

RTDS Training course of IEPG

DAY 5: Solar PV and dynamic load models

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1. Introduction

The objective of this lab session is to describe a simulation case to analyse the operation of a grid-connected photovoltaic system using the PV model and dynamic load model in RSCAD library.

At the end of this tutorial, you should be able to:

- Configure the PV model to a desired output power.
- Understand the PV control system.
- Integrate the PV model to the grid.
- Use the dynamic load model.

2. Prerequisite Knowledge

From previous lab sessions:

- You should be familiar with running basic cases in RSCAD Draft and Runtime.

3. Attached folders

- 'PV System and dynamic load' folder. This files in it shall be used to carry out tasks given in session 5.

4. Explanatory Notes

Grid-connected photovoltaic systems are gradually becoming a major contributor to the energy mix, so it is important to consider their characteristics while modelling a distribution grid. Figure 1 shows the block diagram of the PV system model which is implemented in this tutorial. The main components of the system are a solar array, electronic power converter with its controllers, and a grid interfacing transformer.

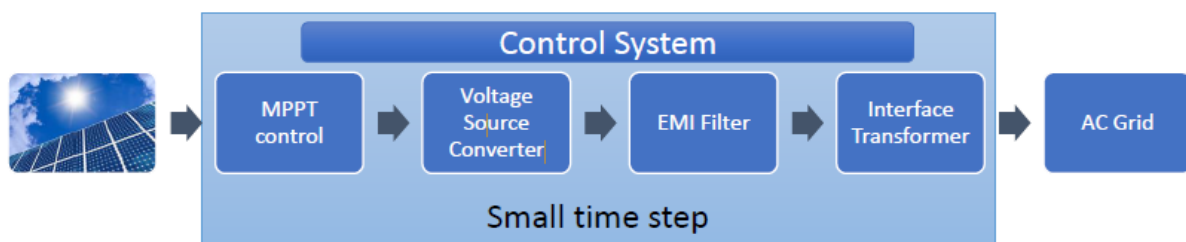


Figure 1: Block diagram of PV System Model

RSCAD/Draft contains a PV array model shown in Figure 2 which can be configured by the user to the desired number of modules in series and parallel to produce an appropriate power output. The parameters of the PV array used in this tutorial are given in Table 1. The model takes the insolation (Watts/m²) and temperature (°C) as inputs and provides the positive and negative DC node voltages VDCp and VDCn as outputs.

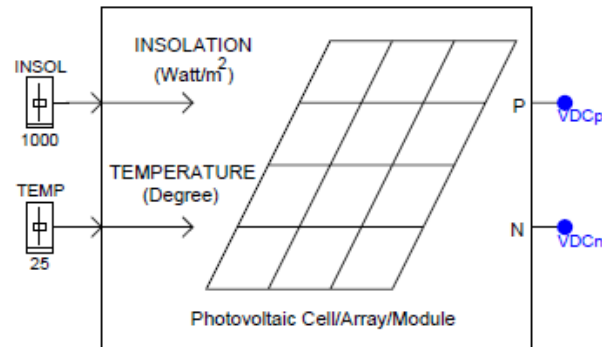


Figure 2: PV array model in RSCAD component library

Table 1: PV Array Parameters

Voc_stc	21.7 V
Isc_stc	3.35 A
Vm_stc	17.4 V
Im_stc	3.05 A
Ki	0.065 %/°C
Eg	1.11eV
Prated	1.74 MW
Ncs	36
Ncp	1
Ns	115
Np	285

Note: Before you continue with the rest of this material, please read the more detailed discussion on the PV model given in the document **PV_Model.pdf** to understand its configuration in RSCAD.

4.1. PV Converter

To connect PV arrays to the grid, converters whose function is to convert the PV output DC power to meet the requirements of the AC grid are required. The topology adopted in this demonstration is the single stage grid connected system shown in Figure 3. The system uses a DC capacitor to limit the oscillations on the DC voltage. The Voltage Source Converter (VSC) controls the DC link voltage, active power supply to the grid and ensures grid synchronization. A delta-wye transformer steps up the VSC AC-side voltage to grid level voltage and reduces harmonic current injection to the grid. Capacitor filters and interface reactors are placed at the point of common coupling (PCC) between the VSC and the grid to further minimize the converter harmonics injected to the grid.

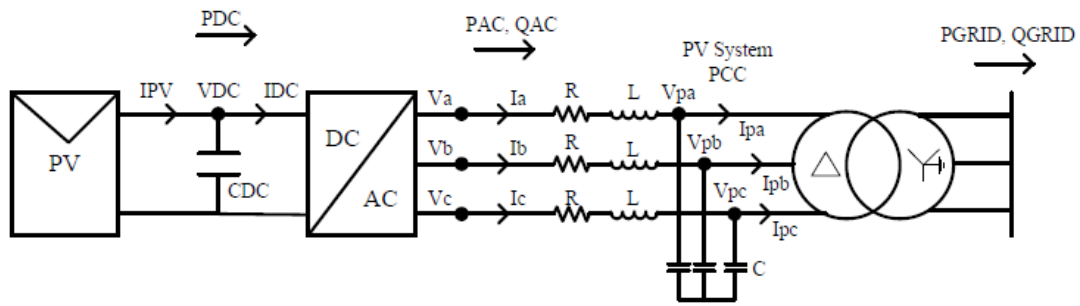


Figure 3: Single-Stage, Grid-connected PV system

4.2. PV Control System

Practical grid-converter control systems are designed to operate within grid standards and codes specified for power quality and reliability. Protection measures such as anti-islanding detection, ground fault detection, fault-ride through capability are implemented in the control operation to ensure stability under different grid operating conditions. However, in this lab session, the details of these protection measures would not be covered. Typically, the topologies of actual control systems are not available to make a detailed simulation model as these systems are kept black box and propriety by manufacturers.

Figure 4 describes the full control scheme implemented in this tutorial. The AC voltages and currents are transformed by the dq axis reference frame into DC signals thus simplifying the parameter tuning process and control design. By tracking the frequency and angle of the grid side AC voltage (delta side of the transformer) using a phase locked loop (PLL) controller, a transform angle ρ is obtained and used to transform the AC voltages and currents to the dq reference frame. The PLL control was designed using a prebuilt PLL component accessible in the RSCAD library. The decoupled current controllers provide modulation signals, m_d and m_q , as outputs. These are transformed to three-phase sinusoidal signals, m_a , m_b , m_c , using a dq-abc transformation block and serve as the modulation waveform in the SPWM control. Thereafter, the SPWM control block generates the firing pulses of the VSC valves.

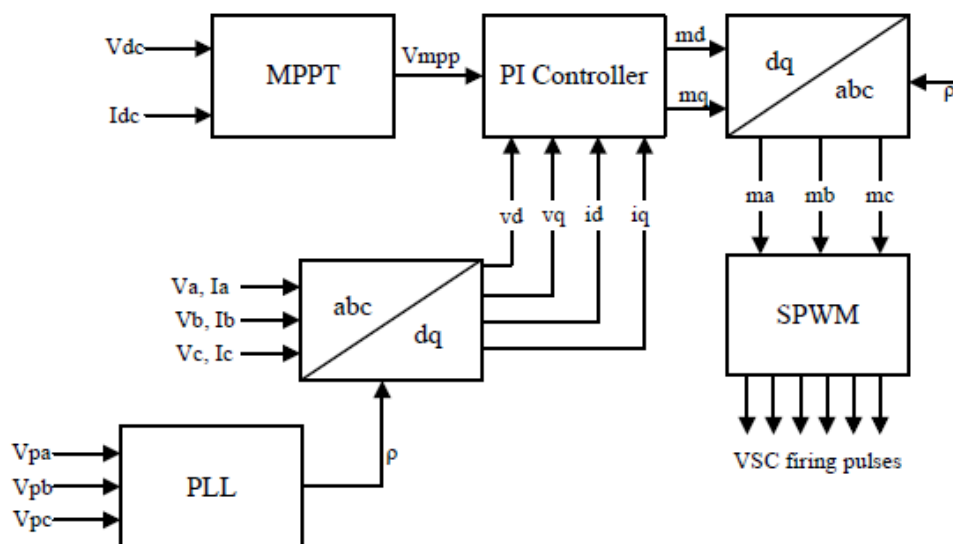


Figure 4: PV system Control

4.3. RSCAD Draft Circuit

Figure 5 is the RSCAD Draft circuit to be used for the demonstration. It shows a PV array, connected to the grid through a small timestep subnetwork. The grid voltage is 13.2KV, therefore the AC side of the inverter must be at the same voltage to achieve proper integration. A dynamic load is connected to the grid and can be supplied directly from the grid or from the Solar PV generator.

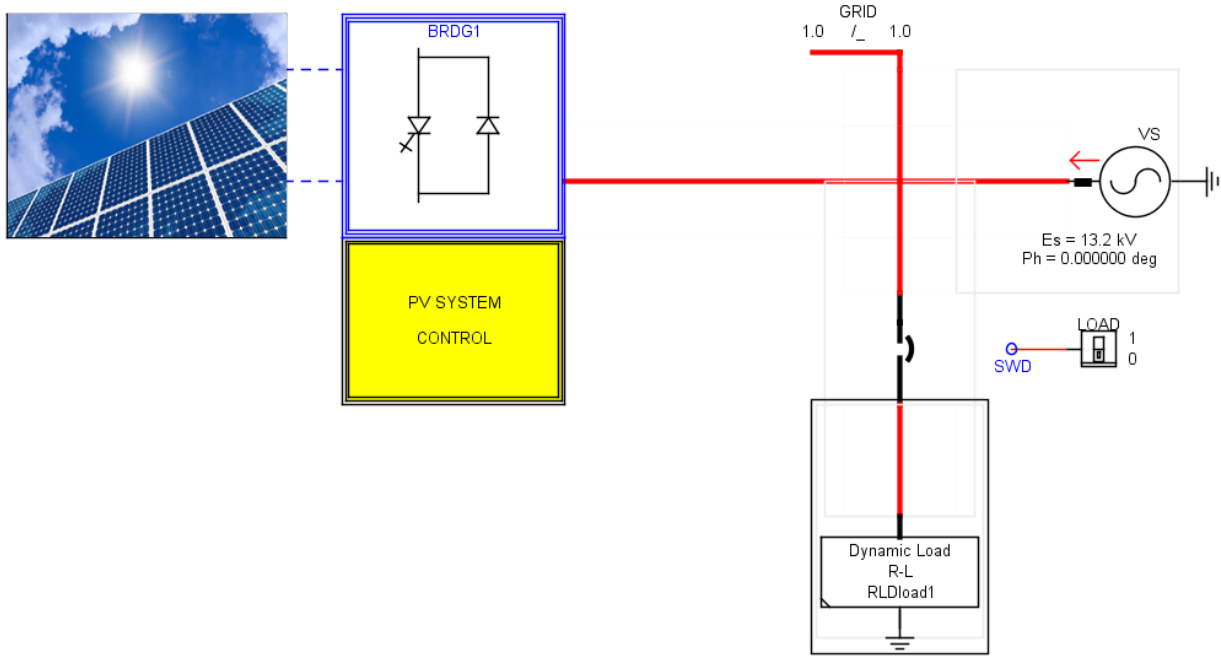


Figure 5: RSCAD Draft Circuit

The VSC switching frequencies are usually in the range of 1 to 4kHz. Due to these, the two-level VSC is modelled in RSCAD within a small timestep sub-network named BRDG1 in Figure 5. This sub-network is solved within a time step range of 1.4 to 3 usecs, allowing the simulation of the high switching frequencies of the VSC in RSCAD. Moreover, the PV array is simulated with a large time step of 50 usecs and was interfaced with the 2-level, VSC simulated with a small timestep of 2.5 usecs using a large timestep to small timestep transmission line interface model in RSCAD as shown in Figure 6.

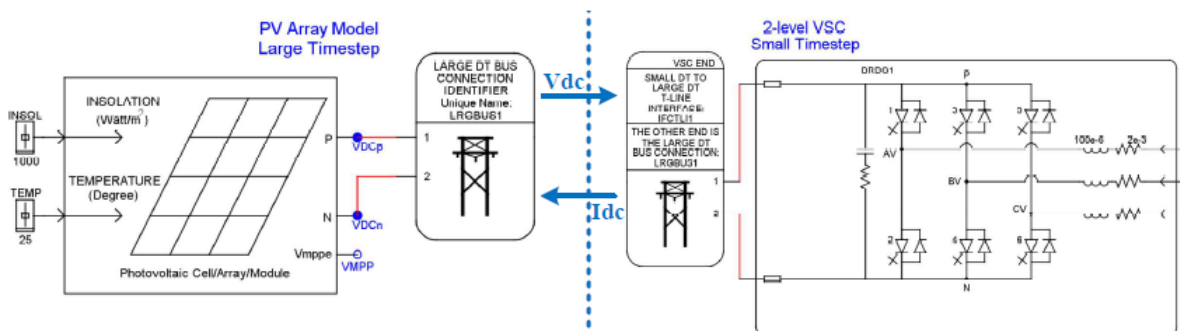


Figure 6: Large to small time-step connection in RSCAD/Draft

Furthermore, the PV system model has a feature which makes it easy to adapt to any size of grid. The small time-step VSC interface transformer which is used to connect the inverter AC side to the grid, has a scale factor to increase the current injection from the PV generator to the grid. Therefore, by selecting “Yes” for the option to ‘include scaling influence on large DT’ in the configuration menu shown in Figure 7, the scale factor can be used to control the solar PV generator power output without changing the array and control parameters.

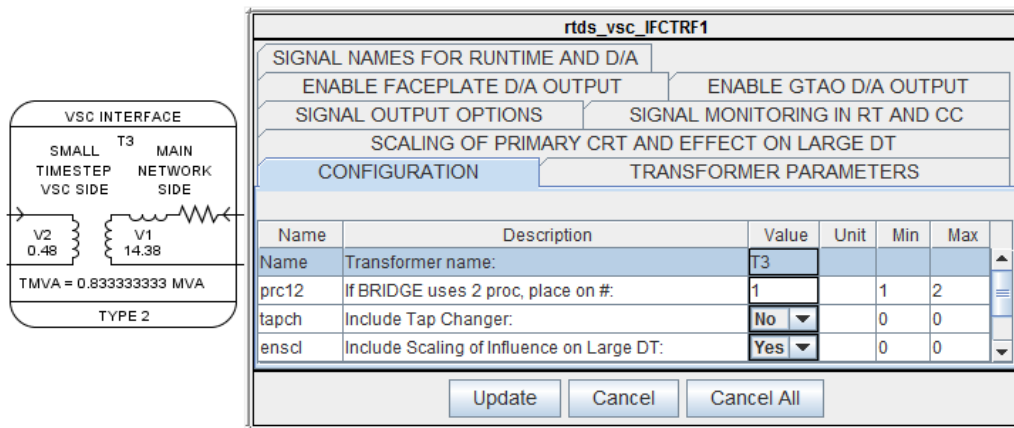


Figure 7: Configuration menu of VSC interface transformer

4.3.1. Tasks

1. Change the ‘Include Scaling of Influence on Large DT’ to YES as shown in Figure 7.
2. Place a slider to control the scale beside the VSC interface model and name the control signal as shown in Figure 8.

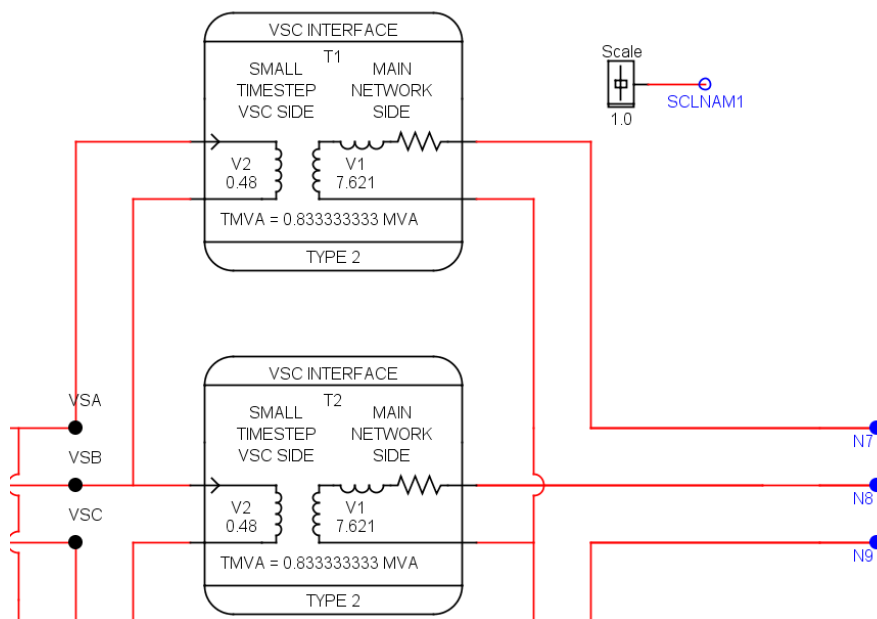


Figure 8: VSC Interface Scaling Slider

4.4. RSCAD Runtime

The description of the simulation and control of the PV system in the RSCAD/Runtime module is given in Figure 9. At the standard test condition of insolation, 1000W/m² and temperature, 25°C, the PV system is designed to deliver about 1.8MW at the DC bus voltage. The AC side of the inverter is interfaced to the selected bus on the distribution system using a 0.8MVA, 0.48/14.38kV, delta-wye VSC interface transformer.

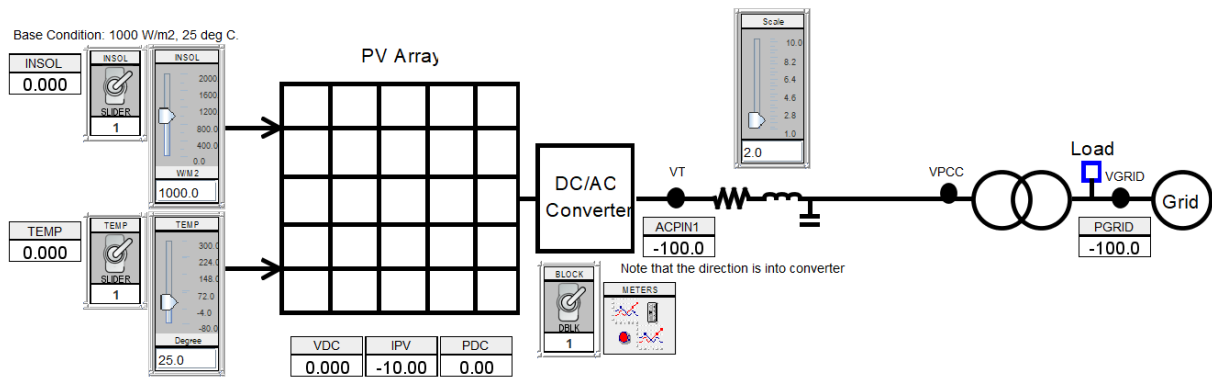


Figure 9: PV Simulation on RSCAD/Runtime

4.5. Dynamic Load Model

Dynamic single phase and three phase load models exist in RSCAD power system component library to represent different loads in the power network. The dynamic models can be used to adjust the load to maintain real and reactive power set points using a variable conductance. The load can be connected either in wye or delta configuration and modelled as series resistance and reactance (R-X) or parallel (R//X) connection. The power set points can be controlled using either sliders, control components or ZIP components through the ‘cc’ option in the load model configuration menu shown in Figure 10. When Slider is selected, the P and Q set points are initialized with the corresponding sliders in RSCAD/Runtime module. However, if the ‘cc’ parameter is set to ZIP component, the load computations are based on the percentages of the load which is constant power (PP, QP parameters), constant impedance (ZP, ZQ parameters) and constant current (IP, IQ parameters). When ‘CC’ is chosen, the power set points can be adjusted through control input wires connected to other control components such as the exponential load computation blocks. Finally, the load can be modelled as a constant impedance by selecting ‘ConstZ’ option thus implying the load is not dynamic.

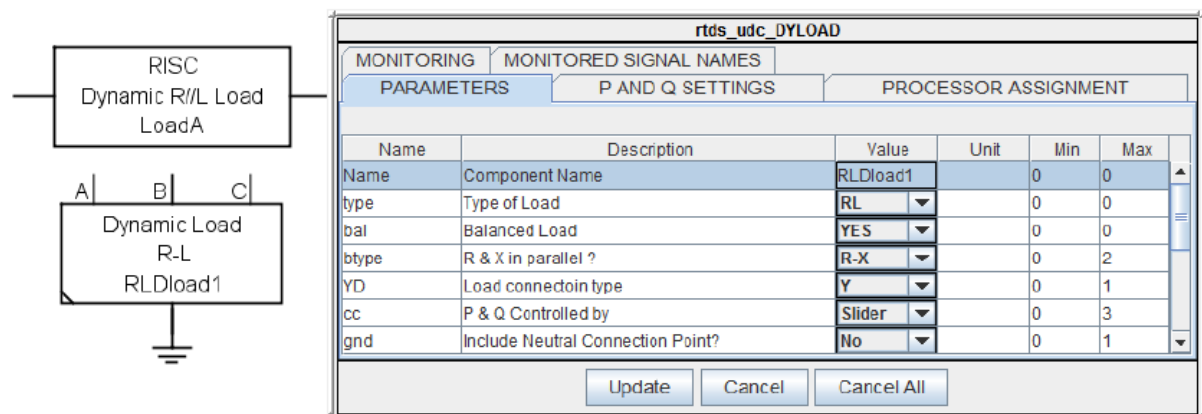


Figure 10: Load Model Configuration menu

5. Tasks

- 5.1. Compile SOLAR.dft and open the runtime file SOLAR.sib.
- 5.2. Start the simulation and observe the platform provided.
- 5.3. Observe the response to insolation changes by adjusting the insolation to 2000 using the slider INSOL and plot the effect on the DC bus voltage.
- 5.4. Return the insolation to the default value, then observe the response to temperature changes by adjusting the TEMP slider to 40. Plot the effect on the PV power output.
- 5.5. Adjust the scale of the PV output and show the effective rise in the injected power.
- 5.6. Switch ON the load, observe the changes in the measurement meters, then double the load demand and state your observations with appropriate plots.
- 5.7. Set all sliders back to their default values and calculate the power conversion efficiency. $\eta = \frac{PAC}{PDC}$
- 5.8. Stop the simulation.
- 5.9. Return to the draft window, open the parameters window of the dynamic load model, change 'P & Q controlled by' from Slider to ZIP component and recompile the case.
- 5.10. Return to the Runtime window and include the sliders for the ZIP component.
- 5.11. Adjust the percentage of the Z, I and P components and observe the effect on the overall load demand.