ENHANCEMENT OF DG’S OPTIMAL PERFORMANCE FOR LOSS REDUCTION AND TO IMPROVE THE VOLTAGE PROFILE BY USING FUZZY AND HARMONY SEARCH ALGORITHM

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ABSTRACT

This project presents a new methodology using Fuzzy and Harmony Search Algorithm (HSA) for the placement and sizing of distributed generation units in the distribution systems to reduce the power losses and to improve the voltage profile within the limits. Distribution systems are typically spread over large areas and are responsible for a significant portion of total power losses. Electrical energy plays an important role in day-to-day life. Keen interest is taken on all possible sources of energy from which it can be generated and this led to the encouragement of generating electrical power using renewable energy resources such as solar, tidal waves and wind energy. Due to the increasing interest on renewable sources in recent times, the studies on integration of distributed generation to the power grid have rapidly increased. The Distributed Generation (DG) sources are added to the network mainly to reduce the power losses by supplying a net amount of power. In order to minimize the line losses of power systems, it is equally important to define the size and location of local generation. This can be achieved by placing the optimal values of distributed generation units at proper locations in distribution systems. Optimal DG placement determines the size and location of DG to be installed on a distribution system. A two-stage methodology is used for the optimal DG placement problem. In the first stage, fuzzy approach is used to find the optimal DG locations and in the second stage, Harmony search Algorithm is used to find the sizes of the DG units. The sizes of the DG units corresponding to maximum loss reduction are determined. Fuzzy logic has the advantage of including heuristics and representing engineering judgments into the DG allocation optimization process. Furthermore, the solutions obtained from a fuzzy algorithm can be quickly assessed to determine their feasibility in being implemented in the distribution system. The Harmony search algorithm is a new metaheuristic approach inspired by natural musical phenomenon. The harmony search algorithm (HSA) is simple in concept, few in parameters and easy in implementation. HSA gives the greatest reduction in terms of power loss and total costs as compared to other optimization methods. The forward/backward power flow is also used to obtain faster power flow solutions. This algorithm is practical and easy to implement in large scale power systems. The suggested method is programmed under MATLAB software and is tested on 15-bus, 33-bus, 69-bus and 85-bus test systems and the results are presented.

1. INTRODUCTION

Electrical energy is modern society’s most convenient and useful form of energy. Without it, the present social infrastructure would not at all be feasible. The increasing per capital consumption of electricity throughout the world reflects a growing standard of living of the people. The conveyance of electric power from a power station to consumer’s premises is known as “Electric Supply System”. Electrical power is produced at the power stations which located at favorable places, generally quite away from the consumers. It is then transmitted over large distances to load centers with the help of conductors known as transmission lines. Finally it is distributed to a large number of small and big consumer’s through a distribution network. Generation voltages are in between 3.3 KV and 33 KV most usual value adopted is around 13.2 KV. Depending upon the voltage of Transmission, the transmission system can be classified as

1) Primary Transmission (132 KV and above)
2) Secondary Transmission (33 or 66 KV).

The transmission system is the bulk power transfer system between the power generation station and the distribution center from which power is carried to customer delivery points. The transmission system includes step-up and step-down transformers at the generating and distribution stations, respectively. The transmission system is usually part of the electric utility’s network. Power transmission
systems may include sub-transmission stages to supply intermediate voltage levels. Sub-transmission stages are used to enable a more practical or economical transition between transmission and distribution systems.

A one-line diagram of a typical electrical power system consists of electrical power generation, transmission, and distribution system shown in fig. 1.1.

![Fig.1: Typical Diagram of Electrical Power System](image)

A part of power system which distributes the electrical power for local use is known as “Distribution system”. It lies between the substation fed by the transmission system and the consumer meters. The typical diagram of distribution system is shown in fig. 1.2.

![Fig 2: A typical Distribution System](image)

### 2. LITERATURE SURVEY

The loss minimization in distribution systems has assumed greater significance recently since the trend towards distribution automation will require the most efficient operating scenario for economic viability variations. Studies have indicated that as much as 13% of total power generated is wasted in the form of losses at the distribution level. To reduce these losses, distributed generation units are installed on distribution primary feeders. The advantages with the addition of these units are to improve the power factor, feeder voltage profile, Power loss reduction and increases available capacity of feeders.

With these various Objectives in mind, Optimal DG Placement aims to determine DG location and its size. Early approaches were based on heuristic techniques. The optimal DG placement is a complicated combinatorial optimization problem, many different optimization techniques and algorithms have been proposed in the past. Optimal Placement of Capacitor using Fuzzy and Harmony Search Algorithm for loss reduction [6] in distribution system has been taken as the primary reference for this project, replacing capacitors y Distributed Generation Units.

In the previous, the problem formulated as a nonlinear programming model and considered both location and sizes as continuous variables [2]-[5]. Sundharajan and Pahwa [7] defined the genetic algorithm approach to determine the optimal placement of capacitors. In that paper, a new design methodology for determining the size, location, type to be placed on a radial distribution system is presented.

A simple heuristic numerical algorithm that is based on the method of local variation is proposed in [8]. Genetic Algorithm is proposed to determine the optimal selection of capacitors. Das [9] proposed the genetic algorithm approach for reactive power compensation in distribution systems to reduce the energy loss under varying load conditions.

Prakash and Sydulu [10] proposed the Particle swarm optimization method to size the capacitors in distribution system capacitor placement problem. This paper presents a novel approach that determines the optimal location and size of capacitors on radial distribution systems to improve voltage profile and reduce the active power loss. Capacitor placement & sizing are done by Loss Sensitivity Factors and Particle Swarm Optimization respectively.

Ng et al [11] proposed a solution approach to the capacitor placement problem based on fuzzy expert system. This paper presents a set of heuristic rules used to determine the capacitor placement suitability of each node in the distribution system. Capacitors are placed on the nodes with the highest suitability.

Damodar Reddy .M and Veera Reddy V.C. presented a two stage methodology using Practical swarm optimization method and Real coded genetic algorithm with combination of Fuzzy approach to optimal capacitor sizing and location respectively for maximum annual savings [12]-[13].

This work presents a new methodology using Fuzzy and Harmony Search Algorithm (HSA) for the placement of distributed generation units in electrical distribution systems to reduce the power losses and to improve the voltage profile [6]. In this work, Fuzzy approach is used to find the optimal locations of DG units and Harmony Search Algorithm (HSA) is used to find the optimal sizes of DGs.
The suggested method is programmed under MATLAB software and is tested on 15-bus and 33-bus test systems and the results are presented.
OPTIMAL DG PLACEMENT USING FUZZY APPROACH

Distribution systems are typically spread over large areas and are responsible for a significant portion of total power losses. Reduction of total power loss in distribution system is very essential to improve the overall efficiency of power delivery. This can be achieved by placing the optimal value of DG units at proper locations in radial distribution systems. DG units are installed at strategic locations to reduce the losses and to maintain the voltages within the acceptable limits.

The advantages anticipated include boosting the load level of the feeder so that additional loads can be carried by the feeder for the same maximum voltage drop, releasing a certain KVA at the substation that can be used to feed additional loads along other feeders and reducing power and energy losses in the feeder.

The objective of the DG placement problem is to determine the locations and sizes of the capacitors so that the power loss is minimized and annual savings are maximized.

This work presents a fuzzy approach to determine suitable locations for DG placement. Two objectives are considered while designing a fuzzy logic for identifying the optimal DG locations. The two objectives are: (i) to minimize the real power loss and (ii) to maintain the voltage within the permissible limits. Voltages and Power loss indices of distribution system nodes are modeled by fuzzy membership functions. A fuzzy inference system (FIS) containing a set of rules is then used to determine the DG placement suitability of each node in the distribution system. Distributed generation units can be placed on the nodes with the highest suitability.

In a distribution system with high losses and low voltage is highly ideal for placement of DG units. Whereas a low loss section with good voltage is not ideal for DG placement. A set of fuzzy rules has been used to determine suitable DG locations in a distribution system.

In the first step, load flow solution for the original system is required to obtain the real and reactive power losses. Again, load flow solutions are required to obtain the power loss reduction by compensating the total reactive load at every node of the distribution system. The loss reductions are then linearly normalized into a [0, 1] range with the largest loss reduction having a value of 1 and the smallest one having a value of 0. Power Loss Index value for nth node can be obtained using equation (4.1).

These power loss reduction indices along with the p.u. nodal voltages are the inputs to the Fuzzy Inference System (FIS), which determines the node more suitable for DG installation.

In this work, two input and one output variables are selected. Input variable-1 is power loss index (PLI) and Input variable-2 is the per unit nodal voltage (V). Output variable is DG suitability index (DGSI). Power Loss Index range varies from 0 to 1, P.U. nodal voltage range varies from 0.9 to 1.1 and DG suitability index range varies from 0 to 1. Five membership functions are selected for PLI. They are L, LM, M, HM and H. All the five membership functions are triangular as shown in Figure 3. Five membership functions are selected for Voltage. They are L, LN, N, HN and H. membership functions are trapezoidal and triangular as shown in Figure 3. Five membership functions are selected for DGSI. They are L, LM, M, HM and H. These five membership functions are also triangular as shown in Figure 3.
node, a set of multiple antecedent fuzzy rules has been established. The inputs to the rules are the voltage and power loss indices and the output is the suitability of DG placement. The rules are summarized in the fuzzy decision matrix in Table 1. The consequents of the rules are in the shaded part of the matrix.

![Fuzzy Decision Matrix](image)

**Table 1 Decision Matrix for Determining the optimal DG Locations**

**Identification of Optimal DG Locations using Fuzzy Approach**

**Optimal DG Locations of 15-Bus System**

The proposed fuzzy approach is applied to 15-bus system. The power loss reduction indices (PLI) along with the P.U. nodal voltages are the inputs to the Fuzzy Inference System (FIS).

![Table 2: P.L.I - Voltage Values (P.U) of 15-bus System](image)

**Optimal DG Locations of 33-Bus System**

The proposed fuzzy approach is applied to 33-bus system. The power loss reduction indices (PLI) along with the P.U. nodal voltages are the inputs to the Fuzzy Inference System (FIS).

![Table 4: P.L.I - Voltage Values (P.U) of 33-bus System](image)
<table>
<thead>
<tr>
<th>BUS NUMBER</th>
<th>DGSI VALUES</th>
<th>BUS NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9183</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>0.9183</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>0.9183</td>
<td>30</td>
<td></td>
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<td></td>
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<tr>
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<tr>
<td>0.1244</td>
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<td>0.1077</td>
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<tr>
<td>0.0850</td>
<td>22</td>
<td></td>
</tr>
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<td>0.0824</td>
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</tr>
<tr>
<td>0.0800</td>
<td>19</td>
<td></td>
</tr>
</tbody>
</table>

Optimal DG locations are identified based on the DGSI values. For this 33-bus system, two optimal locations are selected as DGSI values greater than 0.9183. Best two locations = [6 28 29 30]

**OPTIMAL DG SIZING USING HARMONY SEARCH ALGORITHM (HSA)**

When listening to a beautiful piece of classical music, who has ever wondered if there is any connection between music and finding an optimal solution to a tough design problem such as the water distribution networks or other design problems in engineering? Now for the first time ever, scientists have found such an interesting connection by developing a new algorithm, called Harmony Search.
Harmony Search (HS) was first developed by Zong Woo Geem et al. in 2001.

Current meta-heuristic algorithms imitate natural phenomena, i.e., physical annealing in simulated annealing, human memory in tabu search, and evolution in evolutionary algorithms. A new HS meta-heuristic algorithm was conceptualized using the musical process of searching for a perfect state of harmony. Musical performances seek to find pleasing harmony (a perfect state) as determined by an aesthetic standard, just as the optimization process seeks to find a global solution (a perfect state) as determined by an objective function.

**Implementation of HSA for DG Placement Problem**

After identifying the n number of optimal DG locations using fuzzy approach, the optimal DG sizes in all these n optimal locations are obtained by using the Harmony Search Algorithm.

**Step 1:** Initialize all the parameters and constants of the harmony search algorithm. They are Qmin, Qmax, HMCR, PARmin and PARmax.

**Step 2:** Run the load flow program and find the total real power loss PLoss1 of the original system. (Before DG placement)

**Step 3:** Initialize the harmony memory i.e., generate [hms x n] number of initial solutions randomly within the limits, where hms is the harmony memory size and n is the number of dg units. Each row represents one possible solution to the optimal dg unit-sizing problem.

**Step 4:** Place all the n dg units of the harmony vector i.e., each row of the Harmony vector at the respective optimal dg location and perform the load flow analysis and find the total real power loss PLoss2 and then obtain the loss reduction (fitness value) using equation

\[ \text{Fitness Value} = \text{PLoss}_1 - \text{PLoss}_2 \]

**Step 5:** Obtain the best fitness value by comparing all the fitness values.

**Step 6:** Start the improvisation (Iteration count is set to one).

**Step 7:** Improvisation of the New Harmony is generating a new harmony.

A New Harmony vector is generated based on the following steps:

1. **Random Selection:** It is used to select one value randomly for a certain element of the new vector from the possible range (Qmin, Qmax) of values.

2. **Memory Consideration:** It is used to choose the value for a certain element of the new vector from the specified HM range.

\[ x_i = x_i \in \{x'_1, x'_2, ..., x_{HMS_i}\} \text{ with probability (1-HMCR)} \]

**Step 8:** Pitch adjustment: It is used to adjust the values of the New Harmony vector obtained in step 7. (Between PARmin and PARmax).

\[ x_i = x_i \pm \text{rand}(0,1) \times bw \]

**Step 9:** Find the fitness values corresponding to the New Harmony generated and pitch adjusted in steps 7 and 8.

**Step 10:** Apply Greedy Search between old harmony and New Harmony by comparing fitness values.

**Step 11:** Update harmony memory, by replacing the worst harmony with the new best Harmony. Obtain the best fitness value by comparing all the fitness values.

**Step 12:** The improvisation (iteration) count is incremented and if iteration count is not reached maximum then go to step 7.

**Step 13:** The solution vector corresponding to the best fitness value gives the optimal DG sizes in n optimal locations.

### 6. RESULTS

**Results of 15-Bus System**

The proposed algorithm is applied to 15-bus system. Optimal DG locations are identified based on the DG.S.I values. For this 15-bus system, three optimal locations are identified. DG sizes in the three optimal locations, total real power losses before and after compensation are shown in Table 6.

<table>
<thead>
<tr>
<th>Bus No.</th>
<th>DG Unit Size in KVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>546</td>
</tr>
<tr>
<td>3</td>
<td>769</td>
</tr>
<tr>
<td>11</td>
<td>364</td>
</tr>
</tbody>
</table>

Minimum bus voltage in p.u. (before) 0.9451
Minimum bus voltage in p.u. (after) 0.9923
Total power loss in kW (before) 61.7339
Total power loss in kW (after) 4.6685
The results show that 92.44% reduction in power loss for 15-bus system is possible as shown in Tables 7 and bus voltages are also improved substantially.

Results of 33-Bus System

The proposed algorithm is applied to 33-bus system. Optimal DG locations are identified based on the DG.S.I values. For this 33-bus system, four optimal locations are identified. DG sizes in the four optimal locations, total real power losses before and after compensation are shown in Table 7.

<table>
<thead>
<tr>
<th>Bus No.</th>
<th>DG Unit Size in KVA</th>
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</table>

Table 7: Results of 33-bus system

The results show that 90.40% reduction in power loss for 33-bus system is possible as shown in Table 8 and bus voltages are also improved substantially.

Results of 69-bus system

The proposed algorithm is applied to 69-bus test system. Optimal DG locations are identified based on DG.S.I values and for this system 3 optimal locations are identified and corresponding optimal DG size values, total real power losses before DG placement and after placement presented with minimum and maximum voltage values in Tables 8.

<table>
<thead>
<tr>
<th>Bus No.</th>
<th>DG Unit Size in KVA</th>
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Table 8: DG Unit sizes at the preferred locations for 69-bus systems

Results of 85-bus system

The proposed algorithm is applied to 85-bus test system. Optimal DG locations are identified based on DG.S.I values and for this system 3 optimal locations are identified and corresponding optimal DG size values, total real power losses before DG placement and after placement presented with minimum and maximum voltage values in Tables 9.

<table>
<thead>
<tr>
<th>Bus No.</th>
<th>DG Unit Size in KVA</th>
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</table>

Table 9: DG Unit sizes at the preferred bus locations for 85 bus systems

CONCLUSIONS

A new two-stage methodology of finding the optimal locations and sizes for reactive power compensation of distribution systems is presented. Fuzzy approach is proposed to find the optimal DG locations and HSA method is proposed to find the optimal DG sizes. Based on the simulation results, the following conclusions are drawn: By installing distributed generation units at all the potential locations, the total real power loss of the system has been reduced significantly and bus voltages are improved substantially. The proposed fuzzy approach is capable of determining the optimal distributed generation locations based on the DG.S.I values. The proposed HSA method iteratively searches the optimal DG unit sizes effectively for the maximum power loss reduction.

SCOPE FOR FUTURE WORK

One of the assumption made in the analysis of this project is the networks are considered as balanced. So, the proposed method can be extended for unbalanced loads. The results of this method can be verified by practically implementing various networks.
6. REFERENCES


Author’s Biography

K. Sreedhar, Student of M.Tech, power systems Dept. of EEE, Global College of Engineering and Technology, Kadapa. He has studied his B.Tech from SVIST, Kadapa in 2011. He worked as Assistant Professor at AITS Rajampet from June 2011 to June 2013.he qualified in gate2013. He is having interest in Power Systems.

N.SREEKANTH received B.Tech degree in 2004 and M.Tech degree in 2006 from JNTU Hyderabad. He has work experience of 9 years, presently working as Associate Professor and Head of the EEE department in Global College of Engineering and Technology, Kadapa, AP, India.