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CENTRALIZED OPERATION OF THE MICROGRIDS WITH DGS

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Abstract- In this paper, a multiobjective solution is proposed for centralized microgrids operation. The proposed multiobjective solution can optimize competing objective functions including overload, voltage drop and voltage stability. We used GIS as a platform for topology of network and database of the static data. Besides, the solution methodology consists employs roulette wheel mechanism and Monte-Carlo Simulation (MCS) for random scenario generation and Multiobjective Mathematical Programming (MMP) formulation based on the ε-constrained approach is implemented for provision of reserve and energy (Whit GIS-GAMS solver). The MMP formulation of the centralized operation is optimized while meeting AC power flow by GAMS software. A sample utility with 13 microgrids and 52 DGs is used to demonstrate the performance of the proposed method.

Keywords: Microgrid, Geographic Information System (GIS), Multiobjective-Centralized Operation.

I. INTRODUCTION

In recent years due to increasing the request of energy, climate changes, power network aging and growing in energy cost forced scientists to work on smart grids for reaching secure, stable and reliable network with usage of new types of energy. Micro grids concept [1] as main part of smart grids is part of distribution network by using of DGs can supply its local load in both grid connected mode and islanding mode [2]. In [2] a software for network management is presented which can be updated by different inputs. For security issue during the faults DGs must be disconnected from networks [3-6].

Different issue such as power quality [7], protection [8], utilization, market interactions in micro grids has be analyzed. in [8] two types of policy market are presented. Demand respond consumers are another part of smart grid [10]. In [11] a model is presented that maximize the profit and increase the power quality which include the variations of loading and DGs. The load and generation are close to each other so it makes the problem more complicated. The uncertainty outside the network effects on utilization.

Many research had been done for optimization of power system considering uncertainty leads to multi objective problems like fuzzy logic for multi objective problems [12]. Probabilistic formulation for optimization of multi object problems [13]. In [14] economical load flow with the development of a constraint of chance for probabilistic formulation is presented. in [15] a problem for line security multi-purpose probability is formulated.

There is no search for multi objective probabilistic model for a network which is consist of combination of multi micro grids including diverse goals like bidding and system security with uncertainty. This subject analyzes this subject.

The main purposes are divided in two parts:
- Pricing in order to centralized operation multi microgrids as multi object problem.
- Uncertainty system (contingencies related to the production and uncertainty in load)

The pricing and unit generation plan in micro grids connected to the network, network security parameters such as voltage stability, the voltage drop lines limitations included. Regarding to [16] the ε-constraint method for solving multi object problem. In this paper this method is used. For solving the problem, a two stage method is presented. the first stage is about Monte Carlo simulation (MCS) and Roulette wheel mechanism for the random behavior of generation units and grid lines under study based on forced outage rate (FOR) and uncertainty based on the probability distribution forecast error.

The optimization problem of each scenario in the first stage (including the improbable state and different from the prior probability) run the Multi Objective Mixed-Integer Non-Linear (MINLP), as the second phase will be solved. Due to the large volume of sample network of this article, Intelligent systems need to deliver the required simulation parameters is very important. The sample network simulation is done on the GIS platform [17].

The remaining sections of this article is categorized in the following way: In the second part, a probabilistic model for operating multi-objective hybrid microgrid in grid connected and by using (MINLP) method is introduced. The method is introduced for solving multi-objective optimization at third stage. In the next section, the sample grid is modeled in the GIS system. In the fifth section is also provided some suggestions.

II. SETTLEMENT RANDOM RETAIL MARKET

A process that network utilization is done in the network control center, short term decisions in electrical retail markets, considering the instantaneous pricing, integrating changes in load according to the variation curve and considering the instantaneous pricing and bids instantaneous price achieved [11].

So generation rate, energy levels and energy prices of each unite, determined as output optimization problem. Prices depend on suggested amounts and established prices by the market that before the current settlement price is obtained. to counter the risk of load changes it is necessary that the operator has stored enough. However, the storage, the extra cost, which the cleanup process in retail market should be considered in the objective function. In this problem stored value, is an uncertainty variable, depending on the contingencies and uncertainties load. To solve the problem of settlement of retail market a two-stage method proposed in this paper:

Due to the large volume changes and possible scenarios on the network, In the first stage scenarios using the Roulette wheel and MCS are produced. And also scenario reduction is used to reduce volume of computation. In the second stage optimization problem resulting from each scenario is modeled and will be analyzed by MINLP method. These two steps will be described in detail below.

A. Step 1: Production and Reduce the Number of Scenarios

In this paper, the load uncertainty based on load forecast error. Based on this method a probability distribution function, defined for load forecast error, then Probability distribution function of each bus by using the rate of bus total load (distribution coefficient load) is define. Figure 1 indicate an example of the probability distribution of load forecast errors as discrete system.

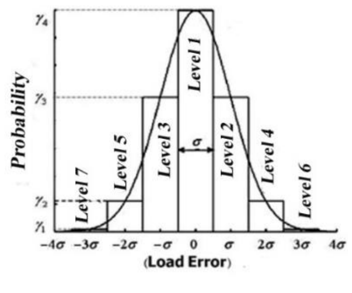

Figure 1. An example of the probability distribution of the load forecast error as a discrete system

In Figure 1, seven levels and each deviation from the standard load as the forecast error (σ) display [18]. According to different estimates of load probabilities obtained from the probability distribution function of the error in load, Roulette wheel mechanism [19], are run to produce scenarios. For this purpose, first the different level of load forecasting normalized and assume as the same, then the range between 0 and 1 is shown in Figure 2 for the different possibility is normalized. This is done for various scenarios predicted by roulette wheel mechanism.

Therefore, based on a random selection of roulette wheel method, the probability of greater amounts has more chance to choose with large roulette wheel. According to this method, in each scenario MCS, a random number between zero and one produced. For each Generation Unit and any line network, the resulting number is compared with the FOR. If the random number generated for a generating unit or line, is higher than the FOR, this unit can be used in supplying the energy of networks, Otherwise, the unit cannot be present in the generation cycle for specific time.

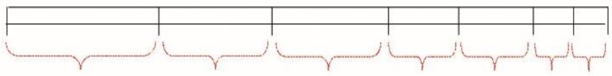

Figure 2. Roulette wheel mechanism for normalizing probability of the prediction load

If the random number for a line is less than the FOR line, that line will be deleted and assume that that line does not exist. This method for all energy sources in the network is the accumulation of several Micro grid will be implemented. This process is achieved with a wide range of scenarios. That cost much and took long to for analyzing. This paper uses the idea used in reference [20] to reduce the scenarios. Under this approach scenario may be more likely to use the random operation procedure, be extracted. The probability of each scenario produced can be calculated as follows:

$$\vartheta = \sum_{k=1}^{NoL} (W_k^G.\lambda_k) \prod_{i=1}^{NoB} \prod_{u=1}^{NoU_i} (W_{i,u}^G.(1-FOR_{i,u}^G) - (W_{i,u}^G - 1)FOR_{i,u}^G) \\ .\prod_{i=1}^{NoB} \prod_{j=1}^{NoB} (W_{i,j}^b.(1-FOR_{i,j}^b) - (W_{i,j}^b - 1)FOR_{i,j}^b) \quad (1)$$

where, W_k^g can be obtained by Roulette wheel, and $W_{i,u}^G$ $W_{i,j}^b$ are from MCS.

B. Step 2: Centralized Operating Model

B.1. Objective Functions

In multi micro grid system, system security and fast determine the power if each unit is so important. Minimizing energy costs and increase customer profit, minimize overload and voltage drop and voltage to maximize the security margin are objective functions. The objective functions are formulated as follows.

B.2. Display Function Cost Energy Supply and Storage System

In the multi-objective market settled prices. The main objective function ($Func_1$) minimizes the energy costs, storage and systems needed to be reduced in consumers. Therefore, the objective function $Func_1$ will be written as follows:

$$Func_1 = \vartheta.\left[\sum_{i=1}^{NoB} \sum_{u=1}^{NoU} w_{i,u}^G . \begin{pmatrix} \rho_{i,u}^e.P_{G_i,u} + Z_{i,u}.(\rho_{i,u}^{DG}.DGP_{i,u}) \\ +Z_{i,u}.(\rho_{i,u}^{DR}.DRP_{i,u}) \end{pmatrix} \right] \quad (2)$$

It should be noted that Equation (2) is for all scenarios. If the index s goes scenario, Equation (2) will be changed to the form of Equation (3).

$$Func_1 = \sum_{i=1}^{Sa} \vartheta . \left[\sum_{i=1}^{NoB} \sum_{u=1}^{NoU} w_{i,u}^{G} . \begin{pmatrix} \rho_{i,u}^{e} . P_{G_i,u} + Z_{i,u} . (\rho_{i,u}^{SB} . SBP_{i,u}) \\ + Z_{i,u} . (\rho_{i,u}^{DG} . DgP_{i,u}) \\ + Z_{i,u} . (\rho_{i,u}^{DR} . DRP_{i,u}) \end{pmatrix} \right] \quad (3)$$

Regarding to inject power as storage is possible when the unit is connected to the network, therefore, the variable *z* as an integer variable shows the unite is connected or not. Parenthesis in the Equations (2) and (3) represent income for microgrid national network of distributed generation in energy supply, Net income for the reserve by the global, distributed generation resources and benefits to meet the time.

B.3. Display Function Lines Limitation and Grid Voltage Drop

In order to protect the distribution network combination of Micro grid during central operation, objective functions of $Func_2$ and $Func_3$ should be minimized:

$$Func_2 = \vartheta . \sum_{i=1}^{NoB} \left(\frac{V_i - V_{ref}}{V_{ref}} \right) \quad (4)$$

$$Func_3 = \vartheta . \sum_{i=1}^{NoB} \sum_{\substack{j=1 \\ j \neq i}}^{NoB} w_{i,j}^{B} . \left(\frac{S_{ij}}{\overline{S}_{ij}} \right) \quad (5)$$

B.4. Display Function of Voltage Stability Margin

Stability margin in terms of large power systems have been evaluated in different references. For example, in [21] Power system voltage stability index is defined in this paper based on the same reference, this index is defined for smart grid network in the steady-state studies, *P-V* curve in Figure 3 is shown is system voltage breaking point. SNB actual voltage breaking point (saddle point) of the curve branch (or point B'' in the *P-V* curves in Figure 3) rather than the point the nose (NP) of the curve *P-V* is (point B').

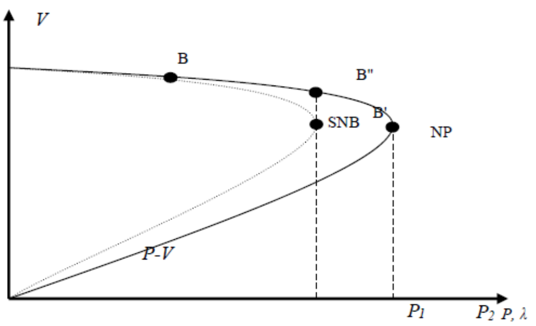

Figure 3. *P-V* curve network and branches

The Equation (6), indicates voltage stability of the grid 8 (VSM) maximum load capacity of the network in terms of stability voltage [22]:

$$VSM = \frac{MVA_{(B')} - MVA_{(B)}}{MVA_{(B)}} \quad (6)$$

In the $Func_4$ to view and extract VSM in all scenarios, is considered. For the purpose of controlling stability of network, this function is one of the functions goal that should be the maximum.

$$Func_4 = \sum_{s=1}^{NS} \vartheta_s . VSM_s \quad (7)$$

III. CONSTRAINTS OF PROBLEM

The multi-objective optimization problem, there are several constraints equality in all scenarios will be considered.

A. Load Flow Constraints

Due to the distribution network is a combination of several microgrid, it doesn't follow the traditional networks and radial arrangement, therefore this paper uses large scale power flow constraints.

$$\sum_{u=1}^{NU_i} w_{i,u}^{G} (P_{G_i,u} + z_{i,u} . (\mathrm{Re}_{i,u}) - (P_{Di} + \Delta P_{Di}) = \\ = \sum_{j=}^{NB} w_{i,j}^{B} |V_i| |V_j| |Y_{ij}| \cos(\delta_{ij} - \theta_{ij}) \quad (8)$$

$$\sum_{u=1}^{NU} (W_{i,u}^{G} Q_{Gi,u}) - (Q_{Di} + \Delta Q_{Di}) = \\ = \sum_{j=}^{NB_i} w_{i,j}^{B} |V_i| |V_j| |Y_{ij}| \sin(\delta_{ij} - \theta_{ij}) \quad (9)$$

Equations (8) and (9) show the balance load in each network node in each scenario. To obtain the updated matrix distribution network GIS system will be used.

B. Inequality Constraints of Energy Sources and Loads

To ensure that each unit is within the allowable range, we get the following constraints.

$$-z_{i,u} . P_{G\max,i} + P_{Gi,\mu} \leq 0 \quad (10)$$

$$z_{i,u} . P_{G\min,i} - P_{Gi,\mu} \leq 0 \quad (11)$$

C. Distribution Network Security Constraints

In Equations (12) and (13), constraints related to security distribution system (allowable range of current and voltage grid lines over the network) is provided.

$$|S_{ij}| \leq |\overline{S}_{ij}| \quad (12)$$

$$|V_{\min_i}| \leq |V_i| \leq |V_{\max_i}| \quad (13)$$

The operation of centralized distribution network in the form of a MINLP problem for each scenario. Non-linear nature of load and relationships broadcast on network load, causes non-linear problem. The Equations (3), (4), (5) and (7) are objective functions. These constraints for all scenarios and index *S* is used for each scenario.

IV. SOLVING MULTI-OBJECTIVE PROBLEM

In Multi-Objective Mathematical Programming (MMP) there are more than one objective function and there is not usually only one optimal solution to optimize all. Therefore, we will find best answer. In MMP optimization problem is replaced by Pareto optimization.

The ε-constraint method is used for optimizing the objective function, so this method is used for network operation. In this optimization $Func_1$ function is the main function and other functions assume as constraints:

$$\min Func_1$$
$$\text{subject to: } Func_2(x) < \varepsilon_2 \text{ , } Func_3(x) < \varepsilon_3 \text{ , } Func_4(x) < \varepsilon_4 \quad (14)$$

To calculate the Payoff table in the MMP with four function, initially each objective function is optimized, then method of solving the optimization problem for $Func_i$, i=1,…,4 the other optimized objective functions $Func_1,\ldots,Func_{i-1},Func_{i+1},\ldots,Func_p$ are shown by $Func_1^i,\cdots,Func_{i-1}^i,Func_{i+1}^i,\cdots,Func_p^i$ for ith row of the final table included $Func_1^i,\cdots,Func_{i-1}^i,Func_i^*,Func_{i+1}^i,\cdots,Func_p^i$. Thus all rows in the table is calculate. The jth column final table includes values optimized for function j ($Func_j$) with usage of ε-constraint method It is noteworthy that the problem of centralized settled operation in the form of MMP, only part of the objective function is calculated, While the main purpose is as a function $Func_1$. Then Objective functions divided to equal intervals (h_2–1), (h_3–1) and (h_4–1). Generally problem has (h_2+1), (h_3+1), (h_4+1) points for $Func_2$, $Func_3$, $Func_4$ therefore (h_2+1)×(h_3+1)×(h_4+1) sub problem must be solved. Considering the maximum and minimum limits. Each sub problem is:

$$\min Func_1(x)$$
$$\text{subject to: } Func_2(x) < \varepsilon_{2i} \text{ , } Func_3(x) < \varepsilon_{3i} \text{ , } Func_4(x) < \varepsilon_{4i} \quad (15)$$

$$\varepsilon_{2i} = \max(Func_2) - \left(\frac{\max(Func_2) - \min(Func_2)}{h_2}\right) \times i \text{ , } i = 0,1,\ldots,h_2 \quad (16)$$

$$\varepsilon_{3i} = \max(Func_3) - \left(\frac{\max(Func_3) - \min(Func_3)}{h_3}\right) \times i \text{ , } i = 0,1,\ldots,h_3 \quad (17)$$

$$\varepsilon_{4i} = \max(Func_4) - \left(\frac{\max(Func_4) - \min(Func_4)}{h_4}\right) \times i \text{ , } i = 0,1,\ldots,h_4 \quad (18)$$

In these relations max(…) and min(…) indicate minimum and maximum of objective function base on payoff table. Optimization by solving each sub problems, a Pareto optimization is done. Some of sub problems may have impossible answers. In this paper each interval assumed as 4 for objective function.

After achieving the optimum solution of Pareto. Operator need to choose the best solution. Due to the limitation in the response speed, the current situation in terms of proximity of the system to respond, the final answer is chosen [23].

V. NUMERICAL RESULTS

The study network to deliver results in this paper, in Figure 4 in the GIS software environment is shown. Micro grid is made in the geographical area of under study network that has 13 Micro grid network, is shown in the form of Figure 5.

In the absence of DG network operates radially, and all the lines are fed in one direction. In the presence of DG some parts of the network will be fed loop mode and multi-directional.

One direction lines are shown by ► and ● displaying of tow side feeding that is cause of DGs which are connected to the networks shows the complicate operation of network more and more. Network information is shown in Table 1. Information on grid matrix is produced using the tools in GIS software environment is extracted. Part of the matrix which contains 1320 pieces and 1734-line connection point is shown in Table 2.

Using data in Table 2, impedance and admittance matrixes will be calculated, Load flow according to Equations (8) and (9) will be created. load subscribers based on subscriber behavior patterns specific to each region and different fees [10]. Part of information about lines current of network is shown in Figure 7. Figure 8 is injected power price in kilowatts during 24 hours. This model is based on [10].

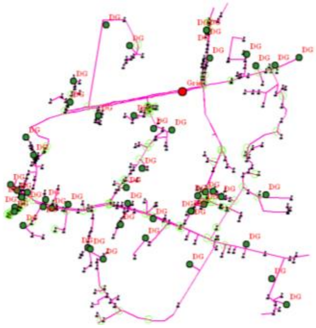

Figure 4. The network for numerical calculations

Figure 5. Micro grid is made up of under study network

Table 1. Network information

Number	Title
13	Micro Grid
52	Network's DG
77	The Maneuver Key
35	Consumer (Demand Respond)
260	Consumer
127	Network (Kilometer)

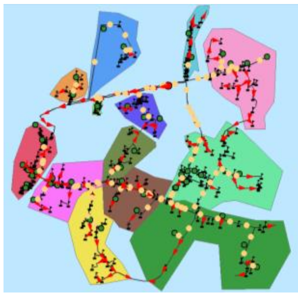

Figure 6. Color lines based on the direction of electrical current

Table 2. Part of the network components to produce sample grid matrix

ID-Code	Bus 1	Bus 2	Length (m)	Resistance (Ω)	Reactance (Ω)
0E4E67	Node(16)	Node(20)	55.14952	0.01092	0.021563
7C9B9E	Node(11)	Node(25)	320.8907	0.063536	0.111349
AAE2DF	Node(17)	Node(31)	55.14952	0.01092	0.01671
FA2FA5	Node(16)	Node(32)	0.330064	6.54E-05	8.55E-05
04238D	Node(20)	Node(28)	446.6937	0.088445	0.096039
729E4D	Node(11)	Node(13)	422.8716	0.083729	0.165343
9F4D7C	Node(20)	Node(36)	281.7094	0.079048	0.097753
E9C7EE	Node(16)	Node(28)	199.5467	0.055993	0.060463
38DD30	Node(13)	Node(31)	213.333	0.059861	0.055253
A804FE	Node(12)	Node(28)	26.09157	0.007321	0.00561
4A3518	Node(21)	Node(39)	11.12449	0.003122	0.00435
85C3F1	Node(5)	Node(11)	235.6233	0.066116	0.081761
25A3FB	Node(14)	Node(22)	141.8978	0.039817	0.042995
C6ECF5	Node(18)	Node(22)	320.8906	0.122548	0.083111

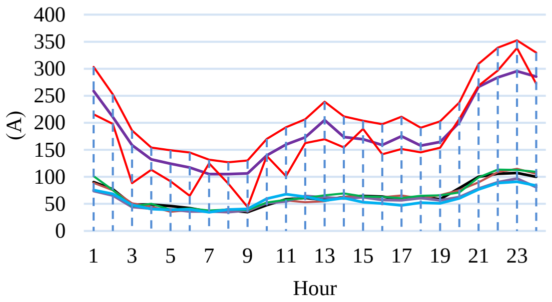

Figure 7. Load (Amps) is part of the main lines of the distribution network

Table 3. Details of DG in sample network

a ($/MWh^2)	b ($/MWh)	c (k$/h)	Min (kW)	Max (kW)	Bid ($/MWh)	Max (kW)	No
0.34	50	700	50	600	25	100	1-7
0.02	13	200	100	800	19	35	8-12
0.04	20	720	75	300	27	60	13-20
0.03	27	600	100	800	35	100	21-27
0.07	39	700	100	360	40	60	28-36
0.02	17	200	100	450	41	40	37-40
0.02	9	200	100	324	39	20	41
0.01	14	400	100	680	30	60	42,43
0.01	17	400	100	900	80	150	44-48
0.01	10	300	50	200	46	20	49
0.01	9	450	100	470	60	50	50-52

The number of consumers with ability of demand respond among the existing models in [10], Real Time Pricing (RTP) is chosen. In Table 4 information about consumers is shown. Other consumers (260 consumers) are calculated by method which is mentioned in Figure 7.

Regarding to network information, location of the breakers. Network equipment. By using GAMS software an interfacing to GIS, the system is evaluated. GIS software system responsible for generating the basic data for calculation (such as the network topology and impedance network admittance matrix - basic and static information of network) and provide final results (in the form of numerical and graphical) is responsible. Using optimization method stated, the injection can be any of the DG for whole day is calculated.

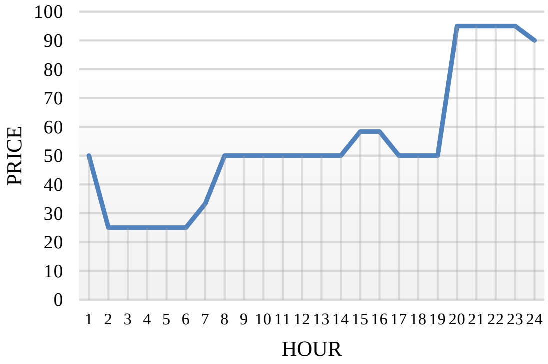

Figure 8. Injected power price curve

Table 4. Information related to loads with ability of demand respond

Max load shedding (kW)	No	Max load shedding (kW)	No
50	27-28	6	1-7
95	34-28	18	15-8
127	35	110	17-18

Table 5. Consumer transformer

Number of customer	Transformer capacity (kVA)
3	15
42	25
63	50
106	100
3	160
47	200
2	250
22	315
2	400
1	630
1	800
3	1000

According to calculations which carried out, At 22, the network load 31,842 kilowatts. The total power supplied by DG network (energy storage) of 29390 kW and 8815 kW of maximum storage will be supplied. The system required reserves at 22, 10% predicted network load, will be 4995 kW. The results of the amount of power supplied injection every DG and store them on the network for 22 hours, is shown in Figure (9). 2279 kW distributed generation supply sources are stored. Price of the reserve is equal to 94.379 of unite.

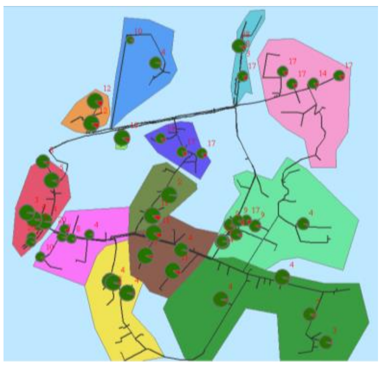

Figure 9. injected and stored power by DG sources

Therefore, the 1734 kW by the network should be supplied. Storage costs by subscribers, will be 37.428 units. The cost of storage through a global network is equal to 131.734=0.095×0.8×1734. The amount of energy supplied by DGs are 21689 kW. Considering the amount of energy required by the system 10153 kWh will be bought of cross-country network. Price for Units will be paid to the network 964.535 unit. The cost will be paid to the DG will be 1648.364 unit.

The allowable range defined for different parts of the network lines and to maintain voltage stability and maintaining the allowable range of the network and network operation is considered as an important part of solving. Lines under normal conditions and boundary conditions is shown in Figure 10. Red lines, display the lines with boundary conditions. The amount of load per subscriber is also shown by the diameter of the circle ● screen will load.

Due to the nature of the subject tested, the volume of results is too much only part of the results is mentioned. For example, in Figure 11 the operation of DG No. 4 is shown. The green part is injected power by DG and red part is stored power by energy supply. Reserve and power of each microgrid is shown at 22 in Figure 12. The results of this study, is reaching the amount of power each and every line for Micro grid during the 24 hours.

Figure 10. Displaying the lines with regard to security and stability of networks

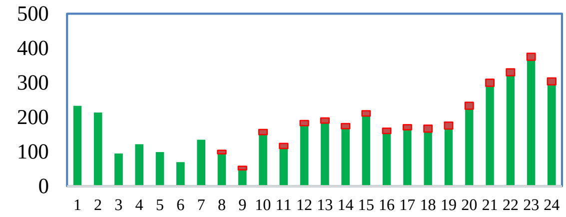

Figure 11. Power injected and stored DG (4)

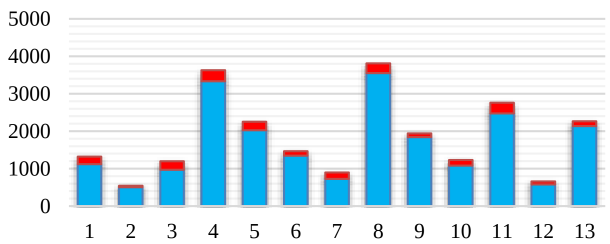

Figure 12. The Power injected into the grid and storage of each Micro grid at 22

VI. CONCLUSION

Due to the subject of centralized operation of microgrid is an immensely complex, this paper attempted to consider main parts and provide an accurate answer. Combination of microgrid operation to a MINLP problem is one of this article advantages. Mass of information and information management was designed on GIS environment. Regarding that fast responding is one of most important issue, the article used intelligent optimization to reach the answers. Analyzing of sample network with accurate information and acting some changes some required changes for smart grid, in some cases took less than 7 minutes. Fast and accurate answers can be proper for one-hour planning. By increasing accuracy, it can be possible to transfer the prediction one day ahead.

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