Fuzzy Logic Based Energy Controlling Strategy for Isolated Wind-PV Hybrid System

Saravanan S., Ramji Tiwari, Pandiyan P., Kumar K., Ramesh Babu N.

Abstract: The paper proposes a fuzzy logic based energy management strategy for isolated hybrid PV-Wind system. This PV-Wind system comprises of 500 W photovoltaic (PV) systems and 600 W permanent magnet based alternator for conversion of wind energy. A step down converter is connected to the system in order to charge the 48V battery electric storage system (BESS). The load of 1 kW system is supplied with the 1.1 kW hybrid systems. The renewable energy sources are intermittent in nature and hence BESS system is used to support the load when there is shortage of energy generated. To optimize the output voltage of the fuzzy logic approach based maximum power point tracking (MPPT) method is employed which is also utilized for the energy management strategy. The proposed topology is modeled and simulated using mathworks tool MATLAB/Simulink and its performance is evaluated.

Keywords: Energy management, Fuzzy logic approach, maximum power point tracking, photovoltaic system.

I. INTRODUCTION

The continuous reduction of finite resources and increase in population led the use of alternative energy instead of coal based production. The renewable energy sources (RES) are the hopeful solutions for clean green energy. The enhanced efficiency and low pollution makes RES as better option to supply of power to the consumers [1]. Solar energy and wind energy are more utilized because it is readily everywhere. The revolutionary advancement in power converters [2],[3] made the system very effective in tracking of maximum power and hence improves the performance of the total system. Permanent Magnet Synchronous Generator (PMSG) based wind turbine is mostly chosen due for its ease, reliability and no requirement of gear box [4].

MPPT control algorithms are generally integrated into system so as to capture the maximum available power from varying wind speed and solar irradiations by changing the firing angle of the converter. Various MPPT techniques have been employed in the literature for Wind Energy Conversion System (WECS) and Solar PV system such as Hill Climbing technique (HC), Incremental and Conductance technique (INC), Perturb and Observe (P&O) technique, Fuzzy Logic approach (FL) and many Evolutionary Algorithms. Perturb and Observe technique is popularly used MPPT technique due to its simplicity and effectiveness. But the rapid variation in wind speed and the solar irradiations causes the P&O to track the optimal point of the system and thus the MPPT fails the primary objective. Thus Fuzzy logic Controller (FLC) is used in this system because it tracks the maximum power for rapid variations because they have pre-defined data for the system [5], [6].

To integrate the proposed system to the DC Microgrid, a buck converter based DC to DC converter is employed in this research. The alternating current (AC) obtained from WECS is converted into direct current (DC), a diode bridge rectifier is implemented [7]-[9]. The MPPT control strategy tracks the variation in wind speed and solar irradiations for generation of corresponding firing pulse [10]-[15].

The proposed topology is integrated with the storage system so as to provide power to load when the renewable energy is not sufficient. To enhance the performance of the renewable based hybrid system, an efficient fuzzy logic controller is used in this paper. The proposed work also analyses the energy loss associated with the DC/DC converter.
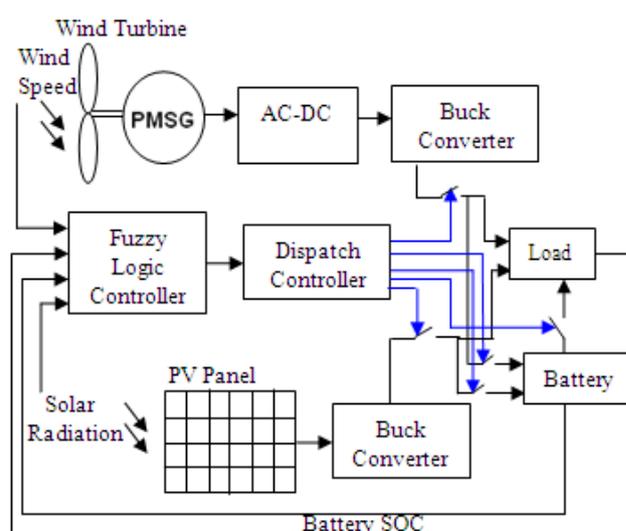

Fig. 1. Proposed topology for hybrid PV and wind.

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780

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II. MODELLING OF HYBRID WIND-PV SYSTEM

The parameter modeling deals with WECS, PMSG, PV system and converters that constitute the whole hybrid system are explained in this section. A hybrid PV-WECS based renewable energy system with individually dedicated buck converters is considered for modelling as shown in Fig. 1.

A. Design of PV system

The power output obtained from PV relies on the availability of irradiance and temperature. A single diode based PV model is implemented in this work as shown in Fig. 2. The PV system used for consideration is 500w of BP Solar SX3190 PV module in this proposed work. The modeling of PV system is derived from I_{PV}-V_{PV} characteristics of PV panel are as follows.
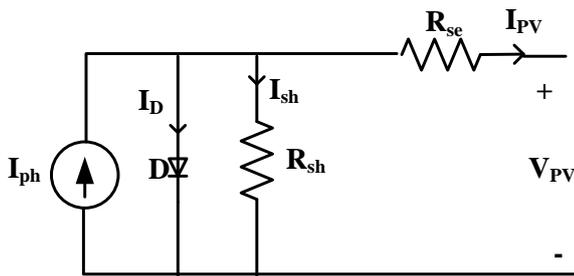

Fig. 2. Equivalent circuit of Solar PV system

$$I_{pv} = I_{ph} - I_{pvrsc}\left(e^{\frac{q(V_{pv}+I_{pv}R_s)}{\eta KT}} - 1\right) - \frac{V_{pv}+I_{pv}R_{se}}{R_{sh}} \tag{1}$$

where, R_{sh}: Shunt resistance of single diode model (Ω), V_{oc}: Open circuit voltage (V), I_{sc}: Short circuit current (A), R_{se}: Series resistance of single diode model (Ω), η : Ideality factor, T: Ambient temperature (K), I_{PV}: PV panel output current (A).

B. Design of WECS

Wind speed (V_w) which is the driving factor for wind turbine (WT) along with rotor speed and pitch angle and it gives mechanical output power . The total mechanical output power (P_m) produced by WT is proportional to the wind velocity and estimated through Eq. (2).

$$P_m = \frac{1}{2}\rho A C_p(\lambda, \beta)V_v^3 \tag{2}$$

Where, A refers to Swept area of wind blade, λ is the Tip speed ratio, β is the Blade pitch angle (degree), ρ denotes the Air density (Kg/m^3) and C_p refers to Rotor power coefficient. A 600W PMSG based WECS system is used for the proposed control strategy topology. The wind power produced by the WECS is purely depends on the wind velocity at the given time.

C. Design of DC/DC Buck Converter

The buck converter is used as a DC to DC converter in this paper. The output voltage of the Buck converter is controlled using duty cycle. The converter proposed in this study works with two varieties of conduction modes such as continuous and discontinuous mode. The relationship between input and output voltage of the converter is represented in the Eq.3

$$V_{out} = V_{in} * D \tag{3}$$

where V_{out} is the average DC output Voltage V_{in} is the input DC voltage and D denotes the duty cycle of switch employed in the buck converter.

Table I - Parameters of buck converter

Inductor (L)	3.65 mH
Capacitor (C)	3 mF
Load (R)	150 Ω

In Table I. gives the value of L and C for simulation study is determined.

D. Design of Battery management system

The lead acid battery rated at 48 V is considered for the study. The battery management system (BMS) is provided with the overcharging and deep discharging protective devices. Thus providing an efficient control system during surplus and depict of power. BMS is a key component of energy management system to provide a constant supply to load during low power generation time. A 48 V lead acid battery is considered for the study. The electrical representation of lead acid battery is as follows,

$$V_s = E_{bat} + I_{bat} * R_{bat} \tag{4}$$

Where, V_s is represented as internal terminal voltage, E_{bat}, I_{bat} and R_{bat} is the battery voltage, current and resistance respectively.

III. PROPOSED ENERGY MANAGEMENT SYSTEM

The power generation of renewable energy generation is purely depends upon the climatic condition. The continuous power supply to load is also a major concern which is purely depending on the battery conditions. The consideration of the energy management system to prove the effectiveness of the proposed system is shown in Table II. The control strategy for controlling the battery system is considered by analysing the rated battery voltage of 48 V and supplying voltage between ±5 V (53 V to 43 V).

The battery regulation employed for hybrid system is considered in this work is depicted in Fig. 3. The regulation consists of two hysteresis band. The reference power remains constant If voltage falls between the hysteresis bands and stops charging the battery if voltage is beyond V_{dc_high}, inside the area "H".
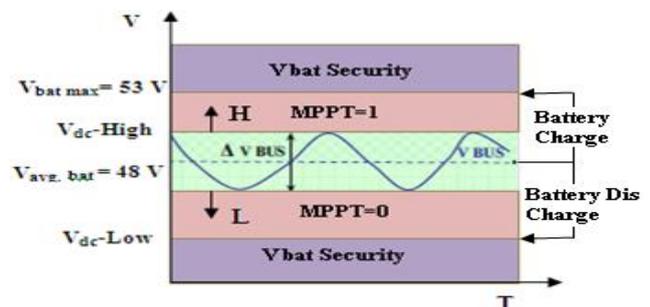

Fig. 3. Regulation of proposed energy management system

TABLE II -Parameter consideration of Fuzzy logic system

Fuzzy input (Solar Irradiation , Wind Speed and Battery)			
Time	Solar irradiance w/m^2	Wind speed m/s	Battery Voltage
T1	Off	Off	48 Vbat_nom
T2	Off	14	45 Vbat_min
T3	1000	10	45 Vbat_min
T4	1000	Off	53 Vbat_max
T5	1000	14	43 Vbat_low (security mode)

A. strategy

The shortcomings encounter in the convention control strategy method Fuzzy Logic approach based controller (FLC) is utilized in this article. FLC system converges very fast and better controllability in non linearity. FLC consists of three steps such as Fuzzification, Rule based lookup table and Defuzzification as shown in Fig.4. The knowledge of the system is required to frame the rule for fuzzy system. The current and voltage are the inputs to the FLC. The firing pulse required for DC-DC buck converter is obtained from the FLC by employing the fuzzy rules.

Table. III, depicts the fuzzy rules used in the present work. The rules are framed in five levels such as Negative High (NH), Negative Low (NL), Zero(ZE), Positive Low (PL) and Positive High (PH). The centroid approach is utilized for defuzzification process.
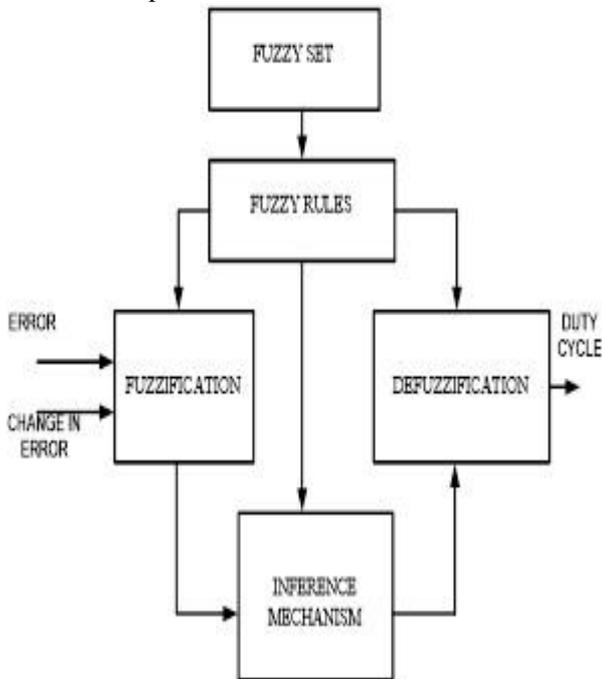

Fig. 4. Block diagram of FLC

Table III- FLC Set of rules

E/CE	NH	NL	ZE	PL	PH
NH	ZE	PH	ZE	NH	NL
NL	PS	ZE	ZE	NH	NL
ZE	ZE	ZE	ZE	ZE	ZE
PL	PL	PH	ZE	ZE	NS
PH	PL	PH	ZE	NH	ZE

The major advantage of FLC system is its ability to track the sudden change in parameters of PV and WECS. The FLC strategy tracks the change in output parameters of the system and an errror signal is generated. The error signal is changed to fuzzy sets by using Mamdani method in fuzzification process. The fuzzy sets are processed using the rules and inference system. Once the fuzzy values is processes, the fuzzy linguistic variable is converter into data set using defuzification process. Thus the firing pulse is obtained using the FLC process for different input variables.

IV. RESULTS

The performance of hybrid PV-WECS system employing DC-DC buck converter integrated with FLC is evaluated using simulation tool MATLAB/ Simulink in this study. The efficiency of the proposed system is validated for different climatic condition is tested as stated earlier. Fig, 5 shows the output DC voltage obtained from the hybrid system. The aim of this proposed hybrid energy harvesting system is to produce constant DC voltage supplied to the load. The output obtained by proposed control strategy by implementing fuzzy logic based control system is illustrated in Fig. 6. Proposed control strategy utilises the battery when the power generation from the renewable energy generation is low. The battery voltage is also showed in the Fig. 6. The proposed control strategy also maintains the constant voltage in order to supply the constant supply to load.
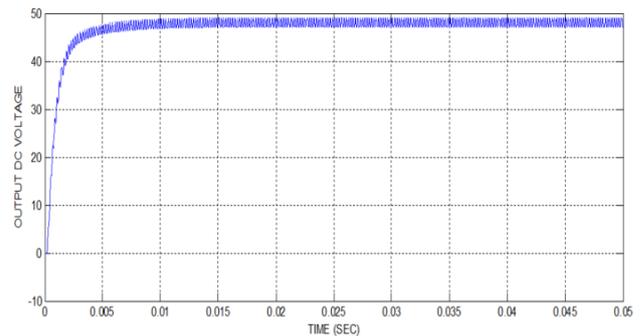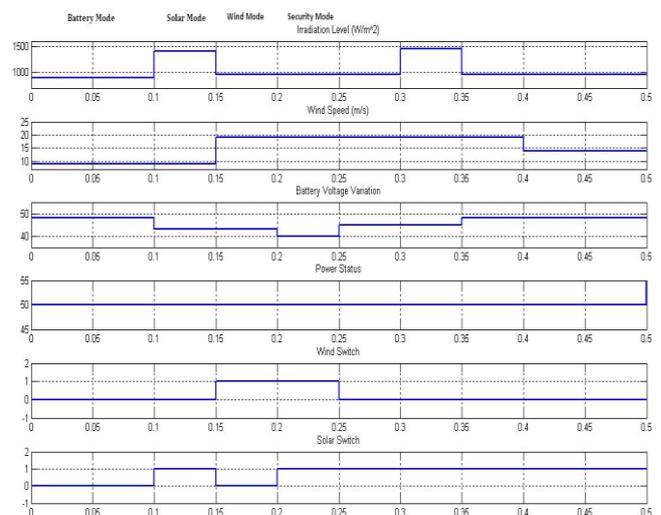

Fig. 5. DC bus voltage

Fig 6. Simulation of overall power management of fuzzy based hybrid Wind-Solar system.

V. CONCLUSION

The fuzzy logic based energy management system is modelled and investigated using MATLAB/Simulink. The proposed topology consists of hybrid system of PV and wind energy conversion system. Battery management system is also utilised in the proposed system in order to support the load during the low power generation condition. The system is incorporated with the buck converter to support the load voltage. The proposed system is considered for the remote location application where the energy management plays a vital role. The wind, solar and battery voltage condition is considered as the input voltage along with reference power which is considered with load demand. The output extracted from FLC is better and efficient than that of conventional approach by means of stability constraint, tracking control and fluctuations. Hence, it is concluded that the FLC based energy management system is the best option for standalone hybrid renewable system for remote location system.

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