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Optimization of Storage Systems for Effective Integration of a Wind Farm into A Power Grid

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Abstract—*This paper presents an approach for better utilization of wind power generated by plants taking into account the demand for energy at specific time.Wind energy harvesting requires Complex Control systems.A Neural networks based approach is employed to forecast the wind power and locational marginal price at specified time.Neural Networks based approach has been chosen to impart modularity into the system.Neural networks are parallel computing units which can be trained to perform non linear computations. An Energy storage system in the form of A Flywheel is also incorporated to solve grid integration problems and to provide financially feasible power dispatch mechanism.LMP data can be used to determine the quantity of energy dispatched.This can ensure profitability to the power producers and optimally meet the power demand.The proposed method is implemented and Verified by using MATLAB software.*

Keywords*: Wind power forecasting, grid interconnection, energy storage systems.*

1. INTRODUCTION

Wind is a carbon free renewable source of electric power which has the potential to electrify the whole world and barring initial investments it is also a cheaper form of energy if the impact of other farms of energy is concerned. Though wind energy was being used primitively, the availability of fossil fuels proved to be a roadblock in technologies associated with wind energy.

Due to adverse environmental impacts such as the emission of hazardous carbon based gases and the depletion of fossil fuels has shifted the focus back to the renewable energy sources which apart from providing cleaner energy, is essentially inexhaustible. But wind energy conversion systems required considerable technological innovations for harnessing and proper utilization of the wind enrgy and wind unlike other energy sources presented peculiar challenges which warranted for further researches

Wind energy was approached with sceptism as the power from the wind farms were sporadic, prone to sudden variations and were difficult to control, making it harder for integrating these wind farms into electric grids. Scientists over the years have suggested and implemented various energy storage and prediction methods to give some accountability to the wind farms. This paper deals with one such concept for making grid interconnection of wind power plant feasible.

2. ANN BASED WIND POWER AND LMP PREDICTION

One among those methods is the artificial neural network based wind power and locational marginal pricing predictions[1]. Artificial neural networks works in a way similar to thought of human brain wherein the process is unknown,but a result is obtained. Neural networks are usually trained and tested before being implemented and satisfactory performance levels are reached by the network.

Historical data can be used to train the network and implementation to real time applications can be done after evalution of their performance. The predicted power value can be used for many applications such as power dispatch scheduling and storage system scheduling and LMP data can be used to incorporate the aspect of profitability into a power system. Data used for the evaluation of the WPP behaviour are sourced from the Energy Regulatory Council Of Texas (ERCOT).

Forecasting wind power and LMP could help in ensuring grid code compliance by making arrangements for the grid interconnection such as penalty for power quality variations due to sudden variations in power output.

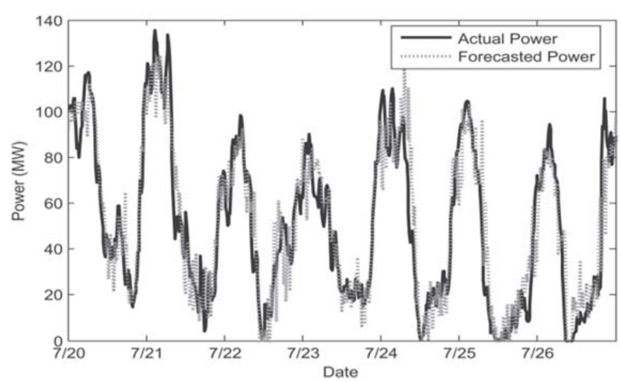


Fig. 1: Actual and Predicted wind power

The neural network employed in this study was trained by using the marqueardt-lavenberg training method and the log-sig activation function was used in the study. While training a network it is important to choose data which would represent a typical day since changes in weather conditions would have a impact on the training of the network. For example, while sampling data, it should be noted that if there is a sudden variations n the weather condition during a particular day ,it is advisable to leave that day so that learning accuracy can be improved.

LMP calculations are done to schedule the power dispatch to the grid in a profitable way for the power generation companies

3. GRID INTERCONNECTION

Usually, a WPP is operated along with energy storage systems to reduce the power output variations in a power plant. A hydro power plant and a battery storage system is the most common confiquration of the storage devices, This confiquration can help the grid interconnection but without compliances with the grid codes

Grid codes are a set of conditions which are to be met by the generating companies, distribution companies and the consumers so as to be interconnected to an electric grid. In case if a WPP does not comply to the grid codes, i.e., paying penalty for the power quality services which are usually provided by other generating companies and a power quality problem to arise in the grid, it is universal practice to cut off the WPP from the grid invariably to restore the grid stability conditions. Thereby reducing the monetary benefits to the generating companies even if there is a large demand in the grid and the power produced is very high

4. FLYWHEEL BASED STORAGE SYSTEM

By understanding the wind farm parameters, the power curve and its geographical location, the type and size of the storage system can be determined. Typically, flywheel based energy storage is employed for grid interconnection applications

Flywheels are an advanced storage mechanism which can double up a storage device as well as power quality improving device. Flywheels store energy in the form of kinetic energy absorbing power from the grid as well as the wind power plant helping to ensure the stability of a power grid. By incorporating the predicted LMP data and devising a suitable power dispatch schedule, profitability and grid security with a wind power plant can be ensured.

The energy stored in this device is dependent upon the speed of rotation of flywheel

$E=1/2\ Jw^2$ (1)

The maximum energy that can be stored in the flywheel is given by

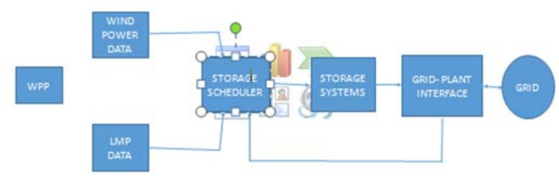
$E=1/2(w_{max}^2-w_{min}^2)$ (2)

It can be understood that the energy storage of the flywheel can be varied by varying the inertia or the speed of rotation of the flywheel until a cetain limits above which the flywheel mechanically breaks down.

Flywheels work based on a reference point by which the differenc between the actual and the measured value generates thr reference signal.

$S_{ref} = S_{actual}-S_{ref}$

For example ,in case of frequency regulation the difference between actual and measured frequency is used to generate the reference signal.



Fiq. 2: Simplified block reprentation of the system

The system also incorporates a power conditioning system between the flywheel system and the point of common coupling to the grid. The interface consists of measuring devices which measure the various quantities associated with the system such as the wind power, locational marginal pricing, storage system capacity and parameters associated with the electric grid such as voltage, frequency. These measurements are essential to provide various power quality solutions associated with the wind power integration .There are different possible modes of integration into a power system. The grid interface measures various quantities and chooses the mode of integration

5. MECHANISM OF FLYWHEEL

Mode 1:Normal Mode: In this mode ,The operation of the grid is considered to be stable and power supply in to the grid is based on the locational marginal pricing.

Algorithm:

Step 1: Check for the power produced, and LMP and grid conditions.

Step 2:Supply the power to the grid if the LMP is feasible if not store charge in battery and flywheel operating it as generator.

Step 3:Make sure the system parameters do not take the system to contingency conditions and supply power continuously.

Mode 2: Emergency mode: The grid undergoes instability and needs immediate corrective action.

Algorithm:

Step 1: Check for the power produced, and LMP and grid conditions

Step 2: Calculate the power demand P_i at a particular time T_i.

Step 3:if the demand is higher than supply, check if power produced from wind will increase after some time T_i if so, operate the flywheel as motor and bring about demand supply match, if the condition comes good, stop operating the flywheel and supply power from wind farm into the grid.

Step 4:If the condition does not improve, increase the speed of rotation of the flywheel and improve the storage conditions, in case vice versa, supply power from both the farm and the battery to meet the increased demand and pricing of the power can be done on the basis of locational marginal pricing.

This modes can provide active power control to the grid and to improve grid wind profile after incorporation of wind energy into the power grid and give grid code compliance ability for the wind farm.

6. SIMULATION AND RESULTS

The simulation of the wind power prediction using matlab ang grid interconnection connected with the storage mechanism can be seen in fiqure.

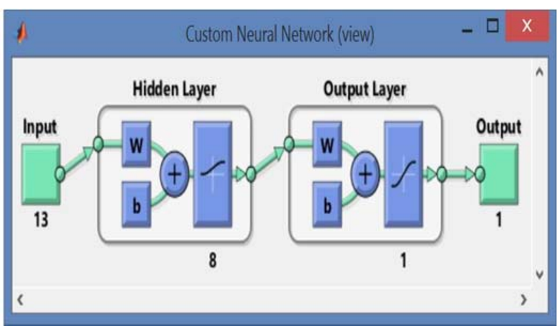


Fig. 3: A Sample Neural network

The network can be then trained using the marquardt lavenberg training algorithm to find out an accurately trained neural network, error parameter mean squared error is used to establish the differences between forecast and actual values,for example an error of 10% during training states that the difference between actual and forecast value is about 10%.Generally number of training iterations are increased to improve forecast accuracy.

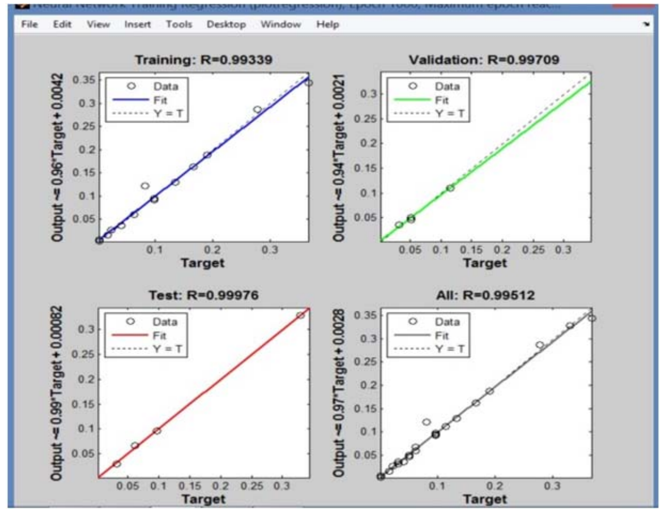


Fig. 5: Performance analysis

The above graphs give the simulated results for wind power forecasting using neural networks toolbox. Similar network can also be used for LMP calculations

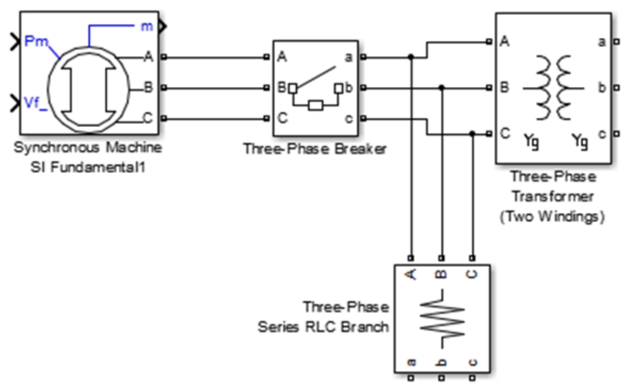


Fig. 6: Simulink Model of motor generator system (Flywheel)

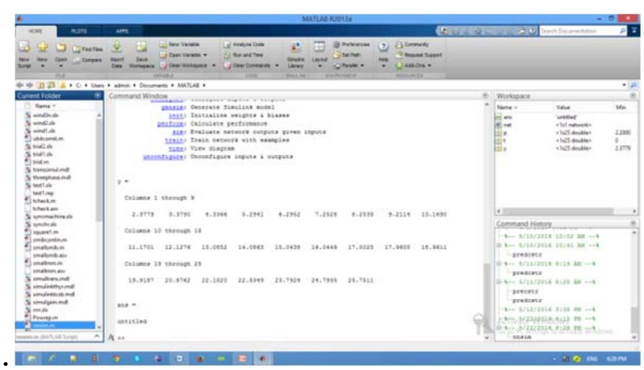


Fig. 7: Predicted Wind power output.

Then afore mentioned algorithms can then be written in the farm of a matlab code and then be implemented using the MATLAB software for valuation of grid code compliance.

7. CONCLUSION

Wind as a nature's gift has great potential for provision of electricity if not for the availability of sophisticated technologies. Researches are being carried out for developing methods for wind energy integration into electric power grid and this paper provided a method for integration without monetary losses to the power generators and the consumers by accurate forecasting using artificial neural networks and the concept of locational marginal pricing.

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