

Enhancing the Control of Iraqi Power System Using FACTS Devices and Renewable Energy with Matlab Simulation

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ABSTRACT: Many Research and Study it is searched to resolve problems of a Power System by best Methods. In this work design Iraqi Electrical Power System contents (25 Bus bars- 400 kilo volt) and Resolve many problem in Electrical Power System, Such as Voltage ripple, Frequency Swing and Unstability Electrical Power System. By using FACTS Devices it is Distribution Static Synchronize Compensator (STATCOM) and (D – STATCOM) resolve Voltage Sag, Swill and reach to Voltage Stability, by injection Reactive Power also response Time about (25ms). Using Renewable Energy it is Wind Turbine (WT) for resolve Demand increase with Clean Energy, Environment-Friendly and Free Energy under MatLab Program Simulation.

Keywords: Iraq, FACTS, Renewable Energy, Control, Power System, MatLab.

I. Introduction

Power quality is certainly a major concern in the present era. It becomes especially important with the insertion of sophisticated devices, whose performance is very sensitive to the quality of power supply. A Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure or a miss-operation of end user equipment's. Modern industrial processes are mainly based on electronic devices such as PLC's, power electronic devices, drives etc., and since their controls are sensitive to disturbances such as voltage sag, swell and harmonics, voltage sag is most important power quality problems It contributes more than 80% of power quality (PQ) problems that exist in power systems, and more concern problems faced by many industries and utilities. [1]. by definition, voltage sag is an rms (root mean square) reduction in the AC voltage at the power frequency, for duration from a half-cycle to a few seconds. Voltage sag is caused by a fault in the utility system, a fault within the customer's facility or a large increase of the load current, like starting a motor or transformer energizing. Typical faults are single-phase or multiple-phase short circuits, which leads to high currents. The high current results in a voltage drop over the network impedance. Voltage sags are not tolerated by sensitive equipment's used in modern industrial plants such as process controllers; programmable logic controllers (PLC), adjustable speed drive (ASD) and robotics. Various methods have been applied to reduce or mitigate voltage sags. The conventional methods are by using capacitor banks, introduction of new parallel feeders and by installing uninterruptible power supplies (UPS). However, the PQ problems are not solved completely due to uncontrollable reactive power compensation and high costs of new feeders and UPS. The D-STATCOM has emerged as a promising device to provide not only for voltage sags mitigation but a host of other power quality solutions such as voltage stabilization, flicker suppression, power factor correction and harmonic control.

1.1 Configuration of D-Statcom

The basic electronic block of the D-STATCOM is the voltage source inverter that converts an input dc voltage into a three-phase output voltage at fundamental frequency. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and

magnitude of the D-STATCOM output voltages allows effective control of active and reactive power exchanges between the D-STATCOM and the ac system. Fig 1 shows the schematic of D-STATCOM. The D-STATCOM employs an inverter to convert the DC link voltage V_{dc} on the capacitor to a voltage source of adjustable magnitude and phase. Therefore the D-STATCOM can be treated as a voltage-controlled source. Figure 1 shows a single phase equivalent of the Statcom. A voltage source inverter produces a set of three phase voltages, V_i , that are in phase with the system voltage, V_s . small reactance, X_c , is used to link the compensator voltage to the power system. When $V_i > V_s$, a reactive current, i_c , is produced that leads V_s and when $V_i < V_s$, the current lags V_s .

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Inductance L and resistance R which represent the equivalent circuit elements of the step-down transformer and the inverter will be the main component of the D-STATCOM. The voltage V_i is the effective output voltage of the D-STATCOM and δ is the power angle. The reactive power output of the D-STATCOM inductive or capacitive depending can be either on the operation mode of the D-STATCOM. Referring to figure 1, the controller of the D-STATCOM is used to operate the inverter in such a way that the phase angle between the inverter voltage and the line voltage is dynamically adjusted so that the D-STATCOM generates or absorbs the desired VAR at the point of connection. The phase of the output voltage of the thyristor-based inverter, V_i , is controlled in the same way as the distribution system voltage, V_s . Figure 2 shows the three basic operation modes of the D-STATCOM output current, I , which varies depending upon V_i . If V_i is equal to V_s , the reactive power is zero and the D-STATCOM does not generate or absorb reactive power. When V_i is greater than V_s , the D-STATCOM shows an inductive reactance connected at its terminal. The current, I , flows through the transformer reactance from the D-STATCOM to the ac system, and the device generates capacitive reactive power. If V_s is greater than V_i , the D-STATCOM shows the system as a capacitive reactance. Then the current flows from the ac system to the D-STATCOM, resulting in the device absorbing inductive reactive power. [2]

1.2 Wind Turbine:

Researchers have begun to show that a floating axis wind turbine (FAWT) could in fact generate cheaper energy than the more standard offshore horizontal axis wind turbine (HAWT).

As shown in the image above, there are several types of floating wind turbines available, but researchers from the Korea Advanced Institute of Science and Technology and University of Tokyo have showed that the installed cost per rated power of the floating axis wind turbine (FAWT) is 50% and 57% of those in the referenced HAWT (horizontal axis wind turbine) and guyed VAWT (vertical axis wind turbine) configurations, respectively.

On top of that, the estimated cost of the electricity produced in a FAWT-style farm would be approximately 25% lower than that of the base HAWT.

The researchers published their results in the journal *Environmental Letters* and outlined the major merits of FAWT:

- (1) The float supports the weight of the turbine and most of its axial load. The bearing rollers swivel like swivel casters of a desk chair. It allows relative heave motion of the rotating float to the bearing mechanism so that only the thrust force of the turbine is on the bearing mechanism. The thrust force of a wind turbine is less than 1/10 of the weight of the VAWT mechanism.
- (2) Power output from the turbine is obtained from torque of the rotating float by rollers contacting on the cylindrical surface of the float. Since the drive train is not in a limited space like the nacelle of a HAWT or the shaft of a VAWT, restrictions on the weight and size of the mechanism are lighter than those in other turbine concepts.
- (3) Non-rigid support of the turbine axis avoids concentration of the load. Since the weight and bending moment of the turbine are not directly on the drive train, the configuration leads to lighter structural requirements. Gyroscopic moment of the turbine and the float stabilizes the direction of the turbine axis in wind fluctuation.
- (4) FAWTs inherit the simple mechanism and low maintenance cost of VAWTs.
- (5) Installation of FAWTs does not require floating cranes and other specifically designed service vessels.

“We have to reassess the costs of renewable energy and explore new possibilities of energy generation which can be substituted for a part of the present share of nuclear power,” the authors write. “In Japan, wind power is one of the prospective candidates. However, in Japan, flat land and shallow water area available for the construction of new wind farms is very limited. Therefore, there is an urgent need for low-cost offshore wind turbines that are applicable to deep water regions.”

The authors are well aware that their hopes may run into difficulties and unknown challenges, but they are confident that the FAWT will help them find a way to create low-cost offshore wind power. [4]

1.2.1-Wind Turbine Types and Characteristics:

- 1-Variable speed and fixed speed
- 2-Pitch and stall control

The vertical and horizontal axis turbines are explained below and for the others three types the links are in the menu aside. It is also added the next sub-section, wind turbine components, to enhance understanding of the text.

Vertical and horizontal axis wind turbines

The wind turbines may be generally categorized in two types: vertical axis and horizontal axis. The vertical axis is named also “Darrieus” in honor to its inventor Georges Darrieus. Its key advantage is that they do not need an orientation mechanism due to their use of the wind flow from any direction and its main disadvantage is a low power coefficient. Additionally, most of the vertical axis turbines are not built for high power capacity because they are installed at ground level where the wind flow is low. Therefore, this webpage will not explain more about the vertical axis wind turbines and will focus on the horizontal axis ones.

In the case of horizontal wind turbines they may contain one or more blades. The number of blades has to deal with the coefficient of power (Cp) that is basically the electricity produced by a wind turbine divided by the total energy available from the wind (better explained in this link). Furthermore, a higher CP is obtained with three blades as shown in the graph above on the right. Nevertheless, for higher wind speed one or two blades would have a higher CP.

The axis represented in the graph at the top on the right are Tip-speed ratio (λ) and the rotor power coefficient (CPR), axis x and y. The Tip-speed ratio is the rotational speed of the blades ($\omega * r$) divided by the wind speed. [5]

1.2.2- How a Wind Turbine Produces Energy?

The solar energy along with earth rotation makes dissimilar air heating which in turn creates wind. The warmer air mass near to the equator is lighter than the cold air mass and tends to go to the North and South Pole creating wind flows. Moreover, by the movement of the earth and its tilt there are other incredible effects are produced, such as Coriolis. By watching the previous video if we consider the ball as an air mass, we can understand the components of wind movement in its total.

Still, there are other aspects to be concerned when it comes to the wind flow e.g. the roughness and topography of the land and atmospheric stability, which will be commented in the section measurement of wind.

To explain a wind turbine let's consider it the opposite of a regular home fan. The regular home fan uses: an electric motor, blades, and electricity in order to produce wind. As the opposite the wind turbine uses: an electric generator, blades, and wind in order to produce electricity. The wind turbine uses the wind flow that strikes the blades, and using the principles of torque or rotational force it produces electricity. The energy that winds produces relies on 3 aspects:

- Air density
- The rotor area
- Wind speed

To explain the wind power generated from a wind turbine it is important to remember the mechanical classic.

The kinetic energy, in this case wind power (P), that as we all know is equal to half of the mass (m) per speed (v) squared.

$$P = \frac{1}{2} * m * v^2$$

And therefore, if we consider the air mass as equal to the density (ρ) per superficial area (S) per wind speed (v)

$$M = \rho * S * v$$

And later substitute the mass into the equation of kinetic energy the result is that wind power is proportional to the swept area from the wind turbine rotor and in cubic relation with the wind speed

$$P = \frac{1}{2} * \rho * S * v^3$$

Nevertheless, the maximum energy that may be obtained by wind is 59% according to the Betz's law (not taking into consideration the electrical losses). [6].

1.2.3-Variable speed and fixed speed

There are two types of speeds that should not be mistaken with each other, the rotor speed (RPM) and the wind speed (m/s). All wind turbines will work until they reach a certain wind speed otherwise they will work as a motor similar to a house fan, withdrawing electricity from the grid. After reaching the minimum level of wind speed (start-up speed) the brakes are released and the rotor accelerates; however, when the maximum wind speed is reached (cut-out speed) the rotor stops by stall or pitch control (mentioned in subsection pitch and stall control)

In the case of fixed speed, first the rotor accelerates until it reaches a fixed number of RPM, and later the wind turbine is connected to the grid and supplies power. The wind turbine remains connected to the grid at a fixed speed regardless of the wind speed, and changes the power supply through the principles of torque in the blades (the blades angle position) until the cut-out speed is reached and it is when the wind turbine stops.

On the other hand, wind turbine that uses variable speed connects to the grid and supplies power at different rotor speed (RPM). It is to say that the speed of the rotor is matched to the wind speed and along with the blade angle effects the power supplied which creates a maximum efficiency. Therefore, the rotor can be connected to the grid at low speeds during light winds and would increase its power proportionally to wind speed.

Finally, an example is shown that you can find in this link (page 4) and also a more detailed explanation. A small turbine rotor is operating at 40 rpm and the wind speed is 3 meters per second (m/s) producing less than 1 kilowatt of power. If the wind suddenly increases at 6 m/s but the machine is using fixed speed and the rotor remains at 40 rpm the machine will produce between one and two kW; in the case of variable speed the wind turbine will produce between three and four kilowatts. [7]

1.2.4- Pith and Stall Control:

The stall and pitch regulation control works to limit the rotor power in high operational wind flows.

Stall control may be passive or active. Passive stall control is when the blades are attached to the hub at fixed angle. The blades are aerodynamically designed in such manner that when the wind flow exceeds the cut-out speed, the blades start to stall and thus the power production decreases. One advantage of passive control is that moving parts inside the rotor are avoided. In the case of active stall control there is an inclination of the blades, similar to pitch control, but only in low wind speeds, to improve efficiency. On the contrary, at high wind speeds which may damage the generators the position of the blades is the same as in the passive stall control so as to stop the movement of the rotor.

On the other hand, in the pitch power control electronic sensors are used to monitor the output of power. Supposing that the level of power is exceeded the blades are turned or pitched out of the wind. Additionally, when there are low wind speeds the blades are pitched back to catch the wind at an optimal angle.

Figure (9) Section of (WT)

Literature Review

MejalyAlkhazragy (2008)This paper presents a brief description of Lyapunov's direct method, and Demonstrates its efficiency with respect to previous indirect step by step method, in order to compute the stability of electromechanically power system. The practical advantages of this direct method of analysis are:

(i) Rapid solution.

(ii) Ability to compute the degree of stability.

(iii) For computing the critical clearing time integrate the faulted equation, until $V=V1$.

The basic concepts and the mathematical formulation of the method are Summarized. Practical test system are used to demonstrate the superior Efficiency of the method relative to step by step method. [8]

Cristian Dragoş Dumitru (2010) The paper presents the modeling of a solar-wind-hydroelectric hybrid system in Matlab/Simulink environment. The application is useful for analysis and simulation of a real hybrid solar-wind-hydroelectric system connected to a public grid. Application is built on modular architecture to facilitate easy study of each component module influence. Blocks like wind model, solar model, hydroelectric model, energy

II. Result And Discussion

M-FILE CODE1

This is MatLab M-file Code for get the voltage of Iraqi Power System with FACTS devices and with Renewable Energy:-

This Code by MatLab Programmable language.

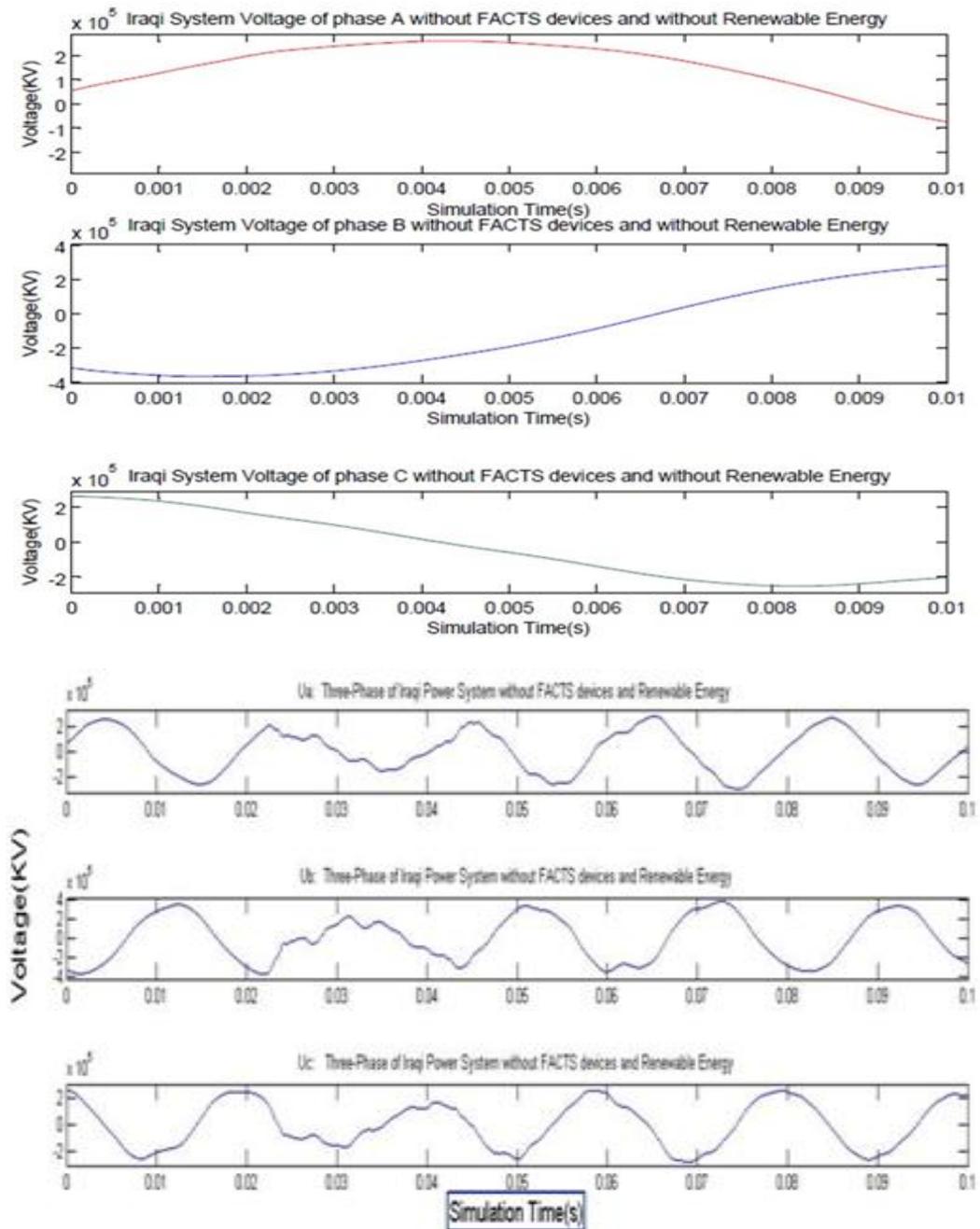
START PROGRAM

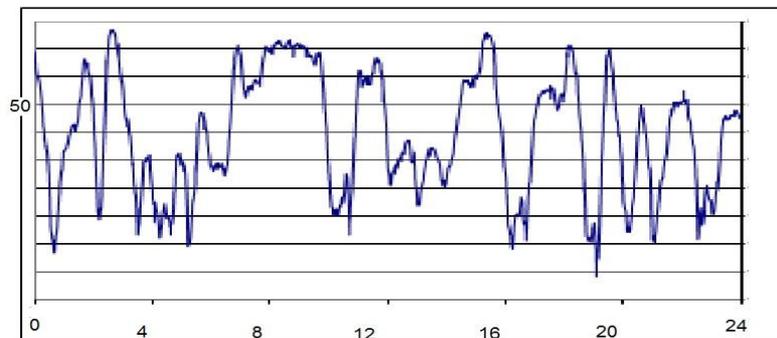
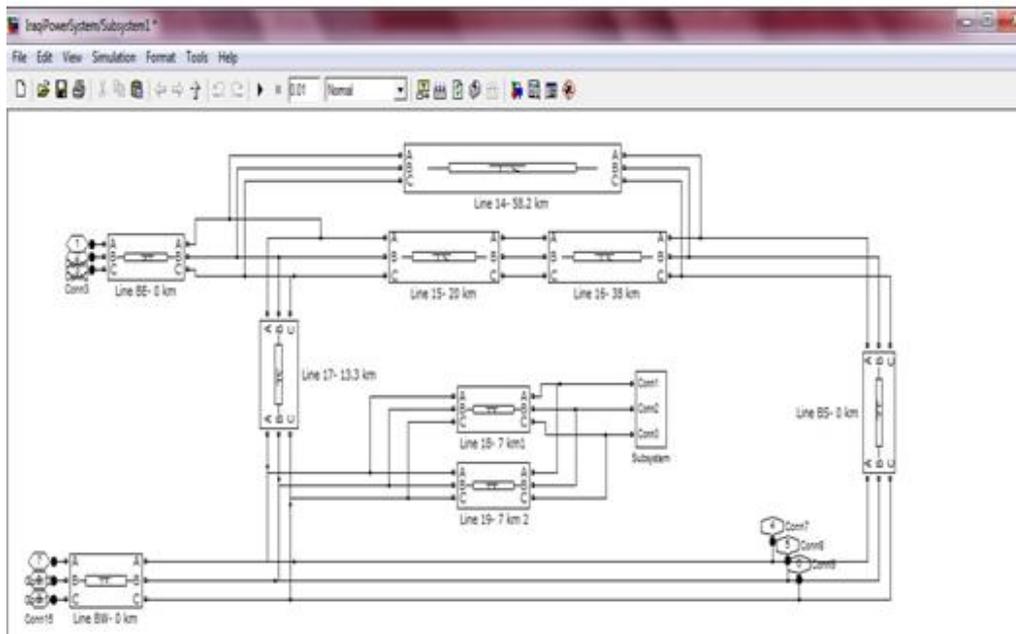
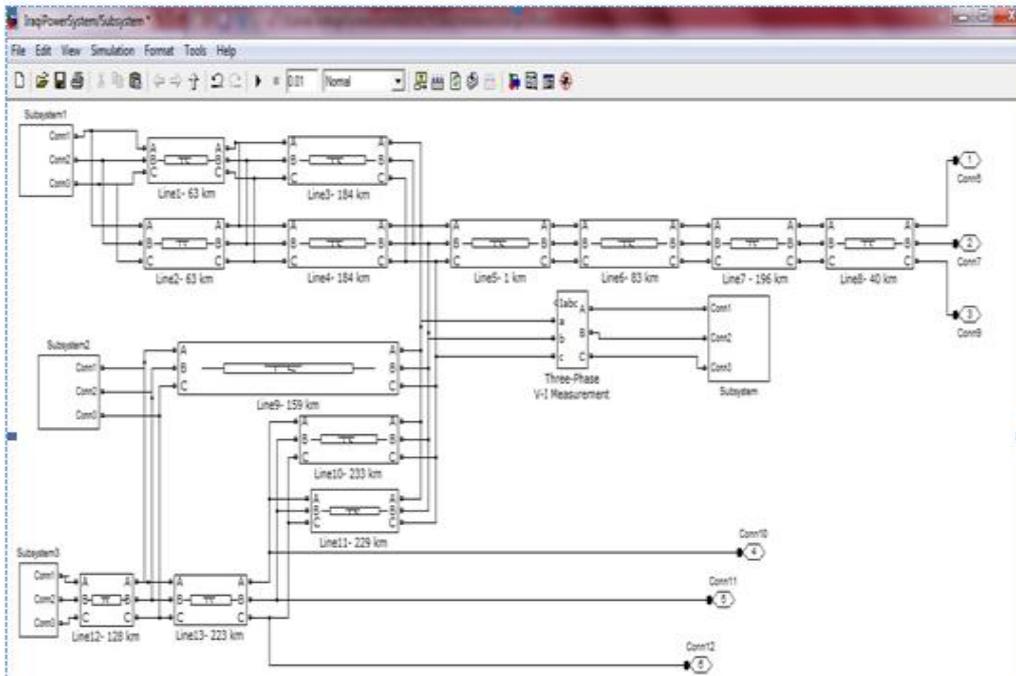
```
function createfigure(X1, Y1, Y2, Y3)
```

```
%CREATEFIGURE(X1,Y1,Y2,Y3)
```

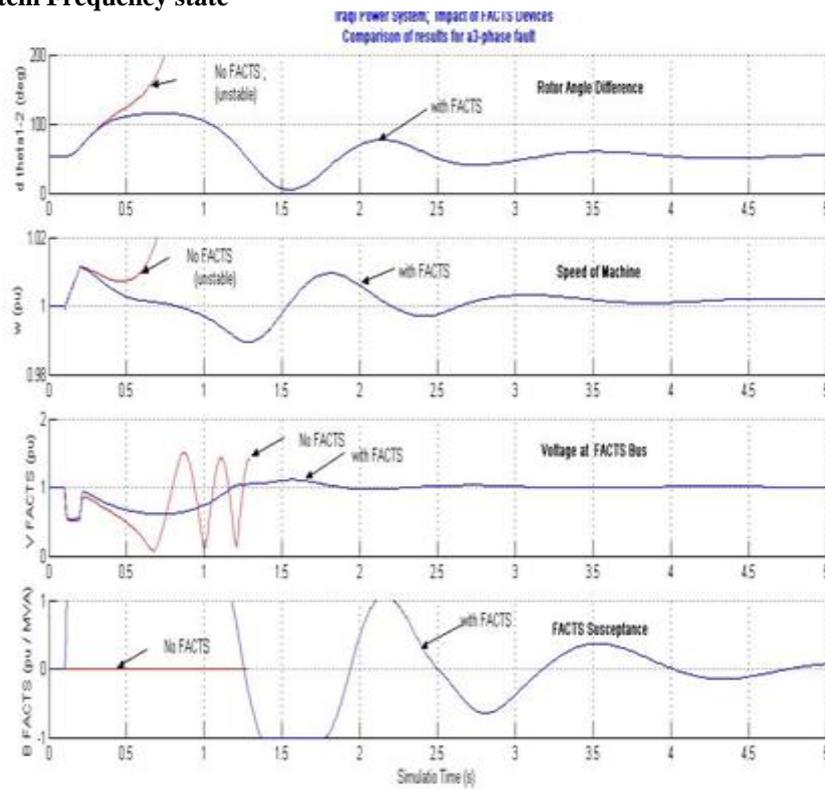
```
% X1: vector of x data
% Y1: vector of y data
% Y2: vector of y data
% Y3: vector of y data
% Auto-generated by MATLAB on 08-Jan-2014 07:22:31
% Create figure
figure1 = figure('NumberTitle','off',...
    'Name','Simulation result for : Multimeter',...
    'IntegerHandle','off');
% Create subplot
subplot1 = subplot(3,1,1,'Parent',figure1);
% Uncomment the following line to preserve the X-limits of the axes
% xlim(subplot1,[0 0.01]);
% Uncomment the following line to preserve the Y-limits of the axes
% ylim(subplot1,[-286833.85846247 286833.85846247]);
box(subplot1,'on');
hold(subplot1,'all');
% Create plot
plot(X1,Y1,'Parent',subplot1,'Color',[1 0 0]);
% Create xlabel
xlabel('Simulation Time(s)');
% Create ylabel
ylabel('Voltage(KV)');
% Create title
title('Iraqi System Voltage of phase A without FACTS devices and without Renewable Energy');
% Create subplot
subplot2 = subplot(3,1,2,'Parent',figure1);
% Uncomment the following line to preserve the X-limits of the axes
% xlim(subplot2,[0 0.01]);
% Uncomment the following line to preserve the Y-limits of the axes
% ylim(subplot2,[-404371.40804379 404371.40804379]);
box(subplot2,'on');
hold(subplot2,'all');
% Create plot
plot(X1,Y2,'Parent',subplot2);
% Create xlabel
xlabel('Simulation Time(s)');
% Create ylabel
ylabel('Voltage(KV)');
% Create title
title('Iraqi System Voltage of phase B without FACTS devices and without Renewable Energy');
% Create subplot
subplot3 = subplot(3,1,3,'Parent',figure1);
% Uncomment the following line to preserve the X-limits of the axes
% xlim(subplot3,[0 0.01]);
% Uncomment the following line to preserve the Y-limits of the axes
% ylim(subplot3,[-288366.691663778 288366.691663778]);
box(subplot3,'on');
hold(subplot3,'all');
% Create xlabel
xlabel('Simulation Time(s)');
% Create ylabel
ylabel('Voltage(KV)');
% Create title
title('Iraqi System Voltage of phase C without FACTS devices and without Renewable Energy');
END PROGRAM
```

III. Figures And Tables





Iraqi Power System Frequency state



IV. Conclusion

This thesis it is found that the Iraqi power system has many troubles, like Voltage unstable, Frequency Swing, power system operation is many time reach to unstable. And in this work try to resolve the Iraqi Power System problems.. to solve the Frequency Swing connected the Renewable Energy Power plants. In this Work used Wind Turbine and connected in Iraqi Southern Region because many Research found the South of Iraq has high speed wind to reach (5 to 9 m/s) and can use to generation.

Acknowledgements

To God for everything
To my parents for their support
To my family for their patience
To my country for his blood being lost every day
To my Ministry for their support to me
To all my professors
To each of the supported me

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