INTERNATIONAL JOURNAL OF ENHANCED RESEARCH IN SCIENCE TECHNOLOGY & ENGINEERING
VOL. 2 ISSUE 1, JAN.-2013 ISSN NO: 2319-7463

A Particle Swarm Optimization based Maximum Power Point Tracking for Fuel Cell Compared with P&O algorithm

Masomeh Rezanejad[1], Mohammad Sarvi[2]
[1]M.Sc. Student, Saveh Branch, Islamic Azad University, Iran
[2]Asst. Prof., Faculty of Technical & Engineering Dept., Imam Khomeini International University, Iran.
[1]masomehrezanejad@yahoo.com, [2]sarvi@ikiu.ac.ir

Abstract: Devices for storage the electrical energy have become increasingly attractive. Fuel cell is a clean and efficient source of electricity. One of the most important factors to increase the density of energy and optimization of the fuel cell stack is utilization of maximum power point tracking (MPPT) algorithm [1]. In this paper a particle swarm optimization (PSO) maximum power point tracking is proposed. Simulations are performed in MATLAB/SIMULINK software. A system includes one proton exchange membrane fuel cell, a DC/DC converter, a resistive load and a maximum power point tracking algorithm control is analyzed and simulated. The simulation result of the proposed PSO MPPT is compared with a (P&O) method. The results verify the accuracy of the proposed scheme. Also the results show that the proposed method has better characteristic and performance in compare with P&O methods [2].

Keywords: Maximum Power Point Tracking, Improved Particle Swarm Optimization, Fuel Cell, Purturb & Observe.

INTRODUCTION

As the global energy reduces rapidly, renewable energy such as should be used. Due to advantages as the pollution-free, low maintenance and no noise, fuel cells systems are gaining increasing importance as a renewable energy [1, 2]. Fuel cell is on of the more promising generation systems of electric power at present and is particularly interesting as vehicle propulsion components. Some of the present-day challenges are the production and optimization of the fuel cell use in fuel cells based systems. In order to optimization, the ability to extract the maximum power from a fuel cell is necessary. When a fuel cell is directly connected to an external load, its output power depends on both the internal electro-chemical reaction and the external load impedance. The system's operating point is at the joint of the fuel cell's I–V curve and the load line [3, 4].

In this paper, a particle swarm optimization (PSO) algorithm, as called variable size of particle swarm optimization, is applied to track the maximum power point (MPP) of a fuel cell system is proposed. PSO is more suitable to search the global optimum in the fuel cell system. The PSO strategy is called variable size of particle swarm optimization. The moving step of particles in this algorithm is smaller than the traditional PSO. The strategy increases the movement step of particles at the initial iteration, and decreases it gradually with iteration. The particles are gradually close to the MPP of fuel cell until the iteration finish. In this paper the iteration is 50 that shows picture below.

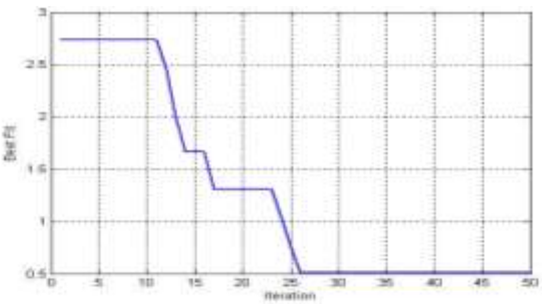

Fig.1: the iteration of simulation (50).

PSO based Maximum Power Point Tracking of Fuel Cell

When examining the typical fuel cell polarization and power curves, a point of maximum power is observed. This point depends on the fuel flow that feeds the fuel cell. It has to be remarked that the analysis is normally done at maximum fuel flow. Two of the effects that cause the degradation of the voltage are present with those conditions: activation voltage loss and ohmic voltage loss. An additional problem of this operation point is that with a small increment in the stack current, an additional power loss due to the concentration effect is experimented. Figure 1 show a simple model of fuel cell system [4]. As it is shown in Figure 1, different auxiliary components are required for the operation of a fuel cell. These components provide the reactive species, regulate the temperature and humidity, and guarantee the fuel cell security.

PSO method is a new evolutionary algorithm in recent years. It was proposed as an alternative method to the gas inspired by the social behavior of the bird swarms. It stars from a random solution, finds the optimal solution through iteration, and evaluates solution quality through the fitness. The PSO algorithm is more suitable to search the global optimum. In addition, the PSO algorithm is simple in principle, and has highly tracing accuracy and fast convergence. It assumes that the PSO algorithm has *m* particle with a coordinate $X_i= (X_{i1},X_{i2}...X_{id})$ in D-dimensional space. There is a fitness function fit_i associated with the objective function $f(X_i)$.
Each particle moves step by step in the D-dimensional space, with a certain speed $V_i=(V_{i1}, V_{i2} \dots V_{id})$. $Xp_i= (Xp_1, Xp_2...Xp_d)$ is the best position that i^{th} particle has passed in the movement, and *Xg* is the best position that all the particles have passed in the movement. Their movements in the space are being updated according to the direction of the best position of the swarm. The IPSO strategy is called variable size of particle swarm optimization. The moving step of particles in this algorithm is smaller than the traditional PSO. The strategy increases the movement step of particles at the initial iteration, and decreases it gradually with iteration. The particles are gradually close to the MPP of fuel cell until the iteration finish.[4]

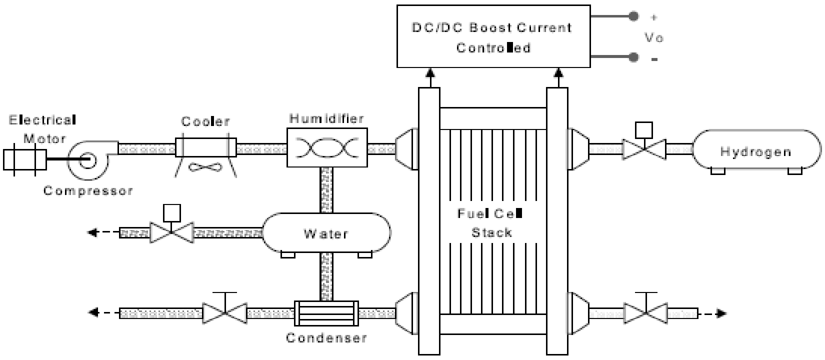

Fig.2: A sample model for Fuel Cell System

Simulation

A system includes one proton exchange membrane fuel cell, a DC/DC converter, a resistive load and a maximum power point tracking algorithm control is analyzed and simulated. The simulations are performed in MATLAB/SIMULINK environment. The simulation result of the proposed IPSO MPPT is compared with a conventional particle swarm optimization (PSO) and P&O (Perturb &Observe) method.[5]

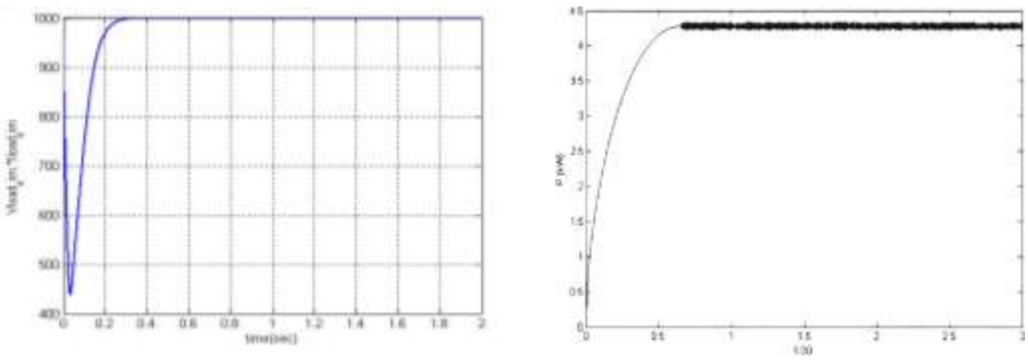

Fig.3: maximum power point tracking (Pmax) in standard condition by PSO compared with P&O Algorithm

The comparison between two algorithms shows that PSO algorithm has a better suitable response ratio P&O algorithm and it has arrived to maximum power point sooner at t=0.2s.
Results and P-I and V-I curves shows that the power of the fuel cell is completely nonlinear of ampere and severely are changed by changing of temperature .figure 4 shows the results.[5]

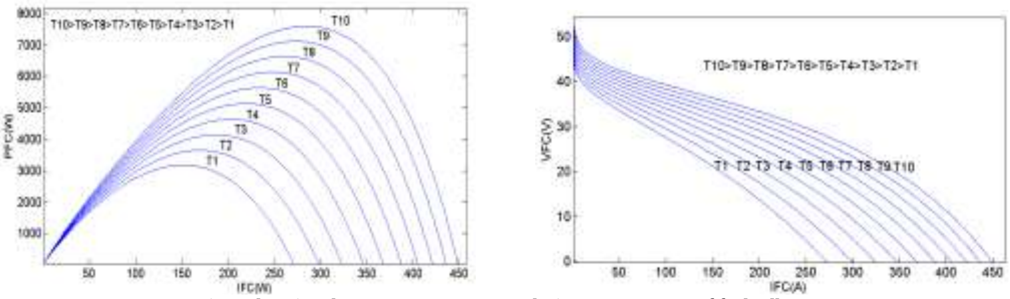

Fig.4: changing the temperature as a one the input parameters of fuel cell

In this section the results of simulation shows the changing of the duty cycle to tracking maximum power point. Fig 5 &6 shows the results.[5]

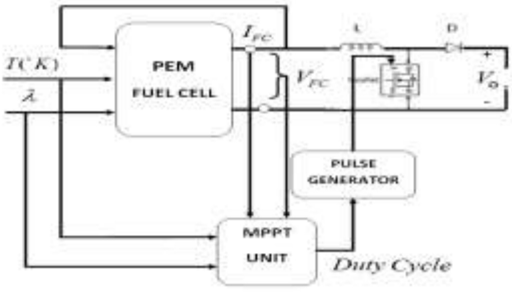

Fig.5: duty cycle in simulation

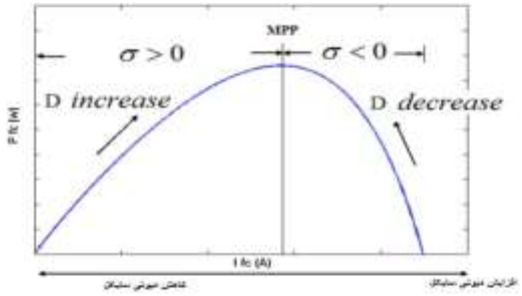

Fig.6: duty cycle in simulation

If we notice the fig 5 we can see one of the parameters of fuel cell that is T(k) and the other one is λ (humidity percentage). In this paper two parameters have compared to find the P-I and V-I curves. So in this paper λ=11 and T=343ºk have selected because we have gotten the best results. So fig 7 & 8 shows the results.

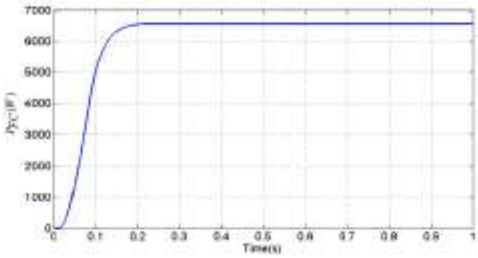

Fig. 7: P-t curve in normal operational condition in fuel cell λ = 11 & T=343ºk

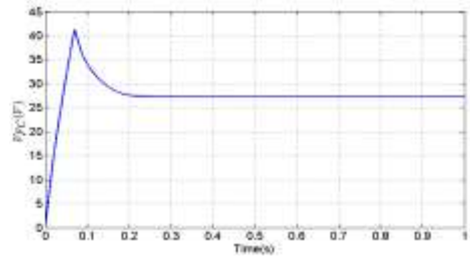

Fig. 8: V-t curve in normal operational condition in fuel cell λ = 11 & T=343ºk

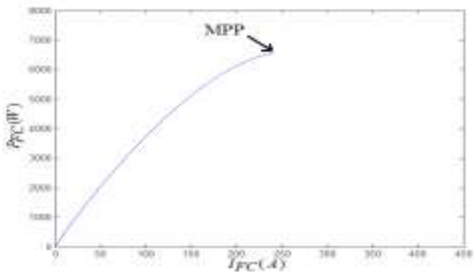

Fig. 9: P-I curve in normal operational condition in fuel cell λ = 11 & T=343ºk

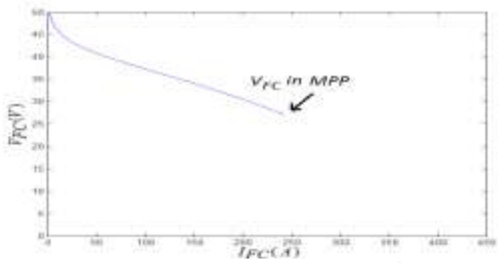

Fig. 10: V-I curve in normal operational condition in fuel cell λ = 11 & T=343ºk

Humidity percentage and temperature (λ=11 , T=343ºk) are constant. So in this status the optimized power point has received to 6.625KW.[6]

When λ=11 is constant and T is changed up and down so we will get good results. fig 11 , 12 , 13 shows. And the comparisom shows in Table 1.

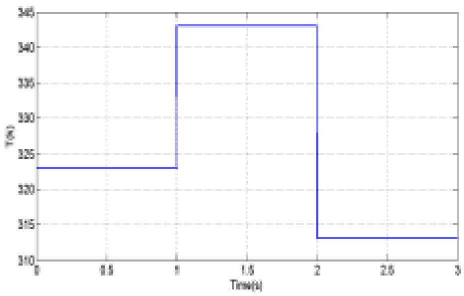

Fig. 11: changing T in t=1,2,3

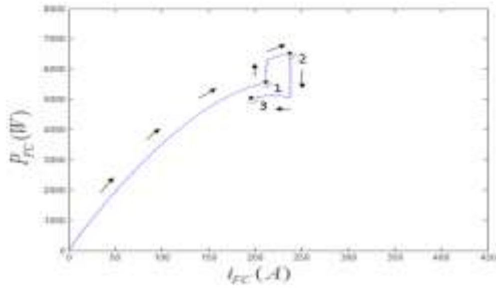

Fig. 12: P-I curve , λ=11 constant and T is variant

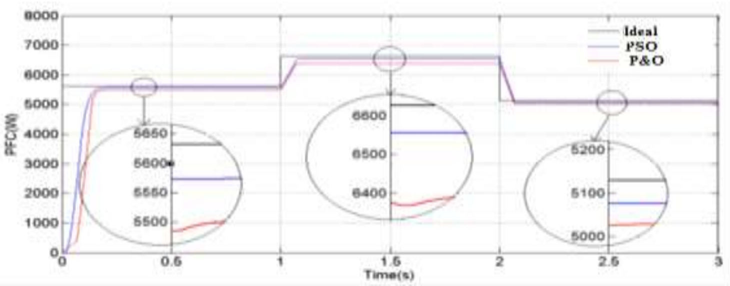

Fig. 13: P-t curve , λ=11 constant and T is variant and comparison with P&O algorithm

Table1. Comparison of PSO and P&O approaches results under fast variation of Fuel cell temperature in constant membrane water content λ=11.

	T=323 K		T=343 K		T=313 K	
Applied Method	Average P_{FC} value (kw)	Accuracy (%)	Average P_{FC} value (kw)	Accuracy (%)	Average P_{FC} value (kw)	Accuracy (%)
Analytical	5.632	100	6.625	100	5.130	100
PSO	5.573	98.95	6.556	98.96	5.077	98.97
P&O	5.501	97.67	6.380	96.30	5.025	97.95

When λ(membrane water content) is variant and changed up and down and T is constant so we will get a good results. fig 14 , 15, 16 shows. And the comparisom shows in Table 2.

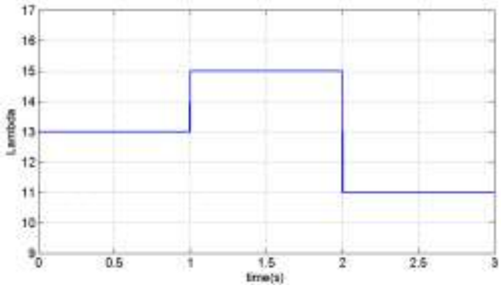

Fig. 14. Variation membrane water content versus time

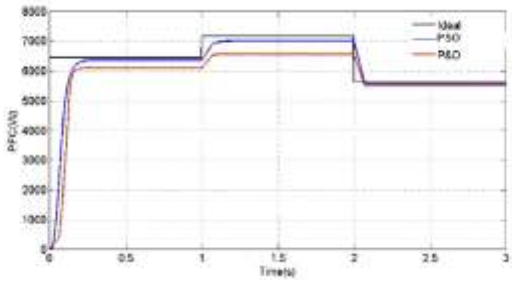

Fig. 15. : P-t curve , λ variant membrane water content and T is constant and comparison with P&O algorithm

Table 2. Comparison of PSO and P&O approaches results under fast variation of the membrane water content in constant temperature (T=323ºk).

	λ=13		λ=15		λ=11	
Applied Method	Average P_{FC} value (kw)	Accuracy (%)	Average P_{FC} value (kw)	Accuracy (%)	Average P_{FC} value (kw)	Accuracy (%)
Analytical	6.441	100	7.179	100	5.632	100
PSO	6.360	98.74	7.035	97.98	5.573	98.95
P&O	6.095	94.63	6.560	91.38	5.505	97.74

Conclusion

In this paper, a new method for tracking of maximum power point of fuel cell is proposed. The fuel flow is adjusted with the maximum power points characterization curve, and the stack current is regulated to produce the desire output power. The results of the proposed PSO based maximum power point tracking are compared with P&O. The results verify the accuracy of the proposed MPPT optimization algorithm. Furthermore, the PSO method has more accurate and convergence speed than P&O method.

References

[1]. M. Veerachary, T. Senjyu, and Katsumi Uezato, "Feed forward maximum power point tracking of PV systems using fuzzy controller", IEEE Transactions on Aerospace and Electronic System, Vol. 38, No. 3, pp. 969-981, 2002.
[2]. Z. Z. dan, H. H. Bo, Z. X. Jian, C. G. Yi, R. Yuan, "Adaptive maximum power point tracking control of fuel cell power plants", Journal of Power Sources, vol. 176, pp. 259–269, 2008.
[3]. J. Pukrushpan, A. Stefanopoulou, and H. Peng, "Modeling and control for PEM fuel cell stack system" Proceedings of the 2002 American Control Conference, vol. 4, pp. 3117 – 3122, 2002.
[4]. F. Barbir and T. G´omez, "Efficiency and economics of proton exchangemembrane (PEM) fuel cells" International Journal of Hydrogen Energy, vol. 22, pp. 1027–1037, 1997.
[5]. Z. Zhi-dan , H. Hai-bo , Z. Xin-jian , C. Guang-yi , R. Yuan, *J. Pow. Sour*. 176 (2008) 259–269.
[6]. N. Chanasut and S. Premrudeepreechacharn, *IEEE Ind. Appl. Soc. Ann. Meet*. (2008)1–6.