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Optimal Capacitor Placement in Distribution Systems by Using DPSO Algorithm

Rasool Feiz Kerendian[1*], Arash Zeynalzadeh[2] and Javad Ebrahimi[1]

[1]Islamic Azad University-South Tehran Branch

[2]Islamic Azad University- Borojerd Science and Research Branch

*Corresponding Author's E-mail: *rasool.feiz@yahoo.com*

Abstract

Usually the parallel capacitor are used in distribution systems with the goal of reducing power losses, improve voltage profile and etc. These goals are depends on how the capacitors are installation and to achieve them, since the capacitor placement is nonlinear problem and has some equally and inequality constraint, so in this paper the dynamic particle swarm algorithm to solve this problem with consider to the changing in load is used. The issue for the 33 bus system sample is implemented and the results are discussed.

Keywords: Capacitor placement, distribution systems, DPSO, power loss

1. Introduction

Studies show that approximately 13% of the power generated in distribution system is spending at the power losses. However, with increasing demand load, voltage profiles during distribution feeders encounter with the decrease and it is less than the extent permitted. Therefore, due to the power losses, reducing voltage and increasing power demands, the necessity of restructuring issue is sense. The parallel capacitor can help to improve the performance the distribution systems. Till now there are many way is used to capacitor placement that in most of them the demand is constant. In [1, 2, and 3] the Genetic

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Algorithms is used and the Immune algorithm is used to capacitor placement [4, 5]. In [5- 7] the combination of fuzzy logic with optimization is used. In [8, 9] the Particle swarm optimization algorithm is used. Different objectives considered in various papers. For example, in [10] is intended to improve voltage stability, or in reference[8] to reduce losses and costs as a target is selected.

In this paper, adynamicalparticle swarmoptimization algorithmis used. Thisalgorithmisa modified version ofthe conventionalparticle swarmoptimizationalgorithms. DPSOisapowerfulalgorithmforsolvingthe problem ofcapacitor placement, thealgorithmiscodedin binary formand by itsoptimization process can prevent to being in localoptimumrather than theglobaloptimum, It alsoincreases the speedis optimized. The objectivefunctionsconsideredisthetotalcost ofpower losses, energy and moneyofcapacitance placement and thevoltage rangeisconsideredasshackles. The method proposedinthis paperhas been carried outon the bus33 system.

2. Statement of problem

In capacitors placement problem the location and optimal size ofcapacitorin theselection ofsubstationsareconsidered, that has some equally and inequality constraint and arediscussedas follows:

2-1- The objective functions

The objective function in capacitor placement is contained reduce the costofsystemlosses, minimizing thecost ofcapacitor banksand minimizing thevoltagedeviation by consideringtheconstrained, thatdefined as follows:

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2-1-1- Totalactive powerlosses

The firstobjective function isto minimizethe activepower losses inthedistributionsystem[8] thatinequation (1)is expressedin thefollowing:

$$f_1 = \sum_{i=1}^{nb} P\,loss_i \qquad (1)$$

Where:

nb:number ofbranchnetwork

$Ploss_i$:thelosses infundamental frequency

2-1-2- Cost of capacitor placement

Another objectiveisto minimizecost ofcapacitors placement thatis expressedas follows:

$$f_2 = \sum_{j=1}^{nc} Q_j \qquad (2)$$

2-1-3- Minimizingvoltagedeviation

Inthis function, the goal is reducingtheamount of voltage deviation, which is expressedas follows:

$$f_3 = \sum_{i=1}^{nb} (V_n - V_{rated})^2 \qquad (3)$$

2-1-4- Cost function

Totalobjective functionorcost functionisthe totalcostoflosses andcapacitor placement which is expressedas follows:

$$F = k_p f_1 + k_c f_2 + k_v f_3 \qquad (4)$$

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Where:

kc:Annualcost ofreactive power injection

kp: AnnualCostper kWpower losses

kv: penalty coefficienttominimize thedistortionvoltage

2-2- Constrainedproblem

Capacitor placementhasequal andunequalproblemconstraintsthatare expressedas follows:

2-2-1- Voltage constrain

Effectivevoltageofeach substationconsists ofthe maincomponentandharmoniccomponentsthat should be placedin the allowed range ofVmax, Vmin. Thisrangeis expressedby theIEEE-519standard[9]. WhereVmax = 1.1puandVmin = 0.9pu.

$$V_{min} \leq V_n \leq V_{max} \tag{5}$$

2-2-2- Constrain of the number andsize ofcapacitors

Parallelcapacitorsinthe industryareavailable. Parallel capacitorare obtained by Integermultiplesof the smallestcapacitor capacity.

$$Q_{ci} = L.Q_0 \tag{6}$$

Q_0: The smallestcapacity ofthecapacitor

However, due to economic problemsand limitedinstallationspace, total capacityavailable oneach substationnot exceedsalimit.

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$$\sum_{i=1}^{nc} Q_{ci} \leq Q_t \quad (7)$$

Q_t:Totalreactive powerdemand

Inthispaper,the smallestcapacitance ofthe capacitor150 andthe numberineach substation is 15.

3-2- power flow

Power flow musthavehigh speed andgoodperformance. Inthispaper,broomsweepmethodis used to power flow.

2-3-1- process

In this part brooms sweep power flow in fundamental frequency to determine voltage profile, lineflowsandlosses inthe distribution system. Thepower flowis based ontwo matrices[BIBC],that is flowinginjected transformation matrix into thelinesflowand[BCBV]thatis branch currenttransformationmatrix into thesubstationvoltage. Substationvoltagesandlinecurrentsare calculatedaccording tothe following equationasaniterativeprocess:

$$[V]^k = [V_0] - [BCBV].Z.[BIBC].[I]^k \quad (8)$$

Where:

V_0 : Thesubstationreferencevoltagevector

Z: the impedancematrix ofthe network

[V]: vectorofsubstationvoltage

K: number of iterations

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[I]:is thevector ofload current

Thefollowing equationis obtained:

$$I = \left(\frac{P_i+jQ_i}{V_i}\right)^* \qquad (9)$$

3. Particle swarm optimization algorithm

The mainideaof thisalgorithm(PSO)byJamesKennedy andRussellC.Eberhartwas introducedin 1995. In PSOalgorithmThere area number oforganismsthatis calledparticle and they are released is space search of function that we want to minimizing that [8, 9].

3-1- Conventionalparticle swarmoptimization algorithm(CPSO)

InPSOalgorithm, each particleis composedof three-dimensional vectordthatare thesearch space. For i particle there are three vectors, x^i current positionofthe particle, v^i the particlespeed and is the bestposition has everexperienced. is a set ofcoordinatesthatrepresentsthe particle'scurrent position, atany stage ofthe algorithmis repeated, x^i is calculated asasolutiontothe problem. Ifthesituationisbetter thanprevioussolutions, it stored in $x^{i,best}$.

3-1-1- Dynamicparticle swarmoptimization algorithm

The particle in PSOchanges the positions ineach iterationbased on thepersonalbest position, the bestposition,sizeand velocity. The newposition ofthe particleas well astheassociatedweightsdepends onthesevalues. These weightscanbedynamicorstatic. Astaticweight specifiedbymany iterationsof an algorithm, usually setbeforethe programisrun.

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Dynamicweight is changedforeach iteration ofPSO. Weight was introduced byPeramand colleaguesin [11] andwas madetousethe coefficientof proportionality. Dynamicweightsused in thispaperin each iteration, depending onthedifference on particle, the best position are changed.

3-2 implements theDPSOalgorithm capacitorplacement

The implementationofthe algorithmisas follows:

1. Read datalineand load
2. Set the level of load
3. Performedpower flowto obtain thesubstationvoltageandlinelosses
4. Implementation DPSOalgorithmto determine thelocation andcapacity ofthecapacitor inload.
5. If thealgorithmconverges, goto the step 6, otherwise gobackto step 4.
6. Power flow and determining the substationvoltageand system loss after optimal capacitor placement.
7. End

4. Simulation results

Tosolvethe problem ofcapacitor placement and showthe power of DPSOalgorithm, it usedin two33substationIEEEsystem. The Informationof thissystemisobtained from [12]. Maximumandminimumvoltages are1.1 and0.9 p.u. The annualcostper kWof power loss andenergyinthereference[8] is considered 168$ / kW. Cost ofreactive power injectioncan be seeninthe table below:

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Table1:Cost ofreactive power injection

Q_c(kVAR)	150	300	450	600
K_c($/kVAR)	0.500	0.350	0.253	0.220
Q_c(kVAR)	750	900	1050	1200
K_c($/kVAR)	0.276	0.183	0.228	0.170
Q_c(kVAR)	1350	1500	1650	1800
K_c($/kVAR)	0.207	0.201	0.193	0.187
Q_c(kVAR)	1950	2100	2250	2400
K_c($/kVAR)	0.211	0.176	0.197	0.170

4-1- Specificationsofnetworksbeforecapacitor placement

Power flow before capacitor placement is expressedasfollows:

Table2: 33substationsystem specificationsbeforecapacitor placement

Total power losses	210.98 Kw
The totalannual cost	35445$
The LowestVoltageSystems	0.9038 p.u. Related tosubstation18

4-2- The results after CapacitorplacementbyDPSOalgorithm

Inthispart, optimal locationand amount ofcapacitanceis performed.

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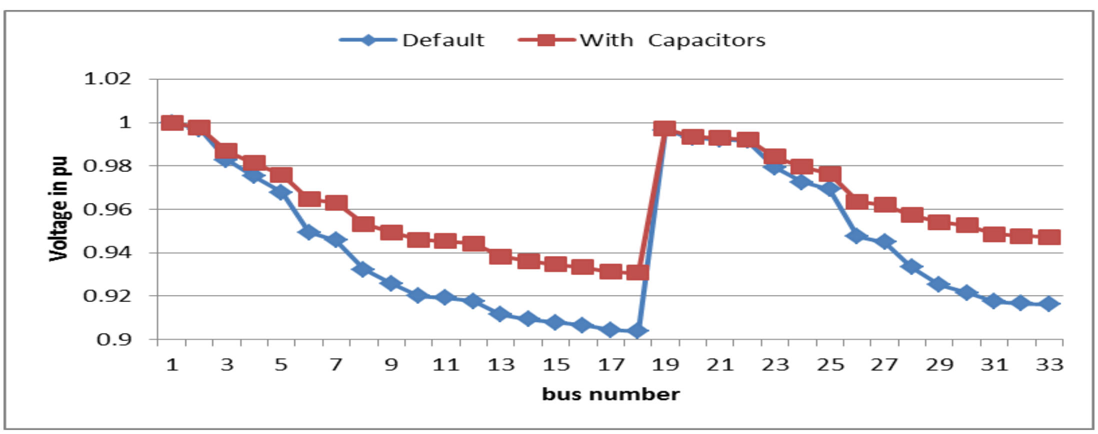
Table3: system specifications of 33substationsaftercapacitorplacement

Substation Number	Amount of capacitor (k var)
12	450
24	450
30	1050

Table4: Comparison of power flowresultsbefore and afterthe capacitanceplacement

33substationsystem	Before capacitor placement	After capacitor placement
Lowest voltage (p.u.)	Substation 18-0.9307	Substation 18-0.9307
HighestVoltage(p.u)	Substation 2-0.9970	Substation 2-0.9977
Power losses(kw)	210.98	138.42
Annualcost ofenergy losses	35445	23255
Capacitorsplacementcost	0.0	467.1
Total cost	35445	23722



Figure(1): diagram ofsubstationvoltage profilesbefore andafter thecapacitorsplacement

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4-3- Analysis

The standardsystemisasystem of33buses, after applying theproposed method onsystemand optimal capacitor placement, the voltage profiles is improved andreactive lossesis reduced.

Conclusion

Optimal Capacitorplacement in distribution networkscaused the reduceoflosses, improve voltage profilesand release the line capacity. In this paper the capacitor placement was performed for Standard33substationsystem. According to theresults, the optimalcapacitor valueobtainedfor thesystem. The resultsindicatethe highperformance ofDPSOalgorithmindiscreteissuessuch asthe capacitorisplacement. High speed,high performanceand flexibilityofthealgorithmshowthat, we can use this algorithm as software at optimal capacitor placement in real distribution network.

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