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Energy Management of Reconfigurable Distribution System in Presence of Wind Turbines by Considering Several Kinds of Demands

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Abstract

Utilizing the distributed generation (DG) units in a power system has positive impacts such as reduction of active and reactive power losses, reduction of load curtailment, increasing the system reliability, and reducing the need for installing new power plants. Wind turbine (WT) is a type of DG. Employing the demand side-management in the residential, industrial, and commercial loads could highlight the role of the consumers in managing the total power, and increase the efficiency of the system. In this work, the impacts of utilizing WTs in improving the technical constraints of the reconfigurable distribution system is evaluated. The Monte Carlo-based power flow equation is implemented in order to present the scheduling problem. The simulation is carried out on the IEEE 33 bus reconfigurable distribution system.

Keywords: *Wind Turbine, Monte Carlo, Demand Response, Micro-grid.*

1. Introduction

In the previous years, the concept of micro-grid has been introduced as a practical way for a better managing of the power network. Micro-grids with a two-way communication between the suppliers and the consumers increase the flexibility and reliability of the electrical power system. Moreover, the local energy sources decrease the dependence of the micro-grid on the electrical energy of the upstream network [1]. One of the main advantages of the micro-grid is the ability of properly applying the demand side-management programs to this type of network. The demand side-management programs are the modification in the demanded side-energy consumption of the power network like micro-grid in order to improve the efficiency and operations in the overall electrical energy system [2].

The local energy resources of the micro-grid have a high effect on its efficiency. The renewable distributed generation units including the wind turbine and the photovoltaic panel are more attractive than the non-renewable ones in the micro-grid due to their green technology. The produced power of renewable units is of low cost, has no pollutant emission, and has an easy accessibility [3]. Although the tendency to utilize the renewable distributed generation units has been increased daily, one of their main disadvantages is the issue of uncertainty in their production of electrical power. The battery or electrical energy storage system is one of the practical methods to resolve this problem. Utilizing the battery beside the renewable energy sources decrease the dependence of the micro-grid on the upstream grid as well as reducing the pollutant gasses. Indeed, the extra produced power of the distributed generation units can be stored in the battery when the demand is low and the stored energy can be used when the generated power of the renewable units is lower than the load of the micro-grid [4]. Of course, the demand response programs can be applied to the micro-grid for better matching the production pattern and load one. In the demand response program, the incentive of the consumers to control their demand is increased using variable electricity prices. Although the demand response is a new concept for the residential consumers, the industrial and commercial units always manage their load profile due to the economic issues [5].

In the previous years, the concepts of the micro-grid, demand response, and local energy sources have been investigated by some researchers. For example, in Ref [6], the simultaneous capacity optimization of the distributed generation units and the electrical storage system has been solved by a sequential quadratic programming method. During the problem solution, the amount of total load curtailment and purchased energy cost has been reduced. In another study, the researchers have evaluated the reliability performance of micro-grids by considering the uncertainties in both the generation and consumption sides [7]. The authors of this article studied the multi-objective optimization, improving the network stability and reducing the cost simultaneously.

According to the previous research works, it can be said that the multi-objective optimization of both the supplier and consumer sides of the smart micro-grid in the presence of renewable technologies is the topic that has been less studied. For this reason, in this work, the multi-objective scheduling of the local energy sources of a micro-grid is studied in the presence of the demand response programs. The innovative contributions of the proposed method can be highlighted as follow:

- Multi-objective managing in the generation and demand sides of the micro-grid.
- Considering the operational cost and amount of ambient pollution in problem formulation.
- Utilizing the wind turbine (WT)-distributed generation units to supplying green energy in the micro-grid. Moreover, using the battery to increase the stability of the produced power.
- Utilizing a combination of the multi-objective ant lion optimizer and the fuzzy decision-making method to find the best demand side-management program.

Thus in this article, a multi-objective optimization method is proposed for optimally operating the wind turbine, and battery of a micro-grid considering the demand response programs. The profit of the operator of the micro-grid from selling the electricity and the produced pollutant gasses of all energy sources are the considered objective functions of the demand side-management problem. The multi-objective ant lion optimizer is used in order to optimize the indices of the micro-grid and create the optimal Pareto-front. After applying the multi-objective optimization algorithm, the fuzzy method is used to select the best particle equal to the optimal operational schedule of the energy sources and the load pattern of the micro-grid.

2. Problem formulation

Profit rate of micro-grid: Economic aspects should be considered in all projects of the power network. For this reason, the profit rate of micro-grid is considered as the economic index of the optimization. This index shows the daily profit of the micro-grid from selling the electricity to the consumers, and also the upstream grid. The profit rate of the micro-grid is calculated by equation 1. Equation 2 is used in order to calculate the revenue from the exchanged power of the microgrid. The revenue of the sold extra produced power of the renewable energy units to the upstream grid is presented in equation 3. The cost of purchased energy from the upstream gird is calculated by equation 4. Although the wind turbine and the photovoltaic panel have no cost for producing electricity, the combined cost including the installation, maintenance, and operation costs is considered in the proposed method. Thus the cost of the produced power of the renewable energy units is calculated by equation 5. Equation 6 is used to calculate the cost of saved energy into the battery. The storage system belongs to the distribution company of the micro-grid; therefore, discharging of it does not have an extra cost for the micro-grid.

$$\Pr of_R = P_{MG} + P_G - C_G - C_{REU} - C_B \tag{1}$$

$$P_{MG} = \sum\sum P_{ij}^{D} \times \Pr_j^{M} \tag{2}$$

$$P_G = \sum P_j^{G} \times \Pr_j^{G} \tag{3}$$

$$C_G = \sum P_j^{G\_MG} \times \Pr_j^{G\_MG} \tag{4}$$

$$C_{REU} = \sum_{s=1}^{H}\sum_{i=1}^{n_H}\sum_{j=1}^{H} Ps_{i,j}^{REU} \times \Pr_s^{REU} \tag{5}$$

$$C_B = \sum_{i=1}^{nH}\sum_{j=1}^{H} PB_{i,j}^{ch} \times \Pr_j^{G-MG} \tag{6}$$

Pollution rate of micro-grid: The environmental condition of the world gets worse by the day due to the high consumption pattern of the non-renewable energies. For this reason, the pollution rate of the micro-grid is considered to select the optimal unit commitment. The produced amount of pollutant gases of various energy sources including the renewable units, the battery and upstream grid is calculated in this index. Mathematically, the pollution rate of the micro-grid can be calculated by equation 7.

$$Poll_r = \sum_{h=1}^{h}\sum_{i=1}^{n_{unit}}\sum_{j=1}^{n_G} P_{unit\_i}(h) \times PG_{ij} \tag{7}$$

3. Optimization algorithm

Firstly, the multi-objective ant lion optimization (MOALO) algorithm is utilized in order to optimize the economic-environmental objective functions and create the optimal Pareto front. This algorithm, which is mimicked by the hunting mechanism of ant lions and the interaction of their favorite prey and ants, approximates the optimal solutions for the optimization problems by employing a set of random particles. This set is improved based on the principles inspired from the interaction between the ant lions and the ants. The MOALO algorithm is proficient, has a fast converging rate, and is effectual to handle the composite non-linear constraint problems, and also has few controlling parameters. Due to these advantages, it has been selected as a preferred method in order to solve the complicated problems like the proposed unit commitment in the micro-grid [8].

After the MOALO algorithm, the fuzzy method is applied to find the best solution between the non-dominated results. This selecting method chooses the optimal particle based on the membership value of the particles so that each particle that has the highest value is selected as the best compromise solution. The normalized membership value of the particles is calculated by equation 8 [9].

$$\mu^k = \frac{\sum_{i=1}^{NO} \mu_i^k}{\sum_{k=1}^{NK}\sum_{i=1}^{NO} \mu_i^k} \tag{8}$$

$$\mu^k = \begin{cases} 1 & F_i^k \le F_i^{\min} \\ \dfrac{F_i^{\max} - F_i^k}{F_i^{\max} - F_i^{\min}} & F_i^{\min} \le F_i^k \le F_i^{\max} \\ 0 & F_i^{\max} \le F_i^k \end{cases} \tag{9}$$

3.1. Monte Carlo (MC)-based power flow

Newton Raphson is one of the traditional power flow calculating methods. According to this method, the active and reactive power of each bus is calculated as follows:

$$P_i = \sum_{L=1}^{TN} |V_i||V_l||G_{il}\,\mathrm{Cos}(\theta_i - \theta l) + B_{il}\sin(\theta_i - \theta_r)| \tag{10}$$

$$Q_i = \sum |V_i||V_l||G_{il}\sin(\theta_i - \theta_l) - B_{il}\cos(\theta_i - \theta_r)| \tag{11}$$

In this section, the proposed MC method is introduced to show the random behavior of the power generated by WT. To this aim, the WT nominal rating is multiplied by a parameter U (uniformly distributed random number sequence generated between [0-1]), as follows:

$$P_{Gi} = P_{Ri} \times U \tag{12}$$

The MC implementing in calculating the current voltage and power loss of branches is defined as follows:

$$P_{Gi} = \frac{1}{NE}\sum_{j=1}^{NE} P_{Gi}(j) \tag{13}$$

$$\overline{I^2_i} = \frac{1}{NE}\sum_{j=1}^{NE} I^2_i(j) \tag{14}$$

$$\overline{V}_i = \frac{1}{NE}\sum_{j=1}^{NE} V_i(j) \tag{15}$$

$$\overline{P_{Lossil}} = \frac{1}{NE}\sum_{j=1}^{NE} (P_{Lossil}(j) - P_{Lossi}(j)) \tag{16}$$

4. Results

The amount of bought power from the upstream grid is 45% of the total demand by employing the demand response. After applying the demand response programs, the main grid participation power becomes almost 41% of the total demand. Therefore, the dependence of the micro-grid on the power of the upstream grid is reduced by about 60% by utilizing the proposed operational schedule of energy sources and demand response programs. WT also has a useful operational schedule so that its role in providing all the demands (residential, commercial, and industrial) is illustrated in figure 1. Figure 2 shows the converged power of WT. Figure 3 illustrates the random power of WT. All the solutions that are received to form the Pareto optimal front are shown in figure 4. Table 1 gives the total profits in the WT scheduling program. Table 2 gives the optimal scheduling solution of WT.

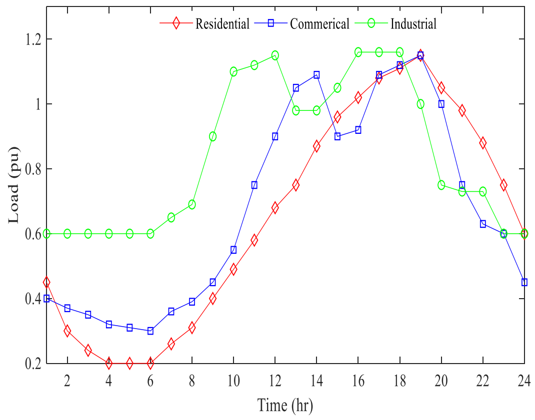

Figure 1. Daily load curve (industrial-commercial-residential demand).

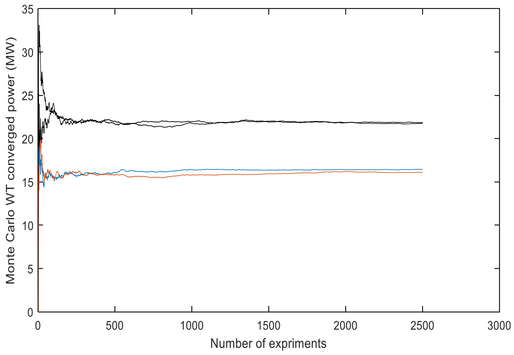

Figure 2. Converged power of WT.

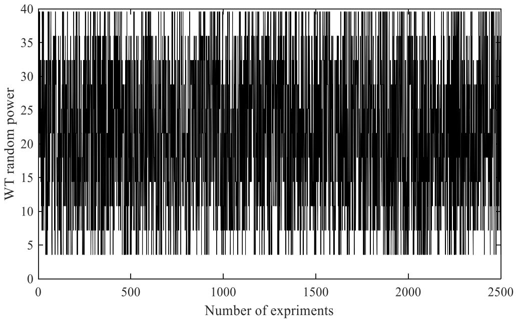

Figure 3. Random power of WT.

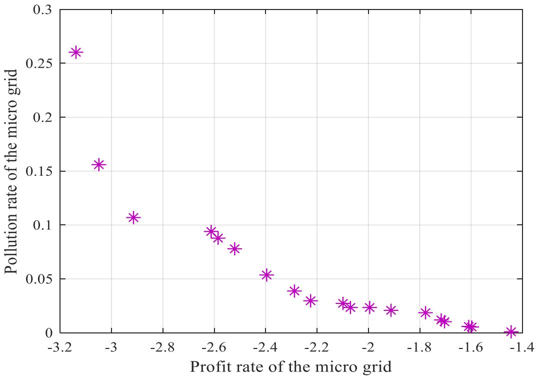

Figure 4. Pareto optimal front.

Table 1. Profits in Pareto optimal front solution.

	(*106 $)				
Solution	**Profit in 106 $**		**Satisfaction**		
#	DNO	DGO	$\mu^{BDNO_k(X_n)}$	$\mu^{BDGO_k^{(X_n)}}$	β
1	1.703	0.248	1	0.101	5
4	1.702	0.286	0.997	0.15	0.15
5	1.692	0.326	0.976	0.20	0.20
6	1.681	0.366	0.952	0.25	0.25
7	1.667	0.405	0.922	0.30	0.30
8	1.652	0.445	0.889	0.35	0.35
9	1.634	0.484	0.851	0.40	0.40
10	1.614	0.525	0.809	0.45	0.45

Table 2. Optimal scheduling Solution of WT.

Value	**System features**	
1	**Maximum voltage (pu)**	
0.9622	**Minimum voltage (pu)**	
12	**Bus**	**Wind turbine**
1 (450 kw)	**Number**	
2	**Number**	
1	**Number**	
98.29	**Power loss (KW)**	
12	**Purchased power from upstream grid (MW)**	
84	**Amount of sold energy to grid (MW)**	

5. Acknowledgment

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6. References

[1] Baboli, Payam Teimourzadeh et al. Two-stage Condition-based Maintenance Model of Wind Turbine: from Diagnosis to Prognosis. In 2020 IEEE International Smart Cities Conference (ISC2). IEEE. pp. 1-6.

[2] Hosseinnia, Hamed; TOUSI, Behrouz. Optimal operation of DG-based micro-grid (MG) by considering demand response program (DRP). Electric Power Systems Research, 2019, 167: 252-260.

[3] Hosseinnia, Hamed; Modarresi, Javad; Nazarpour, Daryoush. Optimal eco-emission scheduling of distribution network operator and distributed generator owner under employing demand response program. Energy, 2020, 191: 116553.

[4] Hosseinnia, Hamed; Nazarpour, Daryoush; Talavat, Vahid. Multi-objective optimization framework for optimal planning of the micro-grid (MG) under employing demand response program (DRP). Journal of Ambient Intelligence and Humanized Computing, 2019, 10.7: 2709-2730.

[5] Hosseinnia, Hamed; Nazarpour, Daryoush; Talavat, Vahid. Benefit maximization of demand side management operator (DSMO) and private investor in a distribution network. Sustainable cities and society, 2018, 40: 625-637.

[6] Hosseinnia, Hamed; Farsadi, Murteza. Effect of reconfiguration and capacitor placement on power loss reduction and voltage profile improvement. Transactions on electrical and electronic materials, 2017, 18.6: 345-349.

[7] Zhou, Quan et al. Distributed control and communication strategies in networked micro-grids. IEEE Communications Surveys and Tutorials, 2020, 22.4: 2586-2633.

[8] Zhou, Quan et al. Privacy-preserving distributed control strategy for optimal economic operation in islanded reconfigurable micro-grids. IEEE Transactions on Power Systems, 2020, 35.5: 3847-3856.

[9] Teimourzadeh Baboli, Payam et al. Integration Reinforcement of Renewable Energy Resources and PHEVs through Hybrid AC-DC Local Network. The Modares Journal of Electrical Engineering, 2012, 12.2: 42-51.