Improvement of Load Ability in Distribution Systems Using Distributed Generation

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Abstract: *Traditional approach of delivering the electrical power to end-users was done in the way that after required power was generated, huge power plants increased the voltage up to a desirable level using transformers. Then, electrical power was delivered via long-distance lines to the destination. After one or two stages of voltage reduction, consumers received the delivered power. Recently, due to higher demand for electricity and higher output of generation units, small power companies are more likely to exploit the mentioned units in their distribution system and near the consumers. These small units attached to the distribution systems are called non-concentrated generation or distributed generation. Nowadays, distributed generation plays a vital role in electrical distribution systems. For instance, reliability improvement index, stability improvement and loss reduction are some good examples. One main aspect of using distributed generation is to displace these resources in distribution networks. Load ability in distribution systems and its promotion are some keys in power systems. Up to now, displacement of distributed generation resources in order to promote the load ability of distribution system has not been discussed. It is obvious that displacement and usage of distributed generation using genetic algorithm improvement maximize the load ability in distribution systems. After the considered flowchart has been extracted, this method is used in IEEE standard 12-bus network. Results have shown the efficiency of the mentioned algorithm.*

Keywords: *load ability, voltage profile, loss reduction, distributed generation, distribution systems .*

Indicators:

VPII	*Voltage profile improvement index*
LLRI	*Line loss reduction improvement index*
DG	*Distributed Generation*
EIRI	*Environmental impact reduction index*
LTAPII	*Line transmission apparent power improvement index*
EIRI	*Dynamic Programming*
DNLP	*Dynamic Non-Linear Programming*
Eld	*Electrical demand*
ES	*Electrical Storage*
ESS	Energy Storage System

1. INTRODUCTION

The interconnected systems, power generation is performed in a concentrated way via huge power plants. In early years of interconnected systems evolution, this system had a 6-7% growth rate of electricity consumption per year. In 1970s, some issues such as oil crisis and environmental problems posed new obstacles for power industry. In 1980s, the mentioned factors and economic changes led to load growth reduction up to 1.6 to 3% annually. At this time, the expense of delivering and distributing electrical power increased significantly. Therefore, central generation of huge plants was impractical due to load growth reduction, higher payment for delivering and distributing electricity, environ-mental issues, technological changes and various legislations[1,2]. Some problems including environmental pollution, new transmission networks, technology development in industrialization of small-scale generation units compared with huge generation units have led to higher usage of small generation units called distributed generation which are mostly attached to the distribution network and are in no need of transmission lines. Studies conducted by research institute such as EPRI indicate above 25% consumption of electricity generated by distributed generation up to 2012. Across the United States and Europe, distributed generation is considered as a practical financial and technical alternative for consumers and generators. [3,4]. It also increases the reliability and creditability of power generation. In the most countries, DG includes 10% of in-stalled capacity of total generation. The mentioned value is above 30-40% for countries such as Netherland and Denmark. It is predicted to be up to 78% in few countries including Australia by 2012.

2. EVALUATION AND SELECTION OF INDICES TO INSTALL DG

2.1. Voltage profile index-VPII

One main problem in distribution networks is improper voltage profile. The effect of distributed generation units on voltage regulation can be positive or negative depending on distribution system, characteristic of distributed generation units and the place selected to install distributed generation units[5]. Because voltage is one the most significant factors in the power quality point of view; therefore, investigation of the effect of distributed generation units upon voltage has been emphasized. Accordingly, DG increases and retains voltage in an acceptable range in the consumer terminal. Using DG reduces the transmission line current and enhances load ability and finally leads to consumer voltage range boosting [6].

$$\mathrm{VPII} = \frac{\mathrm{VP_w/DG}}{\mathrm{VP_{WO}/DG}} \tag{1}$$

$$VP = \sum_{i=1}^{N} V_i . L_i . K_i \tag{2}$$

2.2. Line loss reduction index-LLRI

Using reduces the power transmission in lines and leads to loss reduction. Line loss is a significant factor in the condition of heavy load such that the expenditure will be paid by consumers as a higher price for energy [4].

$$\mathrm{LLRI} = \frac{\mathrm{LL_w/DG}}{\mathrm{LL_{wo}/DG}} \tag{3}$$

$$LL = \sum_{i=1}^{M} I_{Li} . R_i . D_i \tag{4}$$

2.3. transmission line apparent power improvement index-LTAPII

Another advantage of using DG is aspect power reduction in transmission lines. This leads to higher load ability and prevents the installation of new lines and other equipment's including transmission and distribution stations. Therefore, less money is spent although network is fed with higher lead [7,8].

$$\mathrm{LTAPII} = \frac{\frac{\mathrm{LTAP_{WO}}}{\mathrm{DG}}}{\frac{\mathrm{LTAP_{W}}}{\mathrm{DG}}} \quad (5) \qquad \mathrm{LTAP} = \sum_{i=1}^{M} \mathrm{I_i}.\mathrm{V_j} \quad (6)$$

3. Objective function

In this problem, objective is defined in a way that the least voltage loss in network buses leads to higher capacity for line. [9,10].

$$\mathrm{BI} = (\mathrm{BW_{VPI}}).(\mathrm{VPII}) + \left(\frac{\mathrm{BW_{LLR}}}{\mathrm{LLRI}}\right) + (\mathrm{BW_{LTAP}}).(\mathrm{LTAPII}) \quad (7)$$

$$\mathrm{BW_{VPI}} + \mathrm{BW_{LLR}} + BW_{LTAP} = 1 \quad (8)$$

4. Genetic Algorithm Method

The most important optimization methods in order to solve the problems of displacement of distributed generation include sensitivity analysis, dynamic programming method, linear programming method, second order gradient method, Newton Raphson method and genetic algorithm method [11]. In order to conduct the genetic algorithm method for displacement of local plants, some points must be considered: objective function, network loss and network voltage. Loss is calculated according to the below equation: [12].

$$\mathrm{P_{Loss}} = \sum_{i=1}^{n} \mathrm{P_{Gi}} - \sum_{i=1}^{n} \mathrm{P_{Di}} \quad (9)$$

Where:
n is the number of busses, P_{GI} indicates the generated power of the bus i and P_{DI} represents consumed power of the bus i. At last, P_{LOSS} is network active loss.

4.1. Using Genetic Algorithm Method

The main obstacles of using the first five methods are approaching local optimized point instead of general optimized point and requiring aid information such as second order gradient, Jacobean matrix and sensitivity matrix. Genetic algorithm is used to resolve the problem of dynamic programming. In the mentioned method, optimization is used according to natural selection and genetic rules[13,14]. Optimization starts with a series of data and follows a chain of numbers. Subsequently, the possibility to reach local optimized point is less. Genetic algorithm works with a collection of encoded parameters. Genetic algorithm begins to research a series point collection instead of one single point. In this condition, there is less possibility for reaching false optimized point [15]. This algorithm uses main information of objective function and there is no need of aid information such as derivation of objective function. Operational method of genetic algorithm is encoding parameters, creating chains and copying them and finally transforming some parts of these chains. In operational phase, there are three phases including duplication, splitting of two chains and creation of new chains along with mutation operator. Duplication is a process in which separated chains are copied according to their specific objective function. Objective function shows the appropriateness and optimization of what is to be maximized [16].

5. Problem Constraints

Problem constraints are: limitation of Power Plants generation power $P_{Gi}min < P_{Gi} < P_{Gi}max$, limitation of Power Plants generation reactive power $Q_{Gi}min < Q_{Gi} < Q_{Gi}max$, limitation of Flow passing of lines $P_{ij}min < P_{Gij} < P_{ij}max$. limitation of bus voltage $V_imin < V_i < V_imax$. Objective function must be solved considering technical conditions and the voltage profile must be maximized. Additionally, the most important conditions of the genetic algorithm are convergence condition and achievement of considered object. Generally, a maximum is induced on generation and the generation is blocked when mean value of appropriateness is constant for some sequential population and no condition is breached[17,18].

6. The Result of Simulation on IEEE 12 BUS Network

This network includes only one main feeder. The voltage of bus 1 is considered as 1pu. basic voltage is 6.5 KV and basic apparent power equals 10 MVA. Figure 1 represents a 12-bus network[19,20].

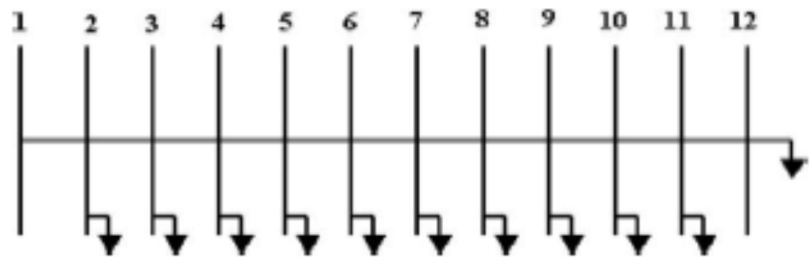

Figure 1: IEEE 12- Bus Network

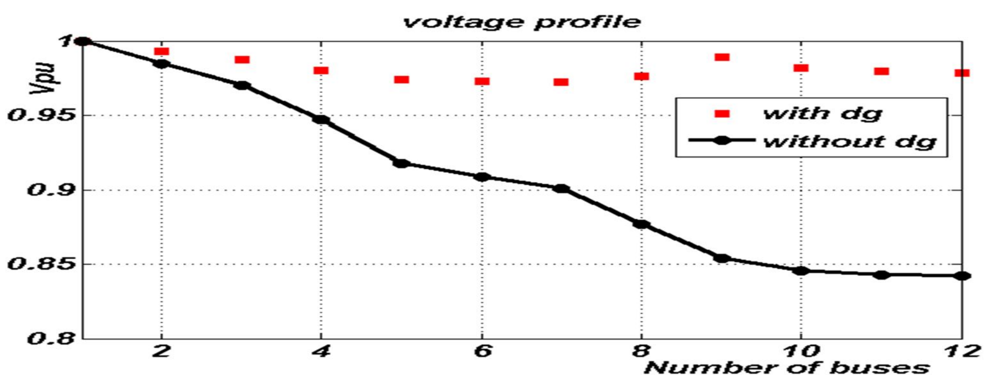

Figure 2: Voltage profile for 12 bus network using one DG

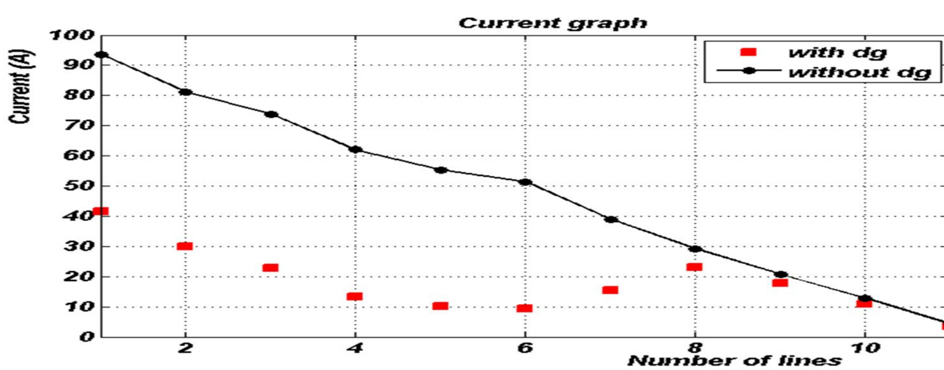

Figure 3: Current profile at the main feeder lines (1-11) using one DG

Table 1: The result using one DG

quantity under study	With DG	Without DG	percentage reduction
Active Losses (KW)	*18.7*	*60.1*	*68%*
Reactive Losses (KVAR)	*7.6*	*23.3*	*67.38%*
Line current 1(A)	*65.02*	*93.6*	*30.5%*
Line current 2(A)	*52.7*	*81.3*	*35%*
Line current 3(A)	*45.4*	*73.8*	*38.4%*

Table 2: The result using two DG in buses 7 and 10 with the capacity of 0.1 MW and 0.125 MW

quantity under study	With DG	Without DG	percentage reduction
Active Losses (KW)	*5.9*	*60.1*	*90.18%*
Reactive Losses (KVAR)	*2.3*	*23.3*	*90.13%*
Line current 1(A)	*41*	*93.6*	*56.2%*
Line current 2(A)	*29.25*	*81.3*	*64%*
Line current 3(A)	*22.2*	*73.8*	*70%*

Table 3: The result using four DG with 25% increase of load

quantity under study	With DG	Without DG	percentage reduction
Active Losses (KW)	*4*	*102.8*	*96%*
Reactive Losses (KVAR)	*1.5*	*39.7*	*96%*
Line current 1(A)	*22.27*	*121.11*	*81%*
Line current 2(A)	*16.88*	*105.58*	*84%*
Line current 3(A)	*18.41*	*96.20*	*80%*

Table 4: Comparison between VPII, LLRI, LTAPII indices using one DG and two DG

indices	Without DG	One DG	Two DG
LLwDG	*0.0020*	*0.0034*	*0.0001*
LLwoDG	*0.0020*	*0.0020*	*0.0020*
LLRI	*1*	*0.3109*	*0.0974*
LTAPwoDG	*0.1140*	*0.1140*	*0.1140*
LTAPwDG	*0.1140*	*0.0616*	*0.0322*
LTAPII	*1*	*0.540*	*0.2822*
VPwDG	*0.0178*	*0.0186*	*0.0190*
VPwoDG	*0.0178*	*0.0178*	*0.0178*
VPII	*1*	*1.045*	*1.071*

Table 5: Comparison between VPII, LLRI, LTAPII indices using three DG and four DG

indices	Without DG	Three DG	Four DG
LLwDG	*0.0034*	*0.0019*	*0.0013*
LLwoDG	*0.0034*	*0.0034*	*0.0034*
LLRI	*1*	*0.0564*	*0.0385*
LTAPwoDG	*0.1464*	*0.1464*	*0.0034*
LTAPwDG	*0.1464*	*0.0291*	*0.0257*
LTAPII	*1*	*0.1990*	*0.1754*
VPwDG	*0.0178*	*0.024*	*0.0243*
VPwoDG	*0.0178*	*0.0216*	*0.0216*
VPII	*1*	*1.011*	*1.126*

As the numbers in Table 5 show, LLRI and LTAPII indices have decreased significantly, which indicates a reduction in losses and a decrease in apparent power at transmission lines, or in other words, an increase in line capacity. VPII also shows the improvement of the voltage profile in the bus bars.

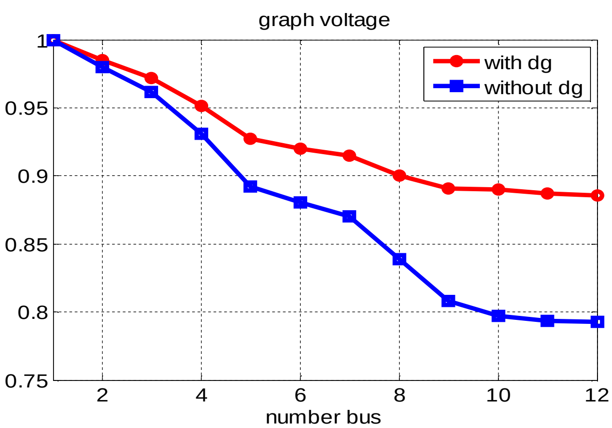

Figure 4: Voltage profile of 12-bus network with 25% increase of load using one DG

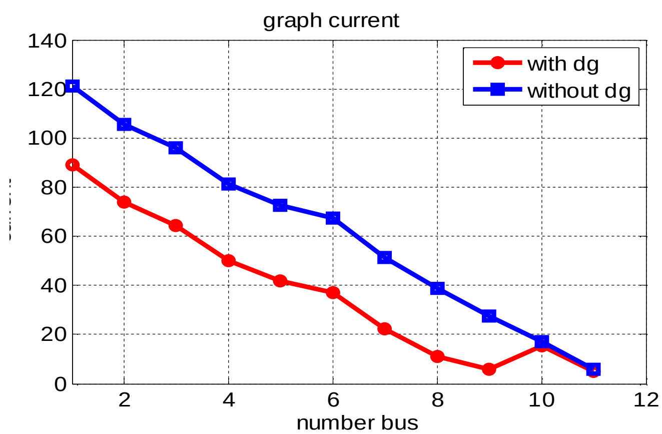

Figure 5: current profile at the main feeder lines (1-11) with25% increase of load using one DG

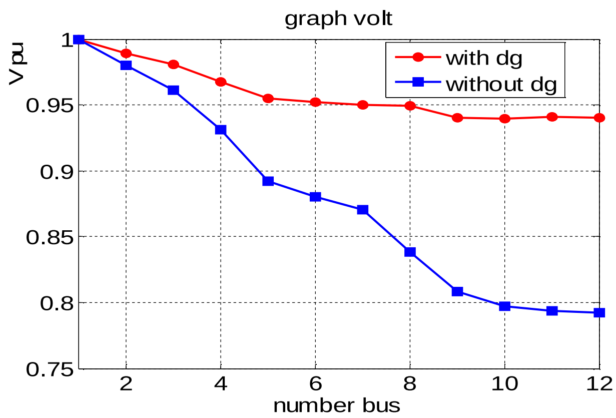

Figure 6: Voltage profile of 12-bus network with 25% increase of load using two DG

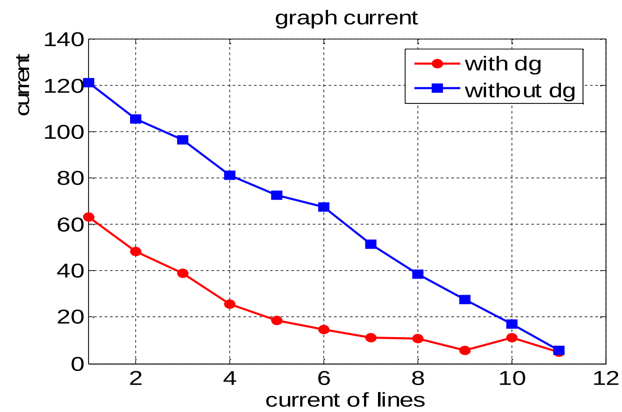

Figure 7: Current profile at the main feeder lines (1-11)with 25% increase of load using two DG

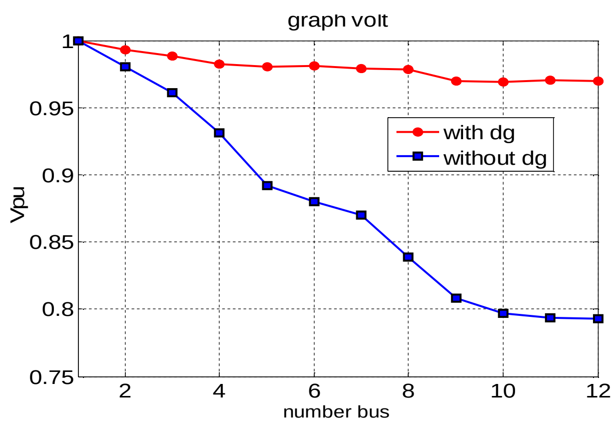

Figure 8: Voltage profile of 12-bus network with 25% increase of load using three DG

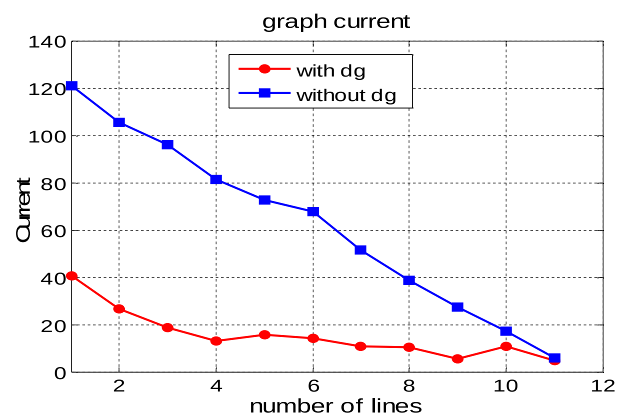

Figure9: Current profile at the main feeder lines (1-11)with 25% increase of load using three DG

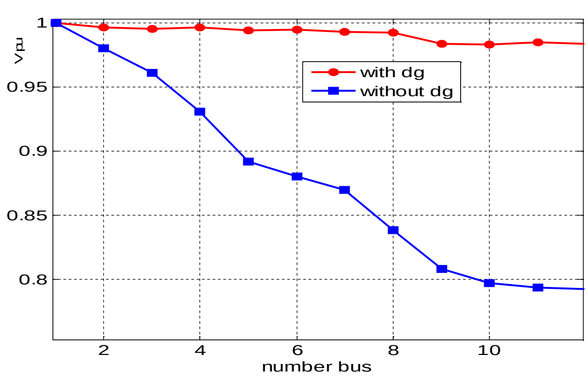

Figure 10: Voltage profile of 12-bus network with 25% increase of load using four DG

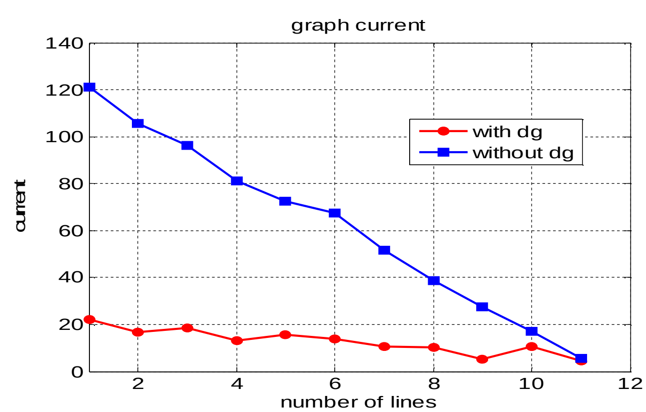

Figure 11: current profile at the main feeder lines (1-11)with25% increase of load using four DG

7. CONCLUSION

In this paper, optimized displacement of distributed generation plants in network is investigated in order to evaluate the effect of displacement on network load ability improvement despite stability in system equipment's. Tables have shown clearly that 25% increase of load leads to less loss index and aspect capacity while using DG compared with the absence of DG. Additionally, voltage profile index is higher in the presence of DG. More DGs means higher growth rate of the mentioned parameters. It means that the presence of distributed generation systems leads to improved load ability of distribution system. in this situation, there is no need for new equipment's. Generally, it is concluded that the presence of distributed systems with optimized displacement reduces lone loss, aspect power and network current. It boosts voltage profile. These enable us to enhance load ability with no need of new network or developing current network. It diminishes expenditures especially in the areas far from concentrated generation resources using distributed generation. Therefore, line capacities are released and load ability is increased. There is no need to have new installation and equipment's. The best condition is possible with 4 DGs. However, according to the studies, the following can be mentioned as the main indicators of decision-making regarding the use of distributed generation resources in Iran. Which need to be considered in the decision-making process.

- Predicting the existing potential and capacity in the country.
- The technological future of distributed generation resources in the world (in terms of cost).
- Predicting access to technology.
- The type of initial energy required and its future.
- Economic evaluation of distributed generation resources (in the present and future conditions).
- The classification of distributed generation sources is suggested as follows:
- Capacities available in the country's industries.
- Urban applications (micro turbines and gas turbines).
- Applications of scatter points (wind, water and photovoltaics).

It is suggested that distributed generation resources be used in more places instead of in one place, to further reduce losses, reduce the apparent power of the transmission line, and ultimately improve the voltage profile of the buses. Optimization algorithms such as genetic algorithm and fuzzy logic, neural network, OPF, ant algorithm, and other algorithms are used to perform the best work.

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