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Simulation of MPPT Controller for photovoltaic system Grid-connected using Modelica

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Abstract - *As solar generation increases globally, there exists a need for innovation and increased operational flexibility. To ensure the stability and reliability in the electricity supply, power systems require complex dynamic analysis. Therefore, to carry out these analysis, modelling and simulation tools are needed. This paper focuses on approach is proposed to track the maximum power point (MPPT) of a photovoltaic system connected to utility grid. a free and open-source modelling and simulation environment based on Modelica language. In the later part, OpenModelica potential in large-scale power system-oriented models is investigated. These issues are addressed by a literature review concerning photovoltaic power systems and OpenModelica functionality, a theoretical analysis of a photovoltaic inverter and detailed simulations. The models are tested under variations in the active and reactive power requirements. The results show an optimal dynamic response and the capacity to perform independent active and reactive power controls. As an outcome, OpenModelica is a promising tool for power system modelling and simulation even though existing barriers and difficulties must be overcome.*

Key Words: *Modelica, (MPPT), photovoltaic, PV array, Solar Panel.*

1. INTRODUCTION

Renewable energy systems are growing very fast in all over the world and the research in PV and wind motivate the researchers to think about new control mechanisms to implement for some useful task. This article mainly focuses on MPPT based PV system. PV modules have nonlinear characteristics which are determined by solar insolation and temperature that affects the overall output power of the system. To account for this non-linearity, maximum power point tracking (MPPT) technique is implemented to increase the efficiency of the photovoltaic system. Commonly, researches developed MPPT techniques in two ways: hardware implementation and software modelling.

The main contribution of the paper is the modelling of buck converter using equation modelling, which allows the input voltage of the buck converter to be controlled by MPPT. PV module, buck converter and MPPT (P&O algorithm) are modelled using Modelica language. Since the main consideration is on tracking the MPP by adjusting the duty cycle of buck converter, output of the buck converter is considered as the general load. It could be a battery or electrical load.

(MPPT) algorithm which is control mechanism is used for extracting maximum power from PV array irrespective of environmental conditions. This results in increased efficiency of solar modules. The proposed model for this for this converter is given in Figure (1).

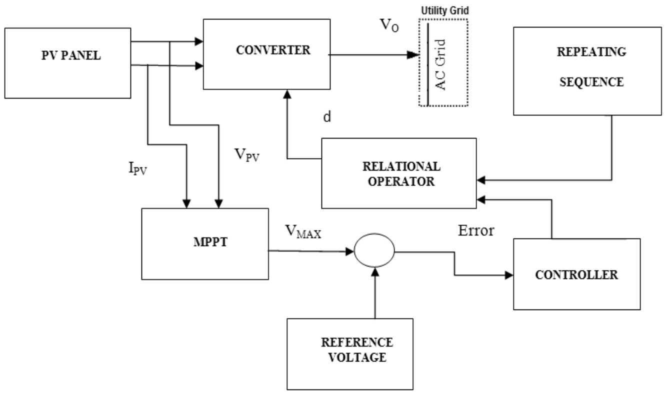

Fig.1: Schematic representation of proposed system

2. DESIGN OF PV MODULE AND MPPT

2.1 Solar cell model

The term PV source is used here to refer to the device where the PV effect is taking place, from the PV cell to the PV array. As it will be shown, a single model is sufficient to model any of these devices, hence the use of this umbrella term.

One of the traditional ways to model a PV source defined in this way is to use the equivalent circuit presented in Figure (2). This is known as the single-diode circuit model of the solar cell. A two-diode model also exists, but the single-diode version provides a decent approximation and is simpler [VGF09]. The relationship between the voltages and currents in Figure (2) can be established in the form of the following equation:

$$I = I_{pv} - I_o \left[\exp\left(\frac{V + R_s I}{V_t\, a}\right) - 1\right] - \frac{V + R_s I}{R_p} \dots\dots\dots (1)$$

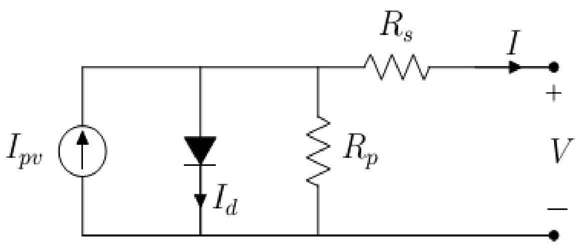

Fig.1: Equivalent circuit of a PV source

In this equation, each of the terms take the following form:

$$I_{pv} = I_{pv,n} + K_I \Delta_T \left(\frac{G}{G_n}\right) \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$I_{pv,n} = \frac{R_p + R_s}{R_p} I_{sc,n} \ldots\ldots\ldots\ldots\ldots (3)$$

$$I_o = \frac{I_{sc,n} + K_I \Delta_T}{\exp\left(\frac{V_{oc,n} + K_V \Delta_T}{a V_t}\right) - 1} \ldots\ldots\ldots\ldots (4)$$

$$V_t = \frac{KT}{q} N_s \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$\Delta_T = T - T_n \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where the values of Isc,n, KI, KV and Voc,n can be established from the data-sheet, the values of the following terms are known:

Gn = 1000W/m2 and Tn = 298.15K are the Standard Testing Conditions (STC) values of solar irradiation and temperature, respectively; k = 1.3806503 × 10−23 J/K is the Boltzmann constant and q= 1.60217646 × 10−19 C is the electric charge of the electron; Ns and Np are the number of cells in series and in parallel, respectively; finally, G, T are the actual solar irradiation and ambient temperature, normally considered inputs to the model, and I and V are the actual panel/array current and voltage.

Figure (3) shows the I-V characteristic curves of a photovoltaic cell at a constant ambient temperature but different radiation levels.

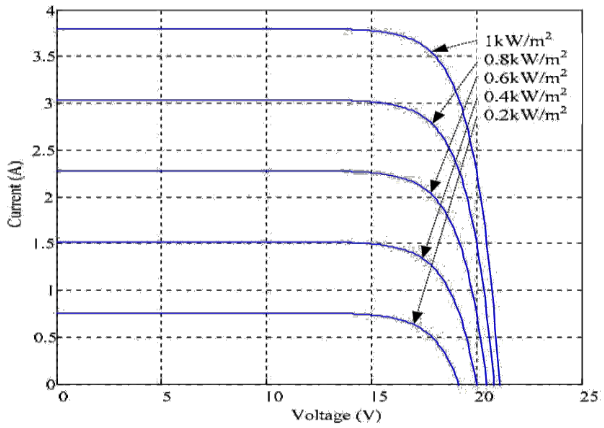

Fig .3: PV cell I-V curve at different solar

Radiation While figure (4) shows the I-V characteristic curves of a photovoltaic cell at a constant solar radiation but different ambient temperature levels.

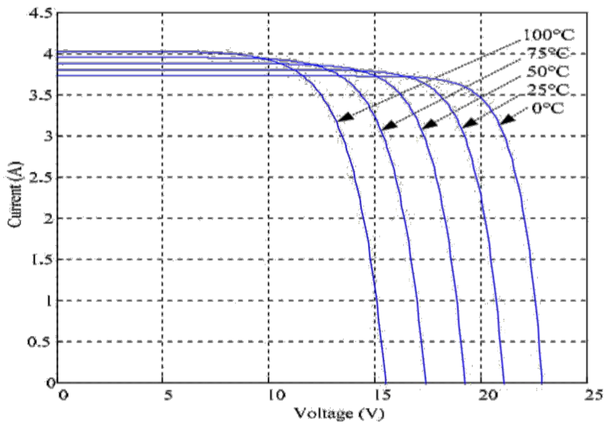

Fig .4: PV cell I-V curve at different temperature

Figure (5) shows the I-V characteristic of the solar cell for a certain ambient irradiation Ga and a certain fixed cell temperature T_C .

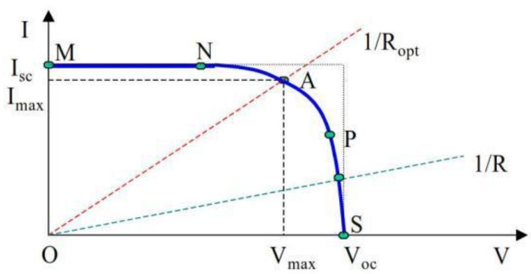

FIG.5: Typical solar cell I-V curve

In the representation of I-V characteristic, a sign convention is used, which takes as positive the current generated by the

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cell when the sun is shining and a positive voltage is applied on the cell's terminals.

If the cell's terminals are connected to a variable resistance R, the operating point is determined by the intersection of the I-V characteristic of the solar cell with the load I-V characteristic - see figure (4). For a resistive load, the load characteristic is a straight line with a slope I/V=1/R. It should be pointed out that the power delivered to the load depends on the value of the resistance only.

2.2 Inverter

As known, the PV arrays produce DC power and therefore when the stand-alone PV system contains an AC load, as it is the case for the inverter tied to grid system, a DC/AC conversion is required. This is thus the reason why this part briefly presents the inverter. An inverter is a converter where the power flow is from the DC to the AC side, namely having a DC voltage, as input, it produces a desired AC voltage, as out-put – see Figure (6).

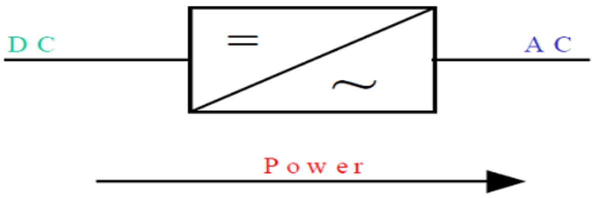

Fig.6: Connection of the inverter

The inverter is characterized by a power dependent efficiency η. The role of the inverter is to keep on the AC side the voltage constant at the rated voltage 230V and to convert the input power Pin into the output power POut with the best possible efficiency. The efficiency of the inverter is thus modelled as:

$$\eta = \frac{P_{out}}{P_{in}} = \frac{V_{ac} I_{ac} \cos \Phi}{V_{dc} I_{dc}} \quad , \quad I_{dc} = \frac{V_{ac} I_{ac} \cos \Phi}{V_{dc} \eta}$$

Where Idc is the current required by the inverter from the DC side (for example, from the controller) in order to be able to keep the rated voltage on the AC side (for example on the load). Vdc is the input voltage for the inverter delivered by the DC side, for example by the controller.

2.3MPPT

The Maximum Power Point Tracking (MPPT) is a technique by means of which maximum power can be extracted from the Photovoltaic (PV) Systems. To improve the energy efficiency, it is relevant to operate the total PV module always at its maximum power point. Many maximum power point Tracking (MPPT) techniques are available in the present era and among all these techniques P&O and incremental conductance algorithms are generally used in PV system for obtaining maximum power point.

In Figure. (7), Pm is the maximum power that can be obtained from a particular panel. The aim of a MPPT algorithm is to track Pm by making VPV to VM or IPV to IM.

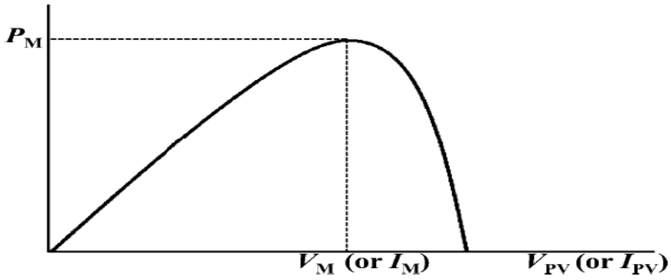

Fig.7: Power–voltage characteristics of photovoltaic systems.

The Perturb and Observe (P&O) algorithm operates perturbs the PV voltage periodically by varying the duty cycle, and observes the PV power to increase or decrease PV voltage in the next cycle. If the perturbation voltage produces an increase of the power, then the direction or slope of perturbation voltage. On the contrary, if the perturbation voltage produces a decrease of the power, then the direction or slope of perturbation voltage (duty cycle) is the opposite from the previous cycle

3. MODELICA IMPLEMENTATION &RESULTS

The system is simulated using Modelica is shown in Figure (8), the input of PV-module block is Va (PV voltage), Suns (irradiation), and TaC (operating temperature).

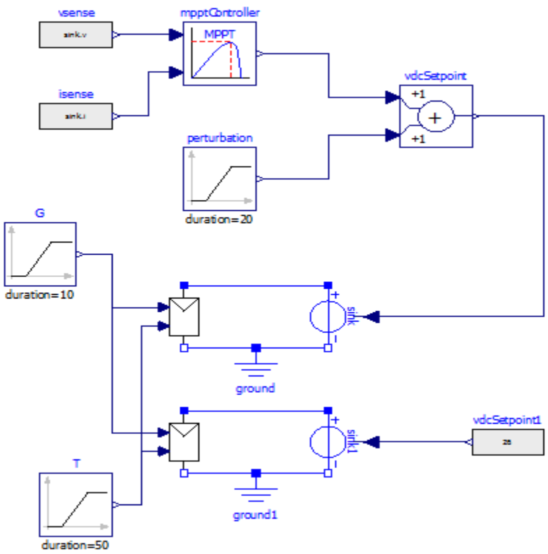

Fig.8: Model of PV system with MPPT & PI controller

A) PV Array

Figure (9)and figure (10) exhibit the current and the voltage of the photovoltaic array. It is clear that when the irradiation conditions change, the current increases (or decreases) significantly and the PV output voltage changes slowly.

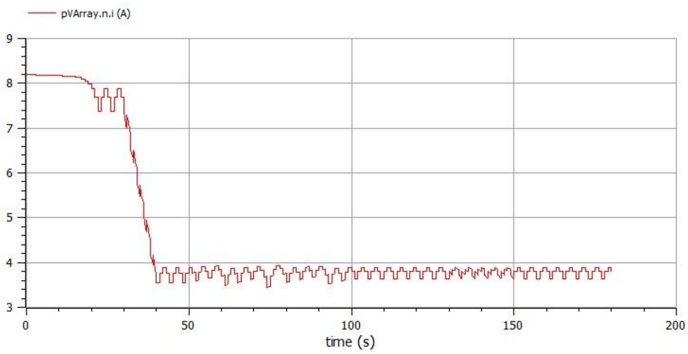

Fig.9: Photovoltaic current.

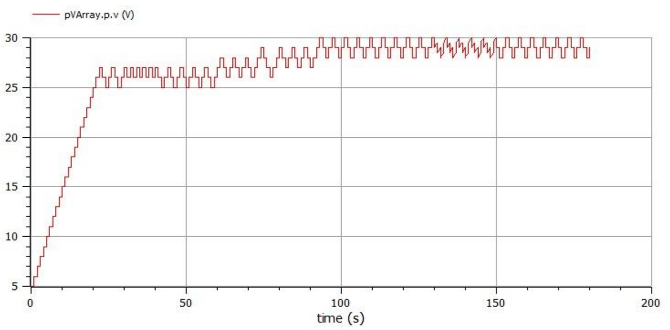

Fig.10: Photovoltaic voltage.

Figure (11) depicts the voltage and current waveform of VSC, connected to utility grid. Small harmonics are observed in the grid current waveform. These harmonics are due to the current injection by the semiconductor devices like wise IGBT based VSC. As expected the voltage and the current Va and Ia are in phase. Therefore, the system provides the power to utility grid with unity power factor.

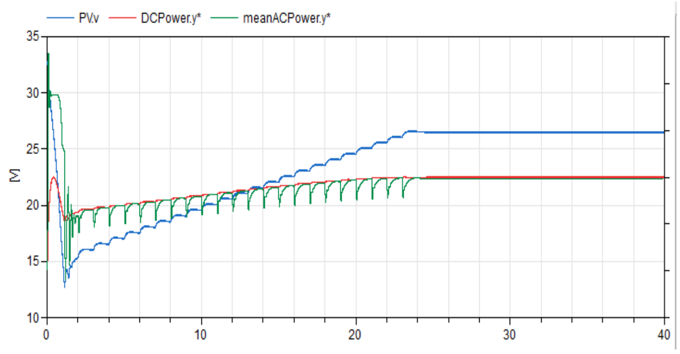

Fig.11: output power to the inverter

CONCLUSIONS

Here the stand-alone solar-PV generation system with CUK converter has been designed and the performance analysis of the system has been presented using Modelica software with different irradiance. From the steady state analysis it can be observed that the system attains the maximum power point tracking successfully despite of fluctuations in insolation. The system can track the maximum power point very quickly when the environmental condition changes.

OpenModelica performance in the studied power system models may not be still competitive with the domain-specific tools. However, consider OpenModelica limited resources compared to conventional commercial power systems software. Modelica is also developed with compensability and reusability in mind, with the inclusion of object orientation and causal equation based modelling and connection of components. This makes it easy to create models integrating several physical domains.

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