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Optimal Allocation of SVC & IPFC in Different Over Load &Contingency Conditions

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Abstract

In this research work two types of FACTS devices i.e. SVC and IPFC are optimally located to reduce active power losses and as well as improvement of voltage profile in normal, over load and contingency conditions using Partial Swarm Optimization Technique. The simulations are performed on an IEEE 30-bus system and results are presented.

Keywords*:* *SVC, IPFC, Over load, Contingency, Power loss, Voltage profile, PSO, IEEE 30 bus.*

Introduction:

The main objective of an electrical engineer is to generate, transmit, and distribute power at rated voltage and rated frequency. In generally, the load is uncertain. Hence, voltage and power are violating the limits. This can be overcome by using different type of techniques such as generator voltages, transformer taps, fixed capacitor and reactive power distribution. In this paper, reactive power distribution is provided using different types of power electronic based FACTS devices.

In previews, the research engineers are found an optimal location of FACTS devices like SVC, TCSC, and UPFC at different load conditions (1-3).

In this paper, a new research method is implemented on an optimal location of SVC and IPFC in normal and as well as contingency conditions.

In normal operating conditions, the power system losses are the minimum and voltages are prescribed limits. The power system may be collapse due to the following reasons such as outage of a generating unit or of a line, sudden increasing or decreasing of the power demand. Most of the times, the system may remains as it original state i.e within the limitations of voltage & power. But sometimes, it does not becomes to its original state i.e its limits are violating. This phenomenon is called contingency.

In recent decades, different types of biological optimization techniques like GA, PSO, AC, EP etc are implemented. In this research, PSO technique is used to optimal location of devices. The simulations are performed on a modified IEEE 30 bus system and results are presented at different contingency conditions.

Problem Formulation:

The power flow through any transmission line can be obtained by using the equation

$P_{ij}= (V_i V_j \sin\Theta_{ij})/X_{ij}$

$Q_{ij}=V_i (V_i\text{-}V_j \cos \Theta_{ij})/X_{ij}$

Where P_{ij} is the active power flow through the transmission line i to j, Q_{ij} is the reactive power flow through the transmission line i to j, V_i, V_j are the bus voltage magnitudes, X_{ij} is the reactance of the transmission line & Θ_{ij} is the phase angle between i and j buses.

The power flow through the transmission line can be controlled by changing any one of the above mentioned parameters using different types of FACTS devices. In this paper two types of FACTS devices are used one is SVC, which is the basic model of shunt type of FACTS device and other is IPFC, which is latest version of FACTS device.

Mathematical models of FACTS devices: The main aim of this objective is to perform a best utilization of the existing transmission lines in normal and contingency conditions by an optimal location of FACTS devices in a network.

STATIC VAR COMPENSATOR: The Static var compensator is a shunt type of FACTS devices, which absorbs or injects reactive power at which it is connected. The size of the SVC is depends on the rating of current and reactive power injected into the bus.

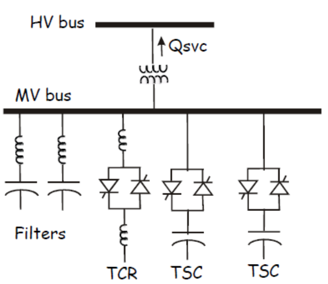


Fig.:1Circuit Diagram of Static VAR Compensator (SVC)

In general, the transfer admittance equation for the variable shunt compensator is

$$i = jBV_K \quad .... \quad (1)$$

and the reactive power equation is

$$Q_K = -V_K^2 \quad .... \quad (2)$$

SVC Total Suscnptance Model H = B_{SVC}

$$\begin{pmatrix} \Delta P_K \\ \Delta Q_K \end{pmatrix}^{(i)} = \begin{pmatrix} 0 & 0 \\ 0 & Q_K \end{pmatrix}^{(i)} \begin{pmatrix} \Delta\theta_K \\ \Delta B_{SVC}/B_{SVC} \end{pmatrix} \quad (3)$$

. . . . (3)

The linearlised SVC Equation is Given by

$$\begin{pmatrix} \Delta P_K \\ \Delta Q_K \end{pmatrix}^{(i)} = \begin{bmatrix} 0 & 0 \\ 0 & \frac{\partial Q_K}{\partial \alpha} \end{bmatrix}^{i} \begin{pmatrix} \Delta Q_K \\ \alpha \end{pmatrix}^{(i)} \quad (4)$$

Where

$$\frac{\partial Q_K}{\partial \alpha} = \frac{2V_K^2}{X_L}(\cos(2\alpha) - 1) \quad ..... (5)$$

At the end of iteration, the firing angle α is updated according to Equ (6)

$$\alpha^{i+1} = \alpha^i + \Delta\alpha^i \quad (6)$$

INTERLINE POWER FLOW CONTROLLER:

The IPFC is a series-series type of FACTS device, which is used to exchange reactive powers in between two or more transmission lines those are connected to the same bus.

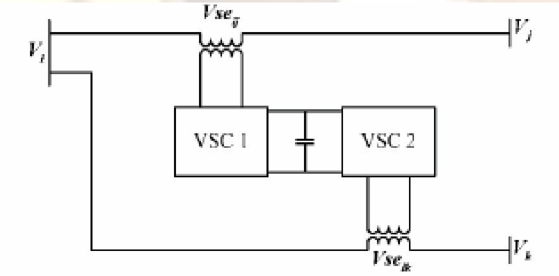


Fig: 2 Schematic diagram of two converter IPFC

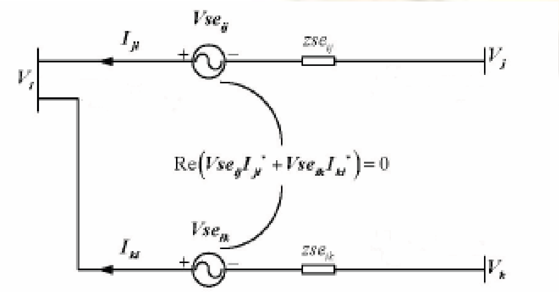


Fig: 3 Equivalent circuit of two converter IPFC

The active and reactive powers injected at each bus using IPFC are given as

$P_{inj,i}$ = Σ Vi Vsein bin sin (Θi-Θsein)
n=j,k

$Q_{inj,i}$ = -Σ Vi Vsein bin cos (Θi-Θsein)
n=j,k

$P_{inj,n}$ = - Vn Vsein bin sin (Θi-Θsein)

$Q_{inj,n}$ = Vn Vsein bin cos (Θi-Θsein)

Where n= i,j.

The active power exchange between the lines is zero. i.e

Re(Vsein I_{ji}^* + Vseik I_{ki}^*) =0

Partial Swarm Optimization

The PSO is based on movement & flocking of birds in searching space. The birds in space are called particles, which fly with a certain velocity and find the global best position. At each iteration, each particle can adjust its position (Pb) and velocity vector (Vt).

The position of the particle is mathematically is represented as

$V_i^{k+1} = wV_i^k + c_1\, rand_1(\ldots) \times (pbest_i - s_i^k) + c_2\, rand_2(\ldots) \times (gbest - s_i^k)$

where, v_i^k : velocity of agent i at iteration k,
w: weighting function,
c_j : weighting factor,
rand : uniformly distributed random number between 0 and 1,
s_i^k : current position of agent i at iteration k,
$pbest_i$: pbest of agent i,
gbest: gbest of the group.

for k=1,2…..n and d=1,2..m.

Using above equation a certain velocity that gradually gets close to p_{best} and g_{best} can be calculated. The current position (searching point the solution space) can be modified by the following equation.

$$X_{id}^{(t+1)} = x_{id}^{(t)} + v_{id}^{(t+1)}$$

The 'W' can be calculated as

$$W = Wmax - [(Wmax - Wmin) * \frac{iter}{itermax}]$$

Where W_{max} and W_{min} are set at 0.9 and 0.4 respectively.

SOLUTION ALGORITHM:

The step by step procedure for the proposed optimal placement of SVC and IPFC devices using PSO is given below:

Step 1: The number of devices to be placed is declared. The load flow is performed.

Step 2: The initial population of individuals is created satisfying the SVC & IPFC constraints.

Step 3: For each individual in the population, the fitness function is evaluated after running the load flow.
Step 4: The velocity is updated and new population is created.
Step 5: If maximum iteration number is reached, then go to next step else go to step 3.
Step 6: Print the best results.
Step 7: stop.

A CASE STUDY:

The PSO based optimal location of SVC & IPFC devices was implemented at contingency conditions using MATLAB 7.5. Here the modified IEEE 30-bus system was tested.
. The following parameters are used for PSO based optimal location of FACTS devices.

- Population =50
- Maximum iterations=200
- Wmax=0.9 and Wmin=0.4
- Acceleration constants C1=1.4 and C2=1.4

The type of the device, the location and rating of the devices are found in normal, over load and contingency conditions. The results are presented.

conditions	**Before compensation real power losses in MW**	**After compensation real power losses in MW**
Normal load	17.599	17.262
Over load conditions	35.975	33.475
contingency occurs in between lines 27-29	36.928	34.096

At normal load conditions:

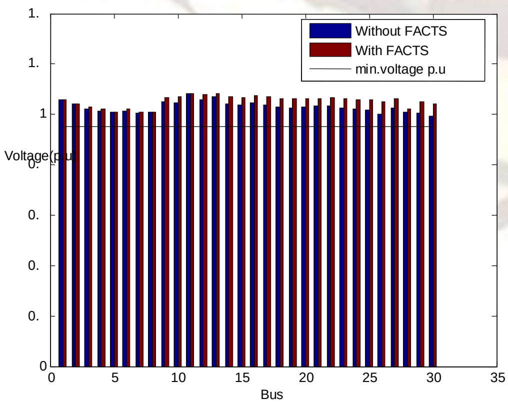


Fig.3: Voltage profile at each bus

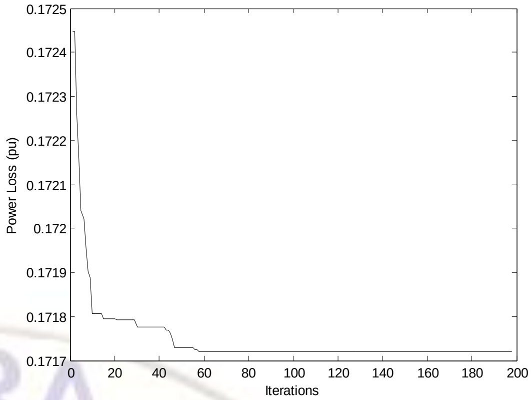


Fig.4: Power losses at different iterations

At different over load conditions:

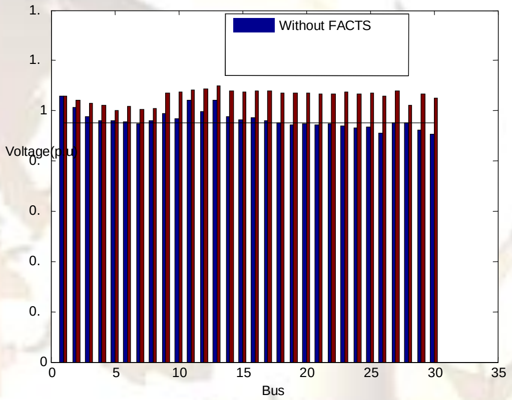


Fig.3: Voltage profile at each bus

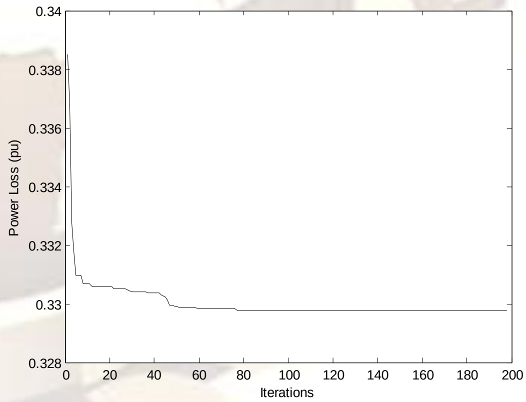
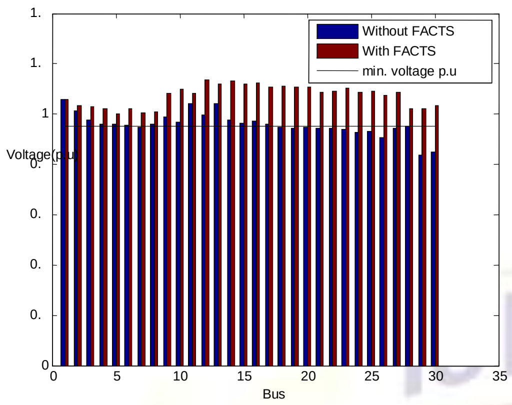
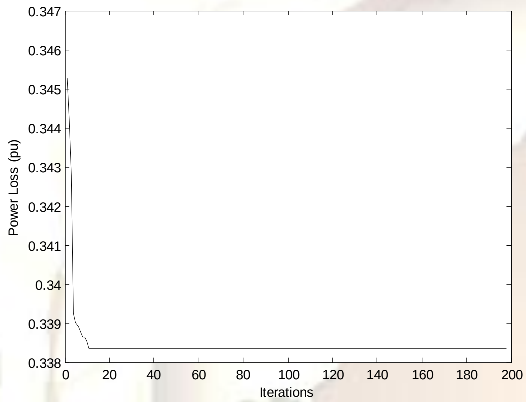


Fig.4: Power losses at different iterations

At contingency condition(the line 27-29 is removed):





Optimal location of SVC & IPFC in different conditions and its rating:

Optimal location of SVC (at each bus)	Normal conditions (the rating of SVC in Mvar)	Over load conditions (the rating of SVC in Mvar)	Contingency conditions (the rating of SVC in Mvar)
1	3	13	3
2	0	14	2
3	4	15	5
4	7	10	10
5	2	6	7
6	2	12	6
7	7	8	11
8	6	10	2
9	4	10	9
10	8	13	12
11	0	6	0
12	3	5	5
13	4	17	3
14	2	4	9
15	0	0	2
16	3	3	12
17	6	15	13
18	0	0	4
19	5	8	5
20	1	1	6
21	2	11	9
22	8	3	7
23	3	12	6
24	6	11	7
25	1	0	7
26	2	3	1
27	2	4	5
28	2	6	5
29	1	4	0
30	2	2	4

Optimal location of IPFC (between the lines)	At normal load conditions (rating of IPFC in Mvar)	At over load conditions (rating of IPFC in Mvar)	At contingency conditions (rating of IPFC in Mvar)
2-5 & 2-6	4.0114	5.3966	3.7427
6-8 & 6-9	0.0040	0.8723	2.4694
12-13 & 12-15	4.9306	2.4572	9.7280
10-20 & 10-17	5.8124	1.7071	0.5749
25-26 & 25-27	3.8179	4.7799	0.5668

By comparing the above cases, the total power losses of the system are reduced and voltage profiles are improved by the optimal location of FACTS devices.

Conclusion

In this paper, the optimal location of IPFC and SVC are studied at normal, different overload, contingency conditions and various parameters such as voltage profile and real and reactive power flow in transmission lines are investigated using PSO.

In this paper, we have proposed a PSO algorithm to place a combination of both SVC and IPFC devices. The future scope of this paper is a complete cost benefit analysis has to be carried out to justify the economic viability of the SVC and IPFC using different combination of optimization techniques.

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