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Power System Security with Contingency Technique by Using SSSC & UPFC

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Abstract— Now days' electrical power requirement has enlarged expanding as expansion & restructuring of electrical power system (PS) for generation & transmission in power sector is critically limited due to current resources & environmental circumstances.

As outcome, approximately of corridors of power transmission overhead lines are greatly loaded & congested. Also major issue of power system voltage stability becomes power transfer restricted and capability issue. A Modern power electronics technology FATCS considered device Static Synchronous Series Compensator (SSSC) is VSC demanded series FACTS equipment. Unified power flow controller (UPFC) is to manage power flow (PF), voltage magnitude & phase angle. In this research paper suggested to maintain voltage magnitude as well as PF of faulty lines. The consequence of mutation of PS parameters like voltage, phase angle, active power, reactive power, & overall power factor with & without SSSC & UPFC have also incorporated. Assessment of PS safety is essential in society to expand customs to sustain system functions when one or more components fail. A PS is "secure" when it can defy loss of one or more ingredients & still go on working without major problems. The Contingency event investigation technique is taken to identify electrical node PF in faulty transmission lines (TL). The Performance of PS has been tested on IEEE 14-Bus System.

Index Terms: SSSC, UPFC, Contingency technique, Power flow.

I. INTRODUCTION

The desired amount of prohibited node PF via TL is interpreted into essential injected voltage. The dominance of direct current (D.C) bus voltage plays important role in electrical PF into overhead TL (OTL). PF manages attained via reactive section of voltage injected. It is noted that SSSC acts as capacitor when system PF via OTL is enlarged & as an inductor while PF is diminished. The system described in Figure 1 consists fundamental configuration of SSSC. For taking concern of PF in transmission line & voltage magnitude at buses use SSSC & UPFC as a FACTS device rated ± 70 MVAR & ± 150 MVAR respectively. Further, transformer has capacity of 300MVA. The main advantage in execution of VSC considered SSSC & VSI based UPFC are adequately maximum value of storage capacitance & consequently not cost effectual. [1]

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WORKING PRINCIPAL OF FACTS DEVICES

A. Static Synchronous Series Compensator (SSSC)

SSSC is series compensation device that is connected controller based on VSC which is shown in fig 1. SSSC is operated moreover capacitive or inductive injected voltage compensation. If line current via 90 lead in AC series injected voltage in SSSC, capacitive series voltage compensation is attain in TL.

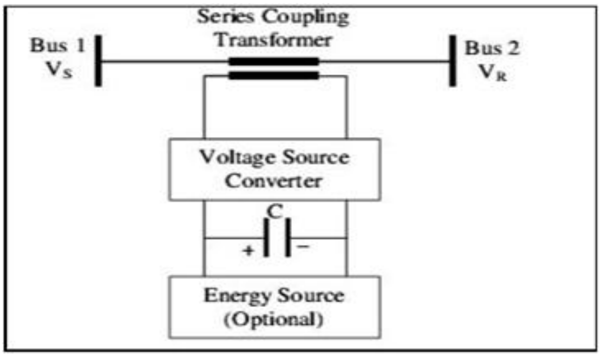

Fig.1: Schematic illustration of SSSC.

On opposite, if AC line injected series voltage of SSSC guide line current via 90°, inductive series compensation may implement. The injection of voltage into line ought to take place only while power is to be subtracted from or added into line. It is too distinguished SSSC acts as capacitor while system PF via line is amplified & as an inductor when PF is to be reduced. [1]

B. Unified Power Flow Controller (UPFC)

UPFC is made up of 2 voltage source converters; series & shunt converter SSSC & STATCOM respectively, coupled via normal DC voltage link. The energy preserving capacity of DC capacitor is usually low & then shunt converter inject APF from transmission grid in accurately similar quantity as active power being injected via series converter.

If this is not subsequently, DC-link voltage ought amplify or reduce with admiration to rated voltage, formation on net power taken up or returned via mutual converters. Under different conditions, RPF in shunt or series converter may manage separately, yielding vast flexibility to PF control.

The coupling transformer is utilized to plug in equipment to arrangement. Figure 2 presents schematic diagram of 3 phases UPFC connected to TL. PF Control can be attained via adding vector of series voltage, Vs with certain amplitude, $|V_s|$ & phase shift (PS), δ to V_1.

This introduces fresh line voltage V_2 with another magnitude & PS. As the angle δ varies, phase shift δ among V_1 & V_2 also varies. Figure 2 presents schematic diagram of UPFC & characteristics of voltage & current [6].

With existence of 2 converters, UPFC not only can provide reactive power but also active power.

In this operation, series converter swaps mutually real & reactive power with TL. The equation for active & reactive power is given as below:-

$$P_{12} = \frac{V_1 V_2}{X_{12}} \sin\delta \quad (1)$$

$$Q_{12} = \frac{V_1 V_2}{X_{12}} (\cos\delta + 1) \quad (2)$$

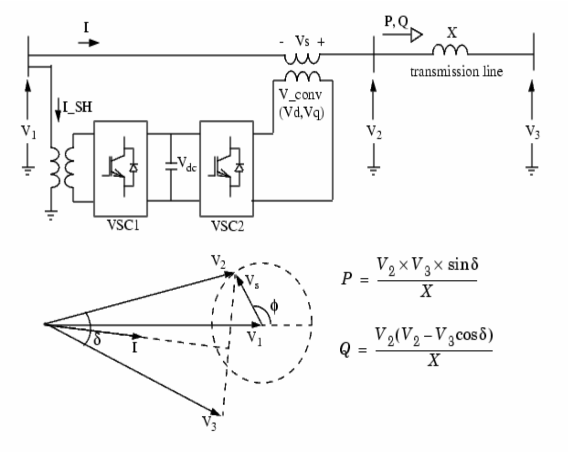

Figure 2: Schematic diagram of UPFC

C. IEEE 14-Bus (Test System)

The single line figure of IEEE 14-bus standard test system is presented in figure 3 that is made up of 20 TL. 5 no. synchronous machines, consisting 2 generators, located at buses 1 & 2 as well as 3 synchronous compensators utilized for RPF handles, located at buses 3, 6 & 8.

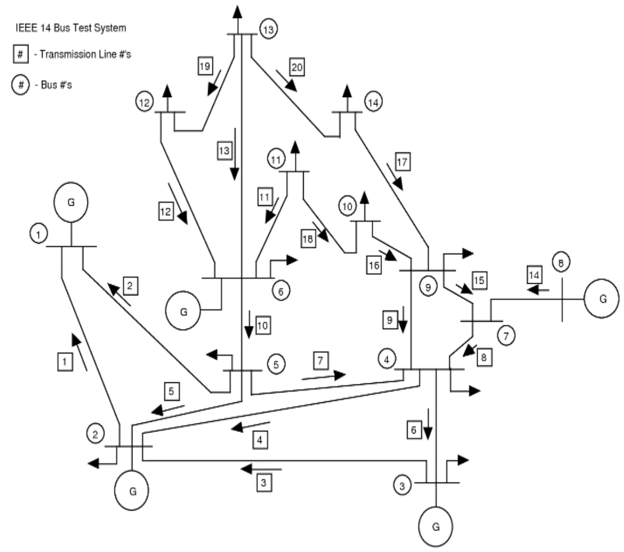

Figure 3: Single line diagram of IEEE 14 Bus

III. CONTINGENCY SELECTION

Maintaining PS security is one of most demanding practical tasks for PS engineers. The safety determination is necessary job as it provides knowledge about system while it is in state of contingency.

Contingency analysis function is used to decide consequence of faults such as failures of devices, TL error etc. & to apply for obligatory actions to prevent PS instability & dependable. The off line analysis of individual contingency is tedious job because PS have a huge amount of elements.

Actually, only selected contingencies will guide to severe conditions in PS. Recognize severe contingencies is referred as contingency selection & this can be performed via manipulative presentation indices for each line. The contingency investigation technique is much time overwhelming and its convoluted calculation of complex AC load flow computation subsequent to every probable fault at different generators & TL [7].

In sort to alleviate above issue, an automatic contingency screening (CS) demand is assume that recognize & ranks faults that actually due to abnormal circumstances. So CS & ranking for unsymmetrical fault. The contingencies are screened as per to severity index or PI in which maximum value of these indices ssymbolize maximum level of hardness.

The major purpose of this work is to hold contingency selection via manipulative the 2 types of performance indices namely, active power performance index (PIP) & reactive power performance index (PIQ) for individual line fault. (PIQ) have been calculated for IEEE-14 bus test system that is presented in fig 3.

Employing algorithm implemented in MATLAB software. With help of Fast Decoupled Load Flow (FDLF), PIP & PIQ played out in MATLAB & contingency ranking is based. Founded on values of the PIQ, contingencies is ranked in TL contingency guiding to maximum value of PIQ has been ranked 1 & at least values of PIQ is ranked last. The solutions of active PF (APF), reactive PF (RPF) in different TL & bus voltages at the buses has been studied [9]. Since contingency analysis techniques involve prediction of effect of individual contingency cases, the above process becomes very tedious & time consuming while complex PS network is wide and big.

In sort to avoid exceeding problem of CS or contingency selection technique found critical concern. As it found overall probable faults do not cause overload voltage or beneath voltage in different PS devices. The procedure of recognizing contingencies that really go to encroachment of real operational restrictions is termed as contingency selection.

The contingencies are chosen via manipulative type of severity indices termed as Performance Indices (PI). These indices are computed utilizing conventional power load flow algorithms for single contingencies in an off line mode. Set along values attained contingencies are ranked in manner, where they obtained maximum value of PI is ranked 1st.

The investigation is basically preliminary via eventuality that is ranked 1 & is persisted in from no severe contingencies are available. Here 2 kinds of PI, that is highly utilize, these are active power, performance index (PIP) & reactive power performance index (PIQ). PIP shows violation of line APF & is shown via equation (3).

$$PIp = \sum_{i=0}^{l} \left(\frac{Pi}{Pmax}\right) \quad (3)$$

Where,
Pi = APF in line i,
Pimax =Maximum APF in line i,
N is precise element,
L is overall no of TL in system If n is big figure, PI will be low bit if overall PFs are in restrictions & larger if 1 or further TL are overloaded, value of n is kept unity.

The highest PF in every line is considered utilizing formula,

$$Pimax = \frac{V_i V_j}{x} \quad (4)$$

Here,
Vi = Voltage at bus i
Vj = Voltage at bus j
X = Reactance of line linking bus i & bus j

Another PI parameter that is utilized to bus voltage magnitude violations.

It mathematically presented in eq. 3,

$$PIv = \sum_{i=1}^{Npq} \left\{\frac{2(Vi - Vinom)}{(Vimax - Vimin)}\right\} \quad (5)$$

Where Vi = voltage of bus i, Vimax & Vimin are highest & lowest voltage limits, Vinom is average of Vimax & Vimin , Npq is overall no. of load buses in system [12].

IV. CONTINGENCY RANKING OF IEEE-14 BUS SYSTEM

To search Contingency Ranking subsequently technique is assumed: The AC power load flow program for contingency analysis (CA) by adopting the Fast Decoupled Load Flow (FDLF) algorithms that provides a quick solution for the contingency investigation as it possesses benefits of matrix alteration equation included & applied to suggest issue of possible contingencies concerning TL fault without reinventing system Jacobian matrix for alliteration. The ranking of line contingency is shown in shown table1.

Table 1: Line by Line Contingency Ranking

Fault Line No.	PIP	PIQ	Ranking
1	1.1693	7.3032	10
2	0.9807	7.6696	11
3	1.1654	10.0014	7
4	0.9999	7.3213	12
5	0.9820	8.8759	9
6	0.9640	13.2572	2
7	0.9915	0.3566	19
8	1.0747	1.1753	17
9	0.9807	10.5776	4
10	1.2396	1.6047	16
11	1.0142	9.5907	8
12	1.0127	1.8089	15
13	1.0569	1.3669	18
14	1.0072	10.4518	6
15	1.0759	0.0844	20
16	1.0114	13.3464	1
17	1.0164	2.3482	13
18	1.0030	10.5217	5
19	1.0008	12.5538	3
20	1.0076	2.2891	14

V. RESULTS AND DISCUSSION

The system has total 20 no. TL, therefore we estimate for 20 line contingency circumstances via having fault on one line at time. The PI are summed in beyond table in which it can infer that fault in line no. 16 is mainly severe one & fallout will effect heavy collision on overall system. The maximum value of PIQ for fault suggests that maximum attention be yielded for this communication channel while surgical procedure. The contingency has been set via ranking in which main severe contingency is ranked 1 & list is ranked 20 that is presented in table 1. Then here it analyzes one by one line from contingency ranking & endpoints shown in table No. 2, 3, 4, and 5 with SSSC and UPFC.

The variations in electric potential, APF & RPF with SSSC are presented in figure 4, 5 & 6 and with UPFC are presented in figure 7, 8, & 9 correspondingly.

Table 2: Voltage variations (VV) at Line No. 16 with SSSC

Bus No.	Bus Voltage (BV) (Main)	BV (After Fault)	BV with SSSC
1.	1.06	1.06	1.06
2.	1.045	1.045	1.045
3.	1.01	0.8701102	1.021002
4.	1.00737206	0.976645107	1.0210003
5.	1.00978292	0.999273311	1.008
6.	1.07	1.07	1.07
7.	1.05120246	1.045275968	1.052
8.	1.09	1.09	1.09
9.	**1.04020686**	**0.831892871**	**1.0501**
10.	**1.03543270**	**0.827530961**	**1.045**

11.	1.04780211	1.043258176	1.051201
12.	1.04926356	1.046920381	1.0521002
13.	1.04198704	1.038429205	1.05
14.	1.01653643	1.007809397	1.026

Table 3: PF variations at Line No. 16 with SSSC

Line No.	APF with Fault	RPF with Fault	Line No.	APF with SSSC	RPF with SSSC
1	219.07528	18.843217	1	220.285	18.4607
2	103.65932	4.4666054	2	113.969	4.37595
3	101.28245	0.6079161	3	111.356	0.59557
4	76.416181	0.8169245	4	84.0166	0.80034
5	56.671777	2.4210430	5	62.3084	2.37190
6	30.215410	9.1470338	6	33.2206	8.96139
7	80.703680	11.870645	7	88.7306	11.6297
8	37.180518	4.3931969	8	40.8785	4.30403
9	21.162005	0.8574258	9	23.2668	0.84002
10	60.773799	4.1488491	10	66.8184	4.06464
11	10.561110	4.3661960	11	11.6115	4.27758
12	10.719247	2.1202118	12	11.7854	2.07718
13	24.437191	6.3732922	13	26.8677	6.24394
14	88.005863	12.944723	14	96.7590	12.6820
15	37.180518	6.8176647	15	40.8785	6.6793
16	6.4686256	1.4869327	16	10.1120	1.45675
17	12.916960	2.2092927	17	13.9832	1.97460
18	6.3462411	3.3971191	18	6.90782	2.98403
19	2.3654228	0.7701694	19	2.60069	0.75453
20	8.1714358	2.3726499	20	8.98418	2.324497

Table 4: VV at Line No. 16 with UPFC

Bus No.	BV (Main)	BV (After Fault)	BV with SSSC
1.	1.06	1.06	1.06
2.	1.045	1.045	1.045
3.	1.01	0.8701102	1.021002
4.	1.00737206	0.976645107	1.0210003
5.	1.00978292	0.999273311	1.008
6.	1.07	1.07	1.07
7.	1.05120246	1.045275968	1.052
8.	1.09	1.09	1.09
9.	**1.04020686**	**0.831892871**	**1.0601**
10.	**1.03543270**	**0.827530961**	**1.055**
11.	1.04780211	1.043258176	1.051201
12.	1.04926356	1.046920381	1.0521002
13.	1.04198704	1.038429205	1.05
14.	1.01653643	1.007809397	1.026

TABLE 5: PF variations at Line No. 16 with SSSC

Line No.	APF with Fault	RPF with Fault	Line No.	APF with UPFC	RPF with UPFC
1	219.052	18.843	1	220.2	18.46079
2	103.659	4.46660	2	113.9	4.375956
3	101.282	0.60791	3	111.3	0.595578

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4	76.4161	0.81692	4	84.01	0.800345
5	56.6717	2.42104	5	62.30	2.371908
6	30.2154	9.14703	6	33.22	8.961395
7	80.7036	11.8706	7	88.73	11.62973
8	37.1805	4.39319	8	40.87	4.304037
9	21.1620	0.85742	9	23.26	0.840024
10	60.7737	4.14884	10	66.81	4.064648
11	10.5611	4.36619	11	11.61	4.277584
12	10.7192	2.12021	12	11.78	2.077182
13	24.4371	6.3732	13	26.86	6.243946
14	88.0058	12.9447	14	96.75	12.68201
15	37.1805	6.81766	15	40.87	6.6793
16	6.46862	1.48693	16	11.11	1.356755
17	12.9169	2.20929	17	13.98	1.974603
18	6.3462	3.39711	18	6.907	2.9840352
19	2.36542	0.77016	19	2.600	0.754539
20	8.17143	2.37264	20	8.984	2.324497

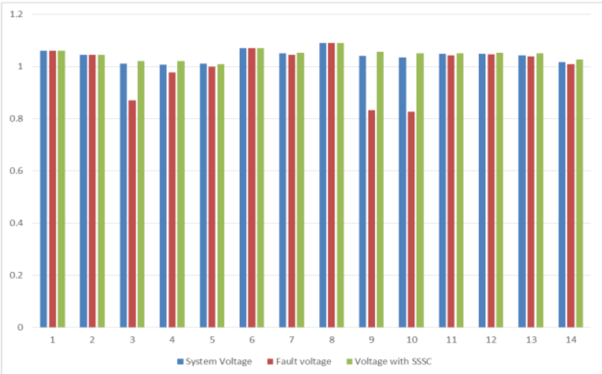

Fig.4. VV at Line no.16 with SSSC

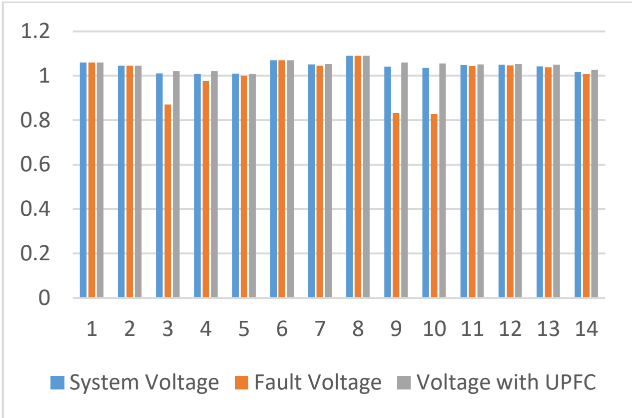

Figure 7. VV at Line no.16 with UPFC

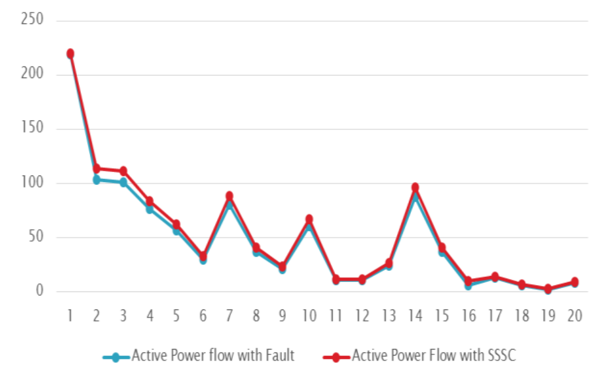

Figure 5. APF at Line no.16 with SSSC

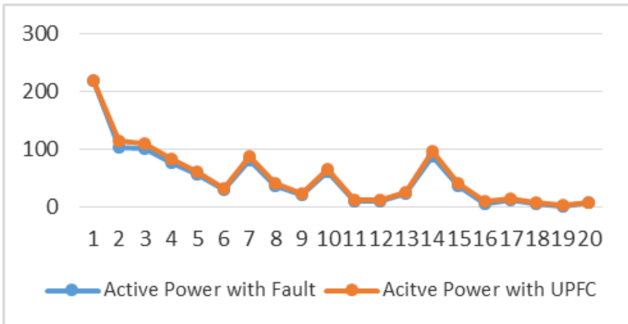

Figure 8. APF at Line no.16 with UPFC

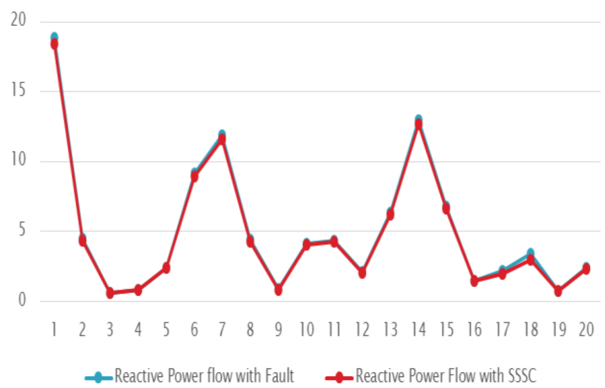

Figure 6. RPF at Line no.16 with SSSC

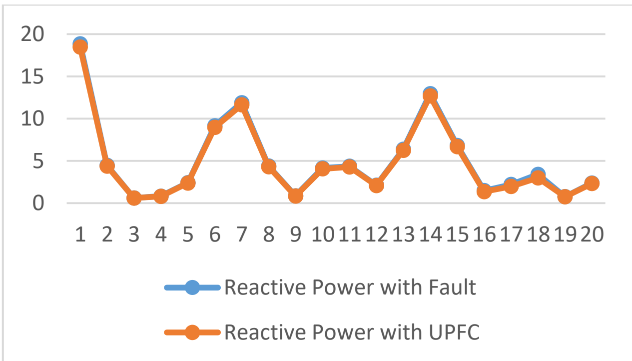

Fig.9. RPF at Line no.16 with UPFC.

VI. CONCLUSION

From outcomes we examine that, bus voltages beneath fault circumstances are drops down as well as PF is disturbing. After connecting SSSC to fault line, power flow is enhanced, but connecting UPFC to fault line, the power flow is improved better than SSSC.

Here we are comparing voltage variation, APF & RPF with and without SSSC and UPFC of line no 16 that is important severe as per contingency investigation as well as VV of Bus no. 9 & 10 that are linked to line no. 16 in table 6.

Table 6: Comparison

Line No./ Bus No.	Fault Condition			With SSSC			With UPFC		
	V pu	P MW	Q MVAR	V pu	P MW	Q MVAR	V pu	P MW	Q MVAR
Line No. 16	---	6.468	1.4869	---	8.812	1.4567	---	11.112	1.356
Bus No. 9	0.83	--------		1.05	-------		1.016	------	
Bus No. 10	0.82			1.04			1.051		

REFERENCES

1. Akhilesh A. Nimje*, Chinmoy Kumar Panigrahi and Ajaya Kumar Mohanty, "Enhanced power transfer capability by using SSSC", Journal of Mechanical Engineering Research Vol. 3 (2), pp. 48-56, February 2011 ISSN 2141 – 2383.
2. A. Seifi, S.Gholami, and A. Shabanpour, "Power Flow Study and Comparison of FACTS: Series (SSSC), Shunt (STATCOM), and Shunt-Series (UPFC)", the Pacific Journal of Science and Technology Volume 11. Number 1. (May 2010.)
3. Ji-Ho Park and Y.S. Baek, "Coordination Control of Voltage between STATCOM and Reactive Power Compensation Devices in Steady-State" Journal of Electrical Engineering & Technology Vol. 7, No. 5, pp. 689~697, (2012.)
4. A. Berizzi, M. Delfanti, P. Marannino, M. Savino, and A. Silvestri, "Enhanced Security-Constrained OPF with FACTS Devices" IEEE Transactions on Power Systems, Vol. 20, No. 3, (August 2005.)
5. J. Zhu, K. Cheung, Senior Member, D. Hwang, and A. Sadjadpour, "Operation Strategy for Improving Voltage Profile and Reducing System Loss" Transactions On Power Systems, Vol. 25, No. 1, (February 2010.)
6. Nashiren.F. Mailah, Senan M. Bashi, "Single Phase Unified Power Flow Controller (UPFC): Simulation and Construction", European Journal of Scientific Research ISSN 1450-216X Vol.30 No.4 (2009), pp.677-684
7. T. Güler, G. Gross, E. Litvinov, and R. Coutu, "On the Economics of Power System Security in Multi-Settlement Electricity Markets", IEEE Transactions on Power Systems, Vol. 26, No. 4, (November 2011.)
8. R. S. Wibowo, N. Yorino, M. Eghbal, Y. Zoka, and Y. Sasaki, "FACTS Devices Allocation With Control Coordination Considering Congestion Relief and Voltage Stability" IEEE Transactions On Power Systems, Vol. 28, No. 2, (May 2013.)
9. T. Mandloi, A. K. Jain "A study of power system security and contingency analysis" International Journal of Scientific Research Engineering & Technology (IJSRET), ISSN 2278 – 0882 Volume 3, Issue 4, (July 2014.)
10. S. Ravindra, V. C. Veera Reddy, S. Sivanagaraju, "Power System Security Analysis under Generator Outage Condition" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 4, Issue 1, (January 2015.)
11. Dr. P. G. Burade, Dr. J. B. Helonde, "Optimal Location of FACTS devices on Enhancing system security," IJSER, vol.2, issue 4, pp.1-9, (April 2012.)
12. V. P. Doshi, S.A. Salgar, "Latest Trends In Contingency Analysis of Power System" Novateur Publications International Journal of Innovations in Engineering Research and Technology [IJIERT] ISSN: 2394-3696 VOLUME 2, ISSUE 2, (FEB.-2015.)G. O. Young, "Synthetic structure of industrial plastics (Book style with paper title and editor)," in Plastics, 2nd ed. vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 15–64.

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