Research Journal of Applied Sciences, Engineering and Technology 4(3): 145-151, 2012
ISSN: 2040-7467

Submitted: July 26, 2011 Accepted: December 28, 2011 Published: February 01, 2012

Multiobjective Optimization of DGs with Considering Power Loss Reduction with Genetic Algorithm (GA)

Mohammad Mohammadi
Department of Electrical Engineering, Borujerd Branch, Islamic Azad University, Borujerd, Iran

Abstract: One of the remarkable phenomena in power systems is the appearance of Distributed Generation (DGs). DGs may reduce the power loss in feeders. So, they increase the efficiency of the system more over. DGs also can improve voltage profile of system. In this study Genetic Algorithm (GA) is used to obtain optimal number, capacity and location of DGs for radial distribution networks. First of all GA is used for optimal placement and capacity of DGs the network. A composite power loss index with net present worth of distribution generation as DG and Distribution Company named DISCO is defined as the objective function in the optimization procedure. This method was carried out on a modified 33-feeder distribution network. Simulation results validate the effectiveness of the proposed method. This study was performed on 33 feeder IEEE test power system.

Key words: Distributed generation, economic analysis, index terms-genetic algorithm, optimization, power loss

INTRODUCTION

The Deregulated energy environment, among other effects, has favored the penetration of Distributed Generation (DG) sources connected near the energy consumers at the medium-voltage or Low-Voltage (LV) side of the distribution network. These sources comprise several technologies, such as diesel engines, Micro Turbines (MTs), and fuel cells either in Combined Heat and Power (CHP) operation or purely for electricity production, Photovoltaic (PV), small Wind Turbines (WTs), hydro turbines, etc. in (Durga and Nadarajah, 2007), the multi objective function in order optimization DGs have not considered .The capacity of the DG sources varies from few kilowatts to 1-2 MW. The resource limitation of fossil fuels and the problems arising from their combustion has led to widespread research on the accessibility of new and renewable energy resources (Ault *et al*., 2003; Katiraei *et al*., 2005). Solar, wind, hydro sources, and biogas are among these renewable energy resources. Solar and wind energy are non-depletable, site-dependent, non-polluting, and potential sources of alternative energy. However, common drawback with solar and wind energy is their unpredictable nature. Standalone Photovoltaic (PV), do not produce usable energy for considerable portion of time during the year (Amin and Masoud, 2007). This is mainly due to dependence on sunshine hours, which are variable. In general, the variations of solar and wind energy do not match with the time distribution of demand. The independent use of both the systems results in considerable over-sizing for system reliability, which in turn makes the design costly (Celli *et al*., 2005; Thomas, 2007). In fact, interconnection of small, modular generation and energy storage to low or medium voltage distribution systems forms a new type of power system, the Hybrid Power System (HPS) (Lopes *et al*., 2006). The most important character of HPSs is that the power generators are distributed and located in close proximity to the energy users. The HPS supplies electricity and heat together. It can interconnect to the larger electricity network, or can operate independently in a deliberate and controlled way. In previous work the multi objective function as will be discussed in this study, has not considered in (Durga and Nadarajah, 2007), the reliability purpose, was considered yet. Hence, in this study a structure is proposed for HPS based on hybrid renewable energy sources with multiple DG units in distribution system. In this research, genetic algorithm has been developed for evaluation and cost optimization HPS. In this study an objective function based on economic indices and power loss reduction is considered and analyzed.

PROPOSED TOPOLOGY OF POWER SYSTEM BASED HPS

In this study distributed power generation system based on hybrid PV/Fuel cell/battery that provides part of real and reactive power to load that is connected to local grid is presented. This section presents a structure for distribution system including HPS and multiple DG units, that shown in Fig. 1. Many types of DGs that can be employed in system are PV, WT, MT, FC, that some of them are illustrated as bellow:

Photovoltaic (PV) power systems are, however, dependent on climatic conditions and their output depends on the time of year, time of day and the amount of clouds. Hybridization of fuel cell with PV will therefore form a very reliable distributed generation where the fuel cell acts as back up during low PV output. The slow dynamics of the fuel cell can be compensated by adding battery energy storage (Colle *et al*., 2004). In the mean time the fuel cell may be starved of fuel which is not good for the electro catalyst shortening its life. Therefore, the fuel cell should be operated under controlled steady state regime during which the battery is providing the demanded power. In this study a ramping current reference is generated to avoid starvation of the fuel cell. Addition of the battery energy storage also avoids over sizing of the fuel cell by taking on the remaining peaking power in surplus of the fuel cell maximum power output. In this study a distributed power generation system based on hybrid PV/Fuel cell/battery that provides part of real and reactive power to load that is connected to local grid is presented. The hybrid power system normally operates under load following mode where only the hybrid power system meets the local demand. For loads beyond the maximum capacity of the hybrid power system and inverter, the grid supplies the rest of the local power demand. This helps to relieve transmission line congestion problem by producing most of the local demand locally, reduce transmission line losses especially for loads very far from the utility grid. The hybrid power system can also provide ancillary service to the utility by allowing the grid operates at unity power factor at the point of common coupling.

Combining fuel cells with energy storages like batteries and super capacitors makes Hybrid Distributed Generation Systems (HDGS) could operate properly under transient conditions in demand power.

The components of hybrid power system analyzed and explained in detail below.

Photovoltaic array: The PV power technology uses semiconductor cells (wafers), generally several square centimetres in size. The present PV energy cost is still higher than the price the utility customers. For that reason, the PV applications have been limited to remote locations not connected to the utility lines. Major advantages of the PV power are available.

The solar power generation for any solar radiation can be predicted by using the formula (Diaf *et al*., 2007):

$$P = Ax^2 + Bx + C$$

where x = solar radiation [W/m^2] and P = power generation [W]

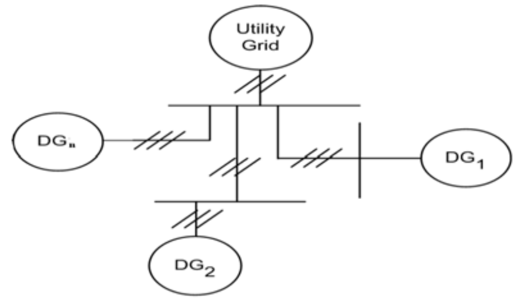

Fig. 1: Structure of distribution system with HPS and multiple Distributed Gnerations (DGs)

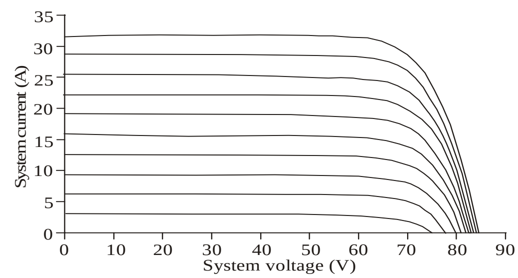

Fig. 2: Voltage-current characterization of a Photovoltaic array

A, B and C are constants, which can be derived from measured data. By using the above formula, solar power generation at any solar radiation can be predicted. This is also useful in estimating the suitable solar photovoltaic panels for many required load. Figure 2 shows the V-I characteristics of PV.

Battery: The battery stores energy in the electrochemical form, and is the most widely used device for energy storage in the variety of applications such as electric and hybrid electric vehicles and hybrid power systems. The PV and wind being intermittent sources of power, cannot meet the load demand all of the time, 24 h a day and 365 days of the year. The energy storage, therefore, is a desired future to incorporate with renewable power systems, particularly in stand-alone plants. It can significantly improve the load availability, a key requirement for any power system.

Fuel cell: The certainty of meeting load demands at all times is greatly enhanced by the hybrid system using more than one power source. Most hybrids use fuel cell with PV or wind, since fuel cells provide more predictable power on demand. For the remote and isolated network areas the best choice to support the network demand is fuel cell. Fuel cells are static energy conversion devices that convert the chemical energy of fuel directly into electrical energy. They show great promise to be an important DG source of the future due to their many advantages, such as high efficiency, zero or low emission (of pollutant gases), and flexible modular structure.

Economic analysis: The economic viability of a proposed plant is influenced by several factors that contribute to the expected profitability. In the economical analysis, all costs such as Capital cost, Replacement cost, Operation and maintenance cost and Fuel cost (just for Fuel Cell) must be considered. For optimal design of a hybrid power system, total annualized costs are defined as follow:

Total annualized cost = Sum of annualized cost of each hybrid system components

where,

Annualized cost = annual capital cost + annual replacement cost + annual operation and maintenance cost + annual fuel cost (just for Fuel Cell)

For this approach all of the factors that will be explained should be considered.

Interest rate: The interest rate that one enters for hybrid power system input is the annual real interest rate (also called the real interest rate or just interest rate). It is a discount rate used to convert between one-time cost and annualized cost. The annual real interest rate is related to the nominal interest rate by the equation:

$$i = \frac{(i' - f)}{(1 + f)}$$

where,

- i = Real interest rate
- i' = Nominal interest rate (the rate at which you could get a loan)
- f = Annual inflation rate

Project lifetime: The project lifetime (R_{proj}) is the length of time over which the costs of the system occur. It uses to calculate the annualized replacement cost and annualized capital cost of each component, as well as the total net present cost.

Capital recovery factor: The capital recovery factor is ratio used to calculate the present value of any annuity (a series of equal cash flows). The equation for the capital recovery factor is:

$$CRF(i, N) = \frac{i(1+i)^N}{(1+i)^N - 1}$$

where, the equation can be calculated by R_{proj} and R_{rep} instead of N.

The present value is the equivalent value at the present of a set of future sums, taking into account the time value of money.

Sinking fund factor: The sinking fund factor is ratio used to calculate the future value of a series of equal cash flows. The equation for the sinking fund factor is:

$$SFF(i, N) = \frac{i}{(1+i)^N - 1}$$

where, the equation can be calculated by R_{proj} and R_{comp} instead of N.

The future value is defined as the equivalent at some designated future date of a sequence of cash flows, taking into account the time value of money.

Replacement cost duration: The replacement cost duration is given by:

$$R_{rep} = R_{comp}.INT \frac{R_{proj}}{R_{comp}}$$

where, R_{comp} = lifetime of the component

Remaining life of the component:

$$R_{rem} = R_{comp} - \left(R_{proj} - R_{rep}\right)$$

Annualized capital cost: The annualized capital cost is given by:

$$C_{acap} = C_{cap}.CRF\left(i, R_{proj}\right)$$

where, C_{cap} is initial capital cost.

Formulation of overall cost function: Figure 3 shows the economic representation of Capital Recovery Factor and Sinking Fund Factor versus of life time project.

According to the proposed structure for distribution system including HPS and multiple DG units, the cost function is considered as follow:

$$F = k1*\left(T_1\right) + k_2*\left(T_2\right)$$

$$k_1 + k_2 = 1$$

which,

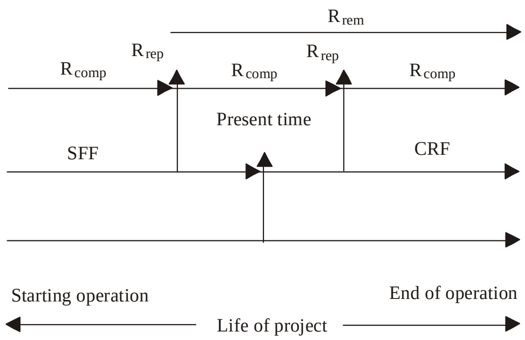

Fig. 3: Economic representation of capital recovery factor and sinking fund factor versus of life time project

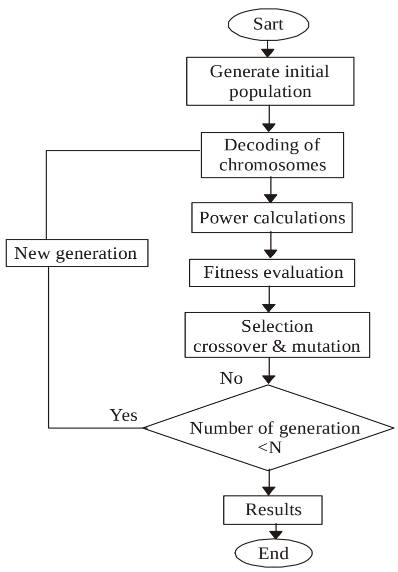

Fig. 4: The block diagram of optimization problem

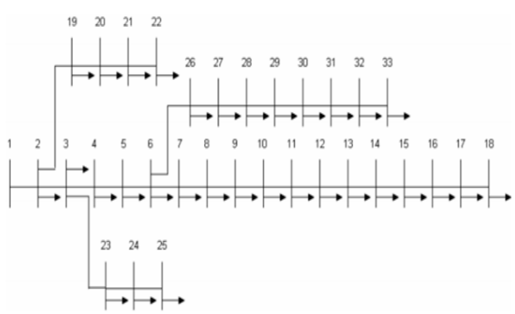

Fig. 5: Study case LV network

$$T_2 = P_{Loss} = \sum_{i=1}^{N} R_i I_i^2$$

V_i Voltage at i^{th} load point
V_b Base voltage that is equal one per unit

$$T_2 = \left(h_1 * NPW_{DG} + h_2 NPW_{DISCO}\right)$$
$$h_1 + h_2 = 1$$

NPW is the Net Present Worth of the overall system. It includes the net present worth of distribution company (DISCO) plus the net present worth of DG units. The DISCO provides the necessary power of customers from DG units. In fact the main purpose is maximizing the benefits of DG units, MG and DISCO. For this purpose FLA has been employed for optimization procedure.

Genetic Algorithm (GA): In the proposed application the goal is to obtain the position of individual devices on the feeder, where these devices may be placed on a limited number of branches or buses. The locations where protective devices may be placed could be coded using discrete number between 1 and M, where M is the number of possible branches in the system where protective devices may be placed. Similarly, possible DGs may be coded using discrete numbers ranging from 1 to P for location and Cmin and Cmax for capacity, that R is the number of possible buses where DGs may be placed and Cmin to Cmax, that Cmin and Cmax are minimum and maximum possible capacity of DGs. So, a single solution can be defined as a specific allocation of individual DGs and protective devices on the feeder, i.e., the kth solution in the population is an)2N+R(-dimensional row vector of discrete numbers:

$$X_k \left\{ \begin{array}{l} [x\,yz] \,\big|\, x_i \in \{1,\dots,P\}, i = 1,\dots,N, y_i \in \{C_{\min},\dots,C_{\max}\} \\ z_i \in \{1,\dots,R\}, j = 1,\dots,M \end{array} \right\}$$

where,
X = Location list of each chromosomes
k = Number of chromosomes
P = Number of buses
N = Number of DGs
R = Number of reclosers
M = Number of lines
C_{min} = Minimum Capacity of DGs
C_{max} = Maximum Capacity of Dgs

GA is a search method based on the natural selection and genetics. GA is computationally simple yet powerful and it is not limited by assumptions about the search space. The most important goal of optimization should be improvement. Although GA cannot guarantee that the solution will converge to the optimum, it tries to find the optimum, that is, it works for the improvement. The GA is basically an evolutionary algorithm, analogous to a part of the physical world. GA is a stochastic optimization technique introduced by Ref. 20 and further discussed by

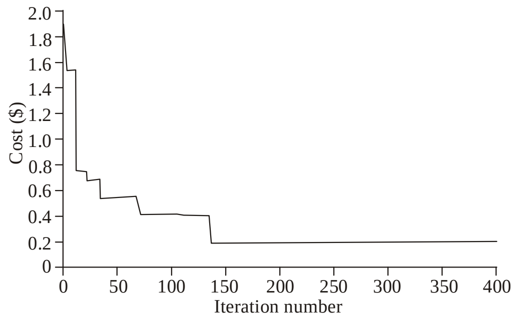

Fig. 6: Best cost value versus iteration number for case (I)

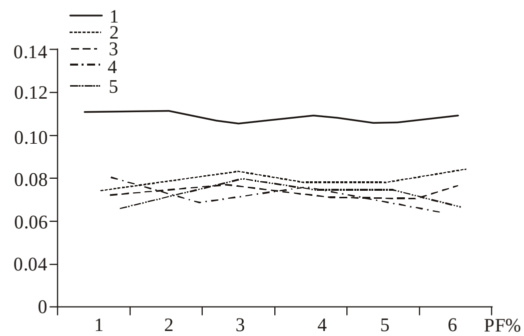

Fig. 7: Variation in power loss with optimum number of DGs and (penetrated factor) PF%

Table 1: Customer data

Bus no	Number of customer	Q (kvAr)	P (kW)	Bus No	Number of customer	Q (kvAr)	P (kW)
1	6	14	28	18	0	0	0
2	0	0	0	19	10	23	52
3	13	41	67	20	1	2	4
4	16	43	82	21	8	20	40
5	41	121	206	22	1	2	5
6	17	393	83	23	27	70	135
7	9	23	45	24	7	17	34
8	83	20	414	25	0	0	0
9	0	0	0	26	0	0	0
10	6	17	32	27	0	0	0
11	1	1	2	28	0	0	0
12	3	7	15	29	0	0	0
13	90	225	450	30	3	8	16
14	0	0	0	31	0	0	0
15	0	0	0	32	11	29	55
16	0	0	0	33	0	0	0
17	1	2	4	34	0	0	0

Ref. (Bakos and Soursos, 2002). Binary and floating-point representations are used to implement GA, for the sake of comparison. In the binary implementation, each element of a string (or chromosome) vector was coded using the same number of bits and each occupied its own fixed position. The minimization process in the binary representation used is characterized by the following:

The implemented GA starts by randomly generating an initial population of possible solutions. For each

Table 2: Line data

Line No	Erea Bus	Dest. Bus	R (p.u)	X (p.u)	B (P.u)	r (f/year)	Time (h)	u (f/year)
1	1	2	0.00285	0.00211	0.006478	1.85	0.15	0.27
2	23	4	0.00017	0.00012	0.000438	0.106	0.01	0.0001
3	3	4	0.00051	0.00037	0.001345	0.328	0.03	0.01
4	4	5	0.00158	0.00116	0.004192	1.021	0.08	0.08
5	5	10	0.00114	0.00087	0.003160	160.77	0.06	0.05
6	6	7	0.00031	0.00023	0.000829	0.202	0.02	0.0004
7	7	8	0.00215	0.001569	0.005694	1.387	0.11	0.15
8	8	9	0.00080	0.00058	0.002112	0.512	0.04	0.02
9	9	10	0.00077	0.00012	0.000438	0.107	0.01	0.0001
10	10	12	0.00344	0.00251	0.009120	2.221	0.18	0.39
11	11	12	0.00344	0.00074	0.002091	0.617	0.05	0.03
12	12	15	0.00139	0.00211	0.007665	1.867	0.15	0.28
13	13	14	0.00289	0.15418	0.616451	4.024	0.32	0.3
14	14	15	0.15447	0.00658	0.008000	1.98	0.16	0.31
15	15	16	0.00307	0.00004	0.000150	0.04	0.01	0.0004
16	16	18	0.00005	0.01588	0.057611	14.035	1.12	15.76
17	17	18	0.02171	0.015059	0.030111	8.891	0.71	6.32
18	18	19	0.01995	0.00022	0.000813	0.198	0.02	0.0004
19	19	20	0.00031	0.00881	0.031973	7.789	0.62	4.85
20	20	22	0.01205	0.00036	0.001314	0.32	0.03	0.01
21	21	22	0.00050	0.00138	0.003911	1.154	0.09	0.11
22	22	26	0.00259	0.00440	0.015971	3.891	0.31	1.21
23	23	24	0.00602	0.00624	0.017734	5.236	0.42	2.19
24	24	25	0.01172	0.02185	0.062145	18.349	0.47	26.94
25	25	26	0.04118	0.00078	0.002207	0.651	0.05	0.03
26	26	27	0.00018	0.00013	0.000485	0.118	0.01	0.0001
27	27	28	0.00006	0.00004	0.000150	0.04	0.01	0.0004
28	28	29	0.01214	0.01212	0.048451	11.33	0.91	10.27
29	29	31	0.01531	0.01529	0.061140	14.291	1.14	16.34
30	30	31	0.00496	0.00263	0.007491	2.212	0.18	0.39
31	31	32	0.01316	0.01314	0.052525	12.282	0.98	12.07
32	32	33	0.00071	0.00071	0.002819	0.65	0.05	0.03
33	33	34	0.00105	0.00105	0.004205	0.983	0.08	0.08

Table 3: Specification of network

Source type	Economic parameters	Component life time
Phot voltaic array	2 [kW], DC, I' = 8%, f = 0.035	25 [yrs]
Fuel cell	800 [kW], DC,i' = 8%, f = 0.035	15000 [h]
Battery	1153 [Ah], 6V, DC,i' = 8%, f = 0.035	12 [yrs]
Other DGs	800 [kW], AC, i' = 7%, f = 0.03	15000 [h]

solution a value of power generation units is chosen between a maximum limit, fixed by the planner on the ground of economical and technical justifications; then, a different size of MG and DG units are randomly chosen until the total amount of power installed reaches the MG and DG penetration level assigned. At this point, the objective function isevaluated verifying all the technical constraints. In order to solve the optimization problem, a modified GA has been use in (Bakos and Soursos, 2002).

In Fig. 4 the block diagram of optimization problem has been shown.

SIMULATION RESULTS

The proposed method is applied to the case study distribution network as shown in Fig. 5.

Network data is given in Table 1. Network specification before implementing the algorithm is given in Table 2.

In this part, the simulation results have been presented. A typical study case LV network, shown in Fig. 4, has been proposed in. The network comprises three feeders: one serving a primarily residential area, one industrial feeder serving a small workshop, and one feeder with commercial consumers. In this study the power loss value versus of Penetrated Factor (PF%) of DGs are presented. This factor is defined as the ratio of total DGs power respect to total generated power with DGs and DISCO.

Table 4: Result of GA

Simulation No	No. of DGs	Bus no. for DGs installation						DGs capacity according to their placment						Objects function
1	1	13						600						2.9102
2	1	13						600						2.6905
3	1	13						600						2.6839
4	1	13						600						2.671
5	1	13						600						2.6627
6	1	13						600						2.6334
7	2	13	9					520	600					1.4961
8	2	7	13					600	590					1.2245
9	2	6	13					600	530					1.0828
10	2	13	7					520	600					1.0491
11	2	13	8					510	600					1.03
12	2	13	8					520	590					1.299
13	3	13	8	13				420	470	540				0.9535
14	3	9	14	13				560	430	440				0.91
15	3	13	14	10				420	470	560				0.8695
16	3	13	5	7				470	520	440				0.8309
17	3	13	8	12				460	540	440				0.8139
18	3	13	12	8				460	490	490				0.8027
19	4	13	8	6	15			410	160	270	600			0.9243
20	4	12	7	13	5			390	190	420	430			0.9061
21	4	4	6	13	14			410	230	440	350			0.8555
22	4	13	4	14	7			440	310	340	340			0.8041
23	4	9	14	2	13			550	220	190	470			0.7986
24	4	13	6	14	4			460	240	350	380			0.7914
25	5	6	13	5	14	13		260	270	380	370	150		0.926
26	5	7	10	13	12	14		360	170	410	170	320		0.8795
27	5	7	8	14	13	25		460	100	160	470	210		0.864
28	5	2	6	15	13	13		380	230	350	300	170		0.8105
29	5	13	13	6	4	15		380	100	290	410	250		0.8034
30	6	2	4	15	7	13		170	170	430	100	390		0.7818
31	6	4	13	13	6	14	2	450	180	250	230	300	300	0.9167
32	6	13	6	6	14	15	10	300	200	260	110	280	130	0.8685
33	6	11	13	7	4	13	2	200	130	290	180	300	230	0.836
34	6	3	13	4	7	13	14	250	280	170	340	130	310	0.7908
35	6	14	13	4	10	6	13	250	190	210	270	240	270	0.7897
36	6	6	13	14	13	8	2	130	360	360	100	270	210	0.7813

Economic parameters of each kind of distributed generations that applied in this study are listed as Table 3.

Results of GA method in proposed algorithm are presented in Table 4. According to value level and final weight of each simulation in this table, answer set is achieved. Regarding to simulations of 15th to 18th, 20th and 21st, optimum number of DGs are achieved. .

The variation of the cost value versus the iteration number is shown in Fig. 6.

Figure 7 shows that variation of power losses and the best variation in losses of network is obtained by allocation of first DG.

CONCLUSION

This study deals with the economic evaluation of a typical HPS participating in a market following different policies. An optimized design of HPS includes sources like, photovoltaic array, fuel cell and battery bank based on an evolutionary algorithm 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 with aim to minimizing of all system costs, has been clarified. A genetic algorithm approach is employed to obtain the best cost value of hybrid power system construction. The developed optimization algorithms are applied on a typical LV study case network operating under market policies. The effects on the HPS and the distribution network operation are presented and discussed. The simulation results validate the effectiveness of the proposed methods. Using of this algorithm, DGs are installed close to the load centers to decrease losses, improve voltage profile.

REFERENCES

Amin, H. and A.G. Masoud, 2007. Intelligent power management strategy of hybrid distributed generation system. Int. J. Electr. Power Energ. Syst., 2(9): 783-795.

Amin, H. and A.G., Masoud, 2010. Control of hybrid fuel cell/energy storage distributed generation system against voltage sag. Int. J. Electr. Power Energ. Syst., 3(2): 488-497.

Ault, G.W., J.R. McDonald and G.M. Burt, 2003. Strategic analysis framework for evaluating distributed generation and utility strategies, in Proc. Inst. Elect. Eng Gen. Trans. Distrib., 150: 475-481.

Bakos, G.C. and M. Soursos, 2002. Technical feasibility and economic viability of a grid-connected PV installation for low cost electricity production. Energ. Build., 34: 753-758.

Carlson, D.E., 1995. Recent advances in photovoltaics. Proceedings of the Intersociety Engineering Conference on Energy Conversion, pp: 621-626.

Celli, G., F. Pilo, G. Pisano and G.G. Soma, 2005.Optimal Participation of a Micro Grid to the Energy Market with an Intelligent EMS, Power Engineering Conference, IPEC, the 7th International, 2(29): 663 -668.

Colle, S., S.L. Abreu and R. Ruther, 2004. Economic evaluation and optimization of hybrid diesel/photovoltaic systems integrated toutility grids. Solar Energ., 7(6): 295-299.

Diaf, S., D. Diaf, M. Belhamel, M. Haddadi and A. Louche, 2007. A methodology for optimal sizing of autonomous hybrid PV/wind system. Sci. Direct Energ. Policy, 35(11): 5708-5718.

Durga, G., Nadarajah Mithulananthan , 2007. Optimal DG placement in deregulated electricity market., Electr. Power Syst. Res. ,77,pp.1627-1636.

Katiraei, F., M.R. Iravani and P.W. Lehn, 2005. Microgrid autonomous operation during and subsequent to islanding process. IEEE Trans. Power Del., 20(1): 248-257.

Lopes, J.A.P., C.L. Moreira and A.G. Madureira, 2006. Defining control strategies for micro grids islanded operation. IEEE Trans. Power Syst., 21(2): 916-924.

Thomas, A., 2007. Distributed resources and re-regulated electricity markets. Electr. Power Syst. Res., 6(3): 1148-1159.