ISSN No: 2348-4845
International Journal & Magazine of Engineering,
Technology, Management and Research
A Peer Reviewed Open Access International Journal

A Stand-Alone Hybrid Wind-Hydro Energy Conversion System With Battery Energy Storage System

Kalimela Venkateswarlu
Assistant Professor,
Department of EEE,
Annamacharya Institute of Science and Technology.

T. Ramesh
M.Tech Student, Power Electronics,
Department of EEE,
Annamacharya Institute of Science and Technology.

Abstract:

In this paper, a new three-phase four-wire autonomous wind–small hydro hybrid system is proposed for isolated locations, which cannot be connected to the grid and where the wind potential and hydro potential exist simultaneously. The issues of voltage and frequency control (VFC) are very important. The wind system was driven by Squirrel Cage Inductors. The proposed system utilizes two back-to-back-connected PWM, IGBT based voltage-source converters (VSCs) with a BESS at their dc link. The proposed hybrid system has advantage of bidirectional active- and reactive-power flow, by which it controls the magnitude and the frequency of the load voltage. The system operation was verified by different types of loads. The performance characteristics of proposed hybrid system had verified by MATLAB/Simulink-SimPower Systems software.

Key words:

Hybrid Renewable energy systems, SCIG, BESS, Maximum Power Point Tracking.

I.INTRODUCTION:

Renewable energy sources have attracted attention worldwide due to soaring prices of fossil fuels. Renewable energy sources are considered to be important in improving the security of energy supplies by decreasing the dependence on fossil fuels and in reducing the emissions of greenhouse gases. The viability of isolated systems using renewable energy sources depends largely on regulations and stimulation measures.

Renewable energy sources are the natural energy resources that are inexhaustible, for example, wind, solar, geothermal, biomass, and small hydro generation [1]. Among the renewable energy sources, small hydro and wind energy have the ability to complement each other [2]. As regards wind-turbine generators, these can be built either as constant-speed machines, which rotate at a fixed speed regardless of wind speed, or as variable-speed machines in which rotational speed varies in accordance with wind speed. For fixed-speed wind turbines, energy-conversion efficiency is very low for widely varying wind speeds. In recent years, wind turbine technology has switched from fixed speed to variable speed. The variable-speed machines have several advantages. They reduce mechanical stresses, dynamically compensate for torque and power pulsations, and improve power quality and system efficiency. The grid-connected variable-speed wind-energy-conversion system (WECS) based on SCIG use back-to-back connected power converters. In such systems, the power converter decouples the SCIG from the grid, resulting in an improved reliability.

In this paper, a new three-phase four-wire autonomous (or isolated) wind–small hydro hybrid system is proposed for isolated locations, which cannot be connected to the grid and where the wind potential and hydro potential exist simultaneously. One such location in India is the Andaman and Nicobar group of islands [3]. The proposed system utilizes variable speed wind-turbine-driven SCIGw (subscript w for wind), and a constant-speed/constant-power small hydro-turbine-driven SCIGh (subscript h for hydro). For the rest of this paper, the subscript w is used to denote the parameters and variables of the wind-turbine generator, and the subscript h is used to denote the parameters and variables of the hydro-turbine generator.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

A schematic diagram of a three-phase four-wire autonomous system is shown in Fig. 1. Two back-to-back-connected pulse width modulations (PWM)-controlled insulated-gate-bipolar transistor (IGBTs)-based voltage-source converters (VSCs) are connected between the stator windings of SCIGw and the stator windings of the SCIGh to facilitate bidirectional power flow. The stator windings of the SCIGh are connected to the load terminals. The two VSCs can be called as the machine (SCIGw) side converter and the load-side converter.

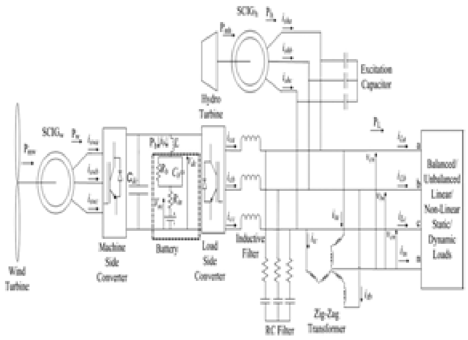


Fig. 1: Schematic diagram of wind–hydro hybrid system.

II.SYSTEM DESCRIPTION:

The system employs a battery energy storage system (BESS), which performs the function of load leveling in the wake of uncertainty in the wind speed and variable loads. The BESS is connected at the dc bus of the PWM converters. The advantage of using BESS on the dc bus of the PWM converters is that no additional converter is required for transfer of power to or from the battery. Further, the battery keeps the dc-bus voltage constant during load disturbances or load fluctuations. An inductor is connected in series with the BESS to remove ripples from the battery current.A zigzag transformer is connected in parallel to the load for filtering zero-sequence components of the load currents. Further, the zigzag windings trap triplen harmonic (third, ninth, fifteenth, etc.) currents. As shown in Fig. 1, the zigzag transformer consists of three single-phase transformers with a turn ratio of 1:1. The zigzag transformer is to be located as near to the load as possible. The neutral terminal of the consumer loads is connected to the neutral terminal of the zigzag transformer. For the hybrid system, a new control algorithm is proposed that has the capability of MPT, harmonic elimination, load leveling, load balancing, and neutral current compensation along with VFC.

The objectives of the machine (SCIGw) side converter are to provide the requisite magnetizing current to the SCIGw and to achieve MPT. In the conventional control of variable-speed SCIGs, the objective of the load-side converter (called as grid-side converter in the grid-connected systems) is to maintain the dc-bus voltage constant at the dc link of two back-to-back connected VSCs. Because in the proposed system the dc-bus voltage is kept constant by the battery, the control objective of the load-side converter is different, i.e., to maintain an active power balance in the system by transferring the excess power to the battery or for providing deficit power from the battery. Further, the load-side converter provides the requisite reactive power for the load. The reactive-power requirement of the SCIGh is provided by the excitation capacitors connected at its stator terminals.

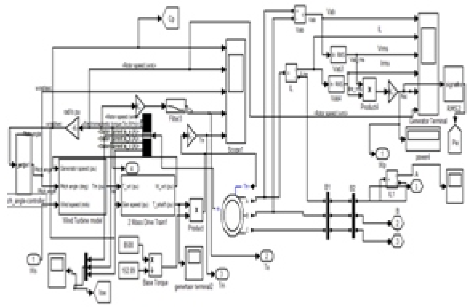


Fig 2: WECS with SCIG

A novel control strategy using indirect current control is proposed for the load-side converter. The control signals for switching of the load-side converter are generated from the error of the reference and the sensed stator currents of SCIGh rather than by the errors of the load-side converter currents. With this control strategy, the switching of the load-side converter is controlled to make the SCIGh currents balanced and sinusoidal at the nominal frequency. Any unbalance and harmonics in the load currents are compensated by the zigzag transformer and the load-side converter.The proposed control algorithm for load-side converter requires sensing of the load voltage and stator currents of SCIGh. For the control purpose, sensing of load-side-converter currents and load currents is not required, thus reducing the requirement of current sensors for the control of load-side converter.

III.FUNCTIONAL OPERATION OF SYSTEM:

As already stated, the proposed system uses two back-to-back-connected PWM-controlled IGBT-based VSCs. These VSCs are referred to as the machine (SCIGw) side converter and load-side converter.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

The objectives of the machine (SCIGw) side converter is to provide the requisite magnetizing current to the SCIGw and to achieve MPT, and the objective of the load-side converter is VFC at the load terminals by maintaining active- and reactive-power balance.To achieve MPT, the SCIGw is required to be operated at optimal tip speed ratio. The tip speed ratio determines the SCIGw rotor-speed set point for a given wind speed, and the mechanical power generated at this speed lies on the maximum power line of the turbine. The operating principle of the controller for the machine (SCIGw) side converter is based on the decoupled control of d- and q-axes stator currents of the SCIGw with the d-axis aligned to rotor flux axis. The reference value for the d-axis or reactive component of the SCIGw stator current is generated from the required magnetizing flux for the SCIGw. The reference value for the q-axis or active component of the SCIGw stator current is generated from error of the desired speed and the sensed SCIGw rotor speed.

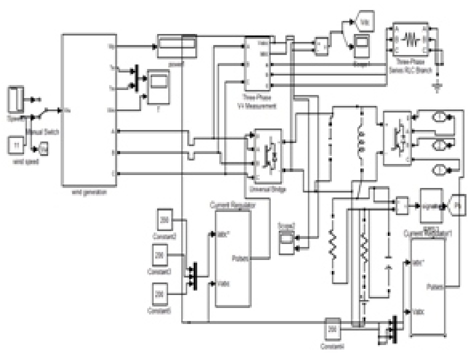


Fig 3: WECS with DC-link converters back-to-back operation.

The output of the speed controller gives the reference q-axis stator current for SCIGw. The reference d–q SCIGw stator currents are transformed to the reference three-phase SCIGwstator currents and compared with the sensed three-phase SCIGw stator currents to generate control signals for the machine (SCIGw) side converter.

The load-side converter is controlled for the regulation of load-voltage magnitude and load frequency. Further, for maintaining the load-frequency constant, it is also essential that any surplus active power in the system is diverted to the battery. Alternatively, the battery system should be able to supply any deficit in the generated power. Similarly, the magnitude of the load voltage is maintained constant in the system by balancing the reactive-power requirement of the load through the load side converter.

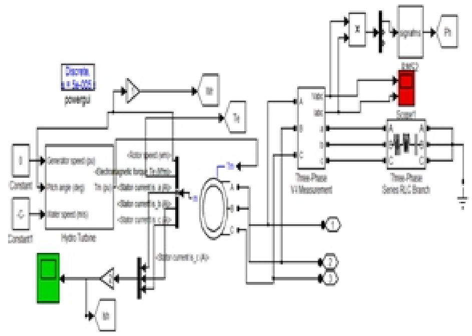


Fig 4: Hydro energy system.

IV.CONTROL STRATEGY:

The objectives of the machine (SCIGw) side converter are to achieve MPT and to provide the required magnetizing current to the SCIGw, and the objective of the load-side converter is to control the magnitude and the frequency of the load voltage.

Machine Side Converter controller:

The objectives of the machine (SCIGw) side converter are toachieve optimum torque for MPT for SCIGw and to providethe required magnetizing current to the SCIGw. The controlstrategy for the machine (SCIGw) side converter control isshown in Fig. 5.

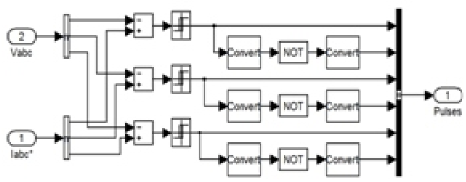


Fig 5: Control scheme of machine-side converter

Speed-Control Loop for MPT and Reference q-axisSCIGw Stator-Current Generation: In the proposed algorithm,the rotor position (θrw) of SCIGw and the wind speed aresensed. The rotor speed (ωrw) of SCIGw is determined from its rotor position (θrw).

The three-phase reference SCIGw stator currents (iswa, iswb,and iswc) are then compared with the sensed SCIGw statorcurrents (iswa, iswb, and iswc) to compute the SCIGw statorcurrenterrors, and these current errors are amplified with gain(K = 5) and the amplified signals are compared with a fixedfrequency(10 kHz) triangular carrier wave of unity amplitudeto generate gating signals for the IGBTs of the machine-sideVSC.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Load-Side Converter controller:

The objectives of the load-side converter are to maintainrated voltage and frequency at the load terminals irrespectiveof connected load. The power balance in the system ismaintained by diverting the surplus power generated to thebattery or by supplying power from the battery in case of deficitbetween generated power and load requirement. Similarly, therequired reactive power for the load is supplied by the load-sideconverter to maintain constant value of the load voltage. Thecontrol strategy for the load-side converter control is shown inFig. 6.

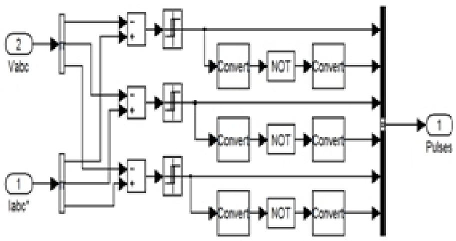


Fig 6: Control scheme of load-side converter.

These current errors are amplified with gain (K=5), and theamplified signals are compared with a fixed-frequency (10 kHz)triangular carrier wave of unity amplitude to generate gatingsignals for IGBTs of the load-side converter.

V.SIMULATION RESULTS:

A simulation model is developed in MATLAB usingSimulink and Sim Power System set toolboxes. The simulationis carried out on MATLAB version 7.8.The electrical system is simulated using Sim Power System.The different loads are modeled using resistive and inductiveelements and diode-rectifier-fed resistive loads combined withan LC filter. The unbalanced load is modeled using breakersin individual phases. The developed MATLAB model for thewind-hydro hybrid system is shown in Fig. 7.

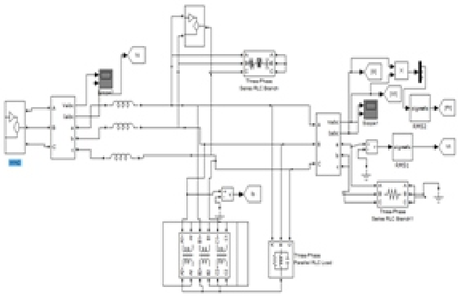
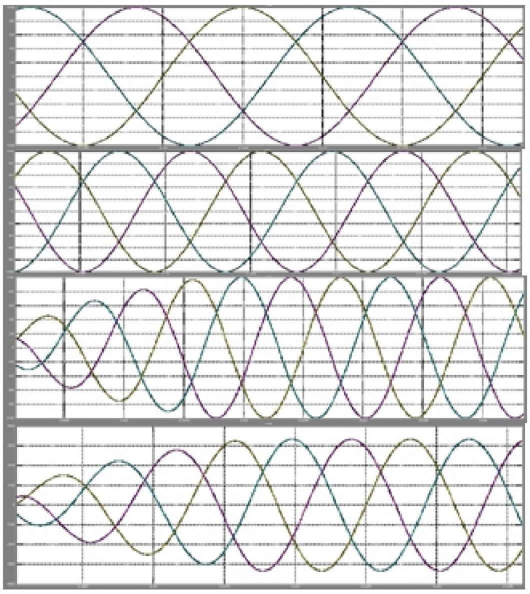


Fig 7: MATLAB simulation diagram of wind–hydro hybrid system

The performance of the wind-hydro hybrid system with theproposed control algorithm is demonstrated under different dynamic condition. Moreover, performanceof the wind-hydro hybrid system is studied withvarious electrical loads, i.e., balanced linear load, unbalanced linear load, balanced/unbalanced nonlinear load, and mixed load consisting of linear, nonlinear, and dynamic loadsthe performance of the systemis also studied under varying SCIGw rotor speeds due to windspeed variations.It is observed that under all theseconditions, the wind-hydro hybrid system performs in the desirablemanner. For nonlinear load under balanced and unbalancedconditions, SCIGw current, SCIGh stator current, and the loadvoltage are balanced, and the total harmonic distortion (THD) in the SCIGw current, SCIGhcurrent, and the load voltage arewithin the desired limit, as shown in Table I.

The SCIGw isable to run at speeds corresponding to the MPT with varyingwind speeds. The simulated transient waveforms of the SCIGwstator current (isw), SCIGh stator current (ish), load-side convertercurrent (iC), three-phase load voltage (vL), three-phaseload current (iL), single-phase load currents (iLa, iLb, andiLc), zigzag transformer currents (ita, itb, itc, and itn), loadfrequency (fL), rms value of phase load voltage (Vt), SCIGwstator frequency (fw), battery current (Ib), battery voltage(Vdc), SCIGw stator power (Pw), SCIGh stator power (Ph),load power (PL), battery power (Pb), coefficient of power(Cp), SCIGw rotor speed (ωrw), and wind velocity (Vw) areshown for different operating conditions.



ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

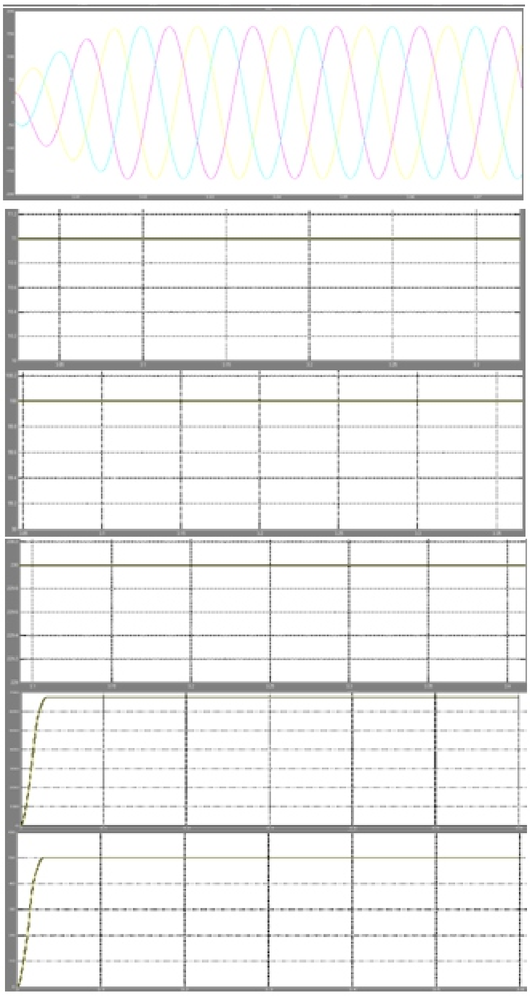
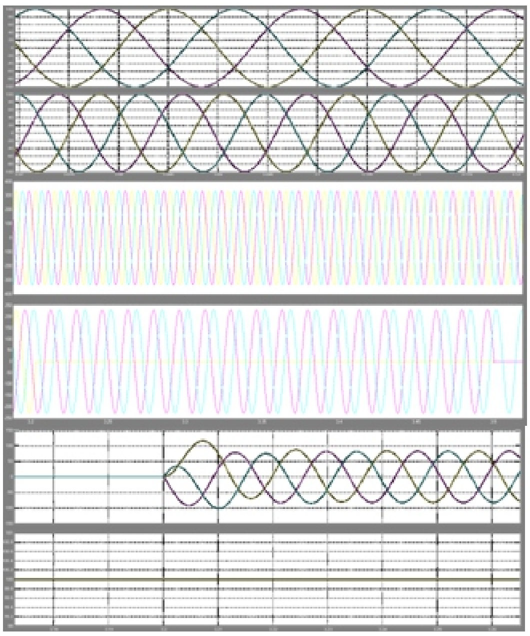


Fig 8: Performance of hybrid system with balanced linear load at wind speedof 11 m/s.



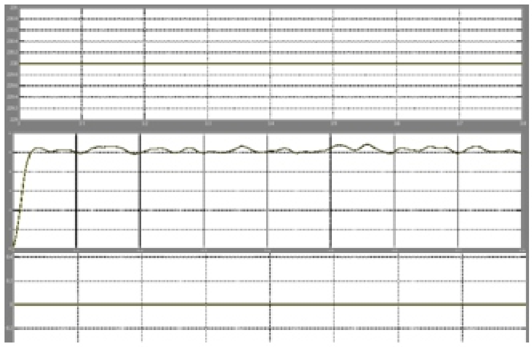


Fig 9: Performance of proposed system with balanced/ unbalanced linearloads at wind speed of 8 m/s.

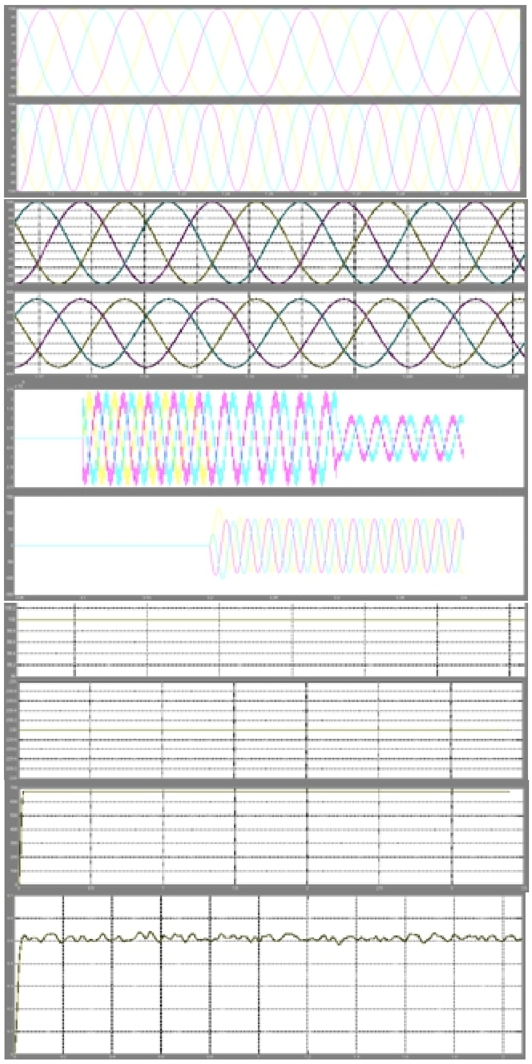


Fig 10: Performance of proposed system with balanced/ unbalanced nonlinearloads at wind speed of 10 m/s.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

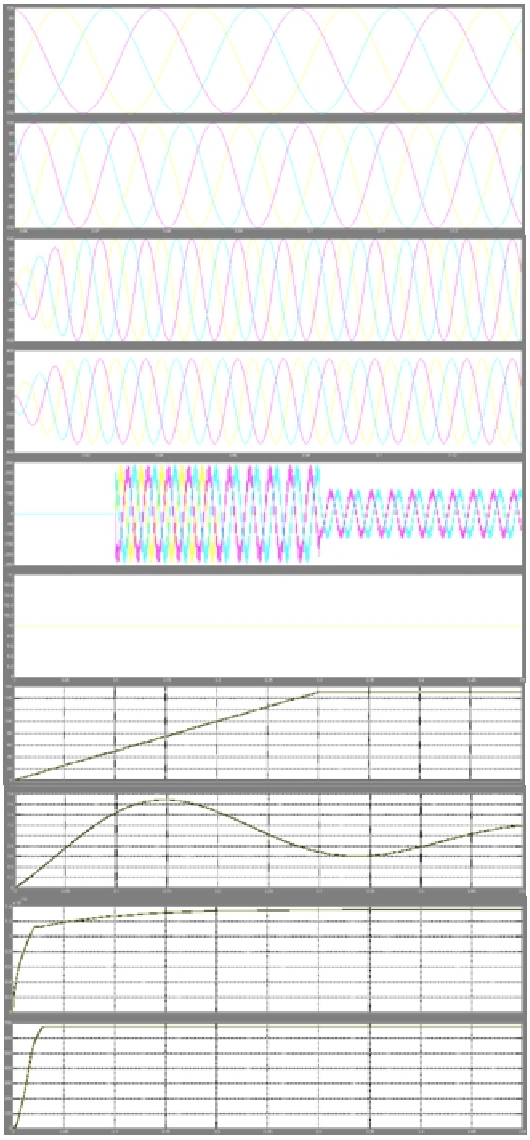
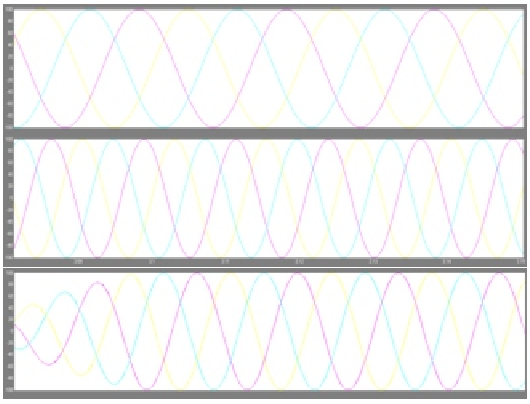


Fig 11: Performance of proposed system with combined load of balancedlinear, nonlinear, and dynamic loads at wind speed of 9 m/s.



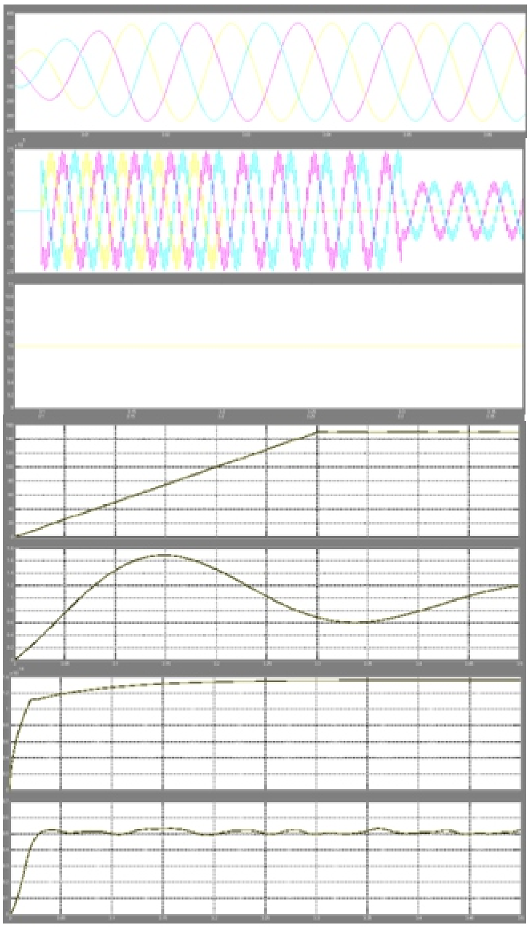


Fig 12: Performance of proposed system with balanced linear loads atvariable wind speeds.

VI.CONCLUSION:

A new three-phase four-wireautonomous wind-hydro hybrid system, using one cagegenerator driven by wind turbine and another cage generatordriven by hydro turbine along with BESS, has been modeledand simulated in MATLAB using Simulink and Sim PowerSystem tool boxes.The performance of the wind-hydro hybrid system with the proposed control algorithm is demonstrated under different dynamic condition. It has been demonstrated that the proposedhybrid system performs satisfactorily under different dynamicconditions while maintaining constant voltage and frequency.

REFERENCES:

[1] L. L. Lai and T. F. Chan, Distributed Generation: Induction and PermanentMagnet Generators. West Sussex, U.K.: Wiley, 2007, ch. 1.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

[2] E. D. Castronuovo and J. A. Pecas, "Bounding active power generationof a wind-hydro power plant," in Proc. 8th Conf. Probabilistic MethodsAppl. Power Syst., Ames, IA, 2004, pp. 705–710.

[3] B. Singh, S. S. Murthy, and S. Gupta, "An improved electronic loadcontroller for self-excited induction generator in micro-Hydel applications,"in Proc. IEEE Annu. Conf. Ind. Electron. Soc., Nov. 2003, vol. 3,pp. 2741–2746.

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

[5] M. Molinas, J. A. Suul, and T. Undeland, "Low voltage ride through ofwind farms with cage generators: STATCOM versus SVC," IEEE Trans.Power Electron., vol. 23, no. 3, pp. 1104–1117, May 2008.

[6] S. Ganesh Kumar, S. Abdul Rahman, and G. Uma, "Operation of selfexcitedinduction generator through matrix converter," in Proc. 23rdAnnu. IEEE APEC, Feb. 24–28, 2008, pp. 999–1002.

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

[8] E. Diaz-Dorado, C. Carrillo, and J. Cidras, "Control algorithm for coordinatedreactive power compensation in a wind park," IEEE Trans. EnergyConvers., vol. 23, no. 4, pp. 1064–1072, Dec. 2008.

[9] L. Tamas and Z. Szekely, "Modeling and simulation of an induction drivewith application to a small wind turbine generator," in Proc. IEEE Int.Conf. Autom., Quality Test., Robot., May 22–25, 2008, pp. 429–433.

[10] A. Luna, P. Rodriguez, R. Teodorescu, and F. Blaabjerg, "Low voltage ridethrough strategies for SCIG wind turbines in distributed power generationsystems," in Proc. IEEE Power Electron. Spec. Conf., Jun. 15–19, 2008,pp. 2333–2339.

Author's Details:

T. Ramesh He is currently pursuing M.Tech in stream of Power Electronics at Annamacharya Institute of Science and Technology, hyderabad. And he has completed his B.TECh from SANA Engineering College, Kodad in 2013. His area of interests are Converters, Renewable Energy Systems, and Isolated Energy Systems.

Kalimela Venkateswarlu has 5 years of teaching experience in various engineering colleges. Presently he is working as an Assistant Professor in Annamacharya Institute of Technology and Sciences, Hyd. He received his B.Tech degree in Electrical and Electronics Engineering from Aurora Engineering College, bhongir, Hyderabad, India and Masters of Engineering (M.E) in college of Engineering, Osmania University Hyderabad, India. His Research interests are including Artificial Intelligence Techniques, power electronic &drive, FACT devices.