Hybrid Algorithm for Capacitor Placement and Sizing in Distorted Distribution Systems

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ABSTRACT

Increasing application of electrical device banks on distribution networks is that the direct impact of development of technology and also the energy disasters that the planet is encountering. To get these goals the resources capability and also the installation place of an important importance. During this paper a brand new technique is planned to seek out the optimum and synchronal place and capability of those resources to scale back losses, improve voltage profile. The advantage of hybrid formula is that it doesn't need external parameters like cross over rate and mutation rate as just in case of genetic formula and differential evolution and it's arduous to work out these parameters in previous. To validate the tactic planned this formula is tested on 14-bus radial distribution system and 39-bus radial distribution system with harmonic current injection.

Keywords------- Distribution systems, Loss Sensitivity Factors, Capacitor placement, Genetic Algorithm, PSO.

I. INTRODUCTION

In distribution systems, shunt capacitors square measure put in to compensate reactive power, scale back active power loss, modify power issue, and improve voltage profile [1]. However, in radial distribution systems, the presence of harmonic distortion have to be compelled to be thought-about for compensating reactive power by adding shunt capacitors. As a result of the installation of shunt capacitors within the distorted distribution systems will cause resonances, increase active power loss, extensive reactive power demand, and overvoltage, if deciding the situation and size of capacitors while not considering the presence of harmonics within the systems [2]. several analysis have taken into consideration the presence of harmonic current and voltage to optimize the position and size of shunt capacitors mistreatment completely different strategies, like Genetic Algorithm(GA) [1], Genetic rule with symbolic logic (GA-FL) [2] and Fuzzy pure mathematics (FST) [3] in an exceedingly balanced three-phase systems. Moreover, in unbalanced three-phase system, Particle Swarm optimization(PSO)[4] and Harmony Search Approach (HSA) [5] are applied to search out the optimum location and size of shunt capacitors within the distorted distribution systems.

Capacitor primarily based power issue correction

As a rural power distribution system load grows, the system power issue typically declines. Load growth and a decrease in power issue result in [3, 5]
1. Voltage regulation problems;
2. Accumulated system losses;
3. Power issue penalties in wholesale power contracts;
4. Reduced system capability.

II. METHODOLOGY

In addition to raising the system Power issue, capacitors additionally offer some fall correction. A capacitor's leading current cause a voltage rise on the system. But care should be exercised as to not cause an excessive amount of voltage rise or offer an excessive amount of leading current. Distribution capacitors may cut back system line losses, as long because the system power issue isn't forced into a number one mode. Properly placed and sized capacitors will typically cut back system line losses, sufficiently to justify the price of their installation [1, II]. Bulk power facilities have to be compelled to use a number of their capability to hold the inductive kVAR current to the distribution system. The resultant reactive current flow produces losses on the majority facilities as well introducing unessential prices. Generators offer the reactive wants of distribution plant inductive hundreds reducing the generator's capability to provide reef power designations.

III. PRIOR APPROACH

CAPACITOR LOCATION
Maximum edges square measure obtained by locating the capacitors as close to the inductive electrical phenomenon kVAR hundreds as potential and by matching the magnitude of the inductive electrical phenomenon kVAR demand. Sensible concerns of political economy and handiness of a restricted range of normal kVAR sizes necessitate that capacitors be clustered close to load centers. Pc modeling or rigorous analysis of sizeable load metering knowledge square measure completely necessary to form the correct condenser placement call and keep line losses as low as potential. The loss reduction edges potential with condenser use will be vital enough to economically justify feeder metering or an outsized share of SCADA system prices. A textbook answer [1] assume a regular distribution of customers, and suggests that because the distance from the station will increase, the amount of customers per path mile of feeder will increase. to get most edges in voltage improvement and reduction of loss on such a line, a for good connected: fixed) capacitor bank ought to be situated at a distance from the station that is 1/2 to 2/3 of the overall length of the Line." This location technique is employed strictly as a "Rule of Thumb" as a result of few rural circuits contains such uniformly distributed loads. Thus, the subsequent technique is healthier suited to locating capacitors: Use a pc model of electrical system and permit the computer program to put the capacitors on the system in blocks of the most important size which will be accustomed limit the voltage changes to three volts per switched bank. Pc models calculate correct condenser placement by attempting the tiniest size condenser a system uses in every line section of each feeder and conniving the overall circuit losses. During this approach, the pc selects the road second with the bottom internet losses then places succeeding extra capacitors within the same manner. The individual result on feeder losses is tabulated for every condenser placed, with every succeeding unit having less profit. At some purpose at but unity power issue, capacitor offers very little additional profit, and adding additional really will increase losses. Capacitors ought to be situated thus on cut back feeder losses the maximum amount as economically sensible. the primary condenser placed provides the foremost improvement per cost as a result of its typically a set condenser and it will increase power issue the foremost. Every succeeding unit is a smaller amount economically sensible [14].

This paper proposes a hybrid algorithmic rule to work out the economical location and size of capacitors [6] in distorted radial distribution systems, so as to reduce active power loss, improve power issue, and suppress the harmonic distortion level. The previous paper [6] applied an on the spot search algorithmic rule for electrical phenomenon compensation in radial distribution systems, however the system doesn't contain any harmonics. During this paper, to contemplate harmonic distortion, a harmonic power flow algorithmic rule supported backward-forward sweep technique [7] is enforced at the same time with radial distribution power flow for the basic part [8].

**PROBLEM FORMULATION**

**Objective Function**

The objective function (1) is minimized to determine the Efficient location and size of capacitors [9]:

\[
P_L = P_{L1} + \sum_{h=h_{max}}^{h_0} P_{Lh}
\]  

(1)

Where

- \( P_L \): total active power loss (kW);
- \( P_{L1} \): fundamental component of total active power loss (kW);
- \( P_{Lh} \): harmonic component of total active power loss (kW);
- \( h \): the harmonic order;
- \( h_{max} \): the highest harmonic order;
- \( h_{0} \): the smallest harmonic order;

**B. Constraints**

**IV. OUR APPROACH**

In order to find the best location and size of shunt capacitors which not amplify the harmonic distortion, it is need to limit the power factor, The Total Harmonic Distortion (THD), and the number of compensators by the following constraints:

1) The power factor of each bus is not allowed less than 0.8.
2) THD of each bus is kept less or equal to 5% as recommended by the IEEE standard 519-1992 [7].

The THD of the ith bus is defined by [7]:

\[
THD_i = \sqrt{\sum_{h=1}^{h_{max}} \left(\frac{|V_{l}(h)|^2}{|V_{l}(1)|^2}\right)}
\]  

(2)

Where \( THD_i \): the total harmonic distortion of the ith bus (%);
- \( V_l \): the magnitude of bus voltage at the fundamental frequency;
- \( V_{l}(h) \): the magnitude of bus voltage at the harmonic frequency;
- \( h_{0}, h_{max} \): the minimum and the maximum harmonic orders;

3) The reactive power injected by shunt capacitors should not exceed the total reactive power demand in the systems[4].

**HARMONIC POWER FLOW**

Fig. 1 shows a single line diagram of a distorted n-bus Radial distribution system.

![Fig.1. A single line diagram of a distorted n-bus radial distribution system [7]](image-url)
The harmonic current absorbed by the ith bus shunt Capacitor is expressed as [7]:

\[
[I_{S}(h)] = [I_{S}(h)]
\]  

The hth harmonic current through the branches are given by:

\[
[I(\theta)] = [I_h(\theta)]
\]  

The harmonic current through the branches is computed using the backward sweep approach expressed as follows (6):

\[
\begin{bmatrix}
B_{12}^{(h)} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1
B_{12}^{(h)} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1
B_{12}^{(h)} & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1
B_{12}^{(h)} & 1 & 0 & 0 & 1 & 1 & 1 & 1 & 1
B_{12}^{(h)} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
\]  

The hth harmonic branch current of any branch can be obtained by

\[
[B_{ij}^{(h)}] = [A_{ij}^{(h)}]T[I(\theta)]
\]  

The coefficient vector of branchij is defined by:

\[
[A_{ij}^{(h)}] = [A_{ij}^{(h)}]
\]

Where \([A_{ij}^{(h)}]\): the coefficient vector of branch \(ij\);  
\([A_{ij}^{(h)}]\): the coefficient vector of branch \(ij\) due to the Harmonic current flows of the nonlinear and linear loads Through branch \(ij\);  
\([A_{ij}^{(h)}]\): the coefficient vector of branch \(ij\) due to the Harmonic current absorbed by the shunt capacitors; The coefficient vector consists of 0 and 1 only, for example if a bus harmonic current flows through the branch, then the corresponding position in the coefficient vector will be 1.

**Hybrid of Improved GA and PSO (HIGAPSO)**

The HIGAPSO maintains the integration of IGA and PSO for the entire run, which consists chiefly of genetic algorithm, combined with PSO and the sequential steps of the algorithm are given below. Briefly, the flows of key operations are illustrated in Fig.1.

![Figure 1. Flow of key operations in HIGAPSO.](image)

**Step 1:** Randomly initialize the population of P individuals within the variable constraint range.

**Step 2:** Calculate the fitness of the population from the fitness function, and order ascending.

**Step 3:** The top N individuals are selected as the elites and reproduce them directly to the next generation.

**Step 4:** The S individuals followed are evolved with PSO and their best positions are updated.

**Step 5:** The bottom individuals are evolved with IGA and produce P-S-N offspring.

**Step 6:** Combine the three parts as the new generation and calculate the fitness of the population. Choose the best position among all the individuals obtained so far kept as the global best.

**Step 7:** Repeat steps 3–6 until a stopping criterion, such as a sufficiently good solution being discovered or a maximum number of generations being completed, is satisfied. The best scoring individual in the population is taken as the final answer.
Simulation Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Without compensation</th>
<th>Compensation by simplified direct search</th>
<th>Compensation by PSO</th>
<th>Compensation by hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q total (kVAR)</td>
<td>4430</td>
<td>3750</td>
<td>3600</td>
<td>3600</td>
</tr>
<tr>
<td>P loss total(kw)</td>
<td>42.796</td>
<td>7.397</td>
<td>7.829</td>
<td>6.755</td>
</tr>
<tr>
<td>cos θ average</td>
<td>.535</td>
<td>.938</td>
<td>.907</td>
<td>.969</td>
</tr>
<tr>
<td>THD average (%)</td>
<td>4.675</td>
<td>3.993</td>
<td>3.995</td>
<td>4.091</td>
</tr>
</tbody>
</table>

Table I: The Comparison of Reactive Compensation

Table I shows the comparison between simplified direct search algorithm and particle swarm optimization (PSO) method to determine the efficient placement and size of shunt capacitors for 14-bus and 39-bus system respectively.

A. Take a look at: 14-bus system
A harmonic current supply was injected into bus 2 and 9. The harmonic injection current was so as of 5, 7, 11, 14, and 17. The load knowledge of 14-bus system is listed in Table I. Within the unpaid system, the measured total reactive power load within the 14-bus system was 4430 kVAR and therefore the total active power loss was 42.796 kW. Victimization harmonic power flow analysis, the computed minimum cos θ within the system was 0.15 and therefore the most THD was 6.036%.

Using the simplified direct search formula, the paid system was made. The whole reactive power injection within the system was 3750 kVAR and therefore the total active power loss reduced to 7.397 kW. The minimum cos θ within the system became .8, whereas the most THD was 4.684%, not up to unpaid power loss.

B. Take a look at: 39-bus System
Table I shows the load knowledge of 39-bus. During this bus take a look at system, a harmonic current supply was injected into bus 4, 11, 15, 25 and 33, with the harmonic injection current was so as of 5, 7, 11, 14, and 17. The load knowledge of 39-bus system is listed in Table I. Within the unpaid system, the measured total reactive power load within the 39-bus system was 4636.5 kVAR and therefore the total active power loss was 42.796 kW. Victimization harmonic power flow analysis, the computed minimum cos θ within the system was 0.15 and therefore the most THD was 6.036%.

Using the simplified direct search formula, the paid system was made. The whole reactive power injection within the system was 3750 kVAR and therefore the total active power loss reduced to 7.397 kW. The minimum cos θ within the system became .8, whereas the most THD was 4.684%, not up to unpaid power loss.
The simulation results area units given in Table 1 and 2 a pair of these results reveal that the inclusions of condenser scale back the road losses of course. It will be shown from the graphs that, LRI decreases marginally, since the core losses of the transformers and also the 55 facet losses stay constant being freelance of the presence of v. It may also be seen that with the rise within the reactive power of condenser, LRI, decrease.

V. CONCLUSION

In this paper, implementation of HYBRID to the best placement of electrical device bank has been illustrated. The effectiveness of the used power flow technique to resolve the capacitor placement downside has been incontestable through the simulation example. The result showed the HYBRID is a correct improvement technique for best placement of capacitors bank in radial distribution network. What is more, it absolutely was showedthat proposed power flow technique in electrical device placement downside is healthier than PSO power flow technique in terms of answer quality and consumed time. The economic study showed the investments prices are salaried during a few years by reduction prices of losses.

REFERENCES