Distributed Energy Resources Optimal Sizing and Placement in a Microgrid

F. Tooryan, S.M. Moghaddas Tafreshi, S.M. Bathae and H. Hamidhassanzadeh-Fard

Abstract: This paper presents a method based on particle swarm optimization (PSO) for determining the optimal size and placement of (Distributed Energy Resources) DER in the micro-grid. The micro-grid considered in this study consists of a wind turbine (WT), a photovoltaic (PV), a micro turbine (MT) and battery storage, interruptible and uninterruptible loads. The total system cost is equal to the sum of the respective components capital, operation and maintenance and replacement costs, penalty for interruptible and uninterruptible loads, cost of exchanging power with utility and total loss of active power costs. In this study, some constraints such as bus voltage, reliability, energy limits of each DER and limits of exchanged power, interruptible and uninterruptible loads are considered. The PV and WT are dependent on their resources which are not dispatchable, therefore, in this study, uncertainty in output of PV and WT is considered. This paper provides different scenarios for evaluating the proposed method. Simulation results on a six-bus micro-grid are given to demonstrate the efficiency of the proposed approach to satisfy the load of micro-grid in lowest cost.

Index Terms— Distributed Energy Resources, Optimum size and placement, Particle swarm Optimization, Reliability

I. INTRODUCTION

In the recent years, the face of electricity generation and transmission are changed with countless incentives that lead to increase the using of distributed energy resources [1]. Distributed energy resources (DER), especially those facilities based on emerging technologies (photovoltaic array, wind power, fuel cells, micro turbine, etc) will play a key role in supporting the available capacity to meet demands. The DER involves small size generators of capacity from 10 kW to 10MW, supplying electricity to consumers [2].

A micro-grid (MG) is set of integrated distributed generators, loads and energy storage units which are working with each other. This set is a subset of a larger power network. The technology of local network managing with small energy resources is, actually, the concept of micro grid technology which has been appeared in recent years [3]. The Micro-grid (MG) can operate as a single controllable system that provides both power and heat to its local area, operated either islanded or connected to the utility grid in a controlled, coordinated way. This concept provides a new paradigm for defining the operation of distributed generation [4].

Refs [5], [6] introduce the benefits of micro-grid, such as, enhance local reliability, support local voltages, reduce feeder losses, provide increased efficiency through using waste heat combined heat and power and voltage sag correction. Ref [7] presents a methodology to evaluate the impact and influence of the installation and the capacity of DG units’ installation on electric losses, reliability and voltage profile of distribution networks. Ref [8] proposes to study the possibility of using a photovoltaic system combined with a high speed micro-turbine and considered that system can work as stand-alone system or grid connected system as it will be a part of a micro-grid. Ref [9], [10] determines the optimum size of the hybrid system components and analyses the impact of different parameters on the system size. Ref [11] developed a methodology of performing the optimal unit sizing for distributed energy resources in MG which aimed at finding the configuration,
among a set of systems components, which meets the desired system reliability requirements, with the minimum cost of energy (COE). In [12] a multi-objective evolutionary optimization algorithm (MOEA) was developed in order to solve the problem of determining optimal size and placement of distributed energy storage in micro-grid. In [13] a methodology based on genetic algorithm was proposed in order to find the optimal sizing of stand-alone PV/WT systems. The optimal number of units ensuring that the 20-year round total system cost is minimized subject to the constraint. Ref [14] proposed a new approach to optimally determine the appropriate size and location of the distributed generator (DG) in a large mesh connected system. Losses, voltage profile and short circuit level was used in the algorithm to determine the optimum sizes and locations of the DG. Ref [15] presented a method based on dynamic programming for determining sitting, sizing and optimal mix of resources from the available types of DER in a micro-grid. Ref [16] presented a multi-objective approach to find the location and sizing of DG units in order to obtain the benefits associated with minimizing the loss of total real power in the distribution networks and the investment costs of installation of DG units. Ref [17] presented a methodology using Fuzzy and Real Coded Genetic Algorithm (RCGA) for the placement of DG units in electrical distribution systems to reduce the power losses and to improve the voltage profile.

The use of different energy sources allows improving the system efficiency and the reliability of the energy supply and reduces the energy storage requirements compared to systems comprising only one single renewable energy source [9]. Therefore the micro-grid which is investigated in this study contains wind turbines, photovoltaic arrays, micro turbines and batteries, interruptible and uninterruptible loads. The main objective in present paper is finding optimal size and placement of distributed energy resources in micro-grid which is connected to the utility grid and can exchange power with utility grid. The proposed method solves the above problem considering a reliability criterion. In this paper, uncertainties of solar irradiation and wind speed are considered. The Optimum size and placement of Distributed energy resources ensure supplying electrical loads in micro-grid regarding to all constraints. In this study, due to consider electrical loads in micro-grid, we neglect the produced heat by micro turbine.

The optimization is aimed at minimizing the present value cost of micro-grid system while constraining it to meet the customer demand. The optimization is carried out using particle swarm optimization (PSO) algorithms. PSO is one the evolutionary computational techniques which has emerged as a powerful and versatile tool because of the simplicity of the algorithm. It was developed through simulation of a simplified social system and has been found to be robust in solving continuous, nonlinear as well as discrete optimization problems. The PSO technique can generate high quality solution within shorter calculation time and has more stable convergence characteristics than other stochastic methods [18]. In this technique, the potential solutions interact with only one solution, rather than interacting with every solution as in other methods such as GA [19]. This paper describes the method and illustrates it by means of an example. The paper is organized as follows. System modelling is presented in Section II. Section III provides a problem solution of the proposed method. The reliability and uncertainty are presented in section IV and V respectively. The objective function of optimization is presented in section VI. The simulation technique is shown in section VII and the obtained results are presented in Section VIII. Section IX concludes the paper.

II. SYSTEM MODELING

Prior to the optimization, system model component are constructed. It is desirable that with optimum sizing and placement of DER, the demands are supplied; the net value cost and total loss of the micro-grid are minimized. Renewable Generating units which are considered in this paper consist of PV and WT. Batteries are used to store the surplus energy during over-generation periods. The outputs of renewable generators are transferred to loads while the energy surplus is used to charge the batteries. When the produced power by PV and WT plus the energy stored in batteries are not sufficient to supply total loads, MT produced power for rest of loads which are not supplied. In this study, we assumed that renewable generators and battery bank are installed on single bus in micro-grid as a package and micro turbine can be installed separately. Modelling is an essential step before any phase of optimal sizing and placement. A methodology for modelling micro-grid components is described below.

A. Model of PV

The performance of PV is a function of the physical variables of the PV cell material and the solar radiation incident on the PV. In this paper, one simplified model applicable to the power output of PV is used. It will be applied to calculate the power output of PV at each time, once solar irradiance on PV is available. With this model, the output power of the PV, $P_{\text{pv}}$ can be determined as following equation [12]:

$$ P_{\text{pv}} = N \cdot P_{\text{STC}} \cdot G \cdot \eta $$

Where $\eta$ is the instantaneous PV efficiency, $P_{\text{STC}}$ is produced power in standard situation ($T=250\text{c}, G_{\text{STC}}=1000\text{ (W/m2)})$, $N$ is the number of arrays, $G$ is irradiance
incident which is normalized by irradiance in standard situation (W/m²) and can be calculated as follows:

\[
G' = \frac{G}{G_{STC}} \quad (2)
\]

Where \( G \) is the global irradiance on the title panel (W/m²). In this analysis, each PV unit has a rated power of 1 kW. Cost of one unit is considered 4000S while replacement and maintenance cost are taken as 3000S and 0S/year respectively. Lifetime of a PV unit is taken to be 20 years [20].

### B. Model of wind turbine

Choosing suitable model plays a significant role in power output calculation. The most simplified model to simulate the power output of wind turbine as a function of wind velocity can be described by equ.3 [21].

\[
P_{WT} = \begin{cases} 0 \\ \left(\frac{P_{rated} \times ((V - V_{cut-in})/(V_{rated} - V_{cut-in}))^2}{P_{rated}}\right) \end{cases} \quad (3)
\]

Where \( V_{cut-in}, V_{cut-off}, V, V_{rated} \) and \( P_{rated} \) are cut-in wind speed (m/s), cut-out wind speed (m/s), wind speed (m/s), nominal wind speed (m/s) and the rated power of wind turbine (kW) respectively. Using this equation, the power output of a turbine can be modelled if the cut-in, cut-out and rated wind speed and the rated power are known. In this paper, each wind turbine has a rated capacity of 30 kW. Cost of one unit is considered 30000S while replacement and maintenance costs are taken as 25000S and 300$/year. Lifetime of a turbine is taken to be 20 years [20].

### C. Model of battery

The power from the battery is needed whenever produced power by PV and WT are insufficient to supply the load, or when the shortage of energy supply occurs in the microgrid. On the other hand, energy is stored whenever the supply from the WT and PV exceeds the load demand.

Therefore, the battery capacity depends on the previous state of battery, the PV and WT energy production and the load energy requirements. Therefore, the battery model can be computed during the simulation [9], [22], [23].

At any time, the storage capacity is subject to the following constraints:

\[
E_{batmin} \leq E_{bat}(t) \leq E_{batmax} \quad (4)
\]

In this paper, we consider the maximum state of charge \( E_{batmax} \) and minimum state \( E_{batmin} \) of the battery which are 100% and 20% of its capacity respectively. The minimum allowable capacity can be determined by equ.5.

\[
E_{batmin} = (1-DOD) \times E_{batmax} \quad (5)
\]

Where DOD (%) represents the maximum allowable depth of battery discharge. In this analysis, each battery bank capacity is 30.4 kWh. Cost of each battery is considered 4000S while replacement and maintenance cost are taken as 4000S and 40$/year. Lifetime of a battery is taken to be 3 years [23].

### D. Model of micro turbine

Micro turbine is small and single-cycle gas turbine with outputs ranging from around 25 to 300 kW. Micro turbines can operate on multiple fuels with low pollution emissions, high efficiency, low fuel consumption rate, low noise, low maintenance cost and high reliability. It is the most popular and competitive business distributed generation device. In this paper, when the power produced by PV and WT plus energy stored in battery are not sufficient to supply load, the power produced by micro turbine is injected to micro-grid. Therefore, the output power of MT depends on the power produced by renewable resources and stored energy in battery storage and can be calculated during the simulation. The operational cost is only calculated for micro turbine in this study by equ.31.

In this study, the rated power of each micro turbine is 25 kW. Cost of each MT is considered 10000S while replacement and maintenance cost are taken as 8500S and 20$/year. Lifetime of a battery is taken to be 5 years.

### E. Model of loads

As mentioned above, the loads in this study consist of interruptible \( (P_{Load1}(t)) \) and uninterruptible \( (P_{Load2}(t)) \). Interruptible loads are consumers who agree to be interrupted, or whose consumption may be reduced by the utility, in order to maintain system security or to reduce micro-grid prices. At each time, the amounts of interruptible loads are \( \alpha \% \) of total load of micro-grid. The cost of electricity interruptions has been estimated. The cost that we use in our model for interruptible loads is 0.56 $/kWh and for uninterruptible loads is 5.6 $/kWh.

\[
P_{load}(t) = P_{Load1}(t) + P_{Load2}(t) \quad (6)
\]

\[
P_{Load}(t) = P_{load}(t) \times \alpha \quad (7)
\]

\[
P_{Load2}(t) = P_{load}(t) \times (1-\alpha) \quad (8)
\]

We assume that in each hour 15% of loads are interruptible and 85% of loads are uninterruptible and at any each hour micro-grid can interrupt only 5% of uninterruptible loads subject to reliability constraint such as Loss of Load Expectation (LOLE).

### F. Model of connection to utility grid

In this study, we assumed that micro-grid is connected to utility and can exchange power with utility grid. Batteries store the surplus power production of renewable generators. If the batteries are charged and received to their maximum
capacity while the energy surplus is remained, the rest of power produced by renewable generators is sold to utility grid. When total produced power in micro-grid can’t satisfy demand, power is purchased from grid. At each time, the amount of exchanged power is limited by equ.9 and 10.

\[ P_{\text{sell}}(t) \leq P_{\text{sell-max}} \quad (9) \]

\[ P_{\text{buy}}(t) \leq P_{\text{buy-max}} \quad (10) \]

\( P_{\text{sell-max}} \) is the maximum amount of selling power to utility grid, \( P_{\text{buy-max}} \) is the maximum amount of buying power from utility grid. The cost of selling energy to grid is considered 0.12$/kWh and purchased energy from grid costs 0.1 $/kWh.

III. PROBLEM SOLUTION

The main objective of the present study is to find the optimum size and placement of units used to support the micro-grid’s load. In this paper, using the priority of supporting renewable energy generation is considered. We consider three situations for micro-grid: over generation, power produced by renewable energy (wind + PV) meets demand and over demand.

A. Over generation

In this case, the demand is less than power produced by wind turbines plus PV. Therefore the energy surplus is stored in battery storage, hence:

\[ E_{\text{bat}}(t+\Delta t) = E_{\text{bat}}(t) + (P_{\text{sell}}(t) \times \eta_{\text{DC/DC}} + P_{\text{sell}}(t) \times \eta_{\text{DC/AC}}) \times \Delta t \quad (11) \]

\[ P_{\text{MT}}(t) = 0 \quad (12) \]

Where \( \eta_{\text{DC/DC}} \) and \( \eta_{\text{DC/AC}} \) are the DC/DC and DC/AC efficiency respectively. It is notable that the simulation time step \( \Delta t \) is taken to be 1 hour in this study. After charging battery, if surplus generated power is overflwed, this power \( P_{\text{sell}}(t) \) is selling to grid. The energy in batteries is equal to \( E_{\text{bat-max}} \).

\[ E_{\text{bat}}(t+\Delta t) = E_{\text{bat-max}} \quad (13) \]

\[ P_{\text{sell}}(t) = (E_{\text{bat}}(t) - E_{\text{bat-max}}) \times \eta_{\text{DC/AC}} \quad (14) \]

B. Power produced by renewable energy (wind + PV) meets demand

In this situation, the produced power by (wind + PV) is equal to the demand. Therefore, in this situation the equations are:

\[ E_{\text{bat}}(t+\Delta t) = E_{\text{bat}}(t) \quad (15) \]

\[ P_{\text{MT}}(t) = 0 \quad (16) \]

\[ P_{\text{sell}}(t) = 0 \quad (17) \]

\[ P_{\text{buy}}(t) = 0 \quad (18) \]

C. Over demand

In this situation, the power demand is not fulfilled by power produced by wind turbine plus PV. We have two cases:

1) Batteries deliver the stored energy to the micro-grid system. In this case, the available energy generated by wind turbines plus PV plus energy stored in batteries is sufficient to satisfy the energy load requirement for hour \( t \). The equations can be expressed as follows:

\[ E_{\text{bat}}(t+\Delta t) = E_{\text{bat}}(t) + (P_{\text{wind}} \times \eta_{\text{DC/DC}} + P_{\text{PV}} \times \eta_{\text{DC/DC}} - P_{\text{load}}) \times \Delta t \quad (19) \]

\[ P_{\text{MT}}(t) = 0 \quad (20) \]

2) Generated power from PV and wind turbine plus Available store energy in batteries cannot meet demand. In this situation the battery banks are completely discharged and the energy in the battery banks is equal to \( E_{\text{bat-min}} \). In this state, load requirements are supplied from the micro turbine \( P_{\text{MT}} \):

\[ E_{\text{bat}}(t+\Delta t) = E_{\text{bat-min}} \quad (21) \]

\[ P_{\text{MT}}(t) = (P_{\text{load}} / \eta_{\text{DC/AC}}) - P_{\text{PV}} \times \eta_{\text{DC/DC}} - P_{\text{wind}} \times \eta_{\text{DC/DC}} - E_{\text{bat}}(t) \times \eta_{\text{disch}} / \Delta t \quad (22) \]

In this situation if the total produced power (PV + WT + Battery + MT) can not satisfy demand, requirement power \( P_{\text{buy}} \) is purchased from utility grid. When total produced power in micro-grid plus purchased power from utility grid cannot satisfy demand, first interruptible and then uninterruptible loads are shed. Shedding interruptible and uninterruptible loads is done with considering penalty for each of them.

\[ P_{\text{sell}}(t) = 0 \quad (23) \]

\[ P_{\text{buy}}(t) = (P_{\text{MT}}(t) - P_{\text{MT-max}}) \quad (24) \]

Where \( P_{\text{MT-max}} \) is the maximum output power of micro turbine.

IV. RELIABILITY

This study is performed for an area in north-west Iran. It is to mention that there are many similar regions around the world with this typical situation that can be expanded. There are various indices which quantify the reliability of a micro-grid system with hourly demand and supply data, such as Loss of Load Expectation (LOLE), Loss of Energy Expectation (LOEE), Energy Index Unavailability (EIU) and Systems Minute (SM) [24].

Reliability study of a system exposes the vulnerable areas of the system. A comprehensive planning strategy based on reliability is necessary to make the system robust. In this paper we regard that LOLE should below than 24.
Neglecting the solar capacity and wind turbine totally generation planning can be harmful for the micro-grid system with increasing installed capacity. Because of the intermittent solar irradiation and wind speed are characteristic, which highly influence the resulting energy production, the uncertainty of solar and wind are considered in this study. 

The deviation for PV power is simulated close to an actual change wave by following function as presented in Ref [25]:

\[ \Delta P_{PV} = 0.7 \times P_{PV} \]  

Therefore, in this paper, the uncertainty of PV power is obtained by multiplying the random output fluctuation derived from the white noise block in MATLAB/SIMULINK (noise) by fluctuations on generation. So the output power of PV considering uncertainty is obtained by following equation:

\[ P_{PV_{un}} = \Delta P_{PV} \times \text{noise} + P_{PV} \]  

The deviation for WT power is calculated by following function as presented in Ref [25]:

\[ \Delta P_{WT} = 0.8 \times P_{WT} \]  

The uncertainty of WT power is obtained by multiplying the random output fluctuation derived from the white noise block in MATLAB/SIMULINK (noise) by fluctuations on generation. So the output power of wind turbine considering uncertainty is obtained by following equation:

\[ P_{WT_{un}} = \Delta P_{WT} \times \text{noise} + P_{WT} \]  

VI. THE OBJECTIVE FUNCTION

The proposed method deals with the location and sizing of DER units with minimizing the cost of micro-grid. We choose present value cost for calculating the cost of micro-grid. The cost function has been modelled as a nonlinear programming problem. A particle swarm optimization (PSO) based method has been used to achieve optimal solution.

As mentioned before, the objective cost function consist of capital, operation and maintenance and replacement costs of DER, penalty for interruptible and uninterruptible loads and total loss of active power costs.

Hence, it can be formulated as the following optimization problem:

Minimize  \[ [PVC] \]

V. UNCERTAINTY

Where LOSS is total loss of active power in micro-grid, PVC\textsubscript{p} and PVC\textsubscript{Pui} are present value cost for interruptible and uninterruptible loads respectively, \( \gamma \) is constant penalty for total loss, IC is the initial cost of units, Cm is the present value of system life of maintenance costs, RC is the present value of the replacement of parts of the installation costs and Cost is the present value of operation cost which are calculated by equ.34 -37[9]. Pi(t) and Pui(t) are interruptible and uninterruptible loads which are not supported in time t.

PVC\textsubscript{P} and PVC\textsubscript{Pui} are calculated by following equ.34 and equ.35.

\[ PVC_{P} = \sum_{i=1}^{\gamma_{760}} R_i(t) \times \frac{1}{CRF(\text{r}, R)} \]  

\[ PVC_{Pui} = \sum_{i=1}^{\gamma_{760}} P_{i\text{load1}}(t) \times \frac{1}{CRF(\text{r}, R)} \]  

C\textsubscript{m} = maintenance cost \times 1/CRF (r, R)  

CRF = replacement cost \times \sum_{i=1}^{\gamma_{760}} \frac{1}{(1+i)^{n}}  

0\textsubscript{i} = FC \times FE \times ADG\textsubscript{i}  

L is the lifetime of each DER(year), N is the optimal number of each component, r is interest rate and R is the lifetime of Project, FC is fuel cost ($/Mbtu), FE fuel heat efficiency (Mbtu /kWh) and ADG\textsubscript{i} annually produced energy of ith MT Operation cost is calculated only for MT and is calculated by equ.40.

\[ ADG\textsubscript{i} = \sum_{t=1}^{\gamma_{760}} P_{MT}(t) \Delta t \]  

VII. SIMULATION TECHNIQUE

Particle swarm optimization was introduced in 1995 by Kennedy (social psychology) and Eberhart (electrical engineer). PSO technique conducts search using a population of particles corresponding to individuals as a potential solution to a problem, having N-dimensional space with a memory of the previous best position as well as the best position among all particles in addition to a velocity component. At each iteration, the particles adjusted their velocity along each dimension, which gives the new particle position. Updating of each dimension is independent [19], [24], [25]. In this study we assumed following PSO data:

Population size: 30, Acceleration constants: \( C_{1}, C_{2} = 2 \), Generation iteration: 300, Inertia weigh factor: \( W = 0.7 \).

The outline of the proposed algorithm is based on the following steps:
1. Randomly generate the initial particles which represent DER sizes and placements;
2. The given sizes are checked to served the loads in cases which are described above (Fig. 1);
3. If given sizes are not satisfied loads, go to step 1 otherwise go to step 4;
4. The Newton- Raphson power flow is done to calculate the total loss of active power and voltage of each bus in micro-grid;
5. If the voltage of each bus is not in its acceptable confine (Umin < U < Umax), go to step 1 otherwise go to step 6;
6. The process is continued until t=8760.
7. If all constraints are in acceptable confine the given size and placement are the optimum.

Fig. 1: The flowchart of algorithm simulating

**VIII. SIMULATION RESULTS**

In this article, the optimum combination of the considered micro-grid is calculated. This system is optimized using PSO algorithm. Lifetime of the project is 20 years. The input data consists of the annual wind data and solar radiation which belongs to a region in northwest of Iran. The load curve is actually an IEEE standard curve with 750 kW peak. The power of the wind turbine and PV could be derived from the wind speed and solar radiation data. The optimization was applied to 6- bus system as shown in Fig. 2. The information of system's line is shown in Table 1.
In this paper, we considered the PV plus WT and battery bank, micro turbine and the net present cost of micro-grid are shown in Table 2.

| TABLE 1: Line information of test system |
|-----------------|-----------------|-------------|-------------|
| From bus | To bus | R (PU) | X (PU) |  |
| 1 | 2 | 0.0912 | 0.418 |  |
| 1 | 3 | 0.0171 | 0.09 |  |
| 3 | 4 | 0.0228 | 0.012 |  |
| 2 | 4 | 0.0114 | 0.3 |  |
| 4 | 5 | 0.0228 | 0.12 |  |
| 3 | 5 | 0.0228 | 0.12 |  |
| 5 | 6 | 0.0228 | 0.12 |  |

The simulation is done in four situations in this study: without uncertainty, with uncertainty of PV, with uncertainty of WT, with uncertainty of PV and WT.

| TABLE 2: Optimum size and placement of each component |
|-----------------|-----------------|-------------|-------------|-------------|-------------|-------------|
| Without noise | With PV noise | With WT noise | With PV+WT noise |  |
| Number Wind turbine | Number PV | Number Battery bank | Number of micro turbine | BWT+PV+ bat | BMT | Total cost $  |
| 5 | 1814 | 100 | 24 | 6 | 6 | 1.47714*10^7 |
| 4 | 1827 | 100 | 24 | 3 | 6 | 1.481*10^7 |
| 6 | 1815 | 102 | 24 | 3 | 6 | 1.485*10^7 |
| 6 | 1821 | 103 | 24 | 6 | 6 | 1.492*10^7 |

1 BWT+PV+bat is the bus number of placement of WT+ PV+ battery
2 BMT is the bus number of placement of MT

In this paper, we considered the PV plus WT and battery can be placed in one bus together. Considering uncertainty of PV leads to increase number of PV than without uncertainty. Also the uncertainty of WT cause the number of WT to increase therefore the cost of micro grid is increased too.

The amount of interruptible and uninterruptible loads and exchanged power with utility grid are shown in Table 3.

| TABLE 3: Optimum amount of exchanged power, interruptible and uninterruptible loads |
|-----------------|-----------------|-------------|
| Interruptible loads (kWh) | Uninterruptible loads (kWh) | Buying power (kWh) |
| Without noise | 11077 | 169.45 | 25690.97 |
| With PV noise | 11697.07 | 179.746 | 26348.50 |
| With WT noise | 11425.07 | 180.65 | 24678.65 |
| With PV+WT noise | 11066.73 | 154.52 | 25566.1 |
| Selling power (kWh) | 46544.58 | 45807.8 | 44285.53 |
| | 47400 |
The amount of some notions of reliability is shown in Table 4 shows that LOLE is in the acceptable confine.

<table>
<thead>
<tr>
<th></th>
<th>LOLE (h/year)</th>
<th>LOEE (MWh/year)</th>
<th>EIU (%)</th>
<th>SM (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without noise</td>
<td>12</td>
<td>11.246</td>
<td>0.275</td>
<td>899.71</td>
</tr>
<tr>
<td>With PV noise</td>
<td>14</td>
<td>11.876</td>
<td>0.291</td>
<td>950.14</td>
</tr>
<tr>
<td>With WT noise</td>
<td>13</td>
<td>11.605</td>
<td>0.284</td>
<td>928.4</td>
</tr>
<tr>
<td>With PV+WT noise</td>
<td>12</td>
<td>11.221</td>
<td>0.275</td>
<td>897.7</td>
</tr>
</tbody>
</table>

Figures 3 to 6 show the output power of PV, WT, micro turbine and Energy of battery respectively when uncertainty of PV and WT is considered.
The uncertainties of PV and WT are shown in figures 7 and 8 respectively. Figures 9 and 10 show interruptible and uninterruptible loads which were not supported.

Figure 11 shows purchased energy from Utility grid, and Figure 12 shows sold energy to grid hourly.
For analysing the results and output power of units, figures 3 to 6 and also 9 to 12 are zoomed in time 2740 as shown in figures 13 to 20. At this time, available battery storage energy is equal to minimum allowable storage capacity and output power of PV and wind turbine is equal to zero. In addition to micro turbine injects power to the micro-grid at this time. At this time purchased power from grid is equal to 80 kW (maximum level). Therefore micro-grid sheds interruptible loads. Fig.19 obviously shows that at the time 2740, micro-grid sells energy to grid. In this hour surplus produced power of PV plus wind turbines after charging batteries is overflowed; this power is selling to grid. It is appear that micro-grid have enough capacity to supply the load. Hence micro turbine does not produce any power.

Fig 13: Output power of WT

Fig 14: Output power of PV

Fig 15: Energy fluctuation of battery

Fig 16: Output power of Micro turbine

Fig 17: Interruptible loads

Fig 18: Uninterruptible loads
 IX. CONCLUSION
The unit sizing and placement of micro-grid using a particle swarm optimization has been done in this work. The micro-grid consists of wind turbines, PV, micro turbine and battery banks. In this paper we assume interruptible and uninterruptible loads for micro-grid and micro-grid can shed uninterruptible loads subject to reliability constraint. In this study micro-grid can exchange power with utility grid. This simulation shows that considering uncertainty in solar irradiation and wind speed cause to increase total cost of micro-grid. Also the size of PV and WT increases. The micro-grid, which is used in this study, has high reliability because micro turbines are as a backup for wind turbines and PV. The main point in this study is the optimum size and placement of DER has been done in order to micro-grid has minimum cost and minimum loss of energy. Considering the noise of PV and WT in this study show that the effect of uncertainty in the optimum size and placement.

REFERENCES
[25] Xiangjun Li and Yu-Jin Song and Soo-Bin Han, J. Power Sources, 180, 468 (2008).