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Determination Of Optimal Location Of Thyristor Controlled Series Compensator To Enhance The Transfer Capability Using Power World Simulator Software

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Abstract

Privatization and deregulation will not only increase competition in the electricity market, but will also result in increased output and consumption. This is likely to put additional strain on the transmission system, clogging it up. As a result, congestion management is a fundamental issue in transmission management. The purpose of this work is to develop an analysis tool for the power market in order to address the problem of congestion management. The tool establishes a connection between the Power World Simulator and other professional software tools for computing power flow. The tool analyses power flow data and performs batch processing on large case studies using the IEEE 9-bus system to simulate the electricity market and validate the proposed method. The results demonstrate that when Thyristor Controlled Series Compensator (TCSC) is included, the amount of re-dispatched power significantly decreases, resulting in an optimal operating point that is closer to the one influenced by market settlement. Additionally, it is established that Thyristor Controlled Series Compensator is a viable option for congestion management, both technically and economically.

Keywords Optimal power flow (OPF) Congestion management, Transfer capability, Distributed generation, Flexible AC Transmission Systems (FACTS), Series compensation,Congestion

1 Introduction

Restructuring and regulation of the electricity industry may enable the transmission open-access scheme to achieve maximum external power transfer using existing facilities. Congestion management is critical during both the operation and planning stages of a mission to alleviate bottlenecks in transmission. Two considerations, namely transmission management and transmission losses, must be made in light of transmission open access. Congestion increases the cost of electricity transmission. Congestion management is a cost-effective method of enhancing electricity transfer on a broad scale. Congestion in the transmission network refers to limitations in the flow of electricity through the network. When open access occurs, all of the limitations become magnified when the electricity restructuring environment is considered [1].

Congestion typically occurs when the state of the grid is determined by one or more violations of the network or plan constraints that govern how the network grid operates in the conventional state or under any one of the contingency cases specified in a set of specified contingencies. Congestion occurs when the transmitted power exceeds the transmission line's power limit or capacity. Congestion is always undesirable in a power network. It will compel producers to set different prices for different segments of the market, resulting in market distortions caused by congestion. Another disadvantage of congestion is the high stakes involved in market exploitation by competitors [1]. This results in a sharp increase in prices in some areas, excess power, and a decline in competition.

This article discusses the Thyristor Controlled Series Compensator and how it can be used to determine the optimal location for congestion management in highly competitive power markets. FACTS device locations are determined by the system's static and dynamic characteristics. A sensitivity-based approach is proposed for determining the optimal location of the Thyristor Controlled Series Compensator (TCSC). To alleviate transmission line congestion, an optimization-based method for determining the location of Flexible Alternating Current Transmission System (FACTS) devices was investigated [2].

Flexible Alternating Current Transmission System devices make use of power system technology that has been developed and applied. These devices are intended to regulate power flow and improve system stability. The optimal allocation of Flexible Alternating Current Transmission System (FACTS) devices, on the other hand, remains a critical issue to resolve. The purpose of this work is to determine the optimal location for a Thyristor Controlled Series Compensator, a type of FACTS device, in order to maximise power stability by controlling bus voltages. Thyristor Controlled Series Compensator (TCSC) is capable of rapidly generating and dissipating reactive power in order to adjust the voltage across a connection. By altering the bus voltages, the system's power flows will also be altered. As a result, the system's power flow can be fixed until it approaches stability [1].

Overloads and congestion on transmission lines are the primary issues confronting the power system's operation. However, the reorganized power system's consequences of this problem include unexpected cost increases in certain areas, an increase in market power, and a reduction in market competition [1].

The optimal power flow framework (OPF) is used in this article to assist in resolving the congestion problem in a deregulated electricity market. Additionally, transmission lines are decongested through the use of the Thyristor Controlled Series Compensator method. After detecting congested lines, the TLR sensitivity of all buses is determined; the bus with the highest TLR sensitivity is observed and TCSC is applied accordingly. IEEE 9-bus system is used to simulate the market, and the proposed method's performance is evaluated. The simulation is performed using POWER WORLD SIMULATOR, and the results indicate that when a Thyristor Controlled Series Compensator is included, the voltage profile of a congested bus improves significantly, thereby reducing congestion. Thus, it can be concluded that TCSC is a technically and economically viable option for congestion management.

2 Background

The entity that will monitor the reliability of the power system and coordinate the power supply as a wholesale electricity market. In the current deregulation environment in the United States, the most popular energy pricing model is based on the concept of node (spot) pricing, which extends the MCP described above to different nodes price energy according to where the energy is extracted or injected into the network. The spot price is based on the principle that unitary energy has different prices at different points in the network transmission and transmission congestion.

In most markets, GENCOS and ESCO are competing to enter the ISO regulated market. The market equilibrium price (MCP) is obtained by overlapping the supply bids in the price increase order and the price increase demand bid. This market clearing process is called a bid auction double side.

There are many entities in today's deregulated electricity market [4] the market on behalf of the plant owners and enters the energy pool through a bidding process for economic dispatch.

Transmitter (TRANSCOS): Construction and maintenance of the transmission network guarantee the economic dispatch all as system entities.

Distributor (DISCOS): Owns and operates local distribution facilities. A possible definition of the electricity market is the continuation: "The electricity market is a system that uses bids of supply and demand to determine the purchase and sale of electricity [7]

Flexible Alternating Current Transmission System devices have been developed and implemented in the power system as a result of rapid advancements in the field of power electronics. FACTS devices can be used effectively to increase system constancy and control power flow. Nowadays, FACTS devices are used to enhance the capabilities of transmission systems and to assist with the power system's oscillation damping problems [2].

The two primary considerations when utilising FACTS devices today are the ability to control power flow in transmission systems and the enhancement of steady-state stability in transient power systems. The article discusses the power flow control capabilities of FACTS devices [2].

However, coordination of FACTS devices in the power system is occasionally an open issue. As a result, this work also investigates the optimal coordination of FACTS devices in a bus system.

The purpose of this project is to determine the Thyristor Controlled Series Compensator's performance in terms of improving the voltage profile in the transmission system. Additionally, this project is expected to identify the effects of varying the bus Q voltage setting on the TCSC and to investigate the optimal coordination for the TCSC integration into a transmission system [2].

Several advantages of utilising FACTS devices in transmission system applications include the following:

I. Power flow control: The primary function of FACTS devices is to optimise power flow in order to meet system power requirements, resolve emergency situations, and so on.

II. Lower generation costs: Increases efficiency and lowers generation costs.

III. Enhancement of dynamic stability: an additional FACTS function. Enhances transient stability, power oscillation damping, and voltage stability.

IV. Increases the transmission line's loading capacity: FACTS devices can be used to meet short-term or seasonal demand, thereby increasing the line's capacity.

V. Providing reliable and secure tie-line connections: By lowering the cost of generation, interconnection requirements can be reduced as well. As a result, tie-line connections between adjacent regions are possible.

VI. Reduced reactive power flow: Transmission lines can thus carry more active power while reducing reactive power flow [3, 6].

3 Line Diagram of IEEE – 9 Bus System

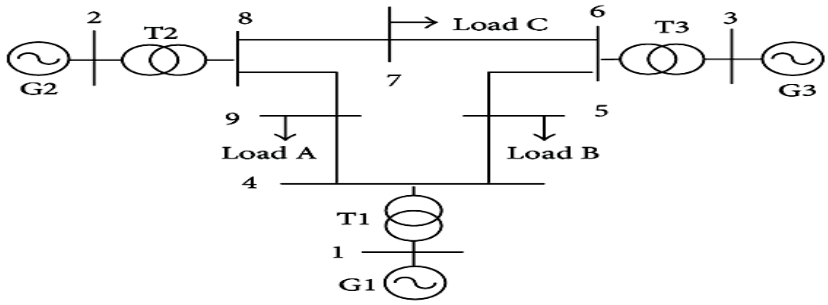

Fig. 1 Line diagram of IEEE 9-bus test system

Qk=input('Enter Qk value between -100 and 100MVAR =');

Q=Qd+Qk; mpc.bus(k,4)=Q;

The data can now be retrieved in MATLAB by entering the command 'results = runoff' and also specifying the bus [6, 7].

1 Methods of Congestion Management

The transmission line i-j that carries power as shown in Eq. 1, Pij is a function of the magnitude of the voltages Vi, Vj, the line reactance Xij, and the phase angle of the transmitting and receiving end voltages δi– δj.

$$P_{ij} = \frac{V_i V_j}{X_{ij}} \sin(\delta_i - \delta_j)$$

4 Load Curtailment by TLR Sensitivities

Sensitivity to Transmission Line Relief (TLR) and Power Transfer Distribution Factors (PTDFs) can be thought of as having an inverse relationship [3]. TLR sensitivities and PTDFs are used to determine a line's sensitivity to load curtailment. PTDFs determine the sensitivity of a component's flow, such as a transmission line, to a single power transfer. On the other hand, TLR sensitivities determine the sensitivity of the flow on a single monitored element to a variety of different system transactions. Thus, the sensitivity of a single monitored element can be determined using TLR sensitivities to various power transfer rates [3, 5].

The TLR sensitivity values for the most congested line at each load bus are considered when determining the required load curtailment to alleviate transmission congestion. The TLR sensitivity for a congested line i−j is Sijk at a bus k and is find out by

$$S_{ij}^{k} = \frac{\overline{\Delta P_{ij}}}{\Delta P_{k}}$$

At the transmission line i – j, the excess power flow is given by

$$\overline{\Delta P_{ij}} = P_{ij} - \overline{P_{ij}}$$

Here

Pij is an actual power flow through transmission line i−j,

Pij is a flow limit of transmission line i – j at the bus k, and the new load Pnew k can be calculated by

$$P_{k}^{new} = P_{k} - \frac{S_{ij}^{k}}{\sum_{i=1}^{N} S_{ij}^{l}} \overline{\Delta P_{ij}}$$

where Pnew k = load at bus k after curtailment Pk = load at bus k before curtailment Sl ij = sensitivity of power flow at bus k on line i−j due to load change N = total number of load buses.

The effect of a single MW power transfer is proportional to the TLR sensitivity, which means that the greater the TLR sensitivity, the greater the effect of a single MW power transfer. Thus, at the load bus, the loads that must be curtailed in order to overcome transmission congestion on the congested line i j are determined by the TLR sensitivity values.

This method is used in systems where load curtailment is a critical component of achieving (N – 1) secure configurations [3, 7].

5 Concept of Optimal Power Flow

The primary goal of an optimal power flow (OPF) problem is to determine the optimal setting of control variables in a power system network in order to maximise an objective function while adhering to operating and physical constraints such as generation and load balance, bus voltage limits, power flow equations, and active and reactive power limits. In general, the OPF problem can be expressed as [4].

The OPF problem that POWER WORLD SIMULATOR can solve is a 'smooth' OPF with no discrete variables or controls. The objective function is the total cost of real and/or reactive generation. These costs can be expressed as polynomials or as piecewise linear functions of the generator's output. The issue is as follows:

$$\min_{P_g, Q_g} \sum f_{1_i}(P_{gi}) + f_{2_i}(Q_{gi})$$

Such that

$P_{gi} - P_{Li} - P(V, \theta) = 0$ (active power balance equations)

$Q_{gi} - Q_{Li} - Q(V, \theta) = 0$ (reactive power balance equations)

$S_{ij}^{f} \leq S_{ij}^{max}$ (apparent power flow limit lines,from side)

$S_{ij}^{t} \leq S_{ij}^{max}$ (apparent power flow limit lines, to side)

$V_i^{min} \leq V_{min} \leq V_i^{max}$ (bus voltage limits)

$P_{gi}^{min} \leq P_{gi} \leq P_{gi}^{max}$ ((active power generation limits)

$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max}$ ((reactive power generation limits)

The costs of active and reactive power generation for generator I at a given dispatch point are denoted by f1i and f2i. Both f1i and f2i are polynomial or piecewise linear functions. The problem can be stated more succinctly as follows [4].

POWER WORLD SIMULATOR is a collection of codes for solving the optimal power flow problem in both alternating current (AC) and direct current (DC) modes. Each has a standard version that is as follows:

$$\min_{x} f(x)$$

Subject to

$$g(x) = 0$$
$$h(x) \leq 0$$
$$\min \leq x \leq \max$$

6 Flow Case Study on IEEE 9-Bus

Fig. 1 illustrates the line diagram of an IEEE 9-bus system created with Power World Simulator. Certain lines have been observed to be congested, as illustrated in Fig. 2. As a result, we determine the TLR sensitivity of each bus, as listed in Table 1.

It demonstrates that bus 9 has a higher TLR sensitivity than other buses, and that bus 5 has a higher TLR sensitivity than other buses. To begin, we apply TCSC to bus 5 and observe the voltage profile depicted in Fig. 3. Table 1 summarises the branch's power. Second, we apply TCSC to bus 5 and inspect the voltage profile shown in Figure 4, as well as the branch power shown in Table 2. It has been observed that after implementing TCSC, the voltage profile of that particular bus improves and congestion is reduced by approximately 80%.

Case study on IEEE 9 Bus system

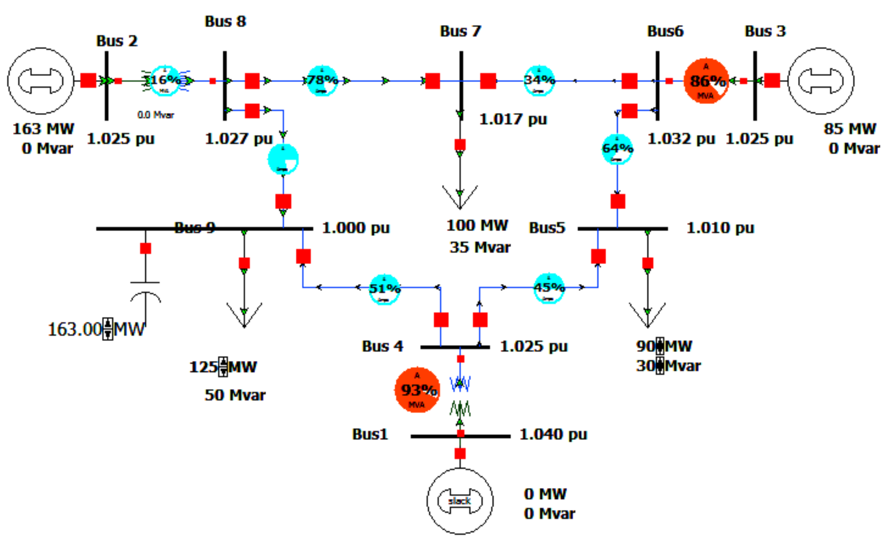

Fig. 2. Single Line Diagram of IEEE 9 bus test system

The Single line diagram of an IEEE-9 Bus system is as shown in Fig. 1 in Power world simulator. The initial generation data is presented. When we increase the load by 50 MW the lines are congested as shown in Fig.2 So we check the TLR sensitivity of all buses which is given [9] in the Table 1. We observed that bus no. 9 and bus no.5 have TLR sensitivity which is comparatively more than the other buses in consideration. But the line connected to bus 4 and bus 9 is congested so we compensate that line by

10% and verify the results which is shown in Fig.4 and table 2. We can see that the congestion problem of all branches is approximately solved by more than 80%.

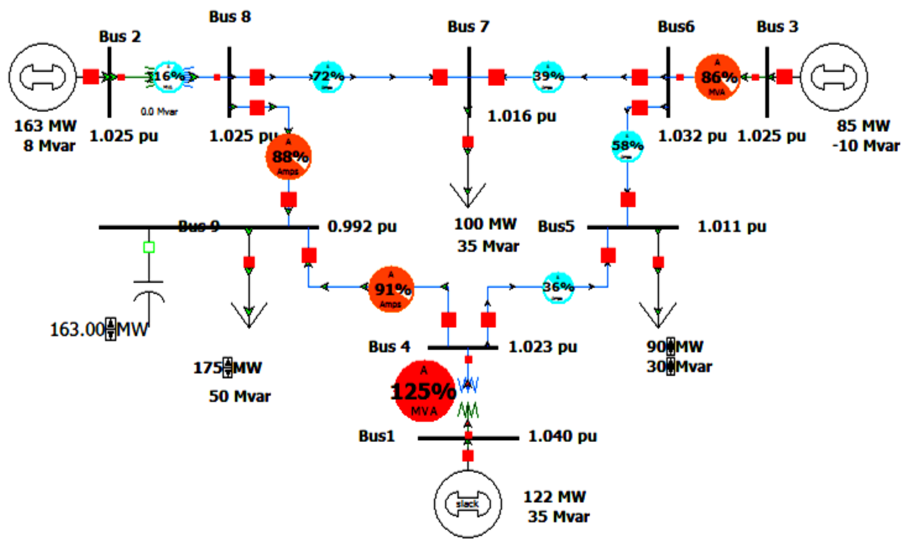

Fig. 3. Single Line Diagram of IEEE 9 bus test system before compensation

Table 1 shows the TLR sensitivity of IEEE 9-bus System

S .N.	Bus No.	TLR Sensitivity
1	1	-0.642
2	2	0.318
3	3	0.324
4	4	0.358
5	5	0.376
6	6	0.369
7	7	0.318
8	8	0.330
9	9	0.385

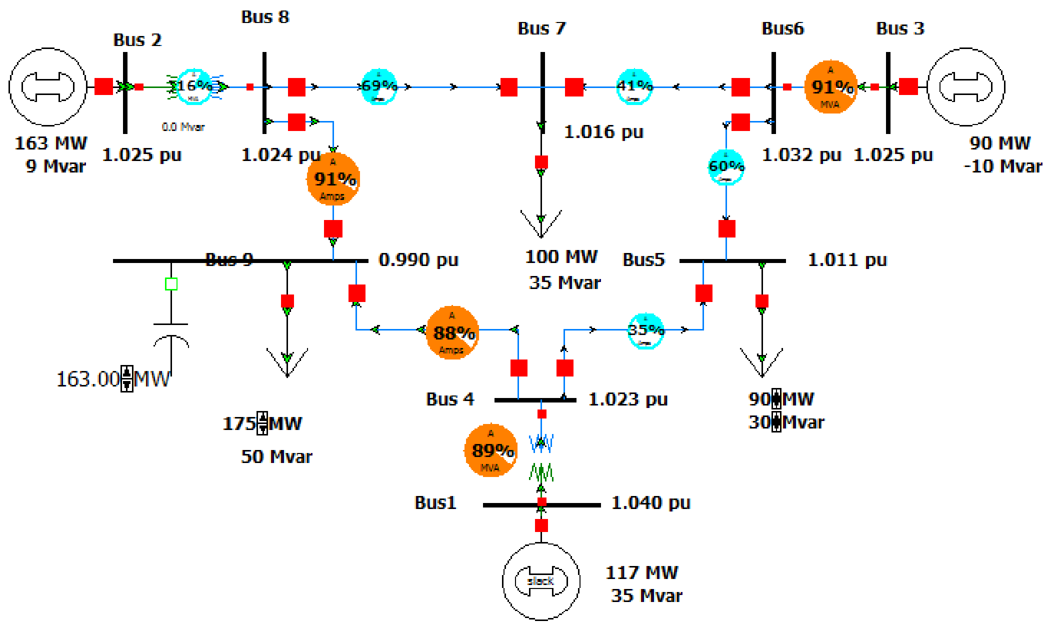

Fig. 4. Single Line Diagram of IEEE 9 bus test system after compensation

Table 2 : Before and After Compensation from 9-4 for IEEE 9 bus system

Branch No.	From Number	To Number	Before compensation MVA rating in %	After compensation MVA rating in %
1	1	4	125	89
2	4	5	36	35
3	5	6	58	60
4	3	6	86	91
5	6	7	39	41
6	7	8	72	69
7	8	2	116	86
8	8	9	97	91
9	9	4	91	88

7 Conclusion

Thyristor Controlled Series Compensator (TCSC) is considered as a first solution in this paper because it has been demonstrated to be an efficient method of managing congestion in the economic load market. The application of a Thyristor Controlled Series Compensator (TCSC) to assist in congestion management is found to benefit the system in terms of congestion resolution. Contracts that are more or less identical to the originally planned schedule are highly valued by both power distributors and consumers. The analysis is performed on an IEEE 9-bus network. The TLR sensitivity is determined here, as well as the location of the Thyristor Controlled Series Compensator (TCSC) for congestion resolution and verification of the simulation results. It has been observed that based on simulation results on various systems, there is a strong possibility of optimising the location of Series Compensation and relieving congestion. The optimal location of Series Compensation to alleviate congestion is both technically and economically advantageous. The TCSC location on bus 9 results in improved congestion management on the IEEE 9-bus system. When it comes to series compensation, location is more important than anything else. The Power World Simulator verifies the results.

In this paper we did the 10% series compensation of overloaded lines and verify the results of IEEE 9 bus system. Simulation is carried out in Power World Simulator. It has been observed that there is also a need of improving transfer capability while maintaining the security of the system. This necessity has created interest among the researchers to propose cost effective methods for a robust power system using the latest technologies. The most suitable means for this purpose are series compensation which can enhance the transfer capability, and there by network security. In this paper a method proposed to determine optimal location of FACTS devices, particularly TCSC considering requirements, such as reduction of loss, increasing transfer capability and there by alleviating congestion in deregulated electricity market. It is shown that this method is very effective and easy to apply in a deregulated system.

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