A Combination of Wind-Hydro System Connected to Two Back to Back Converters with an Energy Storage Battery System

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ABSTRACT : *This paper presents the simplified control of hybrid system (wind –hydro) system connected to two back-to-back converters in which one is connected to hydro turbine and the other is connected to wind turbine system through squirrel cage induction generators (SCIG) feeding three phase four wire loads in isolated locations. The main objective of this work is to provide a better control algorithm for the VSC and to achieve maximum power tracking (M.P.T) through rotor speed control of the wind turbine driven S.C.I.G under varying speeds at the machine side and to control the magnitude and frequency of the voltage at load side. The system mainly ensures in sending the power generated by* $SCIG_w$ *is supplied to the load through the load-side converter and remaining power is stored in ESBS. And at the same time if the required active power of the load is more than the total power generated by* $SCIG_w$ *and* $SCIG_h$*. Then the deficit power is supplied by the ESBS. Simulation models of the proposed hybrid system and the simulation results are obtained in MATLAB using Simulink and Sim Power System set toolboxes, with different load condition at different wind conditions*

Keywords - *energy storage battery system (ESBS) system, small-hydro, squirrel-cage induction generator (SCIG), MPT, Voltage Source Converter (VSC.)*

1. INTRODUCTION

Now a days most of the countries are aware of global warning problems. The most common problem is the pollution from burning fossil fuels while producing the energy. .in order to reduce this problem energy resources like wind, hydro, solar ,biomass etc. must be encouraged further. Utilization of wind energy resources is the fast growing and most promising re source among all the resources due to its economically variable nature. India ranking in 5^{th} position in the world with an installed capacity of 11807MW as on 31-3-2010 as per information collected from Ministry of New and Renewable Energy (MNRE), India. According to this report, in India the total installed capacity as on 31^{st} March, 2009 is approximately 2430MW [1], [2]. Among all the present renewable energy sources, mini hydro and wind energy have the ability to get more advantage with each other. For power generation by mini hydel or micro hydel as well as wind systems, the acquirement of squirrel cage induction generators (SCIGs) are more prominent due to its various advantages [5].Now a days the wind-turbine technology is been increasing its range from fixed speed to variable speeds. The variable-speed machines have gained lots of advantages. These are helpful in reducing the mechanical stresses and useful as of increased efficiency [4]. Natural energy based power generation systems are mostly worked with the combination of energy storage battery system (ESBS) to balance the power outages in the system. More over with the case of stand-alone system lots of problems are arising in maintaining the proper active and reactive power due to drop in voltage and frequency [8]. So, here a new and flexible battery-based controller is proposed to control voltage and frequency in the Wind Energy Conversion Systems (WECS). However, Maximum Power Tracking (MPT) shall not be satisfied by this battery-based system employed with SCIG operating at constant speeds [7]. The two Voltage Source Converters (VSCs) for the wind and hydel turbine are connected between the stator windings of $SCIG_w$ at wind power generation side (machine side) and the stator windings of $SCIG_h$ at hydel power generation (load side) to provide the required power flow. In the proposed system, there are two modes of operation. Here the two modes explain about, when the active power generated is greater the load power, then how it will be transferred to battery and in the second mode, for suppose, the necessary active power for the load is more than the power generated by the wind and hydel turbine then how the battery provide the remaining power to the load through the load-side converter and is shown in Fig.1.

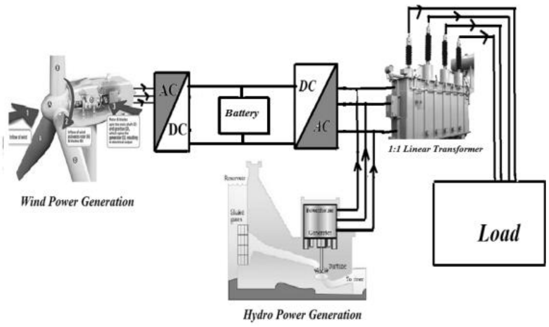


Fig. 1: Block diagram of Hybrid system

2. PRINCIPLE OF OPERATION

From the above shown Fig.1, the main purpose of the work is to provide a constant voltage to the load at constant frequency with the help of load-side converter. To improve the load-frequency and to make it constant, the additional active power should be transferred to the battery. Here, the design of the battery is such that it is capable of storing the excess active power and discharges back to the load at the time of power shortages [6]. At the same time the voltage is also set to be constant to balance the reactive power of the load by means of load side converter. In this work, in order to achieve maximum power tracking (MPT) pitch angle controller was been used [9].As Pitch-angle controller with adjusting variable-speed wind turbines are gaining a lots of advantages these are mostly preferred. The pitch-angle reference, βref, is mainly controlled by three values called wind speed, Generator rotor speed and input generator power. Here, the calculated pitch angle will be controlled by the input generator power. The error signal in the generator power is sent to a PI controller and then the PI controller produces the reference pitch angle βref.There the new pitch-angle reference will be controlled by the input value of the generator power. The calculated reference power and generated power of the turbines are compared with each other and the error signal will be given to the PI controller. The output of the PI controller will produces the final reference value of pitch angle (βref) and will be given to the machine side converter.

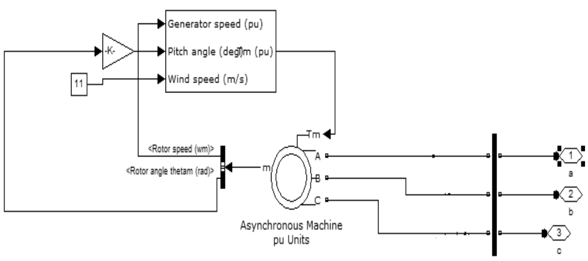


Fig.2: Simulink model of wind turbine

3. MODELLING OF WIND-TURBINE WITH S.C.I.G

A wind turbine in Fig.2 is characterized by its power–speed characteristics [4]. For a horizontal turbine, the power produced, Pt, is

$$P = 0.5 \times A \times \rho \times C_p \times v^3 \qquad (1)$$

Where A = *Swept rotor area in* m^2

C_p = *Coefficient of power*

V^3 = *wind speed in m/s*

p = *Density of air in* kg/m^3

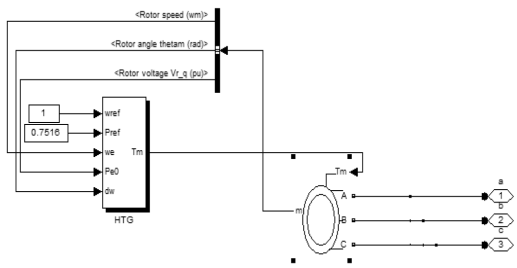
4. MODELLING OF MINI HYDRO-TURBINE WITH S.C.I.G

The power available in a flow of water depends its head and the discharge. The water powers a turbine, and its rotational movement is transferred through a shaft to an electric generator [9]. The power hydro generating unit in Fig.3 is given by

$$P_h = 9.81 \times 10^{-3} \times \eta_t \times \eta_g \times q \times h \qquad (2)$$

Where q = Flow of turbaned water,

η_t= Turbine efficiency,



η_g = Generator efficiency,

h = Water head.

Fig. 3: Simulink model of Hydel turbine

5. DESIGN OF ESBS

Lead acid batteries are used in many electrical systems to store or deliver energy. These are rechargeable and thevenin equivalent circuit is a simple way of demonstrating the behavior of battery voltage for small rating of hybrid renewable energy power generation. model of a battery is shown in Fig.4

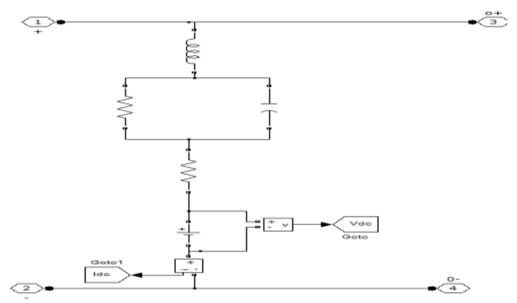


Fig.4: Simulink model of battery

6. CONTROL TECHNIQUE OF THE LOAD SIDE CONVERTER

Objective is to maintain constant voltage and frequency at the load terminals irrespective of the load. The reference voltages (**v^*** *an*, **v^*** *bn***,** and **v^*** *cn*) for the control of the load voltages at time t are given as

$v^* an = \sqrt{2}\, v_t \sin(2\pi ft)$ (3)

$v^* bn = \sqrt{2}\, v_t \sin(2\pi ft - 120^0)$ (4)

$v^* cn = \sqrt{2}\, v_t \sin(2\pi ft + 120^0)$ (5)

Where ***f*** = nominal frequency which is 50Hz **v_t** = r.m.s phase-to-neutral load voltage which is 240. The error voltages are given by

$van\ err(n) = v^*\ an(n) - van(n)$ (6)

$vbn\ err(n) = v^*\ bn(n) - vbn(n)$ (7)

$vcn\ err(n) = v^*\ cn(n) - vcn(n)$ (8)

The references are compared with the sensed ones to compute errors signals as

$i_{sh}\ a\ error = i^*_{sh}\ a - i_{sh}\ a$ (9)

$i_{sh}\ b\ error = i^*_{sh}\ b - i_{sh}\ b$ (10)

$i_{sh}\ c\ error = i^*_{sh}\ c - i_{sh}\ c$ (11)

By applying the PWM technique to these current errors is to generate the gate signals for IGBTs of the load-side converter.

7. CONTROL TECHNIQUE OF THE MACHINE SIDE CONVERTER:

7.1 To achieve the maximum power tracking to the wind turbine

In the proposed algorithm, the rotor speed (ω_{rw}) of $SCIG_w$ is determined from its rotor position (θ_{rw}).The tip speed ratio (λ_w) for a wind turbine of radius (r_w) and gear ratio η_w at a wind speed (v_w) of is defined as:

$$\lambda w = \omega_{rw.}\, r_w / \eta_{w.} v_w \quad (12)$$

For MPT in the wind turbine generator system, the SCIGw should be operated at optimal tip speed ratio (***λ*w***).The tip-speed ratio determines the SCIG rotor set speed point for a given wind speed and the mechanical power generated at this speed lies on the maximum power lines of the turbine.For a horizontal turbine, the power produced, ***Pt***, is:

$$P_t = 0.5C_p(\lambda\omega,\beta).\rho.A.V_w^3 \quad (13)$$

Where Cp =Coefficient of power,

p = Density of air,

A= Area of wind turbine and

Vw = Velocity of air.

β = Pitch angle

7.2 Generation of Gating signals to converter

The rotor-speed error (ω_{rw} *error*) at the nth sampling instant as

$\omega_{rw}\, error(n) = \omega^*_{rw}(n) - \omega_{rw}(n)$ (14)

This error is given to the Speed PI controller to get the reference q-axis SCIG w stator current is,

$I^*_{qsw}(n) = I_{qsw}(n-1) + K_{p\omega}(\omega_{rw}\ error(n) - \omega_{rw}\ error(n-1)) + K_{i\omega}\, \omega_{rw}\, error(n).$ (15)

The reference d-axis SCIG w stator current (I^*_{dsw}) is determined from the rotor flux set point (ϕ^*_{drw}) at the nth sampling instant as

$I^*_{dsw}(n) = \phi^*_{drw} / L_{mw}$ (16)

Where

L_{mw} = *magnetizing inductance of* $SCIG_w$

By d-q to abc transformation reference SCIG w stator currents are given by

$i^*_{sw}\, a = i^*_{dsw} \sin(\theta_{rotor\ flux}\, w) + i^*_{qsw} \cos(\theta_{rotor\ flux}\, w)$ (17)

$i^*_{sw}\, b = i^*_{dsw} \sin(\theta_{rotor\ flux}\, w - 2\pi/3) + i^*_{qsw} \cos(\theta_{rotor\ flux}\, w - 2\pi/3)$ (18)

$i^*_{sw}\, c = i^*_{dsw} \sin(\theta_{rotor\ flux}\, w + 2\pi/3) + i^*_{qsw} \cos(\theta_{rotor\ flux}\, w + 2\pi/3).$ (19)

These references are compared with sensed ones to compute the error signals. By using of PWM technique to this error signals will be generated to the machine side VSC and is shown in Fig.5.

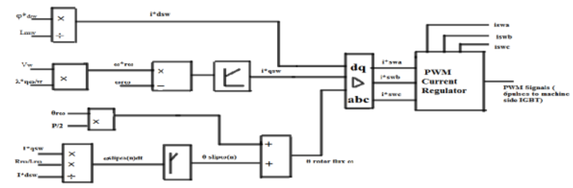


Fig.5: Control block of machine side converter for generating pulses

8. SIMULINK OF HYBRID SYSTEM AND PERFORMANCE PARAMETERS

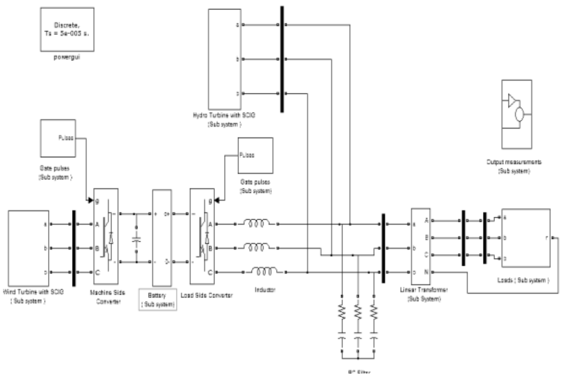
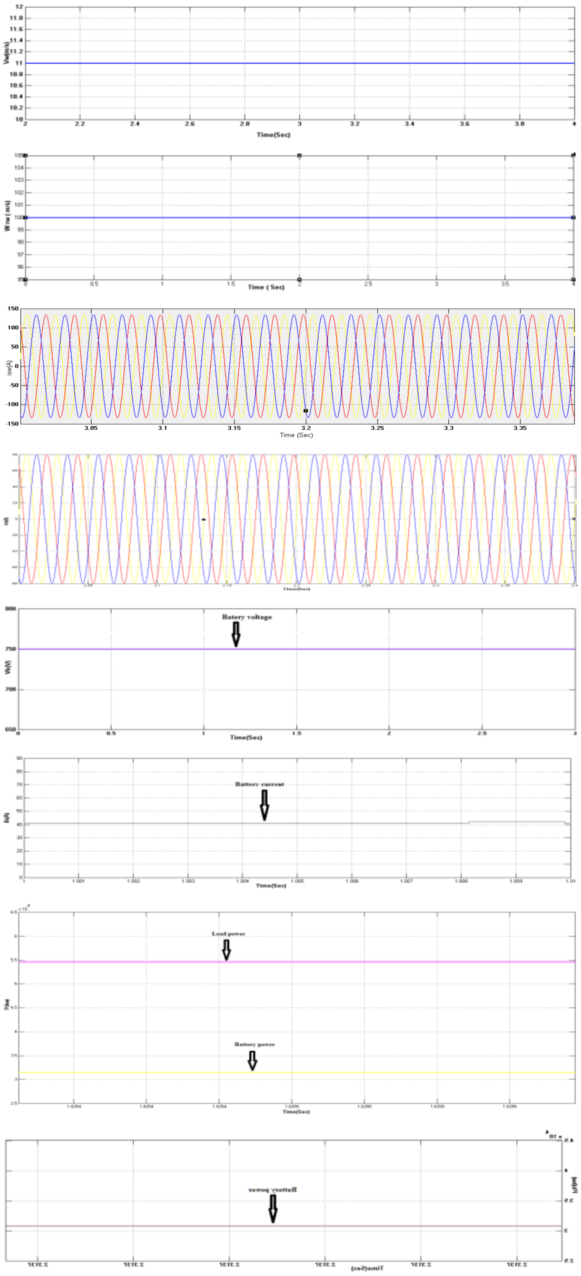
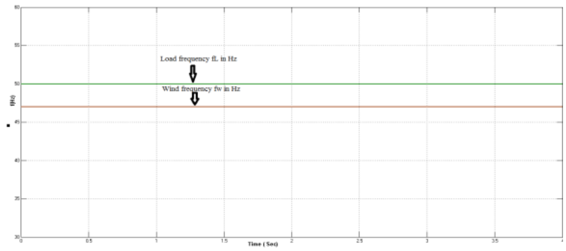


Fig.6: Simulation diagram of Hybrid system

8.1 Performance of balanced three phase linear loads of 20kW and 10kVAR at wind speed of 11m/s





8.2 Performance of hybrid system with unbalanced loads

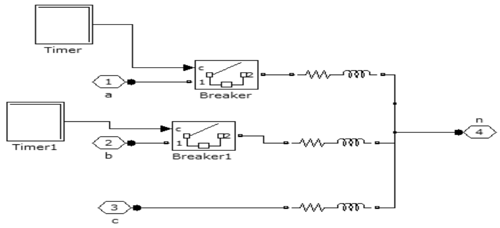
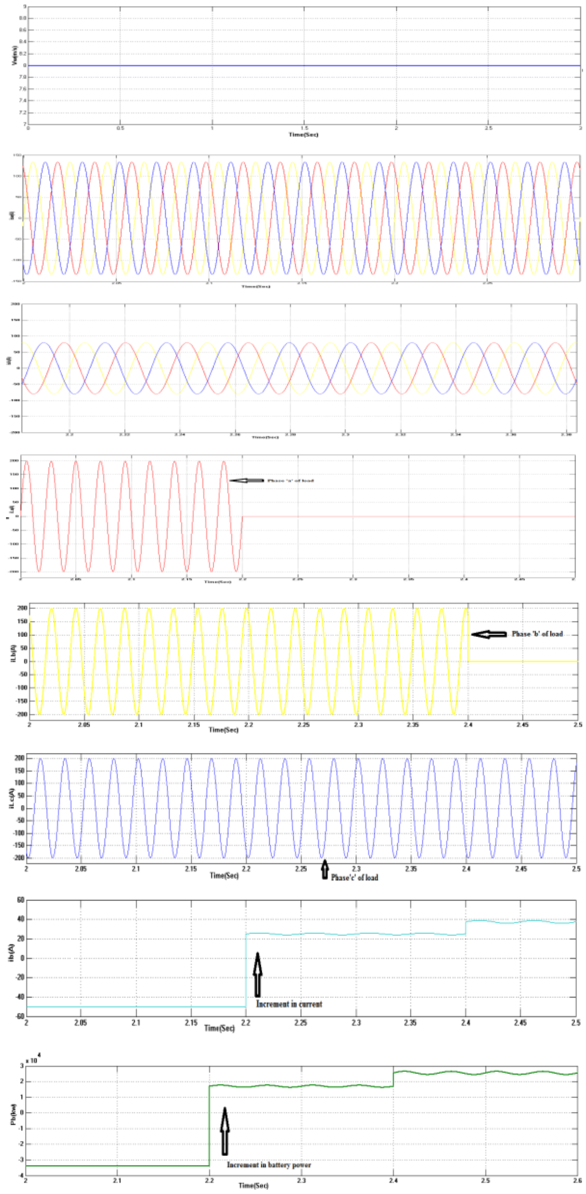
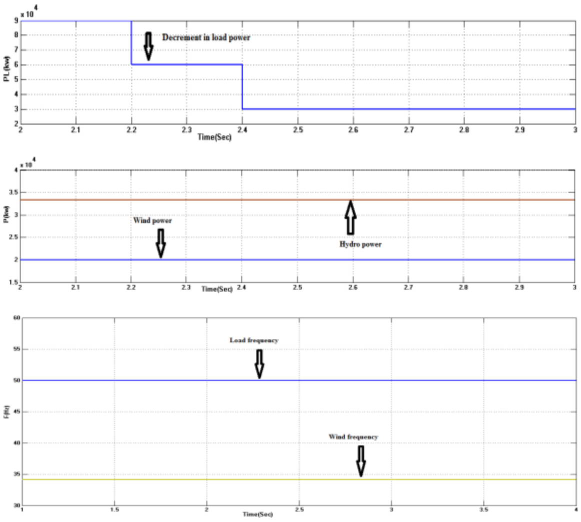


Fig.7 Simulink of unbalanced loads





8.3 Performance of hybrid system with balanced /unbalanced nonlinear loads

In this case of Fig.8, the system is started with a three single phase diode bridge rectifier, each of 16 kW and three single phase linear loads each of 5kw at wind speed of 10m/s.

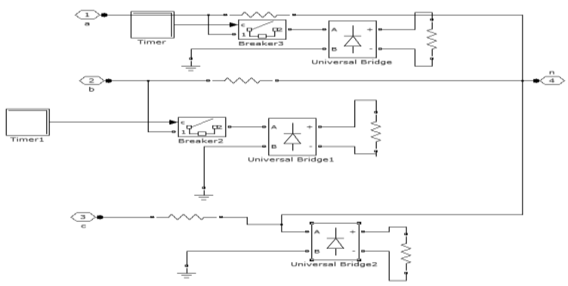
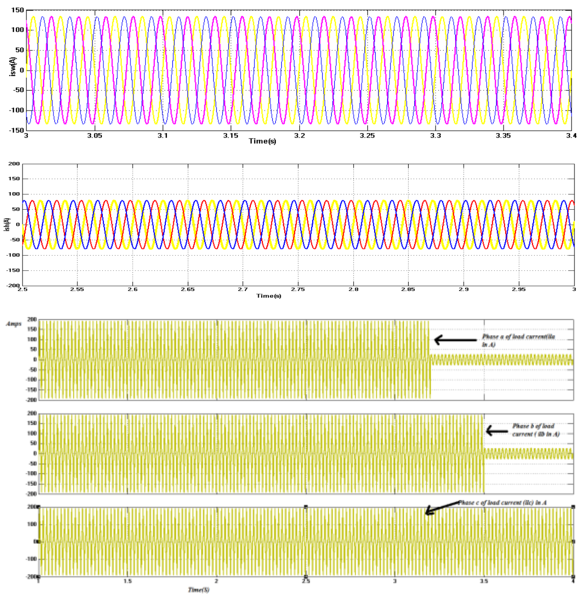
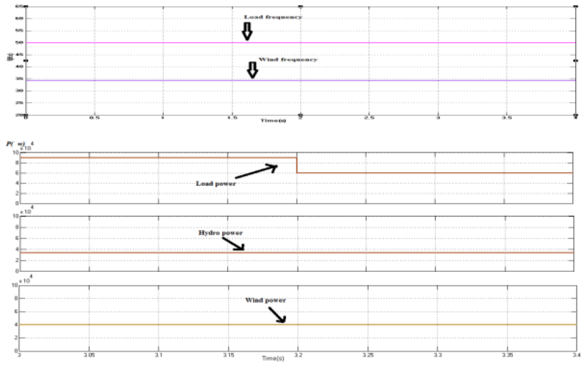


Fig.8: Simulink of balanced/unbalanced loads





8.4. Performance of wind-hydro hybrid system with mixed loads

In this condition at wind speed of 9 m/s the system in Fig.9 started with balanced three single phase linear loads of 3.3 and an Induction generator of 15kw

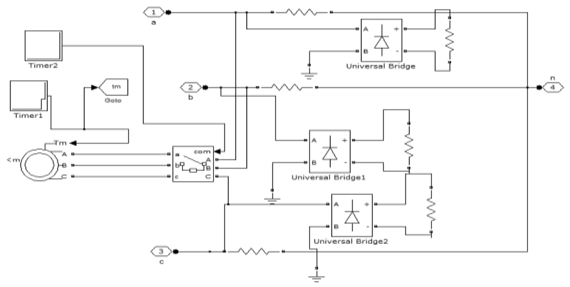
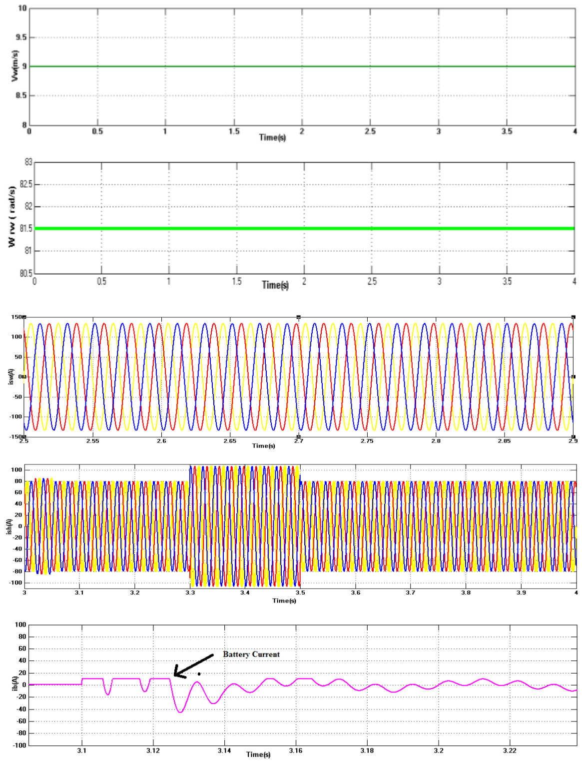
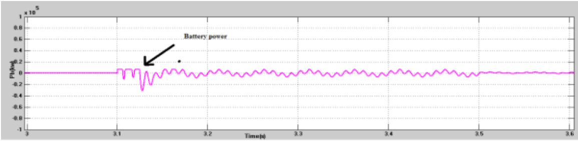


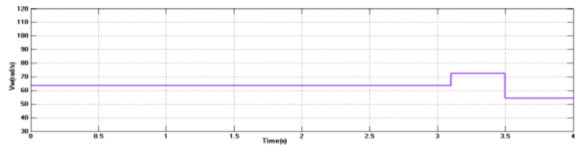
Fig.9: Simulink of mixed loads

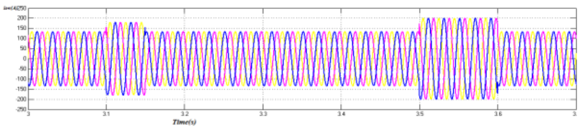


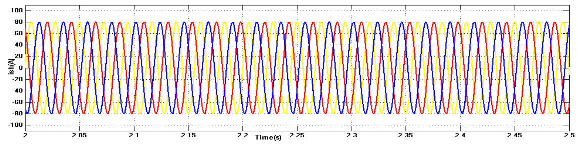


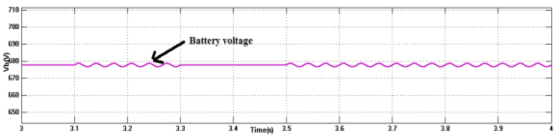
8.5 Performance of the system under varying wind speeds with constant balanced linear loads

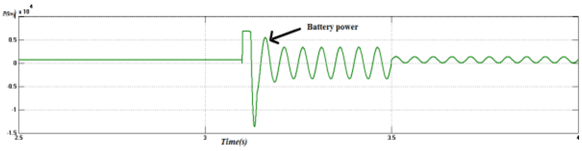
In this case the performance of the system is studied with linear balanced load of three single phase loads totaling to 45 kW at varying wind speed conditions

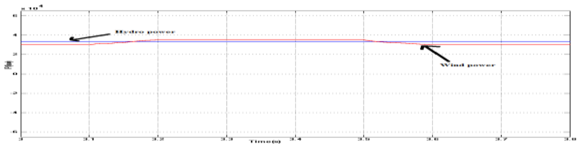


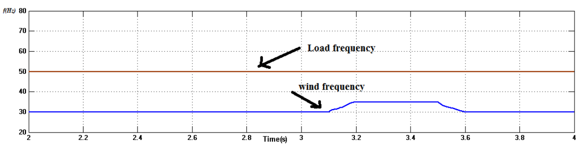












9. CONCLUSION

A three phase four wire mini system of wind and hydro turbine connected to two squirrel cage induction generators is designed and modeled using MATLAB/SIMULINK. Here, the pitch angle controller is provided by means of using PI control technique to maintain a constant voltage and frequency even with the change in load.

The system has been demonstrated in such a way that the proposed hybrid system performs satisfactorily under different performance conditions by maintaining the constant voltage and frequency at load side by means of load side converter for different load conditions at various wind speed conditions . Moreover, the designed MPT controller has shown it's at wind turbine side (Machine side converter side) and load balancing and resulted in reduced harmonics at different wind speed and load conditions.

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References

[1]. D.P Kothari, K.C Singal and Rakesh Ranjan, "Renewable Energy Sources and Emerging Technologies", edition-2, pp.378-384.

[2]. J. B. Ekanayake, "Induction generators for small hydro schemes," *IEEE Power Eng. J., vol. 16, no. 2, pp. 61–67, 2002.*

[3]. B. Fox, D. Flynn, L. Bryans, N. Jenkins, D. Milborrow, M. O'Malley,R. Watson, and O. Anaya-Lara, Wind Power Integration Connection and System Operational Aspects. *London, U.K.: IET, 2007, ch. 3.*

[4]. G. Quinonez-Varela and A. Cruden, "Modeling and validation of a squirrel cage induction generator wind turbine during connection to the local grid," *IET Genre., Transmits. Distrib., vol. 2, no. 2, pp. 301–309, Mar. 2008.*

[5]. Burak Ozpineci and Leon Tolbert "Simulink Implementation of Induction Machine Model – a Modular Approach," *0-7803-7817-2/03@2003IEEE*

[6]. G.Quinonez-Varela and A.Cruden, "Modelling and validation of a squirrel cage induction generator wind turbine during connection to the local grid," *IET Gener., Transmiss. Distrib, vol. 2, no. 2, pp. 301–309, Mar. 2008.*

[7]. Tamas and Z.Szekely, "Modeling and Simulation of an Induction Drive with Application to a Small Wind Turbine Generator," in *Proc. IEEE Int. Conf. Autom., Quality Test., Robot., May 22–25, 2008, pp. 429–433.*

[8].B.Singh and G. K. Kasal, "Voltage and frequency controller for a three-phase four-wire autonomous wind energy conversion system," *IEEE Trans. Energy Convers., vol. 23, no. 2, pp. 505–518, Jun. 2008.*

[9]. Bhim Singh and V.Rajgopal, "Digital Control of Voltage and Frequency of Induction Generator in Isolated Small Hydro System," *2012IEEE International Conference on power Electronics, Drives and Energy System, vol.no1, pp 4673-4508*