OPERATION AND CONTROL OF HYBRID STANDALONE SYSTEM

J.Jayaudhaya[1], P.Rangarajan[2], C.R. Nandhini[3], B. Nandini[4]

Abstract—Due to the periodic nature of the wind and solar, the power from the wind turbine and the photovoltaic is not sufficient to satisfy the load demand. As a result energy storage systems are necessary to provide continuous and reliable operation. This paper proposes the control and the operation of hybrid standalone systems. The proposed system consists of wind-solar-battery system and load. This system is used to regulate the fluctuations in the power output and battery state of charge. The proposed system is implemented using MATLAB/ Simulink.

Index Terms---- Boost Converter, Permanent Magnet Synchronous Generator (PMSG), Photovoltaic, Energy storage and MPPT

I. INTRODUCTION

Power from the wind is the one of renewable, clean, free sources of energy for power production. Solar power is another clean source of energy. Both solar and wind systems are seasonal, they cannot provide source of energy continuous. For example, during non-sunny day's standalone solar energy system cannot provide reliable power. Due to variations in the wind speeds throughout the year, the standalone wind system cannot provide constant power. Therefore, the hybrid system power transfer and reliability can be improved significantly by combining these two intermittent sources and by incorporating MPPT algorithms. As a result, energy storage systems are used for continuous and reliable operation.

To improve the power quality and to minimize the cost, various wind turbines have been developed. Based on the rotational speed, turbines can be Classified into variable speed, limited variable speed and fixed speed. Based on the power regulation, these can be divided into stall control and pitch control. Based on the drive train, it is classified into geared drive and direct drive. During 1980's and 1990's SCIG with multiple-stage gearbox is used for fixed speed stall control wind turbines. After 1990's variable speed control is used due to increased power Level more than 1.5MW.The generator system consists of DFIG with multiple-stage gearbox and power electronic converters. Since 1991, to reduce the failure of gearbox and to lower maintenance problems, direct drive wind turbine system is used. Rotor blades are directly connected to the hub, Gearless generator rotates at low speed. The direct drive generator can be divided into electrically excited synchronous generator and PMSG (permanent magnet synchronous generator).

The direct drive PM machines offer numerous benefits such as reduction of the weight of active material, elimination of the excitation losses, higher power to weight ratio, field excitation does not require additional power supply, higher reliability, and increased efficiency [2]. High efficiency PM generators are used due to development in the permanent magnet materials [3].

The main purpose of this paper is to control the power generated in a proposed standalone wind-solar hybrid energy generation systems as shown in fig.1. The key is to perform power flow control so as to get the maximum power from the PV panels. Hence, a highly independent generation system from day to night is obtained from this hybrid generation system.

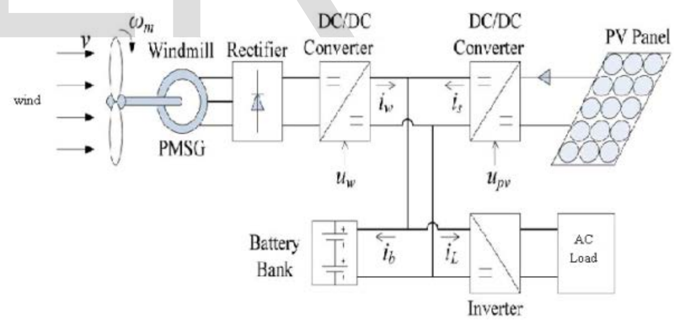


Fig.1.Proposed hybrid energy generation system

II. WIND TURBINE MODELLING

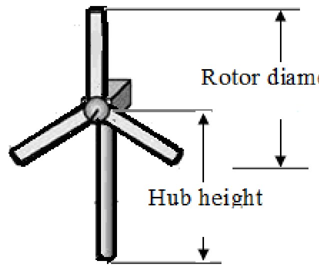
The power generated in the wind turbine is given in equation (1)

$$P_{mech}=0.5\rho A V_w^3 C_P(\lambda, \beta) \quad (1)$$

The mechanical power depends on the wind speed (V_w) and the power coefficient (C_P), which is a function of the tip speed ratio (λ), and the pitch angle (β), Air density (ρ) and swept area (A). The λ is defined as the ratio of tip speed to the wind speed. The

1 **.J.Jayaudhaya,** PhD Research scholar,
R.M.D.Engineering College,
2. P.Rangarajan, Professor,
R.M.D.Engineering College.
3. C.R. Nandhini,
R.M.D.Engineering College.
4. B. Nandini,
R.M.D.Engineering College.

diameter of the rotor calculated from the equation (1) is shown



in the Fig.2.

Fig. 2 Rotor dimension

Rated speed is calculated from the equation (2)

$\lambda * V_w / R = \Omega_t$ (2)

Where R is the radius of the rotor, Ω_t is the rotational speed of the wind turbine.

For different values of β, graph is plotted between C_P and λ as shown in Fig.3.

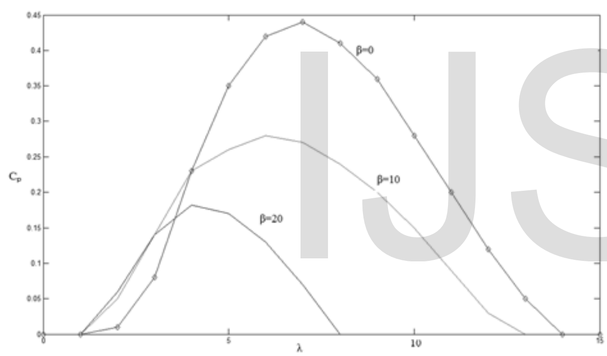


Fig.3. C_P vs.λ for different pitch angles (β)

C_P reaches maximum value for a given pitch angle β for λ_{opt}. The C_{Pmax} and λ_{opt} vary with pitch angle. These two parameters decreases as the pitch angle increases as given in table .1

The tip speed ratio assumed as the optimum value, depending on the wind speed, gives the optimum turbine speed (Ω_{opt}) through equation (2). The optimum torque and the maximum active power are given by the expressions (3) and (4).

$T_{opt} = K_{opt}\ \Omega_{opt}^2$ (3)

$P_{opt} = T_{opt}\Omega_{opt} = K_{opt}\ \Omega_{opt}^3$ (4)

Where

$K_{opt} = 0.5\rho\pi R^5 C_{Pmax} / \lambda opt^3$, (5)

$C_{Pmax} = C_P(\lambda opt, 0)$ (6)

It is shown that the wind speed and the torque follow a quadratic function, whereas the wind speed and the power relationship is a cubic function.

III.STANDALONE WIND-SOLAR SYSTEM CONFIGURATION

A. WIND SUBSYSTEM MODEL

The proposed standalone hybrid system distributes single phase supply to the load. From the wind, power is not extracted fully. Generally, the wind turbine power utilization stands at a mere 59%. The mechanical output from the wind turbine is connected to the wind generator and it converts the mechanical energy into electrical energy. The ac output from the wind generator is converted to dc with the help of rectifier. The rectified output is given to boost converter to get the required voltage level. For various wind speeds, the converter voltage should be maintained constant. The excess power from the wind generator is stored in the battery when the speed of the wind is too high. When the wind speed is low, the solar energy and energy from the battery bank will satisfy the demand.

B. MODELING OF PMSG

In two-phase synchronous reference frame, based on the direction of rotation, the *q*-axis is 90◦ ahead of the *d*-axis. In synchronous reference frame, the electrical model of PMSG is given by (1)

$di_d/dt = -(R_a/L_d).i_d + \omega_e(L_q/L_d)i_q + (1/L_d)v_d$
$di_q/dt = -(R_a/L_q)i_q - \omega_e((L_d/L_q)i_d + (1/L_d)\Psi_{PM}) + (1/L_q)v_q$ (8)

where subscripts q and d are the physical quantities, R_a is the armature resistance, ω_e is the rotating speed which is associated with the mechanical rotating generator speed since $\omega_e = n_p \cdot \omega g$, where n_p refers to the number of pole pairs; and ψ_{PM} is the magnetic flux of permanent magnet. The torque can be calculated using the formula (9)

$T_e = 1.5n_p[(L_d - L_q)i_d i_q + \psi_{PM} i_q]$ (9)

Consider $Ld = Lq = L$ in PMSG, then (8) can be written as

$di_d/dt = -(R_a/L)\ i_d + \omega_e i_q + (1/L)v_d$
$di_q/dt = -(R_a/L)i_q - \omega_e(i_d + (1/L)\Psi_{PM}) + (1/L)v_q$ (10)

and the torque is given by

$T_e = 1.5 n_p \psi_{PM} i_q$. (11) .

C. BOOST CONVERTER MODEL

Between the battery and the rectifier, a unidirectional boost converter is connected. The block diagram represented in Fig.4 shows the simplified boost converter model. The primary and secondary voltage relation is given in equation (12)

$V_{out} = V_{in} / (1-D)$ (12)

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where$D$ isthe pulse-width modulation (PWM) factor. When $V_{in} \geq V_o$, the boost converter is not working, and the current supplied to the generator is channeled through the bypass Schottky diode which is connected across the diode and inductor. From equation (12), assumed that no power loss in the converter

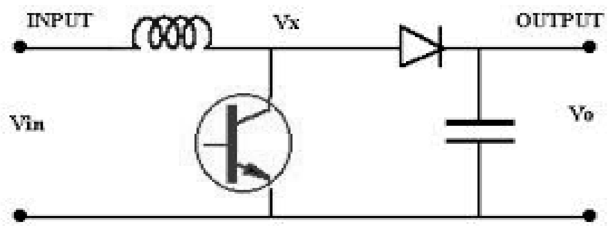

Fig.4 Simplified boost converter model

D. PV SYSTEM

The PV system is consists of PV panel and converter (DC-DC Boost converter). Through dc/dc converter, the DC bus is connected to the solar subsystem. In this solar subsystem, converter is used to get the required voltage. Thus the converter controls the operating point .Here we use the MPPT technique to track the maximum power obtained at all time. To boost the voltage obtained in solar panel, converter (DC-DC) is used. This increased voltage is given to the dc bus to maintain the voltage constant. When the solar power generation exceeds the demand, the excess power is sent to the battery bank for storage. When the power generated is less than the demand, battery bank supplies the required power to the load.

E. **MPPT ALGORITHM**

Maximum power point tracking is used to get the maximum power from solar panel. The MPPT control adjusts the position of the solar panel to get the maximum power depending upon the insulation and temperature. PI controller is used to implement the MPPT function. It provides the reference power to the boost converter based on the temperature measurements. Fig.5 represents the MPPT control block diagram.

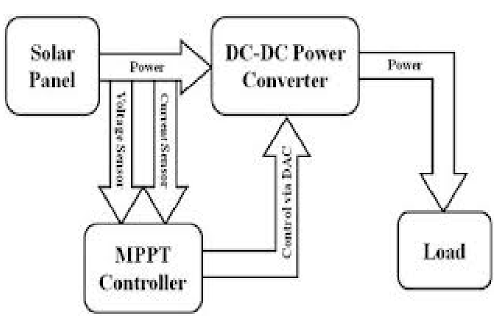

Fig.5 MPPT control block diagram

F. **ENERGY STORAGE SYSTEM**

Energy storage system consists of lead acid battery bank each of 12V and single-phase MOSFET inverter. Lead acid battery is connected in series to get a required voltage. The battery bank is used to compensate the power in times of shortage to supply the demand i.e., it will be used when the wind speed is lower or insulation is not sufficient. When the generation exceeds the demand, the excess power is charged to the battery in parallel. When the generation is lesser than the demand, the power needed is satisfied by discharging the battery. Both the wind and solar subsystem share the same battery bank for energy storage.

IV.SIMULATION RESULTS

A.OUTPUT FROM WIND SYSTEM

Time in X-Axis, Voltage in Y-Axis

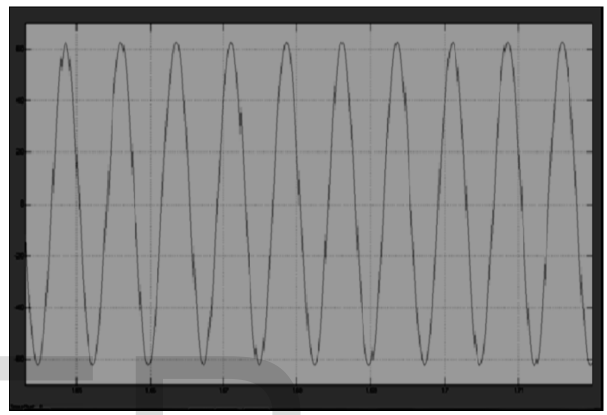

Fig.6.output from the wind system

B.OUTPUT FROM SOLAR SYSTEM

Time in X-Axis, Voltage in Y-Axis

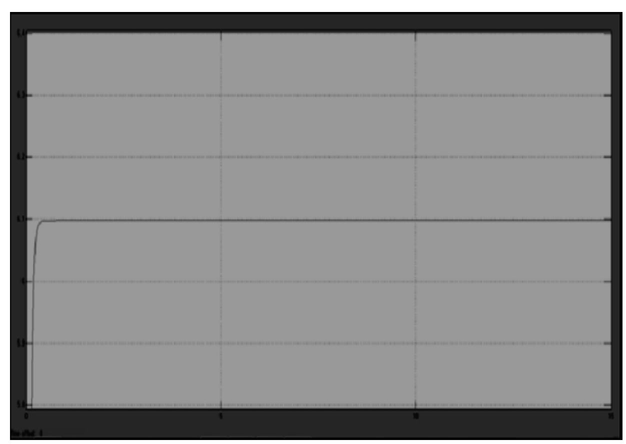

Fig.7.solar output

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C. OUTPUT ACROSS LOAD

Time in X-Axis, Voltage in Y-Axis

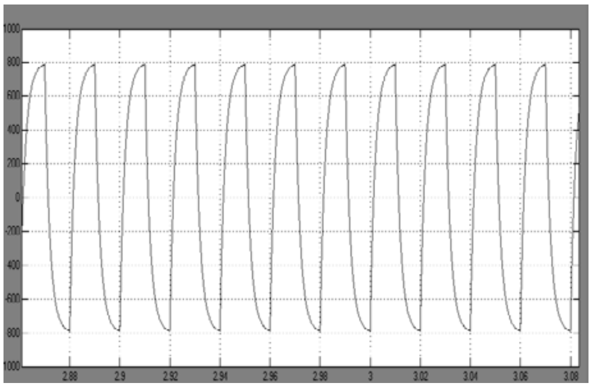

Fig.8. output across the load

V.EXPERIMENTAL MODEL

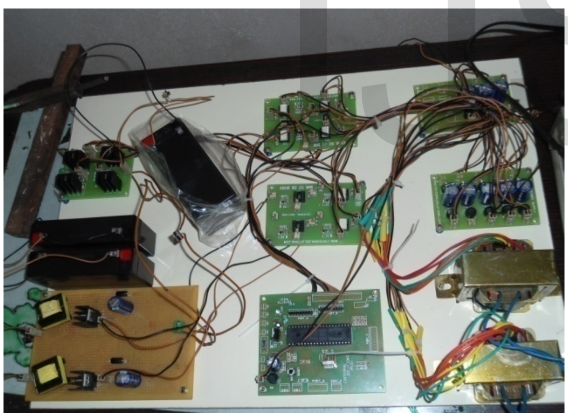

Fig.9.Experimental setup for wind and battery

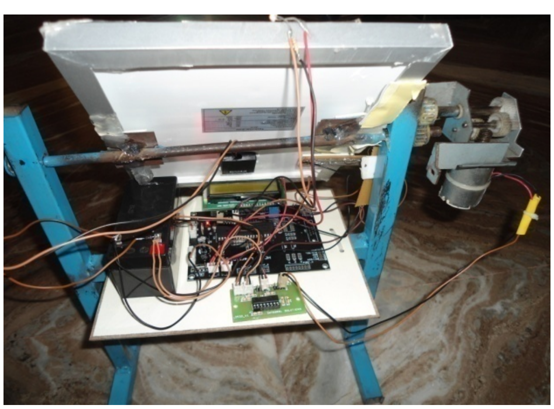

Fig.10.setup for solar and MPPT

TABLE. ISPECIFICATION OF PROPOSED HYBRID SYSTEM

Solar Panel	
Number of cells	12
Solar panel voltage	6V
Type of coating	Black coating of polycrystalline type
Watts	3W
Current	1.3A
Battery	
Voltage	12V
Current	1.3A
Load	
Voltage	12V
Current	1.3A

VI. CONCLUSION

In this work, we focus on the control of the standalone wind-solar energy subsystem. Here, MPPT technique is used to track the maximum energy generated from the solar subsystem at all the time. The power generated in excess is sent to the battery bank to satisfy the demand of the load when there is minimum power generation. We have discussed here on how to satisfy the load demand during all conditions. Simulation results show the output of the model proposed. Future work, taking into account the information of future weather forecast, will include the investigation of large time span behavior of the hybrid wind-solar generation system and also the investigation of performance of the system given the provision that the power demand of the future is not known.

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