TÜV Rheinland (India) Pvt. Ltd.

Plant Inspection & Testing Report of 1 MW Solar PV Plant Of

[redacted]

TUV Report No: 02154711

Bangalore, February 2015

Report No: 02154711

On

Plant Inspection & Testing Report of 1 MW Solar PV Plant for [redacted].

Client	:	D-85, Phase Vll, Indl Area, S A S. Nagar, Mohali (Punjab) -160055 INDIA.
TUV Quotation No	:	TUVRI / BANG / IS/ 217 / 12-2014
Order No	:	TC/Barwala/PO/01/Feb/14-15
Examiners	:	**Sridhara C.K** **Senior Manager- PV Power Plants** E-Mail: sridhara.ck@ind.tuv.com M: +91 9538998628 **Prabhu M** **Project Engineer – PV Power Plants** E-Mail: prabhu.m@ind.tuv.com M: +91 8884889993 **Harshavardhan.U** **Project Engineer – PV Power Plants** E-Mail: harsha.vu@ind.tuv.com M: +91 9620588864
Department	:	Industrial Services - PV Power Plants
No of Pages	:	38

Content s

List of Abbreviations

A	:	Ampere
AC	:	Alternate Current
ABT	:	Availability Based Tariff
CB	:	Combiner Box
CO2	:	Carbon Dioxide
CUF	:	Capacity Utilization Factor
DC	:	Direct Current
EN	:	European
EPC	:	Engineering Procurement and Commissioning
HT	:	High Tension
I	:	Current
IDMT	:	Inverse Definite Minimum Time
IEC	:	International Electrotechnical Commission
IGBT	:	Isolated Gate Bipolar Transistor
Imp	:	Maximum Peak Current
INST	:	Instantaneous
IP	:	Ingress Protection
Isc	:	Short Circuit Current
JB	:	Junction Box
kWh	:	kilo Watt hour
kV	:	kilo Volt
LCD	:	Liquid Crystal Display
LT	:	Low Tension
MΩ	:	Mega Ohm
MCB	:	Miniature Circuit Breaker
MVA	:	Mega Volt Ampere
MWh	:	Mega Watt Hour
MW	:	Mega Watt
MWp	:	Mega Watt peak
O & M	:	Operation and Maintenance
ONAN	:	Oil Natural Air Natural
PR	:	Performance Ratio
PV	:	Photo Voltaic
PPA	:	Power Purchase Agreement
PCB	:	Pre Combiner Box
Rp	:	Parallel Resistance
Rs	:	Series Resistance
SCADA	:	Supervisory Control and Data Acquisition
SLDC	:	State Load Dispatch Centre
Voc	:	Open Circuit Voltage
V	:	Volt
Vmp	:	Maximum Peak Voltage
Wp	:	Watt Peak
W/m^2	:	Watt per square meter
XLPE	:	Cross-Linked Polyethylene

1 Executive Summary

[redacted] has given an order to TUV Rheinland (India) Pvt. Ltd., to carry out the inspection and performance tests of their 1 MW AC / 1 MW DC Solar PV Power Plant located at Village Sarakpur, Barwala, Distt Panchkula, Haryana, India. The SPV power plant is configured with XL Energy make Poly crystalline modules with fixed tilt configuration at collector plane angle of 30.5 degree for the optimum utilization of solar energy and it was commissioned on 13th March 2012. The plant EPC was done by XL Energy and responsible for Engineering, Procurement and construction. The inverters used in the plant are santerno 500 KW. The inspection has been carried out as per EVS-EN 62446-2010 (Grid connected photovoltaic systems – Minimum requirements for system documentation, commissioning tests and inspection). All system components PV arrays, Inverters, Transformers and HT Panel were in operation. The plant is connected to 11 kV state grid.

Safety of Human, Installation and components

- Evaluation of the concept of the installation regarding the fulfilment of the requirements of electrical safety (operator safety and safety of installation)
- Evaluation of the suitability of the used components based on the technical data and according to the requirements.
- Visual Inspection of the PV plant
- Inspection of inverter and functionality tests Module strings.

The system was inspected and evaluated, especially the following parts:
PV Panels XL Energy make Poly crystalline 230Wp.
Inverters – Santerno 500KW
Cabling, grounding, and Connections
Module mounting structure

2 Description of the Inspected Plant Elements

2.1 System Description

The power plant is having an overall capacity of 1 MW and connected to 11 kV grid. Each string is designed to have 20 modules connected in series and 16 strings are connected to one CB via 12A fuses and 7 CB's are connected to one 500 KW inverter, Two Inverters are connected to one 1250 KVA ONAN type 270V/11KV transformer. And Transformer O/P's are connected to 2P Structure via HT Panel.

2.2 PV Modules

Manufacturer	Type (Wp) (a)	Modules/String (b)	Total No of Strings (c)	Quantity (Nos) (d)= (b*c)	Total Capacity (kW) (a*d)
XL Energy	230	20	221	4420	1016.6
Total Capacity					1016.6

Manufacturer	Module Type	Pmax (Wp)	Vmp (V)	Imp (A)	Voc (V)	Isc (A)
XL Energy	XL 6P60G230	230	30.60	7.54	37.08	8.08

2.3 Inverter

Manufacturer	Type (a)	Qty (Nos.) (b)	Total Capacity (kW) (a*b)
Santerno	TG 610 TE 800V	2	1000
Total capacity			1000

Inverter has inbuilt the following protections:

- DC Under, Over Voltage, Current and power
- AC Under, Over Voltage, Current, Frequency and power
- Phase Mismatching
- Earth fault protection

Inverter has standard display functions & Indications like:

- Indication lamp shows Inverter Operation, Earth fault and Failure
- LCD display- State of inverter
- PV Array Voltage, Current
- Output Voltage, Current, Power and Frequency
- Interface RS485

2.4 Transformer

Manufacturer	Type	Capacity	Qty (Nos)	Total Capacity (MVA)
Universal Power	ONAN, 270V/11 kV	1.25 MVA	1	1.25

One 1.25 MVA ONAN type three phase 270V / 11 KV transformer are used in the plant to step up to three phase 11 KV from 270 V. Transformers are working properly. Safety fencing is done for all the transformers and earthing is done properly for all the transformers.

2.5 Module mounting structure

Hot dip Structures are used for structure & structure rigidness is very good. Gap between two structures is not sufficient. Inter row shadow observed after 3pm (in summer time). Structure base part is fixed with MMS foundation. All structures & legs are aligned properly.

2.6 String Monitoring Unit

CB used are Thermoplastic IP 65 type, the rated insulation voltage of 1000 V and suitable for outdoor application.

All CBs are installed neatly on between the rows and earthed properly.

Observation: String monitoring units are not working.

2.7 Cables

Proper size cable is used in plant and no discrepancy observed.

Area	Cable Type and size
Modules to CB	6 mm^2 single core Copper double insulated
SCB to Inverter	95 mm^2 Single core Copper XLPE
Inverter to LT Panel	800 mm2 Single core Al XLPE
LT Panel to Transformer	3R Three core 300 mm^2 Al cable
Transformer to HT Panel	1R, 3C X185 SQ.MM 11kV, AL, Ar. XLPE
RMU Panel to HT Panel	1R, 3C X120 SQ.MM 11kV, AL, Ar. XLPE
HT Panel to 2P Structure	1R, 3C X120 SQ.MM 11kV, AL, Ar. XLPE

2.8 Earthing

There are sufficient earth points in the plant. Inverters, Transformers, and HT Panels are earthed properly. Earth resistance check was done for structure, Inverter, Transformer, LT and HT panels. Earth resistance measured is less than 2 Ohms (in PV Yard earting higher than the standard value) and is less than the standard requirement of 2 Ohms.

2.9 Surge / Lightning Protection

Lightning arresters are installed for the Inverters area and for the switch yard.

2.10 Weather Monitoring Station

Weather monitoring station is installed in the Plant for monitor following parameters

- Solar radiation
- Ambient temperature

- Module temperature
- Wind speed

Currently weather station is not working due to communication problem.

2.11 HT Panel

11kV HT Panel is installed in the plant.

HT panel has all the required monitoring and safety equipment's like

- Vacuum Circuit breaker
- INST over current protection
- IDMT over current protection
- INST earth fault protection
- IDMT earth fault protection
- Reverse power protection
- Under voltage protection

2.12 Plant Monitoring

Plant SCADA for overall monitoring of the plant is not working. And needs to be rectifying the SCADA system. SCADA will give following parameters

- Irradiation – Day, Month, Year and Total
- Meteorological data – Ambient temperature, Module temperature, Irradiance, wind speed and wind direction
- Energy data – Day, Month, Year and Total
- DC Input power
- Inverter outputs

3 Inspection and Testing

3.1 Visual Inspection

Area	Observation	Corrective Action
Module	Most of the modules where affected with Bypass diode and cell burnt. string. Refer image 1	All faulty modules needs to be replaced. For time being all faulty modules needs to be removed from string and can be connected as separate string
	Inter row shadow falling on to module from 3 pm (in summer period).	No Option for correction

	Module JB burnt. Modules Need to be replaced. Refer image-2	Modules needs to be replaced
Cable	All DC and AC cable are laid without cable tag and ferrules. Needs to be use cable tag and ferrules for all cables. Refer image-3	Cable Identification to be done
Connector	Module connector loose connection. Refer image-4.	Needs to be check all MC4 connectors in the plant
CB	Dust observed inside the CB. Refer image-5	CB needs to be cleaned as per preventive maintenance schedule
Inverter	Inverter display meter Showing wrong radiation data.	Needs to discuss with Inverter supplier for correction
	Inverter DC disconnected switch not available.	Needs to discuss with Inverter supplier for correction
	Dust observed inside the inverter. Refer image-6	Inverter needs to be cleaned as per preventive maintenance schedule to avoid inverter failure
HT Panel	B- Phase Indication lamp and Ammeter not working. Refer image-7.	Needs to be corrected
ACDB	Phase indication lamp not working. Refer image-8.	Needs to be corrected
Transformer	WTI and OTI indicator not working. Refer image-9.	Needs to be corrected
	Wood waste and paper waste in inside the cable trench. Refer image-10.	Needs to be removed and cleaned
Radiation sensor	Radiation sensor needs to be fixed at module plane in mid of the structure. Refer image-11.	Needs to be corrected
SCADA	String monitoring unit not working.	Needs to be corrected
	Weather station not working.	Needs to be corrected
UPS	Plant UPS not working. Refer image-12.	Needs to be corrected

Images

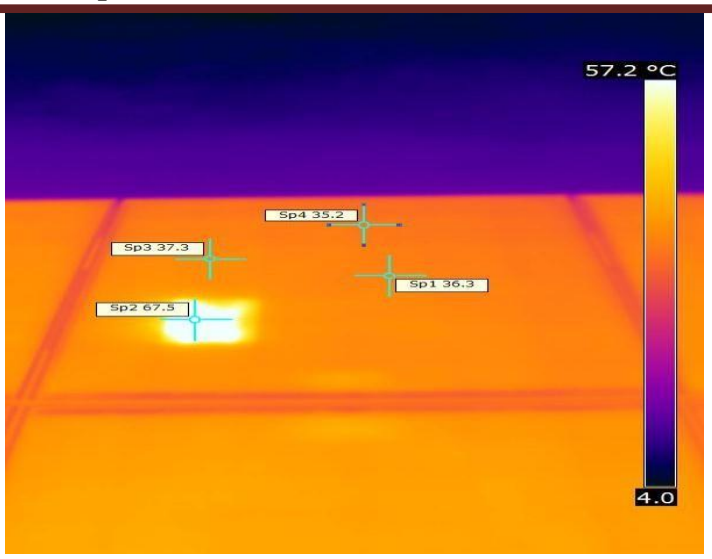


Image-1

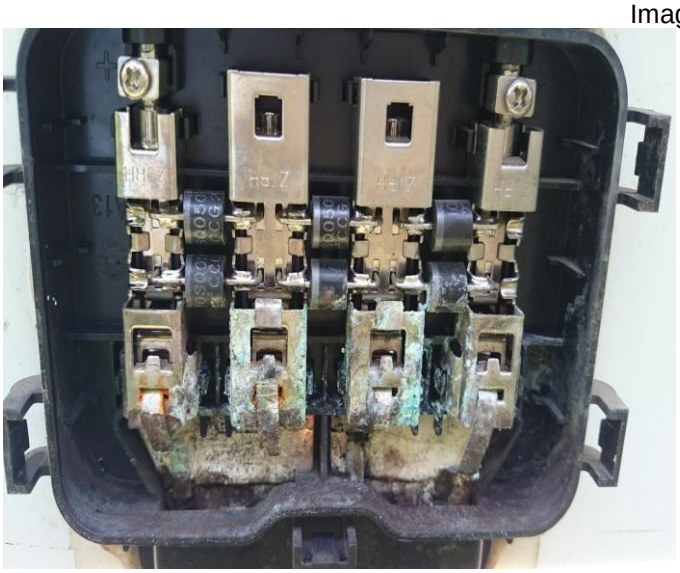


Image-2

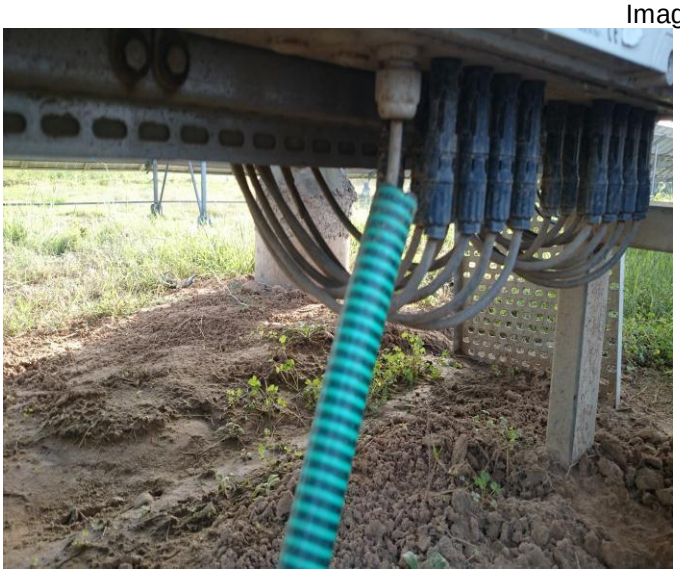


Image-3

Image-4

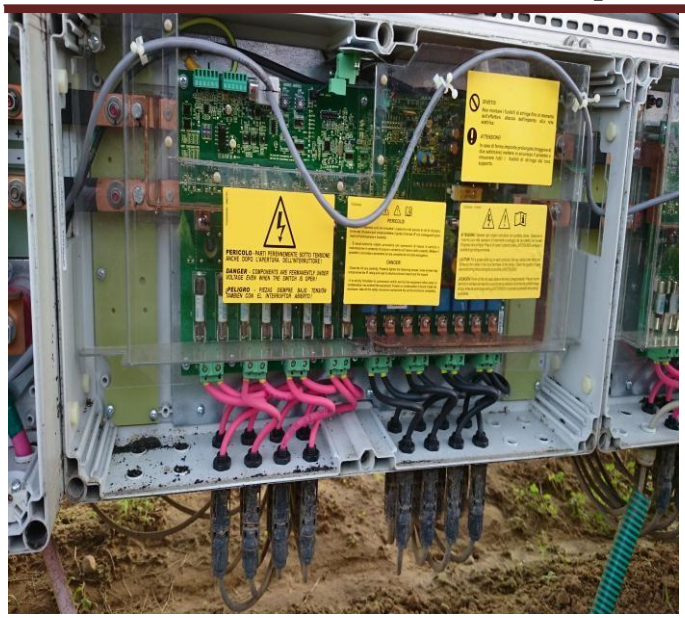


Image-5

Image-6

Image-7

Image-8

Image-9

Image-10

Image-11

Image-12

3.2 Inspection Checklist as per the IEC/EN 62446

Sl.#	Description	Observation
1	**DC system inspection**	
1.1	The DC system has been designed, specified and installed to the requirements of IEC 60364 in general and IEC 60364-7-712 in particular. needs PV String over current protection device PV String disconnection device PV Sub array disconnection device PV main array disconnection device	DC 12 A Fuse and disconnector used
1.2	All DC components are rated for continuous operation at DC and at the maximum possible DC system voltage and maximum possible DC fault current ($V_{oc\ stc}$ corrected for local temperature range and based on module type; and current at 1,25 x $I_{sc\ stc}$ according to IEC 60364-7-712.433).	Yes
1.3	Protection by use of class II or equivalent insulation adopted on the DC side - yes / no (class II preferred - IEC 60364-7-712.413.2:2002).	Yes
1.4	PV string cables, PV array cables and PV DC main cables have been selected and erected so as to minimize the risk of earth faults and short-circuits (IEC 60364-7-712.522.8.1:2002). Typically achieved by the use of cables with protective and reinforced insulation (often termed “double insulated").	Double insulation cables used
1.5	Wiring systems have been selected and erected to withstand the expected external influences such as wind, ice formation, temperature and solar radiation (IEC 60364-7-712.522.8.3:2002).	Yes
1.6	For systems without string over-current protective device: verify that the module reverse current rating (I_r) is greater than the possible reverse current; also, verify that the string cables are sized to accommodate the maximum combined fault current from parallel strings (IEC 60364-7-712.433:2002).	Yes
1.7	For systems with string over-current protective device: verify that the string over-current protective devices are fitted and correctly specified to local codes or to the manufacturer's instructions for protection of PV modules according to the note of IEC 60364-7-712.433.2:2002.	Yes
1.8	Verify that a DC switch disconnector is fitted to the DC side of the inverter (IEC 60364-7-712.536.2.2.5:2002).	Yes
1.9	If one of the DC conductors is connected to earth, verify that	Yes

	there is at least simple separation between the AC and DC sides and that earth connections have been constructed so as to avoid corrosion (IEC 60364-7-712.312.2:2002).	
2	**Protection against overvoltage / electric shock**	
2.1	To minimize voltages induced by lightning, verify that the area of all wiring loops has been kept as small as possible (IEC 60364-7-712.444.4:2002).	Yes
2.2	Verify that array frame and/or module frame protective earthing conductors have been correctly installed and are connected to earth. Where protective earthing and/or equipotential bonding conductors are installed, verify that they are parallel to, and bundled with, the DC cables (IEC 60364-7-712.54:2002).	Yes
3	**AC system**	
3.1	A means of isolating the inverter has been provided on the AC side;	Yes
3.2	All isolation and switching devices have been connected such that PV installation is wired to the "load" side and the public supply to the "source" side? (IEC 60364-7-712.536.2.2.1:2002);	Yes
4	**Labelling and identification**	
4.1	All circuits, protective devices, switches and terminals are suitably labelled.	Yes
4.2	The main AC isolating switch is clearly labelled.	Yes
4.3	A single line wiring diagram is displayed on site.	No
5	**Safety Audit**	
5.1	Security for the plant a. Plant should have security and proper fencing	Plant has proper boundary wall. Sufficient nos. security guards deployed round the clock.
5.2	Emergency contact no. of responsible officer, Contact no. of Fire Station and Doctor needs to be displayed in Inverter rooms and control room	No
5.3	Emergency shutdown procedure to be displayed in inverter room and control room	No
5.4	Fire Extinguisher needs to be installed near door of every inverter room and where ever applicable	Yes

5.5	First Aid kit need to be kept in specified area	Yes
5.6	All workers needs to wear shoes, needs to use hand glows during working on AC/DC and tools handle should have proper insulation	No
5.7	Earthing – Structure, electrical equipment, system must be earthed to obtain a low resistance path for dissipation of current in to earth. IEEE Recommended a ground resistance value of 5 ohms or less	Earthing done for Structures, Inverters, Transformers and Panels. Earth resistance measured is less than 2 ohms(in PV Yard earting higher than the standard value)
5.8	Protection surge/high voltages – Lightning protection needs to be provided for plant	Yes
5.9	All underground cables are needs to be double insulated/Armoured	Yes
a) 5.10	All LT & HT underground cable drawn line/area needs to be properly identified/marked	Yes
b) 5.11	All AC and DC cables needs to be identified properly	Ferrule needs to be use on all cables for identification.
c) 5.12	Inverter and Panel area needs to be covered with rubber mat to avoid any electrical shock	Yes
d) 5.13	All cable trench inside and outside the building needs to be closed properly	Yes
e) 5.14	Battery bank room should have proper ventilation	Yes (UPS not working for battery bank charging)
f) 5.15	All high voltage switch yard should have proper fencing, gate with lock, Danger sign board on fencing and Co2 buckets	Yes

3.3 Modules String IV Curve Measurement

Measurement done on random basis as given below

- IV Curve measurement taken for 5 strings out of 221 strings and 35 Modules.

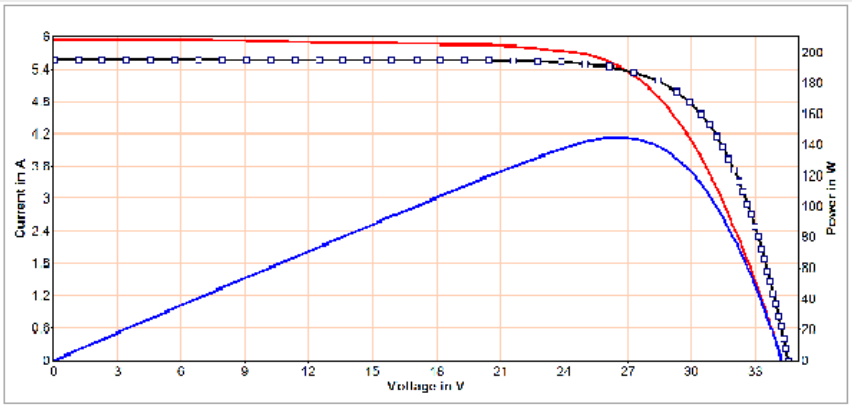
Readings are Annexture-1.

- Module has required approval of IEC 61215 (Crystalline terrestrial photovoltaic (PV) modules - Design qualification and type approval) IEC 61730 -1 and 2 (Photovoltaic (PV) module safety qualification, Part 1- requirement for construction and part 2 - Requirement for testing)

IV Curve of String

TÜVRheinland®
Precisely Right.

Result of PVPM Power Measurement



Measurement Results

Module type: XL 6P60G230 (XL Telecom & Energy Ltd.)

In series: 1 - Parallel: 1

		Measurm.:	Nominal:	Deviation:
Values at STC:	**Peak power P pk:**	**219.1 Wp**	**230.0 W**	**-4.8 %**
	Ppk max:	230.0 W	235.0 W	
	Ppk min:	208.1 W	230.0 W	
	I pmax0:	7.96 A	7.54 A	5.6 %
	Vpmax0:	27.5 V	30.6 V	-10.1 %
	I sc0:	8.63 A	8.08 A	6.8 %
	Voc0:	36.5 V	37.1 V	-1.6 %
Maximum values (actual)	P max:	145.1 W		
	I pmax:	5.49 A		
	Vpmax:	26.5 V		
	I sc:	5.95 A		
	Voc:	34.3 V		
Calculated values	Rs:	0.6 Ohm	0.3 Ohm	85.0 %
	Losses by add. Rs:	-19 W		
	Rp:	371 Ohm	300 Ohm	23.6 %
	FF:	0.71	0.77	-7.5 %
	NOCT:	39 °C		
Conditions during measurement:	Cell temperature T mod:	36.7 °C		
	Irradiance E eff:	689 W/m2		
	Temperature reference cell T ref:	36.7 °C		

Additional Informations

File: C:\Users\prabhum\Desktop\Tayal & co\Measurement series1\28-02-2015 10_39_24.SUI

PVPM Serial No.: PVPM1000C00214	Sensor: Si-02 poly #14080002
Customer:	PV plant:
Plant part:	Date of measurement: 28.02.2015 10:39:24
Description:	

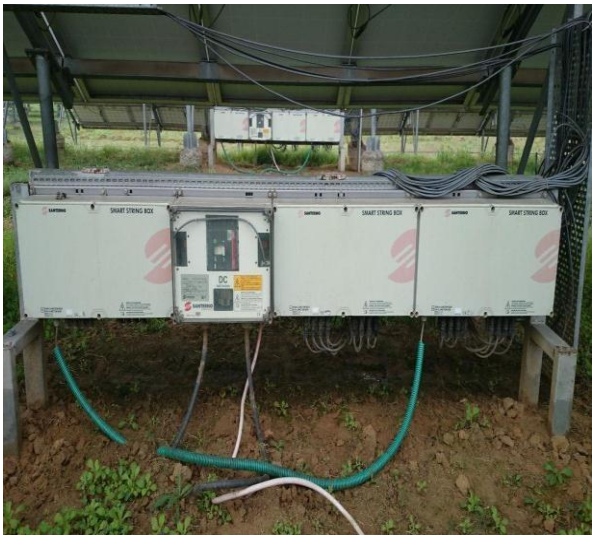
PV-Engineering GmbH * Augustastr. 24 * DE-58644 Iserlohn

Date: 3/5/2015 Page 1

4 Site Photos

Module

Structure



CB

Inverter

LT Panel

HT Panel

Transformer

2P Structure

Lightning Arrester

Radiation Sensor

5 String Insulation Resistance Measurement

String and module Insulation Measurement done on random basis. Readings are in annexture-2.

Minimum values of insulation resistance: EN62446:2010

Test method	System voltage ($V_{oc\ stc}$x1.25) V	Test voltage v	Minimum insulation resistance Mega Ohms
Test method 2 Array positive and negative shorted together	<120	250	0.5
	120-500	500	1
	>500	**1000**	**1**

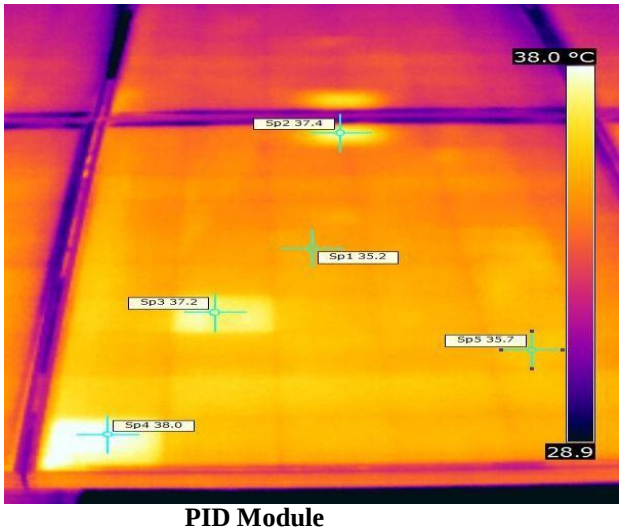
The insulation resistance of all tested samples are more than 1 MΩ.

6 Thermograph of the Plant Components

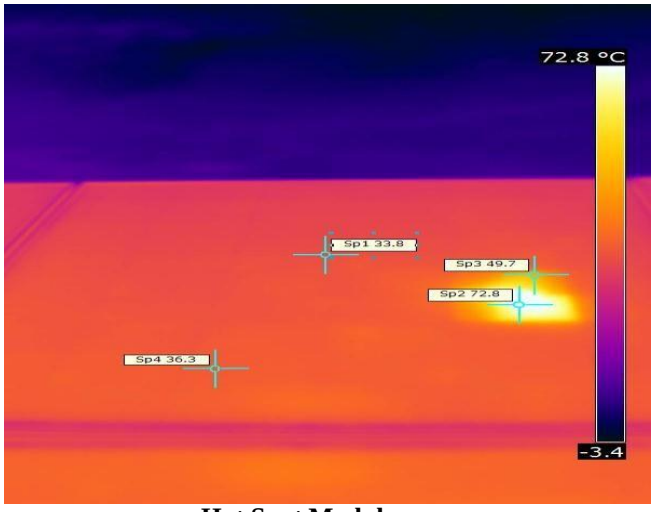
Infrared scanning was performed on modules, CB, Inverters & other components. Temperature rise, Hot spot, cell crack observed in the plant. List of defective modules are attached as Annexure 3.

6.1 Modules failure details

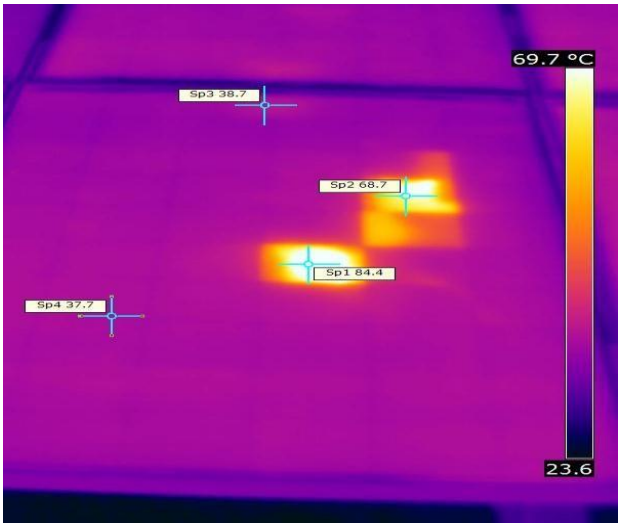
Failure Type	XL Energy
Module Broken	1
Cell burnt Module	172
Hot spot	952
PID	54
Bypass diode defective module	84
Bypass diode and Hot spot	59
Total	1322



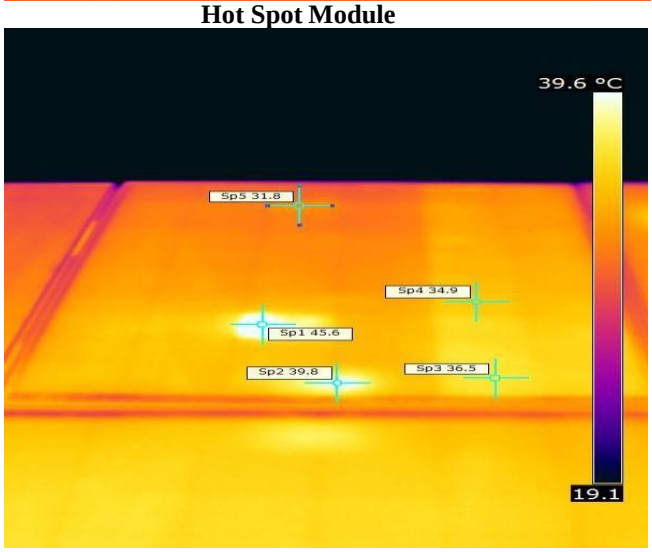
PID Module



Hot Spot Module

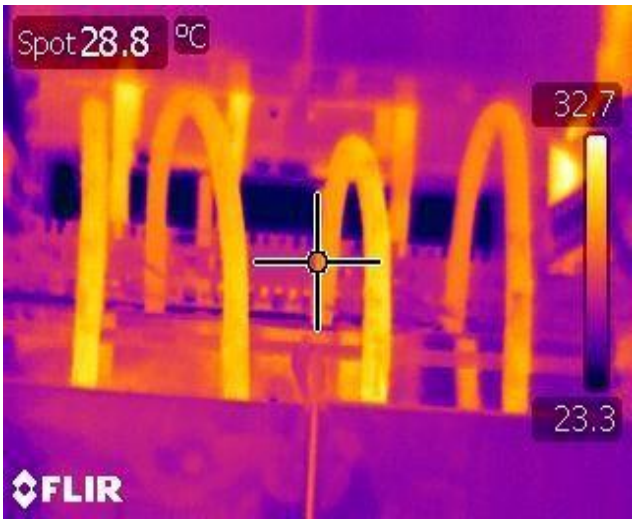


Cell Burnt Module



Bypass Diode Failure Module

CB



Inverter

7 Energy Yield

Energy Yield Estimation

An independent energy yield calculation is done by TUVR using PVSyst software considering the following parameters.

PVSyst is the very popular software for energy yield calculation. Meteonorm data's are used for calculation & following details considered for design

1. Latitude : 30.5°, Longitude :77°, Altitude: 321 m
2. Average monthly Irradiance, Air temperature and wind velocity
3. Fixed tilt
4. Free Horizon
5. No shading
6. Losses

Loss	Description
Low irradiance	The conversion efficiency of a PV module reduces at low light intensities - PVSyst default
Module temperature	The characteristics of a PV module are determined at standard temperature conditions of 25°C. For every °C temperature rise above this, crystalline modules reduce in efficiency, generally by around 0.4%
Soiling	Losses due to dust and bird dropping. Normally 2-3% losses are considered in India. 2% loss is considered for this site.
Module quality	Most PV modules do not match exactly the manufacturers nominal specifications In this case loss considered is 1.5 %
Module mismatch	Losses due to mismatch are related to the fact that the real modules in an array do not all rigorously present the same current / voltage profiles. Considered loss is about 1.5 %
Ohmic wiring loss	Electrical resistance in the wires between the power available at the modules and at the terminals of the array gives rise to ohmic losses. Standard loss considered is 1% to 2%
Inverter performance loss	Inverters convert from DC to AC with a maximum efficiency. Conversion loss depends on the design.
AC losses	Losses at LV/HT panel and AC wiring. Normally 1 % to 2 % is considered

Solar Resource

A variety of solar irradiation data sources are available. The datasets either make use of ground based measurement at meteorological stations or use processed satellite imagery.

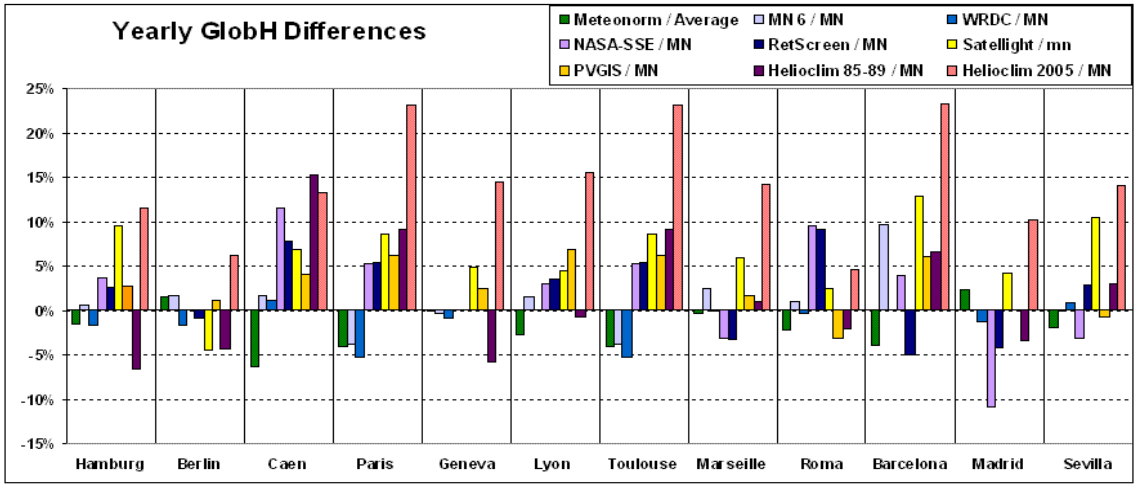
Meteonorm: Global climatological data base and synthetic weather generator. This contains a database of ground station measurements of irradiation and temperature on hourly basis. Site resource data is interpolated from these stations and satellite data. Meteonorm data is widely used for solar resource assessment. It has 8055 stations worldwide & only data which is directly measured from weather monitoring stations. All other resource available for India other than Meteonorm and IMD is from satellite measurements.

The METEONORM radiation data base is based on 10-20 year measurement periods, the other parameters mainly on 1996-2005 means. Comparisons with longer term measurements show that the discrepancy in average total radiation due to choice of time period is less than 2 % for all weather stations.

NASA: Surface Meteorology and solar energy data set. This holds satellite derived monthly data for a grid of 1°x1° covering the globe for ten year period (1983 - 1993).

Global comparison between all sources:

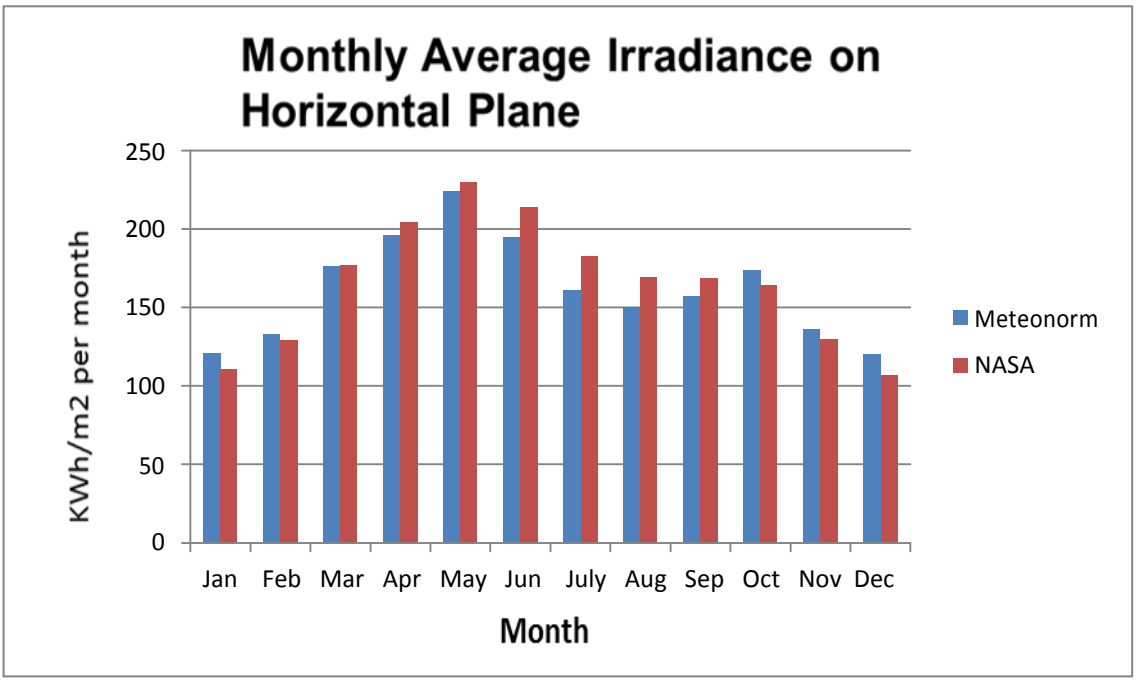
The figure shows a comparison between all available sources, for 12 locations in Europe. All values are by respect to the Meteonorm values (PVSyst internal default). Meteonorm often gives lower values than the average. This means that simulations with default values in PVSyst will be rather conservative, and give prudent results for the final yield of the customer's systems.



7-1: Comparison of Global Horizontal radiation from various sources

Meteonorm data is used for yield estimation because it interpolates the data of nearest measurement stations and satellite data.

Solar irradiance data of Site: Month	Mean Irradiance of Global radiation Horizontal (kWh/m² per month)- Meteonorm period 1981-2000	Mean Irradiance of Global radiation Horizontal(kWh/m² per)- NASA period 1983-1993
Jan	120.5	110.7
Feb	133.1	129.1
Mar	176.3	177
Apr	195.8	204.3
May	223.9	230
Jun	194.4	213.6
July	160.7	182.6
Aug	150.3	169.3
Sep	157	168.6
Oct	173.4	164
Nov	136	129.6
Dec	120	107
Year	1941.4	1985.7



Comparison of Meteonorm and NASA data

Yearly Generation

82/A, West Wing, 3rd Main, Electronics City Phase I - 560 100 - Bangalore - Indi

Grid-Connected System: Simulation parameters

Project :	**Grid-Connected Project 1 MW at Sarakpur hariyana**			
Geographical Site	**Sarakpur hariyana**		Country	**India**
Situation	Latitude	30.5°N	Longitude	77.0°E
Time defined as	Legal Time	Time zone UT+5	Altitude	321 m
	Albedo	0.20		
Meteo data:	**Sarakpur hariyana**	Synthetic - Meteonorm file		

Simulation variant :	**New simulation variant**			
	Simulation date	05/03/15 16h19		

Simulation parameters

Collector Plane Orientation	Tilt	31°	Azimuth	0°
Models used	Transposition	Perez	Diffuse	Erbs, Meteonorm
Horizon	Free Horizon			
Near Shadings	No Shadings			

PV Array Characteristics

PV module	Si-poly Model	**XL 6P60G230 Poly**		
	Manufacturer	XL Energy Ltd.		
Number of PV modules	In series	20 modules	In parallel	221 strings
Total number of PV modules	Nb. modules	4420	Unit Nom. Power	230 Wp
Array global power	Nominal (STC)	**1017 kWp**	At operating cond.	910 kWp (50°C)
Array operating characteristics (50°C)	U mpp	544 V	I mpp	1673 A
Total area	Module area	**7371 m²**	Cell area	6455 m²

Inverter	Model	**SUNWAY TG 610 - 800V - MT**		
	Manufacturer	Santerno		
Characteristics	Operating Voltage	430-760 V	Unit Nom. Power	468 kW AC
Inverter pack	Nb. of inverters	2 units	Total Power	936 kW AC

PV Array loss factors

Array Soiling Losses			Loss Fraction	2.0 %
Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	5.5 mOhm	Loss Fraction	1.5 % at STC
Module Quality Loss			Loss Fraction	1.5 %
Module Mismatch Losses			Loss Fraction	1.5 % at MPP
Incidence effect, ASHRAE parametrization	IAM =	1 - bo (1/cos i - 1)	bo Param.	0.05

System loss factors

AC wire loss inverter to transfo	Inverter voltage	270 Vac tri		
	Wires	50 m 3x1500 mm²	Loss Fraction	1.0 % at STC
External transformer	Iron loss (24H connexion)	998 W	Loss Fraction	0.1 % at STC
	Resistive/Inductive losses	1.1 mOhm	Loss Fraction	1.5 % at STC

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Grid-Connected System: Main results

Project : **Grid-Connected Project 1 MW at Sarakpur hariyana**

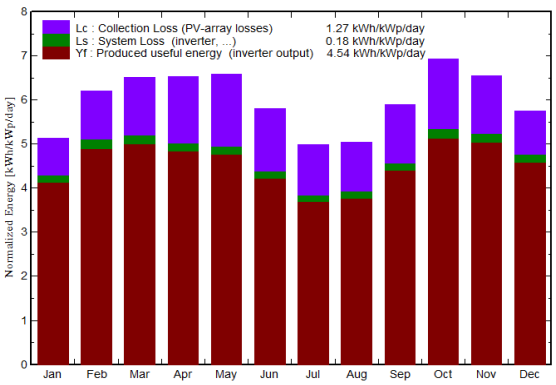
Simulation variant : **New simulation variant**

Main system parameters	System type	**Grid-Connected**			
PV Field Orientation	tilt	31°	azimuth	0°	
PV modules	Model	XL 6P60G230 Poly	Pnom	230 Wp	
PV Array	Nb. of modules	4420	Pnom total	**1017 kWp**	
Inverter	Model	SUNWAY TG 610 - 800V - MT		468 kW ac	
Inverter pack	Nb. of units	2.0	Pnom total	**936 kW ac**	
User's needs	Unlimited load (grid)				

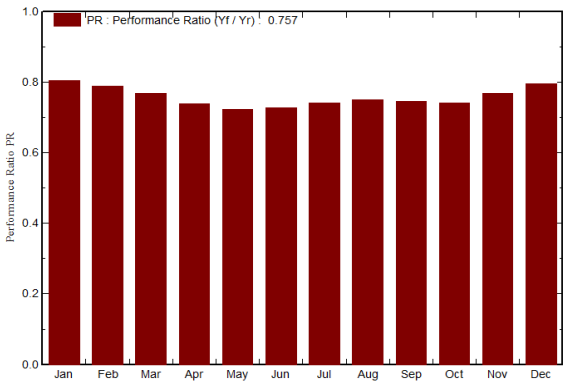
Main simulation results

System Production	**Produced Energy**	**1684 MWh/year**	Specific prod.	1657 kWh/kWp/year
	Performance Ratio PR	75.7 %		

Normalized productions (per installed kWp): Nominal power 1017 kWp



Performance Ratio PR



New simulation variant

Balances and main results

	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	EffArrR %	EffSysR %
January	107.1	12.74	159.0	152.3	135.4	130.1	11.55	11.10
February	128.3	14.62	173.9	166.8	145.4	139.6	11.34	10.89
March	172.3	19.35	202.2	193.0	164.0	157.8	11.01	10.59
April	189.8	26.34	196.0	186.4	153.2	147.5	10.60	10.21
May	217.0	31.08	204.0	193.5	156.0	150.1	10.37	9.98
June	192.7	32.44	173.9	164.7	134.0	128.9	10.45	10.06
July	168.1	30.49	154.4	146.1	121.2	116.5	10.65	10.24
August	160.6	28.84	156.2	148.1	123.8	119.0	10.76	10.34
September	160.5	28.03	177.2	168.7	139.5	134.2	10.68	10.28
October	165.2	24.84	215.0	206.3	168.6	162.0	10.64	10.22
November	129.3	18.63	196.7	188.8	159.8	153.8	11.02	10.60
December	109.7	14.06	178.5	171.1	150.1	144.3	11.41	10.97
Year	1900.5	23.50	2187.0	2085.9	1751.0	1684.0	10.86	10.45

Legends:

GlobHor	Horizontal global irradiation	EArray	Effective energy at the output of the array
T Amb	Ambient Temperature	E_Grid	Energy injected into grid
GlobInc	Global incident in coll. plane	EffArrR	Effic. Eout array / rough area
GlobEff	Effective Global, corr. for IAM and shadings	EffSysR	Effic. Eout system / rough area

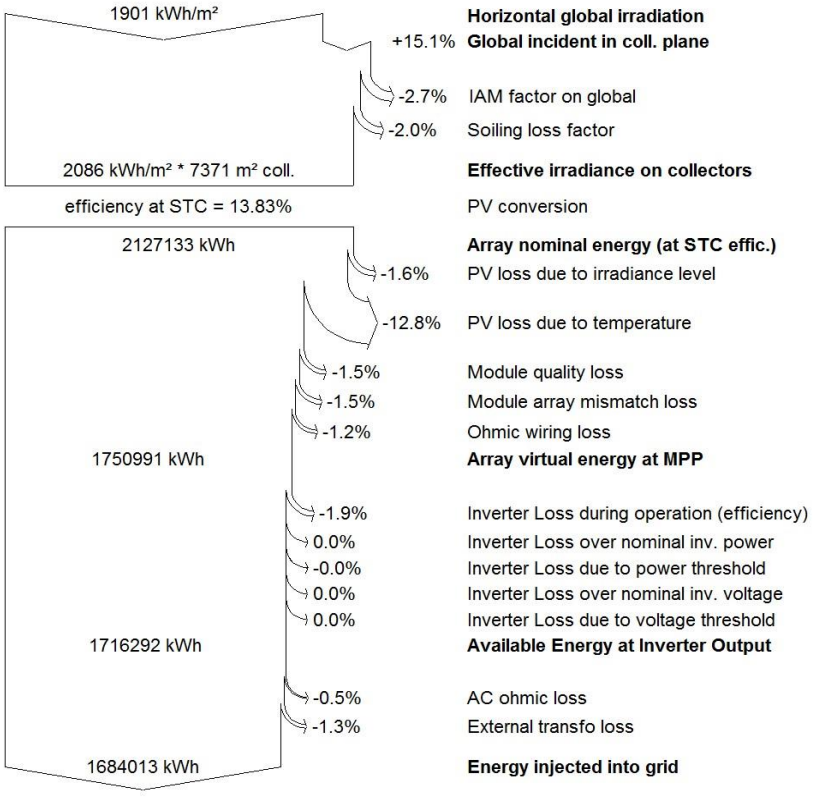
Grid-Connected System: Loss diagram

Project : **Grid-Connected Project 1 MW at Sarakpur hariyana**

Simulation variant : **New simulation variant**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	31°	azimuth	0°
PV modules	Model	XL 6P60G230 Poly	Pnom	230 Wp
PV Array	Nb. of modules	4420	Pnom total	**1017 kWp**
Inverter	Model	SUNWAY TG 610 - 800V - MT		468 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**936 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



Available energy at the plant ABT meter	1684013 KWh
Generation for Year 2013 (-0.8%)	1670541 kWh
Generation for Year 2014 (-0.8%)	1657177 kWh

7.1 Uncertainty Analysis

The Uncertainty in energy prediction is challenging to quantify as it is a function of many independent factors. Solar radiation is one of the core parameter which creates maximum uncertainty in the measurement. Meteonorm data has been used for the energy yield calculation which has been generated through synthetic weather data generator. The uncertainty with irradiance has been taken 6% according to Meteonorm website. Below table shows the uncertainty parameters considered for calculation

Sl #	Parameters	Uncertainty (%)
1	Meteonorm data	6.0
2	Module performance	1.0
3	System and Grid availability	1.0
5	Degradation Uncertainty	1.0

Total uncertainty= $\sqrt{6^2+1^2+1^2+1^2}$ = 6.24%

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Grid-Connected System: P50 - P90 evaluation

Project : **Grid-Connected Project 1 MW at Sarakpur hariyana**

Simulation variant : **New simulation variant**

Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	31°	azimuth	0°
PV modules	Model	XL 6P60G230 Poly	Pnom	230 Wp
PV Array	Nb. of modules	4420	Pnom total	**1017 kWp**
Inverter	Model	SUNWAY TG 610 - 800V - MT		468 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**936 kW ac**
User's needs	Unlimited load (grid)			

Evaluation of the Production probability forecast

The probability distribution of the system production forecast for different years is mainly dependent on the meteo data used for the simulation, and depends on the following choices:

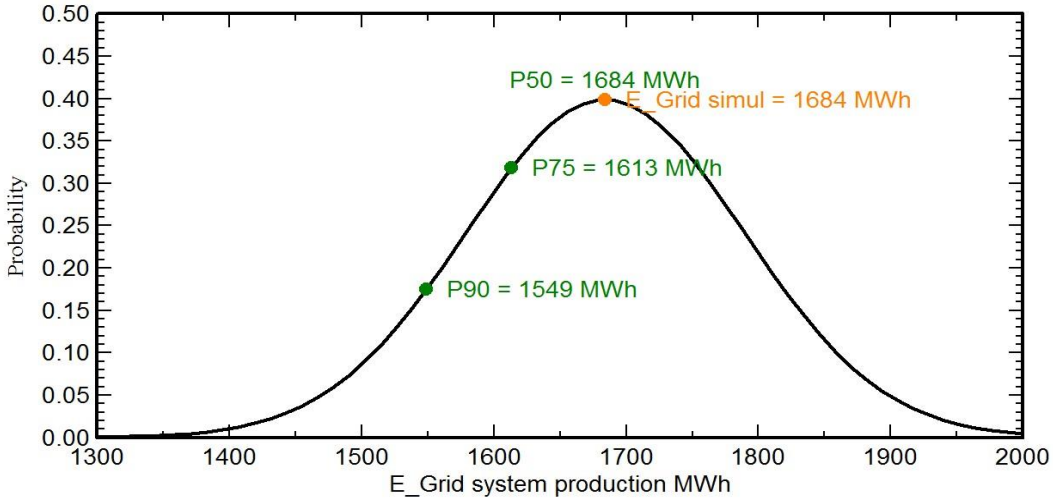
Meteo data source		Meteonorm file		
Meteo data	Kind	Not defined	Year	1995
Specified Deviation	Year deviation from aver.	3 %		
Year-to-year variability	Variance	6.0 %		

The probability distribution variance is also depending on some system parameters uncertainties

Specified Deviation	PV module modelling/parameters	1.0 %	
	Degradation uncertainty	1.0 %	
	plant and grid availability	1.0 %	
Global variability (meteo + system)	Variance	6.2 %	(quadratic sum)

Annual production probability	**Variability**	**105167 kWh**
	P50	**1684013 kWh**
	P90	**1549159 kWh**
	P75	**1613113 kWh**

Probability distribution



7.2 Degradation and Energy Yield Probability

Modules are warranted for 90% for first 10 years and 80% up to 25 years. Average degradation is 0.8% per year.

Probability of exceedance is considered from the point of bankability. These parameters have been arrived based on the experience and standard thumb rule and this consideration is based on a normal distribution of the expected yields. The predicted yield represents the p50 value, while p75 and p90 value means the yield exceeded with a probability of 75% and 90% with a standard deviation of 6.24 % which gives a difference of 4.18% and 7.98 % from the p50 value.

Probability p50 and P90

Year	P50	P75	P90
	kWh	kWh	kWh
1	1684013	1613113	1549159
2	1672225	1601821	1538315
3	1660519	1590608	1527547
4	1648896	1579474	1516854
5	1637353	1568418	1506236
6	1625892	1557439	1495692
7	1614511	1546537	1485222
8	1603209	1535711	1474826
9	1591987	1524961	1464502
10	1580843	1514286	1454251
11	1569777	1503686	1444071
12	1558788	1493161	1433962
13	1547877	1482708	1423925
14	1537042	1472330	1413957
15	1526282	1462023	1404059
16	1515599	1451789	1394231
17	1504989	1441627	1384471
18	1494454	1431535	1374780
19	1483993	1421514	1365157
20	1473605	1411564	1355600
21	1463290	1401683	1346111

22	1453047	1391871	1336689
23	1442876	1382128	1327332
24	1432776	1372453	1318040
25	1422746	1362846	1308814

8 Generation from Plant

8.1 Comparison of Estimated yield and actual yield

Month	Estimated Generation-TUVR (MWh)-P50	Estimated Generation-TUVR (MWh)-P90	Estimated Irradiation kWh/m2	Actual Generation (MWh)	Deviation form estimated yield P90	Estimated CUF (%)	Actual CUF (%)	Grid and Plant down time
12-May	150	138	217	112	12%	20%	15%	40 hrs
12-Jun	129	119	193	107	6%	18%	15%	44hrs46minutes
12-Aug	119	110	161	108	1%	16%	14%	22hrs24mins
12-Sep	134	123	161	108	10%	19%	15%	20hrs38mins
12-Oct	162	149	165	125	14%	22%	17%	07hrs25mins
12-Nov	154	142	129	103	30%	21%	14%	05hrs38mins
12-Dec	144	133	110	86	42%	19%	12%	11hrs35mins
Annual 2012	**992**	**913**	**1135**	**749**	14%	**19%**	**15%**	**113Hrs6mins**
13-Jan	130	122	107	67	51%	17%	9%	06hrs50mins
13-Feb	140	129	128	99	23%	21%	15%	03hrs13min
13-Mar	157	144	172	135	5%	21%	18%	08hrs08min
13-Apr	146	134	190	130	2%	20%	18%	09hrs48min
13-May	149	137	217	123	7%	20%	16%	18hrs48min
13-Jul	116	107	168	95	7%	16%	13%	32hrs06min
13-Aug	118	109	161	84	16%	16%	11%	38hrs37min
13-Sep	133	122	161	111	7%	18%	15%	12hrs50min
13-Oct	161	148	165	102	28%	22%	14%	13 hrs 48 min.
13-Nov	153	141	129	105	28%	21%	15%	37 hrs 21 min
13-Dec	143	132	110	97	31%	19%	13%	7hrs 49 min.
Annual 2013	**1545**	**1422**	**1708**	**1147**	16%	**19%**	**14%**	**189hrs18mins**
14-Jan	129	119	107	80	36%	17%	11%	18 hrs 47 min.
14-Feb	138	127	128	93	27%	21%	14%	7hrs 38 min.
14-Mar	155	143	172	129	8%	21%	17%	3hrs 13 min.
14-Apr	145	133	190	133	0%	20%	18%	4hrs 41 min.
14-May	148	136	217	125	5%	20%	17%	15hrs 11min
14-Jun	127	117	193	108	4%	18%	15%	9 hrs 16 min.

14-Jul	115	106	168	97	5%	15%	13%	7 hrs 46 min.
14-Aug	117	108	161	110	-2%	16%	15%	2 hrs 32 min.
14-Sep	132	121	161	107	9%	18%	15%	4 hrs 45 min.
14-Oct	160	147	165	107	24%	21%	14%	9 hrs 23 min.
14-Nov	152	140	129	118	17%	21%	16%	36 min.
14-Dec	142	131	110	84	42%	19%	11%	18 hrs23 min.
Annual 2014	**1660**	**1528**	**1901**	**1292**	12%	**19%**	**15%**	**102hrs10mins**
Total	**4197**	**3863**	**4744**	**3188**	14%	**19.10%**	**14.50%**	**404hrs34mins**

9 Conclusions

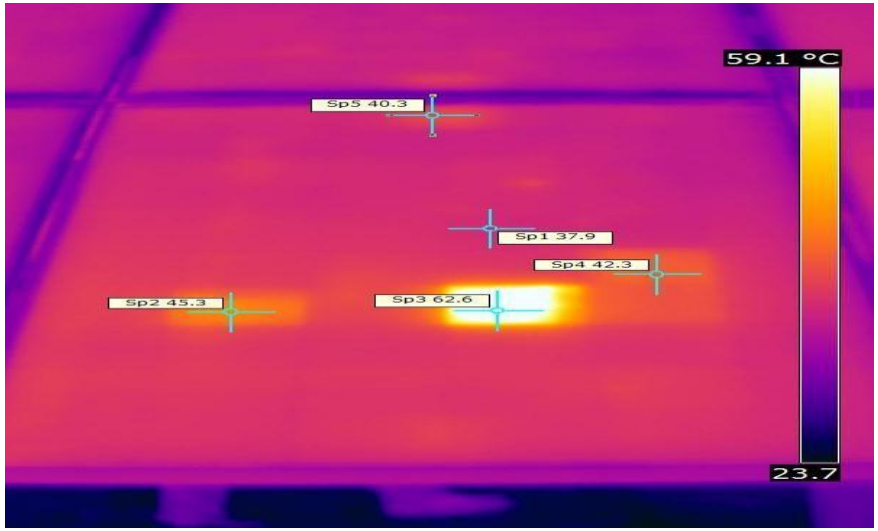
The following conclusions were drawn from the present work,

- Plant is underperforming comparing with the estimated TUVRI P90 Generation. Year 2012 has 14%, Year 2013 has 16% and Year 2014 has 12% lesser generation due to Module failure and grid unavailability.
- Total 4200 modules were scanned by IR camera and observed that failure of 1322 modules.

Failure Type	XL Energy
Module Broken	1
Cell burnt Module	172
Hot spot	952
PID	54
Bypass diode defective module	84
Bypass diode and Hot spot	59
Total	1322

- Random faulty modules IV curve was taken through the IV Curve tracer. Power loss up 88% observed in the burnt modules. Modules failure is due to process/manufacturing problem
- Inverter –ve needs to be earthed to avoid Potential Induced Degradation (PID) effect on modules. Needs to discuss with Inverter supplier to install the –ve earth kit to Inverter
- Total 1322 faulty modules are mixed in the 221 strings. Due to this the string will give less output. All 1322 modules needs to be removed from the strings and can be made separate string till the replacement of modules.
- As first priority all the bypass diode failure modules and cell burnt module needs to be removed from strings to avoid further loss in generation
- Corrective actions needs to be taken immediately on points raised in visual inspection table

Cell Burnt Module



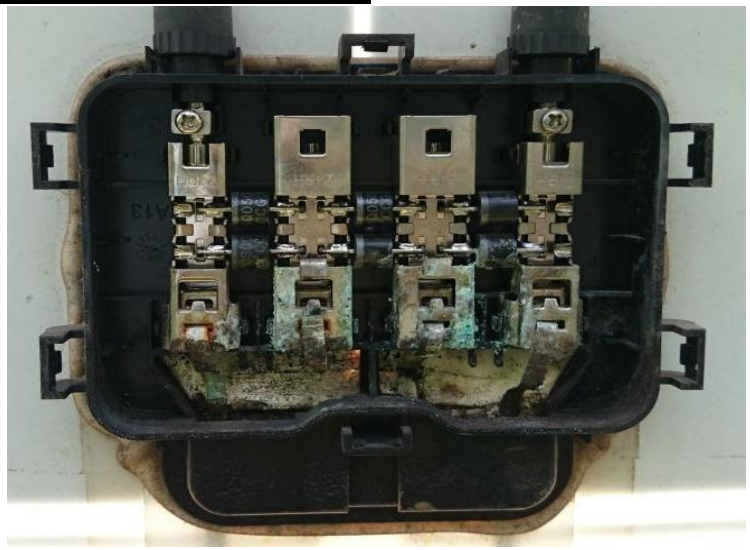
Module O/P with Cell burnt module

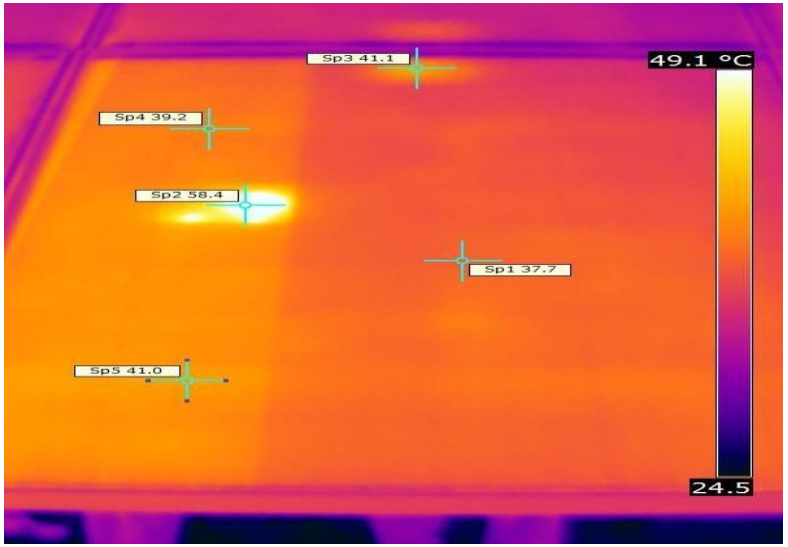
Row #	CB #	Module Sl #	Datum Zeit	T sens	T mod	E eff	Isc	Uoc	Ipmax	Upmax	Pmax	Isc 0	Uoc 0	Ipmax0	Upmax0	Ppk	Nominal Module out put	Deviation from nominal Wp	%Deviation from nominal Wp
			Date Time	°C	°C	W/m2	A	V	A	V	W	A	V	A	V	W			
9	**3**	**XL1111C00315**	**2/28/2015 11:16:12**	**40.5**	**40.5**	**782.1**	**6.2**	**33.6**	**5.2**	**17.3**	**90.9**	**8.0**	**33.4**	**6.7**	**14.3**	**95.6**	**230**	**-134**	**-58%**
9	3	XL1112C03756	2/28/2015 11:17:32	41.8	41.8	787.5	6.3	33.5	4.4	15.0	66.4	8.0	31.0	5.6	9.7	54.6	230	-175	-76%
9	3	XL1111C02349	2/28/2015 11:19:08	41.9	41.9	767.6	4.6	33.4	2.6	14.8	38.0	6.1	29.3	3.4	8.0	26.9	230	-203	-88%

String O/P with Cell burnt module

Row #	CB #	Datum Zeit	T sens	T mod	E eff	Isc	Uoc	Ipmax	Upmax	Pmax	Isc 0	Uoc 0	Ipmax0	Upmax0	Ppk	Nominal Module out put	Deviation from nominal Wp	%Deviation from nominal Wp
		Date Time	°C	°C	W/m2	A	V	A	V	W	A	V	A	V	W			
27	**14**	**2/27/2015 14:23:02**	**47.6**	**47.6**	**846.0**	**7.3**	**664.6**	**5.2**	**335.6**	**1738.4**	**8.6**	**677.6**	**6.1**	**317.1**	**1941.7**	4600	**-2658**	**-58%**

Bypass Diode Defective Modules





Bypass diode defective module O/P

Row #	CB #	Module Sl #	Datum Zeit	T sens	T mod	E eff	Isc	Uoc	Ipmax	Upmax	Pmax	Isc 0	Uoc 0	Ipmax0	Upmax0	Ppk	Nominal Module out put	Deviation from nominal Wp	%Deviation from nominal Wp
			Date Time	°C	°C	W/m2	A	V	A	V	W	A	V	A	V	W			
24	**14**	**XL1111C02359**	**2/27/2015 15:02:14**	**42.5**	**42.5**	**742.6**	**5.9**	**22.5**	**4.7**	**16.0**	**75.1**	**7.9**	**25.5**	**6.3**	**18.6**	**117.1**	**230**	**-113**	**-49%**
17	10	XL1111C01657	2/28/2015 10:38:18	40.2	40.2	729.7	6.2	23.0	5.1	17.8	90.8	8.5	26.5	7.0	21.4	149.5	230	-81	-35%

Bypass diode defective module O/P (string)

Row #	CB #	Datum Zeit	T sens	T mod	E eff	Isc	Uoc	Ipmax	Upmax	Pmax	Isc 0	Uoc 0	Ipmax0	Upmax0	Ppk	Nominal Module out put	Deviation from nominal Wp	%Deviation from nominal Wp
		Date Time	°C	°C	W/m2	A	V	A	V	W	A	V	A	V	W			
9	**3**	**2/28/2015 11:05:20**	**36.0**	**36.0**	**678.4**	**5.5**	**684.3**	**4.1**	**376.0**	**1548 .5**	**8.1**	**676.2**	**6.1**	**293.9**	**1784. 1**	4600	**-2816**	**-61%**

10 Annexure 1

Module I-V curve measurement

Sl #	Row #	CB #	Module Sl #	Datum Zeit	T sens	T mod	E eff	Isc	Uoc	Ip max	Up max	P max	Isc 0	Uoc 0	Ip max0	Up max0	Ppk	Module Wp	Deviation from nominal Wp	%Deviation from nominal Wp	Remarks
				Date Time	°C	°C	W/m2	A	V	A	V	W	A	V	A	V	W				
1	27	14	XL1111C00623	2/27/2015 14:11:58	46.1	46.1	865.9	7.4	33.4	6.6	15.2	100.5	8.6	33.9	7.6	13.7	104.6	230	-125	-55%	HotSpot
2	27	14	XL1112C03443	2/27/2015 14:13:38	46.6	46.6	864.3	4.1	33.2	2.1	14.4	30.5	4.8	31.7	2.5	11.5	28.2	230	-202	-88%	Burnt
3	27	14	XL1111C01058	2/27/2015 14:15:14	46.7	46.7	864.5	7.2	33.2	4.9	21.7	106.2	8.3	37.5	5.7	25.5	144.3	230	-86	-37%	Burnt
4	27	14	XL1111C00500	2/27/2015 14:17:22	46.1	46.1	861.6	7.0	33.3	5.6	23.6	132.3	8.1	36.6	6.5	26.7	173.8	230	-56	-24%	HotSpot
5	27	14	XL1111C02960	2/27/2015 14:21:16	49.9	49.9	850.1	6.9	33.2	5.2	22.1	114.6	8.1	37.2	6.1	25.7	156.4	230	-74	-32%	Backsheet Bulged
6	26	14	XL1112C04071	2/27/2015 14:28:14	46.7	46.7	841.4	7.0	33.8	6.3	25.0	156.7	8.3	36.6	7.4	27.5	204.5	230	-26	-11%	PID
7	26	14	XL1112C04119	2/27/2015 14:30:06	47.9	47.9	841.8	7.0	33.7	6.3	24.7	155.2	8.3	36.5	7.5	27.1	202.5	230	-28	-12%	PID
8	26	14	XL1112C04167	2/27/2015 14:31:56	47.8	47.8	835.7	6.9	33.8	6.3	24.8	156.7	8.3	36.5	7.6	27.1	204.8	230	-25	-11%	PID
9	26	14	XL1111C02988	2/27/2015 14:36:56	45.1	45.1	815.6	6.7	33.4	6.0	15.4	92.0	8.2	33.5	7.3	12.5	91.6	230	-138	-60%	Bypass Diode & Hotspot
10	26	14	XL1111C02248	2/27/2015 14:38:36	45.8	45.8	809.0	6.6	33.5	6.0	24.4	146.4	8.1	36.1	7.4	26.4	195.0	230	-35	-15%	PID
11	24	14	XL1111C02417	2/27/2015 14:52:10	43.7	43.7	776.1	6.4	33.7	4.8	24.9	120.8	8.3	39.8	6.2	31.0	193.6	230	-36	-16%	Backsheet Bulged
12	24	14	XL1111CO2642	2/27/2015 14:53:24	43.5	43.5	773.2	6.5	33.9	5.2	25.9	135.2	8.4	39.0	6.8	31.1	210.3	230	-20	-9%	Backsheet Bulged
13	24	14	XL1111C00307	2/27/2015 15:00:02	43.1	43.1	751.4	6.3	33.7	5.4	14.7	80.1	8.4	32.2	7.2	8.7	62.9	230	-167	-73%	Bypass Diode & Hotspot
14	24	14	XL1111C02359	2/27/2015 15:02:14	42.5	42.5	742.6	5.9	22.5	4.7	16.0	75.1	7.9	25.5	6.3	18.6	117.1	230	-113	-49%	Bypass Diode & Hotspot
15	24	14	XL1111C02993	2/27/2015 15:03:54	43.6	43.6	737.5	6.3	33.7	5.7	16.1	92.4	8.6	33.3	7.8	11.0	85.9	230	-144	-63%	Bypass Diode
16	24	14	XL1111C02305	2/27/2015 15:05:30	43.5	43.5	728.7	6.3	33.6	5.4	25.4	137.1	8.6	37.5	7.4	28.9	213.9	230	-16	-7%	HotSpot
17	23	14	XL1112CO3381	2/27/2015 15:32:08	39.4	39.4	633.2	5.3	33.9	3.4	27.5	92.5	0.0	0.0	0.0	0.0	0.0	230	-230	-100%	Burnt

18	23	14	XL1112C04373	2/27/2015 15:33:26	39.1	39.1	625.6	5.4	33.8	4.9	25.7	126.6	8.7	36.7	7.9	27.1	213.4	230	-17	-7%	Good Module
19	23	14	XL1112C04263	2/27/2015 15:35:36	38.9	38.9	629.6	5.3	33.9	4.8	25.6	123.2	8.4	36.7	7.7	26.7	204.1	230	-26	-11%	Good Module
20	23	14	XL1112C04261	2/27/2015 15:37:32	38.8	38.8	618.9	5.2	33.8	3.4	25.5	86.8	0.0	0.0	0.0	0.0	0.0	230	-230	-100%	HotSpot
21	23	14	XL1112C03376	2/27/2015 15:39:28	39.3	39.3	614.3	5.0	34.0	4.6	26.1	119.6	8.2	37.0	7.5	27.5	205.4	230	-25	-11%	PID
22	17	10	XL1111C01657	2/28/2015 10:38:18	40.2	40.2	729.7	6.2	23.0	5.1	17.8	90.8	8.5	26.5	7.0	21.4	149.5	230	-81	-35%	Bypass Diode
23	17	10	XL1111C01062	2/28/2015 10:39:24	36.7	36.7	689.1	5.9	34.3	5.5	26.5	145.1	8.6	36.4	8.0	27.4	218.2	230	-12	-5%	Good Module
24	17	10	XL1111C01668	2/28/2015 10:41:54	38.3	38.3	709.9	5.7	34.1	4.7	27.5	128.1	8.0	40.1	6.6	33.9	223.1	230	-7	-3%	HotSpot
25	17	10	XL1111C01583	2/28/2015 10:42:42	42.1	42.1	695.8	5.6	34.1	5.2	26.6	139.2	8.1	36.7	7.5	28.1	211.7	230	-18	-8%	Good Module
26	17	10	XL1111C01680	2/28/2015 10:48:42	38.9	38.9	639.3	5.2	33.6	4.3	27.1	115.1	8.1	40.8	6.6	35.0	232.8	230	3	1%	HotSpot
27	9	3	XL1111C00312	2/28/2015 10:55:20	35.9	35.9	692.0	4.5	33.9	3.3	27.5	90.8	0.0	0.0	0.0	0.0	0.0	230	-230	-100%	HotSpot
28	9	3	XL1111C00406	2/28/2015 10:56:38	38.0	38.0	717.9	5.9	33.9	5.4	26.1	139.7	8.2	36.3	7.5	27.6	206.1	230	-24	-10%	Good Module
29	9	3	XL1111c00584	2/28/2015 10:57:28	37.0	37.0	643.8	5.2	33.6	4.1	17.1	70.6	8.1	31.0	6.4	9.3	59.4	230	-171	-74%	HotSpot & Bypass diode
30	9	3	XL1111C00649	2/28/2015 11:04:28	35.5	35.5	689.5	5.6	34.2	4.5	17.3	77.6	8.2	32.0	6.5	10.6	69.1	230	-161	-70%	Burnt
31	9	3	XL1111C00315	2/28/2015 11:16:12	40.5	40.5	782.1	6.2	33.6	5.2	17.3	90.9	8.0	33.4	6.7	14.3	95.6	230	-134	-58%	Burnt
32	9	3	XL1112C03756	2/28/2015 11:17:32	41.8	41.8	787.5	6.3	33.5	4.4	15.0	66.4	8.0	31.0	5.6	9.7	54.6	230	-175	-76%	Burnt
33	9	3	XL1111C02349	2/28/2015 11:19:08	41.9	41.9	767.6	4.6	33.4	2.6	14.8	38.0	6.1	29.3	3.4	8.0	26.9	230	-203	-88%	Burnt
34	9	3	XL1111C01735	2/28/2015 11:20:24	42.0	42.0	501.3	4.0	32.8	3.8	16.7	62.8	8.1	30.6	7.5	2.3	17.5	230	-213	-92%	HotSpot & Bypass diode
35	9	3	XL1112C02738	2/28/2015 11:21:04	42.6	42.6	609.6	4.9	33.1	4.5	16.7	74.9	8.0	31.9	7.3	7.7	56.9	230	-173	-75%	HotSpot & Bypass diode
36	9	3	XL1112C03057	2/28/2015 11:22:16	39.1	39.1	678.2	5.5	33.5	5.1	16.8	85.5	8.2	32.7	7.5	10.0	75.0	230	-155	-67%	Burnt
37	9	3	XL1111C02481	2/28/2015 11:30:22	39.4	39.4	709.5	5.6	34.0	2.5	19.5	49.3	0.0	0.0	0.0	0.0	0.0	230	-230	-100%	Burnt
38	9	3	XL1111C00359	2/28/2015 11:30:58	40.2	40.2	696.5	5.6	33.9	4.6	24.8	114.0	8.1	38.7	6.6	28.9	190.6	230	-39	-17%	Burnt
39	9	3	XL1111C00637	2/28/2015 11:31:58	39.8	39.8	696.4	5.5	33.9	3.4	24.4	83.4	7.9	47.9	4.9	39.4	193.7	230	-36	-16%	Burnt

String I-V curve measurement

Sl #	Row #	CB #	Datum Zeit	T sens	T mod	E eff	Isc	Uoc	Ip max	Up max	P max	Isc 0	Uoc 0	Ip max0	Up max0	Ppk	Nominal Module out put	Deviation from nominal Wp	%Deviation from nominal Wp	Remarks
			Date Time	°C	°C	W/m2	A	V	A	V	W	A	V	A	V	W				
1	27	14	2/27/2015 14:23:02	47.6	47.6	846.0	7.3	664.6	5.2	335.6	1738.4	8.6	677.6	6.1	317.1	1941.7	**4600**	-2658	-58%	Cell burnt and bypass diode module string
2	26	14	2/27/2015 14:34:08	46.7	46.7	825.2	7.1	672.1	6.3	476.8	2988.0	8.6	725.6	7.6	517.5	3930.1	**4600**	-670	-15%	Bypass diode module string
3	24	14	2/27/2015 14:55:40	43.7	43.7	765.1	6.6	671.8	5.4	496.9	2681.4	8.7	760.7	7.1	580.1	4090.8	**4600**	-509	-11%	Hot spot Module String
4	24	14	2/27/2015 15:17:10	41.3	41.3	696.1	6.1	675.4	5.1	501.4	2559.0	8.7	760.2	7.3	572.7	4198.8	**4600**	-401	-9%	Good String
5	9	3	2/28/2015 11:05:20	36.0	36.0	678.4	5.5	684.3	4.1	376.0	1548.5	8.1	676.2	6.1	293.9	1784.1	**4600**	-2816	-61%	Cell burnt and bypass diode module string

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Insulation resistance measurement – Module

Sl #	Row #	CB #	Module Sl #	Insulation Resistance
1	27	14	XL1111C00623	32.3
2	27	14	XL1112C03443	33.3
3	27	14	XL1111C01058	24.5
4	27	14	XL1111C00500	18.27
5	27	14	XL1111C02960	23.2
6	26	14	XL1112C04071	22.5
7	26	14	XL1112C04119	40.5
8	26	14	XL1112C04167	35.4
9	26	14	XL1111C02988	33.5
10	26	14	XL1111C02248	30.4
11	24	14	XL1111C02417	39.3
12	24	14	XL1111CO2642	31.5
13	24	14	XL1111C00307	83.5
14	24	14	XL1111C02359	49.5
15	24	14	XL1111C02993	60.2
16	24	14	XL1111C02305	70.5
17	23	14	XL1112CO3381	32.3
18	23	14	XL1112C04373	33.5
19	23	14	XL1112C04263	39.5
20	23	14	XL1112C04261	42.5
21	23	14	XL1112C03376	35.3
22	17	10	XL1111C01657	57.1
23	17	10	XL1111C01062	64.7
24	17	10	XL1111C01668	33.8
25	17	10	XL1111C01583	28.6
26	17	10	XL1111C01680	35.3
27	9	3	XL1111C00312	54.6
28	9	3	XL1111C00406	41.2
29	9	3	XL1111c00584	37.1
30	9	3	XL1111C00649	58.4
31	9	3	XL1111C00315	62.5
32	9	3	XL1112C03756	45.9
33	9	3	XL1111C02349	33.2
34	9	3	XL1111C01735	56.4
35	9	3	XL1112C02738	31.7
36	9	3	XL1112C03057	49.5
37	9	3	XL1111C02481	54.6
38	9	3	XL1111C00359	39.5
39	9	3	XL1111C00637	61.7

Insulation resistance – String

Sl #	Row #	CB #	Insulation Resistance
1	27	14	27.6
2	26	14	31.6
3	24	14	23.5
4	24	14	25.5
5	9	3	26.1