International Journal of Engineering and Advanced Technology Studies
Vol.3, No.3, pp.23-31, October 2015
Published by European Centre for Research Training and Development UK (www.eajournals.org)

Practical Capacitor Bank Location Optimization Based On Genetic Algorithm

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ABSTRACT: *One of the most common and efficiency in distribution network for power factor improvement and voltage regulation control is shunt capacitor bank. The most important parameter in power factor improvement and voltage regulation process is the location and value of the capacitor bank. Many issues should be considering in Capacitor bank location select. In this paper use simulation of IEEE 14 bus on Matlab Simulink an use genetic algorithm to select capacitor bank location and values base on fitness function included Cost and P.F values. Result shows construability of genetic algorithm in cost and PF values depend on client demand by Capacitor bank location optimization location and value.*

KEYWORDS: IEEE14 Bus, Matlab Simulink, Genetic Algorithm. Per Unit System, Power Factor and Fitness Function.

INTRODUCTION

One of the most common and efficiency in distribution network for power factor improvement and voltage regulation control is shunt capacitor bank. The most important parameter in power factor improvement and voltage regulation process is the location and value of the capacitor bank. Also, as Capacitor location problem is a highly nonlinear problem, a lot artificial techniques has been use such (using combined fuzzy-HPSO method [1], Reinforcement Learning Optimization Method for Capacitor Allocation Considering Variable Load [2], Optimal Capacitor Placement for Loss Reduction in Distribution Systems Using Bat Algorithm [3], and Combination of Fuzzy and Second Order PSO based Capacitor Placement in Radial Distribution Feeder [4]).

The difficult issue in capacitor bank placement optimization is:

1. Complex of the network and un precision of network parameters
2. Capacitor bank affects in harmonic amplification
3. Capacitors bank installation , operation and loses cost
4. Capacitor bank over voltage impacts
5. Capacitor bank discharging problems

One of the important issues in placement of capacitors is considering the load variations of the network. In some methods [5], [6], [7], [8]-[10], and [11]-[12], load variation has been considered at several different levels, and in some other methods [13]-[19], it has not been considered at all, and the load has been presented in a fixed form. Moreover, Capacitor placement is also advised to be done with the daily real value in the market, so that the

ISSN 2053-5783(Print), ISSN 2053-5791(online)

distribution companies may be assured of its productivity. This has been taken into consideration but only in references [6], [13], and [9]. In the previous works presented by researchers, capacitor placement has been done on the basis of different techniques including: integer programming method [5], mixed linear integer programming method [12], nonlinear programming method [13], method of sensitivity analysis [9], [16], and [11], method of optimization of the Equal Area Criterion for selecting the sites of fixed capacitors [17], dynamic programming method [18], and some methods based on the experimental criteria. In these methods in order to solve the capacitor placement problem, some assumptions have been considered on the type of the objective function and also on the type and number of problem restrictions. There is also the difficulty of trapping the answer of the problem in a local optimal solution. Moreover, since the capacitor banks contain discontinuous values, solving the problem in continuous domain and then approximating the results leads to a large error in optimal solution. With due regard to the above problems, the genetic algorithm is a very useful tool in solving the optimization problems [15]-[20].

In this research, the objective is to find the optimal location and values of the fixed and switched capacitors in distribution networks by using Genetic Algorithm. The important characteristics of this new method are:

1. Calculation for one year period.
2. Network modelling for per unit system to be applicable for any volte level.
3. Using fitness equation including all cost items further than power factors values (actual price in market, Maintenance rate, loss rate, electrical cost and life time included).
4. Distribution capacitive bulk on load bus.

Genetic Algorithms

Genetic algorithms (GAs) are search algorithms that reflect in a primitive way some of the processes of natural evolution. As such, they are analogous to artificial neural Networks' status as primitive approximations to biological neural processing. GAs often provides very effective search mechanisms that can be used in optimization or classification applications. Evolutionary computation (EC) paradigms work with a population of points, rather than a single point; each "point" is actually a vector in hyperspace representing one potential, or candidate, solution to the optimization problem. A population is thus just an ensemble, or set, of hyperspace vectors. Each vector is called an individual in the population; sometimes an individual in GA is referred to as a chromosome, because of the analogy to genetic evolution of organisms. Because real numbers are often encoded in GAs using binary numbers, the dimensionality of the problem vector might be different from the dimensionality of the bit string chromosome. The number of elements in each vector (individual) equals the number of real parameters in the optimization problem. A vector element generally corresponds to one parameter, or dimension, of the numeric vector. Each element can be encoded in any number of bits, depending on the representation of each parameter. The total number of bits defines the dimension of hyperspace being searched. If a GA is being used to find "optimum" weights for a neural network, for example, the number of vector elements equals the number of weights in the network. If there are w weights, and it is desired to calculate each weight to a precision of b bits, then each individual will consist of b * w bits, and the dimension of binary hyperspace being searched is

International Journal of Engineering and Advanced Technology Studies
Vol.3, No.3, pp.23-31, October 2015
Published by European Centre for Research Training and Development UK (www.eajournals.org)

2wb. The series of operations carried out when implementing a "plain vanilla" GA paradigm is:

1. Initialize the population,
2. Calculate fitness for each individual in the population,
3. Reproduce selected individuals to form a new population,
4. Perform crossover and mutation on the population, and
5. Loop to step 2 until some condition is met.

In some GA implementations, operations other than crossover and mutation are carried out in step four.

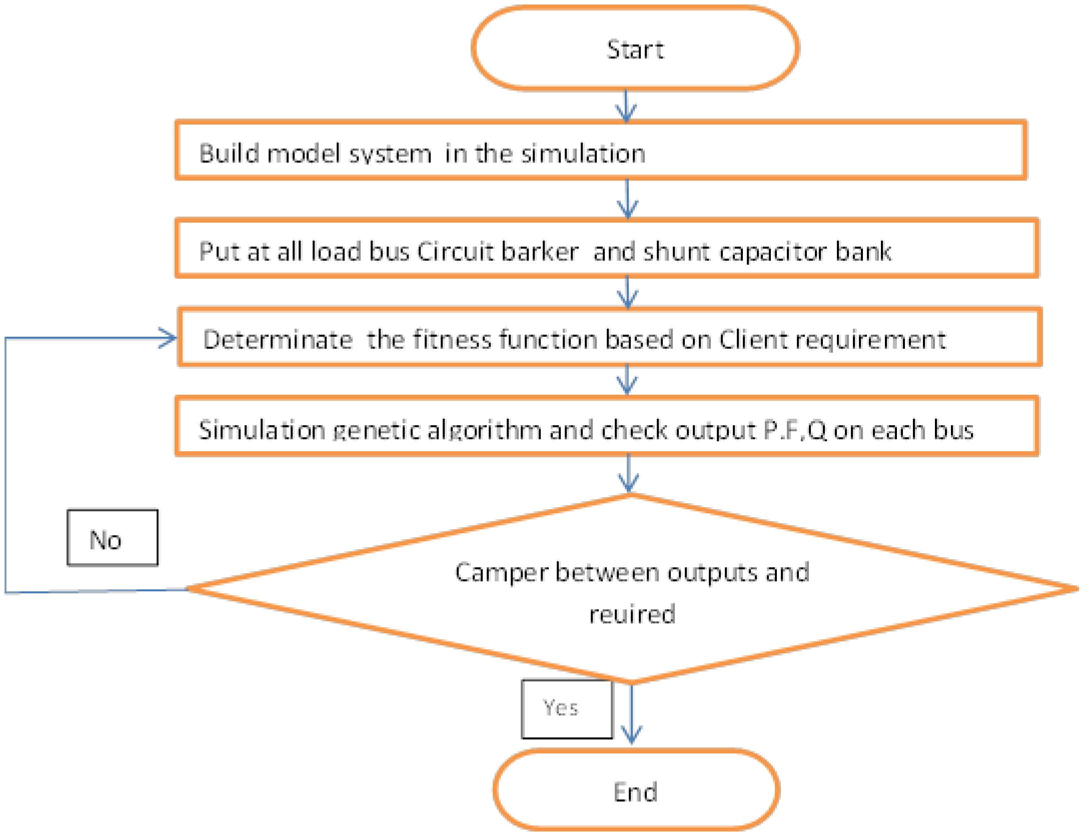


Figure (1): Block Diagram of Design Procedure.

Model system

Figure (1) shows Block Diagram of Design Procedure with main concept based on Put at all load bus Circuit barker and shunt capacitor bank and genetic algorithm will suggest the optimal value of each capacitor bank value. Mile stone points in genetic algorithm techniques are cross over probability factor, mutation probability factor and fitness functions. Normal selection of

ISSN 2053-5783(Print), ISSN 2053-5791(online)

cross over probability factor, mutation probability factor value depend on each problem but there are some preferable range for cross over probability factor between 0.4 to 0.8 and mutation probability factor preferable to be small value between 0.01 to 0.1 to achieve global optimization solution and avoid stop in local optimization solution .

The most important point is fitness function which explains all concern points in our problem should be taken care as shown below.

Fitness function

$$\sum_{i=1}^{n} x(i)[C(i) + maintenance\ rate(i) * life\ time + losses\ cost * life\ time * 8760] - k * sum\ PF$$

Where

X: 0 or 1 Represents C.B status which means capacitive or inductive bulk connects or disconnect, K= adaptive after factor to make PF value affective in the cost value.

Assume data

Cost of MVAR and installation (Medium / H.V) =165000 L.E, Life time= 15 year.

Operation cost percentage /year from total cost=0.001%, KWH cost =0.2 L.E.

Total hours per year = 8760, Base power =100MVA, K=-100*165000.

Concept of this program to minimize fitness function (which mainly depends on cost) based on genic algorithm. Input data can modification depend on user requirement and importance factor as, example K factor many be increased or decreased based on min requires power factor accepted. Also, controls which bus purity connection to capacitor bank based on factor comparison optimization C.B status value from genetic by any value required from 0 to 1 as example if we don't have special required for bus _4 we can but comparison factor 50%, but if it is required to connected we can reduce comparison factor to (.1,.2 and .3) and versa vice as shown in below code.

Equal change to connect capacitor bank code:

```
if kb10(i)>= 0.5

   set_param( 'Fourteen_bus/Brk4','InitialState','close')

   CB4=1;

   else

   set_param( 'Fourteen_bus/Brk4','InitialState','open')

   CB4=0;
```


ISSN 2053-5783(Print), ISSN 2053-5791(online)

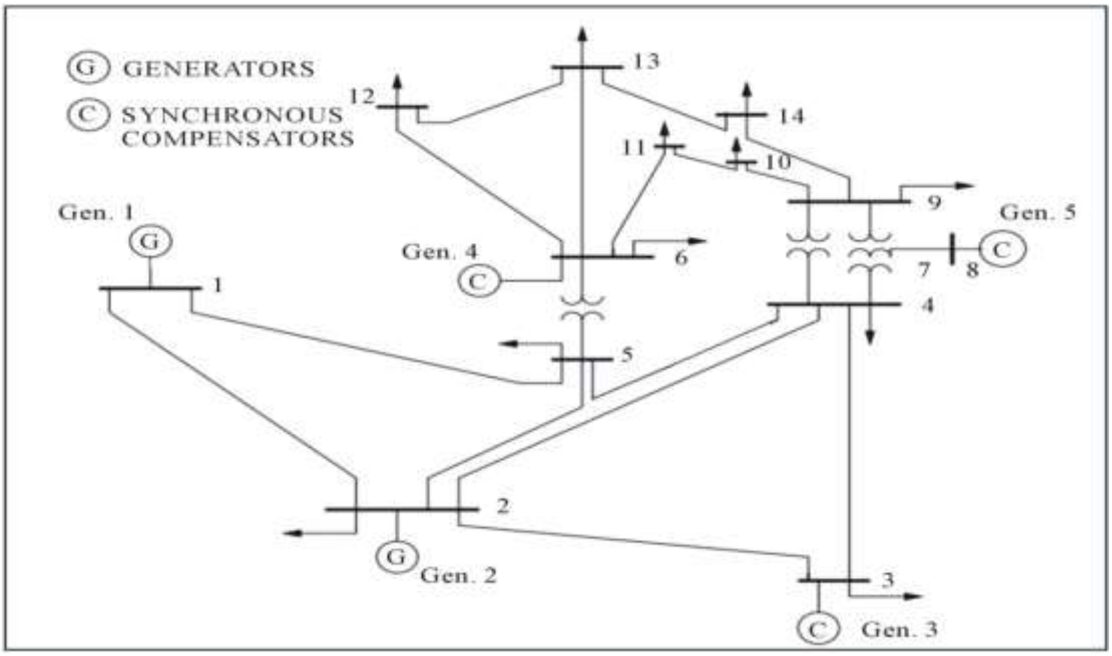
Higher probability to connect capacitor bank code:

```
if kb10(i)>= 0.2
   set_param( 'Fourteen_bus/Brk4','InitialState','close')
   CB4=1;
   else
   set_param( 'Fourteen_bus/Brk4','InitialState','open')
   CB4=0;
```

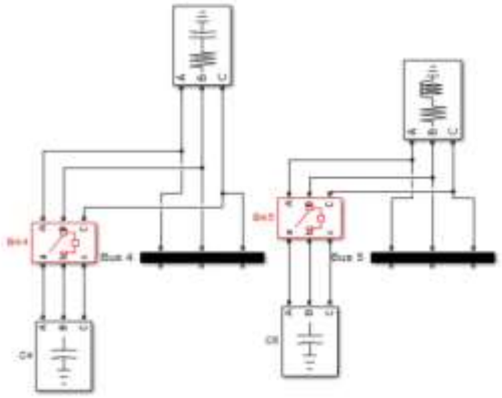
Lower probability to connect capacitor bank code:

```
if kb10(i)>= 0.7
   set_param( 'Fourteen_bus/Brk4','InitialState','close')
   CB4=1;
   else
   set_param( 'Fourteen_bus/Brk4','InitialState','open')
   CB4=0;
```

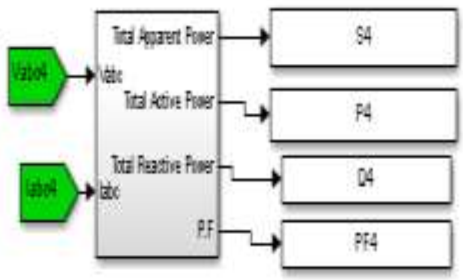
RESULTS



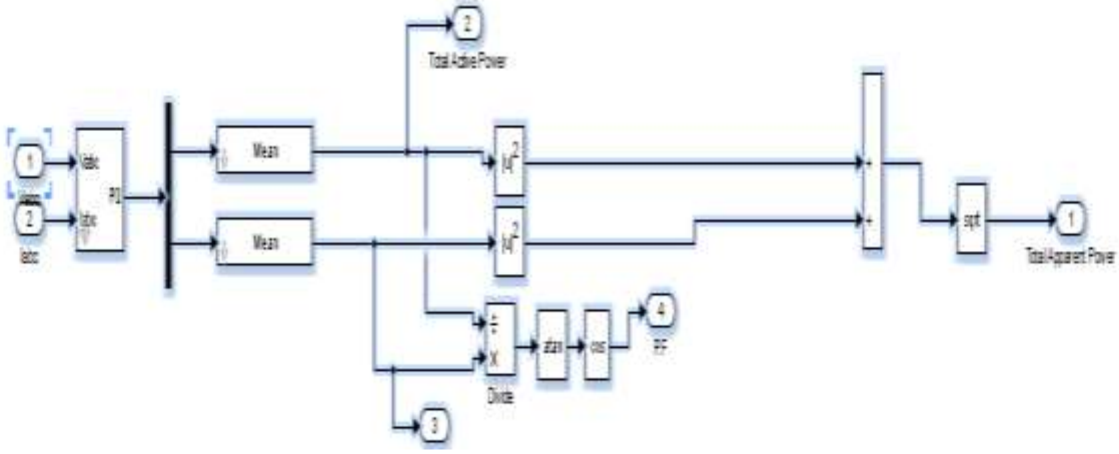
(a)



(b)



(c)



(d)

Figure (2.a, b, c and d) IEEE 14 Bus model.

Figure 2.a shows all system which includes all generation bus and load bus, figure 2.b shows to load bus and how to connect capacitor bank through C.B which operated depended on genetic algorithm results, figure 2.c shows measured block diagram input /output and Figure 2.d shows power factor and apparent power block diagram details.

ISSN 2053-5783(Print), ISSN 2053-5791(online)

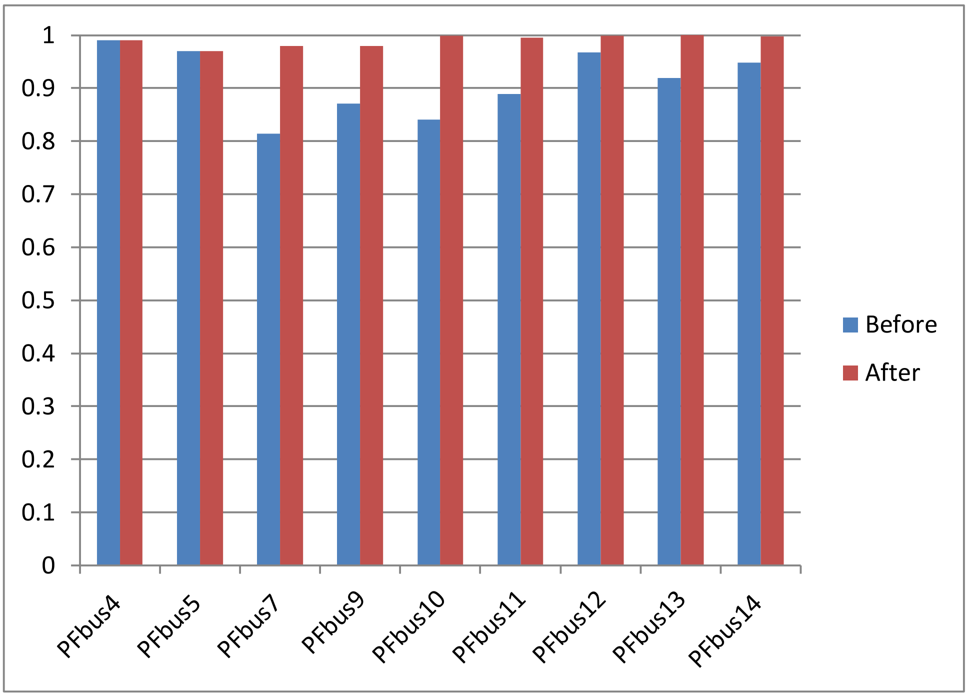


Figure (3): P.F values comparison.

Table (1) Power factor before and after capacitor bank placement

	Before	After
PFbus4	0.99	0.99
PFbus5	0.97	0.97
PFbus7	0.8145	0.98
PFbus9	0.8715	0.98
PFbus10	0.8406	0.9994
PFbus11	0.8893	0.9952
PFbus12	0.9673	0.9991
PFbus13	0.9188	0.9997
PFbus14	0.9480	0.9972

In the figure (3) shows that genetic algorithm has achieved great improvement in power factor values with suitable cost, also in Table (1) shows comparison PF before and after capacitor bank placement load bus (Bus4, Bus5, Bus7, Bus9, Bus10, Bus11, Bus12, Bus13 and Bus14).

CONCLUSION

An approach incorporating the use of genetic algorithm has been presented in this paper to determinate optimization location and values of Capacitor bank based on optimization function which include power factor required, installation, operation maintenance and losses cost. As per above cost data the total cost in case of use genetic algorithm about 12.24Million L.E comparison with total cost 19.664 Million L.E in case of connect capacitor bank bulk for

ISSN 2053-5783(Print), ISSN 2053-5791(online)

each bus depend on its power factor as normal. Results shown improvement in all power for each and every bus with reduction on total cost about 37.6% . In next researchers may be use Simulation for all load levels condition like, Network modelling for both balanced and unbalanced load cases, Utilization of fixed and switched capacitors available in the market, Utilization of the load model of the network at different load levels and Using of standard values of capacitors in the market.

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ISSN 2053-5783(Print), ISSN 2053-5791(online)