THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Optimal Location of UPFC by Using Modified Particle Swarm Optimization for Voltage Stability

Kumar D.
PG Student, EEE Department, Kottam College of Engineering, Kurnool, India
K. Siva Ramudu
Assitant Professor, EEE Department, Kottam College of Engineering, Kurnool, India
P. Naga Prasad
Assitant Professor, EEE Department, Kottam College of Engineering, Kurnool, India

Abstract:
Voltage security is a crucial issue in power systems especially under heavily loaded condition. In the new scheme of restructuring, voltage stability problem becomes even more serious. In order to solve the kind of thorny problem, experts employ various methods for relieving congested difficulties. There are many new power-electronics-based devices using to solve the difficult problems recently. Unified Power Flow Controller (UPFC) is the most powerful device of these devices. A new model is proposed in this thesis to improve existing power-based model by using the Norton Equivalent Theorem. The proposed model can be integrated with the Equivalent Current Injection (ECI) power flow model easily. By ECI algorithm, it is much quickly and precisely to implement power flow calculations. By making use of modified particle swarm optimization (MPSO), the optimal location of UPFC in power system will be obtained. Finally simulation shows the optimal location and capacity of new UPFC with ECI model to enhance power system voltage stability by using MPSO. The proposed method demonstrates the improvement of voltage stability margin.

Keywords*: Modified particle swarm optimization (MPSO), voltage stability, Unified Power Flow Controller (UPFC), Equivalent -Current-Injection (ECI)*

1. Introduction

Power systems components mainly consist of generators, transmission lines, transformers, switches, active or passive compensators and loads. Power system networks are complex systems that are nonlinear, non-stationary, and prone to disturbances and faults. Reinforcement of a power system can be accomplished by improving the voltage profile, increasing the transmission capacity and others. Flexible AC Transmission System (FACTS) devices are an alternate solution to address some of those problems.

The FACTS devices can be categorized into three types, such as series controllers, shunt controllers and combined series-shunt controllers. In principle, the series controllers inject voltage in series with the line and the shunt controllers inject current into the system at the point of connection. The combined series-shunt controllers inject current into the system with the shunt part of the controllers and voltage in series in the line with the series part of the controllers.

In the case of voltage support, shunt FACTS devices, such as STATCOM and SVC are typically used. This study is focused on the steady state performance of multiple UPFC devices in the power system. Particularly, it is desired to determine their optimal location and capacity.

Traditional optimization methods such as mixed integer linear and non linear programming have been investigated to address this issue; however difficulties arise due to multiple local minima and overwhelming computational effort. In order to overcome these problems, Evolutionary Computation

Techniques have been employed to solve the optimal location of FACTS devices.

This paper applied the ability of the modified particle swarm optimization (MPSO) efficiency. The objective of MPSO is to improve the searching quality of ants by optimizing themselves to generate a better result. This method can not only enhance the neighborhood search, but can also search the optimum solution quickly to advance convergence.

The load flow analysis (commonly called load flow or power flow) is the basic tool for investigating power system state variables, and it is very important part of the system supervisory, planning and optimal operation. The unbalance three-phase load flows based on the Equivalent-Current-Inject (ECI) were applied successfully to the distribution system It is unable to apply the ECI model to the high voltage transmission systems, because of the voltage – controlled buses (PV Bus). In this a new power flow approach based on ECI model and Cartesian coordination is presented. PV Bus model were developed, and according to the network characteristics, the decoupled models were also proposed.

This paper introduces the application of MPSO for optimal location and capacity of a new UPFC with ECI model in the power system. It is organized as follows: Section II UPFC with ECI. Section III presents the basic concepts of modified particle swarm optimization (MPSO). In section IV the objective function to be optimized is described. In section V simulation results are presented. In section VI conclusions and future work are given.

2. UPFC with ECI Model

2.1. UPFC Basic Concept

The Fig. 1 shows a conceptual representation of UPFC in a two-machine power system. In Fig. 1, the series branch of UPFC is modeled as a generalized synchronous voltage, and represented at the power system frequency by voltage phasor, *VCR*, and its phase angle, ρ, in series with the transmission line. Therefore, it is clear that the effective sending end voltage is modified by the UPFC series injected voltage in both magnitude and it phase angle, and as a result it is able to control, by adjusting the magnitude and the phase of V_{CR}, the transmittable active power as well as the reactive power. Moreover, in dynamic control applications, it is also able to provide power oscillation damping by real-time modulating the real power of the ac system. This is the result of its ability to alternatively insert a virtual positive and negative damping resistor in series with the line in accordance with the angular acceleration and deceleration of the disturbed generators.

In practical hardware implementations, the UPFC consists of two voltage sourced converters, as illustrated in Fig. 1. The two back-to-back converters, as labeled “Shunt Converter” and “Series Converter” in the figure are designed to be operated from a common DC link voltage supported by a DC storage capacitor. In normal operations, the phase angle of the series voltage can be chosen independently of the line current between 0 and 2π, and its magnitude can be varied between zero and a pre-specified maximum value. Therefore the real power can freely flow in either direction between the AC terminals of the two converters and each converter can also generate or absorb reactive power independently at its own AC output terminals to affect system voltages.

In the UPFC system, Series Converter, the series branch, operated as a SSSC, is used to perform the main control functions of a UPFC. It generates voltage, VCR, at the system frequency controlled by a proper switching control technique. During the operation the voltage, VCR, is added to the AC system terminal voltage, V_k, by the series connected injection series transformer, T_{se}. The transmission line current

flows through this voltage source resulting in reactive and active power exchange between it and the ac system. The reactive power exchanged at the ac terminal is generated internally by the converter. The active power exchanged at the ac terminal is converted into dc power which appears at the dc link as a positive or negative active power demand.

Shunt Converter connected in shunt with the AC power system via a shunt transformer, T_{sh}, operated as a STATCOM, is used primarily to provide the real power demand of series converter at the common DC link terminal from the AC power system. Since shunt converter can also generate or absorb reactive power at its AC terminal, independently of the real power transferred to (or from) the DC terminal. It follows that, with proper controls, it can also fulfill the function of an independent STATCOM operations providing reactive power compensation for the transmission line and thus executing an indirect voltage regulation at the input terminal of the UPFC.

It is important to note that there is a closed direct path for the active power negotiated by the action of series voltage injection through two converters back to the line, the corresponding reactive power exchanged is supplied or absorbed locally by series converter and therefore doesn’t have to be transmitted by the line. Thus, shunt converter can be operated at a unity power factor or controlled to have a reactive power exchange with the line independent of the reactive power exchanged by converter 2. Obviously, there is no reactive power flow through the UPFC dc link. In addition, the UPFC has the flexibility the control either its series or shunt branch or both to achieve a desired effect on the power flow transmitted between two buses.

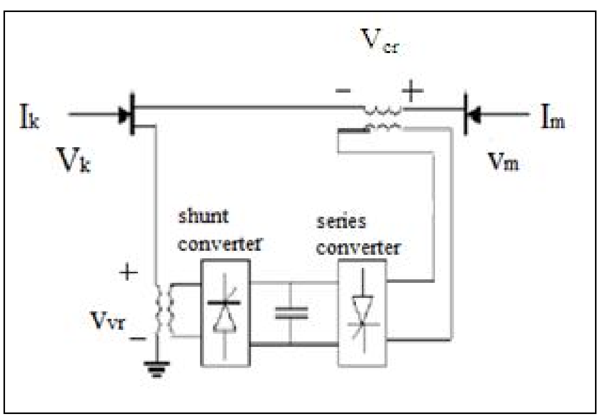

Figure 1: UPFC Connected to power system

The UPFC active *Pm* and reactive power *Qm* are shown in (1) and (2).

$$P_m = \frac{(V_k + V_{CR}) \cdot V_m}{X} \sin\delta$$
$$Q_m = \frac{(V_k + V_{CR}) \cdot V_R}{X} (1 - \cos\delta)$$

where *X*: is coupling transformer equivalent reactance .δ: θ_k-θ_m

In voltage control mode, the reactive current is automatically regulated to maintain the transmission line voltage at the point of connection to a reference value, with a defined droop characteristic. The droop factor defines the per unit voltage error per unit of reactive current within the current range of the converter. The convert supplies leading current to the AC system if the converter output voltage *Vsh* is made to lead the corresponding AC system voltage *Vk*. Then it supplies reactive power to the AC system by capacitive operation. Conversely, the converter absorbs lagging current from the AC system; if the converter output voltage *Vsh* is made to lag the AC system voltage *Vk* then it absorbs reactive

power to the AC system by inductive operation. If the output voltage is equal to the AC system voltage, the reactive power exchanges.

2.2. UPFC with ECI

The UPFC can act as on equivalent voltage source series reactance. Voltage source can transform the current source byway of Norton Theorem of the π-circuit as shown in Fig. 2. It is important to note that there is a closed direct path for the active power negotiated by the action of series voltage injection through converter 1 and 2 back to the line.

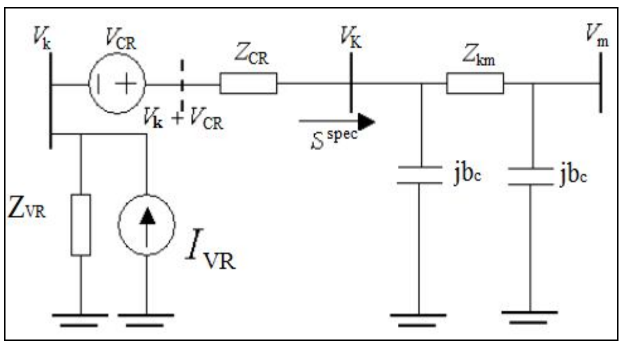

Figure 2

According to Fig. 2 with ECI model inferential reasoning as follows in equations.

$I_{VR}=V_{VR}/Z_{VR}$

That is the device does not generate or absorb active power internally. This constraint can be stated as:

$P_{CR}=P_{VR}$

$S_{VR}=V_K I^*$

$=V_K\{(V_K-V_{VR})/Z_{VR}\}^*$

$= (V_K^2/Z_{VR})-V_K (V_{VR}/Z_{VR})^*$

$= (V2_K/Z^*_{VR}) - V_K I^*_{VR}$

Where I_{VR}=Branch current

V_{VR}=Shunt branch voltage

Z_{VR}=Shunt branch impedance equals $R_{VR}+JX_{VR}$

P_{CR}, P_{VR}: are the active powers supplied or absorbed in the series and shunt converters respectively.

According to the Newton-Raphson algorithm, the ECI mismatch equation with UPFC model can be written a new admittance matrix as

$I_{K,K'}=S^{SPEC}/V_{K'}$

$I_{K,K'}=(V_K+V_{CR}-V_{K'}).(g_{cr}+jb_{CR})$

$I=Y^{NEW}{}_{MATRIX}V$

$$\begin{bmatrix} \vdots \\ I_k \\ \vdots \\ \bar{I}_k \\ \vdots \\ I_{k,k'} \end{bmatrix} = \begin{bmatrix} \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & g_{cr}+jb_{cr} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \vdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & -g_{cr}-jb_{cr} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \vdots \\ 0 & g_{cr}+jb_{cr} & 0 & -g_{cr}-jb_{cr} & 0 & g_{cr}+jb_{cr} \end{bmatrix} \begin{bmatrix} \vdots \\ V_k \\ \vdots \\ V_{K'} \\ \vdots \\ V_{cr} \end{bmatrix}$$

where $g_{CR}+jb_{CR}=1/(Z_{CR})$, *S*spec is the specified constant apparent power,

$$Y_G^{new} = \mathrm{Re}\left(Y_{matrix}^{new}\right),\ \ Y_B^{new} = \mathrm{Im}\left(Y_{matrix}^{new}\right).$$

3. Modifiedparticleswarm Optimization

3.1. Basic PSO

PSO, as a population-based algorithm, exploits a population of individuals to probe promising regions of the search space. The population is called a swarm and the individuals, particles. As the swarm iterates, the fitness of the global best solution improves (decreases for minimization problem). It is expected to happen that all particles being influenced by the global best eventually approach the global best. If the fitness does not improve despite however many runs the PSO is iterated, then convergence has been achieved. In the pioneering work of Kennedy and Eberhart in 1995, the particle position and velocity is defined by
where:
[i],[j]: Population number and particles number.
V[i_k][j] : Velocity of the particle in the kth iteration.
X [k_i][j] : Position of the particle in the kth iteration.
X _ L_{best}[ki][j] : Ith fitness best in the kth iteration.
X _ G_{best}[ki][j] : Population global best in the k th iteration.
C1, *C2*: Cognitive and Social component, respectively: they influence how much the particle's personal best and the global best (respectively) influence its
movements.
rand1 , rand2: Uniform random numbers between 0 and 1.

3.2. Modified PSO

A weight factor, ω*k*, was added to the previous velocity of the particle. This allows control on the mechanism responsible for the velocities magnitude, which fosters the danger of swarm explosion and divergence, or fast convergence and being trapped in local minima. Thus, equation (10) can be re-written including the weight factor, ω_k.

$$\begin{aligned} V_{[i][j]}^{k+1} &= \omega_k * V_{[i][j]}^{k} + C_1 \cdot rand_1 \cdot (X\_Lbest_{[i][j]}^{k+1} - X_{[i][j]}^{k+1}) \quad (11) \\ &+ C_2 \cdot rand_2 \cdot (X\_Gbest_{[i][j]}^{k} - X_{[i][j]}^{k+1}) \\ X_{[i][j]}^{k+1} &= X_{[i][j]}^{k+1} + V_{[i][j]}^{k+1} \end{aligned}$$

The second challenge is to find a feasible weight factor that prevents prematurely because it affects the convergence and the ability of the swarm to find the optimum. A suitable value of ω*k* provides the desired balance between the global and local exploration ability of the swarm and, consequently, improves the effectiveness of the algorithm. At the beginning, a large inertial weight is better because it gives priority to global exploration of the search space. It can be gradually decreased so as to obtain refined solutions. To introduce chaotic behavior, the iterator called Logistic Map is defined by the following equation:

$$f_k = \mu \cdot f_{k-1}(1 - f_{k-1})$$

Where μ is a control parameter and has a real value between 0 and 4. Despite the apparent simplicity of the equation, the solution exhibits a rich variety of behaviors. The value of μ determines whether *fk* stabilizes at a constant size, oscillates between a limited sequence of sizes, or behaves chaotically in
an unpredictable pattern. And also the behavior of the system is sensitive to initial values of *fk*. Equation (12) displays chaotic dynamics when μ=4.0 and Ï 0 *f*
{0, 0.25, 0.5, 0.75, 1.0} [18]. After some tests, the value chosen for *_0*, μ and *f*0 are 3.5, 4.0 and 0.65, respectively. Therefore, the weight inertial factor is calculated in every kth iteration as:

$$\omega_k = \left\{ \frac{\omega_0}{1+(\log k)^2} \right\} \cdot (f_k) \qquad (13)$$

4. Objective Function

In such a power network, it is desirable to keep the voltage deviations between ±5% to avoid voltage collapses during faulty conditions. In general, if the load requirements increase, the voltages at the corresponding buses may drop below 0.95p.u. and consequently an additional voltage support is needed at that particular bus. In this study, the voltage support will be provided by a UPFC with ECI model, and its optimal location and capacity will be determined by using MPSO.

For instance, the IEEE 30-Bus system in Fig. 4 has 5 generators buses where voltage is regulated by the generator AVRs. These generator buses do not need a UPFC and are omitted from the MPSO search process. Also considering the topology of the system, the bus numbers are limited to the range from 1 to 30.

4.1. UPFC selection to install the location principle

- Because UPFC are expensive, therefore the minimum device installed is searched for economic efficiency reasons.
- Generator buses where voltages are regulated by the generator do not need UPFC installation.
- Each bus is limited to the installation of one device. Installing more does not represent a significant effect.
- If the bus voltage is above 0.95 p.u., then UPFC is not installed.

According to the above discussion, candidates Bus are

5. Simulation Results

A 30-Bus test system as shown in Fig. 3 is used for this paper. The test system consists of 5 generators and 24 PQ bus (or load bus). The problem to be addressed consists of finding the optimal location (bus number) and power rating (MVA) of UPFC with ECI model. In this case the MPSO is able to find different options for capacity of the UPFC with the ECI model.

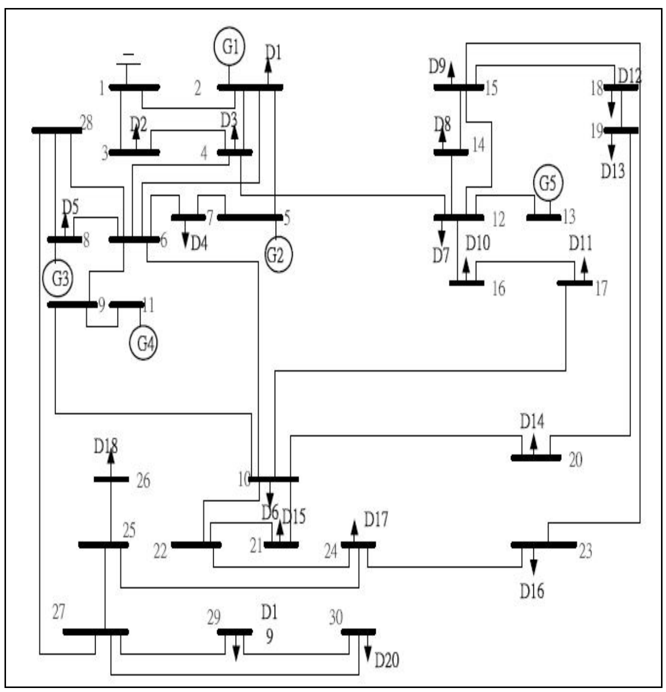

Figure 3: The 30-bus test system

BUS No.	V_{mag} (pu)	V_{angle}	Active (P)	Reactive (Q)
1	0.8480	0	2.0876	-16.3343
2	0.8360	-4.3026	0.1464	34.6956
3	0.8169	-6.0229	-0.0192	-0.9600
4	0.8098	-7.4235	-0.0608	-1.2800
5	0.8080	-11.3190	-0.7536	13.327
6	0.8085	-8.8440	0.0000	0.0000
7	0.8021	-10.2819	-0.1824	-8.7200
8	0.8080	-9.4379	-0.2400	4.8890
9	0.8409	-11.2784	-0.0000	-0.0000
10	0.8363	-12.5505	-0.0464	-1.6000
11	0.8656	-11.2784	0.0000	12.8460
12	0.8459	-11.9463	-0.0896	-6.0000
13	0.8568	-11.9463	0.0000	8.3606
14	0.8340	-12.6596	-0.0496	-1.2800
15	0.8303	-12.7331	-0.0656	-2.0000
16	0.8357	-12.4123	-0.0280	-1.4400
17	0.8321	-12.6800	-0.0720	-4.6400
18	0.8227	-13.2242	-0.0256	-0.7200
19	0.8207	-13.3630	-0.0760	-2.7200
20	0.8240	-13.2058	-0.0176	-0.5600
21	0.8264	-12.9045	-0.1400	-8.9600
22	0.8268	-12.8931	-0.0000	0.0000
23	0.8219	-13.0453	-0.0256	-1.2800
24	0.8175	-13.1862	-0.0696	-5.3600
25	0.8141	-12.8436	-0.0000	0.0000
26	0.8000	-13.1792	-0.0280	-1.8400
27	0.8188	-12.4241	-0.0000	-0.0000
28	0.8057	-9.3418	0.0000	0.0000
29	0.8030	-13.4075	-0.0192	-0.7200
30	0.7938	-14.1133	-0.0848	-1.5200

Table 1: Bus Voltage And Power Flow Result Without UPFC

Power loss in tr. line without UPFC is 0.2p.u.
WITH UPFC:
When particle swarm optimization algorithm is executed then the following results came in below results the number iteration are shown and the optimal place net of UPFC is indicated.

Iterations	fGBest	fevals
10	9935.5	330
20	1135	630

Table 2: Number Of Iterations
When UPFC placed between the buses that given by particle swarm algorithm technique,

Bus No.	V (pu)	Angle degree	P Flow (pu)	Q Flow (pu)
1	1.0600	0.0000	0.9451	0.9314
2	1.0430	-5.3585	0.9421	0.9283
3	1.0189	-7.5267	0.9377	0.9239
4	1.0094	-9.2798	0.9360	0.9223
5	1.0100	-14.1846	0.9361	0.9224
6	1.0086	-11.0506	0.9359	0.9221
7	1.0014	-12.8653	0.9346	0.9208
8	1.0100	-11.8277	0.9361	0.9224
9	1.0366	-14.0831	0.9409	0.9271
10	1.0166	-15.7094	0.9373	0.9235
11	1.0820	-14.0831	0.9491	0.9353
12	1.0466	-15.1839	0.9427	0.9289
13	1.0710	-15.1839	0.9471	0.9333
14	1.0276	-16.0515	0.9393	0.9255
15	1.0194	-16.0117	0.9378	0.9240
16	1.0266	-15.6766	0.9391	0.9253
17	1.0142	-15.9128	0.9369	0.9231
18	1.0000	-16.4708	0.9343	0.9206
19	0.9972	-16.6961	0.9338	0.9200
20	1.0012	-16.5100	0.9346	0.9208
21	1.0028	-16.2514	0.9348	0.9210
22	1.0060	-16.0166	0.9354	0.9216
23	1.0029	-16.2595	0.9349	0.9211
24	0.9917	-16.3227	0.9329	0.9191
25	0.9914	-16.0447	0.9328	0.9190
26	0.9732	-16.4871	0.9295	0.9157
27	1.0000	-15.5960	0.9343	0.9206
28	1.0056	-11.6790	0.9354	0.9216
29	0.9796	-16.8850	0.9307	0.9169
30	0.9679	-17.8117	0.9286	0.9148

Table 3: Bus Voltage And Power Flow Result With UPFC
Power loss in transmission line with UPFC is 0.002116pu.

UPFC Bus	V_{sh}(pu)	Theta (Degree)	P (pu)	Q (pu)
18	1.0000	-16.4708	0.9343	0.9206
27	1.0000	-15.5960	0.9343	0.9206

Table 4: Optimal Location Of UPFC

6. Conclusion

In this paper a PSO based modified method is analyzed for the IEEE 30 bus system by placing a UPFC with Equivalent current injection to achieve optimal location and voltage stability in inter connected transmission system.

The results are shown to through performing simulation analysis in MATLAB programming .By inspecting we can proved that modified Practical Swarm Optimization can improve the stability of transmission line .The UPFC model with ECI is algorithm will provide Power flow calculation with in shortest time and accurate results will be provided.

7. Future Work

Like every other investigation, there is always space to improve. In this section some suggestions are made about some of the future work that can be based on this thesis. The objective of this paper was to find a deterministic approach to the problem of placement of UPFC units with the objective of enhancing the voltage stability margin. This objective was accomplished in the last chapter, however, one might argue if there is a even more deterministic approach to this problem. This argument comes from the fact that, in the algorithm developed in this thesis, the optimal location(s) of the UPFC(s) are calculated, but the number of UPFC units is still left to the judgment of optimization problem designer. Certainly there exist situations where the optimal number of UPFC(s) is one, and in other situation the optimal number of units is another. Hence further investigation upon this matter should study a way to integrate the number of UPFC(s) needed in the optimization problem, so that the optimal solution to the new optimization problem has the optimal number of UPFC(s). Further studies can also investigate if there is a optimal configuration of the PSO algorithm to the problems of placement and sizing of not only UPFC unit but of other power network's equipment.

In this Paper, the configuration used is the one suggested by certain studies that test the performance of the algorithm with mathematical functions, however, if the performance were to be tested in objective functions similar to the ones used in the this optimization problem, an optimal configuration regarding this sort optimization could emerge

8. References

1. R. Z. Mi˜nano, "Optimal power flow with stability constraints," Ph.D. dissertation, Universidad de Castilla - La Mancha, 2010.
2. V. Ajjarapu, Computational Techniques for Voltage Stability Assessment and Control. Springer, 2006.
3. P. H. E. Azadani, S. Hosseinian, "Optimal placement of multiple statcom for voltage stability margin enhancement using particle swarm optimization," Springer Berlin Electrical Engineering (Archiv fur Elektrotechnik), pp. 503–510, 2008.
4. Y. del Valle, J. C. Hernandez, G. K. Venayagamoorthy, and R. G. Harley, "Multiple Statcom allocation and sizing using particle swarm optimization," Power Systems Conference and Exposition, pp. 1884–1891, 2006.
5. P. Kundur, Power System Stability and Control.McGraw-Hill, 1993.
6. J. P. S. Paiva, Redes de Energia El ´ ectrica - Uma An´ aliseSist ´emica, 2nd ed. IST Press, 2007.
7. M. B. Keskin, "Continuation power flow and voltage stability in power systems," Master's thesis, The Graduate School of Natural and Applied Sciences of Middle East Technical University, September 2007.
8. C. A. Ca˜nizares, Voltage collapse and transient energy function analyses of ac/dc systems," Ph.D. dissertation,University of Wisconsin-Madison, 1991.
9. F. Milano, Power System Modelling and Scripting. Springer, 2010.
10. W. F. Tinney and C. E. Hart, "Power flow solution by newton's method," IEEE Transactions on Power Apparatus and Systems, pp. 1449–1460, 1967.
11. V. Ajjarapu and C. Christy, "The continuation power flow: A tool for steady state voltage