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Static economic dispatch incorporating wind farm using Flower pollination algorithm☆

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Summary Renewable energy is one of the clean and cheapest forms of energy which helps in minimizing the carbon foot print. Due to the less environmental impact and economic issues integration of renewable energy sources with the existing network gained attention. In this paper, the impact of wind energy is analysed in a power system network using static economic dispatch (SED). The wind energy is integrated with the existing thermal systems. Here, the generation scheduling is optimized using Flower pollination algorithm (FPA) due to its robustness in solving nonlinear problems. Integration of wind power in the existing system increases the complexity due to its stochastic nature. Weibull distribution function is used for solving the stochastic nature of wind. Scenarios without and with wind power penetration are discussed in detail. The analysis is carried out by considering the losses and installing the wind farm at different locations in the system. The proposed methodology is tested and validated on a standard IEEE 30 bus system.

Introduction

Wind Energy is one of the cleanest and rapid growing renewable energy resource. It is available almost free of cost. The variability and uncertain nature of wind power plants poses challenges in terms of operation and control when they are integrated with the existing grid (Wu et al., 2015). Economic dispatch is generally allocating the loads, optimally on the available generators (Hetzer et al., 2008). Recently Renewable sources are also incorporated in generation dispatch along with thermal generators. For this, suitable modelling of the wind energy sources is a required. Weibull distribution is best suited probability density function for modelling the wind farm output (Jadoun et al., 2015). In the present scenario Meta heuristic techniques are widely used for solving non linear problems like economic dispatch, optimal power flow and unit commitment. These techniques are essential tools for attaining a global best solution. Several methods are implemented on economic dispatch problem by considering the constraints.

In this paper economic dispatch is carried out for combined wind thermal system. Wind farm is modelled using

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weibull distribution and the expected output is output considered as negative demand. Flower pollination algorithm,a recent optimization technique (Yang, 2012) is used to solve this combined economic dispatch problem due to its simplicity and robustness in solving constrained problems. The remaining paper is organised as follows

In Section 2 economic dispatch model for both convectional as well as combined wind thermal system is presented. Section 3 explains the basic steps involved in solving economic dispatch using Flower pollination algorithm. In Section 4 the results obtained using FPA are discussed and the performance of FPA is shown. Finally the conclusions of the proposed method are given.

Problem formulation

Economic dispatch helps to minimise the operating cost of generators participating for supplying the demand. The objective function for cost minimisation is given by

$$F_i(P_i) = \sum_{i=1}^{n} (a_i P_i^2 + b_i P_i + c_i) \quad (1)$$

where a_i, b_i, c_i are the cost coefficients of convectional ith generator

The equality and inequality constraints for the problem are

$$\text{Power balance}: \quad \sum_{i=1}^{m} P_i - P_D - P_L = 0 \quad (2)$$

$$\text{Transmission Loss}: \quad P_L = \sum_{i=1}^{n}\sum_{j=1}^{n} P_i B_{ij} P_j \quad (3)$$

$$\text{Operating Limits}: \quad P_i^{\min} \le Pi \le P_i^{\max} \quad (4)$$

Economic dispatch incorporating wind farm

The probability function for Weibull distribution is given by

$$f_v(V) = \left(\frac{k}{c}\right) \cdot \left(\frac{v}{c}\right)^{(k-1)} \cdot e^{-(v/c)^k} \quad (5)$$

where k and c are the shape factor and scale factor.

The output power for a particular wind speed in given range is given by

$$P_{wr} = \begin{cases} 0 & v < v_{\text{in}} \quad \text{or} \quad v > v_{\text{out}} \\ (a * v^3 + b * \mathrm{P}_r) & v_{\text{in}} \le v \le v_r \\ \mathrm{P}_r & v_r \le v \le v_{\text{out}} \end{cases} \quad (6)$$

where $a = \mathrm{P}_r/(v_r^3 - v_{\text{in}}^3)$, $b = v_{\text{in}}^3/(v_r^3 - v_{\text{in}}^3)$ are the constants related to nominal wind speed

The estimated power output for a specific time interval is given by

$$P_{we} = P_w \times f_v(V) \quad (7)$$

The cost paid for wind power producer is

$$C_j(P_{jwe}) = d_j(P_{jwe}) \quad (8)$$

The updated power balance equation is

$$\sum_{i=1}^{m} P_i + \sum_{j=1}^{n} P_{jwe} - P_D - P_L = 0 \quad (9)$$

Flower pollination algorithm for solving economic dispatch

Flower pollination algorithm is a recent optimization technique developed by Yang (2012). It is developed based on the phenomenon of pollination of flowers. The steps for solving economic dispatch using Flower pollination algorithm are as follows

Step1. Read the system data and initialise the parameters i.e. *Population of Flowers and Probability switch*.
Step2. Run the load flow and obtain the B-coefficients
Step3. **while** A specified number of evaluations has not been reached **do**.
Step4. Determine the optimal generation by each generator and each flower corresponds to occupy the candidate node location.
Step5. *if rand* < *P*, Draw a step vector which obeys Levy distribution. Do global pollination and evaluate latest solution.
Step6. *else* Do local pollination and evaluate latest solution, *end*.
Step7. Update the new solution if it is better than the previous solution.
Step8. **end while**
Step9. Give the statistics of the solved objective function.

Results and discussion

Economic dispatch is carried out using Flower pollination algorithm for the cases with and without incorporating wind energy. The proposed methodology is implemented on standard IEEE 30 bus system (Modiri-Delshad and Rahim, 2015) and compared with few available methods in literature. Two wind farms of 30 MW capacity, with shape factors k = 1, 2 and scale factor of 15 are chosen for the analysis. The cut-in speed, cut-out speed and rated speed for the considered wind turbine are 3 m/s, 30 m/s and 12 m/s, respectively. The feed in tariffs for wind farms are considered as 1 $/h and 1.25 $/h, respectively. The output power from wind farms is calculated using the Weibull distribution function and is incorporated as negative demand in the test system. The probability distribution function for various wind speeds is given in Fig. 1.

Initially, ED is carried out only with thermal generators and the results are furnished in Table 1. The obtained results are compared with few recent algorithms and is observed that the cost is minimum and the losses are within the acceptable level. The cpu time required for converging 100 iterations is just 0.492 s. The convergence curve is shown in Fig. 2.

In Table 2, ED is carried out by considering thermal as well as wind energy systems simultaneously. From the table it is understood that the cost and losses are significantly reduced with the integration of wind power in to the system.

Table 1 Comparison of dispatch for convectional test system.

Parameter	DE (Yang, 2012)	MBFA (Perez-Guerrero and Cedeno-Maldonado, 2005)	BSA (Hota et al., 2010)	FPA
P1 (MW)	12.1	13.19	12.097	12.1602
P2 (MW)	28.6	30.67	28.6317	15.0908
P3 (MW)	58.4	57.59	58.3554	60.3645
P4 (MW)	99.3	95.35	99.2853	97.2231
P5 (MW)	52.4	53.64	52.3964	82.7103
P6 (MW)	35.2	35.51	35.1903	18.1675
PT (MW)	286	285.95	285.9561	285.7164
PL (MW)	2.6	2.55	2.5562	2.3165
TOC ($/h)	606	606.17	605.9984	605.4552

Table 2 Economic dispatch for wind thermal system.

P1 (MW)	P2 (MW)	P3 (MW)	P4 (MW)	P5 (MW)	P6 (MW)	PW1 (MW)	PW2 (MW)	PL (MW)	TOC ($/h)
7.1318	26.06	51.6741	92.617	44.5246	29.7264	12.5451	20.5451	1.8598	567.4181

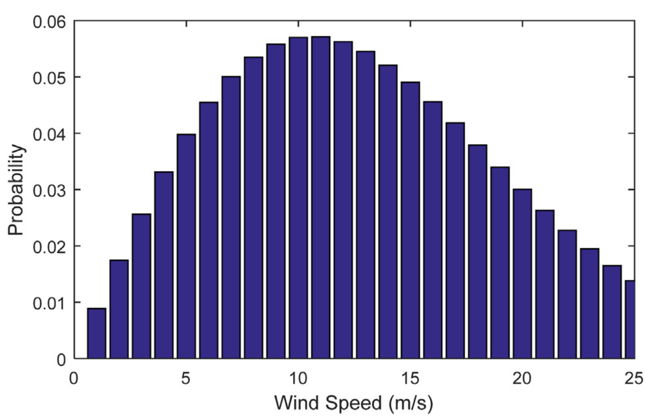

Figure 1 Wind speed probability distribution function for $k = 2$.

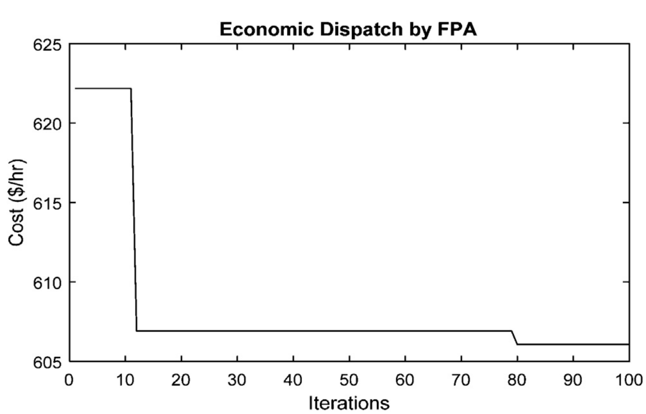

Figure 2 Convergence characteristics of FPA for cost optimization.

Conclusion

Static Economic dispatch for wind thermal systems is solved using Flower pollination algorithm. Scenarios without and wind energy are solved on IEEE 30 bus system and the results are compared with few other methods. The results clearly indicate that proper location of wind farms and suitable forecast methods helps in maximum extraction of wind power. It is observed that increased penetration of renewable energy sources benefits the power producers and also helps in minimising in carbon footprint.

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