



# Power Analytics Software for Complex Electrical Systems

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# Solar Variability, Forecasting, and Modeling Tools

Jan Kleissl, Byron Washom\*, Chi Chow, Matt Lave, Jennifer Luoma, Patrick Mathiesen, Anders Nottrott, Bryan Urquhart  
Mechanical & Environmental Engineering

\*Director, Strategic Energy Initiatives, UC San Diego <http://solar.ucsd.edu>

Kevin Meagher, Silviu Darie  
Power Analytics (formally EDSA)

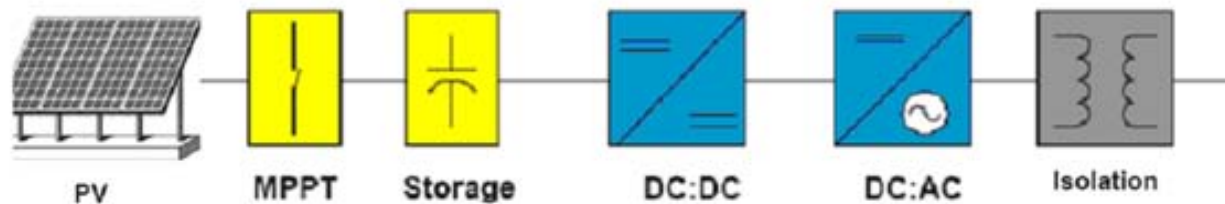
[www.poweranalytics.com](http://www.poweranalytics.com)

- **Year 1 Objectives**
  - ✓ **Literature Survey**
  - ✓ **Development of Power Flow (steady-state) Model**
  - ✓ **Development of Short Circuit Model**
  - ✓ **Development of Dynamic Model**
  - ✓ **Implement and Test above Models in the EDSA's Power System Analysis Software**
  - ✓ **Integration Issues, Reliability and Development of Interconnection Guide (to be completed 3/11)**
- **Year 2 Objectives – Utility Command/Control Interface (UCCI)**
  - ✓ **Literature Survey – proposed existing standards**
  - ✓ **Requirements – use case development and review**
  - ✓ **Protocol development**
  - ✓ **Testing and review**
  - ✓ **Final report**

# Schematic Diagram of a PV grid connected system

The inverter typically consists of the following parts:

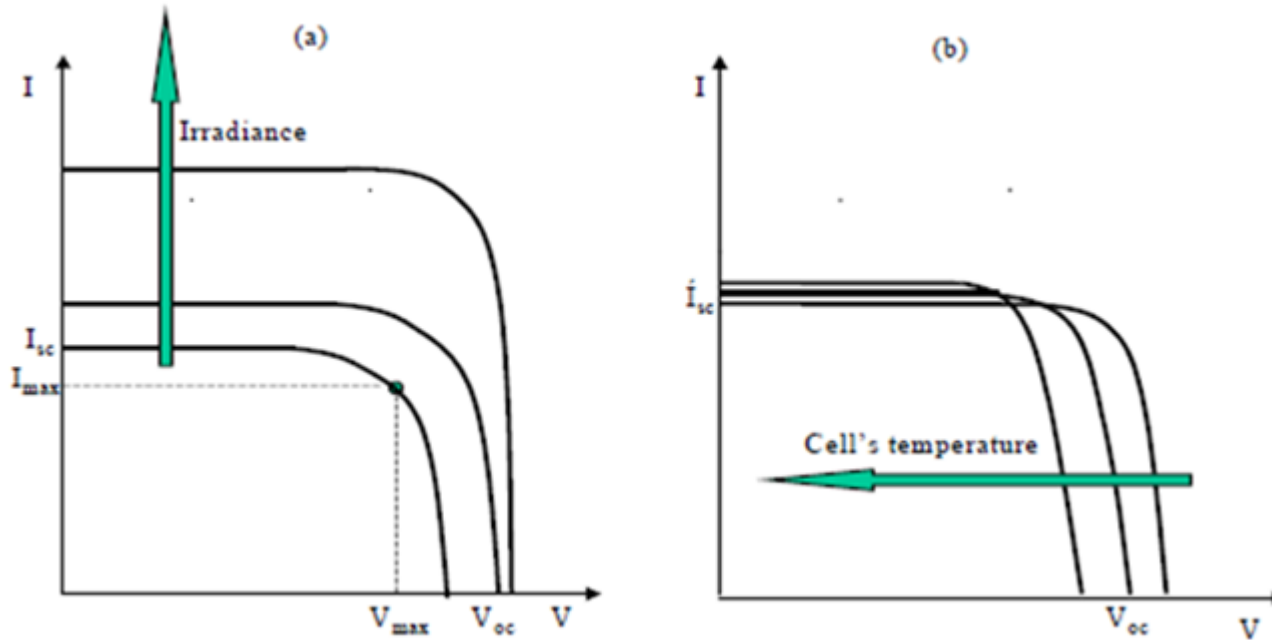
- Maximum power point tracking (MPPT) circuit.
- Optional energy storage element; a capacitor and/or batteries.
- Optional DC/DC converter.
- An AC inverter (DC to AC).
- An Isolation transformer to prevent DC from being injected into the power system.



# Characteristics of New Forms of Generation

Technology	Primary Source	Rotating Machinery	Generator	Power Electronic
Wind	Wind	Yes	Yes	Yes (optional)
HP	Water	Yes	Yes	No
Micro Turbines	Diesel or Gas	Yes	Yes	Yes (optional)
Fuel Cells	Hydrogen	No	Yes (optional)	Yes
Biomass	Biomass	Yes	Yes	No
Photovoltaic	Sun	No	No	Yes
Solar Thermal	Sun	Yes	Yes	No
Geothermal	Earth Temperature	Yes	Yes	No
Wave	Ocean Wave	Yes	Yes	Yes
Tidal	Tidal Current	Yes	Yes	Yes
SMES	Storage	No	No	Yes
BES	Storage	No	No	Yes
Flywheels	Storage	Yes	Yes (optional)	Yes

# Influence of the irradiation & cell temperature on cell characteristics

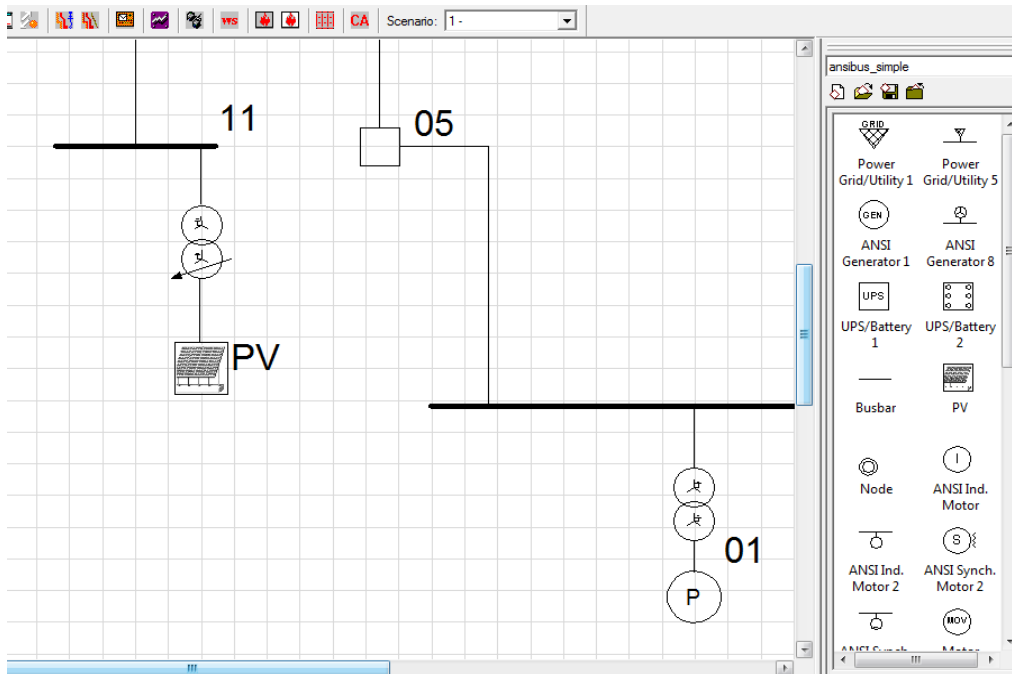


- ❖ **Photovoltaic power plant in the steady-state analysis (I.e. Powerflow) can be modeled similar to a classical generator**
- ❖ **More advanced PV/inverters do offer reactive power (voltage) support. This feature is taken into account in the developed PV model**
- ❖ **Modeling of the solar irradiance variation is an important part of PV farm performance assessment. The solar irradiance variations is implemented in the EDSA Powerflow software**

- ❖ Based on the literature survey the most appropriate dynamic model of PV system selected for implementation in the Transient Stability program.
  
- ❖ Dynamic models of PV systems including its protection and control was implemented using Universal Control Logic Modeling and Simulation (UCLMS)



# Power Flow Model of PV



EDSA JobFile [MODELLING] - Device [PV-G1] - ID [100141]

Connection Information  
 Name: PV-G1  
 Library: 1000 KVA

Voltage  
 System KV: 0.4800  
 Gen Actual KV: 0.4800

Operating Status  
 On:  1  
 Normal

Frequency: 60  
 Temperature: 25

Optional Location Information  
 Zone:  Area:

Description | Short Circuit | **Load Flow** | PDC | Reliability | Installation | Optimization

Type of PV  
 PQ Bus  
 PV Bus

Units  
 Kw Kvar  
 Mw Mvar  
 Per Unit

Generation Characteristic  
 Generator  
 Swing Bus

Generation Limits  
 PG: 623.2000 Kw  
 Volt: 0.480 KV  
 QG Min: -0.00000 Min  
 QG Max: 0.00000 Max

PV Voltage Control Settings  
 Controlled Bus: PV-G1  
 Desired Voltage: 1.000 (PU)

Load Connected to Bus  
 PL: 0.00000 Kw  
 QL: 0.00000 Kvar  
 Constant Impedance

Save to Library | OK | Cancel

Generation for Scenarios

Scenario #	Scenario Na...	P	Desired Vol...	Voltage	QG Min	QG Max	
<input type="checkbox"/>	1	PEAK-LOAD ...	0.00	1.00	480.00	-0.00	0.00
<input type="checkbox"/>	2	8am	123.90	1.00	480.00	-0.00	0.00
<input type="checkbox"/>	3	10am	123.90	1.00	480.00	-0.00	0.00
<input type="checkbox"/>	4	12pm	623.20	1.00	480.00	-0.00	0.00
<input type="checkbox"/>	5	2pm	582.56	1.00	480.00	-0.00	0.00
<input type="checkbox"/>	6	4pm	395.08	1.00	480.00	-0.00	0.00
<input type="checkbox"/>	7	6pm	81.23	1.00	480.00	-0.00	0.00
<input type="checkbox"/>	8	8pm	0.00	1.00	480.00	-0.00	0.00

Select Scenario to edit by clicking  
 <- in desired row in list

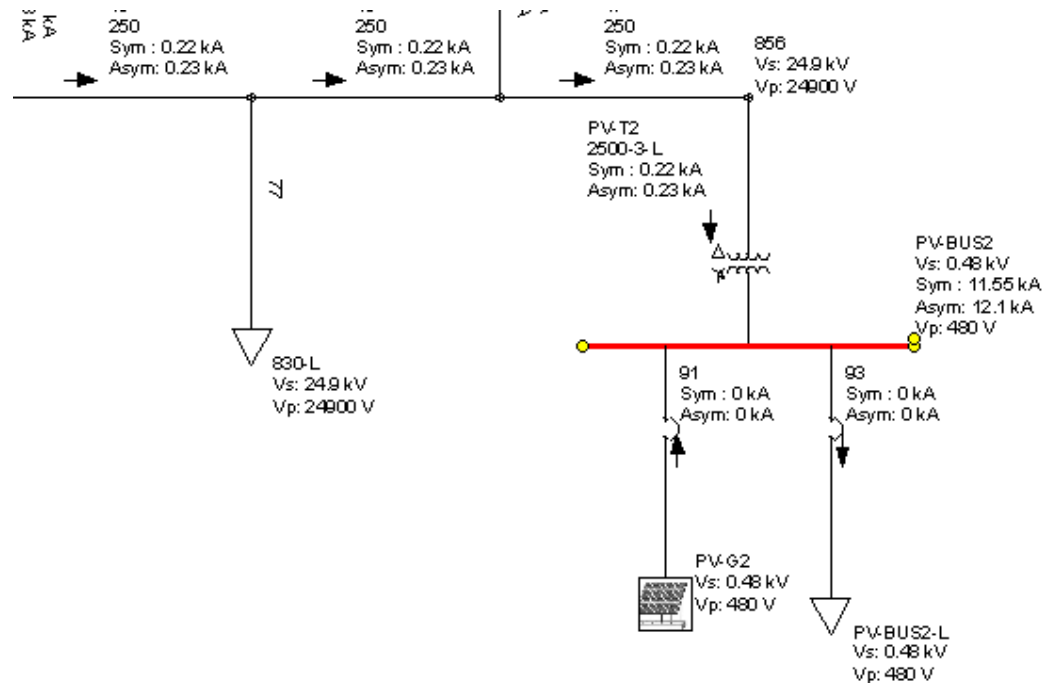
4 | 12pm

Desired Voltage: 1.000 (PU)  
 Generation P: 623.20 (kW)

Generation Voltage: 480.00 (V)  
 QG Min: -0.00  
 QG Max: 0.00

# Short Circuit Model of PV

- PV/Inverter plants *normally* don't contribute to fault (short circuit) current
- Advanced PV/Inverters (with or without battery storage) can contribute to faults for short period of time (a few hundred mille-seconds). This feature is implemented in the EDSA short circuit software

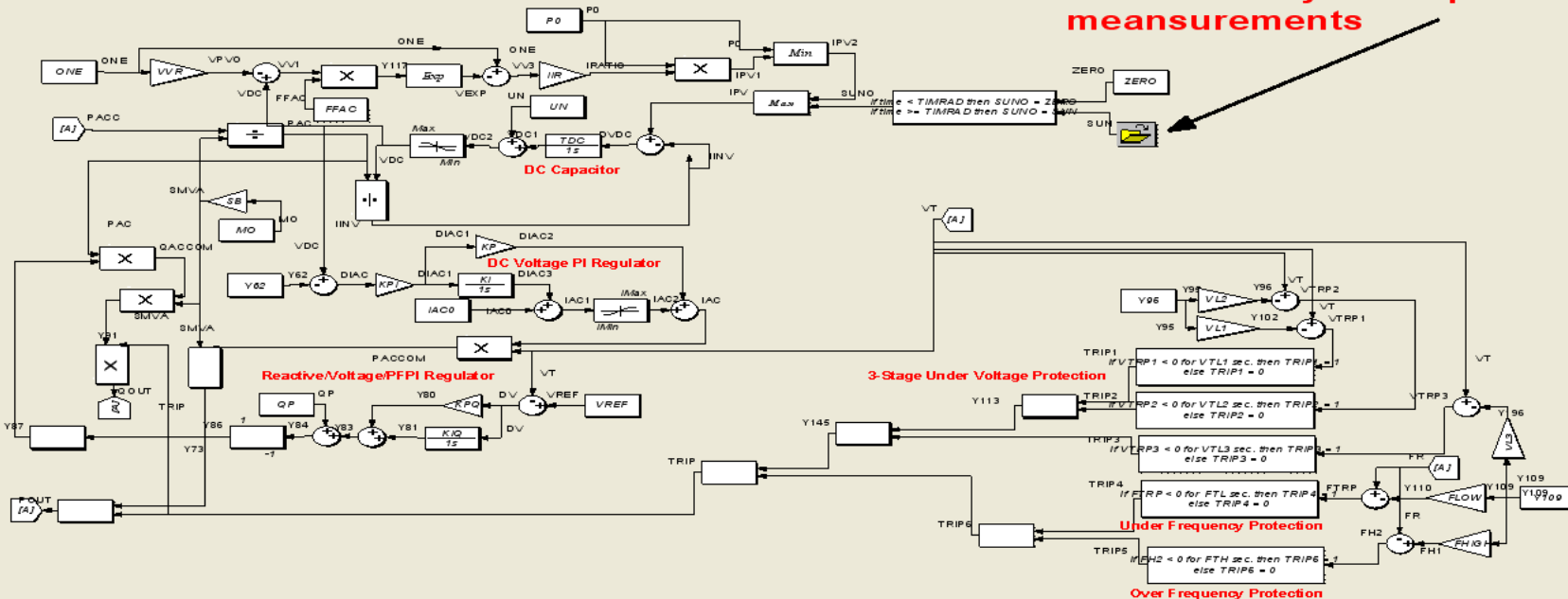


- Goal is to evaluate influence of high penetration solar to power system.
- PV has no inertia. Transient behaviour of system with reduced inertia.
- Constant fluctuation of power injected to the system.

# General Photovoltaic / Inverter Model

## Generic Photovoltaic/Inverter Model

Solar irradiance model - Irradiance changes are introduced by user specified measurements




# PV unit: Steady State and Dynamic Input Data

EDSA JobFile [TEST-PV-XANTREX] - Device [PV] - ID [100099]

Connection Information

Name: PV  
Library: [ ]

Optional Location Information  
Zone: [ ] Area: [ ]

PV 

Voltage  
System KV: 0.4800  
Gen Actual KV: 0.4800

Operating Status  
On [ ] 3  
MAXC LOAD 10 AM PV

Frequency: 60  
Temperature: +25

Description | Short Circuit | Load Flow | PDC | Reliability | Installation | Optimization

Type of PV  
PQ Bus  
PV Bus

Units  
Kw Kvar  
Mw Mvar  
Per Unit

PV Voltage Control Settings  
Controlled Bus: PV  
Desired Voltage: 1.000 (PU)

Generation Characteristic  
Generator  
Swing Bus  
Schedule

Generation Limits  
PG: 1232.00 Kw  
Volt: 0.480 KV  
QG: -0.00000 Min  
QG: 0.00000 Max

Load Connected to Bus  
PL: 0.00000 Kw  
QL: 0.00000 Kvar  
Constant Impedance

Save to Library OK Cancel

Select Library Entry.

Edit PV Model

Label: PV-GENERAL-MODEL  
Description: [ ]

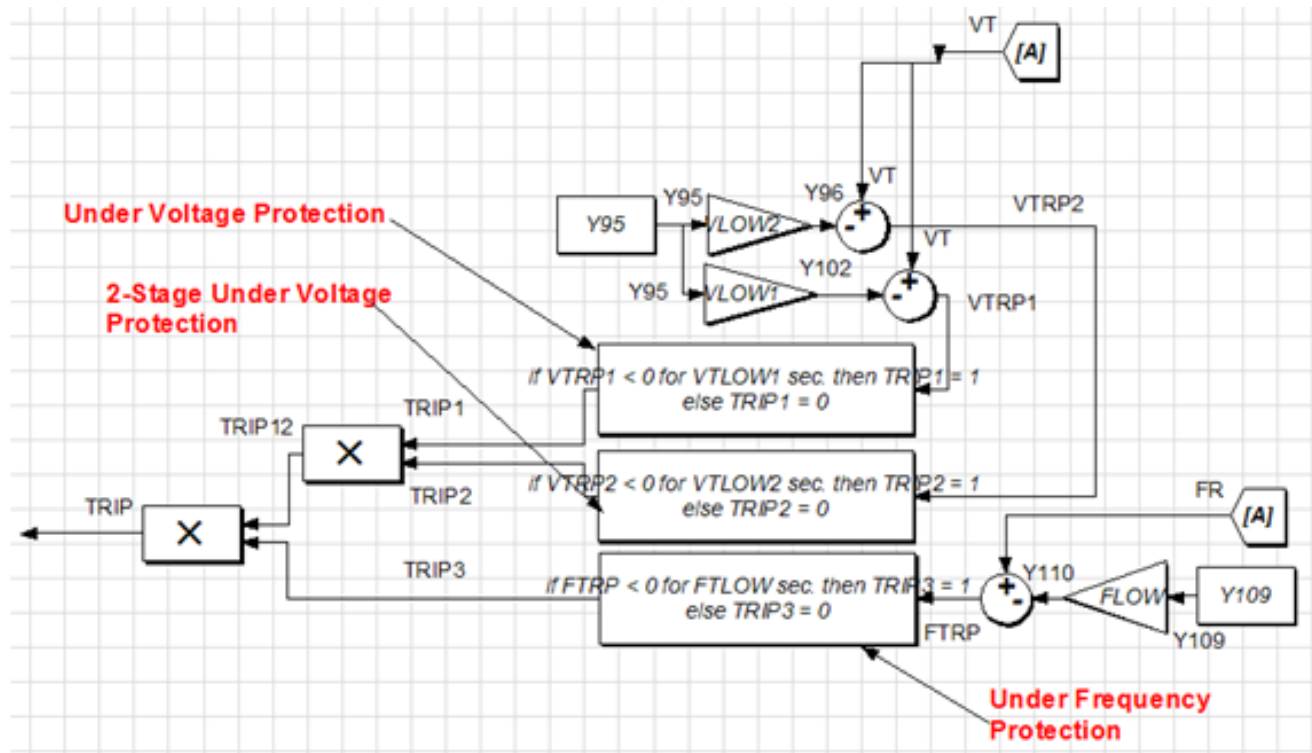
IB: PV  
SB: 10  
VVR: 1.18  
IIR: 1.07  
TDC: 1  
Max: 1.18  
Min: 0.05  
KPI: 5  
KI: 1  
KP: 0.1  
IMax: 1.1  
IMin: 0.001  
KPO: 0.1  
KIQ: 0.1  
TIMRAD: 0.1  
VL2: 0.5

VL1: 0.1  
VTL1: 0.3  
VTL2: 1  
FLOW: 0.95  
FTL: 1  
VTL3: 2  
VL3: 0.9  
FHIGH: 0  
FTH: 0

Symbol Description  
SB - Inverter Base Power in MVA  
Default Value: 10.00000 Max. Limit: 99999.00000 Min. Limit: -99999.00000

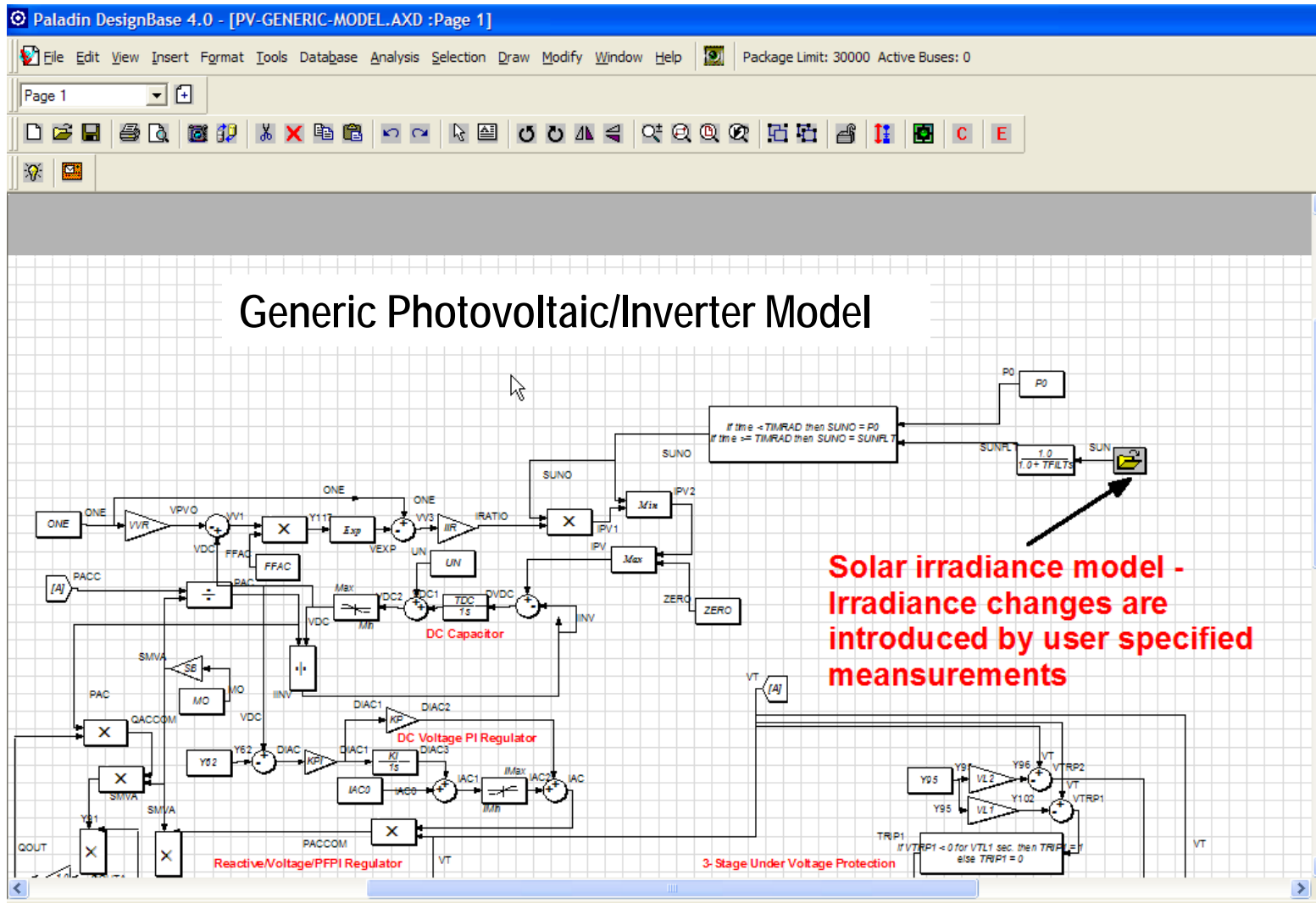
OK View Cancel

# Voltage and Frequency Protection

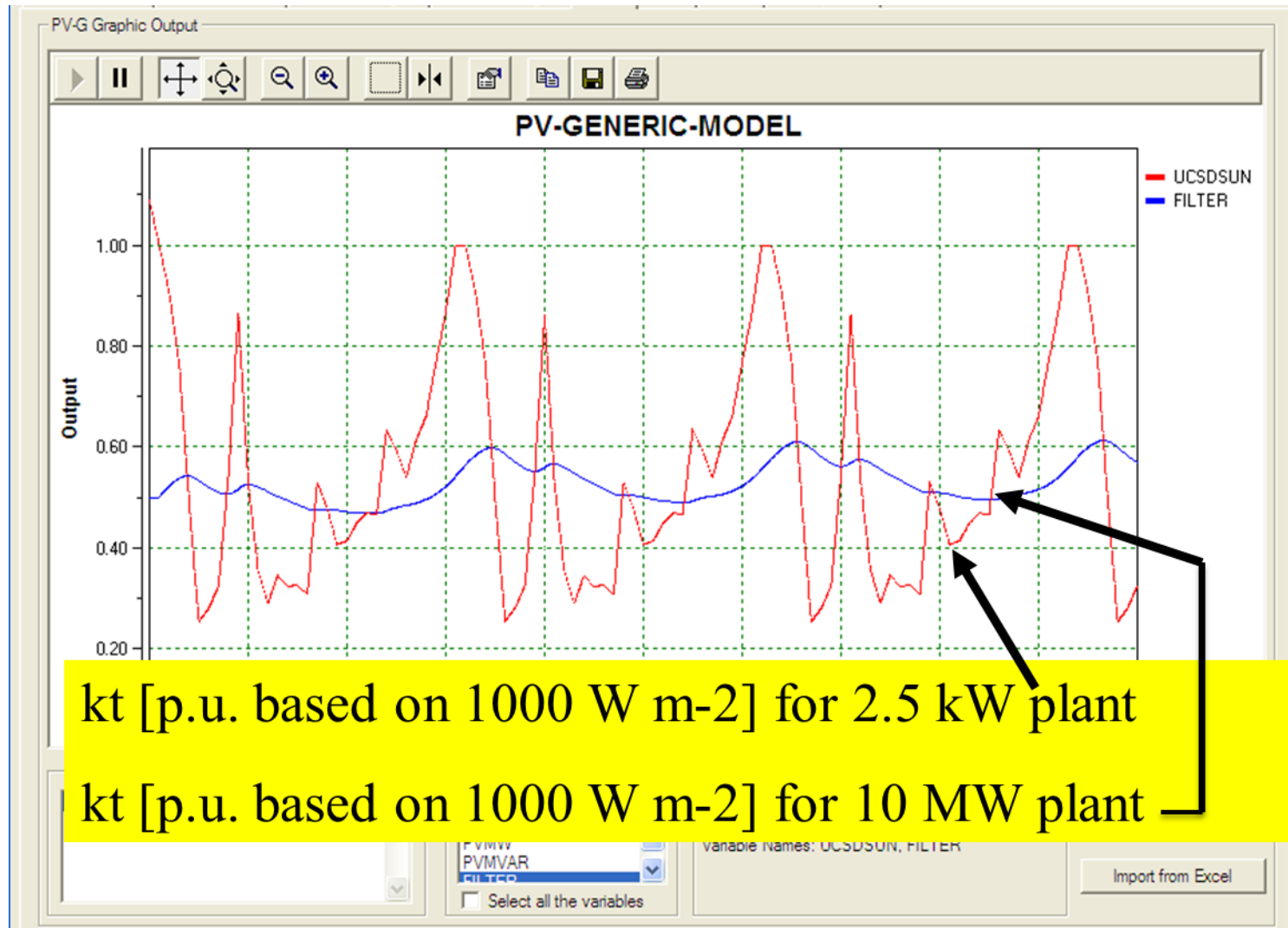


The protection of PV against abnormal voltage and frequency operation is extremely important not only from device protection point of view also from the power utility operation. For planning, operation engineer 's would like to know how long and to what level PV can ride through disturbances.

# Input for Irradiance Changes

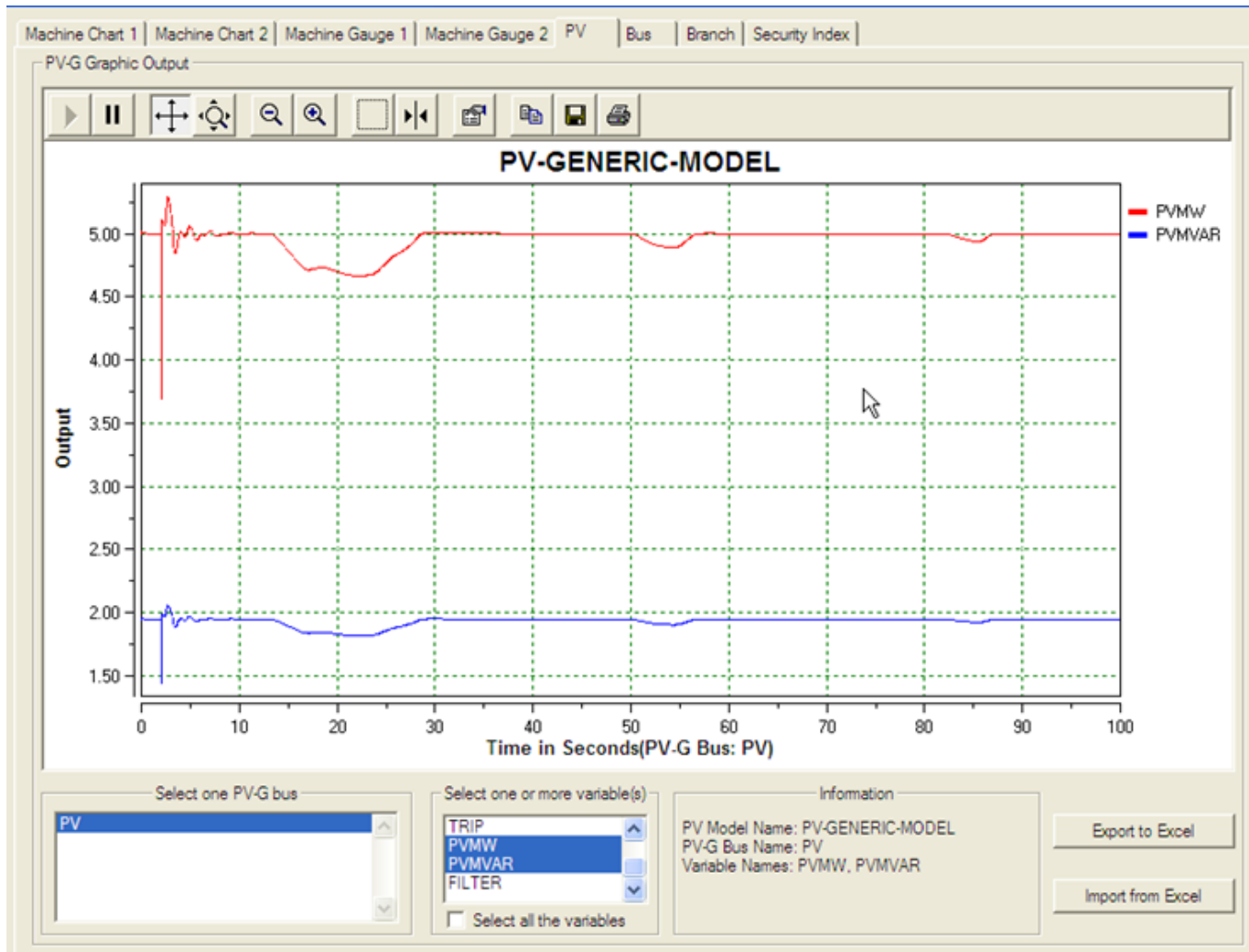


# Irradiance (UCSD Data)

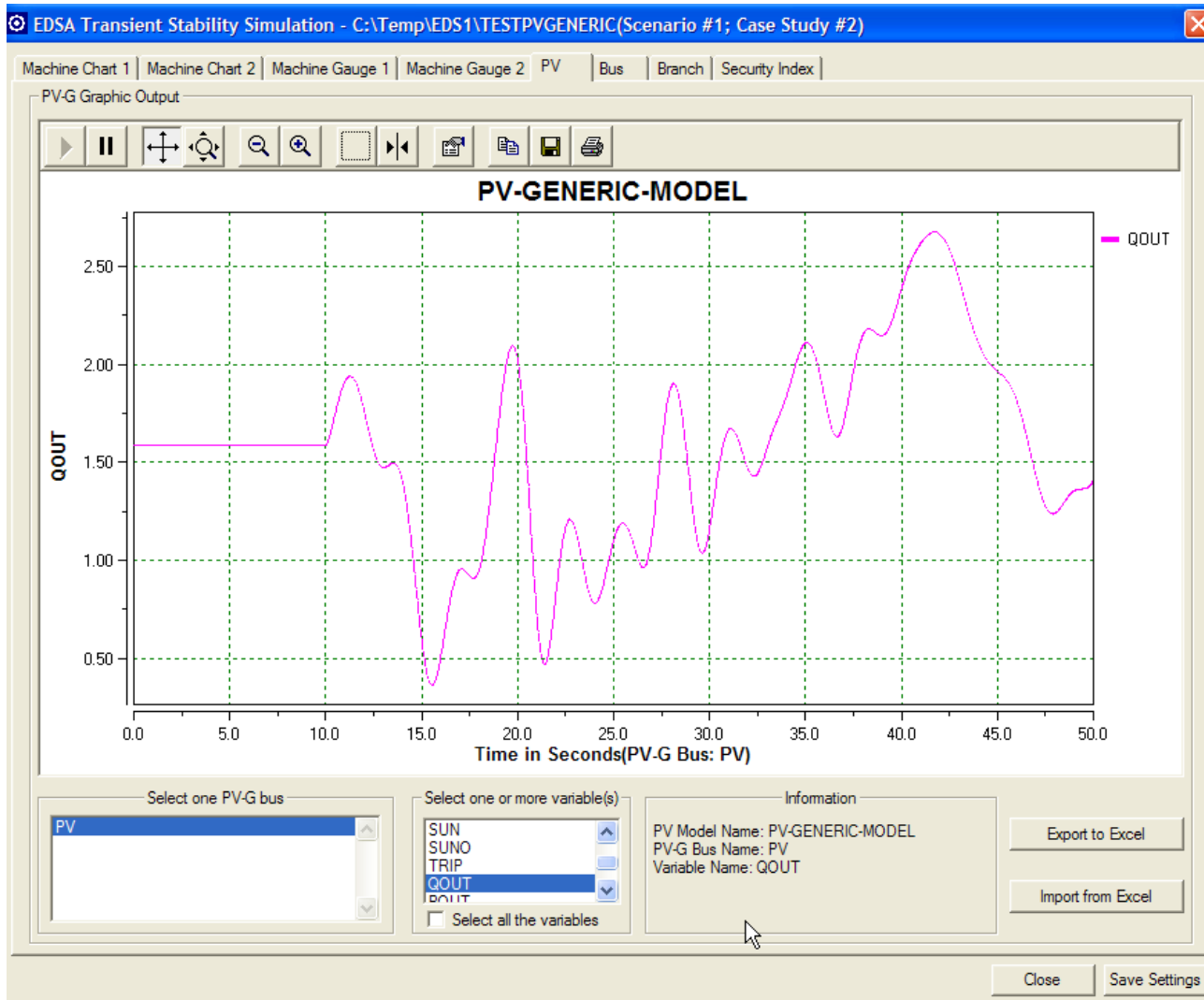




# PV Active Power – Irradiance Changes



# PV Reactive Power – Irradiance Changes



- **Modeling PV (with specific and generic inverter parameters) significantly changes opportunity for planning and deployment of PV**
- **Accurate irradiance data input into the dynamic modeling of the entire network provides realistic modeling and evaluation.**
- **The opportunity to combine local and national irradiance (analogous to wind resources maps) database into modeling and planning.**
- **Combining modeled PV, real time irradiance and real time power/energy data in a combined microgrid.**