

A Review on Power Factor Correction for Distribution Systems

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Abstract: This paper centers for ideal designations and measuring of capacitors in different distribution systems. First the most hopeful buses for introducing capacitors are recommended utilizing Loss Sensitivity Factors (LSF). At that point the proposed FPA is utilized to find the areas of capacitors and their estimating from the chose value of capacitor. The proposed calculation is tried on spiral distribution systems. The got comes about through the proposed calculation are contrasted with others with feature the advantages of the proposed calculation in decreasing aggregate cost and expanding the net utilization.

Keywords—reactive power, active power, PFC loads, buses, power loss etc.,

INTRODUCTION:I

A).OPTIMAL SIZING AND PLACEMENT OF CAPACITORS

In distribution systems, reactive power streams cause high power losses, high voltage drop and low power factor. These impact filter be reduced optimally introducing of shunt capacitors. Compensation of reactive power presents the basic role in power system planning to provide compatible locations of the compensation apparatus to guarantee the minimum cost of compensation with suitable voltage profiles. Numerous strategies and streamlining calculations have been tended to in writing to manage the issue of areas and measuring of capacitors in distribution systems. Genetic Algorithm(GA), Particle Swarm Optimization (PSO).

B). FLOWER POLLINATION ALGORITHM (FPA)

Flower Pollination Algorithm (FPA) is proposed for ideal allocations and sizing of capacitors in different distribution systems. First the most hopeful buses for introducing capacitors are proposed utilizing Loss Sensitivity Factors (LSF). At that point the proposed FPA is utilized to conclude the areas of capacitors and their estimating from the chose buses. The proposed calculation is tried on 10, 33 and 69 buses outspread distribution systems. The got comes about by means of the proposed calculation are contrasted with others with feature the advantages of the proposed calculation in sizing aggregate cost and augmenting the net saving. In addition, the outcomes are acquainted with check the viability of the proposed calculation to improve the voltage profiles for different distribution systems.

C). LOSS SENSITIVITY FACTORS

Loss Sensitivity Factors (LSF) are utilized in this paper to appoint the hopeful buses for capacitors installation [4]. The zone of pursuit is extraordinarily lessened and subsequently the time devoured in enhancement process by utilizing LSF.

For a transmission line 'l' connected between 'i' and 'k' buses, as given in fig.1. These values are given from the base case load flow and are ordered in descending order for all transmission lines. At that point, standardized voltages are acquired by isolating the base case voltages by 0.95. On the off chance that the estimations of these voltages are under 1.01 they can be considered as applicant buses for compensation devices[5].

$$P_{ik-loss} = \frac{(P_k^2 + Q_k^2) R_{ik}}{(V_k)^2}$$

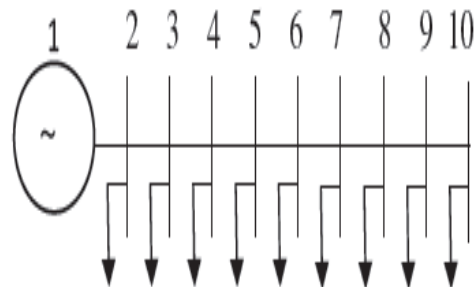


Fig. 1 The schematic diagram of the 10 bus system

D).STEPS FOR FLOWER POLLINATION ALGORITHM (FPA)

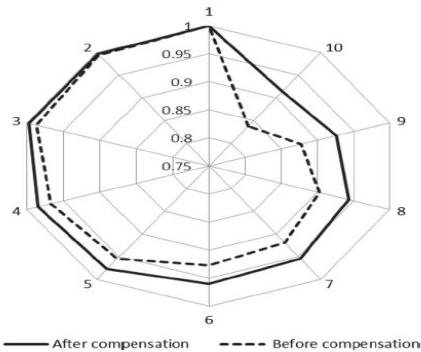
STEP 1: Global pollination represented in biotic and crosspollination processes, as pollen-carrying pollinators fly following Lévy flight [6].

STEP 2: Local pollination represented in abiotic and self pollination as the process does not require any pollinators.

Step 3: Flower constancy which can be created by insects, which is on a standard with a proliferation likelihood that is relative to the likeness of two flowers included.

Step 4: The cooperation of neighborhood and worldwide pollination is controlled by a switch likelihood delicately one-sided toward nearby pollination.

E). RESULTS



F). SUMMARY

FPA has been effectively actualized with LSF for ideal location and sizing of shunted capacitors in different distribution systems. The composed issue has been planned as a streamlining errand with computing cost of power losses, installation and vars. The effectiveness of the suggested approach is clarified by using different test systems. The results have been compared with those obtained using other algorithms. It is obvious from the comparison that the proposed approach provides a notable performance in terms of total cost and net saving.

INTRODUCTION:II

A).OPTIMAL PLANNING OF SHUNT CAPACITORS

In this chapter while going through distribution networks are the vital part which directly connects the generated power to reach the corners of the utility consumers. Because of higher network loss and voltage drop along the extensive feeder lines and its lateral feeders prompts poor voltage regulation at the last end consumers. There is a need to keep up the improved power delivery network to give better quality of power to the consumers, situation of compensating equipment like shunt capacitors is of central significance. Critical misfortune minimization is acknowledged with the position of shunt capacitor at adept areas with appropriate sizes in closeness to the consumer loads. Heuristic algorithms methods are productive for taking care of ideal shunt capacitor position issue in light of its exploration.

B). HYBRID EVOLUTIONARY APPROACH FOR OPTIMAL PLANNING OF SHUNT CAPACITORS

The objective is confined to limit power loss and to maximize voltage stability. To search for the ideal location of shunt capacitors, the combinatorial utilization of loss sensitivity factor and hybrid HSA-PABC algorithm is used. In this paper, distinctive types of voltage subordinate load models are contemplated to research their effect on the active power loss and voltage stability of the RDN. Simulation results shows that the voltage dependent load models lead to completely different solutions in terms of power loss reduction, voltage stability improvement.

C). HARMONY SEARCH ALGORITHM

The main advantages of HS algorithm are (a) it can have the capability to handle discrete as well as continuous decision variables (b) it does not require initial value setting for the decision variables. In this work, the discretisation step has been incorporated to the primary program to handle the restriction of the capacitor placement problem (capacitor location and discrete size of shunt capacitors). Harmony Memory Consideration Rate (HMCR), Pitch Adjustment Rate (PAR) and bandwidth (BW) are the tuning parameters in HSA to choose the execution of the algorithm. The computational techniques of HSA to refresh the harmony memory vector are (a) irregular initialization of choice factors in the harmony memory vector (HMV) (b) Improvisation of HMV esteems by memory thought (c) pitch alteration system. The above said improvisation creation strategy is dull until the point that the end criteria is arrived, where "BW" speaks to an random distance bandwidth. Along these ways the HMV is improved iteratively. k is the amount between two adjacent values in discrete decision variables (shunt capacitor size and its location). The classical HS algorithm is well suited for discovering a good solution within a reasonable computational time. In any case, it has inept nearby looking capability and it experiences the issue of slow convergence, traps in local ideal answer for numerical streamlining applications [24]. Different changes were received to enlarge the first HS algorithm execution, for example, dynamic variety of its parameters like (HMCR) Harmony Memory Consideration Rate, (PAR) Pitch Adjustment Rate and bandwidth(BW). To help the investigation amid the underlying stage and misuse in the last period of the hunt procedure, the bandwidth is balanced dynamically.

E). LOSS SENSITIVITY FACTOR (LSF)

The Loss sensitivity factor (LSF) reflects the sensitivity of nodes to the change in active power loss with respect to change in reactive power injection when the shunt capacitors are placed in the distribution network

$$P_{line\,loss} = \left(\frac{P_{i+1,eff}^2 + Q_{i+1,eff}^2}{|V_{i+1}|^2} \right) R_{i,i+1}$$

2.4 STEPS OF THE PROPOSED HYBRID HSA-PABC ALGORITHM

Step 1: Initialize the parameters of hybrid HSA-PABC calculation; HMS, PAR, HMCN, MCN.

Step 2: Initialize the Harmony Memory Vector (HMV) with haphazardly generated populations.

Step 3: Employed bee phase initiation. (I) Generate new populaces in the area of arrangement achieved utilizing

$$V_{jk} = [\omega X_{jk} + C_1 \phi_{jk} (X_k^{best} - X_{jk}) + C_2 \phi_{jk} (X_{nk} - X_{jk})]$$

Eq(1)

Step 4: On looker bee stage commencement: (I) Based on the best wellness likelihood of the utilized bee stage, make new populations. (ii) The new sustenance source area $V_{j,k}$ new in the area of nourishment source $X_{j,k}$ old is figured utilizing

$$V_{j,k}^{new} = \{X_{j,k}^{old} + u(X_{j,k}^{old} - X_{n,k})\}$$

Eq.(2)

Step 7: Retain the best arrangement got so far in HMV.

Step 8: The populaces in the HMV is ad libbed by HMCN, PAR and Random choice procedure of the HS calculation.

Step 9: Check the new improvised vectors in the HMV is superior to existing HMV. Assuming this is the case, renew HMV with new values.

Step 10: Cycle = Cycle + 1.

Step 11: Check if the aggregate number of MCN is come to.

Stage 12: If not, go to step 4 and rehash from step 4 until Cycle = MCN.

F). SINGLE LINE DIAGRAM OF 69 NODE RDN

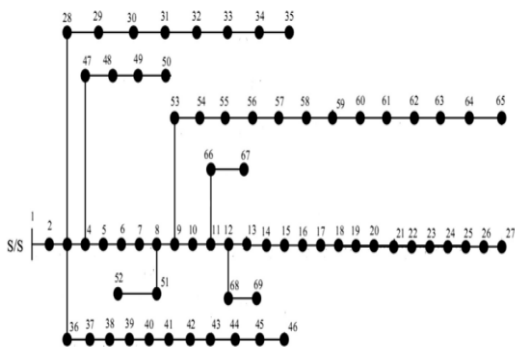


Fig no.2 Single line diagram of 69 Node RDN

G). RESULTS AND DISCUSSION

The ideal allotment and estimating issue of shunt capacitors in RDN with voltage subordinate load models are detailed multi-objective obliged enhancement issue. A hybrid HSA-PABC calculation is proposed for illuminating the ideal allocation and sizing of shunt capacitors. To demonstrate the productivity of the proposed half and half calculation in taking care of capacitor placement problem, it is connected to 69 and 118 node test networks. The quantity of nodes for compensation is chosen in view of the size of the RDN. The

conceivable capacitor banks in discrete sizes to be set in ideal locations in both test systems are from 50 kVAR up to 1500 kVAR in products of 50 kVAR. The node voltage and line loss of RDN are gotten utilizing in reverse/forward range based power flow method (BFS) technique proposed in the proposed mixture calculation and the BFS based power flow method is executed utilizing Matlab7.7.0 platform. To show the relevance of the proposed method, distinctive static load models, for example, CP, CC, CZ, composite load models at ostensible load states of the test systems are contemplated.

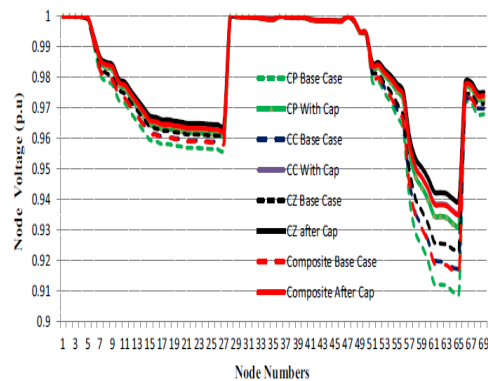


Fig. 3. Voltage profile of 69 node RDN with different load models.

H). 118 BUS SYSTEM

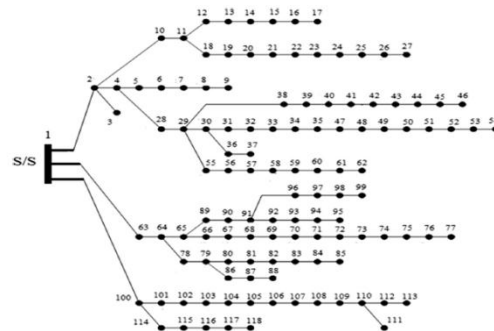


Fig.4. Single line diagram of 118 node RDN (node numbers are reordered).

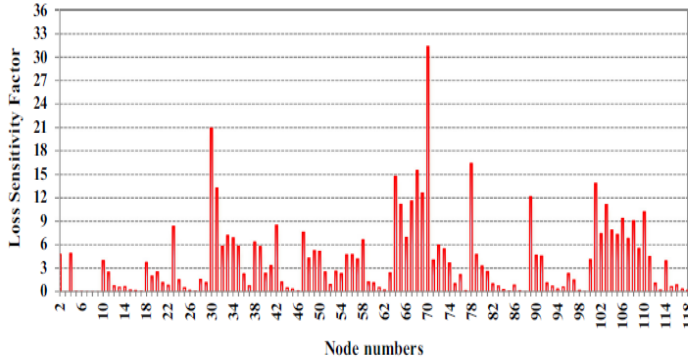


Fig. 5. The values of LSF for 118 node RDN

J). PROBLEM FORMULATION

Single line diagram portrayal of a RDN is delineated in Fig. 1. Real and reactive power flow in the distribution network feeder lines is acquired utilizing rearranged recursive Eqs. (1)–(3) as, The real and reactive power flow at $i + 1$ th branch can be mathematically expressed as,

$$P_{i+1} = \left[P_{i,j+1} - \left(R_{i,j+1} \frac{P_{i,j+1}^2 + Q_{i,j+1}^2}{|V_i|^2} \right) - P_{i+1}^L \right] \quad (1)$$

$$Q_{i+1} = \left[Q_{i,j+1} - \left(X_{i,j+1} \frac{P_{i,j+1}^2 + Q_{i,j+1}^2}{|V_i|^2} \right) - Q_{i+1}^L + \alpha_q Q_{i+1}^C \right] \quad (2)$$

$$|V_{i+1}|^2 = \left[|V_i|^2 + \frac{R_{i,j+1}^2 + X_{i,j+1}^2}{|V_i|^2} (P_{i,j+1}^2 + Q_{i,j+1}^2) - 2(R_{i,j+1}P_{i,j+1} + X_{i,j+1}Q_{i,j+1}) \right] \quad (3)$$

$i = 1, 2, \dots, m$

The current in the branch connecting the i th node and $i + 1$ th node is calculated as in Eq. (4)

$$I_{i,j+1} = \sqrt{\frac{P_{i,j+1}^2 + Q_{i,j+1}^2}{|V_i|^2}}$$

The real power loss allied with the feeder branch in between the i th node and $i + 1$ th node can be calculated as in Eq. (5)

$$P_{\text{loss } i,j+1} = |I_{i,j+1}|^2 R_{i,j+1} \quad (5)$$

J). POWER LOSS REDUCTION INDEX (PLRI)

The active power misfortune minimization is refined through reactive power injection utilizing shunt capacitors dispensed with reasonable size at appropriate places in the RDN. The aggregate system loss (PlossT) before capacitive pay in the system is processed by summation of power loss related with the real and reactive parts of branch currents of the RDN as in Eq. (6).

$$P_{\text{lossT}} = \left[\sum_{i=1}^{nb} P_{\text{loss } i,j+1} \right] = \left[\sum_{i=1}^{nb} |I_{P(i,j+1)}|^2 R_{i,j+1} + |I_{Q(i,j+1)}|^2 R_{i,j+1} \right] \quad (6)$$

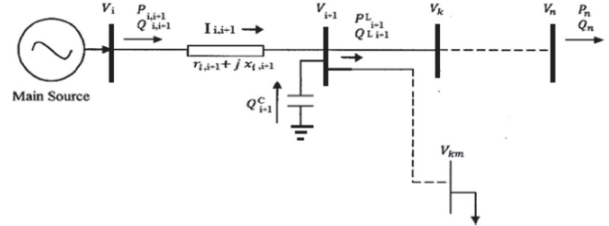


Fig. 6. Single line representation of radial feeder

K). SUMMARY

The multiple integers of least size of shunt capacitors and the aggregate reactive power injection by the shunt capacitors is considered as one of the limitation. Where Q_{cj} is the reactive power injection by the j^{th} shunt capacitor (kVAR) and K is an integer number and Q_c is the smallest shunt capacitor rating ($Q_c = 50$ kVAR each). For each location, K number of shunt capacitor with each 50 kVAR $\{Q_c, 2Q_c, 3Q_c, \dots, KQ_c\}$ are to be placed. Another hybrid HSA-PABC approach has been connected for solving the ideal allocation and sizing of shunt capacitors in the radial distribution networks with voltage subordinate load models. To demonstrate the capability of the proposed hybrid approach, the recreations are performed on medium and huge scale RDN. The outcomes got with proposed hybrid HSA-PABC are superior to anything other comparative strategies in ideal capacitor arranging issue. Aside from the generally utilized constant power (CP) load model, simulations with voltage subordinate load models, for example, constant impedance (CZ), constant current (CC), and composite loads are performed to examine their effect on real power loss and voltage stability of the RDN.

INTRODUCTION:III

A). PENALTY FREE GENETIC ALGORITHM

Genetic Algorithm with special requirement taking care of technique is proposed for the discrete enhancement issue of capacitor position and sizing in distribution system for cost decrease and power quality improvement. We utilize quality encoding that empowers basic whole number portrayal of conceivable distinctive number of capacitors of different standard sizes to be set on a bus. A couple shrewd correlation in competition choice administrator is utilized so it doesn't require any parameter tuning, accordingly maintaining a strategic distance from the most troublesome part of the choice of fitting penalty parameters. Proposed Penalty Free Genetic Algorithm (PFGA) is tried on 18-bus, 69-bus and 141-bus systems and the acquired results are better than the results from other methods. Recreations with various load models are likewise performed. It is demonstrated that load models where active and reactive loads are voltage reliant, for example, private, commercial and industrial, constant Z and constant I display prompt totally extraordinary arrangements. Along these lines, careful load modeling ought to obtain more realistic picture of the total savings.

Optimal capacitor arrangement has been a test for power system planners and researchers for a long time. The methodology points towards finding at least certain target work by taking care of a combinatorial issue in which the location and sizes of capacitors are to be resolved. There are plenty of published papers where different formulations of the problem along with solution methods have been proposed. By and large, the objective is to discover ideal areas and sizes of shunt capacitors with the end goal that the cost of aggregate genuine power/vitality misfortune and that of shunt capacitors is limited. In the meantime, satisfactory voltage levels must be kept up all through the whole network. As of late, more articulated nearness of harmonic sources in distribution systems complicate the issue much more.

B). PROBLEM FORMULATION

The non-linear integer issue of capacitor situation in distribution system is unraveled with discrete values of capacitor sizes and determination of their locations. The goal work, as in [10], involve yearly system operation costs including costs for capacitor installation, power and energy losses and it is given with where floss energy loss cost; Fcap: cost of capacitors; Fpow: cost comparing to power misfortunes (e.g., utilized limit of the system); Ce electricity cost per kilowatt-hour (\$/kW h); DW yearly electricity losses(kW h); p settled annuity installment rate communicated in relative units; Cf fixed costs for capacitors

installation (\$/location); Cv capacitors costs per unit size (\$/kvar); Qc;k capacitor size at location k (discrete values in kvar), C set of locations where capacitors are installed; Cp saving per kilowatt for reduction in losses which is price for peak power (\$/kW) and DPmax power losses at peak power (kW).

$$\min F = F_{\text{loss}} + F_{\text{cap.}} + F_{\text{pow.}}$$

$$= C_e \Delta W + p \sum_{k \in C} (C_f + C_v Q_{c,k}) + C_p \Delta P^{\text{max}}$$

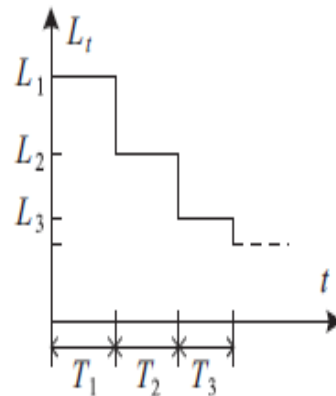


Fig. 3.1. Load duration curve.

where Smax is the peak value of the load. Choosing complex values for Lt, enables for modeling of load power factor as well. If we denote the number of intervals in the LDC as NLDC then for the total energy loss we may write:

$$\Delta W = \sum_{i=1}^{N_{LDC}} \Delta P_i \cdot T_i$$

where DPi is the active power loss in time interval i whose duration is Ti. Note that in this paper all complex variables are underlined, otherwise they are either real variables or magnitudes of corresponding complex variables.

One major concern arising from the use of capacitors in a power system is the possibility of a system resonance, which imposes voltages and currents that are considerably higher than in the case without resonance. The reactance of a capacitor bank decreases with frequency and the capacitor bank therefore acts as a sink for higher harmonic currents. This effect increases the heating and dielectric stresses which yields shortened capacitor life.

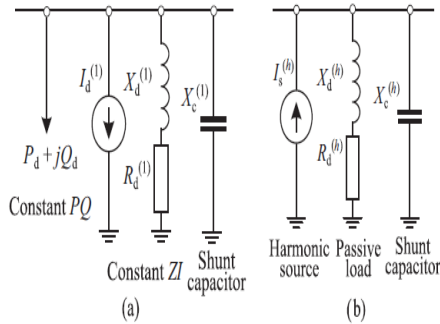


Fig. 3.2. Load representation

C). PENALTY FREE GENETIC ALGORITHM

The optimization tool used in this paper is based on GA which is a search heuristic that mimics the processes of natural selection. The chromosomes are a structure comprised of integer and binary strings with two field names code and state with NB columns as shown in Table 3. The first field is an integer vector containing genes with coded information about the type and size of the capacitors per bus. The second field is a binary matrix with $NLDC - 1$ rows that holds information about the capacitor switching states during all time periods of the LDC assuming that all capacitors are switched on in the first time period when the peak load occurs. During the initialization stage, both chromosome fields are randomly generated. For each bus, in the field code we define an integer gene with a minimum value of 0 and a maximum value of $\delta N_{max} \times 10^3 - N_{types} - 1$, where N_{max} is the maximum number of capacitors per bus and N_{types} is the number of standard capacitor types available for the given case. Therefore, each gene is bounded with the following bounds:

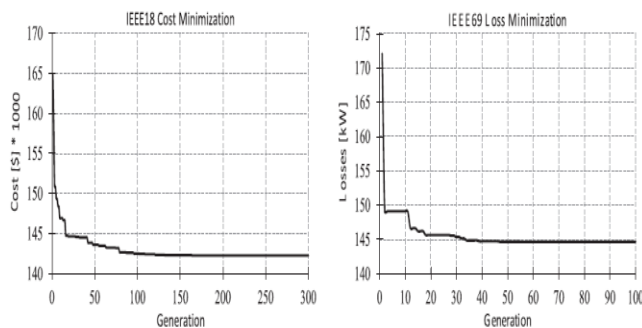


Fig. 3.3. Convergence properties:(a) cost minimization and (b)loss minimization

The reason we change the population/generation number for the latter two systems is because the methods

we're comparing our work to uses the same settings and at the same time to provide for computation time comparison. Convergence properties for loss minimization and cost minimization are presented in Fig. 9. It can be seen that the convergence curves run smoothly towards the optimum.

D). SUMMARY

The paper presents a GA based approach for the discrete optimization problem of fixed shunt capacitor placement and sizing in the presence of voltage and current harmonics. The objective function is a sum of costs for power and energy losses, as well as capacitor costs. We use gene encoding that enables simple integer representation of possible different number of capacitors of various standard sizes to be placed on a bus. Unlike in most traditional GA applications, this method handles constraints without penalty functions. Constraint handling procedure is based on a special selection operator that always leads the optimization process towards the feasible region where no constraint is violated. During the process, there are no penalty parameters to tune. The method has also proven to be very efficient when dealing with large number of constraints. Dealing with large number of constraints and not having to do any penalty parameters tuning and/or taking care of constraints inter relations is a very big advantage and time saver, especially when dealing with optimization problems for which the penalty coefficients/multipliers are not known in advance.

INTRODUCTION:IV

A). DISTRIBUTION SYSTEMS WITH NON-LINEAR LOADS

In this chapter while going in methodologies for capacitor placement in primary distribution circuits is a recurrent topic in the specialized bibliography. Most of the presented formulations consider the minimization of the energy losses and the peak power losses of the circuit as well as the cost of the capacitors. However have been considered some additional objectives like: minimum deviation of voltage. Only few of the methods presented are able to determine the frontier of Pareto of the multi-objective optimization problem, while the rest of the contributions use just a single function objective that includes all the objectives by means of factors of weight. Besides, most of the contributions are applied to circuits balanced with linear load. In the present work develops a method to determine the number, placement, control and size of the fixed and switched capacitor banks in primary distribution circuits contaminated by harmonics. The necessary power quality constraints and of overstress of the capacitors are used. The developed program is based on the multi-objective optimization algorithm NSGA-II

B). OPTIMIZATION ALGORITHM

One of the methods of more success in the multi-objective optimization is the Non-dominated Sorting Genetic Algorithm(NSGA-II). A very simple description of this method is reproduced here:

- (1) A random initial population of size N is generated.
- (2) The population is sorted by a non-dominated sorting procedure.
- (3) The following steps are repeated until a determined number of generations are obtained.

a. The parents for the next generation are selected by a tournament.

b. The descendent are produced by crossover and mutation of parents.

c. The offspring generation of size 2N is formed by the parents and the descendent.

d. A new generation of size N is obtained by sorting and selecting the off spring generation. Like every genetic algorithm, the solving of a particular problem by the NSGA-II implies some adaptations and the programming of certain parts of the algorithm. In this case, a real-coded NSGA II implemented in Matlab has been adapted for the presented problem. A modification of the genetic operators to include the crossover and mutation of integer-type variables was made in order to represent the variables of this problem. The probabilities of crossover and mutation are respectively 0.9 and 1/size of the chromosome, with a distribution index of 20 for both of the genetic operators: simulated binary crossover and polynomial mutation. Representation of the variables (chromosome) Due to that the NSGA-II implementation that is used employs a chromosome coded in real numbers, there is no need to codify the variables. So, the chromosome defined for this problem contains an array of integers capable of representing all the parameters of a maximum number of capacitor banks

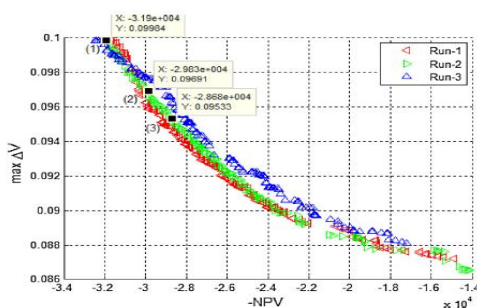


Fig. 10. Frontiers of Pareto

C). SUMMARY

The minimization of three objective functions NPV, maximum voltage deviation and maximum THD of voltage, the presented formulation allows the obtaining of a group of alternative solutions with diverse effect on the power quality indexes of the system. This way, are obtained solutions that not just comply with the recommendations of the standards but that can further improve these power quality indexes.

CONCLUSION:V

ideal location and sizing of shunted capacitors in many distribution systems. The designed problem has been formulated as an optimization task with computing cost of power losses, installation and vars. The effectiveness of the suggested approach is clarified by using different test systems. The results have been compared with those obtained using other algorithms. It is obvious from the comparison that the proposed approach provides a notable performance in terms of total cost and net saving. The multiple integers of minimum size of shunt capacitors and the total reactive power injection by the shunt capacitors is considered as one of the constraint, where Q_{cj} is the reactive power injection by the j th shunt capacitor (kVAR) and K is an integer number and Q_c is the smallest shunt capacitor rating ($Q_c = 50$ kVAR each). For each location, K number of shunt capacitor with each 50 kVAR $\{Q_c, 2Q_c, 3Q_c, \dots, KQ_c\}$ are to be placed. A new hybrid HSA-PABC approach has been applied for solving the optimal allocation and sizing of shunt capacitors in the radial distribution networks with voltage dependent load models are explained.

A).SCOPE FOR THE FUTURE WORK

Power factor correction is used for electrical stabilization in cases of rapid load changes. DPFC is useful when standard power factor correction would cause over or under correction.¹ DPFC uses semiconductors and typically thyristors to switch capacitors or inductors from the network in order to improve power factor.

REFERENCES:

- [1] A.Y. Abdelaziza, E.S. Ali b,†, S.M. AbdElazim “Flower Pollination Algorithm and Loss Sensitivity Factors for optimal sizing and placement of capacitors in radial distribution systems, Elsevier
- [2] Yang HT, Huang YC, Huang CL. Solution to capacitor placement problem in radial distribution system using tabu search method. In: IEEE international conference on energy management and power delivery, vol. 1, 21–23 November 1995. p. 388–93.

- [3] Swarup KS. Genetic algorithm for optimal capacitor allocation in radial distribution systems. In: Proceedings of the 6th WSEAS international conference on evolutionary, Lisbon, Portugal, June 16–18, 2005. p. 152–9.
- [4] Prakash K, Sydulu M. Particle swarm optimization based capacitor placement on radial distribution systems. IEEE power engineering society general meeting, 2007, 24–28 June 2007. p. 1–5.
- [5] SamimiAsl T, Jamali S. Optimal capacitor placement size and location of shunt capacitor for reduction of losses on

distribution feeders. In: International conference on clean electrical power, Capri; 2009. p. 223–6.

- [6] K. Muthukumara, S. Jayalalitha "Multiobjective hybrid evolutionary approach for optimal planning of shunt capacitors in radial distribution systems with load models, Elsevier

- [7] Prakash K, Sydulu M. Particle Swam Optimization based capacitor placement on radial distribution systems. In: Power engineering