A NEW METHOD TO DETERMINE AND MAINTAIN THE MAXIMUM POWER OPERATING POINT OF GRID -CONNECTED SOLAR POWER SYSTEM

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ABSTRACT

Grid-connected solar power system is increasingly widely used to exploit renewable energy sources infinite that nature presents to humans, which is solar. In this system, the maximum power that is emit from the photovoltaic panels (PV) depends on the intensity of solar radiation and temperature depends on the device. For each value of the intensity of solar radiation and temperature photovoltaic panels exist a maximum power point (MPP). To enhance the performance of the device we need to maintain the system work followed the maximum power point when the intensity of solar radiation and temperature change on the panels. This paper presents a method of determining and maintaining workplace that has a maximum capacity of grid-connected solar power system with using Adaptive Neuro - Fuzzy Inference System (ANFIS). The simulation results show that the intensity of solar radiation and various temperature changes the working point of the system is always sticking point that with maximum power.

Keywords: *grid-connected solar power system, MPPT, ANFIS*

INITIATION

Solar energy is one of the most important renewable energy sources that gifted by nature. Nowadays, one popular method to exploit and make use of solar energy that attracts multiple countries as well as Viet Nam is converting them to alternate electricity and connecting to general electrical power grid based on power electronic converter. That system is called grid connected solar power system. In the grid connected solar power system, the following parts are included: Photovoltaic cell, DC-DC converter, DC-AC converter, grid, maximum power point tracking (MPPT), and controller (Figure. 1).

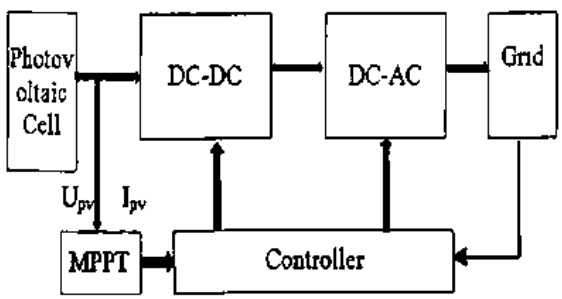

Figure 1: *Diagram of the grid connected solar power system*

The corresponding electrical diagram of a photovoltaic cell (PV) is indicated in Figure 2. Besides, the relation between current, voltage, and power (I, U, and P) of a photovoltaic cell (PV) depends on the intensity of solar radiation and their own temperature as explained in expression (1) [1, 2, 3,5]

$$I = I_{ph} - I_0\left(e^{\frac{U-IR_s}{AV_t}} - 1\right) - \frac{U-IR_s}{R_{sh}} \qquad (1)$$

where:

- I_{ph}: photovoltaic current (A)
- I_0: saturated reverse current (A)
- R_s: continous resistor of cell (Ω)
- R_{sh}: parallel resistor of cell (Ω)
- $V_t = \frac{N_s K T_c}{q}$
- N_s: the number of continuous photovoltaic;
- K: Boltzmann constant ($1.338.10^{-23}$J/^{0}K)

T_c: Working temperature of photovoltaic cell (^{0}C)

- q: charge of electronic ($1,602.10^{-19}$C)

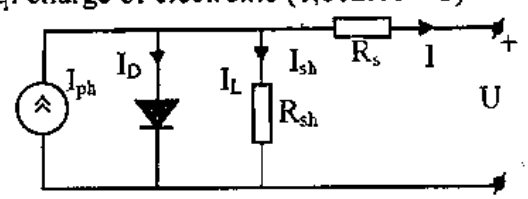

Figure 2: *The corresponding electrical diagram of photovoltaic cell*

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The relation I(U) and that of P(U) of photovoltaic cell are expressed in Figure 3, they are nonlinear relations.

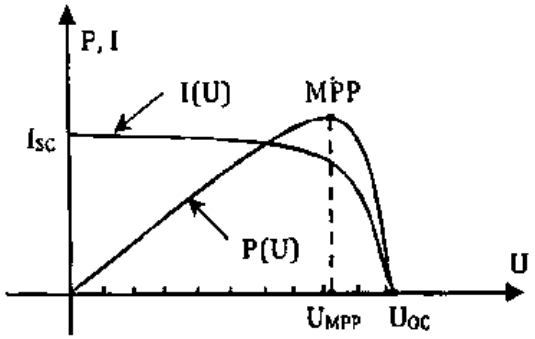

Figure 3: *The relation I(U) and (U) of PV*

On the curve of P(U), an existence of a point where the solar panel provides the biggest power which is called the maximum power point.

Supposing that a photovoltaic cell PV has characteristic of I(U) and P(U) corresponding to the defined value of solar radiation and temperature as Figure 4, the load characteristic of PV is a straight line 0m crossing the origin of coordinates, the working point of PV is the cross point between characteristic I(U) of PV and load characteristics of them. It is clearly seen that if PV module working at point C, it has the maximum power. The essence of detecting is modifying the gradient of load characteristic (line 0m) in such a way as to cross the curve I(U) at point C.

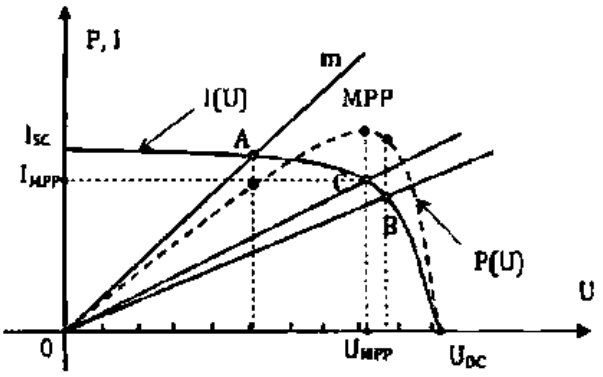

Figure 4: *V-A characteristics of load and solar cell*

During operation, due to solar radiation and the random adjustment of solar power panel temperature, the maximum power point (MPP) of PV is changed randomly. In order to efficiently utilize the power produced by solar cell at any time, the system must contain the maximum power point tracking and ensure that the system works at maximum power point incessantly.

Search algorithm for maximum power point normally carried out in DC-DC converter, for system without DC-DC converter, MPPT is implemented in DC-AC converter. There are variety of researches about MPPT such as the constant voltage method [3,4]; the disturbance and observation methodology [4]; the incremental conductance methodology [4]; the fuzzy control method [1, 5, 6]. In this research, we propose a method of applying Adaptive Neuron – Fuzzy Inference System (ANFIS) to determine and maintain the maximum power point for grid connected solar power system. The following parts present mathematic algorithm, modelling and simulating, report and conclusion.

THE ADAPTIVE NEURON FUZZY INFERENCE SYSTEM

ANFIS is a combined inference between fuzzy model Sugeno and artificial neural network. The ANFIS bears advantages of fuzzy system including explicit structure, simplicity of design but benefits the advanced priority of learning ability of Neuron network. ANFIS has 5- class structure as Figure 5 [3]. The first class has responsibility of fuzzilization of input variables, each of incident function is described by one neuron, the sharp of incident function can be either triangle, trapezium, or Gauss function... The output of ANFIS can be constants or linear functions. The invisible classes 2, 3, 4 have responsibilities of fuzzy inference, neuron in class no. 5 finishes the defuzzilization. The ANFIS may have multiple inputs but single output; the output variable is determined by expression (2)

$$\sum_i \underline{w}_i f_i = \frac{\sum_i w_i f_i}{\sum_i \underline{w}_i} \qquad (2)$$

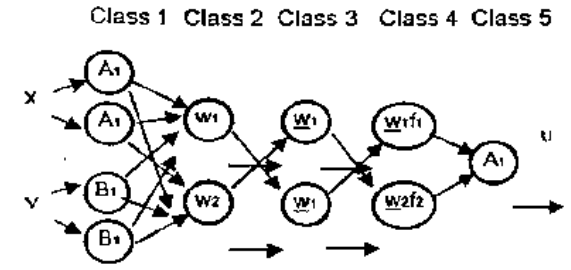

Figure 5: *Structure of ANFIS Network*

There are two possible training algorithms for ANFIS: Backropa and Hybrid [7].

ESTABLISHING MPPT BASED ON ADAPTIVE NEURON FUZZY INFERENCE SYSTEM

In this section, authors present the algorithm to indicate the maximum power point based on ANFIS foundation. The major contents include: choosing control structure, establishing training data and verification, installation of neuron fuzzy network, implementation of training and adjusting network to achieve desired error, modelling and simulating.

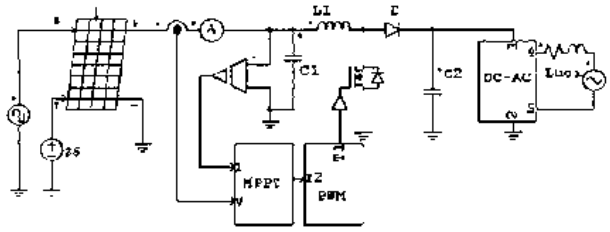

Figure 6: *Diagram of principle of grid connected solar power system*

The algorithm to determine and maintain the maximum power point is carried out by modifying operating condition of incremental voltage DC-DC converter. Therefore, the output voltage and output current of solar power panel must be measured.

The ANFIS controller has two inputs: voltage and current of photovoltaic cell. The output of ANFIS is brought to pulse width modification controller (PWM) to change the working regulation of voltage increase, therefore, the load characteristic is adjustable to cross the characteristic of I(U) of solar cell at the maximum power point.

Selecting the ANFIS controller has voltage and current inputs of photovoltaic cell. The voltage input is fuzzilized by six series of fuzzy which has Gauss function form, the current input is fuzzilized by eight series of fuzzy of Gauss function form. The incident functions are chosen similarly and separately, the output fuzzy is linearity. The training data include 300 data, 200 data for inspection part. Table 1 and table 2 illustrate several values of training data and table 2 indicates several values of inspection data.

Table 1: *Several values of training data*

u	i	u_{dk}
13.75167	3.747421	-3.34833
14.68876	3.746101	-2.41124
15.62247	3.717419	-1.47753
16.54304	3.635333	-0.55696
17.43195	3.456673	0.531952
16.59632	3.62848	-0.50368
16.99887	3.552842	0.098866
17.01408	3 537665	0.114079
17.29628	3.460079	0.396282
17.47939	3.391673	0.579386
17.19056	3.443852	0.29056
17.20692	3.413048	0.306918
16.97866	3.43067	0.078655

Table 2: *Several values of inspection data*

u	1.000000	u_{dk}
16.754242	2.146848	-0.345758
17.107153	2.101330	0.207153
16.700232	2.161279	-0.199768
17.040278	2.128492	0.040278
17 293020	2.102262	0.393020
17.040849	2.163080	-0.059151
17.572851	2 087284	0.672851
16.756802	2.252328	-0.343198
17.313973	2.199298	0.213973
16.688942	2.327389	-0.311058
17.265768	2.281062	0.165768
16.773211	2.397109	-0.126789

Start of training follows Hibrid method with 100 training period, we obtain the training error of 0.68564 and inspection error of 0.06861 that of acceptance. The parameters of ANFIS controller after being trained are shown in Figure 7 – Figure 11, where Figure 7 illustrates input and output data of the ANFIS, Figure 8 shows the discrepancies

after each training period, Figure 9 and Figure 10 describe the inference function forms after trained, Figure 11 presents the input-output relation after being trained It can be seen that after training, fuzzy sets for voltage variables rarely changed, however, a significant modification was recorded for fuzzy sets of current in both forms and their positions.

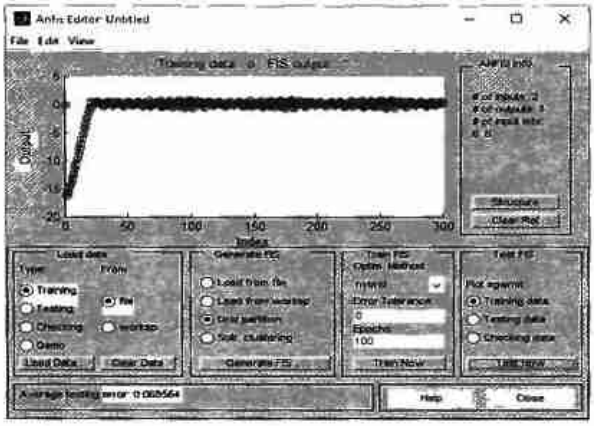

Figure 7: *Data sets for training and inspection*

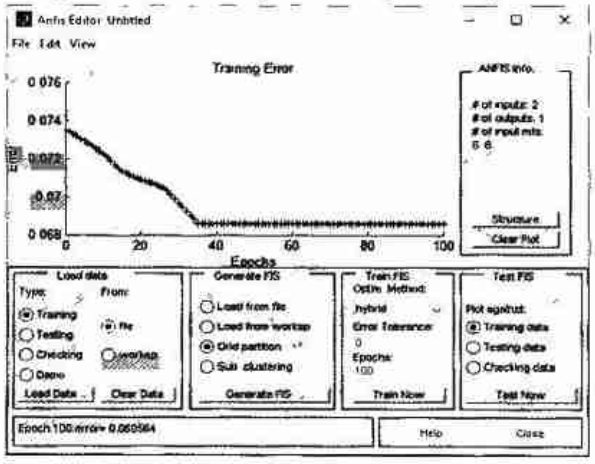

Figure 8: *The error curve during training process*

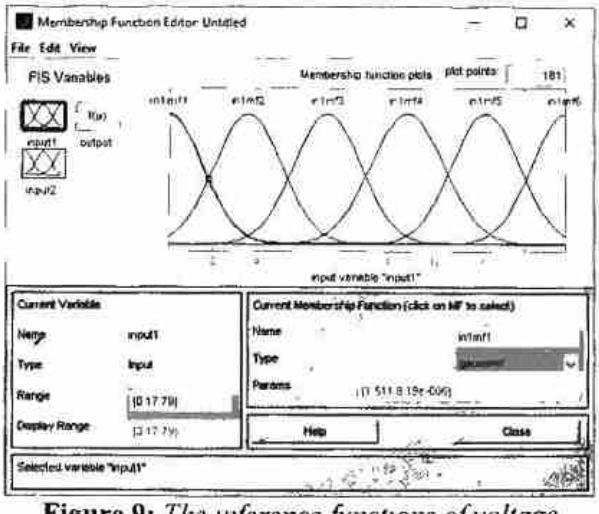

Figure 9: *The inference functions of voltage variable after being trained*

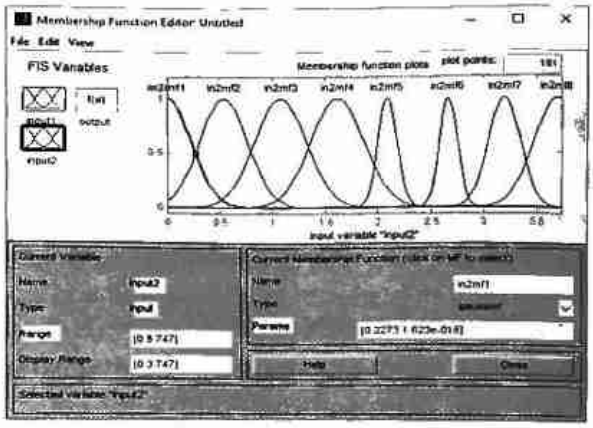

Figure 10: *The inference function of current variable after being trained*

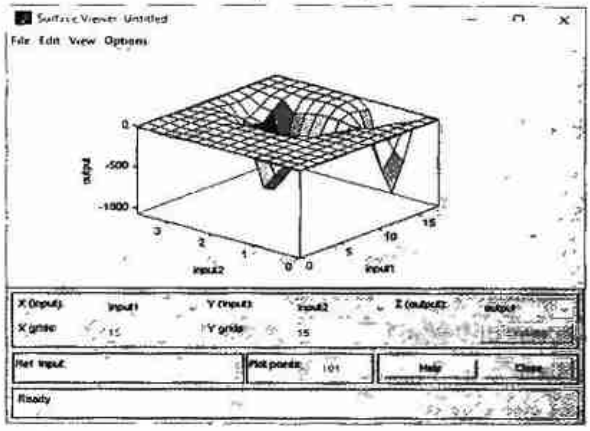

Figure 11: *The input-output relation of ANFIS after training*

Table 3: *Parameters of photovoltaic cell*

Parameter	Values
The number of cell pin (cell pin)	72 cell
Alternate range of solar radiation	from (800 – 1000)W/m^2
Operating temperature of solar cell	25^{0}C
Parallel resistor of solar cell	1000Ω
Continuous resistor of solar cell	0,008Ω
Short-circuit current	3,8A
Saturated current of diot (I_{s0})	2 10^{-8}A
Energy band E_g	1,12
Form factor A	1,2
Temperature affection coefficient	0,0024

SIMULATION RESULTS

To verify the proposed MPPT algorithm, we successfully modelled and conducted simulation for the grid connected solar power system. The simulation process was carried on Matlab-Simulink and Psim commercial software synchronously The parameters of the photovoltaic cell for numerical investigation are listed in Table 3, the output

voltage of voltage increase is 300V, the structure of Matlab simulation is shown in Figure 13 and that of Psim is presented in Figure 14.

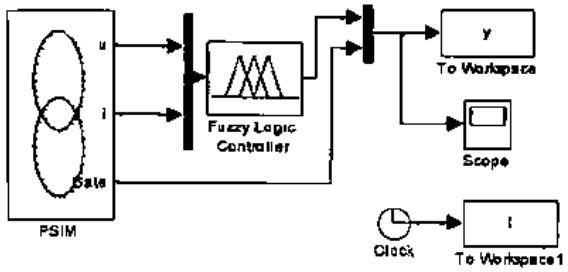

Figure 12: *Diagram of simulation in Matlab*

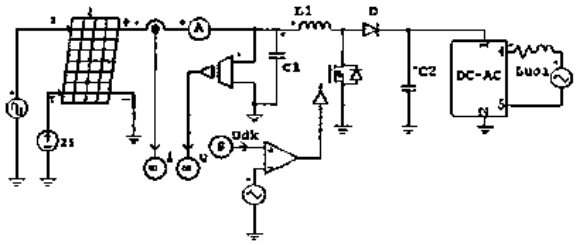

Figure 13: *Structure of simulation in Psim*

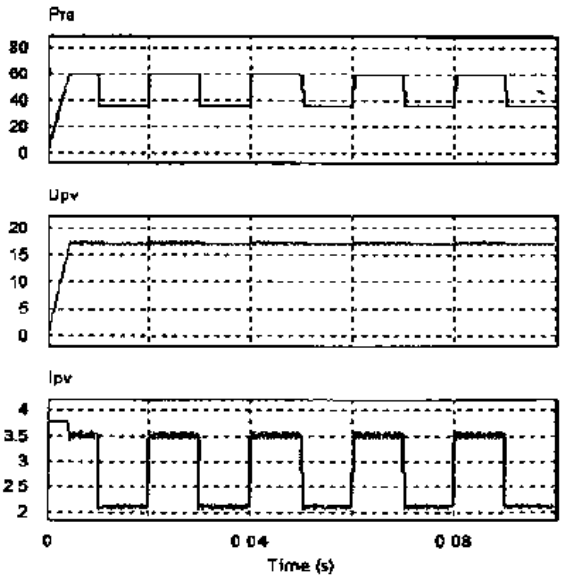

Figure 14: *Dynamic response of system*

Remark: The simulation results show on the figure 14 that the MPPT algorithm ensures the solar power system tracking the maximum power point while the solar radiation modifying.

CONCLUSION

Applying Adaptive Neuron-Fuzzy Network is able to train in order to implement determination algorithm and maitainance of the maximum power operating point of grid connected solar power. The simulation results obatained from Matlab-Simulink and Psim indicate that our proposed method is feasable.

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6. Matlab simulink.

TÓM TẮT

MỘT PHƯƠNG PHÁP MỚI XÁC ĐỊNH VÀ DUY TRÌ ĐIỂM LÀM VIỆC CÓ CÔNG SUẤT CỰC ĐẠI CỦA HỆ THỐNG ĐIỆN MẶT TRỜI NỐI LƯỚI

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Hệ thống điện mặt trời nối lưới đang ngày càng được sử dụng rộng rãi để khai thác nguồn năng lượng tái tạo vô hạn mà thiên nhiên ban tặng cho con người, đó là năng lượng mặt trời. Trong hệ thống này, công suất cực đại do các tấm pin quang điện (PV) phát ra phụ thuộc vào cường độ bức xạ của mặt trời và phụ thuộc vào nhiệt độ làm việc của thiết bị. Ứng với mỗi giá trị của cường độ bức xạ mặt trời và nhiệt độ tấm pin quang điện, có một điểm công suất do tấm pin phát ra là lớn nhất, gọi là điểm có công suất cực đại (MPP). Để nâng cao hiệu suất của thiết bị thì cần phải duy trì hệ thống làm việc bám theo điểm có công suất cực đại khi cường độ bức xạ của mặt trời và nhiệt độ tấm pin thay đổi. Bài báo này trình bày một phương pháp xác định và duy trì điểm làm việc có công suất cực đại của hệ thống điện mặt trời nối lưới bằng cách sử dụng bộ điều khiển nơ ron - mờ thích nghi (ANFIS). Kết quả mô phỏng cho thấy với các cường độ bức xạ mặt trời và nhiệt độ thay đổi khác nhau điểm làm việc của hệ thống luôn bám điểm có công suất cực đại.

Từ khóa: *Điện mặt trời nối lưới, MPPT, Anfis*

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