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Power Analytics Software for Complex Electrical Systems

March 1-2, 2011

Solar Variability, Forecasting, and Modeling Tools

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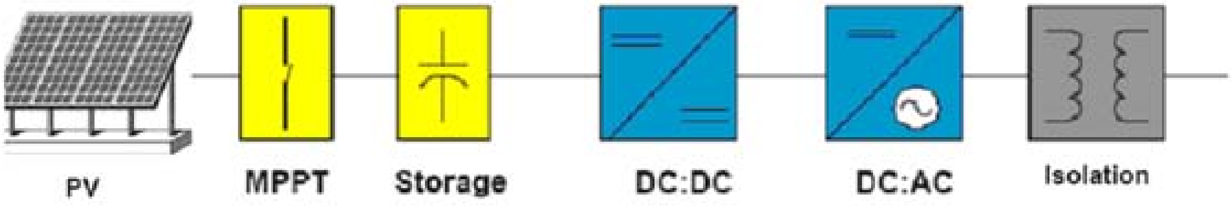
PV Project Objectives

- **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

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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

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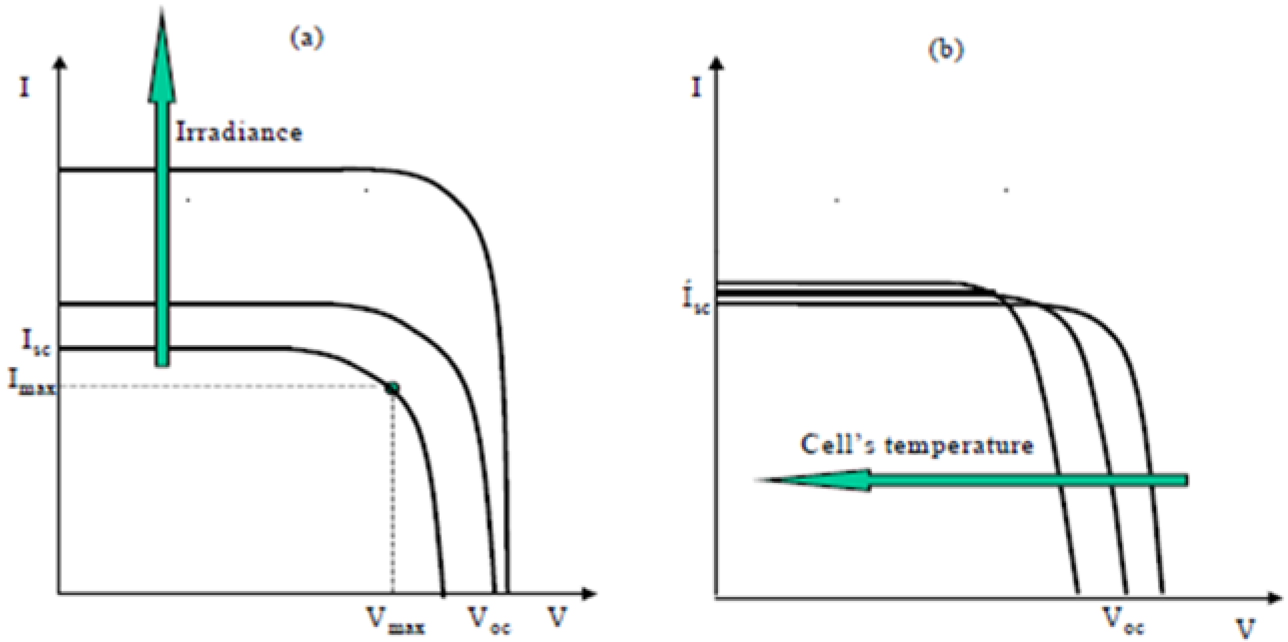
Influence of the irradiation & cell temperature on cell characteristics



Power Flow Model of PV

- 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

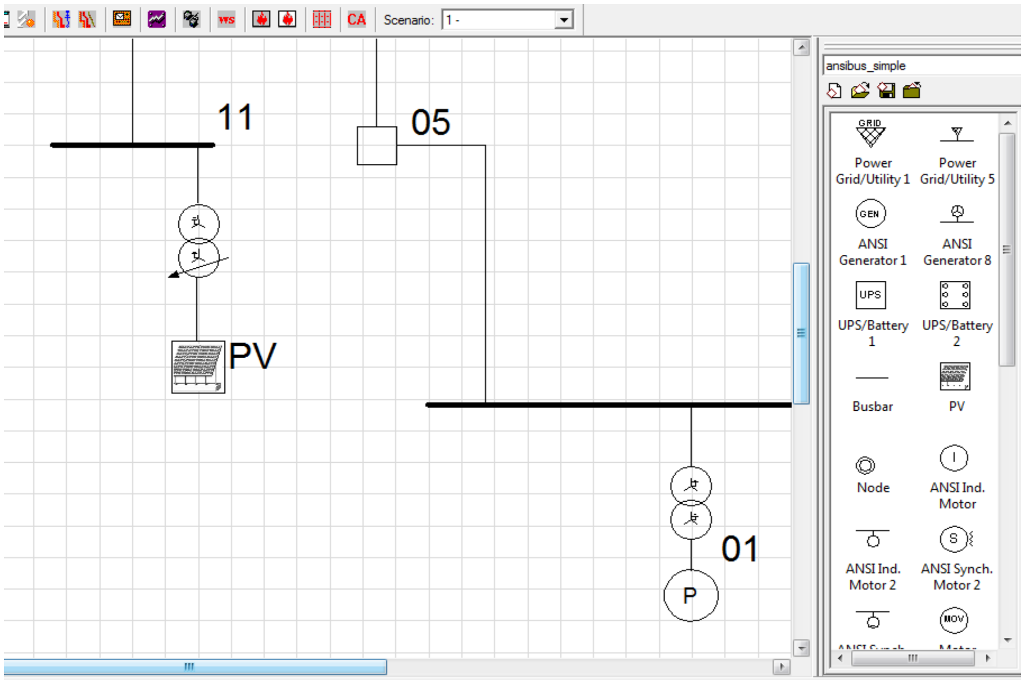
- Modeling of the solar irradiance variation is an important part of PV farm performance assessment. The solar irradiance variations is implemented in the EDSA Powerflow software

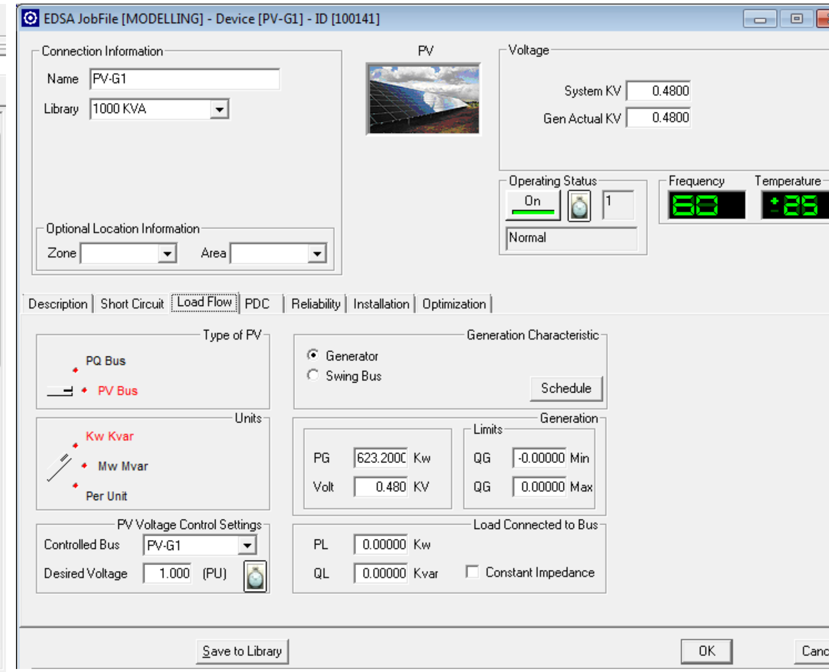
Modeling of PV Systems' Dynamics

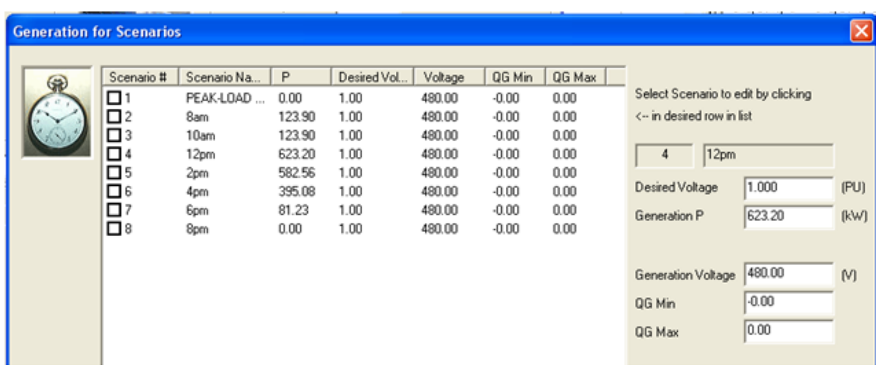
- Based on the literature survey the most appropriate dynamic model of PV system selected for implementation in the Transient Stability program.

- 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







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

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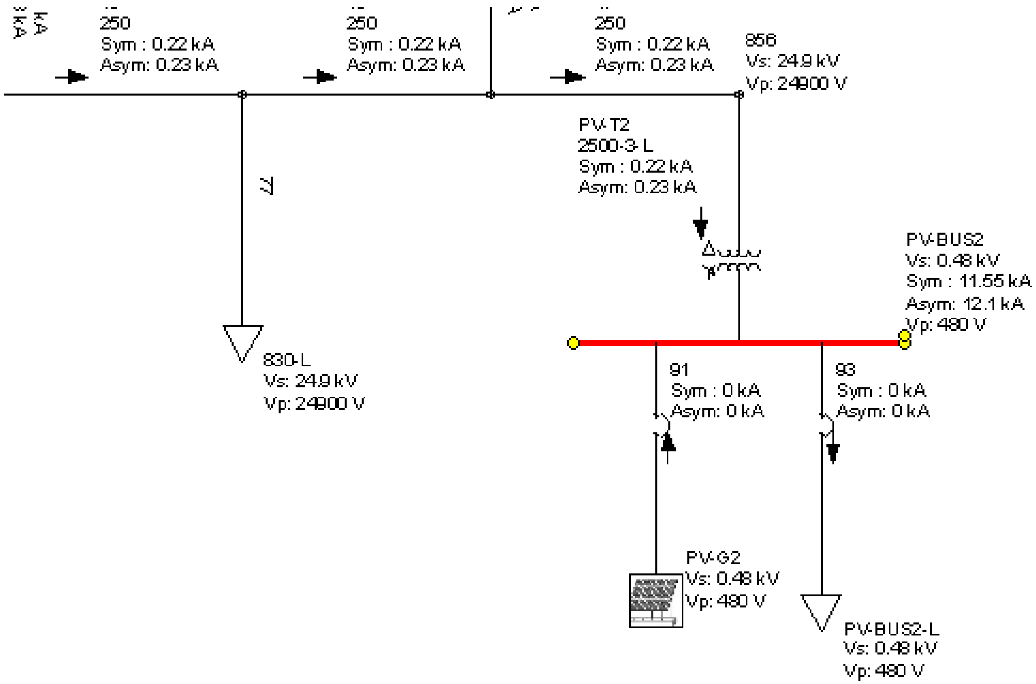
Short Circuit Model of PV

- **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**



Modeling of PV Systems' Dynamics

- 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.

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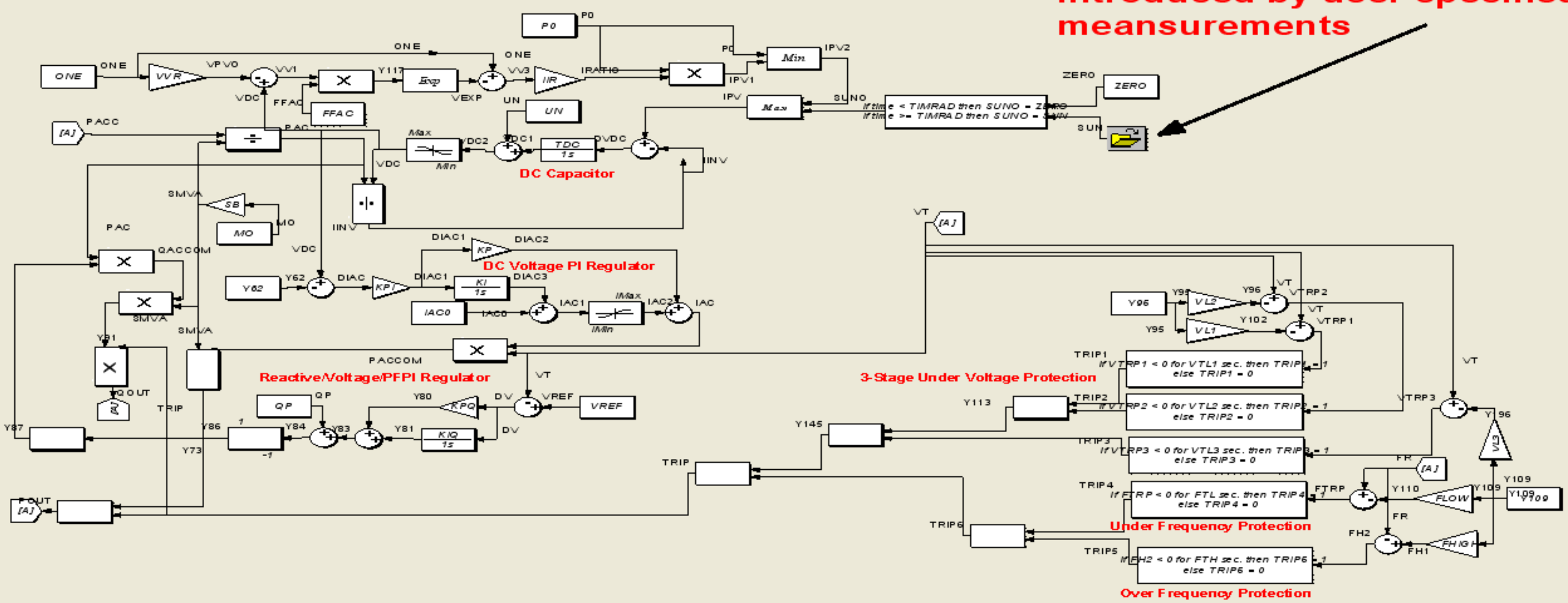
Generic Photovoltaic/Inverter Model

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



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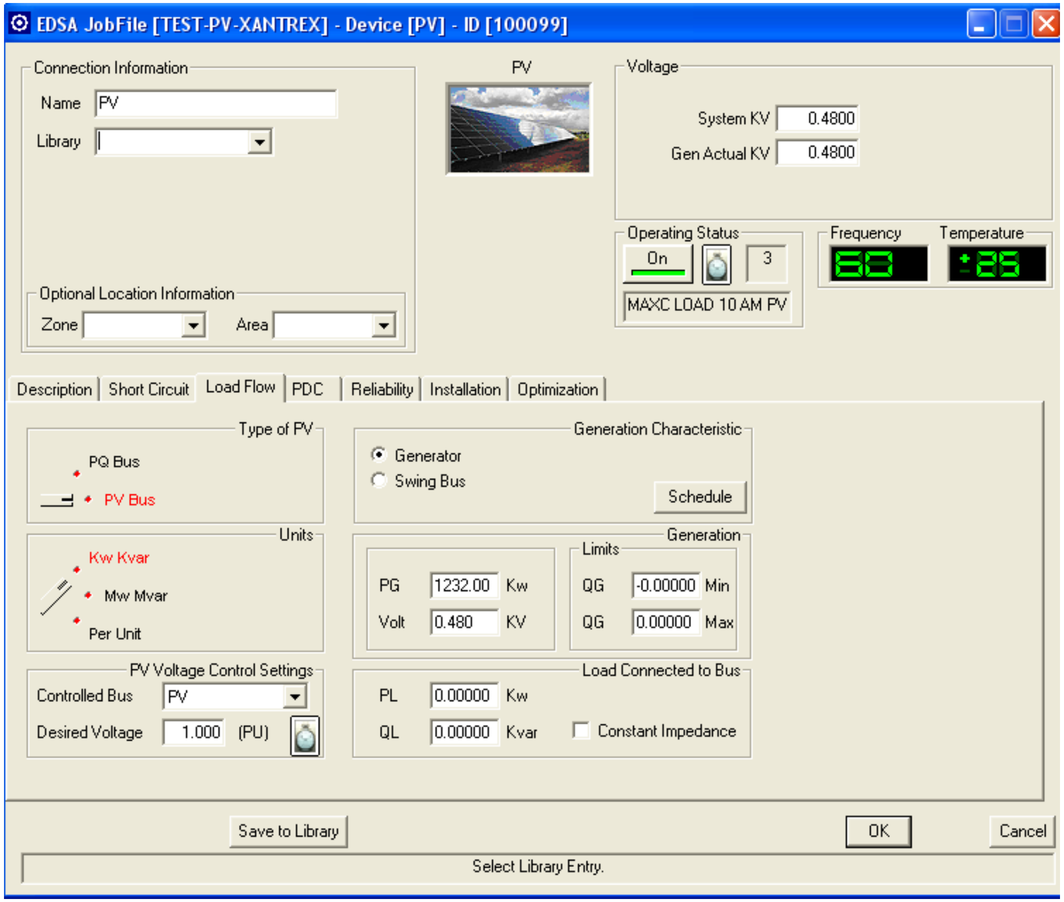
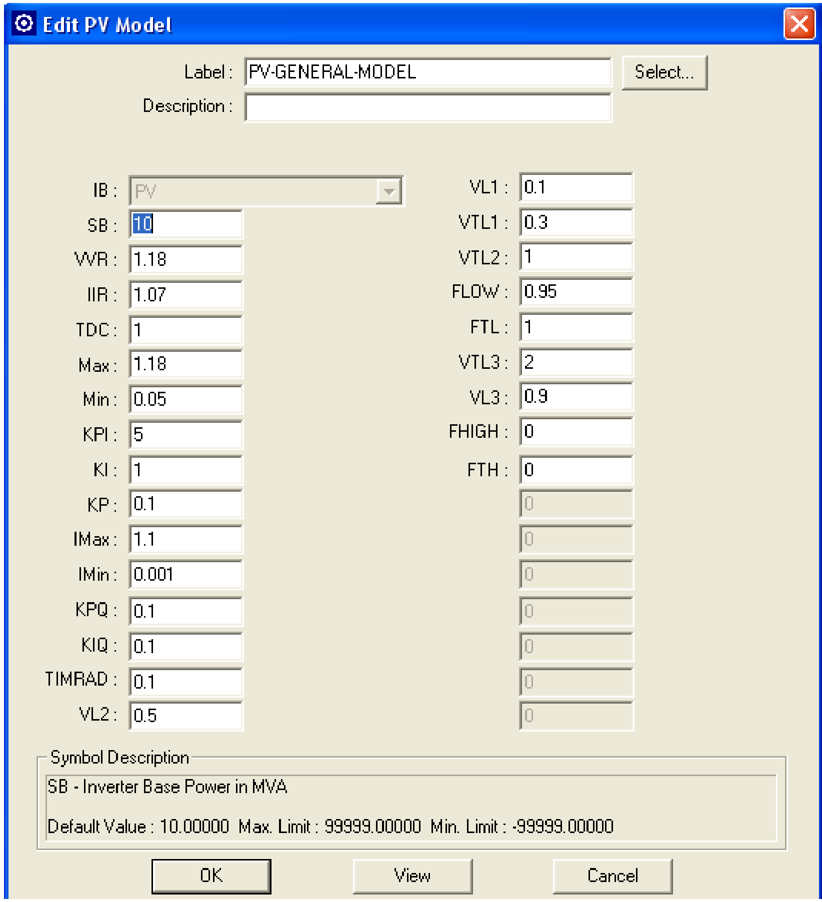
PV unit: Steady State and Dynamic Input Data





Voltage and Frequency Protection

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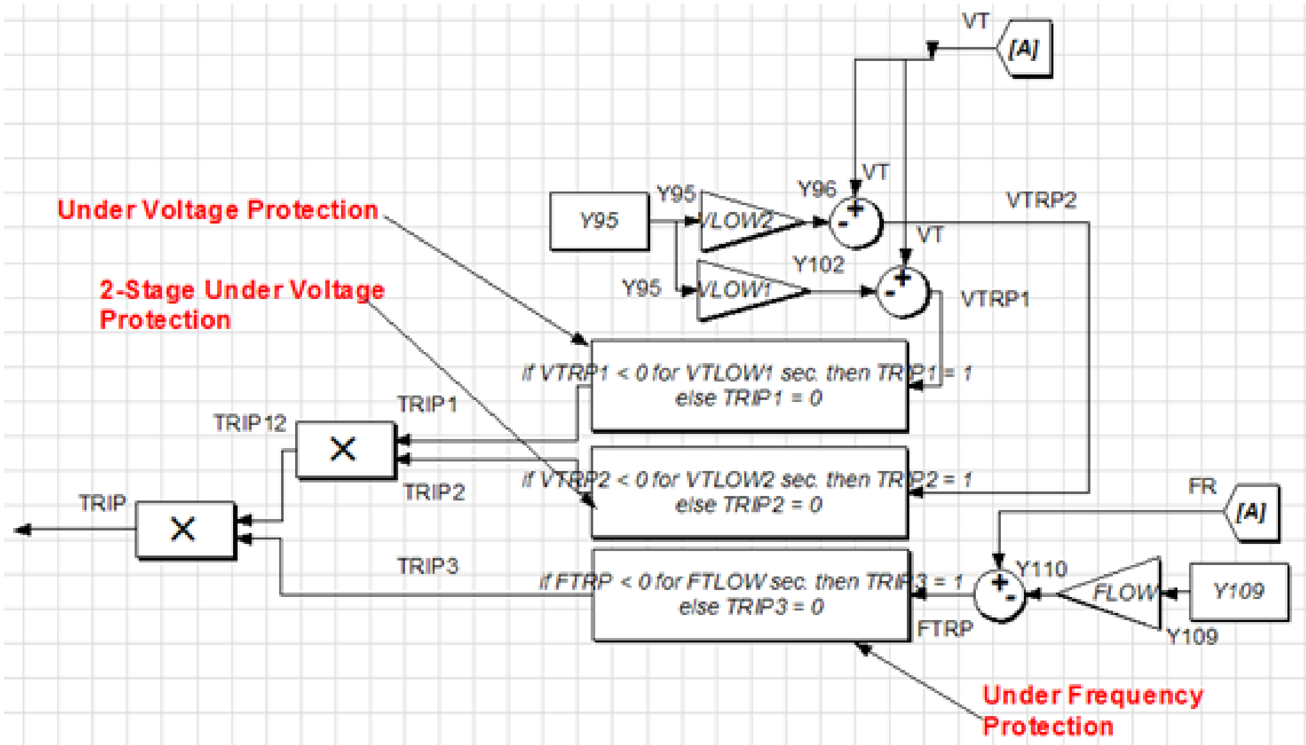

The protection of PV against abnormal voltage and frequency operation is extremely important not only from device protection point of view also from the power utility operation. For planning, operation engineer 's would like to know how long and to what level PV can ride through disturbances.

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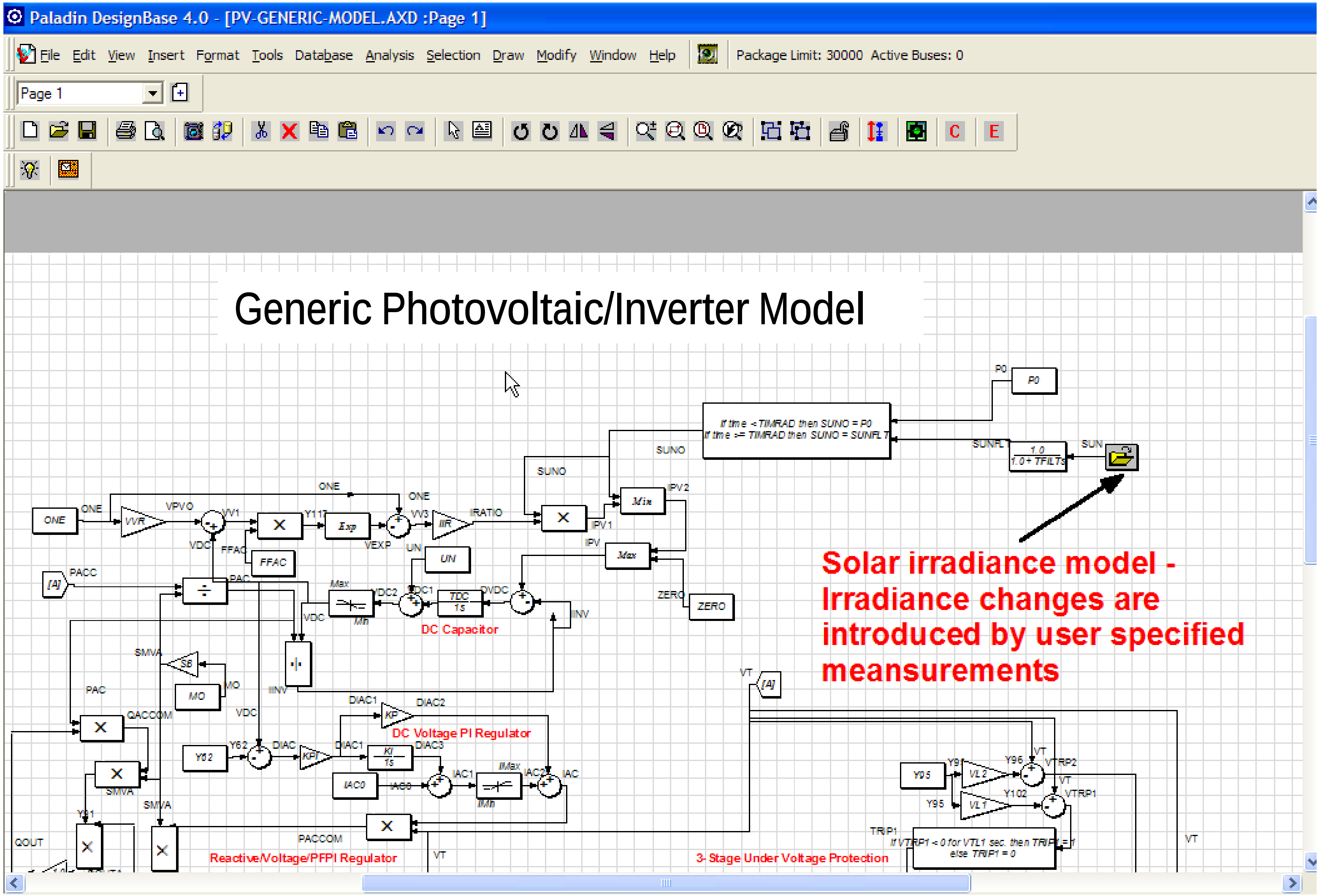
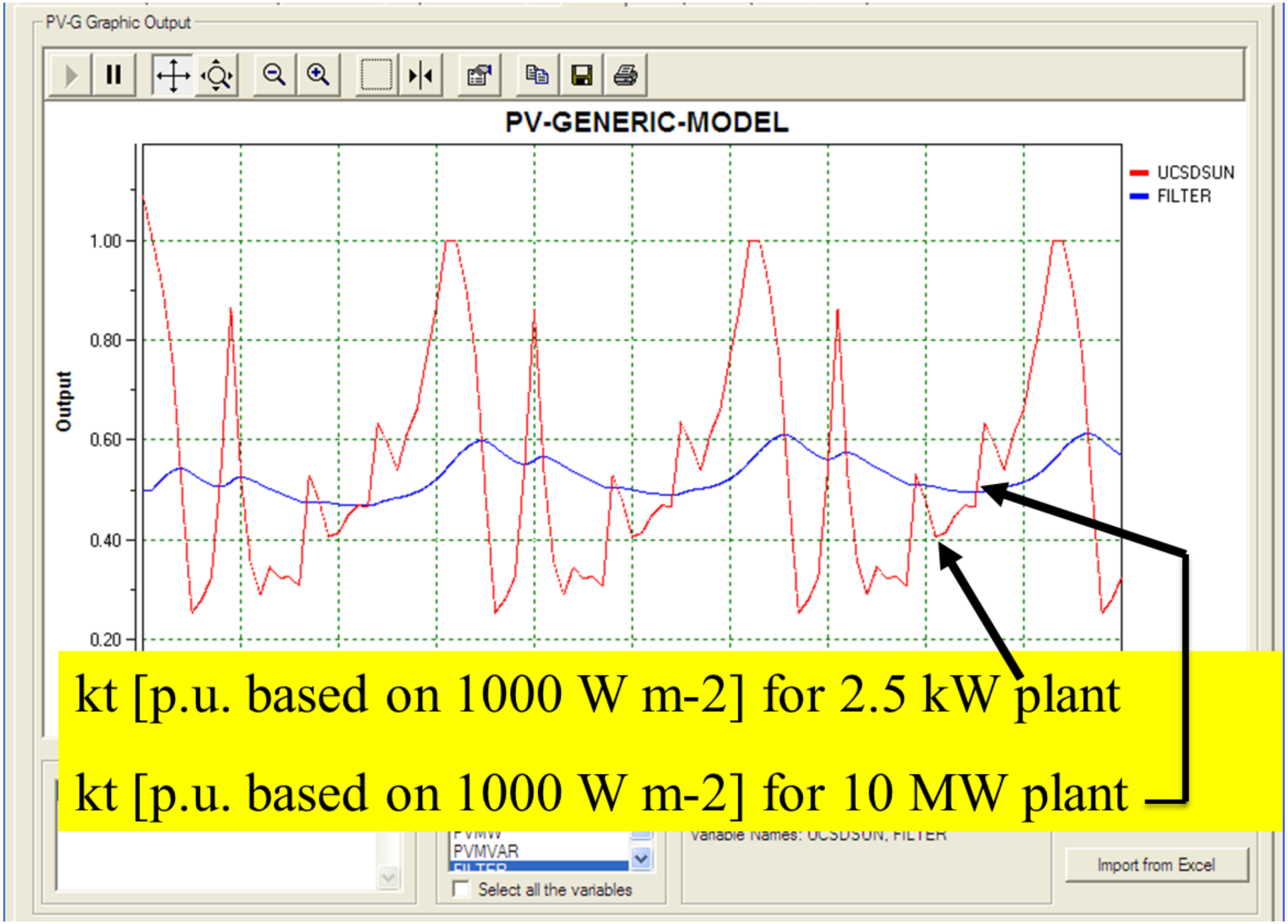
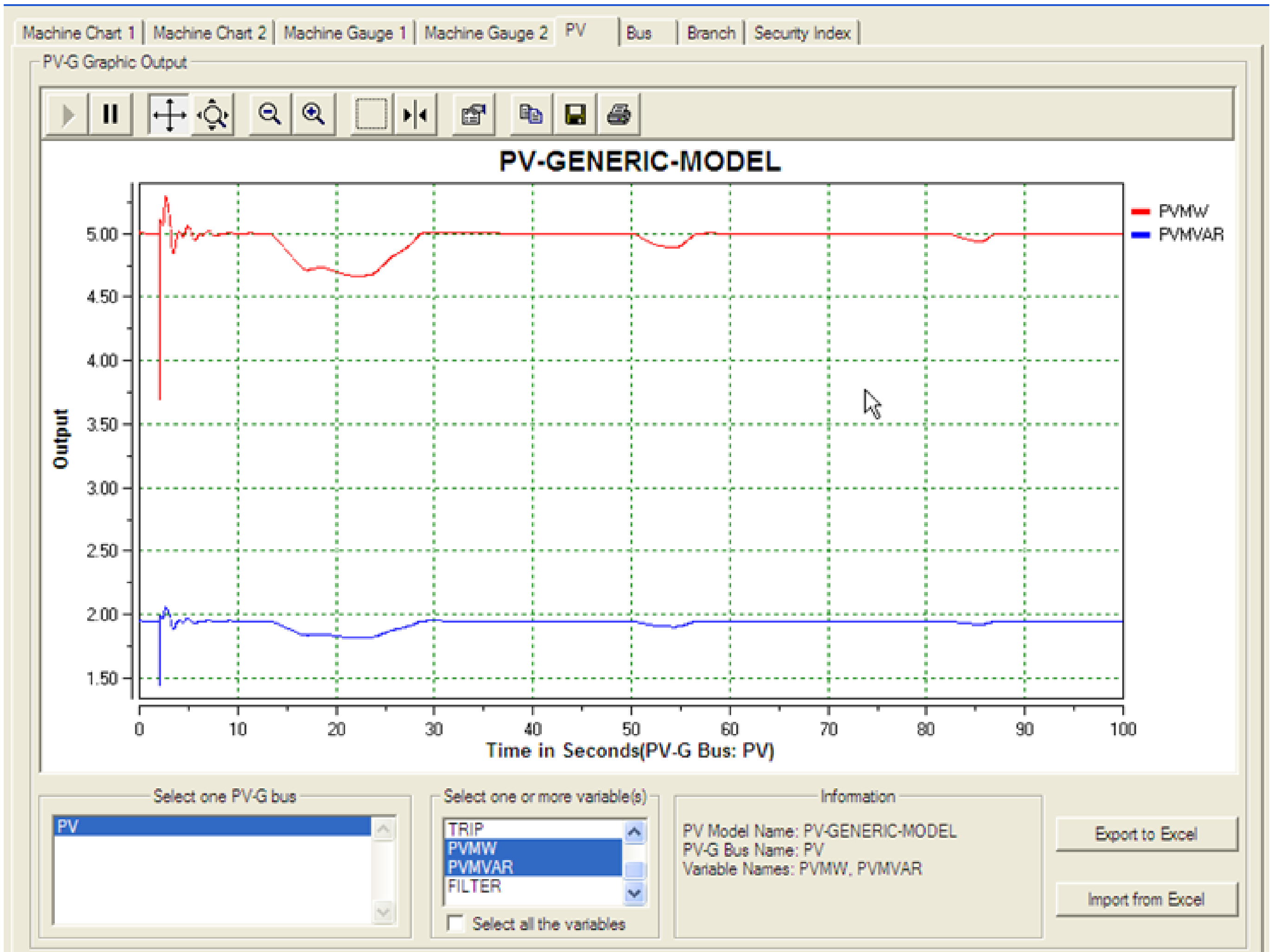
Input for Irradiance Changes



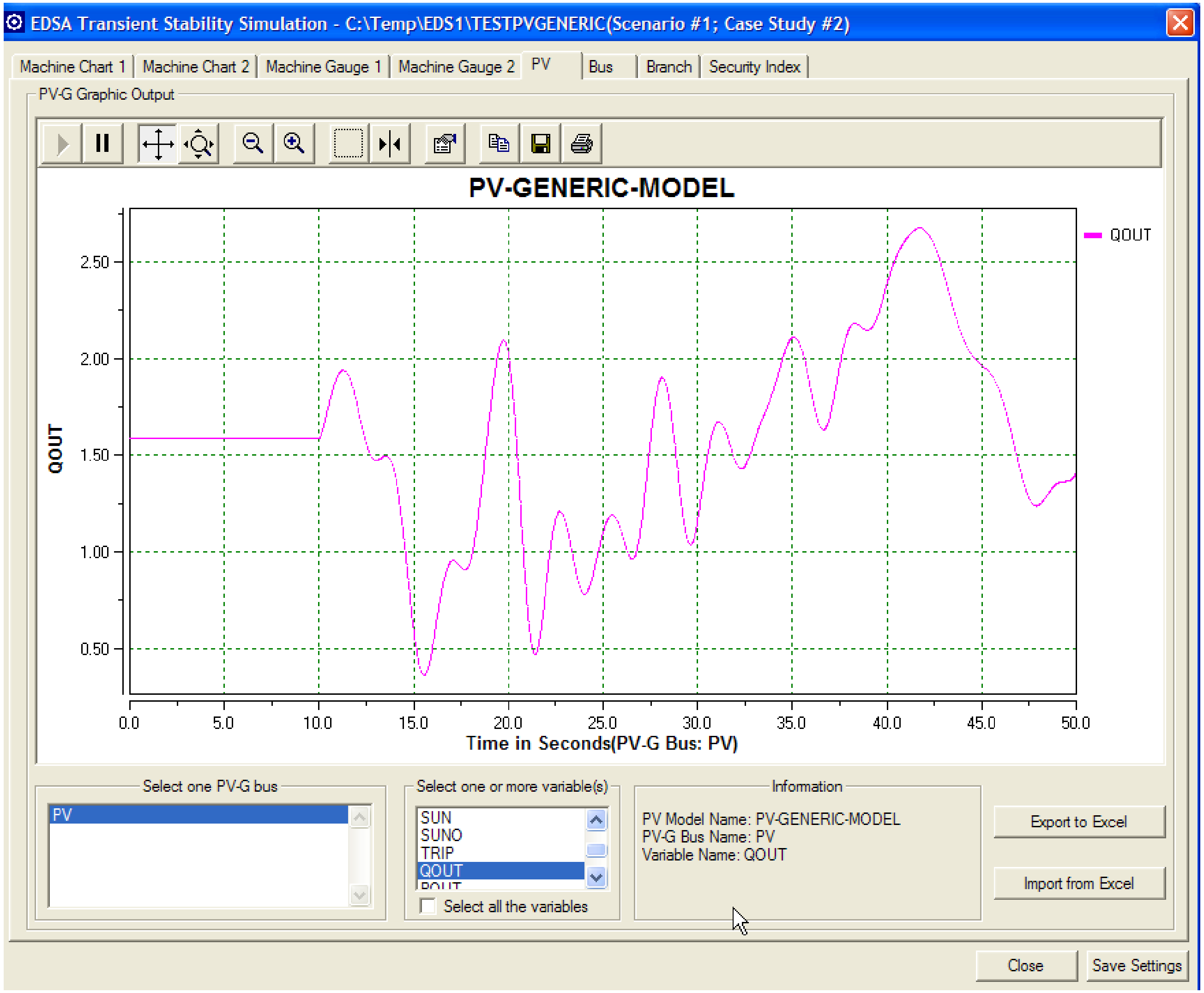
Irradiance (UCSD Data)



PV Active Power – Irradiance Changes



PV Reactive Power – Irradiance Changes



Conclusions

- **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.**