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Optimal Placement of Capacitors for Achieve the Best Total Generation Cost by Genetic Algorithm

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***Abstract*—**Economic Dispatch (ED) is one of the most challenging problems of power system since it is difficult to determine the optimum generation scheduling to meet the particular load demand with the minimum fuel costs while all constraints are satisfied. The objective of the Economic Dispatch Problems (EDPs) of electric power generation is to schedule the committed generating units outputs so as to meet the required load demand at minimum operating cost while satisfying all units and system equality and inequality constraints. In this paper, an efficient and practical steady-state genetic algorithm (SSGAs) has been proposed for solving the economic dispatch problem. The objective is to minimize the total generation fuel cost and keep the power flows within the security limits. To achieve that, the present work is developed to determine the optimal location and size of capacitors in transmission power system where, the Participation Factor Algorithm and the Steady State Genetic Algorithm are proposed to select the best locations for the capacitors and determine the optimal size for them.

***Keywords*—**Economic Dispatch, Lagrange, Capacitors Placement, Losses Reduction, Genetic Algorithm.

I. INTRODUCTION

DURING the last decade, the electrical power market became more and more liberal and highly competitive. The main goal is to generate of a given amount of electricity at the lowest possible cost. This need proper planning, operation and control of such large complicated systems [1].

The economic dispatch (ED) problem is one of the optimization problems in power system operation. The objective of ED problem is to schedule the optimal combination of outputs of all generating units and to minimize the operating cost while satisfying the load demand and system equality and inequality constraints. Improvements in scheduling of the unit power outputs can lead to significant cost savings [2], [3].

As power demand increases and since the fuel cost of the power generation is exorbitant, reducing the operation costs of power systems becomes an important topic. The main goal of Economic Dispatch (ED) in power systems is to distribute the total required generation between the generation units economically, while the equality and inequality constraints are satisfied. There are different algorithms to kind rate of optimum product for each power generation unit.

Conventional algorithms such as lambda iteration, gradient method, and Newton method can solve the ED problems [4].

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The Energy Management System or (EMS) as we know it today had its origin in the need for electric utility companies to operate their generators as economically as possible. To operate the system as economically as possible requires that the characteristics of all generating units be available so that the most efficient units could be dispatched properly along with the less efficient [5]. In addition, there is a requirement that the on/off scheduling of generators units be done in an efficient manner as well. The scheduling of generators with limited fuel or water supplies is incorporated in energy management systems. This allows operators to further reduce the cost of operation by taking advantage of cheaper fuels or hydropower.

II. INEQUALITY CONSTRAINTS

Practical optimization problems contain inequality as well as equality constraints. The optimization problem can be started as:

A. Minimize the Cost Function

$$F(x_1, x_2, ..., x_n) \tag{1}$$

B. Subject to the Equality Constraints

$$g_i(x_1, x_2, ..., x_n) = 0, i = 1, 2, ..., m \tag{2}$$

C. Inequality Constraints

$$h_j(x_1, x_2, ..., x_n) \le 0, j = 1, 2, ..., p \tag{3}$$

The Lagrange Multiplier is extended to include the inequality constraints by introducing the *m*-dimensional vector μ of undetermined quantities [6].

III. ECONOMIC DISPATCH INCLUDING LOSSES

The active power transmission losses may amount to 20 to 30% of the total load demand, ideally, the exact power flow equations should be used to obtain the active power transmission losses in the system, however, and the electric power system engineer may OPF for expressing the losses in terms of power generations only [7].

One common practice for including the effect of transmission losses is to express the total transmission loss as a quadratic function of the generator power outputs in one of the following forms:

A. Simple Form

$$P_L = \sum_{i=1}^{N}\sum_{j=1}^{N} p_i B_{ij} p_j \tag{4}$$

B. Kron's Loss Formula

$$P_L = \sum_{i=1}^{N}\sum_{j=1}^{N} p_i B_{ij} p_j + \sum_{j=1}^{N} B_{0j} p_j + B_{00} \tag{5}$$

B_{ij} are called the loss coefficients, which are assumed to be constant for a base range of loads, and reasonable accuracy is expected when actual operating conditions are close to the base case conditions used to compute the coefficients. The economic dispatch problem is to minimize the overall generation cost, C, which is a function of plant constrained by:

C. The Generation Equals the Total Load Demand Plus Transmission Losses.
D. Each Plant Output is Within the Upper and Lower Generation Limits Inequality Constraints.

Mathematically:

$$F:\ C_{total} = \sum_{i=1}^{N} C_i = \sum_{i=1}^{N}\left(a_i + b_i p_i + c_i p_i^2\right) \tag{6}$$

$$g:\ \sum_{i=1}^{N} p_i = P_D + P_L \tag{7}$$

$$h:\quad p_{i(\min)} \le p_i \le p_{i(\max)} \quad i = 1,\dots,N \tag{8}$$

The resulting optimization equation becomes:

$$L = C_{total} + \lambda\left(P_D + P_L - \sum_{i=1}^{N} p_i\right) + \sum_{i=1}^{N}\mu_{i(\max)}(p_{i(\max)} - p_i) + \sum_{i=1}^{N}\mu_{i\,(\min)}(p_i - p_{i\,(\min)}) \tag{9}$$

$$p_i < p_{i(\max)} : \mu_{i(\max)} = 0 \quad p_i > p_{i(\min)} : \ \mu_{i(\min)} = 0$$

The minimum of the unconstrained function is found when:

$$\frac{\partial L}{\partial p_i} = 0 \tag{10}$$

$$\frac{\partial L}{\partial \lambda} = 0 \tag{11}$$

$$\frac{\partial L}{\partial \mu_{i(\max)}} = p_{i(\max)} - p_i = 0 \tag{12}$$

$$\frac{\partial L}{\partial \mu_{i(\min)}} = p_i - p_{i(\min)} = 0 \tag{13}$$

When generator limits are not violated:

$$\frac{\partial L}{\partial p_i} = 0 = \frac{\partial C_{total}}{\partial p_i} + \lambda\left(0 + \frac{\partial P_L}{\partial p_i} - 1\right) \tag{14}$$

$$\frac{\partial C_{total}}{\partial p_i} = \frac{\partial}{\partial p_i}\left(C_1 + C_2 + \dots + C_N\right) = \frac{dC_i}{dp_i} \tag{15}$$

$$\therefore\ \lambda = \frac{dC_i}{dp_i} + \lambda\frac{\partial P_L}{\partial p_i} = \left(\frac{1}{1 - \partial P_L / \partial p_i}\right)\frac{dC_i}{dp_i} = PF_i\,\frac{dC_i}{dp_i} \tag{16}$$

$$\frac{\partial L}{\partial \lambda} = 0 = P_D + P_L - \sum_{i=1}^{N} p_i \quad \therefore \sum_{i=1}^{N} p_i = P_D + P_L \tag{17}$$

where PF_i is known as the penalty factor of plant i and is given by:

$$PF_i = \frac{1}{1 - \frac{\partial P_L}{\partial p_i}} \tag{18}$$

The effect of transmission losses introduces a penalty factor that depends on the location of the plant.

E. The Minimum Cost Is Obtained When the Incremental Cost of Each Plant Multiplied by Its Penalty Factor Is the Same for All Plants.

The incremental transmission loss is obtained from Kron's loss formula as,

$$\frac{\partial P_L}{\partial p_i} = 2\sum_{j=1}^{N} B_{ij} p_j + B_{oi} \tag{19}$$

By setting the fuel cost equal to 1 \$/MBTU, can be rewritten as:

$$\frac{dC_i}{dp_i} = b_i + 2c_i p_i \tag{20}$$

Substituting (19) and (20) in (16), yields:

$$\lambda = \frac{dC_i}{dp_i} + \lambda\frac{\partial P_L}{\partial p_i} = b_i + 2c_i p_i + 2\lambda\sum_{j=1}^{N} B_{ij} p_j + \lambda B_{oi} \tag{21}$$

Rearranging (21) as:

$$\left(\frac{c_i}{\lambda} + B_{ii}\right)p_i + \sum_{\substack{j=1\\ j\neq i}}^{N} B_{ij} p_j = \frac{1}{2}\left(1 - B_{oi} - \frac{b_i}{\lambda}\right) \tag{22}$$

Extending (22) for all plants results in the following linear equations (in matrix form),

$$\begin{bmatrix} \frac{c_1}{\lambda} + B_{11} & B_{12} & \cdots & B_{1N} \\ B_{21} & \frac{c_2}{\lambda} + B_{22} & \cdots & B_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ B_{N1} & B_{N2} & \dots & \frac{c_N}{\lambda} + B_{NN} \end{bmatrix}\begin{bmatrix} p_1 \\ p_2 \\ \vdots \\ p_N \end{bmatrix} = \frac{1}{2}\begin{bmatrix} 1 - B_{o1} - \frac{b_1}{\lambda} \\ 1 - B_{02} - \frac{b_2}{\lambda} \\ \vdots \\ 1 - B_{oN} - \frac{b_N}{\lambda} \end{bmatrix} \tag{23}$$

where to find the optimal dispatch:

F. The simultaneous linear equations in (23) are solved for an estimated value of the solution will be $p_i^{(1)}$, i=1,N .
G. Then the iterative process is continued using the gradient method for the (N+1) system equations formed by (7) and (23).

$$E * P = D \tag{24}$$

$$E=\begin{bmatrix}\frac{c_1}{\lambda}+B_{11} & B_{12} & \cdots & B_{1N}\\ B_{21} & \frac{c_2}{\lambda}+B_{22} & \cdots & B_{2N}\\ \vdots & \vdots & \ddots & \vdots\\ B_{N1} & B_{N2} & \cdots & \frac{c_N}{\lambda}+B_{NN}\end{bmatrix}, P=\begin{bmatrix}p_1\\ p_2\\ \vdots\\ p_N\end{bmatrix}, D=\frac{1}{2}\begin{bmatrix}1-B_{01}-\frac{b_1}{\lambda}\\ 1-B_{02}-\frac{b_2}{\lambda}\\ \vdots\\ 1-B_{oN}-\frac{b_N}{\lambda}\end{bmatrix}$$

To find the optimal dispatch for in estimated value of $\lambda^{(1)}$, the simultaneous linear equation given by (24) is solved. In MATLAB use the command $P=\frac{E}{D}$.

Then the iterative process is continued using the gradient method. To do this, from (22), Pi at the K^th iteration is expressed as:

$$Pi(K)=\frac{\lambda^{(K)}(1-Boi)-bi-2\lambda^{(K)}\sum_{i\neq j}BijPj^{(K)}}{2(ci+\lambda^{(K)}Bii)} \tag{25}$$

Substituting for Pi from (25) in (7) results in

$$\sum_{i=1}^{ng}\frac{\lambda^{(K)}(1-Boi)-bi-2\lambda^{(K)}\sum_{j\neq i}BijPi^{(K)}}{2(ci+\lambda^{(K)}Bii)}=PD+PL^{(K)} \tag{26}$$

or

$$f(\lambda^{(K)})=PD+PL^{(K)} \tag{27}$$

Expanding the left –hand side of the above equation in the Taylor series about an operation point $\lambda^{(K)}$ and neglecting the higher – order terms result in

$$f(\lambda)^{(K)}+(\frac{df(\lambda)}{d\lambda})^{(K)}\Delta\lambda^{(K)}=PD+PL^{(K)} \tag{28}$$

or

$$\Delta\lambda^{(K)}=\frac{\Delta P^{(K)}}{(\frac{df(\lambda)}{d\lambda})^{(K)}}=\frac{\Delta P^{(K)}}{\sum(\frac{dP}{d\lambda})^{(K)}} \tag{29}$$

where

$$\sum_{i=1}^{ng}(\frac{\partial Pi}{\partial\lambda})^{(K)}=\frac{ci(1-Boi)-Biibi-2ci\sum_{j\neq i}BijPi^{(K)}}{2(ci+\lambda^{(K)}Bii)^2} \tag{30}$$

and therefore,

$$\lambda^{(K+1)}=\lambda^{(K)}+\Delta\lambda^{(K)} \tag{31}$$

where

$$\Delta P^{(K)}=PD+PL^{(K)}-\sum_{i=1}^{ng}Pi^{(K)} \tag{32}$$

The process is continued until $\Delta P^{(K)}$ is less than a specified accuracy, and a specified accuracy =0.0001. If an approximate loss formula expressed by

$$PL=\sum_{i=1}^{ng}BiiPi^2 \tag{33}$$

is used, Bij=0, B00=0, and solution of the simultaneous equation given by (26) reduced to the following simple expression

$$Pi^{(K)}=\frac{\lambda^{(K)}-bi}{2(ci+\lambda^{(K)}Bii)} \tag{34}$$

In addition, (30) is reduced to

$$\sum_{i=1}^{ng}(\frac{\partial Pi}{\partial\lambda})^{(K)}=\frac{ci+Biibi}{2(ci+\lambda^{(K)}Bii)^2} \tag{35}$$

IV. Outline of the Basic Steady-State Genetic Algorithm

Start: Generate random population of *n* chromosomes (suitable solutions for the problem).

1. Fitness : Evaluate the fitness *f(x)* of each chromosome *x* in the population
2. New population : Create a new population by repeating following steps until the new population is complete:
   a. Selection: Select two parent chromosomes from a population according to their fitness (the better fitness, the bigger chance to be selected).
   b. Crossover: With a crossover probability cross over the parents to form a new offspring (children). If no crossover is performed, an offspring is an exact copy of parents [8].
   c. Mutation: With a mutation probability mutates a new offspring at each locus (position in chromosome).
   d. Accepting: Place a new offspring in a new population.
3. Replace: Use new generated population for a further run of algorithm
4. Test: If the end condition is satisfied, stop, and return the best solution in current population.
5. Loop: Go to step 2.

V. The Capacitor Placement

The capacitor placement problem comprises two terms; first term represents the cost of capacitor placement, which has two components:

1. Fixed installation cost.
2. Purchase cost.

The second term represents the total cost of energy loss. The energy loss is obtained by summing up the power losses for each load level multiplied by the duration of the load level. In practice, capacitors banks of standard discrete capacitance are ground. Hence, capacitor size is the discrete variables [9]. The cost of capacitor placement at location k with sizing U_K^0 is:

$$C_K(U_K^0)=K_C\cdot\left(\frac{U_K^0}{U_S}\right)+C_K^f\left(U_K^0\right) \tag{36}$$

where K_C is the cost of one bank of capacitor or is a fixed capacitor to be installed. $C_K^f(U_K^0)$ C_K represents the cost associated with the capacitor installation at location k.]. For each load level, let the real power loss in the system be $P_{loss,i}\left(X^i, U^i\right)$, then the total cost of energy loss can be written as:

$$K_e \sum_{i=1}^{Nt} T_i . P_{loss,i}\left(X^i, U^i\right),$$

where T_i is the duration for load level i and constant K_e is the energy cost per unit. Let N_C possible location to place capacitors and N_t different loads levels. Let C represent the set of fixed capacitors,

Let $n_t = [1,2,......N_t]$ and $n_c = [1,2,.....N_C]$, then the general capacitor placement problem is formulated as follows:

$$Minimize\ \left(U^0, U^k\right)\sum_{K=1}^{N_C} C_K\left(U_K^0\right) + K_e \sum_{i=1}^{N_t} T_i . P_{Loss,i}\left(X^i, U^i\right) \tag{37}$$

subject to:

$$C_K\left(U_K^0\right) = \left(K_C . \left(U_K^0 / U_s\right) + C_K^f\left(U_K^0\right)\right)/10$$

where $C_K\left(U_K^0\right)$ is the annual cost of capacitor at location K with size U_K .

In this work we have developed the equation formulated of the general capacitor placement to find the annual cost by dividing the cost of capacitor by 10 by assuming that the capacitor lasts 10 years at least. These assumptions assist in minimizing the energy cost and the total cost of the system by the ability of an addition of the many of capacitors to the system.

U^0 is the sizing vector whose components are multiples of the standards size of one bank . U^i is the control setting vector at load level i.

VI. Computing of Eigenvalues and Eigenvectors

The modal analysis mainly depends on the power-flow Jacobian matrix.

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{bmatrix} . \begin{bmatrix} \Delta\theta \\ \Delta |V| \end{bmatrix} \tag{38}$$

By letting ΔP = 0 in (30):

$$\Delta P = 0 = J_{11}\Delta\theta + J_{12}\Delta |V| , \Delta\theta = -J_{11}{}^{-1} J_{12}\Delta |V| \tag{39}$$

and

$$\Delta Q = J_{21}\Delta\theta + J_{22}\Delta |V| \tag{40}$$

Substituting (40) in (41): yields

$$\Delta Q = J_R \Delta |V| \tag{41}$$

where

$$J_R = \left[J_{22} - J_{21} J_{11}{}^{-1} J_{12}\right] \tag{42}$$

J_R is the reduced Jacobian matrix of the system.

Equation (43) can be written as:

$$\Delta |V| = J_R{}^{-1}\Delta Q \tag{43}$$

The matrix J_R represents the linearzed relationship between the incremental changes in bus voltage (ΔV) and bus reactive power injection (ΔQ). It's well known that, the system voltage is affected by both real and reactive power variations. In order to focus the study of the reactive demand and supply problem of the system as well as minimize computational effort by reducing dimensions of the Jacobian matrix *J* the real power ($\Delta P = 0$) and angle part from the system in (38) are eliminated. The eigenvalues and eigenvectors of the reduced order Jacobian matrix J_R are used for the voltage stability characteristics analysis. Voltage instability can be detected by identifying modes of the eigenvalues matrix J_R . The magnitude of the eigenvalues provides a relative measure of proximity to instability. The eigenvectors on the other hand present information related to the mechanism of loss of voltage stability. Eigenvalue analysis of J_R results in the following:

$$J_R = \Phi\Lambda\Gamma \tag{44}$$

where

Φ = right eigenvector matrix of J_R

Γ =left eigenvector matrix of J_R

Λ =diagonal eigenvalue matrix of J_R

Equation (44) can be written as:

$$J_R{}^{-1} = \Phi\Lambda^{-1}\Gamma \tag{45}$$

where $\Phi\Gamma = 1$. Substituting (43) in (45) gives

$$\Delta |V| = \Phi\Lambda^{-1}\Gamma\Delta Q \tag{46}$$

or

$$\Delta |V| = \sum_i \frac{\Phi_i \Gamma_i}{\lambda_i}\Delta Q$$

where λ_i is the i^{th} eigenvalue, Φ_i is the of i^{th} column right eigenvector and Γ_i *is* the i^{th} row left eigenvector of matrix

J_R Each eigenvalue λ_i and corresponding right and left eigenvectors Φ_i and Γ_i, define the i^{th} mode of he system. The i^{th} modal reactive power variation is defined as:

$$\Delta Q_{mi} = K_i \Phi_i \tag{47}$$

where K_i is a scale factor to normalize vector ΔQ_i so that

$$K_i^{\ 2} \sum_j \Phi_{ji} = 1 \tag{48}$$

where Φ_{ji} the j^{th} element of Φ_i .The corresponding i^{th} modal voltage variation is:

$$\Delta |V|_{mi} = \frac{1}{\lambda_i} \Delta Q_{mi} \tag{49}$$

Equation (49) can be summarized as follows:

1. If $\lambda_i = 0$, the i^{th} modal voltage will collapse because any change in that modal reactive power will cause infinite modal voltage variation.
2. If $\lambda_i \succ 0$, the i^{th} modal voltage and i^{th} reactive power variation are along the same direction, indicating that the system is voltage stable.
3. If $\lambda_i \prec 0$, the i^{th} modal voltage and the i^{th} reactive power variation are along the opposite directions, indicating that the system is voltage unstable.

If Φ_i and Γ_i represent the right-hand and left-hand eigenvectors, respectively, for the eigenvalue λ_i of the matrix J_R, then the participation factor measuring the participation of the K^{th} bus in i^{th} mode is defined as

$$P_{ki} = \Phi_{ki} \Gamma_{ik} \tag{50}$$

Note that for all the small eigenvalues, bus participation factors determine the area close to voltage instability. Equation (50) implies that P_{ki} shows the participation P_{ki} of the i^{th} eigenvalue to the sensitivity at bus *k*. The node or bus *k* with highest value is the most contributing factor in determining the sensitivity at i^{th} mode. Therefore, the bus participation factor determines the area close to voltage instability provided by the smallest eigenvalue of J_R.

VII. The Discussion of the Proposed System

We will test case in the proposed system: The case of 22-bus bars with 10 generators. It is aimed in this research to reduce the total generation cost of power system using optimum economic dispatch by placing some capacitors on the bus bars of power system to reduce the losses of power and this will lead to reduce the total cost. To select the optimal locations and sizes of the capacitors, we will use the Participation Factor to get the best locations in the bus bars of power system. And we will use the Genetic Algorithm steady state to get the best sizes for these capacitors. In this section we will present how we will get the best total cost and compare with the previous cost that will get it before the adding of capacitors. So we will present the procedures that will fellow them to get the cost of system:

1- Compute the Newton-Raphson method.
2- Compute the losses of power system.
3- Determine the economic dispatch before compensation using Lagrange multiplier method.
4- Compute the Participation Factor to detect the optimal locations in the power system.
5- Apply the Genetic Algorithm to select the best sizes for the capacitors that will place in the selected locations (in the previous procedure).
6- Compute the optimum economic dispatch to get the total cost, and compare with the previous cost.

A 10- generator case with 22 bus bars is taken to illustrate the proposed algorithm to solve the economic dispatch problem.

As in the previous section the same procedures will be computed to get the reduced total cost.

To reduce the total cost, the method of Participation factor is performed by computing the Jacobian Matrix reduction JR to analyze the stability of the voltage. This can be made by computing the eigenvalues and eigenvectors for JR matrix, where the values of eigenvalues give a proximate for the voltage instability at the load level, and from this we can determine the Participation Factor for the buses of the system , and the buses that have the minimum eigenvalues are selected and large PF(participation factor) values are used to inject the capacitors in the buses.

Fig. 1 presents the load level participation factor. Tables I, II present the results of eigenvalues for the selected buses and the Participation factor for these buses:

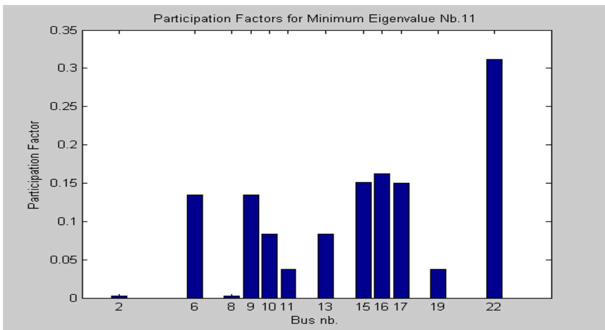

Fig. 1 The Load Level Participation Factor for the Eigenvalues

TABLE I
THE EIGENVALUES OF THE SELECTED BUSES

Location	Eigenvalue
2	247.071
6	288.752
8	224.783
9	105.238
10	87.196
11	77.561
13	51.724
15	23.209
16	17.698
17	5.614
19	4.597
22	4.642

TABLE II
THE PARTICIPATION FACTOR FOR THE SELECTED BUS

Bus No.	Participation Factor
2	0.0025
6	0.1344
8	0.0025
9	0.1344
10	0.0836
11	0.0374
13	0.0836
15	0.1514
16	0.1623
17	0.1500
19	0.0374
22	0.3115

From the results of the participation factor, the 10 candidate locations in the system are selected for placing the capacitors (see Table III).

After the best candidate buses are obtained, the next step is to get the optimal sizes for the capacitors to place them in these buses; this is done by using the *Steady State Genetic Algorithm (SSGA).* And to achieve this target, we need to building an initial population and getting the fitness function and determined the number of generations. At initial, random populations are selected and the encoding of the chromosomes of the population use integer values (because each chromosome will present the number of capacitors that will be injected to system). Each of chromosome is added to the buses data array to the field of Q_{sht} (which present the field of capacitors) and compute the power losses for the system.

The value of power losses will be multiplied by the cost of energy and will be added to the price of capacitors and their maintenance to give the fitness function. So, to get the minimum total cost we must get the best chromosome that has the minimum fitness function.

FitFun= the cost of capacitor+ the power losses*energy cost + the maintenance (fixed installment cost Energy cost (Ke) = 60$/ MW.h The cost of capacitor

a- Fixed installment cost = 1000$.
b- Purchase = 3500$/bank.

Table III presents the location of candidate capacitors and their optimal sizes which are obtained from the SSGA and Table IV presents the final results to get the reduced total generation costs:

TABLE III
THE FIXED CAPACITORS PLACEMENT AND THEIR SIZES

Optimal locations (bus No.)	Optimal Size of Capacitors (MVAR)
6	6
9	7
10	15
11	2
13	9
15	5
16	13
17	6
19	11
22	1

TABLE IV
THE OPTIMAL DISPATCH OF GENERATION

Optimal Dispatch of Generation
187.5000
139.0000
400.0000
279.1755
345.2646
268.2019
125.4000
279.0975
300.0000
268.1165

VIII. CONCLUSIONS

The following conclusions are derived from this work:

- The power flow method, together with the system losses and the economic dispatch methods can be used to obtain the optimal dispatch of generation. To get this target will need reducing the losses of system by reducing the loss coefficients. The dispatch method produces a variable named dpslack. This is the difference (absolute value) between the scheduled slack generation determined from the coordination equation, and the slack generation, obtained from the power flow solution. A power flow solution obtained with new scheduling of generation results in a new loss coefficient, which can be used to solve the coordination equation again. The process continues until dpslack is within a specified tolerance, but it is seen that the dpslack value must not be very small because this will increase the iterative and this will lead to increase the cost (it is found that the best value for dpslack is at 0.1).
- The Participation Factor and Steady State Genetic algorithm are used to determine the candidate buses and the number of reactive power gives the accuracy and the enhancement to the work because the first stage (participation factor stage) simultaneously contributes to narrowing down the search domain for the second stage

(GA optimization), as well as ensures those buses that are sensitive to voltage problems considered for reactive power compensation.

- The use of SSGA gives more accurate results than the simple genetic algorithm SGA because the SGA replaces the entire parent population with the children. And in elitism the fittest individuals pass unchanged from the parent population to the children while the SSGA replaces few individuals, and it provides a set of solutions rather than only one solution.

Finally, from the computational results, the following can be observed:

1. The total generation cost for the initial operation condition is reduced by using the total generation cost with optimal dispatch of generation and genetic algorithms.
2. MVAR of generators is reduced by using injection capacitors.
3. The solution methodology is based on an optimization technique chosen by genetic algorithms to minimize the objective function while the load constraints and operational constraints like the voltage profile at different load levels are satisfied.
4. SSGA, which is based on the laws of natural selection and survival of the fittest, has been used successfully to reduce power loss considering balanced condition, because SSGA reaches quickly the region of optimal solutions and its accuracy for one reason: SSGA avoids local minima by searching in several regions.

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