Finding Optimal position of SVC and Decreasing of Real Power Loss and Voltage Deviation Using Genetic Algorithm (GA)

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Abstract **-** In this paper a challenge is made to discover optimal position and sizing of static Var compensator (SVC) in a power structure network in order to decreasing the real power loss and load voltage deviation and also to progress voltage profile for with and without line out of a power system network. This paper proposes a genetic algorithm (GA) that tries to 21 times for discover the optimal position of the SVC. The planned approach has been tested on IEEE-30 Bus test system with different objectives. The principle of this reading is to decreasing the real power loss and load voltage deviation (VD) only single line outage contingency and rising loading condition in power structure network. The SVC can create or absorbs reactive power very fast to regulate the voltage magnitude at the point of installation of SVC. The value of the planned algorithm for decreasing power loss and voltage deviation and improving voltage profile is demonstrated by comparing the results that the load voltage deviation is enhanced and also there is a reduce in real power loss by GA when compared with the conventional method.

Keywords **- Genetic Algorithm (GA), optimal location, Active power loss, Load Voltage deviation, Voltage Profile, SVC.**

1. INTRODUCTION

The most favorable process of the power system networks have been based on an economic criterion now other criterion such as; progress voltage profile, decreasing real power loss and voltage deviation (VD) of transmission line etc. An optimal power flow program has been solved an optimization problem where the objective function, equality, and inequality constraints are non linear equation [1]. The most commonly used shunt FACTS devices within power system network are the static Var compensators (SVC). The SVC is mainly installed for voltage support and, furthermore, when installed in a proper location, it can also reduce power losses. Identifying the best location for SVCs implies calculating steady-state regimes for the network; as the load flow equation are non linear, the problem proves to be very complex, and extensive investigations have been under taken to solve it [2]. Voltage collapse typically occurs on power systems that are heavily loaded, faulted and/or reactive power shortage. Therefore, the voltage collapse problem is closely related to a reactive-power planning problem including contingency analysis, where suitable conditions of reactive power reserves are necessary for secure operations of power systems [3]. When contingencies like line outage or generator outages occur, sometimes the power system becomes insecure from the viewpoint of bus voltage/loading of transmission lines. [4]. The optimal location of SVC and other types of shunt compensation devices for voltage stability enhancement is suggested [5]. The SVC is a shunt connected reactive compensation equipment which is capable of generating reactive power whose output can be varied to maintain control of specific parameters of the electric power system [6]. The location and ratings of FACTS devices were optimized by GA and the system load ability and minimization power loss. FACTS devices are able to enhance the performance of power system and can able to provide control flow to enhance voltage profile [7]. This paper focuses on enhancement of the system performance under contingency through an optimal location and optimal setting of SVC. There are several methods have been suggested to optimally locate these controllers in the system. In this paper, Genetic Algorithm (GA) is used to discover the optimal location and rating of FACTS devices in order to decreasing real power loss and voltage deviation.

2. Modeling OF Static Var Compensator (SVC);

SVC is an electrical device which is used to connect in parallel with transmission network busses. SVC acts like shunt connected variable reactance; it generates or absorbs reactive power to control the voltage magnitude at its location in the network. It is mainly used to provide fast acting reactive power control and voltage regulating device.

SVC is a stationary device; it does not have any moving parts. Some of the advantage of SVC in a power system network are small maintenance cost, easy control more flexibility, removing extra voltage, enhancing power factor, good certainty, avoidance of voltage collapse rapid response and removing harmonics. A shunt connected device; SVC which consists of a Thyristor Controlled Rectifier (TCR) in parallel with a bank of capacitor. The diagram of SVC is shown in Figure1.

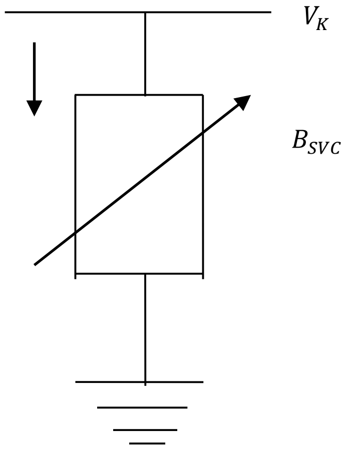

Fig I. Basic circuit of SVC

The nonlinear of power equations is to derive by the SVC, and the linearised equations derive by the Newton's load flow method. In general, the transfer admittance equation for the variable shunt compensator is,

$$I_{SVC} = jB_{SVC} V_K \quad \ldots\ldots\ldots\ldots (1)$$

The reactive power injected by the SVC into the bus bar K is given by the equation is below

$$Q_{SVC} = -V_K^2 B_{SVC} \quad \ldots\ldots\ldots\ldots (2)$$

3. Problem Formulation

In this paper, outages of single line in a power system are included as contingencies for optimal location of static Var compensator (SVC).

The severity of a contingency (i.e., single line outage) is evaluated using Voltage Performance Index (VPI).

$$\text{VPI}= \sum_{i=1}^{NB} (\Delta|V_i| / \Delta|V_i^{max}|)^{2m} \quad \ldots\ldots\ldots\ldots (3)$$

Where, $\Delta|V_i^{max}|$ is bus voltage magnitude. $\Delta|V_i|$ is difference between the voltage magnitude under line outage and base case condition.

In this case, the value of the exponent *m* has been considered as 2 and $\Delta|V_i^{max}|$ has been considered as 0.2 p.u

A. Minimization of real power loss

The active power loss (P_{Loss}) as first objective function F_1 (u, v) is defined as;

$$P_{Loss} = \sum_{K=1}^{NTL} G_k [V_i^2 + V_j^2 - 2V_i V_j \cos(\delta_i - \delta_j)] \quad \ldots\ldots (4)$$

Where, NTL is the number of transmission line, G_k is the conductance of K^{th} line;

B. Minimization of Load Voltage Deviations

The voltage deviation (V_d) of load as second objective function F_2 (u, v) is defined as;

$$V_d = \sum_{K=1}^{NLD} |V_k - V_k^{ref}| \quad \ldots\ldots\ldots\ldots (5)$$

C. Multi-Objective function

The objective function for the optimization problem can be obtained by combining real power loss and voltage deviation mentioned above as;

$$F(u, v) = F_1(u, v) + F_2(u, v) \ldots\ldots\ldots\ldots (6)$$

D. Constraints

I) Equality Constraints

The equality constraints represent the active and reactive power flow balance equations are as follows

$$P_{Gi} - P_{Di} = V_i \sum_{j=1}^{NB} V_j [G_{ij} \cos(\delta_i - \delta_j) + B_{ij} \sin(\delta_i - \delta_j)] \qquad i = 1 \ldots NB \quad \ldots\ldots (7)$$

$$Q_{Gi} - Q_{Di} = V_i \sum_{j=1}^{NB} V_j [G_{ij} \sin(\delta_i - \delta_j) + B_{ij} \cos(\delta_i - \delta_j)] \qquad i = 1 \ldots NB \quad \ldots\ldots (8)$$

Where, P_{Gi} and P_{Di} are the active power of generator and load.
Q_{Gi} and Q_{Di} are the reactive power of generator and load.
NB is the number of buses, B_{ij} and G_{ij} are the transfer susceptance and conductance between bus i and bus j respectively.

II) Inequality constraints

Inequality constraints represent the maximum and minimum limits of the generator reactive power, slack bus active power,generator bus voltage respectively.

i) Generator reactive power generation limit

$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max}$$

ii) Slack bus active power generation limit

$$P_s^{min} \leq P_s \leq P_s^{max}$$ P_S, real power generation of slack bus

iii) Generator bus voltage limit

$$V_{gi}^{min} \leq V_{gi} \leq V_{gi}^{max}$$ i ∈ N_B where, N_B total number of buses

4. Simulation Results

The simulation results is performed on IEEE 30 bus system [ ], the test bus system consists of 41 transmission lines, 6 generators, one slack bus, 5 PV (generator bus), 24 PQ (load bus). For optimal location of SVC, outages of single line are considered in the test power system. The objective function is formulated as a multi objective optimization problem.

Table I. Voltage Profile of increasing loading 10%, 30%, 50% Without Line Out

The voltage profile of IEEE 30 bus system with and without of SVC without LO are given in Table I. These results provide optimal locations of SVC at bus no. 4 for three increasing loading conditions i.e. 10%, 30% and 50%. When SVC is placed at bus no. 4 the best results for power loss and voltage deviation are given in Table V.

Bus No.	Increasing Loading 10%		Increasing Loading 30%		Increasing Loading 50%	
	Without SVC	With SVC	Without SVC	With SVC	Without SVC	With SVC
1.	1.06	1.06	1.06	1.06	1.06	1.06
2.	1.043	1.043	1.0343	1.043	1.0188	1.043
3.	1.0194	1.017	1.0124	1.0203	1.0001	1.0142
4.	1.0107	1.0078	1.0032	1.0076	0.9897	1.0068
5.	1.01	1.01	1.01	1.01	0.968	1.01
6.	1.0106	1.0077	1.0055	1.0067	0.994	1.0159
7.	1.0022	1	0.9983	0.9975	0.9732	1.0011
8.	1.01	1.01	1.01	1.01	1.01	1.01
9.	1.0496	1.0371	1.0453	1.0413	1.0373	1.0411
10.	1.0425	1.0183	1.037	1.0282	1.0275	1.0233
11.	1.082	1.082	1.082	1.082	1.082	1.082
12.	1.0561	1.0476	1.052	1.0474	1.0449	1.043
13.	1.071	1.071	1.071	1.071	1.071	1.071
14.	1.0402	1.0293	1.0342	1.0273	1.0249	1.0199
15.	1.0353	1.0225	1.0287	1.0208	1.0185	1.0126
16.	1.0428	1.0272	1.0374	1.0298	1.0285	1.0236
17.	1.037	1.015	1.0312	1.0216	1.0213	1.0152
18.	1.0249	1.0073	1.0171	1.0072	1.0054	0.9975
19.	1.0221	1.0019	1.014	1.0034	1.002	0.9934
20.	1.0263	1.0051	1.0189	1.0085	1.0073	0.9997
21.	1.0296	1.0055	1.0229	1.0118	1.012	1.0042
22.	1.0302	1.0065	1.0235	1.0126	1.0126	1.005
23.	1.0242	1.0082	1.0165	1.006	1.0049	0.9961
24.	1.0183	0.9985	1.0101	0.9976	0.9974	0.9872
25.	1.0158	1.001	1.0076	0.9967	0.9944	0.989
26.	0.9972	0.9812	0.987	0.9731	0.9716	0.9614
27.	1.0232	1.0122	1.016	1.0076	1.0034	1.0035
28.	1.0091	1.006	1.0043	1.0042	0.9944	1.0095
29.	1.0018	0.99	0.9914	0.9809	0.9752	0.9722
30.	0.9894	0.9771	0.9769	0.9655	0.9585	0.9541

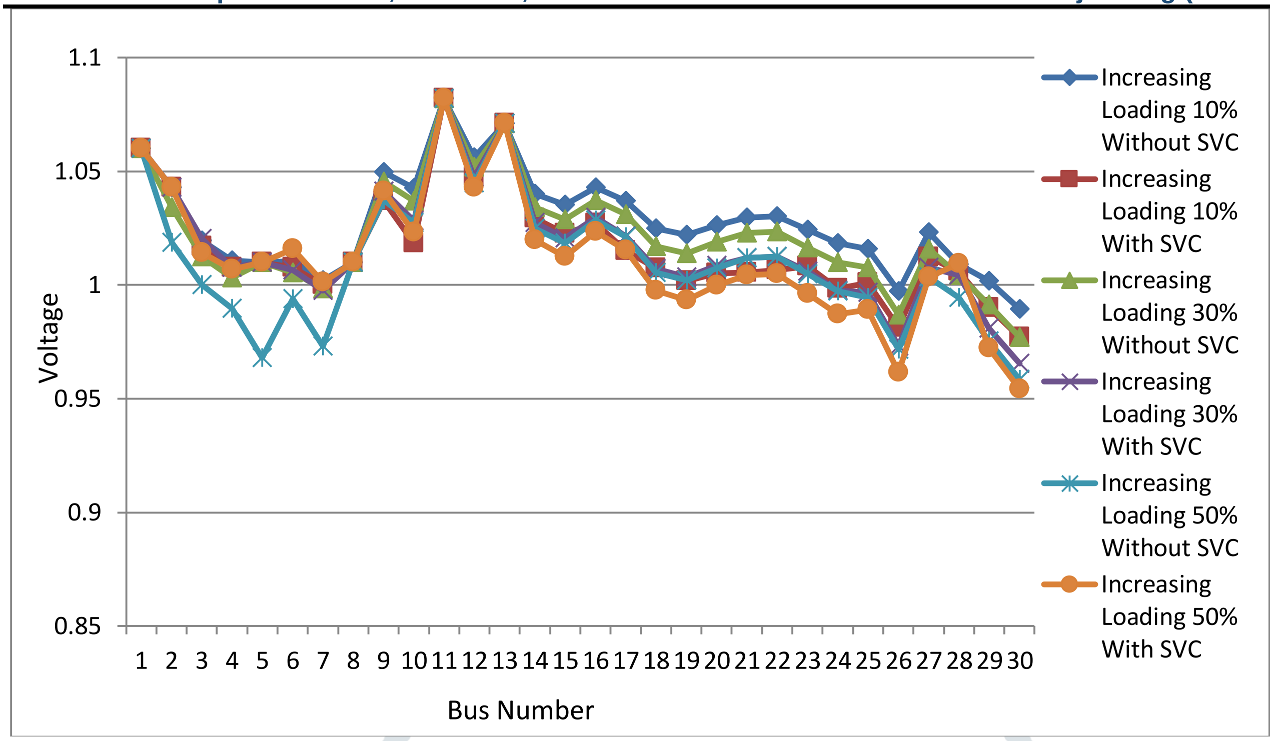

Fig2. Voltage Profile of increasing loading 10%, 30%, 50% Without Line Out

Voltage Profile of increasing loading 10%, 30%, 50% With Line Out

A) Outage of line no. 36

The voltage profile of IEEE 30 bus system with and without of SVC for line outage 36 are given in Table II. These results provide optimal locations of SVC at bus no. 30 for three increasing loading conditions i.e. 10%, 30% and 50%. When SVC is placed at bus no. 30 the best results for power loss and voltage deviation are given in Table V.

Table II. Voltage Profile of IEEE 30 Bus System with and without of SVC for LO 36

Bus No.	Increasing Loading 10%		Increasing Loading 30%		Increasing Loading 50%	
	Without SVC	With SVC	Without SVC	With SVC	Without SVC	With SVC
	LO36	LO36	LO36	LO36	LO36	LO36
1	1.06	1.06	1.06	1.06	1.06	1.06
2	1.043	1.043	1.029	1.043	0.9748	1.043
3	1.0177	1.0182	1.0072	1.0147	0.9278	1.009
4	1.0087	1.0093	0.997	1.0057	0.903	1
5	1.01	1.01	0.9873	1.01	0.8911	1.01
6	1.0098	1.0103	1.0007	1.0079	0.8972	1.0042
7	1.0017	1.0015	0.986	0.9981	0.8832	0.994
8	1.01	1.01	1.01	1.01	0.9052	1.01
9	1.0439	1.0471	1.0352	1.0415	0.8962	1.0391
10	1.0321	1.0384	1.0207	1.0281	0.8655	1.0261
11	1.082	1.082	1.0814	1.082	0.9487	1.082
12	1.0509	1.0535	1.0432	1.0468	0.902	1.0436
13	1.071	1.071	1.071	1.071	0.9377	1.071
14	1.032	1.036	1.0213	1.0263	0.8682	1.0218
15	1.0228	1.0285	1.0103	1.019	0.8484	1.0149
16	1.0352	1.039	1.0252	1.0294	0.8757	1.0251
17	1.0274	1.0326	1.0159	1.0214	0.8609	1.0176
18	1.013	1.0185	0.9992	1.0061	0.8349	1.0001
19	1.0106	1.0161	0.9964	1.0026	0.832	0.9962
20	1.0152	1.0208	1.0015	1.0079	0.8391	1.0024
21	1.0137	1.0225	0.9994	1.0106	0.8289	1.0089
22	1.0125	1.0224	0.9978	1.0109	0.8241	1.0103
23	0.9984	1.011	0.9808	1.0018	0.79	1.0021
24	0.9753	0.9977	0.9525	0.9897	0.7275	0.9982
25	0.9102	0.9706	0.8719	0.9708	0.5344	1.015
26	0.8893	0.9501	0.8479	0.9519	0.4923	0.9979
27	0.8827	0.9678	0.8376	0.9664	0.4477	1.031

28	1.0139	1.0143	1.0069	1.0124	0.4027	1.0096
29	0.8574	0.9634	0.8066	0.9624	0.3752	1.0359
30	0.8427	0.971	0.7884	0.9683	0.3326	1.0499

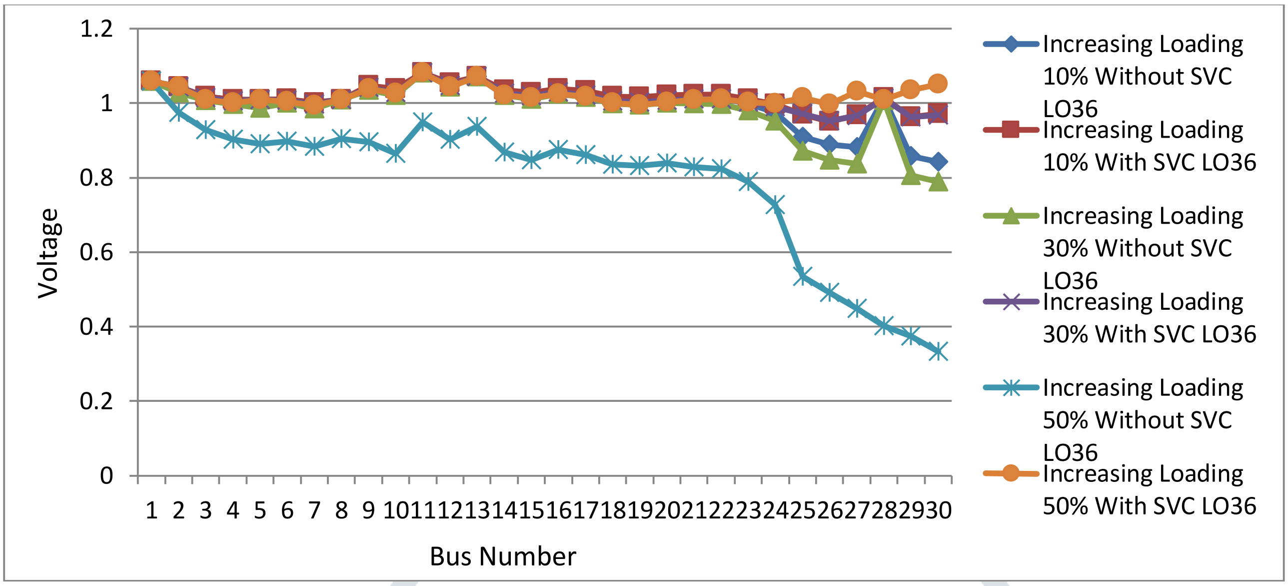

Fig3. Voltage profile for outage of line no. 36 with and without SVC

B) Outage of line no. 5

The voltage profile of IEEE 30 bus system with and without of SVC for line outage 5 are given in Table III. These results provide optimal locations of SVC at bus no. 12 for three increasing loading i.e. 10%, 30%, 50%. When SVC was placed at bus no. 12, the computed results for power loss and voltage deviation are given in Table V.

Table III. Voltage Profile of IEEE 30 Bus System with and without of SVC for LO 5

Bus No.	Increasing Loading 10%		Increasing Loading 30%		Increasing Loading 50%	
	Without SVC	With SVC	Without SVC	With SVC	Without SVC	With SVC
	LO5	LO5	LO5	LO5	LO5	LO5
1	1.06	1.06	1.06	1.06	1.06	1.06
2	1.043	1.043	1.0127	1.043	0.4679	1.043
3	1.0061	1.0103	0.9587	1.004	0.0096	1.0026
4	0.9959	1.001	0.9402	0.9953	0.3964	0.995
5	0.9114	1.01	0.8286	1.01	0.5647	1.01
6	0.9942	1.0029	0.928	1.0019	0.2396	1.0061
7	0.9468	0.9916	0.872	1.0145	0.1512	0.9856
8	1.01	1.01	0.9354	1.01	0.1797	1.01
9	1.0402	1.0427	0.9773	1.0377	1.3792	1.0374
10	1.0319	1.0323	0.969	1.0232	1.2308	1.0206
11	1.082	1.082	1.0252	1.082	2.0449	1.082
12	1.0497	1.0476	0.9959	1.0433	1.1379	1.0411
13	1.071	1.071	1.0281	1.071	1.5469	1.071
14	1.0333	1.031	0.976	1.0232	0.9687	1.0195
15	1.0275	1.0253	0.9683	1.0162	0.9661	1.012
16	1.0344	1.0329	0.9757	1.025	1.0609	1.0218
17	1.027	1.0265	0.9647	1.0166	1.1613	1.0132
18	1.016	1.0142	0.9534	1.0023	0.788	0.9973
19	1.0126	1.0111	0.9485	0.9984	0.8241	0.9932
20	1.0165	1.0155	0.9526	1.0035	0.9098	0.9989
21	1.019	1.0186	0.9543	1.0068	1.3475	1.0027
22	1.0196	1.0192	0.9549	1.0075	1.3636	1.0035
23	1.0152	1.0134	0.9523	1.0012	1.1668	0.9961
24	1.0079	1.0068	0.9413	0.9926	1.4417	0.9872
25	1.0037	1.0045	0.9337	0.9914	1.1231	0.9874
26	0.9848	0.9848	0.912	0.9677	1.1414	0.9616
27	1.0102	1.0127	0.9394	1.0023	0.734	1
28	0.9966	1.0028	0.9275	1.0004	0.0237	1.0028
29	0.9885	0.9905	0.9135	0.9755	0.9322	0.9709

30	0.9759	0.9777	0.8983	0.96	1.0275	0.954

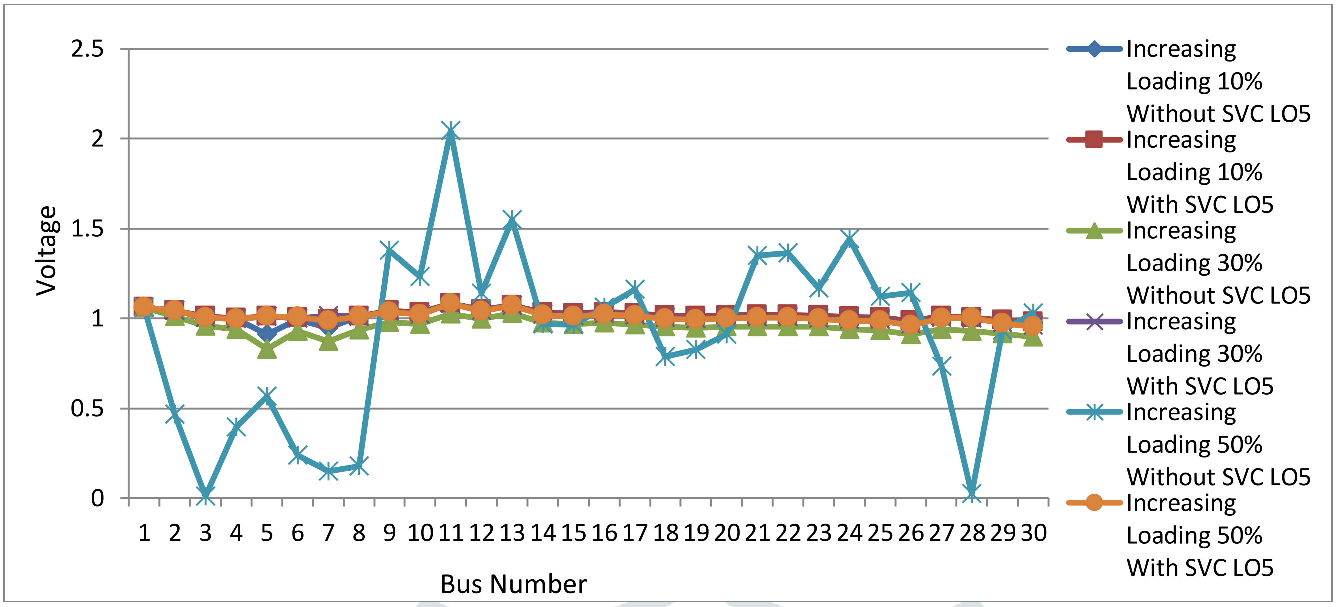

Fig4. Voltage profile for outage of line no. 5 with and without SVC

C) Outage of line no. 15

The voltage profile of IEEE 30 bus system with and without of SVC for line outage 15 are given in Table IV. These results provide optimal locations of SVC at bus no. 21 for three increasing loading i.e. 10%, 30%, 50%. When SVC was placed at bus no. 21, the computed results for power loss and voltage deviation are given in Table V.

Table IV. Voltage Profile of IEEE 30 Bus system with and without of SVC for LO 15

Bus No.	Increasing Loading 10%		Increasing Loading 30%		Increasing Loading 50%	
	Without SVC LO15	With SVC LO15	Without SVC LO15	With SVC LO15	Without SVC LO15	With SVC LO15
1	1.06	1.06	1.06	1.06	1.06	1.06
2	1.043	1.043	1.0291	1.043	0.9742	1.043
3	1.0252	1.0297	1.0141	1.021	0.9387	1.015
4	1.0176	1.0223	1.0051	1.0136	0.9155	1.0076
5	1.01	1.01	0.9856	1.01	0.8852	1.01
6	1.009	1.0133	0.9976	1.0064	0.8876	1.0015
7	1.0012	1.0033	0.9835	0.9973	0.8751	0.9924
8	1.01	1.01	1.01	1.01	0.8933	1.01
9	1.042	1.0393	1.0259	1.0492	0.8834	1.0464
10	1.0313	1.0173	1.0118	1.0497	0.8584	1.0491
11	1.082	1.082	1.0725	1.082	0.9367	1.082
12	1.0002	0.9616	0.9707	1.0237	0.7928	1.0168
13	1.0328	1.071	1.0042	1.071	0.8331	1.071
14	0.9869	0.9552	0.9559	1.0061	0.7733	0.9966
15	0.9907	0.9605	0.9612	1.0092	0.7817	1.0004
16	1.0061	0.9811	0.9798	1.0255	0.8085	1.0196
17	1.0182	1.0015	0.996	1.0355	0.835	1.0322
18	0.9914	0.9686	0.9631	1.0068	0.7862	0.9979
19	0.9953	0.9759	0.9685	1.0097	0.7949	1.0017
20	1.0035	0.9857	0.9783	1.0187	0.809	1.0122
21	1.0168	1.0021	0.9956	1.0427	0.8368	1.0452
22	1.017	1.0023	0.9956	1.0407	0.8366	1.0419
23	0.9896	0.9682	0.9614	1.005	0.7846	0.996
24	0.9979	0.9842	0.9732	1.0115	0.805	1.0046
25	1.0066	0.9964	0.986	1.0107	0.8282	1.0012
26	0.9878	0.9765	0.9649	0.9874	0.8004	0.9739
27	1.0211	1.0122	1.0045	1.0219	0.8576	1.0137
28	1.0064	1.0098	0.9951	1.0039	0.8779	0.9985
29	0.9997	0.99	0.9795	0.9956	0.8234	0.9827
30	0.9873	0.9771	0.9648	0.9805	0.8032	0.9642

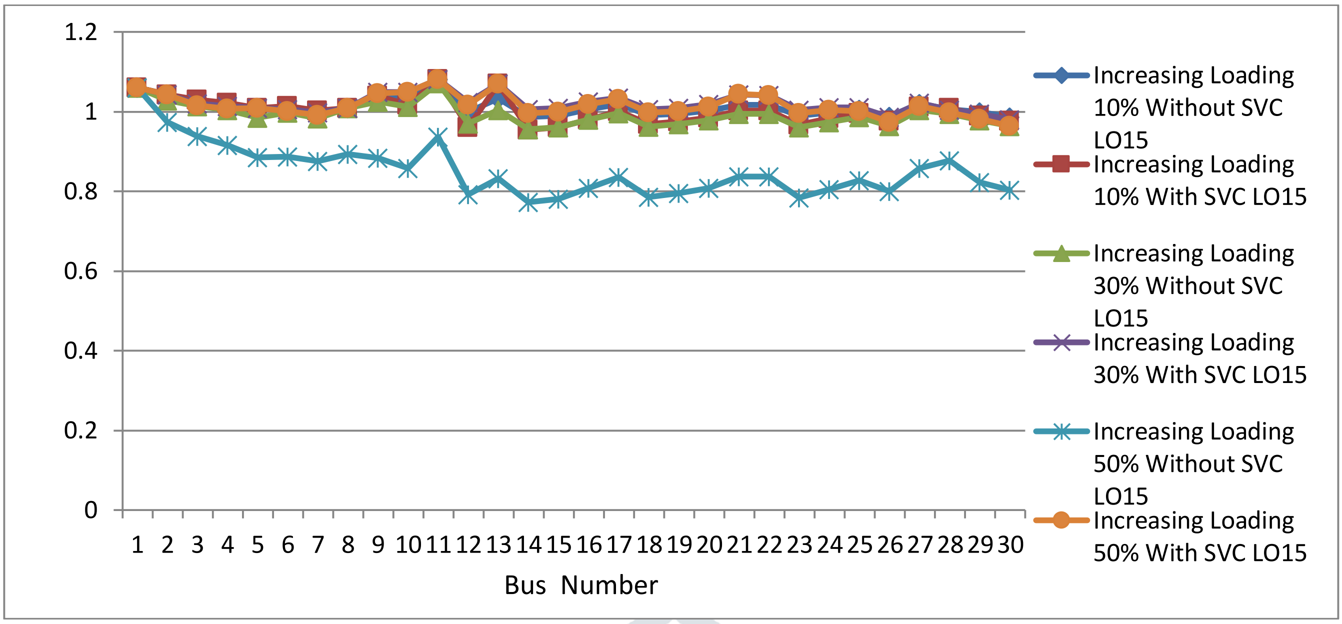

Fig5. Voltage profile for outage of line no. 15 with and without SVC

Table V. Comparison of Power Loss and Voltage Deviation With and Without of SVC at With Line Out and With Out Line Out of 36, 5, 15.

Increasing Loading	Without LO	With LO	Without SVC	With SVC	Without SVC	With SVC	Optimal Location
			P loss	P loss	VD	VD	
10%	-		0.2182	0.2165	0.5851	0.5832	4
		36	0.2468	0.2419	1.0052	0.8353	30
		5	0.4081	0.4062	0.4879	0.4859	12
		15	0.2518	0.1779	0.2956	0.2783	21
30%			0.3202	0.2191	0.4843	0.6493	4
		36	0.3677	0.2934	1.1264	0.7015	30
		5	0.5551	0.5534	1.2925	0.6058	12
		15	0.3742	0.369	0.49	0.396	21
50%			0.4527	0.4412	0.4021	0.652	4
		36	0.726	0.4397	5.5104	0.5965	30
		5	0.8852	0.8832	0.5864	0.5807	12
		15	0.6247	0.5156	0.6298	0.6227	21

5. CONCLUSION

This paper has been proposed finding optimal location of SVC and rating for load change 10%, 30%, 50%, for single line contingencies with line out and without line out for minimization real power loss and voltage deviation using genetic algorithm(GA). This method has been implemented on IEEE 30 bus system. Simulation results can be performed improving voltage profile for line out 36, 5, 15 and without line out and minimization of real power loss and voltage deviation.

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