Intelligent Control Based MPPT Method for Fuel Cell Power System

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Abstract: In this paper we have discussed with the maximum power point track of fuel cell power system using intelligent controller. We investigated in different types of MPPT method and its performance then finalized fuzzy logic based MPPT method for fuel cell system. This paper we have been analysis PEM fuel cell electrical characteristics with respect to fuel flow rate. The proposed fuzzy logic based MPPT system has been modelled in Matlab Simulink software and analysis system performance at various conditions under intelligent control then optimal fuel usage. The resulting waveforms have been evaluated and prove the effectiveness of the system.

Keywords: Fuel cell, MPPT, Fuzzy, Matlab

I INTRODUCTION

In recent years the usage of renewable energy and awareness has been increase in public and the renewable energy sources have the important role to meet the power demand island areas. The renewable energy sources are environmentally friendly and green sources. We have used different types of renewable energy sources like Photovoltaic cell, Wind power system, hydro, tidal and fuel cell power system. The some renewable energy sources are generating the power supply at a particular time period only it doesn't support and doesn't generate power continually because the availability of sources as an example the PV system only generate at day time only, the wind system it has generated when wind have sufficient velocity and particular places only like hills area, offshore. The hydro system, it's only generating the power system when we have water in dam this is system also generating the power some particular session only. We need the continued power generation using renewable sources So this paper we have investigated and select the fuel cell power system is the only solution to generate the uninterrupted. power supply The fuel cell power system which is convert chemical energy into electric power and its has capability to store the energy itself but other renewable energy sources are needed storage device like battery , capacitor bank and etc. In this paper we have analysis the performance of PEM fuel cell electrical characteristics at under various fuel flows and find the optimum fuel flow then find out the Maximum power point tracking of fuel cell system using intelligent control. The overview of this paper, section II is described the fuel cell modelling and its operation. Section III has the design of MPPT for fuel cell power system. The section IV has designed fuzzy logic controller. Section V the proposed system has been simulated by using matlab simulation software. The has result analysis of proposed system simulation system and compare to existing model. The section VI has conclusion

II THE FUEL CELL

A. Description of a Fuel Cell

The proton exchange membrane (PEM) fuel cell is one of the important sources of renewable energy, which converts chemical energy into electrical energy. This type of fuel cell is well developed and appears to be the first hydrogen technology to be used for substantial addition into the Electrical Power System. The generation of power from the fuel cell is produced from a few watts to some tens of kilowatts [5].

This range of power generation is perfectly with integration to the LV distribution network and so in future consumers may use locally in many places by standalone individual loads. The behaviour of these FCs can be described as follows: at the anode of the fuel cell, the hydrogen gas oxidizes releasing electrons and creating $H+$ ions (or protons).

$$2H_2 \rightarrow 4H^+ + 4e-$$

During this reaction, energy is produced by the hydrogen ions. During this chemical reaction at the cathode , oxygen reacts with electrons taken from the electrode and $H+$ ions react with oxygen to produce the by-product of water which is a waste product.

$$O_2 + 4e^- + 4\ H^+ \rightarrow 2H_2O$$

The aim of this chemical reaction is to achieve the optimal working condition of the fuel cell with proper air flow as well as humidification of the gases must be safeguarded.
The overall reaction taking place at the FC can be summarized as:

$$O_2 + 2H_2 \rightarrow 2H\ O + heat + electricity$$

Four major irreversibility can be highlighted in FC

Activation losses. Due to the slowness of the chemical reactions taking place inside the fuel cell. This process can be reduced by maximizing the catalyst contact area of reactions.

Internal current losses. Due to the leakage of electrons, that passes through the membrane to the cathode side instead of flowing through the electric load.

Resistive losses. Due to the current flow through the resistance of the whole electrical circuit including the membrane and the interconnections. This term can be reduced if the membrane is well hydrated.

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Mass transport or concentration losses. Due to the gas change concentration at the surface of electrodes.

The most important among them are due to the activation and ohmic losses. At high temperatures the activation losses become less significant than that of the ohmic losses. The PEM FC voltage-current characteristic is as shown in Fig 1.

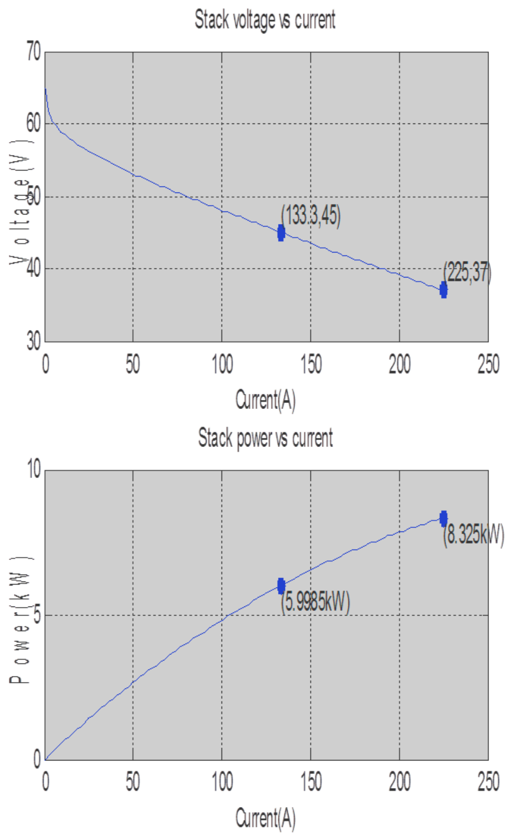

Fig 1. PEM Fuel Cell V-I characteristic.

B. Equivalent model of a Fuel Cell

The steady state FC voltage, VFC, is calculated using the following equation:

$$V_{FC} = E_{rev} - \eta_{act} - \eta_{ohmnic} - \eta_l \qquad (6)$$

Where E_{rev} is the reversible voltage and the other variables are the irreversible loss Voltages, or over potentials:

- η_{act} = The voltage loss produced by the activation polarization (activation over potential)
- η_{ohmnic} = The voltage drop related to the ohmic polarization (ohmic over potential).
- η_l = The drop introduced by the concentration polarization (concentration over potential).

An accurate model can be obtained developing equation and substituting the value of the differences over potentials. The resulting equation is as in (7).

$$V_{FC} = E_{rev} - (2.3RT/\alpha nF) \, In(I_{FC}/I_o) - R^{int}.I_{FC} - (RT/nF) \, In(1 - (I_{FC}/I_l)) \qquad (7)$$

Where the different parameters are:

- *R* = Universal gas constant (8.31451 J/(mol·K))
- *F* = Faraday's constant (96485Coulomb/mol)
- *T* = Stack temperature.
- *α* = Transfer coefficient.
- *n* = Number of electrons involved in the reaction.
- *Rent* = Sum of electric and protons resistance.
- *IFC* = Fuel Cell current.
- *I0* = Exchange current.
- *Il* = Limiting current of the FC.

III MAXIMUM POWER POINT TRACKING

A typical fuel cell converts only 80 present of the fuel into electrical energy. Maximum power point tracking technique is used to improve the efficiency of the Fuel cell stack.. We need to track the maximum power from a fuel cell under various fuel flow rate to help of MPPT controllers [1, 2, 3].

There are so many methods are used MPPT techniques applied to Photovoltaic power system

A. One cycle control method

This is a nonlinear MPPT method. It has concentrated the single stage inverter, and inverter output current can be attuned by change of inverter voltage with the help of L and C parameters.

B. Feedback voltage and current method

This method mostly used without storage Photovoltaic power system. In this method the PV panel actual output voltage or current values have compared with reference voltage and current value and calculate the error. The DC/DC converter duty cycle has a design based on error value and operates the FC stack near to MPP

C. Feedback of power variation with voltage and current

This method is similar to that of feedback voltage and current method, in addition to this method monitoring the power variation with voltage or current $\frac{dp}{dv}$ or $\frac{dP}{dI}$ equal to zero under power feedback.

In this method the power measured from load terminal not from a FC stack because power conversion loss is there due to the converter. Hence the duty cycle are adjusted $\frac{dp}{dv}$ or $\frac{dP}{dI}$ for achieving MPP.

D. Perturbation and Observation

This method has to measure FC voltage and current at the present atmosphere condition the FC power P_1, is calculated then consider the small changes from duty cycle and the FC power P_2 is calculated. The FC power P_2 and P_1 were compared if P_2 is more than P_1, then the perturbation is correct otherwise it should be reversed. This method has major drawbacks are occasional deviation from the maximum

E. Proposed model Intelligent control based MPPT method

DC-DC converter control: In this method we have been designed fuzzy logic controller, from this method we have studied fuel cell electrical characteristics under variable atmosphere condition. The fuzzy logic controller has two inputs one actual voltage and reference voltage or

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actual current and reference current. We have been from the fuzzy rules based on input value and calculate the modulation index is the output of the fuzzy controller. The fuzzy interference is designed by Mamdani's method because the minimum number of rules can achieve the target output and Defuzzification uses centre of gravity method to compute the output modulation index of the converter and close to MPPT as shown in fig 2.Fuel Flow Regulator: In this method we have selected two input variable gas pressure and temperature gases flow and pressure

Block Diagram

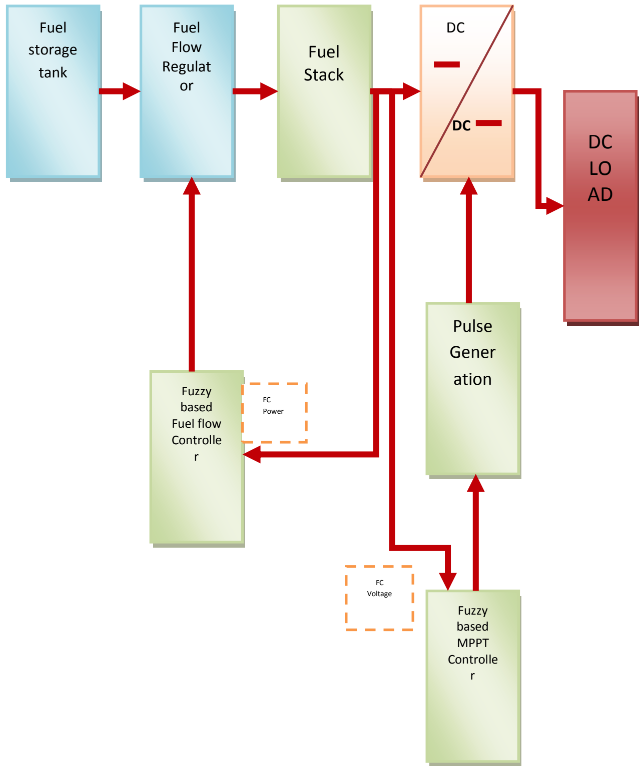

Fig 2: Proposed model intelligent control based MPPT for FC system and fuel optimization

IV FUZZY LOGIC CONTROLLER:

Basically the fuzzy logic controller has four stages as follows

1. Fuzzification module 2. Knowledge Base
3. Interference engine 4. Defuzzification.

In this paper we have designed two fuzzy logic controls, first one for the fuel flow regulator and another one for maximum power point tracking of DC/DC controller [6].

The fuel flow regulator controller has one input variables is feedback fuel cell current. The controller output is flow rate. The two input variables are converted into fuzzy value using Fuzzification process (Triangular membership function) and then design the fuzzy inference rule (If and Then) based on input parameters. Finally the output variable is converted into fuzzy to crisp value using Defuzzification process (centre of gravity).

The fuzzy based maximum power point tracking method focuses on DC/DC converter switching operation. In this method we have selected voltage feedback system. We have compared the feedback fuel cell voltage and reference voltage the error value is fed to fuzzy logic system inputs the input error signal is converted fuzzy value using Fuzzification process (Triangular membership function) and then design the fuzzy inference rule (If and Then) based on input parameters. Finally the output signal (Modulation Index α) is converted into fuzzy to crisp value using Defuzzification process (centre of gravity).

V MATLAB SIMULATION MODEL

The above proposed model has been simulated by using matlab simulation software and analysis the system performance as shown in fig 3. The simulation model we have designed fuzzy logic based fuel flow controller and fuzzy logic based DC-DC controller.

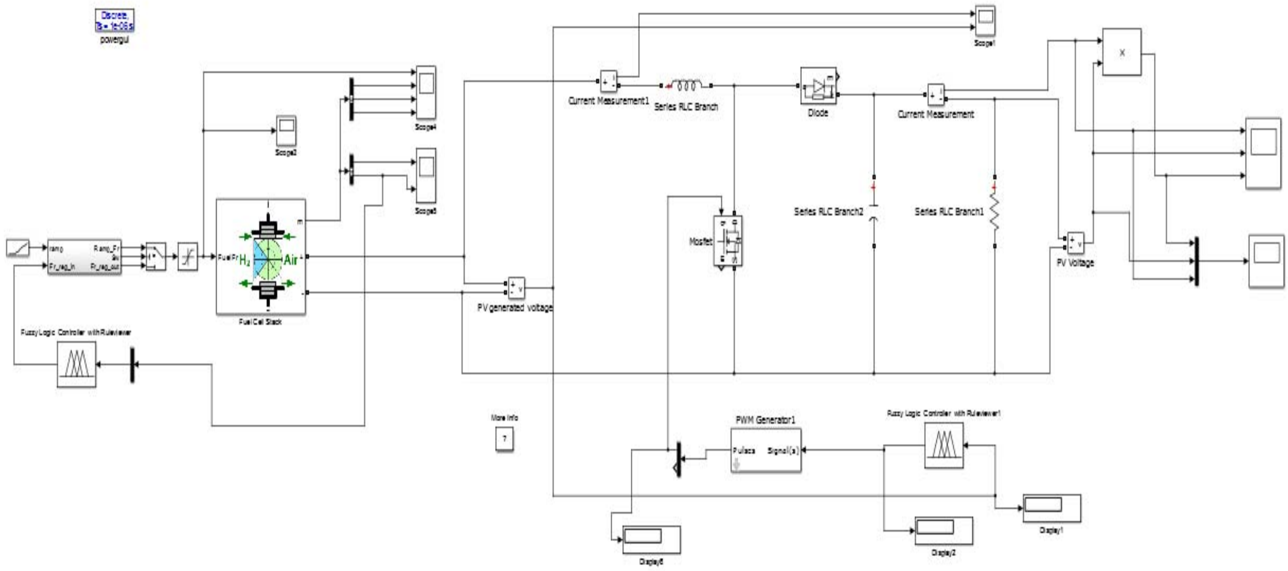

Fig 3: The matlab simulation model of 6kW PEM fuel cell with fuzzy logic controller

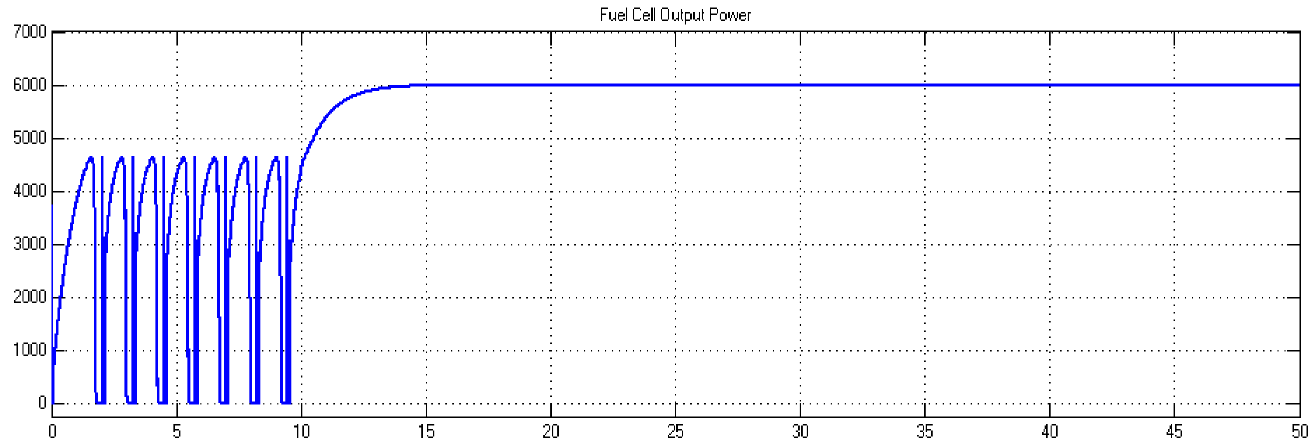

Fig 4 : The fuel cell power output waveform

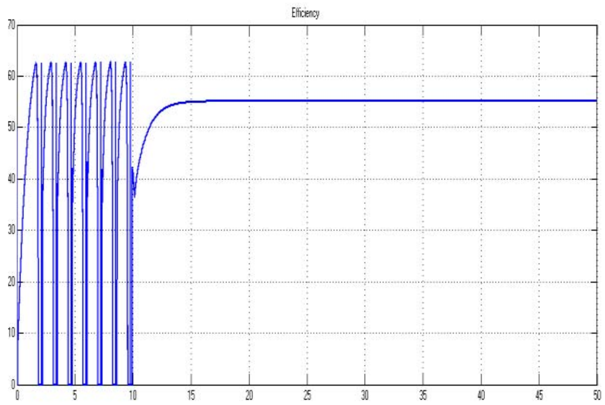

Fig 5: The fuel cell stack efficiency 55% with fuzzy controller

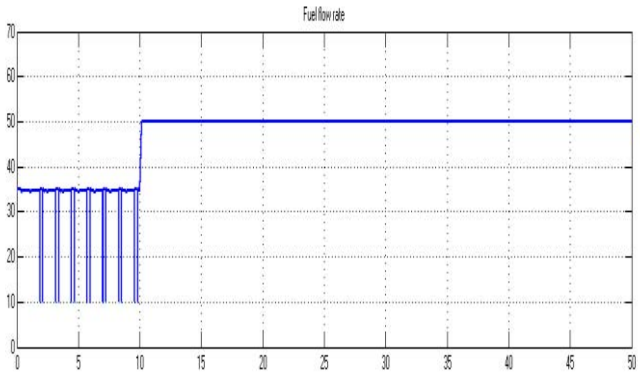

Fig 6: Fuzzy logic based fuel flow controller

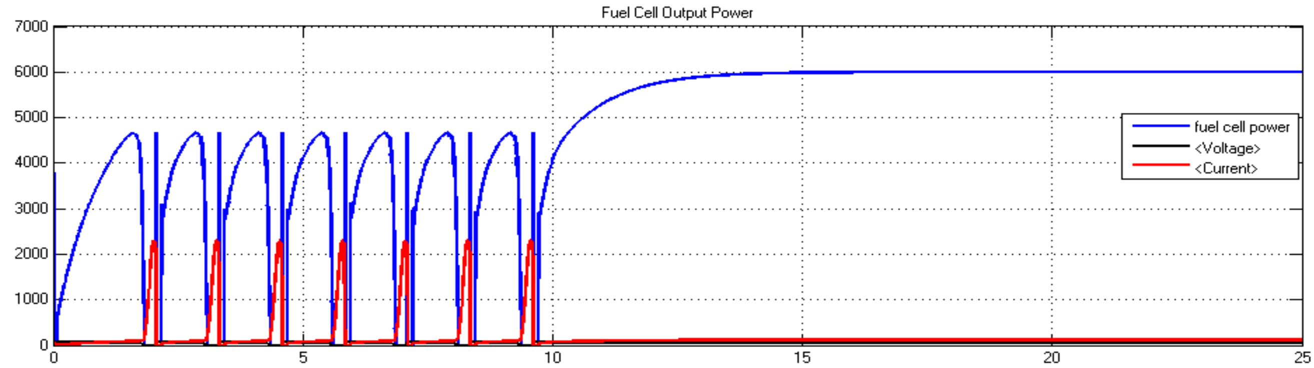

Fig 7 : The output waveform for fuel cell power, voltage , current waveform

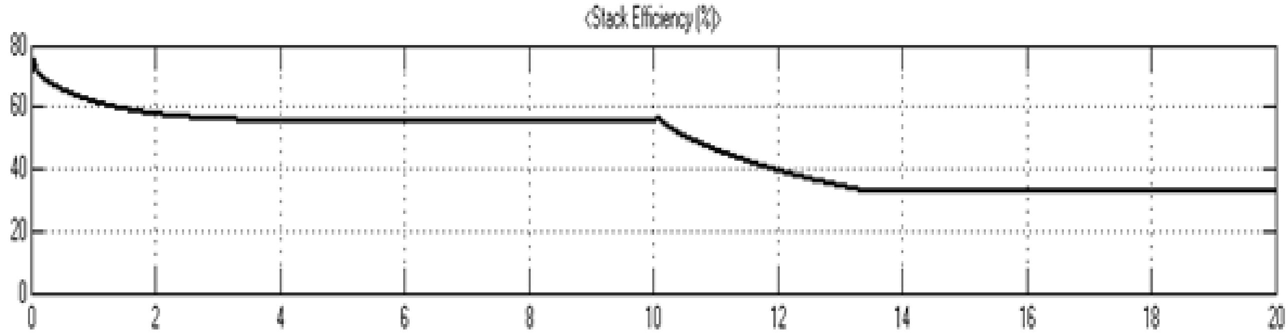

Fig8: the fuel cell efficiency with fuzzy controller 35%

A. Result analysis

The figure 4 shows the fuel cell stack output power of 6kW. The fuel cell efficiency is reached at 55% by using fuzzy logic controller as shown in fig 5. The fuel flow rates are controlled using fuzzy controller and regulate the fuel flow rate at 50% as shown in fig 6. The output fuel cell voltage, power and current value are shown in fig 7. The fig 8 is presented the fuel cell efficiency is 35% without a fuzzy logic controller.

VI CONCLUSION

In this paper we have discussed about the MPPT of PEM fuel cell operation and fuel flow rate regulation by using fuzzy logic controller and studied different types of MPPT controller then select the intelligent controller is best for to reach the maximum power point tracking in fuel cell system. The efficiency of the fuel cell power system has improved using fuzzy logic control from 35% to 55% and proves the effectiveness of the proposed MPPT controller.

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