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DYNAMIC STABILITY IMPROVEMENT OF MULITIMACHINE POWER SYSTEMS BY USING AVR, POWER SYSTEM STABILIZER AND TURBINE GENERATOR

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ABSTRACT
This paper introduced a three method used for controlling electrical power systems for multi-machines under dynamic loads by using artificial intelligence.
This paper includes complete descriptions of the three method used to controlling dynamic power system stability through the method of recognizing pattern and proposition of suitable control systems for re-adjusting the machines in power system for instable cases. PSAT program had been used in analyzing the stability in the power systems. In this paper, the studied power system included dynamic load model, the program gave excellent results in suitable time, and the used network consists of 14 bus bars – 5 generators.

KEYWORDS: Transient and Dynamic Stability, Load Model, Event Definition, AVR, PSS and TG Control, Case Study.

تحسين الاستقرار الديناميكي للآلات المتعددة في أنظمة القوي باستخدام منظم الجهد ، ومثبت نظام الطاقة ، ومولد التوربينات

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الملخص:-
قدم هذ البحث ثلاث طرق تستخدم للتحكم في أنظمة الطاقة الكهربائية للآلات المتعددة تحت الأحمال الديناميكية باستخدام الذكاء الاصطناعي.
يتضمن هذا البحث وصًفا كامًلا للطرق الثلاثة المستخدمة للتحكم في استقرار نظام الطاقة الديناميكي من خلال طريقة التعرف على النموذج واقتراح أنظمة تحكم مناسبة لإعادة ضبط الآلات في نظام الطاقة للحالات غير المستقرة. وقد استخدم برنامج PSAT في تحليل الاستقرار في أنظمة الطاقة. في هذا البحث ، تضمن نظام الطاقة المدروس نموذًجا للحمل الديناميكي ، حيث حقق البرنامج نتائج ممتازة في وقت مناسب ، وتتكون الشبكة المستخدمة من ١٤ قضيب ناقل - ٥ مولدات

الكلمات المفتاحية:الاستقرار العابر والديناميكي ، محاكاة النظام ، تعريف بالمفاهيم ، منظم الجهد ، نظام التحكم المستخدم ، النظام محل الدراسة.

1. INTRODUCTION

Power system is a dynamic system. Nowadays, the electric power systems are not operated as isolated system, but as interconnected systems which having thousands of electrical elements and be spread over wide areas. Synchronous Generator is widely used in a power system as a source of electrical energy. The power systems are frequently exposed to different instabilities such as low frequency oscillations and disturbances that occur due to minor variation in load and generation which results in change in Generator rotor angle. Excitation control is very useful for maintaining stability of power system. Excitation systems constitute the fast acting AVR. Automatic voltage Regulator (AVR) is required to regulate the terminal voltage of Generator whenever any drop in terminal voltage due to sudden change in loading or at any fault occurrence. However, it produces a negative damping at higher values of system reactance high generator output. Thus, it is very essential to increase the damping torque in order to reduce the rotor angle oscillations. The Power system stabilizer (PSS) is added to damp the Generator rotor oscillations by controlling its excitation by providing supplementary signal in the excitation system to damp out low frequency Oscillations. To offer damping, the stabilizer must provide component of electrical torque in phase with rotor speed deviation. The use of PSS has become very common in operation of large power system. The Conventional Power system stabilizer (CPSS), which uses lead lag compensation, where gain settings designed for specific operating condition is giving feeble performance under various synchronous generator loading circumstances. [1-2-3].

2. DYNAMIC STABILITY.

Is a concept used in the study of transient conditions in power systems. Any electrical disturbances in a power system will cause electromechanical transient processes. Besides the electrical transient phenomena produced, the power balance of the generating units is always disturbed and thereby mechanical oscillations of machine rotors follow the disturbance .A system is said to be dynamically stable if the oscillations do not acquire more than certain amplitude and die out quickly. [4, 5].

3. LOAD MODEL

According to the description depicted in the previous section, the load composition of a particular area is characterized by the load class data, the composition of each one of the classes, and the characteristics of each single load component. The load class data is often grouped in industrial, residential, commercial and agricultural load data. The industrial load is mainly related to industrial processes, and most of the load corresponds to industrial motors, up to 95%. Heavy industries may include electric heating processes such as soldering. The residential load includes most of the devices related to housing habits, but also a big percent of electric heating and air conditioner units during winter and summer respectively. The commercial load corresponds to air conditioner units and a large percent of discharge lighting, and agricultural load to induction motors for driving pumps. In general the different load components that constitute the different load classes can be included in one of the next four groups;

- Loads with 'fast dynamic' electrical and mechanical characteristics such as induction motors.
- Loads that under voltage excursions present significant discontinuities such as discharge lighting and motor protections.
- Loads whose response to voltage faults does not present significant discontinuities or delays such as incandescent lighting, and
- Loads with 'slow' characteristics such as electric heating.

A brief description of some imperative load components. [7].

3.1 Dynamic Load Models

When the traditional static load models are not sufficient to denote the behavior of the load, the alternative dynamic load models are necessary. The parameters of these load models can be determined either by using a measurement-based approach, by carrying field measurements and observing the load response as a result of alterations in the system, or by using a component-based approach; first by identifying individual load characteristics and then by aggregating them in one single load.

3.2 Exponential Dynamic Load Model

Due to the large amount of electrical heating loads in Sweden and its critical effect on voltage stability have proposed a load model with exponential recovery. The model is presented below, as a set of non-linear equations, where real (active) and reactive power have a nonlinear dependency on voltage [8, 9].

$$T_p \frac{dP_r}{dt} + P_r = P_o\left(\frac{U}{U_o}\right)^{\alpha_s} - P_o\left(\frac{U}{U_o}\right)^{\alpha_t} \qquad (1)$$

$$Pl = P_r + P_o\left(\frac{U}{U_o}\right)^{\alpha_t} \qquad (2)$$

Where U_o and P_o are the voltage and power consumption before a voltage change, Pr is the active power recovery, P_l is the total active power response, T_p is the active load recovery time constant, *αt* is the transient active load-voltage dependence, and αs is the steady state active load voltage dependence. Similar equations are also valid for reactive power.

The load behavior is thus characterized by a time constant and transient and steady state load-voltage dependence parameters. T_p represents the time that the power recovery needs to reach 63% of its final value, αs the steady state load-voltage dependence quantifies how much load has been restored after the recovery; a value equal to *0* means a fully restored load, while a different value indicates partly restored load.

Furthermore, the parameter αs, steady state voltage dependency, may present negative values, the stationary level reached by the load after the recovery is then higher than the expected one, resulting in an overshooting in the load αt the transient load-voltage dependence, describes how the load behaves at the disturbance moment. If αt is equal to 0, the load behaves as a constant power, if it is equal to 1 the load behaves as a constant current, and if it is equal to 2 as constant impedance.[10]

4. POWER SYSTEM CONTROL

This paper describes AVR, PSS and TG controllers used to control of power system dynamic stability. This control models are described by means of a set of differential equations, as follows [11]:

$$\dot{x} = f(x, y, z_{in}) \qquad (3)$$

$$z_{out} = z_{out}(x, y, z_{in}) \qquad (4)$$

Where x are the state variable of the component, y the algebraic variables (e.g. bus voltages in case of AVRs), z_{in} are the input variables (e.g. the rotor speed in case of TGs), and z_{out} are the output variables (e.g. the synchronous machine field voltage and mechanical torque).

4.1 Automatic Voltage Regulator

Automatic Voltage Regulators (AVRs) define the primary voltage regulation of synchronous machines. Several *AVR* models have been proposed and realized in practice. PSAT allows defining three simple different types of *AVRs*. *AVR Type I* is a standard Italian regulator (ENEL), whereas *AVR Type II* is the standard IEEE model 1. *AVR Type III* is the simplest AVR model which can be used for rough stability evaluations [1].

4.1.2 Automatic Voltage Regulator *Type I*

The *AVR Type I* is defined by the block diagram shown in Figure 1

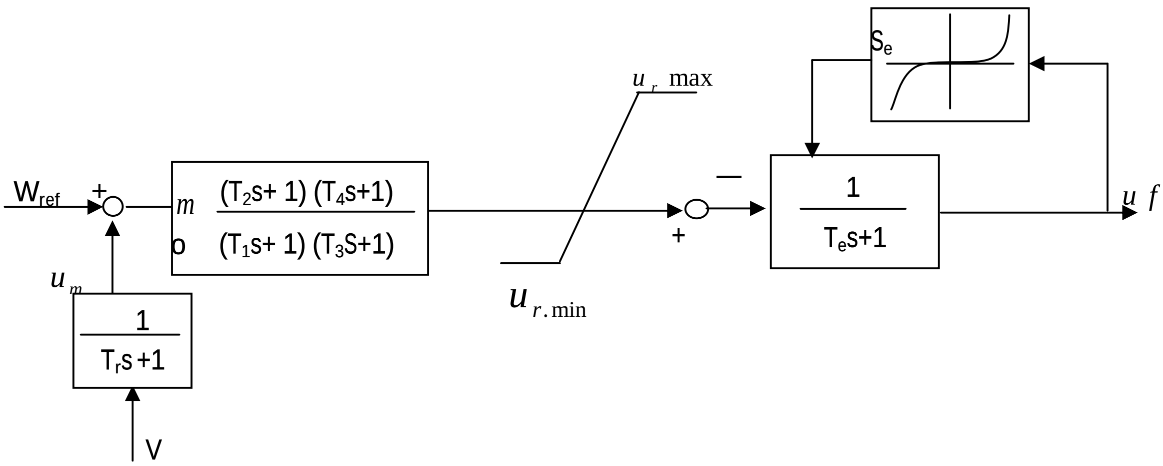

Fig. 1. Exciter Type I.

4.1.3 Automatic Voltage Regulator *Type II*

The *AVR Type II* is defined by the block diagram shown in Figure 2

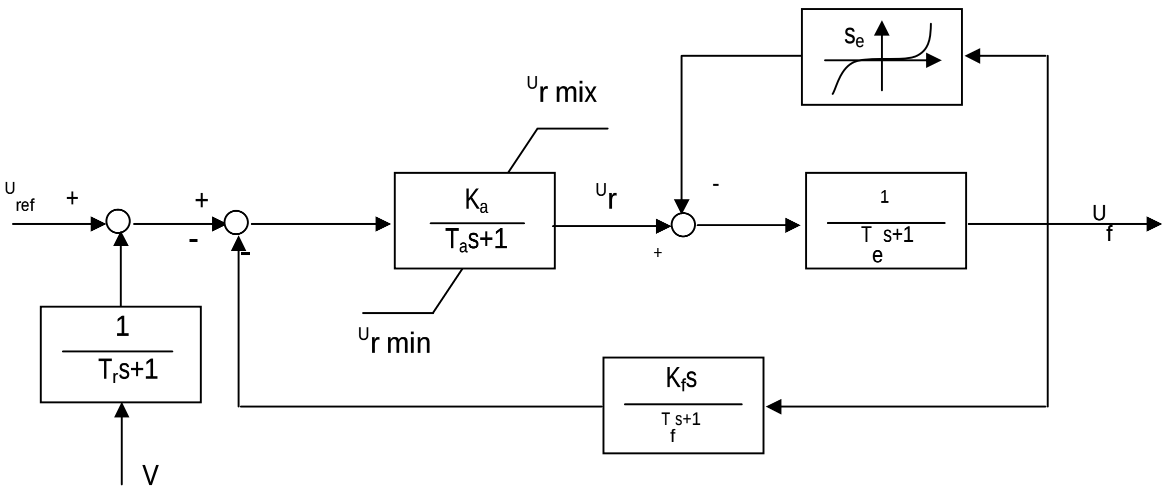

Fig. 2. Exciter Type II.

4.1.4 Automatic Voltage Regulator Type III

The *AVR Type III* is defined by the block diagram shown in Figure 3

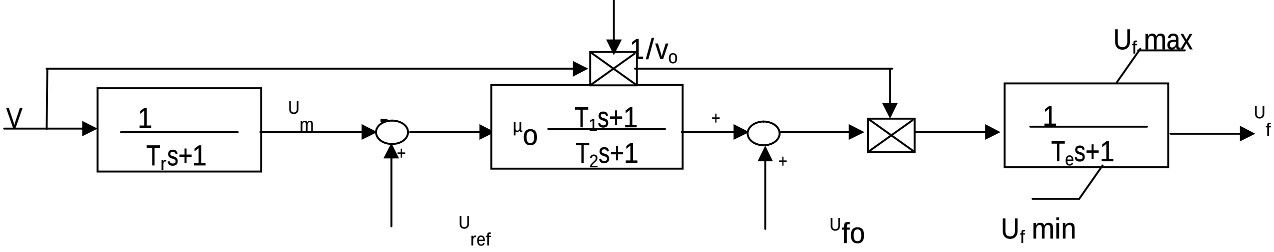

Fig. 3. Exciter Type III.

5. POWER SYSTEM STABILIZER

Power System Stabilizers (PSSs) are typically used for damping power system oscillations and many different models have been proposed in the literature. In addition to the simple PSS embedded in the synchronous machine equations (models *III, IV,V.1, V.2 and VI*), five models of PSS are implemented in *PSAT* [1]. All models accept as input signals the rotor speed ω, the active power P_g and the bus voltage magnitude Vg of the generator to which the PSS is connected through the automatic voltage regulator. The PSS output signal is the state variable υ_s, which modifies the reference voltage υ_{ref} of the *AVR*. The output signal v_s is subjected to an anti-windup limiter and its dynamic is given by a small time constant T_ϵ = 0.001 s.1 Note that PSSs cannot be used with order II generators. Each PSS model has two algebraic equations, as follows:

$$0 = g_s(x, y) - \upsilon_{ss} \qquad (5)$$

$$0 = \upsilon_{ref0} - \upsilon_{ref} + \upsilon_{ss} \quad (6)$$

Where (5) defines the PSS signal υ_{ss}, and (6) sums the signal υ_{ss} to the AVR reference voltage.

5.1 Power System Stabilizer Type I

PSS Type I is defined by the block diagram shown in Figure 4

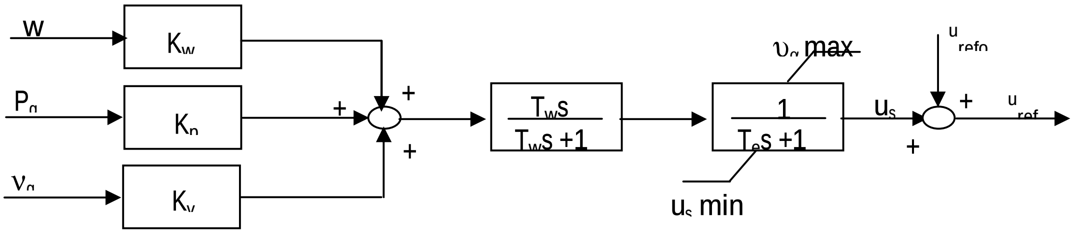

Fig. 4. Power system stabilizer Type I.

5.2 Power System Stabilizer type II

PSS Type II is defined by the block diagram shown in Figure 5

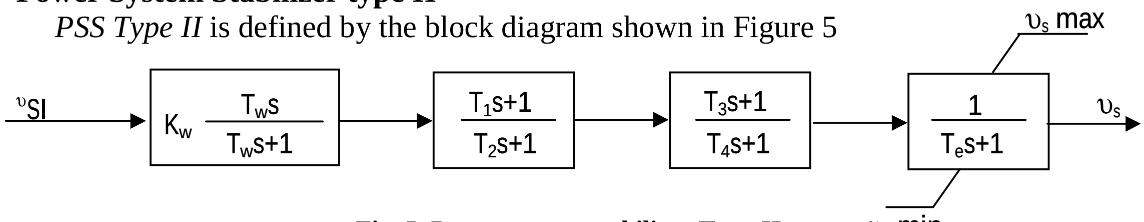

Fig. 5 Power system stabilizer Type II. υs min

5.3 Power System Stabilizer type III

PSS Type III is defined by the block diagram shown in Figure 6

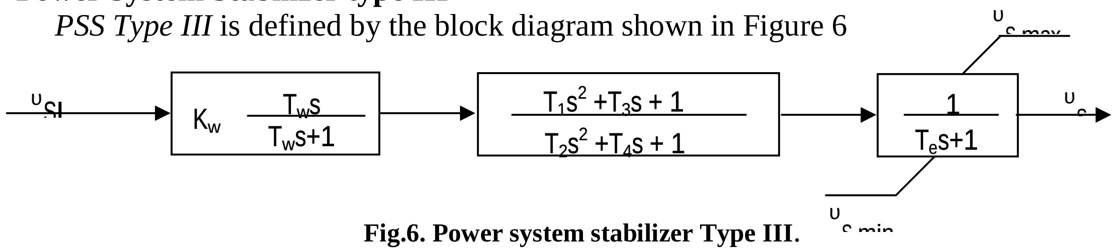

Fig.6. Power system stabilizer Type III.

5.4 Power System Stabilizer Type IV and V

PSS Type IV and V are a slight variation of Type *II and III* respectively. The block diagram is depicted in Figure 8. The additional signal υ_α is generally disabled, being the switch S1 open. S1 closes if the machine field voltage is lower than a threshold value $\upsilon_f < e_{thr}$ and remains closed even after $\upsilon_f \geq e_{thr}$. S1 opens if the rotor speed is lower than a threshold value $\omega < \omega_{thr}$. It is possible to enable the action of a second switch S2 after the lag block of the additional signal υ_α. If S2 is enabled, it stays generally open. S2 closes when the rotor speed deviation $\Delta\omega < 0$ and remains closed even after $\Delta\omega \geq 0$ **[1]**

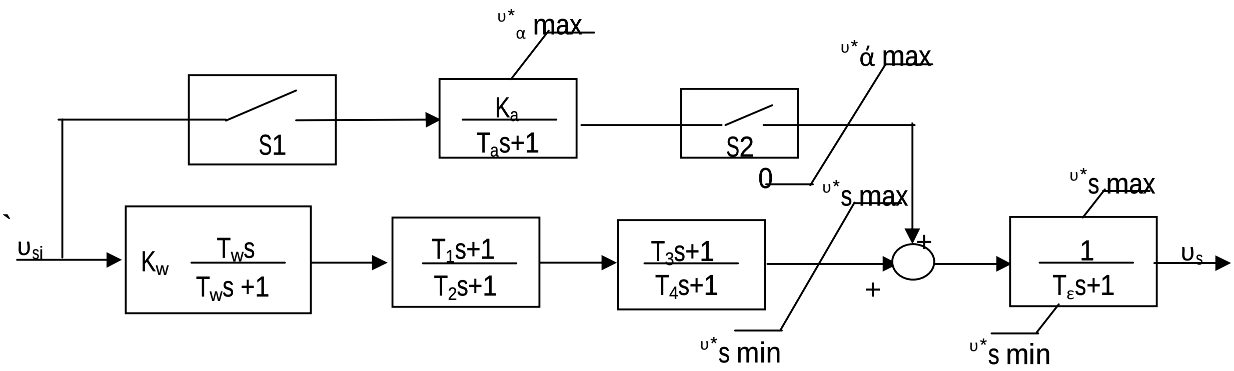

Fig.7. Power system stabilizer Type IV.

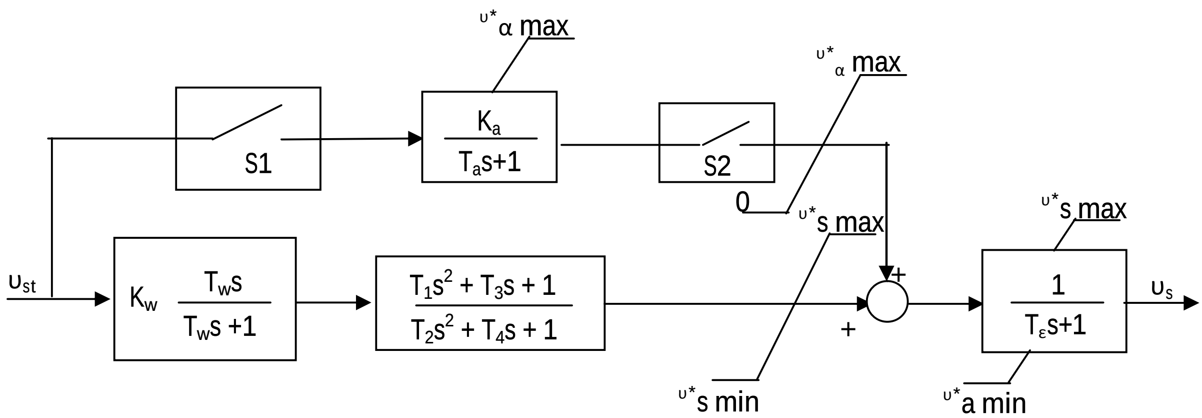

Fig. 8. Power system stabilizer Type V

6. TURBINE GOVERNOR

Turbine Governors (TGs) define the primary frequency regulation of synchronous machines. The TG consists of two types. These are TG type 1and TG type 2 [12-13-14].

6.1 Turbine Governor Type I

The TG type I is defined by the block diagram shown in Figure 9:

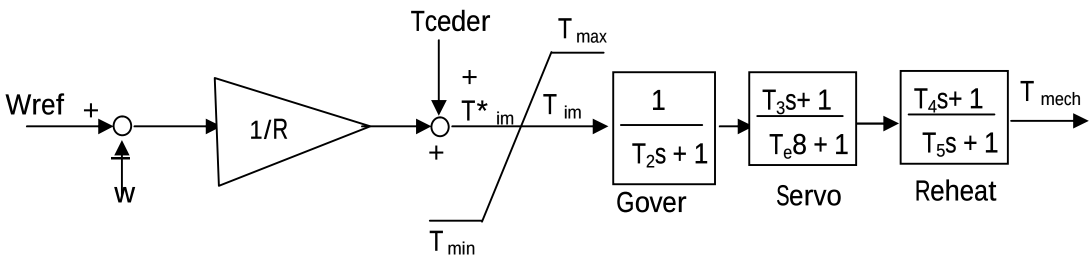

Figure.9. Turbine Governor Type I.

6.2 Turbine Governor Type II

The TG type II is illustrated by the block diagram as displayed in Figure 10:

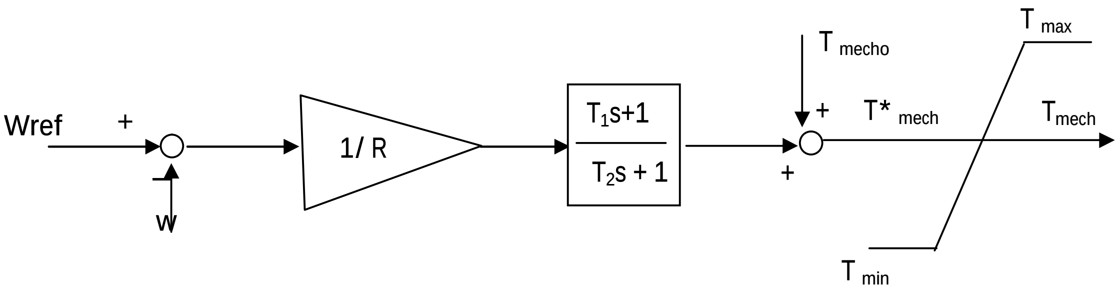

Figure 10. Turbine Governor Type II.

7. CASE STUDY

Test results are providing on the 14 Bus systems. Figure 11 show the single line diagram for network used in case study.

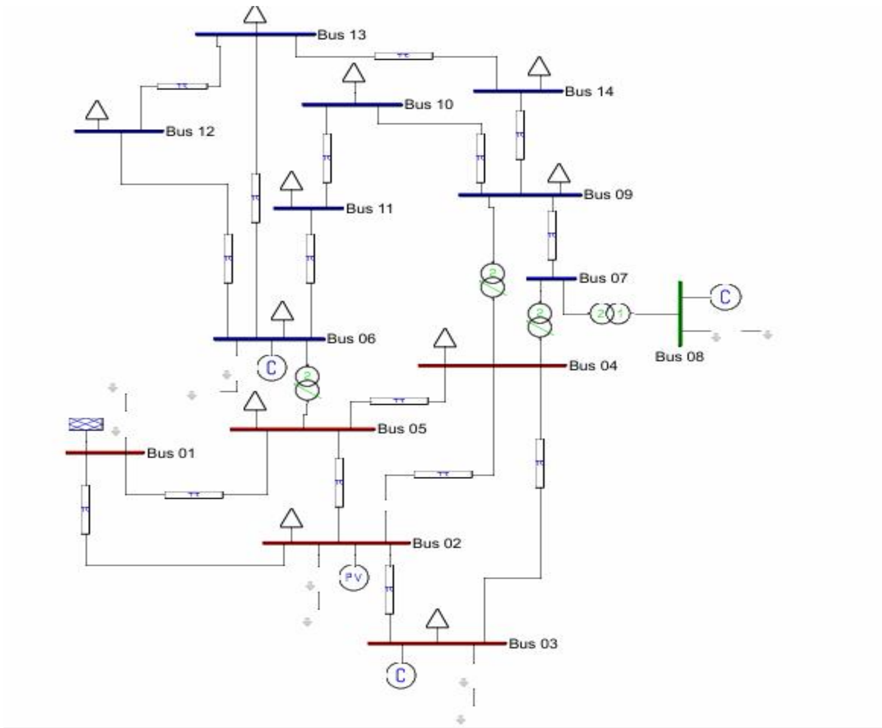

Fig. 11. Show the single line diagram for 14 Bus Network

A three new event was considered and the *PSAT* program was used to analysis , evaluate the dynamic stability of the system and to propose the required a suitable preventive control action fore readjustment the network to steady state.
These three events were:

1. A 3-phase short circuit at the bus 11 (load bus)
2. A 3-phase short circuit at the bus 2 (generator bus)
3. A line 2-4 outage from the network

In the following cases, three phase short circuit made for bus No. 11, and the following curves for power angle against time and speed against time to all generators without control.

6.1. Case No. 1: A 3-Phase Short Circuit At The Bus No. 11 (Load Bus) Occurred At 9sec and Cleared At 9.25

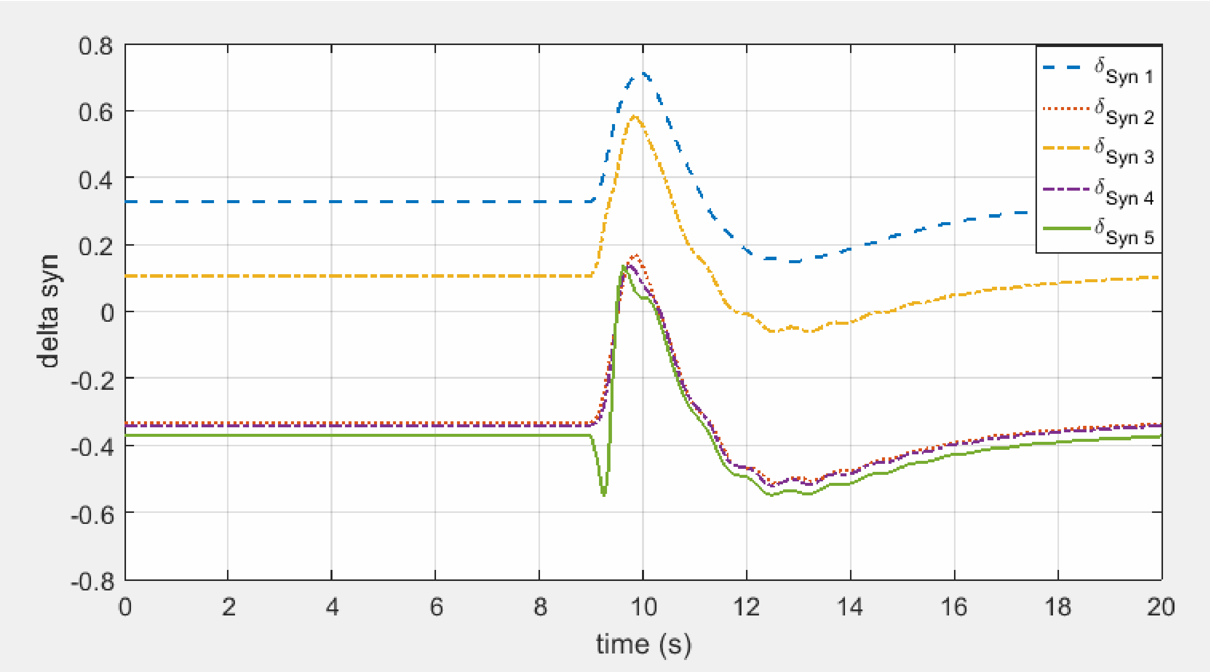

Fig. 12. Represent Delta against Time for All Generators When the Fault Occurs at Bus No.11 - without Control.

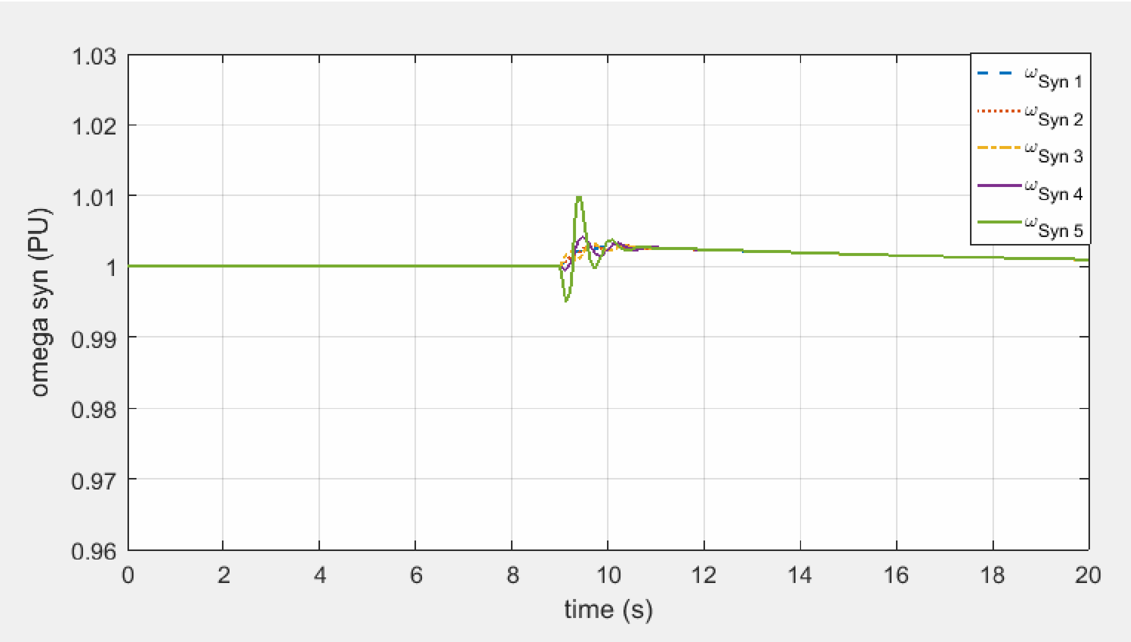

Fig. 13. Represent Speed against Time for All Generators When the Fault Occurs At Bus No.11 – Without Control

In this case, the fault that lasted for 0.25 seconds results oscillation after the fault occur for all generators in the network , AVR type 1 , TG type 2 and PSS type1 were used for re-adjusting the damping of the oscillation for all generators and the following curves indicates Delta against time and speed against time after using control devices.

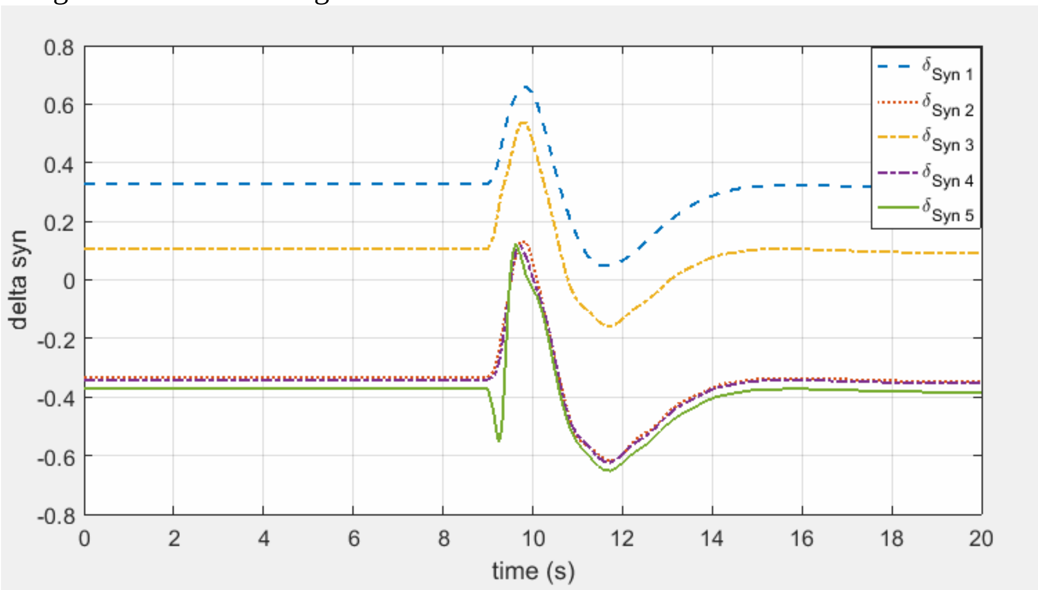

Fig. 14. Represent delta against Time for All Generators When the Fault Occurs At Bus No.11 – With AVR, TG and PSS Control are used

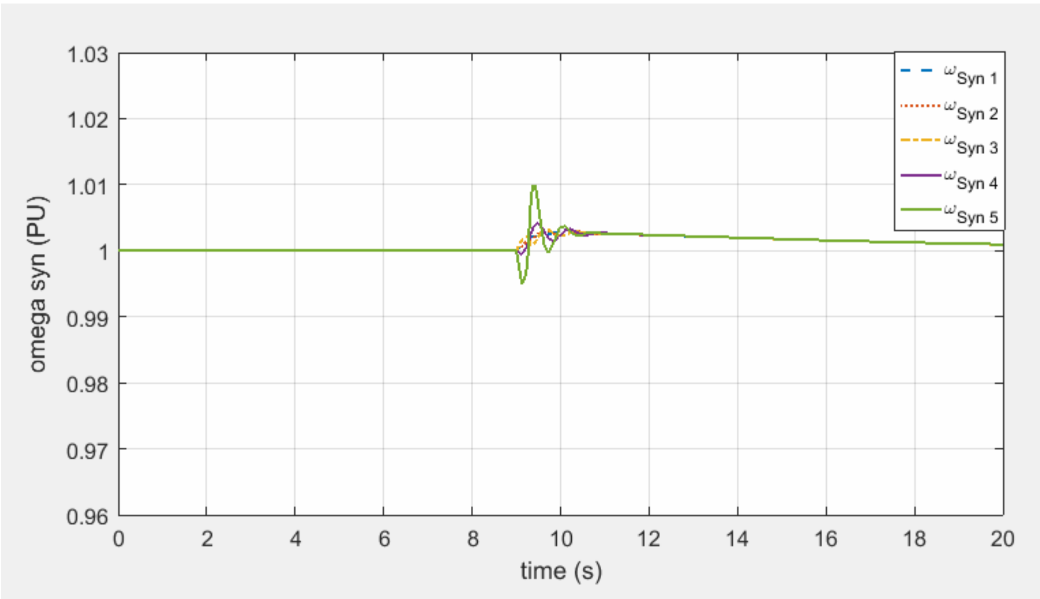

Fig. 15. Represent speed against Time for All Generators When the Fault Occurs At Bus No.3 – With AVR, TG and PSS Control are used

6.2. Case No. 2: A 3-phase short circuit at the bus No. 2. (Generator bus) occurred at 9sec and cleared at 9.25

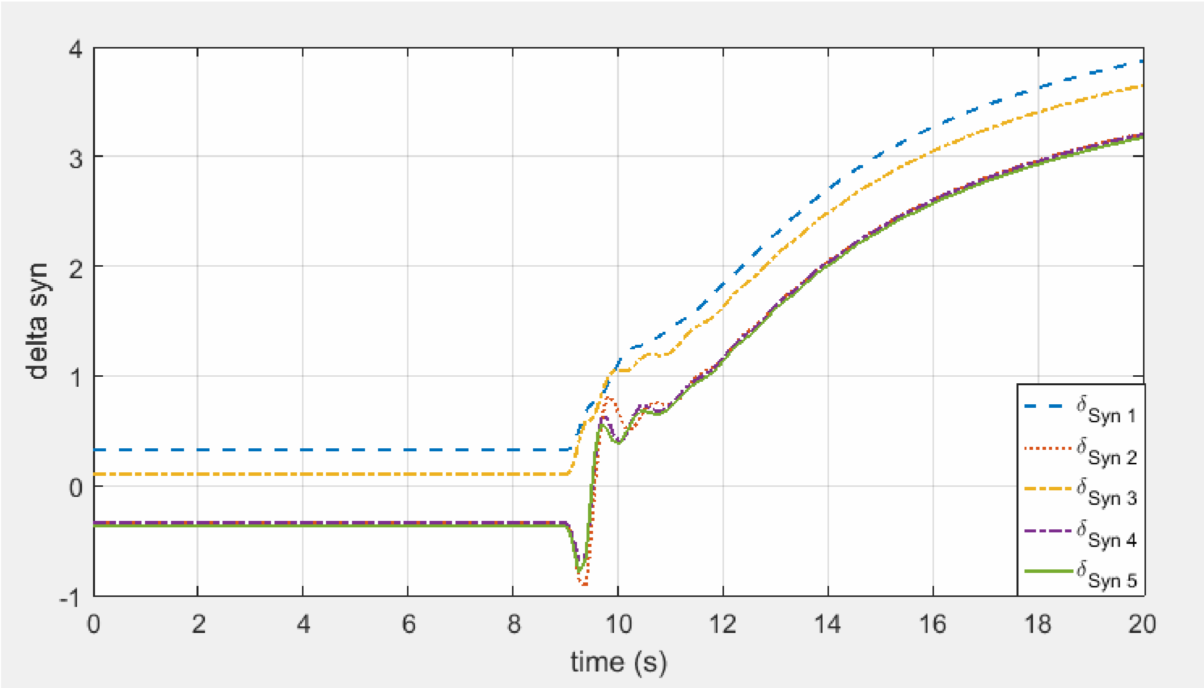

Fig. 16. Represent delta against Time for All Generators When the Fault Occurs At Bus No.2 – Without Control

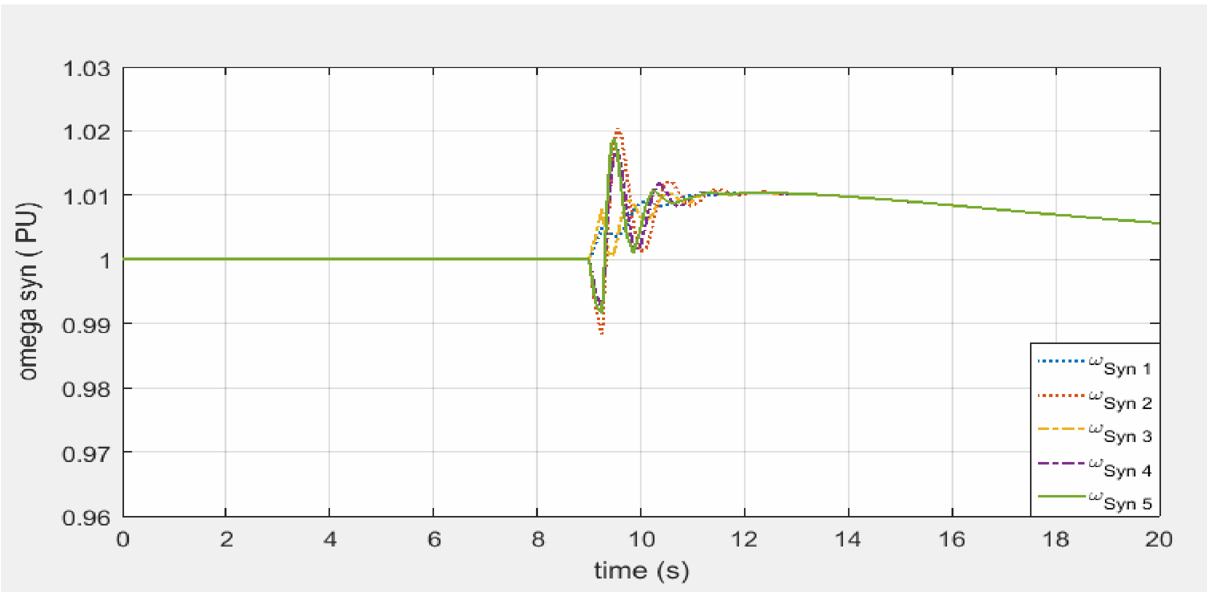

Fig.17. Represent speed against Time for All Generators When the Fault Occurs At Bus No.2 – Without Control

In this case, the fault that lasted for 0.25seconds results instability for all generators after fault occurs. AVR type 2, TG type 2 and PSS type 3 were used for re-adjusting the generators and the following curves elucidates Delta against time and speed against time after using control devices.

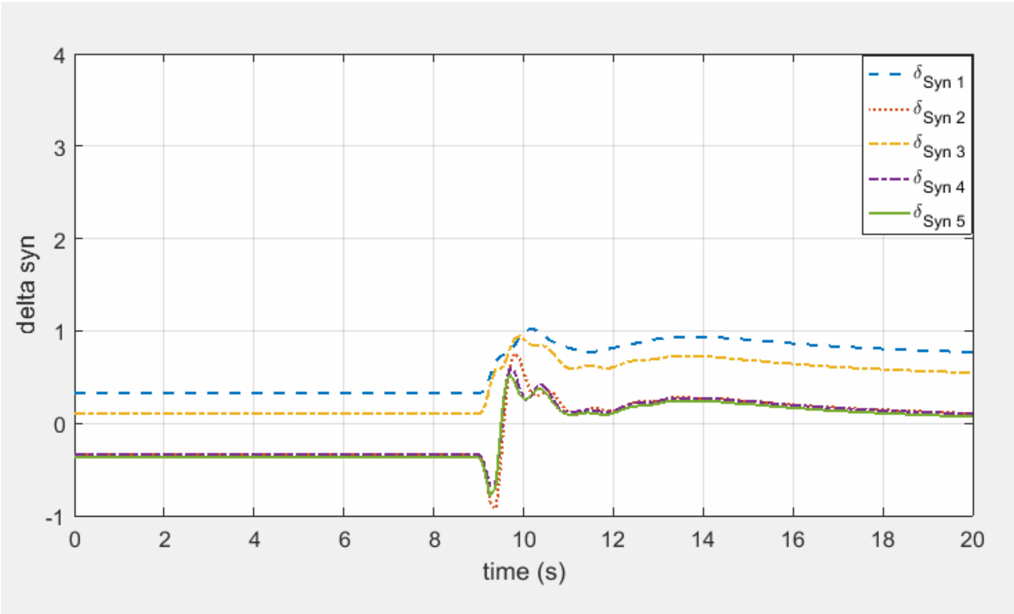

Fig.18. Represent delta against Time for All Generators When the Fault Occurs At Bus No.2 – With AVR, TG and PSS Control

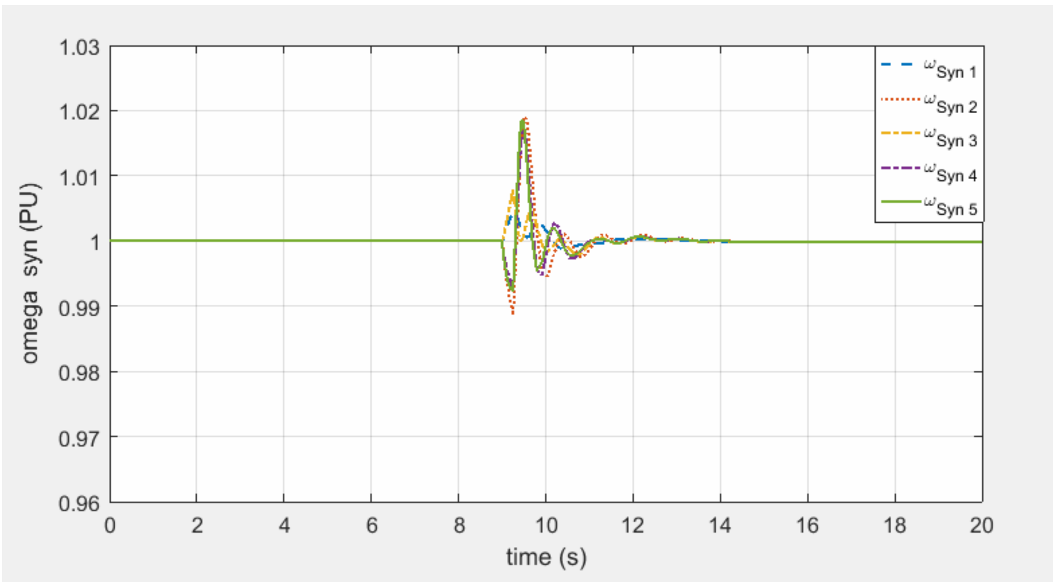

fig.19. Represent speed against Time For All Generators When The Fault Occurs At Bus No.2 – With AVR, TG and PSS Control

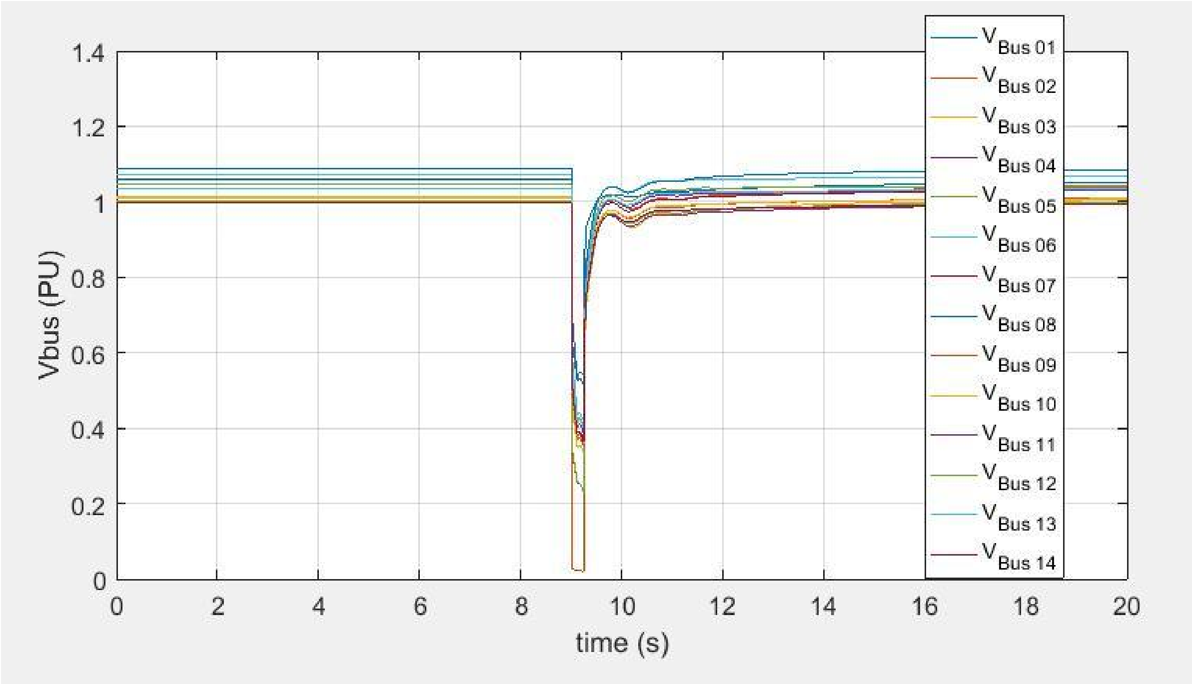

fig.20. Represent Voltage against Time For All buses When The Fault Occurs At Bus No.2 – With AVR, TG and PSS Control

6.3 Case No. 3: A line 2-4 outage from the network

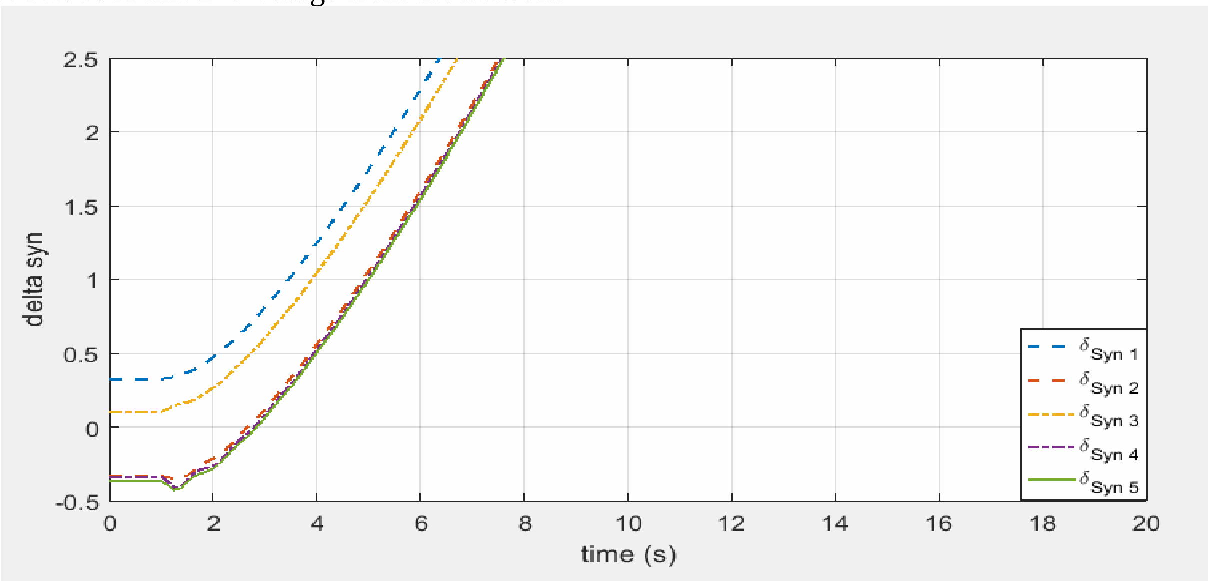

Fig.21. Represent Delta Against Time For All Generators When The Line 2-4 Outage From The Network Without Control

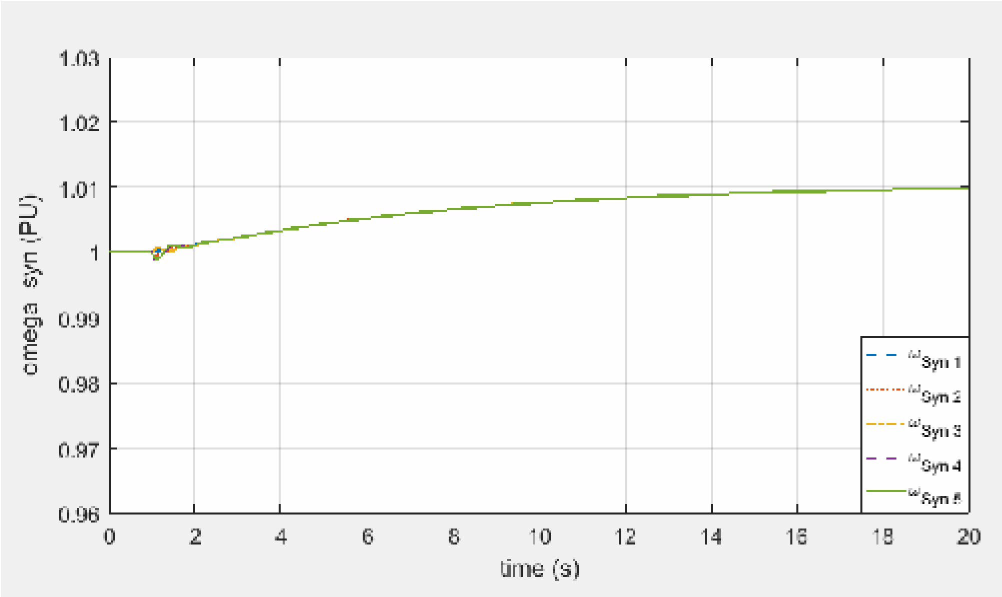

Fig.22. Represent speed against Time for All Generators When the line 2-4 outage from the network without control

In this case, after outage of the line 2-4 results instability for all generators after line 2-4 outage, AVR type 2, TG type 1 and PSS type 2 were used for re-adjusting the generators and the following curves displays Delta against time and speed against time after using control devices

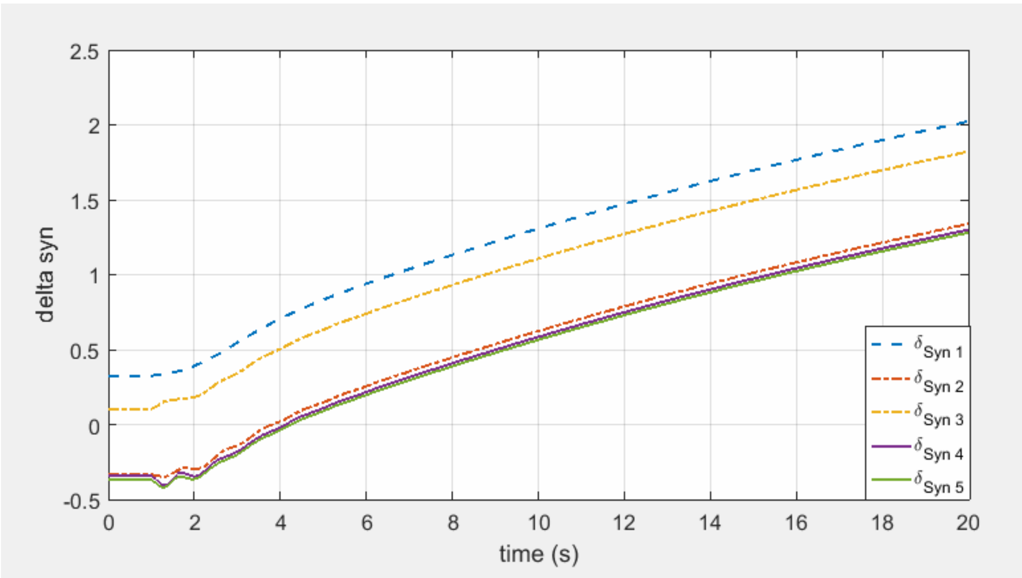

Fig.23. Represent delta against Time for All Generators When the line 2-4 outage from the network with control.

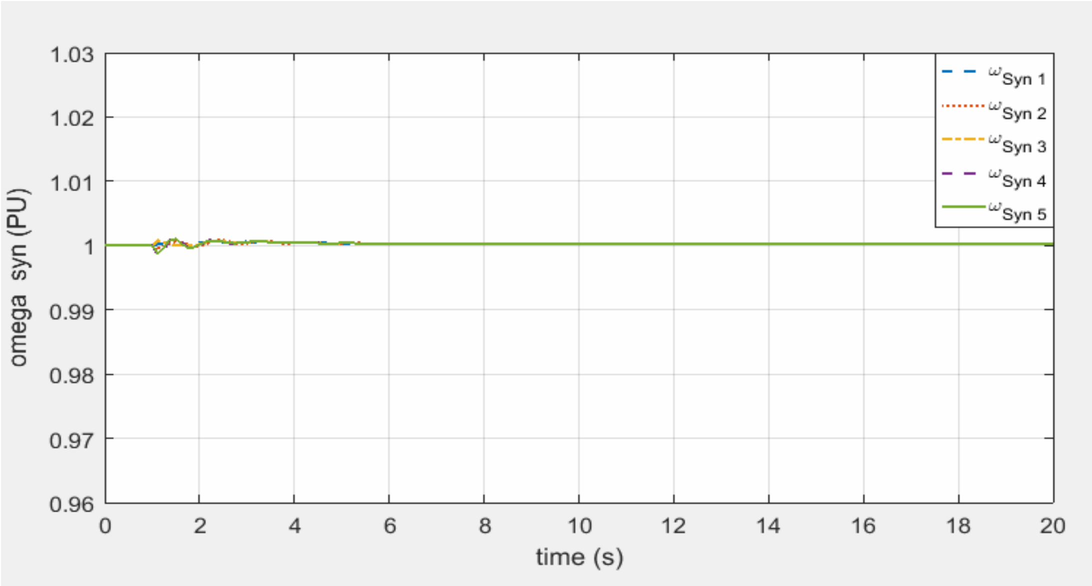

Fig.24. Represent sped against Time for All Generators When the line 2-4 outage from the network with control.

7. CONCLUSIONS

1- The three methods are used in re-adjusting control devices is a suitable controller for readjusting devices.
2- Both TG & AVR had proven effectiveness in readjusting unstable generators
3- P.S.S had proven its effectiveness in damping the oscillations that occurs in stable and unstable generators after stability.
4- The network of 14 bus and five generators had given positive and excellent results
5- This method had succeeded in re-adjusting the control equipment for instable generator in standard time.
6- Voltage profile after readjusting machines at synchronism are suitable

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