Impact of Deregulation on a Congested Energy Market

OGWATA, C. M[1], ABANG, P. A[2]

[1, 2] *Department of Electrical and Electronic Engineering Technology, Federal Polytechnic Oko, Anambra State*

Abstract- The deregulated power sectors suffer from congestion management problems. The congestion occurs when the generation and consumption of electric power causes the transmission system to operate beyond transfer limits. This paper deals with congestion on deregulated energy market and methods of managing its effects. The use of TCSC is also proposed to enhance the transfer capability which is needed to meet the rapidly changing demand of competitive markets. Power system load growth is increasing at a faster rate as compared to the increase in transmission capability. This has forced the system to move large amount of power over transmission system and created challenges associated with it. In the open access system where anybody can buy or sell energy there is a heavy transmission utilization in certain areas which was not planned initially. This has increased the need of improvements in the transfer capability of the system while maintaining the system security and reliability. This paper proposes an innovative technique for location of FACTS device using complex valued neural network.

Indexed Terms- Congestion management, Thyristor controlled series compensator (TCSC), Flexible Ac Transmission Systems (FACTS), Transmission line.

I. INTRODUCTION

Congestion management is a prime issue in power system. When the generation and consumption of electric power causes the transmission system to operate beyond transfer limits, the system is said to be under congestion. Congestion is the most fundamental transmission management problem. Congestion management is the process to avoid or relieve the congestion. In a broader sense, congestion management is considered as a systematic approach for scheduling and matching generation and loads in order to reduce the effect of congestion.

II. EFFECT OF DEREGULATION AND PRIVATIZATION ON ENERGY MARKET

Deregulation and privatization of energy market has a wide range of impact on the present day power systems around the world. The main objective of the deregulation of power industry is to introduce competition among the power producers and prevent monopolies. Deregulation has increased complexity of the system as anybody can participate in the transactions to sell or buy electricity [1]. As market participants can produce and consume energy in amounts, transmission lines are operated beyond their capacities causing congestion. It may occur due to lack of coordination between generation and transmission utilities, other reasons that could lead to short fall of transmission capability are:

- Difficulty in getting right of way permissions due to property devaluation.
- Health hazards due to electromagnetic effects.
- Large impact on land use.
- Ecological system effects.
- Capital cost involved in construction and maintenance of new lines and lack of investors for the proposed projects.

All the above mentioned factors and rapid growth of the load lead to congestion of the system. The challenge of transferring power over the existing grids has created an interest among researches in recent years for developing a more robust power system applying new technologies. The concept of flexible AC transmission systems (FACTS) to power system is widely applied to alleviate this problem. FACTS devices have the ability to allow power systems to operate in a more economic, secure, flexible, and sophisticated way.

III. METHODOLOGY

The recent restructuring of energy system with existing generation and transmission resources requires new methods for congestion management and it also provides an opportunity for these approaches. Allocation of transmission resources to support the competitive electricity market is the current area of interest. Various new approaches are proposed and being implemented which will provide feedback about their suitability and contribution in improving the efficiency and reliability. The two methods used for congestion management are:

1. Cost free methods: Outaging of congested lines, adjusting transformer taps, phase shifters or FACTS devices. The marginal costs involved in their usage are nominal.
2. Non-cost free methods: Re-dispatch of generation, load or transaction curtailment.

Under this method, the system transmission capability can be improved by system upgrading which involves the following:

- Installing FACTS devices.
- Reconductoring transmission lines with larger size conductor of higher power carrying capability and replacing terminal equipment.
- Voltage upgrade i.e. by increasing operating voltage of a transmission line. This method requires up gradation of towers, substations, circuit breakers, transformers and other equipment.
- Installation of new transmission lines to alleviate overloads by providing additional path.
- Conversion from single line to double circuit by modifying the tower structure.
- By series compensation using a series capacitor in long distance transmission lines.
- Installing phase angle regulators.
- Using small inertia generators and dispersed generation.
- Insertion of switching stations along the transmission line.

All the above mentioned factors are means of reducing congestion on a power system, but the discussion here will be limited to the use of Thyristor controlled series compensator (TCSC) which is a FACTS device.

IV. FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS)

With the advent of flexible ac transmission system (FACTS) devices power utilities all over the world are able to improve the system stability limit, control the power flow, improve the transmission system security and provide strategic benefits for better utilization of the existing power system. The operation of FACTS devices is based on power electronic controllers. These devices are also used to enhance transfer capability and to minimize the total power loss of a system thereby improving the system efficiency. In a competitive electric power system the most important aspect is better utilization of existing lines in the context of growing demand and outgrowth of energy trading markets. In the context of restructuring the existing power systems FACTS devices have assumed an importance since they can expand the usage potential of transmission systems by controlling power flows in the network. FACTS devices are operated in a manner so as to ensure that the contractual requirements are fulfilled as far as possible by minimizing line congestion [2].

V. FLEXIBLE AC TRANSMISSION SYSTEM (FACTS) DEVICES

For the enhancement of available transfer capability using FACTS controllers it is assumed that the time constant of these devices is negligible hence only static models are considered. Thyristor Controlled Series Compensator (TCSC) is one such device which offers smooth and flexible control for security enhancement with much faster response compared to the traditional control devices [3]. The detailed model of TCSC and brief discussion is given below.

VI. THYRISTOR CONTROLLED SERIES COMPENSATOR (TCSC)

Thyristor controlled series compensator (TCSC) are connected in series with transmission lines. It is equivalent to a controllable reactance inserted in series with a line to compensate the effect of the line inductance [4]. The net transfer reactance is reduced and leads to an increase in power transfer capability. The voltage profile are also improved due to the insertion of series capacitance in the line. Series compensation is usually a preferable alternative for increasing power flow capability of lines as compared to shunt compensators as the ratings required for series compensators are significantly smaller [5]. The transmission line model with a TCSC connected between the two buses *i* and *j* is shown in Figure 1.Equivalent pi model is used to represent the transmission line. TCSC can be considered as a static reactance of magnitude equivalent to *-jXc*. The controllable reactance *Xc* is directly used as control variable to be implemented in power flow equation.

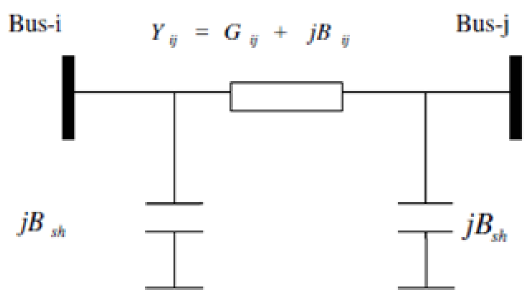

Fig 1Model of transmission line

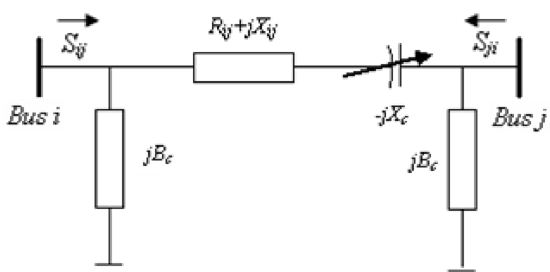

Fig. 2 Model of TCSC

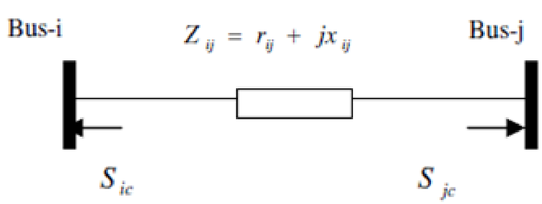

Fig.3 Injection model of TCSC

The following equations are used to model TCSC. Let the voltages at bus i and bus j represented by

$V_i \angle \delta_i$ and $V_j \angle \delta_j$

The complex power from bus *i* to *j* is

$$S^*_{ij} = P_{ij} - Q_{ij} = V_i^* I_{ij_i} \quad (1)$$

$$= V_i^* \left[(V_i - V_j) Y_{ij} + V_i (jB_c) \right] \quad (2)$$

$$= V_i^* \left[[G_{ij} + j(B_{ij} + B_c)] - V_i^* V_j (G_{ij} + jB_{ij}) \right] \quad (3)$$

Where

$$G_{ij} + jB_{ij} = 1/(R_L + jX_L - jX_C) \quad (4)$$

From the above equations the real and reactive power equations can be written as

$$P_{ij} = V_i^2 G_{ij} - V_i V_j G_{ij} \cos(\delta_i - \delta_j) - V_i V_j B_{ij} \sin(\delta_i - \delta_j)$$

(5)

$$Q_{ij} = -V_i^2 (B_{ij} + B_c) - V_i V_j G_{ij} \sin(\delta_i - \delta_j) + V_i V_j B_{ij} \cos(\delta_i - \delta_j)$$

(6)

Similarly the real and reactive powers from bus *j* to *I* can also be represented by replacing V*i* with V*j* .The real and reactive power loss in a line are represented by equations 7 and 8

$$P_L = P_{ij} + P_{ji} \quad (7)$$

$$Q_L = Q_{ij} + Q_{ji} \quad (8)$$

VII. NETWORK DECONGESTION USING TCSC APPROACH

In recent years, deregulation of electric industry in the world has created competitive markets to trade electricity [6]. For deregulated transmission network, one of the major consequences of the non-discriminatory open access requirement is substantial increase of power transfers. Congestion management of deregulated transmission network is important to accomplish non discriminative network access. In this example congestion management approach using TCSC is demonstrated considering a 5 bus system. This approach aims at maximization of transmission margin without changing contracted power. In this approach TCSC modelled as a variable reactance is used. In order to check the validity of the proposed method of congestion management, numerical results for a 5-bus system are shown in Figures 4 and 5.

Fig. 4 shows the transmission line flows without TCSC. It is observed that Lines 1-2 and 2-5 are over loaded compared to other lines. The efficient utilization of existing transmission lines installing TCSC in line 1-3 is shown in Fig 5.

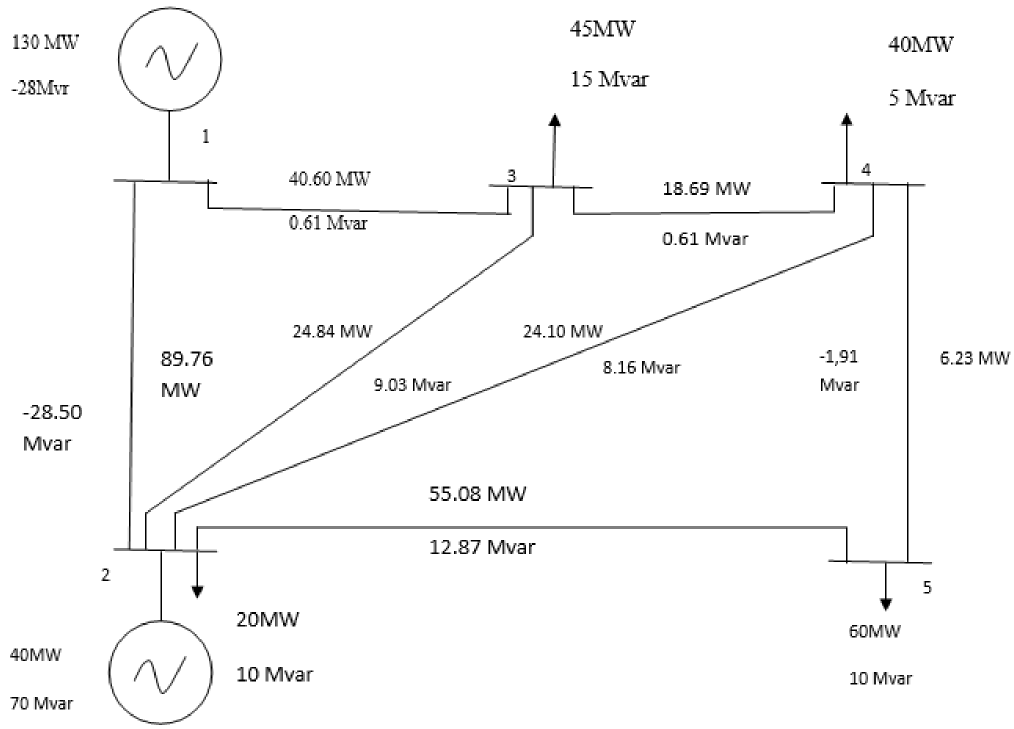

Fig. 4 Transmission margins without TCSC

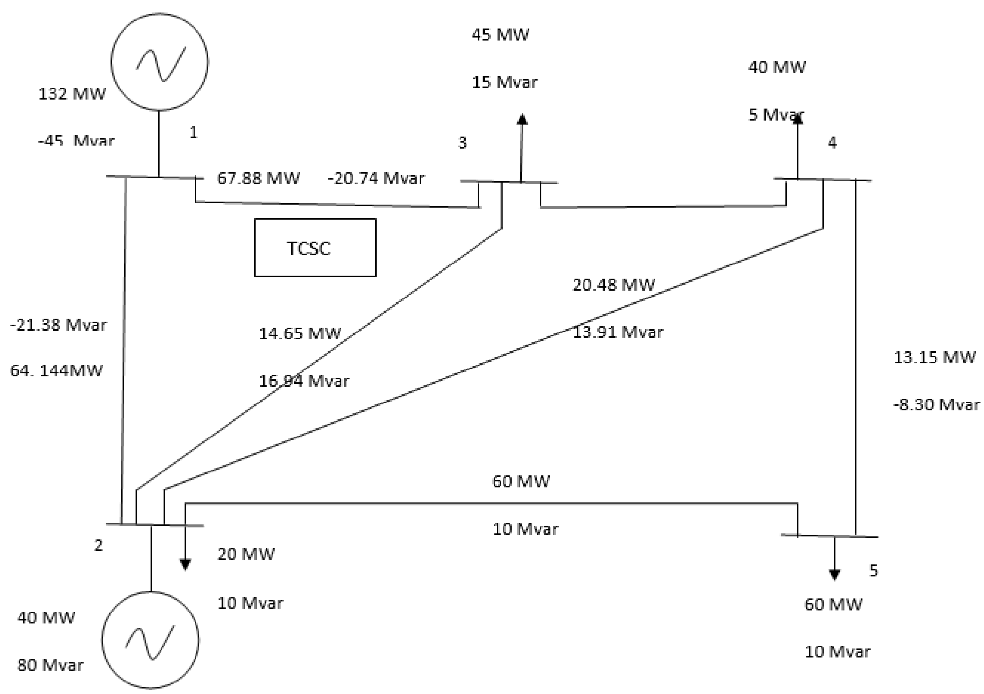

Fig.5 Transmission margins with TCSC

VIII. ECONOMIC IMPLICATIONS OF DECONGESTION IN POWER NETWORK

One of the responsibilities of the transmission Companies, whether they are involved with a large or a small utility control area, is to maintain system reliability [7]. This involves developing generation and load schedules that can be balanced in real time. The Transcos must make sure that the scheduled flows do not exceed a maximum for any link on the system. Scheduling of generators and loads must carefully consider any transmission link that could potentially become constrained. This consideration includes not only the current flows on the system's lines and equipment, but it also must consider the post contingency capacity. For any link the transmission system must provide enough capacity that any single contingency within the system (and any credible multiple contingency) could be handled to minimise system breakdown and maximise profit [8].

CONCLUSIONS AND RECOMMENDATIONS

With the advent of deregulation and policies of open access, allocation of scarce transmission resources has become a key factor for the efficient operation of electricity markets as well as reliability and control of market power [9]. This trend has been reinforced as expansion of the transmission capacity has failed to keep pace with the demand for power and the emerging trends to transfer power over longer distances. These trends make it increasingly important that congestion management is structured to facilitate economically efficient allocation of transmission capacity. Because of the policies of open access coupled with the inability to economically control flows on individual lines within an AC power system, transmission capacity is characterized as a communal resource and otherwise subject to the externalities of overuse. Congestion management can also provide insight into where transmission enhancements are needed. The restructuring of generation and transmission resources not only requires new approaches to congestion management but also provides an opportunity for them. As might be expected, congestion management is in a period of tremendous flux. Serious debates over the best approach to allocate transmission resources to support competitive markets are taking place. New approaches are being implemented, and these will provide feedback about how congestion management can best support efficiency and reliability. As these approaches are made operational, they will provide real-world experience that will provide the basis for evaluating the most effective techniques for congestion management.

REFRENCES

[1] Alaywan. Z (1999). *Facilitating the Congestion Management Market in California*, IEEE PES Conference Proceeding Paper, Edmonton, Canada.

[2] Taher SA (2008).*Transmission Congestion Management By Determining Optimal Locations of Facts Devices In Deregulated Power Systems*. Am. J. Appl. Sci., 5(3): 242-247.

[3] Rajalakshmi L, Suganyadevi MV, Parameswari S (2011). *Congestion Management in Deregulated Power System by Locating series FACTS devices*. IJCA 13(8).

[4] Singh SN, David AK (2001). *A New Approach for Placement of FACTS devices in Open Power Markets*. IEEE Power Eng. Rev. 21:58-60.

[5] Vijay KK (2011). *Optimal Location of FACTS Devices for Congestion Management in Deregulated Power System*. IJCA, 16(6).

[6] Lehmkoster C (2002). *Security Constrained Optimal Power Flow For An Economical Operation of FACTS Devices in Liberalized Energy Market*. IEEE Trans. Power Deliv., 17(2).

[7] B. J. Kirby et al,(2002). *Congestion Management Requirements, Methods and Performance Indices*. Consortium for Electric Reliability Technology Solutions

[8] Harry S, Shan Y, Alex P (1998). *"Transmission congestion management in competitive electricity market." congestion management in competitive electricity market*. IEEE Trans. Power Syst., pp. 672-680, May

[9] Naresh A, Mithulananthan N (2006). *Locating Series Facts Devices For Congestion Management In Deregulated Electricity Markets*. Electric Power Systems Research