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# Optimal allocation of energy storage system in distribution systems

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**Abstract**

In this paper, a methodology is proposed for optimally allocating energy storage system (ESS) in distribution systems with a high penetration of wind energy. The aggregated capacity of an ESS is determined so as to accommodate all amounts of spilled wind energy, and the ESS is optimally allocated in the system in order to minimize the annual electricity cost. The annual hourly wind speed and load profile are generated using the auto regression moving average (ARMA) technique and the IEEE-RTS system, respectively. Further, these data are incorporated in order to determine the annual cost of spilled energy and the optimum allocation of the ESS in the distribution system. A cost/benefit analysis was also conducted by comparing the annual cost of different ESS techniques with the total profit for both the utility and the distributed generation (DG) owner. The results show that integrating an ESS with the distribution system for the proposed application is economically feasible only when the least expensive ESS is used.


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## 1. Introduction

Environmental concerns and fuel cost uncertainties associated with the use of conventional energy sources have resulted in rapid growth in the amount of wind energy connected to distribution grids. However, based on Ontario's standard offer program (SOP), the utility has the right to curtail (spill) wind energy in order to avoid any violation of the system constraints. This means that any increase in wind energy production over a specific limit might be met with an increase in the wind energy curtailed.

In spite of their cost, energy storage systems (ESSs) are considered to be a viable solution to this problem [1-7]. Therefore, in this paper a methodology for allocating an energy storage system (ESS) in a distribution system with a high penetration of wind energy is proposed. The ultimate goal is to maximize the benefits for both the distributed generation (DG) owner and the utility by sizing the ESS to accommodate all amounts of spilled wind energy and by then allocating it within the system in order to minimize the annual cost of the electricity. In addition, a cost/benefit analysis has been conducted in order to verify the feasibility of installing an ESS from the perspective of both the utility and the DG owner.

## 2. Methodology

The proposed application of an ESS is to store wind energy at night rather than spilling it and to release it during the day. The details of this application can be summarized as follows:

- The ESS will be allowed to charge and discharge for several hours (high energy application).
- The ESS will be charged during the off-peak night and discharged during the on-peak day, resulting in one charge/discharge cycle every day.
- The ESS will be charged mainly by the spilled wind energy.
- If the ESS can accommodate more energy, that is, if it is not fully charged, it will be charged from the utility.

## 3. Procedures

This section presents the procedures that must be conducted in order to accomplish the proposed work as shown in Fig 1.

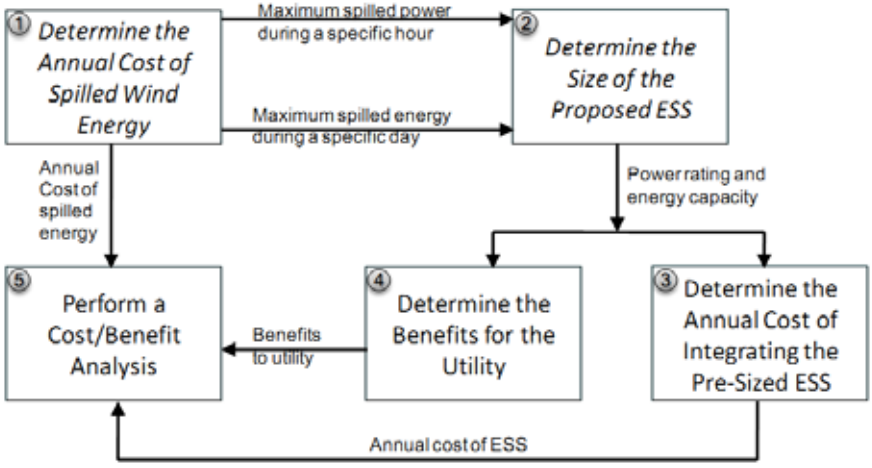


Fig. 1. Proposed steps for optimal allocation of ESS in distribution systems