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Congestion Management in Power System by Optimal Location And Sizing of UPFC

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Abstract: *This paper presents a particle swarmoptimization (PSO) based algorithm to perform congestionmanagement by properplacement and sizing of one unified power flow controller (UPFC). The proposed approach makes use of the PSOalgorithm to allocate the near-optimal GenCos as well as the optimal location and size of UPFC whereas the Newton–Raphson solution minimizes the mismatch of the power flow equations. Simulation results (without/with the line flowconstraints, before and after compensation) are used to analyses the impact of UPFC on the congestion levels of the5-bus test system.*

I. Introduction

Promising idea has been rapidly developing over the last two decades for controlling the power flow in transmission lines with the application of flexible AC transmission systems (FACTS) through the utilization of large power converters. Different approaches have been presented for optimal placement of FACTS devices [1] including sensitivity analysis[2], congestion management by interline power flow controller and unified power flow controller (UPFC) [3].Application of artificial intelligent approaches for optimal congestion management is increasing in deregulated power systems. Recent approaches are mainly based on market models, particle swarm optimizations (PSOs) [4],genetic algorithms (GAs) and sensitivity analysis.Some studies have concentrated on maximizing social and individual welfare, as well as, social welfare considering reactive power and congestion management in deregulated environments.On the other hand, there have been a few studies on the UPFC application for congestion management. An artificial bee colony algorithm is proposed into minimize the generation fuel costs using UPFC unit[5].

This paper proposes a PSO-based algorithm for alleviatingcongestion in power systems by optimalplacement and sizing of one UPFC. The cost of UPFC is alsoincluded as the location index of merit in the optimization process. Simulations are performed to investigate the impactof UPFC oncongestion levels of the 5-bus test system.

II. Mathematical Model Of Upfc

In this paper, UPFC is selected to improve congestion management because of its flexibility and abilities in regulating the bus voltage and simultaneously controlling the active and reactive power flow.

2.1 Power injection model of UPFC

Newton–Raphson power flow formulation is used and UPFC is represented using the power injection model[6, 7], UPFC consists of two back-to-back voltage-source converters connected to power system through series and parallel power transformers.Impacts of UPFC on the network is reflected by a series connected voltage source $V_T$and W_T, shunt current sources I_T and I_q, connected to the network through series and shunt transformers as shown in Fig. 1. Therefore UPFC includes three adjustable parameters: voltage magnitude and phase angle of the series transformer ($V_T$and W_T) and reactive current (I_q) of the shunt transformer. According to Fig. 1, UPFC can be modeled based on the followingequations

$$I_i = I_T + I_q + I_i^{'} \quad (1)$$

$$I_T = \frac{Re[V_T \times I^{'*}]}{V_i} \quad (2)$$

$$V_i^{'} = V_T + V_i \quad (3)$$

The real and reactive power injections at buses i and j with a UPFC unit connected in lineij can be expressed as

$$S_{ij} = P_{ij} + jQ_{ij} = V_i \times I_{ij}^{*} = V_i \times (I_i + jV_iB/2)^{*} \quad (4)$$

$$S_{ji} = P_{ji} + jQ_{ji} = V_j \times I_{ji}^{*} = V_j \times \left(jV_jB/2 - I_i^{'}\right)^{*} (5)$$

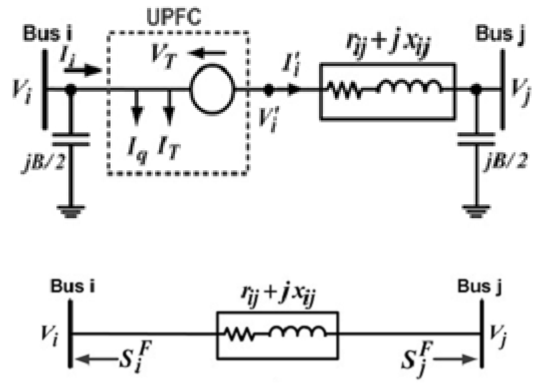

Figure.1 Model of transmission line with an UPFC

$$P_{is} = -g_{ij} V_T^2 - 2V_i V_T g_{ij} cos(\varphi_T - \delta_i) + V_j V_T \left[g_{ij} cos(\varphi_T - \delta_i) + b_{ij} sin(\varphi_T - \delta_i)\right] \quad (6)$$

$$P_{js} = V_j V_T \left[g_{ij} cos(\varphi_T - \delta_i) + b_{ij} sin(\varphi_T - \delta_i)\right] \quad (7)$$

$$Q_{is} = V_i V_q + V_i V_T \left[g_{ij} sin(\varphi_T - \delta_i) + b_{ij} cos(\varphi_T - \delta_i)\right] \quad (8)$$

$$Q_{js} = -V_j V_T \left[g_{ij} sin(\varphi_T - \delta_i) + b_{ij} cos(\varphi_T - \delta_i)\right] \quad (9)$$

Where B, g_{ij}, b_{ij}, P_{is}, Q_{is}, P_{js} and Q_{js} are line charging admittance, conductance of line ij, susceptance of line ij, and active and reactive power injections at buses i and j, respectively. Equations (6)–(9) are added to the Jacobin matrix in load flow formulations.

2.2 Cost of UPFC

For more practical optimal placement and sizing of FACTS devices, it is recommended to also consider their investmentcosts in the OF [8].

$$C_{UPFC} = 0.0003S_{UPFC}^2 - 0.2691_{UPFC} + 188.22 \quad (10)$$

Where C_{UPFC} and S_{UPFC} are the total investment cost (in US$/kVar) and the size (in MVar) of UPFC, respectively.

III. Problem Formulation

3.1 Objective function

In the market-based power systems, the conventional objective of market operator is to minimize the total generation cost. In this paper, the costs associated with congestion and voltage profile improvement are also included in the OF. Therefore we are faced with a more complex multi-objective optimization problem that includes load flow equality and operational inequality constraints

$$min\left\{\sum_{i=1}^{n}\left(\frac{TGC_i}{TGC_{Base,i}} + \frac{VV_i}{VV_{Base,i}}\right) + n * C_{UPFC}^{Annual}\right\} \quad (11)$$

Where TGCi, and VVi are the total GenCos and voltage violation respectively.

3.2 The GenCos cost functions

To allocate the best network settings that minimize the overall generation cost function while imposing all network constraints. In this paper, the overall generation cost function is modeled by a quadratic function as follows

$$TGC\ (P_G) = \sum_{i=1}^{N_G}\left(a_{gi} + b_{gi} P_{Gi} + c_{gi} P_{Gi}^2\right) \quad (12)$$

3.3 The Voltage Violation

Voltage violation is to allocate the best network settings that minimise the overall voltage violation while imposing all network constraints. In this paper, the overall voltage violation function is presented by the following quadratic function

$$VV = \sum_{i=1}^{NB} PF \times (V_i - 1)^2 \quad (13)$$

Where V_i is the voltage magnitude of bus i, NB is the number of buses in the test system and PF is the voltage penalty factor.

3.4 The UPFC cost function

In this paper, one UPFC unit is used to minimise the total system cost (including the total GenCos and congestion costs) andimprove the voltage profile.

$$Min \quad \sum_{j=1}^{n}\left\{\frac{\sum_{i=1}^{N_G}(a_{gi}+b_{gi}\,P_{Gi}+c_{gi}\,P_{Gi}^2)}{\sum_{i=1}^{N_G}(a_{gi}+b_{gi}\,P_{G\,Base\,,j}+c_{gi}\,P_{G\,base\,,j}^2)}+\frac{\sum_{i=1}^{NB}PF\times(V_i-1)^2}{\sum_{i=1}^{NB}PF\times(V_{Base\,,i}-1)^2}\right\}+n\times C_{UPFC} \quad (14)$$

3.5 Constraints

In this paper, the OF (11) is subjected to the followingconstraints:

1. Power injection: The net injections of real and reactivepower at each bus are set to zero.
2. Generation limits: The limits on the maximum andminimum active (PG) and reactive (QG) power generation ofthe generators are included as

$$P_{Gi}^{min} \le P_{Gi} \le P_{Gi}^{max}\ , \qquad Q_{Gi}^{min} \le Q_{Gi} \le Q_{Gi}^{max}$$

$$i = 1,2,\ldots,N_G$$

Where P_{Gi} and Q_{Gi} are the active and reactive powergeneration vectors at bus G_i, respectively.

Compensation limit: The maximum and minimum valuesof UPFC parameters are included as

$$V_T^{min} \le V_T \le V_T^{max}$$

$$\varphi_T^{min} \le \varphi_T \le \varphi_T^{max}$$

$$I_q^{min} \le I_q \le I_q^{max}$$

IV. Development Of Proposed Pso

One of the most difficult parts encountered in practical engineering design optimizations is handling constraints. Real-world limitationsfrequently introduce multiple, nonlinear and non-trivial constraints in the engineering design problems. Constraintsoftenlimitthefeasible solutionstoasmallsubsetofthedesignspace.A generalengineeringoptimizationproblemcanbedefinedasfollows:

4.1 PSOBasedOPF

Thoughawidevarietyofoptimizationtechniques havebeenappliedforsolvingthe singleobjectiveOPFproblemasmentionedearlierbuttheresults obtainedbyusingPSO methodaremuchmore promisingandbetterascomparedtoothertechniques[13].Many advantages ofPSOovertheothertechniquesinclude;-

Itisless susceptibleinbeingtrappedtolocalminima.

- Itcandealwithnon-differentiableobjectivefunctions.
- Itismoreflexibleand robust.
- Noproblemofprematureconvergence.
- Solutionqualityindependentoftheinitialpopulation.

4.2 PSOAlgorithmforOPF problem

Thevarious stepsinvolvedintheimplementationofPSOtotheOPFproblemare

Step1:Inputparametersofsystem,andspecifythelowerandupperboundariesofeach variable.

Step2:Initializerandomlytheparticlesofthe population.These initialparticlesmustbe feasiblecandidatesolutions that satisfythepracticaloperationconstraints.

Step3:Toeachparticlesofthepopulation,employtheNewton-Raphsonmethodtocalculatepowerflow andthetransmissionloss.

Step 4:Calculatetheevaluation valueofeach particle, inthepopulationusing theevaluationfunction.

Step5:Compareeachparticle’sevaluationvaluewithits*gBest*.Thebestevaluation valueamongthe*pBest*is denotedas *gBest.*

Step6: Update thetimecounter*t*=t+1

Step7: Updatetheinertiaweight*w*givenby

$$W = W_{max} - \frac{W_{max} - W_{min}}{iter_{max}} = iter \quad (15)$$

Step8:Modifythevelocity*v*ofeachparticleaccording to the mentionedequation.

$$V(k,j,i+1) = w * V(k,j,i) + C1 * rand * (pbestx(j,k) - x(k,j,i) + C2 * rand * (gbestx(k) - x(k,j,i))(15)$$

Step9:Modifythepositionofeachparticleaccordingtothementionedequation.Ifa particleviolates theits positionlimitsinanydimension,setits positionattheproperlimit

$$x(k,j,i+1) = x(k,j-1,i) + v(k,j,i)(16)$$

Step10:Eachparticleisevaluatedaccordingtoitsupdatedposition.Iftheevaluation valueofeach particleisbetterthantheprevious*pBest*,thecurrentvalueissettobe *pBest.* Ifthebest*pBest*is betterthan*gBest*,thevalueis settobegbest.

Step11:i f oneofthestoppingcriteriaissatisfiedthengotoStep12.Otherwise,goto Step6.

Step12:Theparticlethatgeneratesthelatest*gBest*is theoptimalvalue.

Theparametersthatmustbeselectedcarefullyfortheefficientperformanceof PSOalgorithmare:-

a. Bothaccelerationfactors C_1 &C_2.
b. Numberofparticles.
c. Theinertiafactor.
d. The searchwillterminateifoneofthebellowscenariois encountered:

|gbest (i)-gbest (i-1)|<0.0001for50iterations
Maximumnumberofiterationreached (500iterations)

e. Numberofintervals N,whichdeterminethemaximumvelocityv_k^{max}.

V. Resultsand Discussion

Matlabprogrammingcodesfor PSO and modified power flowalgorithm toincludeUPFCaredevelopedand incorporated together for the simulation purposes in this work.Thesuggestedalgorithmisappliedtothe5- bus test system.

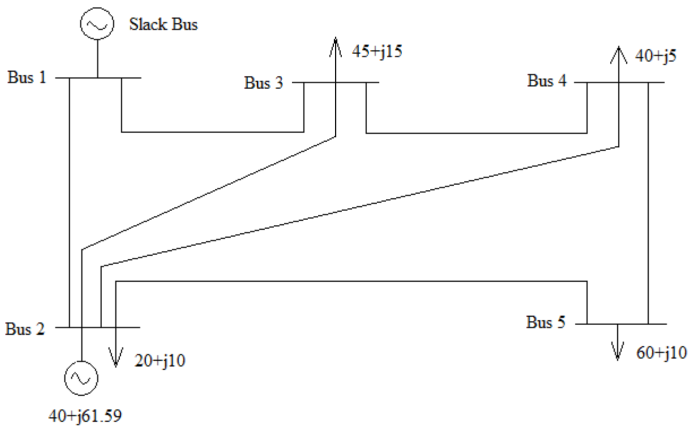

Figure 2.5 Bus test System

Table -1 UPFC rating

Parameter	Rating
X_{cr}	0.1
X_{vr}	0.1
P_{sp}	0.4
P_{Sta}	1
Q_{sp}	0.02
Q_{Sta}	1
V_{cr}	0.04
T_{cr}	-87.13/57.3
V_{crLo}	0.001
V_{crHi}	0.2
V_{vr}	1.0
T_{vr}	0.0
V_{vrLo}	0.9
V_{vrHi}	1.1
V_{vrTar}	1.0
V_{vrSta}	1.0

Table-2 comparative result of Without UPFC and With UPFC

Line		Without UPFC		With UPFC	
From	To	Line Flow (MVA)	Line Loss (MVA)	Line Flow (MVA)	Line Loss (MVA)
1	2	90.251	9.210	92.334	9.025
1	3	41.147	7.499	39.82	7.818
2	1	87.636	9.210	89.643	9.025
2	3	24.787	7.687	22.183	7.964
2	4	28.098	7.416	31.161	7.032
2	5	54.752	3.369	56.503	3.171
3	1	39.629	7.498	38	7.818
3	2	24.912	7.687	21.653	7.964
3	4	20.488	4.160	18.521	4.193
4	2	27.808	7.416	31.346	7.032
4	3	19.245	4.160	15.955	4.193
4	5	7.802	10.509	7.445	10.459
5	2	53.8	3.369	55.539	3.171
5	4	8.746	4.160	6.664	10.459

VI. Conclusion

Inthispaper,theeffectivenessoftheoptimallocationofUPFCforenhancingthesecurityofpowersystems by alleviate the congestionunder singleline contingencies has been investigated.A PSO technique has beensuccessfully appliedtotheproblem underconsideration. Alleviation of congestion is consideredas the optimization criterion.

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