Stability Improvement Of the (400kV) Iraqi Grid using the best FACTS Devices

Dr. Rashid H. Al-Rubayi
Electrical Engineering Department, University of Technology /Baghdad
Email: dr.rashid56@yahoo.com
Shaimaa Sh. Abd Alhalim
Electrical Engineering Department, University of Technology /Baghdad
Email: shaimaa.shukri@yahoo.com

Abstract

Electrical power system is become large and complicated so it subject to sudden changes in load levels. Stability is an important concept which determines the stable operation of power system. The modern trend is to employ by installing Flexible Alternating Current Transmission System (FACTS) devices in the system for effective utilization of transmission resources. The FACTS devices contribute to power flow improvement besides they extend their services in transient stability improvement as well, study and analyze the stability of system through rotor angle and voltage .The object of this work is to improve the stability of the Iraqi National Super Grid System (INSGS) by using optimal FACTS devices in different optimal locations under fault conditions. Two test systems are studied, the first system is IEEE or WSCC (9-bus bars), and the second system is the Iraqi (400 KV) electrical network 24-bus bars. The load flow program was implemented using Newton-Raphson method and the numerical solutions of non-linear differential equations are solved using Trapezoidal method. A comparison has been made between five type of FACTS (UPFC, SSSC, TCSC, SVC, STATCOM) at optimal location of the Iraqi grid and (9-bus bars) to get optimal FACTS devices by (voltage stability, rotor angle).The results obtained showed that the installation of Unified Power Flow Controller (UPFC) is optimal devices for an improvement of the stability by damping the voltage and rotor angle oscillations.

Keywords: FACTS, UPFC, SSSC, STATCOM, TCSC, SVC, PSAT.

تحسين إستقرارية منظومة الشبكة العراقية (400 KV)بأستعمال افضل جهاز من اجهزة ال (FACTS)

الخلاصة

يعتبر نظام القدره الكهربائيه من الانظمه الضخمه والمعقده لاحتوائها على عدد كبير من محطات التوليد وخطوط النقل وأجهزة السيطرة لذلك فانه يخضع الى تغيرات مفاجئه في مستويات الحمل ، حيث اصبح من الصعب جداً الحفاظ على نظام مستقرمع التغيرات التي يشهدها النظام, لذلك فمن المهم جداً تحسين أستقرارية منظومة القدرة

التطور الحديث في نظام القدره الكهربائيه هو عن طريق تنصيب اجهزة ال(FACTS) في اماكن مثاليه مختلفه حيث تساهم هذه الاجهزه الكهربائيه في تحسين تدفق القدره الكهربائيه الى جانب تحسين الاستقرارية

https://doi.org/10.30684/etj.33.7A.5
2412-0758/University of Technology-Iraq, Baghdad, Iraq

العابره عن طريق الفولتية وزاوية الدوار الغرض من هذا العمل هو تحسين استقرارية منظومة القدرة للشبكة العراقية عن طريق استخدام افضل جهاز للـ**(FACTS)** ونصب هذه الاجهزه في اماكن مثاليه مختلفة تحت ظرف الخطأ تم دراسة منظومتان, المنظومة الأولى هي(IEEE or WSCC) المكونة من (9) عقدة والمنظومة الثانية هي الشبكة الوطنية العراقية (400 KV) المكونه من (24) عقدة ,في المنظومتان تم اختبار عطل ثلاثي الأطوار عند مواقع مختلفة و حالات مختلفة (عطل وقتي, عطل دائم) . تم في هذا البحث دراسة وتكوين برنامج لسريان الحمل(Load Flow) باستخدام طريقة (Newton-Raphson) وتم حل المعادلات التفاضلية الغير خطية باستخدام الطرق العددية وذلك باستخدام طريقة (Trapezoidal) . البرامج المستخدمة في هذا البحث تم تطبيقها باستخدام برنامج MATLAB (7.11.0.584)اصدار(R2010b) المبني على اساس برامجيات (PSAT version 2.1.6)(2002-2010 ©). في هذا البحث تم المقارنه بين خمسة انواع من ال (FACTS) هي UPFC, SSSC, TCSC, SVC, (STATCOM) وتنصيبها في اماكن مثالية ومختلفه في الشبكه الوطنيه العراقية ومنظومة (9) عقدة للحصول على جهاز مثالي لتحسين القدره المنقوله والمقارنة تمت عن طريق الفولتية وزاوية الدوار.

INTRODUCTION

In recent years, with increasing demand for electricity the power transfer grows, the power systems are large and widely interconnected and probably more complex network comprising numerous generators, transmission lines, variety of loads and transformers it become difficulty to operate and the system can become less secure for riding through the major outages. The electric companies are looking for ways to maximize the utilization of their existing transmission systems[1].An increased demand of generation requires with increase power transfer through lines which is limited by the thermal, voltage and stability of lines. As the lines are operated near to their critical limits of power angles or voltage limits; any disturbance in such a system can result in instability like power system oscillation and may lead to generator outages and ultimately blackout.A solution is to develop new lines, but this requires a high system cost, complexity of protection system design, time requirements and environmental issues etc.These restrictions on the construction of new transmission lines have persuaded the power system designers to look for some alternative solutions to increase the power system stability and efficiently transmit power over the transmission lines. All these problems of environmental and regulatory concerns, and reliability and stability issues are mitigated by a new class of Power electronic devices named as Flexible AC Transmission Systems which brings us to the second option and that is implementation of FACTS devices[2] .Depending on technological features, the FACTS devices can be divided into two generations [3]:

❖ First generation: used thyristors with ignition controlled by gate(SCR),it work like passive elements using impedance or tap changer transformers controlled by thyristors such as :

1. Static Var Compensator (SVC).
2. Thyristor- Controlled Series Capacitor(TCSC).
3. Thyristor-Controlled Phase Shifter (TCPS).

❖ Second generation: semiconductors with ignition and extinction controlled by gate [gate-turn –off thyristor (GTO),integrated gate –commutated thyristor (IGCT) and insulated-gate bipolar transistor (IGBT) ,etc] it work like angle and module controlled voltage sources and without inertia, based in converters, employing electronic tension sources(three-phase inverters, auto-switched voltage sources, synchronous voltage sources, voltage source control) fast proportioned and controllable and static synchronous voltage and current sources such as:

1. Static Synchronous Compensator (STATCOM).

2. Static Synchronous Series Compensator (SSSC).
3. Unified Power Flow Controller (UPFC).
4. Interline Power Flow Controller (IPFC) .

Concept of Facts

The FACTS, are defined by IEEE as follows:
"Alternating current transmission systems incorporating power electronics based and other static controllers to enhance controllability and power transfer capability" [4].

Benefits From Facts Technolog

i. Control of power flow as ordered.
ii. Increase utilization of lowest cost generation.
iii. Power system stability enhancement.
iv. Increase the loading capability of lines to their thermal capabilities, including, short term and seasonal demands.
v. Provide secure tie-line connections to neighboring utilities and regions there by decreasing overall generation reserve requirements on both sides.
vi. Reduce reactive power flows, thus allowing the lines to carry more active power.

Typical Facts Devices

Static VAR Compensator(SVC)

The static VAR Compensator (SVC) is a shunt connected device whose consists of thyristors to achieve fast control of shunt-connected capacitors and reactors. From an operational point of view, the SVC behaves like a shunt-connected variable reactance, which either generates or absorbs reactive power in order to regulate the voltage magnitude at the point of connection to the AC network[5]

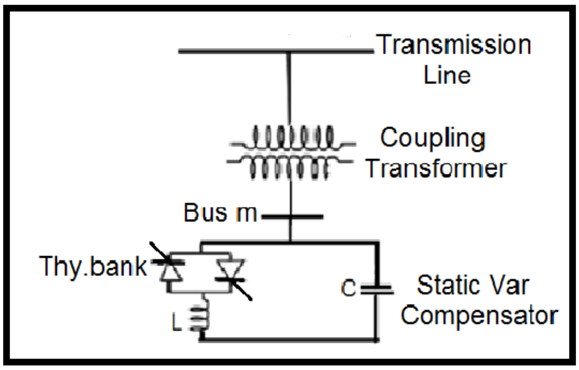


Figure (1) SVC connected to a transmission line

$I_{SVC} = jB_{SVC}V_m$ …(1)

The reactive power injected at bus m

$Q_{SVC} = Q_m = I_{svc}V_m = -V_m^2 B_{svc}$ …(2)

The equivalent susceptance of the BSVC, is given by

$$B_{svc} = \frac{1}{X_C X_L}\,\frac{X_L - X_C[2(\pi-\alpha_{SVC})+\sin 2\alpha_{SVC}]}{\pi} \quad \dots(3)$$

α_{SVC} is firing angle of the two thyristor $\frac{\pi}{2} \le \alpha \le \pi$

X_L=wL, $X_C = \frac{1}{wc}$

A Jacobian matrix that accounts for the SVC is given as:

$$\begin{bmatrix} \Delta Pm \\ \Delta Pk \\ \Delta Qm \\ \Delta Qk \end{bmatrix} = \begin{bmatrix} \frac{\partial Pm}{\partial \delta m} & \frac{\partial Pm}{\partial \delta_K} & 0 & V_K \frac{\partial Pm}{\partial V_K} \\ \frac{\partial Pm}{\partial \delta m} & \frac{\partial Pm}{\partial \delta_K} & 0 & V_K \frac{\partial Pm}{\partial V_K} \\ \frac{\partial Qm}{\partial \delta m} & \frac{\partial Qm}{\partial \delta k} & \frac{\partial Qm}{\partial \alpha_{SVC}} & V_K \frac{\partial Qm}{\partial V_K} \\ \frac{\partial Qk}{\partial \delta m} & \frac{\partial Qk}{\partial \delta m} & 0 & V_K \frac{\partial Qm}{\partial V_K} \end{bmatrix} \begin{bmatrix} \Delta \delta m \\ \Delta \delta k \\ \Delta \alpha_{SVC} \\ \frac{\Delta |V_K|}{|V_K|} \end{bmatrix} \quad (4)$$

Thyristor- Controlled Series Capacitor(TCSC)

Thyristor Controlled Series Capacitor (TCSC) is one of the important member of FACTS family that is increasingly applied with long transmission lines by the utilities in modern power system .It can have various roles in the operation and control of power system ,such as scheduling power flow; decreasing unsymmetrical component; reducing net loss; providing voltage support; limiting short-circuit current; mitigating sub-synchronous resonance (SSR); damping the power oscillation; and enhancing transient stability.The TCSC consists of three main components: capacitor bank C, by pass inductor L and bidirectional thyristors SCR1 and SCR2. The firing angles of the thyristors are controlled to adjust the TCSC reactance in accordance with a system control algorithm, normally in response to some system parameter variations. According to the variation of the thyristor firing angle or conduction angle, this process can be modeled as a fast switch between corresponding reactances offered to the power system [6].

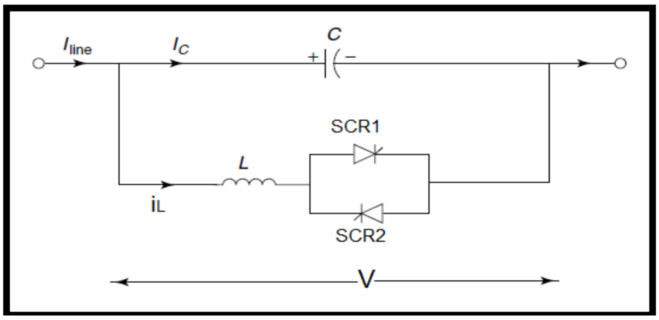


Figure (2) TCSC Configuration

$$c = \frac{dv}{dt} \quad ...(5)$$

$$v = L\frac{di_L}{dt} \quad ...(6)$$

where

v is the instantaneous voltage across the TCSC. The instantaneous current of the controlled transmission line is the sum of the instantaneous values of the currents in the capacitor banks and inductor respectively. Assuming that the total current passing through the TCSC is sinusoidal; the equivalent reactance at the fundamental frequency can be represented as a variable reactance X_{TCSC} The TCSC can be controlled to work either in the capacitive or in the inductive zones avoiding steady state resonance. There exists a steady-state relationship between the firing angle α and the reactance X_{TCSC} [6] . This relationship can be described by the following equation:

$$\mathrm{Xtcsc}(\alpha) = \mathrm{Xc} - \frac{\mathrm{Xc}^2}{(\mathrm{Xc}-\mathrm{Xp})}\,\frac{(\sigma+\sin\sigma)}{\pi} + \frac{4\mathrm{Xc}^2}{(\mathrm{Xc}-\mathrm{Xp})}\,\frac{\cos\left(\frac{\sigma}{2}\right)\left(\mathrm{K}\tan\left(\frac{k\sigma}{2}\right)-\tan\left(\frac{\sigma}{2}\right)\right))}{(\mathrm{Xc}-\mathrm{Xp})\,(\mathrm{K}^2-1)\,\pi} \quad \text{...(7)}$$

where,

Xc = Nominal reactance of the fixed capacitor C.

X p = Inductive reactance of inductor L connected in parallel with C.

$\sigma = 2(\pi - \alpha) =$ Conduction angle of TCSC controller.

$\mathrm{K} = \sqrt{\frac{\mathrm{Xc}}{\mathrm{Xp}}}$ = Compensation ratio.

the set of linearized power flow equation is:

$$\begin{bmatrix} \Delta P_i \\ \Delta P_j \\ \Delta Q_i \\ \Delta Q_j \\ \Delta P_{ij}^{X_{TCSC}} \end{bmatrix} = \begin{bmatrix} \frac{\partial P_i}{\partial \theta_j} & \frac{\partial P_i}{\partial V_j} V_i & \frac{\partial P_i}{\partial V_j} V_j & \frac{\partial P_i}{\partial V_j} V_j & \frac{\partial P_i}{\partial X_{TCSC}} X_{TCSC} \\ \frac{\partial P_j}{\partial \theta_i} & \frac{\partial P_j}{\partial \theta_j} & \frac{\partial P_j}{\partial V_i} V_i & \frac{\partial P_j}{\partial V_m} V_j & \frac{\partial P_m}{\partial X_{TCSC}} X_{TCSC} \\ \frac{\partial Q_i}{\partial \theta_i} & \frac{\partial Q_i}{\partial \theta_j} & \frac{\partial Q_i}{\partial V_i} V_i & \frac{\partial Q_i}{\partial V_j} V_j & \frac{\partial Q_i}{\partial X_{TCSC}} X_{TCSC} \\ \frac{\partial Q_j}{\partial \theta_i} & \frac{\partial Q_j}{\partial \theta_j} & \frac{\partial Q_j}{\partial V_i} V_i & \frac{\partial Q_j}{\partial V_j} V_j & \frac{\partial Q_i}{\partial X_{TCSC}} X_{TCSC} \\ \frac{\partial P_{ij}^{X_{TCSC}}}{\partial \theta_i} & \frac{\partial P_{ij}^{X_{TCSC}}}{\partial \theta_i} & \frac{\partial P_{ij}^{X_{TCSC}}}{\partial V_i} V_i & \frac{\partial P_{ij}^{X_{TCSC}}}{\partial V_j} V_j & \frac{\partial P_{ij}^{X_{TCSC}}}{\partial X_{TCSC}} X_{TCSC} \end{bmatrix} \begin{bmatrix} \Delta \theta_i \\ \Delta \theta_i \\ \frac{\Delta V_i}{V_i} \\ \frac{\Delta V_j}{V_j} \\ \frac{\Delta X_{TCSC}}{X_{TCSC}} \end{bmatrix} \quad \ldots(8)$$

Static Synchronous Compensator (STATCOM).

A static synchronous compensator (STATCOM) is a shunt connected FACTS device and is usually used to control the bus voltage magnitude by By controlling the bus voltage magnitude, the power flow through some lines can also be regulated[7].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. It regulates voltage at it terminal by changing the amount of reactive power in or out from the power

system. When system voltage is low, the STATCOM inject reactive power.When system voltage is high,it absorbs reactive power

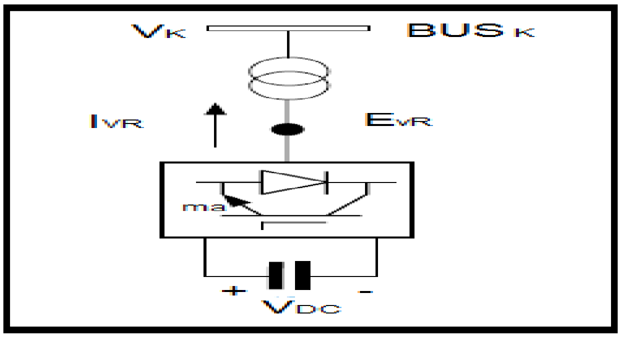


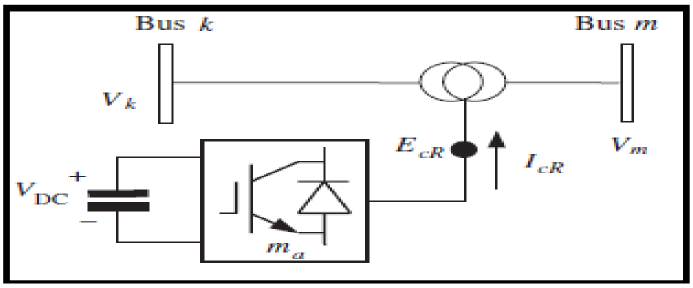
Figure (3) STATCOM Configuration

Using these power equations, the linearized STATCOM model is given below, where the voltage magnitude V_{VR} and phase angle δv_R are taken to be the state variables**:**

$$\begin{bmatrix} \Delta P_k \\ \Delta Q_k \\ \Delta P_{vR} \\ \Delta Q_{vR} \end{bmatrix} = \begin{bmatrix} \frac{\partial P_k}{\partial \theta_k} & \frac{\partial P_k}{\partial V_k} V_k & \frac{\partial P_k}{\partial \delta_{vR}} & \frac{\partial P_k}{\partial V_{vR}} V_{vR} \\ \frac{\partial Q_k}{\partial \theta_k} & \frac{\partial Q_k}{\partial V_k} V_k & \frac{\partial Q_k}{\partial \delta_{vR}} & \frac{\partial Q_k}{\partial V_{vR}} V_{vR} \\ \frac{\partial P_{vR}}{\partial \theta_k} & \frac{\partial P_{vR}}{\partial V_k} V_k & \frac{\partial P_{vR}}{\partial \delta_{vR}} & \frac{\partial P_{vR}}{\partial V_{vR}} V_{vR} \\ \frac{\partial Q_{vR}}{\partial \theta_k} & \frac{\partial Q_{vR}}{\partial V_k} V_k & \frac{\partial Q_{vR}}{\partial \delta_{vR}} & \frac{\partial Q_{vR}}{\partial V_{vR}} V_{vR} \end{bmatrix} \begin{bmatrix} \Delta \theta_k \\ \frac{\Delta V_k}{V_k} \\ \Delta \delta_{vR} \\ \frac{\Delta V_{vR}}{V_{vR}} \end{bmatrix} . \quad ...(9)$$

Static Synchronous Series Compensator (SSSC)

The Static Synchronous Series Compensator (SSSC) is a member of FACTSfamily which is connected in series with a power system [8].It consists of a solid state voltage source converter which generates a controllable alternating current voltage at fundamental frequency .When the injected voltage is kept in quadrature with the line current ,it can emulate as inductive or capacitive reactance so as to influence the power flow through the transmission line .While the primary purpose of a SSSC is to control power flow in steady state , it can also improve transient stability of a power system**[**6].The SSSC emerges as a potentially more beneficial controller than the TCSC because of its ability to not only modulate the line reactance but also the line resistance in consonance with the power swings, there by imparting enhanced damping to the generators that contribute to the power oscillations[8]. The system of equations is as follows:



Figure(4) SSSC Configration

$$\begin{bmatrix} \Delta P_K \\ \Delta P_m \\ \Delta Q_K \\ \Delta Q_m \\ \Delta P_{mk} \\ \Delta Q_{mk} \end{bmatrix} = \begin{bmatrix} \frac{\partial P_k}{\partial \theta_k} & \frac{\partial P_k}{\partial \theta_m} & \frac{\partial P_k}{\partial V_k} V_k & \frac{\partial P_k}{\partial Vm} Vm & \frac{\partial P_k}{\partial \delta_{cR}} & \frac{\partial Pk}{\partial VcR} VcR \\ \frac{\partial P_m}{\partial \theta_k} & \frac{\partial P_m}{\partial \theta_m} & \frac{\partial P_m}{\partial V_k} V_k & \frac{\partial P_m}{\partial Vm} Vm & \frac{\partial P_m}{\partial \delta_{cR}} & \frac{\partial Pm}{\partial VcR} VcR \\ \frac{\partial Q_k}{\partial \theta_k} & \frac{\partial Q_k}{\partial \theta_m} & \frac{\partial Q_k}{\partial V_k} V_k & \frac{\partial Q_k}{\partial Vm} Vm & \frac{\partial Q_k}{\partial \delta_{cR}} & \frac{\partial Q_k}{\partial VcR} VcR \\ \frac{\partial Q_m}{\partial \theta_k} & \frac{\partial Q_m}{\partial \theta_m} & \frac{\partial Q_m}{\partial V_k} V_k & \frac{\partial Q_m}{\partial Vm} Vm & \frac{\partial Q_m}{\partial \delta_{cR}} & \frac{\partial Qm}{\partial VcR} VcR \\ \frac{\partial P_{mk}}{\partial \theta_k} & \frac{\partial P_{mk}}{\partial \theta_m} & \frac{\partial P_{mk}}{\partial V_k} V_k & \frac{\partial P_{mk}}{\partial Vm} Vm & \frac{\partial P_{mk}}{\partial \delta_{cR}} & \frac{\partial Pmk}{\partial VcR} VcR \\ \frac{\partial Q_{mk}}{\partial \theta_k} & \frac{\partial Q_{mk}}{\partial \theta_m} & \frac{\partial Q_{mk}}{\partial V_k} V_k & \frac{\partial Q_{mk}}{\partial Vm} Vm & \frac{\partial Q_{mk}}{\partial \delta_{cR}} & \frac{\partial Qmk}{\partial VcR} VcR \end{bmatrix} \begin{bmatrix} \Delta \theta_k \\ \Delta \theta_m \\ \frac{\Delta V_K}{V_K} \\ \frac{\Delta V_m}{V_m} \\ \Delta \delta_{CR} \\ \frac{\Delta V_{CR}}{V_{CR}} \end{bmatrix} \quad \ldots(10)$$

Unified Power Flow Control (UPFC)

The UPFC is a member of the second generation FACTS family devices was introduced and defined first by Gyugyi in 1991, with very attractive features, which enables independent control of active and reactive power besides improving reliability and quality of the supply[9].UPFC is the most versatile one that can be used to improve steady state stability, dynamic stability and transient stability. It can independently control many parameters since it is the combination of (STATCOM) and (SSSC),these devices offer an alternative mean to mitigate power system oscillations and acts as a shunt compensating and a phase shifting device simultaneously. The UPFC can improve stability of single machine infinite bus system and multi machine system

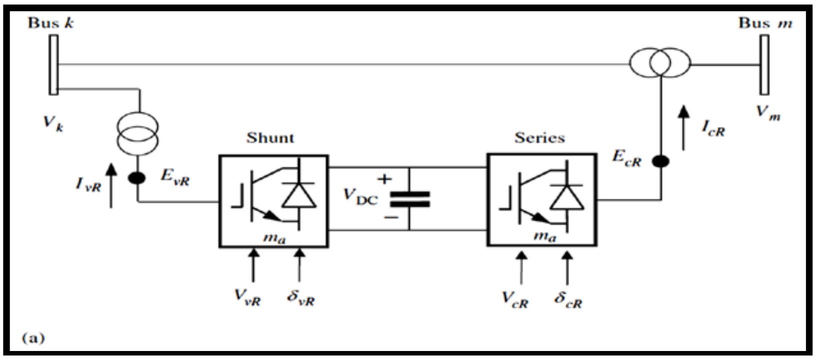


Figure (5) UPFC Configration

The UPFC is capable of both supplying and absorbing real and reactive power and it consists of two ac and dc converters .One of the two converters is connected in series with the transmission line through a transformer.The linearized system of equation is as follows:

$$\begin{bmatrix} \Delta P_k \\ \Delta P_m \\ \Delta Q_k \\ \Delta Q_m \\ \Delta P_{mk} \\ \Delta Q_{mk} \\ \Delta P_{bb} \end{bmatrix} = \begin{bmatrix} \frac{\partial P_k}{\partial \theta_k} & \frac{\partial P_k}{\partial \theta_m} & \frac{\partial P_k}{\partial V_{vR}} V_{vR} & \frac{\partial P_k}{\partial V_m} V_m & \frac{\partial P_k}{\partial \delta_{cR}} & \frac{\partial P_k}{\partial V_{cR}} V_{cR} & \frac{\partial P_k}{\partial \delta_{vR}} \\ \frac{\partial P_m}{\partial \theta_k} & \frac{\partial P_m}{\partial \theta_m} & 0 & \frac{\partial P_m}{\partial V_m} V_m & \frac{\partial P_m}{\partial \delta_{cR}} & \frac{\partial P_m}{\partial V_{cR}} V_{cR} & 0 \\ \frac{\partial Q_k}{\partial \theta_k} & \frac{\partial Q_k}{\partial \theta_m} & \frac{\partial Q_k}{\partial V_{vR}} V_{vR} & \frac{\partial Q_k}{\partial V_m} V_m & \frac{\partial Q_k}{\partial \delta_{cR}} & \frac{\partial Q_k}{\partial V_{cR}} V_{cR} & \frac{\partial Q_k}{\partial \delta_{vR}} \\ \frac{\partial Q_m}{\partial \theta_k} & \frac{\partial Q_m}{\partial \theta_m} & 0 & \frac{\partial Q_m}{\partial V_m} V_m & \frac{\partial Q_m}{\partial \delta_{cR}} & \frac{\partial Q_m}{\partial V_{cR}} V_{cR} & 0 \\ \frac{\partial P_{mk}}{\partial \theta_k} & \frac{\partial P_{mk}}{\partial \theta_m} & 0 & \frac{\partial P_{mk}}{\partial V_m} V_m & \frac{\partial P_{mk}}{\partial \delta_{cR}} & \frac{\partial P_{mk}}{\partial V_{cR}} V_{cR} & 0 \\ \frac{\partial Q_{mk}}{\partial \theta_k} & \frac{\partial Q_{mk}}{\partial \theta_m} & 0 & \frac{\partial Q_{mk}}{\partial V_m} V_m & \frac{\partial Q_{mk}}{\partial \delta_{cR}} & \frac{\partial Q_{mk}}{\partial V_{cR}} V_{cR} & 0 \\ \frac{\partial P_{bb}}{\partial \theta_k} & \frac{\partial P_{bb}}{\partial \theta_m} & \frac{\partial P_{bb}}{\partial V_{vR}} V_{vR} & \frac{\partial P_{bb}}{\partial V_m} V_m & \frac{\partial P_{bb}}{\partial \delta_{cR}} & \frac{\partial P_{bb}}{\partial V_{cR}} V_{cR} & \frac{\partial P_{bb}}{\partial \delta_{vR}} \end{bmatrix} \begin{bmatrix} \Delta \theta_K \\ \Delta \theta_m \\ \frac{\Delta V_{VR}}{V_{VR}} \\ \frac{\Delta V_m}{V_m} \\ \Delta \delta_{CR} \\ \frac{\Delta V_{CR}}{V_{CR}} \\ \Delta \delta_{VR} \end{bmatrix} \quad \ldots (11)$$

Power system stability

Power system stability may be broadly defined as that property of power system that enables it to remain in a state of operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to a disturbance[10].

Practically , power system stability can be classify into two category:

1-Voltage Stability

2-Rotor Angle Stability.

Results and Discussion

In this work, it is assumed that a three phase to ground fault occurs near at the bus bars with (Z_f = j0.001) for test system (IEEE or WSCC) and for the Iraqi electrical network (400 KV), the voltage magnitude should not be dropped below 0.9 per unit (the permissible reduction in voltage is ($\pm$10%)at the high voltage and extra high voltage networks),in each tests system PAST has been used to find the result load flow with and without all type of FACTS then it has been used minimum total losses to find optimal location

Fault Conditions :

- Condition 1. Permanent Fault.
- Condition 2. Temporary Fault.

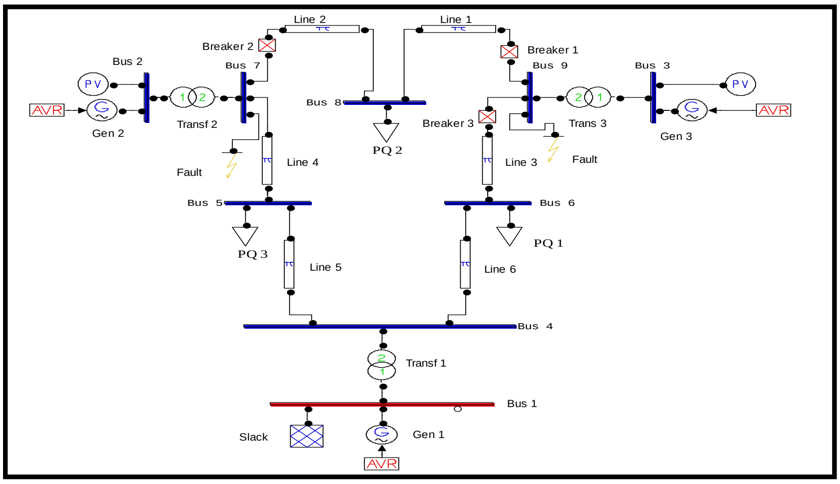


Figure (6) IEEE 3-machine, 9-bus system

Table (1) Real power loss with and without UPFC

	Line No.	Location of UPFC	Total Generation System [p.u]		Total Load System [p.u]		Total Real power Losses System [p.u]	Total Reactive Power Losses System [p.u]
		Bus number.	Real	Reactive	Real	Reactive		
System with UPFC	1	8-9	3.1962	0.46093	3.15	1.15	0.04615	-0.68907
	2	7-8	3.192	0.38348	3.15	1.15	0.04195	-0.76652
	3	6-9	3.1811	0.60169	3.15	1.15	0.0311	-0.54831
	4	**5-7**	**3.1709**	**0.52319**	**3.15**	**1.15**	**0.02094**	**-0.62681**
	5	4-5	3.1938	0.41719	3.15	1.15	0.04382	-0.73281
	6	4-6	3.1949	0.40327	3.15	1.15	0.04489	-0.74673
Without UPFC			3.1964	0.2284	3.15	1.15	0.04641	-0.9216

Table (2) Real power loss with and without SVC

	Location of SVC	Total Generation System [p.u]		Total Load System [p.u]		Total Real Power Losses System [p.u]	Total Reactive Power Losses System [p.u]
	Bus number	Real	Reactive	Real	Reactive		
System with SVC	5	3.1686	0.48146	3.15	1.15	0.0185	-0.66854
	6	3.1948	0.39987	3.15	1.15	0.04484	-0.75013
	7	3.1917	0.37122	3.15	1.15	0.0417	-0.77878
	8	3.1961	0.4574	3.15	1.15	0.04609	-0.6926
	9	3.1792	0.57978	3.15	1.15	0.02924	-0.57022
Without SVC		3.1964	0.2284	3.15	1.15	0.04641	-0.9216

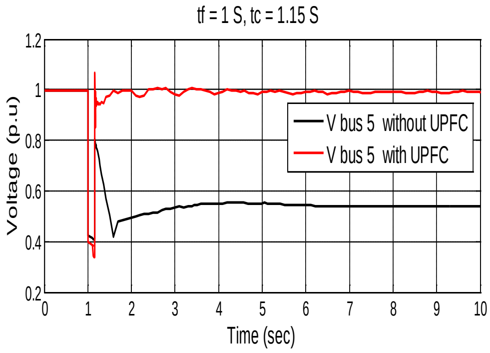
Table (3) Real power loss with and without SSSC

	Line No	Location of SSSC	Total Generation System [p.u]		Total Load System [p.u]		Total Real Power Losses System [p.u]	Total Reacive Power Losses System [p.u]
		Bus number	Real	Reactive	Real	Reactive		
System with SSSC	1	8-9	3.1961	0.4574	3.15	1.15	0.04609	-0.6926
	2	7-8	3.1917	0.37122	3.15	1.15	0.0417	-0.77878
	3	6-9	3.1792	0.57978	3.15	1.15	0.02924	-0.57022
	4	**5-7**	**3.1686**	**0.48146**	**3.15**	**1.15**	**0.01855**	**-0.66854**
	5	4-5	3.1935	0.40811	3.15	1.15	0.04352	-0.74189
	6	4-6	3.1948	0.39987	3.15	1.15	0.04484	-0.75013
Without SSSC			3.1964	0.2284	3.15	1.15	0.04641	-0.9216

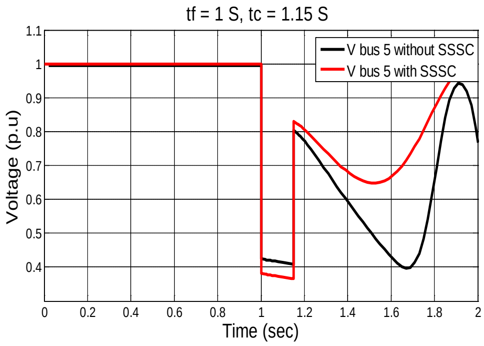
From result of the optimal location it is observed that line 4 between bus 7-5 is more sensitive towards system security.Therefore it is more suitable location for type of FACTS to improve power system security and stability.After the optimal location of FACTS device has been selected, the system stability is tested for the two conditions, by applying three phase to ground fault at bus 7,9 because two buses are maximum loading therefore most critical buses.

Fault near bus 7

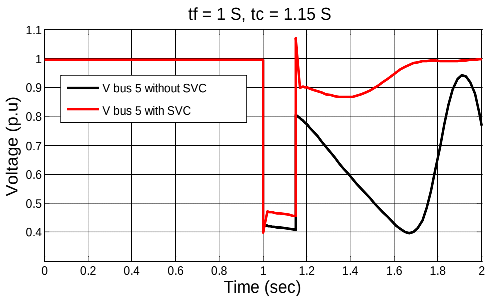
(7a)



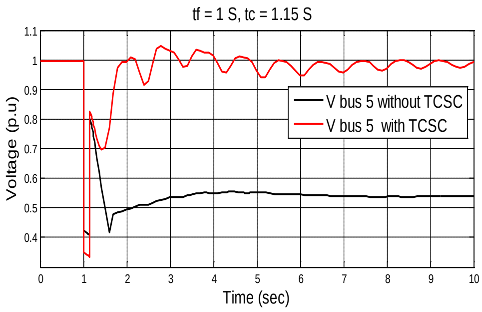
(7b)



(7c)



(7d)



(7e)

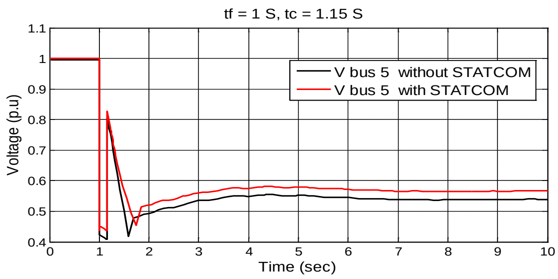


Figure (7a,b,c,d,e)Voltage with and without UPFC,SSSC,STATCOM ,SVC,TCSC

Table (4) critical clearing angle and critical clearing time

	Critical Clearing Time TC (sec)	Critical Clearing Angle $\boldsymbol{\delta}$(deg)
Without FACTS Device	1.15	69.352
With UPFC	1.46	93.37
With SSSC	1.195	90.67
With TCSC	1.19	89.08
With SVC	1.23	85.086
With STATCOM	1.22	84.819

From table (4) it is observed that critical clearing time and angle of fault is given for with and without FACTS device.When three phase to ground fault is obtaind near bus 7 and all FACTS type is placed at optimal location the critical clearing time and angle of the fault is increased with all type of FACTS.The result show that UPFC is more effective when compare to other FACTS. The conclusion from curves and tables show the UPFC device effects on the damping of the rotor angle oscillations ,it protect the system until fault is cleared by increased duration time of circuit breaker more than its design**.**

Implementation of Iraqi (400 KV) Electrical Network

The transmission level in the Iraqi electrical network consists of 400 kV network, and the 132 kV network is connected to it. This work is limited to the 400 kV network with its buses and transmission lines.The network under consideration consists of 24 buses and 39 transmission lines; with total length of 3750 Km. The loads are represented by a static admittance and the lines by the nominal π sections. All network data are expressed in per-unit referred to a common base power of 100 MVA and common base voltage of 400 KV.The Iraqi grid (400 KV) has 24 buses, 11 generation buses and 19 load buses. In the load flow solution, Musayab station (MUSP) is selected as a slack bus

The same procedure for 9 bus test system first it must found optimal location for all FACTS depend on the minimum total real power losses and calculated by change the location of all types of FACTS to obtained the best location to analyze the reduction in losses.From results of optimal location it is observed that (line 3 between bus 1-22 ,line 11between bus 3-13,line 13 between bus 5-15,line 20 between bus 9-11 and line 36 between bus 20-17) are more sensitive towards system security therefore these are more suitable locations to connecting types of FACTS from result of optimal location, the optimal location of FACTS are:

i. UPFC,SSSC,TCSC at lines (3,11,13,20,36)
ii. SVC near bus (5,11,13,20,22) and STATCOM near bus(1,3,5,11,20)

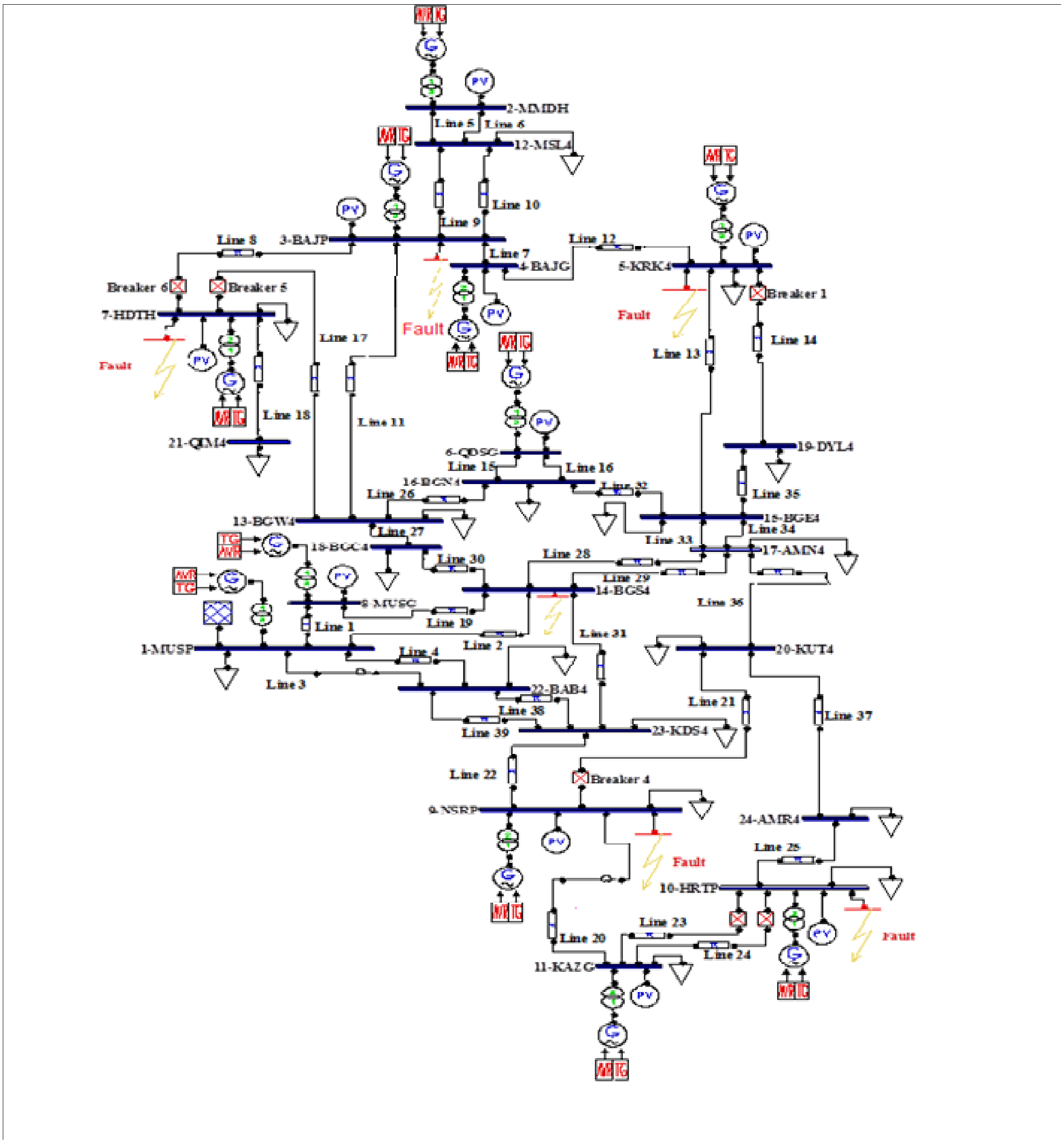


Figure (8) Iraqi (400kv) National Super Grid System(Insgs)

Table (5) Real power losses with and without UPFC

	Line No	Location Of UPFC	Total Generation System [p.u]		Total Load System [p.u]		Total Real Losses System p.u	Total Reactive Losses System p.u
		Bus number	Real	Reactive	Real	Reactive		
System with UPFC	1	1-8	58.481	21.9332	58	28.5138	0.48095	-6.5806
	2	1-14	58.4577	22.0453	58	28.5138	0.47774	-6.4685
	3	1-22	58.4657	21.9898	58	28.5138	0.45166	-6.524
	4	1-22	58.4657	21.9898	58	28.5138	0.46566	-6.463
	5	2-12	58.4579	22.0508	58	28.5138	0.49793	-6.463
	6	2-12	58.4579	22.0508	58	28.5138	0.45793	-6.463
	7	3-4	58.4808	21.9181	58	28.5138	0.4808	-6.5957
	8	3-7	58.4493	22.3226	58	28.5138	0.49432	-6.1912
	9	3-12	58.4797	22.4697	58	28.5138	0.47965	-6.0441
	10	3-12	58.4797	22.4697	58	28.5138	0.47965	-6.0441
	11	3-13	58.4133	22.429	58	28.5138	0.41333	-6.0848
	12	4-5	58.4627	22.1237	58	28.5138	0.46272	-6.3902
	13	5-15	58.4513	22.5577	58	28.5138	0.45129	-5.9561
	14	5-19	58.4546	22.4431	58	28.5138	0.45458	-6.0707
	15	6-16	58.4773	21.9217	58	28.5138	0.47731	-6.5921
	16	6-16	58.4773	21.9217	58	28.5138	0.47731	-6.5921
	17	7-13	58.4697	22.5743	58	28.5138	0.4697	-5.9395
	18	7-21	58.4775	22.2983	58	28.5138	0.47746	-6.2155
	19	8-14	58.456	22.0295	58	28.5138	0.45603	-6.4843
	20	9-11	58.4149	22.3283	58	28.5138	0.41489	-6.1855
	21	9-20	58.4268	22.3348	58	28.5138	0.46675	-6.179
	22	9-23	58.4417	22.3498	58	28.5138	0.48165	-6.164
	23	10-11	58.4806	22.0797	58	28.5138	0.48063	-6.4341
	24	10-11	58.4806	22.0797	58	28.5138	0.48063	-6.4341
	25	10-24	58.4645	22.2456	58	28.5138	0.46444	-6.2682
	26	13-16	58.4786	22.0289	58	28.5138	0.47855	-6.4849
	27	13-18	58.4808	22.0019	58	28.5138	0.48078	-6.5119
	28	14-17	58.4747	22.024	58	28.5138	0.47464	-6.4898
	29	14-17	58.4747	22.024	58	28.5138	0.47464	-6.4898
	30	14-18	58.4746	22.0397	58	28.5138	0.47458	-6.4742
	31	14-23	58.4767	22.3433	58	28.5138	0.47674	-6.1705
	32	15-16	58.478	21.936	58	28.5138	0.47797	-6.5778
	33	15-17	58.4803	21.9775	58	28.5138	0.48025	-6.5364
	34	15-17	58.4803	21.9775	58	28.5138	0.48025	-6.5364
	35	15-19	58.4796	22.0327	58	28.5138	0.47961	-6.4811
	36	17-20	58.4349	21.8401	58	28.5138	0.43492	-6.6737
	37	20-24	58.4751	22.5645	58	28.5138	0.4751	-5.9493
	38	22-23	58.467	22.2074	58	28.5138	0.46701	-6.3064
	39	22-23	58.467	22.2074	58	28.5138	0.46701	-6.3064
Without UPFC			58.481	21.9154	58	28.5138	0.48095	-6.5984

Table (6) Real power losses with and without SSSC

	Line No.	Location of SSSC	Total Generation System [p.u]		Total Load System [p.u]		Total Real Losses System p.u	Total Reactive Losses System p.u
		Bus number	Real	Reactive	Real	Reactive		
System with SSSC	1	1-8	58.481	21.9332	58	28.5138	0.48095	-6.5806
	2	1-14	58.4567	22.0626	58	28.5138	0.45978	-6.4512
	3	1-22	58.4671	21.0039	58	28.5138	0.41709	-65099
	4	1-22	58.4671	21.0039	58	28.5138	0.46709	-6.5099
	5	2-12	58.451	22.00711	58	28.5138	0.45999	-6.4427
	6	2-12	58.451	22.00711	58	28.5138	0.45999	-6.4427
	7	3-4	58.4808	21.9181	58	28.5138	0.4808	-6.5956
	8	3-7	58.4509	22.3507	58	28.5138	0.4509	-6.1631
	9	3-12	58.4796	22.4408	58	28.5138	0.47987	-6.043
	10	3-12	58.4796	22.4408	58	28.5138	0.47987	-6.043
	11	3-13	58.4209	22.425	58	28.5138	0.42092	-6.0213
	12	4-5	58.4634	22.1403	58	28.5138	0.46335	-6.3735
	13	5-15	58.4549	22.5858	58	28.5138	0.42493	-5.928
	14	5-19	58.4777	21.9261	58	28.5138	0.4777	-6.5877
	15	6-16	58.4777	21.9261	58	28.5138	0.4777	-6.5877
	16	6-16	58.471	21.5852	58	28.5138	0.47095	-5.9286
	17	7-13	58.4775	22.3015	58	28.5138	0.47746	-6.2124
	18	7-21	58.458	22.0481	58	28.5138	0.45795	-6.4657
	19	8-14	58.4178	22.3877	58	28.5138	0.44777	-6.1261
	20	9-11	58.4301	22.3909	58	28.5138	0.43012	-6.1229
	21	9-20	58.4427	22.3875	58	28.5138	0.44265	-6.1263
	22	9-23	58.4806	22.0792	58	28.5138	0.48063	-6.4346
	23	10-11	58.4806	22.0792	58	28.5138	0.48063	-6.4346
	24	10-11	58.4651	22.2671	58	28.5138	0.46509	-6.2467
	25	10-24	58.479	22.0344	58	28.5138	0.47897	-6.4794
	26	13-16	58.479	22.0344	58	28.5138	0.47897	-6.4794
	27	13-18	58.4808	22.0024	58	28.5138	0.48077	-6.5115
	28	14-17	58.4751	22.0284	58	28.5138	0.47511	-6.4854
	29	14-17	58.4751	22.0284	58	28.5138	0.47511	-6.854
	30	14-18	58.4747	22.0448	58	28.5138	0.4747	-6.4691
	31	14-23	58.4774	22.3482	58	28.5138	0.47739	-6.1656
	32	15-16	58.4781	21.9391	58	28.5138	0.47808	-6.5747
	33	15-17	58.4803	21.9774	58	28.5138	0.48025	-6.5364
	34	15-17	58.4803	21.9774	58	28.5138	0.48025	-6.5364
	35	15-19	58.4797	22.0342	58	28.5138	0.47964	-6.4796
	36	17-20	58.4409	21.8813	58	28.5138	0.44088	-6.6325
	37	20-24	58.4757	22.5755	58	28.5138	0.47568	-5.9383
	38	22-23	58.4686	22.2206	58	28.5138	0.46859	-6.2932
	39	22-23	58.4686	22.2206	58	28.5138	0.4685	-6.2932
without SSSC			58.481	21.9154	58	28.5138	0.48095	-6.5984

Table (7) Real power losses with and without TCSC

	Line No.	Location of TCSC	Total Generation system[p.u]		Total Load system [p.u]		Total Real Losses System p.u	Total Reactive Losses System p.u
		Bus number	Real	Reactive	Real	Reactive		
System with TCSC	1	1-8	58.4992	22.419	58	28.5138	0.49924	-6.0949
	2	1-14	58.4598	22.3713	58	28.5138	0.45975	-6.1425
	3	1-22	58.4811	22.4076	58	28.5138	0.42108	-6.1062
	4	1-22	58.4811	22.4076	58	28.5138	0.48108	-6.1062
	5	2-12	58.4666	22.4047	58	28.5138	0.46655	-6.1091
	6	2-12	58.4666	22.4047	58	28.5138	0.46655	-6.1091
	7	3-4	58.4991	21.4034	58	28.5138	0.49913	-6.1101
	8	3-7	58.4618	22.6557	58	28.5138	0.4618	-5.8581
	9	3-12	58.4962	22.9453	58	28.5138	0.4685	-5.5685
	10	3-12	58.4962	22.9453	58	28.5138	0.4962	-5.5685
	11	3-13	58.3885	22.4423	58	28.5138	0.3885	-6.0715
	12	4-5	58.4789	22.5252	58	28.5138	0.47886	-5.9886
	13	5-15	58.4472	22.8241	58	28.5138	0.44714	-5.6897
	14	5-19	58.4598	22.7569	58	28.5138	0.45976	-5.75976
	15	6-16	58.4935	22.3784	58	28.5138	0.49351	-6.1355
	16	6-16	58.4935	22.3784	58	28.5138	0.49351	-6.1355
	17	7-13	58.4799	22.9813	58	28.5138	0.47991	-5.5325
	18	7-21	58.4958	22.7702	58	28.5138	0.49579	-5.7436
	19	8-14	58.4602	22.3556	58	28.5138	0.46014	-6.1582
	20	9-11	58.4232	22.5132	58	28.5138	0.42321	-6.0006
	21	9-20	58.4336	22.5278	58	28.5138	0.45359	-5.986
	22	9-23	58.4554	22.6417	58	28.5138	0.45544	-5.8721
	23	10-11	58.499	22.5726	58	28.5138	0.49896	-5.9412
	24	10-11	58.499	22.5726	58	28.5138	0.49896	-5.9412
	25	10-24	58.4807	22.6284	58	28.5138	0.48065	-5.8854
	26	13-16	58.4944	22.4806	58	28.5138	0.49444	-6.0332
	27	13-18	58.4992	22.4855	58	28.5138	0.4992	-6.0283
	28	14-17	58.4911	22.4787	58	28.5138	0.4911	-6.0351
	29	14-17	58.911	22.4787	58	28.5138	0.4911	-6.351
	30	14-18	58.4932	22.4982	58	28.5138	0.49322	-6.0156
	31	14-23	58.4797	22.7175	58	28.5138	0.47965	-5.7964
	32	15-16	58.4956	22.405	58	28.5138	0.49562	-6.1088
	33	15-17	58.4989	22.4638	58	28.5138	0.49887	-6.05
	34	15-17	58.4989	21.4638	58	28.5138	0.49887	-6.05
	35	15-19	58.4978	22.5118	58	28.5138	0.49783	-6.002
	36	17-20	58.4009	21.9093	58	28.5138	0.4009	-6.6045
	37	20-24	58.491	22.9877	58	28.5138	0.49094	-5.5261
	38	22-23	58.4576	22.4634	58	28.5138	0.45757	-6.054
	39	22-23	58.4576	22.4634	58	28.5138	0.45757	-6.054
Without TCSC			58.481	21.9154	58	28.5138	0.48095	-6.5984

Table (8) Real power losses with and without STATCOM

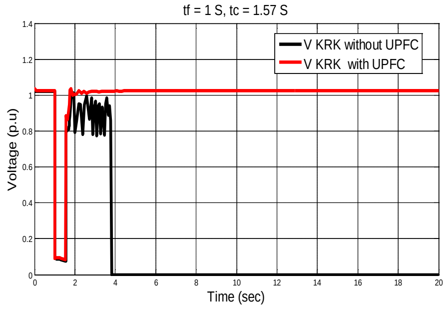
The system stability is then tested by applying a three phase to ground fault at

	Location of STATCOM	Total Generation system [p.u]		Total Load system [p.u]		Total Real Losses System p.u	Total Reactive Losses system p.u
	Bus number	Real	Reactive	Real	Reactive		
	Without STATCOM	58.481	21.9154	58	28.5138	0.48095	-6.5984
System With STATCOM	1	58.462	21.9479	58	28.5138	0.42201	-6.5659
	2	58.4528	21.9915	58	28.5138	0.45278	-6.5278
	3	58.3924	22.2304	58	28.5138	0.3924	-6.2834
	4	58.4657	21.9177	58	28.5138	0.4808	-6.5961
	5	58.4409	22.4679	58	28.5138	0.44086	-6.0459
	6	58.4763	22.9089	58	28.5138	0.47629	-6.605
	7	58.4459	22.2479	58	28.5138	0.44589	-6.2659
	8	58.4459	22.2479	58	28.5138	0.44589	-6.2659
	9	58.4395	22.2566	58	28.5138	0.45953	-6.2572
	10	58.4632	22.1926	58	28.5138	0.46315	-6.3212
	11	58.4088	22.1762	58	28.5138	0.40878	-6.3376
	12	58.3924	22.2304	58	28.5138	0.4924	-6.2834
	13	58.475	22.3282	58	28.5138	0.4794	-6.1856
	14	58.4409	22.4679	58	28.5138	0.44086	-6.0459
	15	58.4773	21.9217	58	28.5138	0.47731	-6.5003
	16	58.4166	21.7013	58	28.5138	0.45657	-6.8125
	17	58.4745	22.026	58	28.5138	0.47447	-6.4879
	18	58.4796	22.0292	58	28.5138	0.47955	-6.4846
	19	58.4166	22.7013	58	28.5138	0.46657	-6.8125
	20	58.4166	22.7013	58	28.5138	0.41657	-6.8125
	21	58.4775	22.2908	58	28.5138	0.47746	-6.223
	22	58.462	22.9479	58	28.5138	0.46201	-6.5659
	23	58.4627	22.1664	58	28.5138	0.4627	-6.3474
	24	58.4627	22.1664	58	28.5138	0.4627	-6.3474

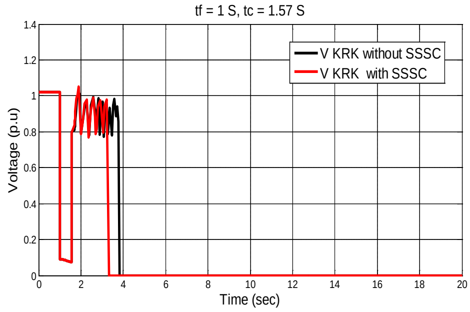
different location (bus KRK4) in each fault the system test repeated for the two conditions(permanent,temporary) and then comparison it made when result are done between all type to found optimal devices for stability improvement for the Iraqi grid.

Fault near bus KRK4

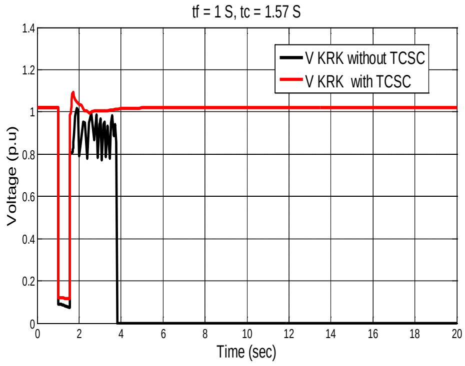
(9a)



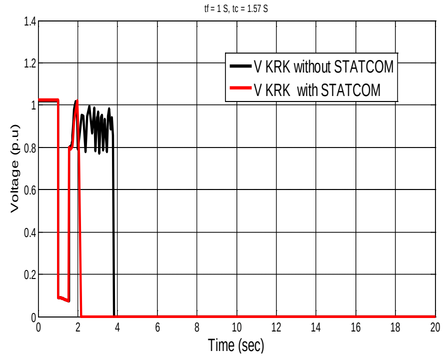
(9b)



(9d)



(9c)



(9e)

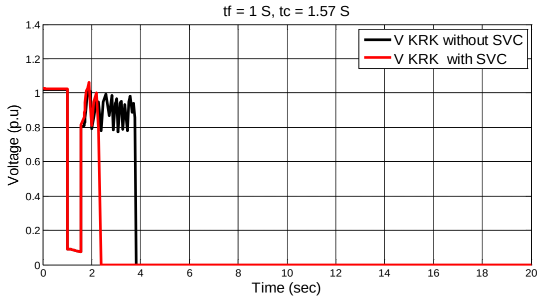
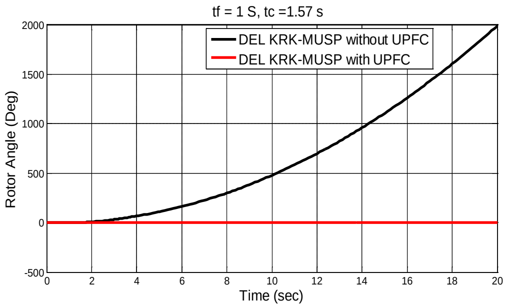


Figure (9 a,b,c,d,e) Voltage with and without UPFC,SSSC,SVC,TCSC,STATCOM.

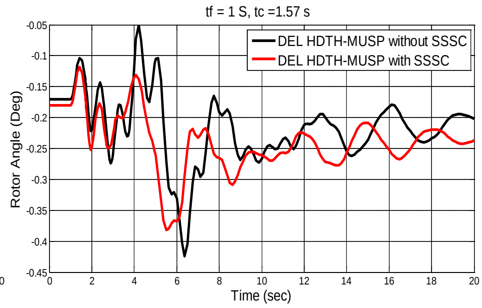
Table (9) Voltage magnitude profile (p.u.) of different buses with and without FACTS devices

Bus Number	Voltage Without FACTS Device	Voltage With UPFC	Voltage With SVC	Voltage With SSSC	Voltage With STATCOM	Voltage With TCSC
Bus AMN4	0.92986	1.0074	0.93123	0.93233	0.9303	1.0071
Bus AMR4	0.97291	0.98136	0.97333	0.97062	0.9744	0.9078
Bus BAB4	1.0263	1.0325	1.03	1.032	1.0318	1.0309
Bus BAJG	1.0189	1.0252	1.0187	1.0186	1.0187	1.025
Bus BAJP	1.02	1.0255	1.0201	1.199	1.0201	1.025
Bus BGC4	0.9681	0.99902	0.97342	0.97423	0.96856	0.9891
Bus BGE4	0.90561	1.0037	0.90672	0.90741	0.90596	1.003
Bus BGN4	0.9835	1.0052	0.98437	0.98461	0.98376	1.005
Bus BGS4	0.97768	1.018	0.97958	0.98014	0.97824	1.017
Bus BGW4	0.97186	0.99685	0.97941	0.98034	0.97223	0.9651
Bus DYL4	0.75232	1.0071	0.75324	0.75381	0.75261	1.0022
Bus HDTH	1.0264	1.0301	1.0276	1.0274	1.0269	1.03
Bus HRTP	1.0144	1.0156	1.0149	1.0143	1.0148	1.015
Bus KAZG	1.0093	1.0097	1.0095	1.0093	1.0096	1.0096
Bus KDS4	1.0089	1.0174	1.013	1.0129	1.0122	1.0133
Bus KRK4	0	1.0243	0	0	0	1.0218
Bus KUT4	0.97263	0.99354	0.97286	0.96627	0.97596	0.99191
Bus MMDH	1.0196	1.02	1.0197	1.0198	1.0197	1.02
Bus MSL4	1.0054	1.0074	1.0055	1.0055	1.0055	1.0074
Bus MUSG	1.039	1.0401	1.0392	1.0392	1.0391	1.04
Bus MUSP	1.0384	1.0407	1.0387	1.0386	1.0386	1.04
Bus NSRP	1.0193	1.0227	1.0196	1.0189	1.0195	1.0197
Bus QDSG	1.0061	1.0075	1.0064	1.0065	1.0064	1.0075
Bus QIM4	1.0183	1.022	1.0195	1.0193	1.0188	1.0218

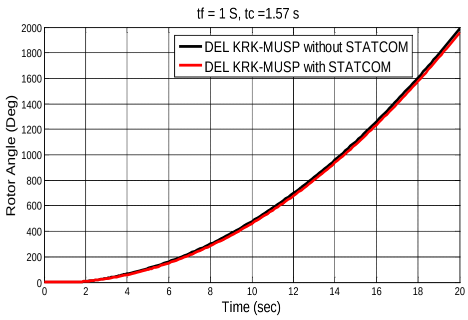
(10a)



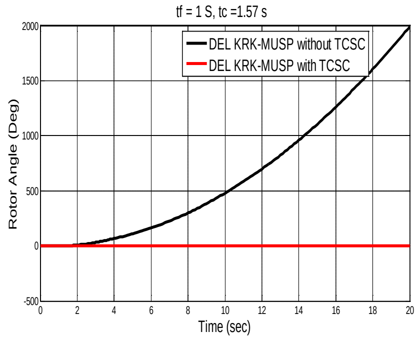
(10b)



(10c)



(10d)



(10e)

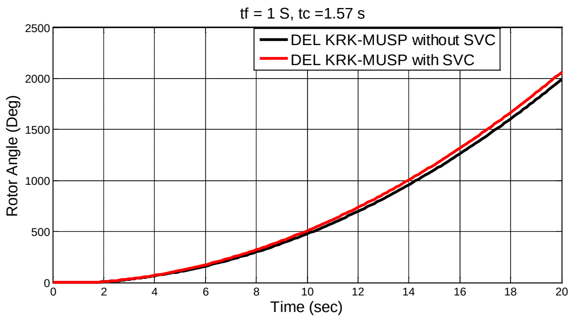


Figure (10 a,b,c,d,e) Rotor angle difference of KRK with and without UPFC,SSSC,TCSC,STATCOM, SVC respectively.

Table (10) critical clearing angle and critical clearing time with and without FACTS,fault near bus KRK4

	Critical Clearing Time TC(sec)	Critical Clearing Angle δ(deg)
Without FACTS Device	1.57	71.8878
With UPFC	1.887	101.312
With SSSC	1.6489	77.329
With TCSC	1.638	80.543
With SVC	1.77	77.2
WithSTATCOM	1.687	77.3449

Conclusions

The conclusions from this work can be summarized as follows:

1. The best location of FACTS depend on the total real power losses, for IEEE 9-bus system between buses (7 and 5) and for Iraqi National Grid System between buses (1 and 22, 5 and 15, 3 and 13, 17 and 20, 9 and 11) these locations enhance the stability performance of the network when fault occurs.
2. All types of the FACTS are very important for improvement of stability of the system and the best device is UPFC when compared with the other FACTS devices such as: SVC, TCSC, STATCOM and SSSC.
3. Stability degree of power system depends on the location and duration time of fault and type of the fault. By using FACTS devices for IEEE 9-bus system and Iraqi National Grid system the critical clearing time and angle are increased.
4. The simulation has been implemented using PSAT based on MATLAB programming language for the theoretically studied (IEEE 9-bus) and (Iraqi national grid).
5. When the system contains two or more types of devices so called hybrid, it is more stable than when it has one device

References:

[1] V. Naresh Babu and S. Sivanagaraju, " A New Approach for Optimal Power Flow Solution Based on Two Step Initialization with Multi-Line FACTS Device", International Journal on Electrical Engineering and Informatics, Vol. 4, No.1, March , 2012.

[2] Ch. Praing et. al., " Impact of FACTS Devices on Voltage and Transient Stability of A Power System Including long Transmssion lines" , IEEE, December, 2011.

[3] K. Mohanty and A. K. Barik, "Power System Stability Improvement Using FACTS Devices", International Journal of Modern Engineering Research, Vol.1, Issue.2, pp-666-672.

[4] L. Cai, et al., " Robust Coordinated Control of FACTS Devices in Large Power Systems", 2004.

[5] V. Ganesh et al.,"Improvement of Transient Stability Through SVC", Internaional Journal of Advances in Engineering and Technology, Vol. 5, Issue 1, pp. 56-66, 2012.
[6] D. Murali et al.,"Comparison of FACTS Devices for Power System Stability Enhancement",International Journal of Computer Applications, Vol.8, No.4, October, 2010.
[7] M.H. Haque, "Use of Series and Shunt FACTS Devices to Improve First Swing Stability Limit", IEEE, 2011.
[8] R. M. Mathur and R. K. Varma, "Thyristor Based FACTS Controllers For Electrical Transmission System"**,** IEEE, 2002.
[9] M. M. Fard et al.," UPFC Using For The Congestion Management Lines In Electricity Market Restructured Using PSO and GA Algorithm", Restructured Using PSO and GA Algorithm, Vol. 5, No. 10, 2011
[10] A. Kazemi and F. Mahamnie, " Improving of Transient Stability of Power Systems By supplementary Controllers of UPFC Using Different Fault Conditions", Wseas Transactions on Power System, Vol. 3, July ,2008**.**