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Optimizing Storage with Artificial Intelligence

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ABSTRACT : *This paper presents the battery energy control system by using Fuzzy Logic Controller (FLC) for a renewable energy sources (Solar Panel, Wind Turbine). A fuzzy control strategy is used in this article for battery control. To improve battery life, fuzzy control manages the desired state of charge (SOC).By using MATLAB/ Simulink, the modelling, analysis and control of the energy generator devices and energy storage devices (ESD) are proposed.*

KEYWORDS : Fuzzy logic controller, ESD, battery energy Management,Lifetime

INTRODUCTION

With increased awareness of the depletion of traditional energy sources and environmental damage caused by increased carbon dioxide emissions from coal-fired power generation, the use of renewable energy has become the goal for energy development [1]. Hybrid power generation systems that combine different renewable energy sources and energy storage systems offer an environmentally friendly alternative for standalone operations [2]. However, there are several challenges for the hybrid power system. Appropriate control and coordination strategies among various elements of the hybrid system are required so it can deliver required power.

Due to the nature of intermittence of renewable energy, the use of the secondary energy storage such as batteries become inevitable which will compensate the fluctuations of power generation [3]. First, the renewable resource such as Wind or tidal energy is used to drive a turbine, translating its power to mechanical Form, which then drives a generator. The AC power generated is generally with a variable frequency and unstable voltage so it will be converted to DC power.

The DC power either is used to serve the load directly or converted to good quality AC power supply to AC loads. Due to uncertainties of the renewable energy availability, battery storage is adopted. So the electricity energy will be saved to the battery when the excessive electricity is generated and the stored energy will supply electricity to the load while there is no enough electrical power being generated.

As we know, frequent charging and discharging will shorten the life time of a battery. With such a system, the problem is how to determine when the battery should be charged to provide the best energy efficiency and to prolong the life time [4]. The proposed fuzzy control is to optimize energy distribution and to set up battery state of charge (SOC) parameters. A control strategy based on fuzzy control theory has been proposed to achieve the optimal results of the battery charging and discharging performance

System configuration as shown in Fig.1 includes power generator, ESD and EMS. The power generator includes PV panel, wind turbines and fuel cell. The energy storage equipment includes Lithium-Ion.

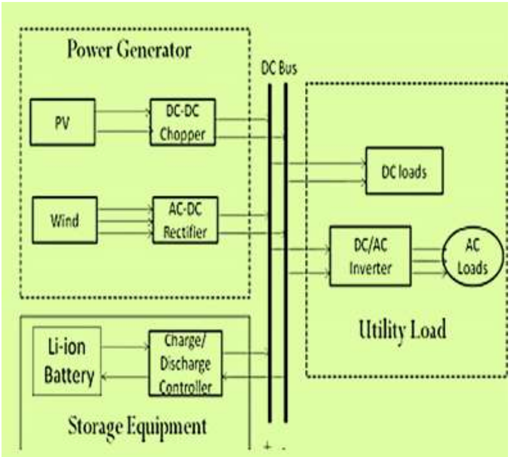

Fig 1: configuration of power generator with EMS

Parameters of the Battery

Battery management system monitor the state of the battery by using various parameters, such as:
Voltage: total voltage, voltage of individual cells, minimum and maximum cell voltage.
Temperature: average temperature, coolant intake temperature, coolant output temperature or temperatures of individual cells.
State of Charge (SOC): it indicates the charge level of battery.
State of Health: a variously-defined measurement of the remaining capacity of the battery as the rate of the original capacity.
State of Power: the amount of power available for a defined time interval given the current power, temperature and other conditions.
Current: current in or out of the battery
For battery management system soc of battery is considered to be most important parameter.
The parameters of the battery is shown in fig2.

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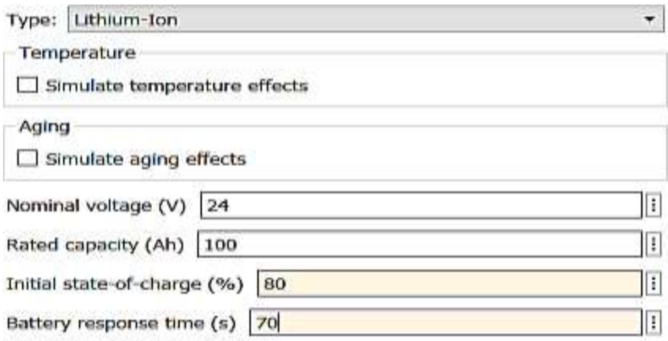

Fig 2:Battery Parameters

Model of the Battery

This model, studied by Olivier GERGAUD, is based on the diagram in fig 3 which represents the equivalent diagram of number elements in series. The battery is represented in this case by a voltage source and an internal resistance.

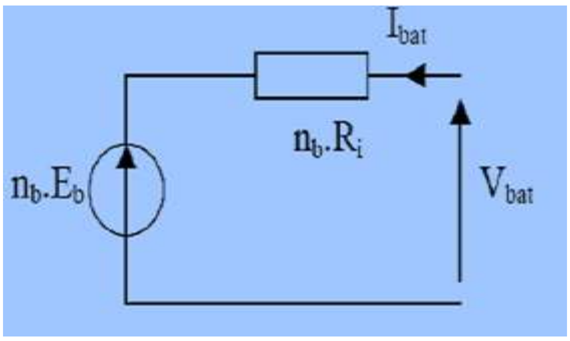

Fig 3:Model ciemat of the battery

The equation of the voltage V_{bat} can therefore be written:

$$V_{bat}=n_b[E_b]+n_b[R_i I_{bat}] \quad (1)$$

Where V_{bat} and I_{bat} are respectively the voltage and current values of the battery in Receiver Convention, E_b represents the emf of the battery which depends on the state of charge and R_i is the internal resistance of a cell.

The equation of state charge is:

$$EDC=[1-\frac{Q_d}{C_{bat}}] \quad (2)$$

The amount of missing charge Q_d depends on the operating mode of the battery, it increases during charging and decreases during discharge.

The equation for the discharge voltage is given by (Gergaud O., 2002):

$$V_{bat-d}=[n_b.(1.965+0.12.EDC)]-n_b.\frac{|I_{bat}|}{C_{10}}.[(\frac{4}{1+|I_{bat}|^{1.3}}+\frac{0.27}{EDC^{1.5}}+0.02).(1-0.007.\Delta T)] \quad (1)$$

Where C_{10} the battery capacity in A.h at constant current discharge is for 10 hours, and ΔT is the temperature deviation of the accumulator from a reference temperature of 25 ° C.

$$V_{bat-c}=[n_b.(2+0.16.EDC)]+n_b.\frac{|I_{bat}|}{C_{10}}.[(\frac{6}{1+|I_{bat}|^{0.86}}+\frac{0.48}{1-EDC^{1.2}}+0.36).(1-0.025.\Delta T)] \quad (2)$$

Energy Management by Fuzzy Logic

The energy management system controls the amount of energy flow between the different components: wind, solar and battery in order To meet the load demand, efficient management of energy exchanges between different components and allows a significant increase in efficiency. The use of renewable energy sources leading to a reduction in pollution. An effective management of energy exchanges between various components allows significant increase in efficiency.
The system configuration consists three blocks see Fig4:

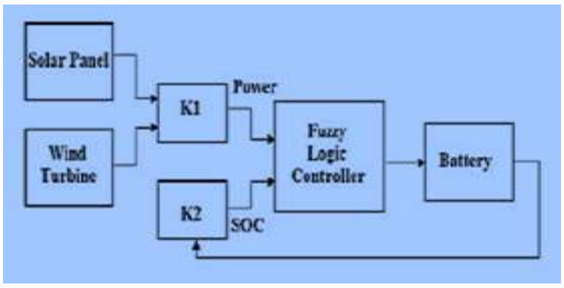

Fig 4:Management System by fuzzy logic

The solar panel system, the wind system and the lithium-ion battery. The photovoltaic system and wind power are non-linear systems and the fuzzy logic controller offers a convenient way to design a non-linear control system. The design of these systems is necessary to maintain maximum power. The difference between the actual power and the power generated is taken to charge and discharge the lithium-ion battery. Battery life and SOC (charge and discharge rate) depend on the battery charge and discharge time. To improve its lifetime, the fuzzy controller keeps the battery SOC at the desired level. The fuzzy logic battery management and control model is shown in Fig 5 is

Composed of 1 KW solar source, 3 KW wind source, 3 KW load and storage battery. The first input of the fuzzy controller is ΔP the difference between the Power of the renewable source (solar + wind) and the power of the load. The other entry is the difference between SOC control and that of the battery. The output gives the output current which is returned to the battery for charging and discharging. In this system, the controller can keep the SOC of the battery at a certain level
Whether the initial SOC value is low or high. The baseline SOC given to the fuzzy controller is 50%, so the battery SOC is kept at 80%.

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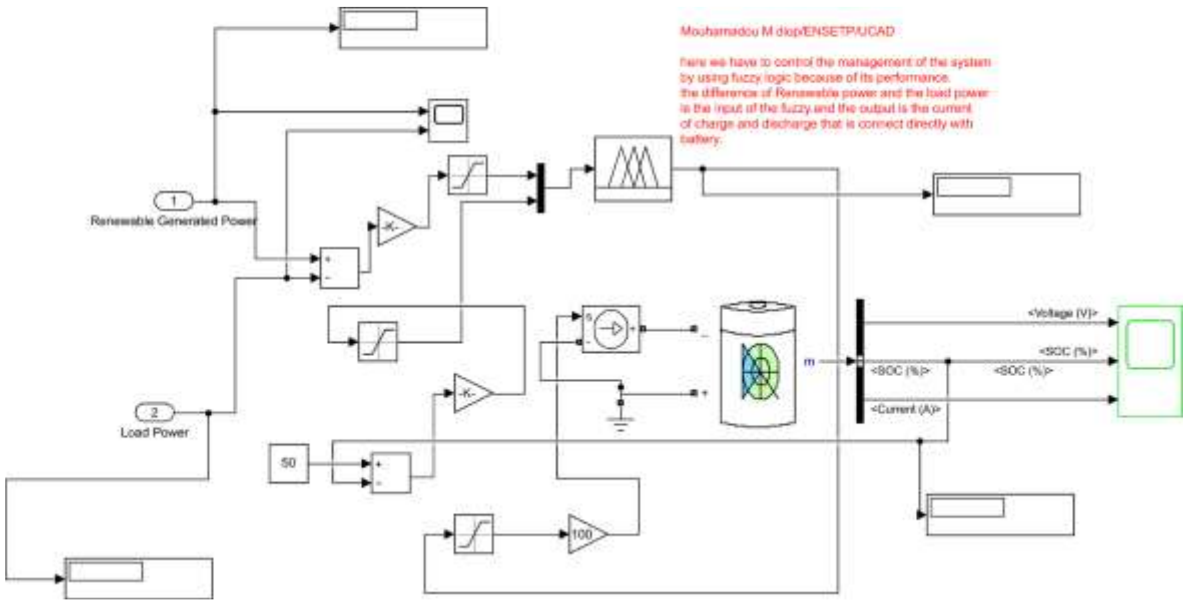

Fig 5:Simulation model of management and control battery with fuzzy Controller

Battery Management Using Fuzzy Logic Controller

In this article, a lithium ion battery was used as an energy storage device. Comparing different types of batteries, lithium-ion battery has a longer service life, which is why it is chosen here. To achieve the desired SOC, the fuzzy controller is designed for regulation. The input of the fuzzy logic is ΔSOC and ΔP, and the output is the variable current ΔI (see fig 6 and 7).

$\Delta SOC = \Delta SOC_{commande} - SOC_{new}$ and

$\Delta P = P_L - (P_{wind} + P_{pv})$

The energy produced comes from the energy of solar panels and wind power. The total power is the difference between the load power and the power generated by the wind turbine and the solar panel. The entry and exit membership function contains five grades:

NB (negative Big), NS (negative small), ZO (zero), PS (positive small), PB (positive big).

We can determine the membership function and replace it with a scale factor to get SOC charge and discharge. If the power is negative, the renewable energy system satisfies the load demand and the fuzzy controller forces the battery to charge.

If the ΔSOC is negative, it means that the SOC of the battery is higher than the SOC of demand. Thus, the battery should operate in discharge mode. The state of the battery is based on the difference between the power of the source and the power of the load.The difference between the SOC state and the controlling SOC directly determines the battery mode.

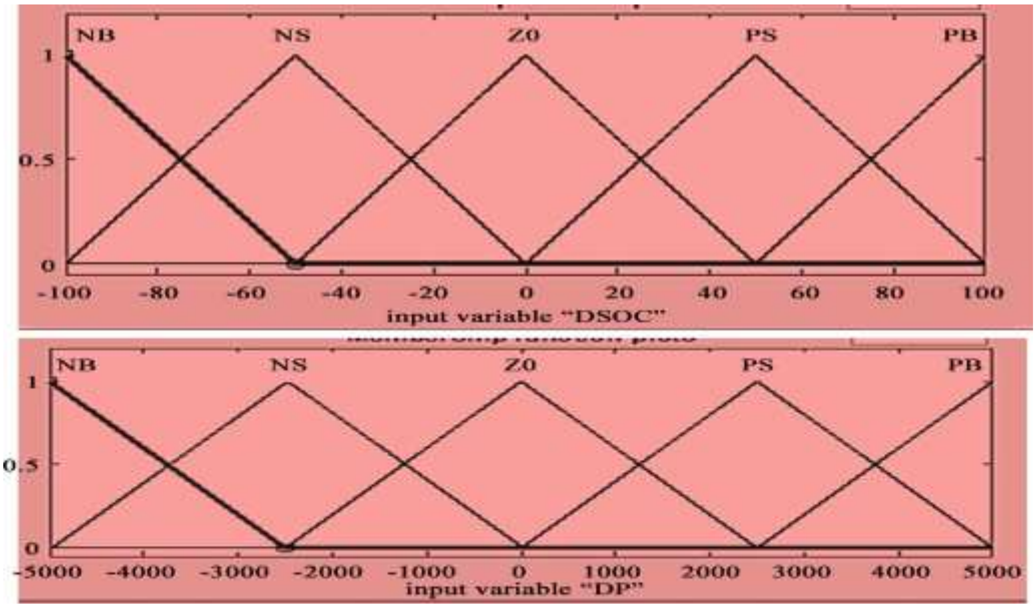

Fig 6:Input membership functions.

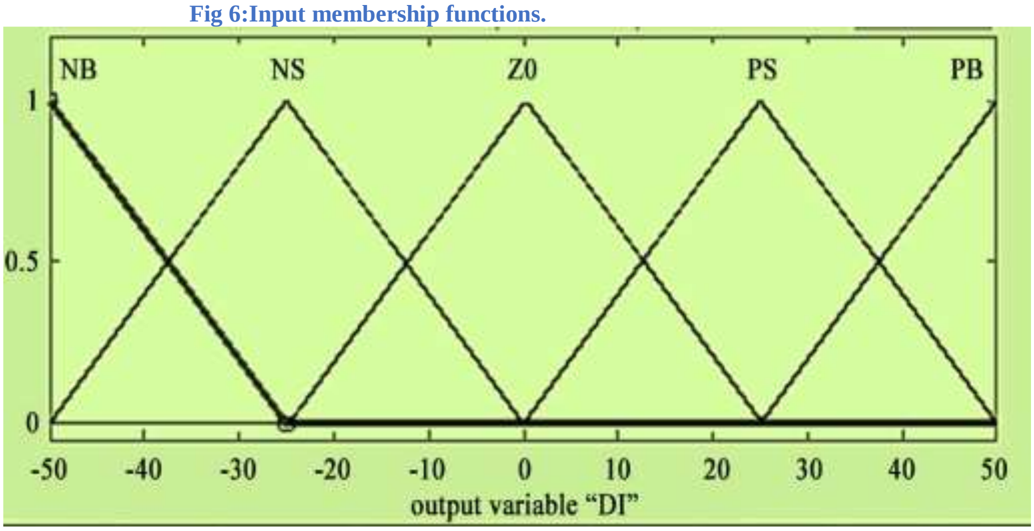

Fig 7:Output membership of variable ΔI.

Table 1 shows the fuzzy rules of our system. For example when the variable input P is NB and ΔSOC is NB, the output I becomes PB. The control SOC applied to fuzzy control is 50%. If the SOC of the battery is less than the SOC of the control, the battery remains in a state of charge. Otherwise the battery is discharged. To extend battery life, fuzzy control rules are set to keep the SOC of the battery above 45% [5].

Table 1 : Fuzzy control rules

ΔI		ΔP				
		NB	NS	ZO	PS	PB
ΔSOC	NB	PB	PB	PB	PB	PB
	NS	PB	PB	PS	PS	PB
	ZO	ZO	ZO	ZO	PS	PB
	PS	NS	NS	NS	NS	PB
	PB	NB	NB	NB	NB	PB

Simulation Result

6.1- Model battery simulating

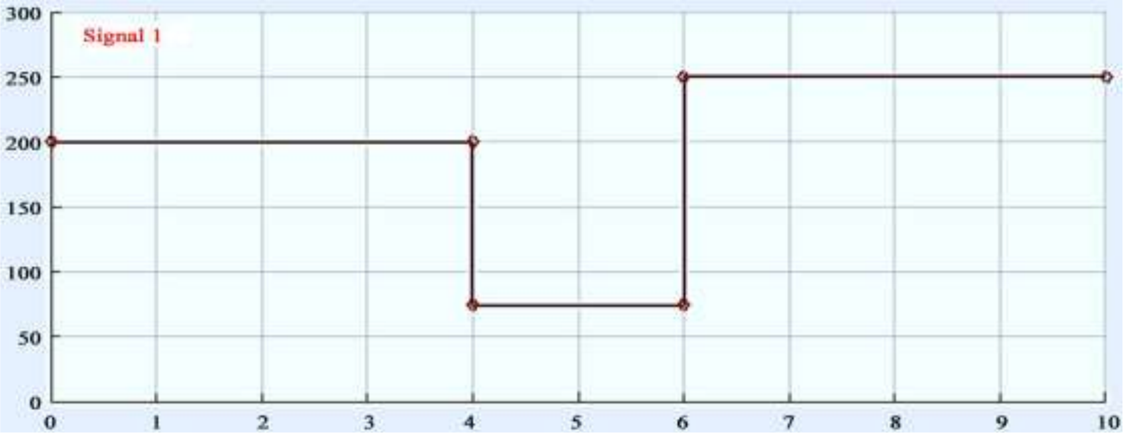

Fig 8: characteristic source

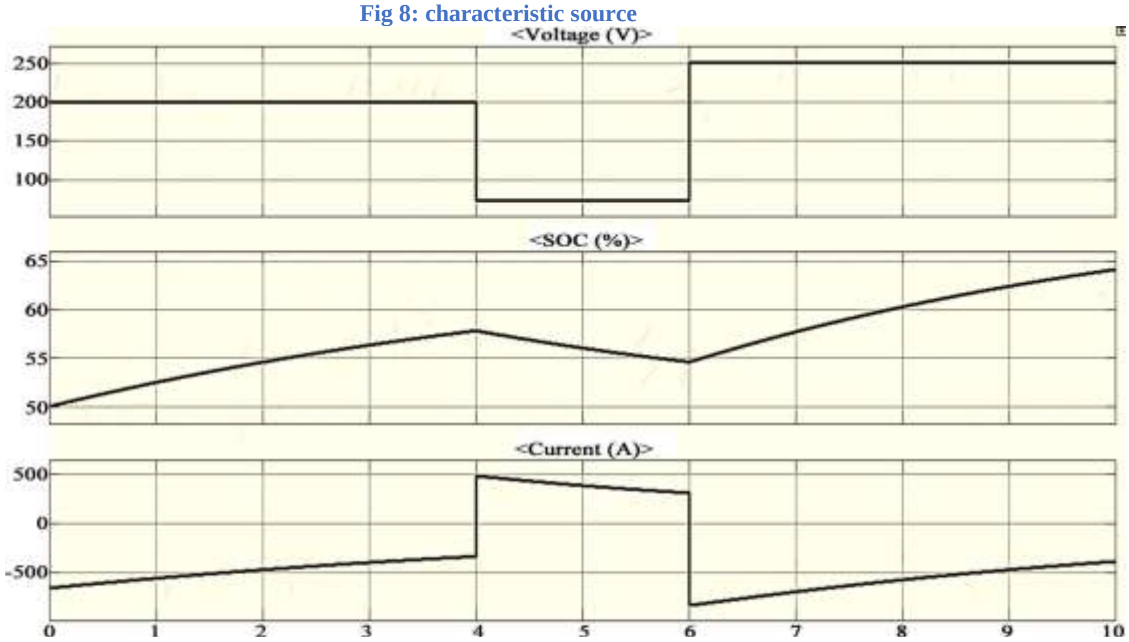

Fig 9: SOC, voltage and current

From 0 to 4 s and from 6 s to 10 s, the battery charges.
From 4 s to 10 s, the battery discharges (see Fig 9).
We can conclude at the state of charge, the shape of SOC is linearly increasing and remains decreasing at the state of discharge. The course of the current follows the course of the charge and discharge.The voltage shape is at the rising edge if the battery is charging and the falling edge if it is discharging.

Battery Charging

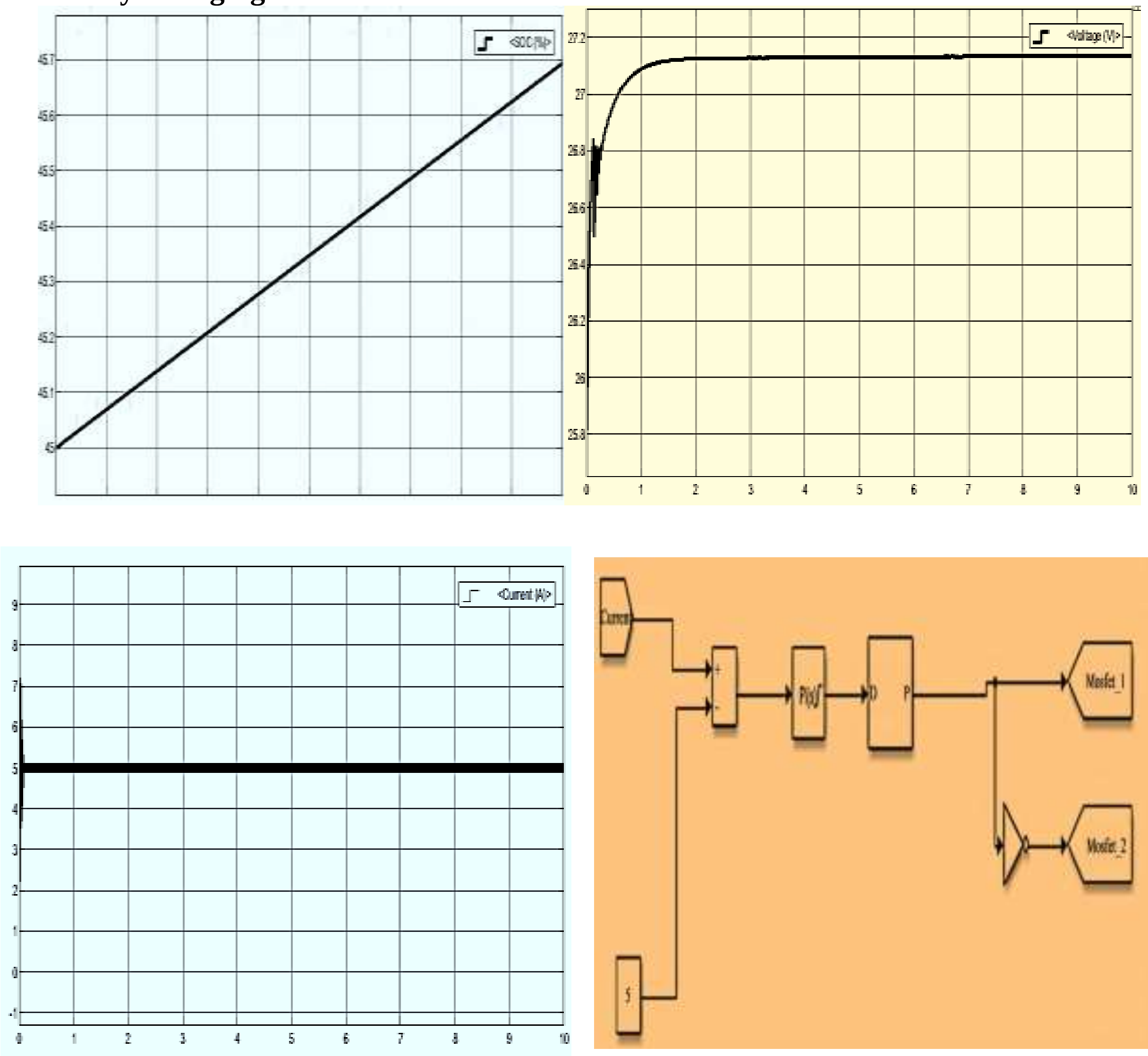

Fig 10:SOC less than 50%.

In Fig 10, the initial SOC of the battery is 40%, which is less than the SOC Command so the battery charges up to 80%.

The battery is maintained at constant current (5A) following a PID control and the voltage evolves until it is stable at 27V.

Battery Discharging

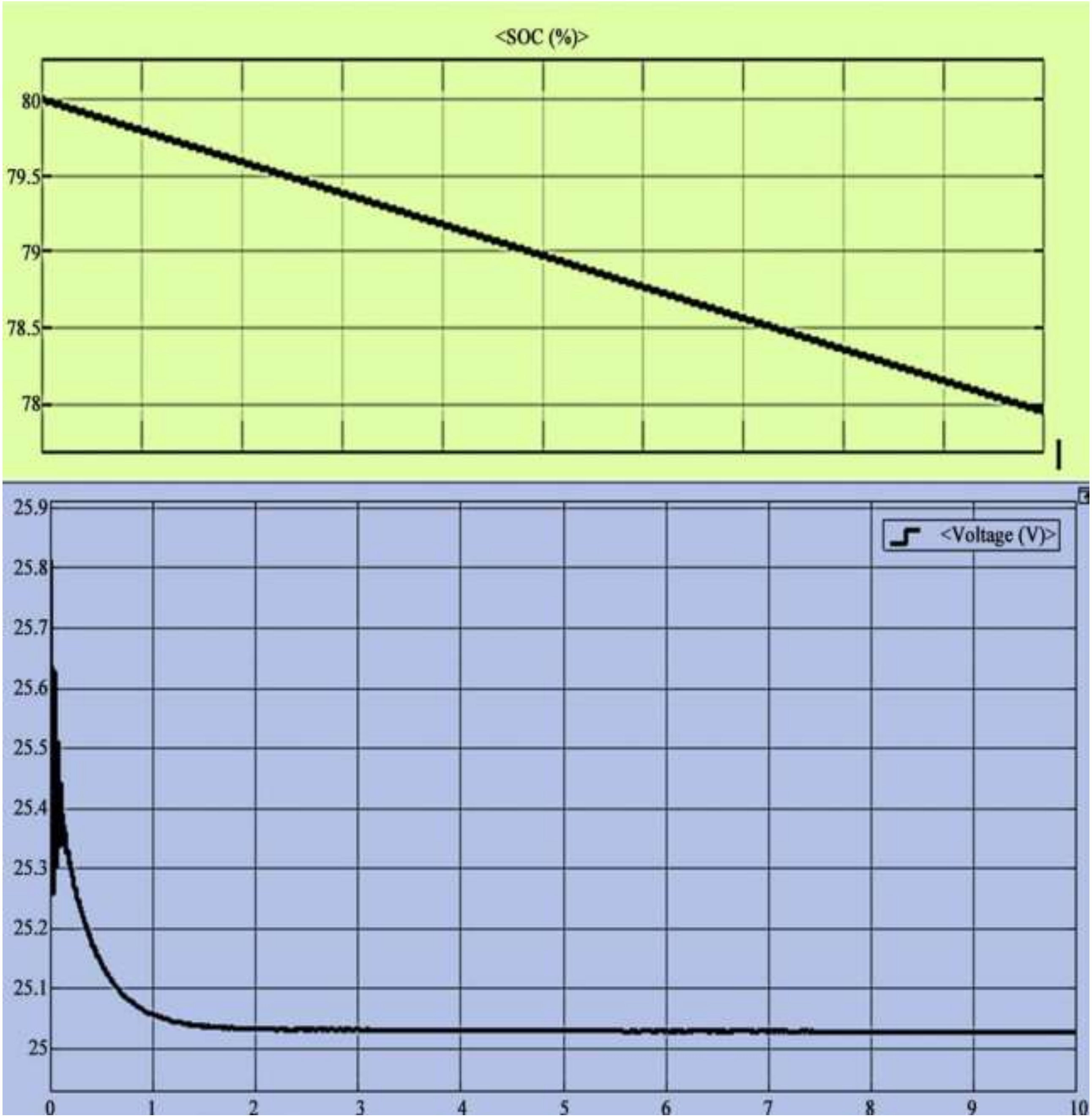

Fig 11:SOC more than 50%.

As shown in fig 11, SOC command is givenat 50% and the initial SOC of the battery is 70%, so the battery discharges to 45 and becomes stable. In this state, the battery current changes for a while, then it becomes constant. In parallel, the voltage decreases and becomes constant for V = 25V.

CONCLUSION

This paper presents the control of battery system by using Fuzzy Logic Controller to achieve optimization of an energy management system. From the results, the battery SOC maintains the desired value to increase the life of battery by using fuzzy control rules and it also saves the surplus power generation from solar panel and wind turbine.

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