NOVEL POWER FLOW PROBLEM SOLUTIONS METHOD'S BASED ON GENETIC ALGORITHM OPTIMIZATION FOR BANKS CAPACITOR COMPENSATION USING AN FUZZY LOGIC RULE BASES FOR CRITICAL NODAL DETECTIONS

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Abstract. *The Reactive power flow is one of the most electrical distribution systems problem which has great interset of the electrical network researchers. It causes active power transmission reduction, power losses decreasing, and the drop voltage increase. In this research we described the efficiency of the FLC-GAO approach to solve the optimal power flow (OPF) combinatorial problem. The proposed approach employ two algorithms, Fuzzy Logic Controller (FLC) algorithm for critical nodal detection and Gentic Algorithm Optimization (GAO) for optimal capacitor seizing.GAO method is more efficient in combinatory problem solutions. The proposed approach has been examined and tested on the standard IEEE 57-bus, the results show the power loss minimization denhancement, voltage profile, and stability improvement. 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, genetic algorithm optimization.

1. Introduction

Power distribution systems of electric power plants must satisfy consumers demand of energy assuring by the transmission system, and distribution lines. Many studies have indicated that as much as 13 % of total power generated is consumed as RI^2 losses at the distribution level. The RI^2 losses can be separated to active and reactive component of current branch, 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 fuzzy logic controller design steps the mathematical model is not necessary. Therefore the fuzzy logic controller has good robustness. Due 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 databases.

The Genetic Algorithm (GA) is used for (OPF) problems because of it's many optimization advantages such as:

1. GA works with a coding of solution set rather than solutions themselves.
2. It searches a population of solutions rather than a single solution.

3. It uses payoff information through fitness function, there is no need to get the derivatives or other auxiliary knowledge for the function to be optimized.
4. It uses probabilistic transition rules, not deterministic rules.

This paper presents a FLC_GAO approach to determine suitable locations for capacitor placement and seizing. 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 for critical nodal detection. The GAO methods have been employed successfully to solve complex optimization problems. It was used to the optimal capacitor banks seizing. Simulation results are given to show the effectiveness of FLC_GAO approach.

The presented paper structure is organized as follow: Mathematical formulation is set in section 2. Section 3 shows the Fuzzy Logic Controller. Section 4 shows the genetic algorithm optimization (GAO). The simulation results of the different studied cases are presented in section 5.

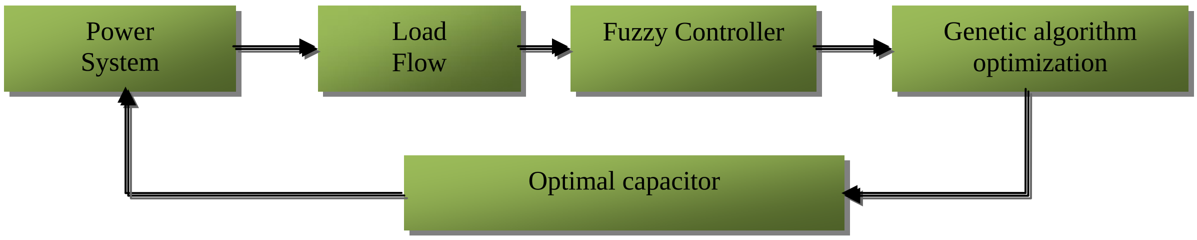

Fig. 1: Bloc of Fuzzy-Genetics approach (FLC_GAO).

2. Mathematical Formulation

The principe of method is presented in Fig. 1. The objective function of capacitor placement is used to reduce the power loss and keep bus voltage with minimum costs. The constraints which have to be take into account are voltage limits. The globally annual cost function due to capacitor placement and power losses are given by [10]:

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

Constraint of voltage

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

where are:

- F the total annual cost function ($),
- K_{PL} the annual cost per unit of power losses ($/KW),
- P_L the total active power loss (KW),
- K_{Cj} the total active power loss (KW),
- N the number of buses,
- V_{min} the minimum permissible voltage,
- V_{max} the 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. Firstly, we set the power loss index PLI and the voltage V as the fuzzy logic controller inputs. 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 Tab. 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 defuzzified 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 (PLI) 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) of each node. The higher values of CSI are chosen as best locations for capacitor placement [1], [2], [3], [4], [5].

The power loss indices PLI are calculated as:

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

Where L_R means loss reduction, L_{MIN} means Minimum reduction, L_{MAX} means maximum reduction and N means Number of bus.

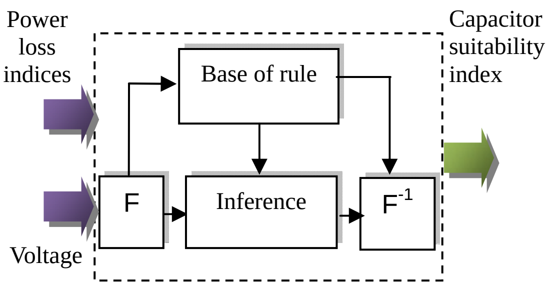

Fig. 2: Structure of fuzzy controller.

Where:

- F is fuzzification,
- F^{-1} is defuzzification.

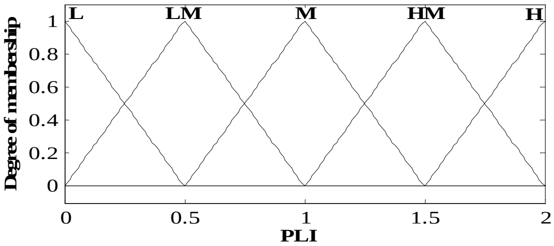

Fig. 3: Power loss indices PLI membership functions.

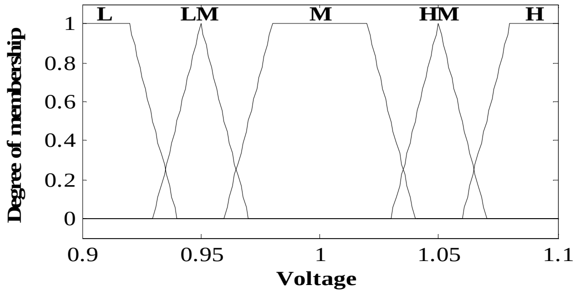

Fig. 4: Voltage membership functions.

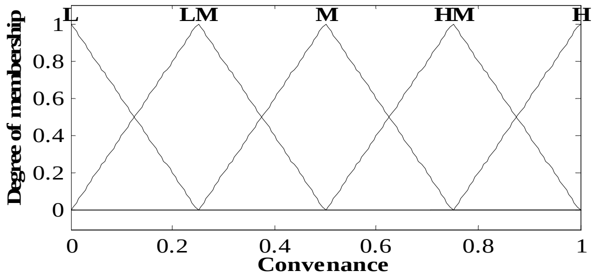

Fig. 5: Capacitor suitability index membership function.

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 Tab. 1.

Tab.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

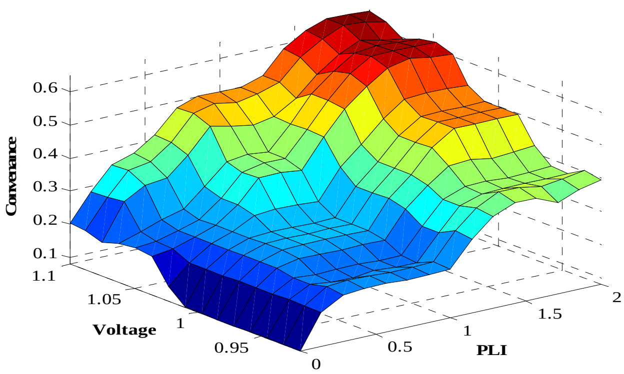

Fig. 6: Fuzzy controller surface.

3.2. FLC Algorithm Application's for Critical Busses Identifications'

The following algorithm steps explain the identification methodologies for critical busses designations, which are more suitable for capacitor placement [6], [10]:

1. Read line and load data of power system,
2. Calculate power flow by Newton Raphson methods,
3. Determinate the globally active power loss,
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,
5. The power loss reduction computations and power flow loss indices,
6. The PLI and the per-unit voltage are the inputs to the fuzzy Controller,
7. The outputs of Fuzzy controller are defuzzified. This gives the CSI Status. The nodes having the highest value of CSI are the most suitable for capacitor placement,
8. Stop.

4. Genetic Algorithm Optimization

Recently, the genetic algorithms are one of the evolutionary algorithms families, which have computational models, inspired from the Nature. Genetic algorithms are powerful stochastic search algorithms based on the mechanism of natural selection and natural genetics. Genetic algorithms consist of a population of binary string, searching many peaks in parallel [10], [11], [12]. The basic construction of a genetic algorithm is as follows:

1. Create an initial population, usually a randomly generated string of individuals.
2. Evaluate all the individuals by applying some function or formula usually called a fitness function.
3. Select a new population from the old population based on the fitness of the Individuals as given by the evaluation function.
4. Apply some genetic operators such as mutation and crossover to the members of the new population to create new solutions.
5. Evaluate these newly created individuals.
6. Repeat steps 3 - 5 applied on one generation until the termination criterion has been satisfied. A generally used end algorithm criterion is to stop after a fixed number of generations.

5. Simulation Results

The FLC-GAO is coded in MATLAB environment version7.6 (R2008a), and run using an Intel Pentium 4, Core Duo 1,87 GHz PC with 2 GB DDR RAM-II and 2 MB 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_GAO method has been applied on the electrical network test IEEE 57 buses that present 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, 8, 9 and 12) injecting their powers for a system nourishing 42 loads as it shown in Fig. 7. The base voltage for every bus is of 135 kV. The proposed method is illustrated with a consisting system of standard IEEE 57-bus test. The location for placement of capacitors is determined by fuzzy controller and the capacitor sizes are evaluated using genetic algorithm optimization.

The FLC-GAO approach applied for IEEE 57 buses results are shown in Tab. 3. In primary case we applied the first algorithm fuzzy logic controller (FLC) which gives the critical busses shown in Tab. 3. (Tab. 4 explain the results obtained compared with those of literature, in this way we optimize the objective function cited in equation (1), with the limit constraints voltage respected of equation (2) .Finally we obtained the optimal cost function and the optimal capacitor value for each critical buses illustrated in Tab. 3.

After application the new FLC-GAO approach, results are improved, the power losses are decreased by 23,29 % as well as the reactive power injected into the electrical distribution system are diminish by 14,56 % and the nodal voltage are improved as it shown in Tab. 4.

Tab.2: Parameters of GA.

Coefficients	value
Population	100
Generation	50
Crossover	0,9
Mutation	0,08

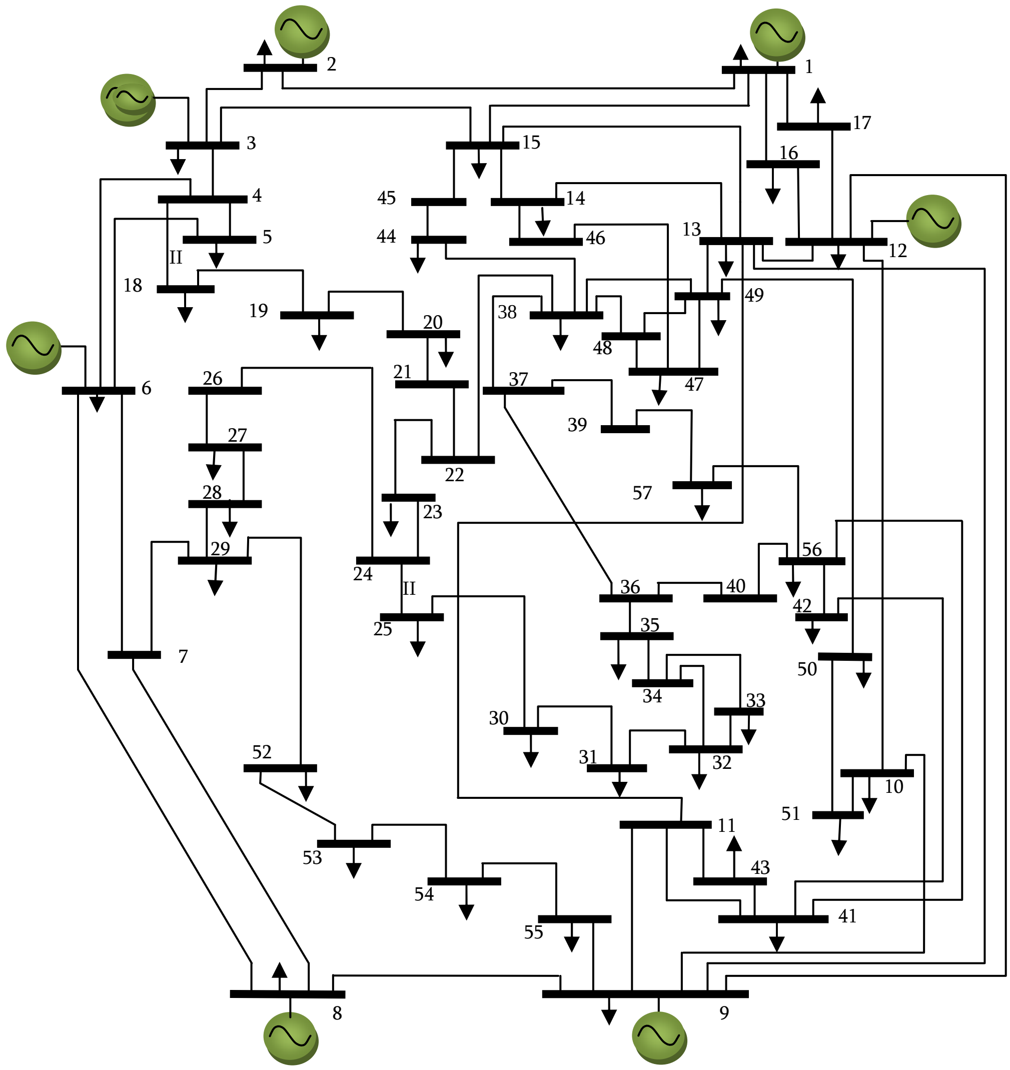

Fig. 7: Topology of the IEEE 57-bus.

Tab.3: Results of FLC-GAO.

Fuzzy logic controller (FLC)		
N° of critical buses	**Value of capacitor [MVAR]**	
10	4,25	
19	2,10	
21	3,05	
28	3,15	
32	5,17	
33	7,29	
52	1,13	
Genetic algorithm optimization (GAO)		
	Before placement of optimal capacitor	**After placement of optimal capacitor**
Power Losses [MW]	18,50	14,19
Minimal Voltage[Per Unit]	0,935	0,977
Reactive Power [MVAR]	275,23	235,14

Tab.4: Comparison of the results gotten by ACO-OPF, QN-OPF, MATPOWER and proposed method FLC-GAO on the 57-bus Electrical Network.

Results	Power Loss [MW]	Reactive Power [MVAR]
QN-OPF	17,16	-
ACO-OPF	17,96	-
MATPOWER	16,51	270,56
FLC-HSO	15,29	239,27
FLC-GAO	14,19	235,14

In our application we have compared the FLC-GAO by another approach explained in the Tab. 3 and Tab. 4: Harmony search optimization based fuzzy logic controller [FLC-HSO], 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 Tab. 3. The constraints of security are also verified for the angles and amplitudes voltages, the voltage levels on (Per Unit) for the IEEE 57-bus Electrical Network are drawn in the Fig. 8 and

Fig. 9 before and after the optimal capacitor placements.

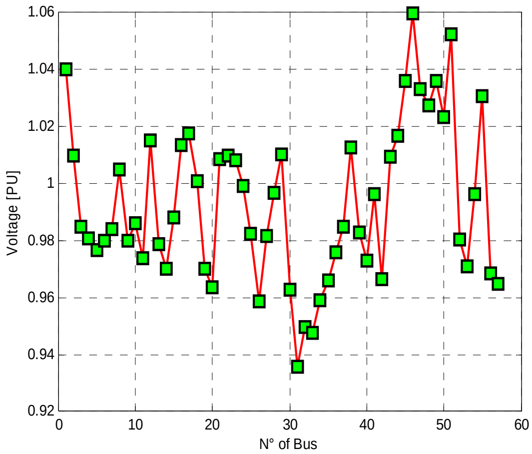

Fig. 8: The voltage levels on (Per Unit) for the IEEE 57-bus Electrical Network Before placement of optimal capacitor.

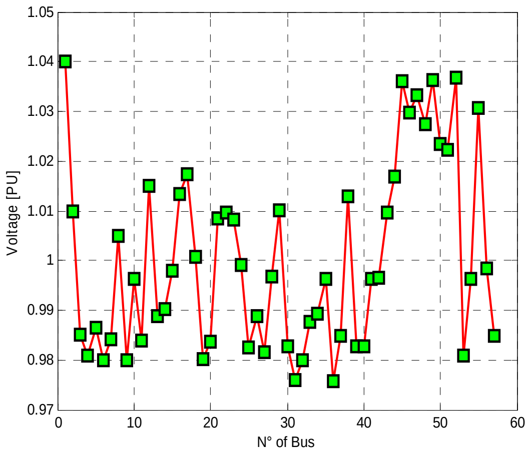

Fig. 9: The voltage levels on (Per Unit) for the IEEE 57-bus Electrical Network After placement of optimal capacitor.

6. Conclusions

In this paper, a novel approach FLC-GAO based genetic algorithm optimization and fuzzy logic controller for OPF problem solutions has been presented. The proposed approach utilizes the fuzzy logic controller for the critical bus identification and the GAO to search the optimal seizing capacitor banks. Instead of FLC_GAO approach different approaches have been employed and compared with the present one to minimize losses for voltage stability enhancement. The proposed approach has demonstrated 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 in OPF problems.

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