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Sustainable Architecture of Wind Energy Conversion System based on Neuro-Fuzzy Approach

B. Sathyavani[1], Harika Rachamalla[2]

Assistant Professor, Dept. of EEE, SR Engineering College, Warangal, Telangana, India[1]

PG Student [Power Electronics], Dept. of EEE, SR Engineering College, Warangal, Telangana, India[2]

ABSTRACT: Due to expanding population, higher fuel costs, and polluted related issues there has been a major push to develop an intelligent grid. The move to wind energy is an evolution. The change begins with simple awareness of controlling and managing of wind energy. Undoubtedly, energy production by means of renewable energy resources gives safe, comfort, eco-friendly generation. This project compiles a brief understanding about the possible path towards the “Clean Energy”. In this paper a simplified Wind Energy Conversion System (WECS) is presented with the Neuro-Fuzzy Inference System is designed for output voltage control and frequency control, has been simulated via SIMULINK Software. Based on the dynamic performance of WECS, ANFIS designed. This WECS consists of Squirrel cage Induction Generator (SCIG) connected to transmission grid through a power electronic interface. The topology of a power converter system consists of a Three-phase Matrix Converter, a direct frequency converter, which consists of nine IGBT switches, control scheme adopted for matrix converter is Space Vector Modulation. This paper aims at simulating the Wind Energy Conversion Systems based on Neuro-Fuzzy approach.

KEYWORDS: Wind Energy Generation, Induction Generator, Matrix Converter, Neuro-Fuzzy mechanism.

I. INTRODUCTION

The conversion of wind kinetic energy into electrical energy is of a multidisciplinary nature, involving aerodynamics, mechanical systems, Electrical Machines, Power Electronics, Control theory and power systems. All electric-generating wind turbines, no matter what size, are composed of a few basic components: Wind turbine (rotor-the part that actually rotates in the wind), electrical generator, a Power Electronic Converter, a speed control system and a tower.

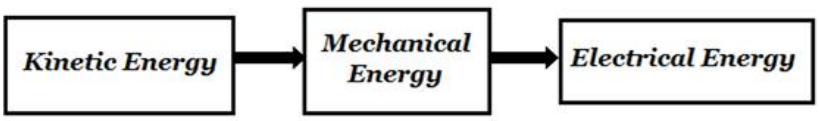

Fig.1 Energy Conversion of Proposed System

Existing system based on Model dependent Algorithms, they are Power Signal Feedback (PSF) algorithm, which uses look up table values that are dependent on the system model and parameter values. Another method based on fuzzy logic principles and four leg improved Matrix Converter model which is also system dependent. Next method is Perturb and Observe (P&O) algorithm, this is also model dependent. Model dependent designs have the drawback that the optimization algorithm and controller need to be redesigned carefully for each WECS. To overcome these difficulties, a new system Neuro Fuzzy mechanism is presented.

The most used generator is the Doubly Fed Induction Generator (DFIG), and we suggest to change it by Squirrel Cage Induction Generator (SCIG), owing to the robustness of SCIG, and since it has low cost with an almost null maintenance. In this paper we use a squirrel cage Induction Generator, despite this type of generator, usually, is applied by the fixed speed windmills, which is directly connected to the grid, or can include a condenser between the

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generator and the grid to compensate the reactive power. In our case, we will introduce a power electronic converter between the generator and the grid thanks to this we will use the variable speed mill. The matrix converter allows us to control the generator. It is important to remark that the squirrel cage is rather common as a motor. Therefore, the control in this way is quite well studied and it also implies a robust machine that needs little, or almost null, maintenance Power electronic converter facilitates electrical energy conversion between source and load based on combined knowledge of energy systems, electronics, and control. Power electronic interface consists of converter and controller. In this paper we use a frequency converter- matrix converter for the variable speed wind turbine. Control scheme adopted for matrix converter is Space Vector modulation.

The objective of this paper is to simulate a low-to-medium power Variable speed Wind Turbine System which is equipped with a Matrix Converter and an Induction Generator.

- To develop a comprehensive dynamic mathematical model for the Wind Turbine System including Matrix converter to be used for controller design purposes.
- Control of Induction Machine based on constant v/f strategy to avoid saturation of the induction generator.
- To develop an enhanced control mechanism based on Neuro-Fuzzy approach.
- A high efficiency three phase to three phase matrix converter (frequency converter) was designed, to connect the wind turbine to the electric grid, the control scheme adopted for the matrix converter was space vector modulation.

The control strategy adopted for WECS is Adaptive Neuro-Fuzzy Inference System to control frequency and output voltage. This control system provides an opportunity to extract maximum power from proposed Wind Energy Conversion System.

II. SYSTEM MODELLING

The Variable Speed Wind Power Generating System has the detailed analysis of Aerodynamic, Mechanical, Electrical System and correlations defining dynamic behaviour of the system. In this study for the purpose of obtaining the dynamic behaviour of WPGS in real time, Sim power systems program involved in the MATLAB/SIMULINK have been used. Before giving the simulation block diagram of Wind Power Generating System, a simplified block diagram of the system is given in Figure 2.

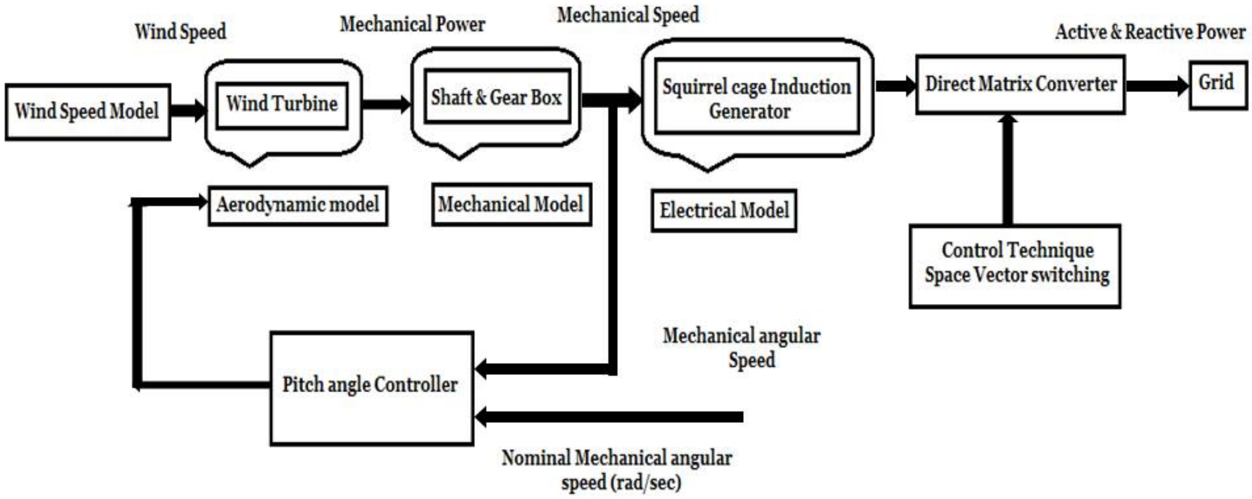

Fig.2 The Proposed Circuit diagram of Wind Energy Conversion System

In the above block diagram, the output of wind speed model is defined as Kinetic Energy or Speed of Wind. The wind speed is converted to Mechanical power. The mechanical power is the first input of the Mechanical model i.e, Shaft and gear box. Another second input of the mechanical system is proportional to the speed of the electrical

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generator, the output of the mechanical system is the wind turbine rotor speed and mechanical power. Inputs of the asynchronous generator model are mechanical energy obtained from Wind Turbine, the output of SCIG is given to Matrix converter, to obtain fixed frequency. The output magnitudes in wind power generating system that can operate in isolation of electrical networks.

Mathematical model of Wind Turbine model:

According to newtons second law of motion,

$$F = ma$$

Kinetic Energy is,

$$E = mas$$

$$E = \frac{1}{2}mv^2$$

$$P = \frac{dE}{dt} = \frac{1}{2}\frac{dm}{dt}v_w^2$$

$$P = \frac{1}{2}\rho A V_w^3$$

$$P_w = \frac{1}{2}\rho A V_w (V_u^2 - V_d^2)$$

$$P_w = \frac{1}{2}\rho A V_u^3$$

Aerodynamic Model:

Tip speed ratio calculations, $\lambda = \frac{\omega_{rotor} \cdot R_{rotor}}{V_{wind}}$

Rotor power coefficient calculations $C_p = \frac{P_{rotor}}{P_{wind}}$

Aerodynamic torque developed $T_{rotor} = \frac{P_{rotor}}{\omega_{rotor}} = \frac{\frac{1}{2}\rho \cdot C_p \cdot \pi \cdot R_{rotor}^2 \cdot V_{wind}^3}{\omega_{rotor}}$

Mechanical Model:

By newtons second law for rotating system

$$J_r\dot{\omega}_t + B_r + \omega_t = T_a - T_{ls}$$

$$J_{ls}\dot{w}_{ls} + B_{ls}(\omega_t - \omega_{ls}) + K_{ls}(\theta_t - \theta_{ls}) = T_{ls}$$

$$T_{ls} = B_{ls}(\omega_t - \omega_{ls}) + K_{ls}(\theta_t - \theta_{ls})$$

Mathematical model for generator is

$$J_g\dot{w}_g + B_g\omega_g = T_{hs} - T_{em}$$

The gear train ratio is $n_g = \frac{T_{ls}}{T_{hs}} = \frac{\omega_g}{\omega_{ls}} = \frac{\theta_g}{\theta_{ls}}$

Electrical Model:

Squirrel Cage Induction Generator

$$V_{sd} = R_s i_{sd} + \frac{d}{dt}\lambda_{sd} - \omega_d\lambda_{sq}$$

$$V_{sq} = R_s i_{sq} + \frac{d}{dt}\lambda_{sq} - \omega_d\lambda_{sq}$$

$$V_{rd} = R_r i_{rd} + \frac{d}{dt}\lambda_{rd} - \omega_{dA}\lambda_{rq}$$

$$V_{rq} = R_r i_{rq} + \frac{d}{dt}\lambda_{rq} - \omega_{dA}\lambda_{rd}$$

$V_{sd}, V_{sq}, V_{rd}, V_{rq}$ – Direct and quadrature axes stator and rotor Voltage

$i_{sd}, i_{sq}, i_{rd}, i_{rq}$ – Direct and Quadrature axes stator and rotor current

ω_d – Angular Velocity, L_m – Mutual Inductance

$$T = \frac{P}{2}L_m(i_{sq}i_{rd} + i_{sd}i_{rq})$$

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Power electronic Interface: Matrix Converter

Matrix converter is a direct frequency changer, consists of nine bidirectional IGBT switches. Previously we used Back-to-Back Converter also called as Indirect AC-AC converter the main drawback is it needs a large energy storage element. But matrix converter has some special features Adjustable input power factor, four quadrant operation, absence of DC-link. There are many modulation strategies for Matrix converter but space vector switching reduces losses in Matrix Converter, so the Control Scheme adopted for Matrix Converter is Space Vector Modulation.

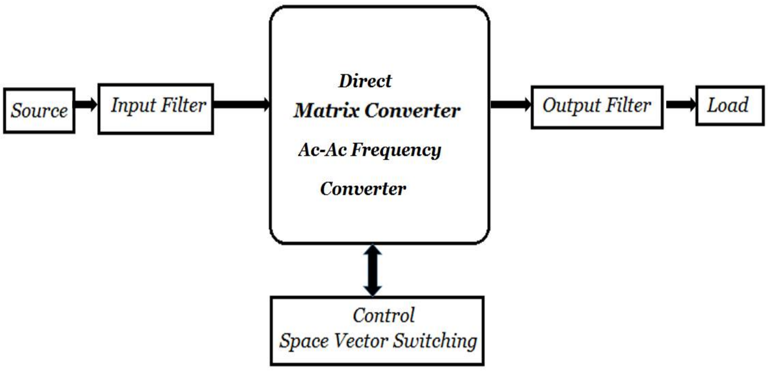

Fig.3 Direct Matrix Converter

There are 27 Switching combinations among them only 21 switching combinations (Groups II and III) are used. Group I switching combinations cannot be used because each switching combination generates an output voltage vector and an input current vector that has variable directions, which are difficult to be applied for synthesizing the reference vector. On the other hand, each switching combination from Group II can be transferred into an output voltage vector and an input current vector with fixed directions. Theses vectors are referred as “Active Switching configurations”. For group III switching combinations, zero input current and zero output voltage vectors are formed.

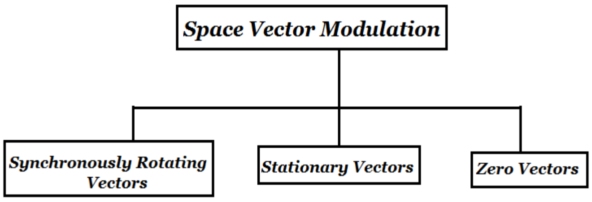

Fig.4 Three Switching states of Space Vector Modulation

III.ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM – CONTROL STRATEGY

Power obtained from the Wind Energy Conversion System is desired to be high-quality output voltage and frequency must be within operation limit values. For this purpose to obtain electrical power in desired quality ANFIS is used. The pitch angle control is made to control wind flow around the turbine blades by controlling the moment spent on the turbine shaft. If the wind speed is lower than the rated speed of wind turbine, the pitch angle is constant at its optimum value. It must be considered that the pitch angle can be changed in limited rate. This rate may be completely low because of rotor blade dimension. By means of blade pitch angle control, in speeds of rotor above slow and nominal values, no problem may occur with respect to the structure of wind Turbine. As long as the wind turbine output power is lower than that for the rated speed of wind turbine, the error signal will have a negative value and gap angle will have optimum value. But if the turbine output power is above the reference value, the error signal will be positive and gap angle will be replaced with a new value in limited rate.

While controlling the blade pitch angle of the wind turbine, an attempt is made to keep the mechanical angular rate of the asynchronous generator at rated value. The Frequency of the system is put under the control of the pitch angle control, there by controlling the electronic output frequency and voltage at specified values.

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To develop the operational performance of the wind power generation system and obtain power in desired quality ANFIS has been designed to regulate the blade pitch angle of the variable speed wind turbine. As frequency of output voltage of VSWPGS is directly proportional to the speed of asynchronous generator, frequency adjustment can be made at the same time

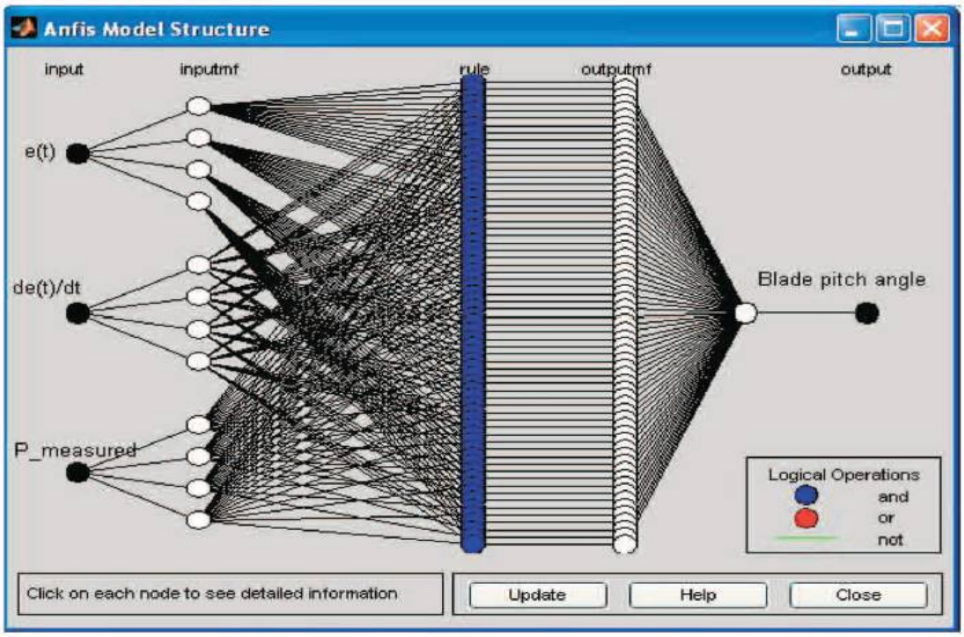

Fig.5 ANFIS structure for blade pitch angle control of Variable speed wind turbine.

IV. SIMULATION RESULTS AND ANALYSIS

In Figure.6, Shows the complete simulation circuit which consists of Wind Turbine, the output of wind turbine given to Matrix Converter and it is connected to the grid.

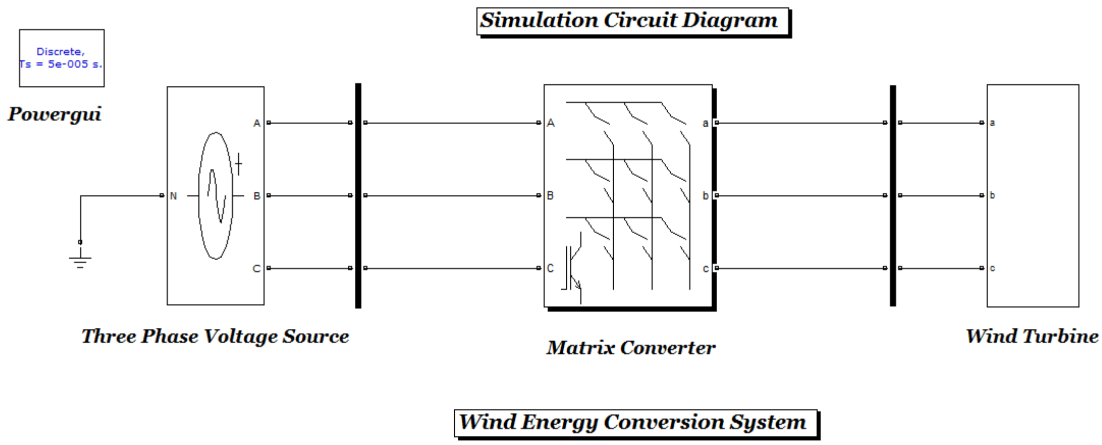

Fig.6 Main Simulation circuit diagram of Proposed Wind Energy Conversion System

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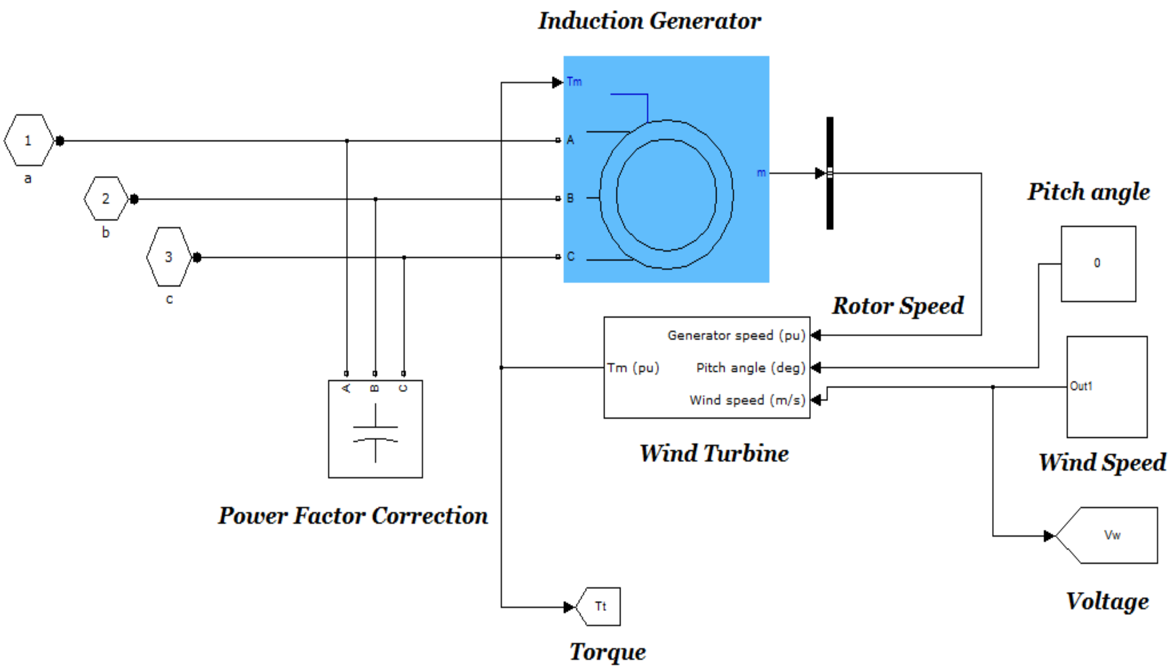

Fig.7 Simulation Circuit of Wind Turbine Model

Figure 7, It is the subsystem of Wind Energy conversion Systems, consists of Wind Turbine, Induction Generator and various inputs to wind turbine they are Pitch angle, wind speed, voltage

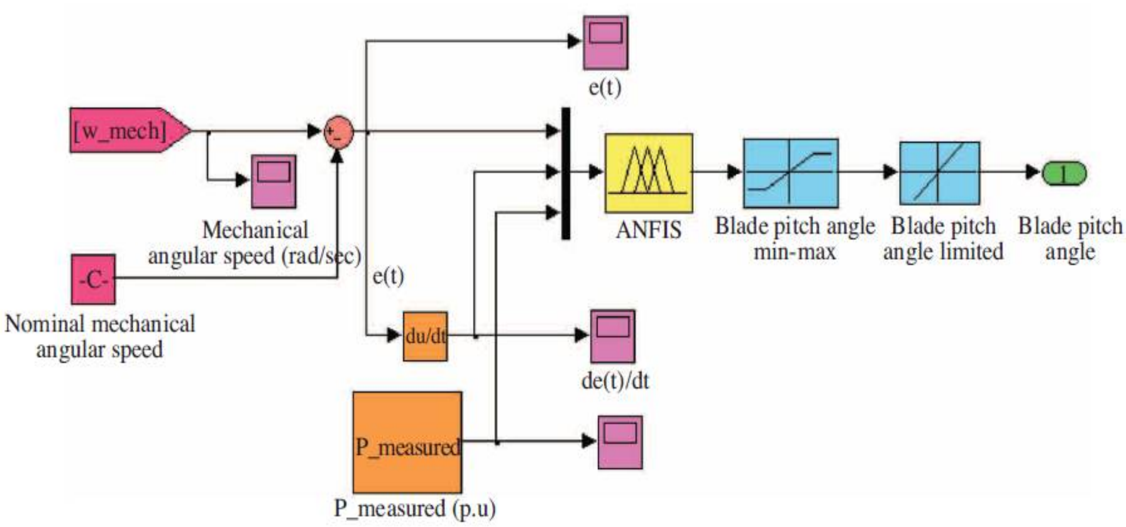

Fig.8 Simulation block diagram of controlling with ANFIS of blade pitch angle of Variable-Speed wind Turbine.

In Figure 8, the simulation block diagram of controlling blade pitch angle of VSWPGS with ANFIS is given.

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In Figure 9, the simulation waveforms in electrical output magnitudes of ANFIS controlled VSWPGS when it is loaded with 180 KW Consumer load.

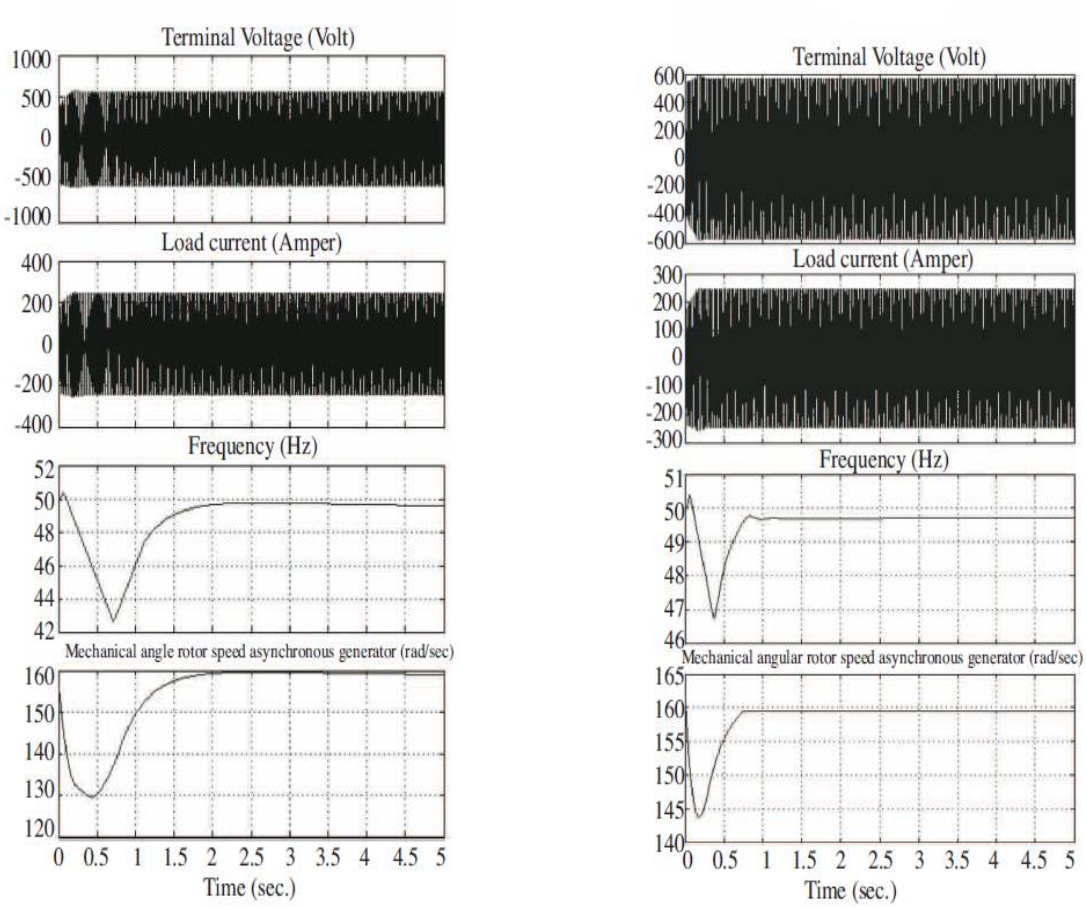

Fig.9 Changing curves in electrical output magnitudes of ANFIS controlled VSWPGS when it is loaded with 180 kW Consumer load

In Figure 10, Stochastic Wind Power is seen, Graph shows the variation of Wind Speed with Time

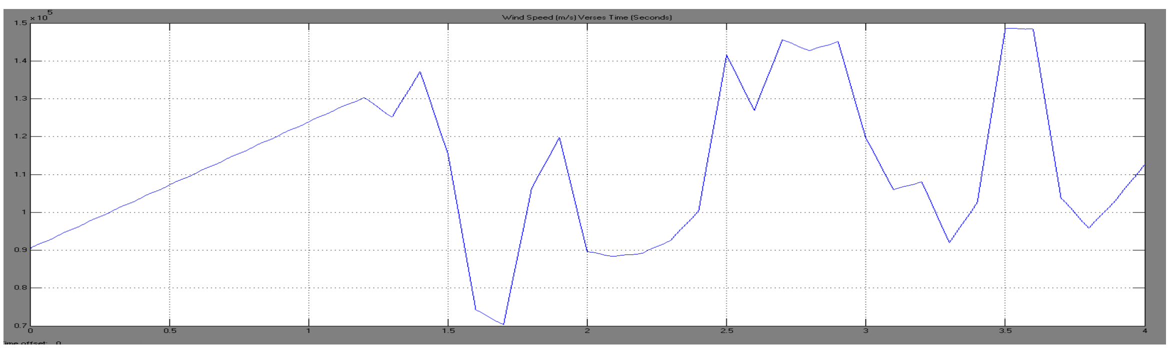

Fig.10 Variation of Wind Speed Vs Time

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VI. CONCLUSION

A unified Wind energy conversion system has been proposed as a way to create a more reliable, secure, efficient, safe, economic and environmentally friendly generation. This project compiles the information about analysing the performance of Variable Speed wind Generation system based on Neuro-Fuzzy approach. For Output Voltage control and frequency control and to obtain high quality of power of the Variable Speed Wind Power Generating System, Adaptive Neuro-Fuzzy Inference System is designed. Speed control of the variable speed wind turbine is performed by means of controlling of Turbine blade pitch angle. Simulation results confirmed the effectiveness of the proposed algorithm.

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BIOGRAPHY

Harika Rachamalla, received B. Tech degree in Electrical Engineering from kakatiya University, Warangal, Telangana, in 2014 and M. Tech degree in Power Electronics from SR Engineering College in 2016. Her current research interests include Power Electronic Converters, AC and DC Drives, Matrix Converters, Inverters, Wind Energy Conversion Systems.