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Journal of Electrical Systems and Information Technology xxx (2016) xxx–xxx
www.elsevier.com/locate/jesit

Solution of wind integrated thermal generation system for environmental optimal power flow using hybrid algorithm

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Received 5 February 2015; accepted 16 January 2016

Abstract

Q2 A new evolutionary hybrid algorithm (HA) has been proposed in this work for environmental optimal power flow (EOPF) problem. The EOPF problem has been formulated in a nonlinear constrained multi objective optimization framework. Considering the intermittency of available wind power a cost model of the wind and thermal generation system is developed. Suitably formed objective function considering the operational cost, cost of emission, real power loss and cost of installation of FACTS devices for maintaining a stable voltage in the system has been optimized with HA and compared with particle swarm optimization algorithm (PSOA) to prove its effectiveness. All the simulations are carried out in MATLAB/SIMULINK environment taking IEEE30 bus as the test system.

Keywords: Hybrid algorithm; Wind integration; Optimal power flow; Optimization

1. Introduction

Q3 With gradual degradation in the environmental conditions, power utilities have shifted their focus toward power generation technologies which are non-polluting in nature. In this regard, a grid integrated wind power generation provides an economic and reliable alternative. However, the nature of intermittency of wind flow poses some complex and challenging issues related to the generation scheduling and other operational problems. Owing to the uncertainty of wind flow, accurate estimation of the generated wind power may not be possible. Therefore, a suitable cost component approximating the cost of the under estimation (*UE*) and over estimation (*OE*) of wind power (Jabr and Pal, 2009) compared to the actual availability of the same is considered in the cost of generation (Jabr and Pal, 2009). Authors in Hetzer et al. (2008) have discussed about the additional components of cost which may be used in wind integrated system. Apart from the generation cost, the WECS based on DFIG, poses another problem of managing the system

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Peer review under the responsibility of Electronics Research Institute (ERI).

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jesit.2016.01.004

Please cite this article in press as: Panda, A., Tripathy, M., Solution of wind integrated thermal generation system for environmental optimal power flow using hybrid algorithm. J. Electr. Syst. Inform. Technol. (2016), http://dx.doi.org/10.1016/j.jesit.2016.01.004

reactive power demands. Because, the power electronics switches used in the converters of DFIG have limited current capacities and therefore also have limited reactive power capabilities (Panda and Tripathy, 2014). With ever increasing WECS based on the DFIG units, the OPF demands the above issue to be included in its formulation, so that the system remains voltage secure, particularly during *UE* situations. Therefore, to provide additional reactive power support as a means to prevent the degradation of system voltage during *UE* scenario, weak bus in the network is installed with shunt FACTS devices. In this regards role of shunt FACTS devices like the static VAR compensators (SVC) and the STATCOM have been investigated in Molinas et al. (2008) and Yome and Mithulananthan (2005) for their capabilities in supplying reactive power to the system. Owing to the operational flexibility and better dynamic performance in the system, the STATCOM has been found to be more beneficial compared to the SVC. In Niknam et al. (2011), the authors have demonstrated the application of meta-heuristic algorithm to OPF problem of power system equipped with thermal generating units. Modeling of wind variability and incorporation of wind power into power system issues are presented in Seguro and Lambert (2000) and Shi et al. (2012) respectively.

1.1. EOPF formulation

To account for the intermittency of wind flow and to mitigate the cost of operation during any condition of imbalance between available and utilized wind power, a component of cost could be added to the system generation cost. Moreover, the converters of DFIG have restrictions (Engelhardt et al., 2011) of handling reactive power. Therefore, provision of additional reactive power support at the DFIG and other suitable buses should be there to maintain satisfactory system voltage profile. However, due to the superior functionality of STATCOM as discussed above, it has been installed at the weakest node (Acharjee et al., 2011) in the system. This cost of installation of STATCOM is suitably formulated in the problem of OPF. As thermal generation plant burns carbon intensive fuel, they generate more carbon dioxide at increased levels of operation and cause a threat to environmental security. So considering this aspect, in this work wind Q4 powered units are used as a means of meeting emissions reduction targets by reducing the stress on thermal generating units. The problem is formulated as follows,

Minimize

$$F = F_1 + F_2 + F_3 \tag{1}$$

In the above equation F_1 corresponds to cost of wind-thermal power generation, F_2 corresponds to cost of real power loss, and F_3 denotes the cost associated with carbon emission from thermal power generators in Rs/ton.

The mathematical interpretation of the above components are described as

$$F_1 = \sum_{t}^{N_g} C_t\left(P_{gt}\right) + \sum_{r}^{N_w}\left[C_{wr}\left(P_{wr}\right) + C_{p,wr}\left(P_{wr,\text{av}} - P_{wr}\right) + C_{r,wr}\left(P_{wr} - P_{wr,\text{av}}\right)\right] + C_{\text{VS}} \tag{2}$$

In this expression, notations t and g denote the thermal units and r and w denote the wind units. The first term in F_1 is the cost of thermal power generation, second term is the cost of purchase of wind power from the wind power producer, third term is the cost due to under estimation of available wind power and fourth term is the cost due to over estimation of available wind power. Fifth term represents the installation cost of STATCOM which is used as a means to improve the voltage stability by providing necessary reactive power support to the network. These terms are explained as

$$C_t\left(P_{gt}\right) = a_t P_{gt}^2 + b_t P_{gt} + c_t \tag{3}$$

where a_t, b_t, c_t are the cost coefficients of tth thermal unit and P_{gt} is the power output of tth generator.

$$C_{wr}\left(P_{wr}\right) = d_r P_{wr} \tag{4}$$

Here d_r is the direct cost coefficient of the rth wind generator and P_{wr} is the scheduled power output of rth wind unit. The cost due to under estimation of available wind power may be expressed as

$$\begin{aligned} C_{p,wr}\left(P_{wr,\text{av}} - P_{wr}\right) &= K_{Pr}\left(P_{w\,\text{av}} - P_{wr}\right) \\ &= K_{pr}\int_{P_{wr}}^{P_{ro}} \left(w - P_{wr}\right) f_w(w)\,\mathrm{d}w \end{aligned} \tag{5}$$