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# Voltage Regulation of Variable Speed Wind Turbine using MATLAB/Simulink

**Arshad Nawaz, Muhammad Naeem Arbab**

***Abstract— The conventional sources of energy are depleting and emphasis is now focused on renewable energy. Wind energy is one of the renewable sources having great potential. It is cheap and requires less maintenance but also have issues associated with it. The main issue associated with Wind turbines (WT) is the unpredictable nature of wind. This makes it difficult to get a constant frequency and constant voltage from wind turbines driven by the variable speed. This paper presents method of regulating the output voltage for standalone wind turbine driven by variable speed wind. The method is based on the using voltage regulator for the fluctuating voltage of wind turbine driven by variable speed. The regulated voltage is supplied to utility. Battery system is also proposed for the system which will provide power when wind regulated voltage is dropped from a threshold value due to low wind speed or absence of wind.***

***Index Terms—Voltage regulation, Renewable energy, Variable speed wind turbine, off-grid***

## I. INTRODUCTION

The conventional sources of energy are exhausting and importance is now focused on renewable energy. The increasing energy demand and limited resources have motivated researchers toward exploring the potential of renewable resources.

Renewable energy originates from resources which are repeatedly reloaded like sunlight, wind, rain, tides, waves and geothermal heat. Sunlight is considered as the mother of all energies. Solar PV panels are used to harnessed sunlight and convert it to DC voltage. PV panels are also equipped with the inverters to provide AC voltage to AC load.[1]

Wind energy is one of the renewable sources having great potential. A wind turbine is a machine for translating mechanical energy from kinetic energy in wind.[2] Electrical energy is then produced from Mechanical energy through generators. It is cheap and requires less maintenance but also have issues associated with it. The main issue associated with Wind turbines (WT) is the unpredictable nature of wind. The speed of wind is not constant due to variable air pressure around the globe. This makes it difficult to get a constant frequency and constant voltage from wind turbines generator driven by the variable speed. Wind energy is also a preferred choice for isolated areas where National grid supply is not available.

Wind turbines are mainly of two types.

1. *Horizontal Axis Wind Turbine (HAWT)*

   A horizontal axis turbine rotates its blades parallel to ground axes.

2. *Vertical Axis Turbine (VAWT)*

   A horizontal axis turbine rotates its blades perpendicular to ground axes.

The *HAWT* is the most preferred type for wind turbine. [3]

The purpose of electrical generator is to provide resources for conversion of energy between the wind as a mechanical torque and rotor of turbine. Wind turbine act as prime mover and enables generator to induces voltage for further supply to the local grid or user.

The generators preferred for energy production from wind are Induction Generators (IG), Permanent Magnet Synchronous Generators (PMSG) and Synchronous Generators (SG) [4]. The main issue associated with Induction generators is the voltage regulation. The generated voltage from IG depends on load, speed and load power factor.[5]

Voltage regulation is degree of variation in the voltage magnitude between the sending and receiving end in coordination with no load and full load. This is described by the equation 1.[6]

$$\text{Voltage Regulation} = \frac{V_S - V_R}{V_R} \qquad (1)$$

Where $V_s$ is sending voltage and $V_R$ is receiving voltage.

Previous work down is summarized as follow

Rajveer Mittal suggested battery storage system for variable speed wind turbine using permanent Magnet Synchronous Generator (PMSG). Off-grid wind energy systems normally contain batteries since the available wind does not always generate the required amount of power. If load demand is less than the power generated by wind, the excess power is deposited in the batteries. The main drawback in this model is the use of PMSG, which has high cost, manufacturing difficulties and demagnetization at high temperature.

K. Premalatha & S.Sudha suggested Squirrel Cage Induction Generator (SCIG) excitation system and voltage control. Induction generator (IG) is driven by wind turbine. DC load by means of Voltage Source Converter is connected to IG .System is given excitation through an external battery. DC Voltage of VSC and speed are detected and feedback for control which is based on space vector modulation scheme. The issue with this design is the use of external battery for excitation and use of SEIG which has poor voltage regulation. Also this model is restricted to DC load.[7]

B.A. Neal & R.N. Clark in their paper suggested the speed control of small turbine by using electrical loading. Their work lack simulation result, model and system design[8]..

K.Kalyan Raj et,al surveyed and compared different methods/schemes for the voltage stability of isolated SEIG driven by variable speed.

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Their finding concludes that power electronics converters provide promising results in voltage control of SEIG.[5]
Xabier Juankorena et,al described a method for primary regulation of wind turbine with variable speed. Primary regulation is the technique by which disproportions or imbalances between generated power and energy demand is compensated. Primary regulation consists of a linear variation of generated power with grid frequency, if grid frequency increases, the generated power should decrease and vice versa. This suggested method consists of changing the power-speed curve of the turbine in accordance to grid frequency, thus varying the percentage of maximum power available injected to the grid. This is achieved by operating turbine at rotational speed different from the optimal, and not controlling the pitch angle. This paper proposes primary regulation method independent of wind speed and not requires pitch angle control. [9]

## II. METHODOLOGY

This paper proposes tap changing transformer and voltage regulator for the regulation of voltage. Storage system is also proposed for off grid operation.
The proposed solution for the output voltage regulation consists of the steps shown in the Figure 1.
Aero-generator (Wind Turbine) is driven by air which is un-predictable in nature. The variable speed air driven turbine injects variable mechanical power into the induction generator. The generator converts the mechanical power feed to it from wind turbine into electrical power. If the input mechanical power is varying then resultant electrical power will also fluctuate in magnitude and frequency. Therefore frequency and voltage regulator is connected to the output of generator.
This regulated output is directly supplied to the user. Battery system is always necessary with the off grid operation of wind turbine. This serves the purpose of uninterrupted power supply to the user.
Automatic switch is also connected before power supplied to the load. If voltage is 220 V ±5%, the switch will also direct supply to the load from regulated and the battery will be getting charged. However if the wind speed get reduced or increased about and generator and regulator assembly is unable to maintain the regulated output, the power supply is switch to battery via inverter.

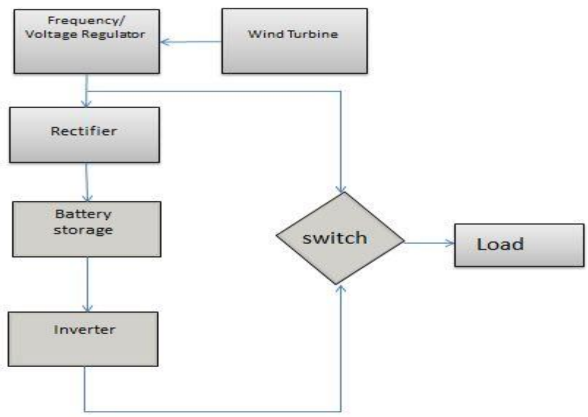


*Figure 1: Wind Turbine Voltage Regulation Algorithm*

## III. MODELS

### A. Wind Turbine Model

This section implements a wind turbine. Simulink model of wind turbine is shown in Figure 2.The inputs are actual and desired speeds and the block gives out mechanical power (Pω) as an output. The amount of power obtained from the wind of velocity v is as given by equation 2.

$$P\omega = 1/2\ \rho A C p v^3 \qquad (2)$$

This is feed to asynchronous generator for generation of electricity as prime mover. Where

*Pω* = wind power in watts
*ρ* = air density in kg/m3
*A*= swept area in m2
*Cp*=power coefficient of wind turbine
*v*= wind speed in m/s

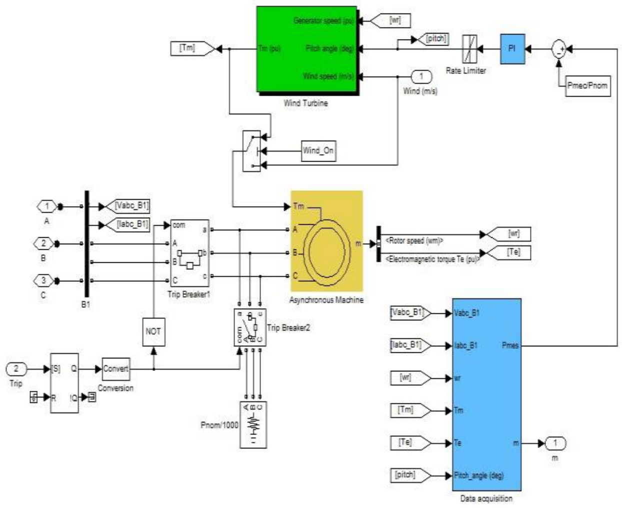


*Figure 2: Wind Turbine Simulink Model*

### B. Regulator Model

This block implements voltage regulation model. The model is shown in Figure 3. The unregulated AC supply is given to the voltage regulator module. The tap changer control module is feedback to voltage regulator module. If voltage is high then rated the tap is change to down turns and vice versa thus regulating the output voltage. The tap changer is automatic switch which is feed backed by the output voltage of generator. Tap changer continuously senses the generator voltage and act in case of any abnormality.

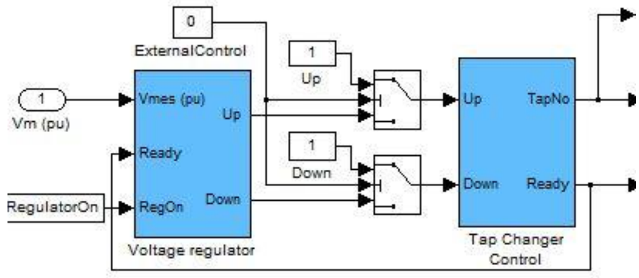


*Figure 3: Regulator Simulink Model*

### C. Rectifier Model

This block implements Simulink model of rectifier. The block and detailed models are shown in Figure 4 and Figure 5 respectively.


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The voltage from regulator output is linked to battery through rectifier model. In first positive half the diodes D1 and D4 conducts while in second negative half diode D2 and D3 conducts. The shunt capacitor is connected in order to smooth the waveform and reduce the ripples. The rectified voltage is then feed to storage device which is battery in this case.

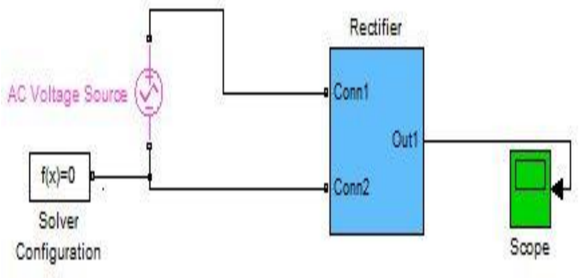


*Figure 4: Rectifier Simulink Model*

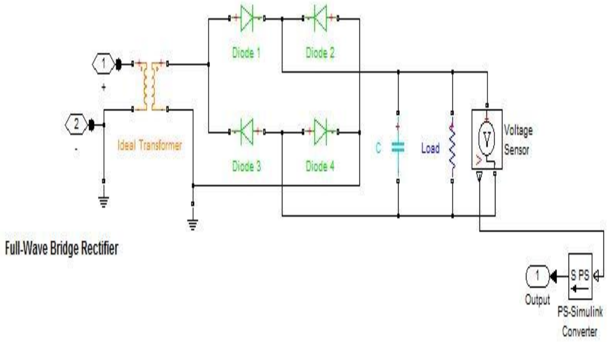


*Figure 5: Detailed Rectifier Model*

***D.Inverter Model***

Inverter model implanted in Simulink is shown in Figure 6. The full bridge inverter is provided by the battery. The full-bridge inverter produces a mono polar voltage fluctuating between 0 and+400V for first half and then between 0 and -400V for second half cycle. The current obtained with the full-bridge is smoother.

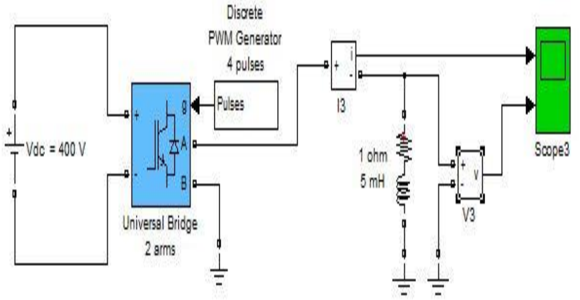


*Figure 6: Inverter Simulink Model*

## IV. RESULT

The Figure 7 shows the output of scope connected to rectifier model. The ripples can be made smooth further by keeping capacitor value appropriate limit. This rectified voltage is supplied to the battery to store energy which would be supplied to the load through inverter when the wind speed exceeds or decrease below some threshold value defined in regulator module.

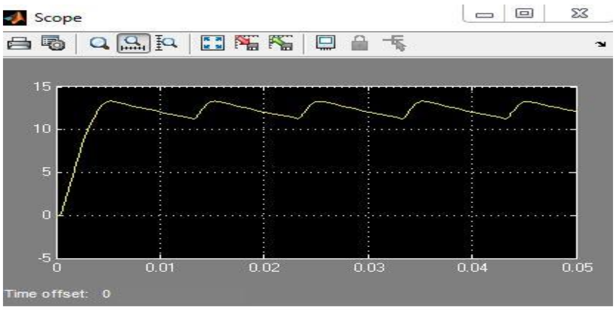


*Figure 7: Rectifier output*

The inverter is supplied by the storage battery. The two arms universal bridge is used to develop inverter block. The output shows the conversion of DC input voltage to Sinusoidal current waveform supplied to load connected shown in Fig. 8.

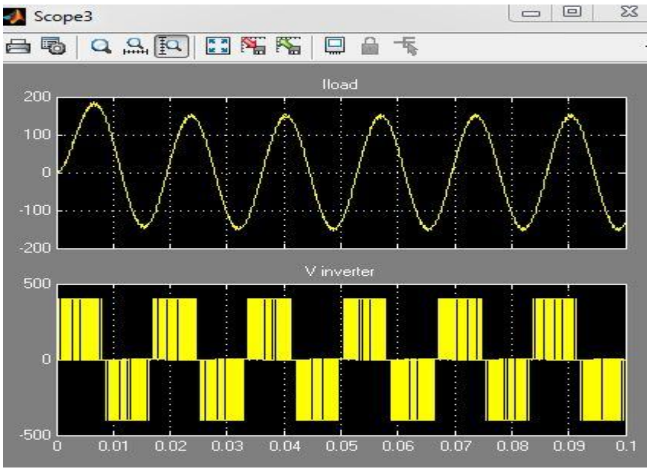


*Figure 8: Inverter Output*

## V. CONCLUSION

The algorithm developed and implemented in MATLAB gives promising results for the voltage regulation, rectification and inverter models. The tap changing regulator model regulates the voltage by changing transformer taping. Integration of these modules can led to the possible solution of voltage regulation problem associated with the wind energy conversion system (WECS). Also this model can be implemented with the variable speed wind induction generators.

## VI. FUTURE WORK

In future work all models will be integrated and combined result will be obtained for wind turbine speed, voltage and frequency control.

## REFERENCES

[1] A. Khattak and M. N. Arbab, "Model and Design for the Control of Hybrid Domestic Power System," vol. 02, no. 02, 2012.

[2] V. D. Induction and M. M. A. Salama, "Voltage Regulation of Wind Farms Equipped Generators Wind Turbines," pp. 1–8, 2010.

[3] W. Turbines, "Wind Turbines," *http://www.springerlink.com/index/10.1007/3-540-29284-5*, pp. 1–7, 2006.



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[4] R. Mittal, K. S. Sandhu, and D. K. Jain, “Battery energy storage system for variable speed driven PMSG for wind energy conversion system,” *2010 Joint International Conference on Power Electronics, Drives and Energy Systems & 2010 Power India*, pp. 1–5, Dec. 2010.
[5] K. Kalyan, E. Swati, and C. Ravindra, “Voltage Stability of Isolated Self Excited Induction Generator ( SEIG ) for Variable Speed Applications using Matlab / Simulink,” no. 3, pp. 186–190, 2012.
[6] B. L. Theraja, *Electrical Technology*. .
[7] K. Premalatha and S. Sudha, “Self-Excitation and Voltage Control of an Induction Generator in an Independent Wind Energy Conversion System,” *ijmer.com*, vol. 2, no. 2, pp. 454–461, 2012.
[8] B. A. Neal, R. N. Clark, B. A. Neal, and R. N. Clark, “Speed Control of a Small Wind Turbine Using Electrical Loading Speed Control of a Small Turbine Using Electrical Loading.”
[9] X. Juankorena, I. Esandi, J. López, and L. Marroyo, “Method to Enable Variable Speed Wind Turbine Primary Regulation,” pp. 495–500, 2009.

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