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Procedure to Determine Battery Energy Storage Capacity for Wind Farm

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ABSTRACT : *The capacity of energy storage system is calculated to minimize the effect of unsteady power. A dc bus capacitor is able to offer a power shaping ability, and battery can function as an energy storage system. 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. A procedure to determine the BESS capacity and the evaluation of the dc voltage is shown.*

Keywords -*Battery energy storage system (BESS), power fluctuation, wind energy.*

I. INTRODUCTION

Wind energy growing more rapidly than any other energy source. Unfortunately, much like other renewable sources such as solar, wind generation tends to be unsteady because wind speed is influenced by natural and meteorological situations. As the output power of the wind farm fluctuates, it can result in network frequency and voltage deviations. Smoothing the wind farm output power using the ESS is one for power quality enhancement purpose. Solving of an observed instability problem in an isolated power system under high-speed wind conditions, through the retuning of the controller of the wind farm power converters is proposed. Hence, the converter control system has to be designed sufficiently robust to cater for wide-operating range. As an alternative to the aforementioned techniques to attenuate the negative impacts of the variability of wind power, the use of battery energy storage system (BESS) has been considered. Use of BESS such that short-term dc-bus voltage deviations due to the fluctuating wind power can be effectively controlled. Researchers have been taking advantage of the flexible charging/discharging ability of battery energy storage system (BESS) in the design of scheduling schemes for wind farms. The role assumed by the BESS in wind power trading is another active topic of research. Where it is shown how suitably designed BESS can bring additional economic benefit to the power generation endeavor. Indeed, if wind power output can be scheduled in a manner similar to that of a conventional power plant, the prospect of wind power will be much improved as optimal economic dispatch can then be achieved. The proposed design of a battery energy storage system (BESS), incorporated into a power buffer for the wind farm. Thus, the present investigation proposes a methodology to determine the required BESS capacity for the purpose of daily load tracking or load leveling. The method is based on a given wind power profile. The corresponding BESS power and energy capacities will be determined while the accompanying converter dc voltage will be controlled within specified limits. This latter requirement is needed in order to maintain proper operation of the converters.

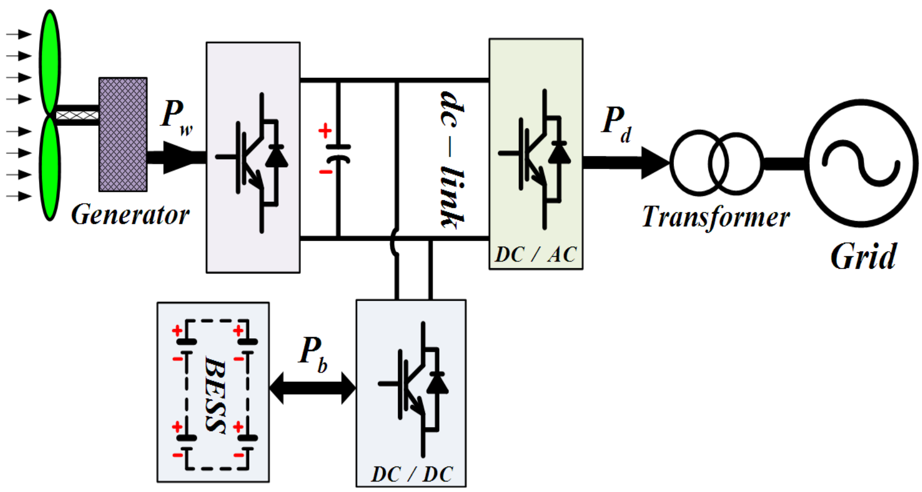

Fig.1.1 variable speed wind turbine with interconnection to the mains grid through power buffer system.

II. CONFIGURATIONS OF WIND-BATTERY POWER SYSTEM

A converter is adopted to provide the grid connection capability. The output of the generator is rectified and stored in the dc-link where the BESS is also connected via a bidirectional dc to dc converter. This bidirectional converter is capable of delivering a negative or positive power in order to discharge or charge the BESS.

2.1 BESS Power and Energy Ratings:

The BESS capacity, which is normally specified in term of energy rating E_b and power rating P_b, is determined based on the dispatched power and the wind turbine output power. If assumption that the power losses in the system is negligible, the BESS power is an outcome of subtracting the dispatched power from the wind power or

$$P_b = P_w - P_d \quad \text{……………..} \quad (1)$$

From this equation, for a given constant P_d , $P_b(t)$ will vary in the same manner as P_w. By setting P_d to another constant value will only result in the $P_b(t)$ curve being shifted up or down, but $P_b(t)$ will remain as the same shape as P_w. (E_b) injected into or discharged from the BESS, up to time t. Corresponding to the changes in $P_b(t)$, the $E_b(t)$ profile will also vary for different P_d. For specific value of P_d, the corresponding value of $P_{b,max}$ determines the BESS power capacity. To achieve the goal of dispatching the constant P_d over the designed period T, the BESS capacity has to be specified to be at least as large as the corresponding $P_{b,max}$.

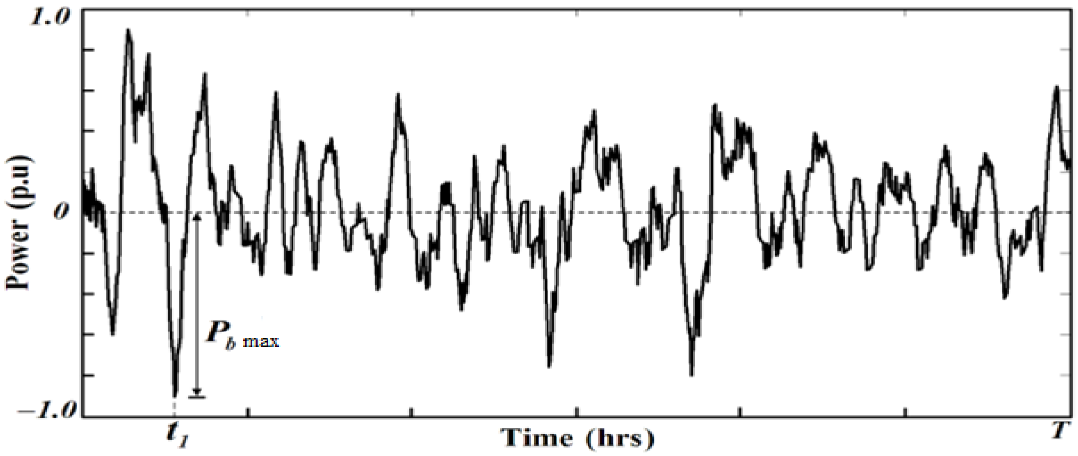

Fig. 2.1 the bess power flow

For example, once the BESS capacity is designed to be at least as large as $P_{b,max}$, the BESS could absorb/supply the surplus/shortfall in power for the corresponding constant dispatched level P_d .

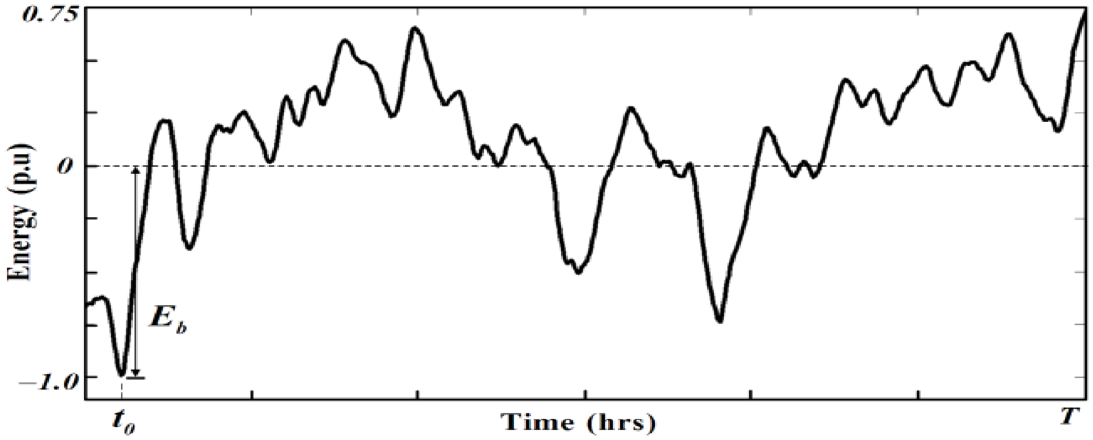

Fig.2.2 The BESS energy determined by integrating the BESS power with respect to time

As described earlier, besides the power capacity, the battery energy capacity should also be considered. For the study undertaken in this paper, the BESS energy capacity is specified in a similar manner as in the case of BESS power capacity: the energy capacity of the BESS has to be as large as that it could absorb/supply the maximum amount of the charged/discharged energy. Hence, the BESS energy capacity should be at least as large as $E_{b,\max}$ for the corresponding P_d value.

2.2 State of Charger of Battery:

Operating cost of the system does depend not only on the BESS capacity but also on the way of utilizing the storage [1]. During the system operation, the BESS technical information needs to be strictly considered, which includes state of charge (SOC) and deep of discharge (DOD). The SOC of a battery is a percentage indicating available energy capacity being stored by the battery compared with its rated capacity. In order to prevent the battery overcharged, the system controller should keep the SOC within a proper limit (usually, 20% to 90%). Moreover, a high DOD causes a significant degradation of the battery cycle life, so that a limitation of DOD needs to be set during discharging the battery; and the maximum DOD is 80% [2].

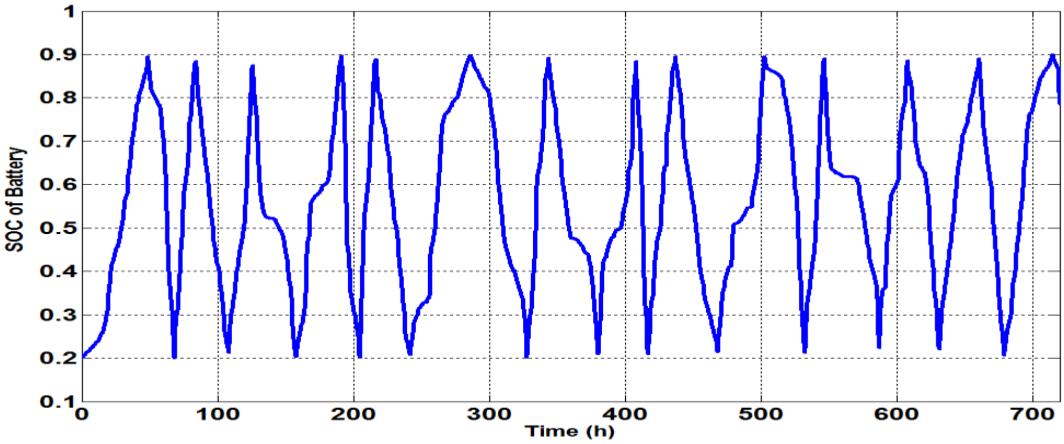

Fig.2.3 SOC of BESS with its optimal capacity

III. DETERMINATION OF PD

*I*t is noted that, with different *Pd*, *P*b,max and *E*b,max will change accordingly. One can assume that the capital cost of the wind turbine and power converters are constant. Therefore, the benefit (per hour) for dispatching *Pd* into the grid over period *T* could be calculated from

$$B = \alpha P_d - \beta P_{b,\max} - \gamma E_{b,\max} \text{ ....(2)}$$

where α is unit price of the wind energy (in dollar per kilowatt hour) sold to the grid, and β (in dollar per kilowatt) and γ (in dollar per kilowatt hour) are the amortized BESS capital costs per hour over *T*.The first term in equation 3.1 denotes the obtainable benefit or income of the wind farm from selling *Pd* per hour at a price of α. The second and third terms determine the amortized capital cost of the BESS sized by *P*b,max and *E*b,max over the designed period *T*. Therefore, the net benefit obtained by the wind farm *B* from incorporating such a BESS could be calculated.

Therefore, with known α, β, and γ, one can search for the optimal P_d to maximize *B* in an iterative manner by first setting $P_d = 0$ and increasing P_d progressively until the optimal P_d, denoted as P_{d^*}, which maximizes *B* is obtained. The optimal P_{d^*} therefore provides the power and energy capacities of the BESS, $P_{b,\max}$, and $E_{b,\max}$.

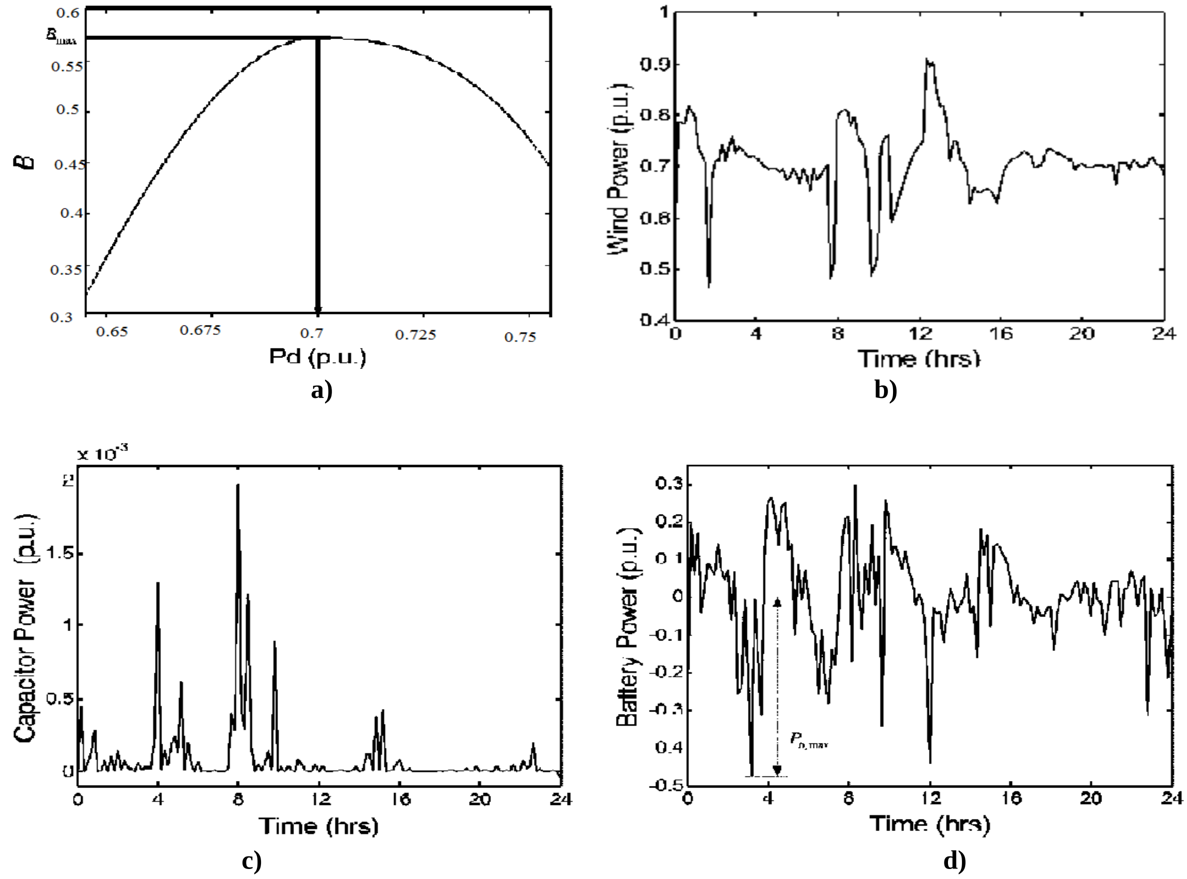

Fig.3.1. (a) benefit b versus dispatched level. (b) Battery power profile a
(c) Power stored/supplied by the capacitor.
(d) Recalculated battery power with the capacitor implemented.

IV. CONCLUSION

The main contribution of this paper is introducing a method to determine the BESS capacity by means of minimizing a lifetime cost function. 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 in terms of the power abstracted from the renewable source against the cost of the BESS installation. By the implementation of such a BESS design approach, the BESS power and energy capacities can be determined, and a constant dispatch level from the wind farm can be guaranteed.

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