Optimal Capacity of Battery Energy Storage System in Wind Farm

Smita V. Kalmegh[1], A. A. Ghute[2]

[1]Student, Sant Gadge Baba Amravati University
[2]Assistant Prof., Sant Gadge Baba Amravati University

Abstract: *In recent years, as fossil energy becomes exhausted and greenhouse effects become more severe, renewable energy generation, especially wind power, draws increasingly much attention. However, because of the variation of natural conditions, such as wind direction and wind speed, the output power of a wind farm is intermittent. It will pose an adverse impact on power quality and stability of the grid when the wind power penetration level is relatively high. To ensure that the wind generation system operates in a safe, economic, high-efficiency and high-quality way, it is necessary to equip battery energy storage system (BESS) in the wind power system, aiming at smoothing power fluctuations and stabilizing voltage and frequency. This paper presents a computational procedure to determine the BESS capacity and the evaluation of the dc voltage. This paper also presents the results of a wind data and provides effectively continuous power for the consumers / grid without any disturbance it also examined for the purpose of attenuating the effects of unsteady input power from wind farms. The design problem is formulated as maximization of an objective function that measures the economic benefit obtainable from the dispatched power from the wind farm against the cost of the BESS. Solution to the problem results in the determination of the capacity of the BESS to ensure constant dispatched power to the connected grid, while the voltage level across the dc-link of the buffer is kept within preset limits. The effectiveness of these methods was verified using MATLAB/SIMULINK software.*

Keywords: Energy storage system, windpower generation, storage battery capacity, optimization model

1. Introduction

With the continuing rapid growth of wind power generation, it has become an important part to the world's energy structure. The size of wind farm groups continues to grow and the penetration of wind power into power grid is increasing rapidly. Bulk wind energy generated from these large-scaled wind farms is transmitted through long distance high voltage transmission line. This accessing scheme makes the integrated wind generators have a much more significant impact on the power system stability and control. Since the wind power output depends on wind, as a natural source, the electrical output always fluctuates due to the weather, site conditions and other possible factors. The wind power generation is not stable and cannot supply constant electrical output. Various system structures and techniques have been proposed, with the view to increase the penetration level of wind energy in grids. As one of them, more and more people realize adding energy storage system to large scale wind farm to eliminate the fluctuation become a solution for developing large scale renewable energy system connected with grid. By introducing the Battery Energy Storage System (BESS) into wind farm, the generated power is smoothed. The purpose of this paper is to fill in the gap in the aforementioned daily load-tracking application. So it addresses the design of a battery energy storage system (BESS), incorporated into a power buffer for the wind farm. Because the BESS possesses higher energy capacity than several other energy storage media, and hence, it is suitable for the long-term load-tracking operation. BESS is also shown to be cost-effective for use in the power systems. This paper proposes a methodology to determine the optimal BESS capacity for the purpose of daily load tracking. The method is based on a given wind power profile and the optimization of an objective function through which the optimal dispatched power level from the wind farm will be obtained.

2. System Description

A wind energy based hybrid renewable energy system consists of the following main parts:

- Wind Power Generation System (WPGS)
- Battery Energy Storage Station (BESS)
- Instantaneous Power Controller

Figure.1 shows the topology of a wind power system with BESS and the system configuration for the proposed hybrid alternative energy system. In this system, the renewable wind power is taken as the primary source while the BESS is used as a backup and storage system.

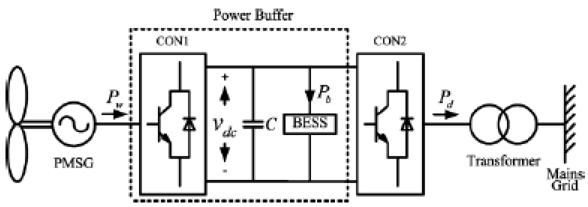

Figure 1: Block diagram of Wind Energy System with BESS

The energy buffer-storage scheme is described here and a method to determine the BESS capacity is presented in this paper. From figure 1 PMSG is interconnected with the grid through a fully rated converter so that the variable ac frequency at the generator terminal is converted to steady grid frequency at the output. The cost of permanent magnet material is low and it is lighter in weight, permanent magnet synchronous generators (PMSG) are becoming more economical and attractive, especially as turbine rating increases. Figure 1 shows that the wind energy captured by the turbine blades is converted through the PMSG into electrical power, denoted by Pw.

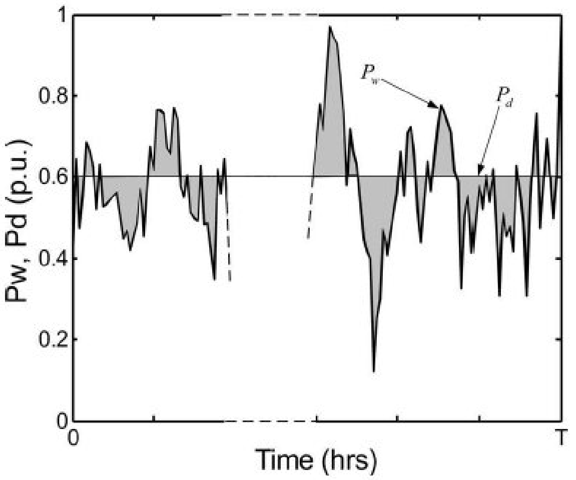

Figure 2: Typical wind power profile

As the main focus of this paper is on the design of the BESS, it is now assume that sufficient wind data are available and the profile of Pw is known over a period of Th. Figure 2 shows a typical profile of Pw, derived from the wind speed data.

3. Mathematical Model

Integration of battery energy storage system (BESS) with a wind farm can smooth power fluctuations from the wind farm. Battery storage capacity (C), maximum 4 charge/discharge power of battery (P) and smoothing time constant (T) for the control system are three most important parameters that influence the level of smoothing (LOS) of output power transmitted to the grid. The economic cost (EC) of a BESS should also be taken into consideration when determining the characteristic parameters of BESS (C, P). In this paper, an artificial neural network-based long-term model of evaluated BESS technical performance and EC is established to reflect the relationship between the three parameters (C, P,T) and LOS of output power transmitted to the grid, the EC of BESS. After that, genetic algorithm is used to find optimal parameter combination of C, P and T by optimizing the objective function derived from the mathematical model constructed. The simulation results of the example indicate that the parameter combination of C, P and T obtained by the proposed method can better not only meet the technical demand but also achieve maximum economic profit.

4. ANN-based modeling of the parameters C, P and T: Short-term modeling of considering only BESS technical performance

An ANN is made up of many interconnected simple processing units, called neurons, which form the layered configurations that possess the ability to learn and adapt. Because of its great nonlinearity, generalization ability and matching precision, the ANN is widely used to model nonlinear system. For modeling the relationship between C, T, P and the LOS of output power in a single day, a multilayer feed forward-type ANN-based model is designed. This network is designed with three layers, the input layer with three, the hidden layer with m (m = 38), and the output layer with four neurons, respectively, as shown in Figure 3

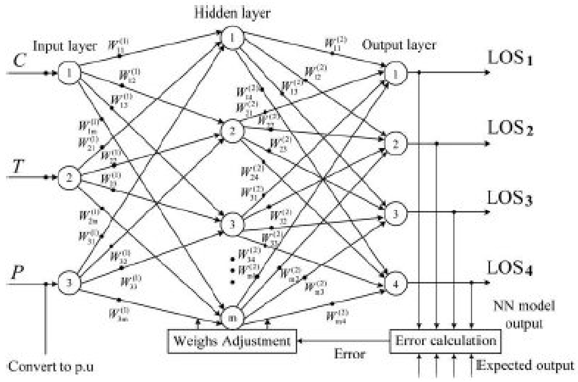

Figure 3: Structure of the ANN

The activation functions chosen are logarithmic sigmoid for the input, hidden and output layers, which is given as follow

$$g(x) = \text{sigmoid}(x) = 1/1 + e{-}x$$

The resilient back propagation optimization algorithm is selected as the training function. In addition, gradient descent with momentum weight and bias is chosen as the learning function to regulate weights.

The network topology of the ANN is as shown in Figure 3 The three neurons in the input layer represent the parameters C, T and P · ΔP1 min and ΔP10 min are defined as the maximum permissible variations of output power of the wind power system when time interval is 1 and 10 min, respectively. when the time interval is 1 min and the maximum permissible variation of output power is ΔP1 min; LOS2 is the value when the time interval is 1 min and the maximum permissible variation is (1 + a%)ΔP1 min; LOS3 is the value when the time interval is 10 min and the maximum permissible variation is ΔP10 min; LOS4 is the value when the time interval is 10 min and the maximum permissible variation is (1 + b%)ΔP10 min. (LOS1, LOS3) and (LOS2, LOS4) can be seen as a double requirement for the LOS of grid-connected active power when the time interval is 1 and 10 min, where LOS1 and LOS3 play leading roles, whereas LOS2 and LOS4 play auxiliary roles. The outputs of neurons in the hidden layer are named V1- Vm.

The output vector of the hidden layer can be described as

$$V(C, T, P) = \text{sigmoid}\,(W(1)(C, T, P)T) \qquad (1)$$

V is the output vector of the hidden layer, W(1) is the weight matrix between the input layer and the hidden layer.

$$LOS(C, T, P) = \text{sigmoid}\,(W(2)V(C, T, P) \qquad (2)$$

Combining (1) with (2), the output vector of the ANN model is obtained as follows:

LOS(C, T, P) = sigmoid (W (2)sigmoid W(1)(C, T, P)T) (3)

The ANN is trained for establishing the mathematical model which can reflect the relationship between the parameters (C, P,T) and the LOS of the output power in a single day. In a similar way, the ANN-based mathematical models of many single days in a year can be established and used to build the long-term mathematical model.

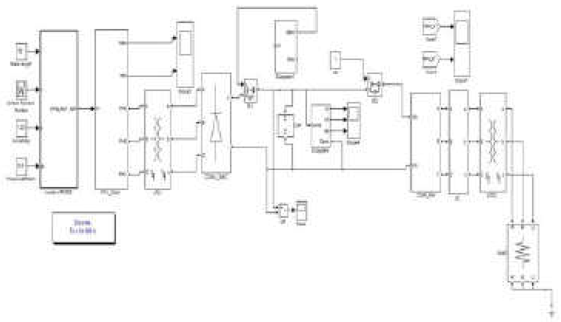

Figure 4: Simulink Model for Wind Energy System through BESS

5. Conclusion

In this paper, the inherently intermittent nature of the wind power can impact negatively on utility operations. One solution to tackle this problem is to utilize the proposed scheme of power buffer with BESS. A method to determine the BESS capacity has been developed with the purpose of not only keeping the injected power from the wind farm constant, but also to achieve maximum economic benefit. Also method to find the optimal parameter combination of C, P and T is presented and criterion is proposed to identify LOS of the output power of a wind power system.

References

[1] S. Mathew, Wind Energy, Fundamentals, Resource Analysis and Economics, 1st Edition, Springer-Verlag, 2006
[2] C. Carrillo, Power Fluctuation in Isolated Power Plant, IEEE Transactions on Energy Conversions, Vol. 19, No. 1, March 2004, pp. 217-221.
[3] T. Y. Lee and N. Chen, "Optimal Capacity of the Battery Energy Storage System in a Power System", IEEE Transactions on Energy Conversions, Vol. 8, No. 4, Dec.1993, pp. 667-673.
[4] G. Sideratos and N. D. Hatziargyriou, "An Advanced Statistical Method for Wind Power Forecasting", IEEE Transactions on Power System, Vol. 22, No. 1, Feb. 2007, pp. 258-265.
[5] P. F. Ribeiro, B. K. Johnson, M. L. Crow, A. Arsoy, and Y. L. Liu, Energy Storage Systems for Advanced Power Application, in Proc. IEEE, Vol. 89, No. 12, Dec. 2001, pp. 1744-1756.
[6] Liang, L., Jianlin, L., Dong, H.: ‚An optimal energy storage capacity calculation method for 100 MW wind farm‟. 2010 Int. Conf. Power System Technology, Hangzhou, China, 2010, pp. 1–4
[7] Wang, X.Y., Mahinda Vilathgamuwa, D., Choi, S.S.: Determination of battery storage capacity in energy buffer for wind farm‟, IEEE Trans. Energy Convers., 2008, 23, (3), pp. 868–878