CONGESTION MANAGEMENT OF A DEREGULATED POWER SYSTEM USING FACTS DEVICES

By

YUSUP KULIEV

FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
in Partial Fulfilment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

UniversitiTeknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak DarulRidzuan

CERTIFICATION OF APPROVAL

CONGESTION MANAGEMENT OF A DEREGULATED POWER SYSTEM USING FACTS DEVICES

by

YusupKuliev

A project dissertation submitted to the
Department of Electrical & Electronic Engineering
UniversitiTeknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

Approved:

____

Ir. PerumalNallagownden
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

AUGUST 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

____

YUSUP KULIEV

ABSTRACT

With the unbundling of power generation, transmission and distribution system, the likelihood of congestion in the transmission lines is greatly increased. Deregulated market need to develop a competitive electricity system that must determine prices that equate the demand and supply. Almost all system variables obtained from load flow solutions are utilized as an input to the neural network. There are several approaches to managing and preventing the occurrence of congestion in a deregulated power system. The usage of Neural Network as one of the methods to manage congestion in a deregulated power system is discussed in this report.

ACKNOWLEDGMENTS

My heartfelt appreciation goes to my supervisor Ir. N Perumal who has given me endless guidance and moral support throughout the duration of this project. I am deeply touched and grateful with his dedication and commitment to advise me while working on his project. The moments working with him will remain a valuable and memorable experience for my future undertakings.

I also, truly appreciate the assistance given by the laboratory technicians of UniversitiTeknologi PETRONAS for helping me out in various ways. Not to forget, my endless gratitude to all the lectures of UTP and my beloved family members and friends have helped a lot by giving feedbacks helpful ideas throughout the development stages of this project.

On the whole, I am really appreciative of all ideas, guidance and moral support which was extended to me. Completing this project was an enjoyment and a very valuable experience for me to learn and also to cherish. I hope that the results produced will show somehow be beneficial and useful.

TABLE OF CONTENTS

LIST OF TABLES

TABLE OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Nowadays we receive power supply to work our electrical devices, and we know that power generated from generators should be transmitted through transmission lines to the end of user.

1.1.1 Regulated Power Systems

Regulated power transmission systems it is known as distribution method until the end of user. This system was monopolized by specific parties only. This is why only one electric utility company monitored by the government. This means that companies produce electric energy but everything is under the control of government.

1.1.2 Deregulated Power Systems

End users or transmission line service provider can only choose the supplier as in a deregulated transmission system due to monopolized system. Power systems' deregulation is very promising in terms of economic considerations. It is strongly believed that deregulation is economically beneficial to transmission service providers, generator companies and end users as well. Although deregulation is believed to be economically beneficial, there are many aspects and points to be emphasized on while using a deregulated power system.

1.1.3 Congestion in Deregulated Power Systems

Common parameters such as geographical factors and transmission losses will have to be reconsidered when transmitting power from the respective power generation companies. This is because in deregulated power distribution system, transmission service providers are provided with the chance to choose the preferred generators for supply.

1.2 Problem Statement

The main problem that that the regulated power system has is the existence of monopoly by companies that control the generation, transmission and distribution systems. In the deregulated power system, it is important to accurately and rapidly quantify the available transfer capability (ATC) of the transmission system. The transmission grid is the only practicable means for independent generators to deliver electric power to their wholesale customers.

1.3 Objectives

1.3.1 To understand the principles and concepts related to the deregulated power system

The basic idea of this kind of power system is to have more than one company or body at the generation (wholesale) and distribution (retail) [5] level. Our main objective in coming out with this new proposed way is to provide more options or alternatives for ends users to choose. As we implement this method the end users will have chance to choose the best or most convenient method by depending on their needs. : The basic idea of this kind of power system is to have more than one company or body at the generation (wholesale) and distribution (retail) level.

1.3.2 To identify methods to manage congestion in deregulated power system

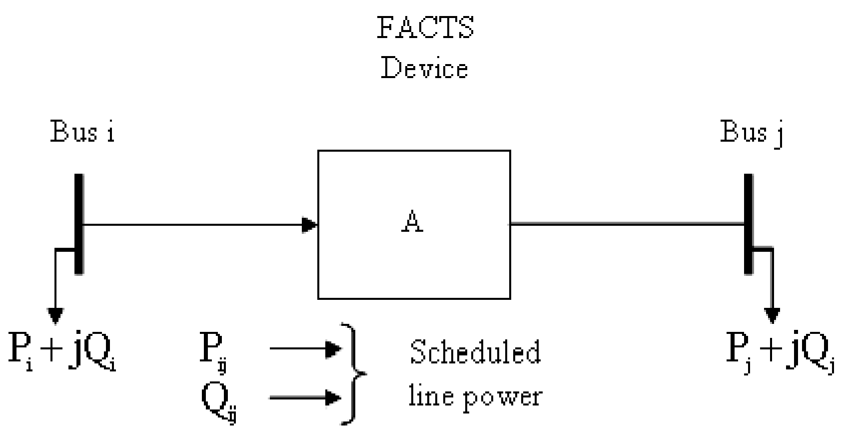
These days several methods have been introduced to help manage congestion which arises along the transmission lines. It is hardly to have any one universal solution for each and every power system, but the considerations and parameters will have to be taken accordingly.

1.3.3 Modeling FACTS Devices Method for Congestion Management

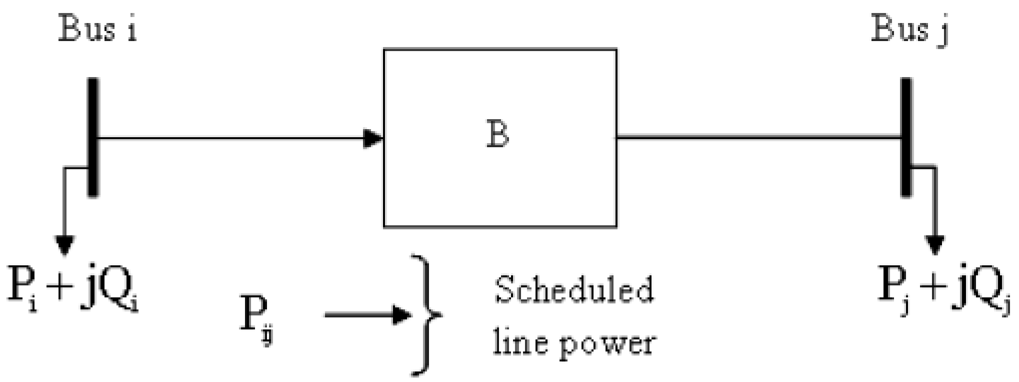
In the deregulated electricity system, electricity concept always changes from one service to a commodity. Currently, FACTS devices are divided into three main groups, current injection, and voltage injection in series and the combination of first and second group.

Table: 1 Types of FACTS devices models.

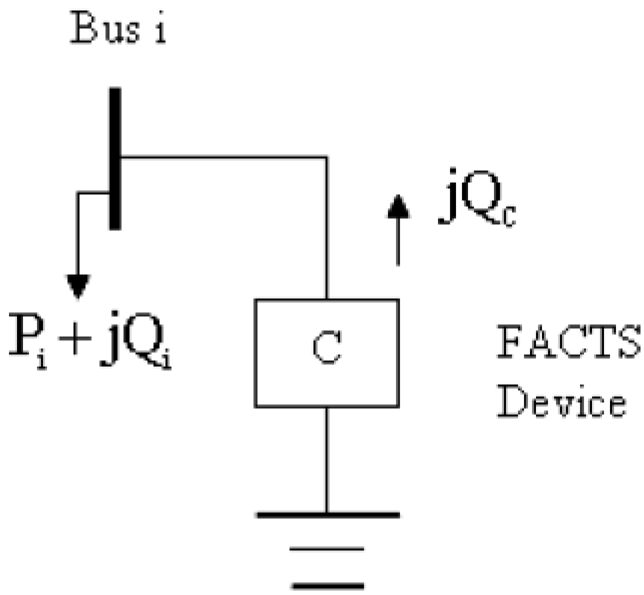
Type designation	Parameter controlled	FACTS devices
Type A	Series P and Q	UPFC
Type B	Series P	TCSC, phase angle regulator
Type C	Series Q	SVC, STATCON



(a)



(b)



(c)

Fig 1 Models of a type (a) (b) and (c) FACTS devices.

After studying and understanding FACTS devices method, It was determined that this method is a better choice for my project. In order to justify this statement, one important concept is modeled on a system.

1.3.4 TYPES OF FACTS DEVICES

Nowadays, FACTS devices are playing important role in the power systems, because they can provide flexible transmission operation and also affect to the revenue of producers and customers. Among them the voltage control and voltage improvement, reliability improvement and network control.

1.3.5 Thyristor-controlled series compensator (TCSC)

A capacitive reactance compensator which consists of a series capacitor bank shunted by a thyristor-controlled reactor in order to provide a smoothly variable series capacitive reactance. TCSCs vary the electrical length of the compensated transmission line with little delay. This characteristic enables the TCSC to be used to provide fast active power flow regulation.

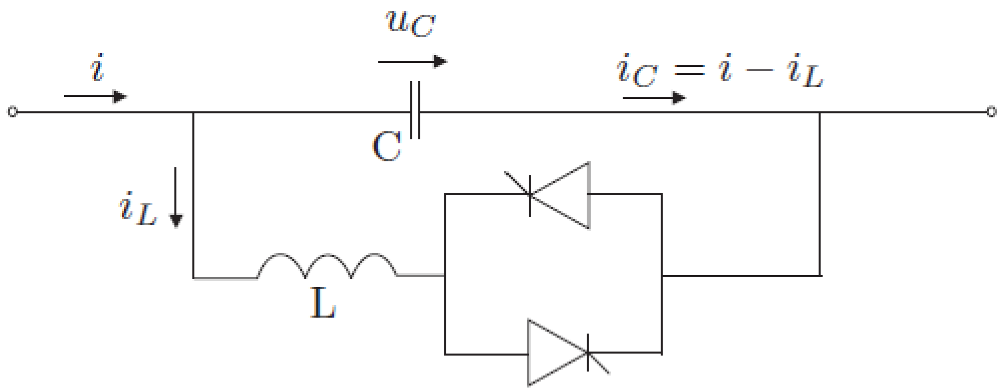


Fig 2 Basic diagram of TCSC

The operating modes of a TCSC are characterized by the so-called boost factor

KB =XTCSC/XC

1.3.6 Static Var compensator (SVC)

Nowadays FACTS devices are playing important role in power systems.

Qsvc =Vi (Vi-Vr) / Xsl.

In this figure you can see a schematic diagram of a static var compensator. The compensator itself includes a thyristor controlled reactor (TCR), thyristor- switched capacitors (TSCs) and also harmonic filters.The harmonic filters itself are capacitive at fundamental frequency.

The TCR is bigger than TCS blocks; it means that continues control is realized. The transmission side voltage is controlled and the Mvar ratings are referred to transmission side in this figure.

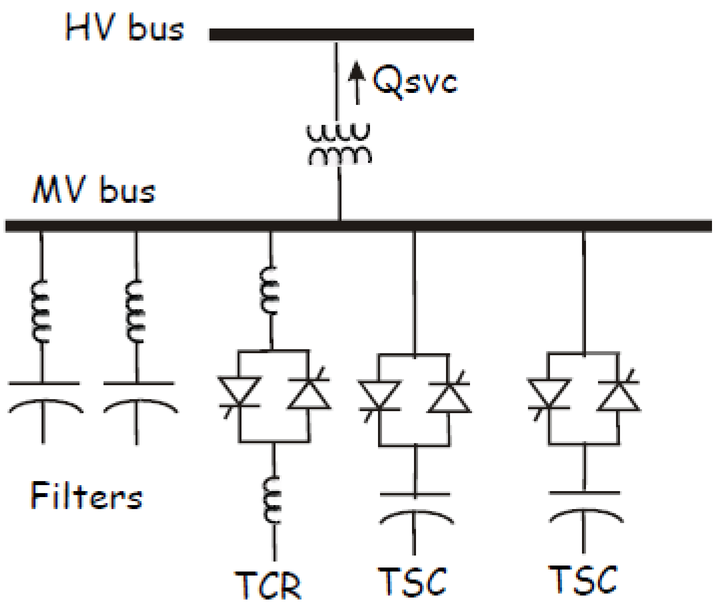


Fig 3 Schematic diagram of an SVC.

1.3.7 Thyristor-controlled phase angle regulator (TCPAR)

The TCPAR is also called a thyristor controlled phase shifting transformer (TCPST) and is defined by IEEE as a phase-shifting transformer adjusted by thyristor switches to provide a rapidly variable phase angle. The TCPAR controls power flow through a transmission line by regulating the effective phase angle between the two buses of the line. TCPARS can help eliminate loop flows. The TCPAR apart from the steady state voltage and power flow control can also be used to handle dynamic events on the power system.

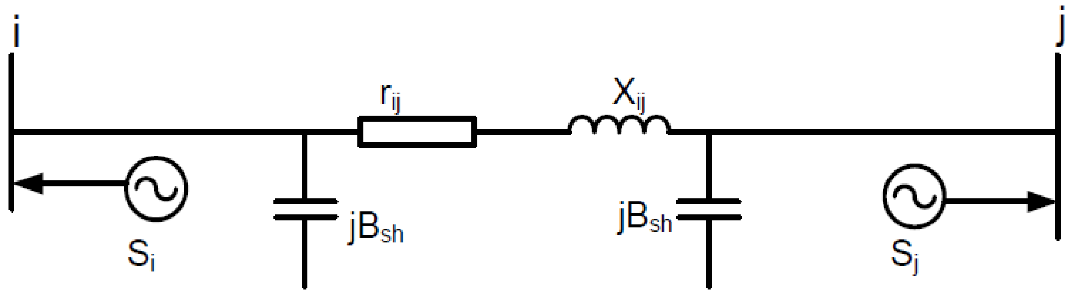


Fig 4 Schematic scheme of TCPR

1.3.8 Static Compensator (STATCOM)

The STATCOM consists of one VSC and its associated shunt-connected transformer. It is the static counterpart of the rotating synchronous condenser but it generates or absorbs reactive power at a faster rate because no moving parts are involved. Basically, it performs the same voltage regulation function as the SVC but in a more robust manner.

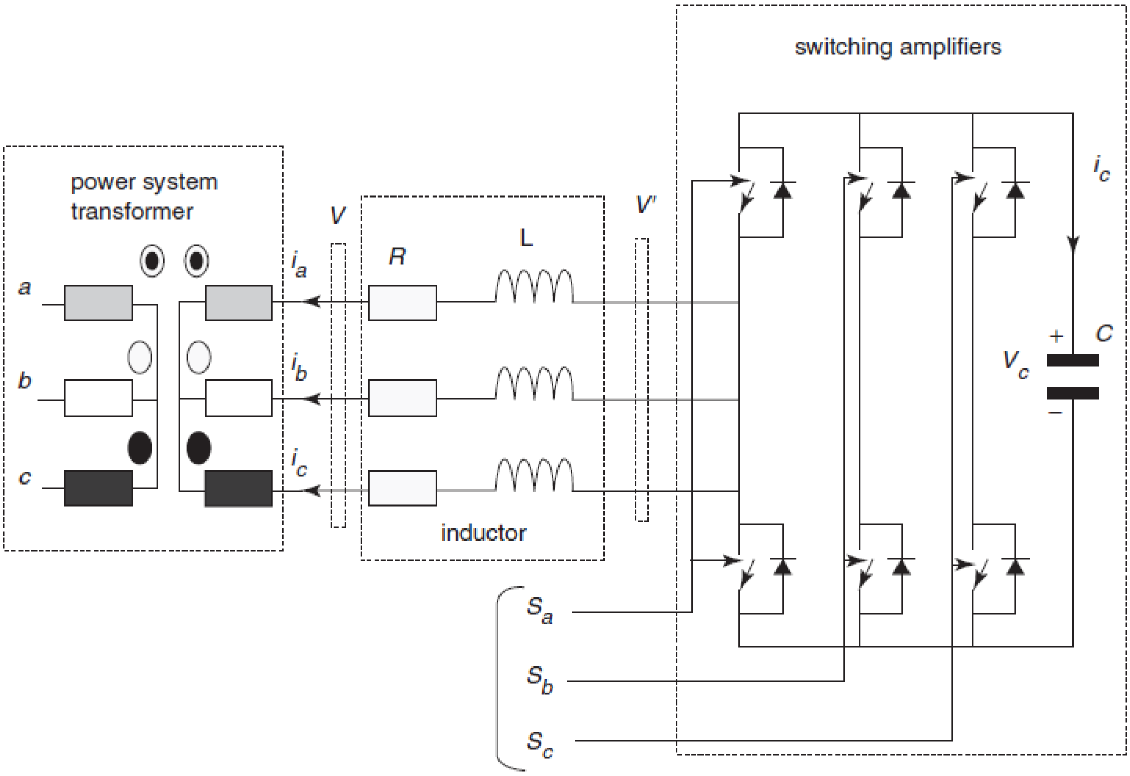


Fig 5 Three phase circuit of STATCOM

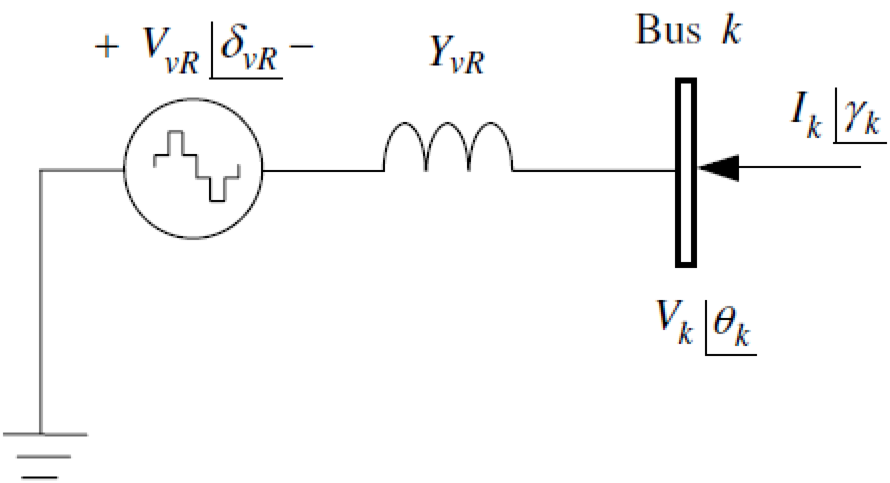


Fig 7 Shunt- solid stage voltage source

The shunt voltage sourceof the three-phase STATCOM may be represented by:

$$E^{\rho}_{vR} = V^{\rho}_{vR}(\cos\delta^{\rho}_{vR} + \mathrm{j}\sin\delta^{\rho}_{vR})$$

With the reference to the equivalent circuit shown in fig 2, the following admittance equation can be written:

$$[\mathbf{I}_k] = [\mathbf{Y}_{vR} \quad -\mathbf{Y}_{vR}]\begin{bmatrix}\mathbf{V}_k \\ \mathbf{E}_{vR}\end{bmatrix}$$

Where:

$$\begin{aligned}
\mathbf{I}_k &= [I^a_k\angle\gamma^a_k \quad I^b_k\angle\gamma^b_k \quad I^c_k\angle\gamma^c_k]^t, \\
\mathbf{V}_k &= [V^a_k\angle\theta^a_k \quad V^b_k\angle\theta^b_k \quad V^c_k\angle\theta^c_k]^t, \\
\mathbf{E}_{vR} &= [V^a_{vR\,k}\angle\delta^a_{vRk} \quad V^b_{vR\,k}\angle\delta^b_{vRk} \quad V^c_{vR\,k}\angle\delta^c_{vRk}]^t \\
\mathbf{Y}_{vR} &= \begin{bmatrix} Y^a_{vR\,k} & 0 & 0 \\ 0 & Y^b_{vR\,k} & 0 \\ 0 & 0 & Y^c_{vR\,k}\end{bmatrix}.
\end{aligned}$$

Scope of Project

1.4. 1 To understand the principle of Regulated Power transmission System Method

Before to recommend this method, we have to be clear with system itself. After we understand, then we can identify effectively the issues and setback of practicing regulation system with deregulation. Only in this way we can determine the suitability of replacing the regulated power system based on concrete reasons

1.4.2 To understand the principle of Deregulated Power transmission System method

To promote the competition at the whole sale and retail of power system and distribution we can proposed deregulated as the main alternatives butit's important and necessary to understand and identify the complications which might arise from the implementation of deregulation in the place of regulation power system.

1.4.3 Congestion management – Challenges of a deregulated Power System

Buyers of electricity are given the opportunity to choose their preferred supply generation location within one of the benefits of a deregulated power system. The buyers choose the source for generation companies which offer the lower rates and transmit the electricity all the way to the location despite the greater distance until the user end. But we know many customers of sales would cause overload in the transmission system known as congestion management [5]. This is why this proves to be the biggest challenges of power system.

1.4.4STATCOM Method and its factors for the consideration

To successfully implement STATCOM Method, we have to identify and understand all factors which need to be taken for consideration. One of these factors could cause great losses to the generator companies and the system itself. In spite of that the effectiveness of the STATCOM Method to reduce congestion would be considerably reduced.

1.4 Feasibility of the Project

The reason this project is implemented is not only to explore the benefits and complications of deregulated power system implementation. On a long term basis, I believe that all countries will eventually have to move into the era of deregulated power systems. Therefore, at the end of this project, it is hoped that the complications associated with deregulation, namely congestion, an effective and feasible solution would have been achieved enabling congestion to be kept at a minimal. On the whole, this project would benefit all where deregulation is implemented or to be implemented as one of the main challenges of deregulation would have been addressed.

1.5 The Relevancy of the Project

This project will focus on the topic of Congestion Management in Deregulated power system. There are several main challenges to be taken into serious consideration. And management of congestion at transmission lines plays a major influence on the trade of electricity. Many approaches have been proposed to help manage congestion system and these approaches include various types of power transfer schemes.

CHAPTER 2

LITERATURE REVIEW

2.1 Regulated Power System

Electric utility is often related to power system whereby electricity is supplied through this huge and widely distributed system. The system itself comprises of many components which are mainly the generators, transmission lines, distribution lines, transformers, regulators and capacitors, and breakers.

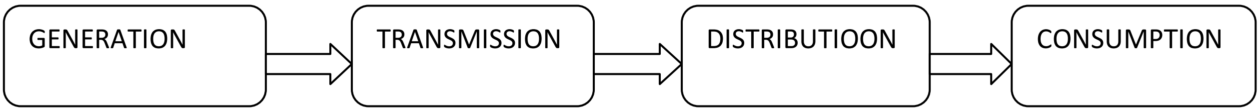


Figure8: Vertically integrated utility diagram

As stated before,in a regulated power system, the process of generation, transmission and distribution is normally governed by a single electric utility company. Nevertheless, upon the sales of energy for consumption by end users, the cost recovery and profit will be obtained as depicted in Figure 2.

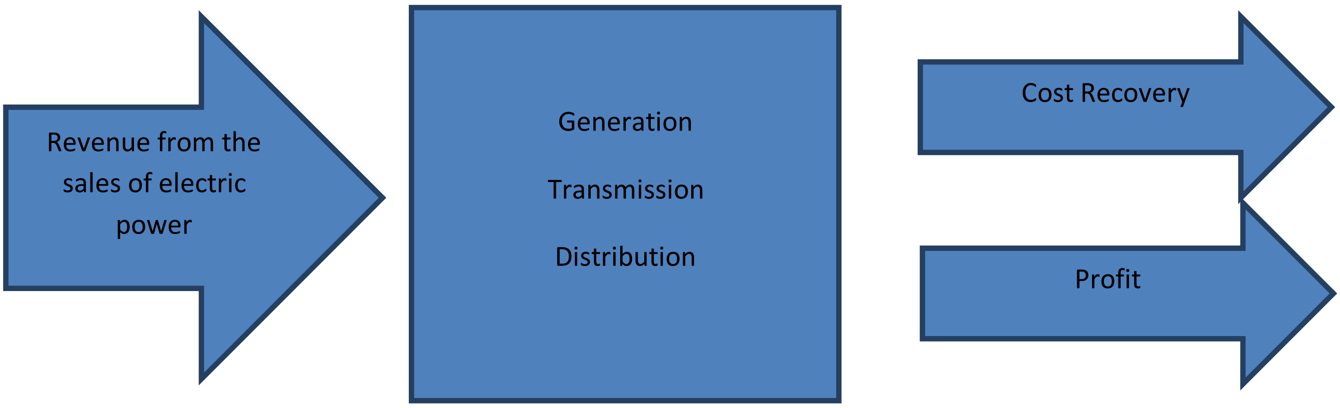


Figure 9: General Operations of a Regulated Power System Electric Utility

2.1.1Characteristics of a Regulated Power System

Before, when the power system was implemented in the early stages of power generation, transmission and distribution, there were several unique characteristics The government has the right to dictate many aspects of operation and production of power utility companies.

These characteristics are shown below [5]

a. Monopoly franchise
b. Obligation to serve
c. Guaranteed rate of return
d. Operating and business practices
e. Least-cost operation

2.1.2 Justifications for the Implementation of a Regulated Power System

Nevertheless, despite the numerous mandatory regulations and policies by the government, there were several original needs to practice regulation in such a manner.

This is a fact that was agreed by both side, government and utility company, despite the disagreements they might have on the implementation of it.

The reasons which make regulation a requirement are shown below [5]

a. Legitimized the electric utility business
b. Provided utilities recognition and limited support from local government
c. Guaranteed a return investment
d. Establish a local monopoly

2.1.3 Deregulated Power Systems

The structure of a deregulated power system is depicted in figure below.

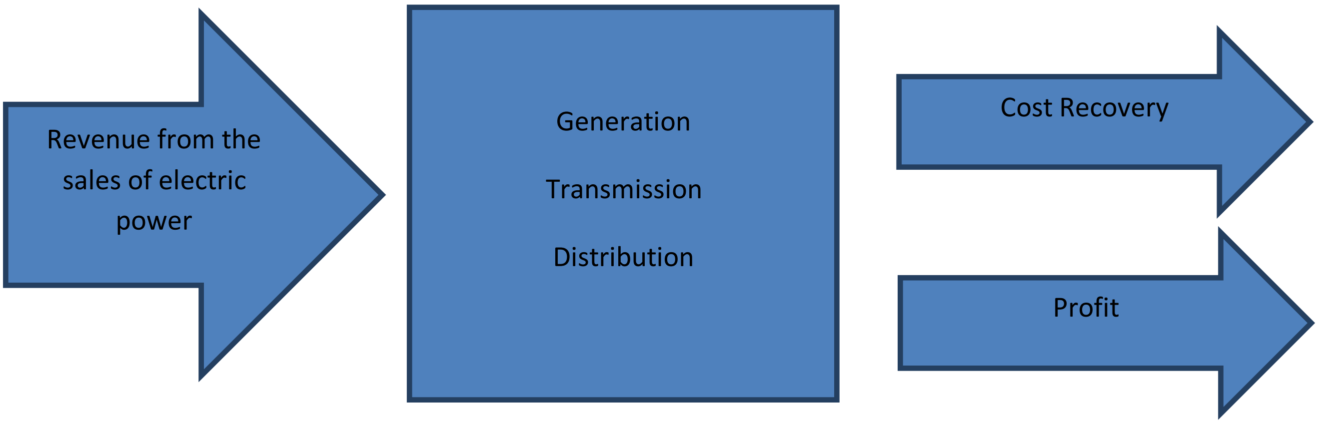


Figure 10: General Operations of a Regulated Power System Electric Utility

General and one the important differentiating characteristics of a deregulated power system is the unbundling of Generation, Transmission and distribution to form individual components. This is why unbundling, it is possible for multiple generators to be in operation and also for multiple retailers. After this the components of generation, transmission and distribution will not be need to be managed by one single utility company.

More clearly view of the deregulated structure which allows multiple generation companies and multiple retailers to share one common transmission line as show in in the figure below.

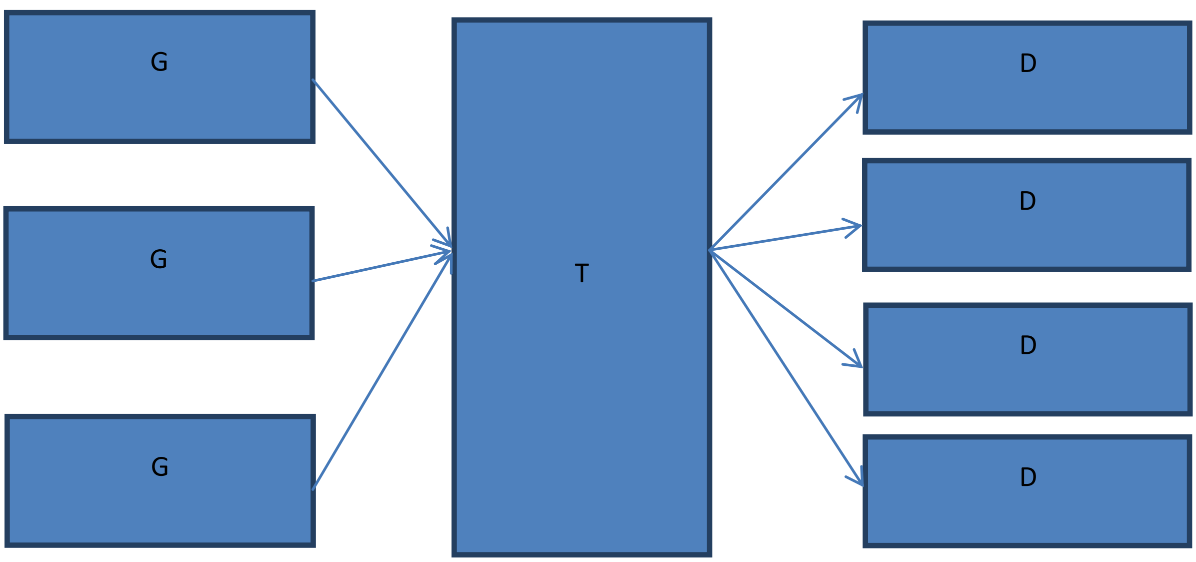


Figure 11: Multiple generation Companies and sharing one common transmission line and distributed by multiple retailers

Unlike regulated power system the deregulated power system would open up more competition amongst supply companies. The rate will be no longer regulated or controlled to be constant, but dependent on the rate charged by Power Supply Company based on their respective incurred costs.

2.1.4Congestion in a Deregulated Power System

Congestion actually occurs in both regulated and deregulated power systems [5] and it is defined to be some sort of an overload in the system especially at the transmission line [4], In other words the occurrence of congestion in the power system, it will be difficult to distribute the contracted power transactions to the buyer.

In this figure you can see scenario that shows a deregulated power system, with more than one supplier of generator supplying power to the multiple retailers. The retailers then would distribute to end of the users. These kinds of suppliers required to supply a different amount of power to their respective retailers.

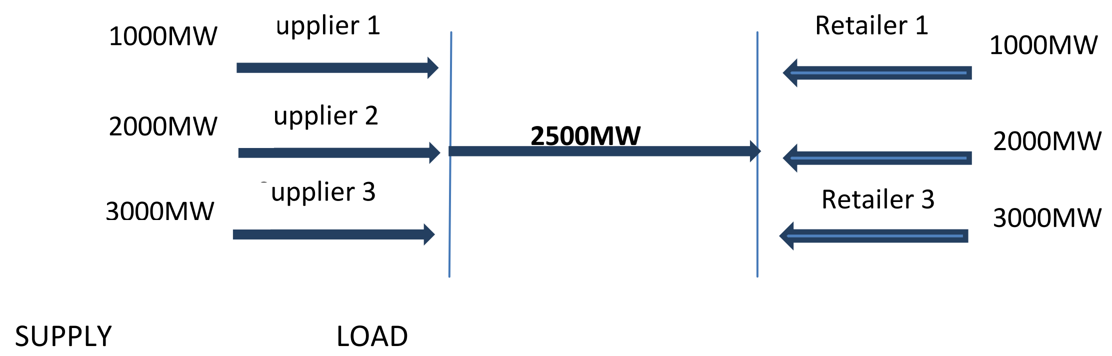


Figure 12: Representation of transmission constraints of 3 retailers with their respective suppliers across a transmission line

2.1.5 Transmission Impedance

Transmission lines are common carrier for electricity regardless where the initial source is transmitted from. Nevertheless, it helps to transport electricity on behalf of the utilities themselves. To be sure that there is no any specific party taking advantage of the situation, it is recommended that ultimately, the government oversees all proceedings and decisions made by commission.

CHAPTER 3 METHODOLOGY

3.1Research Methodology

Based on research that have been done and literature review, the one useful method to be used to manage congestion is STATCOM method. Nevertheless, it was finally decided that the application of the STATCOM method to improve the efficiency of transmission lines and managing and preventing congestion from occurring, was the best method to be taken.

3.2Project Activities

The following is a flowchart which shows the workflow which has been done for this project.

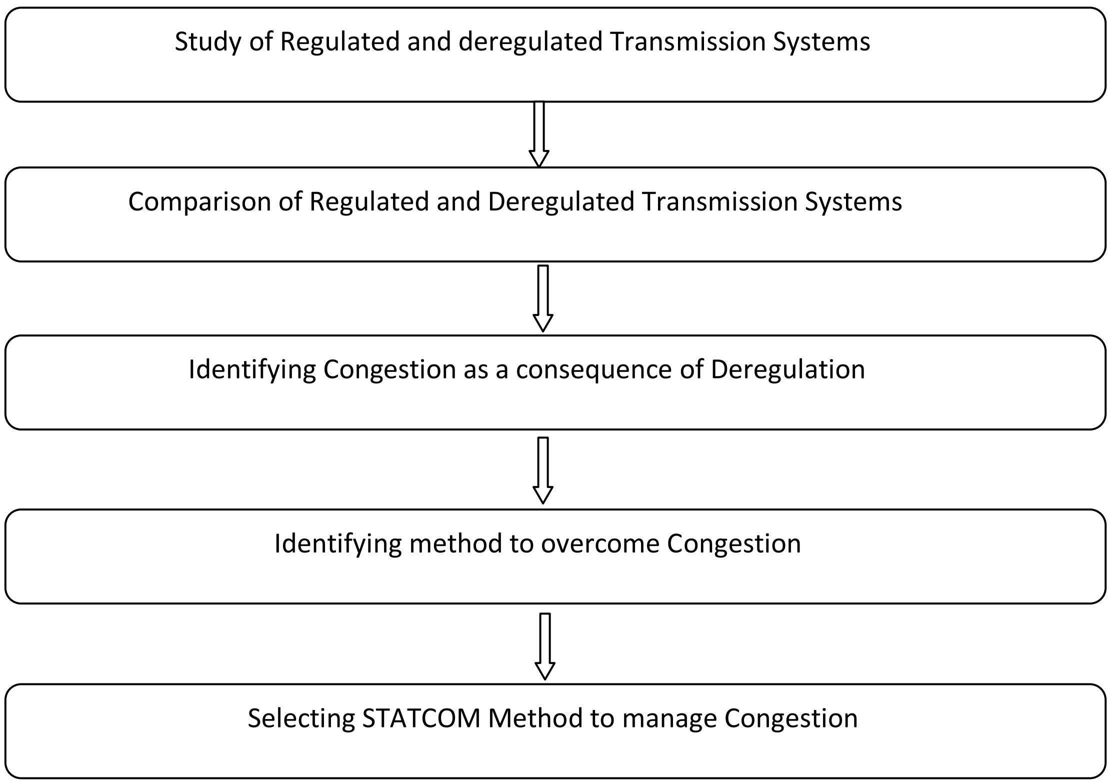


Figure 13: Project Activities

3.3Key Milestone Achieved and Gantt Chart

Through the project, the following are the key milestones which were achieved.

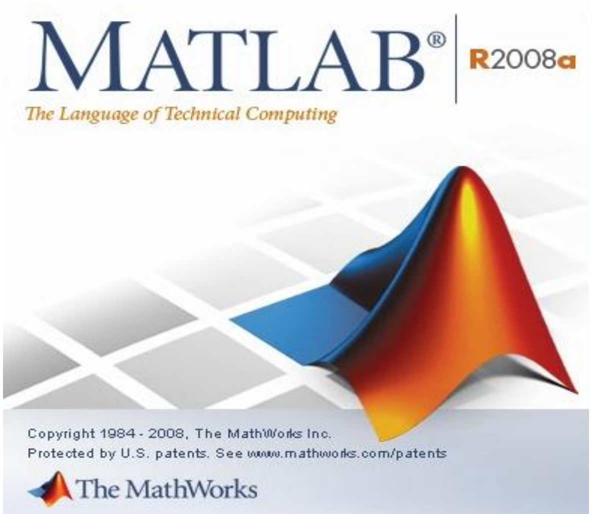
1. Identify an effective approach to manage congestion which is STATCOM.
2. Identify the essential and important components to be considered when performing STATCOM.
3. Modeling and calculating Optimal Power Flow analysis on selected bus system.
4. Modeling and Calculating STATCOM on selected bus system.

3.4Tools

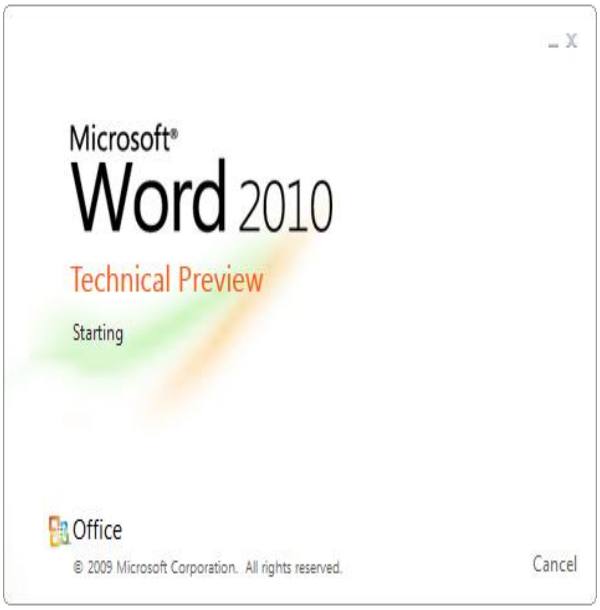
In order to accomplish this project, certain tools are essential. These tools comprises of a number of software applications.

3.4.1 Software

1. MATLAB 7.6



2 Microsoft Office Word 2010



No	Detail/Week	1	2	3	4	5	6		7	8	9	10	11	12	13	14
1	Selection of Project Topic: Analyzing the effect of polarization in imaging															
2	Preliminary Research Work: Research on literatures related to the topic															
3	Submission of Proposal Extended															
4	Project Work: Study on the research scope and method							Mid-Semester Break								
6	Submission of Progress Report															
4	Presentation of Proposal Defense															
8	Project work continues: Further investigation by getting the images samples of the skylight and human skin.															
9	Submission of Interim Report Final Draft															

CHAPTER 4 RESULTS AND DISCUSSION

4.1Discussion

4.1.1Deregulation versus Regulation

Based on the research for both regulated and deregulated power systems, it can be observed that deregulation is much more beneficial to end users in the long run. It is true that there are several complications which would arise from the implementation of deregulation. Nevertheless, with proper planning and implementation of improvements on the system, it is possible to effectively manage these complications especially congestion in transmission lines.

4.1.2Managing Congestions in Transmission Grids

As stated before, the implementation of deregulation would cause numerous new kinds of complications to arise. The introduction of 'unbundling' concept to enable multiple power suppliers to transmit electrical power over the transmission and distribution lines is one of the major contributors of congestions. With 'unbundling', the likelihood of congestion occurring is dramatically increased. This is especially based on the face that buy and sell transactions occurs before the actual transmission is done.

Therefore, to counter this effect, it is important that measures are taken to manage congestion effectively. Among the methods which can be used to manage congestion are as listed below.

1. Calculation Approach
2. Power Flow Analysis Approach
3. Transmission and Distribution System Improvement Approach

4.1.3 RESULTS

Results show here have been obtained with assistance of Matlab version 7.6Analysis was performed for a selected 24 bus systems.

This data was taken from the IEEE Reliability Test System-1996 for my Progress report to compare these results and result with STATCOM.

Assume that the STATCOM is operating in voltage control mode. This means that the STATCOM absorbs proper amount of reactive power from the power system to keep $|V_k|$ constant for all power system loading within reasonable range. The ohmic loss of the STATCOM is accounted by considering the real part of Y_{stat} in power flow calculations. The net active/reactive power injection at Bus k including the local load, before addition of the STATCM, is shown by P_k+jQ_k.

The power flow equations of the system with STATCOM connected to Bus k, can written as:

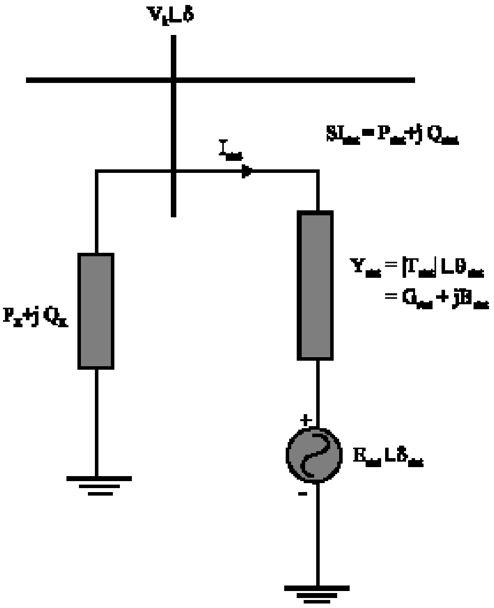
$$P_K = P_{stat} + \sum_{j=1}^{N} |V_k||V_j||Y_{kj}|\cos(\delta_k - \delta_j - \theta_{kj})$$

$$Q_K = Q_{stat} + \sum_{j=1}^{N} |V_k||V_j||Y_{kj}|\sin(\delta_k - \delta_j - \theta_{kj})$$

$$P_{stat} = G_{stat}|V_k|^2 - |V_k||E_{stat}||Y_{stat}|\cos(\delta_k - \delta_{stat} - \theta_{stat})$$

$$Q_{stat} = B_{stat}|V_k|^2 - |V_k||E_{stat}||Y_{stat}|\sin(\delta_k - \delta_{stat} - \theta_{stat})$$

where, $|E_{stat}|$, δ_{stat}, $|Y_{stat}|$ and θ_{stat} are shown in Fig



Bus No	**Bus** Code	**Voltage** magnitude	**Angle** Degree	**Load** MW	**Load** MVar	**Gen** MW	**Gen** MVar	**Gen** Qmin	**Gen** Qmax	**Injected** MVar
1	1	1,025	0	51	41	0	0	0	0	4
2	2	1,02	0	22	15	79	0	40	250	0
3	2	1,025	0	64	50	20	0	40	150	0
4	2	1,05	0	25	10	100	0	40	80	2
5	2	1,045	0	50	30	300	0	40	160	5
6	0	1	0	76	29	0	0	0	0	2
7	0	1	0	0	0	0	0	0	0	0
8	0	1	0	0	0	0	0	0	0	0
9	0	1	0	89	50	0	0	0	0	3
10	0	1	0	0	0	0	0	0	0	0
11	0	1	0	25	15	0	0	0	0	1,5
12	0	1	0	89	48	0	0	0	0	2
13	0	1	0	31	15	0	0	0	0	0
14	0	1	0	24	12	0	0	0	0	0
15	0	1	0	70	31	0	0	0	0	0,5
16	0	1	0	55	27	0	0	0	0	0
17	0	1	0	78	38	0	0	0	0	0
18	0	1	0	153	67	0	0	0	0	0
19	0	1	0	75	15	0	0	0	0	5
20	0	1	0	48	27	0	0	0	0	0
21	0	1	0	46	23	0	0	0	0	0
22	0	1	0	45	22	0	0	0	0	0
23	0	1	0	25	12	0	0	0	0	0
24	0	1	0	54	27	0	0	0	0	0

Table 1: Bus Load Data

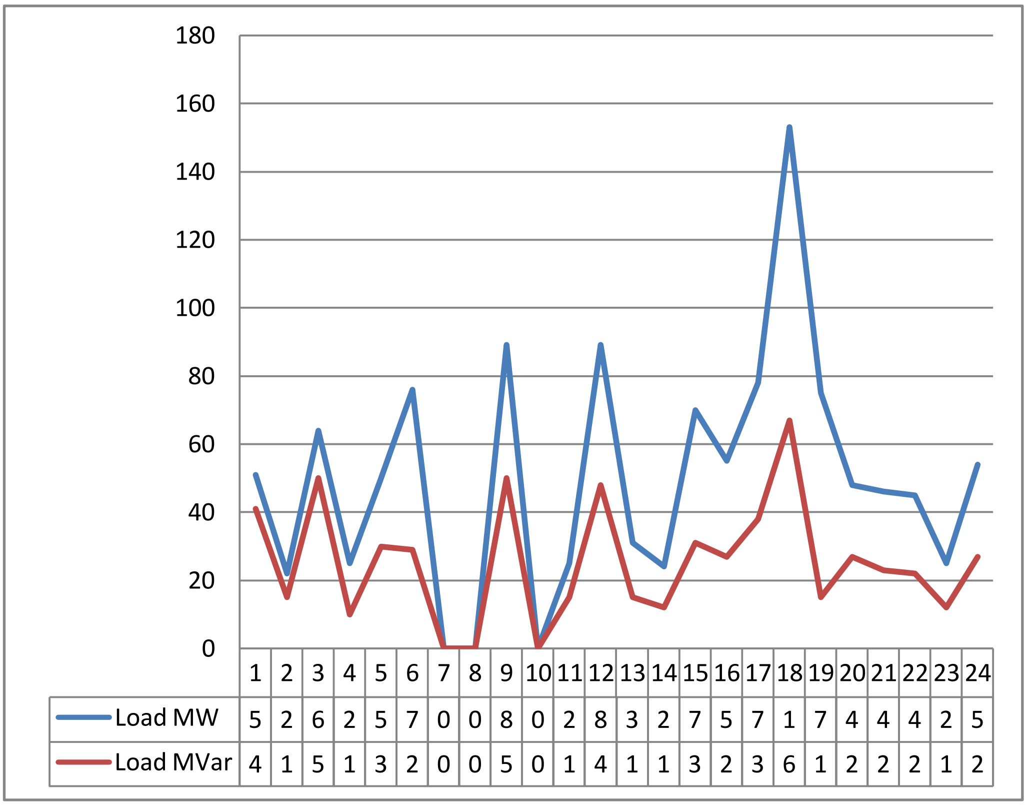


Fig 14 Result for 24 bus system without STATCOM

Next step is to get data from STATCOM. The following figure is showing the result from STATCOM. Based on this figure I can say that STATCOM is very useful method for my project.

Bus No	**Bus** Code	**Voltage** magnitude	**Angle** Degree	**Load** MW	**Load** MVar	**Gen** MW	**Gen** MVar	**Gen** Qmin	**Gen** Qmax	**Injected** MVar
1	1	1,025	0	108	22	0	0	0	0	4
2	2	1,02	0	97	20	79	0	40	250	0
3	2	1,025	0	180	37	20	0	40	150	0
4	2	1,05	0	74	15	100	0	40	80	2
5	2	1,045	0	71	14	300	0	40	160	5
6	0	1	0	136	28	0	0	0	0	2
7	0	1	0	125	25	0	0	0	0	0
8	0	1	0	171	35	0	0	0	0	0
9	0	1	0	175	36	0	0	0	0	3
10	0	1	0	195	40	0	0	0	0	0
11	0	1	0	25	15	0	0	0	0	1,5
12	0	1	0	89	48	0	0	0	0	2
13	0	1	0	265	54	0	0	0	0	0
14	0	1	0	194	39	0	0	0	0	0
15	0	1	0	317	64	0	0	0	0	0,5
16	0	1	0	100	20	0	0	0	0	0
17	0	1	0	78	38	0	0	0	0	0
18	0	1	0	333	68	0	0	0	0	0
19	0	1	0	181	37	0	0	0	0	5
20	0	1	0	126	26	0	0	0	0	0
21	0	1	0	46	23	0	0	0	0	0
22	0	1	0	45	22	0	0	0	0	0
23	0	1	0	25	12	0	0	0	0	0
24	0	1	0	54	27	0	0	0	0	0

Table 2: Bus Load Data

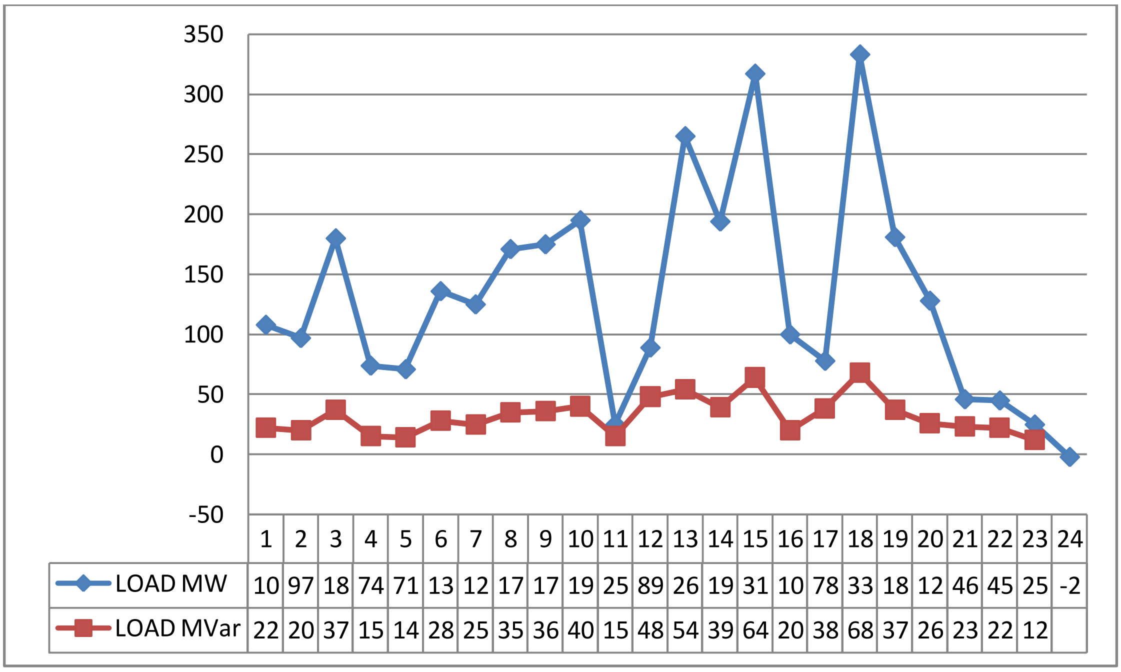


Fig 15 Result for 24 bus system with STATCOM

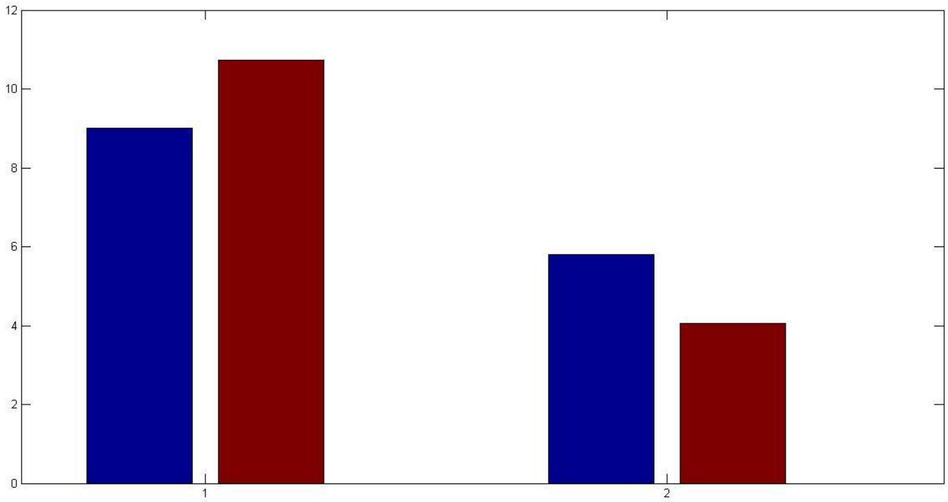


Fig 16 Compare Active and Reactive power

CHAPTER 5 CONCLUSION

5.1Conclusion

In view of the technological advancements and the increasing market demand of electricity, deregulated power system seems to be the more promising's method of power generation, transmission and distribution. As a conclusion of my proposal i would like to emphasize and underline advantages of my project. As i have discussed before, deregulated power system is promising method of power generation, transmission and distribution. And as i know my goals which are set according to users of my project, I will do my best to advance this technology.

5.2 Recommendation

The following is a list of recommendation on areas for improvement should further study be conducted in the area of Facts devices (STATCOM).

1. Identify long term benefits of using STATCOM to manage congestion
2. Produce a software which can calculate the STATCOM based on input parameters
3. Attempt to increase the accuracy and effectiveness on STATCOM on a larger bus system

5.3. REFERENCES

1. Hingorani, G. N., Gyugyi, L.: Understanding FACTS. Concepts and Technology of Flexible AC Transmission Systems. New York: IEEE Press, 2000.ISBN 0-7803-3455-8.

2. Anderson, P.M and A.A Fouad, 1997. Power System Control and Stability. Iowa State University Press, USA.

3.Seyed Abbas Taher, HadiBesharat, Transmission Congestion management by Determining Optimal location of FACTS Devices in Deregulated Power Systems, Department of Electrical Engineering, University of Kashan, Kashan, Iran, American Journal of Applied Sciences 5 (3), 2008

4LorrinPhillipson and H.Lee Willis, "Understanding electric utilities and deregulation," Marcel Dekker Inc., New York, 1998

5. Ly Fie Sugianto, Xue-Bing Lu, Demand Forecasting in the Deregulated market: A Bibliography Survey

6. Fred C. Schweppe, Michael C. Caraminis, Ruchard D. Tablors and Roger E. Boh, “Spot Pricing of Electricity”, Kluwer Academic Publishers, 1988.

7. Fred I. Denny and David e. Dismukes, “Power System Operations and electricity markets”, CRC Press LLC, Florida, 2002.

8. Loi Lei lai, “power System Restructuring and Deregulating: trading, performance and information technology” John Wiley & Sons LTD, England 2001.

9. John A. Casazza and George C. Loehr, “ The Evolution of Electric Power Transmission Under Deregulation Selected Readings”, The Institute of Electrical and Electronics Engineers, Inc., New Jersey, 2000

10. Hingorani, N.G., 2000. Role of FACTS in deregulated market.Proceedings of the IEEE Power Engineering Society Summer Meeting, Seattle, WA., USA.

11. Douglas J. Gotham and G.T. Heydt, “ Power Flow Control and Power Flow Studies For Systems With FACTS Devices,” IEEE Transactions on Power Systems, Vol.13, February 1998.

12. Anthony J. Pansini and Kenneth D. Smalling, “basics of Electric Power Transmission”, Pennwell Publishing Company, Tusla, 1998.

13. HadiSaadat, “Power System Analysis”, Second Edition, McGrwa Hill International, Singapore, 2004.

14. Keshi Reddy Saidi Reddy, narayana Prasad padhy, and R.N. Patel, “Congestion management in Deregulated Power System using FACTS Devices”, Institute of Technology Roorkee, Roorkee, Uttaranchal, India.

15. Enrique Acha, Caludio R. Fuerte-Esquivel, Hugo ambriz-Perez, and Cesar angeles-Camacho, “FACTS: Modeling and Simulation in Power Networks”, John Wiley and sons, Ltd, The Atrium, Souther Gate, Chichester, West Sussex.