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SIMULATION AND ANALYSIS OF THE PERFORMANCE SINGLE-PHASE ONE-STAGE PHOTOVOLTAIC SYSTEM

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ABSTRACT
Photovoltaic systems have a particularly important role among renewable resource-based technologies. The conversion of solar energy into electricity is carried out without harmful emissions. Taking into account that, on the one hand, old coal-based technologies have a problem with the emission of harmful particles, nuclear technology carries with it a high risk of electricity production, and on the other hand, the photovoltaic conversion is pure and harmless based on almost limitless source of solar irradiation, it can be said that photovoltaic systems will be the unavoidable energy potential of the future. The fact is that an increasing share of electricity produced comes from photovoltaic systems.
However, the main problem of the photovoltaic systems is that the level of the newly produced electrical energy depends on the working conditions of the photovoltaic arrays. The voltage at which the maximum output power is obtained varies depending on the period of day (the solar irradiation) and the ambient temperature.
In this paper, single-phase one stage grid connected photovoltaic system performance will be analyzed, with particular reference to the possibility of obtaining maximum output power for the purpose of using a specially created algorithm.
Keywords: photovoltaic, cell, MPP tracking, PWM generator, modulation

1. INTRODUCTION
The basic part of each photovoltaic system is photovoltaic solar cell. For higher output power of PV cells connect by making photovoltaic modules. Depending on the required power, the module group is merged by making a photovoltaic string. The characteristics of individual modules differ in each other, regardless of whether they are made of the same manufacturer and the same material. The most important feature of each photovoltaic cell is efficiency. Efficiency of the whole system includes the efficiency and performance of the individual components of the system that depend on the way the system is installed. The output power of the photovoltaic system is the power available on the charge controller, indicating a peak or medium power value produced during one day. Criteria that determine the PV output performance are power, output energy, and energy conversion efficiency.

2. MODEL OF IDEAL AND REAL PHOTOVOLTAIC CELL
Provided that I_S is current of saturation, U_D voltage on diode, and U_T thermal voltage, then the basic equation from the semiconductor theory, that mathematically describes the U-I characteristic of the ideal PV cell is given by Shockley's equation:

$$I = I_{Ph} - I_D = I_{Ph} - I_S \cdot \left(e^{\frac{U_D}{m \cdot U_T}} - 1 \right) \quad (1)$$

The U-I charactereristic of the real PV cell include the presence of a voltage drop across the serial resistance R_S and drain current cross parallel resistance R_P:

$$0 = I_{Ph} - I_D = I_{Ph} - I_S \cdot \left(e^{\frac{U + I \cdot R_S}{m \cdot U_T}} - 1 \right) - \frac{U + I \cdot R_S}{R_P} - I \quad (2)$$

3. PHOTOVOLTAIC SYSTEM CONFIGURATION

In general, all PV topologies are classified according to the number of degrees of power processing, the location of the DC link capacitor, the use of transformers, the types of network interface and the number of phases. In this paper, a single-phase one stage model is used as an example, the topology of which is shown in the Figure 1. and which is realized in the Matlab/Simulink, Figure 2.

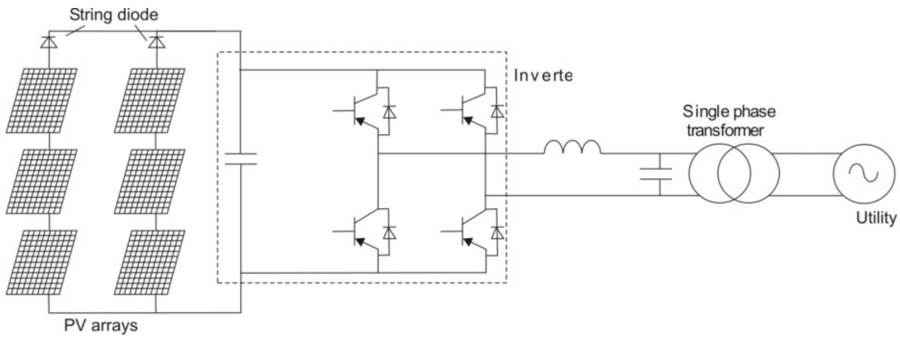

Figure 1. Topology of single phase, one stage PV systems

In the example used in this paper, the PV string consists of 14 Trina Solar TSM-250 modules connected to the series. At a temperature of 25 C and a solar irradiation of 1000 W/m^2 string produces 3500 W of power.

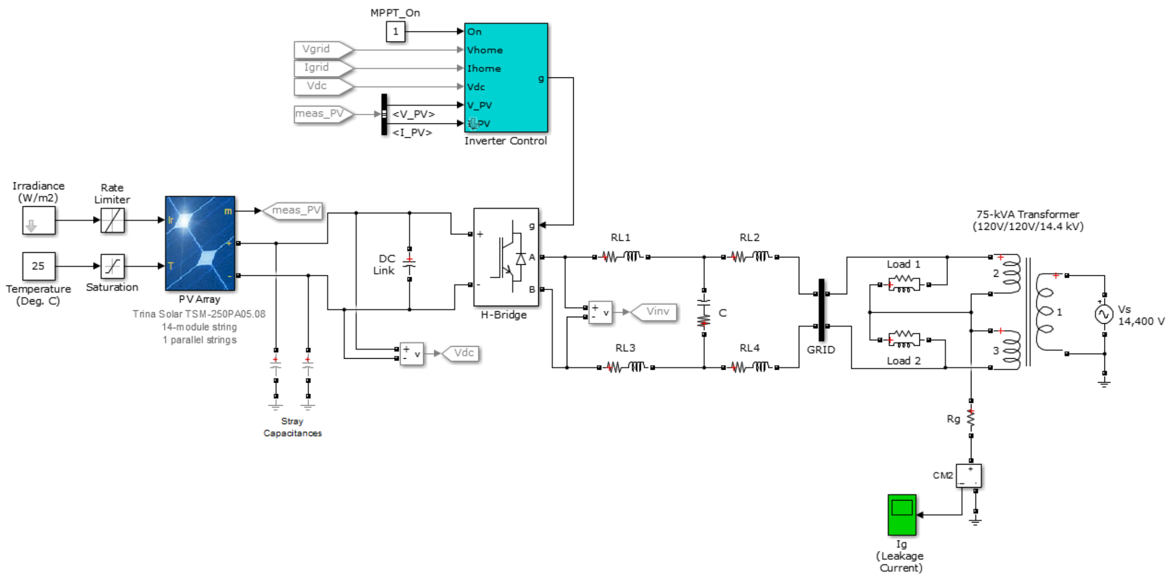

Figure 2. Model of single phase, one stage PV system realized in Matlab/Simulnik

Two small capacitors connected to + and - terminals of the PV string are used to model the parasitic capacitance between the PV module and the earth. The input parameters of the PV string are solar irradiation in (W/m^2) and temperature in (°C).

3.1. Single phase DC/AC inverter

Inverter converts the DC output voltage of the solar PV module to AC voltage of the network with a certain degree of efficiency. This conversion depends on the efficiency, precision and speed of the location of the maximum power point (MPP tracking). The maximum power point location efficiency is based on the maximum power point algorithm. It should be taken into account that photovoltaic arrays can produce a certain amount of electrical power only under certain conditions.

3.2. Inverter control system

Inverter control system consists of five main Simulink based subsystems:

1. MPPT controler: MPPT controler is based on algorithm „Perturb and Observe'. This MPPT system automatically changes the V_{DC} reference signal of the inverter controller to obtain the DC voltage at which the maximum power of the PV string is achieved.
2. V_{DC} Regulator: determines the required I_d (active current) of the current controller
3. Current regulator: Based on reference currents I_d and I_q (reactive current), the regulator determines the required reference voltage of the inverter. In example used in this paper I_q is equal to 0.
4. PLL and measurements:it is necessary for the synchronization of voltage and current measurements
5. PWM generator: It uses the PWM method of bipolar modulation to generate the IGBT fired signal, because in that case there is no current flowing through the stray capacitance of the PV modules.

3.3. Load and network

The network is modeled using a medium-voltage transformer and an ideal AC source of effective voltage of 14.4 kV. The secondary winding of the transformer is made with midpoint which is grounded through a small R_g resistance. The load of 20 kW / 4 kVAr, 240 V voltage, is connected between two output terminals of the transformer.

4. SIMULATION AND ANALYSIS OF THE RESULTS

Initial input irradiation 250 W/m^2 and operating temperature 25 °C. In the stationary state (about t = 0.25 sec), PV voltage (V_{dc}) of 424.5 V is obtained and the extracted power (P_{DC}) from the string is 856 W. In t = 0.4 sec, irradiation is significantly increased from 250 W/m^2 to 750 W/m^2, Figure 3. Due to the performance of the maximum power trucker, the control system increases the reference voltage V_{DC} to 434.2 V to extract the maximum power from the PV string (2624 W). These values correspond to the expected values. For comparison purposes, I-V and P-V characetristics of PV strings have been shown based on the factory specifications, Figure 4.

If the I_g current is observed by SCOPE, it can be noticed that there is no current flowing through the stray capacitor of the PV module. This is due to the PWM method used in the filter topology. If the PWM unipolar modulation is selected (from the Invertor Control Menu) and the simulation repeats, a significant drain current is obtained.

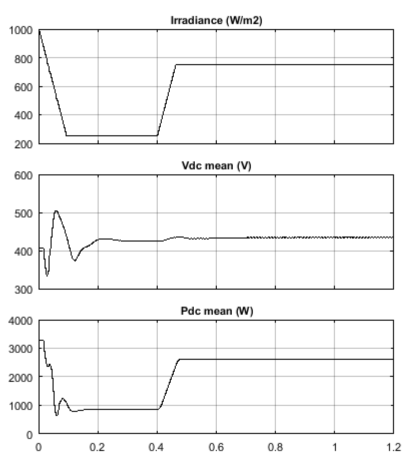

Figure 3. Irradiation, voltage of DC link and power output during simulation

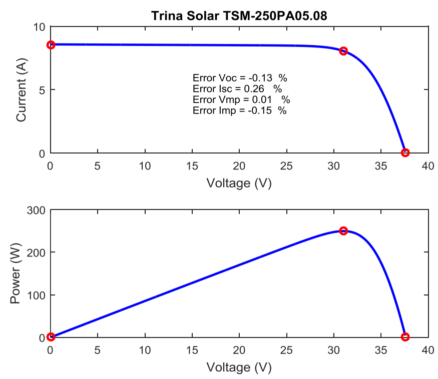

Figure 4. U-I and power characteristics of Trina Solar module

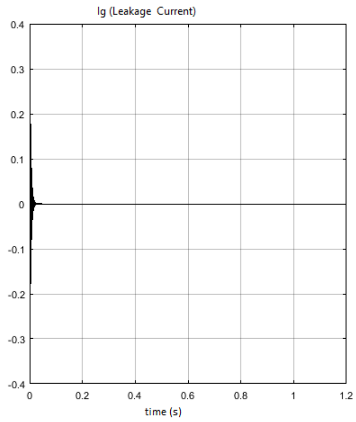

Figure 5. Leakage current in the case of PWM bipolar modulation of inverter control

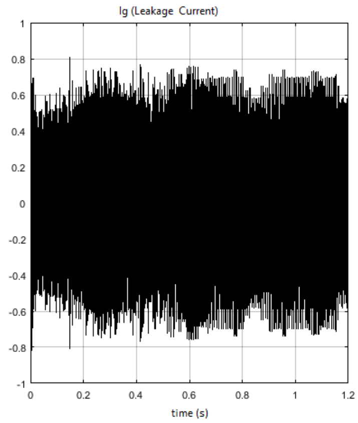

Figure 6. Leakage current in the case of PWM unipolar modulation of inverter control

5. CONCLUSION

The basic component of each photovoltaic system is the cell. The real photovoltaic cell differs from the ideal because it takes into account the voltage drop in the cell when transporting the carrier carriers from the semiconductor to the contacts. In addition, in the real photovoltaic cell, there are drain currents at the edges of the cell. It is important during the modeling of a whole photovoltaic system.

One of the most important features of the photovoltaic system is the energy conversion efficiency. In order to get the maximum ouput power, the photovoltaic system owns the MPP trucker. The MPPT system works on the principle of using a certain algorithm to achieve the maximum solar string power, whereby solar irradiation and temperature can be changed. The voltage at which the module produces maximum power is called the maximum power point. Maximum power changes with solar irradiation, ambient temperature and solar cell burst.

6. REFERENCES

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