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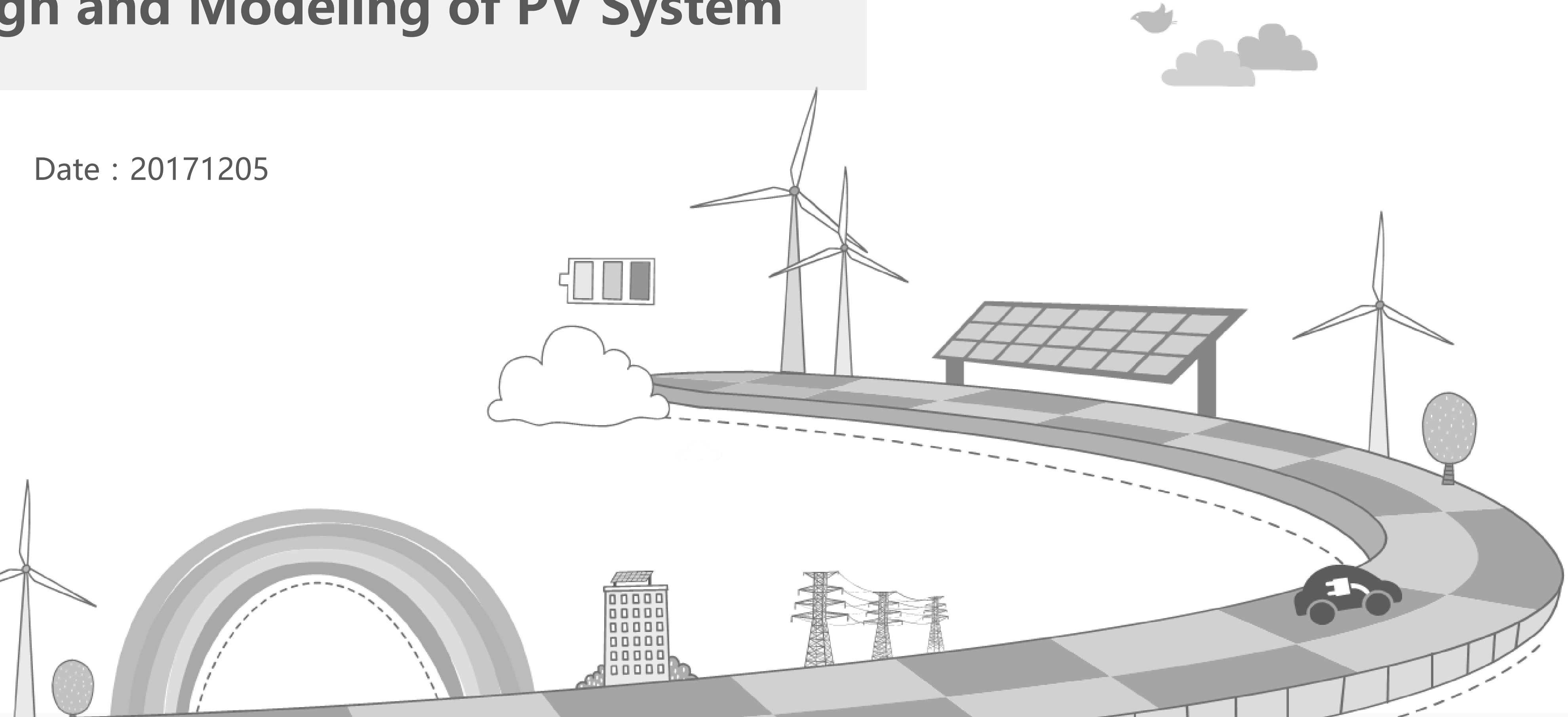
Green and Effective

Precise Design and Modeling of PV System

Lecturer：Chen Wei   Date：20171205



Sungrow :The leading Inverter Manufacturer

Utility

Central Inverters

SG3125HV

SG3125HV-MV


SG2500U


SG2500U-MV


SG2500HV
SG3000HV


SG2500HV-MV
SG3000HV-MV


SG2000
SG2500


SG2000-MV
SG2500-MV

String Inverters

SG125HV (1500Vdc)


SG80KTL (1000Vdc)


SG60KTL (1000Vdc)

Commercial


SG33K3J


SG49K5J


SG33KTL-M
SG36KTL-M


SG50KTL-M


SG30KU
SG36KU


SG60KU-M

Residential

SG10KTL- M
SG12KTL-M

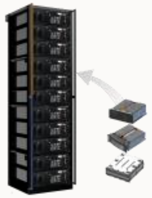

SG3KTL-D
SG5KTL-D


SG2K-S
SG2K5-S
SG3K-S

Energy Storage

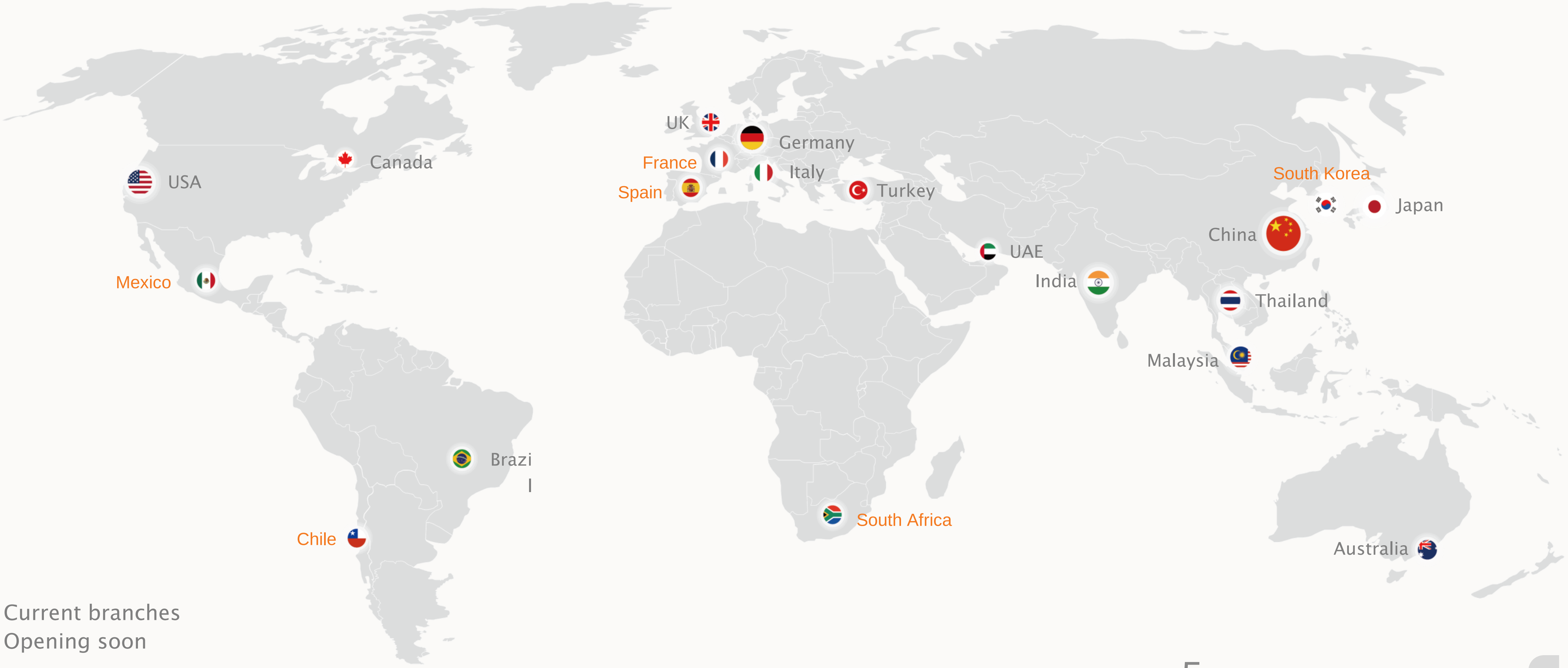

Hybrid Inverter
SH5k+


Hybrid Inverter
SC100/250/500/1000


SAMSUNG

Battery Pack
Supplied by the joint venture with Samsung SDI

About Sungrow: Global Footprint

Over 49 GW of SUNGROW inverter equipment were installed globally by June 2017.



- Current branches
- Opening soon

目录

Challenges of PV Systems

Challenges

Challenge I : Lower Initial Investment

- Lowest PPA prices refresh to 1.77¢
- Civil-Work cost increase
- Grid parity target by 2020

Solution

Through the precise modeling and simulation reduce system costs, improve efficiency and increase power generation

Challenge II : Grid-Support Requirements

- PV generation has larger influence to the grid due to high penetration
- Comprehensive commands required by the grid

Solution

- Inverter Incorporates more grid support functionality
- Inverter manufacturer offer various simulation models for grid study

Modeling and Optimization of DC Side

Traditional PV Plant Design Procedure

Traditioanl PV plant Design Steps

1. Site Selection: ground power station, hill power station, water power plant, agricultural sheds etc.
2. Measurement and Mapping: topography, environmental climatic mapping, contouring terrain mapping, environmental data collection.
3. Design: string design ,distance design, block design electrical design

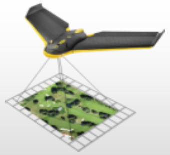
Traditional Design Problems

1. Heavy manual terrain survey: mapping inefficient.
2. Inaccurate results for irregular terrians: Inconvenient to carry mapping equipment.
3. 2-dimension CAD schematics : not intuitive way for final design display
4. Each part design is separate cannot verify each other in a closed-loop

Intelligent Closed-loop Design

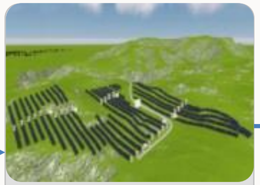
Customer Requirements

Prepare for Design



Terrain Survey

Terrain Import



3D Design

Interaction

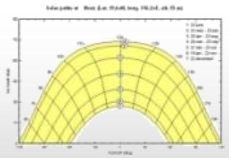
Report

Helios3D Design

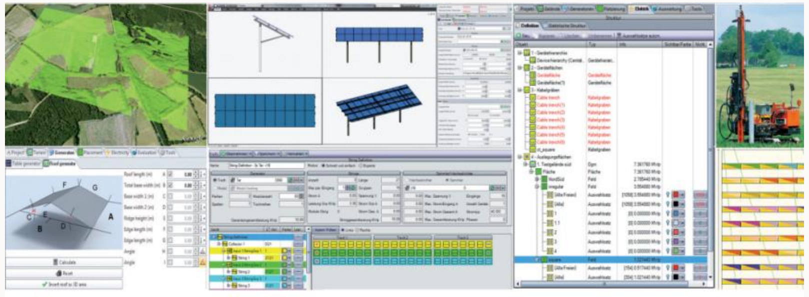
PVsyst Simulation Report

Intelligent Design of PV Plant

MeteoNorm File



Simulation



Values of Intelligent Design ：

- Reduced period of design
- Complete design, simulation proved, risk reduced, cost saved
- 3D design, verify timely, detailed data

Intelligent Design with Improved Efficiency

1. Convenient Drawing: drone mapping, high efficiency, high precision
2. Fast Design: Helios 3D professional design, visual dynamic modeling
3. Closed-loop Simulation: System simulation software PVsyst interaction with Helios 3D in seamless way

50MW ground station project	Traditional design time-consuming (days)	Intelligent design time-consuming (days)
Topographic Mapping	5~7	0.5-1
Topographic Processing and Mapping	1~2	0.5-1
Photovoltaic Board Layout Design	7~10	2-3
Electrical Design	5~7	3-4
Cable Statistics	2-3	-
Total	20~29	6~9

PV Plant 3D Design Tools Introduction-Helios

3D Design and Simulation :

Helios 3D, is a smart PV plant design software, the design is divided into three parts:

Model Creation

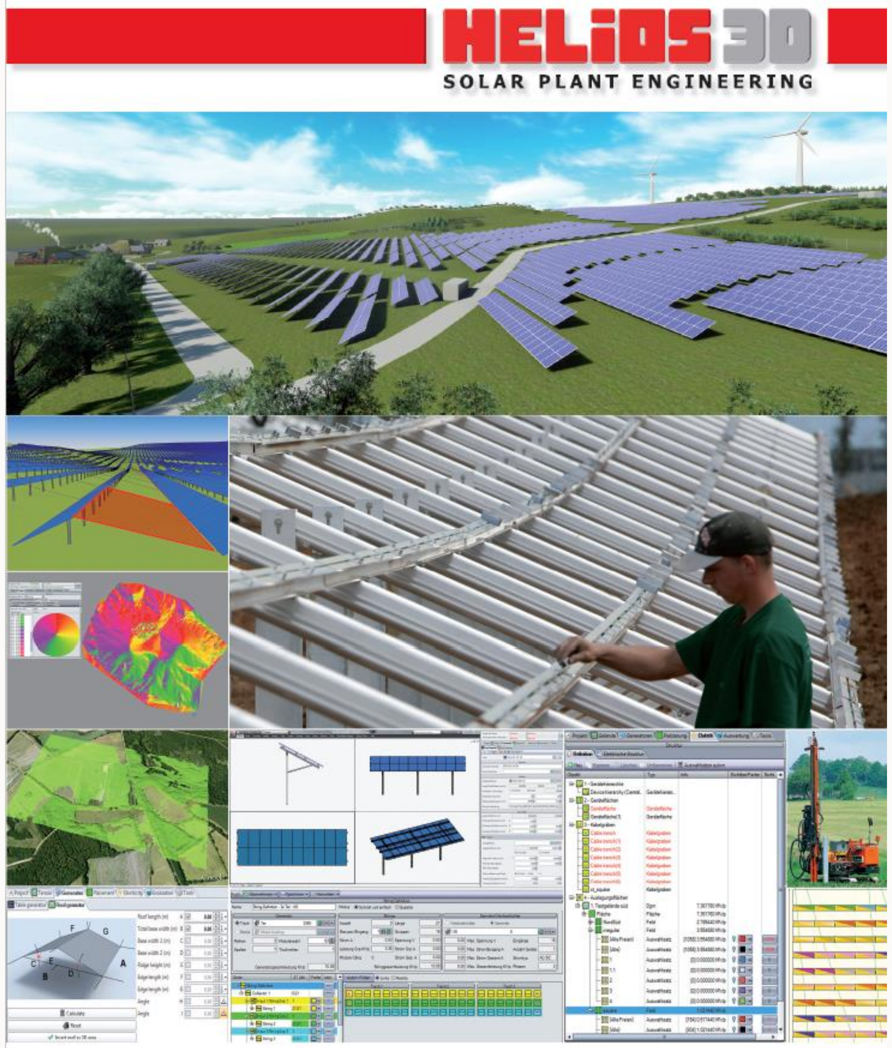
- Create components, scaffolds and other components of 3D model

PV Plant Design

- Analyze the terrain, design the power station
- Export plant 3D model

Document Generation

- Power plant equipment list
- Cable statistics
- Interacts with the PVsyst

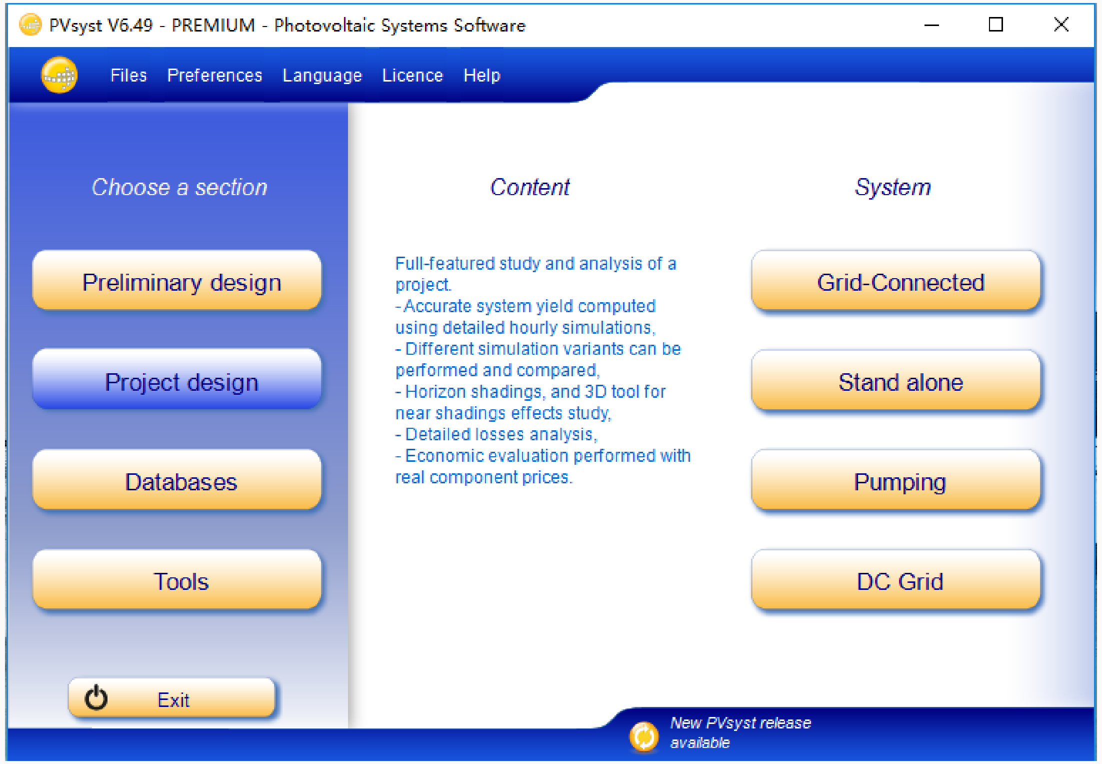


PV Plant 3D Design Tools Introduction-PVSyst

Simulation Tool:

PVsyst is a mainstream photovoltaic system simulation software. Three main parts:

Database	• Set or import plant location weather data，components and inverter models
Pre-design Mode	• Preliminary simulation and parameter setting according to the meteorological data
System Simulation Mode	• Analyze system power generation, efficiency, shading simulation reports, guide design optimization

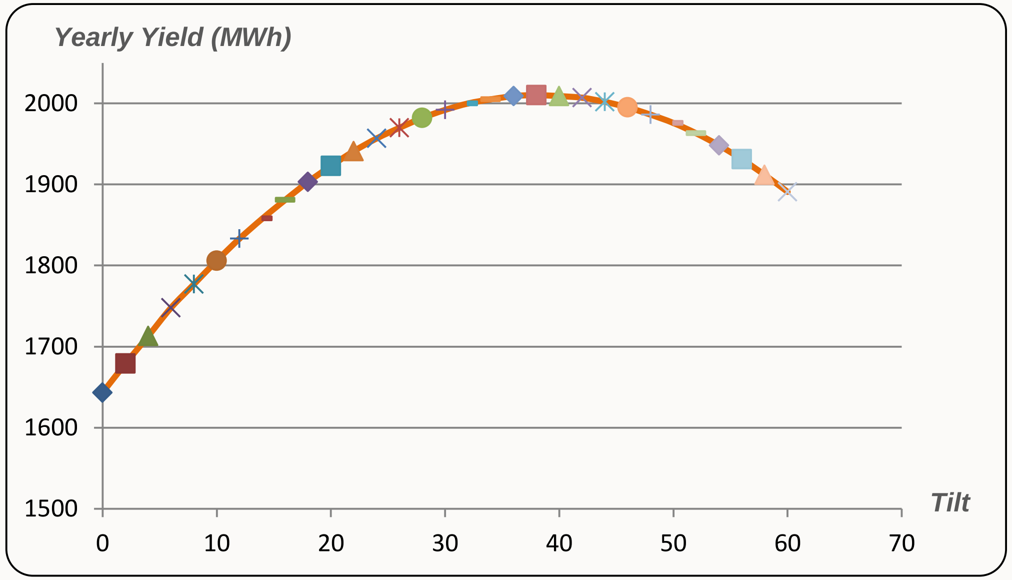


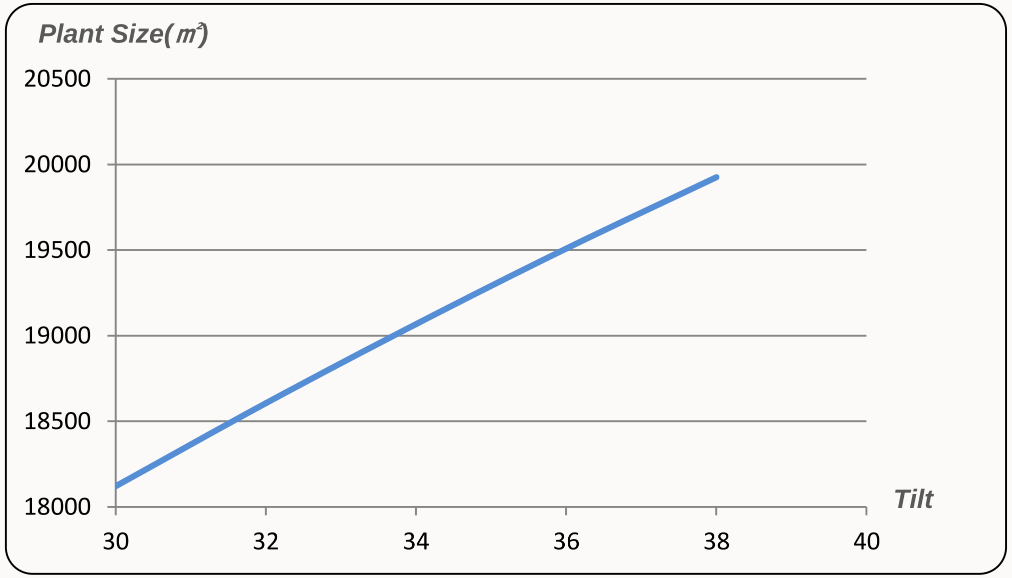
Module Layout Optimization- Tilt Angle Optimization

Plane tilt optimized, 10% land utilization rate can be improved(only 0.49% yield reduced) and land cost reduced.

Golmud, Qinghai, China, 38° optimized Plane tilt:

1. Yield difference of 32°-44° plane tilt: less than 0.49%;
2. Land utilization rate of 38° plane tilt: 10% higher than that of 32°.





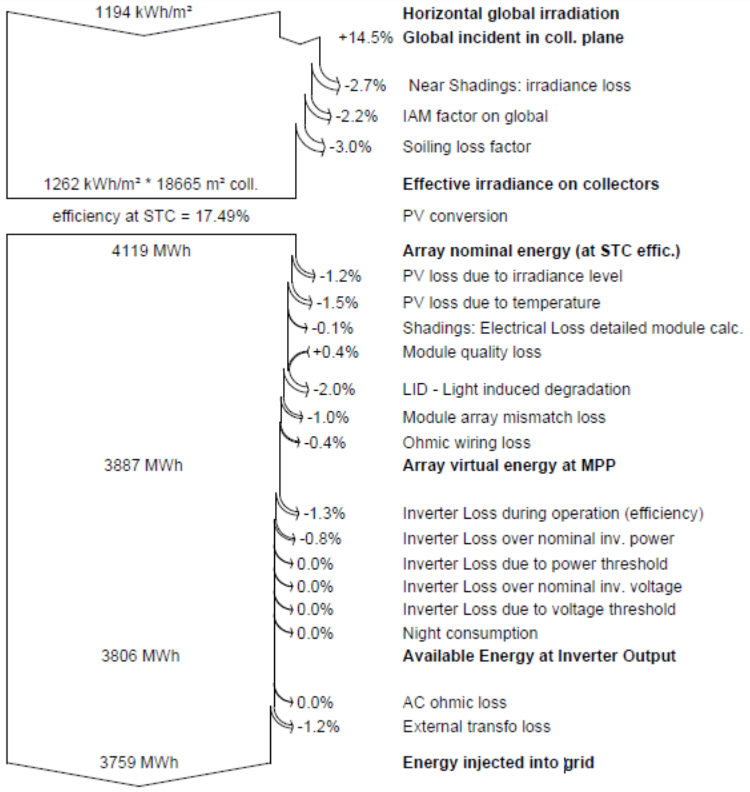
Yearly Yield and Plant Size Curves in Golmud, Qinghai, China (1MW)

Module Layout-String Distance Optimization

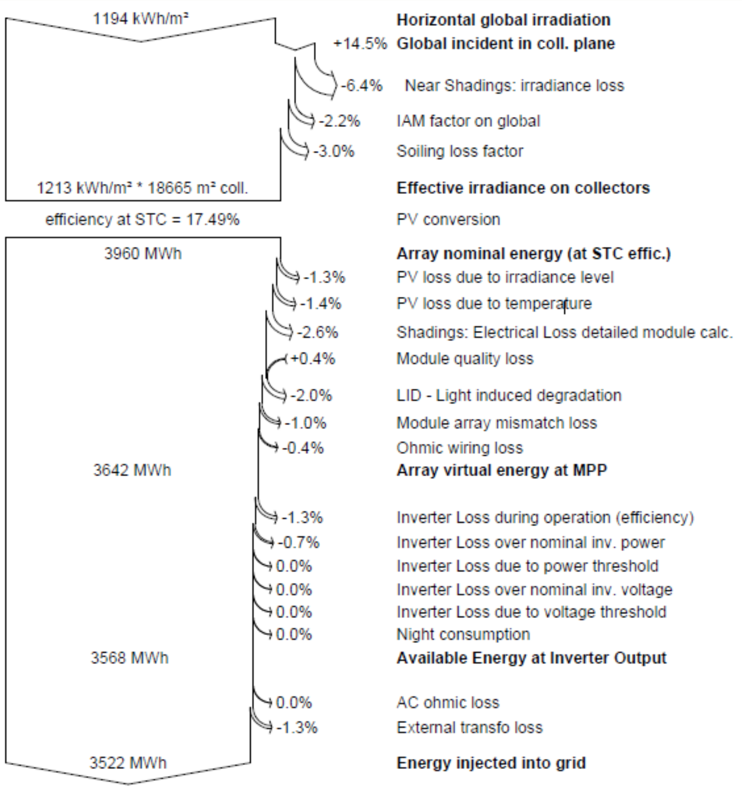
Rules for distance Design : No shading from 9:00 am. to 3:00 pm.

Power Station	Parameters
Site	Telgoan, India
Module	CS6U-340M-AG 1500V
Modules/ String	30
Combiner	16 input, 1 output
Inverter	SG125HV
Inverter Num.	20
AC Capacity	2.5MW

a. Tilt: 38° , distance: 15 m



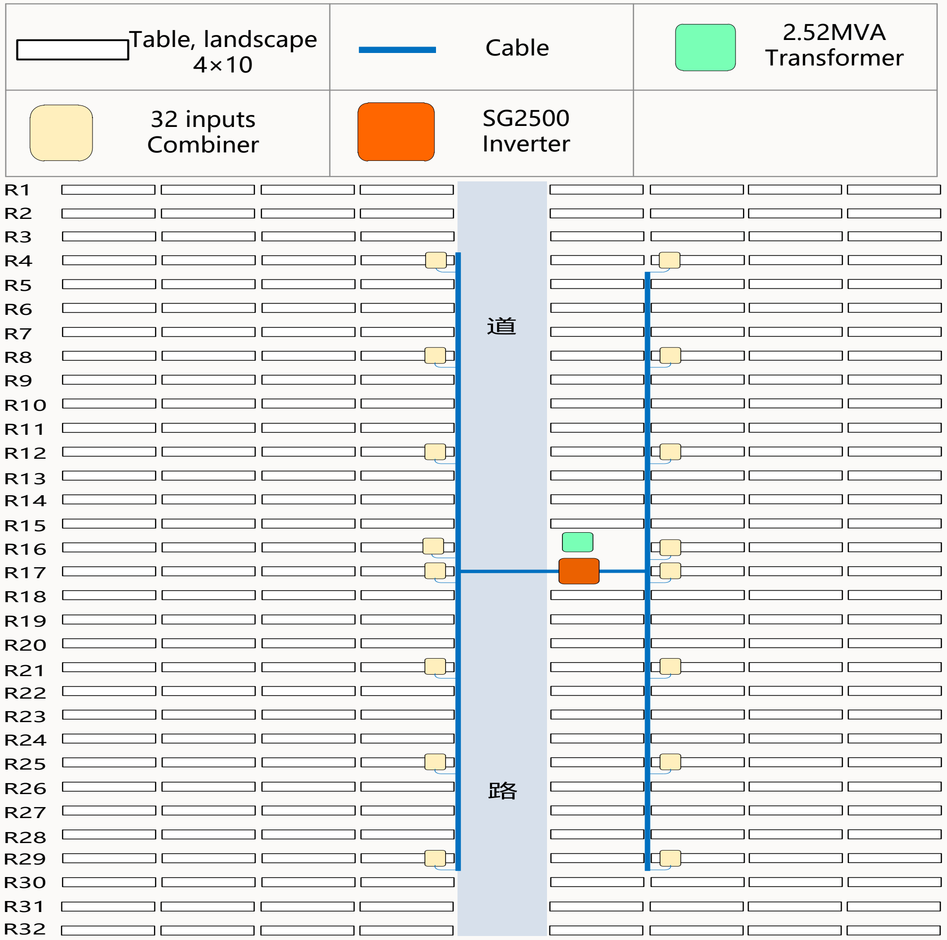
b. Tilt: 38° , Distance: 8 m

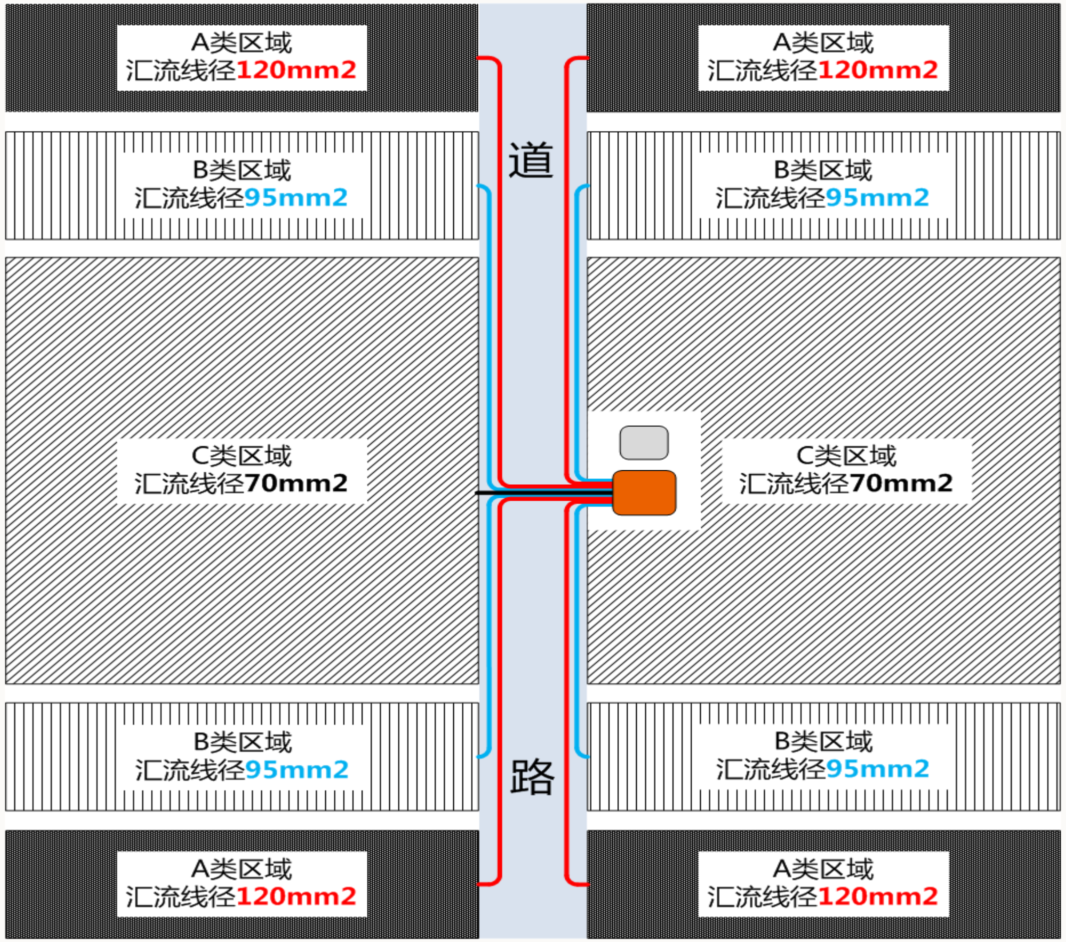


Note: In actual design, adjust distance considering land price and real terrain.

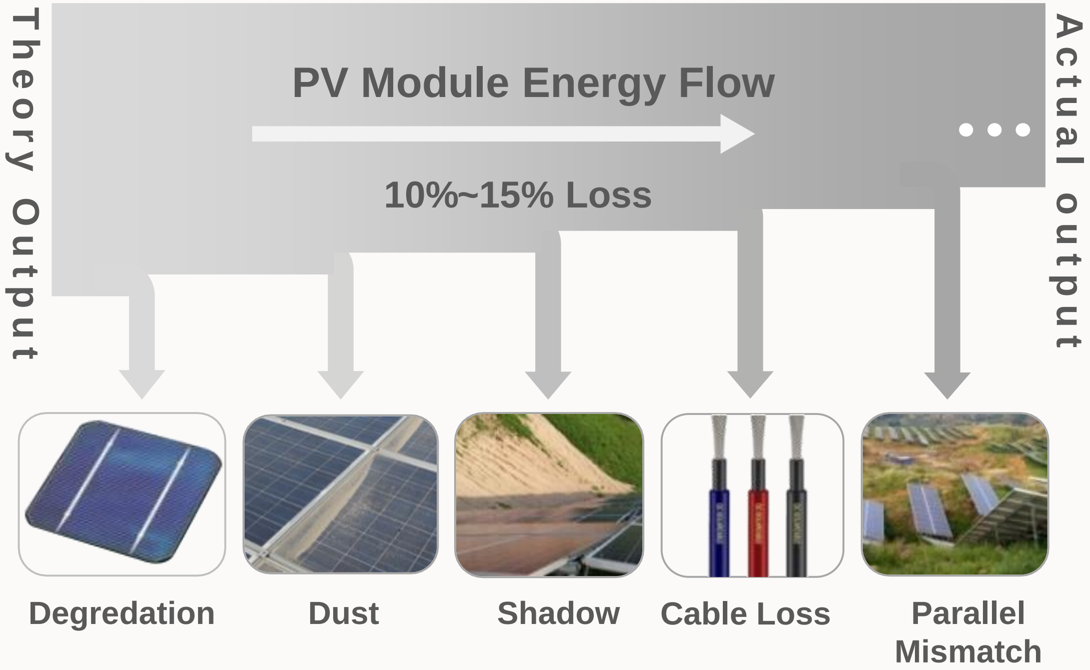
Key Points –Cable Selection and Loss Optimization

Through cable matching for a 2.5MW block, compared with the 1.6MW block, the cable cost is even, but the system cable loss decreased 0.3% to 0.5%.



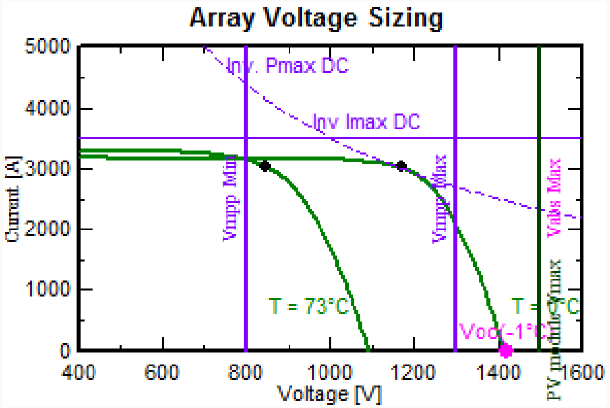


Key Points–DC/AC Ratio

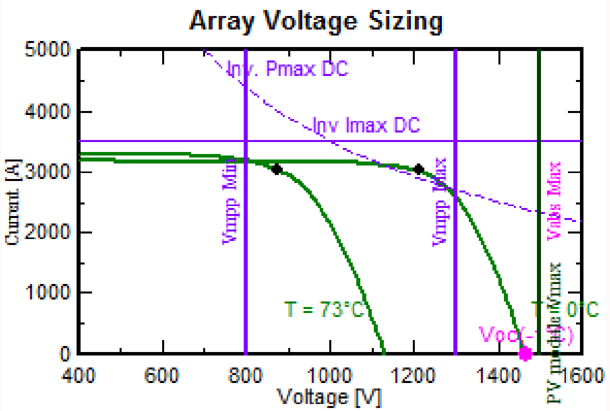


- Due to the system loss and different lighting conditions, the inverter utilization is low if setting the configuration in accordance with 1: 1.
- Choose the optimal DC/AC ratio according to different irradiation or PPA contract etc.

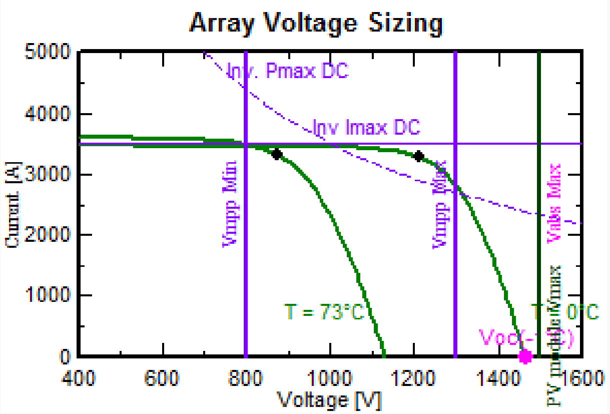
Location: Pakistan's western city of Kida;
Inverter: SG2500HV
When DC/AC ratio is 1.29，there is no “Clipping” phenomenon.



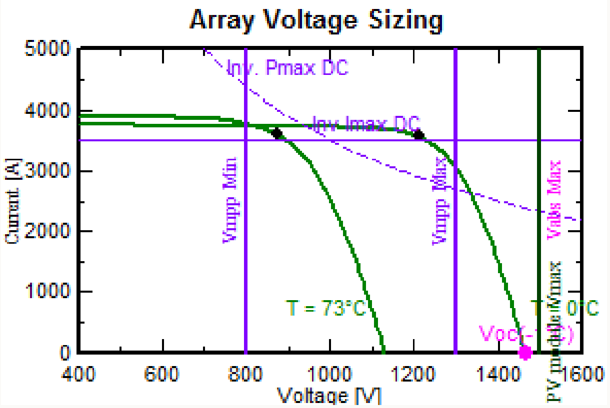
(1) DC/AC ratio 1.29



(2) DC/AC ratio 1.33



(3) DC/AC ratio 1.45

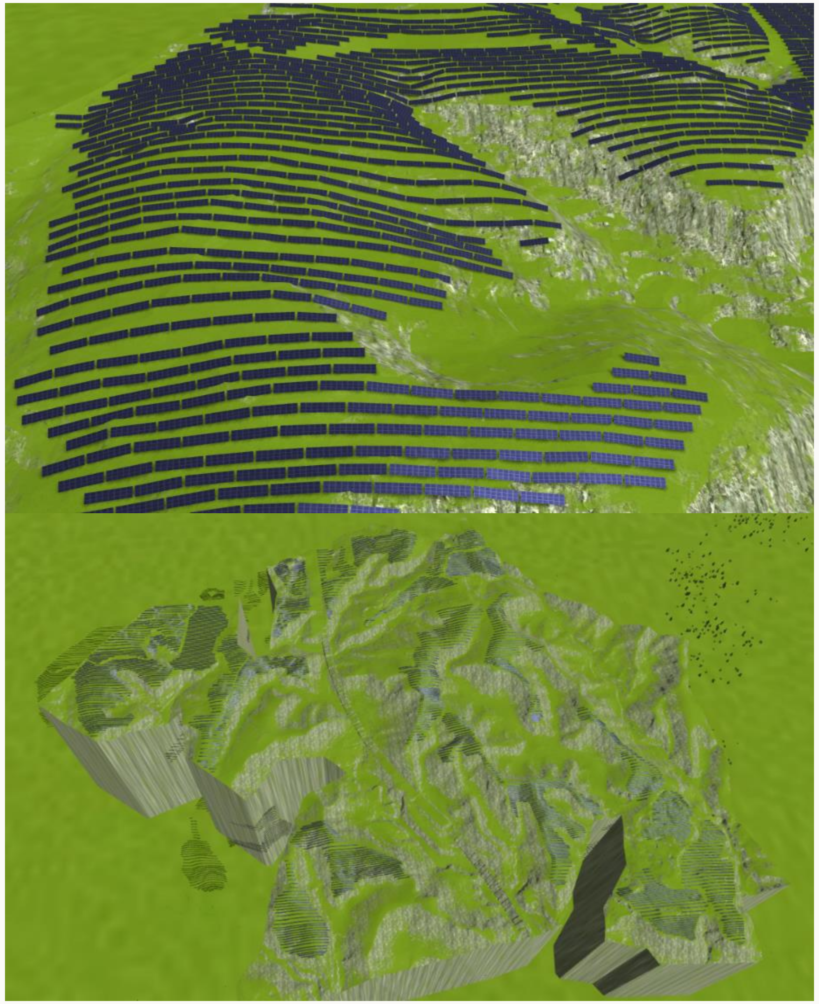


(4) DC/AC ratio 1.57

Modeling Optimizaiton Reference: a 50MW Project

the design scheme of a 50MW power station is as follows:

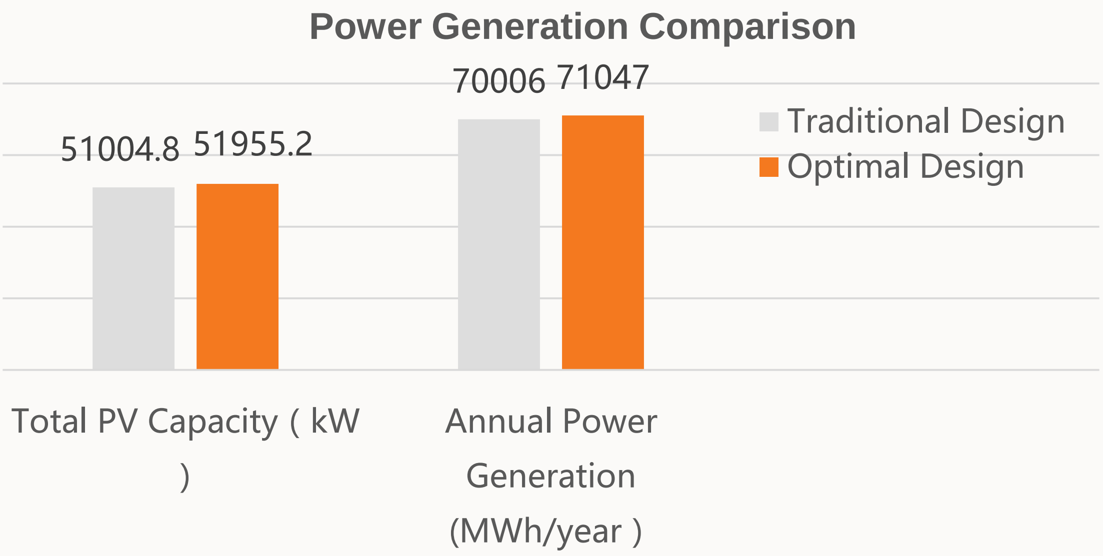
1. Total system capacity: 51.9552MW; System sub-array capacity: 1.2672MW; Numbers of system sub-arrays: 41; Numbers of inverters: 984;
2. Traditional Design angle: 32 °; Azimuth: 0 °;
3. Optimized Simulation angle: 34 °; Azimuth: -4 °;
4. System annual yield: 71047MW,PR: 86.27%



Comparison

Advantages of intelligent design:

1. Drone mapping significantly improve the efficiency;
2. Rapid terrain analysis, PV modules optimization;
3. PV modules layout optimization through simulation ;
4. Increase the land utilization, improve system efficiency and reduce system costs;

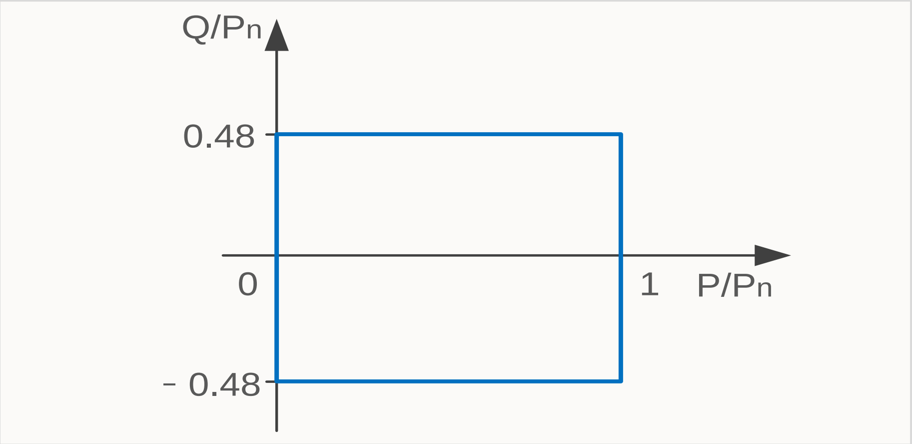


Parameter	Traditional Design	Intelligent Design
No. of supports	7728	7872
Total Capacity	51.0048 MW	**51.9552 MW**
Comprehensive Tilt Angle	34°	34°
Integrated Azimuth	-1°	-4°
Slope Variation Range	0~55.8°	0~46.3°
Spacing Range	0.56~39.6 m	0.73~24.9 m
Average Spacing	8.9 m	6.38 m
Annual Generation	70006 MWh/year	**71047 MWh/year**
Per-watt Power Generation	1.372 kWh/W	1.367 kWh/W
System Per-watt Costs	5.5 USD cent/W	**4.9 USD cent/W**

Modeling and Utility Requirements of Inverter

Utility Requirement of Inverter

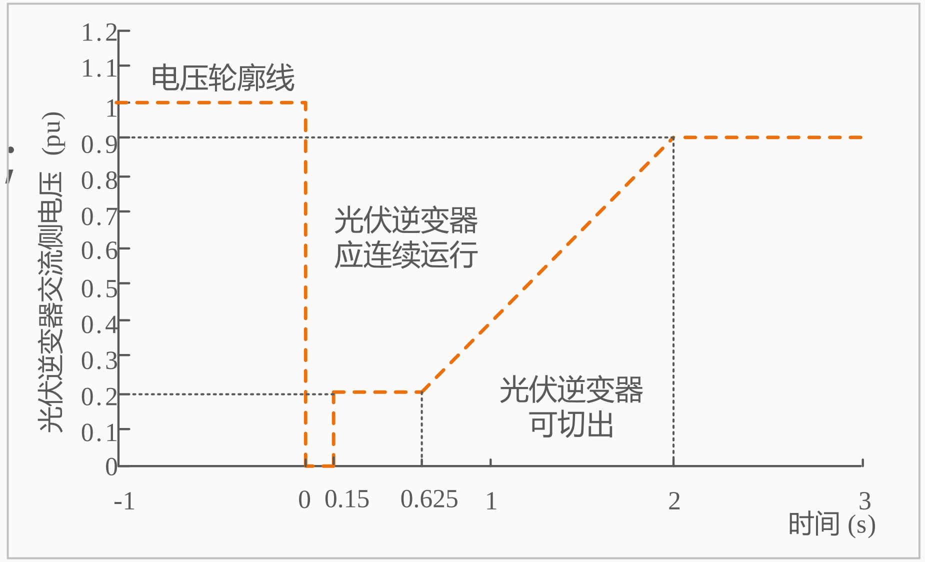
- PV power plants are required to participate in the utility management
- Utility need inverter simulation models to validate PV plant support functions under specific conditions in a fast way



Reactive Power Curve

- Inverter and Simulation Model Requirements ：

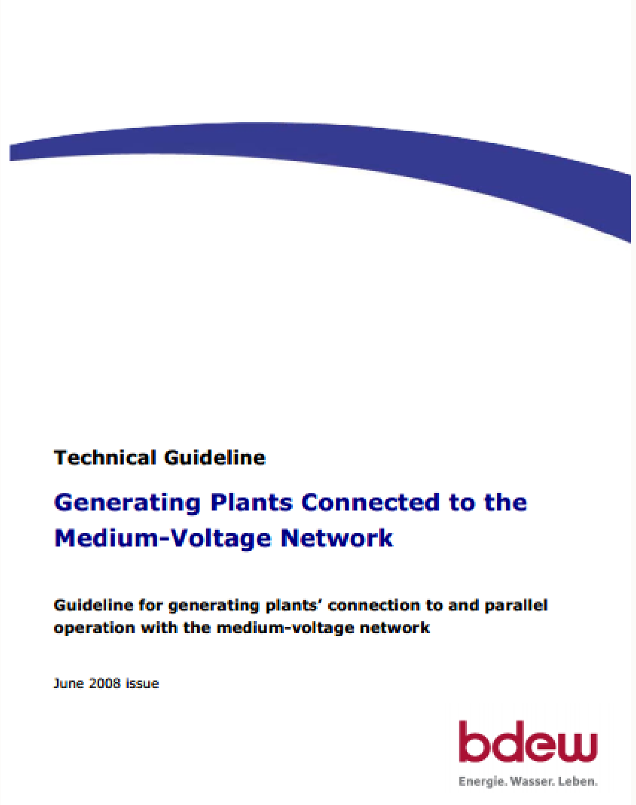
1. The inverter has LVRT function and frequency control etc. ；
2. Able to establish the simulation model of the inverter ；
3. Able to verify the consistency of inverter and simulation model



LVRT Requirements

Utility Requirements of Models -Germany

Simulation model requirement	DigSILENT



Technical Guideline

Generating Plants Connected to the Medium-Voltage Network

Guideline for generating plants' connection to and parallel operation with the medium-voltage network

June 2008 issue

bdew
Energie. Wasser. Leben.

DNV·GL

Determination of the electrical characteristics of a Sungrow SG60KTL according to FGW technical guideline 3, Rev. 23

Manufacturer:	Sungrow Power Supply Co., Ltd.
Manufacturer's Address:	New&High Technology, Industrial Development Zone, 2 Tianhu Road, 230088 Hefei, Anhui China
Report no.:	GLGH-4280 14 12665 250-A-0001-A
Site:	Hefei
project no.:	4280 14 12665 250-
Customer contact:	Mr. Chen Wei
Status:	Final
Date of order:	2014-04-15
Contractor:	GL Garrad Hassan Deutschland GmbH Sommerdeich 14 b 25709 Kaiser-Wilhelm-Koog, Germany
Author:	Jiang Hongyu Project Engineer, Power Quality
Checked by:	Dipl.-Ing.(FH) Tim Heesch Deputy Head of Section Power Quality
Approved by:	Dipl.-Ing.(FH) Marko Ibsch Head of Section Power Quality

Kaiser-Wilhelm-Koog, 2014-12-16

Dipl.-Ing. (FH) Marko Ibsch   Dipl.-Ing. (FH) Tim Heesch

DAkkS Deutsche Akkreditierungsstelle D-PL-11134-01-00

DNV·GL

Determination of the voltage dip capability of a SG60KTLSungrow according to FGW technical guideline 3, Rev. 23

Manufacturer:	Sungrow Power Supply Co., Ltd.
Location:	New&High Technology, Industrial Development Zone, 2 Tianhu Road, 230088 Hefei, Anhui China
Report No.:	GLGH-4280 14 12665 250-A-0002-A
Site:	Hefei
Order No.:	4280 14 12665 250
Person of contact:	Mr. Chen Wei
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Kaiser-Wilhelm-Koog, 2014-12-16

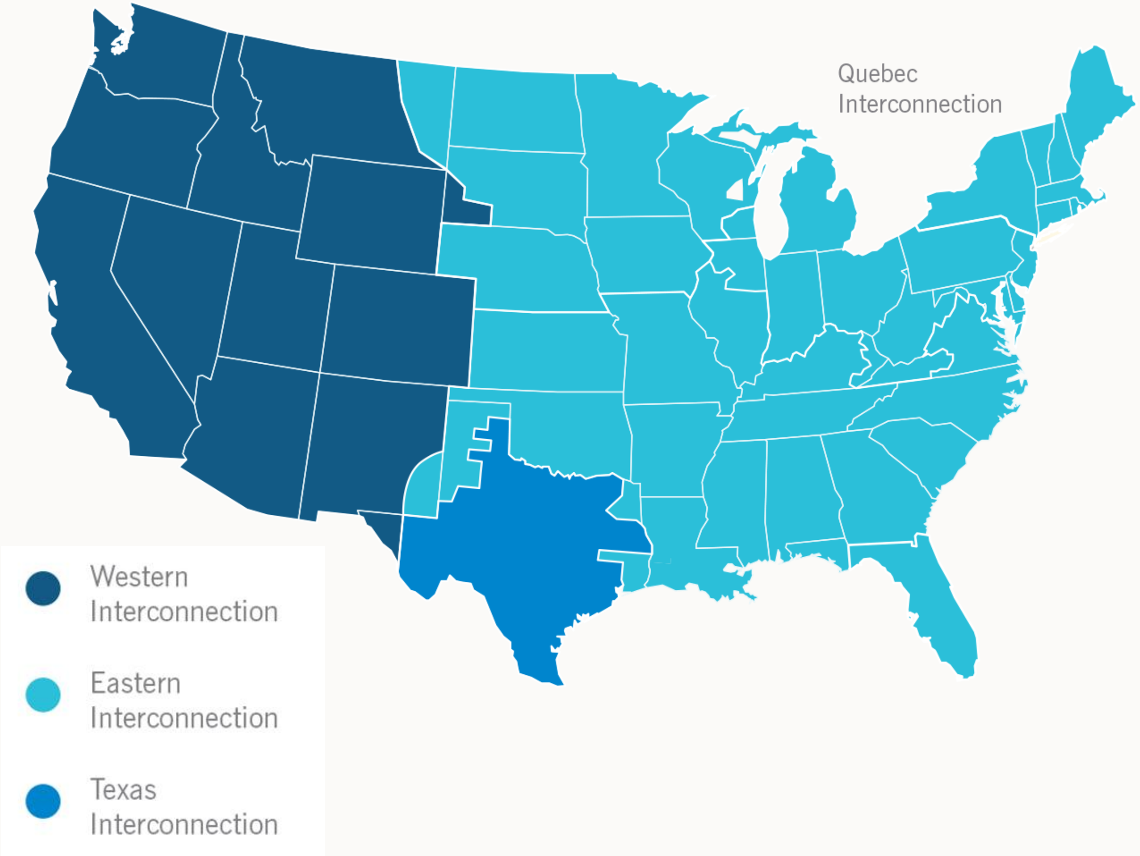
Dipl.-Ing.(FH) Marko Ibsch   Dipl.-Ing.(FH) Tim Heesch

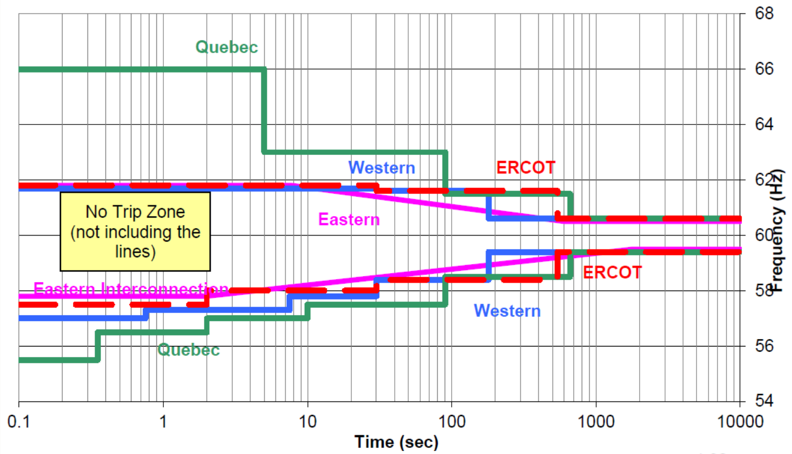
DAkkS Deutsche Akkreditierungsstelle D-PL-11134-01-00

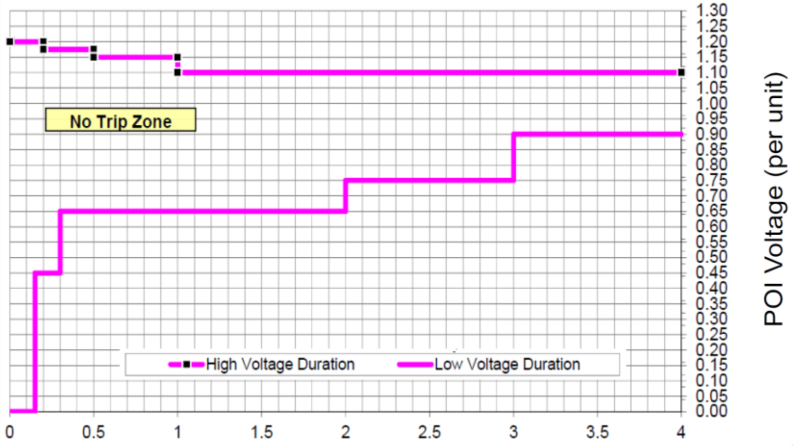
LVRT test and power quality test is mandatory
Digsilent model will be accessed to test report by third party
Unit certificate of inverter is necessary for plant certificate after simulation

Utility Requirements of Models -US

- For different region, the utility will require different voltage/frequency protection settings.
- The PSLF/PSSE/PSCAD model should be adjusted according to specific requirement.







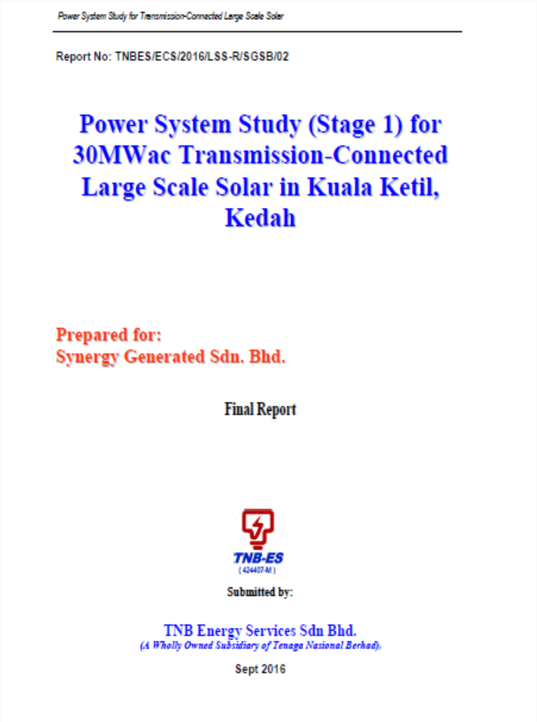
Utility Requirements of Models - Australia

1	Simulation Model	AEMO region	West Australia
	Digsilent	NA	Required
	PSS/E	Required	NA
	PSCAD	Required	NA
2	inverter models are used for the assessment of NTS（Network technical study） or GPS(general performance study) report		

Utility Requirements of Models -Malaysia

Simulation model requirement	PSSE

- PSSE simulation report is mandatory for each project developer , they will submit simulation report to Grid Company– TNB;
- Items in the test report which are directly related with inverter: reactive power capacity, harmonics; flicker; short circuit.



Power System Study for Transmission-Connected Large Scale Solar

Report No: TNBES/ECS/2016/LSS-R/SGSB/02

Power System Study (Stage 1) for 30MWac Transmission-Connected Large Scale Solar in Kuala Ketil, Kedah

Prepared for:
Synergy Generated Sdn. Bhd.

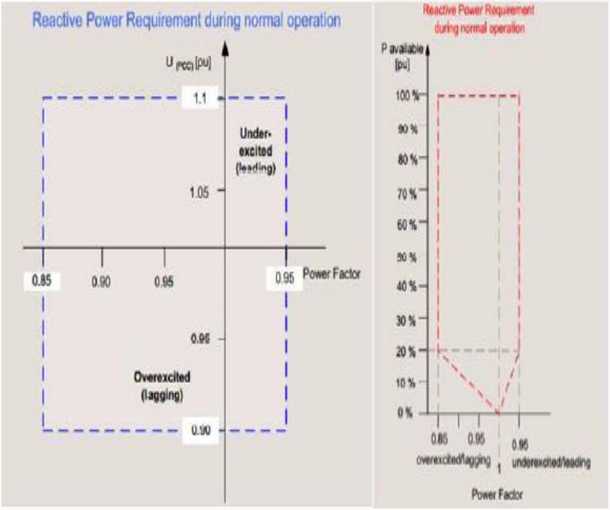
Final Report

TNB-ES

Submitted by:

TNB Energy Services Sdn Bhd.
(A Wholly Owned Subsidiary of Tenaga Nasional Berhad)

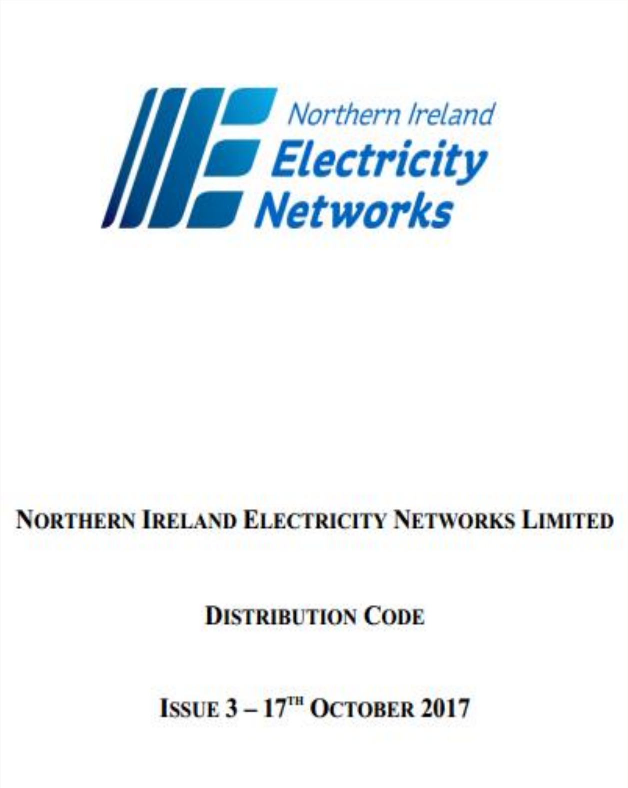
Sept 2016



Malaysia grid requirement– PV power station’s reactive power could be adjusted from -0.85-0.95.

Utility Requirements of Models -Northern Ireland

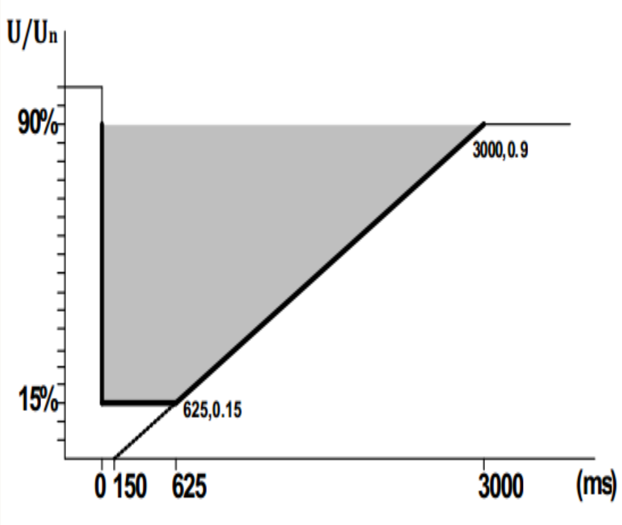
Simulation model requirement	PSSE


Northern Ireland Electricity Networks

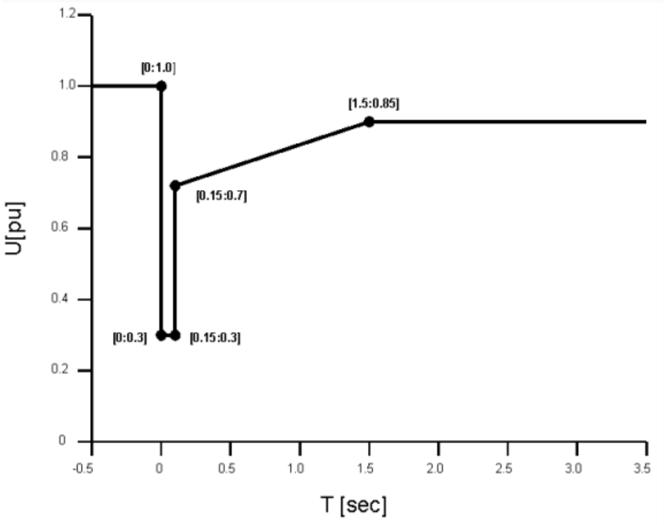
NORTHERN IRELAND ELECTRICITY NETWORKS LIMITED

DISTRIBUTION CODE

ISSUE 3 – 17TH OCTOBER 2017



(a)



(b)

(a) Fault Ride Through capability for Power Stations < 5 MW

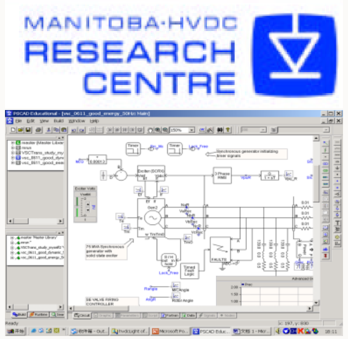
(b) Fault Ride Through Capability for Power Stations ≥ 5MW connected to the Distribution System

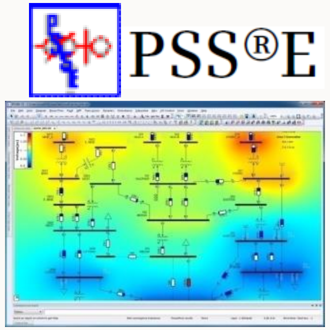
Inverter Model –SUNGROW Solutions

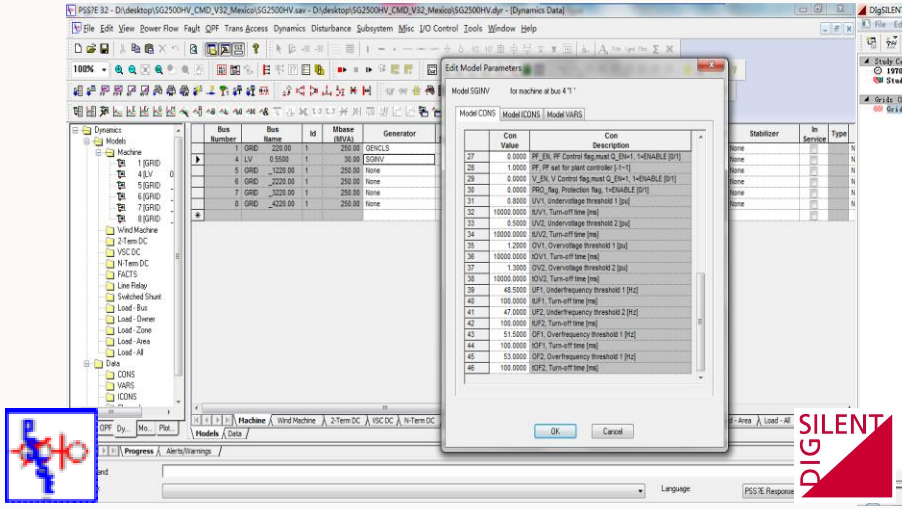
- LVRT/HVRT/FRT/Active Power/Reactive Power Control functions are basics

- Third party PPC or communications compatibility shall be extendable

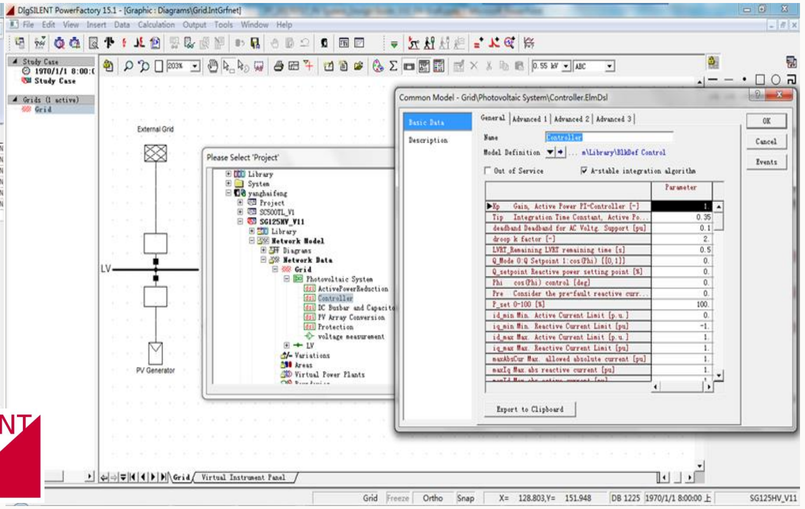
- SUNGROW inverter model has various communication interface, compatible with the majority PPC manufacturers, and meet the grid requirements.







LVRT，FRT Parameter Setting

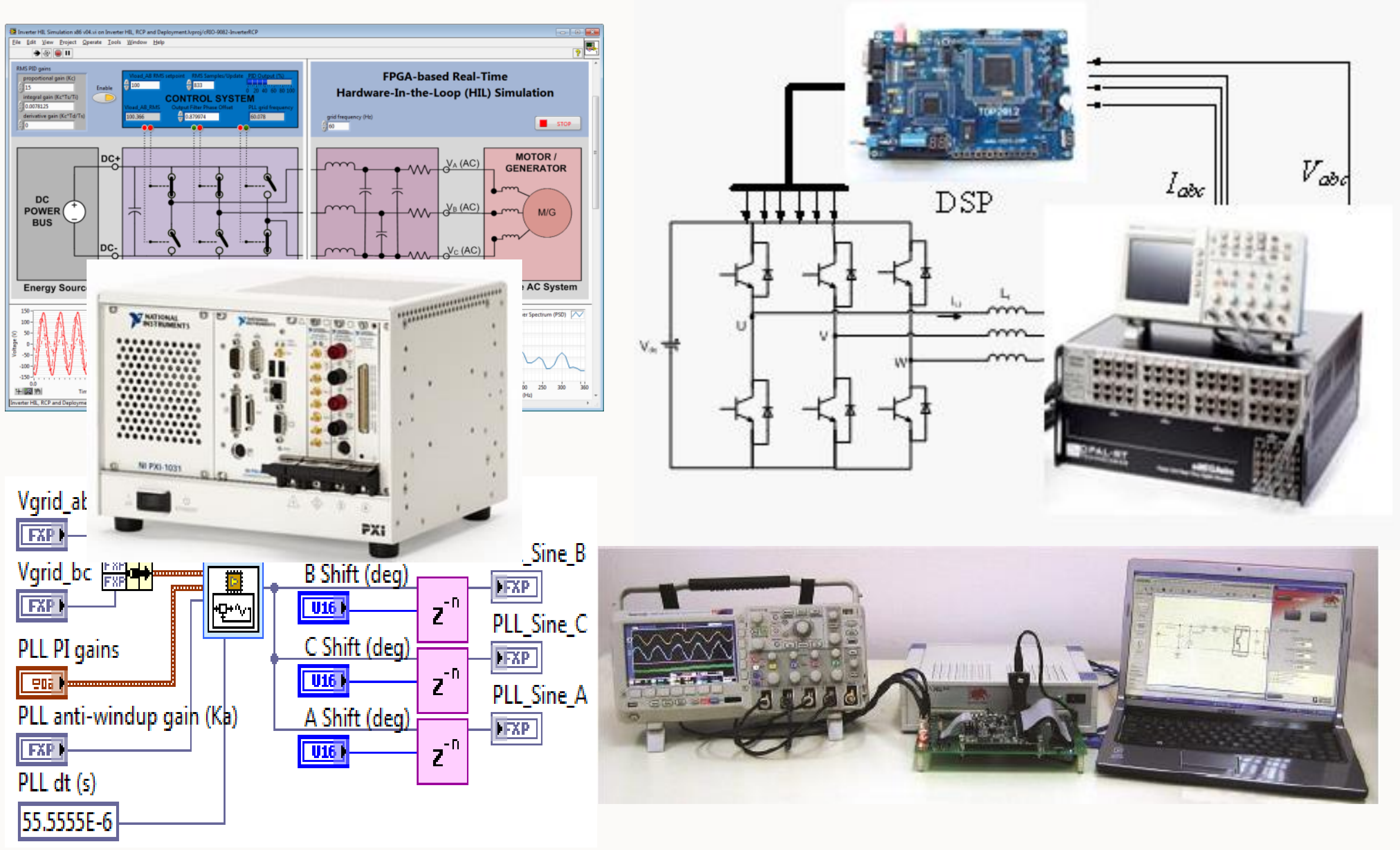


PPC Interface Setting

Future Concerns

Performance Verification Method Requires Innovation

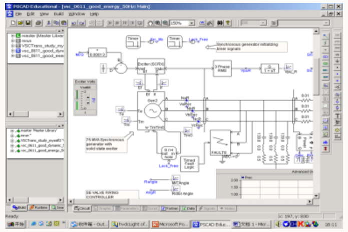
- Higher AC power of inverter lead to harder test platform setup
- Key items like harmonics/flicker/islanding/ resonances is difficult to simulate

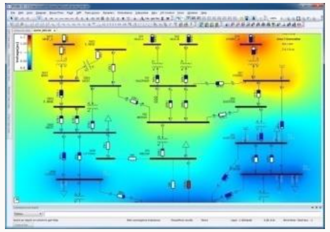


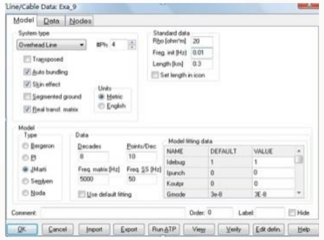
Aim to Unify Simulation Platform

- Too many simulation tools that will set high burden for inverter manufacturer :
- SUNGROW suggest to choose 2 or 3 mainstream software to keep comparison under the same benchmark.

Software	Countries and Regions
PSS/E	US, Northern Ireland, AU(AEMO),Malaysia
DigSILENT	Germany, AU(AEMO),
PSCAD	US, Western Australia
PSLF	US
ANATEM	Brazil
ATP	Brazil

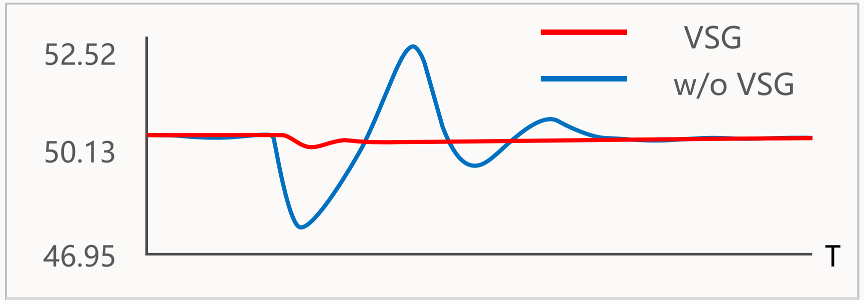






Compliant to Smart Grid standards

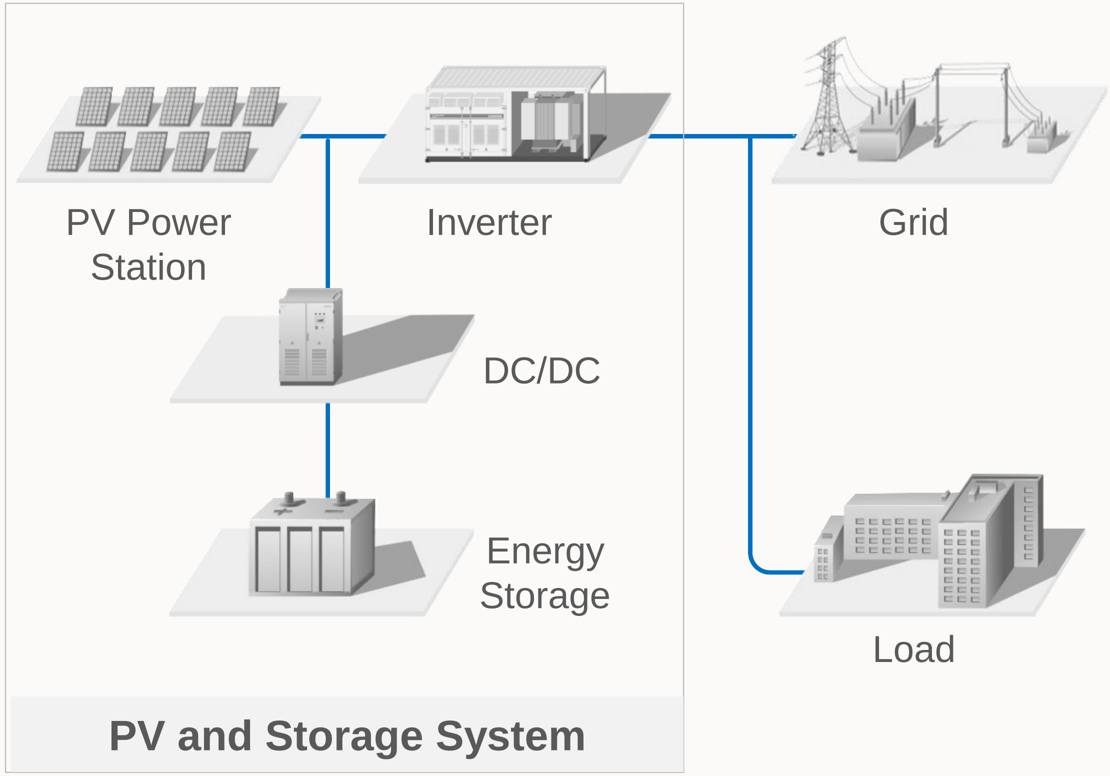
- Take PV plant control as the normal coal generator : through inverter as is VSG control method (Virtual Synchronous Generator).
- Compliance to latest codes : IEC 61850 / IEEE 2030.5 / SUNSPEC



Frequency Variation Decreases When load is Input

Combined PV+ Storage makes System more Complex

- Bi-Directional Power Flow/Charge-Discharge Control/ EMS management requires innovate tools for modeling and verification



Smooth Output

Micro-grid

Voltage/Frequency Control

Demand Side Response

Other Challenges

- Distributed PV generation control and simulation
- Environmental factors that will affect performance like Dust ,corrosion modeling
- 25 years theoretical/filed reliability prediction(HALT ,ALT ,HASS) and calculation and simulation for better O&M

THANK YOU!

致 力 于 清 洁 高 效

Green and Effective