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DC-DC CONVERTER WITH VOLTAGE CONTROLLER FOR STAND ALONE WIND ENERGY SYSTEM

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ABSTRACT

This paper deals with the design and simulation of DC-DC voltage regulator using closed loop system with pulse width modulation technique and are simulated using MATLAB/SIMULINK power system blocks. This system has advantages like current source characteristics, reduced filter size and reduced transformer size. The simulink circuit model for open loop controller and closed loop model with PI controller are developed, compared and used for simulation studies. Results of the simulation are presented.

KEYWORDS: Stand Alone wind Farm, Resonant converter, DC-DC Converter.

INTRODUCTION

Now–a-days the renewable energy sources are tremendously increasing in nature due to their unique advantages like pollution free, low maintenance cost, less requirement of skilled labor. The non-renewable energy sources have a lot of drawbacks like high pollution, need to search for the fuel, requirement of high skilled labor. In order to overcome these problems with non-renewable energy sources we are going for renewable energy sources like wind farms, solar plants, biomass plants.

In these renewable energy sources, wind energy system plays a major role and gives high income once they are installed at suitable locations. This wind farm has unique advantages like less land requirement, low maintenance unlike solar and biomass plants. And also they can be able to produce bulk power if many of them are installed. In wind energy systems, particularly stand alone wind energy systems are used for remote areas and ranches where the grid connected transmission lines are difficult to lay. And hence they are suitable for the remote areas.

In the stand alone wind energy systems [1], the speed of the turbine or voltage at the output is to be controlled in order to get the constant voltage at the load terminals. For this purpose, there is a need to implant the voltage stabilizer circuits or there is a need to control the speed of the turbine. As the wind speed is uncontrollable, the other way is to control the output voltage from the generator. This can be done through the use of voltage regulators. As the stand alone wind energy system connected to the loads directly, there is a need to connect to the batteries in the absence of the loads. So, a proper voltage is to be given to the battery. For this, a suitable DC-DC converter circuit is used as a controller with the help of CLL resonant converter.

Here for controlling the voltage [2] two methods are used. One is maximum power point tracking method and other is predetermined voltage controlled method. In maximum power point tracking method, if the DC voltage changes continuously, the power output may increases. This system is complex and it changes rapidly with the small change in the tracking. The high turbine inertia can cause a significant time lag between the observed power and DC link voltage. Even the predetermined relationship is complex, here in the proposed work we are going to use this method. For the speed measurement, it requires costly anemometer for the system control. The system is used in remote areas, therefore the system design includes simple control and a fault tolerance topology. This paper has a step down DC-DC converter which achieves high wind turbine efficiency for a wide range of wind speeds. In this paper both open loop and closed loop systems are simulated using MATLAB.

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ANALYSIS OF THE WIND ENERGY SYSTEM INCORPORATED WITH CONTROLLER

Generally wind energy consists of a wind turbine which captures the wind energy and generates mechanical energy. This mechanical energy is given as input to the permanent magnet generator which converts mechanical energy into the electrical energy. Wind turbines are of two types- one is horizontal axis and other is vertical axis wind turbine. Integrating an appropriate energy storage system like batteries with the PMSG wind energy system removes fluctuations and increases the reliability of load power supply.

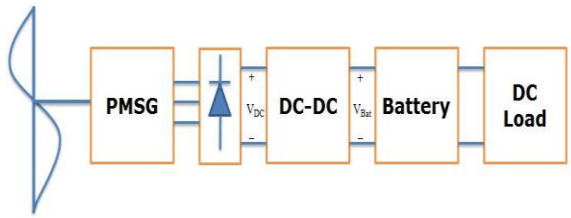

Fig.1: Schematic Diagram of Stand Alone wind energy system

PMSG [7] produces AC voltage but for the storing purpose that AC voltage should be converted to DC voltage using rectifier. Rectifiers are of controlled and uncontrolled type Controlled rectifiers uses controlled devices like thyristors, MOSFETS, IGBT's and GTO's for converting alternating current to direct current. IN the uncontrolled rectifier, it uses uncontrolled devices like diode for converting AC to DC. In this paper full wave rectifier is implemented for the better analysis. The step down DC-DC converter [3] is used as DC link for regulating the DC voltage at the output terminals. This converter will allow the voltage at the output terminal of a diode bridge rectifier to be controlled. At low wind speeds, the voltage is lowered to prevent the DC link from reverse biasing the diode rectifier. At high wind speeds the voltage may be increased to reduce the I2R losses. It provides control over the current flowing over the generator. Rapid charge and discharging batteries should be used for standalone wind energy system for storing and releasing energy in adequate time. With low cost and high efficiency, battery should be preferred for this purpose [4]. Remote areas relatively require small load applications and hence the standalone wind energy systems are best suited for them. Always load terminals require constant voltage supply for the better performance.

Table.1: Wind turbine Data

Effective Turbine Radius	1.0Mts.
Phase-Phase Winding Inductance	3.3mH
Phase-Phase winding Resistance	0.510Ω
Peak per phase turbine constant	0.71N-m/A
No. of poles	8
System Inertia	1.2 Kg-m^2
System Damping	0.16 N-m/KDPM

THEORETICAL APPROACH FOR THE PROPOSED CONTROLLER

The power captured from the wind turbine mainly depends on the turbine power swept turbine area, air density, turbine coefficient of performance and wind speed. Coefficient of performance is dependent on the function of Tip Speed Ratio (TSR). Any small deviation to either side of this TSR leads to the reduction of electrical power significantly. BY employing control system over the speed TSR is controlled and maximum power can be captured by maintaining maximum performance coefficient. The terminal voltage of the generator is controlled by rotational speed of the turbine. Considering the current and terminal voltages are in phase by neglecting harmonic current, we can get an ideal fundamental relationship.

The output of the generator terminals is connected to diode rectifier. Neglecting the magnetizing current and saturation, the following calculations are made. The fundamental equation,

$$E_1 = 4.44 \times N_1 \times \phi_1 \times f \quad (1)$$

$$E_2 = 4.44 \times N_2 \times \phi_2 \times f \quad (2)$$

And

$$f_r = 1/(2\pi \times \text{sqrt}(L_r C_r)) \quad (3)$$

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From the above equations, we will find the values of N_1, N_2, C_r. Now, the resultant values are to be connected to simulate circuit.

SIMULATION RESULTS AND ANALYSIS

The MOSFET's are used in rectifier circuit for high power applications and also it increases the efficiency of the regulator. The pulses to the MOSFET's are given and scopes are connected for displaying the driving pulses. The inverter outputs, transformer, rectifier outputs are viewed in scopes connected to them. In this, 48V AC is stepped down to 12V and is rectified by MOSFET rectifier and capacitor filter to give them to battery bank. Ripple free DC output is obtained at the load side. In this paper, mainly open loop system and closed loop system with PI controller are developed and these are simulated and their results are compared. The Fig.2 shows the DC-DC converter circuit [6] of wind energy system.

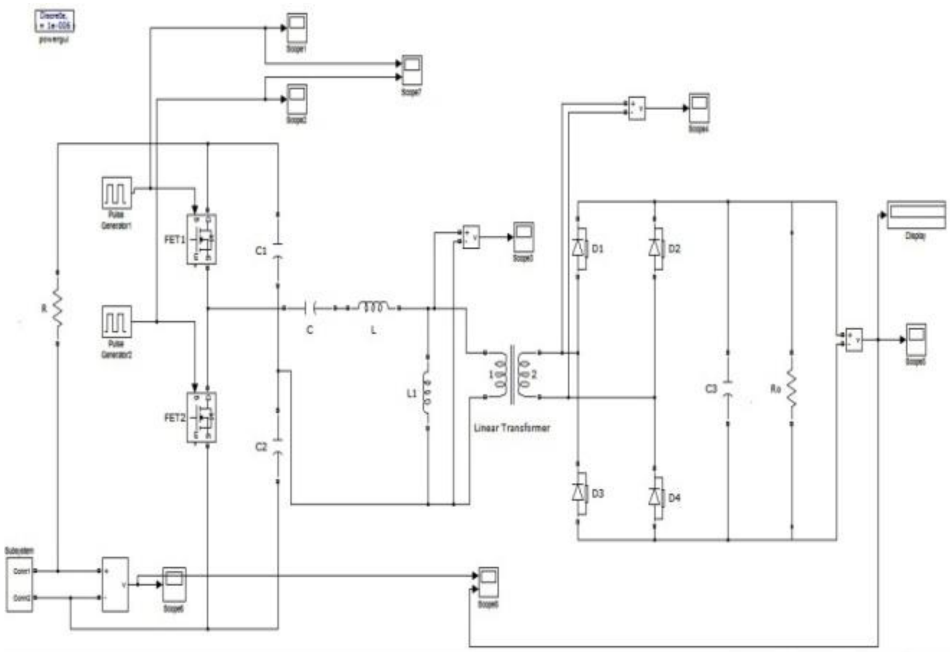

Fig.2: open loop DC-DC converter circuit of the wind energy system

The input and output from the converter without any disturbance in it is shown in the Fig.4 (a) and Fig.4 (b) respectively.

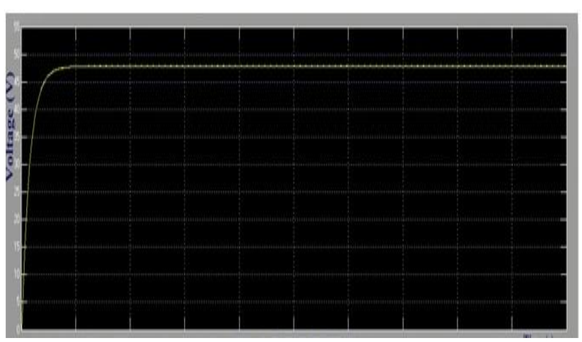

Fig.4(a): Converter input without disturbance

4(b): Converter outputs without disturbance

The above simulations are for the converter system without any disturbance at the input side. As we know that the speed of the wind is not constant and so the turbine speed also changes at some time. If the speed of the turbine changes, the voltage at the output of the generator will also changes. The change in the output with change in the input speed of the turbine is shown in the Fig.5 (a) and Fig.5 (b)

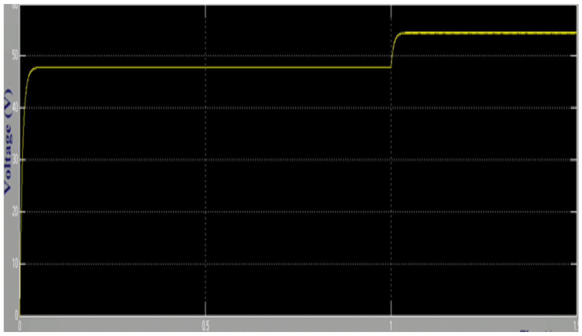

Fig.5 (a): Converter input with disturbance

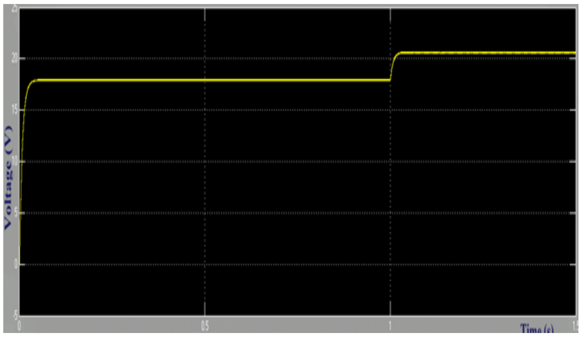

Fig.5 (b): Converter output with disturbance

From the above simulation results we can clearly see that there is a change in the output voltage with the change in the input speed of the turbine. If this is not rectified and controlled, the battery banks will get damage due to the over voltage at the output terminals. So, for avoiding this, we are going for the closed loop converter system in which PI controller is used as the feedback path controller and the output from the PI controller will be gives as the input gto the comparator. Now, the comparator compares the input signal and the signal from the PI controller and sends the corresponding signal to the MOSFET gate.

The circuit diagram for the implementation of the closed loop control of the converter system is shown in the Fig.6. And the simulation results of system input and the output under the disturbance is shown in the Fig.7 (a) and Fig.7 (b) respectively.

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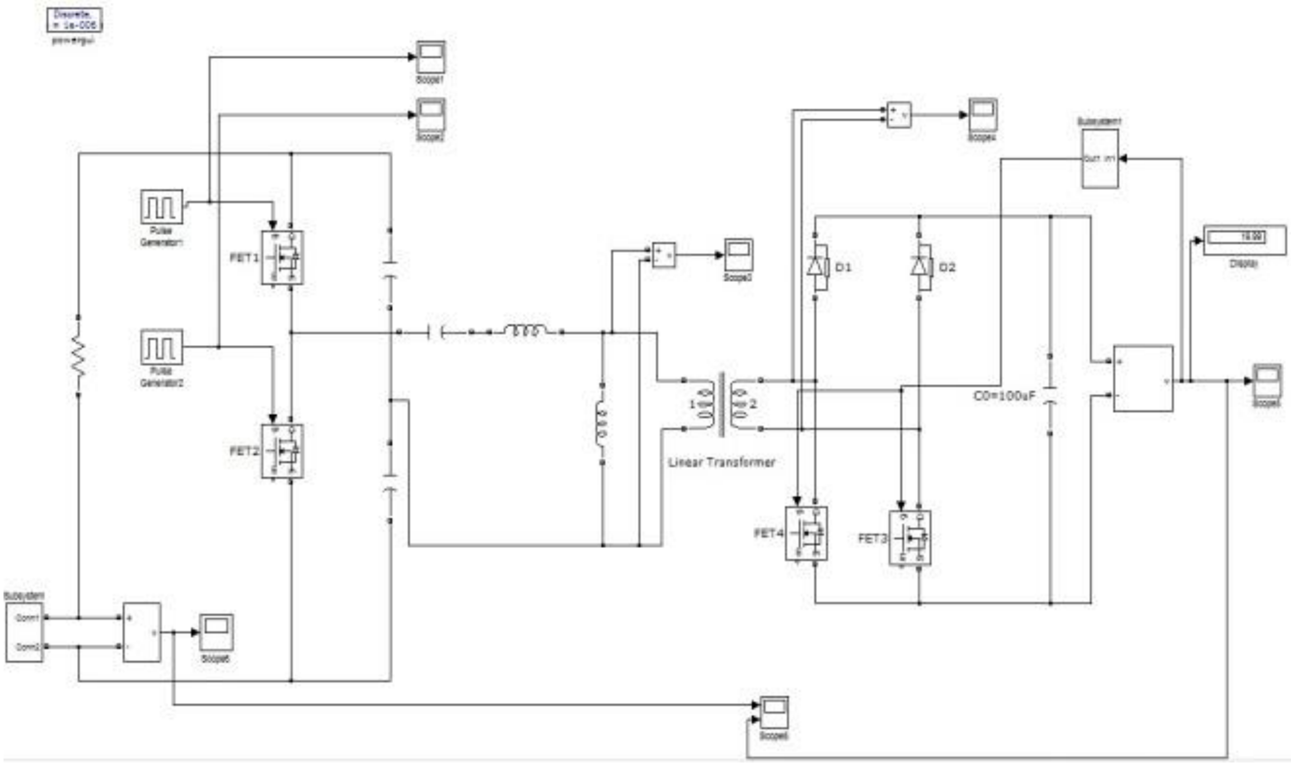

Fig.6: Converter with closed loop PI controller

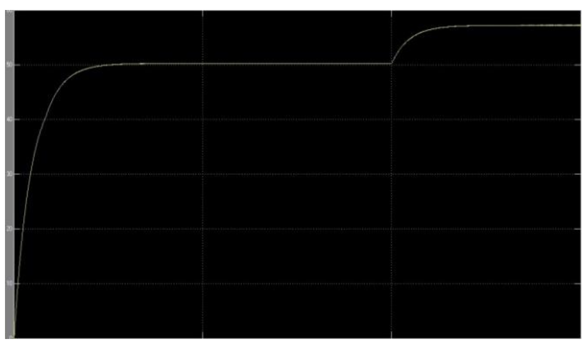

Fig.7 (a): Closed loop converter input voltage with disturbance

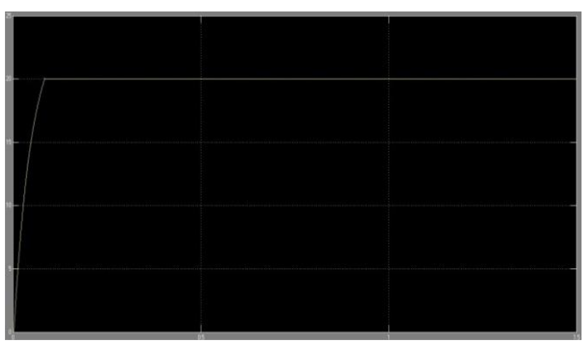

Fig.7 (b): Closed loop converter terminal voltage with disturbance

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By comparing the Fig.5 and Fig. 7, we can say that there is a constant output terminal voltage in the circuit with PI controller. Though there is a change in the input speed of the turbine, because of the controller, it's effect is not present at the output terminal voltage.

CONCLUSIONS

The open loop and closed loop systems for the DC-DC converter are interrogated by using the MATLAB and the simulation results are presented. Also the comparative study between the closed loop model and open loop model are investigated. From the simulation results we can say that, by the use of the closed loop control of the DC-DC converter, though there is a change in the speed input for the wind turbine, the corresponding terminal voltage can be made constant by the use of this converter.

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