Research Journal of Recent Sciences ISSN 2277-2502
Vol. **2(12),** 54-64, December **(2013)** *Res.J.Recent Sci.*

Capacitor Replacement in Distribution Networks using Genetic Algorithm

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Available online at: www.isca.in, www.isca.me
Received 26th February 2013, revised 27th May 2013, accepted 8th July 2013

Abstract

In researches, some of the algorithms such as genetic algorithms belong to the larger class of evolutionary algorithm, which generates solutions to optimization problems using techniques inspired by natural evolution. Genetic algorithm, neural networks, and the methods such as cement grout, Morchegan theory and Body Immune Algorithm are involved in the algorithms and methods which have been obtained through phenomena and natural matters .through this, genetic algorithm is one of the optimal algorithms which is based on the base of Darwin's theory of evolution, driven by the survival of the fittest .Today, genetic algorithm have found application in engineering science. In a genetic algorithm, a population of strings, chromosomes, which encode candidate solution to an optimization problem, is evolved toward better solutions. Traditionally, solutions are represented in binary, but other encodings are also possible. The evolution usually starts from a population of randomly generated individuals and happens in generations. In this article, different methods of Capacitor replacement in distribution networks have been considered, which these methods could be accomplished through genetic algorithm. Hence, in this article the optimal criterion and the Capacitor replacement in sensitive points of network would be determined; also the objective function and intervention of different economical parameters have been introduced in this article as well.

Keywords: Genetic algorithm, capacitor, chromosome**,** economical parameters**,** distribution networks.

Introduction

Genetic algorithms in particular became popular through the work of John Holland in the early 1970s, and particularly his book Adaptation in Natural and Artificial Systems which was published in 1970. His work originated with studies of cellular automata, conducted by Holland and his students at the University of Michigan. Holland introduced a formalized framework for predicting the quality of the next generation, known as Holland's schema theorem. As academic interest grew, the dramatic increase in desktop computational power allowed for practical application of the new technique. Later, General Electric started selling the world's first genetic algorithm product, a main frame-based toolkit designed for industrial processes. Genetic algorithm is the evolutionary algorithm which involves the populations of solutions with primarily mutation and selection and arbitrary representations. self-adaptation are used to adjust parameters, and can include other variation operations such as combining information from multiple approaches in genetic algorithm, population involves a particular number of chromosomes, in which each chromosome has been generated of some genes. Genes also use the populations of computer programs. These complex computer programs are encoded in simpler linear chromosomes of fixed length, in this case Computer programs evolve because the chromosomes undergo mutation and recombination. A schematic of a chromosome has been shown in figure-1[1,2,3].

Initially many individual solutions are randomly generated to form an initial population. The population size depends on the nature of the problem, but typically contains several hundreds or thousands of possible solutions. Traditionally, the population is generated randomly, allowing the entire range of possible solutions. Occasionally, the solutions may be seeded in areas where optimal solutions are likely to be found. The evolution usually starts from a population of randomly generated individuals and happens in generations. In each generation, the fitness of every individual in the population is evaluated; multiple individuals are stochastically selected from the current population, and modified to form a new population. The new population is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population. If the algorithm has terminated due to a maximum number of generations, a satisfactory solution may or may not have been reached.[4,5]

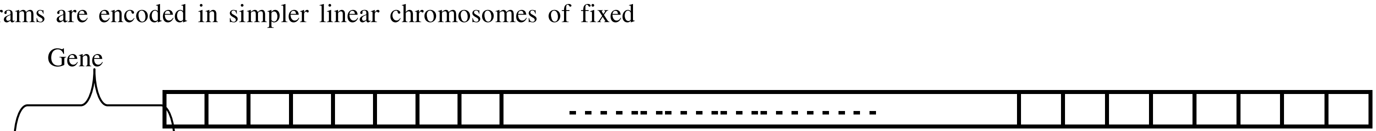

Figure-1
The structure of chromosome

If $\vec{a}$ =($a_1, \ldots, a_2$) indicates the standard base 2, and $\vec{b}$ =($b_1, \ldots, b_k$) Indicates the alteration of system to standard base 2 ; so the alterations would be accomplished through following relations , equation 1:

$$b_i = \begin{cases} a_1 & if \quad i = 1 \\ (a_{i-1}) XOR\ (a_{i-1}) & Otherwise \end{cases} \qquad (1)$$

Where we could define $a_i \quad as \ , a_i = \sum_{j=1}^{i} XOR\ (b_i)$

The variables in each encoding methods are different in term of the type of variable. For integral variables, the numbers within base 2 would be linearly changed to the numbers within base 10. The numbers which are changed to base 10 would be as following , equation 2 :

$$2\ )\ T_G\ (a_{i1}, \ldots, a_{ilx})U_i + \frac{V_i - U_i}{2^{lx} - 1}\{(\sum_{j=0}^{l_{x-1}} a_j\ (I_{x-j})x2^j)\} \qquad (2)$$

Where V_i and U_i are respectively the alteration intervals of i_{th}, and l_x is the length of binary numbers for the variables. It is clear that the accuracy criterion would be as following, equation 3:

$$\Delta_{xi} = \frac{V_i - U_i}{2^{lx} - 1} \qquad (3)$$

It would be shown that if n variables be in inputs, and each one involves l_x bit, in this case each chromosome‘s length would be equal to n l_x. In most applications, problems’s variables and solutions are in 10 base. Hence, if we use the encoding method within 2 base or 10 base, it would be essential to change the saved numbers of chromosome to base 10. Recently, in order to avoid changing numbers, and to prevent from long numbers, the numbers have to be saved in base 10 in chromosomes. Fitness proportionate selection, also known as roulette-wheel selection, is a genetic operator used in genetic algorithms for selecting potentially useful solutions for recombination. Fitness proportionate selection, as in all selection methods, the fitness function assigns fitness to possible solutions or chromosomes. Usually a proportion of the wheel is assigned to each of the possible selections based on their fitness value. This could be achieved by dividing the fitness of a selection by the total fitness of all the selections; thereby we have to normalize them to 1. Then a randomized selection is made similar to how the roulette wheel is rotated, in which the measurement of each sector is as following, equation 4[5,6,7]:

$$S_i = \frac{Fitness\ (\vec{T})}{\sum_{i=1}^{\mu} Fitness(\vec{T})} \qquad (4)$$

While candidate solutions with a higher fitness are less likely to eliminated, there would be still a chance that they may be. Contrast this with a less sophisticated selection algorithm, such as truncation selection, which will eliminate a fixed percentage of the weakest candidates. With fitness proportionate selection there is a chance, in which some weaker solutions may survive the selection process; this is an advantage, as though a solution may be weak, it may include some component which could prove useful following the recombination process[8,9].

The analogy to a roulette wheel can be envisaged by imagining a roulette wheel in which each candidate solution represents a pocket on the wheel; The size of the pockets are proportionate to the probability of selection of the solution. Selecting N chromosomes from the population is equivalent to playing N games on the roulette wheel, as each candidate is drawn independently[5].

Main body: Distribution networks are divided into two groups as low voltages and medium voltage, also High-voltage is used for transmission of large blocks of power over long distances, but not for distribution to customers. Electric power is normally generated at 11-25kV in a power station. Power is carried through a transmission network of high voltage lines. Usually, these lines run into hundreds of kilometers and deliver the power into a common power pool called the grid. The grid is connected to load centers (cities) through a sub-transmission network of normally 33kV lines. These lines terminate into a 33kV substation, where the voltage is stepped-down to 11kV for power distribution to load points through a distribution network of lines at 11kV and lower[10-12].

Load flow solution within Newton–Raphson method: The power flow study, also known as load-flow study, is an important tool involving numerical analysis applied to a power system. A power flow study usually uses simplified notation such as a one line diagram and per unit system, and focuses on various forms of powers such as voltages, voltage angles, real power and reactive power. It analyzes the power systems in normal steady-state operation. A number of software implementations of power flow studies exist one of the main method to determine flow, voltage and wastages in distribution network in order to compare different cases of capacitator and observing the condition of network in pre and post Capacitor performance, that it would be Newton–Raphson method. Most of the main algorithms apply this method and it‘s derivation, this method particularly could be used for load flow solution of power transferring systems involving the annulated structure[3,13,14].

The load flow methods of Newton–Raphson: NR method and the analyzed sequence: There are several different methods of solving the resulting nonlinear system of equations. The most popular method is known as the Newton–Raphson method. This method begins with initial guesses of all unknown variables (voltage magnitude and angles at Load Buses and voltage angles at Generator Buses). Next, as it is written, with the higher order terms ignored, for each of the power balance equations included in the system of equations, in which to apply single-voltage load flow within zero and negative equations, the load flow model within mathematical method would be as following, equation 5[15,16]:

$$J_1 \Delta V_1 = \Delta S_1 \qquad (5.1)$$

$$Y_2 V_2 = I_2 \qquad (5.2)$$

$Y_0 V_0 = I_0$ (5.3)

J_1 is Jacobean matrix which is positive in the load flow study, or in sequence matrix. ΔV_1 is the error vertex of voltage measures and it's angles, $\Delta S_1$is the vertex of difference between positive sequence powers, in which the power has to be involved in the Asymmetric lines. Admitas positive and zero components of Asymmetric lines have been applied in two other equations. Solving three above equations is recommended; in a way that analytical technique could be applied. Anyway, one of the convergence criterions could be applied[17,18].

Applying NR method and the method of analyzed sequence in parallel process: In this method, the load flow problem has been solved within parallel process through section 5-1 to 5-3 equations. The recommended method of present research is based on the methods of analyzed sequence, in which presenting the equations are as mathematical model of load flow; it means that section 5-1 to 5-3 equations have been rewritten as following in 5-4 to 5-7 equations, and the problem has divided from Δp to ΔQ.[19,3,20]

$-B_1^{\square}|V_1|\Delta\theta_1 = \Delta P_1/|V_1|$ (5.4)

$-B_1^{\square\square}\Delta\theta_1 = \Delta Q_{11}/|V_1|$ (5.5)

$Y_2 V_2 = I_2$ (5.6)

$Y_0 V_0 = I_0$ (5.7)

Where $Y_0 \, and \, Y_2$ are zero and negative Admitas components, and V_2, V_0 , $I_2 \, and \, I_0$ are respectively vertexes of negative and zero components .Through solving 5-4 to 5-7 equations simultaneously within a parallel process by some processors, the unknown values of load flow could be obtained within a minimum time and maximum accuracy, that this could be accomplished through authors[21].

NR method and load flow analysis: The polar coordinate of Jacobean matrix in NR method is as following, equation 6:

$$J = \begin{bmatrix} \frac{\partial P}{\partial \theta} & \frac{\partial P}{\partial V} \\ \frac{\partial Q}{\partial \theta} & \frac{\partial Q}{\partial V} \end{bmatrix} \qquad (6)$$

In NR method, instead of power, the alternative flow is used for branch flow. The determined load flow such as P^{spec} and Q^{spec} could be changed to alternative flow of I $^{sp\text{-}equ}$. As a sample, the alternative flow of I, would be repeated in K^{th} and it would be as following in equation 7:

$$I^{sp\text{-}equ} = \left[\frac{(P1+jQ)^{spec}}{V(K)}\right]^* = \mathrm{Re}[I_i^{sp-equ}] \qquad (7)$$

Then each feeder of three voltages changing to calculated flows, I ^{cal}, could be as following, in equation 8:

$$\begin{bmatrix} I_i^{cal} \\ I_h^{cal} \\ I_c^{cal} \end{bmatrix} = \begin{bmatrix} y_{aa} y_{ab} y_{ac} \\ y_{ba} y_{bb} y_{bc} \\ y_{ca} y_{cb} y_{cc} \end{bmatrix} \begin{bmatrix} V_a - V_a \\ V_b - V_b \\ V_c - V_c \end{bmatrix} \qquad (8)$$

Where $Y_{ij} = g_{ij}$ + j b_{ij} is the Admitas of line from i to j knob, therefore the flow difference function could be as following, in equation 9 :

$$\begin{bmatrix} \Delta I^y \\ \Delta I^m \end{bmatrix} = \begin{bmatrix} \frac{\partial I^y}{\partial f^y} & \frac{\partial I^y}{\partial f^m} \\ \frac{\partial I^m}{\partial f^y} & \frac{\partial I^m}{\partial f^m} \end{bmatrix} \qquad (9)$$

Where,
$\Delta I = \Delta I^y + j\Delta I^m \quad \Delta I = I^{sp} - I^{cal}, \Delta f = \Delta f^y + j\Delta f^m$, are real and imaginary components of flow are difference. In radial networks within considering the network as a voltage, the flow in IEEE flow would be as following, in equation 10:

$$I_{i,p} = I_{i,p}^y + jI_{i,p}^m = \sum f_{i,p}^y + j\sum f_{i,p}^m \qquad (10)$$

Where p is the flow index .the observation of I $_m$ and I $_y$ Partial derivatives to the f_m and f_y variables is simple, which this would lead to unique Jacobean matrix that this matrix is a fixed matrix which is shown in equation 11 , and 10 equation could be analyzed to voltage .

$$\begin{bmatrix} \Delta I_a^y \\ \Delta I_a^m \\ \Delta I_b^y \\ \Delta I_b^m \\ \Delta I_c \\ \Delta I_c^m \end{bmatrix} = \begin{bmatrix} Jaa & 0 & 0 & 0 & 0 & 0 \\ 0 & Jaa & 0 & 0 & 0 & 0 \\ 0 & 0 & Jbb & 0 & 0 & 0 \\ 0 & 0 & 0 & Jbb & 0 & 0 \\ 0 & 0 & 0 & 0 & Jcc & 0 \\ 0 & 0 & 0 & 0 & 0 & Jcc \end{bmatrix} \begin{bmatrix} \Delta f_a^y \\ \Delta f_a^m \\ \Delta f_b^y \\ \Delta f_b^m \\ \Delta f_c^y \\ \Delta f_c^m \end{bmatrix} \qquad (11)$$

While in weak annulated networks, within adding each ring to network based on KVL principle, an extra variable would be created, and for each ring a KVL would be as following , in which the number of this ring 's branches would be shown with n , showing in equation 12:

$$\textstyle\sum_{i=1}^{n} z_{i,p} f_{i,p} = 0 \qquad (12)$$

Equation 12 could be separated as following, showing in equation 13:

$$\textstyle\sum_{i=1}^{n} y_{i,p} f_{i,p}^y - x_{i,p} f_{i,p}^m + j\sum_{i=1}^{n} y_{i,p} f_{i,p}^m - x_{i,p} f_{i,p}^y \qquad (13)$$

the following equation, equation 14, and then equation 15, would be resulted:

$$\begin{bmatrix} R_{aa} - X_{aa} & R_{ab} - X_{ab} & R_{ac} - X_{ac} \\ X_{aa} \quad R_{aa} & X_{ab} \quad R_{ab} & X_{bb} \quad R_{ac} \\ R_{ba} - X_{ba} & R_{bb} - X_{bb} & R_{bc} - X_{bc} \\ X_{ba} \quad R_{ba} & X_{bb} \quad R_{bb} & X_{bc} \quad R_{bc} \\ R_{ca} - X_{ca} & R_{cb} - X_{cb} & R_{cc} - X_{cc} \\ X_{ca} \quad R_{ca} & X_{cb} \quad R_{cb} & X_{cc} \quad R_{cc} \end{bmatrix} \begin{bmatrix} \Delta f_a^y \\ \Delta f_a^m \\ \Delta f_b^y \\ \Delta f_b^m \\ \Delta f_c^y \\ \Delta f_c^m \end{bmatrix} \begin{bmatrix} -g_a(\Delta f) \\ -h_a(\Delta f) \\ -g_b(\Delta f) \\ -h(\Delta f) \\ -g(\Delta f) \\ -h_c(\Delta f) \end{bmatrix} \qquad (14)$$

$$g_p(\Delta f) = \sum_{i=1}^{n} y_{i,p} f_{i,p}^y - x_{i,p} f_{i,p}^m \qquad (15)$$

$$h_p(\Delta f) = \sum_{i=1}^{n} y_{i,p} f_{i,p}^m - x_{i,p} f_{i,p}^y \qquad (16)$$

Where R_{cc}, R_{bb}, R_{aa} are the blocks of spontaneous Impedance, and R_{cc} ,R_{bb}, R_{aa} are the blocks of bilateral induction. The Jacobean matrix could be obtained within combination of matrix and 11 and 14 equations as following, showing in equation 16:

$$\begin{bmatrix} J_{aa} & \circ & \circ & \circ & \circ & \circ \\ R_{aa} & -x_{aa} & R_{ab} & -x_{ab} & R_{ac} & -x_{ac} \\ \circ & J_{aa} & \circ & \circ & \circ & \circ \\ x_{aa} & R_{aa} & x_{ab} & R_{ab} & x_{ac} & R_{ac} \\ \circ & \circ & J_{bb} & \circ & \circ & \circ \\ R_{ba} & -x_{ba} & R_{bb} & -x_{bb} & R_{bc} & -x_{bc} \\ \circ & \circ & \circ & J_{bb} & \circ & \circ \\ x_{ba} & R_{ba} & x_{bb} & R_{bb} & x_{bc} & R_{bc} \\ \circ & \circ & \circ & \circ & J_{cc} & \circ \\ R_{ca} & -x_{ca} & R_{cb} & -x_{cb} & R_{cc} & -x_{cc} \\ \circ & \circ & \circ & \circ & \circ & J_{cc} \\ x_{ca} & R_{ca} & x_{cb} & R_{cb} & x_{cc} & R_{cc} \end{bmatrix}$$

This Jacobean matrix is totally symmetric, in which NR algorithm could be useful to solve the load flow problem. We have to notice that NR method is a minimization problem of gradient, which it is used in nonlinear equations. Simplification of Jacobean matrix would change the direction, and this would increase the repetitions. Now through considering the point that spontaneous impedance is more than bilateral induction, and the analyzed voltage within omitting the no-diagonal.[14]

Blocks, so we would have the equation 17 for voltage a:

$$\begin{bmatrix} J_{aa} & 0 \\ R_{aa} & -X_{aa} \\ \cdot & J_{aa} \\ X_{aa} & J_{aa} \end{bmatrix} \begin{bmatrix} \Delta f_a^y \\ \Delta f_a^m \end{bmatrix} = \begin{bmatrix} \Delta I_a^y \\ g(\Delta f) \\ \Delta I^m{}_0 \\ h(\Delta f) \end{bmatrix} \quad (17)$$

The analyzed difference functions could be developed for two other voltages such as b and c. thus, the analysis could be accomplished without any condition for θ, V or r/x , and this method is not sensitive for sensitive parameters of line , and it is very efficient.

Voltage in K^{th}

If flow of branches be definite, then the voltage would be determined, and it would be shown as equation 18, in which V_i is shine voltage in input and V_j is the output voltage, and z is the impedance line:

$$V_1 (K) = V_1 (K) - f_1 (K)\, z \quad (18)$$

The reformed method of NR: In this method, based on the point that the load flow problem to solve $\Delta\theta$ *and* ΔV, is as the equation 19, so the Jacobean matrix would be altered to UDU^r :

$$\begin{bmatrix} H & N \\ J & L \end{bmatrix} \begin{bmatrix} \Delta\theta \\ \Delta V/V \end{bmatrix} = \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} \quad (19)$$

That the following equations would be resulted as well;

$$H_{ij} = -V_i v_j \left(G_{ij} sin\theta_{ij} - B_{ij} cos\theta_{ij}\right), j \neq i \quad (19.1)$$
$$H_{ij} = V_i \sum_{j\neq i} V_j \left(G_{ij} sin\theta_{ij} - B_{ij} cos\theta_{ij}\right) \quad (19.2)$$
$$N_{ij} = -V_i V_j \left(G_{ij} cos\theta_{ij} + B_{ij} sin\theta_{ij}\right), j \neq i \quad (19.3)$$
$$N_{ij} = -V_i \sum_{j\neq i} V_j \left(G_{ij} cos\theta_{ij} + B_{ij} sin\theta_{ij}\right) - 2V_1^2 G_{ij} \quad (19.4)$$
$$J_{ij} = V_i V_j \left(G_{ij} sin\theta_{ij} - B_{ij} cos\theta_{ij}\right), j \neq i \quad (19.5)$$
$$J_{ij} = V_i \left(G_{ij} cos\theta_{ij} + B_{ij} sin\theta_{ij}\right) \quad (19.6)$$
$$L_{ij} = -V_i v_j \left(G_{ij} sin\theta_{ij} + B_{ij} cos\theta_{ij}\right), j \neq i \quad (19.7)$$
$$L_{ij} = -V_i \sum_{j\neq i} V_j \left(G_{ij} cos\theta_{ij} + B_{ij} sin\theta_{ij}\right) + 2V_1^2 G_{ij} \quad (19.8)$$

Where we would have 19.1 to 19.8 , in which G_{ij} +j B_{ij} is the element of knob Admittance matrix . While the difference of potential between two knobs be low, we would have $G_{ij} + jB_{ij} = -\sum_{j\neq i}(G_{ij} + jB_{ij})$.
For the systems without parallel branch, Jacobean matrix would be as following in 20.1 to 20.8:

$$H_{ij} \approx V_i V_j B_{ij} cos\theta_{ij}, j \neq i \quad (20.1)$$
$$H_{ij} \approx -V_i \sum_{j\neq i} V_i B_{ij} cos\theta_{ij} \quad (20.2)$$
$$N_{ij} \approx -V_i V_j G_{ij} cos\theta_{ij}, j \neq i \quad (20.3)$$
$$N_{ii} \approx V_i \sum_{j\neq i} V_j G_{ij} cos\theta_{ij} \quad (20.4)$$
$$J_{ij} \approx V_i V_j cos\theta_{ij}, j \neq i \quad (20.5)$$
$$J_{ii} \approx -V_i \sum_{j\neq i} V_j G_{ij} cos\theta_{ij} \quad (20.6)$$
$$L_{ij} \approx V_i V_j B_{ij} cos\theta_{ij}, j \neq i \quad (20.7)$$
$$L_{ij} \approx -V_i \sum_{j\neq 1} V_i B_{ij} cos\theta_{ij} \quad (20.8)$$

It could be concluded that H, N, J and N matrixes , and all relations of symmetry properties are similar to Admittance matrix of first knob, which it could be as following, in 21 and 22 equations :

$$H = L = A_{n-1} D_B A_{n-1}^r \quad (21)$$

$$J = -N = A_{n-1} D_G A_{n-1}^r \quad (22)$$

Where D_G and D_B are diagonal matrixes within diagonal elements as $V_i V_j G_{ij} cos\theta_{ij}, V_i V_j B_{ij} cos\theta_{ij}$. Hence, the equation 19 would be as following in equation 23:

$$\begin{bmatrix} A_{n-1} & 0 \\ 0 & A_{n-1} \end{bmatrix} \begin{bmatrix} D_B & -D_G \\ D_G & D_B \end{bmatrix} \begin{bmatrix} A^r_{n-1} & 0 \\ 0 & A^r_{n-1} \end{bmatrix} \begin{bmatrix} \Delta\theta \\ \frac{\Delta V}{V} \end{bmatrix} = \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} \quad (23)$$

Electrical devices are considered grid friendly if they operate in a manner that supports electrical power grid reliability. Basic grid-friendly devices may incorporate features that work to offset short-term undesirable changes in line frequency or voltage; more sophisticated devices may alter their operating profile based on the current market price for electricity, reducing load when prices are at a peak. Grid-friendly devices can include major appliances found in homes, commercial building systems such as HVAC, and many industrial systems. Most electric systems use alternating current with a nominal frequency of 50 or 60 Hz to deliver energy produced by electrical generators to the electricity consumers. When the amount of electrical power produced by the generators exceeds the power used by the customers, the frequency of the electricity rises. Conversely, when the amount of electric power produced is less than what is consumed, the frequency drops. Therefore frequency is an accurate indicator of the system-wide balance between supply and demand. One of the most common load models would the load model within the combination of fixed power, flow and impedance. Overall, based on voltage and load, the 24 and 25 equations as the criterion for consumed active and radioactive powers could be obtained for each of the costumers[6,22]:

$$P_{load} = P^0_{load}(A_o + A_1 V + A_2 V^2) \quad (24)$$
$$Q_{load} = Q^0_{load}(B_o + B_1 V + B_2 V^2) \quad (25)$$

Where Q^0_{load}, P^0_{load} are the active and reactive powers of load, $B_0 A_0$ is a percentage of load within fixed power index , B_1, A_1 is a percentage of load within fixed flow index, and B_2, A_2 is a percentage of load within fixed impedance index, and v is the ratio of voltage to load voltage. According to above equations, if the voltage be equal to the considered amount, then the active and radioactive power has to be equal to Q^0_{load}, P^0_{load} In the other word, the summation of coefficients would be equal to one as equation 26 and 27:[4]

$$A_0 + A_1 + A_2 = 1 \quad (26)$$
$$B_0 + B_1 + B_2 = 1 \quad (27)$$

A decoupling capacitor is a capacitor used to decouple one part of an electrical network (circuit) from another. Noise caused by other circuit elements is shunted through the capacitor, reducing the effect they have on the rest of the circuit.

For example, if the voltage level for a device is fixed, changing power demands are manifested as changing current demand. The power supply must accommodate these variations in current draw with as little change as possible in the power supply voltage. When the current draw in a device changes, the power supply cannot respond to that change instantaneously. As a consequence, the voltage at the device changes for a brief period before the power supply responds. The voltage regulator adjusts the amount of current it is supplying to keep the output voltage constant but can only effectively maintain the output voltage for events at low frequencies, depending on the regulator. For transient events that occur at frequencies above this range, there is a time lag before the voltage regulator responds to the new current demand level.

The objective function of Capacitor replacement: The objective function includes the cost of power losses, energy losses and that of the capacitor banks. Constraints include voltage limits, number, size and locations of installed capacitors (at each bus and the entire feeder) and the power quality limits. Candidate buses for capacitor placement are selected based on an initial generation of chromosomes. Using a proposed fitness function, a suitable combination of objective and constraints is defined as a criterion to select (among the candidates) the most suitable buses for capacitor placement[14].

Optimal capacitor placement problem is not an easy optimization problem. As the problem formulation approaches real time problem the degree of complexity increases. Previous researches on capacitor placement optimization problem employed various simplifying assumptions to reduce the complexity of the problem. Usually, these assumptions are far from actual system and the solved solution may be far from real optimal values .This is where the decoupling capacitor comes in. The decoupling capacitor works as the device's local energy storage. The capacitor cannot provide the power of decoupling capacitor because it stores only a small amount of energy but this energy can respond very quickly to changing current demands. The capacitors effectively maintain power-supply voltage at frequencies from hundreds of kHz to hundreds of MHz (in the milliseconds to nanoseconds range). Decoupling capacitors are not useful for events occurring above or below this range[21].

Costs of Energy wastage: Definite costs would be calculated in term of each Kw, that based on fuel price and production costs, this cost is different in each country. To calculate the network's energy wastages, the summation of wasted energy in different charge levels has to be calculated in the studied period. In the equation 28, the calculation of wasted energy has been presented:

$$P_{E_{loss}} = \sum_{i=1}^{n} P_i T_i \quad (28)$$

The cost of energy wastages would be calculated based on the equation 29 , and the price of each Kw (h) energy (K_e):

29) cost of energy wastages = $K_e . P_{E_{loss}}$

Production price at peak point: The cost of electricity (kWh) generated by different sources is a calculation of the cost of generating electricity at the point of connection to a load or electricity grid. It includes the initial capital, discount rate, as well as the costs of continuous operation, fuel, and maintenance. This type of calculation assists policy makers, researchers and others to guide discussions and decision making. Generally, cost of establishing powerhouses is calculated based on each Kw powerhouse and the lifetime of powerhouse[7].

Electric-power transmission is the bulk transfer of electrical energy, from generating power plants to electrical substations located near demand centers. This is distinct from the local wiring between high-voltage substations and customers, which is typically referred to as electric power distribution. Transmission and distribution lines were owned by the same company, but starting in the 1990s, many countries have liberalized the regulation of the electricity market in ways that have led to the separation of the electricity transmission business from the distribution business. To calculate the cost of each Kw ampere equipments and network lines, we have to consider the lifetime of equipments[23].

Grid energy storage refers to the methods used to store electricity on a large scale within an electrical grid power. Electrical energy is stored during times when production (from power plants) exceeds consumption and the stores are used at times when consumption exceeds production. In this way, electricity production need not be drastically scaled up and down to meet momentary consumption; instead, production is maintained at a more constant level. This has the advantage that fuel-based power plants can be more efficiently and easily operated at constant production levels .in each Capacitor placement, we have to consider the following to limit the flow of each branch[5]:

$$\forall\ i \in n \quad V_{\min} \leq V_i \leq V_{\max}$$

Where V_i, $V_{\max}$ and b are respectively the flow in $V_{\min}$ branch , the maximum flow in n branch and the summation of network branches.

The available banks may be limited for installing in the network, thus the optimal amount for the cost function has to be specified, in which the compensation has not to be maximized, and the maximum compensation could be effective in the optimal response[24]. As example, if the maximum compensation be considered with the maximum radioactive charge of network, at this time for finding the optimal response it is not essential to find the parts of response in which compensation is not more than radioactive power, and this fact has been shown in following:

$$\sum_{i=1}^{M} Q_i \leq Q_{\max}$$

Where M, Q_i and i are respectively the number of knobs for compensation, the compensation in $Q_{\max}$ knob, the maximum compensation in network.

Pre the Capacitor placement, the appropriate points have to be specified for the placement, whatever the number of points be more, then the genetic algorithm would have more environment for finding optimal response, and at this time the possibility of reaching to the optimal point would be less. In this article, the network points would be determined through analysis. Through sensitive analysis, The previous proceedings have been accomplished in base of stability case, controlling the voltage, and peak wastages in order to replacing radioactive in power network; in this article an approach to choose the network points has been accomplished in order to place the Capacitor, the sensitive analysis has been considered effective to reduce the finding environment for optimization. Sensitive analysis would be specified in the points which have the most impact on system from the energy wastages and peak[10,25,26].

Solving the Capacitor replacement through genetic algorithm (GA): A genetic algorithm computes improved generations of chromosomes and candidate buses until the solution is obtained. Simulation results could be obtained through distorted networks, and solutions of the genetic algorithm could be compared with those of the maximum-sensitivities selection, the maximum sensitivities selection-local variations, and the fuzzy set algorithms[27]. Capacitors are often installed in distribution system for reactive power compensation to carry out power and energy loss reduction, voltage regulation, system security improvement and system capacity release**.** Genetic algorithm are general-purpose search techniques based on principles inspired from the genetic and evolution mechanisms observed in natural systems and populations of living beings. Their basic principle is the maintenance of a population of solutions to a problem as encoded information individuals that evolve in time. Generally, GA comprises three different phases of search: creating an initial population, evaluating a fitness function, and producing a new population[28]. A genetic search starts with a randomly generated initial population within which each individual is evaluated by means of a fitness function. Individual in this and subsequent generations are duplicated or eliminated according to their fitness values. Further generations are created by applying GA operators. This eventually leads to a generation of high performing individuals[11,12,24].

The followings have to be considered for solving the Capacitor replacement through genetic algorithm: i. Creating the initial population, ii. Evaluating the superior amounts for each chromosome and evaluating the purpose function, iii. Doing the load flow based on the initial population of Capacitors for each chromosome, iv. Calculating the lines wastages, v. Calculating fitting of each chromosome, vi. Determining the superior amounts of each population for homogenizes, vii.

Accomplishment of homogenises through combination and genetic mutation operators, viii. Repeating second and third stages to reach the determined homogenises or fitting function, ix. Determining the capacity of capacitor for each candidate chromosome to achieve the best produced chromosome

Methodology

Analytical methods: Analytical methods are from the most primary methods used in capacitor placement, and in general speaking in these methods, firstly a linear objective function is defined and then the optimal point is calculated with derivation. Analytical methods are used more while the logic units and computers with high speed were not accessible. One of the simple rules for capacitor placement obtained from Analytical methods is law of 2/3. In this method, a feeder without lateral plugs and even charge with equal voltage in all points of it, could be considered. With the purpose of minimizing the wastes and placements, the exact value for capacitor at the time while some exact points in feeder are considered could be determined (figure-2).

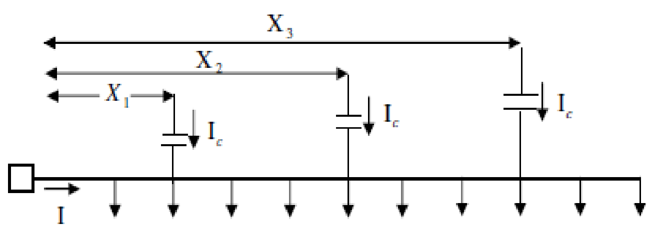

Figure-2
Placement of specific numbers of capacitor in feeder with even charge

$$C = \frac{I_1}{I_C} = \frac{2}{2n+1} \qquad X_I = 1 - \frac{(2i-1).C}{2}$$

Where n is the number of capacitors and X_i is the place for i^{th} capacitor capacity. Through this, the optimal place for the first capacitor would be in distance of 2/3 feeder length from the start point of feeder and the optimal value for capacitor is 2/3 of the value for reactive power in the feeder. In the method mentioned above, the hypotheses like the even charge in feeder are considered which this way does not go true in distribution network. Also, the calculations mentioned above are considered with the purpose of reducing the wastes in the charge which this is far from reality and it could say that charge is varied in various periods. capacitor placement has been done by analytical methods. In this paper, a method to estimate the section of feeder in case of feeder with various conductive has been represented, and further to estimate wastes for all the surfaces of charge, the coefficient for the feeder's charge has been represented to calculate the wastes. with regard to objective function as reducing the wastes, two matters including capacitor placement and placement of voltage adjusters have been considered. In these papers, an adjusted network has been considered and the performance of the capacitors in case of connecting or disconnecting to the network has been considered, also the wastes function only with regard to the reactive current has been calculated.

The methods based on the numerical planning: With the emergence of advancement in technology and by the accessibility of strong and useful resources, analytical methods were used instead of numerical methods by which access to maximum or minimum objective function would be gained. By applying these methods, a concept for the consumption functions would be provided and this is in a way that real points of the distribution network would be shown and the necessary conditions in this matter would be stated in more comprehensive way. The methods based on numerical planning include linear planning, numerical planning, and dynamic planning which a discussion about these plans has been represented in following.

Linear planning: Linear planning is one the mathematical methods using to minimize or maximize an objective function regarding limitations and circumstances. The main difference between linear planning and other mathematical methods is that all the goals and conditions of matter are stated linearly. Generally speaking, the main structure of a linear planning could be shown by the equation brought about in following.

$$f(x_1, x_2, x_3) = c_1x_1 + c_2x_2 + .. + c_nx_n$$
$$a_{11}x_1 + a_{12}x_2 + ... + a_{1n}x_{1n} \geq b_1$$
$$a_{21}x_1 + a_{22}x_2 + ... + a_{2n}x_{2n} \geq b_2$$
$$\vdots$$
$$a_{m1}x_1 + a_{m2}x_2 + ... + a_{mn}x_{mn} \geq b_n$$

As shown, all the relations mentioned above are such linear relation which in this relation, the method for resolving the placement and measurement of capacitor is the very linear planning. In this paper, the matter is stated linearly using approximation of wastes in a distribution network, and with linear planning the optimal place and value for capacitor is determined. Surely, a comprehensive outlook to the conditions in distribution network has not reported and only methods for optimization are considered. It has to be noticed that linear changes of variables is those hypotheses showing measurement and placement of capacitor.

Innovative methods for optimal capacitor placement: Generally, there are complexities in numerical methods and in some cases; there is no rule about this matter using numerical methods. In these cases, Innovative methods are used to get to a reasonable answer about optimal place and value for capacitors in distribution network. These methods are based on empirical rules by which fewer spaces for optimization methods are considered. It has to be paid attention on a point that applying this method would not come useful for reaching to an optimal point comparing to numerical methods. Innovative method has been used to resolve the matters for capacitor placement. In this paper, at first a feeder with maximum waste power was used and then among all the nodes which their charge was used from the feeder, the node which its charge had the most impact on feeder wastes was used as the best point for capacitor placement. Algorithms are represented for most of capacitor placement methods using empirical methods. an innovative algorithm has been used to observe the matter of capacitor placement in case of any change in charges. In this way, different charge levels in various periods like different seasons, the days in a week and holidays have been categorized and based on the samplings for the charge in any point, a coefficient has been defined which based on this coefficient, the recued value of energy in different terms of year would be specified. In 13, firstly the sensitive nodes in the network were obtained with the empirical method and then the optimal value for capacitors with the purpose of minimizing the wastes analytically was gained. an innovative method to determine value and place for capacitor has been used. The main issued discussed in this paper is about representing a device to measure power and represent a method to estimate the common power.

Using Heuristic methods in representing solution for the matters of capacitor placement: Heuristic method is an innovative method to determine optimal position of capacitors. By this method, an optimal response with testing various combinations of capacitor capacities in chosen nodes in length of feeder is obtained. To reduce the response time, chosen points were ordered based on Heuristic factor which the highest node in the capacitor is considered the best for optimization. In a node by which capacitor placement causes the highest saving, a fixed capacitor is placed there. At the time while there is maximum number of capacitors in a network or at the time while improvement is not seen in objective function, in this case optimization process would be ended. In case of resulting various charge levels, fixed capacitors would be gained with various capacities and for this, the capacitors with plug could be used. Objective Optimization function with the purpose of maximizing reduction of energy wastes and increasing the investment cost in capacitor placement:, is brought about as following:

$$J = K_P \Delta P_L + K_E \Delta E_L + K_R \Delta S - C_Q$$

Where K_p, K_E, K_R are constants transforming the saving of power wastes, energy wastes and capacity free to monetary unit. ΔP_l, ΔE_l, ΔS are saving of power wastes, energy wastes and capacity of free energy. C_Q is the cost of capacitor which it is relied on its size and it includes the cost for buying and placing the capacitors. To reduce the calculation time, all the cases testing for placing capacitors have to reduced. In this method, nodes with the most impact on reducing maximum power and energy wastes are obtained using Heuristic methods. Heuristic coefficient is calculated as following:

$$\frac{\partial P_L}{\partial Q_K} = 2\sum_m (\alpha_{km} Q_m - \beta_{km} P_m)$$

Where β_{KM} and α_{KM} are the coefficients' for reactive and active charge. P_l is the wastes of active power, Q_k is the injective reactive power connected to node K and M is the number of node. In case of any change in a node, the Heuristic coefficients are calculated in that node and nodes would be ordered. The highest node would be the best choice for placing the next capacitor. After sequential repetitions and ordering the nodes, placing the next capacitors would be mentioned essential. Determination of highest preference of nodes for placing capacitors would become new priorities for replacing previous preferences. This process is logical up to the time while the cost of installing and purchasing the capacitor do not be in the next node for placement. With capacitor placement in the nodes above the chosen nodes, logic test for each of them would be started. In any repetition, total saving in a year would be calculated and it has to be compared with the previous responses, and in case of higher values comparing to previous value, the new response for save would be reported. Then, capacitor is transferred to next node in the preference list and this process would be repeated. In the end of this repetition, capacitor would be placed in a node by which capacitor placement causes the highest saving. For the next repetition, Heuristic coefficients would be calculated and the nodes would be ordered through the methods mentioned above. Nodes chosen in previous repetitions for capacitor placement are placed above chosen points. After each time which determination of capacitor placement assigned, in this case the calculations for distribution of charges would be prepared and the obtained voltage would be compared with high admissible limits and low voltage. Also, calculation for power wastes, energy and the value for free energy would be presented. Using these methods are useful for reducing the number of probable cases to place the capacitor to find optimal response.

Results and Discussion

Simulation of IEEE 34 grid: IEEE 34 is the first studied sample of network; figure one shows the structure of this network. The load axis of shines has been divided into three time periods, which the load amount could be determined based on the load coefficient and shine load. In table one, cost of capacitor, energy wastages and peak have been inserted. The sensitive shines of network have been presented within the analysis, in which these shines's Capacitor amounts were specified post presenting genetic algorithm, the results of sensitive analysis and genetic algorithm have been presented in figure two. Post Capacitor placement, the network's wastages amount have been calculated within accomplishing the analysis of load flow and calculating the lines wastages[4].

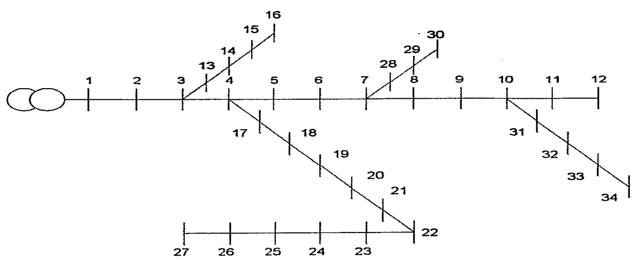

Figure-3
The structure of IEEE 34 grid

Table-1
The cost of Capacitor, energy wastages and peak

Capacitor 's annual cost ($/kVar)	5.5
The cost of active power production at peak ($/kW)	120
Energy cost ($/kWh)	0.07

Performing the program with the first load level: Post performing the program and choosing 18, 9, 17, 20 and 25 shines, which these shines introduced as the most sensitive shines of network , then the amount of Capacitors was obtained respectively as 3.026, 2.35, 0.78, 1.52 and 0.83. Here the reduction of energy westages is the main point. Also the amount of less than this price, 51929 $, would make 211870 $ interest for the company. The other main point is the improvement of shines within high voltages in the first load level, that it has been obtained post capacitor placement. The improvement of voltage has been shown pre and post capacitor placement in figure 2, in which red points show the voltage level pre capacitor placement of each shine, and blue points shows the voltage level post Capacitor placement of each shine. Surely, it is observed that some of the shines have not be inserted in 5he voltage level, which this could be due to various reasons such as the irrelevancy of network.

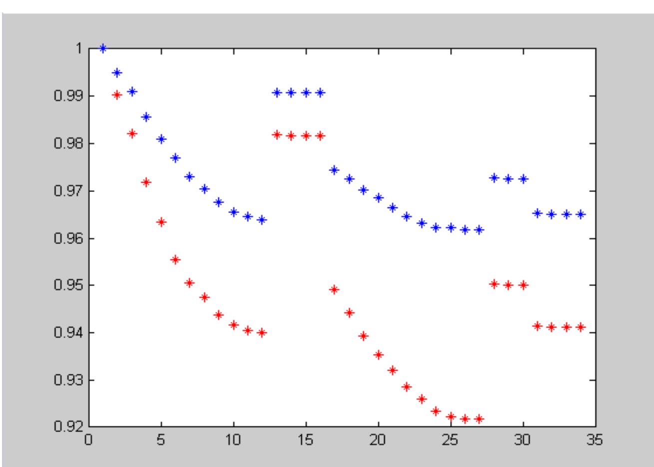

Figure-4
Voltage criterions in the first load level pre and post Capacitor placement

Performing the program with the second load level: In this case, Post performing the program and choosing 18, 9, 25, 20 and 19 shines, which these shines introduced as the most sensitive shines of network, then post performing the genetic algorithm, the amount of capacitors was obtained respectively as 0.375, 0.091, 0.166, 0.379 and 0.061. Through performing the analysis of load flow, and calculating the network wastages and shines's voltage, the annual interest was obtained 4190 $. The improvement of voltage in the second load level is definite pre the capacitor placement, which this has been shown in figure 3. due to the different pattern of obtained interest consumption in this level , the load has been reduced comparing to the first load level.

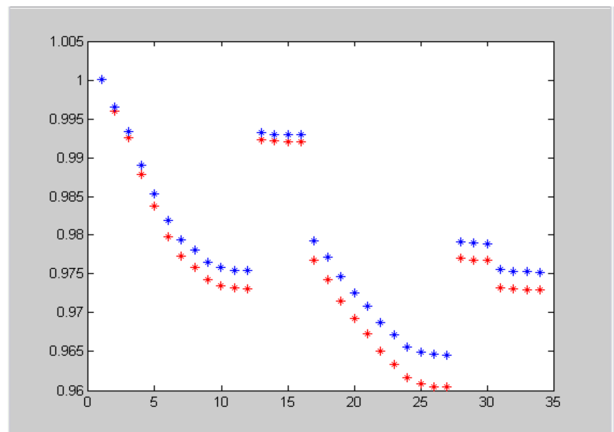

Figure-5
The voltage criterions in the second load level pre Capacitor placement

Performing the program with the third load level: In this case, Post performing the program and choosing 25, 9, 19, 20 and 10 shines, which these shines introduced as the most sensitive shines of network, then post performing the genetic algorithm, the amount of capacitors was obtained respectively as 0.312, 0.061, 0.24, 0.045 and 0.071; in which pre and post capacitor placement, voltage amounts did not make any difference in the third load level comparing to second load level. The results of three load levels have been shown in the table 2.

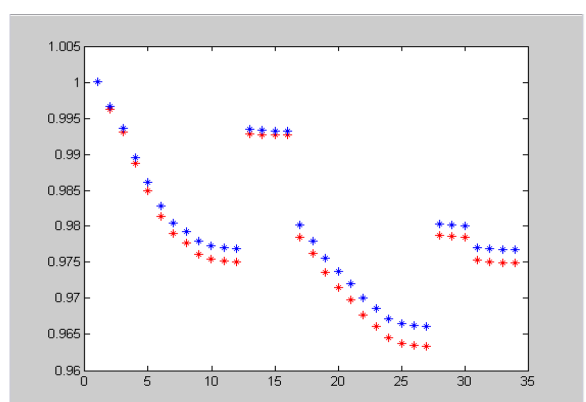

Figure-6
Voltage amounts in the third load level pre Capacitor placement

Table-2
The results of three load levels within the genetic algorithm

	First load level	Second load level	Third load level
Candidate points and Capacitor criterions (mvar)	25-3.026 20-2.356 17-0.758 9-1.525 18-0.839	25-0.375 18-0.091 9-0.166 19-0.379 20-0.061	25-0.312 19-0.061 9-0.24 20-0.071 10-0.045
The summation of Capacitor placement (mvar)	8.532	1.074	0.731
Energy wastages pre Capacitor placement (Mwh)	423	900	770
The cost of energy wastages pre Capacitor placement($/Mwh)	451340	217230	208180
energy wastages post Capacitor placement (Mwh)	474	683	612
The cost of energy wastages post Capacitor placement($/Mwh)	187550	202130	19719
The cost of Capacitor placement($/Mvar/year)	51929	10910	9025
The resulted interest ($/ year)	211870	4190	1964
Candidate points and Capacitor criterions (mvar)	25-3.026 20-2.356 17-0.758 9-1.525 18-0.839	25-0.375 18-0.091 9-0.166 19-0.379 20-0.061	25-0.312 19-0.061 9-0.24 20-0.071 10-0.045
The summation of Capacitor placement (mvar)	8.532	1.074	0.731
Energy wastages pre Capacitor placement (Mwh)	423	900	770
Energy wastages pre	451340	217230	208180

Conclusion

This study conclusion is following: Through comparing the obtained results within two algorithms for the IEEE 34 test network, it could be specified that optimization within the genetic algorithm is more accurate and thrifty, and it would be accomplished in a minimum time. Also we have used the answers of the genetic algorithm as the initial presupposes for the algorithm of metals for getting cold sooner, so we have to know the answer from the first for the algorithm of metals while getting cold sooner.

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