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PERFORMANCE ANALYSIS ON PMSG BASED WIND GENERATION SYSTEM INTERFACED MULTILEVEL CONVERTER WITH ARTIFICIAL INTELLIGENCE TECHNIQUE

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Abstract- This paper focuses on the development of ANN based MPPT interfaced Permanent magnet synchronous generator (PMSG) for wind energy conversion system (WECS). There are many drawbacks to conventional energy sources, such as higher fossil fuel prices, damaging to the environment, a shortage of resources, and increased pollution. Due to the unpredictable and arbitrary nature of wind energy, it is crucial to introduce several control strategies in order to maximize its efficiency. In this work, Levenberg algorithms are developed for Artificial Intelligence Technique using MPPT algorithms for PMSG-based wind energy conversion systems. The proposed system consists of 3 kW PMSG integrated WECS, DC to DC boost converter, multilevel inverter and different loads. The DC to DC converter is connected to the multilevel inverter through a DC link capacitor. The inverter power is fed to the grid through a step-down transformer. MPPT controllers are used in the standalone wind energy conversion system. The goal of this research is to develop an MPPT controller using Levenberg-based Artificial Intelligence Technique for wind energy conversion systems. With the proposed Levenberg-based Artificial Intelligence Technique, MPPT uses voltage and current as input variables for DC to DC boost converter duty ratios. The Artificial Intelligence Technique of MPPT controller for standalone wind energy conversion systems with various different input/output conditions is modeled and simulated in MATLAB/ Simulink environment. The performance of the Artificial Intelligence Technique-based MPPT controller versus the conventional incremental conductance MPPT controller. Simulation results show that for a wide range of input wind speed, Artificial Intelligence Technique based MPPT controller shows improved performance than the conventional MPPT at various operating conditions. The response of the developed Levenberg based Artificial Intelligence Technique based MPPT algorithms for PMSG based wind energy conversion system in MATLAB/ Simulink environment to investigate the robustness of the developed control strategy and validate the reliability and stability under different input/output conditions for grid connected wind generation system.
Keywords: ANN, MPPT, P&O, MLI, DC to DC boost converter.

1. INTRODUCTION

The Renewable energy sources (RES) have now been relied upon more regularly. It has provided us the other option for clean energy generation compared to conventional sources. Among renewable sources of energy wind are becoming popular these days due to current scenario of increasing concerns about depletion of fossil fuel reserves, global warming, greenhouse gases and increasing environmental pollution. The advantage of the AI-based model is the fast-Maximum Power Point (MPP) approximation according to the parameters of the wind system. The Artificial Neural Network (ANN) is the component of AI. The advantage of ANN based algorithm is this is that there is no need to solve the complex mathematical relation between output power. The proposed ANN based MPPT system can search the MPP quickly and exactly in accordance with the change in environmental conditions. With neural networks, any continuous nonlinear function can be approximated by a multilayer neural network with one or more hidden layers. Neural networks have a parallel design and a simple structure which is composed of many processing elements. In addition, ANN generalize the learning experience and even provide predictions for the knowledge never experienced before, thus shortening the online learning time and improving the learning efficiency. The main objective is to achieve fast and stable response for the real power, controlled by an ANN based controller. The solar system uses ANN based technique to achieve effective maximum power point tracking. In this paper developed ANN based MPPT controller are most efficient technique compared to conventional methods. It achieves maximum power with more stability, precision and better performance with good dynamic response under variable wind speed conditions.

2. DYNAMIC MODELING OF WIND TURBINE MODEL

This section described the modeling and the control principles of the wind turbine and wind turbine characteristics. The power P_{wind} (in watts) extracted from the wind is given as:

$$P_{wind} = \frac{1}{2}\rho A v^3 C_p(\lambda, \theta) \quad (2.1)$$

Where ρ is the air density in kg/m^3, A is the area swept by the rotor blades in m^2, v is the wind velocity in m/s. C_p is called the power coefficient or the rotor efficiency and is function of tip speed ratio (TSR) and pitch angle (θ). The power accessible in the air which is changed into mechanical energy through wind turbine is mathematically given as

$$P = \frac{1}{2}\rho A v_w^3 \quad (2.2)$$

The effectiveness of wind energy conversion system is virtually 60 %. It preserve be analyzed at the same time as a part of kinetic energy is delivered to the rotating part and the respite of energy is wasted. The total energy changed can be scientifically interrelated to power coefficient (Cp). The power coefficient Cp is the ratio of total power changed into mechanical energy to the total power received by the wind turbine. This is shown as mathematically below

$$C_p = \frac{P_{total}}{1/2\rho A v_w^3} \quad (2.3)$$

Where P_{total} is the total power received by the wind turbine as of wind at connection. It is the maximum value of the power coefficient in wind energy conversion system. Again the power coefficient is a function of many further components such as blade arrangement, rotor blades and setting etc. hence optimized Cp is obtained by precision and accurate pact of these factors. Numerous different report of power coefficient has been worn. The accurate mathematical method for power coefficient is given as

$$C_p(\lambda,\beta) = 0.5\left(116\frac{1}{\lambda_1} - 0.4\beta - 5\right)e^{-\left(\frac{21}{\lambda_1}\right)} \quad (2.4)$$

$$\frac{1}{\lambda_1} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{1+\beta^3} \quad (2.5)$$

In this model, the value of the pitch angle of the wind turbine is assumed as zero. The attribute of power coefficient is a role of tip speed ratio, thrust force and the rotor torque obligatory by rotor blades.

The $Cp{-}\lambda$ characteristic shows the rotor presentation irrespective of rotor dimension and position parameters.

The maximum rotor efficiency C_p is achieved at a particular TSR, which is specific to the aerodynamic design of a given turbine. Groups of C_p–curves with pitch angle as the parameter obtained by measurement or by computation can be represented as a nonlinear function. The following function is used.

$$C_p = C_1(C_2 - C_3\theta - C_4)\exp(-C_5) \quad (2.6)$$

where θ is the pitch angle.

Proper adjustment of the coefficients C_1– C_5 would result in a close simulation of a specific turbine under consideration. The values for C_1– C_5 used in this study are listed in Table 2.1. The $C_{p\text{-}\lambda}$ characteristic curves at different pitch angles are plotted in Fig. 2.1, we can observe that when pitch angle is equal to 2 degrees, the tip speed ratio has a wide range and a maximum C_p value of 0.35, suitable for wind turbines designed to operate over a wide range of wind speeds. With an increase in the pitch angle, the range of TSR and the maximum value of power coefficient decrease considerably.

Table-2.1: Parameter Values for C_1 – C_5

C_1	0.5
C_2	116/k□
C_3	0.4
C_4	5
C_5	21/ K□

kθ in Table 2.1 used to calculate C_2 and C_5 is determined by λ and θ:

$$k_\theta = \left[\frac{1}{\lambda + 0.08\theta} - \frac{0.035}{\theta^3 + 1}\right]^{-1} \quad (2.7)$$

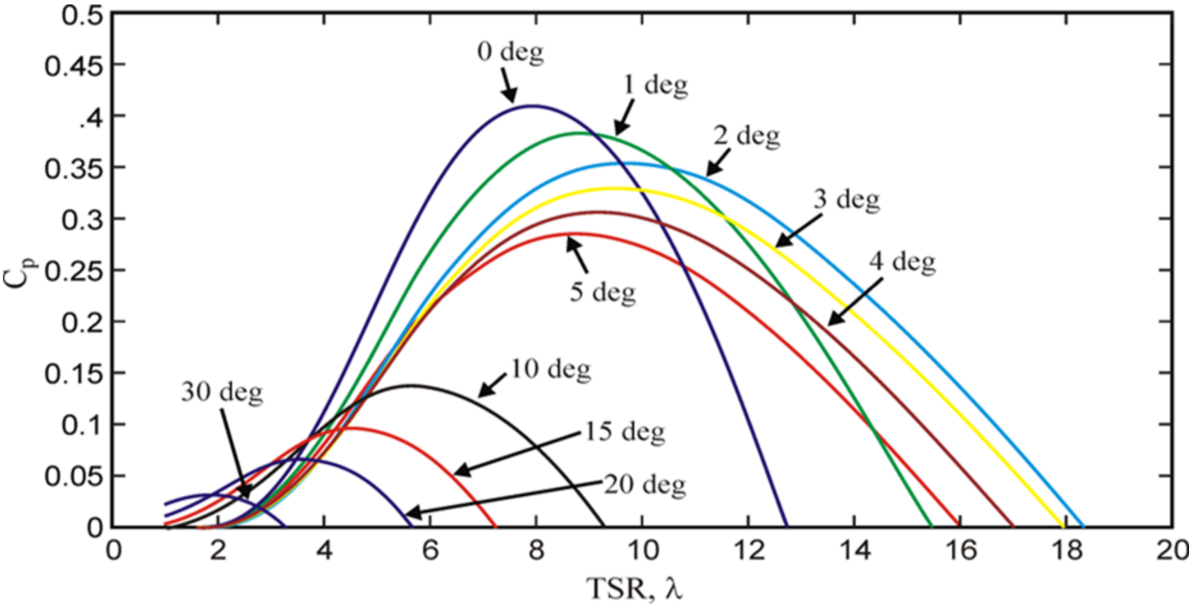


Fig. 2.1 C_p-λ Characteristics at Different Pitch Angles (θ)

From Fig. 2.1, it is plain that power coefficient increases with augment in tip speed ratio. Except when tip speed ratio increases further afar the optimized value, power coefficient starts to cry off at same slope. Hence there is only one optimized point where power extraction is maximum.

3. ARTIFICIAL NEURAL NETWORKS (ANN) IMPLEMENTATION

Artificial Neural Networks (ANN) are massively parallel interconnected networks of simple organisations (processing elements) which are intended to interact with the objects of real work in the same way as the biological neural system do.

These parallel distributed models are potentially capable of performing non-linear modeling and adaptation without any assumptions about the model. In very broad terms, the ANN may be defined as an attempt to capture the human brains capabilities for solving complex problem.

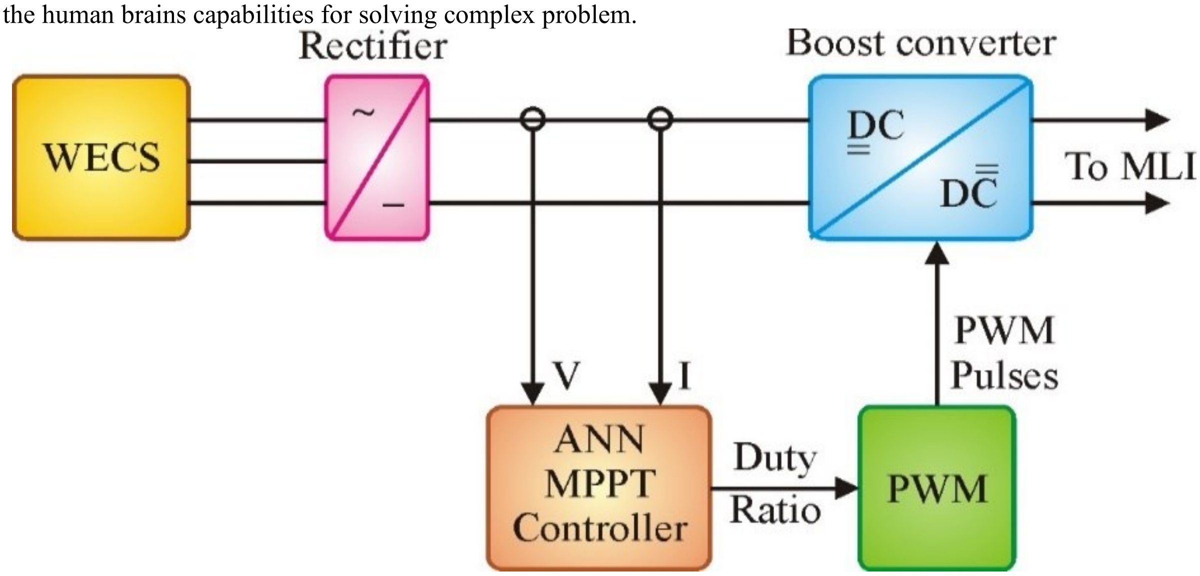


Fig. 3.1 Block Diagram of ANN MPPT Controller

The ANN consists of several artificial neurons that are connected through variable weights connections. Basic Architecture of the ANN consists of three layers as an input layer, hidden layer and output layer. The neural network for a wind system consists of two input variables; voltage and current. Hidden layer consists of 15 neurons.

Levenberg-Marquardt algorithm is used for the training of the neural network for the MPPTs. Block Diagram of MPPT controller scheme is shown in Fig. 3.1 and Fig. 3.2 shows the architecture of the Levenberg-Marquardt ANN.

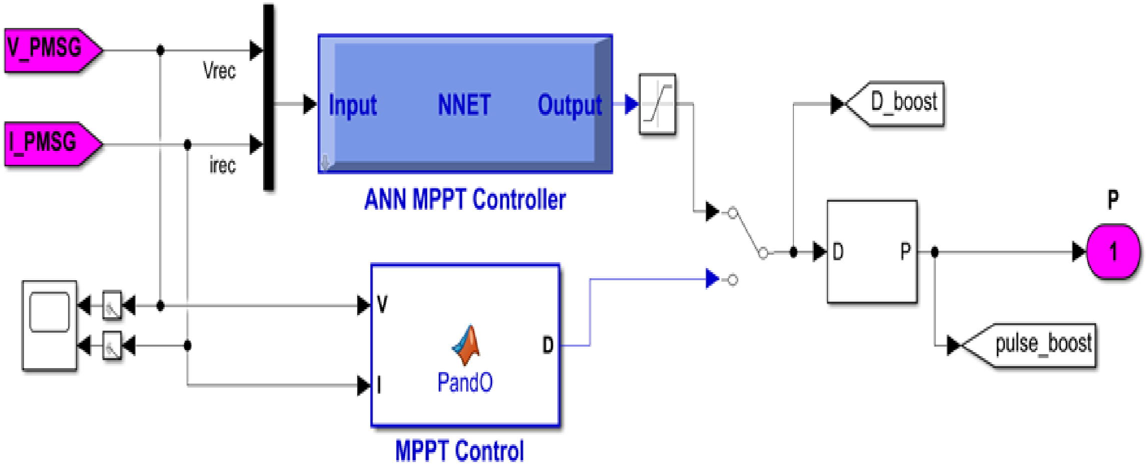


Fig. 3.2 Simulink block diagram of ANN based MPPT for Wind System

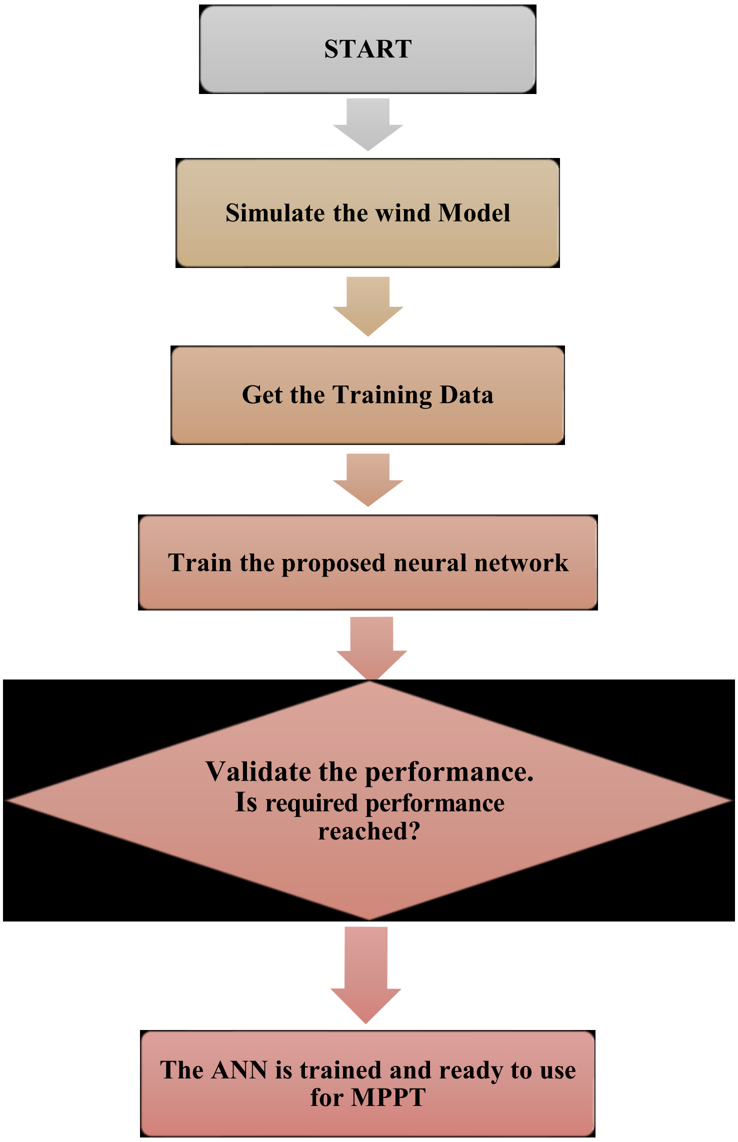


Fig. 3.3 Flow chart for Training Procedure of ANN based MPPT for Wind System

To extract the maximum power from wind system, artificial neural network based MPPT is proposed. The basic architecture of ANN consists of three layers as an input layer, hidden layer and output layer. The basic architecture of ANN is shown in Fig. 3.3.

ANNs are used in MPPT system as it can provide accurate and fast response for different input and output conditions.

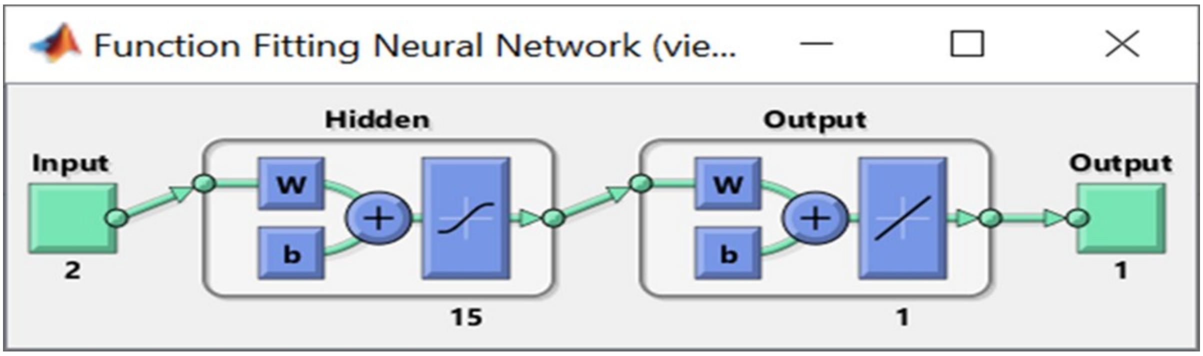


Fig. 3.4 Architecture of ANN

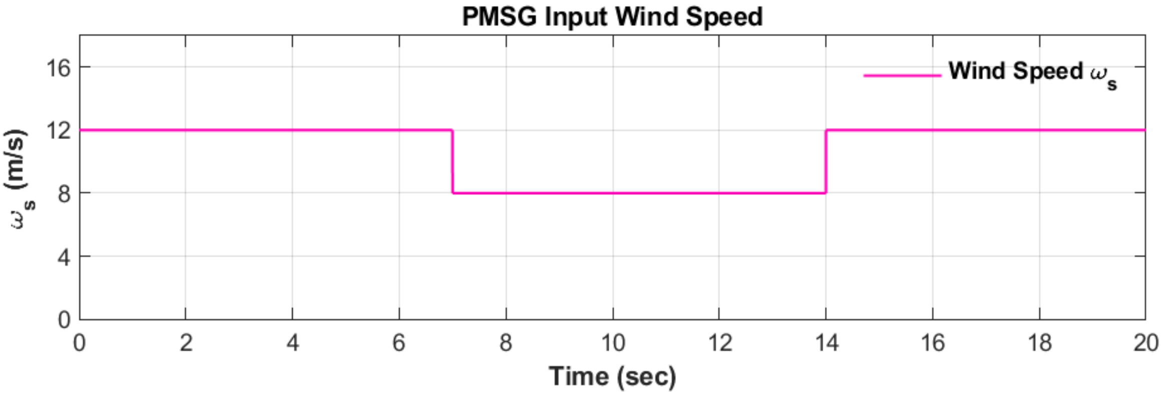
4. SIMULINK MODEL OF WECS BASED ON ARTIFICIAL INTELLIGENCE TECHNIQUE

The configuration shows that various components are presented in MATLAB/Simulink software which has Simulink blocks and their required interfacing circuitry used for better power generation from ANN based MPPT system. This system consists of renewable energy sources which generate continuous power and this power is converted in DC through bridge rectifier. Multilevel inverter is used to convert DC to AC power. Fig.4.1 shows the block diagram of ANN based MPPT Controller Wind Energy Conversion System.

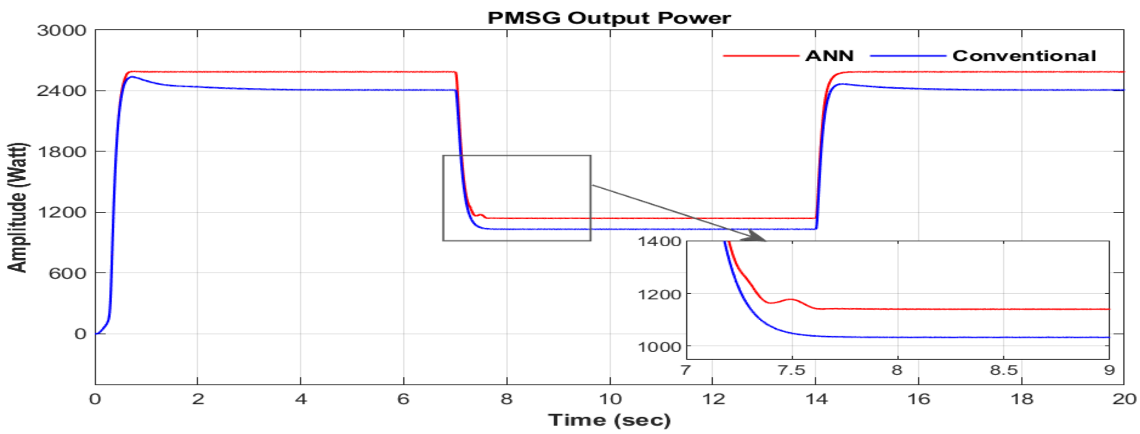
4.1 Comparative Simulation Results of ANN and P&O MPPT Algorithm during Step Change in Wind Speed from 12-8-12m/s

In this case step changes in wind speed from 12m/s to 8m/s and 8m/s to 12m/s for and load remains kept constant for both the MPPT algorithms. The comparative simulation results of the proposed system with conventional MPPT algorithms are shown in Fig. 4.1 to Fig. 4.3.

Fig. 4.1 (a) and (b) shows, the waveform of input wind speed and PMSG output power, respectively. In fig. 4.1 (b), zoomed axes are taken between time period of t=7 to t=9 sec. At the time t=7 sec wind speed changes from 12m/s to 8m/s. Where can be observed that the PMSG output power by ANN MPPT is changing from 2.6KW to 1.2KW and 2.4KW to 1.1KW by the conventional P&O MPPT algorithm.



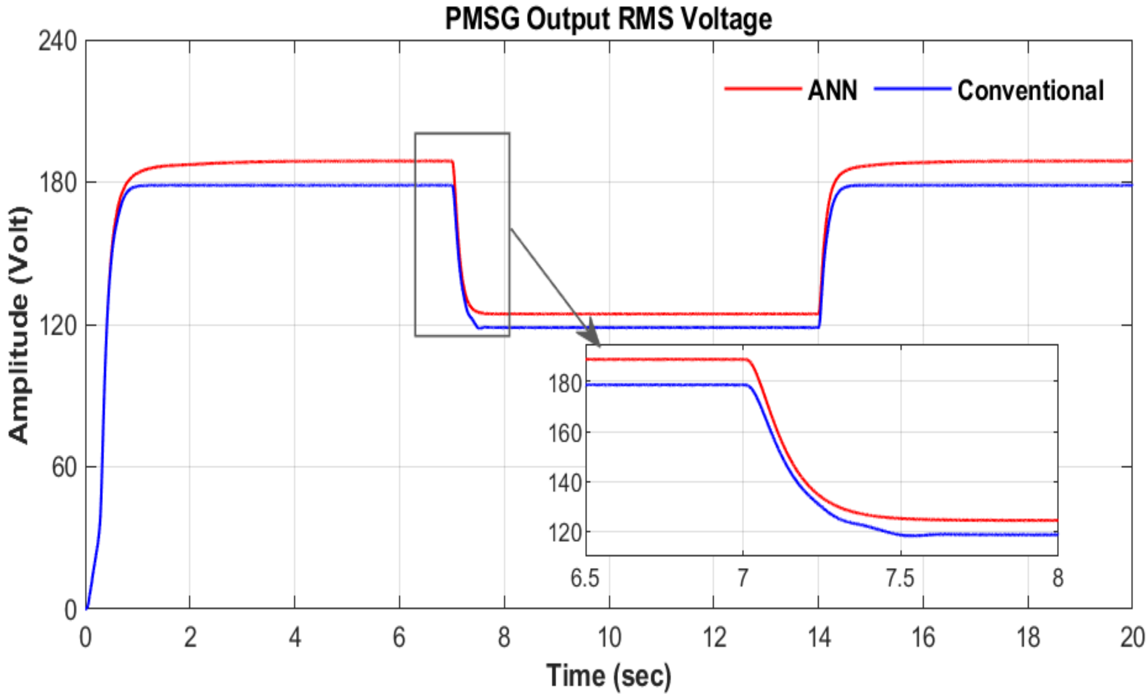
(a)



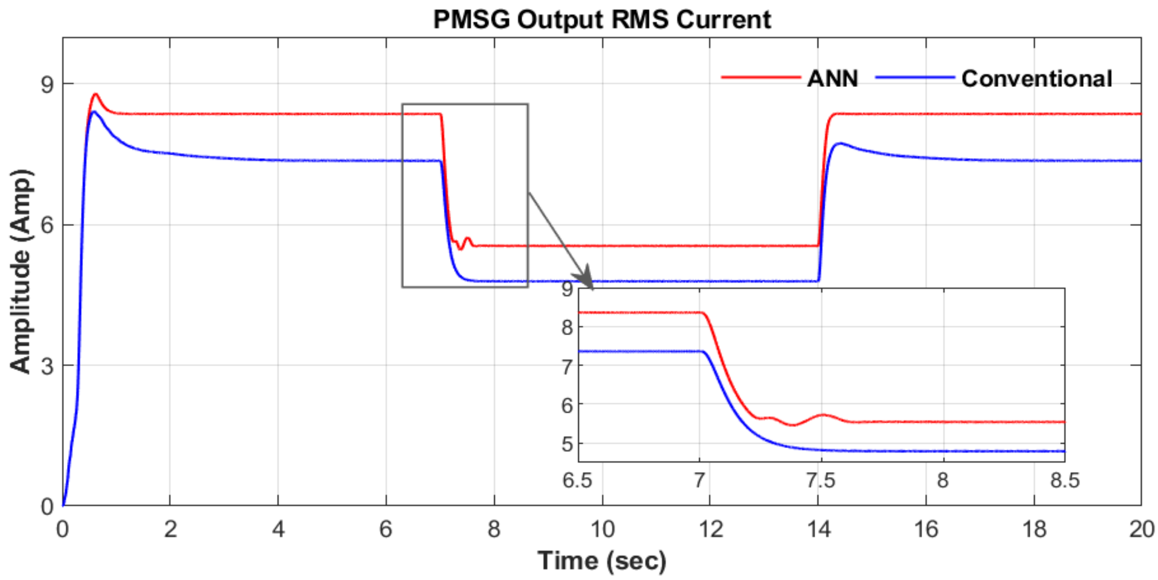
(b)

Fig. 4.1 Comparative Simulation Results of ANN and P&O MPPT Algorithm during Step Change in Wind Speed from 12-8-12m/s, Waveform of (a) Wind Speed (b) PMSG Output Power

Fig. 4.2 (a) and (b) shows, waveform of PMSG output RMS voltage and RMS current, respectively. In fig. 4.2 (a) and (b), zoomed axes are taken between time period of t=6.5 to t=8 sec where, can be observe that the response by ANN MPPT algorithm is more efficient and reliable in compare with conventional MPPT algorithm.



(a)



(b)

Fig. 4.2 Comparative Simulation Results of ANN and P&O MPPT Algorithm during Step Change in Wind Speed from 12-8-12m/s, Waveform of PMSG (a) RMS Voltage (b) RMS Current

The comparative results of duty ratio generated by ANN MPPT and conventional P&O MPPT algorithm is shown in fig. 4.3. In fig. 4.3, there are three zoomed axes are taken i.e., axes-I axes-II and axes-III. Axes-I is taken between time period of t=0 to t=3.5 sec where can be observed that at the starting of simulation, duty ratio generated by conventional MPPT takes more time to stabilize whereas ANN MPPT algorithm takes small time to generate duty ratio to achieve MPPT. Between time period t=0 to t=7 sec duty ratio generated by ANN MPPT algorithm is 75% and 10% by P&O MPPT algorithm for wind speed of 12m/s. Also, to achieve 75% of duty ratio at wind speed of 12m/s ANN takes less time about 1 sec whereas conventional MPPT algorithm takes more time about 3.5 sec to achieve 10% of duty ratio at wind speed of 12m/s. Axes-II and axes-III are taken between time period of t=7 to t=10 sec and time period of t=14 to t=16 sec, respectively where can be observed that the response of ANN MPPT algorithm is more efficient in compare with P&O MPPT algorithm for generating duty ratio to achieve MPPT.

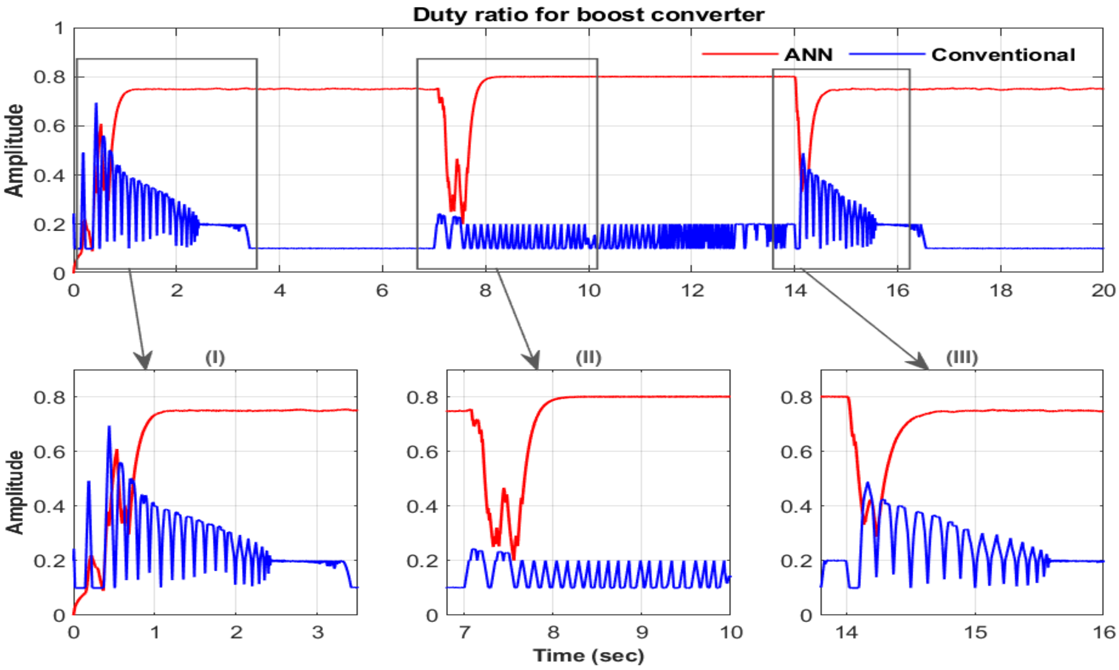


Fig. 4.3 Comparative Simulation Results of ANN and P&O MPPT Algorithm during Step Change in Wind Speed from 12-8-12m/s, Waveform of Boost Converter Duty Ratio

It is clearly observed that at every instant of wind speed the PMSG output power generated by ANN MPPT algorithm is greater in compare with PMSG power generated by conventional P&O MPPT algorithm. As we can say, by the implementation of ANN MPPT algorithm, it is more efficient and reliable for the wind energy conversion system in compare with conventional P&O MPPT algorithm.

4.2 Performance Evaluation of ANN Training Data for WECS

The comparative results of error histogram with 20 bins, performance, regression and training set and developed Levenberg based Artificial Intelligence Technique based MPPT algorithms for PMSG based wind energy conversion system. From comparative results, it can be seen and verified that developed system gives better results.

According to Fig. 4.4, the regression, R = 1, corresponds to the most accurate prediction of output based on input information. Furthermore, it correlates the output voltage of the PMSG based WECS with its target voltage. To calculate an error, subtract the output from the target. As shown in Figure 4.4, the Levenberg-Marquardt algorithm is used to train the data with negligible error, resulting in an output value that follows the target value perfectly.

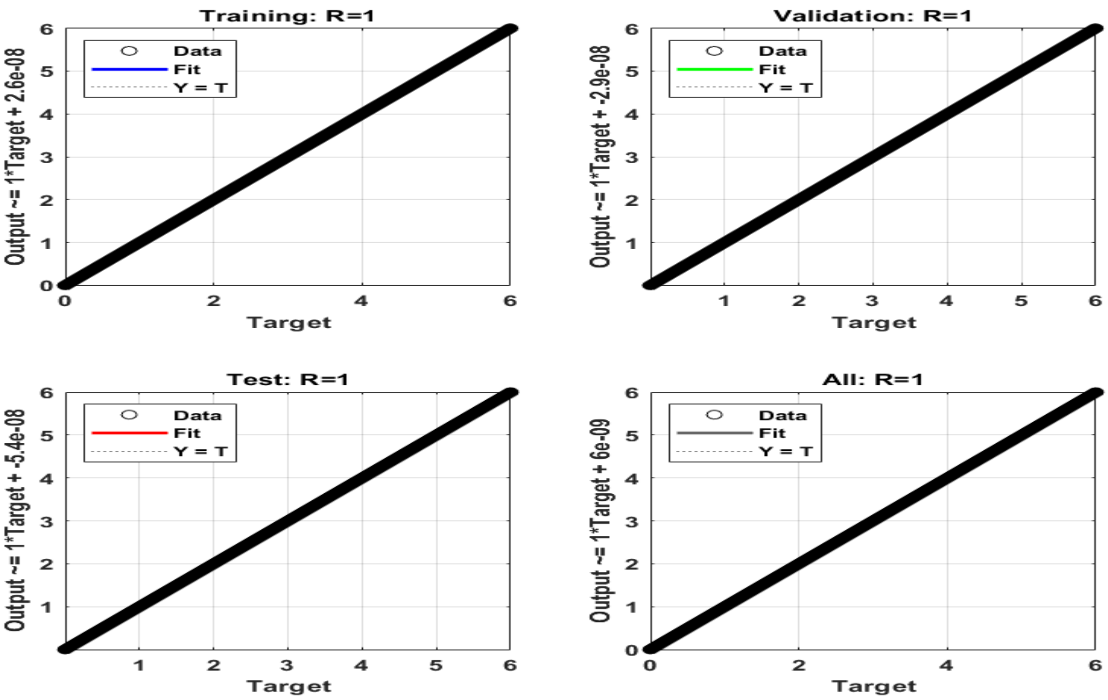


Fig. 4.4 Regression Plot of the ANN Model

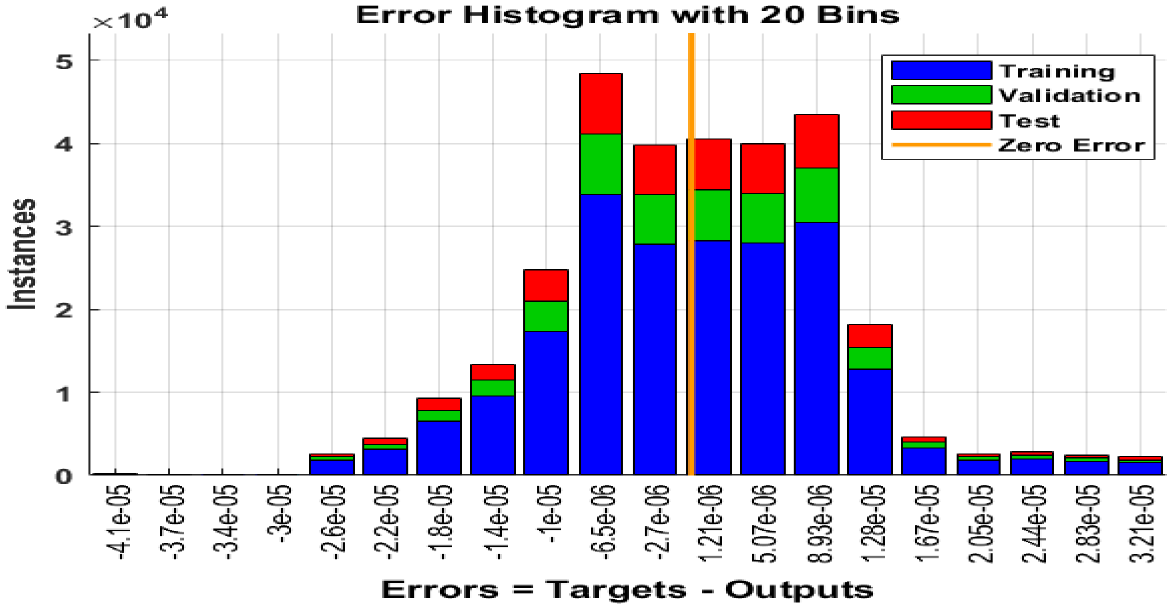


Fig. 4.5 Error Histogram Plot of ANN Training data for PMSG based WECS

Additionally, Fig 4.5 shows that the ANN algorithm provides zero error in the training, validation, and test phases. Based on the error histogram in Fig 4.5, the leftmost bin shows a total error of –4.1e-05, while the rightmost bin shows a total error of 3.21e-05.

The bins represent the number of vertical bars in the error histogram. Each vertical bar represents the number of samples within a particular bin from the selected dataset. Each bin is divided into 20 smaller bins with a bin width of 0.0000147. Based on the validation dataset, the middle bin has an error of 1.21e-06 for 150 samples. The error histogram converges to zero after 20 bins, which indicates that ANNs are applicable to MPPTs.

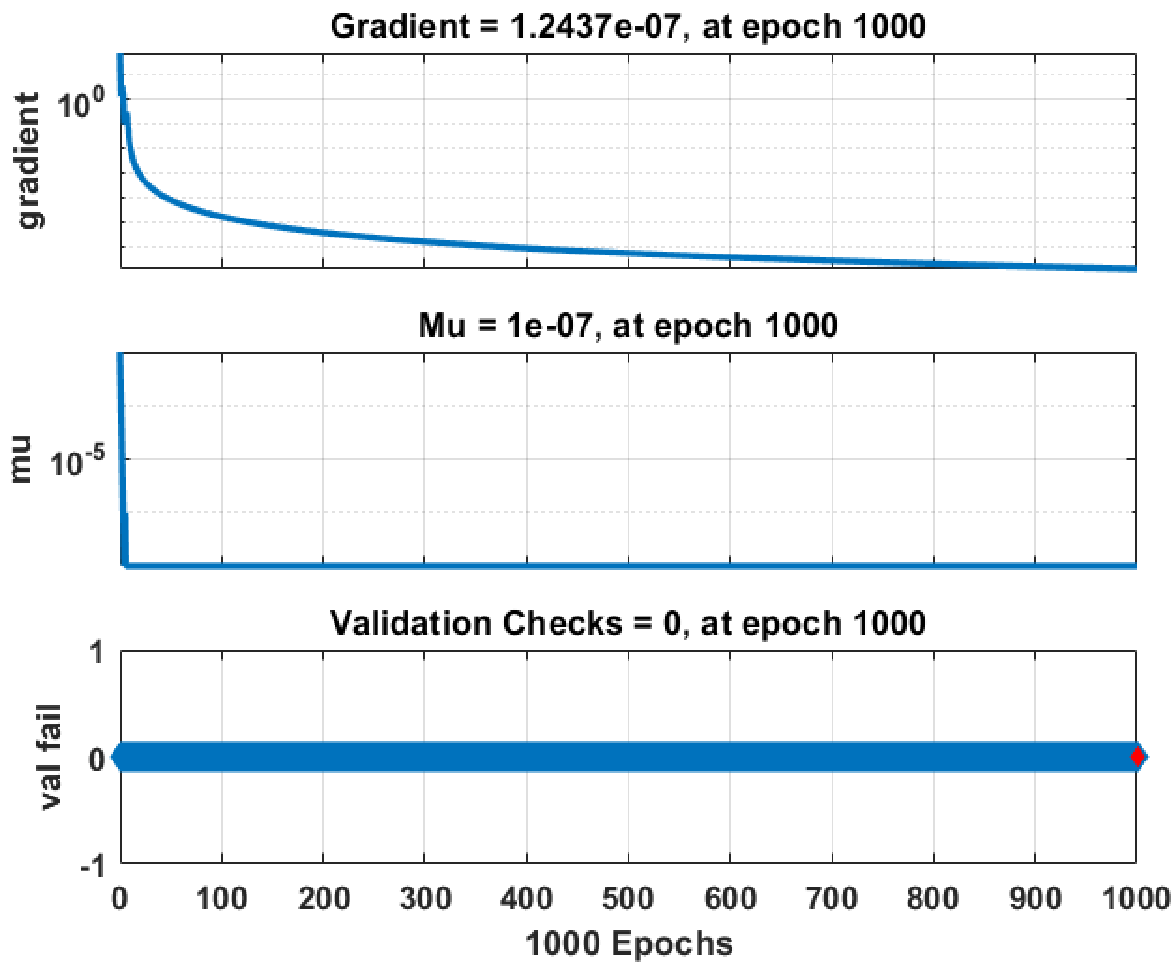


Fig. 4.6 Training State Plot of ANN MPPT

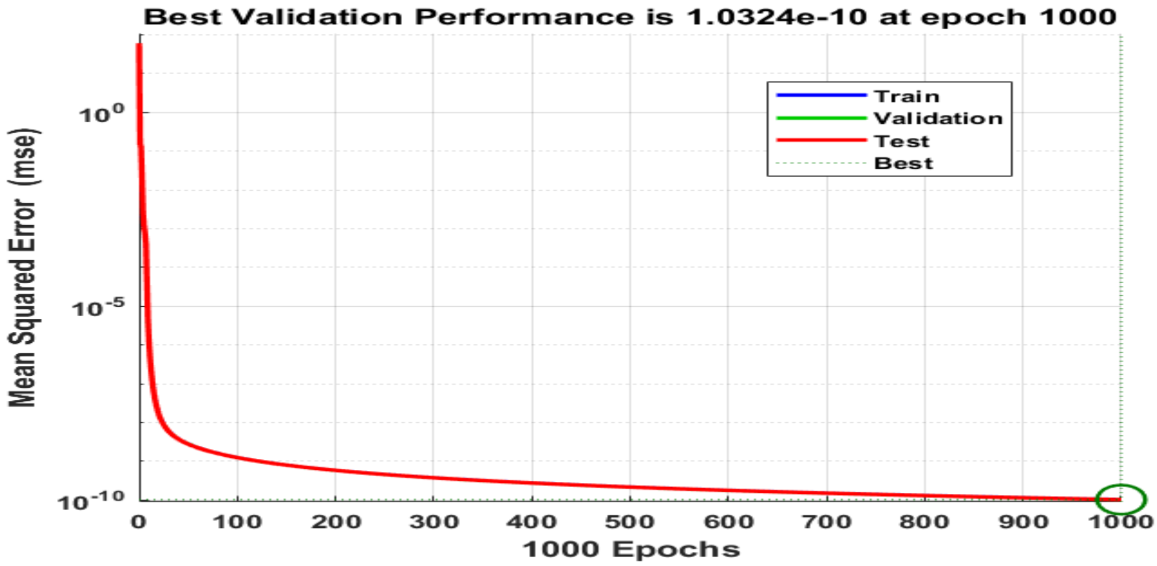


Fig. 4.7 Performance Test of ANN Algorithm

Fig. 4.6 and 4.7 illustrate the training state and performance phase of ANN for handling the selected dataset. The gradient, momentum parameter (Mu) and validation check of the trained dataset are shown in Fig 4.6. The simulation shows that the gradient is 1.2437e-07 at 1000 epochs, which indicates negligible deviation from the conditioned data. Simulated results indicate that the summed error is the mean per input vector and a zero-output decision. It is clear from the very small value of Mu, gradient and validation checks of the trained dataset that the Levenberg Marquardt algorithm can be applied to MPPT.

A convergent dataset of 1000 epochs is shown in Fig 4.7 where the mean squared error is shown for each epoch. It is therefore at 1000 epochs that the trained dataset achieves its most effective validation performance. Simulation results indicate that 1.0324e-10 is the optimal validation performance at 1000 epochs. According to Levenberg Marquardt's MPPT prediction, "nearly zero" validation performance indicates negligible error.

CONCLUSION

The aims of this paper are to developed ANN based MPPT algorithm for wind energy system and simulate the system that combines the PMSG based wind model and grid related system with the assistance of AC-DC-AC conversion. The PMSG based WECS was modeled and simulated utilizing MATLAB & SIMULINK. The analysis is carried out for various wind speed profile. This thesis presents, completely different simulation outcomes to analyze the robustness of the developed control technique with multilevel converter for grid related wind generation system. Based on the simulations outcomes and the efficiency evaluation carried out following level may be concluded:

- The proposed algorithm was examined underneath completely different wind circumstances together with constant wind speed, abruptly changing wind speed, and randomly various wind speed. In all of the eventualities, the ability extraction from the turbine was on the peak with respect to the wind curves for the turbine. The reduced ripple in power and elevated effectively are the most important achievements of proposed ANN based MPPT algorithm.
- The proposed MPPT approach makes use of dc link voltage and current as inputs. By computing the ratio of current and voltage and evaluating the modifications in signal, the responsibility ratio of the enhance converter is adjusted. There is not any requirement for wind speed measurements or system characteristics. Hence this technique is easy by way of implementation.
- The proposed algorithm it exhibits the enhancements for the developed system and control action for stability/unbalanced regular state as well as transient, dynamic response circumstances.

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