Dynamic Modeling of Photovoltaic System under Shading Effects using Neuro-Genetic Algorithm

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Abstract— *This paper introduces photovoltaic (PV) system considering shading for modeling and controlling study. A neuro-genetic algorithm is proposed to modulate and control a simple PV system consist PV module, DC-DC boost converter and load. Proposed intelligent algorithm is used to overcome many problems recognized with conventional modeling methods like Newton Raphson and classical maximum power point tracking (MPPT) controller techniques. Artificial neural networks (ANN) is used for identify PV model and to ensure the boost converter control. Genetic algorithm (GA) is second supply for training neural networks. Through the introduction of the heuristic structure, the distributed model and the clever MPPT algorithm are presented. The effectiveness of the proposed algorithm and the advantages and disadvantages of Incremental Conductance (INC) MPPT algorithm are examined, via comparative study, using MATLAB.*

Keywords: *PV system, MPPT, shading, neuro-genetic algorithm, modeling, controlling.*

I. Introduction

The energy through the solar photovoltaic effect can be considered the most necessary and prerequisite sustainable resource because of the ubiquity, large quantity, and sustainability of solar energy [1]. The study of photovoltaic systems in an efficient manner requires a precise knowledge of the IV and PV characteristic curves of PV modules. In [2] Seyed et al. have used Newton Raphson method due to the nonlinearity relationship between the output voltage and the current of the PV array. Converter characteristics are significant for PV applications. However the transfer of energy resulting from PV is not regular. Therefore, many MPPT controllers have been proposed in existing literatures. The more used are Perturb and observe ‘P&O’ and Incremental Conductance ‘INC’ [3], [4]. Also, many researchers have been considered other techniques in order to improve conversion power capabilities. Sliding mode [5], Fuzzy logic/Neural [6], Particle Swarm Optimization [7] and, many advance algorithms.

In this work Back Propagation (BP) neural networks algorithm has been developed to modeling and controlling PV system. In this method, genetic algorithm is used to off-line learning neurons in use. This purpose is feature advantages of high flexibility and less fluctuation around the maximum power point (MPP) which increase efficiency of the PV system. Also, it presented a simplifying model. This intelligent algorithm performed under shading of PV arrays. Obtain results show that the proposed Neuro-genetic MPPT method can track maximum power point in different temperature and irradiation, which has excellent output characteristic of high accuracy and good robustness as compare with incremental conductance method.

The sequential workflow of this paper is as follows: Section **2** covers mathematical modeling of PV panel using Newton Raphson method, and followed by brief discussion on boost dc-dc converter and incremental conductance MPPT algorithm. In sections **3** and **4** respectively, after problem formulation, proposed neuro-genetic MPPT control algorithm is explicate and designate as simulation works and results are discussed. Lastly, a precise conclusion has been added as confronted the work.

II. Modeling of PV Panel Using Newton Raphson Method

Fig 1 illustrates global scheme of the proposed PV system. It is composed of PV generator and DC-DC boost converter controlled by an MPPT to ensure the maximum generated power. Output voltage of the PV generator is very limited and very low for the application. To maximize the conversion efficiency of the power, it is necessary to have the operating point between the PV generator and the load very close to the MPP of the PV source. However, MPP changes with radiation and temperature, it is difficult to track at all radiations. A solution consists to introducing an adaptation stage between the PV source and the load is proposed to overcome this problem. The adaptation stage is a DC-DC converter controlled by an MPPT which works as an impedance adjustment.

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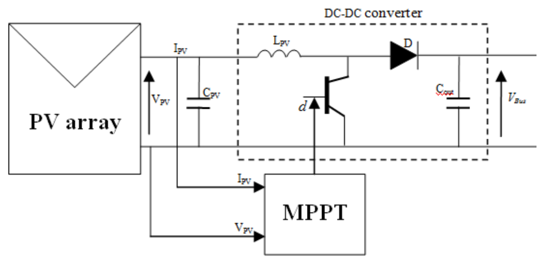

Fig 1: PV conversion power system.

Photovoltaic cell is the principal component in PV system. The association of a number of series and parallel cells create the PV module the same operation applied for modules create PV generator or array. For large arrays modules the previous equation of current is given by [8]:

$$I_{PV} = N_P.I_{ph} - N_P.I_0\left(\exp\left(\left(\frac{1}{A.K.\frac{T}{q}}\right).\left(\frac{V_{PV}}{N_S}+\frac{R_s.I_{PV}}{N_P}\right)\right)-1\right)$$
$$-\frac{N_P}{R_{sh}}.\left(\frac{V_{PV}}{N_S}+\frac{R_s.I_{PV}}{N_P}\right) \qquad (1)$$

Newton Raphson method is proposed as a solution for non linear systems. The method is based on linearizing the nonlinear equations and solving the resulting linear equations repeatedly [9]. First, the initial value $x^{(0)}$ should be chosen to be close to the true solution □x Considering a Taylor series expansion of $f(x)$ around $x^{(0)}$, $f(x)$ can be transformed :

$$f(x) = f\left(x^{(0)}\right) + \frac{df}{dx}\left(x - x^{(0)}\right) + \frac{1}{2}\frac{d^2 f}{dx}\left(x - x^{(1)}\right) + \ldots \qquad (2)$$

The third term of (2) is expected to be very small due to the square. Therefore, the linearized model (3) can be formed.

$$f(x) = f\left(x^{(0)}\right) + \frac{df}{dx}\left(x - x^{(0)}\right) \qquad (3)$$

Solving $f(x)=0$ for x leads to (4) on the assumption of $df(I^{(k)})/dt \ncong 0$.

$$x^{(1)} = x^{(0)} - \frac{df}{dx}\left(x - x^{(0)}\right)^{-1} f\left(x^{(0)}\right) \qquad (4)$$

If $x^{(1)}$ satisfies $f(x^{(1)})<\delta$ which is the threshold value of the end condition, can be determined as the approximate solution of □x . Otherwise, the above procedure is calculated repeatedly until satisfying | $f(x^{(1)})<\delta|0$. An iterative scheme of the method is described by:

$$x^{(k+1)} = x^{(k)} - \frac{df}{dx}\left(x - x^{(k)}\right)^{-1} f\left(x^{(k)}\right) \rightarrow (k = 1,2,3,\ldots.) \qquad (5)$$

The proposed method using one variable, will allow us to calculate the current I_{ph} with the initial value $x^{01} = I_{ph}$ as shown in Fig 2.

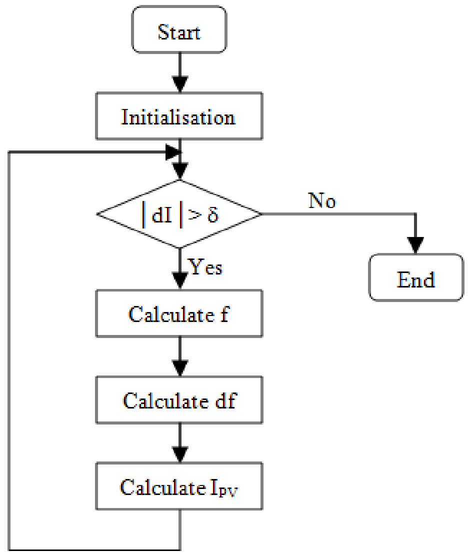

Fig 2: A flow chart of the proposed method of calculating Ipv current of PV array.

DC-DC converters are used to transfer generated power from solar panel to load side ensuring that maximum power has been transferred. The regulation is normally achieved by pulse within modulation (PWM). Boost DC-DC converter function is to step up DC voltage. Maximum power is reached when the MPPT algorithm changes and adjusts the duty cycle of the boost converter. Among various MPPT algorithms, convergence speed is one of the most important features which improves the efficiency and also increases the stability of the system. Incremental Conductance (INC) MPPT technique is used in this particular work. INC algorithm is based on Ipv and Vpv analysis of the output P-V characteristic. So the duty cycle must be augmented while the voltage rises on the positive side of the curve, otherwise the duty ratio had to be decreased on the negative side which features by Vpv reduction (Chiang et al., 2008).

III. PROBLEM FORMULATION AND PROPOSED ALGORITHM

Partially shaded of PV systems poses many problems of security and minimized the potential of the conversion system. Still, under partially shaded conditions, the P-V curve of PV arrays will have the characteristics of multi-summit, which makes the maximum power point tracking very difficult to accomplish. Fig 3 shows the shading on PV arrays.

Fig 3: Shading on photovoltaic arrays.

A P-V curve of PV model under shading effects is illustrates by Fig 4.

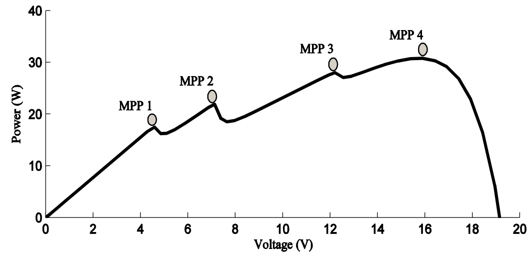

Fig 4: P-V curve of PV model under shading effects.

At present, the most commonly used MPPT are perturb and observe and incremental conductance methods which are also has some shortcomings, such as the tracking speed is slow, and the output oscillation is big. In other part, neural network is the most generic form of Artificial Intelligence for emulating the human thinking process, is particularly suitable for solving many important problems as PWM. For this raison, this work introduced the identification of PV model and MPPT method based on back propagation neural network (BP NN). The trained neural networks can output the optimal voltage for the maximum power point under various environment conditions. For training, genetic algorithm optimization technique has been adopted. GA has been recognized as an effective technique to solve optimization problems [10], [11]. Generally GA consists of three main stages; selection, crossover and mutation ([12], [13]). Solar radiance and temperature are input system and duty cycle is the output. The neuro- genetic algorithm is also used to prove more the performance of soft computing. The complete system block diagram of the proposed neurogenetic process is shown in Fig 5.

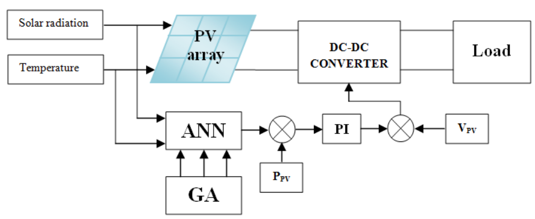

Fig 5: Proposed Process of PV system based NN-GA.

ANN should be trained periodically. Neural network inputs can be selected as PV array parameters and climate data, temperature or both of them .The output is usually selected one reference signal like duty cycle. Temperature and solar irradiation can be considered as input variables and PV power at maximum point is output. ANN trained at first using gradient descent rule and, after that by using GA. Fig 6 show training of ANN without and with using GA by means a many running of the process. It is notice that by training using GA we obtain an optimal error. Fig 7 illustrates the coherence of the GA algorithm that proves the fidelity. Many running of the algorithm show the density of the convergence of the GA algorithm always converged to around zero.

- The important parameters of GA are: Population size= 20; Crossover constant=0.7; Mutation rate=0.2; Maximum Generations=100.
- The important parameters of ANN are: Input layer: 2 neurons; Hidden layer: 10 tansig neuron; Output layer: 1 purelin neuron; Bais: 5 bais in Input layer and 10 bais in Hidden layer.

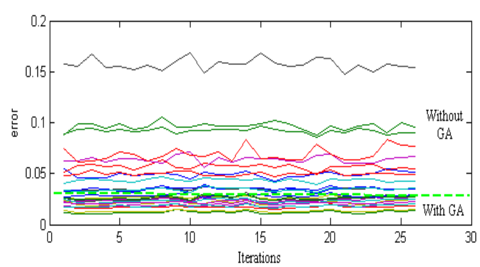

Fig 6: ANN trained without and with GA.

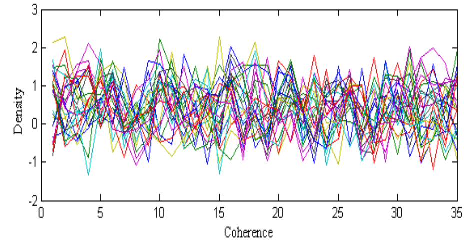

Fig 7: Coherence of GA.

IV. Simulation Results

At first, the INC and the NN-GA algorithms are simulated with constant values of solar radiations and temperature. Despite effect towards maximum power point from Fig 8, the INC show slow response time and produces high oscillation as compared with NN-GA maximum power point tracker method. The last simulation discuss with shading effects of MPPT algorithms in use. In this section, power is tested in four conditions in apply of different shading percentages of module during times are flowing:

- t=0→0.5s: panel not shaded.
- t=0.5→1s: panel 10% shaded.
- t=1→1.5s: panel 60% shaded.
- t=1.5→2s: panel 30% shaded.

The generated power illustrates by Fig 9. It is observed that the using of INC method generate less power compared with NN-GA. This fewer produce power is increased in case of more shading module always with INC but not with NN-GA. Consequently, INC did not find the MPP under shading. NN-GA can find the maximum power point of the power.

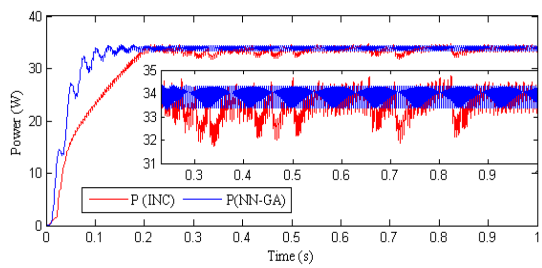

Fig 8: PV Power in out shading.

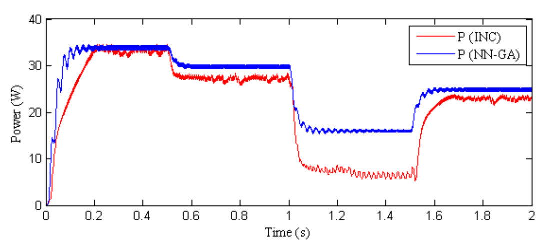

Fig 9: PV Power in shading.

V. Conclusion

In this work a proposed intelligent technique based on artificial neural network and genetic algorithm optimization technique for modeling and controlling a PV conversion system was presented. Artificial neural network was used to elaborate model and to control PV system. Genetic algorithm optimization technique was introduced for training the ANN. A simulation test of PV array under shading effects, via comparison analyze obviously, shows that the proposed neuro-genetic algorithm better performance with fast dynamic, low oscillation, more stable and extra conversion PV power due to ability of finding MPP under shading effects as compared to both conventional Newton Raphson modeling method and incremental conductance MPPT controller design.

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