Power Quality Improvement Through Minimizing the Deviation of the Bus Voltage With Considering Cost Analysis With Optimal Sizing of Multi Type Dgs Using Pareto Solutions and Comparison With Ga and PSO

Engineering

KEYWORDS : Pareto solutions, wind energy, solar energy, fuel cell, power quality

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ABSTRACT

This paper deals with a multi-objective optimization problem with conflicting objectives aims to find the best compromise tradeoffs among the feasible solutions in the search space. These kinds of solutions are known as non-dominated solutions or Pareto solutions. In the test system two wind turbines, one fuel cell and two photovoltaic arrays have implemented to optimal the system operation under two conflicting objective function. The first power quality improvement and second the minimization total cost. The power quality index which considered in this research is deviation of the bus voltage concept. Using NSGAII application, the Pareto set, the best compromise solution is selected according to the fuzzy based decision ranking.

1. INTRODUCTION:

Many investigations have been focused on renewable energy utilization. In [1] economic evaluation and optimization of hybrid diesel/photovoltaic systems integrated to utility grids in investigated. In this study, an analytical approach to evaluate and to optimize the life cycle savings of hybrid diesel-photovoltaic plants is carried out, of course in another study; this type of hybrid system in stand alone was analyzed. In this research Hybrid photovoltaic/diesel systems for isolated communities in the Brazilian are considered and using genetic algorithm optimized [2]. In [3] Particle swarm optimization for AC-coupling stand alone hybrid power systems including PV/wind/diesel hybrid power system at Chik Island, Thailand, was selected as a reference system and optimized. Chen in [4] later considered a variety of renewable energy sources in their simulation studies, including solar power, wind power, ocean wave energy, hydro power and water resources. In [5], economic analysis of stand-alone and grid-connected hybrid energy systems has been studied

2. POWER QUALITY ANALYSIS

Bus voltage is one the most significant security and power quality indices, which can be described as follows:

$$f_1(X) = \sum_{i=1}^{N_{bus}} \frac{\left|V_{Rating} - V_i\right|}{V_{Rating}} \qquad 1$$

Where, Nbus is the total number of the buses. Vi is the real voltage of the i^{th} bus and V is the nominal voltage [6].

3. ECONOMIC ANALYSIS

The economical approach, according to the concept of life cycle cost (LCC), is developed to be the best indicator of economic profitability of system cost analysis in this study. According to the studied system, the life cycle cost (LCC) takes into account the initial capital cost (IC_{cap}), the present value of replacement cost (Crep) and the present value of maintenance cost (Cmain). Thus, LCC may be expressed as follows:

$$f_2(X) = LCC\,(DA) = IC_{cap} + C_{rep} + C_{main} \qquad 2$$

The initial capital cost for the hybrid system, (***ICcap***) is given by:

$$IC_{cap}(DA) = C_{PV} * C_{Unit,PV} + C_{FC} * C_{Unit,FC} + C_{WT} * C_{Unit,WT} \qquad 3$$

Where ***CPV***, ***CUnit,PV*** are the total capacity (W) and unit cost (DA/W)of PV array respectively; ***CWT, CUnit, WT*** are the total capacity (W) and unit cost (DA/W) of the wind turbines set respectively; ***CFC, CUnit, FC*** are the total capacity (W) and unit cost (DA/W) of the fuel cells respectively.

The present value of replacement cost considering the inflation rate of component replacements (***f0***) and real interest rate (***kd***), the present value of replacement cost (***Crep***) can be determined as follows [7]:

$$C_{rep} = C_{Unit} C_{nom} \sum_{i=1}^{N_{rep}} \left[\frac{(1+f_0)}{(1+k_d)}\right]^{N_i/N_{rep}+1} \qquad 4$$

Where ***Cnom*** is the nominal capacity of the replacement system component; ***CUnit*** is the unit component cost and ***Nrep*** is the number of component replacements over the system life period.

Also the present value of operation and maintenance cost of the hybrid system ***CO&M*** is expressed as [8]:

$$C_{O\&M} = \begin{cases} C_{(O\&M)_0}\left(\frac{1+f_1}{k_d - f_1}\right)\left[1-\frac{1+f_1}{1+k_d}\right]^{L_p} & for\ k_d \neq f_1 \\ C_{(O\&M)_0} * L_p & for\ k_d = f_1 \end{cases} \qquad 5$$

Where ***f1*** is the inflation rate for operations; ***kd*** is the annual real interest rate and ***Lp*** is the system life period in years.

C(O&M)0 is the operation and maintenance cost in the first year. It can be given as a fraction "k" of the initial capital cost (***CIC***) is expressed as:

$$C_{(O\&M)_0} = k * C_{IC} \qquad 6$$

4. NSGAII ALGORITHM BASED OPTIMIZATION

The set of non-dominated solutions or Pareto solutions, construct the Pareto front or front of non-dominated solutions. This set provides a number of options for decision makers to choose the best option with regard to the other quantitative or qualitative parameters. In general, a multi-objective optimization problem can be formulized as follows:

$$\min_{x \in X^{n_x}} \ f(x) = \{f_1(x) \quad f_2(x) \quad ,..., \quad f_M(x)\} \qquad 7$$

$$g(x) \le 0,\ h(x) = 0 \qquad 8$$

Where $g(x) \le 0,\ h(x) = 0$, are the sets of the problem constraints

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that determine the boundaries of the feasible solution space in ^{n}x dimensional search space, and $f(x)$ is an M dimensional vector of objective values. A map between decision variables of $x \in X^{N_x}$ and objective space of $f \in F^M$ is determined by objective functions.

The computational algorithm of NSGA-II is used to address the hybrid renewable energy resources problem through the following steps:

Step 1 Initialization. In this step a population is generated randomly in the search space as initial solutions of the algorithm.

Step 2 objective evaluations. For each individual of the population, the values of objective functions are evaluated in this section.

Step 3 Non-dominated sorting. The NSGA-II algorithm sorts a population into distinctive non-dominated levels (fronts). Initially, it achieves the Pareto optimal set of the present population (RANK = 1), then it disregards temporarily these solutions and search again the Pareto optimal set among the residual individuals of the population (RANK = 2). This procedure is repeated until all fronts are recognized and allocated to all individuals. This attribute is one of the two features that illustrate the fitness of the solutions. The second feature is crowding distance.

Step 4 Crowding distance. After completing the non-dominated sorting, the crowding distance is applied to sort the individuals in the same front.

In order to estimate the density of solutions neighboring the i^{th} individual in each non-dominated set, the average normalized distances of the two adjacent neighbors for each objective function are calculated and summed all together, as follows [9]:

$$CD(X_i) = \sum_{j=1}^{m} \left| \frac{f_j(X_{i+1}) - f_j(X_{i-1})}{f_j^{max} - f_j^{min}} \right| \quad 9$$

Where $CD(X_i)$ is the overall crowding distance of solution X_i, m is the number of objective functions, $f_j(X_{i+1}), f_j(X_{i-1})$ are j^{th} objective function values of the two nearest neighbors of the i^{th} individual, f_j^{max}, f_j^{min} are the maximum and minimum values of j^{th} objective function.

Step 5 Selection. The binary tournament based selection carried out between two randomly chosen individuals from the population.

Step 6 Cross-over.

Step 7 Mutation
The above procedure except Step 1 is repeated for the maximum number of iterations. Fig.1 shows the NSGAII algorithm's flowchart.

In order to decision making, a fuzzy based method is applied in this paper to select the favored solution among non-dominated solutions. Through fuzzy set theory, a linear membership function assigned for each objective function Eq. (10) and (11) are used respectively, for normalizing monotonically decreasing and increasing objective functions [10].

$$\mu_i^k = \frac{f_i^{max} - f_i}{f_i^{max} - f_i^{n}} \quad 10$$

$$\mu_i^k = \frac{f_i^k - f_i^{min}}{f_i^{max} - f_i^{min}} \quad 11$$

f_i^{max}, f_i^{min} are the maximum and minimum values of i^{th} objective function.

Mathematically, none of the solutions in the trade-off region has a priority with respect to other solutions. Due to the subjective imprecise nature of the decision maker's judgment, a fuzzy satisfying method is applied here to select the preferred solution among non-dominated solutions. Through fuzzy set theory, each objective function is presented with a linear membership function.

If the objective function is monotonically decreasing, Eq. (10) is used for normalizing vice versa if the objective function is monotonically increasing Eq. (11) is applied.

The normalized membership function of the kth non-dominated solution is defined as follows:

$$\mu^k = \frac{\sum_{i=1}^{m} \mu_i^k}{\sum_{k=1}^{N_p} \sum_{i=1}^{m} \mu_i^k} \quad 12$$

Where Np is number of non-dominated solutions and m is number of objective functions.

The solution with the maximum membership value is selected as the best compromising solution.

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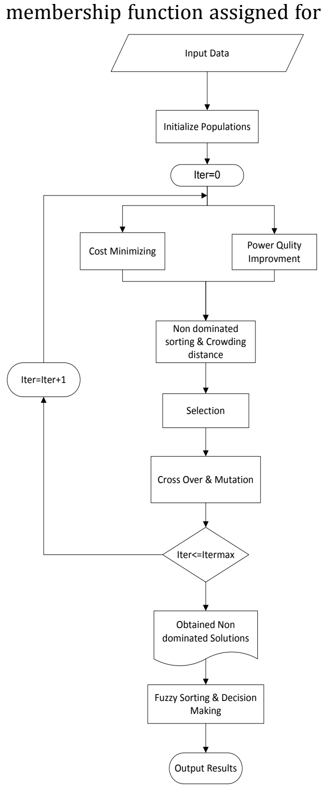

Fig.1.The proposed algorithm's flowchart

5. SIMULATION AND RESULTS:

In this section the results of dispersed hybrid clean energy resources optimization using proposed algorithm based voltage profile enhancement and economic analysis is presented. The hybrid system which simulated in this research is grid connected and it is supposed that the dispersed renewable energy resources including photovoltaic cells and wind turbines together fuel cell with 63/20 substation is responsible to support demand.

Te information of the each system component, e.g. investment cost, operation and maintenance cost, fuel cost of fuel cell, wind turbine, photovoltaic and utility grid are given in Table 1. Te one line diagram of 30-bus test system is shown in Figure 2. The system demand is 283.4 MW in all simulations.

Table.1. Specification of different energy sources and grid utility

	Rated capacity	Investment cost ($/kW)	Fuel cost ($/kWh)	O&M Cost ($/kWh)	Capacity Factor	Life time (year)
WT	400(kW)	4500	0	0.005	0.2	20
FC	400(kW)	3674	0.029	0.010	0.4	10
PV	400(kW)	6675	0	0.005	0.25	20

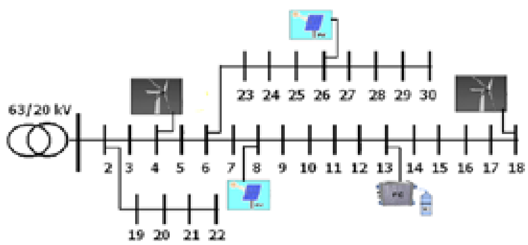

Fig.2.The 30 bus distribution test system at the presence of hybrid PV/WT/FC system

In this paper we have changed MATPOWER by adding NSGAII codes in order to implement the multi-objective OPF problem in power systems. Te parameters required for implementation of the NSGAII algorithm are listed in Table 2.

Table 2.Parameters of the NSGA-II algorithm

Max_Iter	Population Size	Crossover Rate	Mutation Rate
250	50	0.8	0.4

To demonstrate the effectiveness of the proposed approach, three cases with different complexity have been considered as follows:

Case 1: Minimize total operating cost.
Case 2: Minimize deviation voltage.
Case 3: Minimize operating cost and voltage deviation at the same time.

Initially, each of the objective functions individual are examined then used Te Pareto-optimal method to obtain the optimal point by optimizing the two objectives simultaneously. Te results are shown in Tables 3 and 4.

In first case which minimizing total operating cost is objective function, the capability and power of proposed algorithm, it has been compared with new heuristic methods that results of this comparison are shown in Table 3. Algorithm has converged in 288.32 ($/h) which is the lowest cost. Convergence curve for this case is shown in Figure 3.

Table 3.Comparison of proposed algorithm with PSO, GA algorithms (Cost)

Method	P_WT,4 [kW]	P_WT,18 [kW]	P_PV,8 [kW]	P_PV,26 [kW]	P_FC,13 [kW]	Cost ($/h)	Vol.Dev. (Pu)
NSGAII	150	6	196.8	150	3	288.32	2.873
GA	184	7	200.6	200	9	288.12	2.893
PSO	199	5	200.3	177	2	286.86	2.987

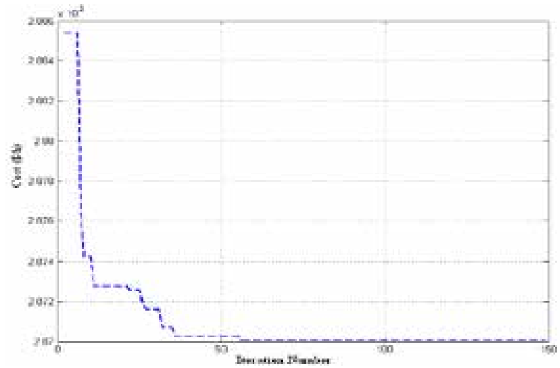

Fig.3.Convergence plot for NSGAII for cost function

In second case which minimizing voltage deviation is objective function, the total amount of voltage deviation will be achieved by the proposed algorithm and the results are shown in Table 4. In this table the results obtained from the proposed algorithm is compared with GA and PSO algorithm. Results of Table 5 indicate how a reduction in voltage deviation could be achieved by a change in generation dispatch schedules. In this case, the amount of pollution that can be emitted by the proposed algorithm is lower than other algorithms and it shows the ability of the proposed algorithm. Figure 4 shows the curve of convergence obtained in this case.

Table 4.Comparison of proposed algorithm with PSO, GA algorithms (Voltage Deviation)

Method	P_WT,4 [kW]	P_WT,18 [kW]	P_PV,8 [kW]	P_PV,26 [kW]	P_FC,13 [kW]	Cost ($/h)	Vol.Dev. (Pu)
NSGAII	150	86.49	196.8	150	13.42	345.64	2.3831
GA	184	77.43	200.6	200	9.32	345.76	2.3851
PSO	199	57.54	200.3	177	12.32	344.43	2.3956

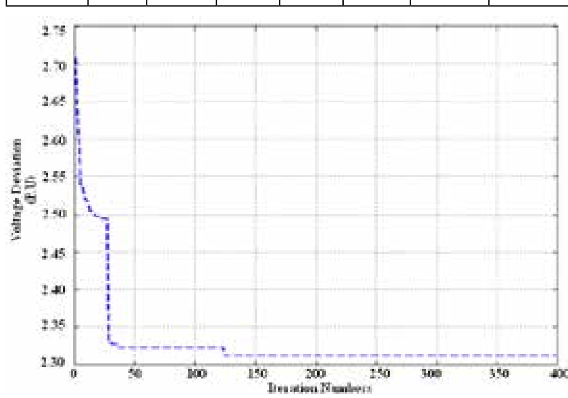

Fig.4.Convergence plot for NSGAII for voltage function

In third case which a multi-objective optimal power flow problem is solved, the Pareto-optimal method is used in this case to solve compromise between the two objectives. Te user based on the importance of each goal and can find different solutions. After NSGAII apply the Pareto set, the best compromise solution is selected according to Equation (12). In this regard Equation (12) is computed for all non-dominate solutions, after sorting them according to their μ^k value, the best solution among them considers as the best compromised solution. Te best solution among the best compromise solution is studied. Figure 5 shows the curve of the solution is compromise.

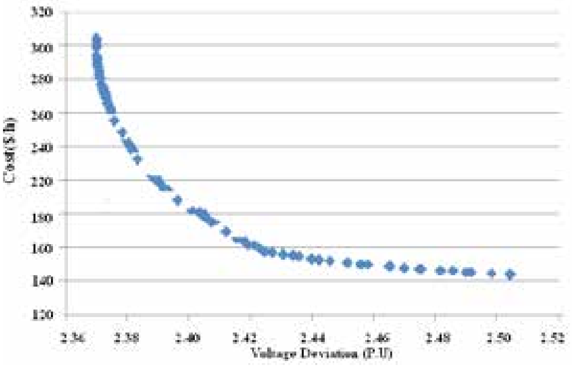

Fig.5.Some of the best non-dominated results

6. CONCLUSION

This paper presents the multi objective optimization of distributed energy resources (DERs) in distribution system. The two objective functions that have been considered in this research are power quality improvement and minimizing total cost of (DERs). Since the two objective functions which considered in this research are two conflicting objective, therefore a Pareto solution based approach using NSGAII is employed to optimize the results. This technique addressed a set of results that based on the decision of operator one of solution can be selected. To validate the results, the optimal results obtained by NSGAII are compared with two intelligent search methods, GA and PSO.

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