Optimal Placement of the Demand Response Program for Voltage Static Stability using TLBO Algorithm

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Abstract - According to the definition of Energy Department, demand response is the ability of domestic, industrial, and commercial consumers to use electrical energy to modify their consumption patterns at peak time to affect the price and reliability of the grid. The power grid voltage static stability could be improved to a satisfactory level using the demand response. For this reason, in this research, this device was used to improve the static stability of the grid voltage. In order to improve the objective functions, the normal state of the grid is considered. Normal mode is considered as the normal state of the grid, which provides the grid in its stable state without any failures in equipment. The optimization algorithm in this study is the TLBO algorithm. The problem of optimal allocation of demand response programs is solved to achieve the best value of the objective function of the grid voltage static stability. The location, the active and reactive power for which the best static voltage stability is achieved in the grid, is presented as an optimal response. The simulation results showed that the best place for this program to improve the static stability of the grid is bus No. 8.

Keywords: Demand Response Program, Voltage Static Stability, TLBO Algorithm, Electrical energy consumption

Introduction

With the evolution of the power industry and the formation of the electricity market, the electricity management programs faced serious challenges and threats. The extent of applicability of the consumption management programs in reconstructed system was questioned and the performing of these programs gradually had lost their importance and as a result, the market was considered as a threat for implementation of the consumption management. This led to the weakening and lack of implementation of the consumption management programs. The lack of implementation of the consumption management programs caused that the electricity market faces many problems after many years, that the most important of them was the prices instability and congestion emergence in the grid. The market controlling factors rapidly found out that solving the abovementioned problems is not possible without the active participation of the consumers in the market, therefore, they searched for methods for reusing the electricity consumption management program according to the market activity, so meanwhile, persuading the consumer to have active presence in market would not decrease the market nature. These methods were named the demand response by the international energy agency [1]. Demand response (DR) programs are used by operators in power networks to maintain system affordability and stability in times of peak demand, peak DER generation, or peak electricity price [22]. Actually, the demand response sources could be utilized as the reserve source. References [2, 3] have investigated the effect of demand response programs on the spinning reserve supply from the two economic and reliability aspects.

With the presence of consumers in the electricity market, they could be considered as new sources in the power system. The presence of consumers in the market will result in the market competitiveness and improvement of the market economy. In recent years (after the publication of the Federal Energy Regulatory Commission [FERC] report in 2006 [4]), various researches has been carried out about the demand response and its economic and technical effects on market and power system that from them, the applied scientific reports of the US Department of Energy (DoE) and its energy regulatory commission (FERC) could be mentioned. The important and experimental reports of independent agencies of US market systems that are sent to the energy regulation committee include the execution experiences of demand response programs in the related markets. Also, the important meeting of executive and academic experts that are held in Washington DC monthly and the latest news and information presented about the demand response could be pointed out [5].

In reference [6] the optimum programming of demand response and electric vehicles parking in order to improve the reliability of the distribution system have been performed. Also, in reference [7] the effect of demand response programs and renewable energy sources on the AC-DC micro grid reliability has been determined. In reference [8], the production development program considering the demand response program has been studied. In the study done by [18], generating electricity from wastewater through a microbial fuel cell was investigated. In [21], Teaching Learning Based Optimization (TLBO) technique was used to find maximum voltage stability and minimum power losses during normal and fault cases, and standard IEEE 30-bus test system was used to validate the developed algorithm.

Nowadays, because many power systems function near their voltage stability limits, voltage stability is brought as an important issue in modern power systems. Several voltage instability problems have already occurred in various points of the world, namely: France, Japan and the United State of America. These failures have attracted a great deal of attraction to the voltage instability problem [20]. Voltage stability is defined as the power system capability to maintain the acceptable persisting voltages for all the busbars after the occurrence of turbulence relative to the primary condition [9, 10]. One of the voltage stability criteria is that in each busbar, when the injected reactive power to that busbar increases, the voltage amplitude increases too. But, if the voltage of the busbar decreases as the injected reactive power to it increases, then the system gets unstable [11]. The reference [12] has studied a large power grid. In reference [13] a new method by utilization of non-linear participation coefficient in the power system has been introduced for improving the voltage static stability using the SVC. Also, in reference [14] a comparison of improvement capability of the voltage stability for FACTS equipment like SVC and STATCOM has been performed. Results of the presented paper represent the performance of the SVC and STATCOM equipment for improving the objective functions. Reference [15] studies the improvement of voltage static stability in the grid using these FACTS equipment. The results of the simulations of this paper have shown that each of these two types of equipment had their expected performance, but as the selection of the better equipment, the SSSC equipment had excellence over the CSC equipment in improving the objective function.

Reference [16] has presented a new probable approach for locating and determining the optimum capacity of some FACTS equipment for improving the static voltage profile of a power grid. Reference [17] has presented an efficient and evolutionary method for solving the optimal reactive power distribution problem in the grid. The results of this paper have been compared and presented with two algorithms of Teaching Learning Based Optimization (TLBO) and genetics. Also, in reference [13], the optimum location and capacity of SVC and TCSC have been determined for improving the voltage static stability, power losses and voltage profile improvement. Therefore, the objectives of this research are to improve the grid voltage static stability by determining the optimum location and capacity of the demand response program in the intelligent grid.

Experimental procedure

The aim of this research is to improve the voltage static stability by utilization of demand response programs. To achieve energy and economic savings by correcting the power factor of the installation, it is necessary to solve an optimization problem. There are many optimization algorithms applied to the resolution of engineering problems, such as the Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Artificial Bee Colony (ABC), etc [19]. To perform the optimization, the TLBO algorithm is used. The active and reactive power of utilization of the demand response programs follows the Equation (1). S_{DR} means the complex power of utilization of the demand response programs that must be considered as at most up to about 10 percent of the busbar demand.

$$0 \leq S_{DR} \leq 0.1 \times S_{Bus} \qquad (1)$$

The following figure shows the simulation similar to the previous section. With this difference that the objective function is the voltage static stability.

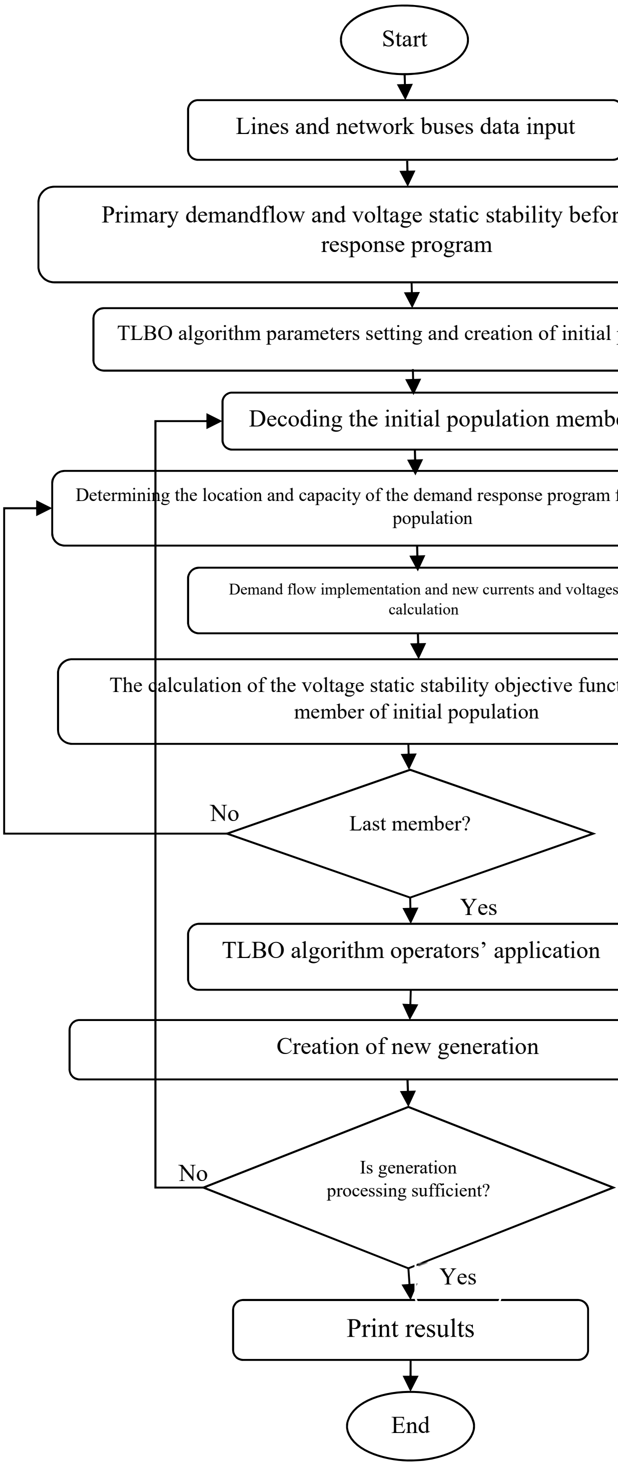

Figure 1: The trend of the locating program of the demand response program for improving the voltage static stability using algorithm. The TLBO

The case study grid is feeder number 3 of Abarkuh super distribution post that is shown in Figure (2). The specifications of the utilized algorithm are also shown in Table (1).

Table 1. The specifications of the utilized TLBO algorithm.

The number of population members	80
The number of generation production	100
Algorithm input	Location and utilization percentage of the demand response program
Algorithm output	Optimum location and utilization percentage of the demand response program and objective functions of the problem
objective functions	Voltage static stability

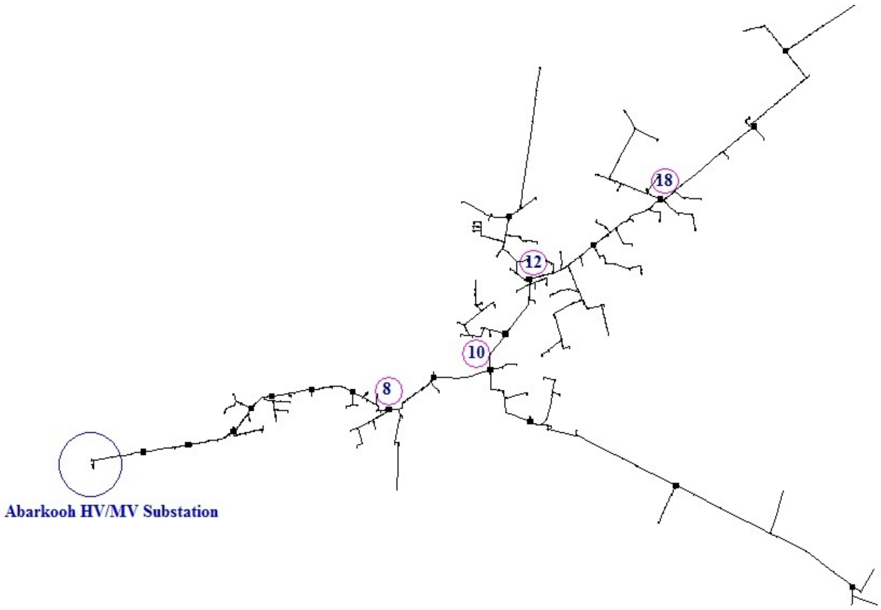

Figure 2. The schematics of the studied feeder.

Findings

The problem-solving trend for locating the optimum demand response program for improving the voltage static stability is also presented in the research methodology. The input of this program (initial population) is the location and demand response program utilization capacity that are in the initial population members and the output of the program is also the optimum location and demand response program utilization capacity and the optimum amount of the objective function of voltage static stability. The results of the program run are shown in Figure (3) and also in Table (2).

Table 2.The characteristics of the output of the optimization program of voltage static stability objective function using the TLBO algorithm.

The optimum location of the demand response program	The optimum capacity of the demand response program	The amount of the voltage static stability objective function before utilization of the demand response program	The amount of the voltage static stability objective function after utilization of demand response program
Bus number 8	10 percent	0.6951 per unit	0.6982 per unit

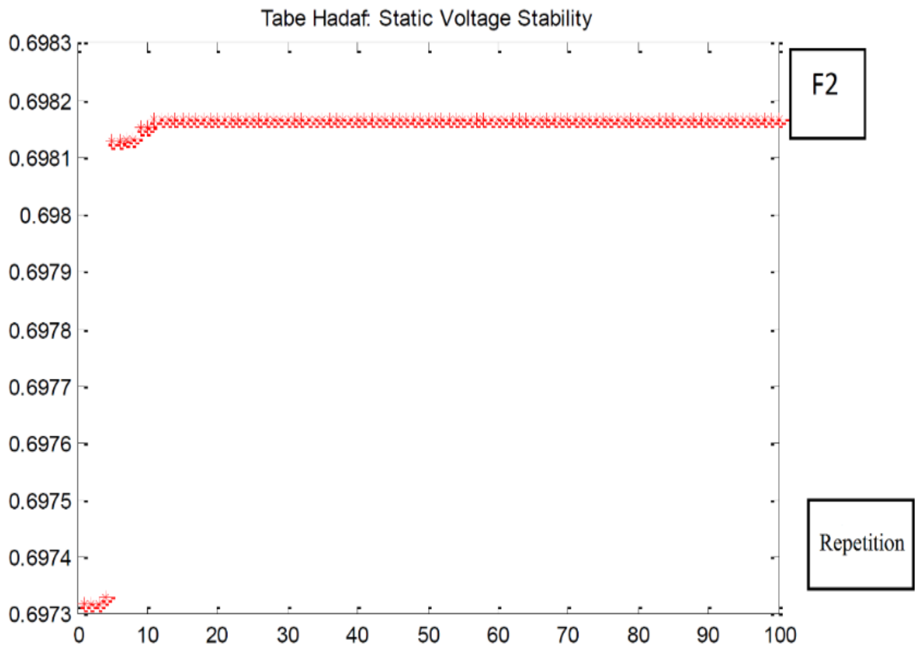

Figure 3.The single objective TLBO algorithm output versus the voltage static stability objective function.

As could be seen in Table (2), the utilization of the demand response program could improve the voltage static stability of the grid. The best bus for utilization of this program is bus No. 14 and the best utilization capacity of this program was obtained to be about 10 percent of the busbar No. 14. The amount of the voltage static stability of the grid was improved for about 0.0031 per unit. Therefore, using the simulation of this section, it was proved that the demand response program is capable of improving the grid voltage static stability.

There was logical reasoning for this subject. Utilization of the demand response program in bus No. 8 of the grid means the demand decrease of this busbar. With the demand decrease of the busbar, the demand-bearing of the grid will certainly increase, because the grid demand has decreased. Therefore, since the voltage static stability improvement is equal to grid demand-bearing improvement, the demand response program will certainly result in the improvement of the grid voltage static stability.

Also, by utilization of the demand response program, the current passing the grid grids for feeding the existing demand in this busbar will decrease and as a result, the voltage drop in this lines will decrease and the voltage collapse probability will decrease that this itself means the grid demand-bearing improvement and voltage static stability improvement. Therefore, as expected, the simulations also confirmed that the demand response program is effective in grid voltage static stability improvement.

Conclusion

The problem of optimum assignment of demand response program to reach the best objective function value of the voltage static stability in the grid has been solved. Location, active and reactive powers that for them the best voltage static stability in the grid will be obtained is introduced as the optimum response.

In his research, the optimum location and capacity of the demand response program for improving the technical indexes of the power system like grid voltage static stability were studied. The results of the simulation showed that the best place for this program for improving the grid voltage static stability is bus No. 8. According to the wide range of work in locating the demand response program and other compensation equipment in the grid, in order to improve the power system parameters, the bases for future study in this field is possible. Therefore, here are some suggestions for more studies in this context.

- Because in this research, only the grid demand peak was considered for locating the demand response program for voltage static stability, the demand uncertainty, which is the consideration of the demand variation during day and night and various seasons of the year, could be considered.
- Besides the demand uncertainty, the grid production uncertainty could also be considered for more realistic simulations conditions. Also, the grid grids correct function uncertainty is amongst the other uncertainties that should be considered in the studies.

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