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Allocation of SVCs & IPFCs in an Electrical Power System using DE

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Abstract: *The proposed method is used to place SVCs & IPFCs optimally in an electrical power system to reduce active power losses and as well as to improve voltage profile in different load and contingency conditions using Differential Evaluation (DE) Technique. The simulations are performed on an IEEE 14-bus system and results are presented.*
Keywords: *SVC, IPFC, Different load, Contingency, Power loss, Voltage profile, DE, IEEE 14 bus.*

I. 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, 4].

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 become 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 14 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

$$P_{ij} = \frac{\left(V_i V_j \sin\theta_{ij}\right)}{X_{ij}}$$

$$Q_{ij} = \frac{V_i\left(V_i - V_j \cos\theta_{ij}\right)}{X_{ij}}$$

Where
P_{ij} is the active power flow through the transmission line from i to j
Q_{ij} is the reactive power flow through the transmission line from 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, and other is IPFC.

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.

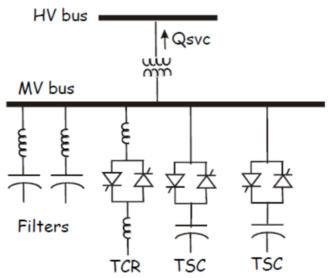


Fig: Circuit Diagram of Static VAR Compensator

II. 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.

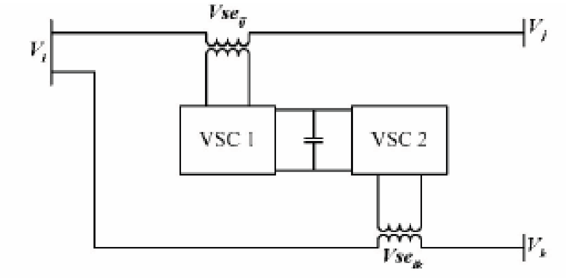


Fig: Schematic diagram of two converter IPFC

Algorithm: The step by step procedure for the proposed optimal placement of SVC and IPFC devices using differential evaluation optimization is given below:
Step 1: The number of devices to be placed is declared. The load flow is performed.
Step 2: A set of populations are initialize randomly which satisfies the constraints of SVC & IPFC.
Step 3: Evaluate the fitness for each population and recorded member.
Step 4: Mutation the population.
Step 5: Crossover between initial & mutation population.
Step 6: Evaluate fitness of mutant vectors and compare it to initial population and record the best member.
Step 7: repeat step 2 to 5 until stopping criterion is met.
Step 8: Stop and print the results.

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 14-bus system was tested.
. The following parameters are used for PSO based optimal location of FACTS devices.

- Population =50
- Maximum iterations=50
- 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, different load and contingency conditions. The results are presented in two cases.

Case 1: Optimal location of SVCs:

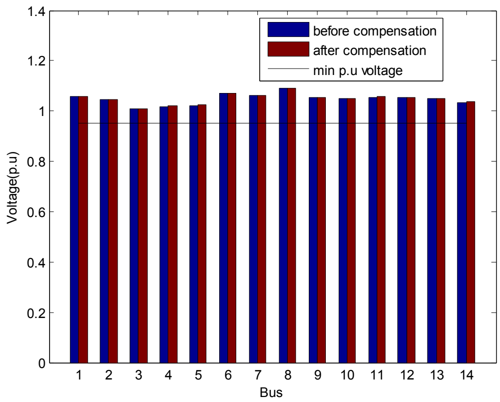
Loading condition	Real power Losses without SVC (MW)	Loc. of SVC	Rating of SVC (MVAR)	Real power Losses with SVC (MW)
Normal loading	13.393	5 14	6.6720 5.2468	13.314
125% loading	22.636	5 14	13.370 5.595	22.094
150% loading	35.011	5 14	30.2925 10.7572	33.866
175% loading	51.295	5 14	66.411 12.379	49.074
Contingency (12-13)	13.401	5 14	15.5691 0.0020	13.340

Case 2: Optimal location of SVCs & IPFCs:

Loadi-ng condition	Real power Losses (MW)	Loc. of SVC	Rating of SVC	Loc. of IPFC	Rating of IPFC (MVAR)	Real power losses with SVC & IPFC (MW)
Normal loading	13.393	5 14	0.9290 3.4588	2-4 & 2-5	7.6385	13.118
125% loading	22.636	5 14	18.352 9.5131	2-4 & 2-5	21.345	21.783
150% loading	35.011	5 14	19.2066.97 45	2-4 & 2-5	21.472	33.876
175% loading	51.295	5 14	38.349 11.678	2-4 & 2-5	15.831	49.349
Conting-ency (12-13)	13.401 (12-13)	5 14	2.8565 5.7719	2-4 & 2-5	9.3076	13.096

Voltages profile in normal conditions:

Bus no	Before compensation Voltage (p.u)	Case 1 Voltage (p.u)	Case 2 Voltage (p.u)
1	1.0600	1.0600	1.0600
2	1.0450	1.0450	1.0450
3	1.0100	1.0100	1.0100
4	1.0183	1.0207	1.0192
5	1.0200	1.0239	1.0213
6	1.0700	1.0700	1.0700
7	1.0608	1.0621	1.0621
8	1.0900	1.0900	1.0900
9	1.0541	1.0555	1.0563
10	1.0495	1.0506	1.0513
11	1.0561	1.0567	1.0570
12	1.0550	1.0553	1.0558
13	1.0501	1.0505	1.0516
14	1.0343	1.0361	1.0407



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.

III. 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 DE.

In this paper, we have proposed a DE 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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