

ATC Computation with Consideration of N-1 Contingency and Congestion Removal Using FACTS Devices

Sampada Thote¹, M. khardennis²

P.G. Student, Department of Electrical Engineering, Government College of Engineering, Amravati, India¹

Asst. Professor, Department of Electrical Engineering, Government College of Engineering, Amravati, India²

ABSTRACT: In deregulated environment, knowledge about available transfer capability is very important aspect in order to operate the power system safely and to reduce load encroachment at any specific transmission line. The purpose of this paper is to remove the congestion due to line outage contingency. ATC is computed here for normal and contingency condition using deterministic approach of ATC computation. Detailed simulation study is performed on IEEE 6 bus system in power world simulator 17.

KEYWORDS: Available transfer capability(ATC), line outage contingency, continuation power flow (CPF), AC power transfer distribution factor (ACPTDF), DC power transfer distribution factor (DCPTDF), congestion.

I. INTRODUCTION

In last few years in order to have a reliable and economical electrical supply, transfer of bulk electrical power over long distances has increased. The maximum power that can be transferred over the existing amount is called the available transfer capability. To operate the power system safely and to gain the benefits of the bulk power transfers, the transfer capabilities must be calculated and the power system planned and operated so that the power transfers do not exceed the transfer capability [1]. There are different methods to compute the ATC divided in two category deterministic method and probabilistic method. Power transfer distribution factor method (PTDF), one of the deterministic method is used by many electric utilities for determination of ATC. The power transfer distribution factor method for both normal and contingency cases explained in [2].

Sometimes due to undesirable load distribution outage of transmission, lines occur causes changes in the line flows and bus voltages on the existing transmission equipment. Outage of transmission line results in N-1 contingency condition. Various outages in power system with its ATC computation technique were explained in [3], [4]. Outage increases the load on another transmission line, which results in load encroachment at that line. Such load encroachment is nothing but the congestion in transmission line. Recently, there has been growing interest in allocation of FACTS devices for relieving transmission congestion as well as enhancing ATC [5], [6]. References [7], [8] have proposed optimal allocation of FACTS devices for ATC enhancement. In reference [9], method for computation of thyristor-controlled series capacitor (TCSC) reactance and its allocation criteria to eliminate the line overloads is explained. It uses the sensitivity index for optimal location of TCSC. Also using UPFC congestion management can be possible is explained in [10]. In this paper, ATC is computed for normal and contingency condition and then congestion management is done with the help of TCSC and UPFC. Also comparison between both FACTS devices is shown here.

II. ATC COMPUTATION

The information of ATC is an important indicator of system performance. ATC provides the knowledge of power system capability about the present system condition [2]. ATC is an indication of the expected transfer capability remaining on the transmission network.

Mathematically ATC given by:

$$ATC = TTC - TRM - (CBM + ETC)$$

Where TTC – Total Transfer Capability
TRM – Transmission Reliability Margin
ETC – Existing Transmission Commitments
CBM – Capacity Benefit Margin

Methods used for ATC calculation are ACPTDF, DCPTDF, CPF..
Here power transfer distribution method is preferred.

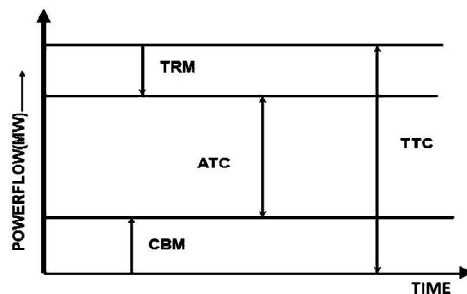


Figure 1-graphical representation of ATC[4].

$$ATC_{mn} = \min \left\{ \frac{P_{ij}^{max} - P_{ij}^0}{PTDF_{ij-mn}} \mid ij \in NI \right\}$$

Where,

P_{ij}^{max} - The maximum MW power flow limit of a line between bus-i and bus-j.

P_{ij}^0 - The base case power flow in the line between bus-i and bus-j.

$PTDF_{ij-mn}$ - The Power Transfer Distribution Factors for the line between bus-i and bus-j for transaction between m and n

NI -The total no. of lines.

III. IEEE 6 BUS SYSTEM MODEL

Model preferred in this paper is given as-

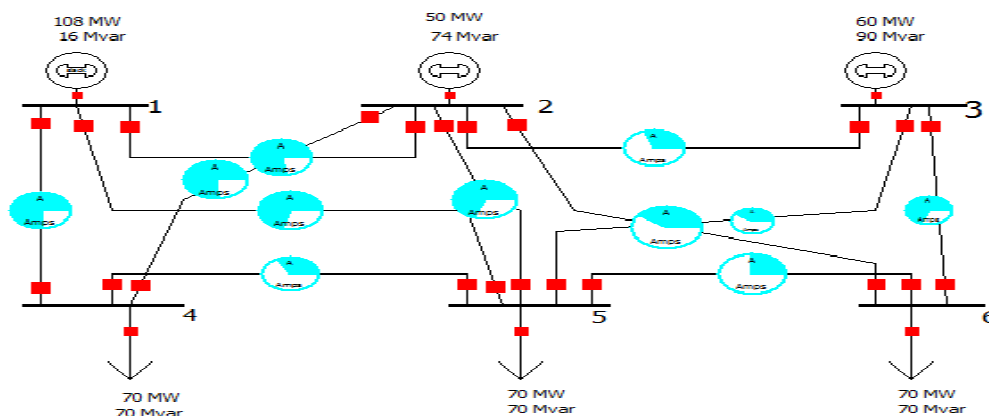


Fig 1:-IEEE 6 bus system model.

Table 1:- line records for normal IEEE 6 bus system.

Line Records					
From Number	To Number	Limiting Flow Used	Limit Used	% of Limit Used	MVA
1	2	32.6	40	81.4	MVA
1	4	48	60	80	MVA
1	5	37.3	50	74.7	MVA
2	3	12.6	40	31.5	MVA
2	4	56.7	70	81	MVA
2	5	23.4	30	78.2	MVA
2	6	30.3	70	43.2	MVA
3	5	31.7	70	45.3	MVA
3	6	74.9	100	74.9	MVA
4	5	6.4	20	32.1	MVA
5	6	9.8	40	24.5	MVA

IV.LINE OUTAGE CONTINGENCY SITUATION

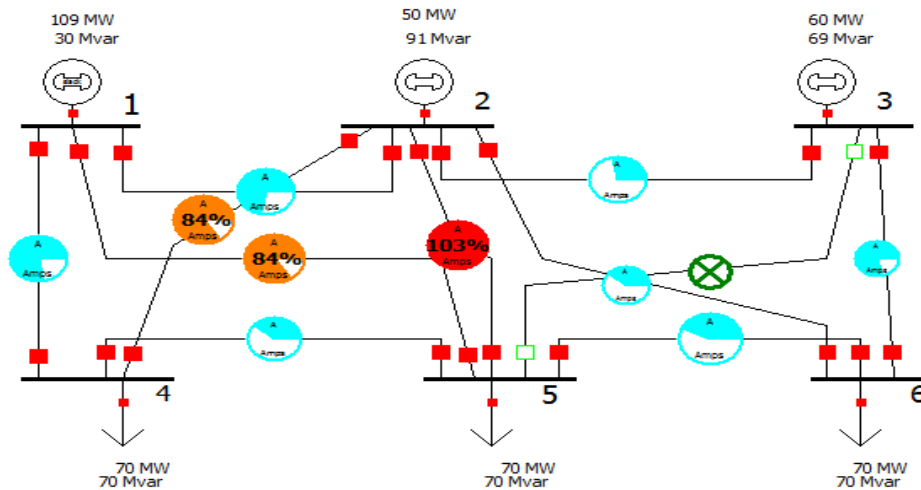


Figure 2- Line outage contingency situation with line 3-5 open.

Table 2- Line records for IEEE 6 bus system with line 3-5 open.

Line Records					
From Number	To Number	Limiting Flow Used	Limit Used	% of Limit Used	MVA
1	2	30.5	40	76.2	MVA
1	4	48.8	60	81.4	MVA
1	5	44.2	50	88.4	MVA
2	3	11.8	40	29.6	MVA
2	4	61.7	70	88.1	MVA
2	5	32.4	30	108	MVA
2	6	29.9	70	42.7	MVA

3	5	0	70	0	MVA
3	6	84.7	100	84.7	MVA
4	5	10.3	20	51.7	MVA
5	6	16.3	40	40.7	MVA

V. FACTS DEVICE MODELLING

FACTS controllers are able to change, in a fast and effective way, the network parameters in order to achieve better system performance. So recently, there has been growing interest in allocation of FACTS devices for relieving transmission congestion as well as improving voltage stability [9]. It is important to appreciate that the series-connected Controller impacts the driving voltage and hence controls current and power flow directly. Therefore, if the purpose of the application is to control the current/power flow and damp oscillations, the series Controller for a given MVA size is several times more powerful than the shunt Controller. In addition, the combination of series and shunt controller can provide the best of both.

a. TCSC MODELLING

The TCSC power flow model presented in this section is based on the simple concept of variable series reactance, the value of which is adjusted automatically to constrain the power flow across the branch to a specified value [3].

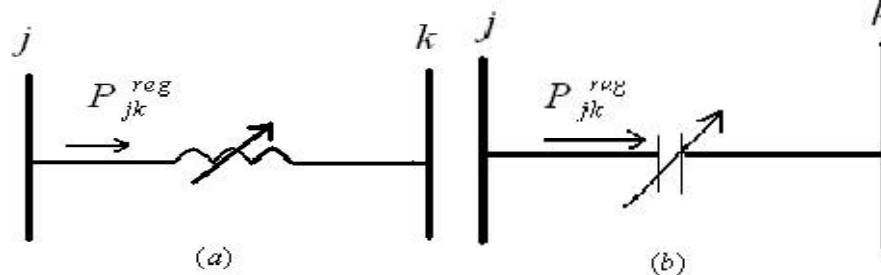


Figure 3- represents the equivalent reactance of all the series connected modules making up TCSC, when operating either in inductive or capacitive regions.

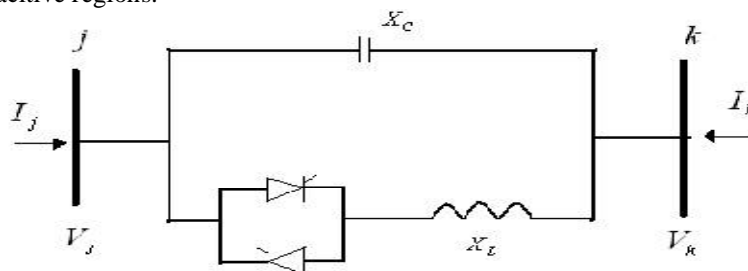


Figure 4- Basic thyristor controlled series capacitor scheme.

B. UPFC MODELLING

The UPFC is the most versatile FACTS controllers with capabilities of voltage regulation, series Compensation. The UPFC is a member of combined series shunt compensator.

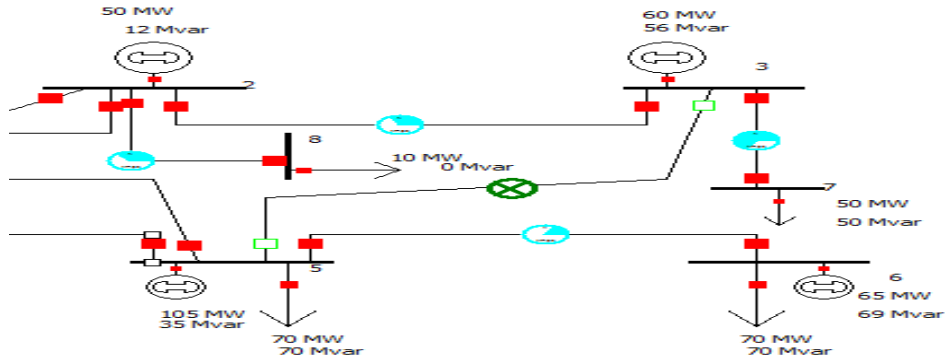


Figure5 - UPFC modelling in Power World Simulator.

VI. SIMULATION WORK

a. WITH TCSC

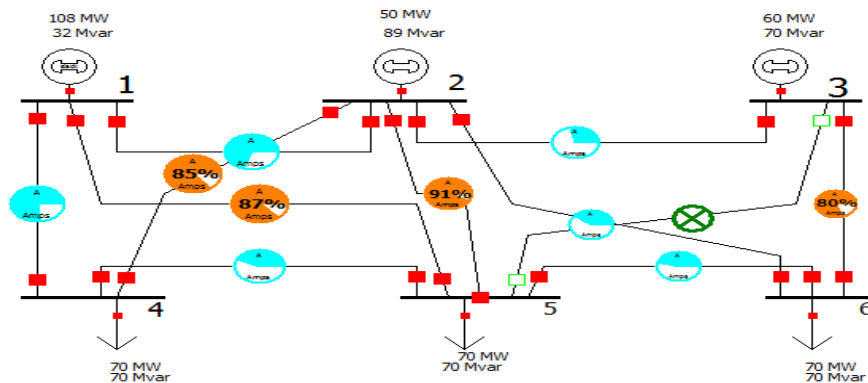


Figure 6 –simulation on 6-bus system with TCSC connected at congested line 2-5.

Table 3- line records for IEEE 6 bus system with TCSC connected at congested line.

Line Records					
From Number	To Number	Limiting Flow Used	Limit Used	% of Limit Used	MVA
1	2	29.5	40	73.7	MVA
1	4	48.7	60	81.2	MVA
1	5	45.7	50	91.4	MVA
2	3	11.7	40	29.4	MVA
2	4	62.6	70	89.4	MVA
2	5	29	30	96.7	MVA
2	6	30.5	70	43.6	MVA
3	5	0	70	0	MVA
3	6	85.7	100	85.7	MVA
4	5	11.2	20	56.2	MVA
5	6	17.4	40	43.4	MVA

B. WITH UPFC

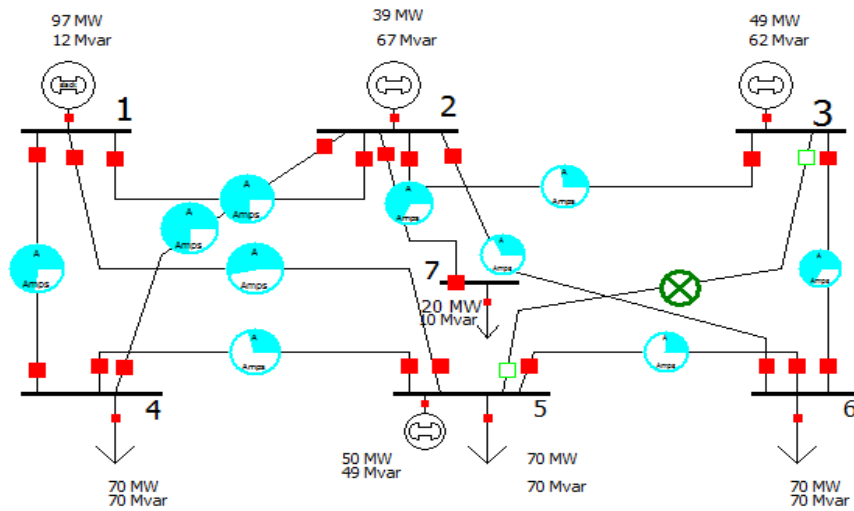


Figure 7-simulation on 6-bus system with UPFC connected at congested line 2-5.

Table 4 - Line records for IEEE 6 bus system with UPFC connected at congested line

Line Records					
From Number	To Number	Limiting Flow Used	Limit Used	% of Limit Used	MVA
1	2	32.3	40	80.7	MVA
1	4	45.9	60	76.6	MVA
1	5	29.1	50	58.1	MVA
2	3	11.5	40	28.9	MVA
2	4	54.4	70	77.7	MVA
2	7	22.4	30	74.5	MVA
2	6	25.8	70	36.9	MVA
3	5	0	70	0	MVA
3	6	73.2	100	73.2	MVA
4	5	5.7	20	28.4	MVA
5	6	9.3	40	23.3	MVA

VII. RESULT

1. Line loading with different compensation of TCSC
- 2.

Table 5- line records with 10% TCSC compensation.

Transmission line	Normal loading	Loading during congestion	Loading with Compensation
2-5	69.3	103	97
1-5	70.9	84	86
2-4	77.2	84	85
3-6	70.0	79.2	79.7

Table 6- line records with 20% TCSC compensation

Transmission line	Normal loading	Loading during congestion	Loading with Compensation
2-5	69.3	103	91
1-5	70.9	84	85
2-4	77.2	84	87
3-6	70.0	79.2	80

Table 7- line records with 30% TCSC compensation

Transmission line	Normal loading	Loading during congestion	Loading with Compensation
2-5	69.3	103	86
1-5	70.9	84	88
2-4	77.2	84	86
3-6	70.0	79.2	80

2. Line loading comparison between TCSC and UPFC

Table 8- line records with TCSC and UPFC compensation.

Transmission line	Normal loading	Loading during congestion	Loading with TCSC	Loading with UPFC
2-5	69.3	103	86	68.8
1-5	70.9	84	88	53.3
2-4	77.2	84	86	74.6
3-6	70.0	79.2	80	68.4

VIII. CONCLUSION

From the above result it is shown that congestion get removed using TCSC and UPFC. So the purpose of using FACTS devices get fulfilled here. Also UPFC shows better performance than TCSC. TCSC is connected at congested line only for giving inductive compensation. As compensation goes on increasing at specific congested line, loading at other line increases. Since the TCSC has performance dominance particularly in active power flow control over UPFC have still to be further investigated.

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