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Analysis and Design of a Maximum Power Point Tracker for a Stand-Alone Photo Voltaic System Using Simscape

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ABSTRACT

This manuscript presents the simulation of an MPPT and DC-DC Cuk converter for a solar photovoltaic module using MATLAB/SIMSCAPE. While the "Perturb and Observe" technique, as an MPPT algorithm, has many advantages, it also has some disadvantages. The widely used technique is simulated and the results are compared with those of other techniques for PV system performance evaluation. The photovoltaic characteristics, I-V & P-V curves are obtained for different solar irradiance values with ambiant cell temperature. Perturb and observe (P&O) and fuzzy logic controller (FLC) algorithms are described and the PV characteristics are obtained for fixed values of solar insulation and temperature for the PV system with a DC-to-DC Cuk convertor.

Key words: Solar Cells, Photovoltaic, PV Module, MATLAB/Simulink/Simscape.

1. INTRODUCTION

The energy extracted from the photovoltaic panel depends on different factors such as temperature, irradiance and efficiency. Moreover, the photovoltaic panel is also limited by the physical structure of photovoltaic cells. In fact, the efficiency of photovoltaic panel is very low. Different techniques can be used to increase the photovoltaic panel's extracted power. An intuitive solution is then to add more PV panels but will result in an increase in the space requirements and in a huge increase in the total cost of photovoltaic systems. However, one can also attempt to force the existing photovoltaic panels to continuously track its highest possible extracted power. To avoid the increment of the PV surface and consequently, the cost, a maximum power point tracking (MPPT) technique is used to force the system to work at its maximum extracted power.

Simscape is similar to Simulink in the sense of using block libraries but in plus, uses more the physical features of real devices and hence, is more suitable for physical components modeling. The non-directionality of Simscape element ports and their physical features allow their connection to be very similar to the connection of real components. Therefore, Simscape components can really be connected as soon as their real counterparts are connectable. In Simscape, all the problems of flow or information are resolved and do not cause any difficulty [1-4].

2. Modeling

The basic element of a PV module is called photovoltaic cell. More than one PV cellblock can be used to form a PV module based on series and parallel connections. As an illustration, a string of six PV cells connected in series is shown in Fig.1. While the figure 1 shows the irradiance to be the only input, temperature is also being an input of the configurable parameters [5].
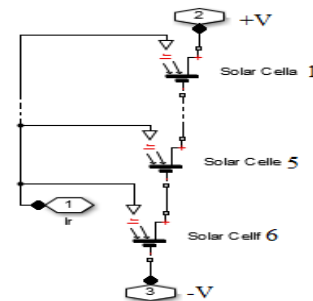

Figure 1: 6 Solar Cells Connected in Series.

A solar cell is modelled as a parallel connection of a current source, resistance R_p with two exponential diodes, all connected in series, with a resistor R_s. The model output current is simplified as in [6].

$$I = Iph - Is\left[e^{\frac{V+IRs}{AKT}} - 1 \right] - \frac{V+IRs}{Rp}$$

3. MAXIMUM POWER POINT TRACKING

Because of the dependence of the PV maximum extracted power on irradiance and temperature, MPPT techniques are necessary for PV performance optimization. MPPT techniques differ in number of sensors, cost, complexity, effectiveness and correct tracking for different irradiations

and temperatures. MPPT does not require mechanical tracking to direct the PV module or system to the sun but rather an electronic scanning system that control the operating point in such a way to result in a maximum extracted power. While environmental conditions such as temperature and irradiation change, the MPPT makes sure that the PV system operates as close as possible to its maximum power operating point. It is then desired to design a controller that forces the PV system to operate at its maximum extracted power (MPPT) [5-9].

4. Perturb and Observe

The Perturb & Observe technique shown in figure 2 is the most widely used algorithm in stand-alone PV systems. The technique consists of measuring the current and voltage and hence, the associated power p_1 is computed. This is then followed by a small perturbation of the voltage Δv, or the associated duty cycle ΔD of the DC-DC convertor, and the corresponding power p_2 is then calculated. The power p_2 is then compared to p_1 and if the difference $\Delta p = p_2$-p_1 is positive then the perturbation is in the right direction. Otherwise, the perturbation is reversed and the procedure continues until the maximum power point is obtained. Finally, the maximum voltage V_{Mpp} and current I_{Mpp} are deduced.

One disadvantage of using P&O is its deviation from the maximum power point when atmospheric conditions change rapidly. Another drawback is its need for precise perturbation size in order to result in dynamical and steady state operation performance [7].
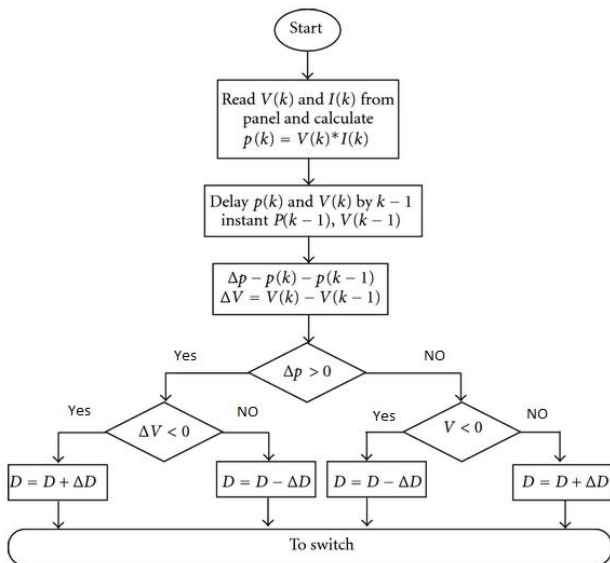

Figure 2: P & O Algorithm flow chart

5. CUK CONVERTER OPERATIONS

Several years ago, Dr. Cuk invented the integrated magnetic concept called DC transformer, illustrated in Figure 3. In this configuration, the DC flux created in the output winding L_2 is equal to the total of DC fluxes created in the input inductor $L_1$and the transformer T, respectively. Because the fluxes are in opposite direction, the resultant DC flux is canceled. One advantage is that the Cuk converter provides capacitive isolation, which protects against switch failure (unlike the buck topology) [8]. Another advantage is that the input current of the Cuk is continuous, and usually can draw a ripple free current from the PV array that is important for efficient maximum power point tracking (MPPT)[10].
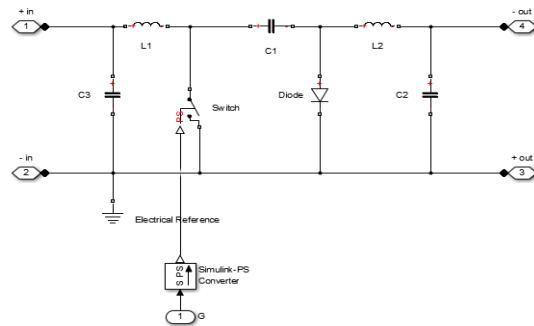

Figure 3: Simulation Model of Cuk converter

6. Fuzzy Logic Control

Among the reasons motivating the use of fuzzy logic control (FLC) in industrial process in recent years are its ease of use, it's no need for an accurate mathematical model and moreover, the possibility of using it in linear and nonlinear models.

Changes in voltage and power are the input variables in the fuzzy controller. The output from the fuzzy controller is then the change in the duty cycle. The fuzzy rules are built in order to control the system to achieve the desired performance. These rules are designed based on the designer experience [8-9].

7. Simulation of PV Module with P&O and FLC Based Controllers

In a first set of simulations, the PV module with the MPPT technique based on FLC is illustrated in Figure 4.
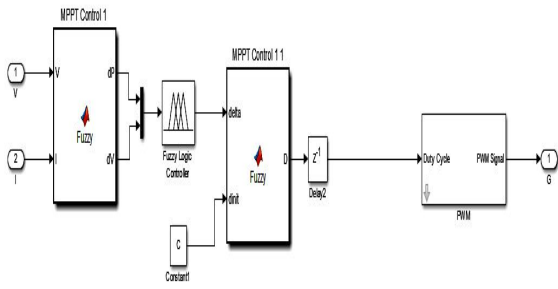
Figure 4: Matlab /Simscape Model of fuzzy logic based MPPT

The adopted PV Cell specifications are as shown in Table1 below,

Table 1: The PV Cell Specifications:

Number of cells in series	72
Open circuit voltage	20V
Short circuit current	5.5A
Voltage at MPP	13.6V
Current at MPP	4.9A
Maximum power	60W

The output power of the PV module with two different MPPT techniques are obtained in MATLB/Simscape environment at irradiance of 1000 W/m^2 and temperature of 25^{0}C. The simulation results demonstrate that the implementation of fuzzy logic and P&O technique for the tracking of the maximum power point is illustrated in Figure 5. The corresponding voltage variations in V$_{MPP}$ for these converters are shown in Figure 6.
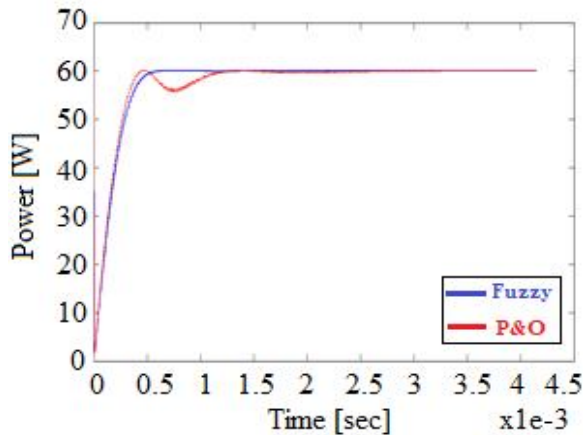

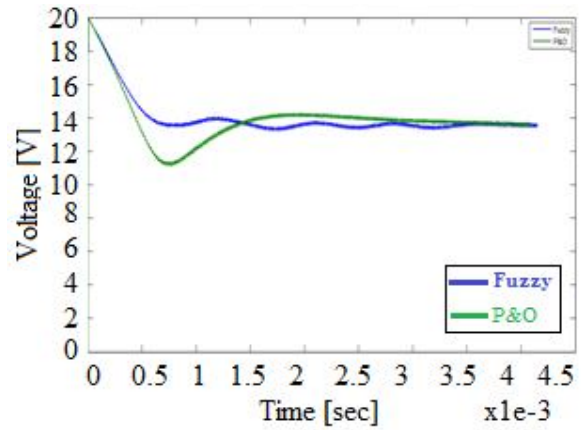**Figure 5:** Time domain behavior of the output power

Figure 6: Time domain behavior of the output voltage

8. CONCLUSIONS

In this paper, a stand-alone photovoltaic system is modeled and simulated using MATLAB/Simscape package. The maximum power point tracking (MPPT) technique P&O is presented and analyzed. The proposed system was simulated using the mathematical equations of each component in Matlab/Simscape. The simulation analysis show that P&O method is simple, but has considerable power loss because the PV module can only run in an oscillatory way around the maximum power point. From the simulation results, Fuzzy based MPPT tracks the power continuously with less fluctuation and has less overshoot than those resulting from the P&O techniques with faster tracking time compared to many other MPP tracking controllers.

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