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# PSO based optimal location and sizing of SVC for novel multiobjective voltage stability analysis during N – 2 line contingency

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**Abstract:** In this paper voltage stability is analysed based not only on the voltage deviations from the nominal values but also on the number of limit violating buses and severity of voltage limit violations. The expression of the actual state of the system as a numerical index like severity, aids the system operator in taking better security related decisions at control centres both during a period of contingency and also at a highly stressed operating condition. In contrary to conventional N – 1 contingency analysis, Northern Electric Reliability Council (NERC) recommends N – 2 line contingency analysis. The decision of the system operator to overcome the present contingency state of the system must blend harmoniously with the stability of the system. Hence the work presents a novel N – 2 contingency analysis based on the continuous severity function of the system. The study is performed on 4005 possible combinations of N – 2 contingency states for the practical Indian Utility 62 bus system. Static VAr Compensator is used to improve voltage profile during line contingencies. A multi- objective optimization with the objective of minimizing the voltage deviation and also the number of limit violating bus with optimal location and optimal sizing of SVC is achieved by Particle Swarm Optimization algorithm.

**Key words:** N – 2 contingency analysis, voltage severity, particle swarm optimization, SVC, power system planning

## 1. Introduction

Installation of new circuits to develop the transmission network has become a challenging issue from electrical, economic, social, and environmental constraints [1]. Hence the existing transmission corridors are operated under highly stressed operating conditions. Transmission line congestion and overloading capacity of transmission lines have led to the voltage instability problems in power system. For secure operation of power system, voltage stability studies have become essential. Adequate reactive power supports during line contingencies enhances the voltage stability. The optimal amount of MVAr generated or absorbed by the

FACTS devices has an intense impact on voltage stability of the system [2]. Various research works have been carried out for voltage stability studies using FACTS devices [3, 4]. But they suffer from the disadvantage of considering the normal state of the system for FACTS location.

Voltage instability may be caused by dynamic instabilities in the system or exhaustion of the reserves in transmission due to a sequence of line tripping leading to voltage collapse. According to Northern Electric Reliability Council (NERC), NERC-compliance studies address the issue of assessing power system performance following normal and contingency conditions [5-7]. The traditional N – 1 security criterion provides only a limited perspective on the actual level of security of a power system.

Various artificial intelligence based techniques such as artificial neural network [8], genetic algorithm [9], Tabu Search [10], ant colony optimization [11], simulated annealing [12], Fuzzy logic [13], Gravitational search algorithm [14],bacteria foraging algorithm [15], firefly algorithm[16], biogeography algorithm [17] and particle swarm optimization[18] techniques for optimal placement of FACTS devices are available. In [19], PSO technique is considered for optimal location of FACTS controllers for system loadability. Single line contingency is considered in [20] and PSO algorithm is adopted for enhancing power system security using FACTS devices. Jumaat et al in [21] has proposed PSO technique for optimal location and sizing of SVC for transmission loss minimization. Reference [22], highlights the merits of PSO by comparing the results of PSO with that obtained from artificial immune system in achieving the task of loss minimization along with the cost function. Modified PSO was used to optimize the location, and the rated value of SVC for increasing the loadability of the IEEE 30 bus system in [23]. Non-dominated sorted Particle Swarm Optimization (NSPSO) was employed in [24] for optimal placement and sizing of SVC to minimize transmission loss and to improve voltage profile.

Voltage deviation from the nominal value alone cannot be a sole factor in determining the voltage instability [25]. Voltage instability also depends on the factors like the number of voltage limit violating buses, the likelihood of occurrence of the contingency, the severity of the contingency and the assessment of cascading outages [26]. Voltage instability valuation using indices assist in identifying the weakest bus and the most critical line. C.Lemaitre et al. in [27] proposed the use of indices to indicate the voltage instability. An index which would become half at voltage collapse point is developed in [28] to trace voltage stability. Many other indices such as voltage collapse index [29], new voltage stability index [30], and fast voltage stability index [31, 32] are also developed to identify the voltage stability.

In this paper, the continuous severity function dealt in [25] is used for analyzing the voltage stability in the practical Indian Utility 62 bus system. Also differing from the existing works, N – 2 line contingency analysis is considered. All the 4005 possible combinations of contingency states are investigated for N – 2 contingency states in Indian utility 62 bus system and contingency ranking is done based on the severity of voltage limit violation and upon the number of limit violating buses. PSO algorithm is used to achieve the objective of optimal location and optimal sizing of SVC and to minimize thereby the deviation from the nominal value and to improve severity index.

## 2. Voltage instability and severity functions

The electric utility industry is paying greater attention to voltage stability problems. In the past, voltage problems were primarily associated with weak systems and power transfers across long transmission lines. Voltage instability has now become a concern in highly developed networks for several reasons. The "Not in My Back Yard" (NIMBY) sentiment has made it difficult or even impossible to build new generation near load centers and to construct or upgrade transmission lines from remotely-sited generation. Electricity consumption, on the other hand, has increased in heavily loaded areas where it is not feasible to install new generating plants. Deregulation has exacerbated this situation by creating new loading patterns, reducing the available transmission capacity. Technological advances in angular stability protection have also contributed to increased occurrences of voltage instability. Improved fast fault clearing, high performance excitation systems, power system stabilizers, and other controls are effective in extending angular stability margins imposed power transfer limits. With these limits diminished, voltage stability often dictates transmission circuit transfer limits. Three types of severity index function for low voltage are detailed in [25]. They are

### 2.1. Discrete severity function

If the voltage magnitude of the bus is lower than its low voltage rating, the severity function is assigned a value 1 or else a value of 0.

$$Sev(v_i) = \begin{cases} 0, & V_i \geq V_i^c \\ 1, & V_i < V_i^c \end{cases}, \tag{1}$$

where $V_i^c$ is the low voltage rating of bus '$i$', $V_i$ is the voltage magnitude at bus '$i$'.

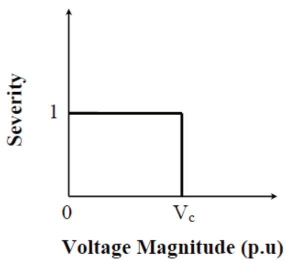


Fig. 1. Discrete severity function

### 2.2. Percentage of violation severity function

The severity function uses the percentage of violation to define the severity of the low voltage problem. The severity function may be stated as

$$\mathrm{Sev}(v_i) = \begin{cases} \dfrac{0.95 - V_i}{0.95}, & V_i \leq 0.95 \\ 0, & V_i > 0.95 \end{cases}, \tag{2}$$

where $V_i$ is the magnitude of voltage in p.u at bus '$i$'.

**2.3. Continuous severity function**

For each bus, the severity function takes a value of 1.0 at the deterministic low voltage limit and the severity function increases linearly as the decrease in magnitude of the bus voltage. In this case, when the bus voltage magnitude stays equal or above the nominal value of the bus, then the severity magnitude is zero. For voltage magnitude values smaller than 1.0, severity is a linear function with 1.0 corresponding to a voltage of 0.95 p.u.

$$Sev(v_i) = \begin{cases} 0, & V_i \geq V_i^b \\ \left(\dfrac{1}{V_i^c - V_i^b}\right) V_i + \dfrac{V_i^b}{V_i^b - V_i^c}, & V_i < V_i^b \end{cases}, \tag{3}$$

where $V_i^b$ is the nominal voltage of the bus '$i$', $V_i^c$ is the low voltage rating of the bus '$i$' and $V_i$ is the voltage magnitude of the bus '$i$'.

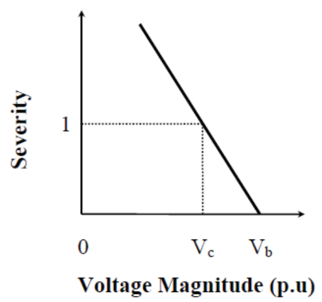


Fig. 2. Continuous severity function

Both the Percentage Severity Function and the Discrete Severity Function determines the severity value of the system only when there are voltage violating buses present in the system. It does not differentiate between the conditions where the voltage level of a bus is operating very close to the lower limits. Another serious drawback in all three severity functions is that the severity due to overvoltage conditions is not accounted in the severity function formulation. The Continuous Severity Function is comparatively a better methodology to effectively quantify the voltage violations as it takes the deviation of voltage value from its nominal voltage rather than the lower voltage limit. Further the severity value is calculated for all the buses irrespective of the presence of voltage violations. Hence this work applies the continuous severity function to quantify the system operating state.

According to Northern Electric Reliability Council (NERC), a catastrophic failure, defined as one that results in the outage of a sizable amount of load, may be caused by dynamic instabilities in the system or exhaustion of the reserves in transmission due to a sequence of line tripping leading to voltage collapse. NERC-compliance studies address the issue of assessing power system performance following normal and contingency conditions.

These studies ensure that the transmission system performance meets NERC Reliability Standards, and that the upgrades to meet future system needs are developed such that reliable and secure operation of the system is maintained. Transmission Planning (TPL) standards define reliable system performance following a loss of single bulk electric element, two or more bulk electric elements, or following extreme events, under its transmission planning standards.

A new NERC TPL standard TPL-001-1 (Transmission System Planning Performance Requirements) that is scheduled to be submitted to the regulatory authorities for approval in 1Q2010 requires a more systematic and diligent contingency analysis, including exhaustive N – 2 contingency analysis (loss of two elements simultaneously), N – 1 – 1 contingency analysis (loss of two elements consecutively), and assessment of cascading outages. The need to provide the system planner with fast and automated process to effectively perform NERC-compliance studies is vital and growing more acute. In addition, this process should be used to assist planners in optimizing transmission system expansion which will reduce blackout risk and improve transmission system reliability.

The traditional N – 1 security criterion provides only a limited perspective on the actual level of security of a power system and a risk-based approach to security assessment provides considerably more information on which to base operating decisions.

## 3. SVC modelling

SVC is used in power system for voltage control to attain system stabilization. SVC can be viewed as an adjustable reactance with either firing angle limits or reactance limits. SVC is treated as a shunt connected variable susceptance ($B_{SVC}$) in this model as shown in Figure 3.

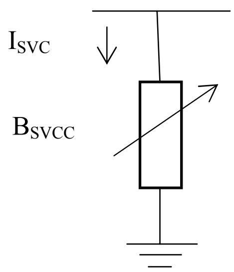


Fig. 3. Equivalent circuit of static VAr compensator

Current drawn by the SVC is

$$I_{SVC} = B_{SVC}V_i. \tag{4}$$

Reactive power injected at bus '*i*' is negative of the reactive power drawn by the SVC. Therefore,

$$Q_{SVC} = Q_i = -V_i^2 B_{SVC}. \tag{5}$$

The bus to which SVC is connected is a voltage controlled bus and is called a PVB type bus, in which voltage magnitude, active and reactive power are specified and equivalent susceptance $B_{SVC}$ is taken as the state variable.

The linearized equation of SVC is

$$\begin{bmatrix} \Delta P_i \\ \Delta Q_i \end{bmatrix}^m = \begin{bmatrix} 0 & 0 \\ 0 & Q_{i\,i} \end{bmatrix}^m \begin{bmatrix} \Delta Q_i \\ \Delta \dfrac{B_{\mathrm{SVC}}}{B_{\mathrm{SVC}}} \end{bmatrix}. \tag{6}$$

At the end of iteration m, variable susceptance $B_{\mathrm{SVC}}$ is updated as:

$$B_{\mathrm{SVC}}^{(m)} = B_{\mathrm{SVC}}^{(m-1)} + \left(\frac{\Delta B_{\mathrm{SVC}}}{B_{\mathrm{SVC}}}\right)^{(m-1)} B_{\mathrm{SVC}}^{(m-1)}. \tag{7}$$

Equation (7) represents total SVC susceptance necessary to maintain nodal voltage magnitude at the specified value.

## 4. Particle swarm optimization

The particle swarm optimization first proposed by J. Kennedy and RC. Eberhart is a standard technique used in many applications. The PSO was inspired from the social behavior of bird flocking. It uses a number of particles (candidate solutions) which fly around in the search space to find best solution. Particle swarm optimization method is based on the social behavior that a population of individuals adapts to its environment by returning to promising regions that were previously discovered. This adaptation to the environment is a stochastic process that depends on both the memory of each individual, called particle, and the knowledge gained by the population, called swarm. The concept of PSO consists of, at each time step, changing the velocity of (accelerating) each particle toward its pbest (local version of PSO). In the numerical implementation of this simplified social model, each particle has three attributes: the position vector in the search space, the current direction vector, the best position in its track and the best position of the swarm. Acceleration is weighted by a random term, with separate random numbers being generated for acceleration toward pbest locations. PSO is mathematically modelled as follows,

$$v_i^{t+1} = wv_i^t + c_1 x \mathrm{rand}\ \ x\left(p\,\mathrm{best}_i - x_i^t\right) + c_2 x \,\mathrm{rand}\ \ x\left(g\,\mathrm{best} - x_i^t\right), \tag{8}$$

$$x_i^{t+1} = x_i^t + v_i^{t+1}, \tag{9}$$

where $v_1^t$ is the velocity of the particle $i$ at iteration $t$, $c_j$ is the weighing factor, rand is a random number between 0 and 1, $x_i^{t+1}$ is the current position of particle $i$ at iteration $t$, $p\mathrm{best}_i$ is the $p$best of agent $i$ at iteration $t$, and $g$best is the best solution so far. The first part of (8), $wv_i^t$ provides the exploration ability for the PSO and the second and third parts of (8), provides private thinking and collaboration of particles respectively. The stepwise procedure for implementation of Particle Swarm Optimization is given below:

1) Generate the initial Swarm with $N$ particles with random positions in the search space.
2) Evaluate the fitness of the particles and calculate the $p$best of each particle and $g$best of the swarm.
3) Check whether maximum iteration is achieved. If yes proceed to step 5.

4) Calculate the new velocity of the particle and update the position of the particle using Equations (8) and (9). Proceed to Step 2.
5) The *g*best of the current swarm is the optimal solution required.

The following are the various parameters used for implementing PSO for the proposed work.

a) *Weighting factor:*
The global search and local search balance is accomplished, by adjusting the values $C_1$ and $C_2$. In the study, $C_1 = 0.5$ and $C_2 = 1.5$.
b) *Population size:*
The number of agents decides the population size. A large population size makes the convergence slow, and a small population size fails to give the global results. The optimal number of agents considered here is 100.
c) *Acceleration constant:*
A large acceleration constant increases the searching process but the tendency to oversee the best value in the search process may exist.
d) *Number of iterations:*
The number of iterations is set to 25.

## 5. Multi-objective optimization problem formulation

The multi-objective function ($J$) is to reduce the severity index value ($J_1$) and to minimize the voltage deviation ($J_2$) by optimally placing the SVC.

### 5.1. Minimization of the severity index:

The security level of the system is identified by the severity of the contingency. For stable operation, the severity of the contingency must be minimized.

$$\text{Min } J_2 = \text{Min}\{\text{Sev}(V_i)\}, \tag{10}$$

where $J_1$ is the severity of the contingency to be minimized.

### 5.2. Minimization of voltage deviations

The deviation of voltage from the nominal value is to be minimized and is given by

$$\text{Min } J_2 = \sqrt{\sum_{i=0}^{N_{\text{bus}}} (V_i - 1)^2}, \tag{11}$$

where $J_2$ is the voltage deviation to be minimized, $V_i$ is the magnitude of the bus '$i$', and $V_{\text{nom}}$ is the nominal operating value of the bus '$i$' $V_{\text{nom}} = 1.0$

The net objective function J to be minimized is:

$$\min J = w_1 J_1 + w_2 J_2, \tag{12}$$

where $w_1$ and $w_2$ are the weights attached to individual functions.

Three different cases are analysed on the system based on the weights value assigned to $w_1$ and $w_2$.

**Case 1. Least system severity solution**

Here the multi-objective optimization function is modified to serve a single objective function of reducing the overall system severity. Hence the weightages assumed are $w_1 = 1$ and $w_2 = 0$.

**Case 2. Least voltage deviation solution**

Here the multi-objective optimization function is modified to lay emphasis on system with least possible voltage deviations in all buses. Hence the weightages assumed are $w_1 = 0$ and $w_2 = 1$.

**Case 3. Combined solution**

In this the multi-objective function is modified to find an optimal compromise solution to achieve the best possible solutions for reduction in voltage severity and voltage deviations combined together. The weightages assigned here are $w_1 = 1$ and $w_2 = 1$.

## 6. Test system data

The practical Indian Utility system with 62 Buses, 89 Transmission lines, 19 generators having a real power demand of 2845 MW, and reactive power demand of 1284 MVAR, is taken as test system. The schematic of the test system is shown in Figure 4. The line numbers designated to each transmission line connecting various buses is provided in the Appendix.

## 7. Results and discussions

The Newton Raphson load flow analysis was used to determine the voltage at all the 30 buses after the occurrence of a particular contingency state. The average computation time for the calculation of voltage at all buses using Newton Raphson method for a particular contingency is 0.0521 seconds. N-2 contingency analysis was done for all possible 4005 contingency states in the practical test system.

The ranking of top 5 contingencies based on continuous severity function of a particular contingency is given in Table 1. Table 2 gives the top 5 contingencies based on number of voltage violations in a particular contingency state. The continuous severity function quantifies the severity based on deviation of the voltage value from the nominal operating voltage of all buses irrespective of voltage limit violations. Hence the numeric quantification by the continuous severity function has numerically higher value than the total number of voltage violating buses.

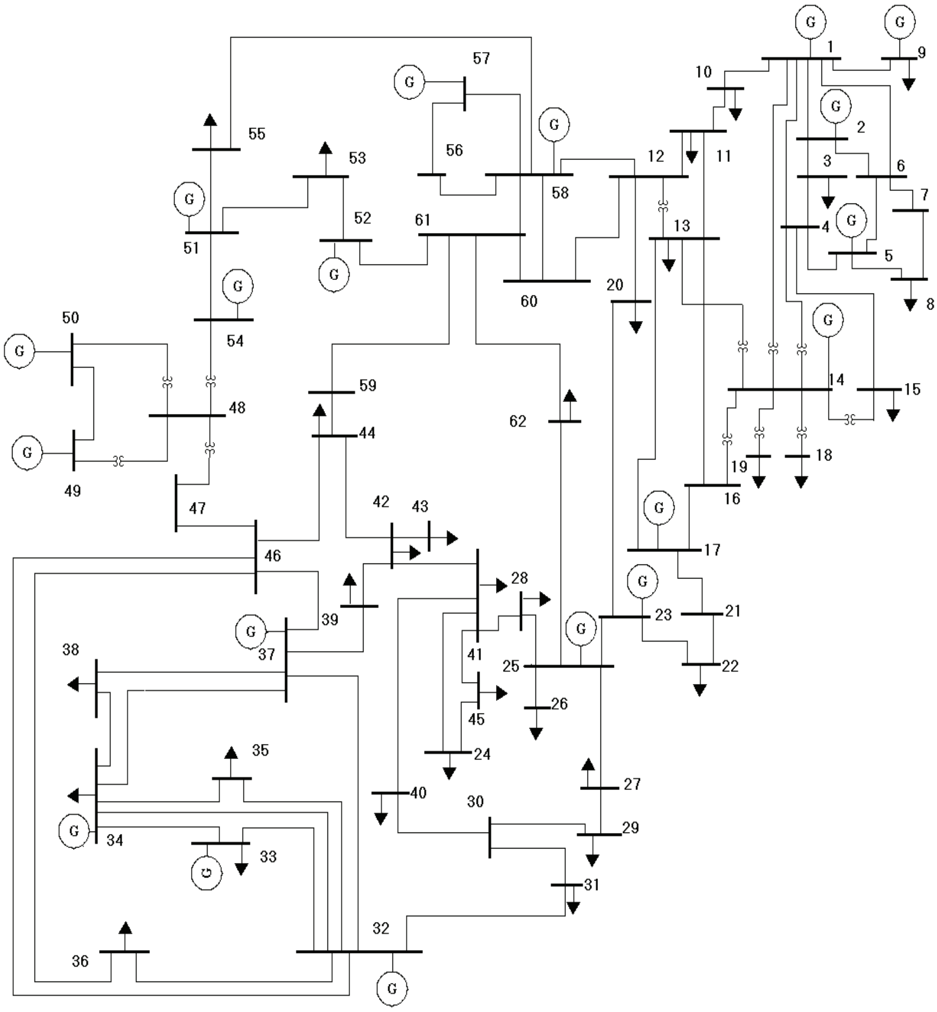


Fig. 4. Schematic of Indian Utility 62 bus system

Table 1. Ranking of top 5 contingencies based on severity values

| **Outage lines** | | **Severity of contingency** | **Number of voltage violating buses** |
|---|---|---|---|
| Line 1 | Line 2 | | |
| 43 | 56 | 28.46 | 5 |
| 27 | 48 | 27.17 | 9 |
| 31 | 56 | 24.30 | 5 |
| 27 | 47 | 21.67 | 7 |
| 4 | 22 | 18.77 | 4 |

Table 2. Top 5 contingencies based on number of voltage violating buses

| **Outage lines** | | **Number of voltage violating buses** | **Severity of contingency** |
|---|---|---|---|
| line 1 | line 2 | | |
| 27 | 31 | 9 | 17.85 |
| 27 | 48 | 9 | 27.17 |
| 27 | 47 | 7 | 21.67 |
| 31 | 44 | 5 | 12.76 |
| 31 | 56 | 5 | 24.30 |
| 43 | 56 | 5 | 28.46 |

On comparing and analyzing Table 1 and Table 2, the overall list of critical contingencies of the system, listed in the order of their severity is given in Table 3.

Table 3. Critical contingencies of test system

| **Outage lines** | | **Severity of contingency** | **Number of voltage violating buses** |
|---|---|---|---|
| line 1 | line 2 | | |
| 43 | 56 | 28.46 | 5 |
| 27 | 48 | 27.17 | 9 |
| 31 | 56 | 24.30 | 5 |
| 27 | 47 | 21.67 | 7 |
| 4 | 22 | 18.77 | 4 |
| 27 | 31 | 17.85 | 9 |
| 31 | 44 | 12.76 | 5 |

Table 4. Reactive power support found by PSO for outage of line 43 & line 56 for case 1

| **Compensating bus** | **Optimal reactive power support in MVAr** | **After compensation** | |
|---|---|---|---|
| | | number of voltage violating bus | severity |
| 27 | 100 | 3 | 11.3202 |
| 29 | 100 | 3 | 7.59311 |
| 30 | 100 | 0 | 0.48154 |
| 31 | 92.9264 | 0 | 0.481707 |
| 40 | 97.0593 | 0 | 0.481754 |

The proposed work utilizes particle swarm optimization algorithm approach to find the optimal reactive power supply by a FACTS device such as SVC at a particular bus so as to reduce the severity of the contingency. Table 4 gives the results of PSO based approach for the most severe contingency i.e., the N – 2 contingency outage of line 43 and line 56 in the test system. The optimization problem was set to analyse for case 1 as discussed in Section 5.

It can be seen from Table 4, that the optimum compensation in view of case 1 will be to compensate with 100 MVAr in Bus 30 to reduce the system severity to a value of 0.48154 from an initial system severity value of 28.46 before compensation. However, on analysing Table 4 from the view of Case 2, then three equally effective compensation solutions exist. Similar analysis was done for each of the critical contingencies listed in Table 3. Table 5 lists the optimum compensation for each of the listed critical contingency in lieu analysis of Case 2.

Table 5. Optimal reactive power support for critical contingencies determined for case 2

| **Outage lines** | | **Compensating bus** | **Compensating MVAr** | **After compensation** | |
|---|---|---|---|---|---|
| line 1 | line 2 | | | severity | number of voltage violating buses |
| 43 | 56 | 31 | 84.4724 | 1.21 | 0 |
| 27 | 48 | 24 | 100 | 8.94 | 4 |
| 31 | 56 | 29 | 95.75 | 2.49 | 0 |
| 27 | 47 | 24 | 97.05 | 6.60 | 0 |
| 4 | 22 | 11 | 100 | 5.24 | 2 |
| 27 | 31 | 29 | 90.57 | 5.59 | 0 |
| 31 | 44 | 27 | 82.47 | 1.429 | 0 |

The choice of the compensating bus depends on the physical considerations of the system and its capabilities. Form Table 4 and Table 5 it can be inferred that the severity and the number of voltage violating buses after compensation depends both on the location of the SVC and also on the reactive power support by the SVC. Hence the multi-objective optimization process to determine the optimal reactive power support was repeated for case 3 which places equal weightage to the reduction in severity as well as the number of voltage violating buses after compensation, so as to achieve a better compromise solution.

Table 6. Optimal reactive power support for critical contingencies determined for case 3

| **Outage lines** | | **Compensating bus** | **Compensating MVAr** | **After compensation** | |
|---|---|---|---|---|---|
| line 1 | line 2 | | | severity | number of voltage violating buses |
| 43 | 56 | 30 | 100 | 0.481 | 0 |
| 27 | 48 | 24 | 100 | 8.947 | 4 |
| 31 | 56 | 29 | 100 | 2.27 | 0 |
| 27 | 47 | 24 | 100 | 6.24 | 0 |
| 4 | 22 | 10 | 100 | 4.77 | 2 |
| 27 | 31 | 29 | 100 | 5.09 | 2 |
| 31 | 44 | 29 | 100 | 0.84 | 0 |

Table 6 shows the optimal compromise solution obtained by the multi-objective optimization for case 3 using PSO for all the listed critical contingencies.

The upper limit of the SVC capability was fixed at 100 MVAR. Figure 5 shows the voltage profile of the system before and after compensation during the outage of Line 43 and Line 56 after compensation in bus 30. It can be seen that after compensation, the voltage profile of all buses are within the acceptable operational limits without any violations.

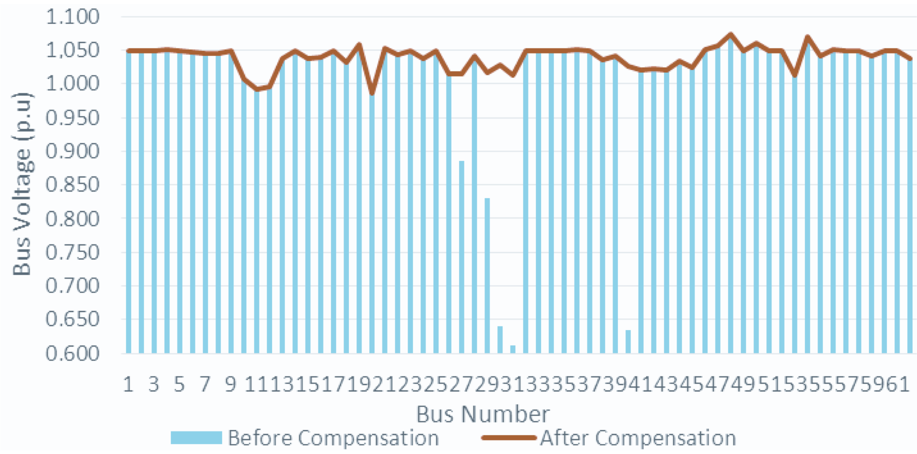


Fig. 5. Voltage profile of test system before and after compensation

## 8. Conclusion

An effective methodology to assist the control actions to be taken by the system operator, is of great importance. In this work, the contingency ranking for N-2 contingency line outages of all the 4005 possible combinations for a practical 62 bus Indian Utility system, were carried out. As outlined in the paper, the discussed method may significantly help in the determination of overall system security. The determined security of the system may be enhanced if needed through proper placement of the FACTS devices and the application of PSO algorithm in the determination of optimum position has been outlined in the paper. The obtained results substantiate the fact of the improvement of system security. The work may however be extended to the development of indigenous severity functions which reflect the over-voltage scenario also. There is scope or extension of the proposed work in the process of analysis of positioning multiple FACTS devices and characterization of their augmented performance. As outlined in the paper, the proposed method significantly helps in system planning, and in improving the overall system security under stressful conditions.

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## Appendix

| Line no# | From bus | To bus |
|---|---|---|
| 1 | 1 | 2 |
| 2 | 1 | 4 |
| 3 | 1 | 14 |
| 4 | 1 | 10 |
| 5 | 1 | 9 |
| 6 | 1 | 6 |
| 7 | 2 | 6 |
| 8 | 2 | 3 |
| 9 | 3 | 4 |
| 10 | 4 | 15 |
| 11 | 14 | 15 |
| 12 | 4 | 14 |
| 13 | 13 | 14 |
| 14 | 12 | 13 |
| 15 | 12 | 11 |
| 16 | 11 | 10 |
| 17 | 4 | 5 |
| 18 | 5 | 6 |
| 19 | 6 | 7 |
| 20 | 7 | 8 |

| | | |
|---|---|---|
| 21 | 5 | 8 |
| 22 | 11 | 16 |
| 23 | 16 | 17 |
| 24 | 17 | 21 |
| 25 | 21 | 22 |
| 26 | 22 | 23 |
| 27 | 23 | 24 |
| 28 | 23 | 25 |
| 29 | 25 | 28 |
| 30 | 25 | 26 |
| 31 | 25 | 27 |
| 32 | 27 | 29 |
| 33 | 29 | 30 |
| 34 | 20 | 23 |
| 35 | 12 | 20 |
| 36 | 13 | 17 |
| 37 | 14 | 19 |
| 38 | 14 | 18 |
| 39 | 14 | 16 |
| 40 | 24 | 45 |
| 41 | 24 | 41 |
| 42 | 41 | 45 |
| 43 | 40 | 41 |
| 44 | 41 | 42 |
| 45 | 42 | 43 |
| 46 | 42 | 44 |
| 47 | 39 | 42 |
| 48 | 39 | 37 |
| 49 | 38 | 37 |
| 50 | 38 | 34 |
| 51 | 34 | 37 |
| 52 | 34 | 33 |
| 53 | 34 | 35 |
| 54 | 35 | 32 |
| 55 | 33 | 32 |
| 56 | 32 | 31 |
| 57 | 30 | 31 |
| 58 | 40 | 30 |
| 59 | 32 | 36 |
| 60 | 32 | 37 |
| 61 | 32 | 34 |
| 62 | 32 | 46 |
| 63 | 36 | 46 |
| 64 | 37 | 46 |

| | | |
|---|---|---|
| 65 | 46 | 44 |
| 66 | 44 | 59 |
| 67 | 59 | 61 |
| 68 | 60 | 61 |
| 69 | 61 | 62 |
| 70 | 62 | 25 |
| 71 | 58 | 61 |
| 72 | 58 | 60 |
| 73 | 55 | 58 |
| 74 | 57 | 58 |
| 75 | 57 | 56 |
| 76 | 56 | 58 |
| 77 | 52 | 61 |
| 78 | 52 | 53 |
| 79 | 51 | 55 |
| 80 | 51 | 53 |
| 81 | 51 | 54 |
| 82 | 48 | 54 |
| 83 | 48 | 50 |
| 84 | 49 | 50 |
| 85 | 49 | 48 |
| 86 | 47 | 48 |
| 87 | 47 | 46 |
| 88 | 60 | 12 |
| 89 | 58 | 12 |