International Online Conference on Advanced Research in Biology, Ecology, Science and Technology
(ICARBEST'15)
Organized by
International Journal of Advanced Research in Biology, Ecology, Science and Technology (IJARBEST)
19th November 2015

PSO BASED EFFICIENT CONGESTION MANAGEMENT ANALYSIS IN WIND POWER CURTAILMENT AND ENERGY STORAGE

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ABSTRACT

The integration of intermittent generation in power grids, such as wind energy, imposes new challenges for transmission congestion management. To solve this problem, energy storage systems (ESS) have been proposed, as they provide an efficient mechanism for balancing variability while reducing operational costs. This project presents a comprehensive analysis of the dynamic interactions between wind energy curtailment and an energy storage system (ESS). An analytical framework is developed to study different mitigation measures in terms of total energy curtailed, total congestion costs, line load factor and congestion probability. This framework is tested in the MATLAB software by developing PSO algorithm in the simulink model.

KEYWORDS

Particle swarm optimization(PSO), Energy storage system (ESS), Genetic algorithm (GA)

INTRODUCTION

Every day it is more recognized the large potential of renewable energies to displace greenhouse gases emissions and to achieve climate change mitigation targets. Among these technologies, wind power has been the fastest growing renewable energy worldwide. However, there are many integration challenges regarding the impact of wind energy in both the design and operation of power systems. Thus, according, a cost effective transition to a system with high levels of penetration of renewable, will need not only improvements in the electricity infrastructure but also fundamental changes in the philosophy of network operation and development. Special attention has to be devoted to the transmission system as new wind capacity deployment may also introduce bottlenecks in the grid. In this context, one of the most important aspects of the future integration of renewable energies is the reduction of transmission congestion while maintaining minimum impact on the reliability of the grid and the capital and operational costs of the system.

In general, congestion management approaches can be classified into systemic and local solutions. Systemic solutions involve a system-level minimization of the total operational costs, while fulfilling the network security constraints. The most common strategy for congestion management is to compensate the fluctuation of the wind energy through a re-dispatch of other power plants. This approach has the disadvantage that deviates from the economic optimality, and the accuracy of the solution is directly affected by the forecasting errors in both wind generation and load. In a comprehensive review of different approaches for congestion management in competitive markets is presented. In a real time congestion supervisor is proposed in

CONGESTION MANAGEMENT

Congestion management in a multi-buyer/ multi-seller system is one of the most involved tasks if it has to have a market based solution with economic efficiency. In a vertically integrated utility structure, activities such as generation, transmission and distribution are within direct control of a central agency or a single utility. Generation is dispatched in order to achieve the system least cost operation. Along with this, the optimal dispatch solution using security constrained economic dispatch eliminates the possible occurrence of congestion. This effectively means that generations are dispatched such that the power flow limits on the transmission lines are not exceeded.

According to reference the congestion management is defined as "the comprehensive set of actions or procedures to ensure that no violations of the grid constraints occur". By following this approach, this work proposes a comprehensive methodology to study the dynamic interactions of wind curtailment and energy storage for transmission congestion management while considering ramp-up and ramp-down rates of generating units. The methodology is applied to a real network system located in the northern part of Chile.

Energy Storage Model

There are different ESS technologies that can be used for congestion mitigation. Due to their current stage of development at a high rated capacity (100 MW), four technologies are the most suitable for

order to reduce the re-dispatching. The deployment of this technique requires the installation of network controllers located in the transmission lines and in each generator. Besides the upgrade of the existing communication network, this congestion management approach would need the modification of the current grid codes as well.

congestion management: pumped hydro system (PHS), compressed air energy storage (CAES), thermal energy storage (TES), and battery energy storage system (BESS). A generic model of an ESS that considers operational rules to deal with the dynamic congestion management is proposed. For simplicity, we assume that the ESS and the wind farm are connected to the same busbar. Note however that, in the general case, not every wind farm busbar holds a connection to an ESS.The final application of the proposed framework is described. The ESS stores energy from the wind farm when there is overload in transmission capacity and supplies power back to the grid when the transmission congestion is relieved. This behaviour translates into a simple control strategy, where other factors like changes in the energy price, operational reserves opportunities, etc., are not considered. Fig. 5 shows the diagram of the ESS model based on reference. Figure shows the ESS model used for operational analysis.

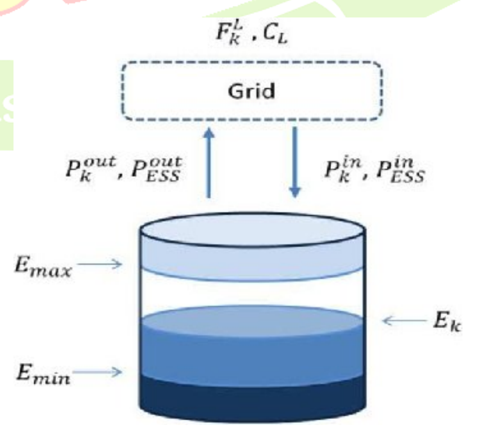

Fig-ESS model used for operational analysis.

PARTICLESWARM OPTIMIZATION (PSO)

Particle Swarm Optimization Swarm Intelligence (SI) is an innovative distributed intelligent paradigm for solving optimization problems. PSO incorporates swarming behaviours observed in flocks of birds, schools of fish, or swarms of bees, and even human social behaviour, from which the idea is emerged. PSO is a population-based optimization tool, which could be implemented and applied easily to solve various function optimization problems. As an algorithm, the main strength of PSO is its fast convergence, which compares favourably with many global optimization algorithms like Genetic Algorithms (GA) Simulated Annealing (SA) and other global optimization algorithms.

Particle swarm optimisation (PSO) is an evolutionary computation technique that applies an analogy of swarm behaviour of natural creatures. It has been motivated by the behaviour of organisms acting as a unit, for example he schooling of shocking of birds. Birds usually seek food (their objective) in swarms. Each individual bird (agent) reconfigures its behaviour, based on its own experience and the experiences of others.

$$\text{Minimize}(x; y)$$

Where x denotes the dependent variables, consisting in bus voltages, transmission line loadings, etc. and where y denotes the independent variables, in this case WT reactive power consumption/generation. Basically, the position of each agent has an associated velocity vki , this is responsible for the movement and the position change of the agents. Each agent knows its best historical value and the corresponding position. In addition, each agent is aware of the value and corresponding position of the best agent of the swarm.

ALGORITHM

In a PSO algorithm, the population has n particles that represent candidate solutions. Each particle is a k-dimensional real-valued vector, where k is the number of the optimized parameters. Therefore, each optimized parameter represents a dimension of the problem space. The modified PSO technique for integer problem can be described in the following steps.

Step 1: (Initialization):

Set t=0 and generate random n particles, $\{X_i\ (0),\ i=1,2,..n\}$. Each article is considered to be solution for the problem and it can be described as $X_i\,(0)=[\,x_{i},1(0);\ x_i\,,2(0);\ \ldots\ldots;x_i\,,m(0)]$ Each control variable will have a range [xmin, xmax]. Each particle in the initial population is evaluated using the objective function f. For each particle, set

$$X_i^*(0) = X_i(0) \text{ and}$$
$$F_i^* = f_i;\ i=1,2,3.....,n.$$

Search for the best value of the objective function fbest .Set the particle associated with fbest as the global best,$X^{**}(0)$,with an objective function. Set the initial value of the inertia weight w(0).In this study the objective function is the optimal power flow ,which will be calculated after running the power flow and meeting all our constraints.

Step 2: Counter Updating:

Update the counter t= t +1

Step 3: Velocity updating:

Using the global best and individual best, the i^{th} particle velocity in the k^{th} dimension in this study (integer problem) is updated according to the following equation:

$V_i,k(t) = w(t).v_i,k(t-1) + b_1s_1(x_i^*,k(t-1)-x_i,k(t-1)) + b_2s_2(x_i^{**},k(t-1) - x_i,k\ (t-1)$

From the previous equation i is the particle number, b_1, b_2 are positive constants, s_1 s_2 are uniformly distributed Random numbers in [0, 1] and k is the k^{th} control variable. Then, check the velocity limits. If the velocity violated its limit, set it at its proper limit. The second term of the above equation represents the cognitive part of the PSO where the particle changes its velocity based on its own thinking and memory. The third term represents the social part of PSO where the particle changes its velocity based on the social-psychological adaptation of knowledge.

Step 4: Position updating:

Based on the updated velocity, each particle changes its position according to the following equation:

$X_i,k(t) = x_i,k(t-1) + v_i,k(t)$

Step 5: Individual best updating:

Each particle is evaluated and updated according to the update position.

Step 6:

Search for the minimum value in the individual best and its solution has ever been reached so far, and considers it to be the minimum.

Step 7:

Stopping criteria: if one of the stopping criteria is satisfied, then stop otherwise go to step-2.

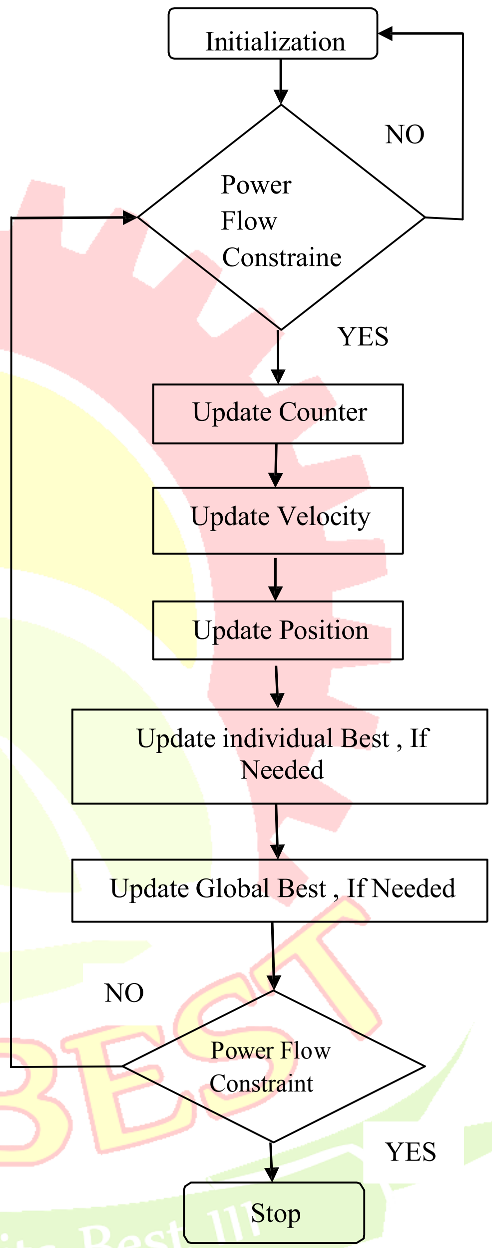

Fig Flowchart for PSO Algorithm

PROPOSED MODEL

In this proposed system, we present a comprehensive analysis of the dynamic interactions between wind energy curtailment and an energy storage system (ESS) when the ramping rates of power plants are considered. An analytical framework is developed to study different mitigation measures in terms of total energy curtailed, total congestion costs, line load factor and congestion probability. This framework is tested in a real case study and a sensitivity analysis is performed to identify the influence of the main ESS design parameters in congestion mitigation performance.

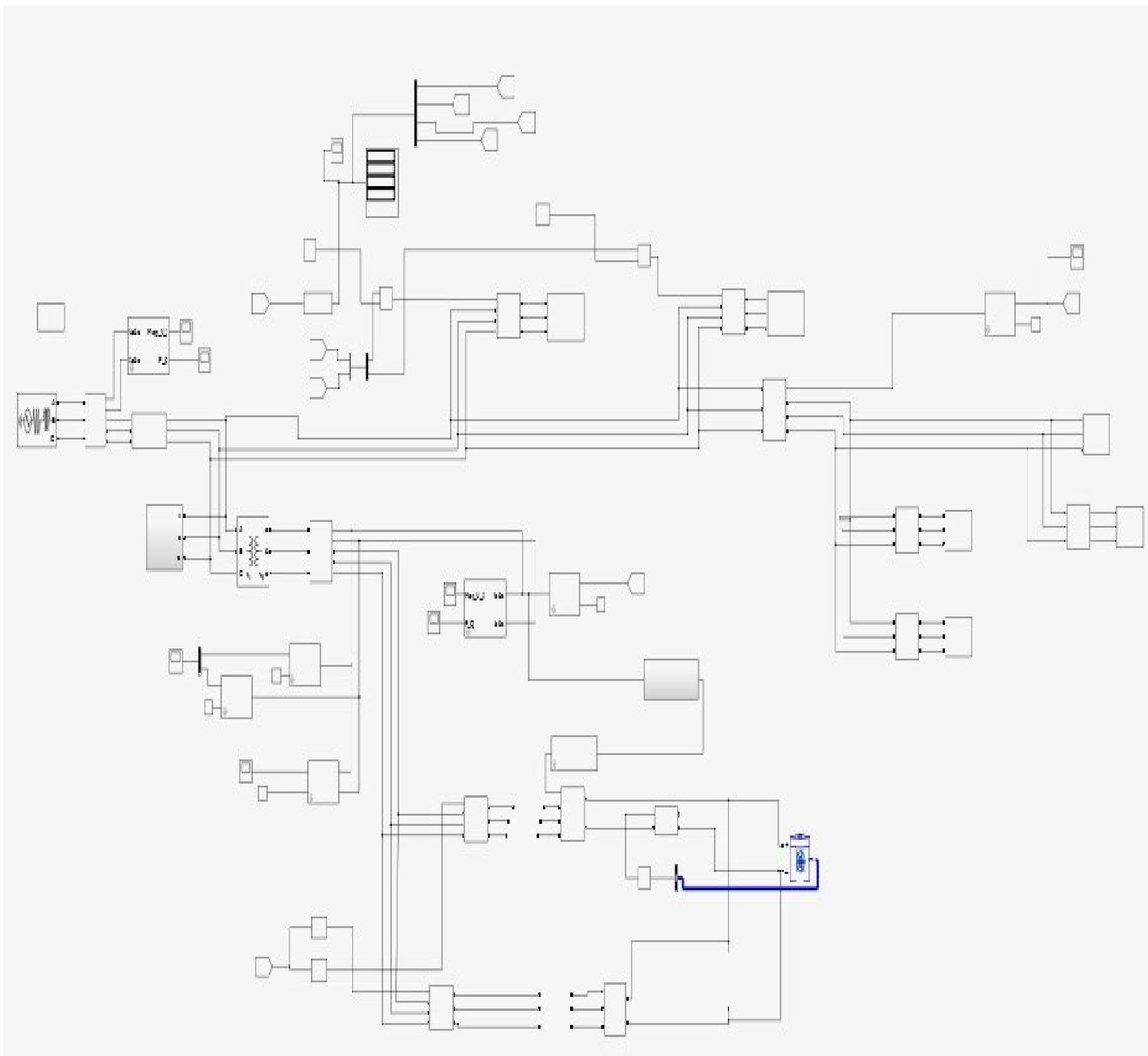

Fig- Simulation Model Of Proposed System

This figure shows the simulation model of the power system. In this system the generation and distribution side was presented in this model. The asynchronous generator was used in the wind turbine. The main component of the generation side is wind generator. The output of this model is given below. The output is taken in the wind generator side and also load side which shows the congestion occur in the transmission side was mitigate and that was managed with the PSO algorithm

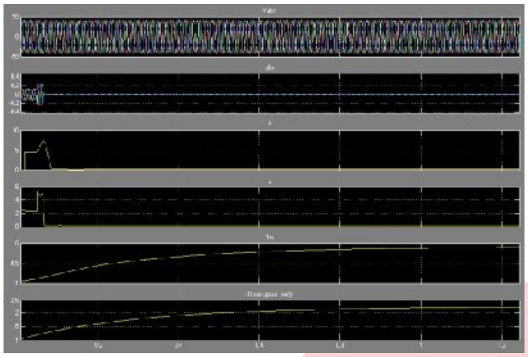

Fig Output of Wind generator

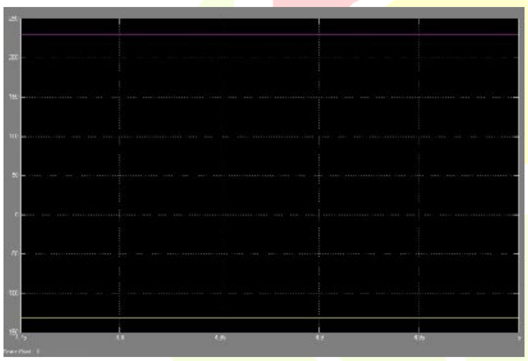

Fig Output of Voltage level in the load

RESULT AND CONCLUSION

In this work, wind power curtailment and energy storage as transmission congestions mitigation measures are analyzed, considering power plants ramp rates. It is found that there is a dynamic interaction that introduces an over cost when slow power plants are re-dispatched. Congestion mitigation measures are compared in terms of congestion probability, line load factor and total energy curtailed. The following behaviour is observed:

- ✓ When using wind curtailment, there are two effects. There is an economic impact on the wind generator, due to the energy curtailed, not sold to the system. Also, there is an over cost on the system due to the re-dispatch.
- ✓ When using ESS in combination with wind curtailment the over cost effect may be reduced, but it cannot be eliminated. As in the previous case, there is an economic impact on the wind generator, and also on the system.

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