Journal of Basic and Applied Engineering Research
p-ISSN: 2350-0077; e-ISSN: 2350-0255; Volume 2, Number 18; July-September, 2015, pp. 1595-1600

http://www.krishisanskriti.org/Publication.html

DVR based BES to Control LVRT in Wind-Grid System

Sunil Verma[1] and Deepesh Sharma[2]

[1,2]EED, DCRUST, Murthal
E-mail: [1]sv.verma007@yahoo.com, [2]dsmurthal@gmail.com

Abstract—*In this paper, a PMSG wind turbine full energy conversion system design and modeling have been performed using MATLAB Simulink. The system is grid integrated and applies MPPT control to extract the maximum power from the wind and utilizes full conversion circuitry to interface the unregulated generator AC power to the grid. Modules of Lithium-Ion Capacitors (LIC) have been placed on the DC bus in order to support the grid with wind energy power smoothing and LVRT, which is further controlled by the DVR. LICs offer high power density and reasonable energy density. During grid faults, wind energy can be stored in the LICs and discharged into the grid as soon as the voltage is restored. This feature will support the grid to stabilize the voltage. Detailed modeling of the architecture and controls has been performed to verify the viability of the proposed system.*

1. INTRODUCTION

Among renewable energy sources, wind energy generation has been noted as the most rapidly growing technology; being one of the most cost-effective and environmental friendly means to generate electricity from renewable sources. The increasing penetration level of wind energy can have a significant impact on the grid, especially under abnormal grid voltage conditions. Thus, wind farms can no longer be considered as a simple energy source. Nowadays, they should provide an operational ability similar to that of conventional power plants. A demanding requirement for wind farms is the fault ride-through capability. According to this demand, the wind turbine is required to survive during grid faults. The ability of a wind turbine to survive for a short duration of voltage dip without tripping is often referred to as the low voltage ride through (LVRT) capability of a turbine. On the other hand, power fluctuation from a turbine due to wind speed variations incurs a deviation of the system frequency from the rated value [2], [3]. As a result, it is necessary to mitigate this power fluctuation for high power quality. Variable-speed wind turbines using a PMSG equipped with full-scale back-to-back converters are very promising and suitable for application in large wind farms. Due to their full-scale power converter, they can deliver a larger amount of reactive power to the grid than a DFIG wind turbine under abnormal grid conditions. The increasing higher penetration of wind energy in the grid has transformed wind energy into major player in grid operation and economics. Wind energy systems now have to participate in grid support and provide ancillary services. Variable wind speed leads to variable wind power generation, voltage fluctuations, and frequency deviations, which are the main problems related to wind energy integration into a grid. These problems become more evident in weak grids. In addition, wind farms have to take the grid problems into consideration and have to provide support during grid instability and transients.

In this work the low voltage ride though capability is maintained by introduction of extra battery storage system. The introduction of extra power is controlled by the dynamic voltage restorer (DVR). To reduce the power fluctuations and low voltage ride through (LVRT) compensation in wind power generator following will be key objectives for our work:

1. Mathematical modeling of wind energy generator with energy storage device. 2. Wind plant will be connected to grid and fault conditions will be analyzed. A battery storage device will be connected at grid side to remove the effect of fault. 3. Introduction of DVR at the end of energy storage device so that power disturbance can be compensated and it doesn't require any feedback loop.

2. DYNAMIC VOLTAGE RESTORER

DVR can compensate voltage at both transmission and distribution side. During the normal operating condition (without sag condition), DVR operates in a low loss standby mode. During this condition the DVR is said to be in steady state. When a disturbance occurs (abnormal condition) and supply voltage deviates from nominal value, DVR supplies voltage for compensation of sag and is said to be in transient state.

The basic principle of the DVR is to inject an appropriate voltage in series with the supply through injection transformer whenever any disturbance like voltage sag or voltage swell is encountered. DVRs are a class of custom power devices for providing consistent distribution power quality. They use a series of voltage boost technology using solid state switches for compensating voltage sags/swells. The DVR applications are mostly for sensitive loads that may be considerably affected by fluctuations in system voltage. Overcome these problems from the concept of custom power devices, DVR is the most efficient and advantageous modern custom power device used. It is usually installed in a distribution system between the utility and the critical load feeder at the point of common coupling. DVR has been modeled with PI Controller to enhance the performance of the system. The main objective of the above model is to improve the power quality of the system during fault conditions. The basic schematic diagram of DVR is shown in Fig. 1 below. And the equivalent circuit diagram of DVR is shown in Fig. 2.

The load impedance Z_{TH} depends on the fault level of the load bus. When the system voltage (V_{TH}) drops, the DVR injects a series voltage V_{DVR} through the injection transformer so that the desired load voltage magnitude V_L can be maintained. The series injected voltage of the DVR can be written as

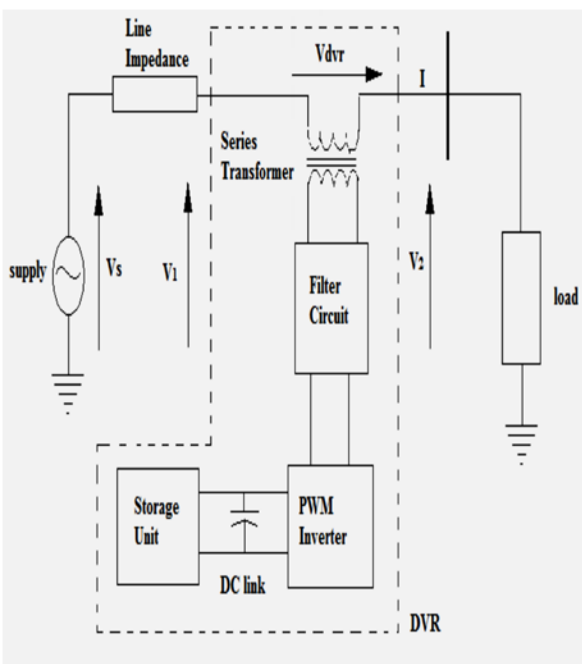

Fig. 1: Schematic of DVR

$$V_{DVR} = V_L + Z_{TH} I_L - V_{TH}$$

Where

V_L: The desired load voltage magnitude

Z_{TH}: The load impedance.

I_L: The load current

V_{TH}: The system voltage during fault condition

The load current I_L is given by,

$$I_L = \frac{[P_L + jQ_L]}{V_L}$$

When VL is considered as a reference equation can be rewritten as,

$$V_{DVR}\angle\alpha = V_L \angle 0 + Z_{TH}\angle(\beta - \theta) - V_{TH}\angle\delta$$

α, β, δ are angles of V_{DVR}, Z_{TH}, V_{TH} respectively and θ is Load power angle. The complex power injection of the DVR can be written as,

$$S_{DVR} = V_{DVR}\dot{I}_L$$

It requires the injection of only reactive power and the DVR itself is capable of generating the reactive power. The control designed in Simulink is shown in appendix.

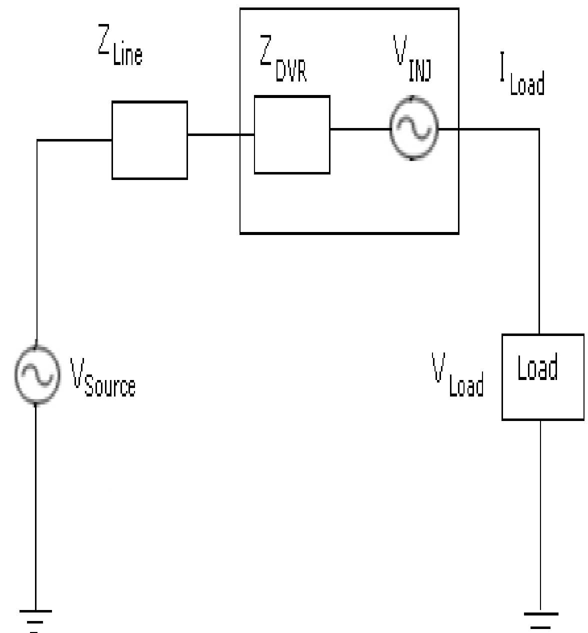

Fig. 2 Equivalent Circuit Diagram of DVR.

3. RESULTS

In this work we have interfaced the wind plant with grid along with a battery source which introduces the extra power. To transmit the wind power to a long distance it is converted into DC using a diode rectifier, then boost converter is used using the dc voltage produced by it in the closed loop. It boosts up the dc level to avoid losses. A primary inverter in which IGBT's are attached back to back is used to convert dc back into ac at grid end. A battery source at grid end is attached which takes the fault voltage in its input and inserts the required voltage in the line after compensating it. The complete simulation diagram is shown in next chapter. The DVR itself is connected with a battery which is controlled by the secondary inverter. The pulses in the inverter are fed though the PWM in which reference input is provided after controlling the angle of sinusoidal wave.

The proposed model is developed in MATLAB Simulink. Wind model is synchronized with grid and a battery is attached to grid end if in case of fault occurs. Our motto to write the paper is to analyze the results once fault is given in to the model and to observe the performance of battery energy source (BES) at the fault time. BES should introduce the extra power at the time of fault occurrence. The complete Simulink model is shown in appendix. Output of wind farm generator is shown in Fig. 3 & 4 below. The pitch angle has been kept 0 so that no effect of wind speed disturbs our system. Fig. 5 shows the voltage and current along with their RMS values of wind power plant.

Now a three phase fault is introduced in the system. The

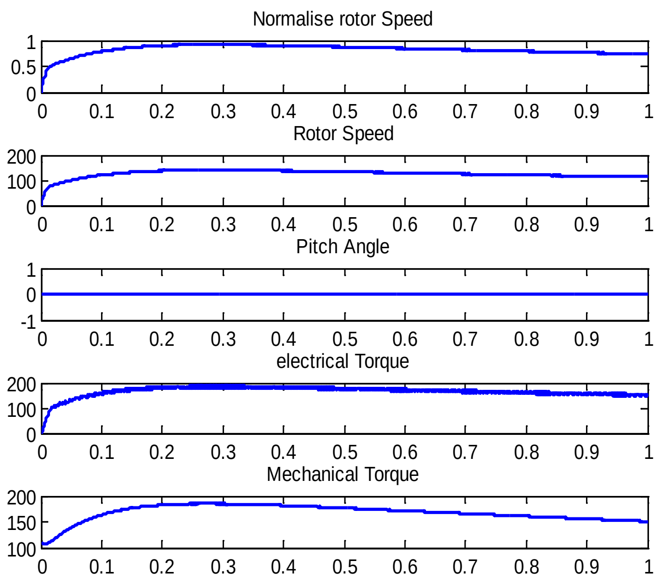

Fig. 3: Wind Generation Power Plant Output

effect of this fault is mitigated by BES and that is controlled by DVR. The controlling block takes the grid voltage and DC output of boost converter as input and introduce a three phase voltage eat the grid. The fault voltage and controlled voltage is shown in Fig. 5. The fault is introduced at 0.1-0.3 sec.

The ESS power rises during fault timings and introduced in the main inverter power as shown in the Simulink model in appendix. Results for fault at 0.3-0.5 are shown in Fig. 6.

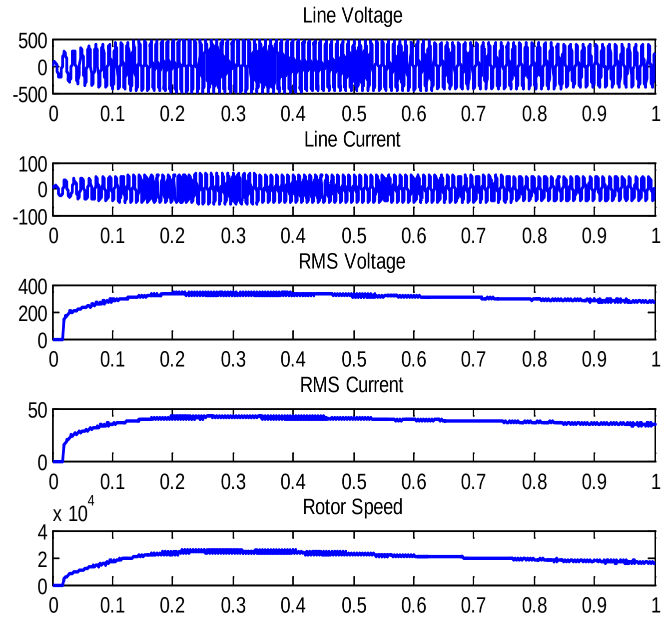

Fig. 4: Wind Plant output at generator side

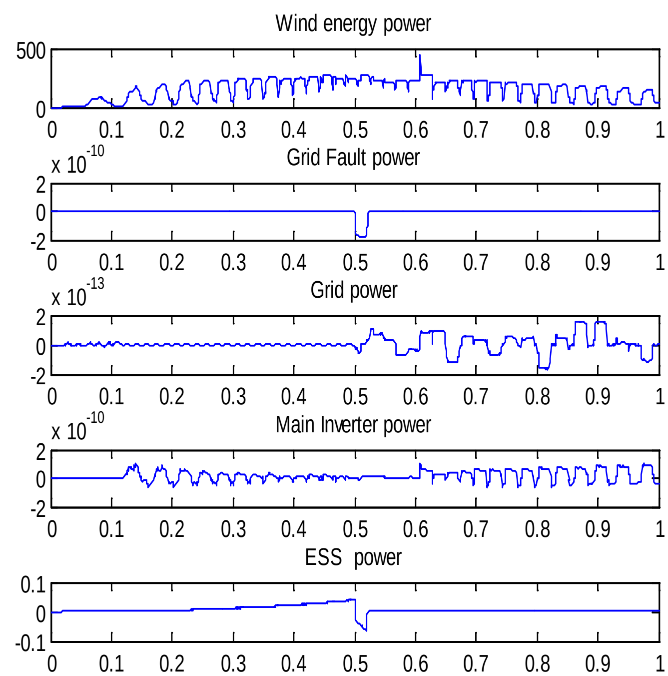

Fig. 5: Power at fault timings

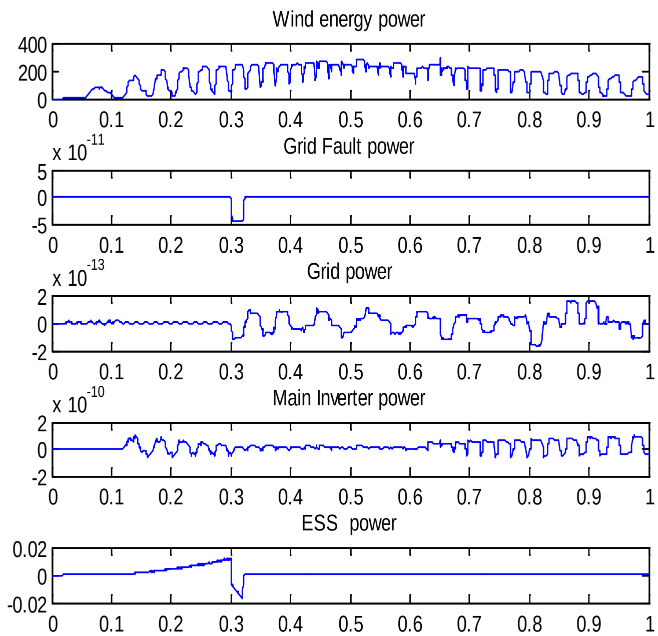

Fig. 6: Power at fault introduced at 0.3-0.5 sec

4. CONCLUSION

Simulation of Wind turbine running at fixed wind speed was done showing good active and reactive power control; it was also simulated using a variable wind speed profile which generates variable and fluctuated power. Variable power delivered to the grid either with DC bus voltage control to keep it equal to a reference value or using an adaptive filter so you deliver a smoothed power.

The adaptive filter technique makes the DC bus voltage fluctuate within a desirable band related to the filter design. Under low voltage ride through (LVRT), Wind turbine system was integrated with a grid voltage profile that will dip to zero. During the low voltage period, simulation shows good results in active a reactive power control. Active power goes to zero when voltage dips and reactive power support should take a place to support the grid voltage. Reactive current was controlled to be 1 pu unit or up to 2 per unit during the LVRT. After the voltage recovers to 0.9, active power was controlled to achieve a ramp rate of 90% of the available wind generated power in 1 second.

REFERENCES

[1] T. Riouch, “Control of Battery Energy Storage System for Wind Turbine based on DFIG during Symmetrical Grid Fault” International Conference on Renewable Energies and Power Quality, 2015.

[2] P. Selvaraj, “Fuzzy Logic Based PMSG Wind Turbine System With Fault Ride Through Technique” International Journal of Engineering Research, 2015.

[3] S. Rajkumar, S. T. Suganthi, ”A Hybrid Control Scheme for Fault Ride-Through Capability using Line-Side Converter and an Energy Storage System for PMSG Wind Turbine Systems” International Electrical Engineering Journal (IEEJ) Vol. 5 ,2014.

[4] Harika G, Jaya kumar N, Thrivonasundari D,” Design and Simulation of Dual Inverter Based Energy Storage Systems for Wind Energy Systems Using MATLAB/SIMULINK” Journal of Engineering Research and Applications, Vol. 4, Issue 4 (Version 7), April 2014.

[5] Hui Huang, “Electronic Power Transformer Control Strategy in Wind Energy Conversion Systems for Low Voltage Ride-through Capability Enhancement of Directly Driven Wind Turbines with Permanent Magnet Synchronous Generators (D-PMSGs)” Energies 2014.

[6] Ujjwal Kumar, “Designing of Controller for DVR to Reduce Harmonics in DFIG Wind Turbine” International Journal of Scientific and Research Publications, Volume 4, Issue 12, December 2014.

[7] Prerna Badoni, “Modeling and Simulation of 2 MW PMSG Wind Energy Conversion Systems” IOSR Journal of Electrical and Electronics Engineering, 2014.

[8] Marwa Ezzat, Mohamed Benbouzid, SM Muyeen, Lennart Harnefors. Low-Voltage Ride-Through Techniques for DFIG-Based Wind Turbines: State-of-the-Art Review and FutureTrends. IEEE IECON 2013, Nov 2013.

[9] BU He, REN Yong-feng, NIU Hai-wei,XUE Yu, HU Hong-bin, LIU Hai-tao,”Grid-Connection Control and Simulation ofPMSG Wind Power System Based on Three-Level NPC Converter” International Journal of Automation and Power Engineering (IJAPE) Volume 2 Issue 4, May 2013.

[10] Goran Mandic, Member, IEEE, Adel Nasiri, Senior Member, IEEE,”Lithium-Ion Capacitor Energy Storage IntegratedWith Variable Speed Wind Turbines forPower Smoothing”IEEE Journal Of Emerging And Selected Topics In Power Electronics, Vol. 1, No. 4, December 2013.

[11] Yskandar Hamam, “Dynamic performance analysis of an integrated windphotovoltaic microgrid with storage” International Journal of Smart Grid and Clean Energy,2013.

[12] P. Yedukondalu1, M. Bala Subbareddy2, Meera Shareef Shaik,”Mitigation Of Power Quality Disturbances In Wind Turbine Integrated Power Grid By Statcom” IJESAT, Volume-3, Issue-4,2014.

[13] Abhishek Mishra, “A Simulation of a STATCOM-Control for Grid Connected Wind Energy System for Power Quality Improvement”International Journal of Engineering Research and Applications , Vol. 3, Issue 4, Jul-Aug 2013.

[14] D Mary, “Modelling and Simulation of Grid Connected Wind Energy System” International Journal of Soft Computing and Engineering , Volume-3, Issue-1, March 2013.

[15] Kapil Parikh, “Modeling, Simulation And Perfomance Analysis of AC-DC-AC PWM Converters Based Wind Energy Conversion System” International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878,Volume-2, Issue-4, September 2013.

[16] Zaijun Wu, “Operation and Control of a Direct-Driven PMSG-Based Wind Turbine System with an Auxiliary Parallel Grid-Side Converter” Energies 2014.

[17] S. M. Muyeen, Member, IEEE, Rion Takahashi, Member, IEEE, Toshiaki Murata," Integration of an Energy Capacitor System With aVariable-Speed Wind Generator" IEEE Transactions On Energy Conversion, Vol. 24, No. 3, September 2009.

[18] S.Venkateshwaran," Statcom With Tbess To Improve The Power Quality In Grid Connected Wind Energy Sys-Tem" International Journal of Advanced Technology & Engineering Research (IJATER), Volume 2, Issue 6, Nov. 2012.

[19] Muhammad Khalid and Andrey V. Savkin," Model Predictive Control of Distributed and Aggregated BatteryEnergy Storage System for Capacity Optimization" 9th IEEE International Conference on Control and Automation (ICCA) Santiago, Chile, December 19-21, 2011.

[20] Wei Li, Student Member, IEEE, Géza Joós, Fellow, IEEE,"Performance Comparison of Aggregated andDistributed Energy Storage Systems in a Wind FarmFor Wind Power Fluctuation Suppression" " IEEE Journal Of Power Electronics, Vol. 3, No. 4, December 2007.

[21] D. Srinivas, " Power Quality Improvement In Grid Connected Wind Energy System Using Facts Device And Pid Controller" IOSR Journal of Engineering , 2012.

[22] Vito Calderaro, "Design and implementation of a fuzzy controller for wind generators performance optimisation" Energies 2010.

[23] Wei Li, "Computational Intelligence for Control of Wind Turbine Generators" IEEE Power and Energy Society General Meeting 2011.

[24] Dewei Xu , Bin Wu , Zargari, N.R. "Unified DC-Link Current Control for Low-Voltage Ride-Through in Current-Source-Converter-Based Wind Energy ConversionSystems" ,IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 26, NO. 1, JANUARY 2011.

APPENDIX

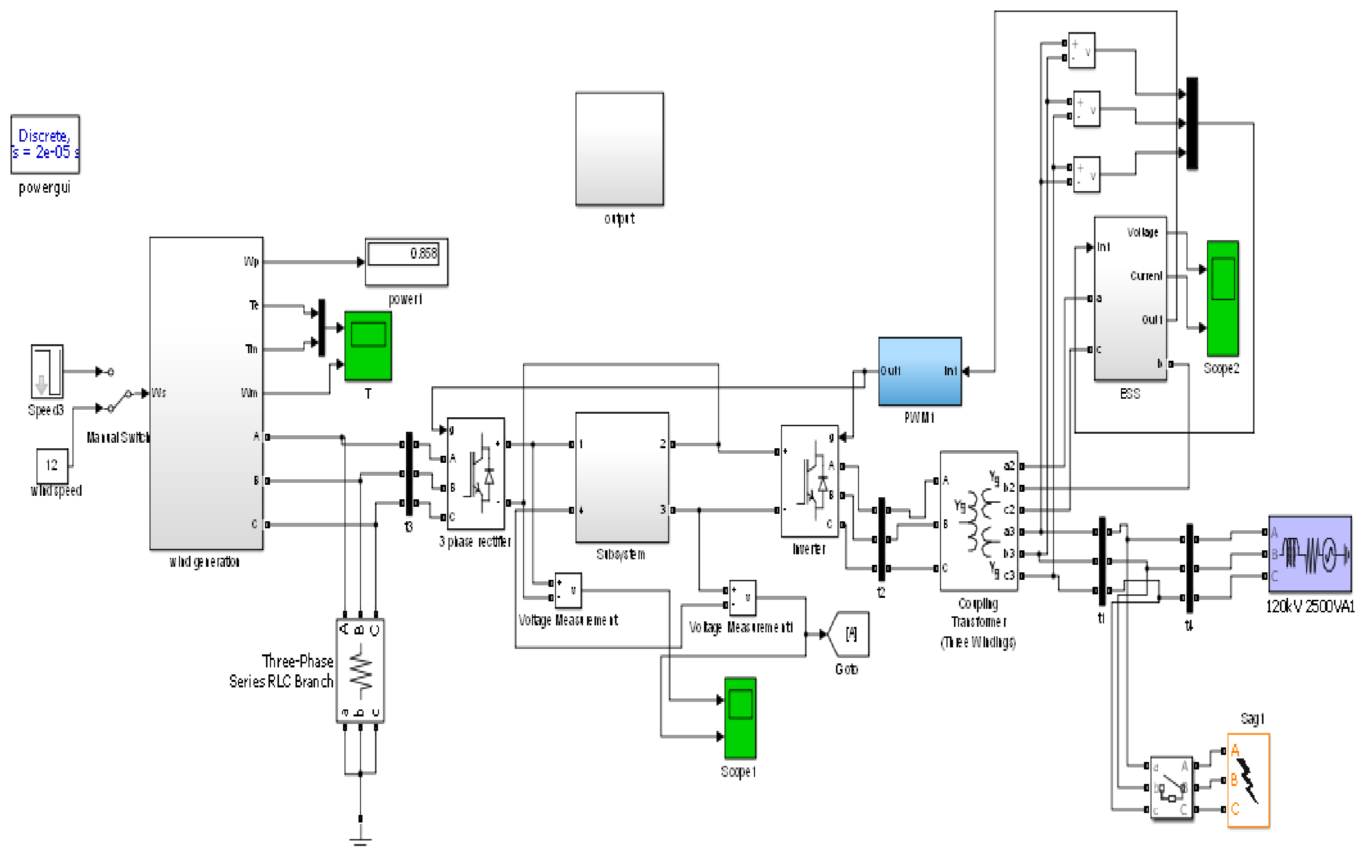

Fig. Complete Simulink Model

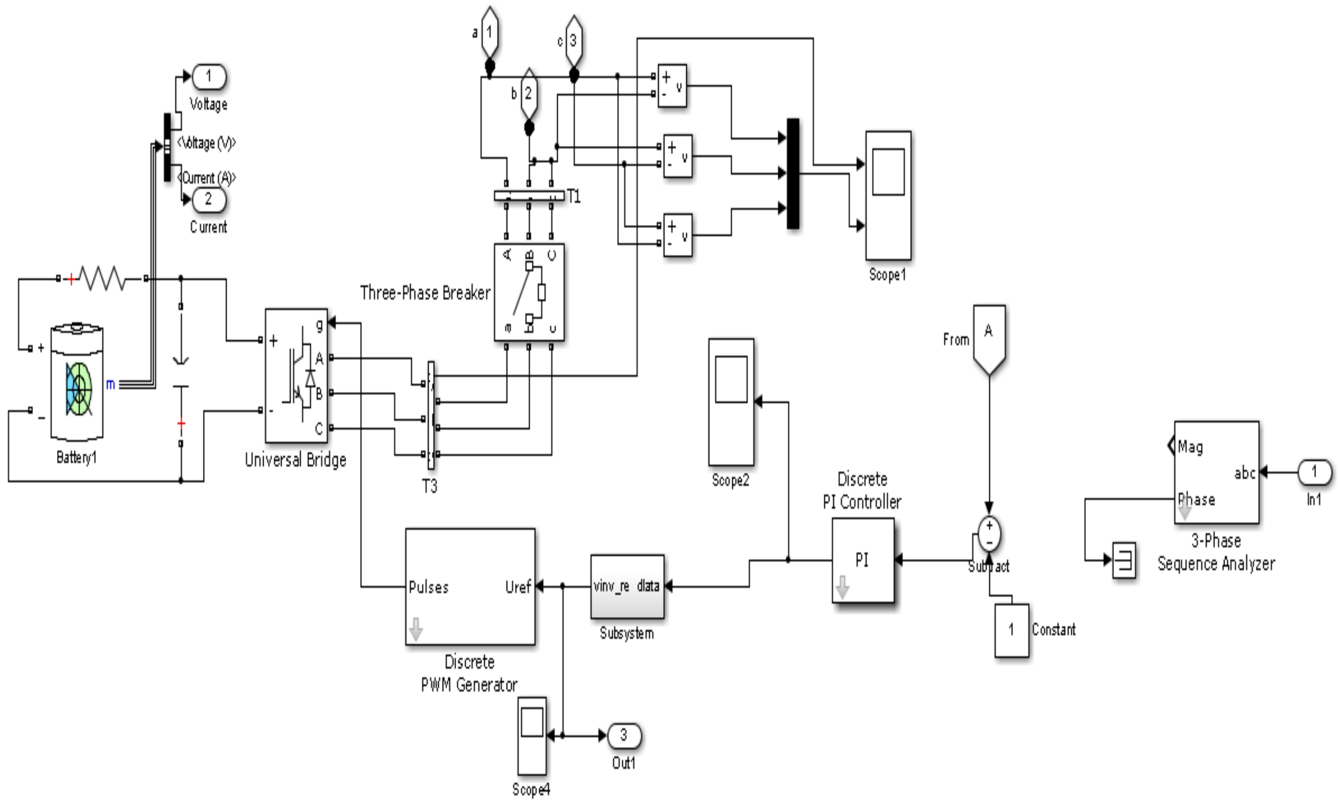

Fig. DVR controlling of BES