

Design and Implementation of Energy Management System with Fuzzy Control for Dc Microgrid Systems

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ABSTRACT: Effective energy management is one of the crucial aspect for the world because of depleted resources and increasing energy demand. A simple MATLAB model is designed considering renewable sources namely solar,wind,fuel cell are considered along with a Battery as backup which will operate whenever generation from any of the sources are operating below their nominal values.Battery control operation is done by Fuzzy control for effective management and improvement of energy transfer which further improves power transmission capacity reducing losses enhancing capability of system.

KEYWORDS: Energy Management System (EMS), Fuzzy Control, Microgrid.

I. INTRODUCTION

Power demand in developing countries has increased tremendously, equally the generation has increased but the transmission system accounting to 26-30% of total losses reducing overall performance of the system. As the energy resources are depleting,demand is increasing in nature it will be better to shift from non-renewable to renewable energy resources. In this solar,wind,fuel cell are considered as sources and battery as a backup source for effective operation and utilization of resources to maximum extent there by reducing the usage of non-renewable resources. The very reason to consider only renewable sources is to reduce the emission levels .So, for that purpose these sources are considered. A step by step mathematical models for the solar,wind,fuel cell, li-ion battery are shown below as in figure1 connected to a simple DC grid.

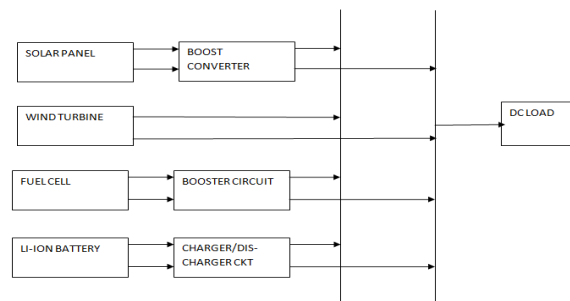


Fig 1: Block diagram of DC microgrid system with EMS.

II MATHEMATICAL MODEL OF PV MODULE

A solar cell is the building block of solar panel. A PV module is formed by connecting many cells in series and parallel .considering only a single solar cell it can be modeled by utilizing a current source, a diode and two resistors.This model also known as single diode model by solar cell. Two diode models are also available but only single diode model is considered here,the same modeling technique is also applicable for modeling of a PV module.The equivalent electric circuit diagram of PV cell is shown in fig 2 which consists of photocurrent source.A current diode and parallel resistor

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called shunt resistor (R_{sh}) expressing a leakage current and also series resistor (R_s) describing external resistance to current flow. The PV cells electrical characteristics under solar irradiance is given in terms of PV cells output current (I), PV cell voltage (V). Referring to fig (2) and based on the first law of kirchoff equations which describing electrical characteristics of PV cell model can be elaborated through the set of equations.

Ideal solar cell

An ideal solar cell can be represented by a current source connected in parallel with rectifying diode as shown in equivalent circuit of fig 2. The corresponding I-V characteristics is described by Shockley solar cell equation

$$I = I_{ph} - I_d = I_{ph} - I_o \left(e^{\frac{qV}{kT}} - 1 \right) \tag{1}$$

PV module & array model

Practically the output power of single solar cell is not strong enough to apply for almost any application so, in order to increase the capability of overall PV systems the cells should be configured in series & parallel features. If we consider N_p as no. of cells connected in parallel & N_s as no. of cells connected in series the relationship between output current and voltage is given by

$$I_{ph, final} = N_p I_{ph} \tag{2}$$

$$I_o, final = N_p I_o \tag{3}$$

$$R_s, final = \frac{N_s}{N_p} R_s \tag{4}$$

$$I = I_{ph} - I_o \left[\exp\left(\frac{V + IR_s}{\frac{n k T}{q}}\right) - 1 \right] - \frac{V + IR_s}{R_{sh}} \tag{5}$$

$$I = N_p I_{ph} - N_p I_o \left\{ \exp\left[\frac{(V + I \frac{N_s}{N_p} R_s)}{N_s \left(\frac{n k T}{q}\right)}\right] - 1 \right\} - V + \frac{N_s}{N_p} R_s / R_{sh} \tag{6}$$

This expression describes the electrical behavior and determines the relationship between voltage, current supplied by photovoltaic module. It is non-linear mathematical equation whose parameters are defined below for ideal condition R_s is very small ($R_s = 0$) and R_{sh} is very large ($R_{sh} = \infty$)

$$I = N_p I_{ph} - N_p I_o \left\{ \exp\left(\frac{V}{N_s} / \frac{n k T}{q}\right) - 1 \right\} \tag{7}$$

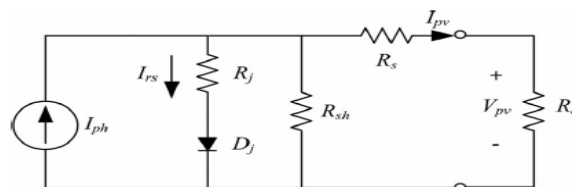


Fig.2: Solar panel equivalent circuit

BOOST CONVERTER

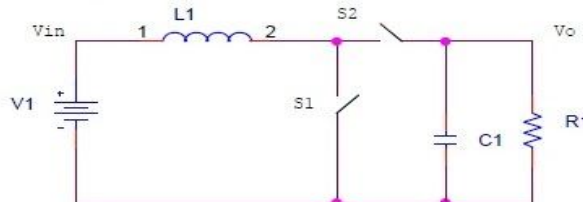
A boost converter (step-up converter) is a DC-to-DC power converter with an output voltage greater than its input voltage. It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple

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Boost Converter with Topological Circuit



Boost converter whose output is larger than the input voltage and output current is smaller than the input current. Conversion ratio is given by

$$V_o / V_{in} = I_{in} / I_{out} = 1 / (1-D)$$

D is the duty cycle
 $V_o = V_{in} (1-D)$



FIG 3: Waveform of Boost Converter

(B) Wind Power estimation

The average specific power available in a cross sectional (A) perpendicular to wind stream moving at speed V (m/s) is calculated and expressed per unit area as follows

$$P_{wind} = \frac{1}{2} \rho v^3 (w / m^2) \tag{8}$$

ρ standard air density $\rho = 1.225 \text{ kg/m}^3$ dry air at atm at 15 deg Centigrade

V= mean wind speed (m/s)

The density of the air is an important parameter related with pressure & temperature, which changes the efficiency of wind turbines, mean air density is estimated as follows

$$\bar{\rho} = \bar{p} / R_d \bar{T} \tag{9}$$

p- average air pressure (n / m^2)

T- monthly average air temperature (k)

R_d - gas constant for dry air $R_d = 287 \text{ J/kg-k}$

Once the corrected power available in wind at height of 10 m can be calculated as

$$p_{10} = \frac{1}{2} \bar{\rho} v^3 \tag{10}$$

For height less than 100 m, 10 meters above the ground level just recommended the usage of Hell man's exponential law under two important conditions the stability of atmosphere and modest roughness of site as follows

$$V_h = V_{10} \left(\frac{h}{10} \right)^\alpha \tag{11}$$

α =roughness factor

α varies from less than 0.1 over tops of step hills to over 0.25

Power density of wind above the ground level will be mainly

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Affected by increase in wind speed with height [h_2]

$$P_h = P_{10} \left[\frac{h}{10} \right]^{3\alpha} \quad (12)$$

The power extracted by the blades is customarily expressed as a fraction of the upstream wind power in watts as follows:

$$P_w = 0.5 \rho A V^3 C_p(\lambda, \theta) \quad (13)$$

A is cross sectional area of wind turbine blade m^2

V is wind velocity (m/sec)

C_p is the wind turbine energy co-efficient

The power coefficient C_p is the most important parameter in the case of power regulation. It is a non-linear function whose value is unique to each turbine type and is a function of wind speed that the turbine is operating in.

$$C_p(\lambda, \theta) = \left(\frac{116}{\lambda_i} - 0.4 * \theta - 5 \right) * 0.5 \exp^{\frac{-16.5}{\lambda_i}} \quad (14)$$

where the values of the coefficients C1–C6 and x depend on turbine type. θ is defined as the angle between the plane of rotation and the blade cross section chord. For a particular turbine type C1 = 0.5, C2 = 116, C3 = 0.4, C4 = 0, C5 = 5, C6 = 21,

(c) Fuel Cell Modelling

The polymer electrolyte membrane (PEM) fuel cell has gained some acceptance in medium power commercial applications such as creating backup power grid tied distributed generation, and electric vehicles. The output voltage E of the PEM fuel cell is represented as,

$$E = E_n - (-V_{act} + V_{ohm} + V_{con}) \quad (15)$$

where E_n is Nernst voltage, V_{act} is the activation overpotential, V_{ohm} is ohmic overpotential, and V_{con} is concentration overpotential

$$V_{ohm} = i_f \cdot R_M \quad (16)$$

Nernst equation taking into account temperature changes with respect to reference standard temperature.

$$V_{act} = -[\xi_1 + \xi_2 \cdot T \cdot \ln(C_{O_2}) + \xi_4 \cdot T \cdot \ln(i_f)] \quad (17)$$

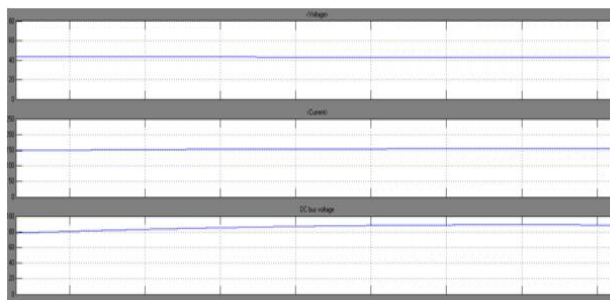


Fig 4: waveform of fuel cell with booster circuit.

(D) Lithium-Ion Battery Modelling

The lead-acid battery model was implemented based on a MATLAB model for a lead acid battery. It is having two modes of operation – charging and discharging modes. When the current to the battery is positive (or negative), the battery is in the charging (or discharging) mode.

The charge and discharge equation of li-ion battery is,

$$f_1(iti^*i) = E_0 - \frac{Q}{Q-it} j^* - K \frac{Q}{Q-it} it + A \exp(-Bit) \quad (18)$$

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SOC of the battery is an important factor, which is calculated by,

$$SOC = 100 \left(1 - \frac{\int_0^t i dt}{Q} \right) \tag{19}$$

Fuzzy Control:

The fuzzy controller is applied in the microgrid power supply system, to get the desired SOC value of battery, controller is designed to be in charging or discharging mode for the corresponding system. The input variables are ΔP and ΔSOC and output variable is ΔI .

$$\Delta SOC = SOC_{command} - SOC_{now} \tag{20}$$

$$\Delta P = P_L - (P_{wind} + P_{pv}) \tag{21}$$

we can focus the participation review and substitute it into the fluffy control tenets to get the yield current for charge furthermore, release difference ΔI of the Li-particle battery. On the off chance that the ΔP is negative, it implies that the renewable vitality does not give enough vitality to the heap. Therefore, the battery must work in charging mode; if the ΔSOC is negative, it implies that the SOC of the battery is more prominent than the interest SOC.

TABLE I: Fuzzy Control Rule.

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

ΔI is NS (the level of charging current is little) when the information variable ΔP is NB (the sum of power to offer is expansive) and info variable ΔSOC is PS (littler than the SOC summon and the participation degree is little). The yield variable is NS rather than NB when the framework is worked in the above conditions in light of the fact that offering power is the first need for this situation. Therefore, the fuzzy control table of the proposed dc microgrid framework is not symmetrical. To develop the life of capacity batteries in the outline of fuzzy control, the fuzzy control guidelines are situated to keep up battery SOC over 50%.

Fuzzy control hypothesis is composed and executed in EMS for the dc microgrid framework to accomplish the enhancement of the framework. The outline model obliges that both the photovoltaic gadget and the wind turbine are supplied by a greatest force direct tracker toward keep up the most extreme working point.

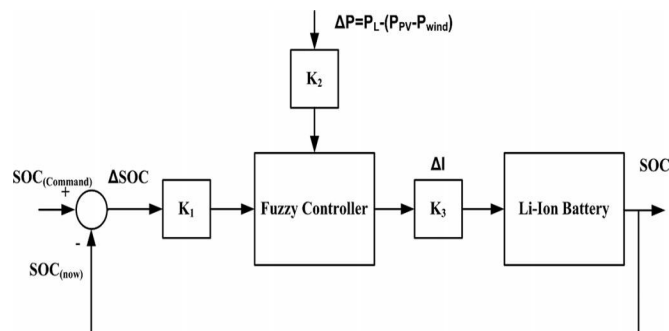


FIG 5: Fuzzy control to keep the desired SOC of the battery

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III SIMULATION MODEL RESULTS AND DISCUSSIONS:

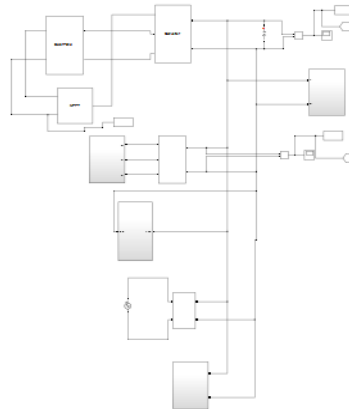


Fig 6: Simulink model for a dc grid connected system

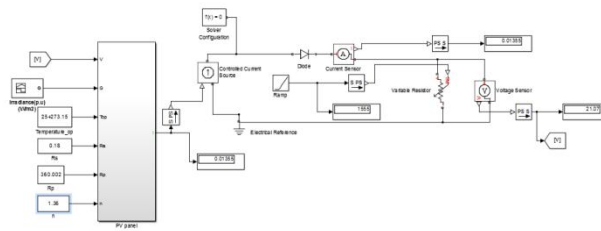


Fig 7: Simulink model for solar PV system

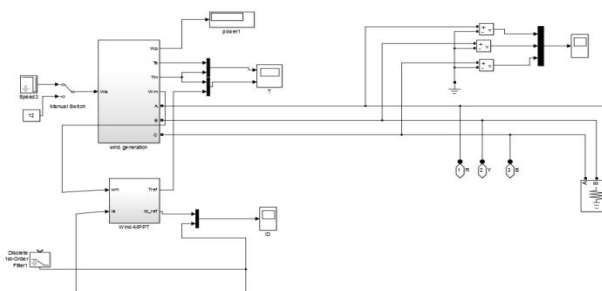


Fig 8: Simulink model for Wind generation system

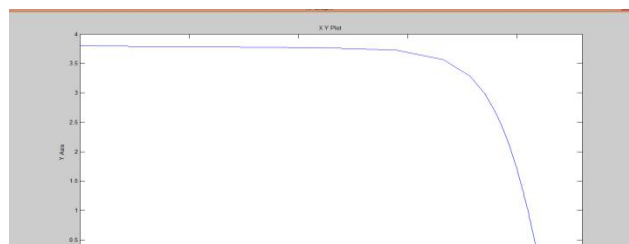


Fig 9: I- V characteristics of PV system

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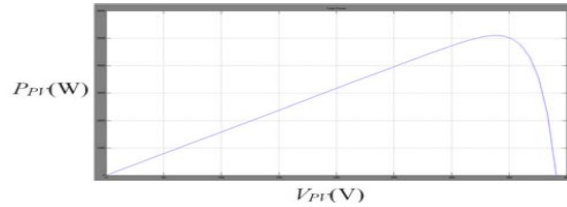


Fig 10: Output power (Ppv) versus peak voltage

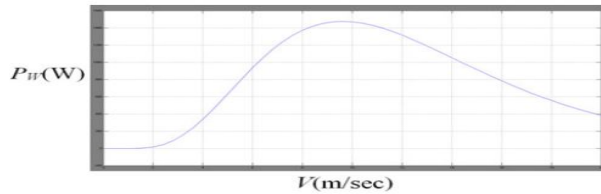


FIG 11: P_w output power with various wind speeds V.

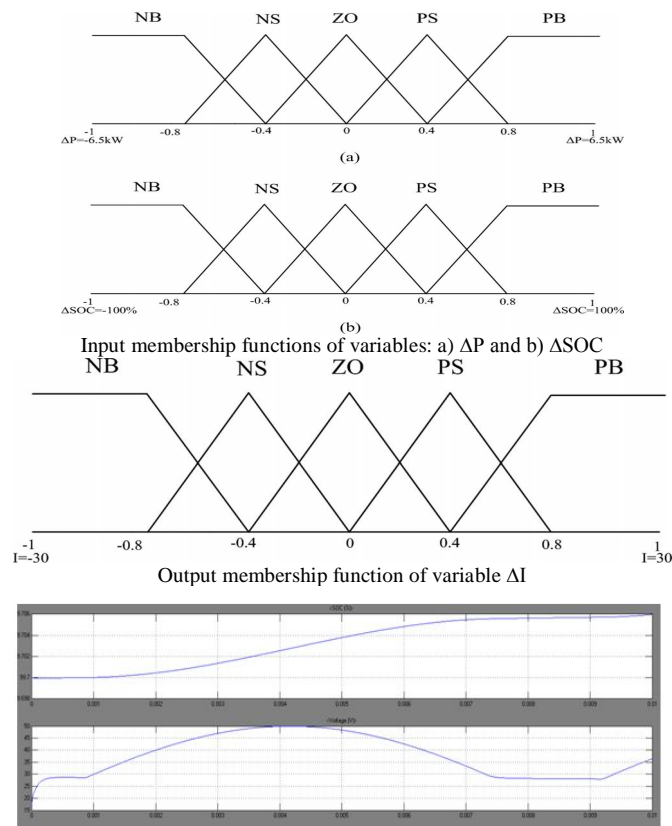


Fig 12: Battery SOC and Voltage

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IV. CONCLUSION

The paper clearly reveals that efficient utilization of resources with efficient energy management can be attained in an optimal way with reduced losses. Further it is found that with effective switching by fuzzy control for a battery efficient energy management is achieved enhancing overall performance of the system.

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BIOGRAPHY



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