# Standalone Wind Turbine using DC Grid for LED Street Light Application

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***Abstract* - This paper presents the modelling and performance analysis of a standalone Wind system in the MatLAB/Simulink environment. Stand-alone systems using renewable energy sources, such as Wind energy with storage battery banks are commonly used to LED Lights. The model of Wind turbine is developed using basic circuit equations governing the operation of the Wind turbine. Permanent Magnet Synchronous Generator (PMSG), which is based on variable-speed operation has been used in this paper. Since the speed of Wind turbine is variable, the generator is controlled by power electronic devices. A rectifier is used to rectify the output voltage of PMSG and DC/DC buck converter is used to decrease this rectified voltage to that of battery and connected DC load. The buck converter is controlled to extract the maximum power output of Wind system. Here the PID Controller is used to extract the Maximum power from the Wind turbine. Performance Parameter are calculated for the proposed system and the result are verified in MatLAB/Simulink.**

***Keywords : Permanent Magnet Synchronous Generator (PMSG), Buck converter, Proportional, Integral and Differential (PID) controller, Maximum Power Point Tracking (MPPT).***

## I. INTRODUCTION

Wind energy is a source of renewable power which comes from air current flowing across the earth's surface. Wind turbines harvest this kinetic energy and convert it into power. Wind generation is one of the fastest growing sources of electricity and one of the fastest growing markets in the world today. The advantages of Wind energy are numerous and clear, and the technology itself has taken a leap forward in recent years Standalone Wind generation system offers a feasible solution to distribute power generation for isolated localities where utility grids are not available. It is also free from pollution what makes it more attractive. The common types of AC generator that are possible candidates in modern Wind turbine systems are as follows: Squirrel-Cage rotor Induction Generator, Wound-Rotor Induction Generator (SCIG), Doubly-Fed Induction Generator (DFIG), Synchronous Generator (With external field excitation); and Permanent Magnet Synchronous Generator (PMSG) [3]. However, in this paper the variable speed directly driven multi pole permanent magnet synchronous generator (PMSG) Wind architecture is chosen for this purpose, it offers better performance due to higher efficiency and less maintenance because it does not have rotor current. PMSG can be used without a gearbox, which implies a reduction of the weight of the nacelle and reduction of costs [1]. The main aim of this paper is to develop a simulation model of a standalone PMSG Wind generation System using MATLAB/SIMULINK system.

## II. WIND TURBINE MODELLING

The typical structure of variable speed Wind energy conversion system, the system comprises Wind turbine, generator, rectifier, Buck converter and Battery. In this system, the Wind turbine captures the Wind energy and the generator converts it to the electrical power. Then the power electronics equipment converts it to the high quality power and controls the rotor speed of the generator. Present The power captured from the Wind turbine is given by the equation (1).

$$Pw=1/2\ Cp\ \rho A Vw3 \qquad (1)$$

Where Cp is the power coefficient,
ρ is the air density which is equal to 1.225 kg/m3
Vw is the Wind speed in m/s
A is the area swept by the rotor in $m^2$.
The volume of aerodynamic torque Tw in N-m is given by the ratio between the power from the Wind and the turbine rotor speed ww in rad/s, as follows

$$Tw = Pw/\ ww \qquad (2)$$

Mechanical torque transferred to the generator is equal to the aerodynamic torque since there is no gearbox. The power coefficient Cp has its maximum value equal to 0.593 which means that the power extracted from the Wind is at all times less than 59.3% (Betz's limit), this is because of the various aerodynamic losses depending on rotor construction. This performance coefficient model $C_P(\beta,\lambda)$ used in this theme is taken from [3].

$$C_P(\beta,\lambda) = C_1(\frac{C_2}{\lambda_i} - C_3\beta - C_4)e^{-C_5\lambda_i} + C_6\lambda) \qquad (3)$$

Since this function depends on the Wind turbine rotor type, the coefficient c1-c6 and x can be different for various turbine designs. The coefficients are equal to: c1 = 0.5, c2 = 116, c3 = 0.4, c4 = 0, c5 = 5, c6 = 21 (x is not used because c4 = 0). Furthermore the parameter is also defined as

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{\beta^3+1} \qquad (4)$$

The simulation of Wind turbine is shown in this Fig. 1. It consists of three input such as Generator speed, pitch angle, Wind speed, and as output as Torque which is given to the generator. The rating of Wind turbine is shown in Table 1.

In this Wind energy conversion system it consists of Wind turbine coupled with the permanent magnet synchronous generator (PMSG), AC-DC rectifier, buck converter. The Wind turbine is the prime mover of the Permanent magnet synchronous generator. As the Wind velocity is non uniform in nature, the output of PMSG will be fluctuating. Therefore it cannot be interfaced directly to the load. The output of PMSG is converted to DC using a full bridge rectifier and the variable DC is converted constant DC by a Buck converter. This constant DC output is stored in battery. The rating of Wind energy is shown in Table 1.

Table 1 Wind energy system rating

| MODEL | RATING |
|---|---|
| Mechanical output | 1000 |
| Base power of electrical generator | 1000 / 0.9 |
| Base Wind speed (m/s) | 12 |
| Maximum power at base Wind speed | 0.73 |
| Base rotational speed | 1.2 |

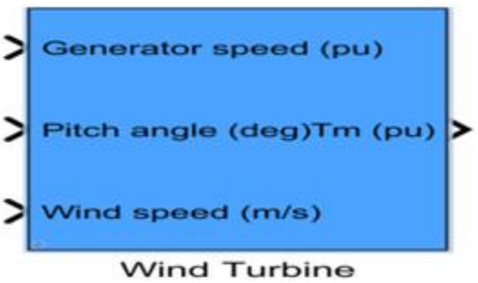


Fig. 1Wind turbine circuit

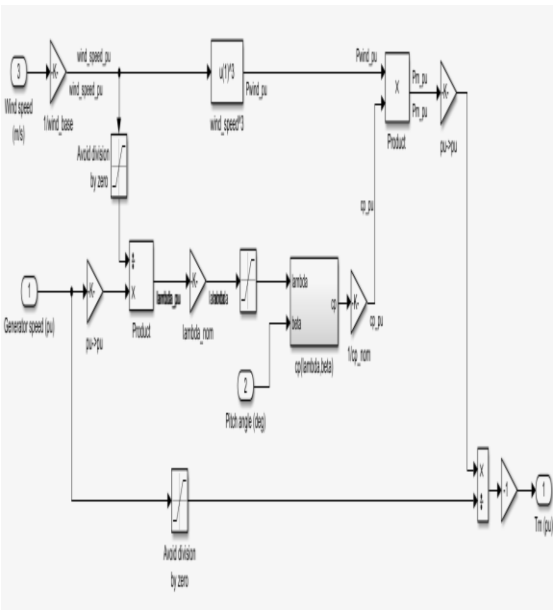

Fig 1(b) Permanent Synchronous Motor

Due to the variations in Wind speed, the output power of the Wind turbine PMSG experiences variations in frequency and amplitude, By maintain the constant voltage and improve the efficiency of Wind turbine is amend by PID controller. A controller suitable for DC-DC converter must match with their nonlinearity and input voltage and load variations, ensuring stability in any operating condition.

Table 2 Wind generator rating

| MODEL | RATING |
|---|---|
| Mechanical output | 1000 |
| Base power of electrical generator | 1000 / 0.9 |
| Base Wind speed (m/s) | 12 |
| Maximum power at base Wind speed | 0.73 |
| Base rotational speed | 1.2 |

The direct driven Wind turbine concept with multi-pole permanent magnet synchronous generator (PMSG) and full-scale frequency converter is a promising but not yet very popular Wind turbine concept for modern Wind turbines. As a gearbox causes greater weight, losses, costs and demands maintenance, a gearless structure represents an efficient and robust answer, which could be very favourable especially for offshore applications. Moreover, due to the permanent magnet excitation of the generator the DC excitation system can be eliminated, decreasing again weight, losses, costs and maintenance requirements. The efficiency of a PMSG Wind turbine is thus assessed to be higher than for other concepts. However, the disadvantages of the permanent magnet excitation are the still high costs for permanent magnet materials and a fixed excitation, which cannot be varied according to the working condition requirement. As multi-pole permanent magnet generators are low speed applications and generally connected to the grid using a frequency converter system, the generator has no damper Winding in the rotor core. Moreover, due to the permanent excitation a PMSG has no field Windings, in which transient currents could be induced or damped respectively. Hence, in case of load changes the field Windings would not contribute to damping either. As neither a damper nor field Winding exists in a PMSG, no transient or sub-transient reactance can be defined for the PMSG. i.e.

$$Xd=Xd' =Xd'' \qquad (5)$$

$$Xq=Xq' =Xq'' \qquad (6)$$

where

Xd and Xq -synchronous reactance

Xd' and Xq' -transient reactance

Xd" and Xq" -sub-transient reactance

Nevertheless, as the multi-pole PMSG is used at low speed application with slow dynamics, a damper Winding is not as much important. However, damping of the system must then be applied by the use of converter control.

## III. BUCK WITH PID CONTROLLER

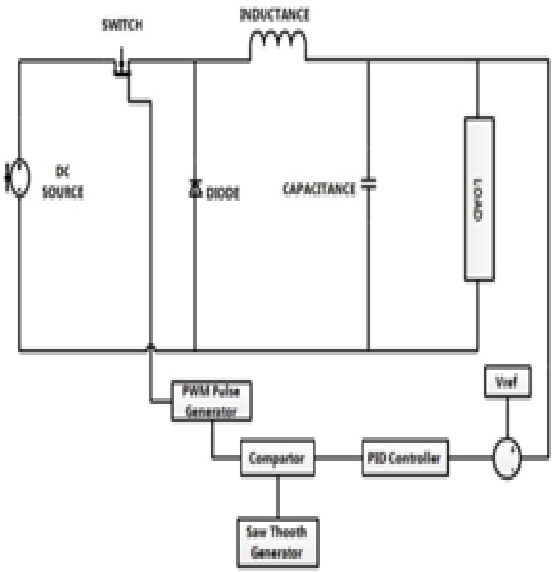


Fig. 2 Buck Converter with PID controller

There are various controller techniques are used, but it need to operate the Wind turbine as it PID controller by using formula

$$C_{PID}=K_P\left[1+\frac{1}{T_i}+T_d\right] \qquad (7)$$

The constants are used in PID controller are kp, ki, and kd. These constants can be adjusted to get acceptable performance. If we increase kp & ki errors will be reduced but we can not get adequate stability. Thus the PID controller provides both acceptable degree of reduction in error and acceptable stability. In this project we have chosen the PID Controller. The values of Kp, Ki and Kd are obtained using the above procedure for the given buck converter and the values obtained are Kp=0.001; Ki=49.7859; Kd=5.0215$e^{-7}$it shown Fig. 2.

**Table 3 Buck converter parameters**

| PARAMETERS | VALUE |
|---|---|
| Input voltage | 424V |
| Output voltage | 80V |
| Inductance | 9.956 mH |
| Capacitor | 8.15 µF |
| Resistance | 6.13 Ω |
| Frequency | 25 KHZ |

As regard, the power converter the buck converter is used to step-down the DC voltage it has buck to 80V. The buck converter were designed with MOSFET (Vs = 424 V, I = 2.46 A, R = 172 Ω). The proposed model is implemented is shown in Fig. 2.

## IV. DC MICROGRID BATTERY

The battery charging system consists of a 12 V / 180 Ah battery. The battery is the most common method of energy storage in standalone systems. The battery should operate with an optimized energy management strategy. A lead acid battery was used due to its low cost and availability. Both output of the system is stored in DC battery. Each battery is connected 6 series and 2 parallel string, totally it as 12 battery. The battery connection is shown in Fig. 3.

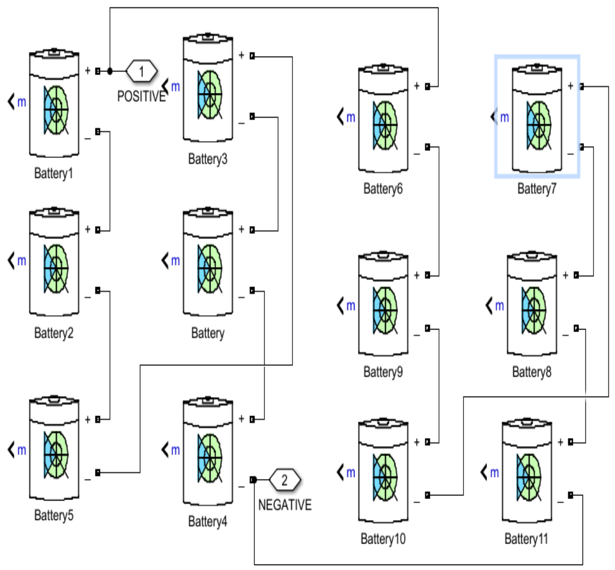


Fig. 3 Battery Bank

SIMULATION RESULT :

The complete system design of the Wind energy input / output analysis of the proposed system was simulated by MatLAB/Simlink, the battery bank is designed, The simulated of Wind turbine, PMSM, buck converter and battery as in Fig. 4, then load as the resistive load. The characteristics of the proposed system were analyzed by changing these elements. The basic condition of the Wind power is shown in Table 2. Fig. 5 – Fig. 11 depicts the simulation of Wind energy system. The Fig. 5 shows the output of Wind turbine as torques as the negative value in 0.5 s. The Fig. 6 & Fig. 7 shows the speed of the Wind in stator, rotor speed and electromagnetic of the Wind. The Fig. 9 shows the line to line voltage of Wind which maintain 300V.

The given output of the close loop of buck converter when PMSM Fig. 10 is run at the rated speed for duration of t = 0.05 sec and maintain the 424 V and using the buck converter it bucks the voltage to 80 V. In order to obtain the constant output voltage, PID Controller is used in Wind source it shown in Fog. 4 and it is connected to the battery.

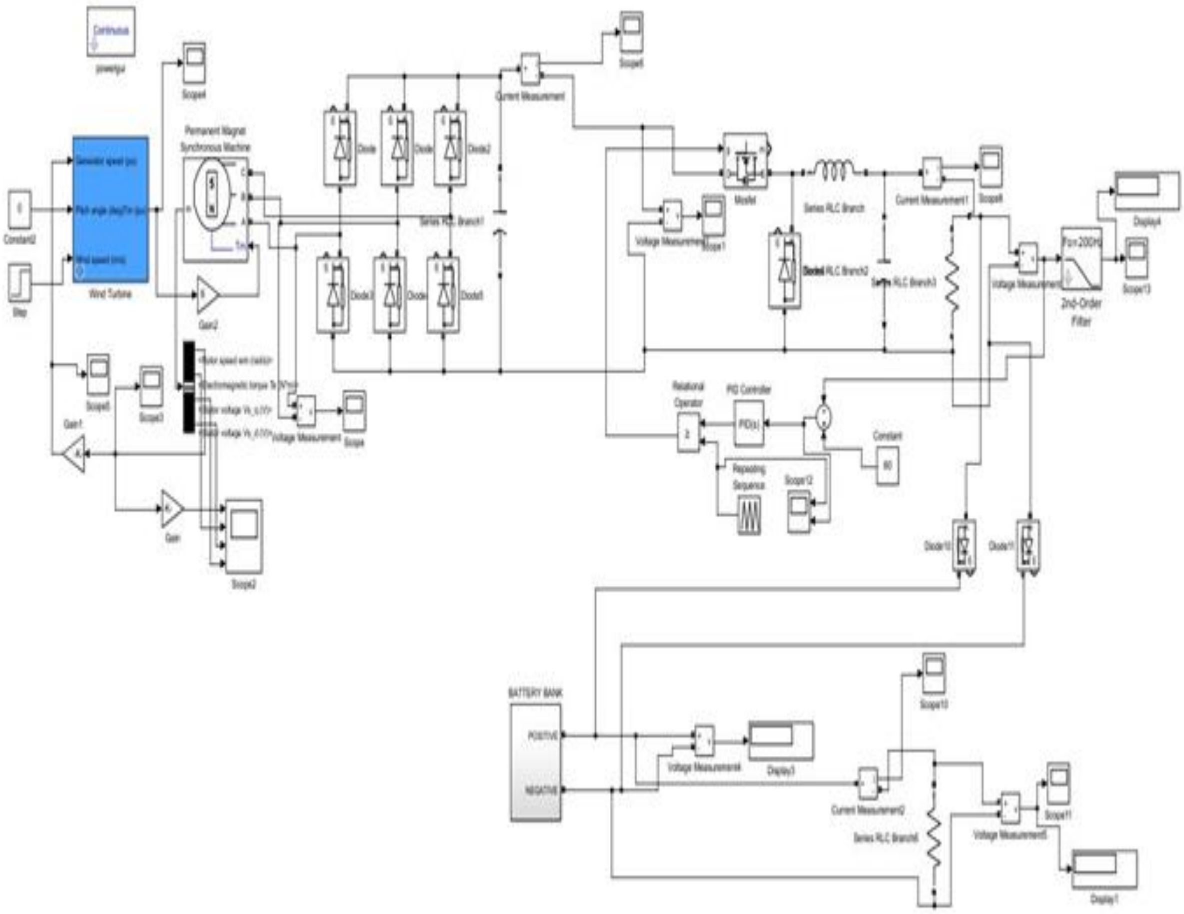


Fig. 4 Overall Wind turbine, DC-DC converter, PID controlled Buck converter

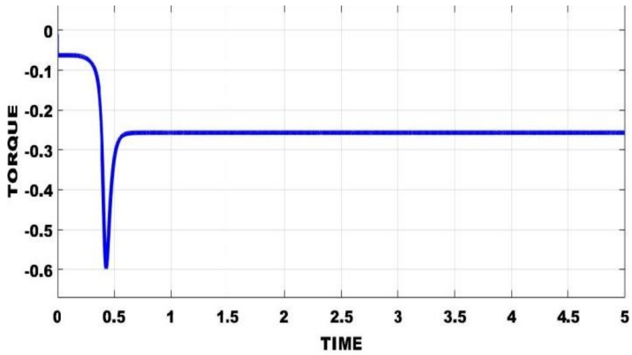


Fig 5 Wind Torque

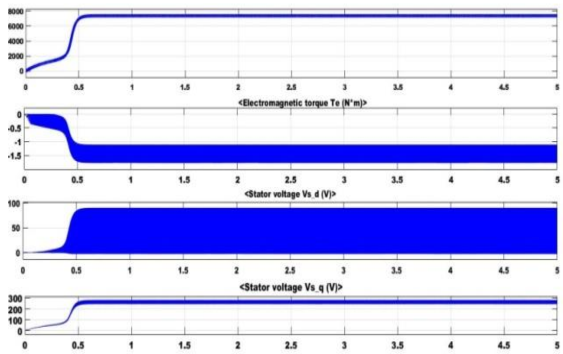


Fig. 7 Stator Speed and Electromagnetic

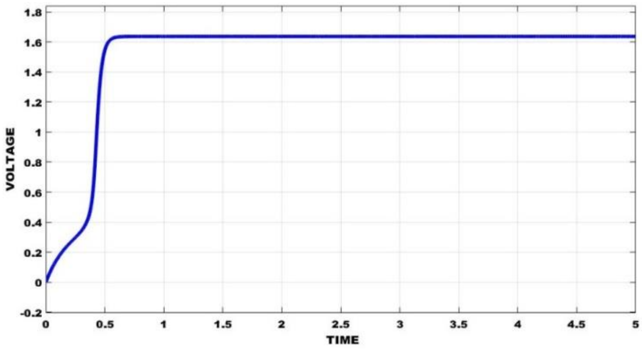


Fig. 6 Rotor speed of Wind

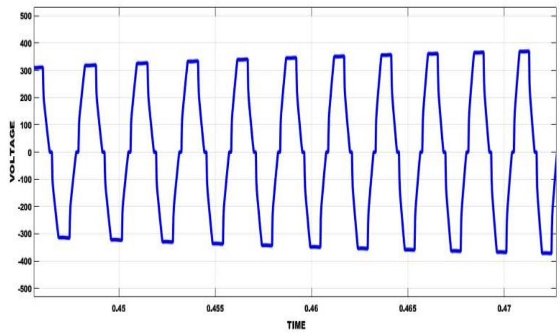


Fig. 8 Wind with Line to Line Voltage

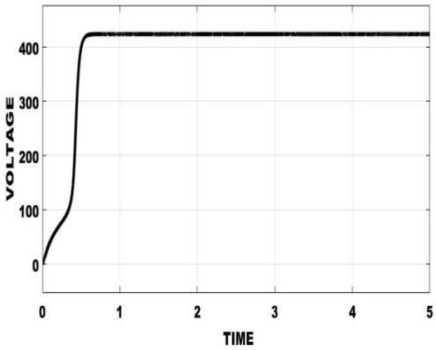

Fig. 9 Wind with PMSM

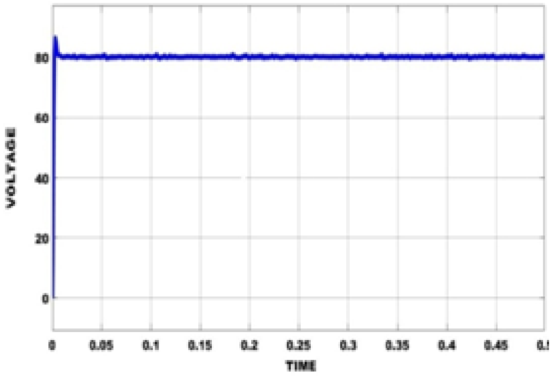

Fig. 10 Buck with PID controller

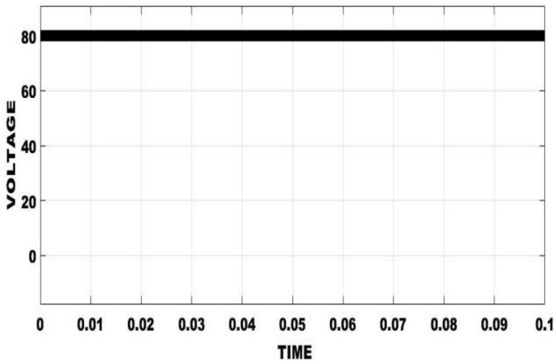

Fig. 11 Wind energy with resistive load with 80V

## CONCLUSION

In this paper a SIMULINK model of the Wind generation system is proposed and the essential models of the system components were addressed. The model of Wind turbine is connected to a PMSG to model a standalone Wind power generation system. The rectified output voltage of PMSG is connected to a dc-dc buck converter connected through the battery and LED is connected through the resistive load the proposed model is simulated. It is observed that with change in Wind speed, the output power of the standalone Wind system changes in accordance with the standard results. With additional modification this model can be used for the modelling and study of Grid connected Wind system or hybrid systems.

## REFERENCES

[1] Alejandro Rolan, AlvaroLuna, Gerardo Vazquez, Daniel Aguilar, Gustavo Azevedo, "Modeling of a Variable Speed Wind Turbine with a Permanent Magnet Synchronous Generator ". IEEE International Symposium on Industrial Electronics (ISlE 2009) Seoul Olympic Parktel, Seoul, Korea July 5-8, 2009.
[2] Polinder H., de Haan S. W. H., Dubois M. R., Slootweg J., "Basic Operation Principles and Electrical Conversion Systems of Wind Trbines", NORPIE / 2004, Nordic Workshop on Power and Industrial Electronics, Paper 069, Trondheim, Norway, 14-16 June, 2004.
[3] MittalR.,Sandhu K. S.and Jain D. K. "Low voltage ride-through (LVRT) of grid interfaced Wind driven PMSG," ARPN Journal of Engineering and Applied Sciences., 2009, vol. 4, no. 5. Pp. 73-83.
[4] Dali M., Belhadj, J., Roboam, X. and Blaquiere, J.M. "Control and energy management of a Wind photovoltaic hybrid system", Proc. EPE Conference, 2-5 Sept. 2007, pp 1-10.
[5] Dali M., Belhadj J., Roboam X., "Hybrid solar-Wind system with battery storage operating in grid–connected and standalone mode: Control and energy management - Experimental investigation", Energy 35 (2010) 2587-2595.
[6] Akhmatov V., "Variable-Speed Wind Turbines with Doubly-Fed Induction Generators Part III: Model with the Back-to-back Converters", Wind Engineering, Volume 27, No. 2, pp 79-91, 2003
[7] Hansen A.D., Michalke G., "Modelling and control of variable speed multipole PMSG Wind turbine", submitted to Wind Energy, 2007.
[8] Hong-Woo Kima, Sung-SooKimb, Hee-Sang Koa, "Modeling and control of PMSG-based variable-speed Wind turbine", Electric Power Systems Research 80 (2010) 46–52.
[9] Mohammed Aslam Husain and Abu Tariq, "Modeling of a standalone Wind-PV Hybrid generation system using MatLAB /SIMULINK and its performance analysis". IJSER Volume 4, Issue11, November-2013. Pp. 1805-1811.
[10] Ali, A. Nazar. "Cascaded Multilevel Inverters for Reduce Harmonic Distortions in Solar PV Applications." Asian Journal of Research in Social Sciences and Humanities 6.Issue : 11 (2016): 703-715.
[11] Ali, A. Nazar. "A Single phase Five level Inverter for Grid Connected Photovoltaic System by employing PID Controller." African journal of Research 6.1 (2011): 306-315.
[12] ali, A.Nazar. "A SINGLE PHASE HIGH EFFICIENT RANSFORMERLESSINVERTER FOR PV GRID CONNECTED POWER SYSTEM USING ISPWM TECHNIQUE." International Journal of Applied Engineering Research 10.ISSN 0973-4562 (2015): 7489-7496.
[13] Ali, A. Nazar. "Performance Enhancement of Hybrid Wind/Photo Voltaic System Using Z Source Inverter with Cuk-sepic Fused Converter." Research Journal of Applied Sciences, Engineering and Technology 7.ISSN: 2040-7459; (2014): 3964-3970.
[14] Ali, A. Nazar. "Ride through Strategy for a Three-Level Dual Z-Source Inverter Using TRIAC." Scientific Research publication 7.ISSN Online: 2153-1293 (2016): 3911-3921.
[15] Ali, A. Nazar. "An ANFIS Based Advanced MPPT Control of a Wind-Solar Hybrid Power Generation System." International Review on Modelling and Simulations 7.ISSN 1974-9821 (2014): 638-643.
[16] Nazar Ali, A. "Performance Analysis of Switched Capacitor Multilevel DC/AC Inverter using Solar PV Cells." International Journal for Modern Trends in Science and Technology 3.05 (2017): 104-109.
[17] Ali, A.Nazar. "FPGA UTILISATION FOR HIGH LEVELPOWER CONSUMPTION DRIVES BASEDONTHREE PHASE SINUSOIDAL PWM -VVVF CONTROLLER." International Journal of Communications and Engineering 4.Issue: 02 (2012): 25-30.
[18] ali, A.Nazar. "A SINGLE PHASE HIGH EFFICIENT TRANSFORMERLESS INVERTER FOR PV GRID CONNECTED POWER SYSTEM USING ISPWM TECHNIQUE." International Journal of Applied Engineering Research 10.ISSN 0973-4562 (2015): 7489-7496.
[19] JAIGANESH, R. "Smart Grid System for Water Pumping and Domestic Application using Arduino Controller." International Journal of Engineering Research & Technology (IJERT) 5.13 (2017): 583-588.
[20] Pau1l, M. Mano Raja, R. Mahalakshmi, M. Karuppasamypandiyan, A. Bhuvanesh, and R. Jai Ganesh."Classification and Detection of Faults in Grid Connected Photovoltaic System."

[21] Ganesh, Rajendran Jai, et al. "Fault Identification and Islanding in DC Grid Connected PV System." Scientific Research Publishing 7.Circuits and Systems, 7, 2904-2915. (2016): 2904-2915.
[22] Jaiganesh, R., et al. "Smart Grid System for Water Pumping and Domestic Application Using Arduino Controller." International Journal for Modern Trends in Science and Technology 3.05 (2017): 385-390.
[23] Kalavalli,C., et al. “Single Phase Bidirectional PWM Converter for Microgrid System.” International Journal of Engineering and Technology (IJET) ISSN : 0975-4024 Vol 5 No 3 Jun-Jul 2013.
[24] Lilly Renuka, R., et al. “Power Quality Enhancement Using VSI Based STATCOM for SEIG Feeding Non Linear Loads. ” International Journal of Engineering and Applied Sciences (IJEAS) ISSN: 2394-3661, Volume-2, Issue-5, May 2015.
[25] Karthikeyan,B. JEBASALMA. “RESONANT PWM ZVZCS DC TO DC CONVERTERS FOR RENEWABLE ENERGY APPLICATIONS .“International Journal of Power Control and Computation(IJPCSC)Vol 6. No.2 – Jan-March 2014 Pp. 82-89©gopalax Journals, Singaporeavailable at :www.ijcns.comISSN: 0976-268X.
[26] Gowri,N, et al. “Power Factor Correction Based BridgelessSingle Switch SEPIC Converter Fed BLDC
[27] Motor.”ADVANCES in NATURAL and APPLIED SCIENCES. ISSN: 1995-0772 AENSI PublicationEISSN: 1998-1090 http://www.aensiweb.com/ANAS2016 March 10(3): pages 190-197.
[28] Ramkumar,R., et al.” A Novel Low Cost Three Arm Ac AutomaticVoltage Regulator” ADVANCES in NATURAL and APPLIED SCIENCESISSN: 1995-0772 AENSI PublicationEISSN: 1998-1090 http://www.aensiweb.com/ANAS2016 March 10(3): pages 142-151.
[29] Kodeeswaran, S., T. Ramkumar, and R. Jai Ganesh. "Precise temperature control using reverse seebeck effect." In Power and Embedded Drive Control (ICPEDC), 2017 International Conference on, pp. 398-404. IEEE, 2017.
[30] Subramanian, AT Sankara, P. Sabarish, and R. Jai Ganesh. "An Improved Voltage follower Canonical Switching Cell Converter with PFC for VSI Fed BLDC Motor." Journal of Science and Technology (JST) 2, no. 10 (2017): 01-11.
[31] Murugesan.S, R. Senthilkumar."DESIGN OF SINGLE PHASE SEVEN LEVEL PV INVERTER USING FPGA."International Journal of Emerging Technology in Computer Science & Electronics, 2016, Vol.20, No.2, pp.207-2012.
[32] S. Murugesan, C. Kalavalli, " FPGA Based Multilevel Inverter With Reduce Number of Switches For Photovoltaic System", International Journal of Scientific Research in Science, Engineering and Technology(IJSRSET), Print ISSN : 2395-1990, Online ISSN : 2394-4099, Volume 3 Issue 6, pp.628-634, September-October 2017.
[33] Vikram, A. Arun, R. Navaneeth, M. Naresh Kumar, and R. Vinoth. "Solar PV Array Fed BLDC Motor Using Zeta Converter For Water Pumping Applications." Journal of Science and Technology (JST) 2, no. 11 (2017): 09-20.
[34] Nagarajan, L. Star Delta Starter using Soft Switch for Low Power Three Phase Induction Motors. Australian Journal of Basic and Applied Sciences, 9(21), 175-178.
[35] Vinusha, S., & Nagarajan, L. (2015). CURRENT SOURCE INVERTER FED INDUCTION MOTOR DRIVE USING MULTICELL CONVERTER WITH ANFIS CONTROL.
[36] Nagarajan, L., & Nandhini, S. (2015). AN EFFICIENT SOLAR/WIND/BATTERY HYBRID SYSTEM WITH HIGH POWER CONVERTER USING PSO.
[37] Subramanian, AT Sankara, P. Sabarish, and R. Jai Ganesh. "An Improved Voltage follower Canonical Switching Cell Converter with PFC for VSI Fed BLDC Motor." Journal of Science and Technology (JST) 2.10 (2017): 01-11.
[38] Compensator, D. S. (2015). AN ADAPTIVE CONTROL AND IMPROVEMENT OF POWER QUALITY IN GRID CONNECTED SYSTEM USING POWER ELECTRONIC CONVERTERS.
[39] Sabarish, P., Sneha, R., Vijayalakshmi, G., & Nikethan, D. (2017). Performance Analysis of PV-Based Boost Converter using PI Controller with PSO Algorithm. Journal of Science and Technology (JST), 2(10), 17-24.
[40] T.Vishnu Kumar, V. Suresh Kumar, T. Sumeet, M.Srimaha “Hybrid Front end Interface DC-DC Converter with ANFIS Based Control of EMS System”. International Journal of Scientific Research in Science and Technology, Volume 3, Issue 8, Print ISSN: 2395-6011, 2017.
[41] T. Vishnu kumar, V. Suresh Kumar, A new approach to front end interface DC-DC converter” International Journal of Multidisciplinary Research and Modern Education (IJMRME) ISSN(online): 2454-6119 Volume I, Issue II, 2015
[42] V.Suresh kumar, T. Vishnu kumar, A certain investigation for the battery charging system” International Journal of Multidisciplinary Research and Modern Education (IJMRME) ISSN(online): 2454-6119 Vol.1 Issue.1 2015.
[43] S.Enimai, S.Jayanthi, T.Vishnu kumar Isolated Power System Design Using Modified P&O Technique” Middle-East Journal of Scientific Research 24 (S2): 150-156, 2016, ISSN 1990-9233