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Contingency Analysis in Deregulated Power System Using FACTS Device (TCSC)

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ABSTRACT:Due to increasing power demand in deregulated power system, the stability of the power system gets affected and sometimes it also cause contingencies in transmission lines of power network. It is the biggest issue for a deregulated power system. Contingency analysis is being widely used to predict the effect of outages like failures of transmission lines and generator etc. To overcome the problem of power flow in heavily loaded lines and to reduce violations power electronic based FACTS device such as TCSC is used. TCSC is one of the series compensating device which is connected in series with the transmission line. The principal operating modes and applications of FACTS equipment in power system such as Thyristor controlled series capacitor (TCSC), are discussed here. The main aim of using TCSC here is to improve the total power transfer capability and to reduce violations & losses. In this project work, performance analysis of electrical network using Power World Simulator Tool and Simulation results before and after compensation are used to analysis the impacts of TCSC on the IEEE 14-bus test system is carried out using Mi power tool.

KEYWORDS: Contingency Analysis, Single Contingency, Multiple Contingency, Thyristor Controlled Series Capacitor (TCSC).

I.INTRODUCTION

In deregulated Power system security is the most challenging task because of the highest competition in the power market. Security estimation is the most difficult work as it gives the idea about the system state in the event of contingency. In the stage of designing and operation of a power system the main thing in all controlling areas is to provide protection. Contingency analysis is one of the most important task encountered by the planning and operation engineers of the bulk power system. Power system engineers use the contingency analysis to examine the performance of the system. In general the state of the system is determined on the basis of ability to meet the expected demand under all level of contingencies. The main objective of contingency analysis is to find out line overloads or voltage violations. Load flow calculations are involved in ascertaining these contingencies and determining the remedial actions.

In paper [1] conventional optimal reactive power dispatch (ORPD) formulations utilize minimization of total system real power loss or voltage deviation as an objective to compute optimal settings of reactive power output or terminal voltages of generating plants, transformer tap settings and output of other compensating devices such as capacitor banks and synchronous condensers. In paper [2] a Thyristor controlled series capacitor (TCSC) is expected to providepower systems with a number of benefits. This paper investigates its effects on bulk power system reliability. The reliability model of a transmission line with a TCSC is built and simplified via the state space approach. Optimal power flow (OPF) including the influence of TCSC is then introduced to decide the load curtailment. To examine the impact of TCSC, system reliability is evaluated in various operation environments, such as different TCSC placement locations and different line thermal limits. Finally, reliability is calculated assuming the TCSC is always working and the results are compared with those obtained using the model in which the failure of TCSC is considered. In paper [3] distribution factors play a key role in many system security analysis and market applications. The injection shift factors (ISFs) are the basic factors that serve as building blocks of the other distribution factors. The line outage distribution factors (LODFs) may be computed using the ISFs and, in fact, may be iteratively evaluated when more than one line outage is considered. We present an analytic, closed-form expression for and the computationally efficient evaluation of LODFs under multiple-line outages. In paper [4] contingency analysis of power system is to predict the line outage, generator outage and to keep the system secure and reliable by using full Newton's method. The full Newton's algorithm is more efficient for large power system. This result tends to be significantly more accurate and allow for gauging voltage/VAR effects.

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II. CONTINGENCY ANALYSIS (CA)

Contingency analysis is defined as outage of a transmission line, transformer or generator leads to over load on the other line in the power system network. Contingency analysis can results the classifications of the power system into two states those are secure and insecure states. Contingency analysis took more time when number of contingencies are more. Contingencies interrupt like generator, transformer and transmission line outages will cause quick and large changes in both the outline and the state of the system. Contingency ranking helps to list the contingencies, whenever the demand of power is maximum than compared with the transfer limits, the line will be damaged. The power demand is reduced then the generator is reviling from power system network then it collapse the system security. Whenever the maximum violations occur line or generators gets damaged. So the contingency analysis is essential.

In contingency analysis single outage case is studied in 60 seconds and for multiple outage it would take 16 mins.Contingency analysis is studied in two types of tools those are off-line analysis and on-line analysis.

Mainly there are two types of contingencies

- Generator Contingency
- Line contingency

III. PRIMARY CONTINGENCY (N-1) ANALYSIS

In this scheme, each node with message searches for possible path nodes to copy its message. Hence, possible path nodes of a node are considered. Using NSS, each node having message selects its path nodes to provide a sufficient level of end-to-end latency while examining its transmission effort. Here, it derives the CSS measure to permit CR-Networks nodes to decide which licensed channels should be used. The aim of CSS is to maximize spectrum utilization with minimum interference to primary system. Assume that there are M licensed channels with different bandwidth values and ydenotes the bandwidth of channel c. Each CR-Networks node is also assumed to periodically sense a set of M licensed channels. Midenotes the set including Ids of licensed channels that are periodically sensed by node i. suppose that channel c is periodically sensed by node i in each slot and channel c is idle during the time interval xcalled channel idle duration. Here, it use the product of channel bandwidth yand the channel idle duration x, tc= xy, as a metric to examine the channel idleness. Furthermore, failures in the sensing of primary users are assumed to cause the collisions among the transmissions of primary users and CR-Networks nodes.It is unplanned event, after N-1 contingency the secondary contingency will occur. N-11 means two components have failed, it is comparatively bad than having only one fail. A ordered series of events consisting of the initial outage of a transmission line or a single generator (N-1 Contingency), followed by system overloads, leads to outage of another transmission line or single generator (N-1-1 Contingency).

IV. MODELLING OF FACTS DEVICES

FACTS as flexible AC transmission system incorporating power electronics based and static controllers to increase the power transfer capability and to improve the quality of controllability. FACTS devices are introduced in the power system to increase the system performance and to control the power flow in quick way.

TCSC is one of the important FACTS device, which has the application like minimizes total power loss, generation cost and reactive power generation limits. Also ensure efficient and reliable operation of power system.

A basic setup of TCSC model is given below.

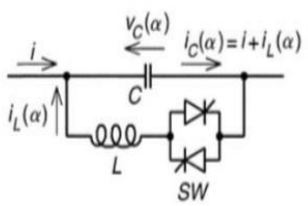

Fig 1: Basic circuit model of TCSC

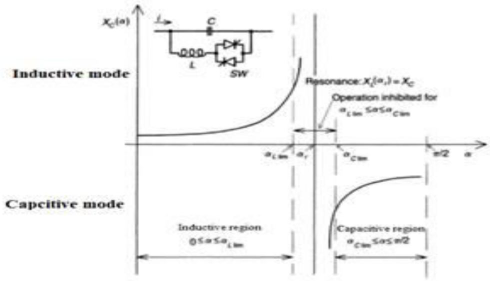

Fig 2: Charecteristics of TCSC

$X_{TCSC}(\alpha) = X_C X_L(\alpha)/(X_L(\alpha) - X_C)$, Where, $X_L(\alpha) = X_L(\pi / \pi\text{-}2\alpha\text{-}\sin\alpha)$, $X_L \leq X_L(\alpha) \leq \infty$ Here $X_L = \omega L$,
X_L = Inductive reactance ,X_C = Capacitive reactance , α = Firing angle
TCSC have two modes of oparation in the direction of circuit response. Those two modes are

1. Inductive mode :The α varies from α_{Clim} to $\pi/2$ with respect to peek of capacitor voltage.
2. Capacitive mode :The α varies from 0 to α_{Llim} with respect to peek of capacitor voltage

Main purpose of TCSC are to minimize genaration cost, total power loss and improves total transfer capability.
Impedance of TCSC is given by : $Z_{TCSC} = (-jX_C.jX_{TCR})/(j(X_{TCR}-X_C)) = -jX_C/(1-(X_C/X_{TCR}))$
The current through TCR is given by :$I_{TCR} = (-jX_C/(j(X_{TCR}-X_C))I_L = I_L/(1-(X_{TCR}/X_C))$

V. SIMULATION AND RESULTS

Due to increasing power demand in deregulated power system, stability of the power system gets affected and sometimes it also cause the congestion in transmission lines. This is the major problem in deregulated power system. Here the objective is to minimize the congestion or contingencies in power network. So DC load flow analysis is used to solve such type of problems. Expansion of power generation and transmission has been limited due to environmental restrictions and less resources. As a consequence, some transmission lines are over loaded due to failure of power system equipment's so that power system engineers not able to provide reliable power to the customers. Flexible AC Transmission Systems (FACTS) device such as TCSC are mainly used for solving various power system problems like reduces losses in transmission lines, reduces power flows in heavily loaded lines and increases stability of the power system. These controllers allow flexible & dynamic control of power systems.
The transmission line, series capacitor and TCR are the main components. Numerous components and subsystems are existing in the TCSC system.

1. To improve the voltage profile series capacitor is used. It is connected in series with the line.
2. Net reactance is used to make and control to increase power transfer capability.
3. TCR connected across the capacitor.
4. TCR contains 2 antiparallelThyristor connected in series with an inductor.
5. Considering transmission line as a pi section line.

The whole work is carried out on IEEE 14 bus system in Power World Simulator.

A. Simulation System Parameters

Values of System Parameters

Resistance R1 = 0.01273 Ω/Km, R0 = 0.3864 Ω/KmInductance: L1 = 0.9337 e-3 H/Km, L2 = 4.126 e-3 H/KmCapacitance: C1 = 12.74 e-9 F/Km, C2 = 7.75 e-9 F/Km

B. Calculations

Line series impedance is given by

$Z_l = R + j\,X1$
$= R + j\,wl$
$= 1.28 + j*w*0.9337e^{-3}$
$= 1.28 + j*2\pi*50*0.9337e^{-3}$
$= 1.28 + j\,29.33\ \Omega$

Considering 70% Compensation

$X_C/X_L = 0.70$
$X_C = 0.70*X_L$
$= 0.70*29.33$
$X_C = 20.531\ \Omega$
$X_C = 1/2\pi fc$
$C = 1/(2\pi*50*20.531)$
$C = 155.038\ \mu F$

Ratio $X_L/X_C = 0.1343$
$X_L = 0.1343 * X_C$
$= 0.1343*20.531$
$X_L = 2.7573\ \Omega$
$X_L = 2\pi fl$
$L = X_L/2\pi f$
$L = 2.7573/(2\pi*50)$
$L = 8.776$ mH

% Compensation = $(X_{C\,TCSC}/X_L)*100 = (20.531 / 29.33)*100 = 70$ %
$X = X_{Line} - X_{FC}$
$X_{TCSC} = X_C / (1-(X_C/X_{TCR}))$
$X_C < X_{TCR}$
$X_{TCR} = \infty$ (When the Thyristors are blocked)
$X_{TCSC} = X_c$
$X_{New} = X_{line} + X_{C\,TCSC} = 0.17103 - 0.062735 = 0.146385$

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C. Primary Contingency (N-1) Analysis

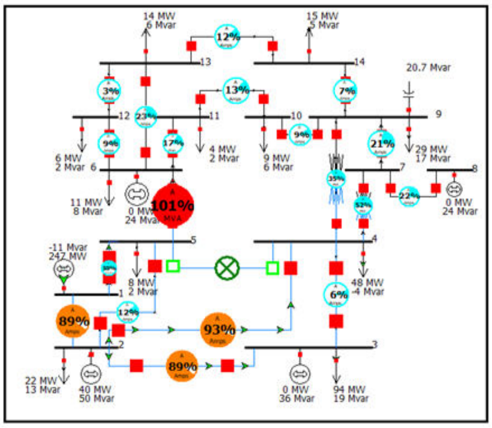

Fig 3: N-1 line Contingency on 14 bus system

Total number of contingencies, violations and losses are tabulated below.

Table 1: N-1 Contingencies and violations list

Sl.No	Line Details	Violations	Max Branch %
1	line 3 to 4 is open	1	154.7
2	L_00000110000022C1	12	205.5
3	L_0000011-0000055C1	10	172.3
4	L_0000022-0000033C1	6	103.3
5	L_0000022-0000044C1	2	126.6
6	L_0000022-0000055C1	2	105.5
7	L_0000033-0000044C1	1	109.3
8	L_0000044-0000055C1	1	105.1
9	T_0000044-0000077C1	1	106.6
10	T_0000044-0000099C1	1	103.2
11	T_0000055-0000066C1	1	112.4
12	L_0000066-00001111C1	1	103.5
13	L_0000066-00001212C1	1	105.4
14	L_0000066-00001313C1	1	102.6
15	L_0000077-0000088C1	1	113.1
16	L_0000077-0000099C1	1	103.1
17	L_0000099-00001010C1	1	102.6
18	L_0000099-00001414C1	1	108.1
19	L_00001010-00001111C1	1	103.1
20	L_00001212-00001313C1	0	
21	L_00001313-00001414C1	0	

Table 2: Results of N-1 contingency analysis

Total no of contingencies	21
No.of proceeds	21
Total no of violations	46
No of unsolvable	0
Total run time	0.90
Average time per contingency	0.043

IEEE 14 bus system consider for the simulation. Table 1 displays the contingency analysis when line 3 to 4 is open. The over loaded line is shown in fig 3. No of violations are tabulated in table 2. After the optimal location of FACTS device (TCSC) placed in the line 2 to 5, preventive and corrective actions are taken to solve violations are given below. After remedial action taken on IEEE 14 bus system is shown in figure below.

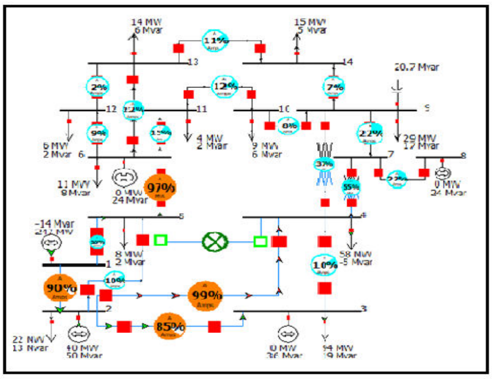

Fig 4: N-1 Violations solved after placing FACTS device (TCSC)

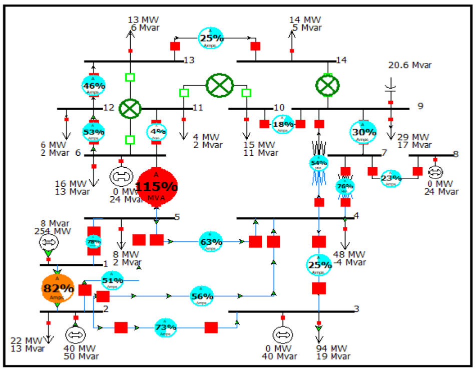

Fig 5: N-1-1 line Contingency on 14 bus system

Result and discussion for violations solved after placing FACTS device (TCSC) on IEEE 14 bus system.

Table 3: Alter placing TCSC N-1 Contingencies

Sl.No	Line Details	Violations	Max Branch %
1	line 3 to 4 is open	3	146.7
2	L_0000011-0000022C1	2	104.7
3	L_0000011-0000055C1	1	105.7
4	L_0000022-0000033C1	1	108.2
5	L_0000022-0000044C1	1	109.5
6	L_0000022-0000055C1	1	120.1
7	L_0000033-0000044C1	1	101.4
8	L_0000044-0000055C1	0	0
9	T_0000044-0000077C1	0	0
10	T_0000044-0000099C1	0	0
11	T_0000055-0000066C1	0	0
12	L_0000066-00001111C1	0	0
13	L_0000066-00001212C1	0	0
14	L_0000066-00001313C1	0	0
15	L_0000077-0000088C1	0	0
16	L_0000077-0000099C1	0	0
17	L_0000099-00001010C1	0	0
18	L_0000099-00001414C1	0	0
19	L_00001010-00001111C1	0	0
20	L_00001212-00001313C1	0	0
21	L_00001313-00001414C1	0	0

Table 4: After placing TCSC Results of N-1 contingency analysis

Total no of contingencies	21
No.of proceeds	21
Total no of violations	10
No of unsolvable	0
Total run time	0.66
Average time per contingency	0.031

Table 5: 70% Compensation for N-1 CA

	Normal case	Without TCSC	With TCSC
Total real power generation	272.4	246.8	275.2
Total reactive power generation	107.5	122.8	117.8
Total real power loss	13.4	18.8	16.2
Total reactive power loss	55.4	71.5	62.8

Table 3 shows the contingency analysis of IEEE 14 bus system when line 4 to 5 is open. After placing the FACTS device on the line 2 to 5 that is compensating the line reactance 70% to its natural value the over loaded line 5 to 6 comes into normal condition. The number of violations reduced from 46 to 10 shown in table 4.

After reducing the reactance of 2-5 line is 0.17388 to 0.146385 (70% compensations) losses are reduced shown in table 5. And overloaded lines comeback to within its operational limits.

D. Multiple Contingency (N-1-1) Analysis

Total number of contingencies, violations and losses are tabulated below.

Table 6: N-1-1 Contingencies and violations list

Sl.No	Line Details	Violations	Max Branch %
1	L_0000022-0000033C1	6	103
2	L_0000077-0000099C1	5	135.8
3	T_0000044-0000077C1	5	135.6
4	T_0000044-0000099C1	5	109.4
5	L_0000011-0000055C1	5	125.6
6	L_00001010-00001111C1	4	100.4
7	6 to 13 open	4	100.4
8	L_0000099-00001414C1	4	100.4
9	L_0000044-0000055C1	4	100.6
10	9 to 14 open	4	100.4
11	10 to 11 open	4	100.4
12	L_0000066-00001313C1	4	100.4
13	L_0000022-0000055C1	4	101.8
14	L_0000022-0000044C1	4	101.5
15	L_0000033-0000044C1	4	100.1
16	L_0000077-0000088C1	4	101.7
17	L_0000066-00001111C1	3	
18	L_0000099-00001010C1	3	
19	L_0000066-00001212C1	0	
20	T_0000055-0000066C1	0	
21	L_00001313-00001414C1	0	
22	L_00001212-00001313C1	0	

Table 7: Results of multiple contingency analysis

Total no of contingencies	22
No.of proceeds	22
Total no of violations	76
No of unsolvable	0
Total run time	0.75
Average time per contingency	0.033

IEEE 14 bus system consider for the simulation. Table 6 displays the contingency analysis when line 9 to 14, 10 to 11 and 6 to 13 are open. The over loaded line is shown in fig 5. No of violations are tabulated in table 7. After the optimal location of FACTS device (TCSC) is placed in the line 6 to 12, preventive and corrective actions are taken to solve violations are given below.

After remedial action taken on IEEE 14 bus system is shown in figure below.

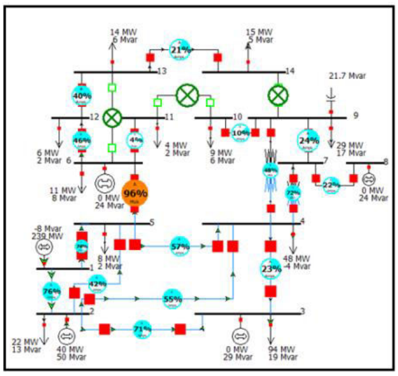

Fig 6: N-1-1 violations solved after placing FACTS device (TCSC)

Table 8: After placing TCSC N-1-1 Contingencies and violations list

Sl.No	Line Details	Violations	Max Branch %
1	L_0000011-0000022C1	15	368.5
2	L_0000022-0000033C1	5	102.8
3	L_0000011-0000055C1	5	125.2
4	T_0000044-0000077C1	3	135.3
5	T_0000044-0000099C1	3	108.7
6	L_0000022-0000044C1	3	0
7	L_0000077-0000099C1	3	135.5
8	L_0000022-0000055C1	3	
9	L_0000077-0000088C1	3	
10	L_0000066-00001111C1	2	
11	6 to 13 open	2	
12	L_00001010-00001111C1	2	
13	L_0000044-0000055C1	2	
14	10 to 11 open	2	
15	L_0000033-0000044C1	2	
16	L_0000066-00001313C1	2	
17	9 to 14 open	2	
18	L_0000099-00001010C1	2	
19	L_0000099-00001414C1	2	
20	L_0000066-00001212C1	0	
21	T_0000055-0000066C1	0	
22	L_00001313-00001414C1	0	

Table 9: After placing TCSC Results of N-1-1 contingency analysis

Total no of contingencies	22
No.of proceeds	22
Total no of violations	63
No of unsolvable	0
Total run time	0.66
Average time per contingency	0.027

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Table 10: 70% Compensation for N-1-1 CA

	Normal case	Without TCSC	With TCSC
Total real power generation	272.4	202.4	280.7
Total reactive power generation	107.5	203.4	124.5
Total real power loss	13.4	43.4	21.7
Total reactive power loss	55.4	145.4	72.7

Table 8 shows the contingency analysis of IEEE 14 bus system when lines 9 to 14, 10 to 11 and 6 to 13 are open. After placing the FACTS device on the line 6 to 12 that is compensating the line reactance 70% to its natural value the over loaded line 5 to 6 comes into normal condition. The number of violations reduced from 76 to 63 shown in table 9.

After reducing the reactance of 6-12 line is 0.25581 to 0.146385 (70% compensations) losses are reduced shown in table 10. And overloaded lines come back to within its operating limits.

VI.CONCLUSION

Contingency analysis is used to predict the effect of outages caused by line outages in a power transmission system. For each outage tested. CA checks the power flows and violations in the power system network. Planning for contingencies forms an important aspect of secure operation. The contingency analysis was successfully tested in IEEE 14 bus system. In this work power transfer capability of transmission line is increased by inserting FACTS device such as TCSC.After inserting TCSC in transmission line the number of violations and losses gets reduced. Results shows that during contingency the number of violations and losses are more after connecting the series compensation device such as TCSC in series with the transmission line it provides smooth control of power flow in transmission line and reduces losses, violations & bring back the overloaded lines to normal operating conditions.

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