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Transmission Line Loadability Improvement by Reactive Support

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Abstract--- The recent trend is towards the deregulation in power markets around the world, transfer capability computation emerges as a key issue in running power system smoothly with multiple transactions and reactive power sources. Total Transfer Capability (TTC) is usually limited by overloaded transmission lines and voltage limits imposed at buses. This paper presents the procedure of ATC calculation and enhancement using powerful power world simulator software considering both thermal limits and voltage limits and enhancement using capacitor placement.

I. 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 series capacitor compensation is a very cost effective option with the former one. However, Series capacitor transmission lines may lead to sub synchronous resonance (SSR) problem [6].

Better flow control would be useful because every link in the transmission system has a limit on the amount of power it can transfer. There are several phenomenons can impose these transfer limits like thermal limits, voltage limits and stability limits [1]. For the understanding of these limits there are certain methods. Available transfer capability (ATC) is the gauge of the ability of interconnected electric systems to reliably move or transfer power from one region to another over all transmission lines under specific 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 [7, 8, 9, 10, and 11]:

$$ATC = TTC-TRM-TBM-ETC$$

Where, TRM is Transmission reliability margin, TBM is Transmission benefits margin. ATC is defined as the Total Transfer Capability (TTC) less the Transmission Reliability Margin (TRM), less the sum of Existing Transmission Commitment (ETC) (which includes retail customer service) and the Capacity benefit Margin (CBM).

There are certain methods for transfer capability calculations. These methods mostly used are continuation power flow (CPF) method, optimal power flow (OPF) method and repeatative power flow (RPF) method, etc.

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 role is to increase the loading capability of the transmission line. The algorithm is tested on the IEEE-6 bus system to show its capability.

II. TOTAL TRANSFER CAPABILITIES

In 1974, NERC established definitions that refer to transfer capability as incremental above normal base power transfers. Normal base transfers usually refer to representative electric power transfers between systems that are modelled in power low base case simulations. Incremental transfer that refers to the additional amount of electric power, above the base level, that the interconnected transmission systems can support or transfer while continuing to maintain electric system reliability. This incremental transfer approach shows the ability of the transmission systems to accommodate additional transfers after all normally scheduled transfers are considered, as well as an indication of the ability of these systems to cope with emergency conditions.

III. FIRST CONTINGENCY TOTAL TRANSFER CAPABILITY (FCTTC)

FCTTC is the total sum of electric power (net of normal base power transfers plus first contingency incremental transfers) that can be transferred between two areas of the interconnected transmission systems in a consistent way. IV**.** Transmission System Limits

A. 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].

B. Voltage Limits**:** Ample voltage must be maintained on the transmission systems at all times, including during and after a system contingency. 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].

C. 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].

IV. CONGESTION MANAGEMENT

In a aggressive electricity market, congestion occurs when the transmission system is unable to accommodate all of the desired transactions due to a contravention of system operating limits. Congestion management that is controlling the transmission system so that 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 fairly exact, the expected costs of less secure operation could not be correctly quantified, and the limits themselves could develop a great deal of litheness when there was money to be saved by approaching 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.

A. *IEEE-6 Bus Test System*

The IEEE-6 bus test system is used in this paper to show the effect of capacitor on ATC. The diagram of the analysis system is shown in Fig, 1. Base value is assumed to be 100 MVA. The ATC being calculated is from one bus to another bus by using transmission line. Only the thermal limit of transmission lines and voltage magnitude limit of each bus are considered. The voltage magnitude limit of every transmission line is supposed to be 0.9 p.u. and 1.1 p.u..

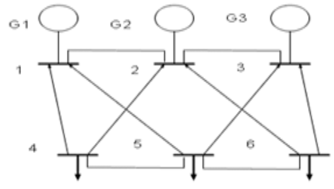

Fig. 1: IEEE 6-Bus Power System

B. *Power World Simulator*

Power World Simulator is a power system visualization, simulation, and analysis tool. Power world has been developed to illustrate some of the basic aspects of operation of an interconnected, high voltage power system[15].The Power world simulation only considers balanced 3-Φ operation. The advantage of analyzing a balanced system is that because all of the electric quantities in the three conductors have the same magnitude, we really do not need to show all three. Rather just a single conductor is shown. This is known as a one-line diagram, and is the way that power systems are always represented in Power world.

C. *Power World Simulation Model*

The IEEE-6 bus system has been created by using Power World Simulator software which is shown in Fig.2. After solving power flows; the results are obtained which are listed in the Table below.

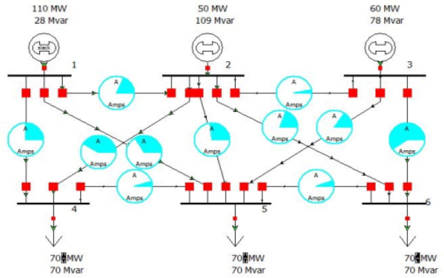

Fig 2: IEEE 6-Bus System Simulation Model

V. RESULTS

A. *Case 1:* Thermal and voltage limit dominant case for increase in load at bus 4

It is always the voltage limit at bus 4 that is violated first when load at bus 4 is increased. Here we took most effective congested case of outage of line 1-4 and from that got the results shown in Table 1. Table 1 shows the detailed results of ATC computation and the summary of the results with and without capacitor. To be brief, the detailed results will not be shown in other cases and only summary of results will be shown.

B. *Case 2:* Thermal and voltage limit dominant case for increase in load at bus 5

It is always the voltage limit at bus 5 that is violated first when load at bus 5 is increased. Here we took most effective congested case of outage of line 1-4 and from that got the results shown in Table 1. Table 1 shows the detailed results of ATC computation and the summary of the results with and without capacitor.

C. *Case 3:* Thermal and voltage limit dominant case for increase in load at bus 6

It is always the thermal limit in line 3-6 that is violated first when load at bus 6 is increased. Here we took most effective congested case of outage of line 2-6 and from that got the results shown in Table 1. Table 1 shows the detailed results of ATC computation and the summary of the results with and without capacitor.

Table 1: ATC Level with and without capacitor with normal and one contingency case

	Without capacitor	With capacitor
Case-1	ATC level (MW) when load at bus no. 4 changes	
Normal	**85.5**	**126.5**
Contingency (1 to 4 line outage)	29.0	66.5
Case-2	ATC level (MW) when load at bus no. 5 changes	
Normal	**104.5**	**163.0**
Contingency (1 to 4 line outage)	96.0	153.5
Case-3	ATC level (MW) when load at bus no. 6 changes	
Normal	**95.0**	**97.0**
Contingency (2 to 6 line outage)	48.0	50.0

From Table 1, it is seen that ATC is increased by using capacitors and the effect of capacitors on ATC is different when it installed in different buses. When capacitor is installed in bus 4, the improvement is 32.41%. When capacitor is installed in bus 5, the effect is the most significant (with an improvement of 35.88%). When capacitor is installed in bus 6, the improvement is 2.06%. It is also observed that when the installation place is closer to the overloaded line, the effect is more obvious compared to the effect when capacitor is installed farther away from the overloaded line.

VI. CONCLUSIONS

Congestion management is an important issue in deregulated power market. Capacitors controlling the power flows in the network can help to reduce the flows in heavily loaded lines. The main objective function is to increase the total generation and load on specific source and sink nodes i.e. to enhance the capabilities of existing transmission lines considering thermal limits of transmission lines, voltage bounds of buses.

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