Improvisation Process for Banks Capacitor Compensation Applied Fuzzy Logic Knowledge for Nodal Detection on Electrical Network

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Abstract:

The main problem of electrical distribution systems is the reactive power flow. It causes reduction of active power transmission, diminishes power losses, and augments the drop voltage. In this research we described an efficiency approach FLC-HSO to solve the optimal power flow (OPF) combinatorial problem. The proposed approach employ tow algorithms, Fuzzy logic controller (FLC) algorithm for nodal detection and harmony search optimization (HSO) algorithm for optimal seizing capacitor of OPF combinatorial problem control variables. HSO method is more proficient in improving combinatory problem. The proposed approach has been examined and tested on the standard IEEE 57-bus test system with different objectives that reflect cost function minimization, voltage profile improvement, and voltage stability enhancement. The proposed approach results have been compared to those that reported in the literature recently. The results are promising and show the effectiveness and robustness of the proposed approach.

Keywords: *capacitor placement, fuzzy logic, Harmony Search Optimization (HSO), capacitor seizing, power flow.*

1. Introduction

Power distribution systems from electric power plants to ultimate consumers are accomplished via the transmission system, and distribution lines. Studies have indicated that as much as 13% of total power generated is consumed as R^2 losses at the distribution level. The R^2 losses can be separated to active and reactive component of branch current, where the losses produced by reactive current can be reduced by the installation of shunt capacitors. Capacitors are widely used in distribution systems to reduce energy and peak demand losses, release the KVA capacities of distribution apparatus, and to maintain a voltage profile within permissible limits. The objective of optimal capacitor placement problem is to determine the size, type, and location of capacitor banks to be installed on radial distribution feeders to achieve positive economic response. The economic benefits obtained from the loss reduction weighted against capacitors costs while keeping the operational and power quality constraints within required limits.

Fuzzy theory was first proposed and investigated by Prof. Zadeh in 1965.The Mamdani fuzzy inference system was presented to control a steam engine and boiler combination by linguistic rules [3, 4]. Fuzzy logic is expressed by means of if-then rules with the human language. In the design of a fuzzy logic controller, the mathematical model is not necessary. Therefore the fuzzy logic controller is of good robustness. Owing to its easy application, it has been widely used in industry. However, the rules and the membership functions of a fuzzy logic controller are based on expert experience or knowledge database.

The harmony search (HS) algorithm is a recently developed meta-heuristic algorithm, and has been very successful in a wide variety of optimization problems. HS was conceptualized using an analogy with music improvisation process where music players improvise the pitches of their instruments to obtain better harmony. The HS algorithm does not require initial values and uses a random search instead of a gradient search, so derivative information is unnecessary. Furthermore, the HS algorithm is simple in concept, few in parameters, easy in implementation, imposes fewer mathematical requirements, and does not require initial value settings of the decision variables. Many of the previous strategies for capacitor allocation in the literature are also limited for the application to planning, expansion or operation of distribution systems. Very few of these capacitor allocation techniques have the flexibility of being applicable to more than one of the above problems. Hence, this paper presents a FLC_HSO approach to determine suitable locations for capacitor placement and the seizing of the capacitor. This approach has the versatility of being applied to the planning, expansion, and operation studies of distribution systems. The proposed method was tested on electrical distribution systems consisting of standard IEEE 57-bus test System.

The fuzzy logic controller is employed to detection the critical nodal. The HSO methods have been employed successfully to solve complex optimization problems. It used to seizing the optimal capacitor banks. Simulation results are given to show the effectiveness of FLC_HSO approach.

The structure of the work presented in this paper is organized in the following sequence: Mathematical formulation is set in section 2. Section 3 shows the Fuzzy Logic Controller. Section 4 shows the Harmony Search Optimization (HSO). Section 5 shows the development space vector modulation technique based DTC for Electric vehicle motorization. The proposed structure of the studied propulsion system is given in the section 6. The simulation results of the different studied cases are presented in Section 6.

2. Mathematical formulation

The Principe of method is presented in Figure 1.

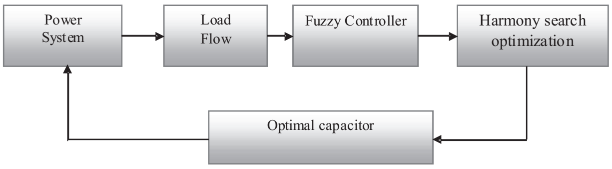

Fig. 1. Bloc of intelligent fuzzy-ant approach.

The objective function of placement to reduce the power loss and keep bus voltage within prescribed limits with minimum cost. The constraint are voltage limits. Following the above notation, the total annual cost function due to capacitor placement and power losses written as [10]:

$$Minimize \quad \left\{ F = K_{PL} P_L + \sum_{j=1}^{N} K_{Cj} B_J \right\} \tag{1}$$

Constraint of voltage

$$V_i^{\min} \le V_i^{\min} \le V_i^{\max} \qquad i = 2,3,....N \tag{2}$$

where:
F : Total annual cost function ($),
K_{PL} : Annual cost per unit of power losses ($/KW),
P_L :Total active power loss (KW),
K_{jC} :Total active power loss (KW),
B_j : Shunt capacitor size placed at bus j (KVAR),
N : Number of buses,
$V_{\min}$: Minimum permissible voltage,
$V_{\max}$: Maximum permissible voltage.

3. Fuzzy Logic Controller

Fuzzy logic is expressed by means of the human language. Based on fuzzy logic, a fuzzy controller converts a linguistic control strategy into an automatic control strategy, and fuzzy rules are constructed by expert experience or knowledge database. First, set the power loss index *PLI* and the voltage V to be the input variables of the fuzzy logic controller. The Capacitor suitable index *CSI* is the output variable of the fuzzy logic controller. The linguistic variables are defined as {L, LM, M, HM, H}, where L means low, LM means low medium, M means medium HM means height medium and H means height. The membership functions of the fuzzy logic controller are shown in Fig. 3. The fuzzy rules are summarized in Table 1. The type of fuzzy inference engine is Mamdani. The fuzzy inference mechanism in this study follows as:

$$\mu_B(u(t)) = \max_{j=1}^{m} \begin{bmatrix} \mu_{A_1^j}(e(t)), \mu_{A_2^j}(de(t)), \\ \mu_{B^j}(u(t)) \end{bmatrix} \tag{3}$$

where $\mu_{A_1^j}(PLI)$ is the membership function of *PLI*, $\mu_{A_2^j}(V)$ is the membership function of V, $\mu_{B^j}(CSI)$ is the membership function of *SCI*, j is an index of every membership function of fuzzy set, m is the number of rules and is the inference result. Fuzzy output *CSI* can be calculated by the centre of gravity defuzzification as:

$$u(t) = \frac{\sum_{i=1}^{m} \mu_B(u_i(t)).u_i}{\sum_{i=1}^{m} \mu_B(u_i(t))} \tag{4}$$

where i : is the output rule after inferring.

3.1. Fuzzy based capacitor location

Node voltages and power loss indices are the inputs to fuzzy controller to determine the suitability of a node in the capacitor placement problem. The suitability of a node is chosen from the capacitor suitability index (CSI) at each node. The higher values of CSI are chosen as best locations for capacitor placement [1], [2], [3], [4], [5].

The power loss indices are calculated as:

$$PLI(i) = \frac{(L_R - L_{MAX})}{(L_{MIN} - L_{MAXN})} \qquad i = 2,3,..N \tag{5}$$

where:
L_R : Loss reduction,
L_{MIN} : Minimum reduction,
L_{MAX} : Maximum reduction,
N : Number of bus

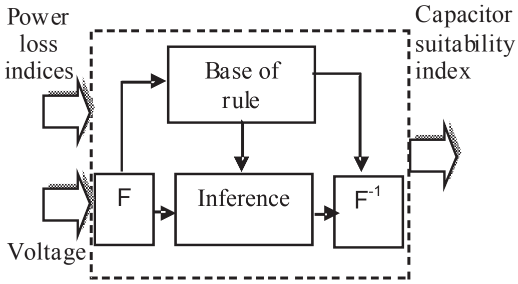

Fig. 2. Structure of fuzzy controller.

where:
F: Fuzziffication, F^{-1} : Defuzzification

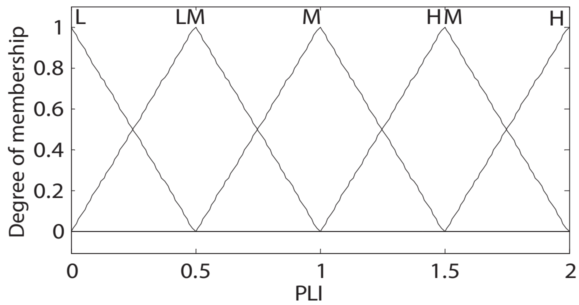

Fig. 3. Power loss indices membership.

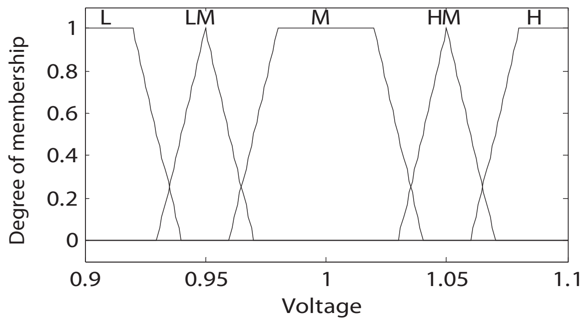

Fig. 4. Voltage membership functions.

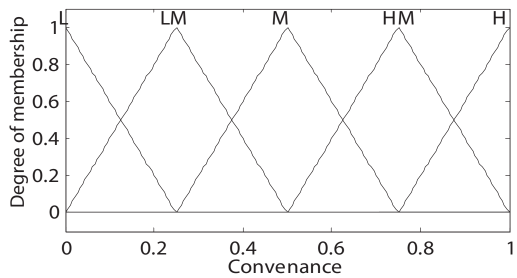

Fig. 5. Capacitor suitability index membership function.

To determine the critical busses the voltage and power loss index at each node shall be calculated and are represented in fuzzy membership function. By using these voltages and PLI, rules are framed and are summarized in the fuzzy decision matrix as given in Table 1.

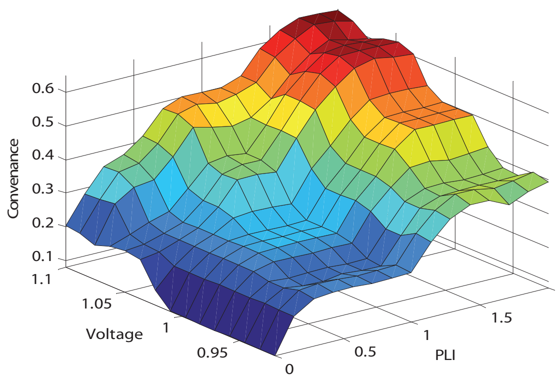

Fig. 6. View plot surface of fuzzy controller.

3.2. Algorithm (FLC) for identification of busses identification

Following algorithm explain the methodologies to identify critical busses, witches are more suitable for capacitor placement [6], [10].

Step 1: Read line and load data of power system.
Step 2: Calculate power flow by Newton Raphson methods.
Step 3: Determine total active power loss.
Step 4: By compensation the self-reactive power at each node and conduct the load flow to determinate the total active power losses in each case.
Step 5: Calculate the power loss reduction and power flow loss indices.
Step 6: The PLI and the per-unit voltage are the inputs to the fuzzy controller.
Step 7: The outputs of Fuzzy controller are defuzzified. This gives the ranking of CSI. The nodes having the highest value of CSI are the most suitable for capacitor placement.
Step 8: Stop.

4. Harmony Search Optimization algorithm

Recently, Geem *et al.* [8] developed a new harmony search (HS) meta-heuristic algorithm that was conceptualized using the musical process of searching for a perfect state of harmony. The harmony in music is analogous to the optimization solution vector, and the musicians' improvisations are analogous to local and global search schemes in optimization techniques. The HS algorithm does not require initial values for the decision variables. Furthermore, instead of a gradient search, the HS algorithm uses a stochastic random search that is based on the harmony memory considering rate and the pitch adjusting rate (defined in harmony search meta-heuristic algorithm section), so that derivative information is unnecessary. Compared to earlier meta-heuristic optimization algorithms, the HS algorithm imposes fewer mathematical requirements and can be easily adopted for various types of engineering optimization problems [15], [16], [17], [18], [19], [20], [21], [22].

The optimization procedure of the HS algorithm consists of steps 1–5, as follows:

Step 1: Initialize the optimization problem and algorithm parameters.
Step 2: Initialize the harmony memory (HM).
Step 3: Improvise a new harmony from the HM.
Step 4: Update the HM.
Step 5: Repeat Steps 3 and 4 until the termination criterion is satisfied.

5. Results

The FLC-HSO is coded in MATLAB environment version 7.6 (R2008a), and run using an Intel Pentium 4, core duo 1.87 GHz PC with 2 Go DDRAM-II and 2 Mo cache memory. All computations use real float point precision without rounding or truncating values. More than 6 small-sized test cases were used to demonstrate the performance of the proposed algorithm. Consistently acceptable results were observed.

The FLC_HSO method has been applied on the network test IEEE 57 buses that represent a portion of the American electric power system (the Midwestern, USA) for December 1961. This electric network is constituted of 57 buses and 7 generators (at the buses Nº: 1, 2, 3, 6,

Table. 1. Decision matrix for determining suitable capacitor.

CSI		V				
		L	LM	M	HM	H
PLI	L	L	L	L	LM	LM
	LM	L	L	LM	LM	M
	M	L	L	LM	M	HM
	HM	L	LM	M	HM	HM
	H	LM	LM	M	HM	H

8, 9 and 12) injecting their powers for a system nourishing 42 loads through 80 lines of transportation (Shown in Fig 1). The base voltage for every bus is of 135 kV. The proposed method is illustrated with a system, consisting of standard IEEE 57-bus test System. The location for placement of capacitors is determined by fuzzy controller and the capacitor sizes are evaluated using harmony search optimization.

FLC-HSO approach is applied for IEEE 57- approach given above is shows in Table 1.

In primary case we applied the first algorithm (FLC) based fuzzy logic controller logic which gives the critical busses shown in Table 1, follows in makes call the particle swarm optimization conceived for difficult combinative optimization to optimize the objective function (1) all respect limit constraints voltage (2) Finally we obtained the optimal cost function and the value of optimal capacitor for each critical buses all that are illustrated in Table 1.

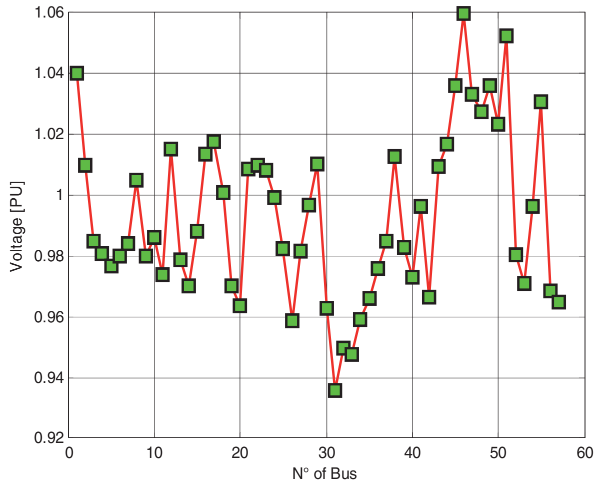

Fig. 9. The levels of voltage (Per Unit) for the IEEE 57-bus Electrical Network Before placement of optimal capacitor.

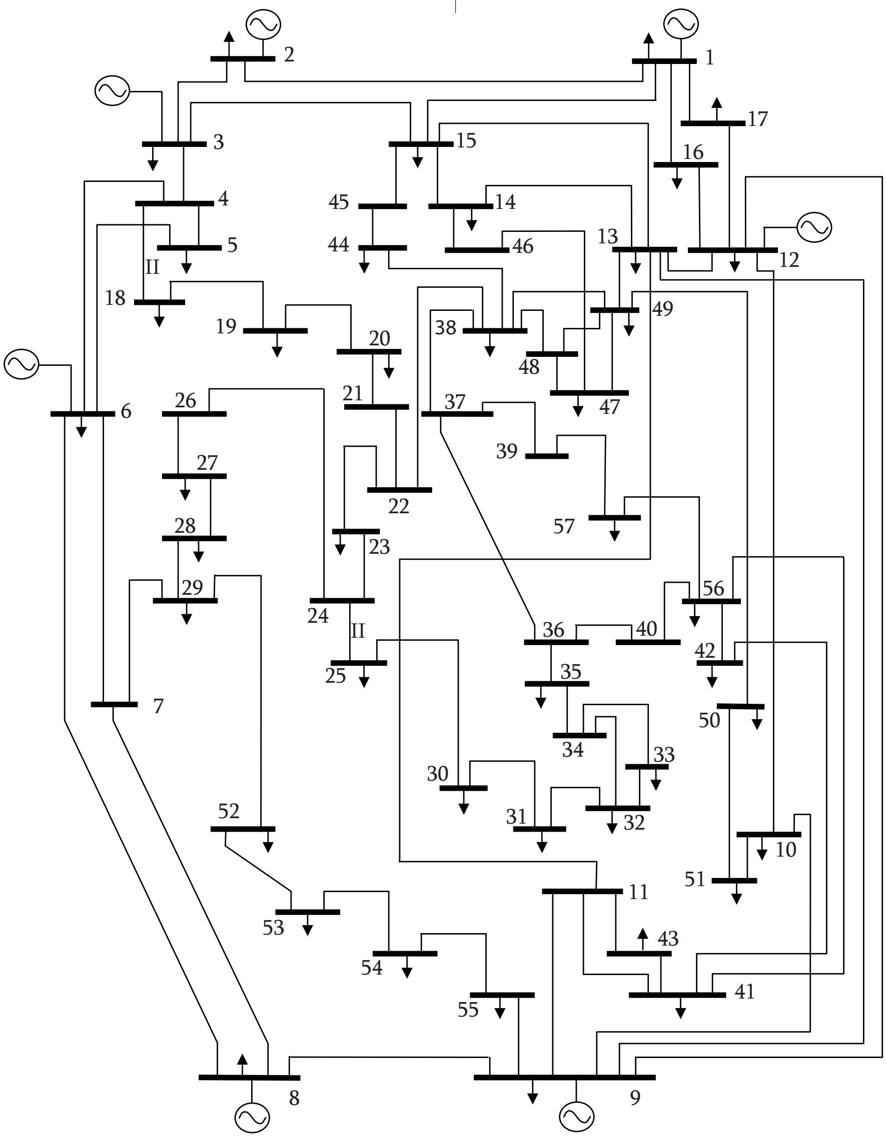

Fig. 10. Topology of the IEEE 57-bus.

Table 1. The initialized coefficients of the HSO.

Coefficients	value
Size of the harmony memory matrix (HMS)	10
Harmony memory considering rate (HMCR)	0.85
Pitch adjusting rate (PAR)	0.45

Table 2. Results of FLC-HSO.

Fuzzy logic controller (FLC)	
Number of critical buses	Value of capacitor [MVAR]
10	4.22
19	2.12
21	3.11
28	3.95
32	5.91
33	7.35
52	1.40

Harmony search optimization (HSO)		
	Before placement of optimal capacitor	After placement of optimal capacitor
Power Losses [MW]	18.50	15.29
Minimal Voltage [Per Unit]	0.935	0.981
Reactive Power [MVAR]	275.23	239.27

Table. 3. Comparison of the results gotten by ACO-OPF, QN-OPF, MATPOWER and proposed method FLC-HSO on the IEEE 57-bus Electrical Network.

Results	Power Loss [MW]	Reactive Power [MVAR]
GA-OPF [29]	18.60	–
QN-OPF	17.16	–
ACO-OPF	17.96	–
MATPOWER	16.512	270.56
FLC-HSO	15.29	239.27

After application the new approach FLC-HSO the results are improved, the loss are decreased by 15.75 %, as well as the reactive power injected into the electrical distribution system are diminish by 13.06% and the nodal voltage are improved.

In our application we have compared the FLC-HSO by another approach explained in the Tables 2 and 3: Genetic algorithm based optimal power GA-OPF [8], Ant Colony Optimization (ACO) algorithm for optimal flow ACO-OPF [14], Quasi Newton based optimal power flow QN-OPF and MATPOWER. Our approach FLC-HSO was proved the satisfactory results illustrated in Table 3. The constraints of security are also verified for the angles and the amplitudes of voltages, the levels of voltage (Per Unit) for the IEEE 57-bus Electrical Network are drawn in the Fig. 5 and Fig. 6.

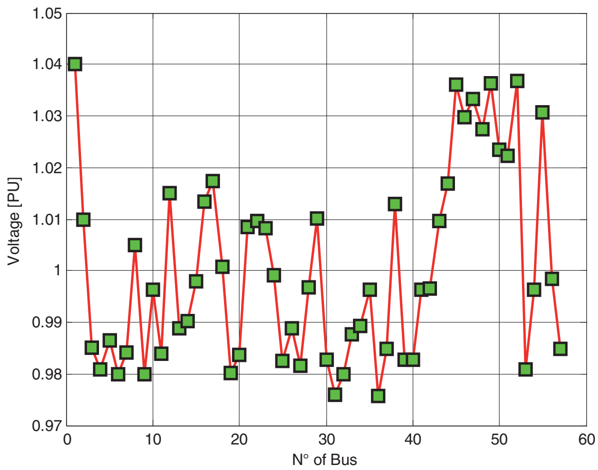

Fig. 10. The levels of voltage (Per Unit) for the IEEE 57-bus Electrical Network After placement of optimal capacitor.

6. Conclusions

In this paper, a novel approach FLC-HSO based harmony search optimization and fuzzy logic controller to OPF problem has been presented. The proposed approach FLC-HSO utilizes the fuzzy logic controller for identification the critical bus and the improvisation Process of HSO to search the optimal seizing capacitor banks. Different objective functions have been considered to minimize losses and, to improve the voltage profile, and to enhance voltage stability. The proposed approach has been tested and examined with different objectives to demonstrate its effectiveness and robustness. The results using the proposed approach were compared to those reported in the literature. The results confirm the potential of the proposed approach and show its effectiveness and superiority over the classical techniques and genetic algorithms.

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