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A Pitch Control Strategy of Wind Turbine by Using Fuzzy Logic Control System

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Abstract – This paper deals with the pitch angle control of wind turbines. Due to the non-linearity and complex dynamics of these wind energy systems becomes a tough job. To solve this purpose we propose a fuzzy logic control system. Major aim is to maximise the energy produced from the wind turbine irrespective of non-linearity of wind. A strategy of maximum power point tracking has been used from so long and the fuzzy logic intervention will make this control system more intelligent. Simulation results are shown and discussed with the Matlab/Simulink simulation software to validate the proposed control strategy. This control strategy has a good performance in terms of dynamic response and output.

Key Words: *Fuzzy logic controller (FLC), Pitch angle controller, THD (Total harmonic distortion), STATCOM (static synchronous compensator), Permanent magnet synchronous generator (PMSG), Insulated gate bipolar transistor (IGBT)*

1. INTRODUCTION

The use of coal for energy production has proven to be one Of the main contributors to climate change. Thermal plants Are a source of carbon dioxide emissions? Even today, these Sources of energy are widespread.
For example, in Spain only in 2016 coal produced 60% of all carbon dioxide emissions. This air pollution is estimated to cause more than 500,000 asthma attacks each year around the world [1]. Therefore, to slow climate change and achieve the
Paris Climate Goals [2], fossil-based energy sources must Be replaced by renewable energy such as wind, hydro and Solar.

The world constraint of fossil fuels reserves and additionally the ever growing environmental pollutants have driven powerfully throughout ultimate many years the occasion of renewable strength sources (RES). The necessity of getting obtainable property power systems for substitution bit through bit trendy ones demands the improvement of systems of power provide based on smooth and renewable resources. At present, solar electric photovoltaic (PV) era is ahead redoubled significance as a RES application because of distinctive blessings like simplicity of allocation, high responsibility, absence of gasoline value, low preservation and absence of noise and wear thanks to the absence of moving factors or practical's. Moreover, the alternative energy characterizes a clean, pollutants-loose and inexhaustible power supply. Additionally to those elements are the declining value and expenses of solar PV modules, associate degree increasing efficiency of sun cells, producing generation enhancements and economies of scale [3].

For the installation of wind energy MNRE scheme (The Ministry of New & Renewable energy) has introduced to aware more and more people about this technology, government also gives incentives in order to promote wind energy. Wind is air in motion; this is actually derived from solar energy. About 2% of total solar flux that reaches the earth's surface is transformed into wind energy due to uneven heating of atmosphere. This kinetic energy of wind is used to gain the rotational motion of wind turbine which is coupled with an electrical generator to supply over a region acting as stand-alone or supplying power to a grid. An actual WECS (Wind energy conversion system) be considered as follow [4]

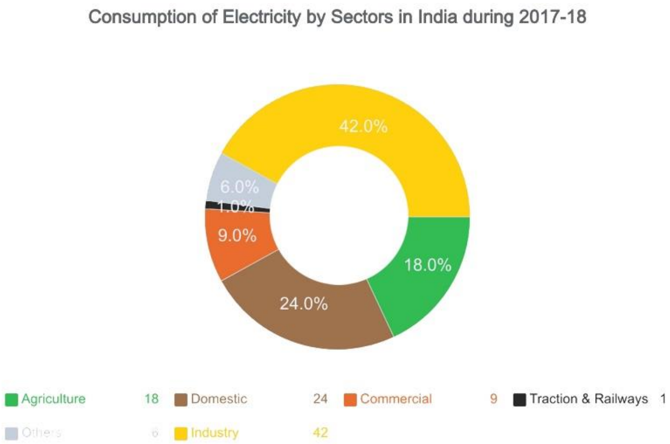

Fig -1: Electricity consumption pattern in India

As per the energy scenario we can see that according to the latest survey from the government of India. Electricity consumption pattern in various sectors like in agriculture it is 18%, domestic 24%, commercial 9%,Railways 1 % and in Industries it is very high approximately 42% of the total electricity generation.
In every developing country the electricity requirements will increase day by day and surveys conclude that the demand will raise up to several lakhs megawatts and for fulfilling the requirements that electricity needed in several upcoming years the option is to generate more and more electricity and will cause a great adverse effects on the environment.
So green energy schemes should be promoted and various researches are going on the field of wind energy as well as solar energy to generate power from this nonrenewable sources and to generate a better output for the supply to loads or grids.
Our work will focus on the pitch control of wind turbine as it requires a good control system for the better output and we propose a fuzzy logic control system with predefined inputs and outputs.

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2. Modelling of wind turbine

This block implements a variable pitch wind turbine. The performance coefficient Cp of the turbine is the mechanical output power of the turbine divided by wind power and a function of wind speed, rotational speed, pitch angle beta, Cp reaches its maximum value at 0 beta.

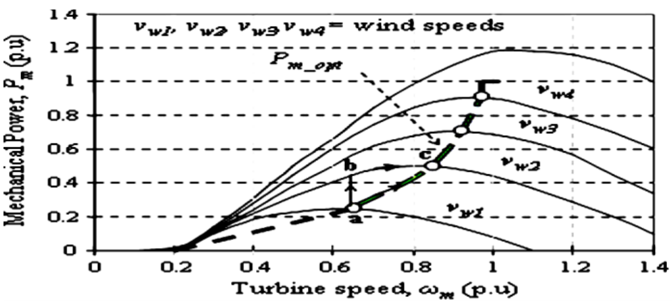

Fig -2: Mechanical power versus rotor speed with optimum power shown

The aerodynamic power of the wind turbine can be expressed as

$$P_r = 1/2\rho\pi R^2 Cp\,(\lambda)\, v^3 \qquad \ldots (1)$$

When the rotor is adjusted to maintain its optimum value the maximum power can be gained as

$$P_{rmax} = k_{opt}\omega^3 \qquad \ldots (2)$$

Where Kopt is decided by

$$K_{opt} = \rho\pi R^5 Cpmax^2 \lambda^3 opt \qquad \ldots (3)$$

$$T_{mopt} = K_{opt}\ (\omega_{opt})^2 \ldots\ldots\ldots\ldots\ldots (4)$$

It is observed from fig 2 that there is always matching rotor speed which produces optimum power for any wind. The function of controller is to keep turbine operating on this curve as the wind velocity varies. If the controller can properly follow the optimum curve, the wind turbine will produce maximum power at any speed with in allowable range.

The optimum torque can be calculated from optimum power from equation 3. For the generator speed below rated maximum speed the generator follows equation 3.If V_{dc} is maintained constant at its reference value and keeping the modulation index of load side inverter is 1.5.

The amplitude of output ac voltage can be controlled and maintained at rated voltage. The relation between dc voltage and output ac voltage of a three phase pulse width modulation inverter is given by

$$V_{LL1} = \frac{\sqrt{3}}{2\sqrt{2}}\, k\, V_{dc} \ \ldots\ldots (5)$$

3. Wind Energy Conversion System

In our work a wind energy conversion system is designed and connected to grid. In this modelling firstly a wind turbine has been designed and pitch control system is attached to the wind turbine. The whole system comprises of turbine, two mass drive train, inverter, converter, control system and grid. The research work is done on the pitch control system by using a fuzzy control system with predefined inputs and outputs to get the desired output.

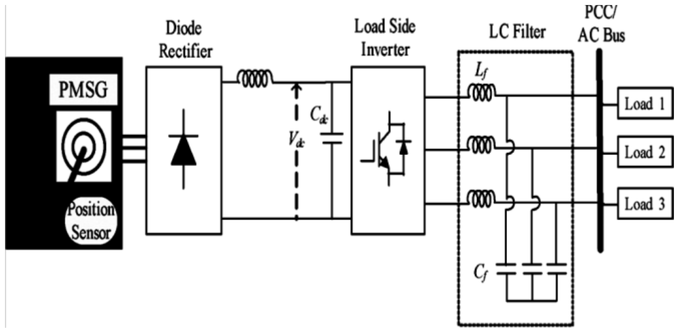

Fig -3: Wind Energy Conversion System

4. Two mass drive train

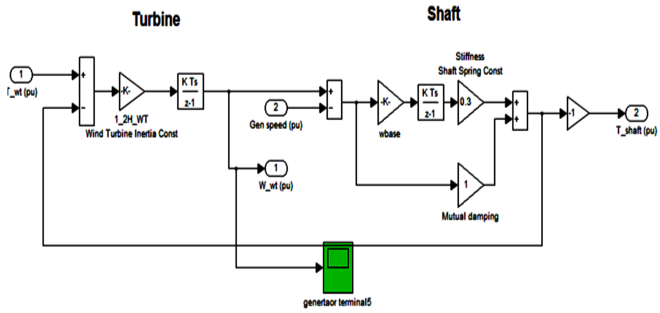

Fig -4: Wind turbine with two mass drive train

The effects on two mass drive train parameters on a variable speed wind turbine. The simulation results illustrates the capability of the described control system to control both active and reactive powers, hence can effectively stabilized itself during transient condition. It was reported that high wind turbine and generator inertia parameters of the two mass shaft model could lead to a longer time for variable speed wind turbine in recovery to its steady state after a network disturbance. It also came from the study that lower shaft stiffness parameters of the two mass shaft model could also delay the assumption of steady state of the variable speed wind turbine after the network disturbance. [5]

$$T_T - K_{sh}(\theta_T - \theta_G) - D_T\omega_T = J_T\frac{d\omega_T}{dt}$$

$$K_{sh}(\theta_T - \theta_G) - T_G - D_G\omega_G = J_G\frac{d\omega_G}{dt}$$

$$T_{sh} - K_{sh}(\theta_T - \theta_G)$$

Where T_T, T_G, T_{sh} are turbine , generator and shaft torques(N/m), ω_G is the generator angular speed (rad/sec), θ_T and θ_G are turbine and generator angular position (rad).

Here wind energy conversion system with two mass drive train model is shown. The difffrential equation governing its mechanical dynamics are presented as follows

$$2H_t \frac{d}{dt}\omega_t = T_m - T_{sh}$$

$$\frac{1}{\omega_{elb}} * \frac{d}{dt}\theta_{tw} = \omega_t - \omega_r$$

$$2H_g \frac{d}{dt}\omega_r = T_{sh} - T_g$$

Where H_t is the inertia constant of the turbine, H_g is the inertia constant of the PMSG , θ_{tw} is the shaft twist angle , ω_t is the angular speed of the wind turbine, ω_r is the rotor speed of the PMSG , ω_{elb} is the electrical base speed and the shaft torque T_{sh} is

$$T_{sh} = K_{sh}\theta_{tw} + D_t \frac{d}{dt}\theta_{tw}$$

Where K_{sh} is the shaft stiffness and D_t is the damping coefficient

5. Fuzzy Control System

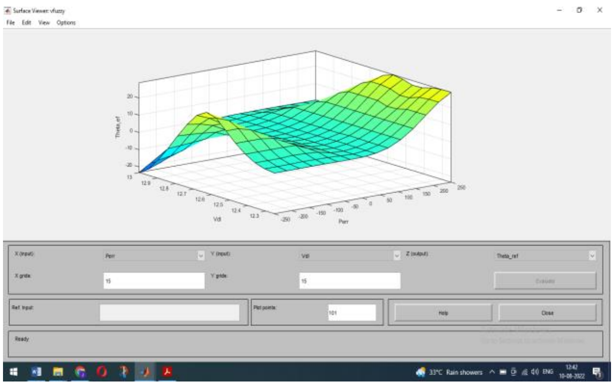

Fig -5: Surface View of control system

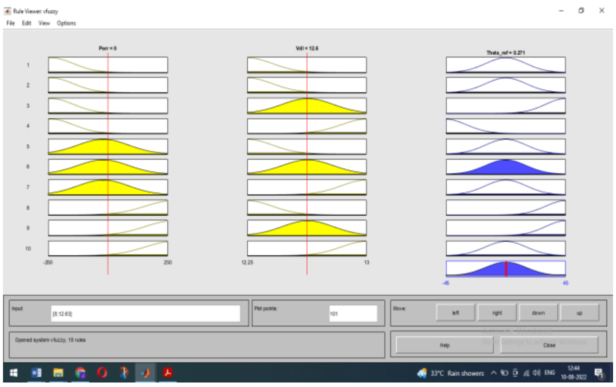

Fig -6: Rule View of control system

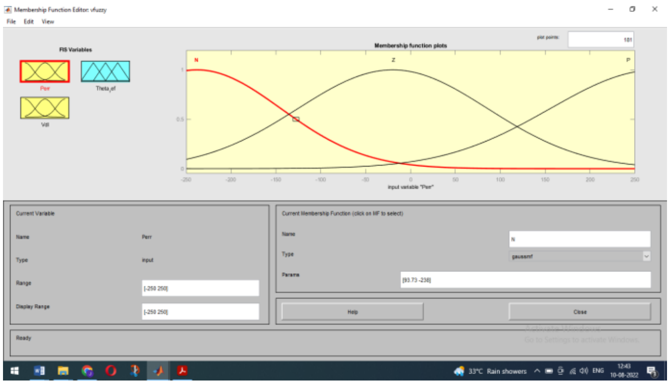

Fig -7: Input membership function 1

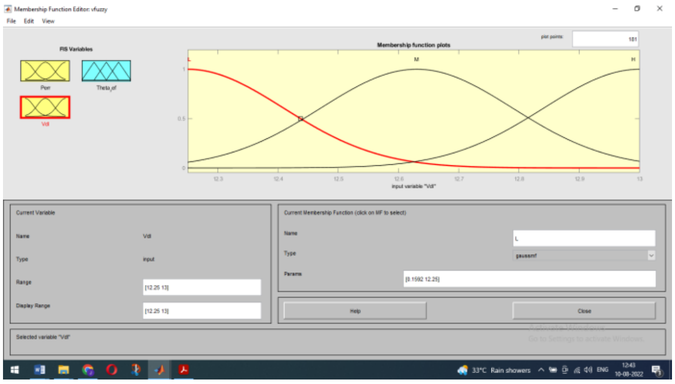

Fig -8: Input membership function 2

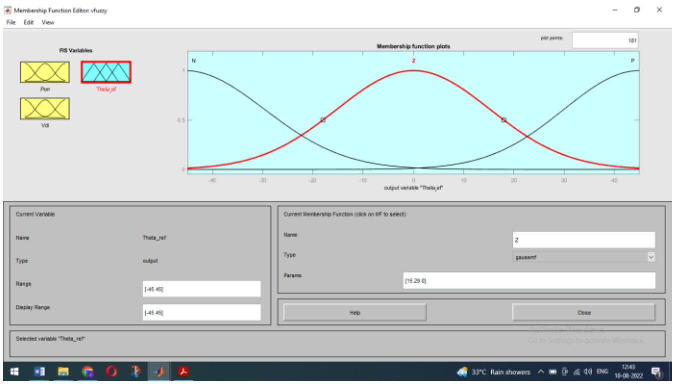

Fig -8: Output membership function Theta

Fuzzy logic is a powerful tool since it allows the control of the system whose parameters are unknown or incomplete and as a result difficult to model mathematically. Fuzzy logic control consist of three main stages: input, processing and output. At the input stage membership functions are used to fuzzify the input values. The now fuzzified input is fed into the processing stage where an inference mechanism applied the appropriate rule from the knowledge base to come up with a set of fuzzy outputs. This output is then defuzzified using an appropriate technique. [5]

The fuzzy controller is implemented by a Takagi–Sugeno Structure with two inputs, Perr and VDL, and one output, href. The input Perr is assigned 3 Gaussian fuzzy sets, Negative, Zero and Positive, uniformly distributed in the Range [- 250, 250] W, The speed VDL is defined by 3 uniformly distributed Gaussian fuzzy sets in the interval [12.25, 13] m/s, the width is 0.175. Its labels Are Low, Medium and High. The output is a singleton that can take 3 values: - $\pi/4$, 0, and $\pi/4$ (rad). The configuration of the fuzzy system has been obtained by trial and Error. Figure above shows the fuzzy sets of the inputs.[6]

- If P_{err} = Neg and V_{DL} = Low then out = 0
- If P_{err} = Neg and V_{DL} = Med then out = - $\pi/4$
- If P_{err} = Neg and V_{DL} = High then out = - $\pi/4$
- If P_{err} = Zero and V_{DL} = Low then out = Zero
- If P_{err} = Zero and V_{DL} = Med then out = Zero
- If P_{err} = Zero and V_{DL} = High then out = Zero
- If P_{err} = Pos and V_{DL} = Low then out = $\pi/4$
- If P_{err} = Pos and V_{DL} = Med then out = $\pi/4$
- If P_{err} = Pos and V_{DL} = High then out = Zero

6. Results

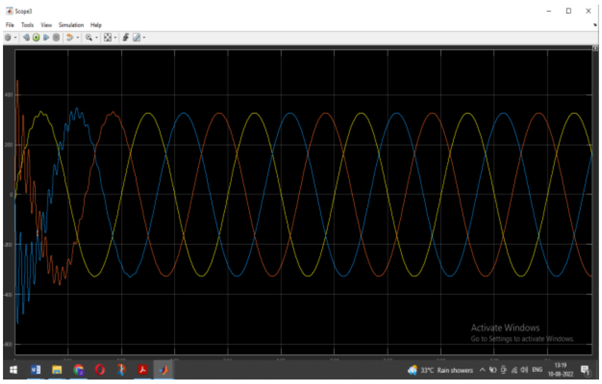

Fig -9: Output Three Phase Voltages

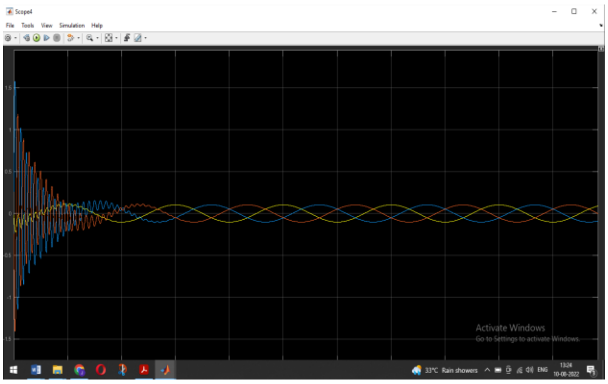

Fig -10: Output Three Phase Currents

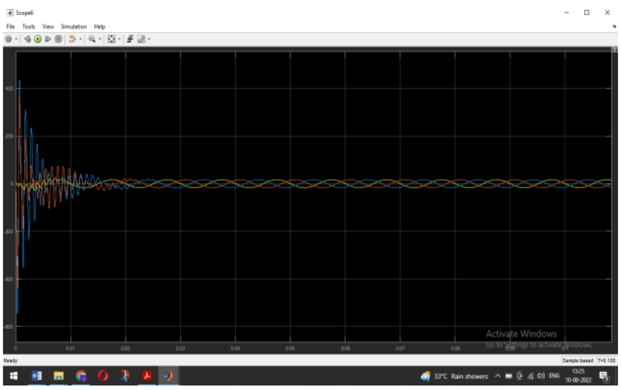

Fig -10: Output Three Phase Power

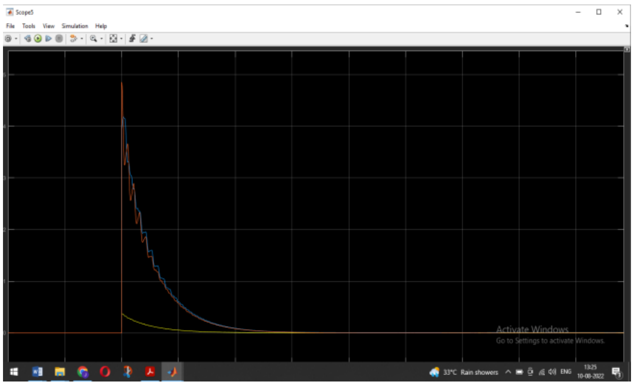

Fig -11: Total harmonic distortion

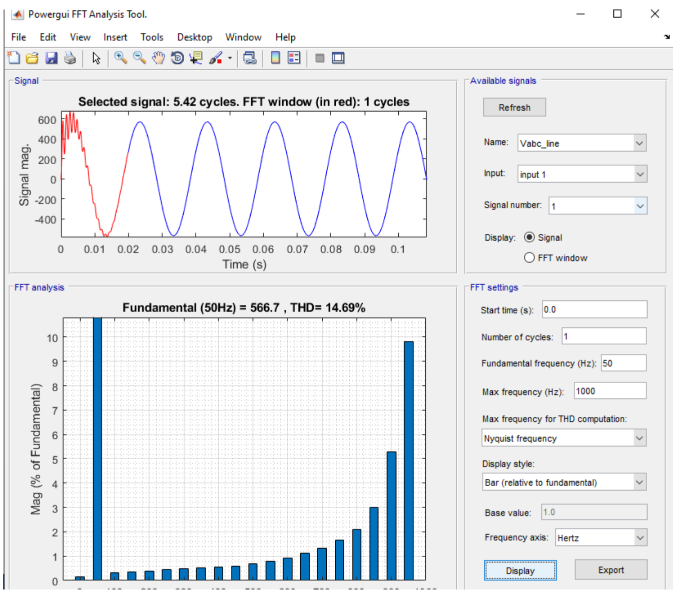

Fig -12: Voltage THD

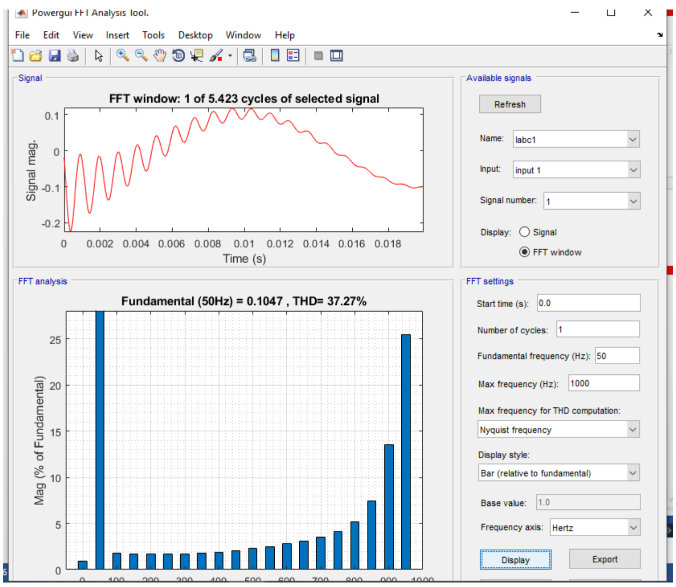

Fig -12: Current THD

7. CONCLUSIONS

A wind energy conversion system has been designed with the IGBT based inverter in which a research has been done in the pitch control strategy by using fuzzy logic control system. The simulation has been done in the Matlab Simulink software. The results obtained consists of three phase output voltage and current as well as total harmonic distortion analysis in the output voltage and current waveforms. Many researches has been done previously with different fuzzy systems we have done this research with takagi sugeno functions and observation comes that THD value of voltage waveform is near about 14 % and THD value of current waveforms is near about 37% which is less as compared with previous research and can be enhanced by modification's in control system and fuzzy logic system.

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