ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 11, Iss 11, 2022

Reactive Power Control in Distribution Network by Optimal Location and Sizing ofCapacitor using Fuzzy and SFLA

R.SHANKAR1, T.ARUN KUMAR2, M.MAHESH3

1Professor Annamacharya Institute of Technology and Sciences ,Rajampet, A.P, India,E-mail:shankarr@gmail.com 2 Assistant Professor, Annamacharya Institute ofE-mail:arunkumar.thulasi@gmail.com 3AssistantProfessor,Annamacharya Instituteof Technology and Sciences ,Rajampet, A.P, India,E-mail: muthyalamahesh38@gmail.com Technology and Sciences ,Rajampet, A.P, India,

Article History:

Received: 04-10-2022

Revised: 19-10-2022

Accepted: 27-11-2022

ABSTRACT: This paper presents hybrid method for the Optimal Capacitor placement in radial distribution networks by using Fuzzy and Shuffled Frog Leaping Algorithm (SLFA). The mainobjective of this thesisisto reduce power losses& to improve voltage profile of distribution networks. Here the fuzzy approach is used to find the optimal capacitor locations and Shuffled Frog Leaping Algorithm is used to find the optimal sizes of capacitorwhich are used to reduce the power losses and improve the voltage profile. The SFLA is a meta-heuristic search method inspired from the mimetic evolution of group of frogs when seekingfor food. The SFLA consists of frog leaping rule for local search and a mimetic shuffling rule for global information exchange. The proposed method is tested on IEEE 15-bus IEEE 33-bus, and IEEE 69-bus test systems and the results are discussed.

KEYWORDS: SLFA, Fuzzy Logic Controller, mimetic.

I. INTRODUCTION

A Powersystemisaninterconnected system composed of generatingstations, which convert fuel energy in to electrical energy, and transmission lines that tie the generating station and distribution substations, substation that distribute Electric power to loads (consumers). According tothe voltage levels power system consists of three major components.

1. Generation
2. Transmission
3. Distribution

In generating phase the fuel energy is converted in to electrical energy. Some of the generating plants are thermal plants, hydro, nuclear power plants and some plants are renewable energy resources. The Transmission system is to deliver the bulk power from station to the load centers and large industrial consumers beyond the economical services range of regular primary distribution lines whereas distribution system is to deliver power from power stations or substations to various consumers. Although electric power can be transmitted or distributed in ACor DC butin practice 3-phase 3-wire ac system is universally adopted for trans mission of large blocks of power.

IJFANS INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES

ISSN PRINT 2319 1775 Online 2320 7876

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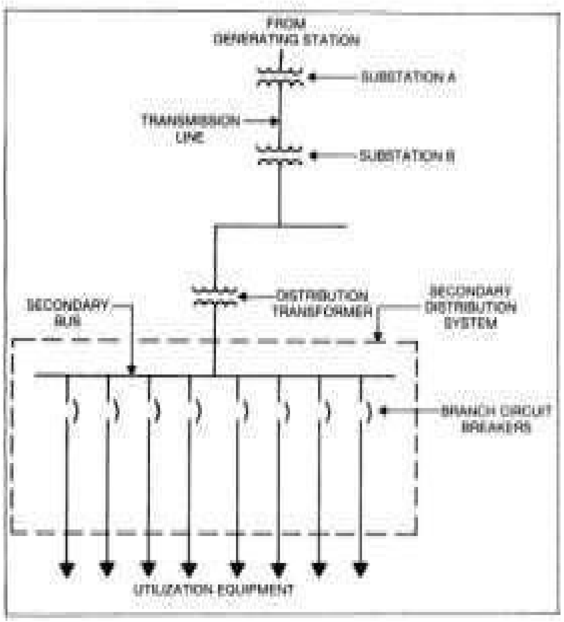

Fig:TypicalElectricalPowerSystem.

Generatingvoltagesareinbetween3.3kVand33kVmostusualvaluesadoptedis around13.2kVmostusualvalueadoptedis around 13.2 kV. Depending upon the voltage of transmission, the transmission system is classified in to

1. Primarytransmission(110kVand above)
2. Secondarytransmission(33or66kV)

II. RELATEDWORK

Withthesedifferenttypesofobjectives in mind, optimal capacitor placement aims to determine the location of a capacitor and its size. Optimalplacementofcapacitorhasbeen investigated over decades.

Optimal capacitor setting has been investigatedsincethe60's,**J.V.Schmill[1]&Duran H [2]** proposed a dynamic programming approach to find the optimum number, location and size of shunt capacitors. These methods are suitable for efficient solution in a digital computer.

Inthe80's,**Baran.M.EandWuF.F [3, 4]** proposed a capacitor sizing problem for capacitorsplacedonaradialdistributionsystem isformulatedasanonlinearprogrammingproblem, and a solution algorithm by Benders decompositionisdevelopedforthecapacitorsizing problem is based on a phase I phase II feasible directions approach.

In the 90's **Sundharajan and A.Pahwa [5]** proposed a dynamic approach of geneticalgorithmfor optimal selection of capacitors for radial distribution systems.

[6-8] presentsoptimalcapacitor placement by reducing the power losses in the distribution systems by using heuristic search strategies.

Inthe2000's**NgH.N.SalamaM.M.A andChikaniA.Y[9]**presentsanovelapproachusingapproximatefuzzyreasoningtodetermine thesuitablecandidatenodesinadistributionsystemforcapacitorplacement.Afuzzyexpert system[FES]containingasetofheuristicrulesis thenusedtodeterminethecapacitorplacement suitabilityofeachnodeinthedistributionsystem.

PrakashK.andSyduluM.[10]presentsa novel approach that determines the optimallocationandsizeofcapacitorsonradial distribution system to improve the voltage profileand reduce the active power loss. Capacitorplacement and sizing are done by loss sensitivity factors and particle swarm optimization respectively.

M.DamodarReddyandV.C.VeeraReddy [11] Presents a paper for optimal capacitor placement using fuzzy and real coded genetic algorithm for maximum savings.

M.DamodarReddyandV.CVeeraReddy [12] Presents a fuzzy and particle swarm optimization (PSO) method for the placement of capacitors on the primary feeders of the radial distributionsystemstoreducethepowerlossesand to improve thevoltage profile.

M.M. Eusuff and K.E Lansey [13,14] proposed a new algorithm shuffledfrog leaping algorithm for optimization of water distribution networkanddiscreteoptimization.The effectiveness and suitability of this method havebeendemonstratedbyapplyingittoaground model calibration problem and water distribution system design problem. Compare to the othermethods the experimental results in terms of likelihoodofconvergencetoglobaloptimal solutionandthesolutionspeedsuggestthat SFLAcanbeeffectivetoolforsolving combinational optimization problems.

Q.Li [15] presents an algorithm i.e. shuffled frog leaping algorithm for based optimalreactivepower flow in the distribution networks for reducing the power losses and improvement of voltage profile.

ISSN PRINT 2319 1775 Online 2320 7876

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III. IMPLEMENTATION OF FUZZYAND SFLAFOROPTIMALPLACEMENT& SIZINGOFCAPACITOR

FuzzyApproach:

Afuzzyapproachisproposedtofinding the suitable locations for placement of acapacitor. Two objectives are considered while designing a fuzzy logic for identifying the optimal capacitor locations. The objectives are:

1. Tomaintaintherealpowerlossand
2. To maintain the voltage within the permissible limits.

Voltages and power loss indices of distribution network nodes are modeled by fuzzy membership functions. A fuzzy inference system (FIS) containing a set of rules is then used to find the capacitor placement. Capacitors are placed on the nodes with the highest suitability.

For the capacitor placement problem approximate reasoning is employed in the following manner when losses and voltage levels of a distribution system are studied, an experienced planningengineercanchooselocationsfor capacitor installations, which are probably highly suitable.For example, it is intuitive that a section inadistributionsystemwithhighlossesandlowvoltage is highly ideal for placement of capacitors. Whereas low section with good voltage is not ideal for capacitor placement. A set of fuzzy rules has been used to load flow solution for the originalsystemis requiredtoobtaintherealandreactivepower losses.Again,loadflow solutions are required to obtain the power loss reduction by compensating the total reactive load at every node of the distribution system. The loss reduction having a value of 1 andthe smallestonehavingavalueof0.Powerloss Indexvaluefor nthnode can be obtainedusing belowequation.

$$PL(n)=[LR(n)-LR(\min)]/[LR(\max)-LR(\min)]$$

These power loss reduction indices along with the p.u. nodal voltages are the inputs to the FuzzyInferenceSystem(FIS),whichdetermines thenodemoresuitableforcapacitor installation. In this present work, Fuzzy Logic toolbox in MATLAB7 is used for finding the capacitor suitability index.

In this thesis, two input and one output variablesareselected.Inputvariable-1isthepower loss index(PLI) and input variable-2 is the per unit nodal voltage (V). Output variable is capacitor suitability index (CSI).

IDENTIFICATION OF SENSITIVE BUS FOR CAPACITOR PLACEMENT:

The fuzzy logicisusedto identify the optimal location to place the capacitor in a radial distributionsystemsoasto minimize the losses whilekeeping the voltage atbuses within the limit and also by taking the cost of the capacitors in to account.

TheFuzzyExpertSystem(FES)containsasetofrules,whicharedevelopedfrom qualitativedescriptions.InaFES,rulesmaybe firedwithsomedegreeusingfuzzyinference, whereasinaconventionalExpertSystem,arule is either fired or not fired. For the capacitorplacement problem, rules are defined to determinethesuitabilityofabusforcapacitor placement. Such rules are expressed in the following general form: IF premise (antecedent), THEN conclusion (Consequent)

Fordeterminingthesuitabilityofaparticular busforcapacitorplacementat aparticularbus, setsof multiple-antecedent fuzzy rules have beenestablished. The inputs to the rules are the bus voltages in p.u., power loss indices, and the output consequent is the suitability ofa bus for capacitor placement.

POWER LOSS INDEX PROCEDURE TO CALCULATE

The power loss index at ith bus, PLI (i) is the variable which is given to fuzzy expert system to identify suitable location for the capacitor.

Step1:Readradialdistributionsystemdata

Step2:Performthe load flowsand calculatethebase case activepowerloss

Step3:Bycompensatingthereactivepower injections (Q)ateachbus(exceptsourcebus)and run the load flows, and calculate the active power loss ineach case.

Step4:Calculatethepowerlossreductionandpower loss indicesusingthefollowingequation

$$PL(i)=[X(i)-Y]/[Z-Y]$$

WhereX(i)=lossreductionatithbus
Y= minimum loss reduction
Z=maximumlossreduction
Step 5 : Stop.

Five membership functions are selected for PLI. They are L, LM, M, HM and H. all the five membershipfunctionsaretriangularasshownin fig-4.1.Fivemembershipfunctionsare selectedfor voltage. They are L, LN, N, HN, and H. these membership functions are trapezoidal and triangular as shown in fig- 4.2. Five membership functions are selected for CSI. They are L, LM, M, HM, and H.thesefivemembershipfunctionsarealsotriangularas shown in fig

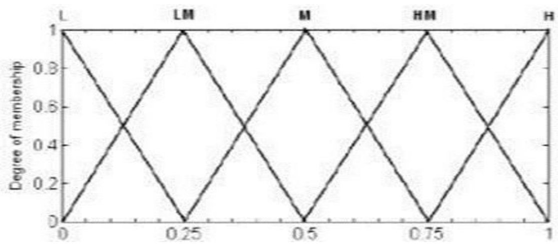

Fig:Membershipfunctionplotforpowerloss index

AND		Voltage				
		L	LM	M	HM	H
PLI	L	LM	LM	L	L	L
	LM	M	LM	LM	L	L
	M	HM	M	LM	L	L
	HM	HM	HM	M	LM	L
	H	H	HM	M	LM	LM

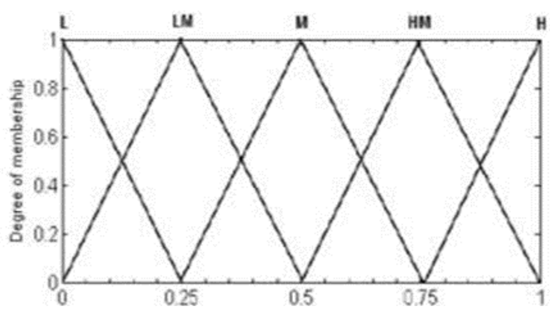

Fig:MembershipfunctionplotforCapacitor Suitability index

The Rule Editor is for editing the list ofrules that defines the behavior of the system. Constructing rules using the graphical Rule Editor interface is fairly self-evident. Based on the descriptions of the input and output variables defined with the FIS Editor, the rule Editor allows us to construct the rule statementsautomatically,by clicking on and selecting one item in each input variable box, one item in each output box and one connection item. Choosing none as one of thevariable qualities will exclude that variable from a given rule.

Choosing not under any variable name will negate the associated quality. Rules may be changed, deleted or added, by clicking on the appropriate button. For the capacitor allocation problem, rules aredefined to determine the suitability of a node for capacitor installation. Such rules are expressed in the below:

IF premise, THEN conclusion. For determiningthesuitabilityofcapacitorplacementata particular node, a set ofmultiple-antecedent fuzzy rules has been established. The inputs to the rules are voltage and power loss indices and the output is the suitability of capacitor placement. The rules are summarized in the fuzzy decision matrix in table 4.1

Table-4.1Decisionmatrixfordeterminingthe optimal capacitor locations.

In the present work 25 rules are constructed. For example:
IfPLIisHandvoltageisLthenCSIisH.
IfPLIisMandvoltageisMthenCSIisLM. If PLI is H and voltage is H then CSI is LM.

The rule viewer is a MATLAB-baseddisplay of the fuzzy inference diagram. Used as a diagnostic, it canshow which rules are active, or how individual membership function shapes are influencing the results. Surfaceviewercandisplayhowoneoftheoutputsdependso nanyoneortwoofthe inputs –that is, it generates and plots an output surface map of the system.

And finally to save the current file uses the commands Export to workspace and Export to disk. By calling this file in the main program, the CSI values corresponding to each bus can be obtained. Thereby, we can find the nodes suitable for capacitor installation.

IV. RESULTS

OptimalCapacitorSizesfor15-BusSystem:

The proposed algorithm is applied to 15 bus testsystem.Optimalcapacitorlocationsare identified based onthe C.S.I values. For this 15-bus system, the optimum locations are identified. Capacitor sizes in optimal locations, total real power losses before and after capacitor compensation are shown in table.

Optimalcapacitorlocations:5

- BasekV=11kV
- BaseMVA=100MVA

Resultsof15-bussystem:

Busnumber	**Capacitorsizein kVAr**
4	344.6547
6	264.9500
7	142.8415
11	300.3639
15	142.9217
TotalkVAr	1195.7318
Totalrealpower lossinkW(before capacitor placement)	61.7944
Totalrealpower lossinkW(after capacitor placement)	29.9079
lossreduction	51.6009

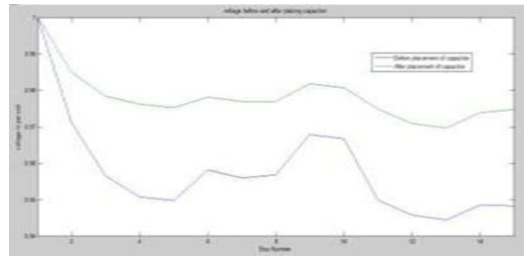

Fig:voltageprofile (beforeandafterplacementof capacitor) for 15-bus system

2Optimalcapacitorsizesfor33-bussystem:

The proposed algorithm is applied to 33 bus testsystem.Optimalcapacitor locationsareidentified based onthe C.S.I values. For this 33-bus system, the optimumlocationsareidentified.Capacitorsizesinoptimal locations, total real power losses before and after capacitor compensation are shown in table.
Optimalcapacitorlocations:2

- BasekV=12.66kV
- BaseMVA=100MVA

Table: Resultsof33bussystem

Busnumber	**Capacitor size in kVAr**
30	826.2841
32	505.2361
TotalkVAr	1331.52
Totalrealpower loss in kW(beforecapacitor placement)	369.2558
Totalrealpower lossinkW(after capacitor placement)	298.6698
%Lossreduction	19.1157

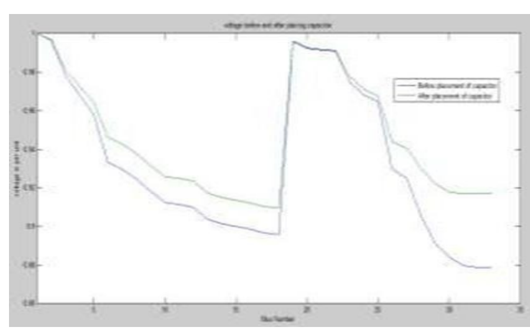

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Fig: Voltageprofile(beforeandafterplacementof capacitor) for 33-bus system

OptimalCapacitorsizesfor69-bussystem:

The proposed algorithm is applied to 69 bus testsystem.Optimalcapacitor locationsareidentified based onthe C.S.I values. For this 69-bus system, the optimumlocationsareidentified.Capacitorsizesin optimal locations, total real power losses before and after capacitor compensation are shown in table optimal capacitor locations: 2

- BasekV=12.66kV
- BaseMVA=100MVA

Table: Resultsof69bussystem

Busnumber	Capacitor size inkVAr
61	829.8772
64	502.1646
TotalkVAr	1332.04
Totalrealpowerlossin kW (before capacitor placement)	225.0041
Totalrealpowerlossin kW (after capacitor placement)	152.3945
%Lossreduction	32.2703

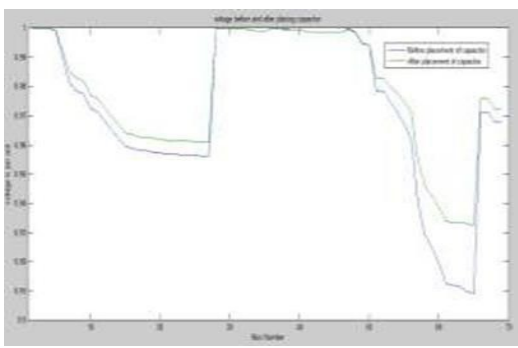

Fig: Voltageprofile(beforeandafterplacementof capacitor) for 69-bus system

V. CONCLUSION:

By placing the capacitors at all the optimal locations, the total reactive power loss of the system has been reduced significantly and bus voltages are improved simultaneously. The fuzzy approachis capableoffindingtheoptimallocationbasedon the CSI values. The proposed shuffle frog leaping algorithmiterativelysearchestheoptimal capacitorsizescorrespondingto minimumloss. Also it is worthy or mentions that the time of performingofthisalgorithmis faster.

Whentheproposedmethod wastestedon15 bus system.

- For 15 bus system it was found that by placing a total of 1195.9 kVAr at different locations (buses4,6,7,11,15)therealpowerlosseswere reducedby51.60%.
- For 33 bus system it was found that byplacing a total of 745.84 kVAr at buses 30, 32 the real power losses were reduced by 19.11%.
- For 69 bus system it was found that by placing a total of1329.6 kVAr at buses 61, 64 the real power losses were reduced by 32.27%.

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ISSN PRINT 2319 1775 Online 2320 7876

 UGC CARE Listed (Group -I) Journal Volume 11, Iss 11, 2022

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