Optimization of Green Energy Resources With Considering These Sources as Dependent or Independent Sectors

Engineering

Hossein Nasiraghdam | Department of Electrical Engineering, College of Engineering, Ahar Branch, Islamic Azad University, Ahar, Iran.

Morteza Nasiraghdam | Department of Computer Engineering, College of Engineering, Ahar Branch, Islamic Azad University, Ahar, Iran.

M. Mohammadi | Department of Electrical Engineering, College of Engineering, Borujerd Branch, Islamic Azad University, Borujerd, Iran.

ABSTRACT   In this study an optimized operation and management of microgrid in distribution systems with multiple distributed generation (DG) units under two different market policies are presented. At the first, it is supposed that DG is under ownership of Disco and in second scenario it is assumed that beside the micro grid, DG is a private sector under market too.

1. Introduction

The interest in microgrid increases due to its potential benefits to provide reliable, secure, efficient and sustainable electricity from renewable energy sources. An optimum dispatch strategy using set points for a photovoltaic (PV)–diesel-battery hybrid power system is investigated in [1]. In [2] the Economic evaluation and optimization of a photovoltaic–fuel cell–batteries hybrid system for use in the Brazilian Amazon was investigated. It outlines the technical and costs characteristics of a pilot project set up in an environmental protection area, located in the state of Tocantins, Brazil. Sizing optimization of a stand-alone street lighting system powered by a hybrid system using fuel cell, PV and battery was investigated by [3]. Solar home systems are typically used for providing basic electricity services to rural households that are not connected to electric grid. In most researches, the economical studies of power system including independent DGs have been implemented [4], but in not of them, the economical studies of each power sources inside microgrid have not been considered in detail and a complete study about the different costs for microgrid and distribution system have not been presented. In the last research, the optimization of hybrid renewable energy resources including PV/WT/Battery has been investigated as grid connected by [5]. The new idea was investigated by this author, was considering distributed generators as another independent private sector in power market beside the microgrid. In the other words, they investigated the optimization of micro grid and DG and Disco as three independent power producers (IPPs) under pool electricity market. But in this study, DG is not considered as independent private sector, rather DG is considered under ownership of Disco and therefore the pool power market analyzed in this paper includes two IPPs i.e. Disco and microgrid. The optimization procedure is implemented based on minimizing total cost of market and finally in order to validate the optimization result a comparison with similar works has been carried out.

2. Micro Grid (Hybrid solar & wind energy resources) structure

The micro grid in this paper is a hybrid renewable energy sources, includes photovoltaic, wind turbine and battery bank as shown in Fig.1.
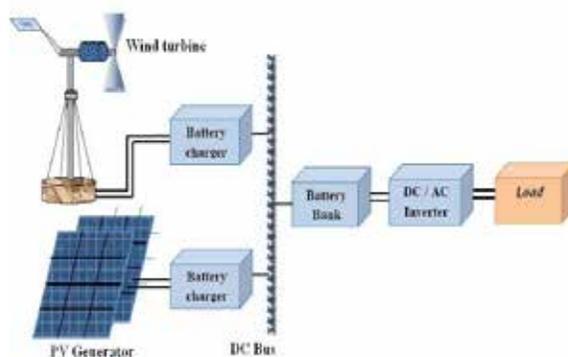
Fig.1.Micro grid structure based on hybrid renewable energy sources

The PV and WT power output depends on climatic conditions. In this paper, a distributed power generation system based on hybrid PV/wind turbine/battery for providing part of active and reactive powers to the, which is connected to the local grid is presented. For loads beyond the maximum capacity of the hybrid power system and inverter, the main grid supplies the rest of the local power demand. This helps to relieve transmission line congestion problem by producing the most of the local demand locally.

3. Distributed Generation (DGs) as independent or dependent

In this study, a grid-connected micro grid in presence of distributed generations in distribution network is considered and optimal operation and sizing of micro grid is analyzed. In this study two cases are investigated. At the first it is supposed that DGs are a part of Disco under its ownership, so with this assumption, the all benefits and costs of installing DGs belong to Disco. Therefore in this state, the pool market consists of two independent sectors, Disco and micro grid. So under pool market, the microgrid and Disco are competing to meet demand power.

The objective function considered in this case study is based on weighting method and includes Disco costs and micro grid costs.

In another case study it is supposed that DGs is an independent private sector and it is not a part of Disco i.e. it is not under ownership of Disco.

In order to better understand of two case studies considered in this paper, the schematic of two points of view to power market in presence of Disco, micro grid and distributed generators are indicated in figures 3.a and 3.b.

As shown in Fig.2 pre installed DGs are considered as an independent private sector and as an independent power producer (IPP) under pool power market. Fig.3 shows the pre installed DGs as a non-independent power producer under ownership of Disco. With this assumption, three independent sector i.e. microgrid , DGs and Disco under pool market are competing for supplying demand power. In this case, all of benefits and costs of DGs don't belong to Disco and all of revenue and costs of DGs belongs to itself and so DGs based on pool power market rules in competition with other power sellers i.e. Disco and micro grid is competing for supplying demand power such a way based on considered objective function, minimum total cost could be obtained.

The objective function considered in this case study is based on weighting method and includes cost of Disco, distributed generation units and micro grid.
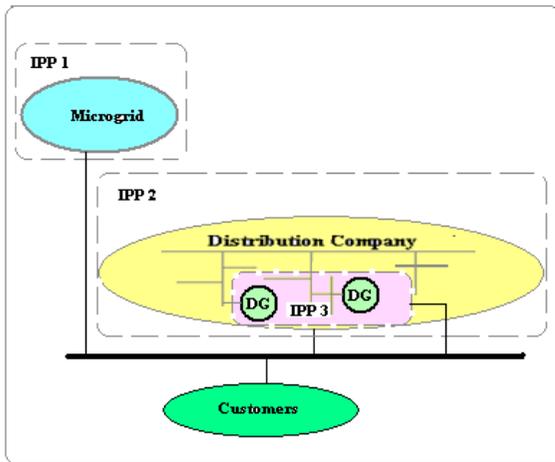

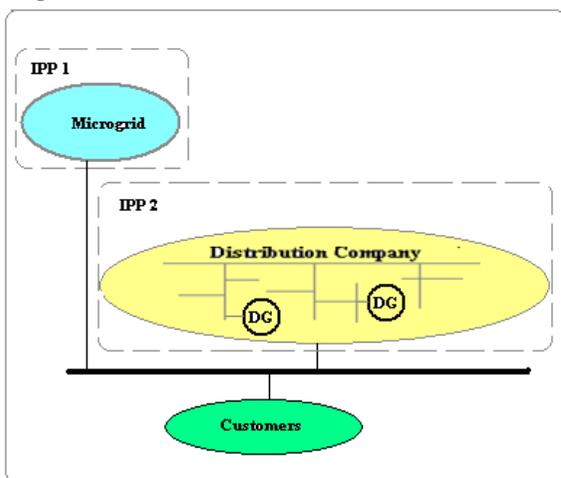**Fig.2. DG as an independent power producer beside of Micro grid and Disco**

Fig.3 DG under ownership of Disco

4. Costs of Systems
In this section, all of the costs of Disco and micro grid are presented.

5.1. Costs of Disco
The cost function for Disco can be determined by the following equation [6]:

$$C_{DISCO} = C_F + C_{S-M\&O} + C_{Buy} + C_{DG} \qquad 1$$

Where, the first term is upgrading costs the network feeders and expressed as:

$$C_F = \sum_{i=1}^{TN} \sum_{j=1}^{M} C_{ij}\sigma_{ij} \qquad 2$$

The second term is maintenance costs as follows [4]:

$$C_{S-M\&O} = \sum_{i=1}^{TN} \sum_{u=1}^{M} C_{i,u}\sigma_{i,u} + 8760\sum_{i=1}^{T}\beta(\sum_{i=1}^{TN}\sum_{u=1}^{TUi} C_u.P_{i,u}) \qquad 3$$

The third term is buying electricity cost from main grid and from micro-grid as follows:

$$C_{Buy} = \sum_{k=1}^{T} P_{k,buy}^{e,UP}\rho_{k,buy}^{e,UP} + \sum_{k=1}^{T} P_{k,buy}^{e,MG}\rho_{k,buy}^{e,MG} \qquad 4$$

The last term is corresponding DG costs utilization by Disco due to its ownership and it is presented as follows:

$$C_{DG} = C_{inv} + C_{r\&m} + C_{P(DG)} \qquad 5$$

The first term indicates the investment cost and installation cost of DG that is spent by Disco. In this study it is supposed that two DG units from kind of micro turbines are installed in two points of system and optimal their size will be calculated from optimization. The second term is the repair and maintenance cost and expressed by the following equation [2]:

$$C_{r\&m} = 8760\sum_{i=}^{T}\beta\sum_{i=1}^{M}(C_{r\&m}.Pf.S_{DGi}) \qquad 6$$

The third term is the production cost, considering fuel cost. The candidate DG is considered in this study is micro turbine. The models of micro turbines are similar to those of fuel cells

The fuel cost of micro turbine is formulated as follows [3]:

$$C_{MT} = C_{nl}\sum_{k}\frac{P_k}{\eta_{lk}} \qquad 7$$

5.2. Costs of Micro-Grid:
The cost function for microgrid can be determined by the following equation:

$$C_{MG} = C_{P(MG)} + C_{OM} + C_{rep,der} + C_{rep,bat} + C_{bw} \qquad 8$$

The first term is generation cost of PV and FC as follows:

$$C_{P(MG)} = \sum_{i=1}^{N_{PV}} C_{PV,i} + \sum_{i=1}^{N_{WT}} C_{WT,i} \qquad 9$$

The second term of (21) is operating and maintenance costs and is assumed to be proportional to the produced power, for unit i, P_i, as follows [5]:

$$C_{OM} = \sum_{i=1}^{N} K_{OM,i} \times P_i \qquad 10$$

The third term of (21) is the replacement cost of DER used in microgrid at the end of its lifetime and calculated by following equation:

$$C_{rep,der} = \sum_{z=PV,WT}\left(\sum_{i=1}^{N(z)}(A_{repi} * P_i + B_{repi})\right) \qquad 11$$

The forth term of (21) is the replacement cost of the battery in microgrid as follows:

$$C_{rep,bat} = A_{rep,bat} \times N_{bat} + B_{rep,bat} \qquad 12$$

The last term of (21) is the battery wear cost.

5. Overall Cost Function

With considering DG as public private sector i.e. considering it as a part of distribution system facilities under ownership of Disco, the cost function is presented, as follows:

Minimize:

$$CTM = \omega_1 \times C_{DISCO} + \omega_2 \times C_{MG} \qquad 13$$

With

$$0 \leq w_i \leq 1 \quad and \quad \sum_{i=1}^{2} w_i = 1 \qquad 14$$

Where, CTM is the Total Cost of Market. It includes the total costs of Disco plus the total cost of micro grid. In this case, cost of Disco is equal to conventional cost of Disco plus the cost of installed DGs in distribution system under Disco ownership. In fact, the main purpose in this case study is minimizing the costs of micro grid and Disco. Another point of view to market is considering a structure for distribution system including micro grid and multiple DG units as two independent private sectors. In this case the cost function is presented, as follows:

Minimize:

$$TCM = \omega_1 \times C_{DISCO} + \omega_2 \times C_{DG} + \omega_3 \times C_{MG} \qquad 15$$
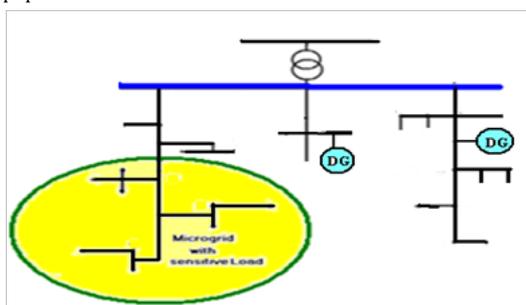
With

$$0 \leq w_i \leq 1 \quad and \quad \sum_{i=1}^{3} w_i = 1 \qquad 16$$

The Disco provides the necessary power of customers from the micro grid and DG units. In fact, the main purpose in current case study is minimizing the costs of DG units, micro grid and Disco.

In this paper under these two case studies, the optimal sizing of micro grid including photovoltaic cells, wind turbines and batteries are presented and disused.

6. Simulation Results

In this section, the simulation results are presented. A typical LV network, shown in Fig.4 and proposed in [7] is used in this paper.

Fig.4. Case study LV network

When DGs are under ownership of Disco, therefore they exchange power with customer and other power participant based on Disco prices and they don't have allow to submit any pay as bid. But when considering them as independent power producer i.e. as an IPP, they can offer their selling power price that Table 1 list this prices. As listed, for each DG units, two prices are considered as off-peak and peak periods.

Table 1.Different periods for DG operation as an IPP

Type	CDGmax	CDGmin_offpeak	CDG_onpeak
Price($/kWh)	0.12	0.06	0.065

Since for two case studies considered in this research, micro grid is an IPP, so the corresponding value of power price for micro grid is listed in Table 2.

For simulations, the annual peak power is considered as the main benchmark. So, the demanded power is considered according to the different pattern loads as given in Table 3.

Table 2.Different periods for micro grid operation as an IPP

Type	CMGmax	CMGmin_offpeak	CMG_onpeak
Price($/kWh)	0.20	0.00	0.075

Table 3.Different pattern load connected to distribution system

Load Profile	Low	Mead	Peak	Super Peak
Demanded power (kW)	1800	2000	2200	2400
Load Duration	6	10	6	2

Also the different load pattern of local load in micro grid is presented as Table 4. It is clear that micro grid is first responsible to meet the local load that is sensitive and emergency load, after it provided by micro grid; micro grid can sells its additional power to Disco for supplying main load connected to distribution system.

Table 4.Different pattern load of local load in micro grid

Load Profile	Low	Peak
Demanded power (kW)	400	800
Load Duration	8	16

The flowchart of developed software based PSO approach is shown in Fig.5.
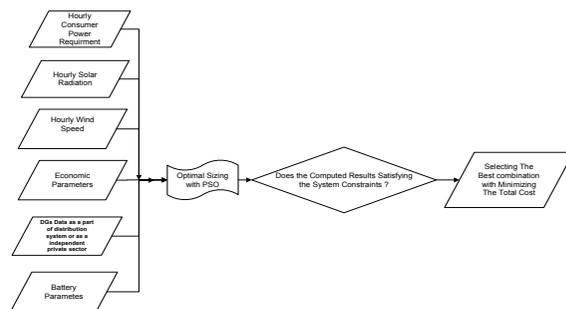
Fig.5.The block diagram of optimization problem

Table 5 lists the simulation results of micro grid sizing for case study 1, that DGs is under ownership of Disco.

Table 6 lists the simulation results of micro grid sizing for case study 2, that DGs is an independent power producer.

Table 5.optimization results while considering DG as public sector under ownership of Disco

Cost [$]	Nbatt	Npv	Nwind
199110	217	15	9
205080	217	15	9
258740	217	15	10
326460	217	17	10
323440	217	17	10
326434	217	17	10

Table 6.optimization results while considering DG as independent private sector and as an IPP

Cost [$]	Nbatt	Npv	Nwind
196420	210	12	8
202310	210	12	8
203290	210	12	8
207040	210	13	10
215880	210	13	10
226271	210	13	10

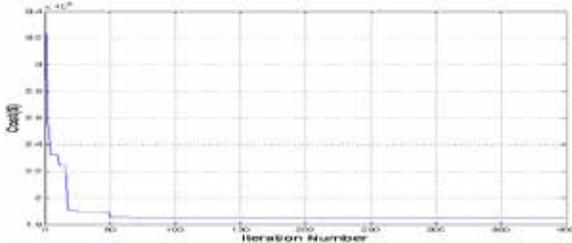The variation of the cost value versus the iteration number is shown in Figs.6 and 7 for case study 1 and 2.

Fig.6.Cost value versus iteration number while considering DG as dependent sector and under ownership of Disco

Fig.7.Cost value versus iteration number while considering DG as independent private sector

The main goal of the proposed algorithm is the calculation of the best capacity of DG units and micro grid. Moreover, the best price for bidding the power of DG and micro grid could be calculated. After minimizing the total cost, the following results are saved and given in Table 7.

Table 7.Optimal cost for MG and DG and Disco

Case	Cost_MG	Cost_DG	Cost_Disco	Cost_total
DG as sector under ownership of Disco	326434	----	274344	363432
DG as private sector	226271	34578$	256428	296818

From the results of Table 8, it is clear that considering DG public sector under ownership of Disco in power market the cost of power production by Disco increases and this leads to increase of total cost of system. In this case as listed by Table 9, the micro grid cost is deceased.

Table 8.Optimal selling powers and prices of DG units during on-peak and off-peak

Case	P_DG(kW) on-peak	P_DG(kW) off-peak	C_DG on-peak ($/kWh)	C_DG off-peak ($/kWh)
DG as sector under ownership of Disco	--------	--------	---------	-------
DG as private sector	1710	1593	0.065	0.06

The optimal powers for total DG units and microgrid and Disco during peak and off-peak conditions are shown in the Tables 9, 10.

Table 9.Optimal selling powers and prices of micro grid units during on-peak and off-peak

Case	P_MG(kW) on-peak	P_MG(kW) off-peak	C_MG on-peak ($/kWh)	C_MG off-peak ($/kWh)
DG as sector under ownership of Disco	780.5	805.1	0.065	0.06
DG as private sector	770.6	790.7	0.060	0.055

Table 10.Optimal selling powers and prices of Disco during on-peak and off-peak

Case	P_Disco(kW) on-peak	P_ Disco (kW) off-peak	C_ Disco on-peak ($/kWh)	C_ Disco off-peak ($/kWh)
DG as sector under ownership of Disco	680.5	705.1	0.075	0.06
DG as private sector	870.6	520.7	0.060	0.07

7. Conclusion

This paper deals with the economical evaluation of a typical microgrid participating in a market. An optimized design of microgrid includes various sources like, photovoltaic array, wind turbine and battery bank based on PSO approach has been presented. For this approach, economic aspects such as interest rate, inflation, capital recovery factor, sinking found factor have been expressed for each power sources, and then an objective function including all system costs, has been clarified. The effect of how considering pre-installed DG in distribution system as public sector i.e. under ownership of Disco or as independent private sector on optimizing micro grid has been analyzed and discussed. The optimization algorithm has been applied to a typical LV network under pool market.

REFERENCE

[1] S.Colle et al. 2004, Economic evaluation and optimization of hybrid diesel/photovoltaic systems integrated to utility grids, Solar Energy, 76,295–299. | [2] Ashari, M., Nayar, C.V., 1999, An optimum dispatch strategy using set points for a photovoltaic (PV)–diesel-battery hybrid power system, Solar Energy 66 (1), 1–9. | [3] M.A. Elhadidy, S.M.Shaahid, 2000, Parametric study of hybrid (wind +solar +diesel) power generating system , Renewable Energy, 21,129-139. | [4] Orhan Ekren , Banu Y. Ekren, 2010,Size optimization of a PV/wind hybrid energy conversion system with battery storage using simulated annealing, Applied Energy ,87, 592–598. | [5] K. Karakoulidis, and et.al, 2011, Techno-economic analysis of a stand-alone hybrid photovoltaic-dieselebattery-fuel cell power system, Renewable Energy, 36, 2238-2244. | [6] J.K. Kaldellis and et.al, 2009, Cost benefit analysis of a photovoltaic-energy storage electrification solution for remote islands, Renewable Energy, 34, 1299–1311 | [7] Louy Qoaider and Dieter Steinbrecht, 2010, Photovoltaic systems: A cost competitive option to supply energy to off-grid agricultural communities in arid regions, Applied Energy, 87, 427–435. |