NEUTRAL NETWORKS BASED MAXIMUM POWER POINT TRACKING (MPPT) OF WIND POWER GENERATION

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***Abstract*: One of the momentous renewable sources is wind energy for generating the electric power throughout the world. The toughest task in wind system is to covert the wind energy to load or grid. Hence, power electronic advancements are required for conversion purpose, which contains grid and generator side converters. In this study, suggested the maximum power point tracking (MPPT) approach is implanted for regulating the generator side converter. Moreover, artificial neural network (ANN) method is used with hill climbing search MPPT algorithm for enhancing the speed and accuracy of the system. Likewise, in this work, sliding mode control (SMC) is presented for mitigating the speed at various circumstances, which is performs efficiently rather than other control approaches. The simulation results reveal the greatest performance with proposed control schemes in terms of speed control and accuracy.**

Index Terms: Wind energy, MPPT, SMC, ANN, Speed control, Accuracy.

I. INTRODUCTION

Nowadays, a lot of attention is directed towards renewable energy resources. The rapidly decreasing amount of fossil fuels along with the increasing global demand for energy makes it very important to exploit new energy resources. Environmental issues also have become serious enough to increase the importance of using renewable energy resources. Wind energy is one of the most important and developed renewable energy resources. Among different types of generators, Permanent Magnet Synchronous Generator (PMSG) is a perfect choice for using in Wind Energy Conversion Systems (WECSs). It has notable advantages such as high-power density, high efficiency, low maintenance, high reliability and elimination of slip rings. PMSGs with large number of poles are available and are suitable for direct drive systems [1]. In [2,3] Doubly Fed Induction Generator (DFIG) has been utilized in a WECS, which has some major drawbacks comparing to PMSG such as lower efficiency and reliability, existence of slip rings and the corresponding problems, and the need for gear box for connecting the generator to the wind turbine. In order to connect the PMSG to the load or the power grid, a power electronic interface, consisted of two stages of rectification and inversion is needed. For the rectification stage, there are mainly two configurations used in PMSG-based WCESs. The first one consists of an uncontrolled diode rectifier followed by a dc-dc converter [4], which has some major drawbacks.

Using diode rectifier will result in high Total Harmonic Distortion (THD) values for generator currents and high ripples in the torque waveform as well. It is also impossible to independently control d- and q-axis currents by this configuration. The second configuration uses a controllable rectifier and does not have the above-mentioned problems of the first configuration [5]. Vienna rectifier was first proposed in 1997 and used in power supply systems for communication applications [6]. This rectifier is a perfect choice for using in a WECS due to its numerous advantages over the other known topologies. Its input power factor is near to unity and has input currents with low harmonic distortion. This three-level converter has only three controllable switches with low voltage stress on them, which results in lower cost and simpler switching control. High efficiency is another advantage of this rectifier [7]. This converter is dead time free, which means it can operate in high frequencies and there is no dead time harmonics in the currents. Vienna rectifier is a unidirectional converter and this fact has limited its application in other industries like electric train systems. In WECSs, however, active power flows only from the generator side to the load, which makes Vienna rectifier a great choice. In [8], control algorithm based on fuzzy logic control (FLC) tracks the maximum power by controlling the WT rotor speed without estimating the effective wind speed. In WT control, several literatures reported either to estimate or to calculate the effective wind speed with WT control. In [9], the rotor speed and aerodynamic torque are estimated by the input and state-based estimation with the known pitch angle, the effective wind speed is calculated by the inversion of the static aerodynamic model. In [9-10], Kalman filter is used to estimate rotor speed and aerodynamic torque, and finally the effective wind speed is calculated using Newton Raphson. For the single mass model given in [6,7] and two mass model given in [11], nonlinear controllers such as nonlinear static state feedback with estimator and nonlinear dynamic state feedback with estimator (NDSFE) are used to control the WT at below rated wind speed.

For both the controllers, the wind speed is estimated using Newton Raphson. In [12], calculation of effective wind speed is achieved by the particle filter, and FLC is used to control the WT at below rated wind speed. In [10-12], the SMC based controllers are applied to the WT without estimating the effective wind speed. References [13-15] discussed higher order sliding mode control (HSMC) of WT at below and above rated speed and concluded that HSMC is more robust with respect to parameter uncertainty of the WT.

In this study, suggested the maximum power point tracking (MPPT) approach is implanted for regulating the generator side converter. Moreover, artificial neural network (ANN) method is used with hill climbing search MPPT algorithm for enhancing the speed and accuracy of the system. Likewise, in this work, sliding mode control (SMC) is presented for mitigating the speed at various circumstances,

λ = Tip Speed ratio
β=Pitch angle of the blade

$$\lambda = \frac{WR}{V\omega}$$

ω = Rotor angular speed in rad/sec
R = Rotor blade radius in meter

$$\frac{1}{\lambda_I} = \frac{1}{\lambda + 0.088\beta} - \frac{0.035}{\beta^3 + 1}$$

Pitch Angle controller will starts at when the wind speed reaches to its rated or above rated value. Up to cut in to rated speed it will maintain zero for Optimum power extraction from the wind.

PMSG Modeling:

The Permanent Magnet Synchronous Machine operates in either generator or motor mode. The mode of operation is dictated by the sign of the mechanical torque (positive for motor mode, negative for generator mode).The sinusoidal model assumes that the flux established by the permanent magnets in the stator is sinusoidal, which implies that the electromotive forces are sinusoidal.

Sinusoidal Model Electrical System:

These equations are expressed in the rotor reference frame (dq frame) which is performs efficiently rather than other control approaches. The simulation results reveal the greatest performance with proposed control schemes in terms of speed control and accuracy. Wind Turbine Modeling

Dynamic model of the wind turbine, involving the behavior of a wind turbine over its region of operation and the output power or torque of a wind turbine is determined by several factors like wind velocity, size and shape of the turbine, etc. Mechanical Power extracted by the rotor (P) is given by

$$P = \frac{1}{2} \rho . A . V_\omega^3 . C_P$$

ρ = Air density in kg/ m^3
A = Area swept by the rotor blades in m^2
V_ω = Wind Speed in m/sec
C_p = Coefficient of Power

$$C_P = 0.5 . \left(\frac{114}{\lambda_i} - 0.4 . \beta - 5\right) e^{-\frac{21}{\lambda_i}} + 0.0068 . \lambda$$

Theoretically Power coefficient maximum is 0.5 but in practical designs, the maximum achievable Cp is between 0.4 and 0.5 for high-speed, two-blade turbines and between 0.12 and 0.3 for slow-speed turbines with more blades.

$$\frac{d}{dt} i_d = \frac{1}{L_d} V_d - \frac{R}{L_d} i_d + \frac{L_q}{L_d} P \omega_r i_q$$

$$\frac{d}{dt} i_q = \frac{1}{L_q} V_q - \frac{R}{L_q} i_q + \frac{L_d}{L_q} P \omega_r i_d - \frac{\lambda P \omega_r}{L_q}$$

$$T_e = 1.5 . P[\lambda i_q + (L_d - L_q) i_d i_q]$$

II. ANN BASED MPPT ALGORITHM

The idea of ANNs is based on the belief that working of human brain by making the right connections can be imitated using silicon and wires as living neurons and dendrites. The human brain is composed of 86 billion nerve cells called neurons. They are connected to other thousand cells by Axons. Stimuli from external environment or inputs from sensory organs are accepted by dendrites. These inputs create electric impulses, which quickly travel through the neural network. A neuron can then send the message to other neuron to handle the issue or does not send it forwarded. ANNs are composed of multiple nodes, which imitate biological neurons of human brain. The neurons are connected by links and they interact with each other. The nodes can take input data and perform simple operations on the data. The result of these operations is passed to other neurons. The output at each node is called its activation or node value.

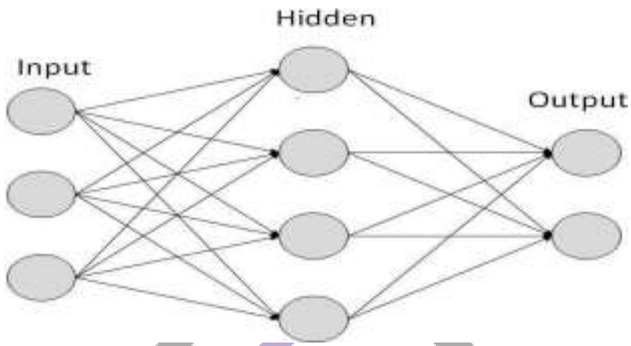

Fig.1 ANN model Representation

There are two Artificial Neural Network topologies –Feed Forward and Feedback. In this ANN, the information flow is unidirectional. A unit sends information to other unit from which it does not receive any information. There are no feedback loops. They are used in pattern generation/recognition/classification. They have fixed inputs and outputs. Here, feedback loops are allowed. They are used in content addressable memories. In the topology diagrams shown, each arrow represents a connection between two neurons and indicates the pathway for the flow of information. Each connection has a weight, an integer number that controls the signal between the two neurons. If the network generates a "good or desired" output, there is no need to adjust the weights. However, if the network generates a "poor or undesired" output or an error, then the system alters the weights in order to improve subsequent results. In this study, ANN based MPPT technique is penetrated for enhancing the system performance.

III. SLIDING MODE CONTROL (SMC)

In control systems, sliding mode control (SMC) is a nonlinear control method that alters the dynamics of a nonlinear system by application of a discontinuous control signal (or more rigorously, a set-valued control signal) that forces the system to "slide" along a cross-section of the system's normal behaviour. The state-feedback control law is not a continuous function of time. Instead, it can switch from one continuous structure to another based on the current position in the state space. Hence, sliding mode control is a variable structure control method. The multiple control structures are designed so that trajectories always move toward an adjacent region with a different control structure, and so the ultimate trajectory will not exist entirely within one control structure. Instead, it will slide along the boundaries of the control structures.

The motion of the system as it slides along these boundaries is called a sliding mode and the geometrical locus consisting of the boundaries is called the sliding (hyper)surface. In the context of modern control theory, any variable structure system, like a system under SMC, may be viewed as a special case of a hybrid dynamical system as the system both flows through a continuous state space but also moves through different discrete control modes.

IV. SIMULATION OUTCOMES

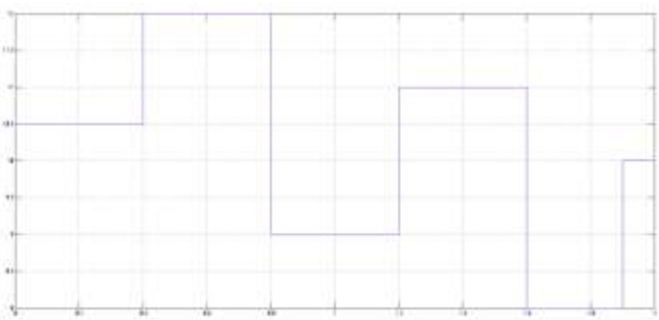

Fig. 2. Wind speed profile

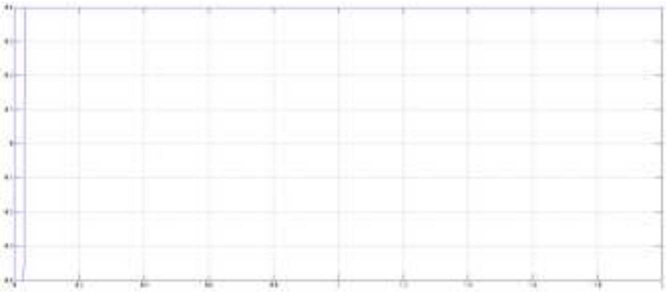

Fig. 3. Power coefficient (The maximum value is 0.48)

Fig. 4. Phase current (Vienna rectifier)

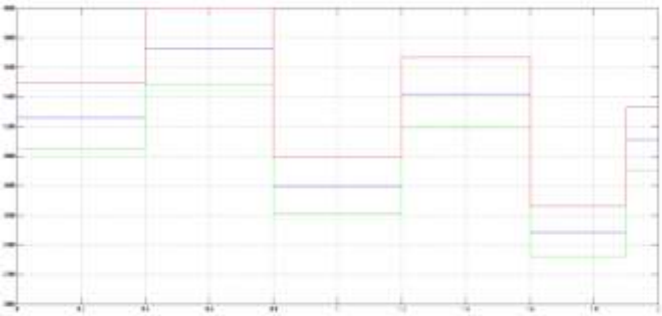

Fig. 5. Mechanical power and the output electrical power of the turbine

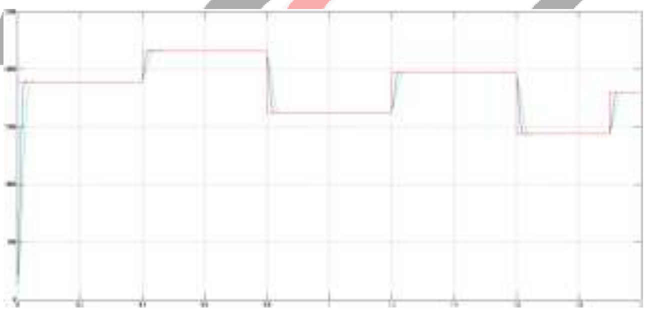

Fig. 6. Reference and real value of rotational speed

V. CONCLUSION

In this study, suggested the maximum power point tracking (MPPT) approach is implanted for regulating the generator side converter. Moreover, artificial neural network (ANN) method is used with hill climbing search MPPT algorithm for enhancing the speed and accuracy of the system. Likewise, in this work, sliding mode control (SMC) is presented for mitigating the speed at various circumstances, which is performs efficiently rather than other control approaches. The simulation results reveal the greatest performance with proposed control schemes in terms of speed control and accuracy. Furthermore, it has demonstrated the less voltage stress and voltage stress is very less as compared to other techniques.

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