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FPGA BASED MAXIMUM POWER POINT TRACKING OF PHOTOVOLTAIC SYSTEM USING ANFIS CONTROLLER

Muhammad Farzul Nizam Zolkifli, Mohamad Solehin Robian, Sharifah Saon and Abd Kadir Mahamad
Embedded Computing System Research Focus Group, Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, Johor, Malaysia
E-Mail: kadir@uthm.edu.my

ABSTRACT

Photovoltaic (PV) system is considered to be a renewable energy which is derived from solar energy. Solar energy is an abundant resource which is clean and green energy taken from nature. However, the amount of electric power generated by solar arrays varies with the weather. This will bring inconsistency in generation of output power. This paper proposes a maximum power point tracking (MPPT) of photovoltaic system based on Adaptive Neural Fuzzy Inference system (ANFIS) controlled using field programmable gate array (FPGA). The performance of proposed method is evaluated using MATLAB/SIMULINK. The proposed method is capable to maintain the consistency of power generated by solar panel under varies conditions.

Keywords: MPPT, FPGA, ANFIS, photovoltaic.

INTRODUCTION

Photovoltaic (PV) systems are widely used in various field. However, unpredictability of solar array makes PV systems less reliable. This caused the conversion efficiency of electric power generation very low. There are three main factors that affect power conversion efficiency; cell temperature, solar irradiation and series system of solar panel. The cell temperature and solar irradiation is an unsteady variable because it changes according to the weather. This will give uncertainty of the maximum power generated. Therefore, this project proposes to develop an Adaptive Neuro Fuzzy Inference System (ANFIS) controller which applies the use of Maximum Power Point Tracking (MPPT) using field programmable gate arry (FPGA) that aims to control and maximizes the output maximum power.

TRACKING ALGORITHM

For controlling the dc-dc converter, an adequate tracking algorithm is required. The tracking algorithm performance is fundamental for an efficient tracking response. Basically the tracking algorithm will receive the inputs which are PV module voltage and current and cooperates with dc-dc converter duty cycles that establishes the system operating point of MPP.

There have many control techniques proposed by other researcher such as Fuzzy Logic Controller (Mohammed S, 2012, Ait M.S Cheikh *et al* 2007, Alajmi M.S 2011), PI controller (Govind A., 2013), particle swarm optimization (Selvapriyanka, 2014) and many other techniques, but the most commonly employed of MPPT tracking algorithm which are Constant Voltage, Perturb and Observe (P&O) and Incremental Inductance (IncCond) (Swathy and Archana, 2012). Meanwhile, this paper work with ANFIS algorithm. Table-1 list the comparison of several MPPT tracking algorithm.

Table-1. MPPT tracking algorithm.

Method	Advantages	Disadvantages
Perturb and Observe (P&O) (Swathy and Archana, 2012)	➢ Limit response ➢ Fast.	➢ Loss generated power.
Incremental Conductance (InCond) (Swathy and Archana, 2012)	➢ Good performance.	➢ Low efficiency.
Adaptive Neuro Fuzzy Inference System (ANFIS) (Shanthi, T, 2014)	➢ Combination of neural network and fuzzy logic. ➢ Smooth and adaptable.	➢ Complex design.

METHODOLOGY

MATLAB and QUARTUS II software are used for simulation part, while FPGA DE2-115 board is used as controller. For the methodology, firstly, PV module is designed based on the SM Solar, SM140P PV module. The PV is designed based on the electrical characteristics provided by the manufacturer.

In MPPT controller, ANFIS method is used. ANFIS system required four inputs to be operated; current, voltage, step size and correction data signal. Throughout these all inputs, ANFIS will produced one output, V_{ref} as voltage reference for generate PWM signal. This PWM signal is crucial for driving the output power of MPPT system.

In designing the ANFIS model, the flowchart of the model design is as shown in Figure-1. The block diagram of the MATLAB-SIMULINK of ANFIS model is shown as in Figure-2.

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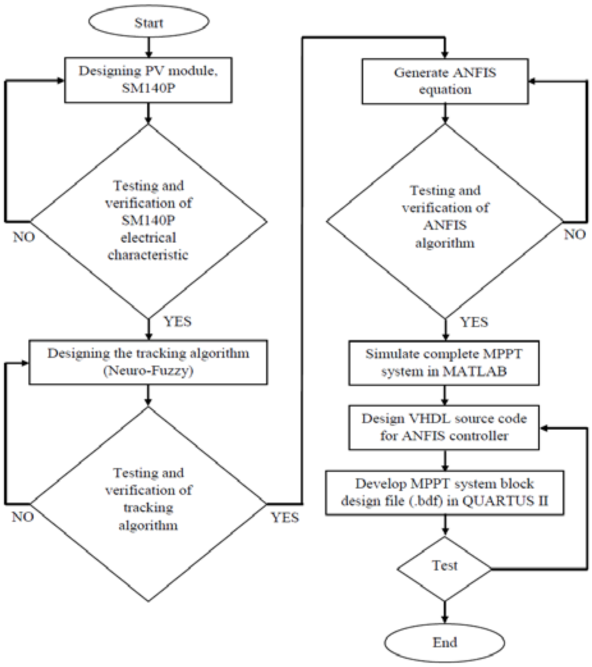

Figure-1. Flowchart of MPPT using ANFIS.

The VHDL of the ANFIS controller is develop for ANFIS block diagram design entry. Figure-3 shows the block diagram of ANFIS method implemented in QUARTUS II. The equation for ANFIS configuration is based on the mathematical expression generated by System Identification Tools by using MATLAB.

RESULTS AND ANALYSIS

In order to evaluate the output simulation, the time span for simulation is from 8am to 4pm. This is due to the dynamic variation of irradiance and temperature. The graph pattern shows the highest temperature and irradiance achieved are around 12pm to 2pm. Figure-4 shows the configuration of PV module inputs.

The performances of the MPPT controller is evaluated in MATLAB and QUARTUS II. The duty cycle generated is based on the current and voltage fed into the controller. By referring to the electrical characteristic of SM Solar SM140P, the maximum power produced is 140W under STC condition. MPPT controller delivered maximum power during the peak time of irradiance and temperature. The peak time of irradiance is between 12pm to 2pm.

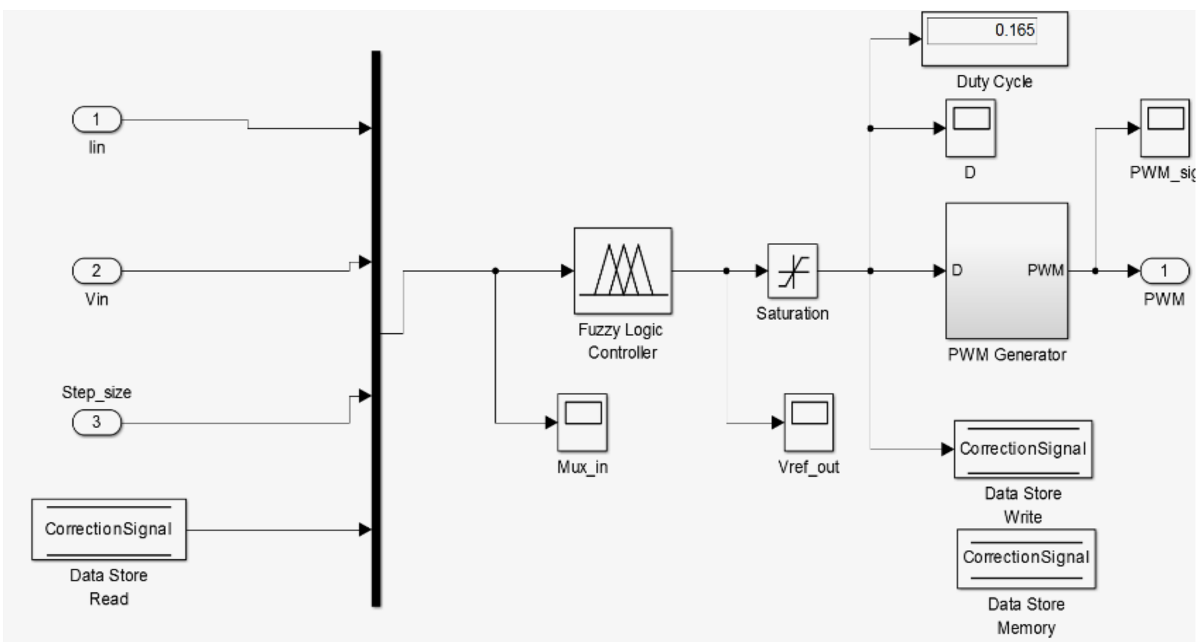

Figure-2. ANFIS model in MATLAB-SIMULINK.

The current and voltage input will calculated based on the ANFIS mathematical expression and produced the duty cycle. Then, the input voltage and current are manually fed into QUARTUS II software. The vector waveform (.vwf) is used to simulate the MPPT controller in QUARTUS II.

From the QUARTUS II, the vector waveform (.vwf) is used to simulate the MPPT controller. Figure-5 shows the output simulation from QUARTUS II.

Lastly the simulation result of MATLAB and QUARTUS II are compared and analysis is performed. Figure-6 shows the comparison between MATLAB and QUARTUS II simulations.

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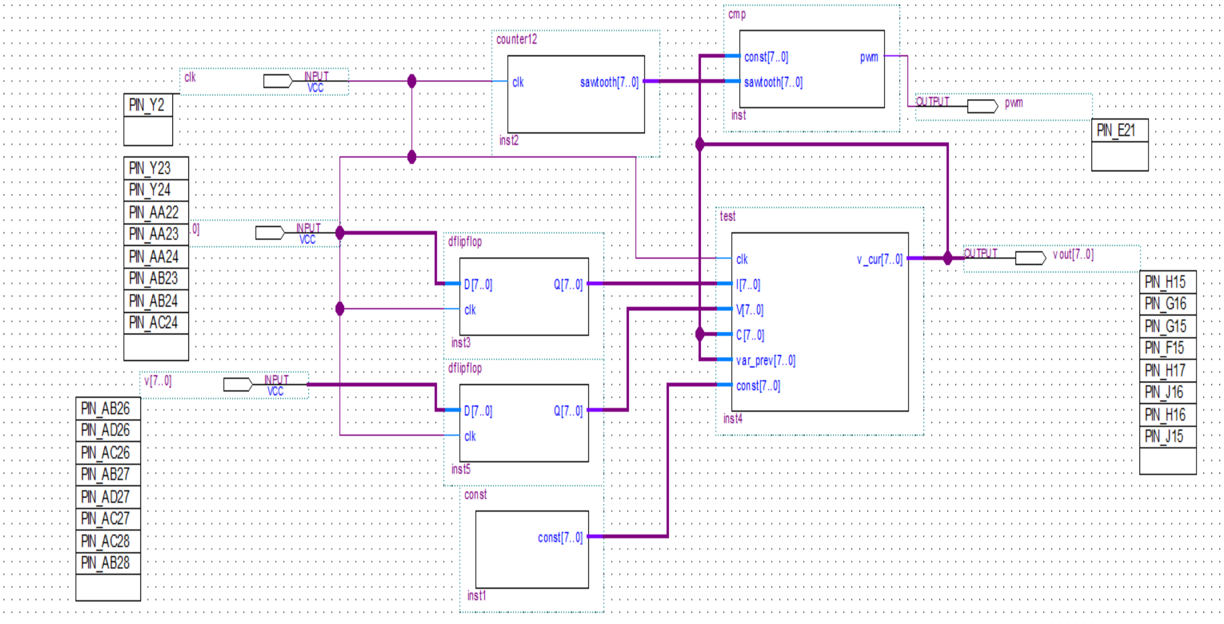

Figure-3. ANFIS block model in QUARTUS II.

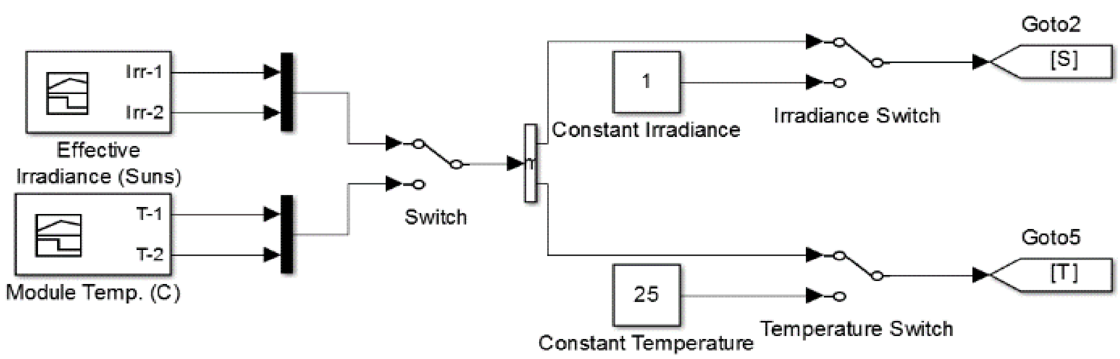

Figure-4. Configuration on input irradiance and temperature in MATLAB-SIMULINK.

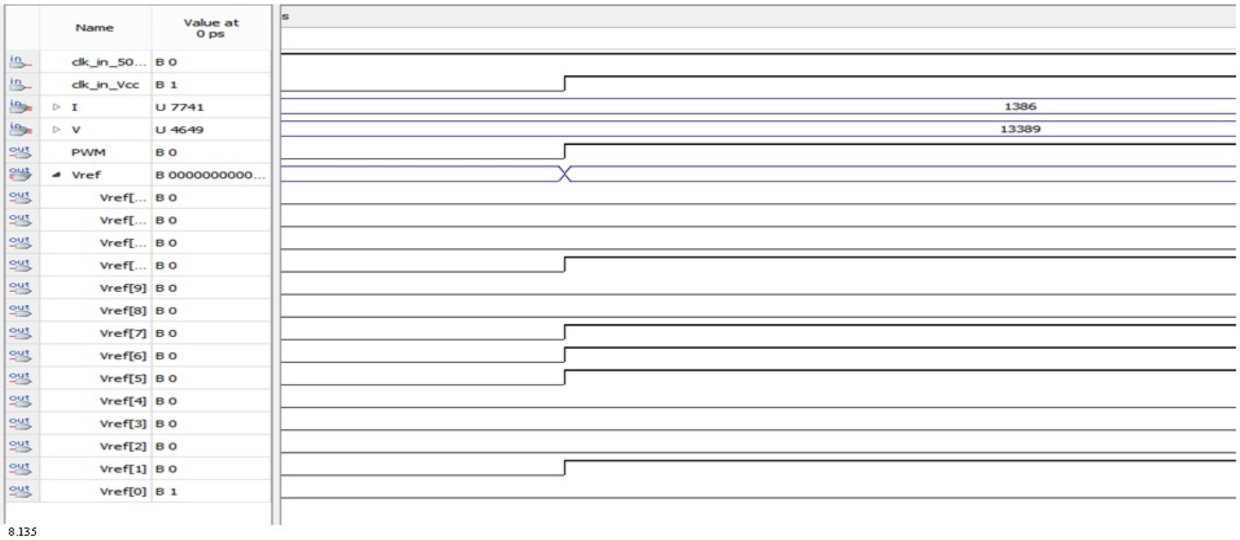

Figure-5. QUARTUS II vwf simulation.

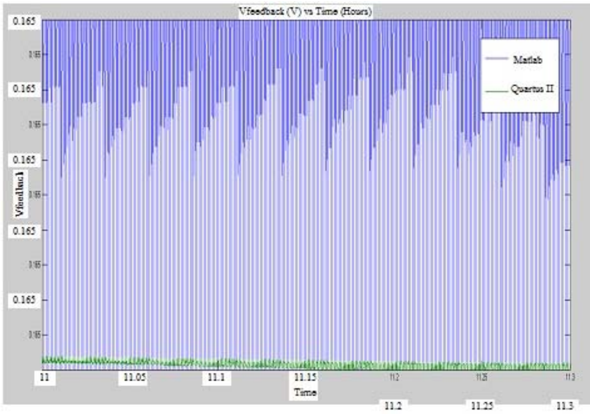

Figure-6. Comparison of MATLAB and QUARTUS II.

From the observation in Figure-6, the tracking pattern of both simulation result is obvious not the same. The amplitude of QUARTUS II simulation is lower due to the miss tracking at certain point. This is because the radix input for QUARTUS II is unsigned type while the input in MATLAB is floating point. Therefore at certain point, the calculation of VHDL is slightly not accurate compare to MATLAB.

CONCLUSIONS

This project aims to design a MPPT using ANFIS controller. The performances of the controller are measured in both MATLAB and QUARTUS II implementation. Based on the MATLAB-SIMULINK simulation result, the project has successfully achieved the objective and covered the scope.

The project proposes an FPGA based implementation which ANFIS is implemented in DE2-115 board. At the core of the system, the ANFIS controller is used to track the maximum current and voltage and eventually produce maximum output power. In implementing the MPPT system on FPGA board, it provides many advantages. Due to the high logic capacity in FPGA, FPGA performance surpasses other microcontrollers and DSPs performances. It can also be used to conduct in-circuit experiment, testing and optimize the parameters that affecting the MPPT system.

The tested scheme proved to work efficiently. The output simulation from QUARTUS II is approximately the same as simulation result from MATLAB-SIMULINK. This paper shows that FPGA can be used in developing a cost-effective and adaptable implementation of MPPT system. Therefore, based on the simulation results and analysis, it can be concluded that the aim and objectives of the project are successfully achieved.

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