Analyzing The Performance Of Hybrid RenewableEnergy System With Electrification In Rural AreasUsing Fuzzy Logic Controller

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***Abstract*—** Rural electrification has become a crucial initiative in India to provide sustainable and long-term electricity to rural areas without causing pollution. To achieve this, an electrical system has been designed based on the challenges and opportunities associated with rural electrification. This system combines a hybrid energy generating setup (solar and wind) of 1KW single-phase grid. Additionally, a fuzzy logic-based maximum power extraction controller has been designed for the PV system. This controller extracts maximum power under varying conditions. Control technique used for DC-AC single phase inverter is based on SPWM switching with dead-beat PI controller. All this fuzzy and dead-beat PI controller will generate minimum THD and pure sinusoidal output voltage. Simulation is conducted in MATLAB/SIMULINK.

***Keywords*—PV panel, Wind turbine, Fuzzy logic controller, SPWM, THD**

I. INTRODUCTION

A hybrid renewable energy system is the combination of different types of energy generating system. A hybrid renewable energy system is a reliable way for phasing out conventional energy resources. Power sources used in a hybrid system are photovoltaic, wind turbines, and battery storage system. Electrification of rural areas with non-availability to grid connection is major problem in developing countries like India [1-2]. Development of villages in India combines all the process of improving economic, social and environmental conditions. It combines of all efforts to improve the quality of life of people living in rural and raise sustainable development through infrastructure development, agricultural improvement, employment, education, health, natural resource management [3]. Electricity in India arrived during the British time in July 1879 in Calcutta (now Kolkata). In Calcutta, it was 1MW plant to supply DC electricity. Tata hydroelectric Agency in 1915 started to supply hydel power in Bombay. During 1947 total electricity installed capacity was 1361 MW. During this time electricity for almost 1500 villages were about 0.3% of total population of villages [4]. Electrification in rural India helps in improving the quality of life by providing regular good electricity services. During the Independence of India, rural areas were minimal electrified. In 1975 it was only 0.6 percent of all rural areas. Green Revolution brought high yield varieties in agriculture sector. This increased demand of electricity in rural areas. Despite of high demand, only 15 % of electrification rate increased [5]. Electricity Act 2003 brought a rapid growth in rural electrification. National policies and local distribution of electricity were formulated for rural electrification. Rajiv Gandhi Grameen Vidyut Karan Yojna in 2005 provided electricity access to unelectrified villages. Electrification Infrastructure provided electricity supply to 1,10,000 households and free connection for all peoples below poverty line. Target of Pradhan Mantri Sahaj Bijli Har Ghar Yojna 2017 had target to provide 30 million unelectrified households by 2019 [6]. Solar Photovoltaic system with Battery storage system fulfil the electricity demand in rural areas. For maximum power extraction from solar PV system, Maximum Power Point Tracking (MPPT) system is used with solar charge controller and transformer coupled dual input converter (TCDIC). This consist of dual input DC-DC converter, inverter. Major challenges are presence of resonant element which are very sensitive to any variation in parameters and other is voltage gain is high. Solar PV system is limited in night and unexpected weather which creates unavailability of electricity during this time [7]. Solar PV and wind turbine energy system connected with battery through bidirectional converter helps in storing excess energy and available during need. Lead-acid battery is used which has high current density, robustness and can deliver high current. For conversion of DC into AC distributed adaptive filter controlled VSC with inductor is used [8]. Hybrid Solar and Wind energy system fulfil the energy demand. Combination of both the system will result in continuous energy supply if any one of them get faulted. By using DC/AC converters power can be transferred to the grid with continuous supply [9]. Lower power density problem of battery can be overcome by using supercapacitor in hybrid storage system. This will help in increasing overall efficiency of storage system by using it. But use of supercapacitor will increase system overall cost to the system [10]. Energy management in hybrid system is essential. Use of appropriate energy storage system, proper sizing of hybrid system keeping in mind cost and efficiency, battery overcharging and discharging is essential factor while designing hybrid system [11]. According to the IEEE Standard 519- 1992, the total harmonic distortion voltage (THD) is less than 5% [12]. Time response is slow when p-q control is used where four PI controller are used [13]. In discrete-time control, to reduce the state variable error to zero and fast dynamic response dead-beat is suitable method [14]. Use of energy system which is pollution free and environmentally friendly is important. Energy generation from conventional system release carbon dioxide which is very harmful to the system. Hybrid solar and wind play major role in zero carbon emission in energy production [15].

II. Methodology

Assessment of Resources: Assessment of wind and solar energy availability at village keeping previous and future energy scenario. Energy demand assessment is analyzed. This data helps in finding the output energy from both solar and wind source. Wind and Solar system establishment requirements: Proper place for both energy sources for getting maximum power output is necessary. It is also important to not keep energy system far from consumers so that transmission loss will be minimum.

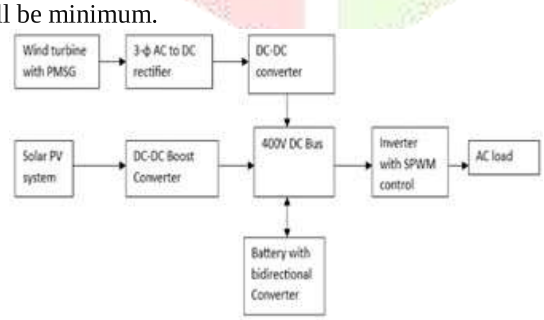

Fig.1. Block Diagram of Hybrid (Solar and Wind)

Developing the DC energy transmission system for reducing transmission losses. Battery designing for fulfil load demand by using bidirectional converters. Proper component selection: Selection of appropriate solar panels, wind turbine, generator, Converter component and battery is very necessary. These components must be efficient, cost effective and reliable.

III. Solar PV System Desging

MATHEMATICAL MODELING

A solar PV system consists of photo current source (I_{ph}), diode connected in parallel with it (I_D), shunt resistance (R_{sh}), and series resistance (R_{Se}) as shown in figure 2 below. Value of shunt resistance is large and value of series resistance is low.

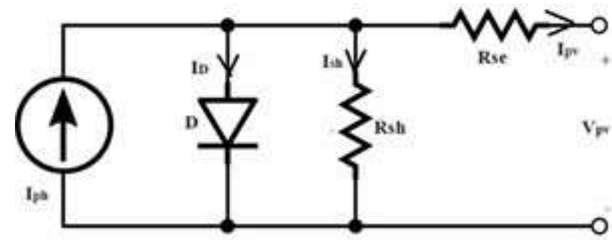

Fig.2. PV Circuit Diagram

Iph is photo current source, ID is current through diode, Ish is current through shunt resistance, Ipv is output solar PV current, Rsh is shunt resistance, Rse is series resistance and Vpv is PV voltage.

Apply KVL in figure 2. The output PV current is given by:

$$I_{PV} = I_{ph} - I_D - I_{sh} \tag{1}$$

The output current generated varies with temperature and irradiation. So, it is given as:

$$I_{PV} = I_{ph} - I_S\left[exp\frac{(V+IR_{se})q}{akTN_s} - 1\right] - \frac{V+IR_{Se}}{R_{sh}} \tag{2}$$

$I_S = reverse\ saturation\ current$

$$I_{ph} = I_r\frac{I_{SC}}{I_{r_0}} \tag{3}$$

$I_{SC} = short\ circuit\ current$

$$I_S = \frac{I_{sc}}{\left[exp\left(\frac{V_{oc}}{aV_t}\right)-1\right]} \tag{4}$$

$$I_D = I_S\left[exp\left(\frac{v+IR_s}{a\ Vt}\right) - 1\right] \tag{5}$$

TABLE I. Specification of Solar PV System

Parameters	Values
Parallel String	1
Series connected module per string	5
Voc	36.3 Volt
Vmax	29 Volt
Isc	7.84 A
Diode ideality factor	0.98
Rsh	313.39 Ω
Rse	0.39 Ω

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IV. Wind Energy Sysetm Desing

$$P_m = \frac{1}{2}\rho A V^3 C_p(\lambda, \beta) \quad (6)$$

Where, V^3 is wind velocity

Cp is the performance coefficient of wind turbine

For maximum power extracted, Cp is 0.5 [16].

For two mass wind turbine model, electromagnetic torque is given by,

$$T_{em} = k_{0pths}\omega_g^2 - k_{ths}\omega_g \quad (7)$$

$$k_{0pths} = \frac{k_{opt}}{n_g^3} = \frac{1}{2}\rho\pi\frac{R^5}{n_g^3\lambda_{0pt}^3}C_{p0pt} \quad (8)$$

$$k_{ths} = k_g + \frac{k_r}{n_g^2} \quad (9)$$

V. Fuzzy Logic Based MPPT Design

Inputs of fuzzy logic controller are $\Delta V$and ΔP. As shown in figure 3, Fuzzy logic designer has two inputs. These inputs are taken from Solar PV system which Solar Voltage and current. Memory unit is used to hold previous value. New power is product of new input current and voltage value, while previous power is product of previous value of current and voltage. Input ΔV is difference between new voltage and previous voltage value, while input ΔP is difference between new power and previous power as shown in equation (10) and (11).

$$\Delta P = P_n - P_b \quad (10)$$

$$\Delta V = V_n - V_b \quad (11)$$

Where, $P_n = VI$ and $P_b = V_b I_b$

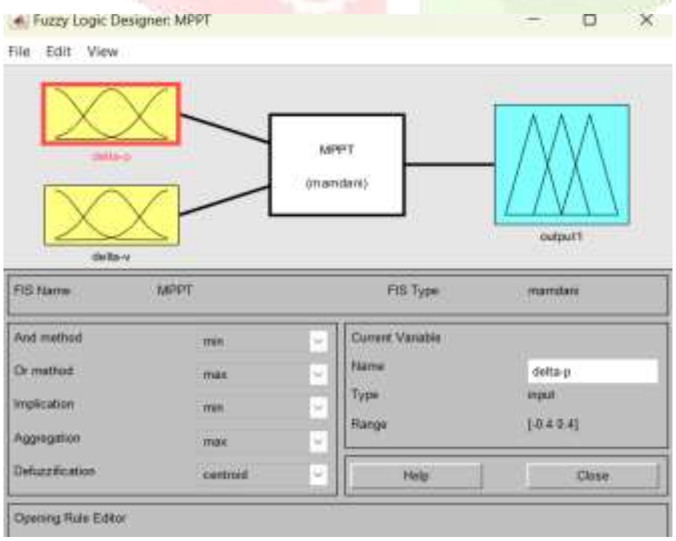

Fig.3. Fuzzy logic designer

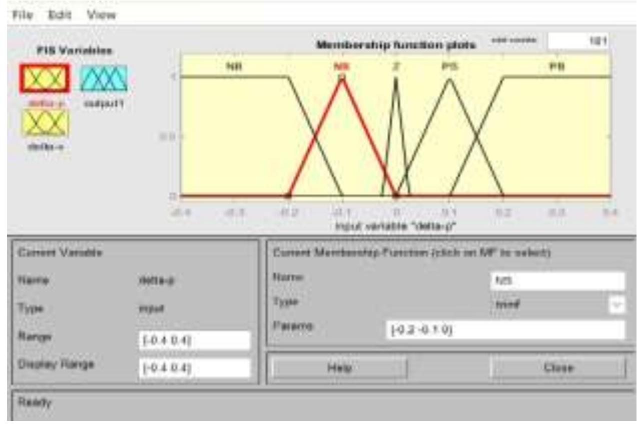

Fig.4. Membership function for input ΔP

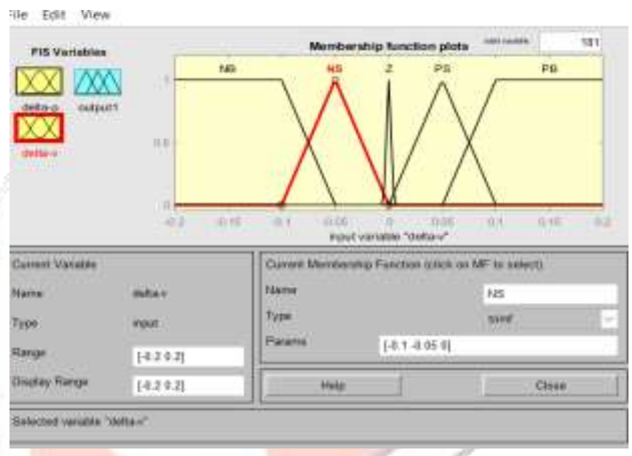

Fig.5. Membership function for input ΔV

ΔV \ ΔP	NB	NS	Z	PS	PB
NB	PB	PS	NB	NS	NS
NS	PS	PS	NB	NS	NS
Z	NS	NS	NS	PB	PB
PS	NS	PB	PS	NB	PB
PB	NB	NB	PB	PS	PB

Fig.6. Fuzzy logic rules

VI. Simulation Results

Output waveform of hybrid Solar and wind with battery storage system is shown in figure 7. The waveform is DC in nature and converted to AC using single phase inverter as shown in figure 7.

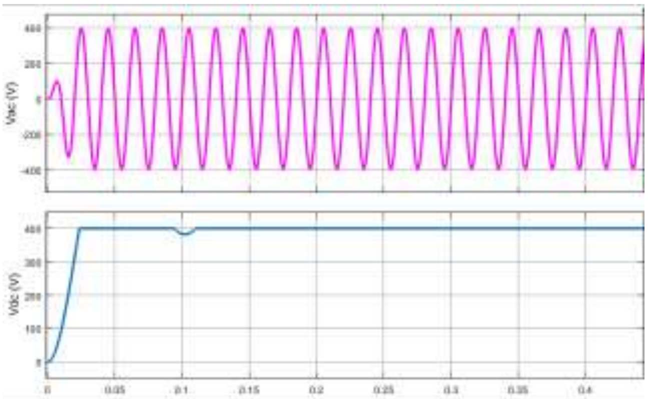

Fig.7. Output AC and DC waveform

Solar irradiation and solar PV voltage and current and power is shown in figure 8. These all parameters are considered for designing converters and controllers.

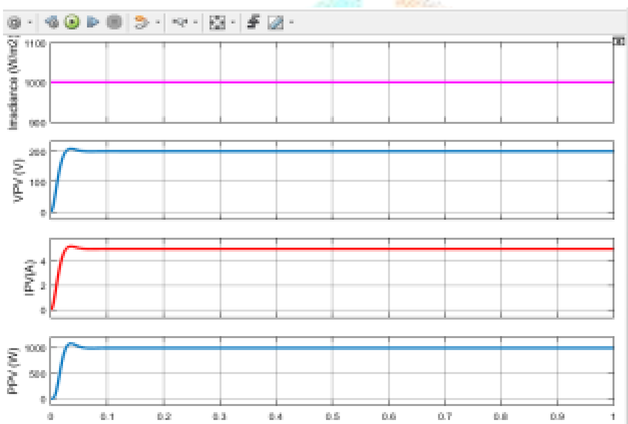

Fig.8. Output Solar Voltage, current, power and irradiation waveform

Wind turbine converts kinetic energy to mechanical energy and feed to permanent magnet synchronous generator. Generator converts mechanical energy to electrical energy. Wind system output current, voltage and power is shown in figure 9.

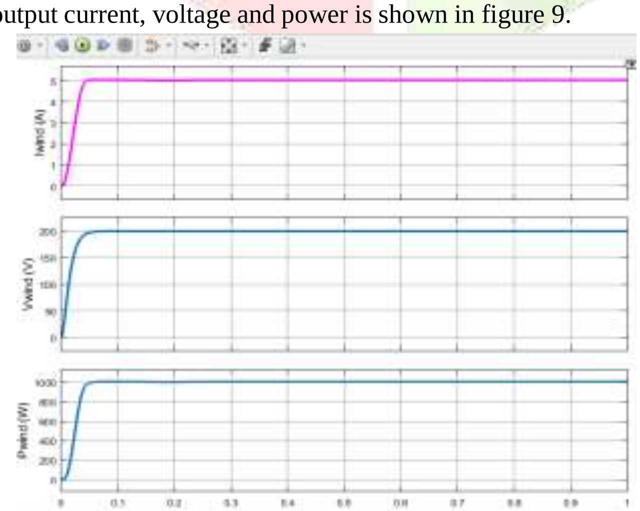

Fig.9. Wind turbine output current, voltage and power waveform

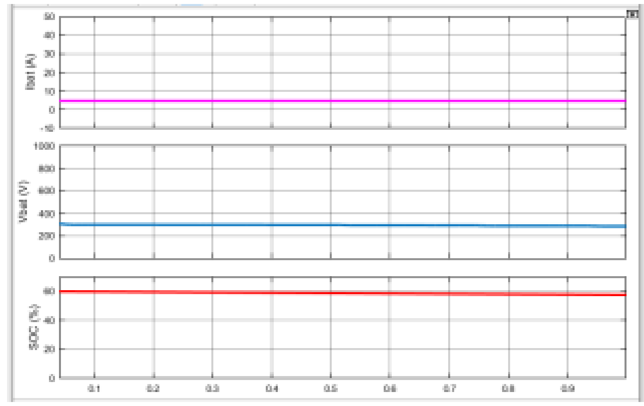

Fig.10. Battery current, voltage and SOC

Battery is used to store excess energy during the time when load is very low. Battery uses bidirectional converters which act as both buck and boost converter. Battery current, voltage and state of charge (SOC) is shown in figure 10.

VII. Conclusion

This study is done completely on 300 people living in 30 households in a village named Tulai-ka-Nagla village, Etah District, village within which for long run everyone was living without electricity. The outcome demonstrates that the PV array met 98% of the load. Due to a time mismatch between power demand and generation, the amount of energy that was discharged reached 1,32,637 kWh, or around 36.8% of the total production.

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