 200 cm x 200 cm . For making the performance measurements a flash pulse is triggered and the irradiance is measured with monitor cell. When the target irradiance level is reached the I-V measurement is initiated. The module is swept from short circuit to open circuit condition and during the 2 ms period of the pulse the voltage, current and the irradiance signals are recorded simultaneously. The measured data is corrected for irradiance and temperature to defined conditions. The system measures 4096 raw data points for each signal and the data is averaged in group of eight to obtain 512, I-V data points.

ALL ELECTRICAL DATA MEASURED AT  
STANDARD TESTING CONDITIONS (STC)



IRRADIANCE: 1000 W/m<sup>2</sup>



MODULE  
TEMPERATURE: 25°C



AM: 1.5



CLASS	AAA
NOMINAL AREA	220CM×160 CM/200CM×200CM
NOMINAL IRRADIANCE	200-1200 W/M <sup>2</sup>
NON UNIFORMITY	<±2 %
TIME INTERVAL	4.3 us
CHARACTERISTICS OF THE PULSE	2 ms
TEMPORAL INSTABILITY	<±0.05% per data point
FLASH PEAK IRRADIANCE	1600 W/M <sup>2</sup>

### b. SPIRE Simulator 240A:

CLASS	A
NOMINAL AREA	80CM×130 CM
NOMINAL IRRADIANCE	70-110 mW/CM <sup>2</sup>
Maximum panel voltage	100 V
Max panel Current	20 A
Characteristics of the pulse	Continuous FLASH



### c. Autosys InvSun Sun Simulator

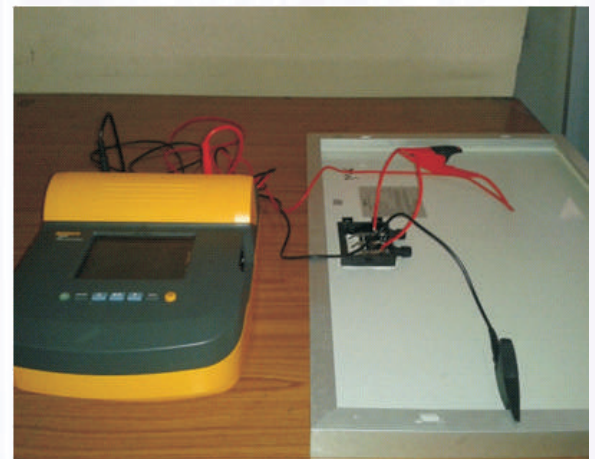


CLASS	B
NOMINAL AREA	200CM×110 CM
NOMINAL IRRADIANCE	70-110 mW/CM <sup>2</sup>
Maximum panel voltage	100 V
Max panel Current	30 A
Characteristics of the pulse	Multi FLASH

### d. Insulation tester:

Fluke 1550c

RESISTANCE MEASUREMENT	200 K $\Omega$ to 2 T $\Omega$
OUTPUT VOLTAGE	0- 5000v DC

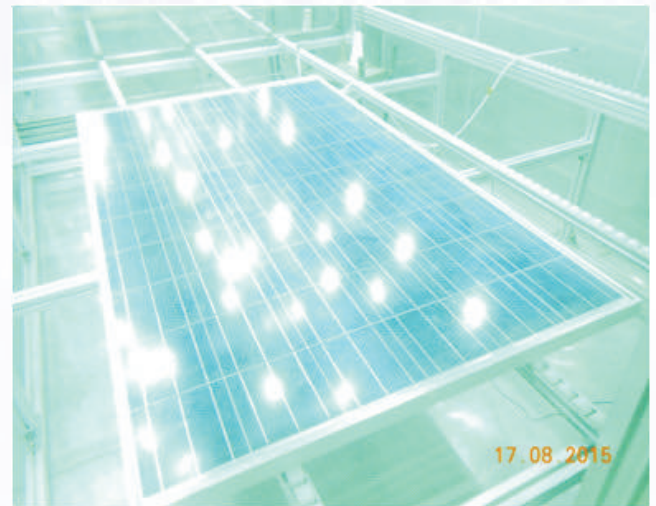


### e. NOCT Measurement set up



Equipments	Nos
Anemometer	1
Pyranometers	2
Data logger	1
Thermocouples	5

### e. UV Exposure Chamber ETSP-UV 6900



UV TEMPERATURE RANGE	70 ° C
UV WAVE LENGTH	280 nm to 385 nm
Dimensions	3000 mm ×2300 mm
Max Intensity	120 W/M2

## g. Environmental Chambers:



Parameters	Ranges
Temperature	-60 °C to 100°C
Humidity	10 to 95% RH
Dew Point Range	5°C to 89°C

## h. Mechanical Load Test



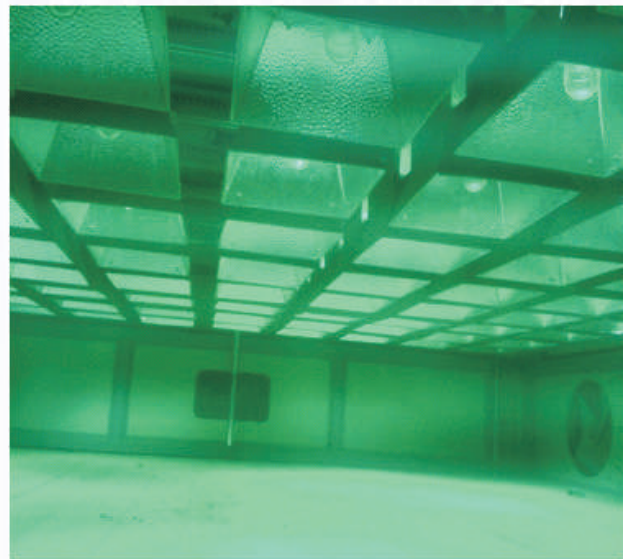
Apparatus	Quantity
Pneumatic Cylinders	9
Applying Pressure	2400K Pa to 5400K Pa
Continuity Checker	1

## I. Hail Impact test



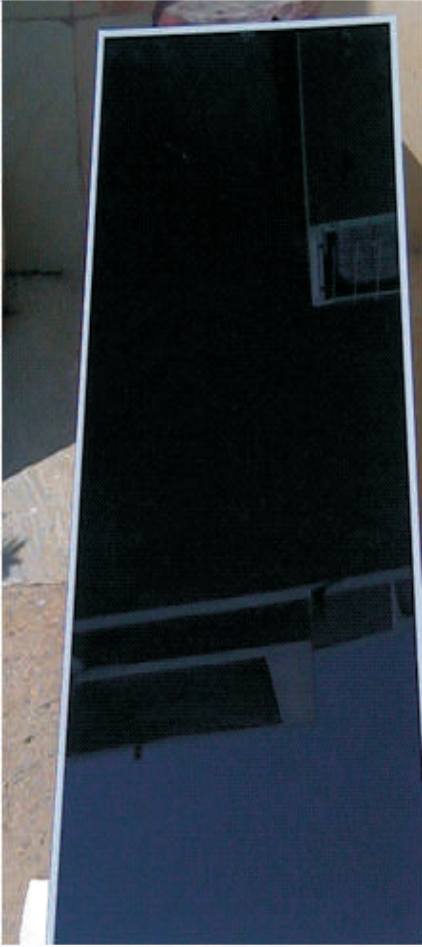
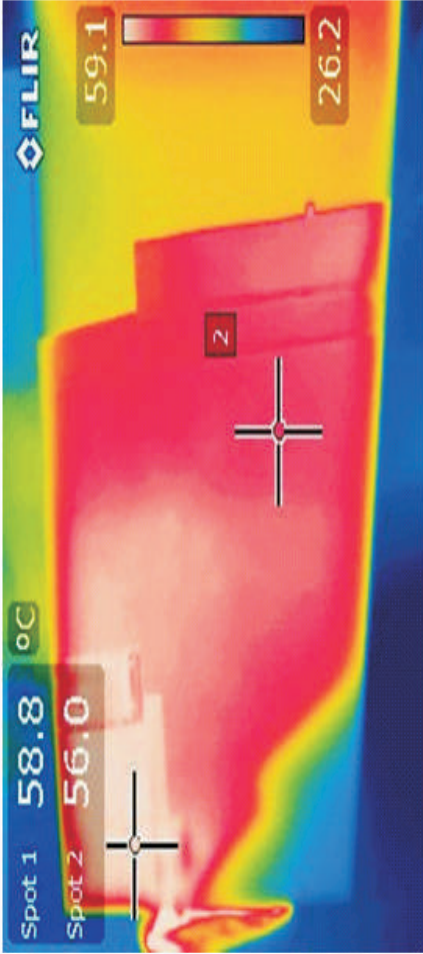
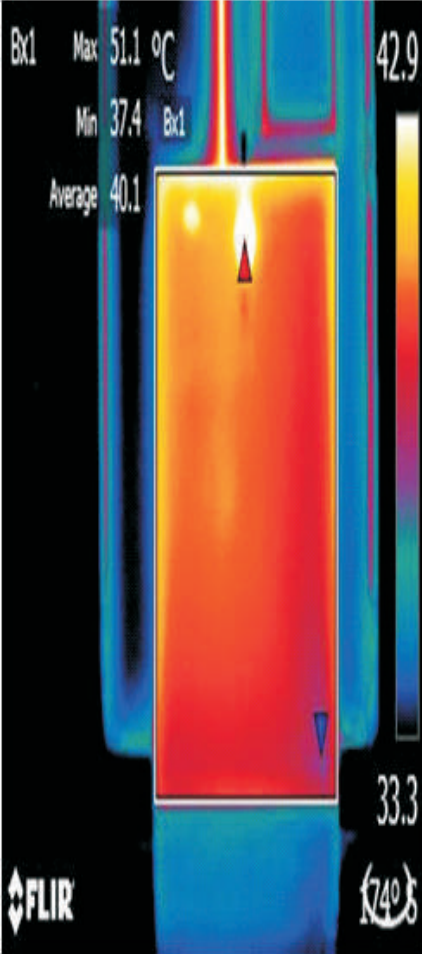
Ice Ball	Specifications
Speed	23±5% m/Sec
Mass	7.53±5% gms
Diameter	25±5% mm

## J. Sun Soak Station:



MAKE	AUTOSYS ,Mumbai
EXPOSURE AREA	3.5 M×3.5 M
Maximum Isolation	1000 w/ m2
Temperature control	40-55 ° c
LIGHT SOURCE	<b>XENON HID LAMP</b>
Reference Pyranometers	Silicon Pyranometers of apogee make

# K. Thermal Image Analysis of Panels:



## OPERATING PROCEDURES AS PER STANDARDS IEC 61215 / 61646:

### I) Preconditioning:

- â Before starting the testing all modules including the control module shall be exposed to sun light to an irradiance level of 5.5 kWh per square meter. The modules shall be divided into groups and subjected to the qualification test sequence

### ii) Visual Inspection

Objective: To detect any visual defects in the module, the visual inspection test facility comprises the following:

- ? Arrangement to inspect the module under an illumination of 1000 lux.
- â A microscope to carefully inspect and record the cracked/broken cells, faulty interconnections or joints, tacky surfaces of plastic materials, cells touching one another or the frame and any other conditions which may affect the performance.

### iii) STC Performance Measurements

To determine how the performance of the module varies with load at Standard Test Conditions (1000 Wm<sup>-2</sup>, 25°C cell temperature, with the IEC 60904-3 reference solar spectral irradiance distribution).

The Equipment: The Quick Sun 700A Sun Simulator, Autosys InvSun, Spire 240A

### iv) Insulation Test

Objective: To determine whether the module is sufficiently well insulated between current-carrying parts and the frame or the outside world.

Test Requirements

- â Dielectric withstand capability at 1000 VDC + twice the system voltage
- â For a module with an area of less than 0.1 m<sup>2</sup> the insulation resistance should be greater than 400 MΩ.
- â Module with an area larger than 0.1 m<sup>2</sup> the measured insulation resistance should be more than 40 MΩ per square meter.
- â No Dielectric breakdown or surface tracking during High Voltage testing.

The Equipment: High Voltage Insulation Tester (Fluke)-1550C.

### v) Measurement of Temperature Coefficients

Objective: The purpose is to determine the temperature coefficients of current ( $\alpha$ ), voltage ( $\beta$ ), and peak power ( $\delta$ ) from module measurements

Equipment: The Temperature coefficients can be measured by using the environmental chamber and sun simulator



### vi) NOCT Measurement

Objective: NOCT is defined as the equilibrium mean solar cell junction temperature within an open-rack mounted module in the following standard reference environment (SRE):

Tilt angle: 45° with the horizontal

Total irradiance: 800 Wm<sup>-2</sup>

Ambient temperature: 20°C

Wind speed: 1 ms<sup>-1</sup>

Electrical load: nil (open circuit)

NOCT = (T<sub>j</sub> – T<sub>amb</sub>) + 20 °C

### Vii) Performance at NOCT

Objective: To determine how the performance of the module varies with load at NOCT (800 Wm<sup>-2</sup>, 25°C cell temperature, with the IEC 60904-3 reference solar spectral irradiance distribution)

Performance at NOCT is evaluated by using the environmental chamber and sun simulators.

### viii) Performance at Low Irradiance

Objective: To determine how the electrical performance of the module varies with load at 25°C and an irradiance of 200 Wm<sup>-2</sup> in accordance with the IEC 60904-1 standard.

The Equipment:

The performance at low irradiance is evaluated by using the available sun simulator by setting the intensity at 200 Wm<sup>-2</sup>.

### ix) Out Door Exposure Test

Objective: To make preliminary assessment of the ability of the module to withstand exposure to outdoor conditions and to reveal any synergistic degradation effects which may not be detected by laboratory tests.

#### The Equipment:

Outdoor test bed for mounting of the module, Pyranometers, Temperature sensor, data acquisition system and arrangement to operate the module near the maximum power point.

### x) Bypass Diode Thermal Test

**Objective:** To assess the adequacy of the thermal design and relative long-term reliability of the by-pass diodes used to limit the detrimental effects of susceptibility of modules to hot-spots.

Equipment:

â Environmental chamber for heating the module to a temperature of 75°C ± 5°C.

â Temperature probe for measuring and recording the temperature of the module to an accuracy of ±1°C.

â Power supply for applying a current equal to 1.25 times the STC short-circuit current of the module under test and means for monitoring the flow of current through the module, throughout the test.



**xi) Hot-Spot Endurance Test**

Objective: To determine the ability of the module to withstand hot-spot heating effects, for example solder melting or deterioration of the encapsulation. This defect could be provoked by cracked or mismatched cells interconnect failures, partial shadowing or soiling.

Equipment:

- â Set of opaque covers for test cell shadowing in 5% increment and sun simulator.
- â IR Camera: Sharp thermal resolution at 76800 pixels, Temperature range up to 1200 0C, Temperature accuracy  $\pm 2\%$ .

**xii) UV Preconditioning Test**

Objective: To precondition the module with ultra-violet (UV) radiation before the thermal cycle/humidity freeze tests to identify those materials and adhesive bonds that are susceptible to UV degradation

Equipment:

- â UV exposure system to control the temperature of the module while it is irradiated by UV lights (280-385 nm, at 60 0C  $\pm$  5 0C).
- â Temperature probes for measuring and recording the temperature of the module.
- â UV radiometer for measuring the irradiation of the UV light produced by the UV light source at the test plane of the module.

**xiii) Thermal Cycling Test**

Objective: To determine the ability of the module to withstand thermal mismatch, fatigue and other stresses caused by repeated changes of temperature.

Equipment:

- â Environmental chambers with automatic temperature control.
- â Power supply for applying a current equal to the STC peak power current of the module(s) under test and monitoring the flow of current through each module during the test.

**xiv) Humidity Freeze Test**

Objective: To determine the ability of the module to withstand the effects of high temperature and humidity followed by sub-zero temperatures.

Equipment: Environmental chambers with automatic temperature control and humidity, Multimeter to monitor the continuity of the internal circuit of each module during conducting

**xv) Damp Heat Test**

Objective: To determine the ability of the module to withstand the effects of long term penetration of humidity.

Equipment:

- â Environmental chamber with humidity and temperature control.

Severities:

Test temperature:  $85 \pm 2$  0C

Relative humidity: 85 %  $\pm$  5 %

Test duration: 1000 h

### xvi) Wet Leakage Current Test

Objective: To evaluate the insulation of the module under wet operating conditions and verify that moisture from rain, fog, dew, or melted snow does not enter the active parts of the module circuitry, where it might cause corrosion, a ground fault or a safety hazard

#### Equipment:

- â A water container for wetting the module
- â Spray equipment for keeping the module wet during test
- â Insulation tester to measure the insulation resistance.

#### Test Requirement:

- â A water/wetting agent solution meeting the following requirements
- â Resistivity : 3500 ohm cm or less
- â Surface Tension : 0.03 N/M or less
- â Temperature: 22 ± 3 0C

### xvii) Robustness of Terminations Test

Objective: To determine that the terminations and attachment of the terminations to the body of the module will withstand such stresses as are likely to be applied during normal assembly or handling operations.

**Equipment:** A set of weights along with hanging arrangement

### xviii) Mechanical Load Test

Objective: The purpose of this test is to determine the ability of the module to withstand wind, snow, static or ice loads

#### Equipment:

- â Mechanical load tester which enables the modules to be mounted front-side up or front-side down. The test base shall enable the module to deflect freely during the load application.
- â Instrumentation to monitor the electrical continuity of the module during the test.
- â Applied 2400 Pa
- â Uniform load for 1hr on the Front and Back surface of the module

### xix) Hail Impact test

The objective of this test is to ascertain the mechanical integrity of the PV module during hail impact.

Test conditions:

- 1 Circular Ice balls of 25mm dia are bombarded with a velocity of 23 m/sec.



## 2.2 Outdoor Test Bed facility

### 1. Outdoor PV performance & reliability

Long-term reliability of PV modules is very important for the commercial success of PV technology, as it is one of the key factors that affect the cost of PV generated electricity. Reliability and life time of PV modules depends upon the degradation of PV modules operating under real outdoor conditions. Therefore studying and understanding degradation of PV modules is of utmost importance. The studies on the degradation and failure mechanism are often based on accelerated degradation experiments. In these experiments stresses such as radiation, temperature, humidity, UV radiations are applied to PV modules in a controlled environment. These tests have been found to be very useful in identifying the infant failures and improve the module designs. However, it is not possible for the accelerated degradation tests to reproduces all the defects and degradation mechanisms identified during the outdoor exposure. This is due to the different reaction rates and the combination of different mechanisms which may take place during real-time field exposure. Fig.1 shows the part of outdoor PV test bed of NISE.

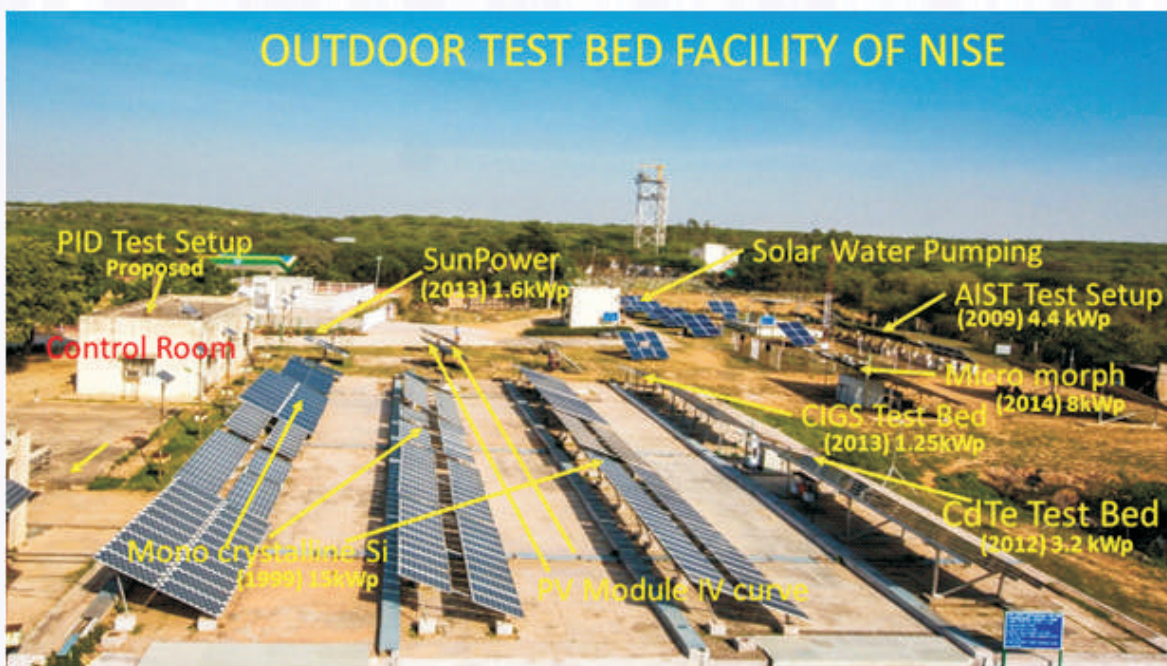


Fig.1 Part of outdoor PV test bed of NISE.

Table 1: Different PV module technology installed at outdoor test bed facility of NISE

Name of Test bed	Type of PV Technology	Capacity (kWp)	Outdoor Exposure Duration (Years)
Mono crystalline test bed	Mono-Crystalline	25	15
AIST-SEC (NISE)	a-Si	1.2	5
	Poly-Crystalline	1.6	5
	HIT	1.68	5
CdTe Test bed	CdTe	3.2	3
CIGS Test bed	CIGS	1.25	2
Sun Power Test bed	Maxeon (high efficiency)	1.64	2
Micro-Morph Test bed	Micro-Morph	8.0	1

Concentrated PV Test bed	GalnP/GaInAs/Ge multi-junction cells embedded in 500X reflector based concentrator unit.	1.02	7
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### Outdoor Module Facility at NISE



Fig 2 Outdoor Module Facility at NISE

#### a. Mono Crystalline Test bed

15 kWp mono crystalline test bed has consisted of 11 different manufacturers. This test bed was installed at NISE in 1999. Initially test bed was established with 25 kWp (10 kWp tracking + 15 kWp Fixed tilt). After long term exposure some of the module needs to be replaced and now, 15 kWp mono-crystalline PV modules are installed at fixed tilt structure (at 28°) and they are currently operational and monitored on regular basis.

#### b. NISE - AIST Test Bed

To study the effect of environmental parameters on different PV technologies AIST-NISE together started project at NISE in October 2009. The three different cell technologies are used in the test bed multi crystalline silicon (mc-Si) (1.6 kWp), amorphous silicon (a-Si) single junction (1.2 kWp) and HIT (Hetero junction with intrinsic thin layer) (1.68 kWp), all from Japan. They are installed at a fix tilt (28°) equal to latitude of the site, in the premises of National Institute of Solar Energy, Gurgaon. The data of solar irradiance (tilted at latitude and horizontal), module temperature, ambient temperature and other parameters are logged (through CR1000 data logger) once in every minute where as I-V data of each PV technology is logged (through CR1000 data logger) once in every ten minute. A comprehensive weather platform along with PV array analyzers installed to record climate change on test bed area in year 2009. The data parameters recorded at the weather station are Global solar radiation at module tilt and horizontal surface, spectral distribution of solar radiation (MS-710 and MS-712 Spectrometer), wind speed and direction (Anemometer), relative humidity and

temperature (Humidity and temperature sensor), solar UV radiation (UV radiometer), atmospheric pressure (Pressure sensor) and dew monitor unit, all the data save on per minute basis.

a. CdTe Test bed Facility

CdTe test bed was installed at the outdoor PV test bed facility of NISE under the joint collaboration project between NISE, India and M/s First Solar, USA. CdTe test bed was installed in June, 2012 along with a weather monitoring station as shown in Fig. 3. This test bed consists of 40 CdTe modules joined together in 4 parallel strings; each string consists of ten modules in series.



Fig. 3 Front and rear view of CdTe test bed installed at NISE

The capacity of this test bed is around 3.2 kWp. All the modules were mounted on fixed mounting structure at a tilt angle  $20^\circ$  facing south. The output of whole of the array was fed in to a 3.3 kVA inverter and generation data is logged and measured data is saved in a CR3000 data logger. CdTe test bed consists of a weather monitoring station and CR 3000 data logger from Campbell Scientific. Pyranometer (Make: Kipp & Zonen, CMP11, error  $<10$  W/m<sup>2</sup>); combined sensor for measuring Pressure, humidity, precipitation, temperature, and, wind speed & direction, (Make: Vaisala, WXT 520, accuracy wind speed  $\pm 3\%$  at 10 m/s; wind direction  $\pm 3^\circ$ ; rainfall 5%); T-type thermocouples are used to record individual PV module temperature. The data monitoring system was installed along with CdTe test bed in July 2012. This monitoring system has been crucial for identifying and correcting performance problem and has greatly enhanced the educational value of PV array. The data of irradiance (at a tilt of 200 and horizontal), module temperature, ambient temperature, wind speed, wind direction, humidity and I-V data are logged regularly after ten minutes of time interval.

a. CIGS Test bed Facility

This is also a joint collaborative project between NISE, India and M/s Stion Corporation, USA. CIGS arrays were installed at NISE in Jan 2013 shown in fig. 4. The total capacity of CIGS test bed is 1.25 kWp. Each module having peak power 125 Wp and 10 modules are connected in series. The power generation data is monitored by Grid interactive type inverter. The module are installed at



Fig.4 CIGS Test Bed Facility at NISE

CIGS modules are connected with a 2.2 kVA inverter. The power generation data is continuously stored in the PC.

a. Sun Power Test bed

The Sun Power test bed was installed at PV outdoor test bed facility of NISE in January 2013. The Sun Power array consist of 5 modules all connected in series with each module rated of 327 Wp, thereby making an array of 1.6 kWp as shown in Fig. 5. The performance is measured on regular basis. I-V data measured on continuous basis on regular interval by using I-V tracer, PVPM 1110C.



Fig. 5 Sun Power Array installed at the outdoor test bed facility of NISE

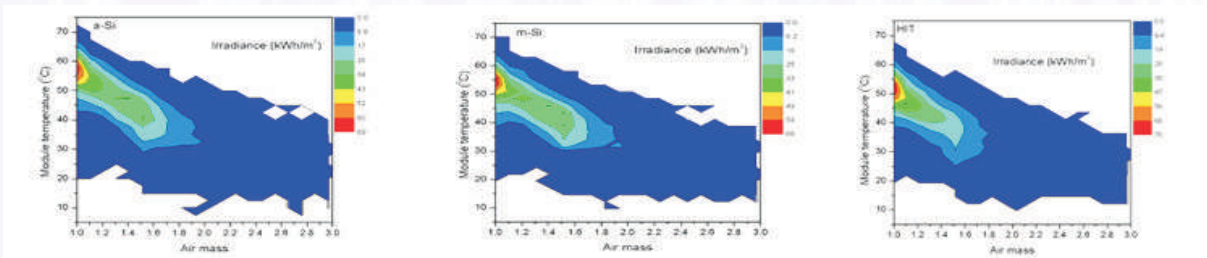
a. Micro-morph PV Test Bed at NISE

A grid connected test bed of micro-morph based thin film PV technology has been commissioned at NISE, Gurgaon in the collaboration with Tokyo Electron Limited (TEL Solar) Japan in April 2014 (Fig. 6). The rated capacity of the test bed is 4.4 kWp having four strings consists of total 40 modules, each of 110 Wp rated capacity. The test bed consists of two SMA inverters, four thermocouples for module and ambient temperature, two reference cells, one Pyranometer, anemometer, wind vane, humidity and rainfall sensor along with the array.

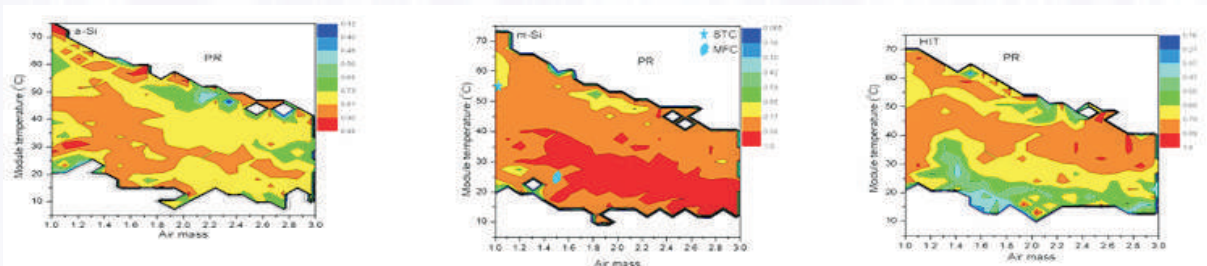


Fig. 6 Micro-morph based thin film PV technology test bed at NISE

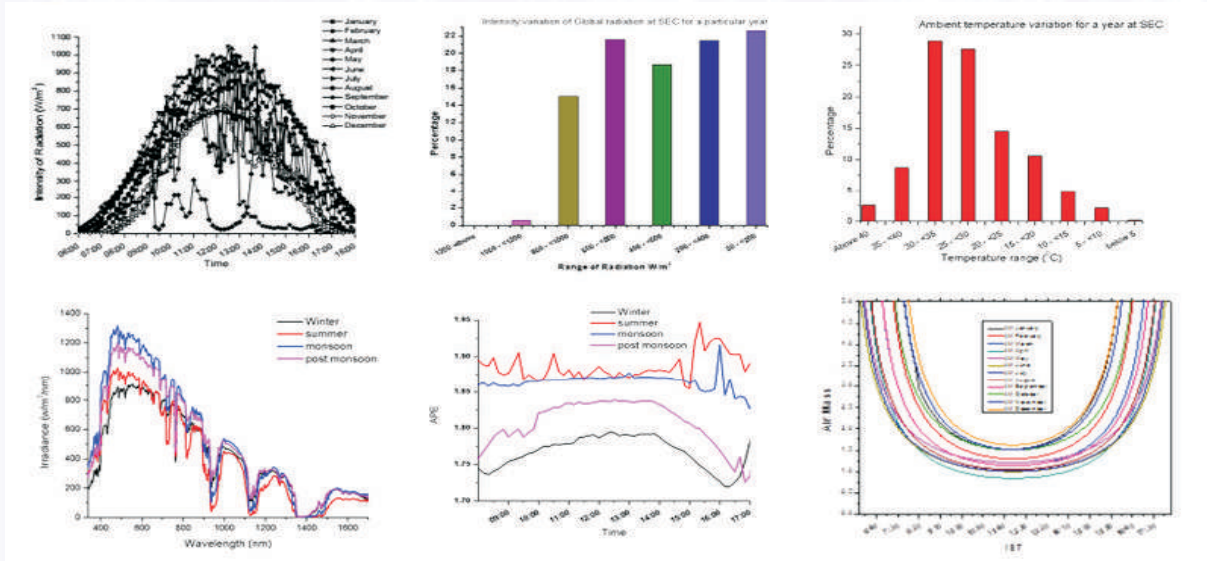
MFC and Site Specific Suitable Three PV Technologies



Variation of PR with Air -mass and Module Temperature



Radiation data, Spectrum and APE Analysis and Feasibility of PV Technology



## 2.3 PERFORMANCE AND RELIABILITY STUDIES OF PV MODULE

### INTRODUCTION

While the Photovoltaic (PV) industry is experiencing an extraordinary growth at present, the main challenge faced today is to make PV generated electricity cost effective. So, it is important to identify factors through which the cost of PV generated electricity can be reduced. The main cost drivers are:

- | Performance of PV modules
- | Cost of PV modules
- | Long-term reliability of PV modules
- | Cost and durability of BOS components

It is well known that performance of PV modules is a function of location, season and the type of technology. A number of technologies ranging from wafer-based silicon to monolithic thin-film technologies are available in the current PV market. Out of these, crystalline silicon PV technology is well established and shares about 90% of the world's PV market. However, the upcoming PV technologies such as Hetero-junction with Intrinsic Thin layer (HIT), Moxeon high efficiency and multi junction (MJ) under concentrated sun are expected to take up larger shares of the PV market in the near future. The main advantage of using mono-crystalline silicon modules is their high efficiency which ranges between 19 to 23%, but the complicated manufacturing processes of these modules, especially those in the high efficiency range, results in low throughputs and high costs. Poly-crystalline silicon technology modules, owing to the lower cost of wafers, are less expensive but have lower efficiencies ranging between 17 to 19%. The CdTe and CIS thin film modules are the most popular thin film technologies today with module efficiencies ranging between 12 to 16%. Recently, there are claims that higher efficiency sub-modules up to 19% have already been fabricated. Multi junction solar cells based on GaAs and employing up to four junctions have shown efficiencies reaching up to 44% in the laboratory under high concentrated (500 Suns) light. These type of cells with high efficiency values up to 37.4% are also available in the world market. It should be noted that these modules can perform better only at high DNI sites such as Ladakh, Rajasthan and Gujarat. Amorphous silicon thin film modules were popular once among the thin film modules due to their low cost, however, their market share has gone almost to nil due to the low efficiency and stability/ reliability issues that these modules suffer from in outdoor conditions. Extensive research is going on to achieve cost break by improving the efficiencies of PV cells/modules.

Further, the cost of PV modules account respectively for 40% to 60% and 30 to 50% of cost of the PV system depending on whether the application is grid interactive or stand-alone type. Due to the advancements in PV technology, the cost of PV modules has declined drastically, from Rs 220/W<sub>p</sub> during the early nineties for the first generation PV modules to Rs. 40 /W<sub>p</sub> during 2014. This cost is expected to decline further to Rs. 30/W<sub>p</sub> or less within the next few years. Several approaches are adopted since 2004 to reduce the cost of PV modules. These include introducing changes in the module design and manufacturing processes as well as developing new, low cost materials.



Many current module designs, especially those manufactured after 2004, are substantially different from the earlier designs in terms of materials and construction. The major changes brought about include use of thinner p-type silicon (Si) wafer (approx. 120 $\mu$ m), less number of encapsulant layers, use of thinner n-type wafers and all back contact technologies to increase the efficiency and counter the Potential Induced Degradation (PID) effects. In monolithic thin film modules, frameless designs, alternative back-sheet materials and modified cell interconnect are adopted to improve reliability and to resist impact due to leakage currents under high temperature, humidity and high voltage environment. The NISE have identified through extensive studies, a variety of failures during the field operation of these modules having different designs. It is not clear whether these failures are due to changes in the design or due to various thermoelectric stresses experienced by these modules under very harsh environmental conditions in India (at NISE) compared to cold and less humid climate of Europe. It is important also to note that the NISE studies on mono crystalline Si modules manufactured before 2000 indicate low degradation even when the modules designs were not qualified as per IEC 61215 . However, some of the latest modules from a few manufacturers based on multi and mono crystalline silicon showed growth of a range of defects and large degradation due to micro cracks and PID. The studies using thin film module based test beds at NISE indicate that even the latest designs of thin film modules suffer from failures such as cracks in the conducting oxide layer, shunts due to pin holes and fast delamination.

One of the reasons for the premature failures could be that many new manufacturers with no or limited prior history or experiences are entering the PV module fabrication business. To reduce the fabrication cost they adopt disorganized and poor quality control methods during fabrication process raising serious questions on the quality of modules. Another important reason is that the PV industry has started finding new large scale ( $MW_p$  capacity) applications worldwide in all the climatic zones with various mounting configurations (ground mounted, roof mounted or Building Integrated etc.) which make the task more challenging. Detection and investigation of the defects is another challenging task in these modules. Some of the defects are visually detectable, however, sophisticated tools such as electroluminescence (EL) testing, infra-red (IR) thermography, cell line checker, high-POT test, bypass diode test and on site I-V measurement techniques are required to identify the nucleation and growth of these defects. Also, efforts are underway in making qualification tests more quantitative by creating a comparative rating system for various conditions encountered worldwide by the PV modules in the field.

Thus, issues related to long term reliability of PV modules is gaining more and more importance today. The qualification standards developed by the International Electro-technical Commission (IEC), such as IEC 61215 (for wafer based crystalline Si modules) and IEC 61646 (for thin film modules) and IEC 61730 have helped ensure to some extent long term reliability of PV modules. Ideally, it is considered that these standards have been devised to simulate severities that a PV module are exposed to under actual field conditions during a span of 20 to 25 years. Merely qualifying IEC standards does not guarantee of long-term performance or service lifetime. The main objective of the IEC qualification standards is to replicate the field identified degradation mechanisms/ defects using the accelerated lab environment and further, extrapolate the results to life time conditions to estimate the power degradation. The qualification testing involves a set of well-defined accelerated stress tests with strict pass/fail criteria. Stresses such as visible radiation, temperature, humidity, UV radiation, wind and operating voltage are applied as per predetermined sequence in order to reproduce in shorter interval of time, the degradation and defects observed during the actual field exposure of modules. Although, these qualification tests provide some useful information regarding flaws in PV module design, materials and process which can lead to premature field failures, they are not designed to check for module wear out and hence are not able to estimate the module life time . While there are numerous reports on modules that have survived in the field for more than 20 years , there are also reports of qualified modules that have failed in the field before completing the required service lifetime. Therefore, it is now broadly opined that the IEC standards do not adequately address the real outdoor conditions.

In recent times, two surveys of photovoltaic module degradation have been conducted by NCPRE and NISE in 2013 and 2014 with the objective of assessing the degradation of PV modules installed in five different climatic zones of India. The result of the survey of these modules, which have been in the field for durations ranging between 1 to 30 years, have yielded mixed results. While the recently (< 5 years) installed modules suffered from high rates of degradation, the older modules (> 20 years) showed degradation lower than that predicted by the IEC standards. As compared to the other zones, a higher percentage of modules suffered from corrosion in the hot and humid zone. The modules installed in the cold climate zone suffered the least degradation.



The term “reliability” for PV modules may be defined in a number of ways. The most acceptable definition of reliability is in terms of safety and performance. The safety condition should be as per the Government norms i.e. as National Electric Codes (NEC). The performance degradation under out-door operation conditions during the period of its lifetime should be within the boundary conditions specified in the standards. As per Mani et al., it may also be defined as a PV module that has a high probability of performing its intended function adequately for 30 years under the operating conditions encountered. The term “high probability” means that 95% of the modules in the field will achieve this success. To be simpler and specific, it may be said that a PV module fails to provide service if its power output decreases by more than 30% after 30 years in its use environment. By “use environment” it is meant all the environmental stresses that a PV module will experience during the service period.

Keeping in view all these aspects, studies on performance and reliability of PV modules have been carried out at the Solar Energy Centre (SEC), now known as the National Institute of Solar Energy (NISE), since 1995. The NISE is an autonomous and apex National R&D institution of the Ministry of New and Renewable (MNRE) in the field Solar Energy. The institute is involved in a variety of activities such as demonstration, standardization, interactive research, training and testing solar technologies and application systems. The main objective of the NISE is to act as an interface between the Government and institutions, industry & user organizations for development, promotion and widespread utilization of solar energy in the country. The results of preliminary studies on module degradation at the NISE has already found recognition in 2010 from several working organizations/ Labs such as NREL, AIST, Fraunhofer ISE etc. who, on realization of the importance of the issues of reliability of PV modules, showed interest to participate in the on-going study and establish test beds for monitoring performance and degradation of PV modules.



## Design of PV module test bed for reliability Study

The long term performance and reliability of PV module is increasingly becoming a critical subject as crores of rupees are being invested annually in this area. The irreversible and reversible degradation of PV modules and the failure modes need to be studied for different climatic conditions. Long term performance of a photovoltaic module is strongly dependent on the site conditions such as irradiance, spectrum, air mass, seasons, angle of incidence, module temperature, wind speed and humidity. In order to study the field reliability of solar modules, it has to be installed in a test bed configuration. Different types of test beds, which are installed at the NISE and their relative advantage over other parameters related to installation and performance evaluation, are discussed in this chapter.

For characterization of electrical energy, the performance indicators such as performance ratio (PR), energy yields ( $Y_i$ ) and reference yields ( $Y$ ) are to be estimated and independently analysed for each site and PV technology. Further, it has been found that the temperature pattern and the variations in the solar spectrum influence the overall performance parameters. To study these parameters of a site for different PV technologies, it is necessary to establish PV test bed for data monitoring and analysis. A PV test bed is a small capacity power plant(s) consisting of arrays of modules with different PV technologies that are to be evaluated for the specific site. The simplest form of test bed is small capacity power plant (up to 1 kW) with a detailed monitoring system. The other type of test bed measures I-V characteristics at a pre-defined interval of time. It may be automated or manual depending upon the monitoring system.

**Design parameters:** A proper design of the test bed is very important because it should have a long operational life, no shadowing throughout the year and should be free from unauthorized tempering of components. There are different factors considered for the establishment of test beds are stated below:

**Site selection:** For the establishment of a test bed, the site selection and preparation for installation are the most important factors. The selection criteria of site for the test bed are given below:

- I. Availability of solar radiation
- II. Availability of vacant land
- III. Topography of the land
- IV. Shadow
- V. Soiling
- VI. Accessibility to the area



### Weather station system:

The test bed should be equipped with a weather station to collect the following data. The height of the weather station should be same as the height of the PV test bed.

Parameter	Instrument to be used	Input/output Range
Global irradiance in plane to the module surface and at horizontal surface	Pyranometer (Thermopile or silicon solar cell based)	For thermopile based Wavelength: 0.3 to 3 $\mu\text{m}$ 0-1400 $\text{W}/\text{m}^2$ For Silicon solar cell Wavelength: 0.3- 1.1 $\mu\text{m}$ 0-1100 $\text{W}/\text{m}^2$
Silicon radiation	Reference solar cell	Wavelength: 0.3 – 1.1 $\mu\text{m}$
Direct normal Irradiance	Pyrheliometer	0-1400 $\text{W}/\text{m}^2$
Spectrum	Spectroradiometer	Wavelength: 0.3 to 1.7 $\mu\text{m}$
Ambient temperature	Digital Thermometer	-40 to +60 $^{\circ}\text{C}$
Wind speed and direction	Anemometer/ wind monitor	For wind speed 0-99 mph For wind direction 0 -359 $^{\circ}$
Atmospheric pressure	Barometer	500-1100 hPa
Rain	Rain Gauge	0 - 9999 mm
Humidity	Humidity probe	10 – 100%
Angle of incidence of Sun light	Sensor of angle of incidence	-90 to +90 $^{\circ}$

### PV monitoring unit:

To assess and characterize the PV systems, necessary equipment needs to be added to the test bed to do electrical measurements and monitor the DC voltage and DC current. The temperature of the module needs to be monitored by using temperature sensor at the back side. Temperature sensor should be placed at three different positions i.e. top, bottom and middle of the PV module.



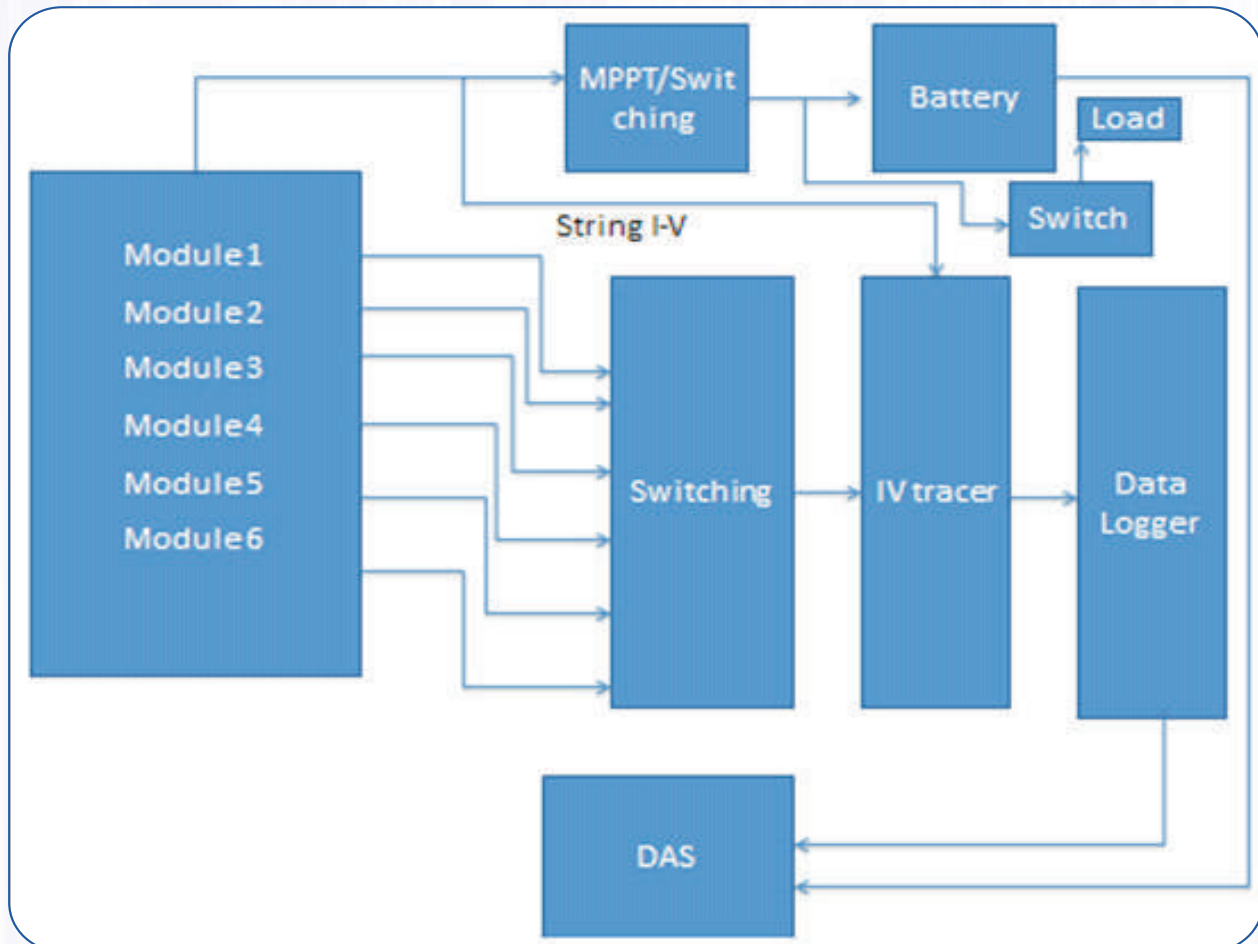
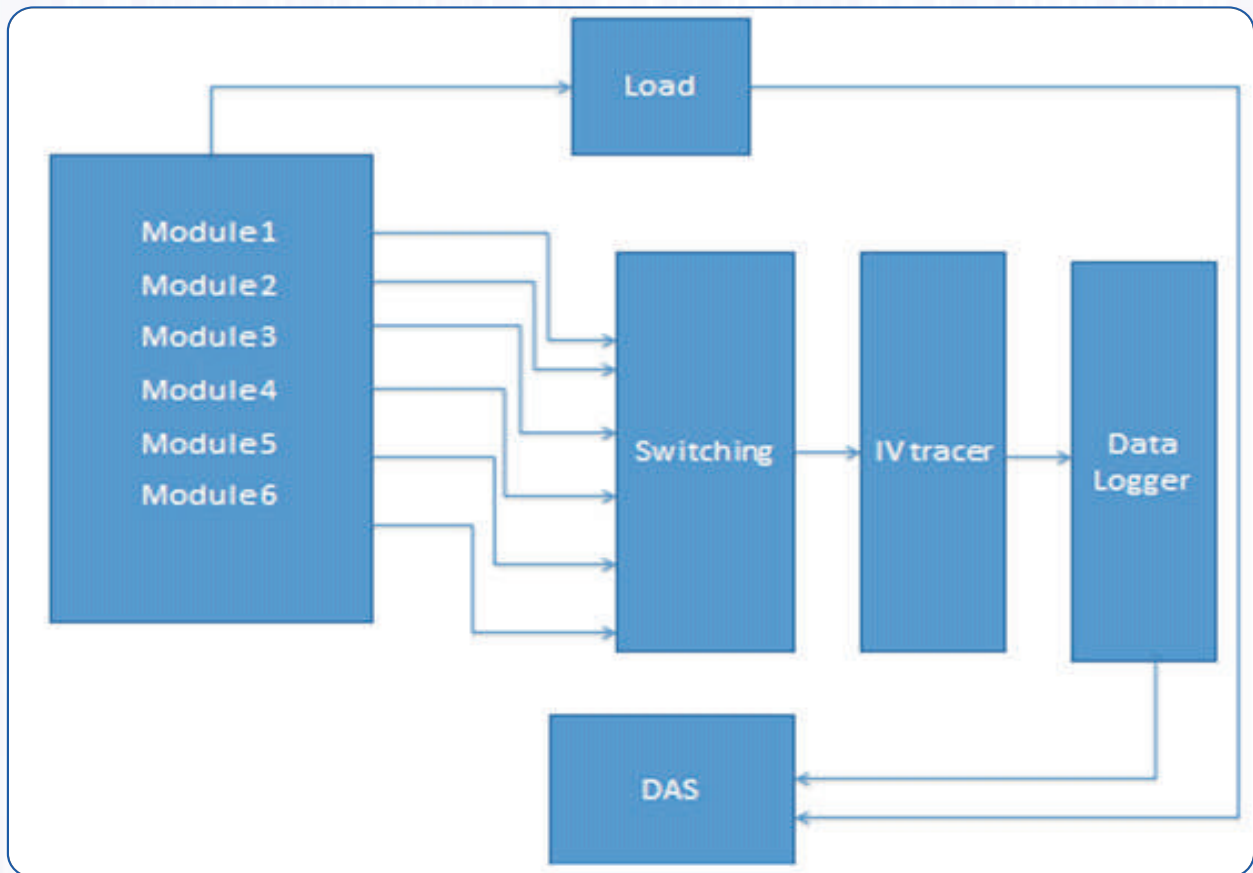
Parameter	Instrument to be used	Input/output Range
Open circuit voltage and voltage at maximum power point	I-V tracer/inverter	0-1000 V DC, Accuracy $\pm 0.5\%$ , $\pm 0.25V$
Short circuit current and current at maximum power point	I-V tracer/inverter	0-20A DC, Accuracy $\pm 0.5\%$ , $\pm 40mA$
Module temperature	Temperature sensor	$-40^{\circ}C$ to $+120^{\circ}C$
Tracker tilt angle	Angle measurement sensor	0 to $180^{\circ}$
Tracker azimuth angle	Angle measurement sensor	0 to $180^{\circ}$

Also, two unexposed reference modules for each technology are required to be kept inside. For studying the effect of unloaded condition one module needs to be installed in open-circuit condition. Usually there are two different PV system designs used to assess the performance of PV module technologies which are stated below.

Test bed with I-V tracer:

Two types of exposure procedures are used in the reliability testing of modules using I-V tracer. In one, known as “module exposure test”, each module is exposed without load and in the other, known as “system exposure test”, the array consisting of several modules is exposed under MPPT control with loads. In each procedure, the I-V characteristics of the module and that of the array are measured at a certain time interval, e.g. five to ten minutes. In the module exposure test, modules are kept in loaded condition during the stand-by or non-measurement mode. These modules are connected to the load in parallel mode. In system exposure test, the operational current under MPPT control flows in the modules during the stand-by mode. This is the same condition in which the modules are maintained during actual use. Moreover, in the system exposure test, the string voltage potential should be similar to the one used in the MWp scale power plants. String voltage potential may cause potential induced degradation during the system exposure test. The procedure of the system exposure test has more possibility of causing failure(s) such as hot-spot, insulation failure, delamination, etc. than the module exposure test.

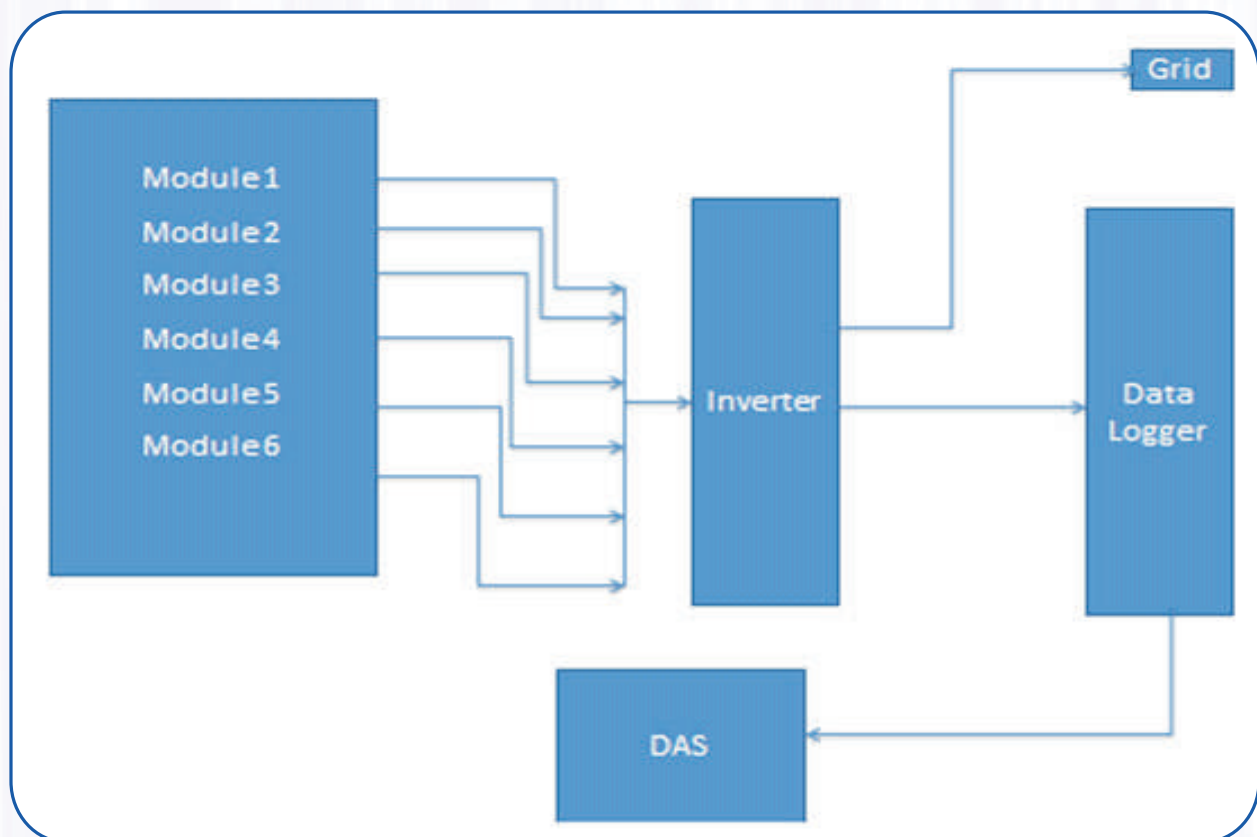
In a grid-connected system, a power conditioning system is included, which maintains the MPPT condition and connects the system to the grid. In case of stand-alone measurement system, the MPPT point of the PV array is controlled by the MPPT unit and the power is stored in battery via the charge controller during the stand-by condition. The power stored in the battery is used for measurements. If the power exceeds the battery capacity, the excess power will be consumed by the electrical load.



### Test bed with Inverter:

In case of a test bed with inverter, modules can be exposed in either way. In case of system exposure, the array of several modules are connected to the inverter as connected in a power plant. The inverter should be operated at MPPT. Operating with MPPT Load, Megawatt scale power plant can also be used as a test bed if the system voltage needs to be maintained. The measurement of maximum current and voltage can be done with the help of a MPPT controller within a certain interval of time (6 times a second). For the measurement of short circuit current and open circuit voltage, usually two reference modules are used with a relay. This can be referred to as the module exposure test. However, for single module exposure test, I-V tracer is the best way to do the measurement.

The MPPT unit samples the output of the PV modules and selects the most appropriate operating point to obtain maximum power under the prevailing environmental condition. The PV performance data collected should include the MPPT efficiency. Operational data needs to be recorded for a sufficient period of time to allow the PV modules to complete any initial light induced degradation and to collect a minimum of one year of operational data in order to visualize the impact of seasonal weather variation on each PV system.



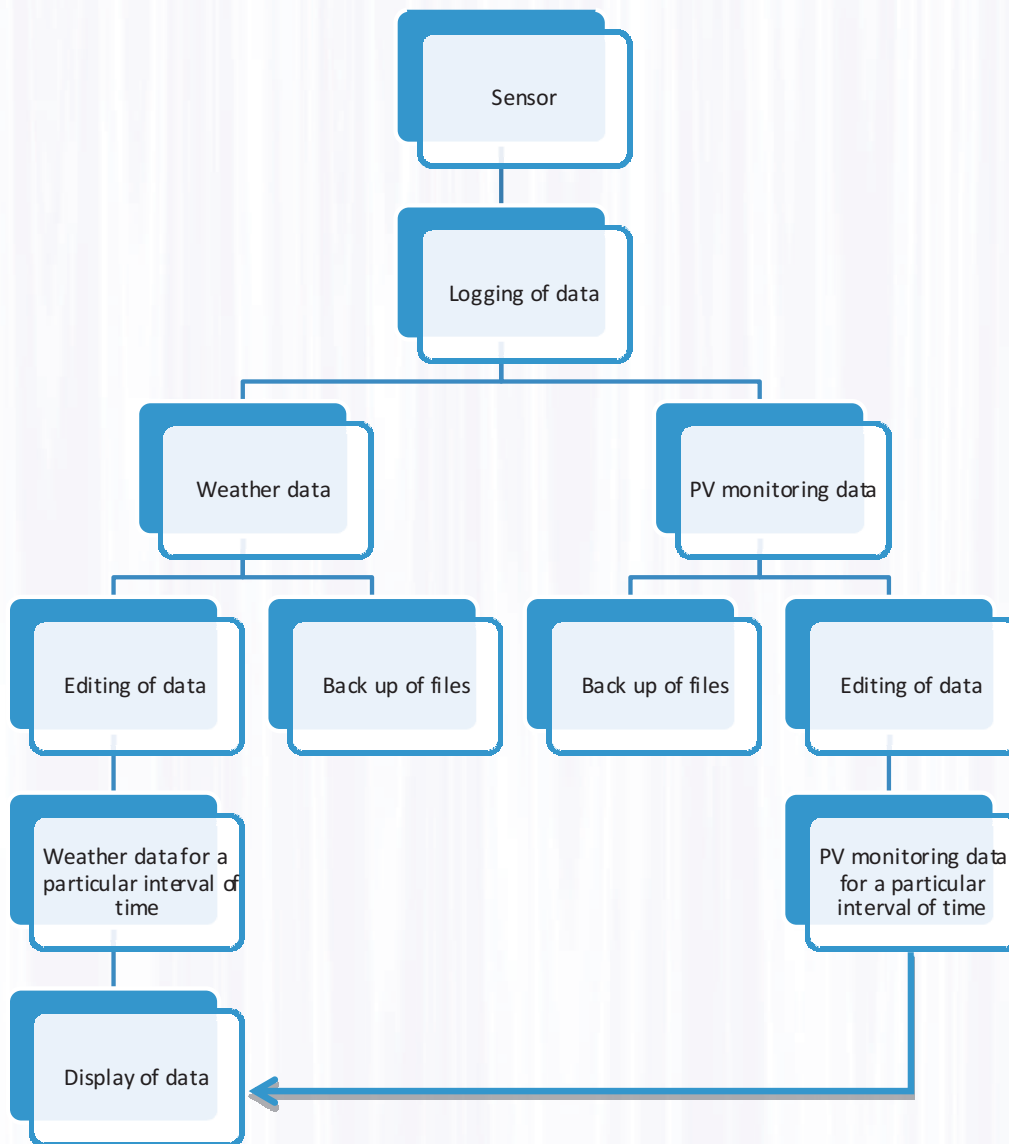
The major advantage of I-V based monitoring is that it can monitor the I-V data all the time and its MPPT can be estimated along with the other parameters such as  $I_{sc}$ ,  $V_{oc}$  etc. In this configuration, it is also possible to check the individual module and study the position dependence of the degradation in the I-V performance to make sure that the string is always in a loaded condition. In case of inverter connected test bed the availability of grid is more important

because energy cannot be fed if the grid is unavailable. This results in an open circuit condition, which might lead to loss of data. This is one of the major problems in case of inverter based test bed in a developing country like India. At NISE, both types of test beds are available. However, the inverter based test bed is connected with the local smart grid such that the data losses can be minimized.

#### **Software and data acquisition system:**

The software should consist of program for sensing the output from weather sensors for estimating, averaging, integrating and tabulating weather parameters. An Embedded device needs to collect all data from weather sensors and form tables in data base using MySQL freeware database package. It is possible to create CSV files containing individual table as well as the entire database. The data can be collected over a long time and the data for a specific period can easily be obtained. The software also includes program for I-V measurements of PV arrays and modules against time. The data should be collected for 24 hours. The heart of the data logging facility is the time stamp which helps the user view and compare the I-V curves over selected time period for modules with different technologies. This is achieved by using indexing feature of the database tables, so that the insertion and retrieval of data can be fast, even if the time span of data collected extends to several years. It is estimated that for measurements spanning a day, about 230 KB are required for weather data and about 3 MB are required for storing PV monitoring data per day for a single technology.





### Desirable features of DAS

The following are the desired features of the data acquisition system or DAS fitted to the PV system under study.

- I. The system should be highly reliable for operating in harsh environment.
- II. It should support the following:
  - a. high channel to channel isolation,
  - b. noise rejection,
  - c. surge suppression and
  - d. Signal conditioning
  - e. low-cost, high-density I/O, analog and digital modules
- III. Should be easily installable and expandable.

### Points to be remembered before installation of a test bed

The following points needs to be kept in mind while installing a reliability test bed:

- I. Initial STC and dark I-V measurement of all modules need to be done after preconditioning and proper records should be maintained of these.
- II. Visual inspection of the modules should be done properly.
- III. Inspection of modules should be done with sophisticated tools like EL, IR, cell line checker, insulation resistance, bi pass diode etc..
- IV. The reference module should always be kept unexposed.

### **Data Analysis tools and performance index**

The data generated out of the actual measurements on the test bed need to be thoroughly analysed. A tool is needed to extract the data as text file to populate an excel database or matlab data base to analyse the performance. The software for this consists of a program for sensing inputs from weather sensors for estimating, averaging, integrating and tabulating weather parameters. An embedded device will collect all the data from weather sensors, form tables in the database using database package. It is possible to create CSV files containing individual table, as well as the entire database. The data can be collected over a long period of time and the data for a specific period can easily be selected. Software also includes a program for I-V measurements with time for PV modules and arrays. This operates only during the sunny hours of a day. The heart of the data logging facility is the timestamp which helps the user view and compare I-V curves over the selected time period for modules using different technologies. This is achieved by using indexing feature of database tables, so that the insertion and retrieval of the data can be done quickly even if the data recorded span years. It is estimated that in a day about 230 KB are required for the data on weather and about 3 MB is required for storing the data on PV monitoring for one technology. The performance index used for analysing the data is given below:

#### **Performance Ratio (PR):**

The final PV system yield,  $Y_f$ , is the net energy output  $E$  divided by the nameplate d. c. power  $P_0$  of the installed PV array. It represents the number of hours that the PV array would need to operate at its rated power to provide the same energy. The units are hours or kWh/kW. The  $Y_f$  parameter normalizes the energy produced with respect to the system size; consequently, it is a convenient way to compare the energy produced by PV systems of different sizes:

$$Y_r = \frac{H}{G} \text{ Hours}$$

The performance ratio PR is the ratio between energy yield and reference yield. By normalizing with respect to the irradiance, it quantifies the overall effect of losses on the rated output due to inverter efficiency, wiring losses, mismatch and other losses when converting from DC to AC power, PV module temperature, incomplete use of irradiance by reflection from the module front surface, soiling or snow, system down-time and component failures:

$$PR = \frac{Y_f}{Y_r}$$

PR values are typically reported on a monthly or yearly basis. Values calculated for smaller intervals, such as weekly or daily, may be useful for identifying occurrences of component failures. Because of losses due to PV module temperature, PR values are greater in the winter than in the summer. If soiling of PV module is seasonal, it may also impact differences in PR from summer to winter. Decreasing yearly values may indicate a permanent loss in performance.

#### **Accuracy of measurements and uncertainty analysis:**

The acuteness or uncertainty of measurements of each system used to characterize the weather and PV system needs to be known accurately. The individual accuracy of each sensor should be within  $\pm 0.1$  to  $\pm 5\%$ . The overall system accuracy calculated by adding all accuracies range from  $\pm 0.5\%$  to  $\pm 5\%$ . However, before the performance analysis of the test bed following collection of the data, there should be data filtration so that the accuracy could be increased.

The accuracy and uncertainty will depend on many factors like repeatability of measurements, calibration of instrument, change in irradiance during measurement, module temperature distribution etc. The repeatability of measurements mainly depends on the data acquisition system, reference cell stability, spectral stability and temporal stability or fluctuations in intensity. However, for some of the modules which are sensitive to preconditioning and show transient and metastable behaviour, system stability is one of the major issues. It is, therefore, desirable to the use modules in the test bed after preconditioning. In case of data acquisition system, the module efficiency can register a change if the rate of sweeping the device voltage is very fast. The sampling rate should be decided based also on this criterion. While the calibration of the reference cell or the Pyranometer should be done regularly, it is also required to correlate with the initial value of the instrument and make an offset value. Otherwise, this would become a source of error for long term measurements. In case of the outdoor measurements, the correction for intensity fluctuations during the measurements need to be made. The irradiance during the measurement and at the time of plotting current-voltage curve from which  $I_{sc}$  and  $P_{max}$  are determined may have different values. The irradiance, therefore, needs to be measured before and after the measurement to eliminate this error. The change in Fill Factor of the module mainly

depends on the probe to metal contact resistance and the surface area of the contact. During long term measurements, if there are large differences in Fill Factor then the reason must be investigated and a solution found to the problem. In case of measurement of the module temperature, there may be day-to-day variation because of the change in calibration. The calibration of the sensor should be done once in a year. It preferred to use the flat type of temperature sensor to prevent it from getting detached from the module. Due to the variations in module temperature throughout the surface of the module, it is desired to measure temperature at three different points, i.e. top, bottom and middle of the module. There could also be an error due to spectral mismatch for different PV technologies, to compensate which a mismatch factor needs to be used during performance analysis of the module.

### **Operation and maintenance:**

For maintaining quality control and safety standards, the installation should be done by qualified personnel only. Safety is a serious concern while installing the test bed. The safety precautions should be taken as per the IEC standards.

Following are the main issues regarding the maintenance of the power plant:

1. Checking of the logged data every day
2. Checking and maintenance of sensors on a daily basis
3. Cleaning of the module and the Pyranometer regularly early in the morning
4. Inspection of the module visually and using sophisticated tools at a regular interval of time
5. Calibration of the measurement instrument every year
6. Dark and Light I-V (STC) measurement every year
7. Replacement of the defective and irreparable modules
8. Downloading of the data at a regular interval

### **Summary:**

Measurement of reliability through long term exposure of PV modules requires regular and repeated measurement of the current and voltage. The installation should be done by skilled and qualified personnel only. Maintenance of the test bed is a high priority task to make the collected data more reliable. However, during analysis of the accumulated data, filtering of the data must be done with caution. The time interval of sampling of data on weather and PV performance should be decided such that the change in irradiance does not affect the performance analysis of the test bed.

## 2.4 Solar cell and outdoor PV module characterization lab

**Introduction:** Solar cell and outdoor PV module characterization group at the National Institute of solar energy (NISE) focuses on sustainable development of photovoltaic technologies by evaluation of technical, environmental, and economic performance, cooperation with institutions & industries and testing & standardization. This group has capabilities and expertise in measurements, characterization, reliability engineering, scientific computing and theory to support photovoltaic (PV) research and development (R&D) across a range of PV technologies. For characterization of solar cells and PV modules in real outdoor condition, this group is closely working with renowned institutes to develop a world class facility at NISE.

### Solar cell characterization lab:

NISE has established a facility for testing and evaluation of performance of Solar Cells as per IEC 60904-1:2006/IS 12762 (Part1). The facility has an ORIEL's class AAA "SUN Simulator" which provides a continuous steady state source and an electronic load capable of testing 6 inch X 6 inch solar cells of any type. The cell can be tested under standard test conditions (1000 W/m<sup>2</sup>, cell temperature of 25°C, air mass 1.5). The spectrum of the source qualify for IEC 60904-9; 2007 edition, or ASTM E 927-05 standards. The current-voltage (I-V curves) measurements, both in dark and under illumination can be studied at different intensities and temperatures. Fig. 1 shows a picture of the solar simulator. The standard spectrum of AM 1.5 is given in Fig. 2.

The components of the Sun simulator include the following:

- I. An illuminator with a built in arc lamp ignitor
- II. An arc lamp power supply (1.6 kW)
- III. An arc lamp
- IV. Heat sink
- V. Lamp socket adaptor
- VI. Air mass filter
- VII. All necessary adapters and cables

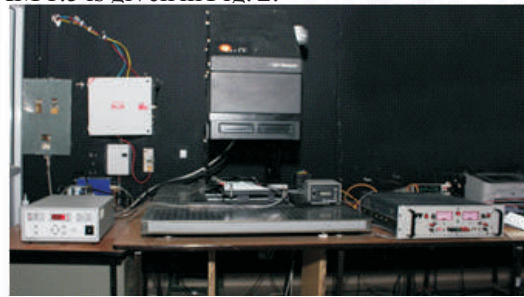


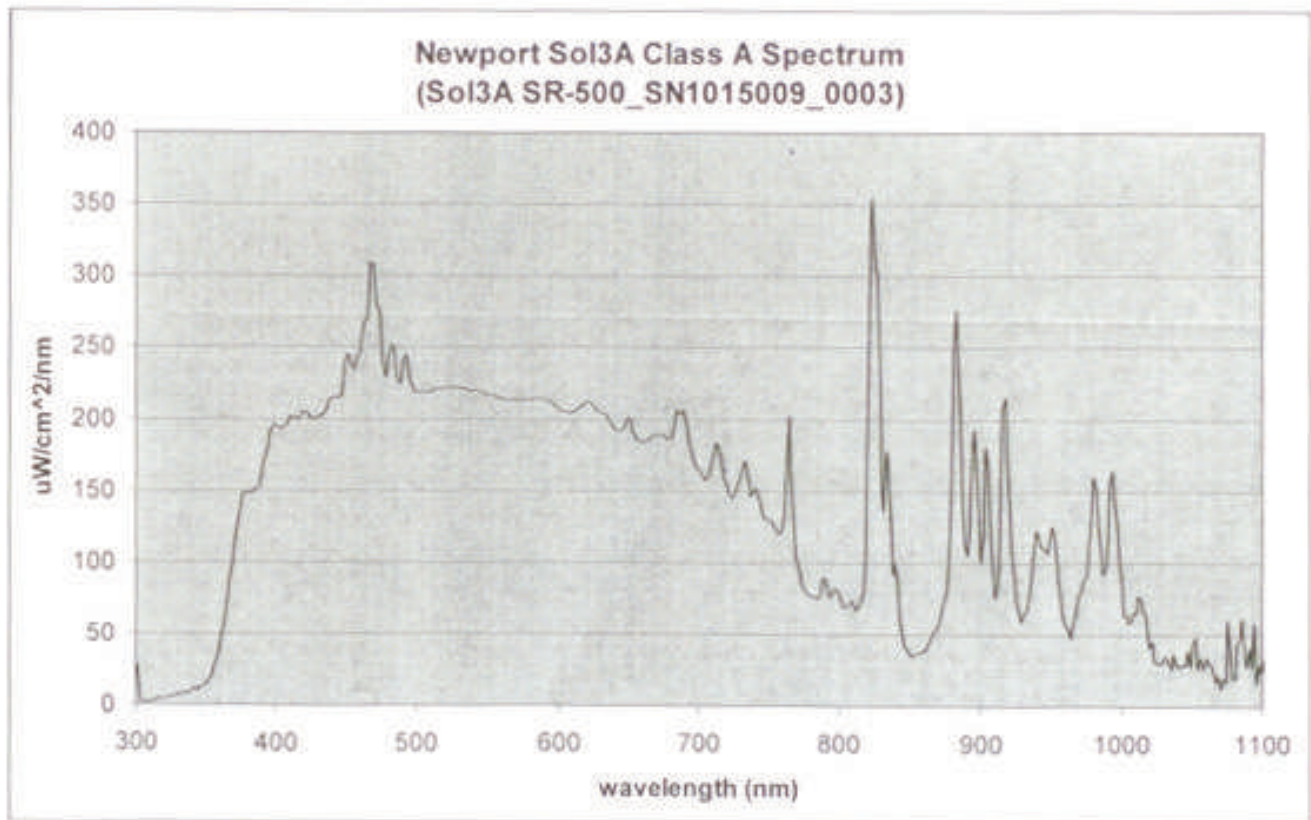
Fig. 1. Oriel 3A Solar Simulator

Table 1: Class AAA solar simulator family

Model	Lamp power (Watts)	Output beam			Collimation
		Inches	Millimeters	Working Distance	
SP1000-4966	1600 W	12 X 12	305 X 305	12.00" ± 0.5"	<±1°

Table 2: Performance specifications of Class AAA Sun simulators

	IEC 60904-9-ED2 Class A	JIS Class A	ASTM Class A
Spectral Match	0.75 - 1.25% Fraction of ideal percentage	.75 - 1.25% Fraction of ideal percentage	0.75 - 1.25% Fraction of ideal percentage
Non uniformity of irradiance	<2.0%	±2%	2%
Temporal instability	<0.5% short term instability (STI) <2.0% Long term instability (LTI)	±1%	±2%



**Fig. 2 AM 1.5 spectrum of the Solar Simulator**

Performance measurement of solar cells consists of the following tests:

- + Measurement of I-V characteristics under STC.
- + Determination of temperature coefficients
- + Measurement of I-V characteristics at different intensities and temperatures
- + Measurement of dark I-V characteristics of solar cell

The test report consists of:

- + I-V Curve
- +  $I_{sc}$ ,  $V_{oc}$ ,  $I_{max}$ ,  $V_{max}$ , F.F.,  $P_{max}$  and Efficiency under STC or specified conditions

#### **Outdoor PV module characterization lab:**

The NISE has an outdoor photovoltaic module testing facility comprising test equipment and set-ups for determining the energy rating of crystalline silicon as well as thin film PV modules as per the International standards such as IEC 61853 (Part1) and IEC 60891 (Edition 2.0). I-V measurements on PV modules under outdoor conditions, close to the standard test conditions, are performed by using a mounting structure which can track the Sun. Long term performance and stability tests for different types of PV arrays is also conducted under various weather conditions. Using an I-V tracer (PVPM) measurements are performed continuously, at preset time intervals. PVPM enables the measurement of I-V characteristics of single photovoltaic module as well as that of a string of modules. Figs.3 and 4 represents the outdoor test setup and I-V tracer used for thin film module testing. The following parameters are measured using this instrument:

- I. Reference cell temperature
- II. Global irradiance at the plane of the module
- III. Module temperature
- IV. Short circuit current
- V. Open circuit voltage
- VI. Maximum voltage
- VII. Maximum current
- VIII. Maximum power
- IX. Series resistance
- X. Shunt resistance
- XI. Fill Factor

**Table 3: Technical details of PVPM**

Measuring range	Voltage DC (V)	Current DC (A)	Temperature	Irradiance
PVPM2450C	250	40	-40°C - +120°C With Pt 1000	(0-1300)W/m <sup>2</sup> (standard sensor)
PVPM1100C	1000	20	-40°C - +120°C With Pt 1000	(0-1300)W/m <sup>2</sup> (standard sensor)

**Table 4: Operating Conditions of PVPM**

	Temperature	Dampness
<b>Operation</b>	0° - 40°C	10%-90%
<b>Storage</b>	-10° - 85°C	5%-95%

The accuracy of the instrument is about  $\pm 0.5\%$  which meets most of the requirements.

The outdoor testing of PV modules consists of the following tests

- + Visual Inspection
- + Determination of maximum power
- + Performance under low irradiance
- + Long term module performance and stability
- + Outdoor median performance



**Fig 3 Test set-up**



**Fig 4 I-V TRACER**

### National/International co-operation/joint projects

**Secondary reference solar cell calibration:** Under the JNNSM, installation of PV systems is steadily increasing in India. In this context, any uncertainty in measurement of efficiency of solar cells/ modules leads to an error in assessment of the product value, both from the point of view of technical and financial considerations. In India, plans are underway for installation of approximately 50 GW of solar PV systems (~ 50 % of 100 GW solar power planned including solar thermal installations) costing ~ Rs. 600 thousand Crore @ Rs 6.0 Crore per MW. In this scenario, even a 1% uncertainty in the measurement of module power may translate to an error of Rs. 6000 Cr. in the product value. This can be minimized using a calibrated reference solar cell which turns out to be of critical importance. Therefore, NISE is closely working with other institutes to develop a secondary reference cell calibration facility in the country. This is a joint project with PTB-Germany and NISE along with IIT Bombay, IACS Kolkata and Fraunhofer Institute for Solar Energy, Germany. Under this project a round-robin testing is in progress between NISE, IIT Bombay and IACS Kolkata. Already a comparison of measurement of four secondary reference cells has been carried out between NISE and IIT Bombay.

2.2 Comparison of performance of thin film modules in India and the USA, a joint project between NISE and NREL, USA: National Institute of Solar Energy and NREL have embarked upon a project to compare the performance of sister thin-film modules deployed in India and in Colorado, USA. NISE purchased a set of modules and shipped a subset of these to NREL. The thin-film modules were deployed in real outdoor condition in December 2013. The modules were then deployed outdoors where they were individually tracked for their maximum power point. Current-voltage (I-V) characteristics of the modules were measured at a regular interval of time. The data on module temperature, ambient temperature and irradiance were recorded along with each I-V curve. To investigate the outdoor performance of modules, the I-V data were filtered to eliminate curves affected by passing of clouds, snow covered modules, irradiance outside the range of 900–1000 W m<sup>-2</sup> and high angles of incidence. The filtered data was then corrected to an irradiance of 1000 W m<sup>-2</sup> and the module temperature to 25°C. The following are the main conclusions that could be drawn out of an analysis of the measured data till now :

- I. The Micromorph modules have lost power after light exposure; they are operating at 92 to 94% of the name plate power.
- II. The manufacturer recommended treatment of the CdTe modules increased the initial STC power (efficiency) by 15 to 18%. The outdoor median performance after treatment is less by 95-98% of the name plate value.
- III. The CIGS modules had the initial STC power improved by 4 – 5 % after light exposure. The modules operated in outdoor at 96 - 97.6% of the name plate efficiency.

### **All India Survey of PV module-II (2014), a joint project between Solar Photovoltaic Division, NISE and NCPRE, IIT Bombay**

This was a joint project between the Solar Photovoltaic division, NISE and NCPRE, IIT Bombay to study the field performance of SPV modules installed over period of time ranging from 20 years to the present covering installations in different climatic zones of India. These data are needed to determine the module reliability and understand the process of degradation of PV modules under Indian field conditions. Although the modules qualify for IEC 61215, 61646 and 61730 standards, the long term performance and annual degradation rates of these modules are different due to the diversity of harsh climatic conditions across the country. The environmental parameters strongly influence the cost economics and user confidence. This data can also be used to review and revise the existing module qualification standards and develop appropriate standards for India. The preliminary analysis of the results shows that new modules installed in the field are showing higher rate of degradation compared to the old modules.

### **SERIIUS Project:**

SERIIUS is a research management plan under Solar Energy Research Institute of India and the United States. It corresponds to the research work package submitted to the US Department of Energy (DOE) and the Government of India in response to the US-India Joint Funding Opportunity Announcement issued in May 2011 for R&D proposals in the priority area of solar energy. Under the SERIIUS project NISE's involvement is in the form of a characterization centre to carry out reliability studies. The main deliverables from NISE under PV module reliability testing is as follows:

- I. Identification of climatic zones and environmental conditions
- II. Modeling the performance of modules belonging to different technologies in different climatic zones
- III. Prepare general specifications of PV modules and components
- IV. Develop models using time-dependent indicators for reliability of module performance

Under the activity of multi-scale modelling and reliability, the activity of NISE is to analyze the effect of dust and its mitigation in different climatic zones of India.

### **STAPP Project**

A consortium of organizations from India and UK are jointly executing a project on “Stability and Performance of photovoltaics (STAPP)”. The project was sanctioned by the Department of Science and Technology (DST), Ministry of Science and Technology, Government of India, and Research Council UK (RCUK). The activity of NISE relates to an understanding of the stability and long-term performance of PV modules and systems. The detailed objectives are as follows:

- I. Map the potential of PV and energy yield in varying climates and operating environments
- II. Uncertainty in prediction of life time energy yield (crucial for thin film technology which show variable degradation rates)
- III. Development of novel measurement and analysis method.

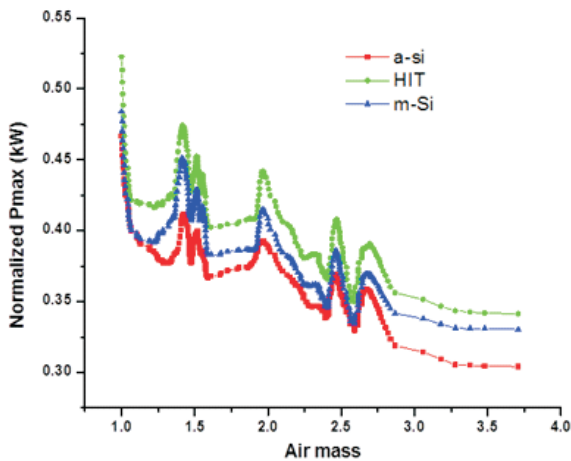


## Research development and demonstration by the group

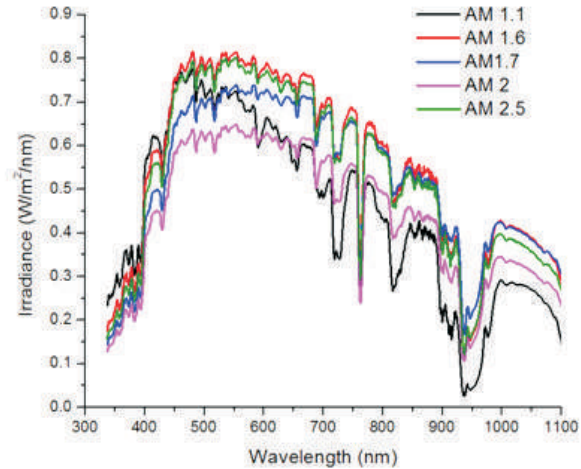
### Performance Evaluation of Solar Photovoltaics Outdoor Test Bed

The outdoor performance of PV modules varies with meteorological parameters like ambient temperature, humidity, wind speed etc. The performance of solar panel increases with increase of radiation level, other ambient conditions like ambient temperature, relative humidity and wind velocity also influence the performance strongly. It has been found that the performance of different PV technologies behave differently in the outdoor conditions. Sastry et al. reported about the performance and the behaviour of different crystalline silicon modules with respect to the climatic condition. The performance of solar panels strongly depends on the solar spectrum of the region. Usually the spectrum depends on the earth-sun distance, and other attenuation factors like Air –Mass (AM), humidity, dust or turbidity of the region. The earth-sun geometrical distance varies with the time of the year, which is often called as geometrical air mass. AM is the ratio between the path-length travelled by the beam radiation to the path length at the time of zenith. If the sun rays make an angle  $\theta$  between the light ray and the zenith, then the AM is given by  $AM = 1/\cos\theta$ . The air mass at the top of the atmosphere or at extraterrestrial is 0 and solar radiation reaching at the surface is around  $1376 \text{ W/m}^2$ . AM 1.5 corresponds to a solar elevation of about  $42^\circ$  and solar irradiation taken to be  $1000 \text{ W/m}^2$ . It has been found from the data recorded under NISE-AIST project that the solar spectrum pattern changes with AM and time. With increase in the air mass the spectrum tends to shift towards longer wavelength, due to which the performance of the different solar technologies will vary with different air mass. The performance of modules belonging to the three technologies (amorphous silicon, multi crystalline silicon, and Hetero-junction with intrinsic thin layer (HIT)) has been estimated with respect to the air mass at NISE. The normalized power output of the three different types of modules decreases with increase of air-mass, and after an air-mass value of 2.75, the rate of decrease is faster for a-Si, compared to the other two technologies. The useful range of spectrum for the designated technologies mainly depends on the effective band gap of the material. The useful range for amorphous silicon is 300-780 nm, for multi crystalline silicon it is 300-1100 nm, for HIT the range is 300 to 1200 nm. The area under the curve of the useful range of solar spectrum is estimated for the three technologies. It is observed that the area under the spectrum curve in their useful wavelength range varies with the spectrum of different air mass. The total useful numbers of photons are estimated for each technology and also the variation of output with respect to useful fraction of the incident spectrum. Fig. 5 represents the normalized power output with respect to air mass at constant radiation. Fig. 6 shows the different solar spectrum at different air mass measured at NISE.





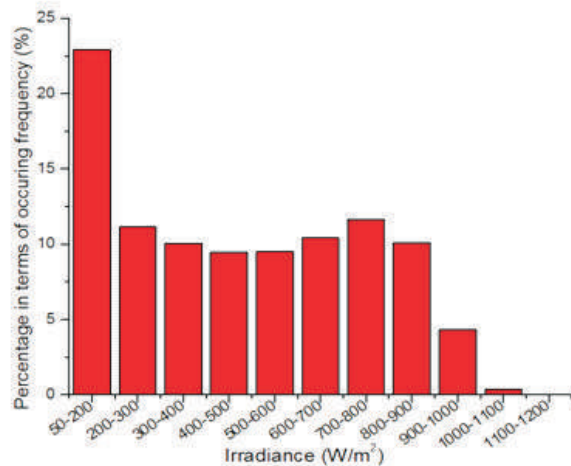
**Fig. 5 Normalized output versus air mass at constant radiation**



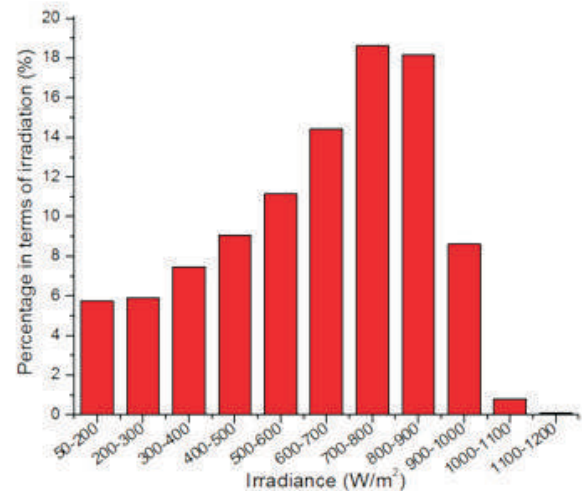
**Fig. 6 Measured Solar spectrums for different air mass at NISE**

#### 4.2 Analysis of the most frequent condition

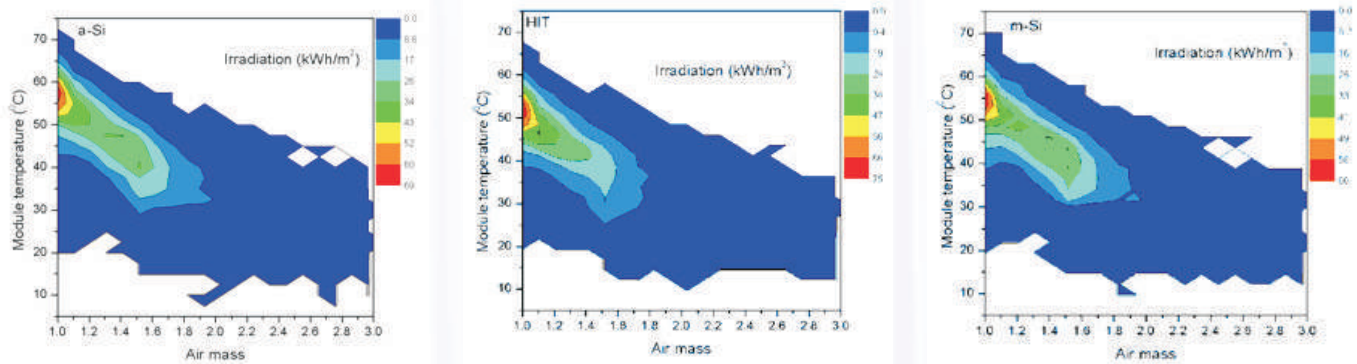
Figs. 7 and 8 shows the percentage of in-plane irradiance distribution for three years 2010, 2011 & 2012 at NISE, in terms of time counts and total incident in-plane irradiation. It shows that about 6% of the incident in-plane irradiation is below 200 W/m<sup>2</sup>; 93% is between <1000 W/m<sup>2</sup> and >200 W/m<sup>2</sup> and remaining 1%, is above 1000 W/m<sup>2</sup>.



**Fig. 7 Percentage of occurring frequency of radiation range**



**Fig. 8 Percentage of occurring frequency of radiation**

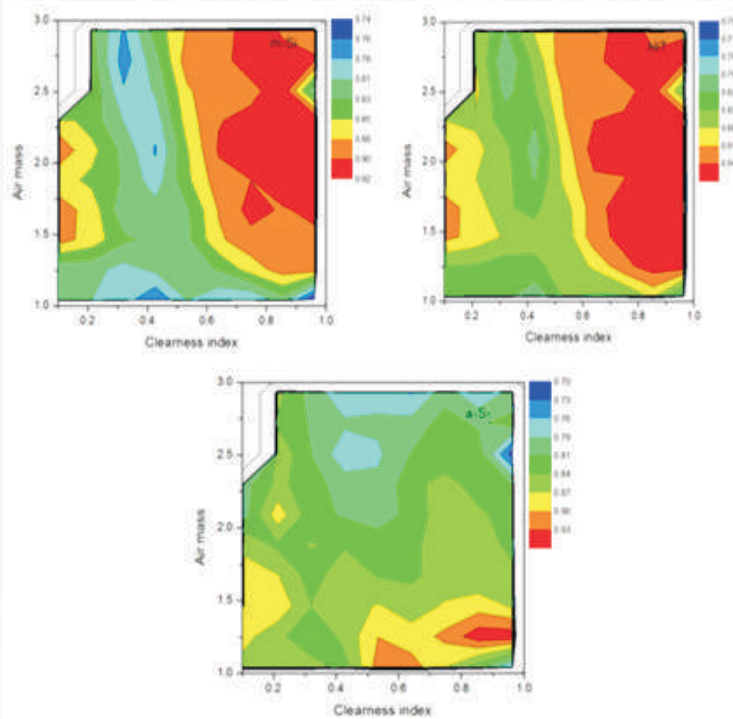


**Fig. 9 MFC in terms of air mass and module temperature for three PV module technologies**

Using the most frequent condition, the condition of maximum energy throughout the period can be identified in terms of AM and module temperature. Fig.9 shows the irradiance as a function of air mass and module temperature of different PV technologies. It shows the frequently occurred condition for a-Si is  $T_{\text{mod}} = 57.5 \pm 1^{\circ}\text{C}$ , and  $\text{AM} = 1.01 \pm 0.01$  and the total energy in this condition is around 69 kWh. For HIT, frequently occurred condition is  $T_{\text{mod}} = 51 \pm 1.5^{\circ}\text{C}$ , and  $\text{AM} = 1.01 \pm 0.01$  and the total energy in this condition is around 75 kWh and for m-Si, frequently occurred condition is  $T_{\text{mod}} = 53.5 \pm 1.5^{\circ}\text{C}$ , and  $\text{AM} = 1.01 \pm 0.01$  and the total energy in this condition is around 66 kWh.

#### 4.3 Performance modeling of three PV module technologies based on clearness index and air-mass using contour map

The energy rating of different PV technologies are different in actual weather condition from the power output in indoor conditions. In India, the environmental parameters in real outdoor conditions are changing throughout the year. So, the modeling of performance for different technologies needs to be done based on the weather parameters. A number of researchers have done modeling based on weather data. In this study the performance modeling is carried out based on PR as a function of air mass and clearness index. A comparison of the output estimation method using air mass and clearness index with irradiance and module temperature is also presented. The error between the estimated outputs and the actually measured value is also discussed. Fig. 10 shows the PR as a function of air mass and clearness index.



**Fig. 10 PR as a function of air mass and clearness index**

#### 4.4 Analysis of Spectrum Variations in different Seasons in Composite Climate zone of India

The solar radiation incident on the earth's atmosphere is relatively constant; the radiation at the earth's surface varies widely due to atmospheric effects, including absorption, scattering and reflections due to local variations in the atmosphere, water vapor, clouds, latitude of the location, season of the year and the time of the day. Before the solar radiation reaches the earth surface, the actual radiation from the Sun undergoes several changes. These changes include the overall power contained in the spectrum, variations in the spectral contents of the light and the angle of incident on the module surface. These effects decrease the performance of PV modules with different band gaps. This is also known as blue shift in the spectrum.

**Average photon energy (APE):** APE is defined as the total irradiance contained in the spectrum divided by the total photon flux density. The APE of each spectrum is calculated from the wavelength range of 350–1050 nm of the measured spectrum. The APE value for the AM 1.5 standard solar spectrum calculated for 350-1050 nm wavelength range is 1.878 eV. APE can also be defined as the integrated irradiance divided by the integrated flux density, which yields the average energy per photon

$$APE = \frac{\int_a^b E(\lambda) d\lambda}{\int_a^b \Phi(\lambda) d\lambda}$$

Table shows the average photon energy of solar spectrum at NISE on a monthly basis.

Module technology	Error	
	Airmass - clearness index method (%)	Irradiance - module temperature method (%)
a-Si	7.36	9.15
HIT	17.73	19.56
mc-Si	13.15	15.78

Month	Maximum occurring Average Photon Energy (eV)
January	1.86
February	1.88
March	1.89
April	1.9
May	1.9
June	1.91
July	1.92
August	1.92
September	1.99
October	1.89
November	1.82
December	1.88

### Modeling the performance of HIT technology for composite climatic zone of India

In this study the performance modeling of HIT technology modules using 7 weather parameters are done. The 7 parameters are irradiance, ambient temperature, wind speed, wind direction, humidity, clearness index and pressure corrected to air-mass. Air mass is calculated using zenith angle ( $\theta_Z$ ) and the atmospheric pressure corrected by using the following equations developed by Kasten et al:

$$AM = \frac{1}{\{\cos\theta_Z + 0.5057 (96.080 - \theta_Z)^{-1.634}\}}$$

$$AM_\alpha = \frac{P}{P_0} \cdot AM$$

**Clearness index is defined as the ratio of global irradiance on a horizontal plane to the extra-terrestrial irradiance, divided by AM. It is given as:**

$$k_t = \frac{H}{H_0/AM}$$

PVUSA (Photovoltaic for Utility Systems Applications) method is used to estimate the power output of any PV module technology. According to PVUSA regression analysis, power is considered to be a function of three parameters, namely irradiance, temperature and wind speed.

## RPN analysis of field exposed mono crystalline Silicon PV modules under composite climate of India

Among the identified failure mode and effects of a system on the basis of priority ranking, a critical analysis can be done by using a quantitative index known as Risk Priority Number. RPN is given as

$$RPN=S.O.D$$

Where “S” is the severity, represents the impact of failure mode within the user defined boundaries of the analyzed system. “O” is the occurrence, represents the probability of occurrence of failure mode within a time boundary based on the feedback of field data. “D” is the detection, represents the recognizing or spotting and removing or preventing of failure modes of the analyzed system. The ranking of different failure modes is done by using data mining of filed data for 190 PV modules. Severity of a failure mode is determined by using the safety and performance degradation of the PV modules, ranked with 1 to 10. Severity ranking of failure mode is done with respect to degradation rate per year which is having a particular failure mode as a dominant factor. Occurrence ranking is performed on the basis of field data. The frequency of occurrence of each failure mode has been calculated by plotting the histogram of number of modules for a particular defect. The number of module failures per thousand per year is calculated as follows

$$\frac{CNF}{100} = \sum_{System} (\%defects) * \frac{10}{\sum_{System} Operating\ time}$$

The ranking of occurrence is ranging from 1 to 5. Ranking of detection of each failure mode is done based on the criteria of detection, i.e. with visual inspection or with the monitoring system or with sophisticated tools or impossible to detect in the field. The physical significance of RPN is the identification or determination the severity of a particular defect which can hamper the power generation by the PV modules. The highest value of RPN of failure modes gets the highest priority for the particular site. Fig.11 shows the Risk priority number of different failure modes of c-Si for composite climate.

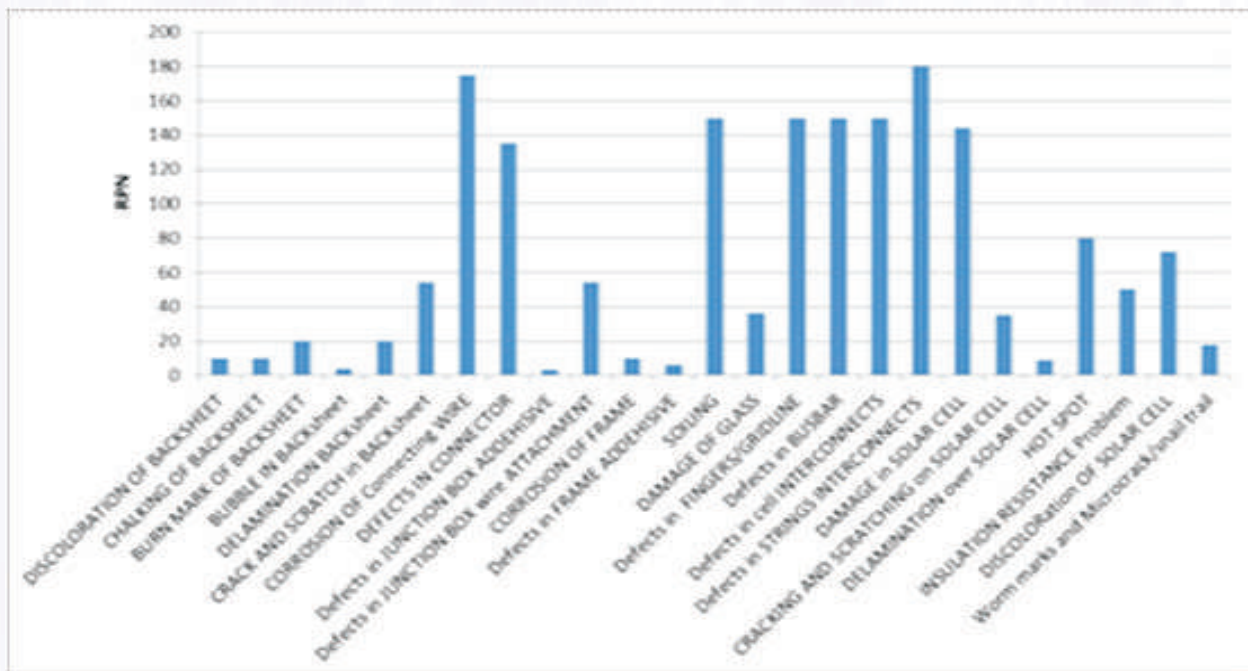


Fig. 11 Risk priority number of different failure modes

## Effect of series resistance on degradation of $I_{sc}$ , Power output and Fill Factor of HIT technology

The objective of this study is to find out the dependence of series resistance on different irradiance and temperature conditions for HIT technology. For 23 different test conditions of temperature and irradiance as per IEC 61853-1, the series resistance has been estimated by using long term outdoor performance data. Earlier determination of  $R_s$  is mainly based on three irradiance levels ( $1000 \text{ W/m}^2$ ,  $800 \text{ W/m}^2$  and  $600 \text{ W/m}^2$ ). The data presented below in Fig. 12 shows nonlinear behavior. The precision level is low as the conversion of data shows non-linearity. For that reason IEC made 23 test conditions near to natural condition occurring in the field. Based on that, conversion is done and series resistance is calculated by using the data. 23 data points include the matrix of lower to higher range of temperature and irradiance, which is very close to the real field conditions and by this conversion accuracy and linearity, is increased. The effect of increase in series resistance on the fill factor, Power and  $I_{sc}$  is studied for HIT technologies after one year outdoor exposure.

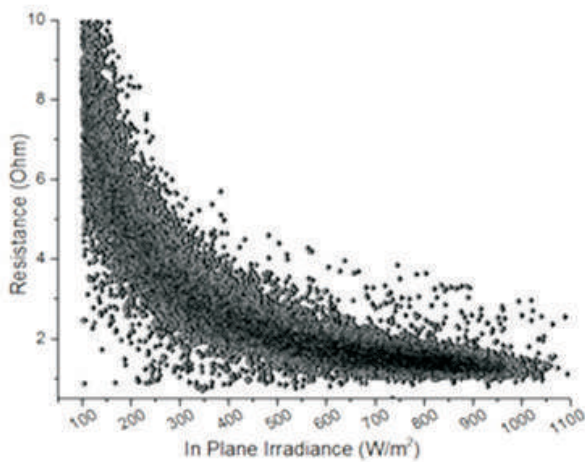


Fig 12 Resistance versus Intensity graph

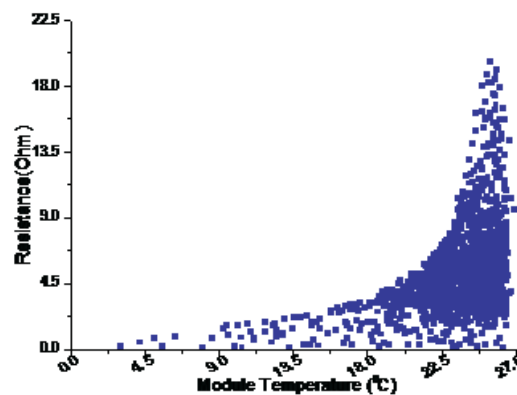


Fig 13 Resistance versus module temperature graph

It has been observed from the Fig. 12 that the series resistance decreases with the increase in irradiance however it increases with the increase in module temperature (Fig. 13) as well. For a particular level of intensity with the increase of module temperature, the series resistance increases. At low Irradiance, the value of resistance is high; however by increasing the Irradiance, the resistance decreases slightly.

5. Lectures delivered in various training programme/conferences  
Several presentations are made by the group in various training programme organized by NISE, together with a demonstration of the test facility and procedure to more than 10 groups of trainees.
6. Equipments/test setup developed

During this period two different test setups are developed by the group for testing of PV modules as per IEC 61853 and for the effect of dust on the performance of PV modules.

### Test set up for testing of PV modules as per IEC 61853:

I-V tracer (PVPM), an instrument for testing of PV modules at NISE, is used for testing the modules in outdoor test bed along with different sensors and PV mounting structures. Fig. 14 show the actual test set up used for the measurement in field. Fig. 15 depicts an arrangement for creating artificial shadow conditions (partial or full) on the test module with the help of a wire mesh. Different sizes of wire mesh are used to reduce the intensity to varying degrees. This arrangement for reduction of incident solar radiation on the module surface retains the spectral characteristics and thus results in accurate data.

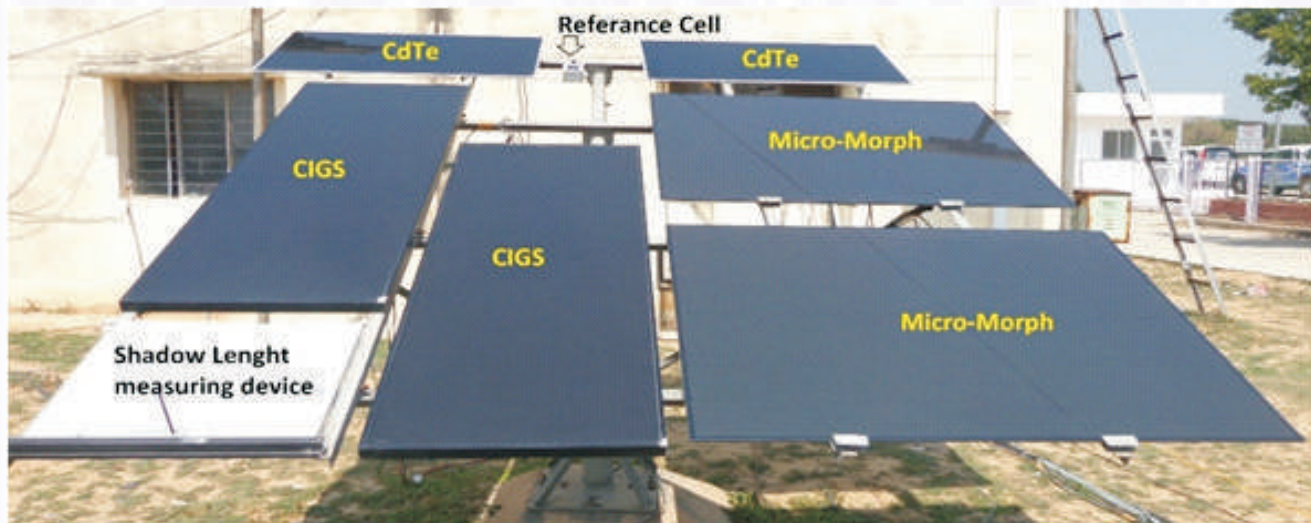


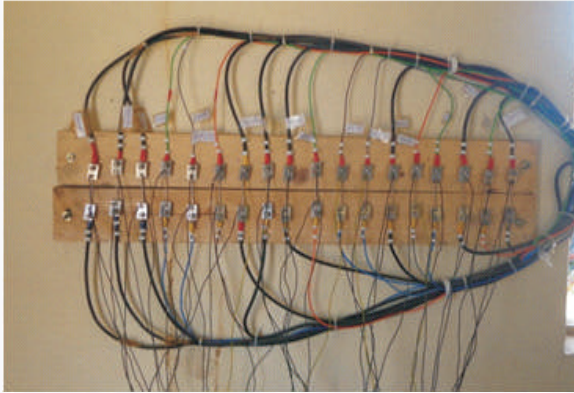
Fig 14 Test set-up



Fig 15 MESH with different transmittivity

### Test setup for dust analysis

In India, the performances of PV module technologies are highly depend on the dust deposition on the surface. Because of dust deposition, there is a change in transmission and spectrum of light absorbed by the solar cell. To find out the effect of these on solar cell modules, our group has developed a test set up with different technology modules at different tilt angle. Fig. 16 shows the test set up used for dust analysis. The short-circuit current is measured as a voltage drop across a set of accurate shunt resistances as shown on the left side of the figure below.



**Fig 16 Test set-up**

### 7. List of students doing training/projects with the group during 2014-15

Sl. No.	Name of students	Institute	Duration	Course
1.	Rashmi Singh	Devi Ahilya Vidhyalaya	6 months	M.Tech
2.	Aman Bajaj	IIT-B	2 months	M.Tech
3.	Ayush Jaiswal	IIT-B	2 months	M.Tech
4.	Pankaj	IIT-B	2 months	M.Tech
5.	Pankaj Kumar	University of Lucknow	2 months	M.Tech
6.	Aasif Khan	University of Lucknow	2 months	M.Tech
7.	Iffam	University of Lucknow	2 months	M.Tech
8.	Pooja Choudhary	University of Kanpur	2 months	B.Tech
9.	Aayushi Behl	P College of women (Delhi university)	2 months	B.Tech 2nd year
10.	Nishtha Jain	IP College of women (Delhi university)	2 months	B.Tech 2nd year
11.	Somya Sarah	Coimbatore university	6 months	M.Tech
12.	Avinash Kumar	Tezpur University	1 year	M.Tech

Sl. No.	Name of students	Institute	Duration	Course
13.	Supriya Rai	Pondicherry university	6 months	M.Tech
14.	Shivendra Kaundliya	Pondicherry university	6 months	M.Tech
15.	Sanjay Ambwani	DPS, RK Puram	2 months	12th standard
16.	Farazuddin Azlan	Central University Of Jharkhand	45 Days	Integrated M.Tech
17.	Pranav Anand	Central University Of Jharkhand	45 Days	Integrated M.Tech
18.	Bapi Kumar Das	Central University Of Jharkhand	45 Days	Integrated M.Tech
19.	Ratan Kuber	Central University Of Jharkhand	45 Days	Integrated M.Tech
20.	Vivek Krishnan	Central University Of Jharkhand	45 Days	Integrated M.Tech
21.	Priyanka Verma	University Of Lucknow	2 Months	M.Sc
22.	Stuti Tripathi	University Of Lucknow	2 Months	M.Sc
23.	Sidra Khatoon	University Of Lucknow	2 Months	M.Sc
24.	Sangram Bana	IIT ROORKEE	2 months	PhD

## **2.4 Solar Water Pumping Test Lab**

Solar Photovoltaic (SPV) Water Pumping can prove to be the most promising application in meeting the energy and water needs of the country. The main advantage of SPV Water pumping is that the demand of water is in synchronization with the Sun's intensity i.e the demand is high when the Sun's energy is at its peak. In areas where grid is not available, it can fulfill the requirement for various activities such as agricultural, drinking and industrial applications. It is the most reliable system as it does not need battery storage which will add on to the cost. The water storage tank can act as a backup in days of autonomy or if the demand is higher or to meet the requirement during the off-sunshine hours. A solar photovoltaic pumping system consists of a solar array, a DC/ AC motor and a pump unit and a controller or inverter with MPPT arrangement. In case of DC pumps, it can be directly coupled to the PV array, whereas in case of AC pump, an inverter is required to invert the Direct Current to Alternating Current. Nowadays, mostly two types of pumps are used in SPV water pumping systems, i.e., centrifugal which uses high speed rotation to suck water in through the middle of the pump and positive displacement pump which usually uses a piston to transfer the water. According to the depth of the well, pumps can be of two types, i.e., Surface which is mounted outside the fluid to be pumped and submersible which is submerged in the fluid to be pumped. The size of a SPV pump varies from 0.2 HP to 10 HP or more.



**Solar Water pump test Facility**

The National Institute of Solar Energy (NISE) is India's premier institute involved in research and development activities, testing and certification of various SPV water pumping systems available in the Indian market. It has a testing facility for SPV water pump systems and is also engaged in performance evaluation and analysis of different types of pumps (AC as well as DC and Submersible as well as Surface pumps) of capacities ranging 0.2 HP to 10 HP for different heads ranging from 10 m to 100 m. The pumps are tested as per the MNRE specifications for different models. The parameters measured and evaluated are wire to water efficiency, total water output per day, water output per day per watt of STC capacity of SPV water pumping system along with the maximum dynamic head, testing for different types of protection i.e., dry running, short circuit protection and open circuit protection.



SPV module setup for pump testing at test bed



A Solar Water pumping testing Rig.

In year 2014-15, NISE has tested 37 different pumps Presently the facility is capable of testing four SPV water pumps at a time. The brief summary of the testing activity is given in the table below:

S. No.	Capacity of PUMP	Type: Surface/ Submersible	AC/DC	Head (in meters)	Total No. of Pumps tested at NISE
1	1 HP	Submersible	2 DC 1 AC	30	3
				30	
2	2 HP	Submersible Surface	4 DC 1AC	10	2
				30	1
				75	1
				90	1
3	3 HP	Submersible	9 AC 1 DC	20	1
				50	9
4	5 HP	Submersible	19AC	30	1
				50	18

The automation and up-gradation of the testing facility is in process for expanding the number of pumps to be tested with more accuracy which will also facilitate indoor testing and simulation of different test conditions. In view of the increase in demand of solar pumps in India, four more facilities have been identified and accredited as test centers by the MNRE for SPV water pumps as per the ministry's specifications and guidelines. The five test centers are Electronics Quality Development Centre, Gandhinagar, TUV Rheinland, Bangalore, SITARC Coimbatore, Central Power Research Institute, Bangalore, & UL Bangalore.



**A Schematic diagram of Automatic Solar Water Pump test Set up**

The NISE, as a R & D institution, has published a number of papers on SPV water pumping in various renowned national and international journals during the year 2014-15. NISE has also conducted many training programmes, site visits and sessions creating awareness and knowledge sharing among students & farmer in the area of SPV water pumping systems.

### **Analysis of Temperature effect on Optimum Sizing of Solar Photovoltaic Water Pumping System**

The Indian ambient varies widely during different seasons and influences the performance and size of the PV array for solar water pumping systems. It is observed that the water output of the same pump varies seasonally due to change in weather. Most of solar pumps use Variable Frequency Drives (VFD) controllers for DC/ AC conversion and driving the solar pumps. However, due to absence of proper MPPT in VFD, there is a difference between MPP voltage and the operating array voltage. Further, due to strong influence of temperature, PV array operating voltage decreases in summer because of higher temperature. The power available at operating voltages decreases significantly during summer, reducing water output. Due to this reason solar pumps using VFD drivers perform poorly during summer. From this study, it is observed that the performance of an SPV water pumping system depends mainly on the power output of module technology at specified VFD bus-bar voltage, which varies with operating temperature

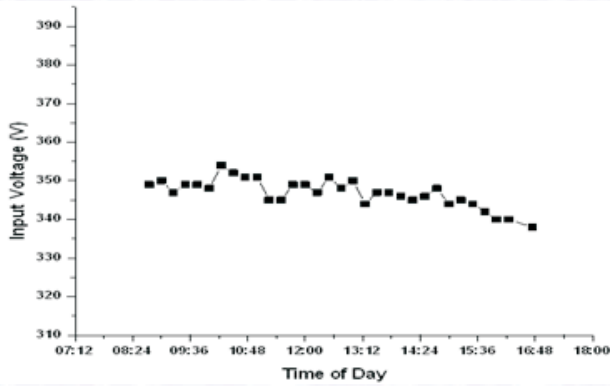


Fig.1 Variation of Voltage over a whole day

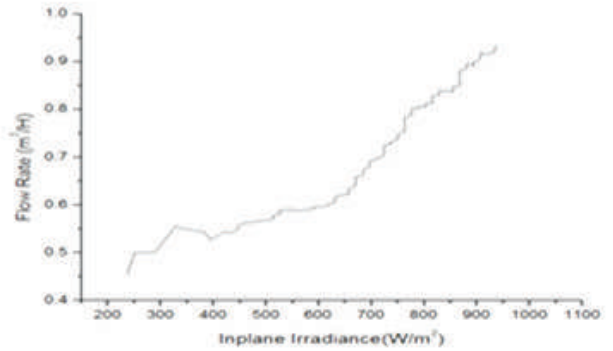


Fig.2. In-plane irradiance Vs Input power

in different seasons. So, an SPV water pumping system should be selected based on its performance vs. input power from the PV module technology. The sizing of its PV array should be done based on its time of operation as there are no formal MPPT available with VFD controllers. A loss of more than 25% in water output from winter to summer season is observed at NISE if improperly designed VFD controllers are used. Therefore, proper designing of PV array for SPV water pumping systems must be done taking into account the loss of power due to high voltage operation and the effect of module temperature on voltage in summer season if the pump is to be operated for the whole year.

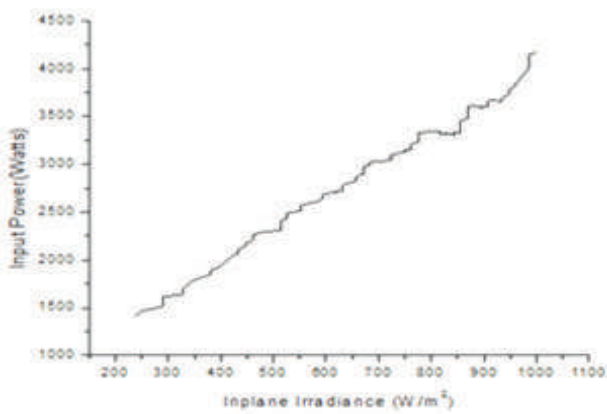


Fig.3. In-plane irradiance Vs flow rate

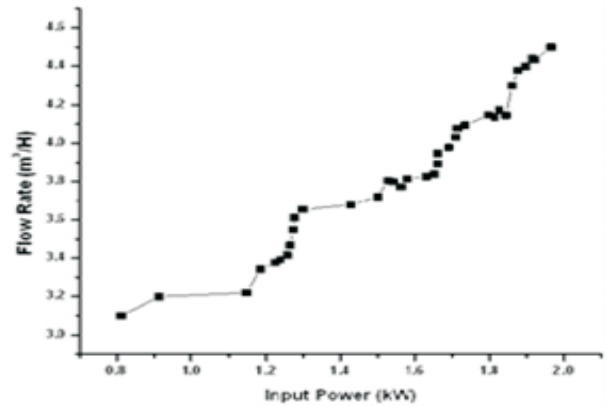


Fig. 4 Flow Rate Vs Input Power

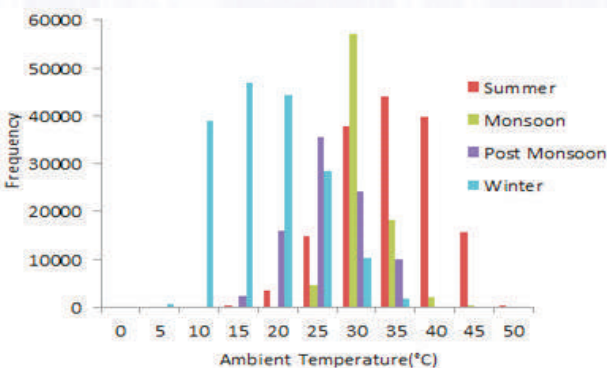


Fig.5 Distribution of Ambient temperature in Composite Climatic Zone

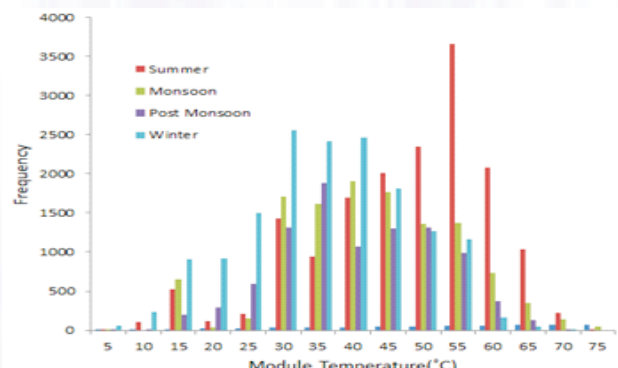


Fig.6 Distribution of Module temperature in Composite Climatic Zone



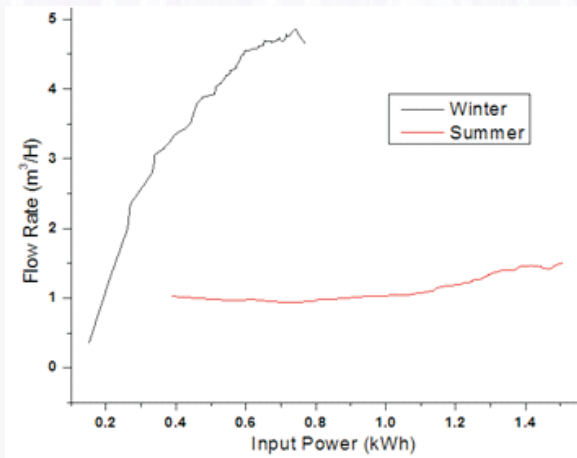


Fig. 7(a) Voltage vs. Flow rate of a 2 hp Pump

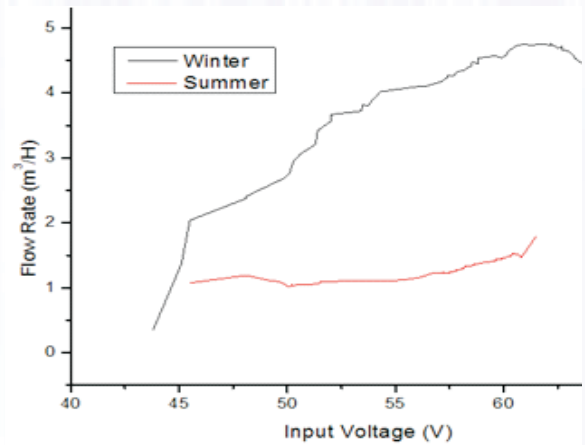
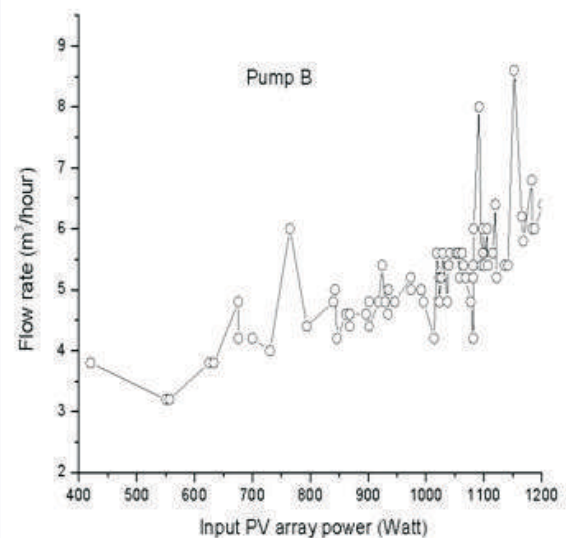
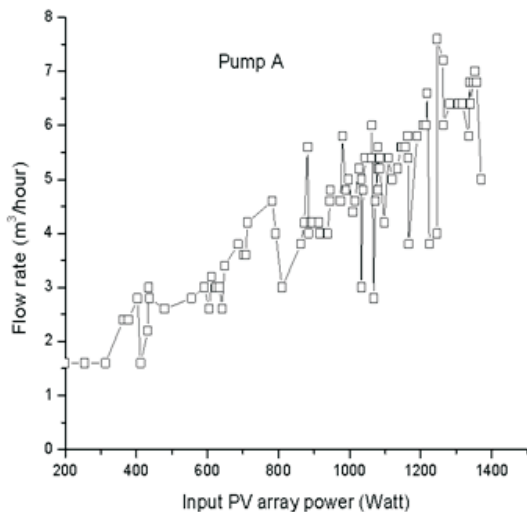


Fig.7. (b) Input Power Vs. Flow rate of a 2 hp

### Design optimization of photovoltaic powered water pumping systems

Ever since the beginning of the Jawaharlal Nehru National Solar Mission (JNNSM) in India, a boom is observed in the applications of Solar Photovoltaic (SPV) systems. Usages of SPV water pumping systems for drinking water and irrigation purpose has increased. National Institute of Solar Energy (NISE) has established test facilities for evaluation of solar water pumping systems, and also studied various different SPV based water pumps of different capacities, types, and applications. It has been observed that the most of the pumps underperform due to poor design of the system, low efficiency of components and mismatch among the components.



It is observed that these pumps could have performed more efficiently if technical barriers discussed above were removed. The study performed at NISE describes the major aspects needed to be incorporated in designing of SPV water pumping systems. A specific case of assessment of two submersible pumps of same capacity and same type but with different array capacities has been presented above.

## 2.5 Power Electronics Lab

Power electronics lab of National Institute of solar energy (NISE) focuses on sustainable development of photovoltaic technologies by Evaluation of Technical, Environmental, and Economic performance, cooperation with institutions & industries and testing & standardization. This group has capabilities and experts in measurements, characterization, reliability, engineering, scientific computing, and theory to support photovoltaic (PV) research, Balance of system and development (R&D) across a range of alteration technologies and scales. For the testing and deployment of and solar Inverters as per Indian conditions, this group is closely working with renowned institutes to developed world class facility at NISE.

### Power Electronics lab:

NISE has established facilities for testing and evaluation of Solar Inverters/ power conditioning Units (PCU) of capacity ranging from 100VA to 10KVA. All types of PCUs, hybrid, standalone, Grid-tied inverters (GI) and pump controllers can be studied. NISE's power electronics lab has Solar Array Simulator (15 kVA), Electronic load (15 kVA), AC source (6 kVA), Four Channel Power Analyzer, Digital Oscilloscopes, Bench Top Dual Display Multi-meters etc., those are needed for the purpose. The test report will contain all the useful parameters measured at NISE, including those parameters required as per IEC 61683, EN 50530, IEC 61728, IEC 62116 and IEC 61727 required in NSM, MNRE 2013-14. The report also includes claims made by manufacturer and observations made during the evaluation of the sample.

### Major Components included

- A. 15KVA Solar Array Simulator
- B. 15KVA Programmable RLC Load
- C. 6KVA Power Source
- D. Power Analyzer (Zimmer make: capability up to measure 50 KVA power)
- E. Insulation Tester
- F. Digital Phosphor Oscilloscopes



Fig. Lab Setup

### Equipment's/Test setup in development phase

Under Up gradation (purchase order have been issued LC has been opened), which are as follows

- 1- 15KVA Solar Array Simulator (3nos).
- 2- 60KVA Programmable Actual RLC load
- 3- An Environmental chamber

### Name of tests and Standard for testing of PV inverters:

PV inverter/ PCU ➤ Safety of power converters  ➤ Installation & Commissioning  ➤ Procedure of measuring efficiency	<ul style="list-style-type: none"> <li>• GI safety test procedure</li> <li>• General requirements (GI/ standalone/ other)</li> <li>• Particular requirements of inverter</li>   <li>• Protection against electrical shock- Common aspects for Installation &amp; Equipment</li> <li>• Parallel operation of inverter</li> <li>• Islanding protection (All except standalone inverter)</li> <li>• Electromagnetic Compatibility, i.e. EMC (applicable to all)</li>   <li>• Procedure for measuring efficiency (GI/ OFF-GRID/ ROOF TOP)</li> <li>• Measuring the efficiency of MPPT algorithm and overall system efficiency of Grid interactive inverter</li> </ul>	IEC 61728 IEC 62109-1  IEC 62109-2  IEC 61140  IEC 61727 IEC 62116  IEC 61000-3-15  IEC 61683  EN 50530
Charge Controller ➤ Charge controller/ MPPT units  ➤ Power conditioners/ Inverters including MPPT and protections	<ul style="list-style-type: none"> <li>• Environmental testing</li>   <li>• Efficiency measurements</li> <li>• Environmental testing</li> </ul>	IEC 60068-2 (1, 2, 14, 30)  IEC 661683/ IS 61683 IEC 60068-2 (1, 2, 14, 30)

### No. of Equipment tested:

Particulars	DOR	Token No.	Quantity	Test Report No.
RITIKA SYSTEM LTD.	01-08-2014	P-I	1	83/2014/CSC/NISE
RITIKA SYSTEM LTD.	01-08-2014	P-II	1	84/2014/CSC/NISE
RC-ALL TECH POWER	25-08-2014	P-III	3	97/2014/CSC/NISE
IND-AUSSIES	19-09-2014	P-5(1)	1	116/2014/CSC/NISE

Particulars	DOR	Token No.	Quantity	Test Report No.
IND-AUSSIES	19-09-2014	P-5(2)	1	117/2014/CSC/NISE
IND-AUSSIES	19-09-2014	P-5(3)	1	118/2014/CSC/NISE
IND-AUSSIES	07-10-2014	P-6	1	126/2014/CSC/NISE
IND-AUSSIES	07-10-2014	P-7	1	127/2014/CSC/NISE
RITIKA SYSTEM LTD.	08-10-2014	P-8	1	128/2014/CSC/NISE
RITIKA SYSTEM LTD.	08-10-2014	P-8	1	129/2014/CSC/NISE
KISAN SOLAR (Pump Controller)	05-09-2014	P-9	1	104/2014/CSC/NISE
VIMAL ELECTRONICS	20-10-2014	P-10 (A)	3	141/2014/CSC/NISE
NAGARJUNA AGRICH	22-10-2014	P-11	1	145/2014/CSC/NISE
NAGARJUNA AGRICH	24-10-2014	P-12	1	145/2014/CSC/NISE
NAGARJUNA AGRICH	24-10-2014	P-13	1	146/2014/CSC/NISE
EAPRO GLOBAL LTD.	19-12-2014	P-14	1	199/2014/CSC/NISE
KISAN SOLAR (Pump Controller)	08-12-2014	14/2014	1	210/2014/CSC/NISE
VIMAL ELECTRONICS	20-10-2014	P-10 (B)	3	141/2014/CSC/NISE
VIMAL ELECTRONICS	20-10-2014	P-10 (C)	3	141/2014/CSC/NISE
Arise India Ltd.	.....	P-8/PCU	1	286/2014/CSC/SEC
VIMAL ELECTRONICS	.....	P-10	1	141/2014/CSC/NISE
G1 Energy Solutions Pvt Ltd	4/7/2015	-----	1	003/2015/CSC/NISE
Cyber Power	4/1/2015	-----	1	001/2015-16/CSC/INV
M/s Emeral Energy Solution Pvt.Ltd.	6/23/2015	-----	1	077/2015-16/CSC/NISE
M/s Cyber Power System Pvt.Ltd	8/10/2015	11/1115	1	120/2015-16/CSC/NISE

### Parameters affecting to SPV power converters output:

Main parameters for efficient SPV power converters is the efficiency and life expectancy of the systems. Efficiency is ratio of the output power of converter to the input power of the converter

$$eff = \left[ \frac{P_o}{P_{in}} \right] \times 100$$

Power converter efficiency depends upon the following parameters:

- I. Operating load %, load type and Operating Voltage range
- II. MPPT performance
- III. System design (Without Transformer or With transformer)
- IV. Transformer core material and core type

Operating load %, types of load and Selected nominal Voltage range:

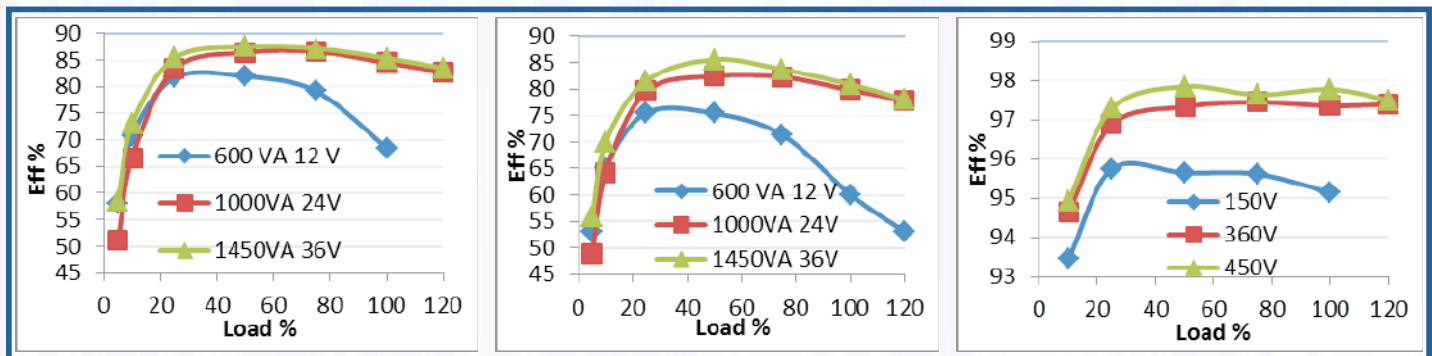


Fig (a) Efficiency curve for resistive load (b) Efficiency curves for reactive load  $PF \geq 80$  for standalone inverters (c) Efficiency curve for Grid interactive inverters

Fig. 2(a) shows the efficiency comparison of the three different standalone inverters of the same make designed at different battery voltage (Nominal voltage). Fig 2 (a) is for resistive load and Fig. 2 (b) is for the reactive load  $PF \geq 80$ . Efficiency increase with increasing load and battery voltage. further efficiency decrease on reactive power. F© 2 © represents efficiency curve for grid type inverter at different voltages

## MPPT performance:

Maximum power point tracking is the one of most important parameter for the SPV power system for utilising maximum green generation. Every SPV module have its Maximum power point, to get maximum energy load impedance should be perfectly match with the SPV module impedance. Direct measuring efficiency through calculating the power at output and input of converter through wires with the help power metre, it is impossible to get the MPPT efficiency.

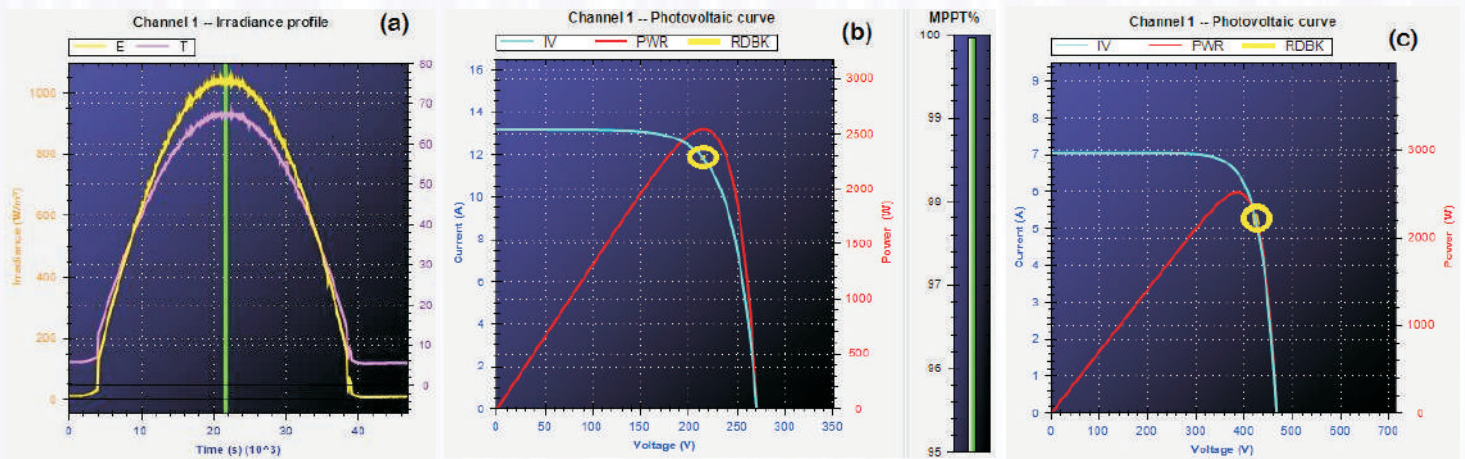


Fig. (a) Whole day radiation profile, (B) I-V, P-V curves and proper MPP tracking and (C) I-V, P-V curves and improper MPP tracking under similar condition

For measuring the MPPT efficiency, the generated peak power should be known. so it is only possible way to measure the efficiency is by using PV array simulator where generated energy is known. While directly following IEC 61683 [Photovoltaic systems –Power conditioners –Procedure for measuring efficiency] complete power conditioner efficiency is not very accurate because it don't consider MPPT loses. So measurement of overall system efficiency is only possible by considering both system efficiency and MPPT efficiency in case of grid interactive system. There are following MPPT algorithms:

- Hill Climbing/P&O
- Incremental Conductance
- Fractional Open-Circuit Voltage
- Fractional Short-Circuit Current
- Fuzzy Logic Control
- Neural Network

- a) **Hill Climbing/P&O:** When PV generator is connected to the power converter: in hill climbing method perturbation of duty ratio is done. For this, in perturb and observe method perturbation of the voltage is done. In actual perturbation of the current and consequently voltage is done by perturbing the duty ratio. Hill climbing and P&O method are different way for doing the same fundamental method. This is most focused algorithm but its performance decrease in the highly cloudy condition or greatly varying condition because it stuck in the loop some times.
- b) **Incremental Conductance:** Incremental conductance works on the slope of power curve. Slope will be zero if the converter is tracking at MPP. If the slope is Positive the converter is tracking on the left of the MPP and if curve have negative slope it is on the right side of the MPP.
- c) **Fractional Open-Circuit Voltage:** This is most preferred in the decentralized applications because of simplicity in nature and cheaper in the cost economics. In which controller tries to make  $V_{mpp}$  0.71-0.78 times of  $V_{oc}$  most of the times. For this  $V_{oc}$  is measured periodically by shutting down the system so there is temporary loss of power. However it is not always MPP so this is not real MPPT tracking technique.
- d) **Fractional Short-Circuit Current:** This is similar as Fractional Open-Circuit Voltage (FSCCV) technique in which controller always tries to make  $I_{MP}$  0.78-0.92 times of  $I_{sc}$ . So this technique has similar limitation as FOCV for going towards MPPT System need Shutdown and short circuited.
- e) **Fuzzy Logic Control:** In this technique tracking is done with microcontrolleres through the fuzzy logic control with less precise inputs because it don't need very accurate mathematical models.
- f) **Neural Network:** Neural networks mostly uses three layers: input, hidden and output layers. The input variable are  $V_{oc}$ ,  $I_{sc}$ , atmospheric data such as irradiance and temperature. Output layers are signals through microcontroller which are the duty cycle. How close the controller track the MPP point depends on the hidden intermediate layer based on their precise mathematical calculation on input data.

#### **System design (Without Transformer or with transformer):**

Here the system design means the logic of boosting and inverting topologies: which are used in inverters. The most preferred is transformer less topologies, in this topology first voltage boost up is done then inversion process is done. Further in the SPV converter with the transformer: first inversion is done at same DC bus bar voltage and then AC voltage is boost up through the transformer. Converter with transformer have main load on transformer in addition to that DC Isolation at AC side and AC isolation at DC side is provided by the transformer because of transformer work on mutual inductance. Transformer less technologies are light in weight because of transformer weight is reduced and main load is on the electronics and switching portion. Transformer less technologies gives better efficiency numbers but Isolation risks and life expectancies prevails.

### Transformer core material and core type:

Again system with transformer are categorised on core material and core type. Core is of two types EI core and toroid core. Power quality and efficiency also depends on core material. In decentralised systems this is one of the main reasons for the difference in efficiency in the lab and the real outdoor condition. Manufactures inhibits quality of material for the cost cutting.

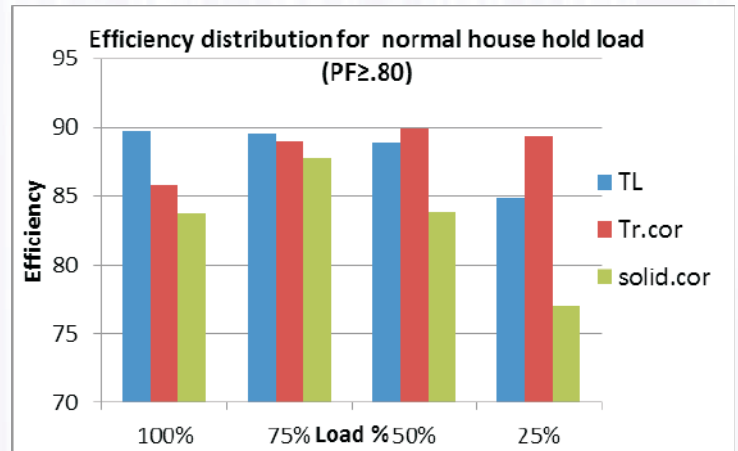


Fig. SPV power converter efficiency distribution based on system Design and transformer core type at different load percent

Fig.4 represents efficiency distribution based on system design and transformer core material at the normal house hold loads power factor. For the random selected sample of same capacity Inverter, efficiency of transformer less inverters are peak on the more than 50% load capacities. Figure represents that for nonlinear load the efficiency of thyridal core inverter is better than that of EI core.

### Power quality of the system:

The life of loads is also dependent on power quality of the power converters output. Researchers have done the evaporative studies on effect on load due quality of the power. According to IEC 61727 permissible limit of total harmonics distortion (THD) is less than 3%. The wave form with higher (THD) can create issues due to amplified thermal stress on systems.

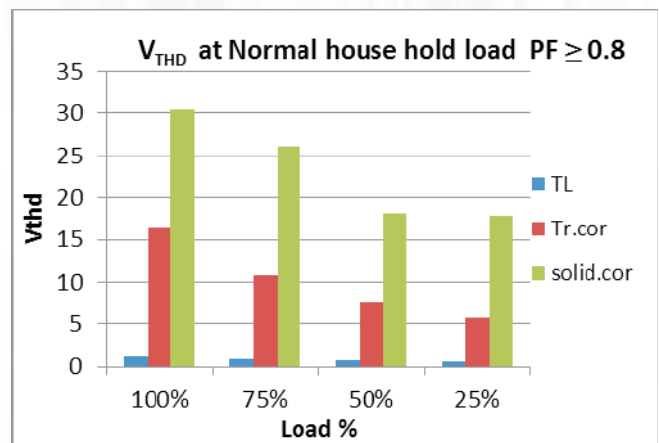
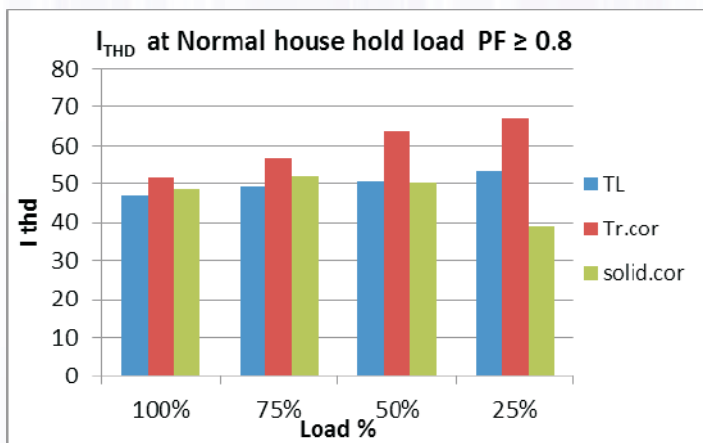


Fig. (a)  $V_{THD}$  distribution (b)  $I_{THD}$  distribution at different house hold load at PF ≥ 0.8

Fig. 5 shows distribution of VTHD and ITHD at different load percent for the same size sample of transformer less inverters and inverters with EI core transformers and inverters with toroidal core transformer. Here VTHD is lowest for transformer less inverter and toroidal core inverter have lower VTHD than that of EI core transformers. Further ITHD of the iron core is better in all the loads greater than 50%.

### **Performance Comparison of Controllers for Solar PV Water Pumping Applications:**

This study presents a detailed comparison of two different electronic controllers used for driving Solar Photovoltaic water pumping systems in India. A recently developed Sine-wave Pump Controller with MPPT (SPCM) having two stage converter topology offered better performance throughout the operational range, over the most popular controllers using the Variable Frequency Drives (VFD). The study presents an exhaustive study of SPCM and VFD based controllers in terms of their operational performance at 10 m, 18 m and 20 m head, in terms of quality of output power and quantity of the total water delivered when connected to the same motor-pump set under similar conditions. SPCM with best MPPT efficiency of 99.4%, lowest THD of less than 3% and pumped 30 to 70% more water for same heads. The overall system efficiency of SPCM based pump is 18% higher than VFD based pumping system for the head corresponding to duty point. The output power quality of SPCM is considerably high, with superior sine-wave (crest-factor 1.42 and 1.56 for voltage & current), ensures no voltage spikes even at 60 meters of cable length. Thus, the paper establishes performance dominance of SPCM over the VFD based controller through the measurement on actual sample.

Water and energy are the most primary requirements for the world. Use of solar energy for fulfilling the energy requirements is one of the best solutions, due to abundance and easy available nature of the source. However water and solar energy are interlinked with each other for human growth, which include pumping of water for irrigation and drinking water, detoxification of water using Bio based photo sensitizing substances, pumped hydro energy storage production, storing and utilization of hydrogen through electrolysis of water using SPV power etc. In case of dye-sensitized solar cell, water can be used to prepare cellulosic electrolytes. This paper deals with the utilization of solar energy for water pumping requirement. In India, the energy requirement for irrigation is very high, approximately 90 million hectare irrigated land area is there in the country as per the report of ministry of statics and Program Implementation, Government of India. The report describes that 62% of irrigated land is based on tube wells, 26 % on canals, 3% on tanks and 9% by other resources. Main medium for pumping of water is through diesel pump sets or grid based pumps. The recent growth in solar photovoltaic market, incentives by the Government of India [[www.mnre.gov.in](http://www.mnre.gov.in)] and reduction in the cost of solar based pumps are the main reasons for increase in the demand for Solar Photovoltaic (SPV) based water pumps in the country. Recently Ministry of New and Renewable Energy Resources (MNRE), under Jawaharlal Nehru National Solar Mission (JNNSM) has announced a target of about 0.5 million SPV water pumping systems to be deployed in the country by 2020 [[www.mnre.gov.in](http://www.mnre.gov.in)]. Successful implementation of such an ambitious program depends on the performance and reliability of SPV pumping systems. Concurrently, with

Government of India's initiatives strenuous efforts are also made by industries for development of efficient pumping system. India has good manufacturing base of conventional water pumping system both, for surface and submersible pumps which are used with conventional grid power. The industry has now started developing motors and pumps suitable for SPV applications such as BLDC motors, variable frequency motor and pumps to be used in JNNSM. However, only those models of SPV water pumping systems will be allowed to be provided with incentive which is qualified by the approved certification centers identified by MNRE under JNNSM. The National Institute of Solar Energy (NISE) is one of the three approved certification centers of MNRE for SPV pumps. NISE has established the test rig and other facilities for evaluation of SPV water pumping systems under real field conditions.

The performance of SPV water pumping systems is not accurate in real field, as estimated because of poor design of the array size, improper pumps and its balance of system (BOS). Extensive research works were reported on the performance estimation, optimum sizing of photovoltaic pumps and the effect of dynamic head variation on pump efficiency. However, one of the major bottlenecks in the design of high quality SPV water pumping system is to develop a suitable controller with MPPT and variable frequency inverter to drive the motors with optimum efficiency. In India under JNNSM, the AC induction motor based SPV pumps installed in the field are used with VFD without MPPT or Constant voltage based MPPT, along with PWM output. It has been observed that performance of both controllers without MPPT and with constant voltage MPPT drops with an increase in dynamic head or module temperature respectively. Having Buck type converter design and too high DC operating voltage is one of the reasons for large difference in water output in summer and winter season even though the radiation on module plane is same. Lots of people have done research on the MPPT algorithms, based on constant voltage, perturb and observe, and incremental conductance methods and effect of power quality on motor insulation. Industry grade VFDs are traditionally used for solar water pumping systems to drive induction motors, however limitations in the performance of VFD encouraged researcher to design a new pump controller such as Sine-wave Pump Controller with MPPT (SPCM). In SPCM, the improvement is incorporated by using perturb and observe MPPT algorithm for optimum PV power tracking, variable frequency concept and as well as sinusoidal power output without harmonics & voltage spikes for longer life by preventing insulation damage of motor.

The main objective of this work is to present a detailed performance comparison between SPV pumps using controllers based on VFD having no MPPT and, newly developed SPCM. The study is done based on parameters such as quantity of the water discharged at a given head, energy efficiency, MPPT efficiency, tracking performance, threshold wattage value to water discharge, power quality, THD, voltage spikes, etc. This study will help to improve the quality and life of solar PV pumping system in real field.



## System Description

Fig. 6(a) shows a typical block diagram of industry grade VFD based pump. A three phase inverter is associated with its controller which manages the variable voltage and frequency based on the operating conditions (radiation level and panel temperature).

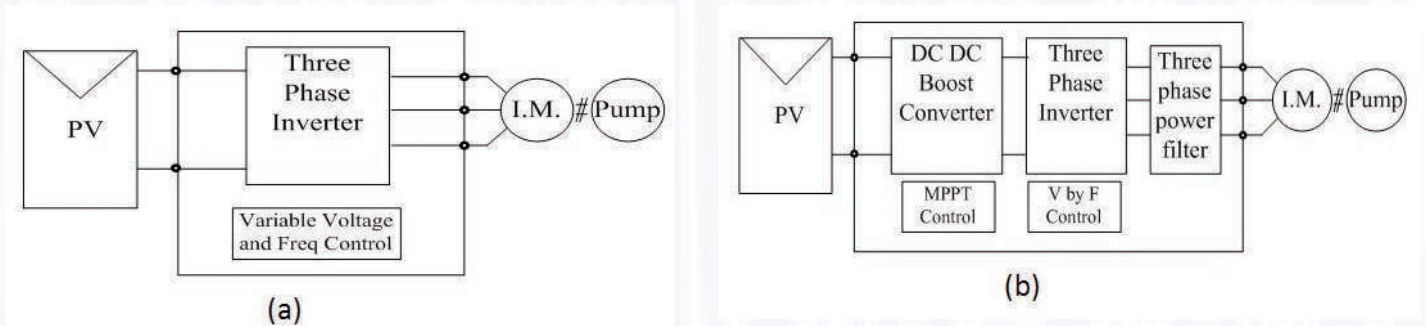


Fig. Block diagram of (a) VFD and (b) SPCM

Fig.6 (b) shows a modified power converter stages for SPCM dedicated SPV water pumping system. Input PV stage is a conventional DC-DC boost converter and MPPT algorithm used for maximum power extraction from PV array during operating conditions. The input stage is followed by three phase inverter which is controlled by using V/F technique so that to maintain a constant flux throughout the operation. This stage is further followed by three phase power filter whose cut off frequency is adjusted such that it eliminates the higher order harmonics and pass only fundamental component. This reduces the losses in machine and ensures no voltage spikes at the motor terminals.

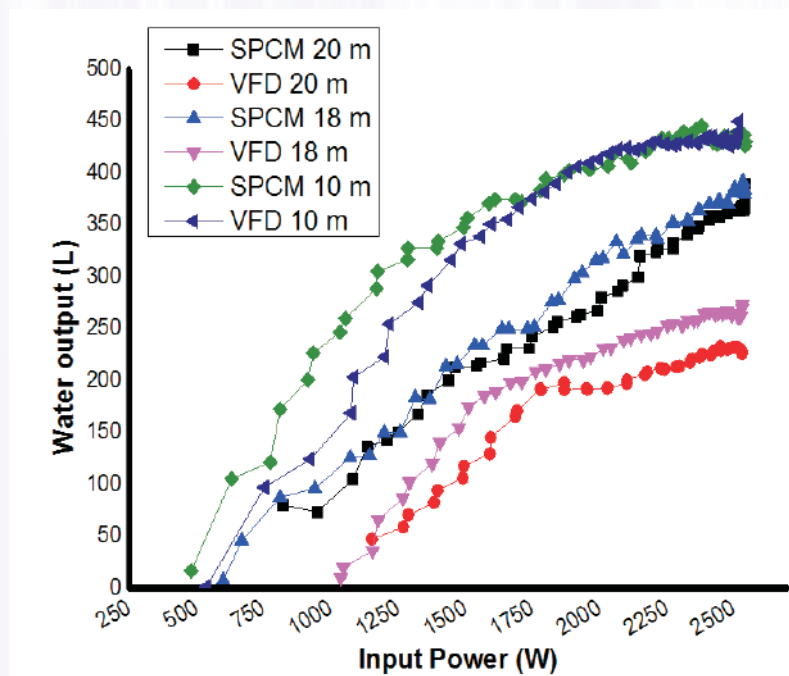


Fig. Input power vs water output at three different head for SPCM and VFD

A detailed comparison of SPCM and VFD based controllers used for driving Solar Photovoltaic (SPV) water pumping systems is presented. SPCM having variable frequency inverter (>94 %) and MPPT (>99 %) offered the best performance throughout the operational range, compared to the Variable Frequency Drives (VFD). This paper presented an exhaustive study of SPCM and VFD based controllers in terms of their operational performance at three different heads. The quality of output power and quantity of the total water delivered using the same motor and pump under similar conditions has been studied for 3 hp pump. SPCM with highest MPPT efficiency of 99.4 %, lowest THD of <3 % pumped 30 to 70 % more water under same head than the same pump with VFD controller. The overall system efficiency of pumping system coupled with SPCM is 18.5% more than that of VFD based controller at 20 m head. As well as higher power quality delivered by SPCM enriched life expectancy of the motor.

### **National/International co-operation/joint projects**

#### **National co-operation/joint projects**

**Ruchi Telecom Private Ltd.:** working for the development of high voltage DC system for home lighting systems and development of centralised street lighting system with the hybrid mode of transmission (High voltage DC / AC) for making streetlight more reliable and economically more viable.

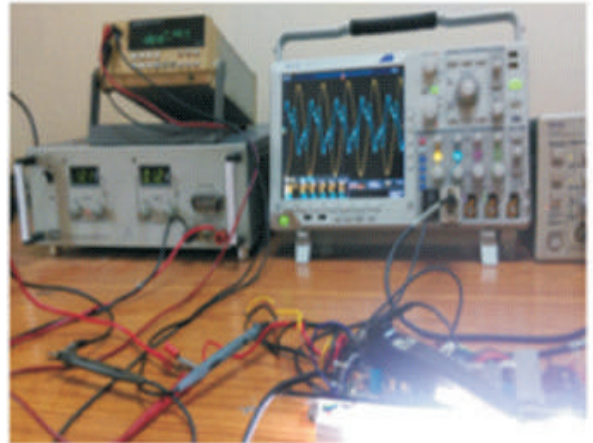
**Kisan solar PVT Ltd.:** working for the development and testing and standardisation of MPPT based Solar Photovoltaic pump controller from 3 HP to 10 HP

#### **International co-operation/joint projects**

**PTB- Physikalisch-Technische Bundesanstalt,** the national standards laboratory of Germany collaborate with Power Electronics Lab for the successful implementation of this mission is the use of premium-quality and secure solar energy systems which are adapted to international standards. Which is necessary for the national quality infrastructure (QI) to render internationally recognized and demand-orientated services which comprise technology and standardization as well as conformity assessment, certification and accreditation. PTB makes an important contribution to the development of solar energy in India and promote the exchange of technical and scientific knowledge. In addition to the NISE and the other Indian executing partners such as the Bureau of Indian Standards (BIS), are involved in the cooperation.



## 2.6 Advance SPV System & Lighting Laboratory



## INTRODUCTION

Advance SPV System & Lighting Laboratory at NISE is engaged in testing of performance and reliability of solar based lighting system as well as validation of performance in the field of solar lighting systems. It is the first solar lighting laboratory deployed by the MNRE to promote electrification program in rural India by solar PV lighting. The MNRE later also approved other testing laboratories i.e. ERTL Kolkata and CPRI Bangalore for similar purposes. The major solar PV lighting systems promoted by the MNRE includes portable Solar Lantern Home Lighting and, Street lighting systems etc. Since 1980's, the MNRE has been promoting the use of Solar PV Lighting systems in rural as well as remote areas and launched of many programmes. Before launching any programme on such a massive scale, it is necessary that the products should have the desired quality, efficiency, reliability, ruggedness and ease of operation.

The National Institute of Solar Energy (NISE) has been playing a major role in the development of solar lighting and other systems. It offers advice to manufactures for improving the quality and also helps prepare performance guidelines through its testing activity. The MNRE has its own Technical specifications for testing for Solar Lanterns, Solar Home Lighting Systems, Solar Street Lighting systems etc. Every year, revised technical specifications and design guidelines issued by the MNRE and NISE for systems to be supported through the government programmes. These guidelines are adopted by the manufacturers and the user agencies in their programmes.

Different type of systems Tested and certified during the past 10 years in the laboratory is shown in Fig. 1 below. The testing and certification is done against payment and month-wise revenue generated in the laboratory is plotted below in Fig. 2. An income of Rs.3721363.20 for the financial year 2014-15 has been generated from the laboratory.

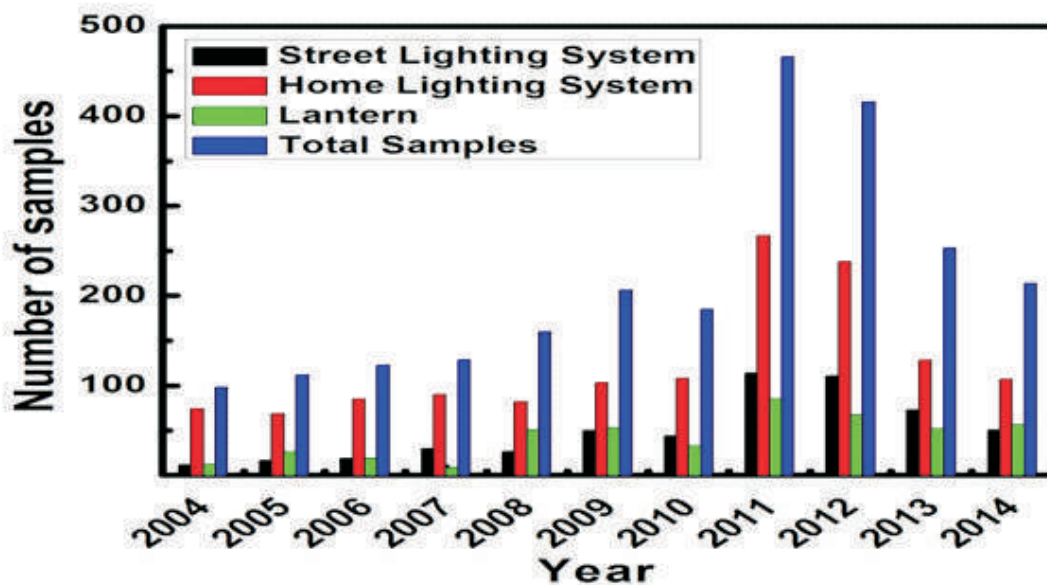


Fig. 1

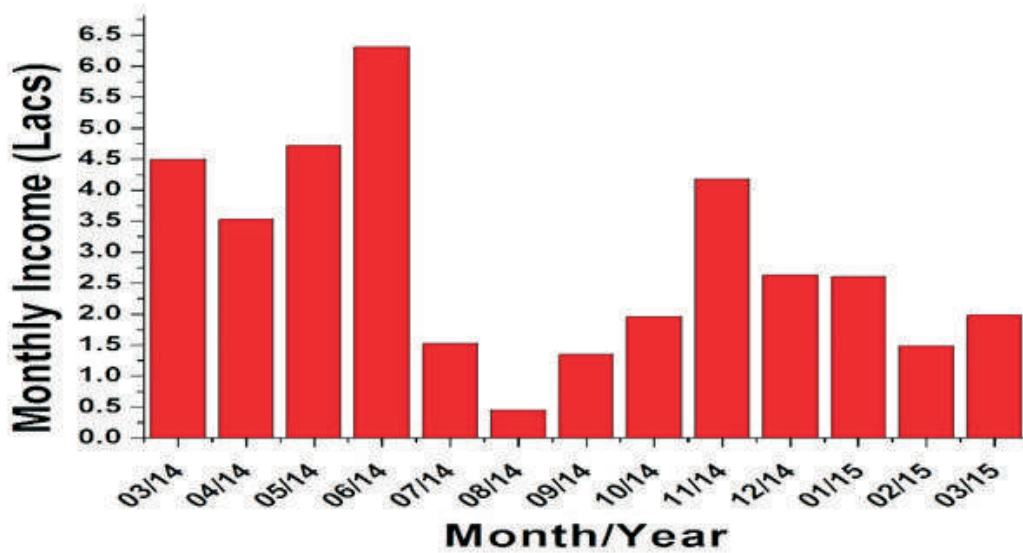


Fig. 2 Revenue generated by the laboratory in the year 2014-15.

### Solar Lighting System

The last few years has seen a rapid evolution of utilization and marketing of the solar based Lighting system. The consumer market has moved from CFL to LED based lighting system with new features and replaced lead acid batteries with Lithium Ion batteries. The advent of high lumen efficiency, ultraviolet free radiation, and wide view angle white light emitting diode (WLEDs) has revolutionized the lighting technology not only by reducing the required wattage, but also by increasing the operational life of the system. The cost of LED based Solar lighting system has been reduced considerably because of the lower wattage of PV modules and storage capacity of batteries.

Depending on the type of applications and utilization, the solar lighting system can be classified into the following categories:

1. Solar Lantern (SL)
2. Home Lighting system (HLS)
3. Street Lighting System (SLS)
4. Solar Task Light (STL)
5. Solar Study Lamp (SSL)
6. Solar Torch (ST)

Each of these systems consist of the following basic components:

1. PV Module
2. Battery
3. Charge controller
4. LED driver
5. Luminary to house the LED.
6. Cables and connectors.

The requirement of different components of the Solar Lighting system is briefly described below:

1. PV Module: The PV module should be of sufficient capacity so that it Should provide power to charge the battery with 120% of the discharged capacity for meeting the requirement of daily operation of the system.

The module wattage should be defined at 16.4 Volt and 8.4 Volt for 12 Volt and 6 Volt Lighting systems respectively.

2. Battery: The battery should be sealed maintenance free (SMF) or spill proof low maintenance and must conform to BIS or equivalent International standards. The Watt –hour efficiency of the battery should be more than 80%.

3. Charge Controller: It must have the temperature compensation for the battery set points i.e. LVR, LVD and BVR by using the external temperature sensors or built-in temperature sensing components. It should also have other protective features such as short-circuit protection, no-load protection and those against self-consumption, battery reverse polarity and PV module reverse polarity.

4. LED Driver: It must provide a constant current to the LEDs irrespective of the battery voltage so that the LEDs can provide constant light during the specified hours of operation. The efficiency of the drive should be more than 85%.

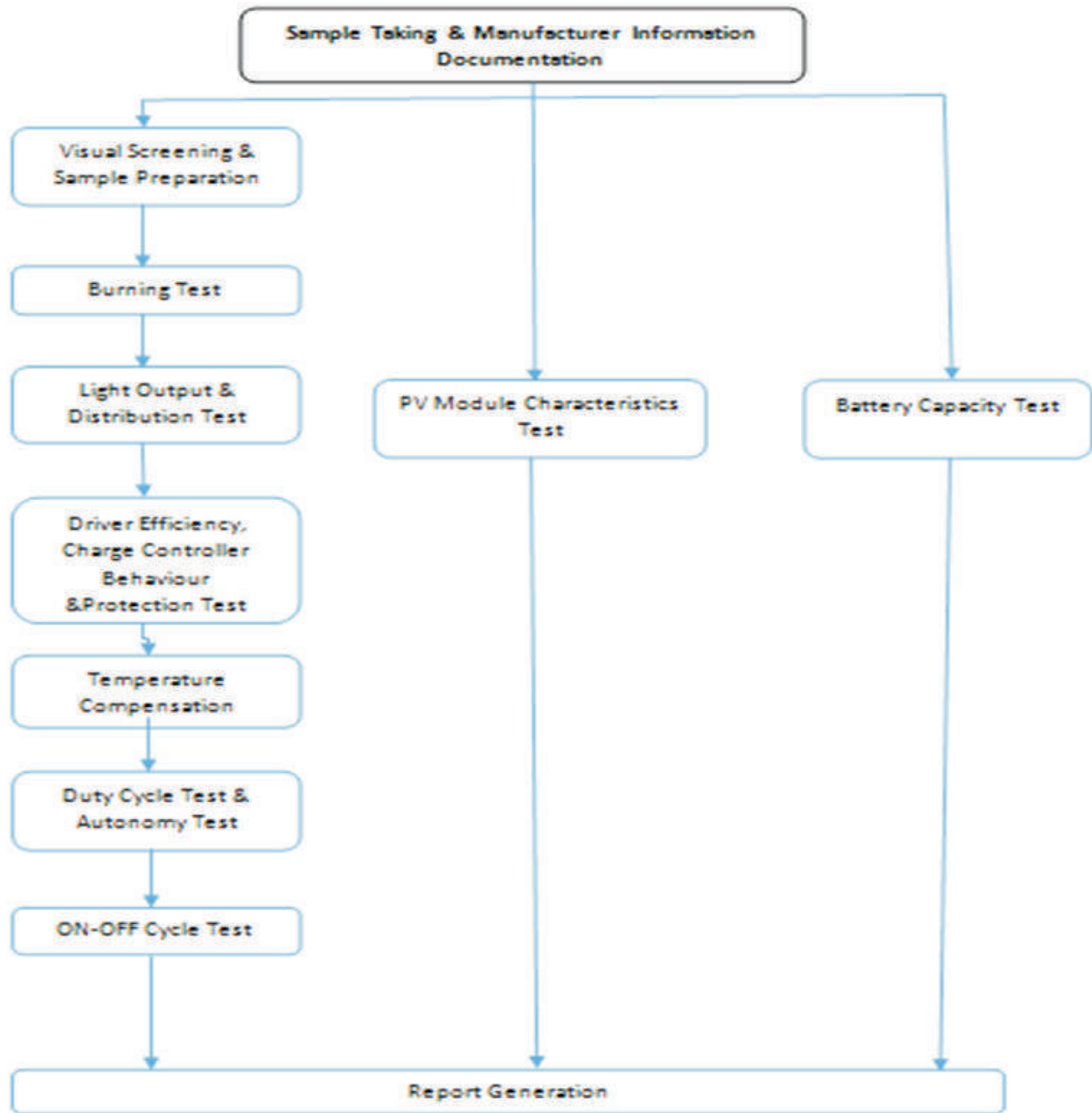
5. Luminary: The luminary which houses the LEDs should have proper optics and diffuser so that the LEDs may provide uniformly dispersed light without dark bands / abrupt variations and soothing to eyes with minimum light losses.

### **Test Facility & Procedure**

The National Institute of Solar Energy (NISE) has established a comprehensive test facility for performance evaluation of PV lighting systems in order to ensure their conformity to the MNRE specifications and to ensure smooth and reliable performance in the field.

The following are the recommended sequence of testing for Qualification testing of SPV Lighting system:





**Visual Screening & Sample Preparation:** Visual Screening should be done before any other tests. In this case, the sample is initially inspected for its physical condition and tested for its normal operation. After the visual screening, the sample is prepared for further testing by partial disassembly to provide easy access to various components.

**Burning Test:** During this test the system is kept ON continuously for 100 hrs. The purpose of this test is to stabilize the lumen output of the light source. However with continuous 100 hrs. of operation, the ruggedness and reliability of the electronic component used in the system is also accessed.



**Light Output & Distribution Test:** The light output (total luminous flux or lumen output) and other light output parameter (i.e. CCT, CRI etc.) can be measured by using an Integrating sphere. The light distribution can vary from one type of system to other (i.e. SL, HLS, SLS or unidirectional and Omni-directional light). The light distribution test is measured by using the LUX meter or light meter after installing the system as specified in the MNRE specification.

**Driver Efficiency, Charge Controller Behaviours & Protection Test.**

The efficiency of the driver circuit is measured by measuring the input power from the battery and the output power of the driver fed to the LEDs. The output of the driver circuit is then measured as a function of the battery operating voltage and the requirement to make sure the constant light output is that the driver output should not change more than  $\pm 3\%$  with the varying battery operating voltage.

The charging behaviour of the charge controller is studied to know the type of the charge controller, specifically whether it is MPPT/PWM/series regulated/ shunt regulated or any other type of the charge controller. Also the compatibility of the charge controller with the battery and the module is checked.

To make the system fully abuse free, the system is tested for battery deep discharge protection, over-charge protection, reverse polarity protection, load short circuit and open circuit protection, and reverse current flow protection.

**Temperature Compensation Test:** This test is conducted at the battery set points i.e. battery charge regulation (BVR), Low voltage disconnect (LVD) and Automatic load reconnect (LVR) are having the temperature compensation for proper charging of the battery irrespective of the operating temperature.

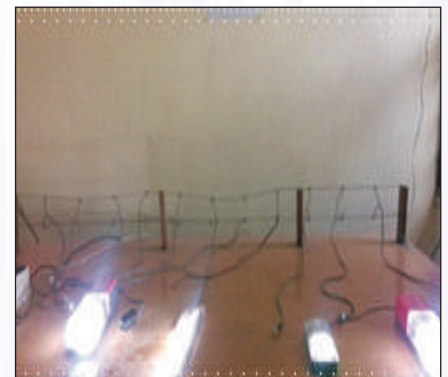
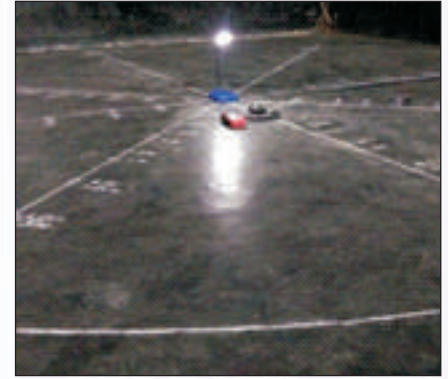
For this test the charge controller is kept inside a chamber and these battery set points are measured at different temperature range from 0 to 50 °C.

**Duty Cycle & Autonomy Test:** This test is conducted to make sure that the PV module provided along-with the system and the charge can put the adequate ampere-hours (AH) capacity inside the storage battery on a daily basis for operation of the specified number of hours of operation at night.

To verify the battery runtime/autonomy, first the battery in the system is fully charged and then the system is kept ON till it automatically turns OFF. The duration from ON to OFF condition of the system gives the battery runtime/autonomy.

During this tests, the Solar Radiation, PV module Voltage & current, Battery voltage & current, Load Voltage & current are plotted & monitored continuously using a data logger.

**ON-OFF Cycle Test:** In this test, the system undergoes 1000 ON-OFF cycle test. Each cycle consists of two minutes ON-time and four minutes OFF-time. These timings are so chosen that the lamps and electronics are provided with adequate time to reach its peak values. The 1000 ON-OFF cycle virtually simulates the switching ON and OFF of the lighting system during a period of 3 years in an accelerated manner. This test is considered as an accelerated life time test of the lamp and the electronics.



### **PV Module Characteristics Test:**

The PV module submitted along with the sample is tested for its standard test condition (STC) performance by using the Sun Simulator in order to verify the claimed wattage of PV module. Before making the STC performance the module is exposed to outdoor sun light equivalent to seven normal sunny days.

**Battery Capacity Test:** During this test the capacity of the battery is tested at the discharge rate at which the battery capacity is rated by the manufacturer by using a Battery Analyser.

To perform the complete testing of the solar lighting system and prepare the final test report usually takes between 25 & 30 days.

### **Other PV system testing**

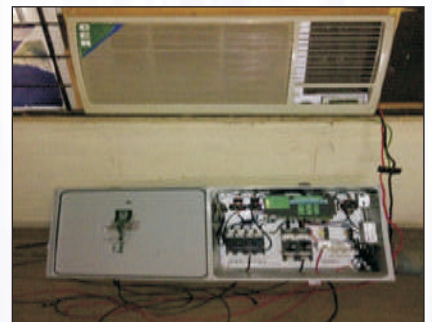
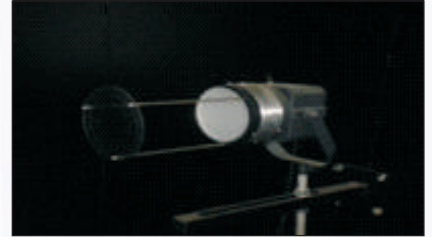
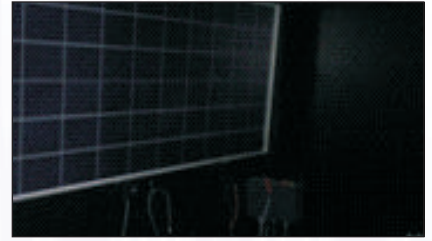
Apart from Solar Lighting System Testing, NISE has been doing development testing of Other PV based systems i.e. Solar e-rickshaw, Solar Air Conditioner etc. NISE has also been making facilities for testing for other PV based system to encourage the manufacturer to develop such systems which are beneficial to the society..

#### **Solar e-rickshaw:**

Solar e-rickshaw consists of one Module (240W), 4 batteries (each 100 Ah), one charge controller, one AC charger and having a motor capacity of 850 W. The complete system is designed is at 48 V. There are two provisions of charging the batteries i.e. through PV Module (DC voltage) and AC charger (AC voltage). It is having seating arrangement of 4 people plus 1 driver.

#### **Solar Air Conditioner:**

It consists of one air conditioner (input power of 950 W), 8 PV Module (each 300 W), 24 Lead acid batteries (2V, 300 Ah) and 1 charge controller. This system has a duty cycle (with a PV array capacity of 2.4 KW) of approx. 7 hrs and run time period (with batteries capacity of 300 Ah) of approx 12 hrs.



## Research & Development:

### Research Paper

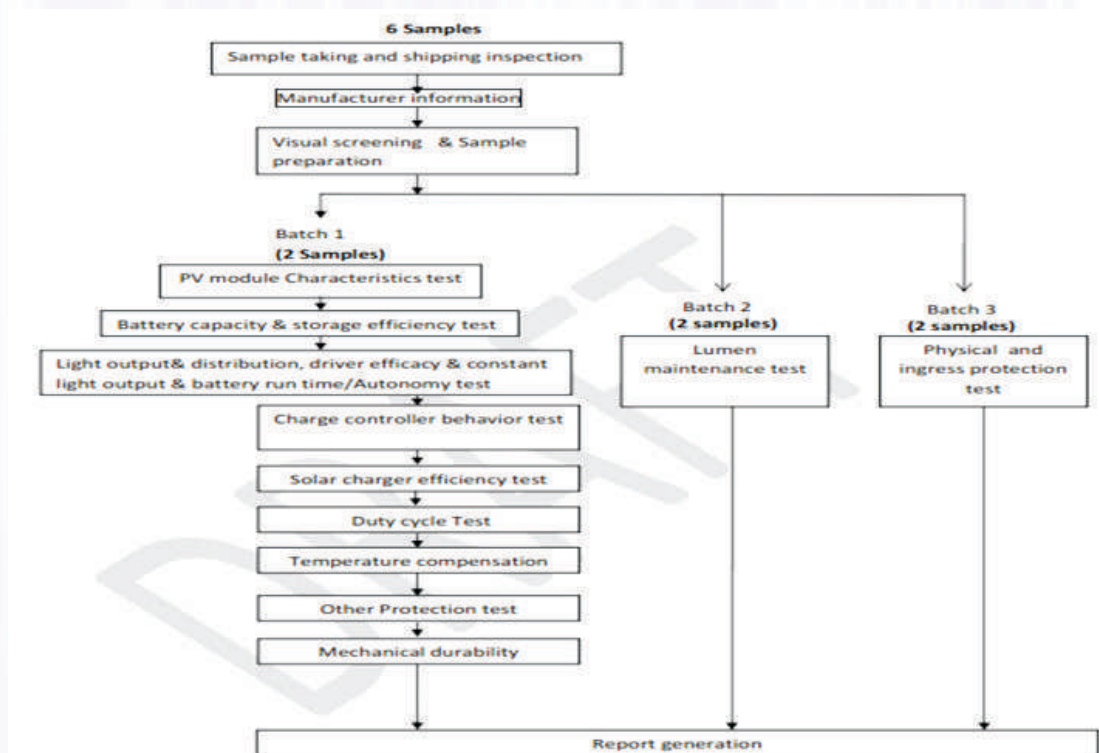
1. Performance, Evaluation, and Development of solar photovoltaic lighting system in India.
2. Development of white LED based PV Lighting systems.
3. Development of test procedure and test facilities for performance & reliability assurance of the LED based PV lighting systems for their trouble free and reliable operation in the field.

### Current Research Work

1. Perform qualification tests as per IEC 61215 of small PV module which comes with different solar lighting system in an indoor & outdoor condition.
2. Perform different environmental tests on different component of solar street lighting system in an indoor condition by using an Environmental Chamber to check the environmental effect on solar street lighting system during operation in field.
3. Design of different electronic driver and charge controller for solar lighting system as per different types of PV modules (i.e. thin film modules) and batteries (i.e. NiMH, Li-Ion, Li-phosphate etc.).

### New Initiatives

1. Upgradation of the test facility as per new lighting standard & testing methods. Presently test facility is being upgraded as per our new test protocol depicted in the figure below.



2. Procurement of new testing instruments such as Goniophotometer, Integrated Sphere, PV Array Simulator, Environmental Chamber etc. for photometric test
3. Inclusion of other testing facilities like Lumen maintenance test, Ingress protection test for the performance & reliability test of the Lighting system.

### **Training Courses Organized (National/International)**

In addition, B.Tech/M.Tech students are also encouraged to carry out their project work and are trained in the technical area. The following are the details of students who received training during the last one year.

S.No.	Trainee	Period	College	State Country
1.	Adarsh Kumar	6 months	Samrat Ashok Technology Institute, Vidisha	Madhya Pradesh, India
2.	Mayank Singh	1 months	Gautam Buddha University Noida	Uttar Pradesh, India
3.	Katell Audrain	1 week	Mody University of science & Technology, Rajsthan	France

## 2.7 500 kWp Multi Technology Power plant

In the year 2013-14, the NISE has embarked upon a major project of setting up in its campus a 500 kWp, multi- technology, solar photovoltaic power plant. With the energy demand in the campus going up day by day, the main impetus of the project is to provide uninterrupted power supply in the campus on a 24 x 7 basis and also serve as a test bed for multiple solar PV technologies. The design of the plant is such that of the total power generated, 200 kWp supply is connected to the battery bank and 300 kWp is fed to the grid. A part of the module mix used in the test bed facility is based on three crystalline silicon PV technologies, namely mono/ multicrystalline silicon (c-Si/ mc-Si) technology, hetero junction with intrinsic thin film (HIT) technology from Panasonic, Japan and interdigitated back contact (IBC) or Maxeon technology from SunPower, USA. The other part is based on thin film PV technologies such as CdTe and CIGS technology. Of these, the HIT and mc-Si technology modules are connected to a battery bank and CdTe, CIGS and SunPower modules are connected to the grid supply. The SunPower modules are mounted with single axis tracking whereas all other modules are inclined at an angle of 21°.

The capacity-wise distribution of the five different technologies are as follows:

1. 100kWp Battery Back-up SPP with Mono/Multi-crystalline modules
2. 100kWp Battery Back-up SPP with Panasonic HIT© modules
3. 100kWp Grid Tied SPP with CdTe modules
4. 100kWp Grid Tied SPP with CIGS modules
5. 100kWp Grid Tied SPP Maxeon© SunPower High Efficiency modules

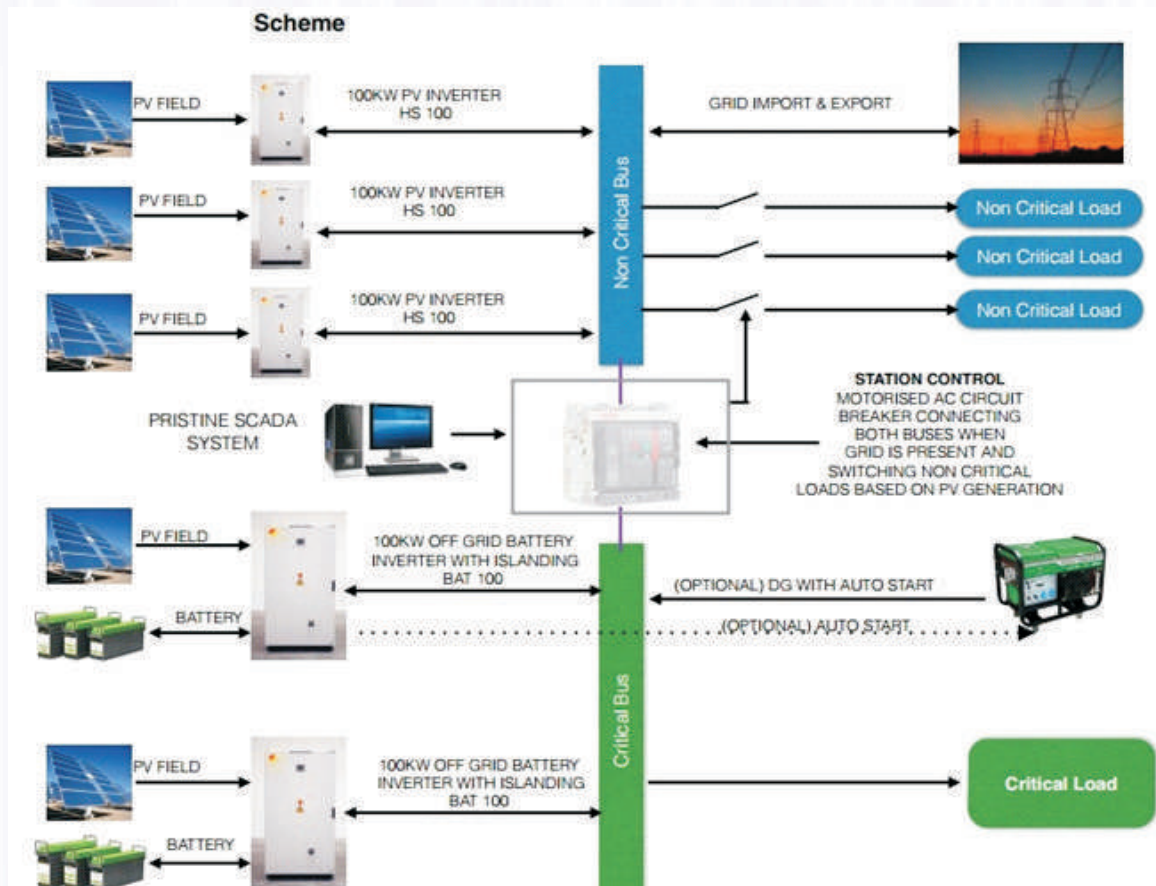
Aim of the 500 kWp multi technology solar power plant

- v There are five different PV technologies (mc-Si, HIT, SunPower, CIGS, CdTe), each having a capacity of 100 kWp.
- v 200 kWp array will be connected to load with a battery bank and SMD inverter whereas 300 kWp will be connected in a Grid Interactive (GI) Mode.
- v The power generated will be used in the campus, to make it a “Net zero energy” campus.
- v Performance and reliability studies will be carried out on large capacity strings.
- v Studies will be carried out on annual degradation and relative comparison of degradation.
- v Studies will also be carried out on Potential Induced Degradation (PID) of modules.
- v Performance evaluation will be made of two different types battery technologies, namely Lead acid & VLRA technologies.
- v Performance studies will be carried out on hybrid and grid interactive inverters.
- v Design of localized Smart Grid will be made and its performance studied.

Conventional power plant	NISE project
Conventional power plant always required a grid supply for synchronization of the inverter.	At NISE 500 kWp project we are using the battery bank facility for synchronizing the inverter during non-availability of the grid supply.
Conventional power plant generally use PV modules from one or two PV technologies.	Five different PV technologies are used at one place in the NISE power plant.
Generally smart grid configuration is not considered.	In NISE project, we are using the smart grid configuration.
	The system is mainly designed for the performance and reliability testing of different types of PV module technology.

## Final layout

The proposed and revised layout is shown in Fig. 1. The scheme is very simple and easy to understand and implement.



**Fig. 1 Schematic of the 500 kWp PV power plant at NISE**

There are two types of busbar arrangements proposed for the plant. The first one is called the non-critical bus and other is called the critical bus. The critical bus bar is always connected to the battery bank facility. The HIT and Multicrystalline technology modules are connected to the critical busbar and all connections are made to the 100kWp, off-grid battery bank with an inverter with islanding BAT 100. These are two types battery bank arrangement; one is lead acid type and the other

is VRLA type of battery bank system, each of which are also connected to a DG set with an auto start feature.

The rest of the 300 kWp power plant are connected to three 100 kW PV inverter models HS 100. Each of these PV branches are connected to the non-critical bus which is used for import and export from and to the grid. There is a special arrangement called station control system in the power plant. The main task of the station control system is to connect both the buses through motorized AC circuit breakers when the grid is present and switching on non-critical loads based on PV generation. The whole system is connected to the Pristine SCADA system. There is a special arrangement for the holidays, Saturday and Sundays when



#### Benefits of 500 kWp multi technology power plant

- v Realization of a “Net Zero Energy” campus.
- v Study of 5 different PV technologies under a composite climate condition.
- v Performance and Reliability study carried out on the system.
- v Load management analysis.
- v Project viewed as a model for conventional megawatt scale power plant.
- v Availability of uninterrupted power supply in the campus on 24 x 7 basis.
- v Study of battery charging and discharging characteristics.

- ✓ Beneficial for training activities at NISE for the government officials, individual entrepreneurs, technicians, charter engineers and students.
- ✓ Project employing renewable technologies that are friendly to the environment.
- ✓ Reduces electricity cost and carbon foot print.

### On-going progress of works at the site

At NISE, work has started on the 500 kWp, multi technology SPV power plant project. All levelling and marking work have been completed. A few photographs of the location, depicting the status of work, are shown below. The support structure and modules have been received for the multicrystalline silicon, HIT, CdTe and SunPower technologies. Of these, the SunPower modules have a tracking structure. The Tata Solar Power Ltd. Is implementing the project. The power plant is planned for commissioning by the end of October 2015.



PRE STAGE OF POWER PLANT LOCATION



CLEANING AREA



LEVELING



STRUCTURE ARRIVAL



MODULE ARRIVAL



BATTERY BANK



DIGING



MARKING OF DIGING



TILT ANGLE ADJUSTMENT



MOUNTEDS RUCTURE



ALIGNMENT OF STRUCTUER



SURYAMITRA TEAM INSPECTION

## CHAPTER-3

### Solar Thermal Energy Division

National Institute of Solar Energy (NISE) has undertaken interactive research with a number of national/ International research institutions/ Organizations & Industries. Institute has setup state-of-the-art Solar Thermal Technologies for different end use applications such as power generation, air-conditioning, cold storage, process heat, desalination, testing of solar thermal technologies, solar water heating system, solar cooker etc. Under the Research and Development Programme NISE has implemented the following projects during the year:

#### 3.1 1 MWe Solar Thermal Power Plant

A grid-interactive solar thermal power plant, with a capacity of 1 MWe at Direct Normal Irradiance (DNI) of  $600 \text{ W/m}^2$ , has been designed developed and commissioned at National Institute of Solar Energy (NISE), in collaboration with IIT, Bombay and other consortium partner as a part of the project entitled **“Development of a Megawatt-scale Solar Thermal Power Testing, Simulation and Research Facility”**. The unique feature of the plant is the integration of two different solar fields (parabolic trough collectors and linear fresnel reflectors) without a fossil fuel backup. The plant intends to combine the advantages of synthetic oil based Parabolic Trough Collector (PTC) field for high efficiency and direct steam generation (DSG) of linear fresnel reflector (LFR) field to lower the cost of generation.



Fig. 3.1:1 MW Solar Thermal Power Plant at National Institute of Solar Energy

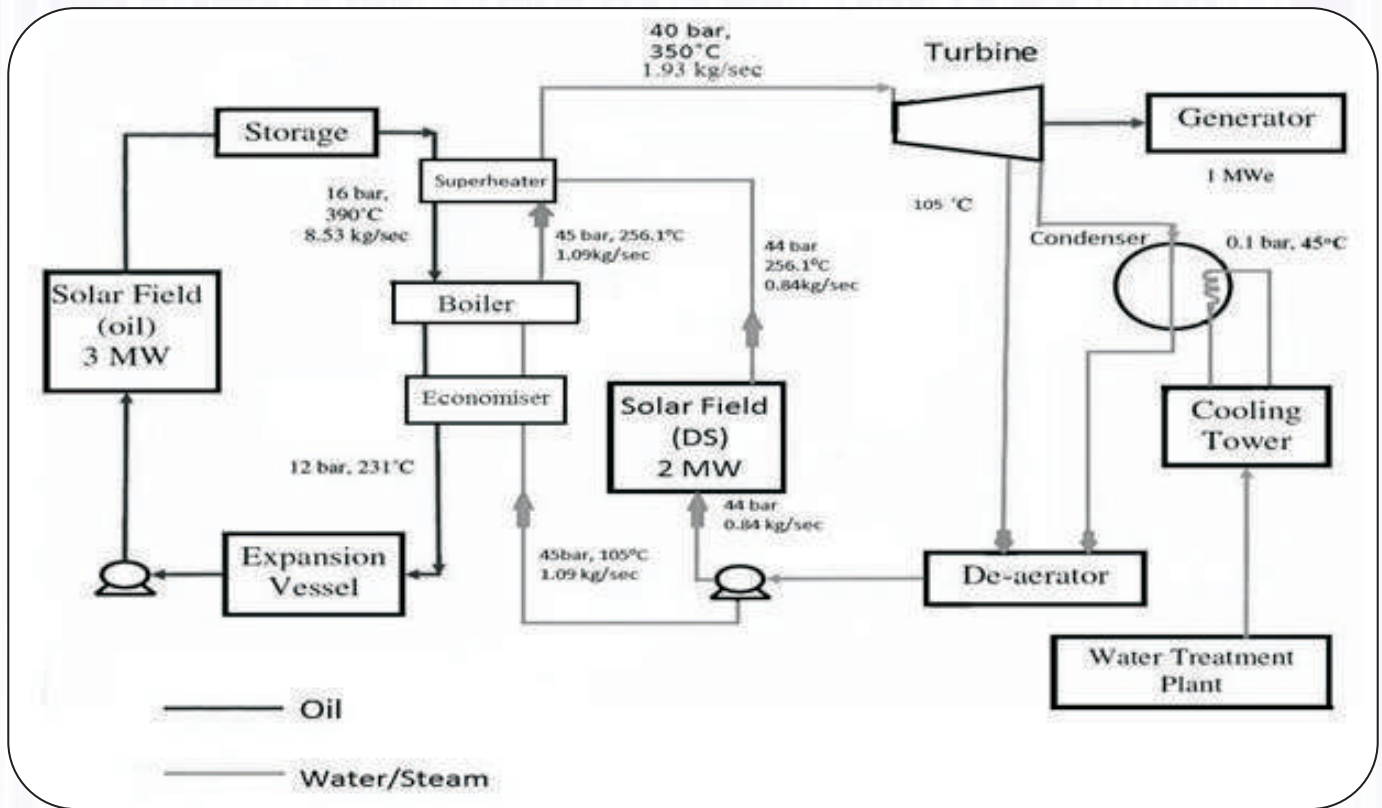


Fig 3.2: Process Flow Diagram of 1MW Power Plant

As per the design specification, steam operating pressure is 40 bar and temperature is  $350^{\circ}\text{C}$  (superheated steam) to run steam turbine. The heat is generated from two different solar fields. The linear Fresnel reflector solar field has been designed to generate saturated steam at 40 bar and  $250^{\circ}\text{C}$ . The parabolic trough field has been designed to heat up Thermic-fluid temperature at  $390^{\circ}\text{C}$ , for parallel steam generation. However, steam generated from both the fields and is superheated from parabolic trough field.

The plant also incorporates 15-18 minutes of sensible (Oil) storage as buffer for periods with when radiation is low or during cloud cover. The control algorithm of the plant ensures optimal utilization of both the solar field.

NISE took over the plant on 7th March, 2015 for operation and maintenance, data collection, long term performance evaluation and research and development on various components of the solar thermal power generation with following objectives:

- | Study of heat losses due to intermittent operation of solar thermal power plant.
- | Characterization of solar thermal technologies associated with 1 MW solar thermal power plant.
- | Optimization of synchronization/ hybridization process to maximize the thermal output of the solar thermal power plant.
- | Optimization of power generation output in different solar radiation conditions.
- | Design and simulation of commercial power plant based on long term performance data.
- | Development of operation protocol for solar thermal power plant.
- | Preparation of operation and maintenance manual.
- | Design, simulation of hybrid solar thermal power plant.

### 3.2 Modular Central Receiver Concentrated Solar Power Plant for Decentralized Power Generation

A Project was undertaken for development of modular central receiver concentrated solar power plant for decentralized power generation in collaboration with SunBorne Energy Technology Pvt. Ltd. Under the project, designing of heliostat along with its numerical analysis and control system, testing and optimization of heliostat have been completed including design, component specifications, assembly and erection procedures, and controls. In house Mirror gluing and curving process was developed which has been documented, tested, and finalized. Canting technique has been developed and 12 Heliostats have been canted and erected. Steel tower of height +32.5 Metre has been completed with Jib crane at top. Electrical wiring and control work for complete solar field and prototype receiver have been completed. Selection of volumetric absorber materials based on experimental investigation carried out at ETH Zurich. Installation of the prototype receiver with heat exchanger along with necessary instrumentation and controls system has been completed. Testing of 50 kWth (Designed) prototype air receiver has been conducted for finalization of design of receiver. A parametric study has been performed to analyze the Thermal Storage behavior. Based on the study a Numerical Model for thermal storage has been prepared and validated against important design parameters. The prototype thermal storage experiment has been carried out at University of South Florida (USF).

The project has been taken over by NISE and remaining work will be completed to achieve the following objectives:

- | Flux characterization of the heliostats testing & optimization of their control system.
- | Reliability test for commercialization of solar field.
- | Design finalization of 1 MWth receiver on the basis of test results from prototype receiver.
- | Designing and construction of a storage element including vessel manufacturing, fill material filling, site preparation and assembling.
- | The testing of the receiver & storage subsystems, including the development of a testing plan, testing for sufficient duration at different solar conditions and performance evaluation.
- | Overall testing & performance evaluation of Heliostat, receiver and Thermal Storage including control strategy during startup, shutdown and transient period.
- | Design Simulation of commercial plant.



Fig. 3.3: Central Receiver Solar Power Plant

completed. Discussions are on with M/s SunBorne Energy Technologies Pvt. Ltd. to takeover the implementation of the project on as-is-where-is-basis by NISE.

### 3.3 Solar Cooling

Under an MNRE sanctioned R & D project, NISE in collaboration with M/s Thermax Ltd. Pune have taken up Design, Development and Demonstration of the following three solar cooling systems in different configurations using Solar Thermal Energy:

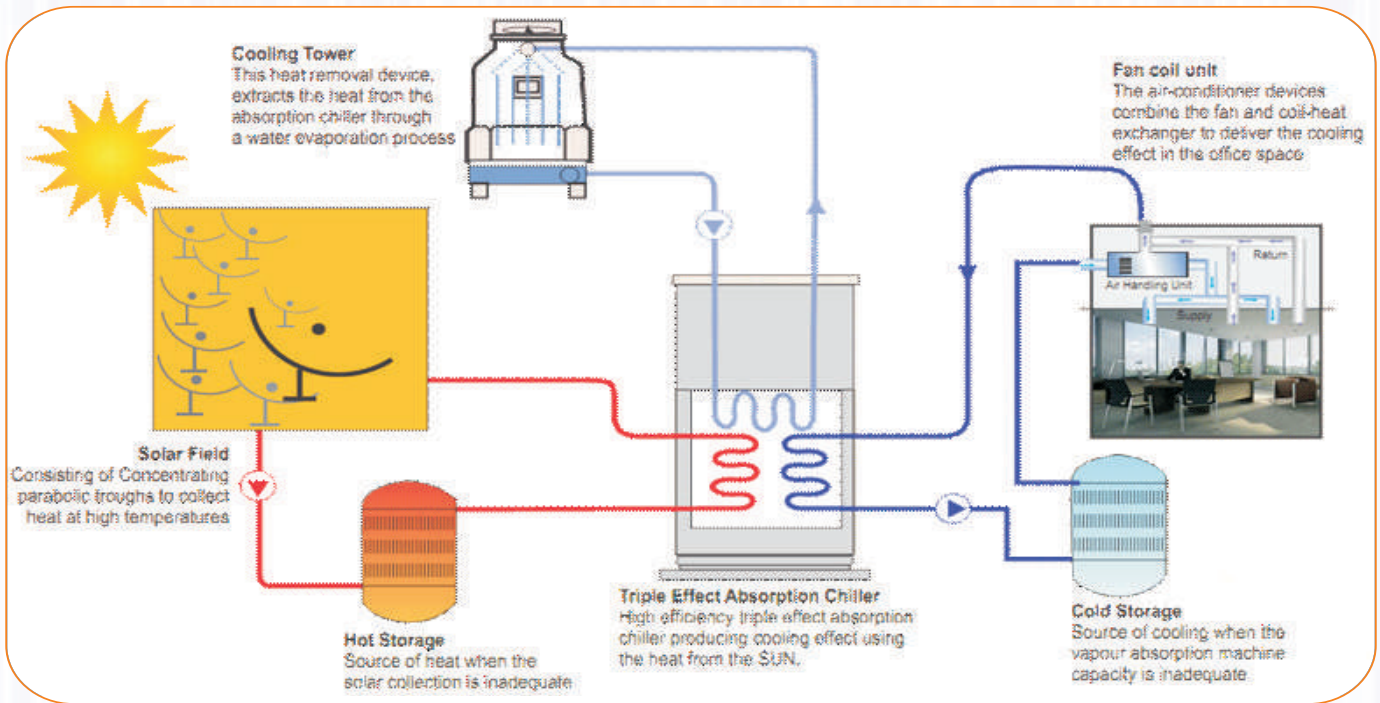
#### 3.3.1 100 kW High Efficiency Absorption Prototype System

The system consists of a high efficiency three stage Vapour Absorption Machine (VAM) based on LiBr-H<sub>2</sub>O cycle with Coefficient Of Performance (COP) of 1.7, at suitable medium temperature of solar concentrating collectors with appropriate storage system. 288 m<sup>2</sup> parabolic trough collectors (PTC) provide 210°C temperature pressurized water. This heat is used in VAM to generate 7°C chilled water which in turn is circulated through the Fan Coil Unit (FCU) installed in various rooms to be cooled. Besides the triple effect unit, the system has indigenously built medium temperature parabolic troughs for the collection of solar energy. System has special arrangement of storage of heat and cool using Phase Change Materials (PCM).



**Fig. 3.4: Solar Field and vapour absorption machine**

In winter, the solar heated water, instead of pushing through the VAM, is circulated through the FCU to provide heating. The system has been working since its commissioning. A study has been undertaken for performance evaluation and system optimization by NISE.



**Fig. 3.5: Process Diagram of Solar Cooling System**

### 3.3.2 15 kW Absorption Prototype System with air cooling

A 15 kW LiBr- water double effect absorption prototype system with air cooling was installed and commissioned in December 2013 at the NISE campus. This unit uses hot water at around  $170^{\circ}\text{C}$  as heat source. Indigenously developed Parabolic Trough Solar Collectors (PTC) are used to provide the required pressurized hot water to the Vapor Absorption Machine. The total collector area is  $96\text{ m}^2$ .



**Fig. 3.6: 15 kW Solar Absorption Refrigeration System (Air Cooled)**

This pressurized hot water in VAM is used to generate chilled water at  $9^{\circ}\text{C}$  which is circulated through the Fan Coil Unit installed in various rooms to be cooled. System has provision of air condensation. Study has been undertaken to optimize the system performance during different radiation and ambient conditions.

### 3.3.3 5 kW Adsorption Prototype System

A 5 kW prototype system based on water cooled adsorption cycle was installed in December 2013 in NISE. The adsorbents are specially synthesized to suite the tropical climatic conditions. The objectives are development of cost effective high efficiency cooling engine and indigenous components for vapor adsorption machine, and non imaginary solar collectors system have been designed to harness sun's energy in an effective manner to provide temperatures up to  $120^{\circ}\text{C}$  with improved efficiency including integration of the components to achieve consistent performance of the system. Compound Parabolic Concentrator (CPC), an enhanced version of Evacuated Tube Collectors are used to provide the required heat to the Adsorption Machine. The total collector area is  $61\text{ m}^2$ . The system provides 5 kW of air conditioning to an office cabin with chilled water at  $9^{\circ}\text{C}$  circulated through a FCU. During 2014-15, NISE has undertaken a study on the effect of cycle time, input temperature and condensation temperature for optimization of the system.



Fig. 3.7: 5 kW Adsorption Refrigeration system

### 3.4 50 kW Solar-Biomass Hybrid Cold Storage Cum Power Generation System For Rural Electrification

National Institute of Solar Energy in collaboration with M/s Thermax Pvt. Ltd., Pune and The Energy and Resources Institute (TERI), New Delhi has developed and installed a 50 kW solar-biomass hybrid cold storage cum power generation system for rural electrification at the NISE campus in February, 2012. The system consists of a 50 kW biomass gasifier including gas cleaning and cooling system, 50 kW 100% producer gas engine, heat recovery unit, 15 kW (ammonia+water) VAM, 4 Scheffler Dishes with 16 m<sup>2</sup> area for each and cold storage room of capacity of 20 metric tons.

The 50 kW biomass gasifier system provides electricity and the waste heat of the engine (exhaust) that is used as the main source of energy for the cold storage. During the day time, when the sunshine is available the Scheffler Dishes along with engine exhaust provide heat to the system. During evening, when there is no sunlight, the gasifier is run to meet the evening electricity load and the cold storage will operate only on engine exhaust. In case, no sunshine is available and engine exhaust is also not sufficient, provision has been made for firing of producer gas in Heat Recovery System to meet balance heat requirement for running the cold storage. Study is carried out for automation of process in different load condition.

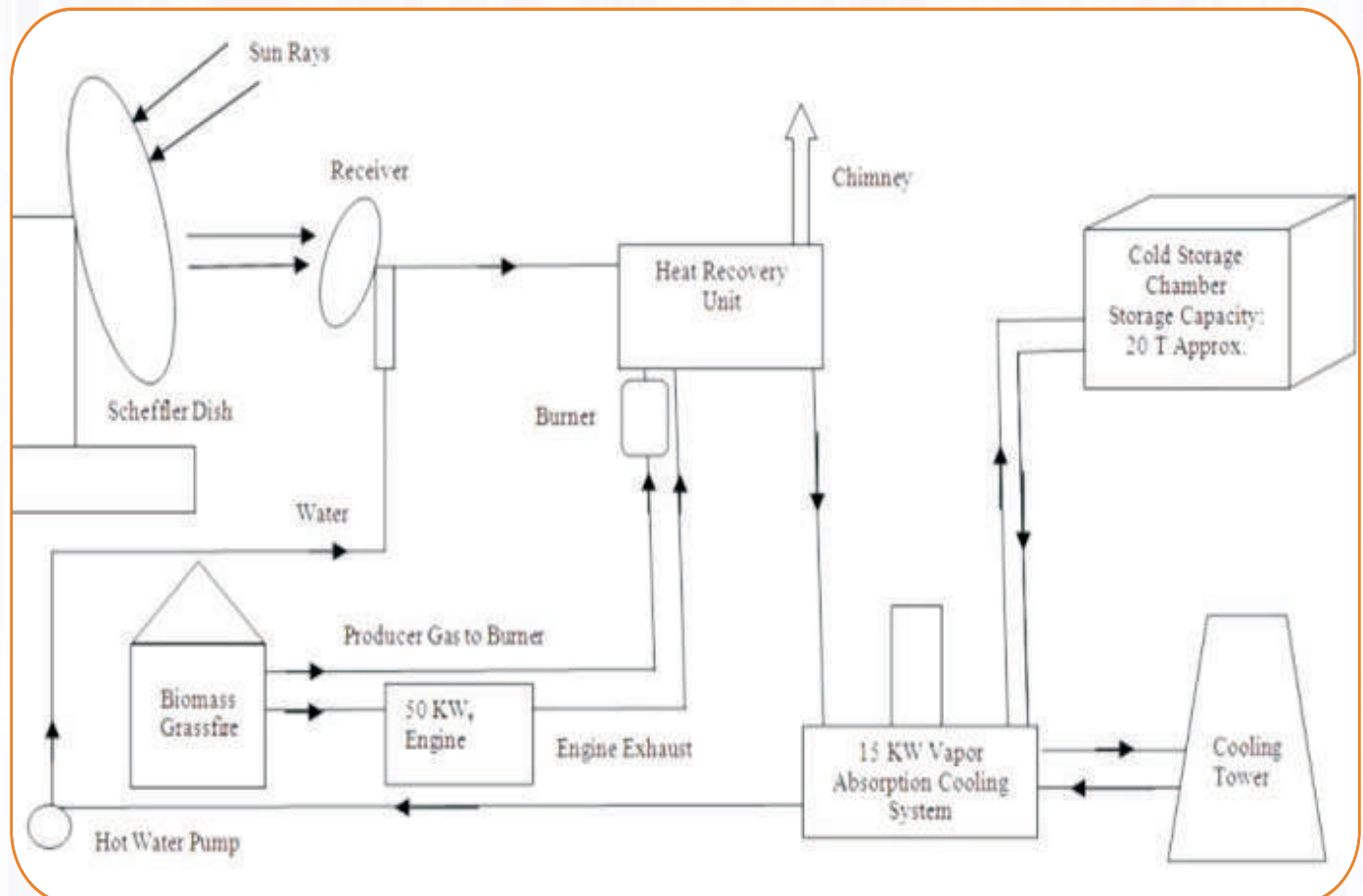


Fig.3.8: Process diagram of solar biomass hybrid cold storage



Fig.3.9: Solar Biomass Hybrid Cold Storage System

### 3.5 Solar Stirling Engine

Three 3 kWe Stirling engines were installed in 2011 at the NISE Campus in collaboration with ONGC Research Centre for performance evaluation and assessing its suitability in Indian conditions. The system consists of Parabolic Dish concentrator, piston free Stirling engine cum reciprocating generator mounted on moving receiver.

Helium is used as working fluid. GPS based 2 axis tracking mechanism has been used for tracking of parabolic dish. As a result, system is facing 'zero cosine losses'. System efficiency is 24% from sun to electricity at 850 W/m<sup>2</sup> DNI and 25°C ambient temperature. Study is carried out to simulate performance of system in different part of the country.



Fig. 3.10: Solar Stirling Engine at NISE

### 3.6 90 m<sup>2</sup> Paraboloid Dish for Industrial Process Heat Applications

National Institute of Solar Energy in collaboration with M/s Megawatt Solution Pvt. Ltd. (MWS) have designed and developed a 90 m<sup>2</sup> parabolic dish concentrator in 2010 at the NISE campus.

The project comprises a test loop used to simulate a typical industrial heating system based on the thermic fluid heating. This heating loop generates steam in the heat exchanger and it is hybridized with diesel firing arrangement to assure the constant steam flow round the clock. The parabolic dish system is seamlessly integrated into the return header of the thermic fluid-heating loop in sun shine hours.



Fig.3.11: Paraboloid Dish for Industrial Process Heat Applications

### 3.7 Solar Water Distillation System

A solar water desalination system was installed in December 2013 at the NISE campus under a collaborative project with an Australian company, FCUBED Pvt. Ltd to evaluate performance in different Indian climatic conditions. The system consists of 10 panels of specially designed solar collector of 3m<sup>2</sup> area each. A provision of SPV panel and DC pump has also been provided for lifting of water from storage tank to solar collector.

Performance evaluation study has been carried out and study reveals that it can produce pure clean drinking water up to 150 litres per day from any type of water. In the month of March on a particular day in a year the output of drinking water was about 5.33 liters/m<sup>2</sup> day at the radiation of 5.6 kWh/m<sup>2</sup>. The inlet brackish water was 350 ppm before distillation and the distilled water was found to have zero ppm. This system is the one of the most efficient and cost effective compared to other water distillation systems.

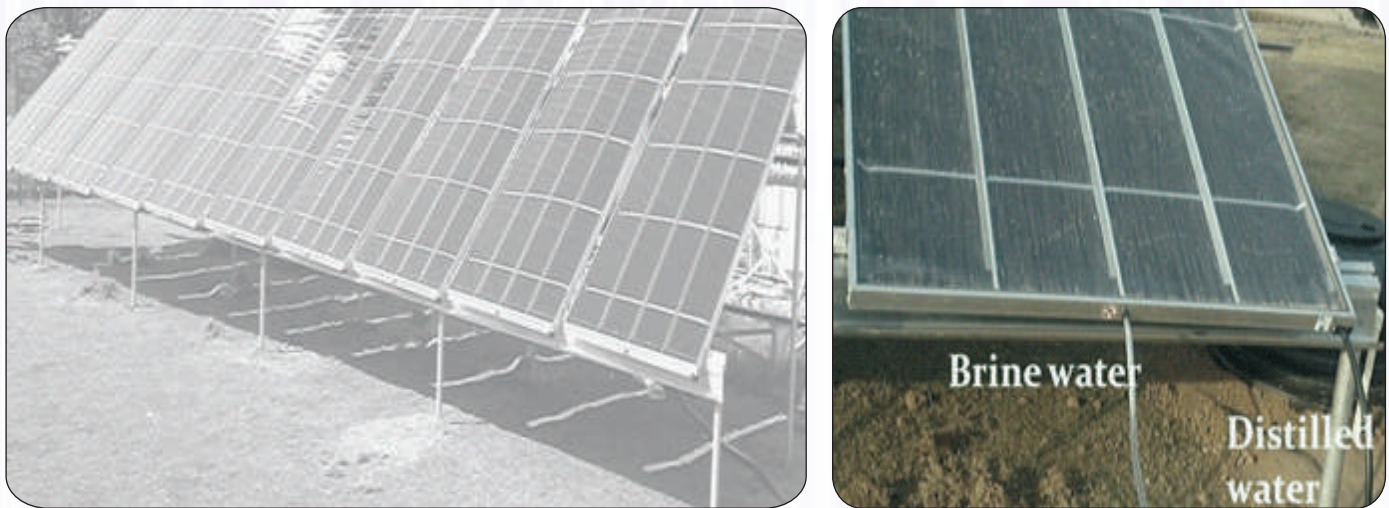


Fig. 3.12: Experimental setup of Flat Plate type Solar Water Distillation system

### 3.8 In house Research and Development activity of National Institute of Solar Energy:

NISE has carried out research, design & development in following areas of solar thermal systems:

- Design, development and fabrication of Multi effect humidification and dehumidification distillation systems with heat storage using phase change material for operation during non-sunshine hours.
- Design, development and fabrication of a high efficiency desalination system using multi condensation of the system.
- Testing of Phase Change Material (PCM) for different end use applications.
- Design and Simulation of poly generation process for multiple output like power, heat, and cooling.
- Design and simulation of hybrid solar-biomass power plant for various regions of India.
- Design, development and fabrication of low cost portable solar distillation systems.

### 3.9 Solar Thermal Test facilities for CST:

National Institute of Solar Energy has created facility for characterization and testing all type of concentrating technologies, solar thermal technologies across the country that could prove to be a foundation for emerging solar thermal and related applications in the booming solar energy industry. Following two types of Test facilities for CST have been set up at the NISE campus.

#### 3.9.1 Hot water/ Steam based Test Set Up

Under UNDP-GEF project “Market Development and Promotion of Solar Concentrator based process heat Application in India”, a facility has been created for testing and characterization of hot water/steam based concentrating solar based technologies.

Test facility is capable in testing of different models of CSTs based systems with output temperature up to 250 °C. The measurements are carried out under quasi steady state conditions.



Fig.3.13 : Testing of Evacuated FPC and Solar Dish for High Temperature at NISE

### 3.9.2 Thermic fluid based Test Set Up

In 2012, NISE established a thermic fluid based CSTs test facility to test the thermal performance as part of the project entitled “Development of a Megawatt-scale Solar Thermal Power Testing, Simulation and Research Facility” in collaboration with IIT Bombay. This test facility is capable to test all the CSTs using thermic fluid as heat transfer fluid with temperature up to 400°C. The heat transfer fluid for testing is Therminol VP-1. The CSTs have been tested using heat transfer oil at various temperatures up to 400°C at oil flow rates from 5-7 kg/s, and pressures up to 10-15 bar. The test facility offers the characterization of CSTs to provide the opportunity for design improvements and selection of concentrators for various applications.



Figure 3.14 : Thermic fluid based Test Set-up for CSTs at NISE

### 3.10 Testing of other parameters

In 2012, NISE has also created a facility for testing of other parameters of solar thermal technologies such as :

- 1 Receiver heat loss characterization in Indoor testing condition.
- 1 Surface reflectivity test of mirrors/reflectors
- 1 Absorptivity and emissivity test of receivers



Figure 3.15: Heat loss testing of heat receiver

### 3.11 Mobile Test Set Up

During 2014-15, NISE established a mobile test facility for characterization and testing of CSTs in actual field conditions. This facility can test surface reflectivity of reflectors, absorptivity and emissivity of receivers, optical and thermal efficiency of CSTs in the actual field condition. The test output will help the manufacturers to estimate the performance of the technology in different climatic and environmental conditions of this country. Various test equipment to measure different parameters of the CSTs are shown in Figure below.







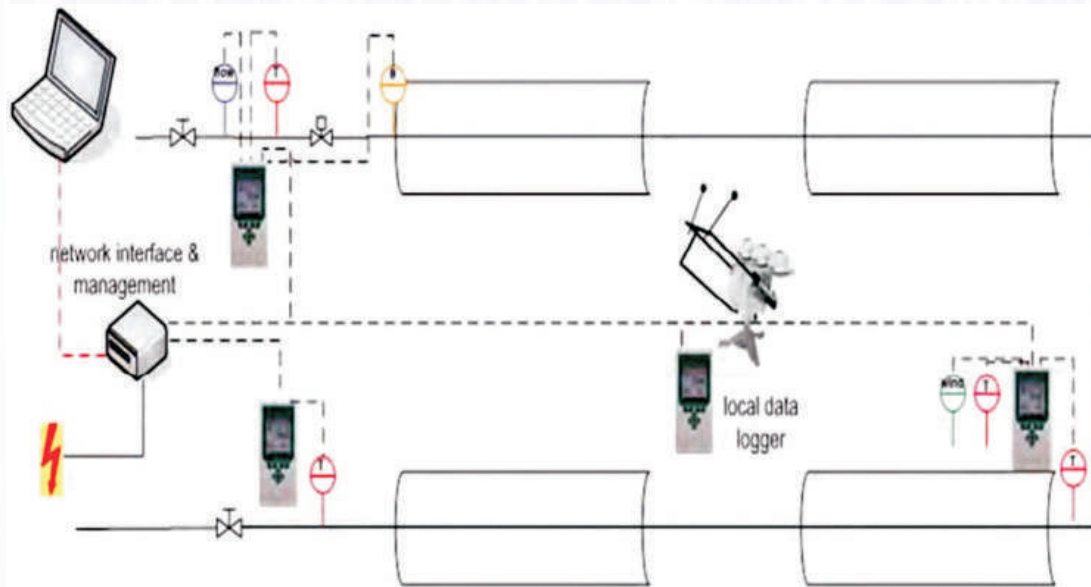
<p><b>Mobile solar tracker with irradiation sensors</b></p>	
<p><b>Ambient temperature and wind sensors</b></p>	
<p><b>Clamp-on ultrasonic flow meter</b></p>	
<p><b>Temperature sensors</b></p>	
<p><b>NIR Handheld Reflectometer</b></p>	
<p><b>Mobile data loggers</b></p>	

Figure 3.16 : Mobile Test Equipment





**Figure 3.17 : Mobile test setup for different CSTs**

### 3.12 Solar Thermal Test Facility as per BIS and MNRE Standards

A Test Rig for testing of Flat Plate Collector (FPC) system as per Bureau of Indian Standards (BIS) and Evacuated Tubular Collector (ETC), solar cooker (i.e. box type and paraboloid solar cooker) has been established at outdoor test bed at the NISE campus.



**Figure.3.18: Test Setup for solar water heating system**

During the year 2014-15, 12 nos. of solar water heating systems have been tested and certificate were issued to the system manufacturers.

## CHAPTER-4

### Skill Development & Consultancy Division

“Skilling India” is the dream project of Honorable Prime minister of India for creating job opportunities for the unemployed youth in the various service and manufacturing sectors throughout the country. It is a flagships program of the PMO targeting to create 500 million skilled manpower by 2020.

Renewable energy is one of these targeted sectors, and National Institute of Solar Energy, an autonomous institute under the Ministry of New & Renewable Energy is assigned with the responsibility to execute the various skill development programmes throughout the country in the field of renewable energy technology. During 2014-15, NISE has created innovative, result oriented skill development division to cater the need of “Make in India” program. At present various programs are being conducted at NISE and at its partner institutes across India. A list of programs under the skill development division of NISE is as follows:

#### 1. Skill Development Activities at NISE

NISE is conducting Solar and Renewable Energy training for the past two decades for national and International Participants. NISE is regularly inviting people from solar and renewable energy industry and interacting with them to identify the skill gaps in the new recruits of the renewable energy industry. A dedicated training program on renewable energy technologies for the senior Defence officers are also being conducted thrice in a year. This year about 50 programs shall be conducted by NISE.

NISE has developed curriculum and content to renewable energy technologies skill development programs, designed for senior Defence ministry officials and conducted three programs during the year. Border security force officers are planning to install several solar photo voltaic power projects at various BSF check posts. To cater the needs of BSF senior officers regarding installation & maintenance of these SPV power plants NISE has designed a specific skill development program and conducted two programs to BSF.

The following Skill development programs were conducted at NISE during 2014-15:

S.No.	Skill Development Programs	Dates
1	INPACT Training of Trainers	19-23rd August 2014
2	Effective Implementation of Solar PV Programs	25-29th August 2014
3	Opportunities in Sourcing and Managing Solar Power	08-12th September 2014
4	Execution of Rooftop Solar PV Plants	22-26th September 2014
5	Solar Rooftops Policy, Regulation and Finance	28-29th October 2014
6	Rooftop SPV Power Plant, Design Modeling and Simulation	30-31st October 2014
7	Solar Resource Assessment Workshop	20-21st November 2014
8	Solar Rooftops SPV Plant: Design, Modeling and Simulation	27-28th November 2014

9	Renewable Energy Technologies Workshop for Armed Forces	8-12th December 2014
10	Training program for Bangladesh delegations.	6th to 11th Jan 2015
11	A training program on renewable energy technologies for Mongolian Delegates	19th-30th January 2015.
12	Training program on Renewable energy technologies for Ansal university students	12 -14 Feb 2015.
13	Training programs for BSF officers on MW range solar power plants operation & maintenance	24-26 march 2015.
<b>Total number of programs</b>		<b>13</b>



*Group photograph of officers from ARMED forces attending Renewable energy technology workshop with NISE officer*



*Group photograph of officers from ARMED forces attending Renewable energy technology workshop with NISE officers (2nd batch)*

## 2. Solar Energy Network (SETNET)

NISE has established the solar energy Training Network (SETNET) institutions across India to build skills and capacities to ensure the availability of qualified solar energy professionals to meet the national solar deployment targets.

Specifically, the objective of SETNET is to ensure the availability of skilled manpower to meet the solar deployment target for 2022. SETNET guiding framework includes:

- ? Prioritization of training needs with concurrent industry interface.
- ? Standardized curriculum and content delivered by accredited trainers.
- ? Training delivery through a range of partner organization

Through a competitive process, NISE has identified 35 SETNET partners across the country which are empanelled by NISE to provide the above four skill development courses. Several programs are launched across India.



**SETNET TEAM WITH 35 SETNET PARTNERS**

NISE has created curriculum development teams and created curriculum for the following major courses:

The four major courses under this program are given below:

- ✍ Aryabhata Certificate (for high level designers)
- ✍ Konark (graduate engineer project management course)
- ✍ Surya (for solar field technicians)
- ✍ Bhaskar ( for Business/ Financial Programs)

**The four major courses under this program are given below :**

- ✍ **Aryabhata** Certificate (for high level designers): This course is meant for engineers with some experience in the solar sector. The aim of this course is to enable the participants to effectively plan, design and operate solar power systems of a range of scales from rooftop collectors and power plants to ultra-megawatts.
- ✍ **Konark** (graduate engineer course). This course is meant for engineers who seek employment as a solar engineers.
- ✍ **Suryan** (for solar field technicians): Suryan program is meant for Participants dealing with home lighting system, solar rooftop, street lighting solar water heaters ,inverters and batteries ,charging stations and solar cookers.
- ✍ **Bhaskar** ( for Business/ Financial Programs):It deals with the aspects of an policy and regulation , business models, finance ,appraising solar projects supply chain management ,solar entrepreneurship development and micro finance amongst others.

### 3. Indian Technical and Economic Cooperation Program (ITEC)

Ministry of External Affairs, Govt. of India has identified NISE as a premier institute to conduct ITEC programs every year for international Participants. For the past several years NISE is conducting about three programs of ITEC every year to the satisfaction of MEA & the participating countries. This program is a three week program focused on latest renewable energy technologies. During the year 2014-15, NISE has conducted two ITEC programs.

### 4. Other International Programs

Apart from ITEC, NISE has conducted various international programs to countries such as Bangladesh, Magnolia etc. on renewable energy technologies skill development this year 2015-16.

Following programs have been conducted:

1	Training program for Bangladesh delegations.	6th to 11th Jan 2015
2	A training program on renewable energy technologies for Mongolian Delegates	19th-30th January 2015.



**Group photograph of Mongolian delegations with NISE officers.**

## **5. Consultancy**

With excellent pool of scientific manpower and management experts NISE is handling various consultancy projects on solar photovoltaic & solar thermal technologies. NISE has got prestigious clients like: Ministry of Food Processing, Ministry of Defense, Kandla Port Trust, ISRO, Doordarshan, NLC, NEEPCO etc. The consultancy includes technical specifications, project management advisory, techno-economic, feasibility reports, clients' engineers, EPC advisory services etc. NISE is also providing expertise to corporates to set a SPV power plants.

- The following sites of Ministry of Defence have been completed :-

1. Palam airport station NEW DELHI
2. Andaman & Nicobar Island
3. Nal, Bikaner Rajasthan
4. Bhatinda, Punjab
5. Bhisiana, Punjab
6. Sri Ganganagar ,Rajasthan
7. Suratgarh , Rajasthan
8. Jalandhar, Punjab
9. Kapoorthala,Punjab
10. Firojpur,Punjab
11. Amritsar,Punjab
12. Talgtse, Leh, J & K
13. Durdukh , Leh, J & K
14. Airforce station , Leh, J & K
15. Dehradun, Uttrakhand
16. Saharanpur, U.P.

## QUALITY VERIFICATION SERVICES of PHOTOVOLTAIC POWER PLANTS

NISE initiated Quality verification services for photovoltaic power plants to meet the quality standards and analyse the technical competence of solar PV plants to assure the customers. The proposed specialized services are designed and offered for various stakeholders, facility owners, investors, financial institutions, banks, EPC contractors, project developers, service providers and insurance firms interested in assessing the operational condition of a given solar PV installation or portfolio.

### Key offerings

#### For Manufacturers & EPC's

- Testing and inspection
- Technical expertise
- Build stakeholder confidence
- Trusted test and inspection results

#### For Owners/operators

- Independent testing and evaluation
- Technical due diligence
- performance, reliability, durability
- site analysis

#### For Banking and Finance

- Field/outdoor measurements
- periodic inspections
- Periodic performance analysis
- Failure analysis and advisory services

#### For Govt. PSU's

- Plant performance verification
- Detailed field Evaluations
- On-site verification,
- Inspection of design and planning documentation

### Customer benefits:

- Maximisation of the energy output/performance ratio in the long term
- Minimisation of risks of failure.
- Plant performance verification
- Post-inspection of PV plants
- Establishment of investment safety and Bankability
- Protection of return on investment in the PV system
- Recommendations for zero-defect planning and installation of future PV systems.
- Improvements of operation and maintenance procedures.
- Facilitated provision of evidence in case of damage

**Services shall verify:**

- ✘ The installation of plant is according to the precise specifications comply with a range of international standards
- ✘ Photovoltaic power plant is operating safely and according to the relevant guidelines and standards.
- ✘ The verification will include SOLAR Parks, Roof top, off grid and other customized systems inspection
- ✘ The verification inspection will include installation components, sizing of components, quality & rating of all the components such as inverters, installation practice and safety concerns.
- ✘ Testing and performance measurement of PV module/array and BOS etc.

**The verification report will includes:**

- ✘ The verification report will includes certificate of verification
- ✘ inspection report
- ✘ PV array test report and suggestions to improve the PV power plant quality wherever necessary

**As per following standards:**

- ✘ IEC 62446,
- ✘ IEC 62124,
- ✘ IEC 60364 (all protective measure parts) - Low-voltage electrical installations
- ✘ IEC 60364-6 - Low-voltage electrical installation – Part 6: Verification
- ✘ IEC60364 – 7 – 712 - Electrical installations of buildings – Requirements for special installations or locations – Solar Photovoltaic (PV) power supply systems

**6. Incubation**

NISE is providing space, expert guidance and financial support for initial few months to the aspirants/ people coming up with innovative ideas in the field of renewable energy technology. Specific infrastructure is crested for this purpose at NISE

**7. Infrastructure for skill development Division – set up of laboratories**

During the year 2014-15 skill development division has created three state of the art laboratories for participants of skill development programs.

- a) Solar design laboratory with exclusive high end software tools like PV Syst, PV Sol, T Sol, Genius etc. with supporting latest hardware.
- b) Solar electronics laboratory for experiments in grid-tied PV, MW range power plants, 1MW solar Thermal simulation, inverter designs & configurations etc.
- c) Exclusive Renewable Energy laboratory with state of the art experimental set ups on Solar PV, Solar Thermal, Bio Mass, Wind etc.



## CHAPTER-5

### HYDROGEN ENERGY & FUEL CELL DIVISION

#### The objectives of the division are:

- 1 Demonstration & Performance Evaluation of various technologies of Hydrogen Energy at the National Institute of Solar Energy, Gwal Pahari, Gurgaon, Haryana
- 2 Operation and Maintenance of Solar Hydrogen facility at NISE, Gwal Pahari
- 3 To demonstrate hydrogen/hydrogen blended fuelled vehicles (3-wheelers & 4-wheelers) developed under other R&D projects supported by the Ministry
- 4 To operate / demonstrate fuel cell based systems for stationary power generation
- 5 To organise training programme on different aspects of Hydrogen Energy and Fuel Cell Technologies

The objective of the Project is to Generate, Store and Utilize Hydrogen as a fuel and for stationary Power Generation. The production of Hydrogen is from a Roof Top Solar PV Power Plant of 120kWp and the power generated from Solar PV is being used for Electrolysis of water, where the molecule of water splits in Hydrogen and Oxygen. The Hydrogen is further pressurized up to 550 bars and stored in gaseous form in Storage tubes. The stored Hydrogen can be used as a fuel in Vehicles and can be used as a source of Stationary Power.

#### Project Background:

The project titled “Establishment and Demonstration of Hydrogen Production and Utilization Facility through Photovoltaic-Electrolyzer system” was sanctioned on 8<sup>th</sup> Feb 2011 via Sanction order no 03/178/2010-NT by Ministry of New and Renewable Energy to University of Petroleum and Energy Studies, Dehradun and completed on 31<sup>st</sup> December. The total budget sanctioned for the Project is Rs 14.01 Crores.

During the month of Jan 2015 it was decided by Ministry and NISE to take over the project from UPES including all the existing man power of the project. For the operation and maintenance of the solar-hydrogen project, MNRE has sanctioned a project titled, “**Demonstration & Performance Evaluation of various technologies of Hydrogen Energy at NISE**” for a duration of two years at a total project cost of Rs.86.65 lakhs. Under this project, the solar-hydrogen facility is to be operated and maintained for carrying out its performance test of individual sub-systems / components. Also, the indigenous and imported fuel cells / stacks would be procured. The systems would then be installed and operated for demonstration and training programme on different aspects of hydrogen energy and fuel cell technologies would be organised.

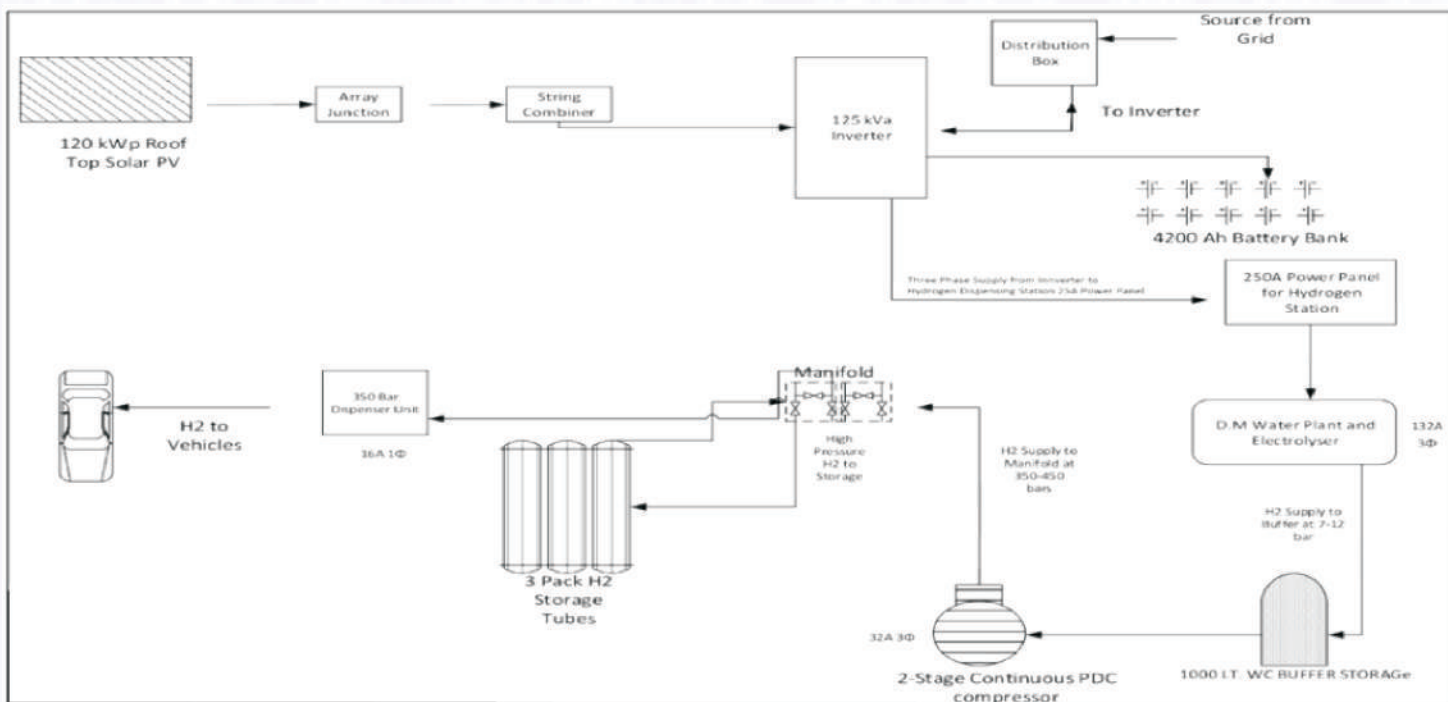


**System specifications :**

Under this process faciator, following are the major subsystems

- 1. 120 kw<sub>p</sub> SPV power plant with battery bank 4200 ah, 2400
- 2. 5Nm<sup>3</sup>/hr Electrolyser (capable of producing 10.5kg for 24h operation at full capacity)
- 3. Compressor ( delivery pressure of 350-550 bar)
- 4. Buffer (1000 liter capacity)
- 5. High pressure storage tanks (up to 550 bar max pressure)
- 6. Dispenser (1kg/min at 350 bar)

This production facility can dispense pure Hydrogen of 99.999% to vehicles.



**Process Flow Diagram of Hydrogen Production and Utilization through Photovoltaic-Electrolyzer**



**Hydrogen Production, Storage and Dispensing Facility at NISE**



### **Fuel cell testing laboratory:**

The proposed fuel cell testing laboratory activities have been started already and infrastructure development for the lab is completed. The tender for procurement of Fuel cell has been floated already. It is proposed to have a Fuel cell stack of 1KW & 2 KW respectively for initial R&D purposes. It has been envisaged to make NISE as Center of excellence for the testing of Fuel cell & Hydrogen sub systems.

### **Approval from Petroleum and Explosives Safety Organization (PESO), Nagpur.**

The Role of PESO is to administer and issue the licenses & its subsequent action as per Explosive Act 1884, Petroleum Act 1934 & rules framed there under, to provide operational, technical Advice and Assistance to the Central Government, State Governments, Local Bodies, Law Enforcement Agencies, Industry, Trade and end users of Explosives, Petroleum products and flammable and nonflammable Compressed gases & to frame the policies towards operation, administration & control of the organization. PESO Functions to ensure public safety in the areas of manufacture, transport, storage, handling, etc. of Explosives, Petroleum, Carbide of Calcium, Inflammable substances and Compressed Gases Advisory in matters of safety to the government and semi-government bodies like Ports, Railways, Defense establishments & Ministry of Surface Transport, Environment & Forest, Petroleum and Natural Gas, Pollution Control Authorities etc.

At NISE we have complied with PESO and received multiple clearances for Generation of Hydrogen, Storage of Hydrogen at 500 bar, and Dispensing of Hydrogen at 350 bar. In addition to this we have also received approvals for Dispensing Hydrogen to Vehicles at a pressure of 350 bar and to use the Hydrogen vehicle for trial purposes.

### **Activities being undertaken**

#### **Hydrogen**

After the approval from PESO was received the Hydrogen facility has been operationalized and Production of Hydrogen was started. The Hydrogen is produced on a day to day basis. The produced Hydrogen is stored in the High Pressure Storage tubes. As of now we have reached pressure of 300bar. The MAWP is 500 bar.

#### **Fuel cell**

As specified earlier the infrastructure development for the Fuel Cell laboratory is completed. For procurement of fuel cell tender has been floated and it is expected that the establishment of lab will be done within two months.

For establishment of Fuel cell laboratory the project members of Hydrogen team visited several laboratories in India.





## CHAPTER-6

### Research and Development (R&D) Cell

One of the important activities at the NISE is to be associated with R&D in the field of Solar Energy (SE) applications which include those in the areas of solar photovoltaics (SPV) and solar thermal (ST). The NISE has been doing so at present by providing active support to the MNRE's R&D initiatives. The institute has been involved in scrutinizing the R&D proposals submitted to the Ministry at the initial stage, getting the experts' comments, arranging RDPAC and RDSPAC meetings and recommending proposals to the MNRE for sanction. Furthermore, it has also been responsible for monitoring the on-going R&D projects through expert visits, organising reviews, suggesting mid-course corrections, and monitoring and verifying claims as an independent, un-biased agency. The NISE is thus involved at all stages of nucleation, growth, correction and logical conclusion of the R&D projects. The NISE is also involved in a few important, thrust area projects where direct participation is envisaged to help achieve the desired goals. The NISE is also executing externally aided, large consortium projects funded by the DST and other ministries on specific topics where there is a requirement or direct intervention is sought.

The responsibilities of R&D coordination and monitoring lies with the R&D Co-ordinating Cell or simply R&D Cell which comprises two departments, namely, a) solar photovoltaic (PV) department and b) solar thermal (ST) department.

#### **Project Monitoring for on-going projects**

In the area of PV, there are 20 projects in the category of on-going or recently closed projects. Similarly, there are 10 on-going projects in the area of Solar Thermal technologies. Monitoring of these projects has until now been sporadic and infrequent but a plan has now been put in place with identification of a panel of experts, from within NISE and outside to monitor the projects in a regular manner for realization of the project objectives and timely completion of the project. Also, a schedule has been prepared for on-site monitoring of the on-going projects. Under this schedule, on-site monitoring has recently been carried out for 8 on-going projects in PV for example at NCPRE, IIT Bombay, IIT, Kanpur, NPL, Delhi, Jamia Milia Islamia, Delhi, Pandit Dindayal Petroleum University, Gandhinagar, AR-IGNOU Community College, Kolkata etc. Monitoring is also planned soon for the project on DSSC underway at the CSIR laboratories, e.g. IICT, Hyderabad and NCL, Pune. For the ST projects, monitoring has been carried out at IIT, Jodhpur, CEPT University, Ahmedabad and RGPV, Bhopal.

The reports of the Project Monitoring Committees have been sent to the Ministry with specific recommendations. For the recently completed projects, a plan is under preparation for independent validation of the claims made by the project team and rating of the projects as per that. Apart from this, all these projects have been evaluated at NISE based on the project status report at the end of the previous financial year and the report forwarded to the Ministry.

Out of the 20 recently completed/on-going R&D projects, 4 projects have so far been completed. The PI of 3 projects have requested for an extension period ranging from 1 to 2 years without escalation of the outlay. The project on thin film solar cells being implemented at NPL, Delhi has recently been truncated in scope and outlay and re-submitted to the Ministry. Also, the project on development of high efficiency CIGS solar cells, taken up at Moser Baer, has been short closed as the implementing agency has expressed its inability to continue with the project as it requires further investment by the company and the prospects of thin film solar cells does not look very bright as of now. In addition, a total of 220 papers have been published in International and domestic journals and 42 patent applications have been



filed out of the work done in the recently closed/ on-going projects. Based on the latest status report submitted by the respective PIs, the projects have been rated at NISE with respect to the deliverance as opposed to the output envisaged. The rating has been done under four categories and the result of the 15 projects monitored has been depicted in the bar-chart above. It is seen that most of the projects fall much below expectation with only one project rated as good. Four projects have been rated as poor, four projects rated as moderate and six project rated as satisfactory. The rest of the projects, have been sanctioned recently (in 2014-15) and therefore do not have the updated project status/rating.

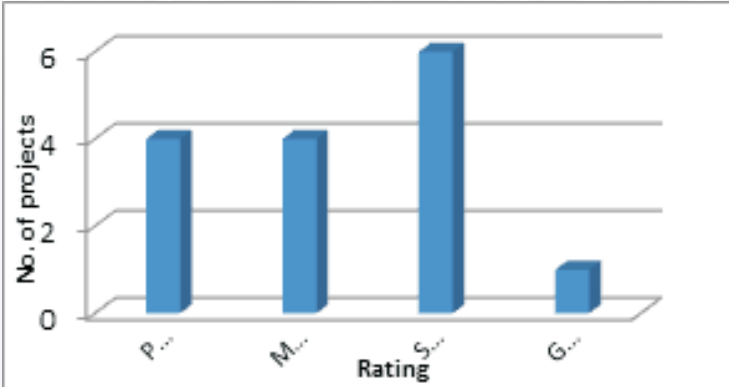


Fig. No. of PV projects vs. Rating at NISE

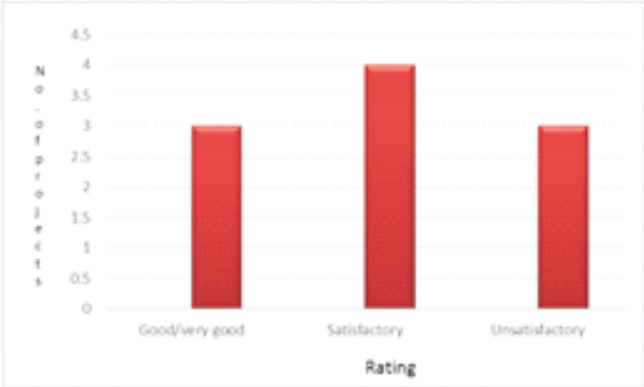


Fig. No. of ST projects vs. Rating at NISE

**Statistics related to the on-going projects**

A brief analysis of the on-going projects, as depicted in the following bar graphs, helps us draw a few conclusions. As far as broad areas/ categories of projects are concerned, the number of projects in third generation solar cell technologies and PV system electronics far exceeds those in crystalline silicon cell processing or in Si material growth though silicon has been and still is considered as the “work horse” of the PV industry.

It is also seen that projects with large outlays have gone to IITs and CSIR labs as these are already equipped with necessary infra-structure and adequate strength of qualified manpower. Both in terms of number and outlay of sanctioned projects, the peak was seen during 2011-12. In 2012-13, both the aspects touched rock bottom but started showing resurgence in 2013-14 and 2014-15 at least in number of sanctioned projects if not in terms of project outlays.

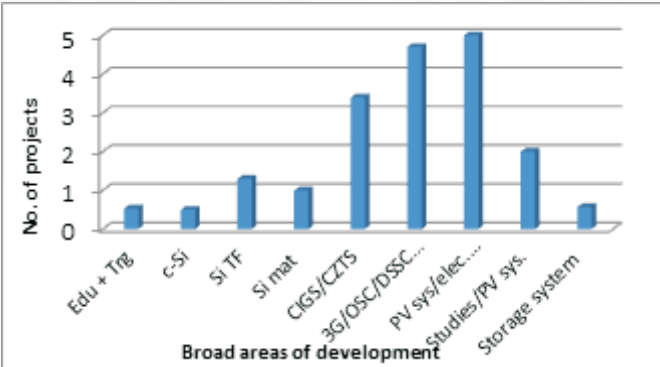


Fig. Distribution of projects vs. area of development



### Evaluation of new project proposals

Since February/ March, 2015, around 60 new project proposals have been received in PV and 20 projects in ST for evaluation and further processing. The PV project proposals are divided into two broad groups namely a) PV cells & materials and b) PV systems and applications with almost equal number of proposals belonging to each category. The NISE has re-visited the existing panel of experts and made a few changes as per the need. All the projects have been sent to selected panels of experts for evaluation. These projects are also being evaluated at NISE. Results of evaluation for around 21 project proposals in PV and 5 project proposals in ST have already been sent to the Ministry for further processing.

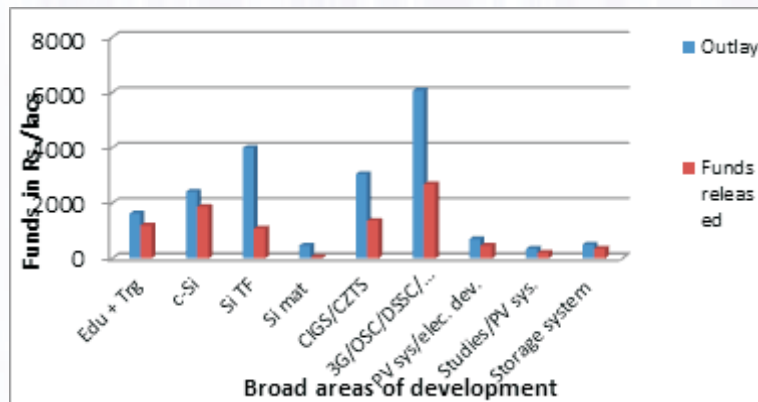


Fig. Project outlay/ funds released vs. broad areas of development

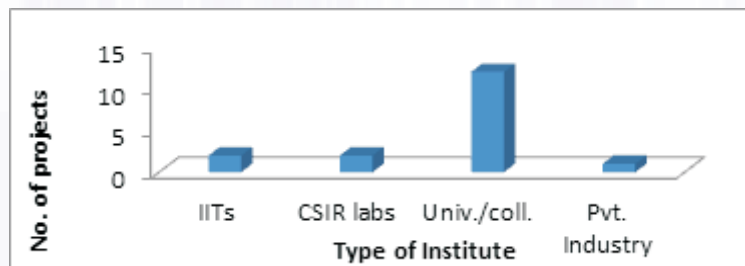


Fig. 4 Distribution of projects among various types of institutes

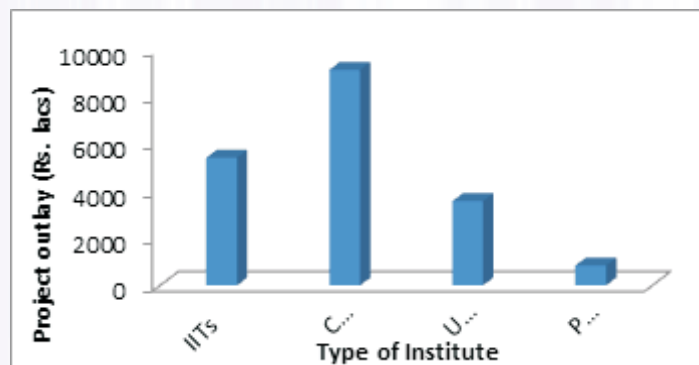


Fig. Distribution of project outlay among various types of institutes





Fig. Plot of no. of sanctioned projects vs. financial year



Fig. Plot of project outlay vs. financial year

Apart from this, some efforts have also been put in acquiring new test facilities (Electroluminescence Tester)/ upgrading the existing ones (solar cell I-V tester) for solar cells and modules with the particular objective of independent validation of claims made in the projects.

It is also proposed to extend/ strengthen the activities of R&D Cell in PV and ST by initiating further activities in areas of Technology Business Incubation (TBI) and Industrial Consultancy/ R&D. In this direction, a joint R&D project proposal by BHEL ASSCP and NISE on “Development of high efficiency silicon solar cells with Passivated emitter and rear cell structure” has been proposed to the Ministry and discussed at the recently held RDPAC meeting. As a part of Institute Outreach Programme, an Annual review cum state-of-the-art series has been planned with an objective to provide quality literature in the field of solar energy to all the stakeholders. The first volume in this series entitled “Solar Energy Science and Engineering” edited by National Institute of Solar Energy (NISE) has been published in 2015. The scope of this serial publication (volumes) is broad and encompasses recent developments in the field and is addressed to serious students, researchers, policy analysts and energy planners seeking a fuller understanding of technical factors underlying Solar Energy Development and commercialisation. The second volume dealing with Solar Thermal Energy and the third volume dealing with Renewable Energy Education, Training and Awareness is under preparation.

## CHAPTER-7

### INTERNATIONAL CO-OPERATION

#### International Corporation

NISE has been interacting with different institutes from both developed and developing countries for co-operation in the field of solar energy from the year of establishment. Following are the main aims of International co-operation of NISE:

- I. Learning and adapting the technical enhancement, research and development, policy related issues.
- II. Sharing and exchanging the knowledge and expertise of solar energy applications and innovative solutions and catalyze ideas.
- III. To drive concerted action of the nation in the field of solar energy in comparison with different countries.

During the year 2014-15, NISE has taken up various activities to promote the international co-operation among various countries. Memoranda of Understanding (MoUs) and Joint Working Group Meetings were convened and participated by NISE. Visits by senior officers were undertaken for the purpose of bilateral / multilateral meetings, signing of MoUs etc. with different countries. Details of the major International co-operative collaborative projects undertaken by NISE are given:

**1. Indo-Us collaboration:** A memorandum of understanding on technical co-operation in the field of solar energy was concluded between NISE and the National Renewable Energy laboratory (NREL) of USA and have embarked on collaborative work to study the radiation data and reliability of PV module. NISE is closely working in various projects with NREL and most of them are ongoing.

**a. Round Robin testing of modules:** NISE was undergoing round robin testing of module with NREL. This can help to reducing the uncertainty of measurement and make the measurement level world class. The modules used in round robin testing are used for calibration purpose of solar simulator at NISE. Three different types of modules were used for this purpose.

**b. Performance comparison of sister thin-film modules deployed in India and in Colorado:** National Institute of Solar Energy and NREL have embarked on a project to compare the performance of sister thin-film modules deployed in India and in Colorado, USA. NISE purchased a set of modules and shipped a subset of these to NREL. The thin-film modules were deployed in November and December 2013 at NREL and NISE and the outdoor performance are evaluated.

**c. SERIUS project:** Under the Solar Energy Research Institute for India and the United States (SERIUS) project NISE's involvement are as characterization centre to carry out reliability studies in collaboration with NREL and other institutes of India and abroad. NISE are carrying out long-term stability and degradation measurements on solar cells and proto type modules. These studies are useful in correlating poor response regions, junction shunts and other weak spots generated of PV module either due to low cost fabricating methods or due to outdoor exposure leading to their early failure. The main activity of NISE to develop a base of reliability data for the PV technologies, especially in the context of the environment of India (with some emphasis on rural area applications), rural applications and testing, integrated databases and predictability etc.



**d. Analysis of Satellite-Based Solar Resource Data:** NISE is involved with NREL in satellite based solar resource data sets for India. The objective of this project was to create a new satellite-derived hourly solar data set for India covering the period of time from January 2002 to June 2012 to supplement and enhance an earlier data production effort. The goal was also to reduce the uncertainty of the data sets through the use of a newer version of a model that has been developed since the previous data sets were created. In particular, this would be accomplished by using a new set of monthly resolved aerosol optical depth (AOD) data. To determine the quality of the product, it was essential to compare the results to high-quality ground measurement data. Thus, the final objective was to procure ground-based measurements, assess the quality of the measurements, and validate the satellite-based product with the quality-checked ground measurement data. NREL provides 10-kilometer (km) solar resource maps and data for India. The 10-km hourly solar resource data were developed using weather satellite (METEOSAT) measurements incorporated into a site-time specific solar modeling approach developed at the U.S. State University of New York at Albany. The data is made publicly available in geographic information system (GIS) format. The hourly data can also be downloaded for specific locations from NREL's Renewable Resource Data Center and MNRE site.

**e. NISE - First Solar project:** NISE and First Solar, USA undergoes a joint collaborative project to study the performance of CdTe technologies throughout the year at NISE. A 3.2 kWp test bed of CdTe technology based PV modules was installed at a tilt of 20°.

## **2. Indo-Japan Co-operation:**

**a. NISE-AIST project:** National institute of Advanced Industrial science and technology (AIST), Japan 2009, undertaken a project with NISE to initiate co-operative research for long term reliability of photovoltaic modules under actual field condition in India and Japan. The activities at NISE were related to long term outdoor PV module exposure test, performance and degradation analysis under precise meteorological data acquisition space in India conditions. The project has been formally closed but data acquisition and analysis are continuing for long term reliability assessment.

**b. NISE-TEL project:** NISE and TEL, Japan undergoes a joint collaborative project to study the performance of Micromorph PV technologies throughout the year at NISE.

**3. Indo-UK project:** As part of Indo-UK collaboration under solar energy activities a consortia project is sanctioned by DST and EPSRC, UK. The project on “Stability and performance of photovoltaics (STAPP)” is joint consortia project involved four Indian and four UK institutions. The project has been formally closed but analyses are continuing for long term reliability assessment.

## **4. Indo-German co-operation:**

a. NISE and PTB, Germany collaboratively started a project on “Strengthening quality infrastructure for the solar industry in India” in 2012 with the objective of strengthening the reliability of photovoltaic and solar thermal systems in particular the quality of central components, the proper installations of the entire system and quality assurance schemes. The preliminary phase of the project continues from 2012 to December 2013. At present a project on establishment of facility of calibration of secondary reference solar cell is under progress.



b. NISE is also working collaboratively with Fraunhofer Institute for Solar Energy Systems (FhG-ISE), Germany in the field of solar cell calibration, round robin testing of PV modules and performance related aspects.

#### **5. Indo-Australia co-operation:**

NISE and FCUBED Pvt. Limited, Australia is doing a joint collaborative project to analyze the performance of FPC based distillation of water system. There are 10 panels (each having 3 m<sup>2</sup>) at a total area of 30 m<sup>2</sup> have been installed at NISE in December 2013. The surface area of each panel covered 3.0 m<sup>2</sup> and the weight is 17 kg. The average water Output is 15 L/day, which depend upon the radiation.

#### **6. UNDP-GEF CSH project on “Market Development and Promotion of solar Concentrated based process**

**Heat Application in India”:** National Institute of Solar Energy, (NISE) has setup state-of-art of test facility for CSTs under UNDP-GEF CSH project on “Market Development and Promotion of solar Concentrated based process Heat Application in India” to develop performance measuring standards, test procedures & test protocols. The test facility is Steam based at temperature up to 250 °C. The measurements are carried out under quasi steady state conditions. Data points which satisfy the quasi steady state conditions is obtained for at least four inlet temperatures spaced evenly over the operating range of the collector. One inlet temperature shall be selected such that the mean fluid temperature in the receiver lies within  $\pm 3^{\circ}\text{C}$  of the ambient temperature in order to obtain an accurate determination of optical efficiency of the system.

#### **7. Establishment of secretariat of INSTA at NISE:**

NISE is undergoing to establishing a secretariat of **International Association for Solar Technologies & Applications (INSTA) in India. This will ensure greater exposure for NISE and prospects of future collaboration with INSTA will bring international fame to NISE.**



## Consultancy Services

### 1. NISE is Offering the “Quality verification services for photovoltaic power plants”

National Institute of Solar Energy (NISE), is offering the Quality verification services for photovoltaic power plants to meet the quality standards and analyse the technical competence of solar PV plants to assure the customers. The proposed specialized services are designed and offered for various stakeholders i.e., facility owners, investors, financial institutions, banks, EPC contractors, project developers, service providers and insurance firms interested in assessing the operational condition of a given solar PV facility or portfolio. The service shall verify that the installation of plant is according to the precise specifications comply with a range of international standards including IEC 62446 - Grid connected photovoltaic systems – Minimum requirements for system documentation, commissioning tests and inspection and IEC 60364-7-712 that photovoltaic power plant is operating safely and according to the relevant guidelines and standards. The verification will include DC/AC system inspection, Testing and performance measurement of PV module/array and BOS etc. The verification report will includes certificate of verification, inspection report, PV array test report and suggestions to improve the PV power plant wherever necessary.

With Excellent pool of scientific manpower and management experts NISE is handling various consultancy projects on Solar Photovoltaic and Solar Thermal Technologies. NISE has given consultancy services to the following sites for designing and installation of PV power plant in 2014-15 and some other projects are ongoing.

- a) Palam airport station, New Delhi
- b) Andaman & Nicobar Island
- c) Nal, Bikaner Rajasthan
- d) Bhatinda, Punjab
- e) Bhisiana, Punjab
- f) Sri Ganganagar ,Rajasthan
- g) Suratgarh , Rajasthan
- h) Jalandhar, Punjab
- i) Kapoorthala, Punjab
- j) Firojpur, Punjab
- k) Amritsar, Punjab
- l) Talgtse, Leh, J & K
- m) Durdukh , Leh, J & K
- n) Airforce station , Leh, J & K
- o) Dehradun, Utrakhand
- p) Saharanpur, U.P.





# VBR & Associates

Chartered Accountants



## Independent Auditor's Report

### Report on the Financial Statement

We have audited the accompanying financial statements of **NATIONAL INSTITUTE OF SOLAR ENERGY** ("the Institute"), which comprise the Balance Sheet as at 31 March 2015, the Statement of Income & Expenditure and the Receipts & Payments Account for the year then ended, and a summary of significant accounting policies and other explanatory information.

### Management's Responsibility for the Financial Statement

The Management is responsible for the preparation of these financial statements that give a true and fair view of the financial position and financial performance of the Institute in accordance with the accounting principles generally accepted in India. This responsibility also includes the maintenance of adequate accounting records in accordance with the provision of the Act for safeguarding of the assets of the Institute and for preventing and detecting the frauds and other irregularities; selection and application of appropriate accounting policies; making judgments and estimates that are reasonable and prudent; and design, implementation and maintenance of internal financial control, that were operating effectively for ensuring the accuracy and completeness of the accounting records, relevant to the preparation and presentation of the financial statements that give a true and fair view and are free from material misstatement, whether due to fraud or error.

### Auditor's Responsibility

Our responsibility is to express an opinion on these financial statements based on our audit.

We conducted our audit in accordance with the Standards on Auditing issued by ICAI. Those Standards require that we comply with ethical requirements and plan and perform the audit to obtain reasonable assurance about whether the financial statements are free from material misstatement

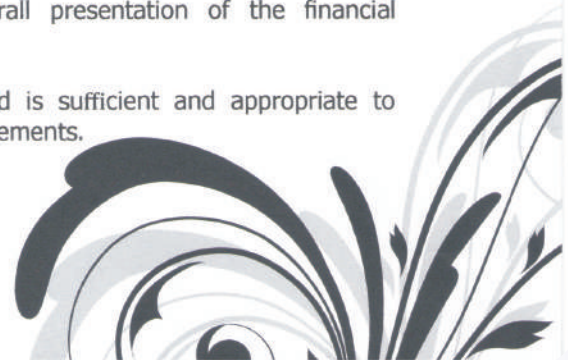
An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial statements. The procedures selected depend on the auditor's judgment, including the assessment of the risks of material misstatement of the financial statements, whether due to fraud or error. In making those risk assessments, the auditor considers internal financial control relevant to the Institute's preparation of the financial statements that give true and fair view in order to design audit procedures that are appropriate in the circumstances. An audit also includes evaluating the appropriateness of accounting policies used and the reasonableness of the accounting estimates made by Institute's Directors, as well as evaluating the overall presentation of the financial statements.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion on the financial statements.

91-11-43022799

[www.vbrindia.com](http://www.vbrindia.com)

611, Roots Tower, Plot No.7  
District Centre, Laxmi Nagar, Delhi-110092  
HO: 66-R, Model Town, Rewari,  
Haryana-123401



### Report on the other Legal and regulatory Requirements

1. The GFR Rules 2005 in several cases during the year relating to the purchases made and the work contracts awarded by the Institute are not complied strictly. Detailed observations in this regard have been provided to the management for compliance.
2. The Internal Control system of the Institute needs to be strengthened.
3. We report that:
  - a) we have sought and obtained all the information and explanations which to the best of our knowledge and belief were necessary for the purposes of our audit;
  - b) in our opinion proper books of account as required by law have been kept by the Institute so far as appears from our examination of those books.
  - c) the Balance Sheet, the Statement of Income & Expenditure, and Receipt & Payment Account dealt with by this Report are in agreement with the books of account.
  - d) In our opinion, the Balance Sheet & Income & Expenditure dealt with by this report complies with the Accounting Standards issued by the Institute of Chartered Accountants of India.

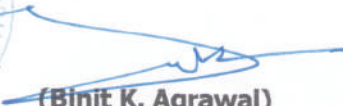
### Opinion

In our opinion and to the best of our information and according to the explanations given to us, the aforesaid financial statements, give the information required by the Act in the manner so required and give a true and fair view in conformity with the accounting principles generally accepted in India:

- a) in the case of the Balance Sheet, of the state of affairs of the Institute as at March 31, 2015;
- b) in the case of the Statement of Income & Expenditure, of the **excess of income over expenditure** for the year ended on that date;

For **VBR & Associates**  
Chartered Accountants  
FRN 013174N



  
**(Binit K. Agrawal)**  
(Partner)  
Membership No. 088042

**Place:** Delhi

**Date :** December 4, 2015

## NATIONAL INSTITUTE OF SOLAR ENERGY

(An Autonomus Institute of Ministry of New & Renewable Energy ,Govt.of India)  
Gurgoan-Faridabad Road, Gwalpahari, Gurgaon, Haryana-122003

### BALANCE SHEET AS AT 31ST MARCH 2015

		Amount in ₹			
CORPUS/CAPITAL FUND AND LIABILITIES	SCHEDULE	AS AT MARCH 31, 2015		AS AT MARCH 31, 2014	
<b>Corpus/Capital Asset Fund</b>	1				
Gross Corpus/ Capital Fund		2003,29,683		-	
Less : Accumulated Depreciation		9,19,380		-	-
Net Corpus/ Capital Fund			1994,10,303		-
Current Liabilities & Provisions	2		1962,72,371		388,67,464
<b>Total</b>			<b>3956,82,674</b>		<b>388,67,464</b>
ASSETS	SCHEDULE	AS AT MARCH 31, 2015		AS AT MARCH 31, 2014	
<b>Fixed Assets</b>	3				
Gross Block		72,86,913		-	
Less : Accumulated Depreciation		9,19,380		-	-
Net Block			63,67,533		-
Current Assets, Loans & Advances	4		3893,08,587		388,60,910
Misc. Expenses to the extent not written off			6,554		6,554
<b>Total</b>			<b>3956,82,674</b>		<b>388,67,464</b>
<b>SIGNIFICANT ACCOUNTING POLICIES AND NOTES TO ACCOUNTS</b>	11				

**As per our Audit Report of even date**

**For VBR & Associates**

Chartered Accountants

(FRN-013174N)

(Binit K Agrawal)

Partner

M. No.088042

Place: Delhi

Dated: December 4, 2015

**For NATIONAL INSTITUTE OF SOLAR ENERGY**

Dr. G. S. Sastry  
(Director General)

Dr. S. K. Singh  
(Scientist F)

<b>NATIONAL INSTITUTE OF SOLAR ENERGY</b> (An Autonomous Institute of Ministry of New & Renewable Energy ,Govt.of India) Gurgaon-Faridabad Road, Gwalpahari, Gurgaon, Haryana-122003				
<b>SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2015</b>				
Amount in ₹				
<b>SCHEDULE 1- CORPUS/ CAPITAL FUND</b>	<b>AS AT MARCH 31, 2015</b>		<b>AS AT MARCH 31, 2014</b>	
<b>General Reserve</b>				
Balance as at the beginning of the year	-		-	
Add : Excess of income over expenditure during the year	86,69,118		-	
	-	86,69,118	-	-
<b>Capital Fund</b>				
Grants adjusted against purchase of assets	48,67,566		-	
Grant utilised for advances given during the year	1867,93,000		-	
		1916,60,566	-	-
<b>Total</b>		<b>2003,29,683</b>		<b>-</b>
<b>SCHEDULE 2- CURRENT LIABILITIES AND PROVISIONS</b>	<b>AS AT MARCH 31, 2015</b>		<b>AS AT MARCH 31, 2014</b>	
<b>Current Liabilities</b>				
Sundry Creditors				
- For goods and services	2,75,803		7,464	
- Creditors For Capital Goods	22,86,541	25,62,344	-	7,464
Deposits				
- Earnest Money Deposit	27,200			
- Advance Received from Customers	11,74,054	12,01,254		-
Statutory Liabilities				
- TDS Payable	6,77,501	6,77,501		-
Other Current Liabilities				
- Salary & Remuneration Payable	16,40,288			
- Payable against cancellation of training	-			
- Excess payment received from customers	3,087	16,43,375		-
Grants Payable to Government of India		1869,65,167		388,60,000
<b>Provisions</b>				
Provision for Income Tax		32,22,730		-
<b>Total</b>		<b>1962,72,371</b>		<b>388,67,464</b>
<b>SCHEDULE 4- CURRENT ASSETS, LOANS &amp; ADVANCES</b>	<b>AS AT MARCH 31, 2015</b>		<b>AS AT MARCH 31, 2014</b>	
<b>Current Assets</b>				
Cash Balance in hand	34,849		-	
Balance with Bank :				
-Saving Accounts	1821,91,161	1822,26,011	388,60,910	388,60,910
Sundry Debtors		16,44,889		-
<b>Loan &amp; Advances &amp; other assets</b>				
Advances and other amounts recoverable in cash or in kind or for value to be received				
- Advances against capital assets	2019,78,000		-	
- Other advances	8,15,000		-	
- Recoverable against TDS deduction	42,270		-	
- Recoverable against excess payment	1,009		-	
- Balances in Staff Imprest Accounts	50,829	2028,87,108	-	-
Deposits				
- Security Deposit with BSNL	10,000		-	
- Input Credit of Service Tax	3,74,361		-	
- TDS Recoverable	2,01,099		-	
- Advance Tax	19,65,120	25,50,580	-	-
<b>Total</b>		<b>3893,08,587</b>		<b>388,60,910</b>



**NATIONAL INSTITUTE OF SOLAR ENERGY**  
(An Autonomous Institute of Ministry of New & Renewable Energy ,Govt.of India)  
Gurgoan-Faridabad Road, Gwalpahari, Gurgaon, Haryana-122003

**SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2015**

**SCHEDULE 3- FIXED ASSETS & DEPRECIATION**

PARTICULARS	GROSS BLOCK						DEPRECIATION				NET BLOCK	
	As at 01.04.2014	Addition before 30.09.2014	Addition After 01.10.2014	Sales/ Adjustment during the year	As at 31.03.2015	As at 01.04.2014	Depreciation on B+C	Depreciation on D	Total Depreciation (G+H)	WDV as on 31.03.2015 (F-I)	WDV as on 31.03.2014	
	B	C	D	E	F		G	H	I	J		
Desktop Computers	-	-	5,33,828	-	5,33,828	-	-	1,60,148	1,60,148	3,73,680	-	
Printers and other Peripherals	-	7,500	86,600	-	94,100	-	1,125	6,495	7,620	86,480	-	
A.C Plant	-	9,53,342	-	-	9,53,342	-	1,43,001	-	1,43,001	8,10,341	-	
Biometric Attendance System	-	-	19,553	-	19,553	-	-	1,466	1,466	18,087	-	
Scientific & Laboratory Equipments	-	25,93,413	9,59,801	-	35,53,214	-	3,89,012	71,985	4,60,997	30,92,217	-	
Cycles	-	-	40,800	-	40,800	-	-	3,060	3,060	37,740	-	
Furniture & Fixtures	-	-	9,08,154	-	9,08,154	-	-	45,408	45,408	8,62,746	-	
Inverter	-	-	8,800	-	8,800	-	-	660	660	8,140	-	
Laptops	-	-	1,80,390	-	1,80,390	-	-	54,117	54,117	1,26,273	-	
Office Car	-	-	5,49,561	-	5,49,561	-	-	41,217	41,217	5,08,344	-	
Training Software	-	-	4,22,699	-	4,22,699	-	-	-	-	4,22,699	-	
Solar Rickshaw	-	-	22,472	-	22,472	-	-	1,685	1,685	20,787	-	
<b>Total</b>	<b>-</b>	<b>35,54,255</b>	<b>37,32,658</b>	<b>-</b>	<b>72,86,913</b>	<b>-</b>	<b>5,33,138</b>	<b>3,86,242</b>	<b>9,19,380</b>	<b>63,67,533</b>	<b>-</b>	



**NATIONAL INSTITUTE OF SOLAR ENERGY**

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Gurgoan-Faridabad Road, Gwalpahari, Gurgaon, Haryana-122003

**RECEIPT & PAYMENT ACCOUNT FOR THE YEAR ENDED 31ST MARCH 2015**

<b>Receipts</b>	<b>2014-15</b>	<b>Payments</b>	<b>2014-15</b>
<b>Opening Balance</b>		<b>Expenses</b>	
Bank Accounts	388,60,910	Consumable Laboratory/Workshop Expenses	78,656
<b>Grants Received</b>		Bank Charges	20,746
From Government of India	3695,50,549	Horticulture Expenses	11,000
<b>Interest Received</b>		Printing & Stationary Expenses	12,238
Bank Interest on Deposits	18,27,838	Repair & Maintenance	3,78,871
<b>Other Income</b>		Office Expenses and Hydrogen Project Expenses	46,724
Receipts from Guest House	1,01,900	Tour/Travel & Transport	65,137
Tender Fees	4,000	Electricity Expenses	37,02,165
Training and Seminars	5,22,706	Vehicle Running & Mint. Exps.	1,43,692
<b>Other Receipts</b>		INDO-US SERIUS Project Exps.	68,039
Solar Energy Centre	1,000	Medical Expenses	30,435
Collection from debtors	193,17,807	Testing/Accredation Exps.	30,650
Earnest Money Deposit	1,56,200	Seminar/conferences/Workshop Training Programmes	1,33,835
		Solar Hydrogen Prjct Exps.	31,956
		Techno Economic Feasible Study(Exp.)	18,157
		<b>Advance Payments Made</b>	
		Participants Training fees	17,000
		Petty Cash Fund/Advance with staff	22,88,238
		Payment made to Creditors	2306,98,874
		<b>Other Payments Made</b>	
		Misc assets purchased	3,570
		Advance Income Tax	19,65,120
		TDS Payable	42,25,943
		Service Tax Paid	9,09,047
		Grant returned to GOI	30,97,807
		Refund of earnest money deposit	1,29,000
		Security Deposit	10,000
		<b>Closing Balance</b>	
		Bank Accounts	1821,91,161
		Cash- in- hand	34,849
<b>Total</b>	<b>4303,42,910</b>	<b>Total</b>	<b>4303,42,910</b>

As per our Audit Report of even date  
For VBR & Associates  
Chartered Accountants  
(FRN-013174N)

(Binit K Agrawal)  
Partner  
M. No.088042

Place: Delhi  
Dated: December 4, 2015

For NATIONAL INSTITUTE OF SOLAR ENERGY

Dr O. S. Sastry  
(Director General)

Dr. S. K. Singh  
(Scientist F)

**NATIONAL INSTITUTE OF SOLAR ENERGY**

(An Autonomous Institute of Ministry of New & Renewable Energy, Govt. of India)  
Gurgoan-Faridabad Road, Gwalpahari, Gurgaon, Haryana-122003

**STATEMENT OF GRANTS FOR THE FINANCIAL YEAR 2014-15**

PARTICULARS	Amount in ₹						
	Opening Balance	Receipt during the year	Utilization against advances	Utilization against Fixed Assets	Utilization against Revenue	Total Utilization	Closing Balance
Grant -500Wp SPV Power Plant - MNRE	180,00,000	-	180,00,000	-	-	180,00,000	-
Grant for Creation of Capital Assets	-	2668,00,000	1679,78,000	38,88,272	-	1718,66,272	949,33,728
Grant for Organising International Training Courses	-	15,00,000	-	-	-	-	15,00,000
Grant Project Hydrogen	-	40,00,000	-	-	5,11,146	5,11,146	34,88,854
Grant in aid- General	-	675,00,000	5,00,000	-	153,55,871	158,55,871	516,44,129
Grant in aid- Salaries	-	100,00,000	-	-	64,26,200	64,26,200	35,73,800
Grant- Skill Development Programme SERIUS	-	137,92,742	-	-	-	-	137,92,742
Training Prog 12 Grant MNRE	60,00,000	28,60,000	3,15,000	-	9,31,461	12,46,461	16,13,539
Grant for Inauguration of New NISE Building- MNRE	30,00,000	-	-	5,12,894	18,12,106	23,25,000	36,75,000
Grant-INDO-UK STAPP Project - MNRE	18,60,000	-	-	-	-	-	30,00,000
Grant for setting up R&D coordination Cell - MNRE	100,00,000	-	-	4,66,399	-	4,66,399	13,93,601
	<b>388,60,000</b>	<b>3664,52,742</b>	<b>1867,93,000</b>	<b>48,67,565</b>	<b>266,87,010</b>	<b>2183,47,575</b>	<b>1869,65,167</b>

## NATIONAL INSTITUTE OF SOLAR ENERGY

(An Autonomous Institute of Ministry of New & Renewable Energy, Govt. of India)

Gurgoan-Faridabad Road, Gwalpahāri, Gurgaon, Haryana-122003

Amount in ₹

### INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED ON 31ST MARCH 2015

PARTICULARS	Schedule	2014-15	2013-14
<b>INCOME</b>			
Receipts from Testing & Operations	5	141,43,673	-
Grants/Subsidies utilised for Revenue Expenditure	6	266,87,010	-
Interest Earned	7	18,27,838	-
Other Income	7	1,05,900	-
Depreciation (As per Contra)	3	9,19,380	-
<b>Total (A)</b>		<b>436,83,802</b>	<b>-</b>
<b>EXPENDITURE</b>			
Establishment Expenses	8	112,24,099	-
Other Administrative Expenses	9	157,78,360	-
Operational Expenses	10	38,70,115	-
Depreciation (As per Contra)	3	9,19,380	-
<b>Total (B)</b>		<b>317,91,954</b>	<b>-</b>
<b>Net Surplus/(Deficit) for the year</b>		<b>118,91,848</b>	<b>-</b>
Provision for Taxation		32,22,730	
<b>Balance being Surplus/(Deficit) for the year transferred to Cospus (A-B)</b>		<b>86,69,118</b>	
<b>SIGNIFICANT ACCOUNTING POLICIES AND NOTES TO ACCOUNTS</b>	11		

**As per our Audit Report of even date**

**For VBR & Associates**

Chartered Accountants

**(FRN-013174N)**



**(Binit K Agrawal)**


Partner


M. No.088042

Place: Delhi

Dated: December 4, 2015

**For NATIONAL INSTITUTE OF SOLAR ENERGY**

  
Dr. O. S. Sastry  
(Director General)

  
Dr. S. K. Singh  
(Scientist F)

<b>SCHEDULES FORMING PART OF INCOME AND EXPENDITURE ACCOUNT AS AT 31ST MARCH 2015</b>				
Amount in ₹				
<b>SCHEDULE 5- RECEIPTS FROM TESTING AND OPERATIO</b>	<b>2014-15</b>		<b>2013-14</b>	
<b>Receipts from Testing</b>				
- Testing of Solar Components	95,98,500	95,98,500	-	-
			-	-
<b>Other Operational Receipts</b>				
- Receipts from Trainings and Seminars- Domestic	6,57,981	45,45,173	-	-
- International	23,91,997		-	-
- Consultancy on Techno Economic Feasibility Study	14,95,195		-	-
<b>Total</b>		<b>141,43,673</b>		<b>-</b>
<b>SCHEDULE 6- GRANTS/SUBSIDIES (Irrevocable Grants &amp; Subsidies Received)</b>	<b>2014-15</b>		<b>2013-14</b>	
Grants Received during the year	3695,50,549	3664,52,742	-	-
Less : Grant Refunded	30,97,807		-	-
Grant unutilised brought forward from the previous year		388,60,000		388,60,000
Grant Adjusted towards Revenue Expenditure :				
Current Year Expenditure	308,72,573		-	-
Less : Expenses adjusted towards current year income	41,85,564	266,87,010	-	-
Less : Grants utilised for purchase of Fixed Assets		48,67,566		-
Less : Grants utilised for Advances against Capital Expenses		1859,78,000		-
Less : Grants utilised for Advances against projects		8,15,000		-
<b>Grants Payable to Government of India</b>		<b>1869,65,167</b>		<b>388,60,000</b>
<b>SCHEDULE 7- OTHER INCOME</b>	<b>2014-15</b>		<b>2013-14</b>	
<b>Bank Interest</b>				
- Interest earned on Savings account	67,538	18,27,838	-	-
- Interest earned on Grants account	17,60,300		-	-
<b>Miscellaneous Income</b>				
- Guest House Charges	1,01,900		-	-
- Tender Fee	4,000	1,05,900	-	-
<b>Total</b>		<b>19,33,738</b>		<b>-</b>
<b>SCHEDULE 8- ESTABLISHMENT EXPENSES</b>	<b>2014-15</b>		<b>2013-14</b>	
Consultancy Charges		46,46,254		-
Project Fellow Stipend		17,32,217		-
Remuneration		43,12,329		-
Honorarium		55,609		-
Manpower Remuneration (Solar Hydrogen Project)		4,77,690		-
<b>Total</b>		<b>112,24,099</b>		<b>-</b>

<b>SCHEDULES FORMING PART OF INCOME AND EXPENDITURE ACCOUNT AS AT 31ST MARCH 2015</b>			
Amount in ₹			
<b>SCHEDULE 9- OTHER ADMINISTRATIVE EXPENSES</b>	<b>2014-15</b>		<b>2013-14</b>
Electricity Expenses		37,02,165	-
Outsourcing Services		23,40,141	-
Security Services		57,89,625	-
Office Expenses		1,94,857	-
Refreshment/Hospitality/Meetings		3,69,306	-
Legal & Professional Charges		5,667	-
Bank Charges		17,640	-
Discount on Training Fees		14,106	-
Horticulture Expenses		11,000	-
Library Books & Periodicals		4,840	-
Printing & Stationery		3,33,872	-
Accounting Software Expenses		54,000	-
Repairs & Maintenance Expenses		9,65,911	-
Telephone Expenses		5,35,001	-
Vehicle Running & Maintenance		3,37,521	-
Tour / Travel & Transport		11,02,707	-
<b>Total</b>		<b>157,78,360</b>	<b>-</b>
<b>SCHEDULE 10- OPERATIONAL EXPENSES</b>	<b>2014-15</b>		<b>2013-14</b>
All India SPV Module Survey-II (2014)		2,85,600	-
SERIIUS Project Expenses		1,23,172	-
Short Film on NISE THE SHINING STAR		5,60,000	-
R&D Cell Expenses		1,94,730	-
Testing/Accredation Charges		97,238	-
Seminars/Conferences/Training Programmes		21,47,371	-
Hydrogen Project Exp.		33,456	-
Consumables/ Laboratory/Workshop Exp.		2,70,264	-
Techno Economic Feasibility Study Expenses		1,58,284	-
<b>Total</b>		<b>38,70,115</b>	<b>-</b>



## NATIONAL INSTITUTE OF SOLAR ENERGY

### SCHEDULE 11

#### SIGNIFICANT ACCOUNTING POLICIES AND NOTES TO ACCOUNTS

#### A. SIGNIFICANT ACCOUNTING POLICIES

##### 1. Basis of Accounting

The financial statements have been prepared as prescribed by ICAI in accordance with generally accepted accounting principles. The National Institute of Solar Energy (here in after referred to as Institute) adopts cash system of accounting in respect of its incomes as well as expenditure.

The accounting policies adopted and applied in the preparation of financial statements by the Institute are consistent with GFR rules 2005 in general.

##### 2. Fixed Assets and Depreciation

- a) Fixed assets are stated at cost less accumulated depreciation.
- b) Depreciation has been provided on the basis of rates as prescribed under Income Tax Act 1961.
- c) The depreciation has been charged to the grant (Corpus Fund/Capital Fund) and is recognized in the Income & Expenditure account as a contra item as per AS-12 Prescribed by ICAI.

##### 3. Grant in Aid

- a) The grants in aid received from Ministry of New & Renewable Energy, Government of India is accounted for on cash basis. The unutilized grants at the end of year have been shown in the financial statements as Grant payable to the Ministry of New & Renewable Energy.
- b) The grants utilized for the purchase of fixed assets and have been shown under the head of Capital Assets Fund.
- c) Further grants utilized for advances against Fixed Assets, goods & services have also been shown under the head of Capital Fund.
- d) In accordance with GFR rules 2005 Chapter 9 Rule 208 (iv) the institute has set off the revenue expenditure related directly to Income of the Institute against the internally generated resources i.e. Income from Testing and Training and the remaining amount has been set off against the Grants.

##### 4. Employee Remuneration & Benefits

All Retirement and other Terminal Benefits such as Gratuity, Leave Encashment and Bonus etc. are not accounted on year to year basis and the same are recognized in the year of occurrence of event.

##### 5. Revenue Recognition

Income and expenditure are accounted for on cash basis, as they are earned or incurred.

## 6. Provision

A provision is recognized, when an enterprise has a present obligation as a result of past event; it is probable that an outflow of resources will be required to settle the obligation, in respect of which a reliable estimate can be made.

## 7. Contingent Liabilities and contingent Assets

A disclosure for a contingent liability is made when there is a possible obligation that may, but probably will not, require an outflow of resources. Where there is a possible obligation or a present obligation but the likely hood of outflow of resources is remote, no provision or disclosure is made.

## B. NOTES TO ACCOUNTS

1. Expenditure on trainings and seminars to the extent they are reimbursed by the ministry directly, are not disclosed in the financial statements
2. The depreciation of ₹ 9,19,380/- has been charged to the Income & Expenditure account. Since the Institute is fully aided by the Government of India, therefore depreciation is charged to the Grant (Corpus Fund/Capital Fund) and is recognized in the Income & Expenditure account as a contra item.
3. Advances paid against capital assets etc. have been directly set off against Grants. However in the financial statements the same have been shown separately.
4. Previous year figures have been regrouped and rearranged to make them comparable with those of current year.

### As per our Audit Report of even date

#### For VBR & Associates

Chartered Accountants

(FRN-013174N)

(Binit K Agrawal)

Partner

M. No.088042

Place: Delhi

Dated: December 4, 2015

#### For NATIONAL INSTITUTE OF SOLAR ENERGY

Dr. O. S. Sastry  
(Director General)

Dr. S. K. Singh  
(Scientist F)



