TRANSMISSION LINE LOADABILITY IMPROVEMENT USING FACTS DEVICE

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Abstract

With the recent trends towards deregulating power systems around the world, transfer capability computation emerges as the key issue to a smoothly running power market with multiple transactions. Enhancement of available transfer Capability (ATC) is an important topic in current deregulation environment considering loop flows and heavily loaded lines. The thermal limits of transmission lines, voltage bounds of buses and upper and lower limits of generator power are considered. In this paper, optimal placement of the STATCOM is found based on Linear Sensitivity Index (LSI). The Modified IEEE 30-bus test system is selected to illustrate the placement of STATCOM and enhancement of ATC by using PSAT software version 2.1.8.

***Keywords:** Available Transfer Capability, TTC, Linear Sensitivity Index, PSAT.*

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1. INTRODUCTION

Due to the significant power demand increases, the transmission line operators are required to increase transmission line power transfer capability. They have various options such as building an additional parallel transmission line which is not a cost effective option, using FACTS device for reactive power compensation is a very cost effective option with the former one. It has faster response than capacitor banks.

In this present open access or deregulated environment all the producers and buyers of electrical energy desire to produce or consume large amounts of energy and may force the transmission system to operate beyond one or more transfer limits. This type of operation leads to congestion of the system.

Therefore accurate determination of available transfer capability is essential to ensure the system security and reliability while serving a wide range of mutual and multilateral power transactions. There are several phenomenon can impose these transfer limits like thermal limits, voltage limits and stability limits [2]. For the understanding of these limits there are certain methods.

Available transfer capability (ATC) is the measure of the ability of interconnected electric systems to reliably move or transfer power from one area to another over all transmission lines under specified system conditions [13]. For obtain ATC, the total transfer capability (TTC) is the largest power flow through selected interfaces of the transmission network which causes no thermal overloads, voltage limit violations or any other system problems [2].

Available transfer capability (ATC) calculation has been a research area of exponentially increasing interest particularly in the past two decades. Available transfer capability (ATC) is an important sub part of a TTC, which is calculated as [9]:

$$ATC = TTC-TRM-CBM-ETC$$

Where, TTC is the total transfer capability, TRM is Transmission reliability margin, ETC is the existing transmission commitment (including retail customer service), CBM is the capacity benefit margin.

There are several methods for transfer capability calculations [1, 7, 11]. These methods mostly used are continuation power flow (CPF) method, optimal power flow (OPF) method and repetitive power flow (RPF) method, ANN based methods etc. In this paper presents an OPF based procedure for calculating the Available transfer capability (ATC) [3, 4].This method is based on an AC power flow solution which accurately determines voltage limits as well as the line flow effect. The objective function is to increase the loading capability of the transmission line.

1.1 Available Transfer Capability [ATC]

Available transfer capability computations are necessary for successful operation of electric power deregulation where power producers and customers share a common transmission network for wheeling power from the point of generation to the point of consumption. The available transfer capability indicates the amounts which inter area bulk power transfers can be increased without compromising system security[1]. The value used for available transfer capability affects both system security and the profits made in mass power transactions. Moreover, market participants can have contradictory interests in a higher or a lower available transfer capability. Thus in deregulation, there is increasing motivation for secure calculations of available transfer capability.

1.2 Transmission Reliability Margin (TRM)

It is defined as that amount of transmission transfer capability required to make sure that the interconnected transmission network is secure under a reasonable range of uncertainties in system conditions [1, 2]**.**

1.3 Capacity Benefit Margin (CBM)

It is defined as that amount of transmission transfer capability taken by load serving entities to ensure access to generation from interconnected systems to meet generation reliability requirements [1,2].

1.4 Transmission System Limits

Thermal Limits: The low of electrical current in a conductor or electrical facility causes heating of the conductor or facility. Thermal limits, in the form of facility normal and emergency ratings, establish the maximum amount of current over a specified period that a transmission line or electrical facility can conduct before it sustains permanent damage by overheating or violates public safety ground clearance requirements due to conductor sag [2].

Voltage Limits: Adequate voltage must be maintained on the transmission systems at all times, including during and after a system contingency (facility outage). As electricity is transmitted along a transmission line, resistive and reactive power losses are incurred and a voltage drop occurs. As an increasing amount of electricity is transferred, resistive losses increase and increasing amounts of reactive power are required to support system voltages [2, 17].

Stability Limits : A basic tenet of reliable system design is that the interconnected systems should be capable of surviving disturbances, coincident with safe maximum electric power transfers, through the transient and dynamic time periods (from milliseconds to several minutes, respectively) [2].

1.5 Congestion Management

In a competitive electricity market, congestion occurs when the transmission network is unable to accommodate all of the desired transactions due to a violation of system operating limits. Congestion management is controlling the transmission system, so that the transfer limits are observed [5]

Congestion is a term that has come to power systems from economics in conjunction with deregulation, although congestion was present on power systems before deregulation. Then it was discussed in terms of steady-state security, and the basic objective was to control generator output so that the system remained secure (no limits were violated) at the lowest cost. When dealing with power flow within its operating area, one entity, the vertically integrated utility, controlled both generation and transmission, gained economically from lower generation costs, and was responsible for the consequences and expected costs when less secure operation resulted in power outages. Conflicts between security and economics could be traded off within one decision making entity. While this process sounds quite exact, the expected costs of less secure operation could not be accurately quantified, and the limits themselves could develop a great deal of flexibility when there was money to be saved by pushing them. In the deregulated power system, the challenge of congestion management for the transmission system operator is to create a set of rules that ensure sufficient control over producers and consumers (generators and loads) to maintain an acceptable level of power system security and reliability in both the short term (real-time operations) and the long term (transmission and generation construction) while maximizing market efficiency.

2. TEST SYSTEM

The Modified IEEE-30 bus test system is used in this paper to demonstrate the effect of FACTS on ATC. Data of the IEEE 30-bus system can be accessed from URL address: http://www.ee.washington.edu. The simulation model for Modified IEEE-30 bus system without STATCOM is shown in fig.1. Base value is assumed to be 100 MVA. Only the thermal limit of transmission lines and voltage magnitude and voltage angle limit of each bus are considered. The voltage magnitude limit of each transmission line is assumed to be 0.9 p.u. and 1.1 p.u..

2.1 PSAT Software [15, 16]

PSAT is a sub tool of MATLAB for electric power system analysis and control. PSAT includes power flow, continuation power flow, optimal power flow, small signal stability analysis and time domain simulation. All operations can be assessed by means of graphical user interfaces (GUIs) and a Simulink-based library provides an user friendly tool for network design.

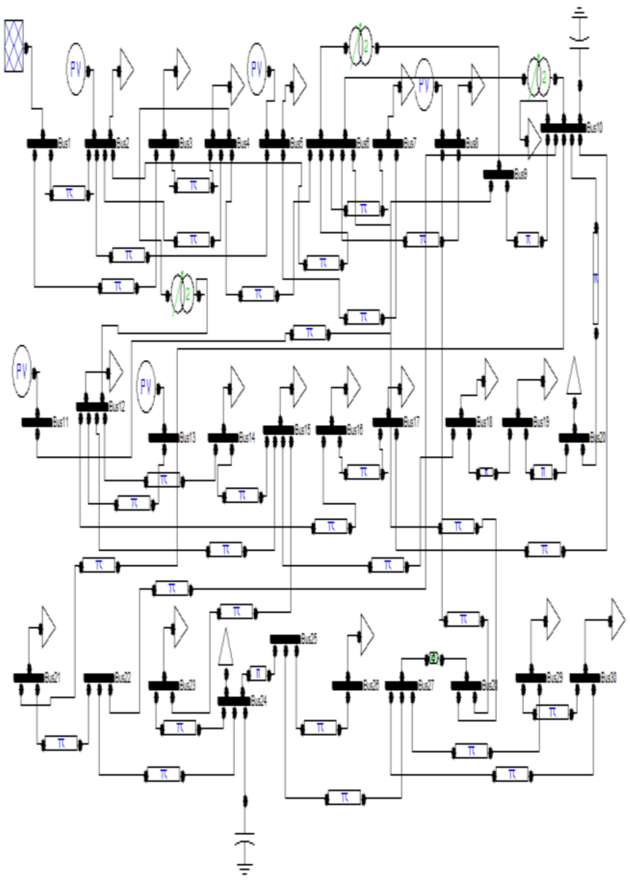

Fig.1 Simulation model for Modified IEEE-30 bus power system without STATCOM

2.2 Placement Strategy of FACTS

FACTS devices are very much costlier so it is not possible to put FACTS devices in every lines or at buses. It should be clear that, only one of FACTS devices is permitted per component of the system. Any type of FACTS devices is placed in random bus or line of interconnected power system which can enhance the power flow at that particular Bus or line. However, FACTS devices can be fully utilized if optimal location is determined through specific techniques. There are certain methods for the placement of the FACTS devices in the power system. Here, the LSI (Linear Sensitivity Index) calculation method used for the optimal location of the STATCOM [13].

2.3 LSI calculation for STATCOM

LSI is equation that is derived from general total loss reactive equation of the whole system. The derived equation is based on the parameters of STATCOM as represented as follows [4, 12, 16];

$$P_L = \sum_{j=1}^{N}\sum_{i=1}^{N}[\alpha_{ik} P_j P_k + Q_i Q_k + B_{jk} Q_j P_k + P_j Q_k] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\alpha_{jk} = \frac{r_{jk}}{V_j V_k}\cos(\delta_j - \delta_k) \quad \ldots\ldots\ldots\ldots \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (2)$$

$$\beta_{jk} = \frac{r_{jk}}{V_j V_k}\sin(\delta_j - \delta_k) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where,
P_L is the real power transmission loss of the system.
r_{jk} is the real part of the jk^{th} element of line impedance
j indicates sending bus number
k indicates receiving bus number.
V_j, δ_j and V_k, δ_k are the complex voltages at j^{th} and jk^{th} buses, respectively.
P_i and P_k are the real power injected at bus-j and bus-k,
Q_i and Q_k are the reactive power injected at bus-j and bus-k, respectively.

For each bus-i, sensitivity index can be expressed as,

$$a_i = \frac{\partial P_L}{\partial Q_j} = 2\sum_{j=1}^{NB} \alpha_{jk} Q_j + \beta_{jk} P_j \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

2.4 Criteria for Placement of STATCOM

The criteria for optimal location for STATCOM based on LSI can be explained as below:

STATCOM must be located at PQ bus which has the most negative LSI based on equation (1). Slack and PV buses are discarded. Since the setting parameters of the FACTS device will be restricted to the parameters of non-load bus[4,10]. Besides that, placing the device in these two buses would produce unexpected results in the power flow solution according to PSAT software requirements.

The calculation results for LSI are shown in Table 1. From the Table 1, the optimal location of the STATCOM is at bus 3 because it has most negative LSI on that bus.

Table: 1 Values of LSI at Various Buses

At Bus	α_i	At bus	α_i
3	**-0.00114**	20	-0.00164
4	-0.00205	21	-0.00967
7	-0.0155	22	0
12	-0.04003	23	-0.00715
14	-0.01008	24	-0.01999
15	-0.01846	25	0
16	-0.00585	26	-0.01169
17	-0.0123	29	-0.00842
18	-0.00288	30	-0.01838
19	-0.00633		

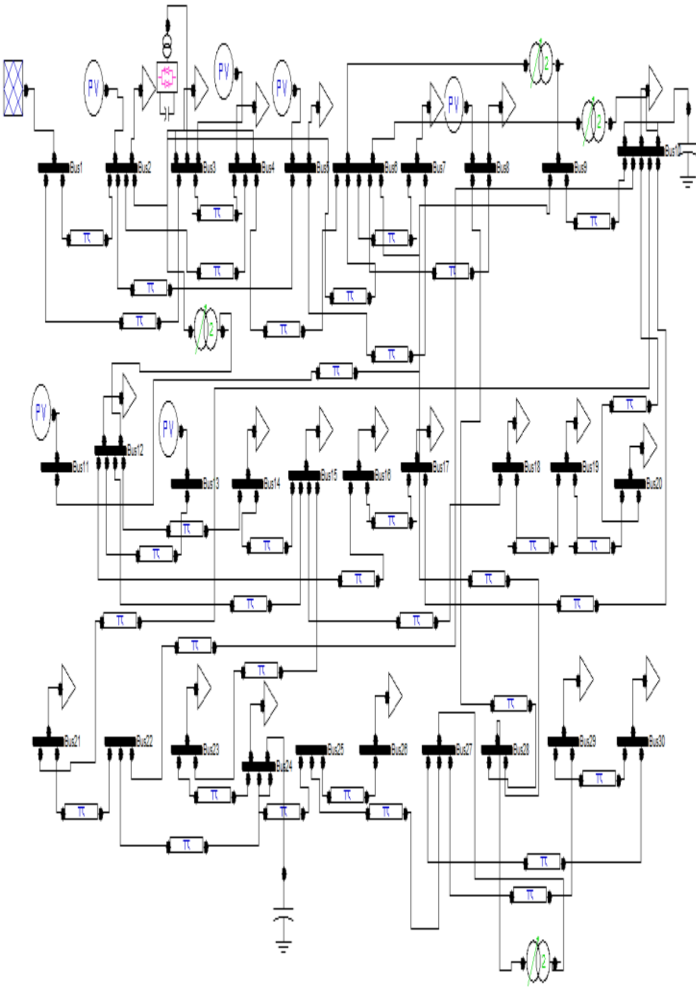

Fig.2 Modified IEEE 30 Bus Test System Simulation Model with STATCOM at Bus 3

Table: 2 Simulation results without STATCOM and with STATCOM placed at bus no. 3

Cases	**Normal case ATC (MW)**	**With STATCOM ATC (MW)**	**% increase in ATC**
From bus no.1 to 7	90	115	27.77
From bus no.1 to 12	39	42	7.69
From bus no.1 to 23	43	47	9.3

As shown in Table 2, the loading capabilities of the lines are increased by using the reactive power support (STATCOM). Here, three cases for the analysis are considered.

In first case when load at the bus 7 increases then reactive power limit of the generator at bus 8 violates first.

In another two cases the reactive power limit at bus 13 violates first when loading increases.

By using STATCOM loadability of the lines are also increased which is shown in table.

3. CONCLUSIONS

Congestion management is an important issue in deregulated power market. Reactive power support at weak bus helps to reduce congestion and their by increase transmission line loadability. Placement of STATCOM device can reduce or increase line reactance and their by increase or decreases MW power flow in line and thereby improve the voltage profile and ultimately reduces congestion. It has fast response and requires less space as passive elements are eliminated.

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Rajnikant H. Bhesdadiya graduated and mastered in 1999 and 2003 in electrical engineering from Gujarat University, Gujarat, India. He has 7 years of experience in field in PGVCL, DISCOM of Gujarat State as a junior engineer. Since, May 2011, he is working as an assistant professor in Electrical Engineering Department of Lakhdhirsinhji Engineering Collage, Morbi, Gujarat. Currently, he is pursuing Ph.D. from R. K. University, Gujarat on ATC indication and congestion management. He is a Life Member of ISTE. He is a member of IEEE. His research interests include congestion management and ATC calculation using artificial intelligence aspects in power systems and electricity markets.

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