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PREVAIL OVER POWER ELECTRIC SYSTEM PROBLEMS BY SIMULTANEOUS OPTIMIZATION OF BOTH TECHNICAL AND ECONOMICAL CRITERIA CONSIDERING LOAD UNCERTAINTY

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Abstract- In recent years, despite significant development in the generation and transmission of electrical energy, blackouts have continued to occur, especially during peak hours of consumption. Hence, with the severely growing demand for electric power, the supply of electricity in peak load conditions has become a major problem. On the other hand with the advent of competitive markets, the importance of reducing the price of delivered energy, and as a result, the interest in electric energy loss reduction has become more highlighted. The presented methods in this article have solved all mentioned problems by providing capability in use of the maximum potential of the power system. Series and parallel FACTS devices and demand response programs have been chosen as the best option for compensation purposes due to their fast installation capability, high controllability and rapid response to disturbances. To achieve nominative goals, new methods for optimal allocation of DR, series and parallel FACTS devices with optimization of both technical and economic criteria are presented. In optimization processes use of multi-objective functions guarantee approaching the goals set by the system operator and minimizing the capacity of the compensating equipment and the DR together. This way, during the technical index optimization process, the preparations of economic criterion optimization is also provided. Due to the use of multi-objective functions, in order to select the best chromosomes, the Pareto front selection method has been developed in accordance with the optimization process and it has been exploited alongside GA and TLBO evolutionary algorithms. Then, by comparing and analyzing the obtained solutions, some interesting suggestions are presented to the system operator. The optimization process is repeated separately for system emergencies as well as for load uncertainty. Simulations are carried out on the IEEE 30 bus standard network using Matlab and PSAT programs.

Keywords: DR, FACTS Devices, Voltage Stability, Loss Reduction, Multi-Objective Function, Evolutionary Algorithms, Genetic Algorithm, Teaching Learning Base Optimization, Pareto Front Method.

I. INTRODUCTION

In the modern world, development of countries and electrification in all areas has caused to a sharp and continuously increase in electricity demand. As regards, development of electric systems did not meet the rapidly growing demand for electricity, blackouts have occurred [1]. The need to respond to these demands and considering the problems in the way of electricity generation has led scientists and experts to find ways to make the most of the capacity of existing systems. Hence, increasing the efficiency of electric systems has become one of the most important research topics. One of the most important and feasible ways to achieve this goal is the use of compensating devices in conjunction with demand management programs at load peak hours.

References [2] suggest ways to reduce losses as a way to increase the efficiency of the power system. In reference [3], in the electricity shortage conditions, increasing system loadability has been pursued as a major goal. Because of the ability of DR programs and FACTS devices in fast reaction to disturbances in the power system, they have been chosen as the best option [4]. In references [5], the necessity of courier shaving has been emphasized. Also in References [6], the impact of DR programs on power system parameters improvement is discussed. References [7, 8] describe the optimization methods for installing FACTS devices on power grids. Also in References [9], mathematical models of SVC and TCSC for optimization problems are presented. In these references, methods for finding optimal locations and optimum capacities of compensating equipment are discussed. As mentioned in references [10], in the load uncertainty conditions, redesign of the optimization processes have gained necessity.

GA and TLBO evolutionary algorithms have been implemented separately to increase the speed of optimization calculations and to achieve global optimal solutions over an acceptable period of time. Then, by comparing and analyzing the obtained solutions, some interesting suggestions are presented to the system operator. In the optimization process, the use of the Pareto front selection method along with evolutionary algorithms ensures the selection of the best chromosomes that satisfy the multi-objective function conditions. As a result, in the output of simulations, instead of an optimal solution, a series of optimal solutions is obtained.

In this paper, first, by use of optimization process of technical indicators, the closest answers to the target defined by the system operator (desired loadability or maximum acceptable loss), the minimum capacity of the compensating equipment and the demand response program are determined. In the next stage, the most economical solutions are selected by analyzing the installation cost of the optimum equipment proposed by the technical optimization process. As well as, the economic cost of the proposed DR by the technical optimization process is calculated and presented based on the lowest cost calculated for the compensating equipment. Finally, the optimization process is repeated for the emergency condition as well as under load uncertainty conditions by use of scenario analysis.

II. COMPENSATION IN ELECTRICAL POWER SYSTEM

At present, the most practical and easy way to solve the vital problems of power systems in peak load and low load conditions is to use fast reactive compensators. Hence, in this study, Demand Response Programs and series and parallel FACTS devices have been suggested for this purpose.

A. Installation forms of Compensators

Location of various types of FACTS devices and load management by Demand Response Program in a simple transmission line are illustrated in Figure 1.

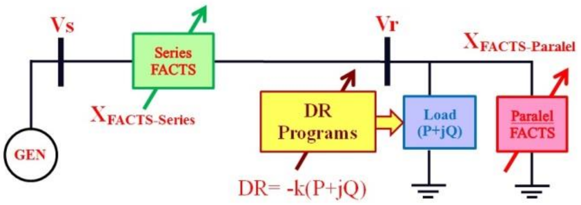


Figure 1. Location forms of Compensators

As shown in the Figure, the series FACTS is connected in series to the line and compensates the line reactance. As well as the parallel FACTS is connected in parallel with the loads and compensates them. Also DR program manage the consumption and shaves the load peak.

Here, the limitation of DR and FACTS devices for installation in the IEEE 30-bus standard network is defined as follows. The location and capacity limits of the DR are explained by equations (1) and (2). Location and Capacity of different type of the FACTS devices depending on their structure are defined by Equations (3) to (7).

$$1 \le L_{DR} \le 30 \tag{1}$$

$$0 \le S_{DR} \le 0.1 \times S_{BUS} \tag{2}$$

$$1 \le L_{FACTS\_SE} \le 41 \tag{3}$$

$$-0.8 \times X_{Line} \le X_{FACTS\_SE} \le 0.2 \times X_{Line} \tag{4}$$

$$1 \le L_{FACTS\_SH} \le 30 \tag{5}$$

$$-2^{pu} \le Q_{SVC} \le 2^{pu} \tag{6}$$

$$-0.1^{pu} \le Q_{DSTATCOM} \le 0.1^{pu} \tag{7}$$

B. The First Generation of FACTS Devices

As shown in Figure 2, SVC, TCSC and PS are among the first generation of static controllers and they have not capability of internal shutdown [11].

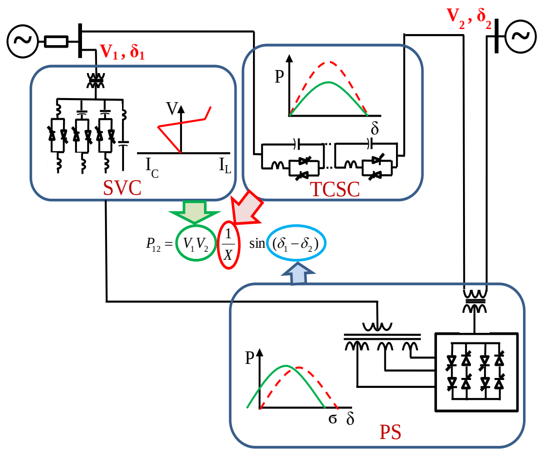


Figure 2. Different types of the First Generation of FACTS Devices

Each of these devices affects one of the three parameters that control the transmitted power. The SVC effects on bus voltage, TCSC changes transmission line impedance and PS regulates transmission angle. This equipment modifies the impedance structure of the network by presenting a variable reactive impedance to it.

B.1 SVC

SVC is formed of capacitors and reactors combination that controlled by thyristor switches and is connected to the transmission network in parallel.

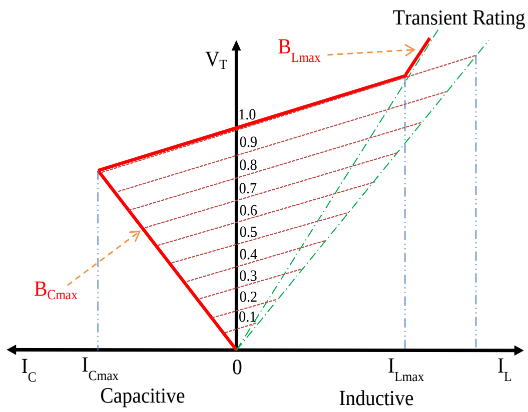


Figure 3. V-I characteristic of the SVC

The reactive power obtained from this equipment is continuously changed between capacitive and inductive situations and is usually used to regulate the voltage of a bus. The V-I characteristic of the SVC is shown in Figure 3.

B.2 TCSC

TCSC is formed by combination of a fixed capacitor with a thyristor-controlled reactor. Also another capacitor may be added in series to the sum of this impedance. TCSC is one of the first generation of FACTS devices, showing itself as SVC in the form of variable impedance, providing a compensatory feature by changing the impedance structure of the network. The first TCSC was installed in the US in the 1990s. This device adjusts the line impedance by changing itself and thus controls power in the line [12].

B.3 DVR

The DVR device is connected to the network in series and is used to improve network voltage as a voltage source and is structurally similar to SSSC. The main task of the DVR is to eliminate or reduce tension or distortion that sensitive loads feel it. The other functions of this device are to reduce phase imbalances and compensate the voltage harmonics. DVR as a voltage source, injects the voltage into the circuit, injects or absorbs active or reactive power into the grid by regulating the voltage angle [13].

B.4 Cost Calculation of FACTS Devices

The cost functions of series and parallel FACTS devices are explained in Equations (8) and (9), respectively. These costs are expressed in dollars / kVAr and they are converted into dollar using equations (10) and (11) [14, 15].

$$C_{FACTS\_S} = 0.0015 \times S_{FACTS\_S}^2 - 0.7130 \times S_{FACTS\_S} + 153.75 \tag{8}$$

$$C_{FACTS\_P} = 0.0003 \times S_{FACTS\_P}^2 - 0.3051 \times S_{FACTS\_P} + 127.38 \tag{9}$$

$$CT_{FACTS\_S} = C_{FACTS\_S} \times S_{FACTS\_S} \times 1000 \tag{10}$$

$$CT_{FACTS\_P} = C_{FACTS\_P} \times S_{FACTS\_P} \times 1000 \tag{11}$$

where,

C_{FACTS_S} : Cost of series FACTS $/kVAr

S_{FACTS_S} : Apparent power series FACTS Mvar

CT_{FACTS_S} : Total Cost of series FACTS $

C_{FACTS_P} : Cost of parallel FACTS $/kVAr

S_{FACTS_P} : Apparent power parallel FACTS Mvar

CT_{FACTS_P} : Total Cost of series FACTS $

C. Demand Response Program

Taking into consideration load side management and DR programs as an affordable energy source, their careful research has become more important. In other words, it is not possible to supply the electricity needed in different sectors without effective consumer participation. Given the many other benefits of DR, in this study Demand response programs are used as an important factor for solving main problems of electrical power system [16].

The mathematical model of DR is expressed using the Equation (12). This equation shows the amount of load change by subscribers due to energy price changes and period sensitivity coefficients for different hours of the day.

$$d(i) = d_0(i)\left\{1 + \frac{E(i)\left[\rho(i) - \rho_0(i)\right]}{\rho_0(i)}\right\} \tag{12}$$

where,

$d_0(i)$: The initial load of the period

$d(i)$: The average load of the period after changing the price of electricity

i : Number of period

$\rho_0(i)$: Initial price of electricity

$\rho(i)$: Average price of electricity

$E(i)$: The sensitivity of the period

III. OPTIMIZATION PROCESS

A. Multi Objective Functions

In solving power system optimization problems, simultaneous maintenance of several important system parameters within acceptable range is very important. To realization of this purpose, multi-objective functions are incorporated into optimization processes. Multi-objective functions have been used extensively in this research to ensure the simultaneous resolution of fundamental power system problems. The proposed objectives for optimization are as follows:

- Minimizing the power loss:

$$(F_1 = \sum_i R_i \times |I_i|^2)_{\min} \tag{13}$$

- Maximum loadability:

$$(F_2 = -\lambda)_{\min} \tag{14}$$

- Minimum capacity of FACTS devices:

$$(F_3 = S_{FACTS\_S})_{\min} \tag{15}$$

$$(F_4 = S_{FACTS\_p})_{\min} \tag{16}$$

- Minimum capacity of DR program:

$$(F_5 = S_{DR})_{\min} \tag{17}$$

- The minimum distance to the target set by the: system operator

$$(F_6 = (PL - PL_{set}))_{\min} \tag{18}$$

$$(F_7 = (\lambda - \lambda_{set}))_{\min} \tag{19}$$

In this paper, the multi-objective function is variable and is determined in the optimization process according to the system conditions and operator requirements at each stage.

$$\text{Multi-Objectiv Function} = \min(F_i)\ \&\ \min(F_j) \tag{20}$$

where, λ is calculated using CPF when running the simulation program. The concept of d is represented by Equation (21).

$$\lambda = \frac{P_D}{P_{D0}} \tag{21}$$

B. Evolutionary Algorithms

Given that problems with multiple extreme points cannot be solved using classical methods, so numerical methods are used to solve such problems. In numerical methods in turn to increase the speed of calculations and to achieve optimal global solutions within acceptable time evolutionary algorithms are used. Experiments have proved the ability of these algorithms to solve practical issues and obtain acceptable answers to them. Evolutionary algorithms work by random methods and have been inspired by events in nature. Their randomness reflects the fact that chance plays a significant role in their laws [17].

In this article among the best evolutionary algorithms, genetic algorithm and teaching learning based optimization methods are implemented.

C. Genetic Algorithm

Genetic algorithm is used as a search technique to solve optimization problems. This algorithm is a special form of evolutionary algorithms that uses Darwin's theory of evolution and biological techniques such as natural selection, inheritance, and mutation to find optimal answers [17].

In this study genetic algorithm are developed to find optimal solution along with multi-objective functions and Pareto Front selection method.

D. Teaching Learning Based Optimization Algorithm

The TLBO algorithm has a smart principle, based on a teacher's teaching in the class and the students' learning styles. The mechanisms of this algorithm are divided into two parts. The first part takes into account the value of the teacher in improving the students' academic level in the class and the second part is done in the same class through interaction between the students and analyzing the lessons [18].

TLBO algorithm uses these principles to solve optimization problems and it was adopted as a searching method. In this study TLBO algorithm is developed alongside multi-objective functions and Pareto Front selection methods to solve optimization problems and achieve more effective solutions. The block scheme of the TLBO algorithm is shown in Figure 4.

E. Pareto Front Selection Method

The block diagram of the PF programming process is explained in Figure 5. When using multi-objective function, population members have more than one property. Hence, it is not easy to select the best members of the population. In this way, by use of the Pareto front selection method along with evolutionary algorithms are ensured selection of the best chromosomes that satisfy the multi-objective function conditions. As a result, in the output of simulation program, instead of an optimal solution, a series of optimal solutions is obtained. Surprisingly, the operator has more opportunity to choose among the answers within the Pareto Front, given the system's conditions and available supplies.

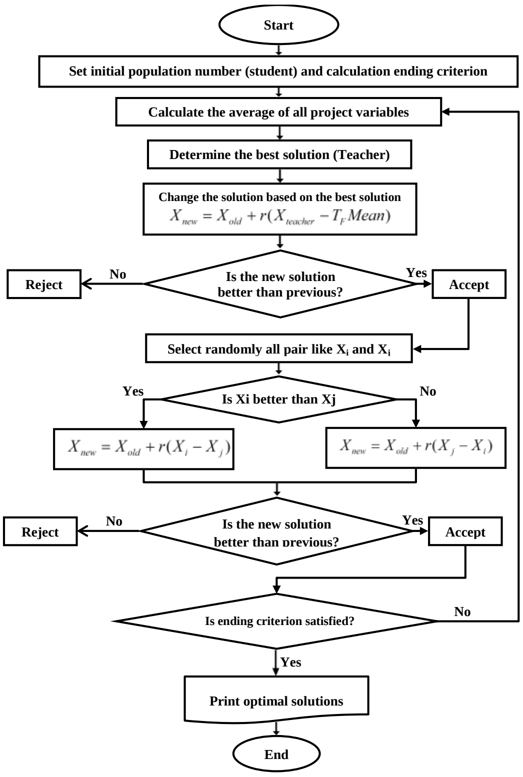


Figure 4. Block diagram of TLBO algorithm

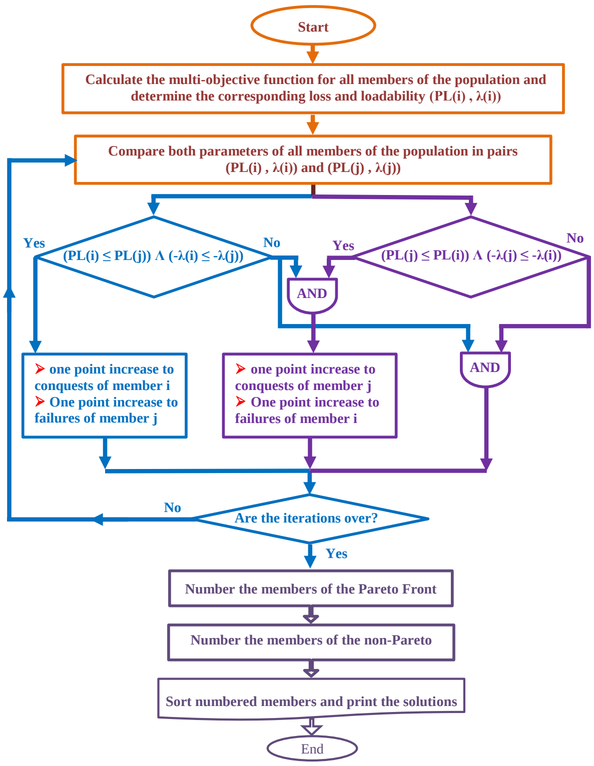


Figure 5. Block scheme of the Pareto front programming

F. Uncertainty Load Condition

Naturally, the amount of loads changes in different seasons of the year and even at different times of the day and some periods reach own peak. given the peak conditions, designing the grid requires high costs and not necessary everywhere.

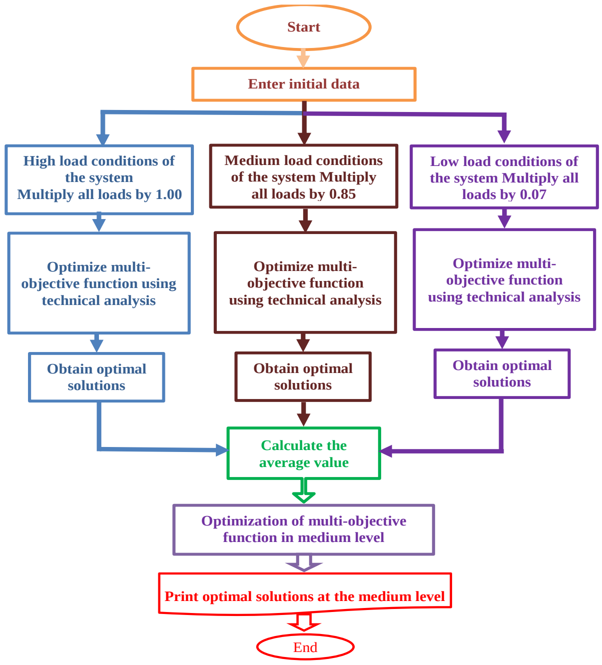


Figure 6. Block diagram of scenario method in load uncertainty condition

In this study, from this economic point of view, network designing at the middle level of it is recommended. That way, it allows for more efficient use of investments. Load uncertainty conditions are simulated using scenario analysis. In the scenario method, network loads are divided into three sections at different hours of the day. Table 1 explains this issue.

Table 1. Allocating loads at different times of the day in the scenario method

Condition	From hour	To hour	Coefficient of loads
High loads	18	23	1.00
Low loads	23	07	0.70
Middle loads	07	18	0.85

The block diagram of scenario analysis process is completely explained in Figure 6. Taking into account the information given in Table 1 the optimization of the system at the peak of three different load conditions was solved and the average response value was calculated and accepted as the final response. For the normal and emergency conditions of power system optimization process has been performed separately considering the loads uncertainty using both evolutionary algorithms GA and TLBO.

G. Economic Analysis Process

In this paper, economic analysis was performed alongside Satisfaction of technical conditions. Hence, the proposed approach allows for more efficient use of the electrical system. Figure 7 summarizes the process of economic analysis.

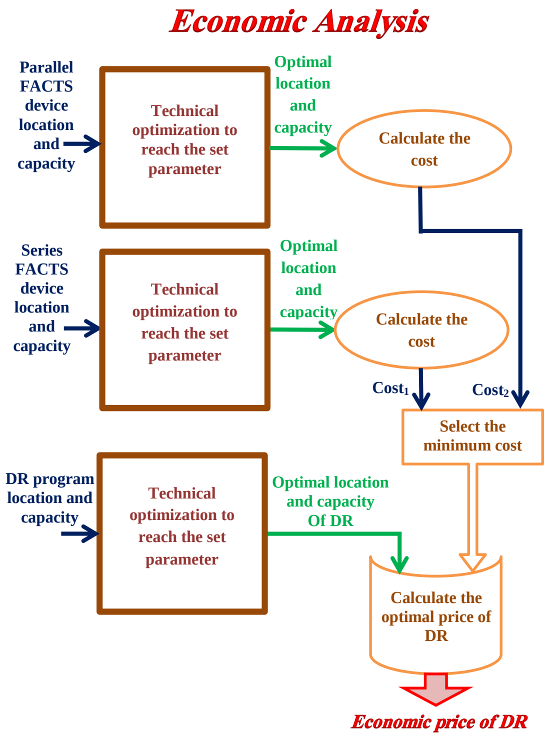


Figure 7. Block scheme of economic analysis

As can be seen in Figure 7, the following steps have been taken in the economic optimization process:

1. The operator declares a certain value of the parameter that needs to be improved, taking into account the system conditions.
2. In the next step, using technical optimization methods, to achieve the determined parameter, optimal location and capacity of different equipment and DR program are separately found.
3. Then for each of the optimal responses from the technical analysis the required capital investment is calculated and the answer corresponding to the least cost is chosen.
4. At the last stage, the cost of DR is calculated based on the lowest costs identified in the third step. In this study, for peak load conditions, increase network loadability parameter (λ) and for low load conditions, the loss reduction parameter (PL) is targeted. As a sample in the next section, the economic optimization process for reaching the network loadability parameter λ set by the system operator is described

H. Increase Loadability

In order to prevent blackouts, it is essential to increase loadability of electrical power system and supply the electricity at peak load conditions. Hence, to achieve this goal certain λ is determined by system operator. The main objective here is to provide the λ parameter set by the operator with the lowest costs. The block diagram of this process is explained by Figure 8.

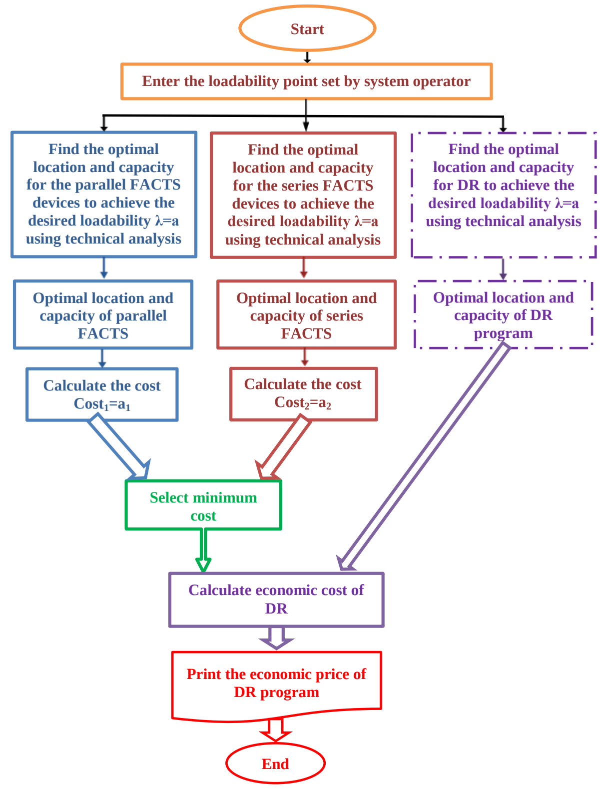


Figure 8. Block scheme of economic analysis to achieve the desired λ

V. SIMULATION RESULTS

In this article 68 separated programs have been implemented to perform simulations. In the output of these programs, 215 optimal responses were achieved in the form of Pareto Front. As well as, in order to more effectively use from power system, through analyzing the mentioned solutions, new suggestions have been made for the system operator.

A. Results of Technical-Economic Optimization

In this section more than 20 simulation program are implemented and several dozen of optimal solutions are achieved. The results are also categorized in different tables and presented using various types of graphs. Given the limitations of space, the samples of mentioned results are presented below.

As can be seen in Table 2, the technical - economic optimization process is performed separately to achieve the parameters set by the network operator λ=2.6 and *PL*=0.0450. Here, the evolutionary algorithm GA is used to perform the optimization process. In this section, grid loads are assumed fixed. In this table the type of compensating devices, the optimal location and capacity of FACTS equipment and DR, the cost of optimal FACTS and the economic price of DR are presented.

Another sample of achieved optimal solutions is represented by table 3. It is also worth to mention, at the beginning of the process depending on the system requirement loss reduction or loadability increasing is targeted by the system operator.

Table 2. Results of technical-economic optimization process under normal condition

Technical-Economic analysis - Normal condition - Fix Loads - Genetic algorithm												
	To obtain target (*PL*=0.0450)						To obtain target (λ=2.6)					
Equipment type	Equipment name	Optimal place (Bus / Line)	Optimal place (Between Buses)	Optimal capacity	Dimension	Optimal cost (Dollar)	Equipment name	Optimal place (Bus / Line)	Optimal place (Between Buses)	Optimal capacity	Dimension	Optimal cost (Dollar)
Series FACTS	TCSC	12	6-10	0.28	kVAr	43.05	TCSC	36	27-28	2.07	Mvar	315220
Parallel FACTS	DSTATCOM	10	-	10	kVAr	1273.8	DSTATCOM	23	-	30	kvar	3821.1
Demand Response	DR	5	-	7.18	MVA	-	DR	21	-	2.01	MVA	-
Economic price of DR	5.99 $/MVA						1901.05 $/MVA					

As can be seen in the Table, the technical - economic optimization process is performed separately to achieve the parameters set by the network operator λ=2.6 and *PL*=0.0450 under emergency condition. Here, the evolutionary algorithm TLBO is used to perform the optimization process. In this section, load uncertainty condition has been applied in optimization process. As well as, the type of compensating devices, the optimal location and capacity of FACTS equipment and DR, the cost of optimal FACTS and the economic price of DR are presented. Finally, on the optimal location assigned to DR, economic prices were offered to conclude contracts with consumers.

Table 3. Results of technical-economic optimization process under emergency condition

Economic analysis - Emergency condition - Uncertainty Loads - TLBO algorithm												
	To obtain target *PL*=0.0450)						To obtain target (λ=2.6)					
Equipment type	Equipment name	Optimal place (Bus / Line)	Optimal place (Between Buses)	Optimal capacity	Dimension	Optimal cost (Dollar)	Equipment name	Optimal place (Bus / Line)	Optimal place (Between Buses)	Optimal capacity	Dimension	Optimal cost (Dollar)
Series FACTS	TCSC	10	6-8	0.27	Mvar	41461	DVR	29	21-22	4.3	kvar	661

Parallel FACTS	DSTATCOM	15	-	10	Mvar	1243590	DSTATCOM	9	-	10	Mvar	1243590
Demand Response	DR	5	-	8.67	MVA	-	DR	2	-	0.41	MVA	-
Economic price of DR	4782.1 $/MVA						1612.2 $/MVA					

B. Analysis of Results

The optimal loadability achieved in normal and emergency conditions are illustrated in Figure 9.

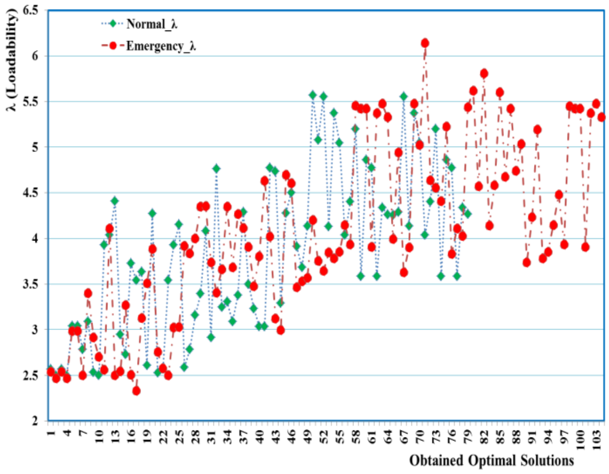


Figure 9. Comparison of achieved optimal loadability under normal and emergency conditions

As can be seen in Figure 9, the optimization process yields optimal solutions in acceptable range for both normal and emergency conditions of the power system.

For specific situations among the optimal solutions, significant increase in loadability is observed. For instance, the optimal solution $\lambda \geq 6$ corresponding to load uncertainty condition is seen. As well as, this comparison proves the importance of sharing unused capacities in interconnected power grids.

Figure 10 shows the results obtained from simulation processes under different network conditions with respect to load uncertainty. As can be seen in the figure, the responses, meet all the conditions of the multi-objective function. In this way, the effectiveness of the optimization process in the load uncertainty has been confirmed. As well as, the optimal solutions shown in Figure 10, Demonstrates the efficiency of the multi-objective function in simultaneously improving the basic parameters of the power system.

Figure 11 compares the performance of simulation processes under different system conditions at constant loads and uncertain loads. It is obvious that, all optimization processes at both fixed loads and uncertain loads have reduced system losses within acceptable level.

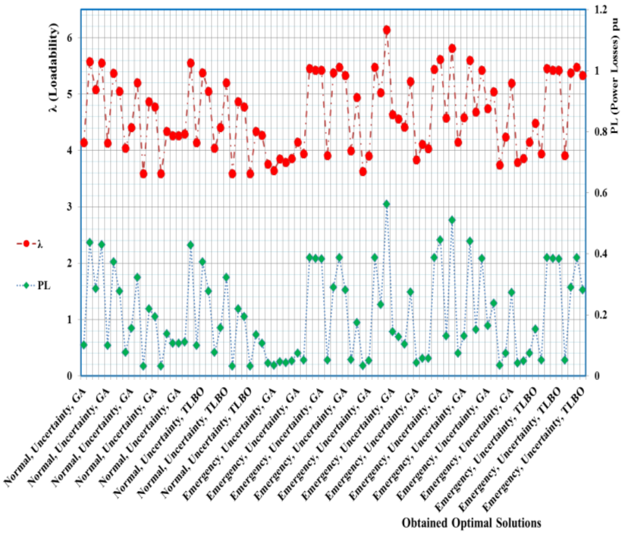


Figure 10. Optimal solutions in various condition of system considering load uncertainty

The number of optimal solution in output of the optimization process is 98 for fix loads and 85 for under uncertainty load condition. The average value of this optimal solutions is PL=0.1997 pu for fix load and PL=0.1967 pu for uncertainty condition. Abundance of optimal solutions in the Pareto Front proves the efficiency of the presented optimization processes. In other words, the possibility of making more choices for the system operator is one of the benefits of dedicated optimization processes.

As it shown in the figure, in most cases the value of power losses is less than 0.1 pu. However, in load peak conditions a significant increase in energy losses is seen. In this situation, to avoid blackouts, the system operator will have to accept losses and choose this optimal solution.

The conditions of the system in which the energy losses are sharply increased are illustrated in Figure 11. Since energy losses are assumed equal the waste of investment made in generation sector, these points have been determined as critical points to the operator. Hence, the operator will try to avoid these conditions.

Figure 12 compares the costs required for the optimal solutions obtained from various optimization processes to achieve λ=2.6. It is worth noting that cost axis in this chart is selected logarithmically. Given the significant difference in the cost of installing optimum equipment, importance of economic analysis has been proven.

VI. CONCLUSIONS

The applied equipment, processes, methods, algorithms, programming and making comparisons used in this article have been thoroughly analyzed in the normal and emergency conditions of the system and in the case of load uncertainty. So it solves the most pressing problems of electrical systems more effectively and it can be used as a research, evaluation, forecasting, decision-making and management method. In this paper the results obtained from the inclusion of FACTS and DR in the optimization process ensures maximum utilization of the capacities available in the electricity generation and transmission sector.

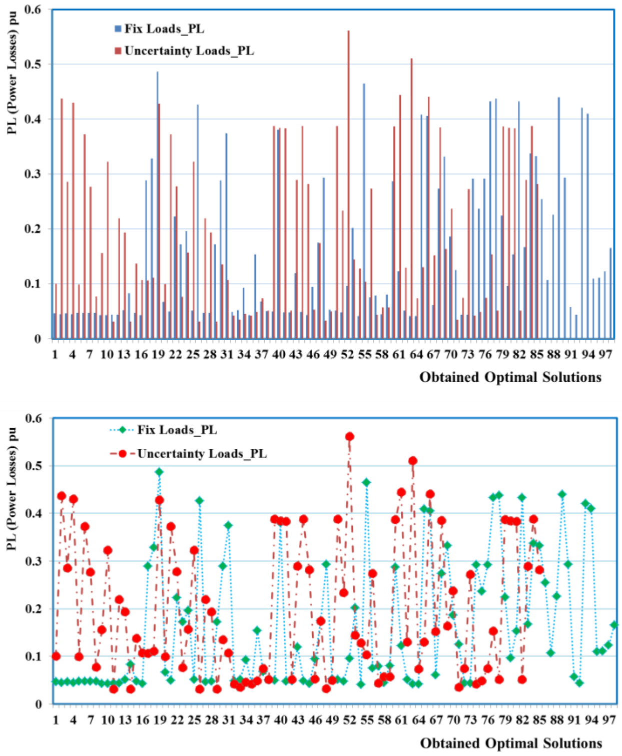
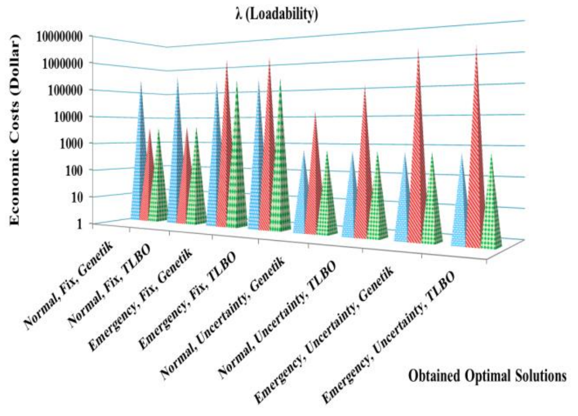


Figure 11. Comparison of optimal solutions under constant load conditions and load uncertainty



	Normal, Fix, Genetik	Normal, Fix, TLBO	Emergency, Fix, Genetik	Emergency, Fix, TLBO	Normal, Uncertainty , Genetik	Normal, Uncertainty , TLBO	Emergency, Uncertainty , Genetik	Emergency, Uncertainty , TLBO
Cost of Series FACTS	315220	340839	207790	207790	661	661	661	661
Cost of Parallel FACTS	3821.1	4203.2	1215700	1221734.16	14008	95363	1243590	1243590
Economic Cost of DR	3821.1	4203.2	207790	207790	661	661	661	661

Figure 12. Comparison of the costs of different optimal solutions in order to maximize the system loadability to λ=2.6

Developing a Pareto Front Selection Method within the simulation program to select the best chromosomes at the outputs of the GA and TLBO evolutionary algorithms yields a series of optimal solutions rather than an optimal one. Therefore, more options are available to the system operator. It is worth to mention, the simultaneous realization of the set goals is made possible by use of multi-purpose functions. AS well as, the analysis of the obtained results proves the efficiency and necessity of economic analysis along with technical optimization even in emergency and uncertainty conditions.

The presented methods in this paper have solved the fundamental problems of the power system under both peak load and low load conditions and finally optimal solutions satisfying the technical and economic objectives for effective utilization of the power system have been presented.

NOMENCLATURES

A. Acronyms

DR	Demand Response
FACTS	Flexible AC Transmission System
TCSC	Tiristor Controlled Series Capacitor
SVC	Static VAR Compensator
DVR	Dynamic Voltage Restoration
GA	Genetic Algorithm
TLBO	Teaching Learning Based Optimization
CPF	Continuous Power Flow

B. Symbols / Parameters

C_{FACTS_S} : Cost of series FACTS \$/kVAr

S_{FACTS_S} : Apparent power series FACTS Mvar

CT_{FACTS_S} : Total Cost of series FACTS \$

C_{FACTS_P} : Cost of parallel FACTS \$/kVAr

S_{FACTS_P} : Apparent power parallel FACTS Mvar

CT_{FACTS_P} : Total Cost of series FACTS \$

$d_0(i)$: Initial load of period

$d(i)$: The average load of the period after changing the price of electricity

i : Number of period

$\rho_0(i)$: Initial price of electricity

$\rho(i)$: Average price of electricity

$E(i)$: The sensitivity of the period

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REFERENCES

[1] Andersson, et al., "Causes of the 2003 Major Grid Blackouts in North America and Europe, and Recommended Means to Improve System Dynamic Performance", IEEE Trans. on Power Systems, Vol. 20, No. 4, November 2005.

[2] V. Cutsem, "An Approach to Corrective Control of Voltage Instability Using Simulation and Sensitivity", IEEE Trans. on Power Systems, Vol. 10, No. 2, pp. 616-622, 1995.

[3] Antonio, et al., "Increasing the Lodability of Power Systems through Optimal Local Control Actions", IEEE Trans. on Power Systems, Vol. 19, No. 1, February 2004.

[4] M.R. Shadmesgaran, A.M. Hashimov, N.R. Rahmanov, O.Z. Kerimov, I.I. Mustafayeva, "Technical Analysis of Demand Response Program and FACTS Devices Implementation Using Multi-Objective Optimization", International Journal of Technical and Physical Problems of Engineering (IJTPE), Issue 32, Vol. 9, No. 3, pp. 21-29, September 2017.
[5] D.G. Choi, V.M. Thomas, "An Electricity Generation Planning Model Incorporating Demand Response", Energy Policy, Vol. 42, pp. 429-441, 2012.
[6] M.R. Shadmesgaran, A.M. Hashimov, N.A. Yusifbeyli, "Optimal Location and Capacity of Demand Response Program due to Simultaneously Power Loss Reduction and Static Voltage Stability Improvement Using Genetic Algorithm", 11th International Conference on Technical and Physical Problems of Electrical Engineering (ICTPE-2015), Bucharest, Romania, No. 16, Code 01PES10, pp. 75-79, 10-12 September 2015.
[7] M.R. Shadmesgaran, A.M. Hashimov, N.A. Yusifbeyli, "Optimal Location of TCSC due to Power Loss Reduction and Static Voltage Stability Improvement Using Genetic Algorithm", Journal of Power Engineering, Institute of Physics, Azerbaijan National Academy of Sciences, Baku, Azerbaijan, No. 4, 2015.
[8] M.R. Shadmesgaran, A.M. Hashimov, N.R. Rahmanov, "Optimal Location and Capacity of Parallel FACTS Devices in order to Improve Voltage Static Stability and Power Losses Reduction Using Genetic Algorithm", 12th International Conference on Technical and Physical Problems of Electrical Engineering (ICTPE-2016), Bilbao, Spain, No. 1, Code 01POW07, pp. 1-6, 7-9 September 2016.
[9] M.A.B. Araff, "Static VAR Compensators in the Malaysian Grid", IEEE, Power Conversation Conference, 1993.
[10] H. Ardashiri, S.M. Barakati, "Implementation of Improved Time of Use Program in Micro Grid Considering Uncertainty of Loads and Market Price", 29th International Conference of Electric Power, 2014.
[11] F. Yue, Q. Bailu, "Electrical Design Aspects of Pingguo TCSC Project", Asia and Pacific IEEE Transmission and Distribution Conference and Exhibition, 2005.
[12] Y.H. Song, A.T. Johns, "Flexible AC Transmission Systems (FACTS)", Institution of Electrical Engineers, London, United Kingdom, 1999.
[13] K.R. Padiyar, "FACTS Controller in Power Transmission and Distribution", 2007.
[14] M.A. Gitizadeh, "New Method for SVC Placement Considering FSS Limit and SVC Investment Cost", Electrical Power and Energy Systems, Vol. 53, pp. 900-908, 2013.
[15] P.K. Tiwari, "An Efficient Approach for Optimal Allocation and Parameters Determination of TCSC with Investment Cost Recovery under Competitive Power Market", IEEE Transactions on Power Systems, Vol. 28, Issue 3, pp. 2475-2484, 2013.
[16] H. Alami, "Demand Response Modeling Based on the Coefficient of Price Sensitivity of Demand", Doctoral Thesis, Tehran Tarbiyat Moallim University, Tehran, Iran, p. 149, 2011.
[17] H.A. Jalili, "New Evolutionary Algorithm Based on Data Sharing Concept for Solving Optimization Problems", Scientific Research and Essays, Vol. 6, pp. 5082-5090, 2011.
[18] R.V. Rao, V.J. Savsani, D.P. Vakharia, "Teaching Learning Based Optimization: A Novel Method for Constrained Mechanical Design Optimization Problems", Computer Aided Design, Vol. 43, pp. 303-315, 2011.

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