Enhancement of Iraqi National Grid Stability using Power System Stabilizers

Dr. Kosay A. Majbor* & Hayfaa M. Al- Rudayni**

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Abstract

In general, electrical power stations are constructed far from load regions because of pollution problems and using long transmission lines for high voltage. Also, the networks are connected with other networks for the purpose of transmission and to return supply the electrical energy. As a result, and because of other factors, such as sudden change in the load, oscillations occur in electrical systems, some time, these oscillations become strong and if they continue they will affect stability system.

This work is devoted to the study of the stability of the Iraqi National Grid when subjected to various operating conditions (fault: large and small load changes). Load changes produce low frequency oscillations which represent an unstable phenomenon, it is important that these oscillations are damped. Supplementary controllers (power system stabilizers, PSS type 2A) may be added to the generators controllers to improve the damping of these oscillations. Part of the work will be focused on studying the oscillation in the generators torque angles of the Iraqi Grid. Three cases of disturbances are investigated; the first is load changing, the second is Single-Line-Ground fault, and the third is three phase fault at the generator terminals.

تحسين استقارية الشبكة الوطنية العراقية باستعمال مثبات النظام الكهربائية

الخلاصة

غالبا ما يكون انشاء محطات التوليد الكهربائية بعيدة عن مناطق الحمل بسبب مشاكل التلوث و أستخدام خطوط نقل طويلة و بفولتيات فائقة و أيضا ربط الشبكات مع بعضها لغرض نقل وأعادة تجهيز الطاقة الكهربائية. و نتيجة لما ذكر وأيضا بسبب عوامل اخرى مثل التغير المفاجئ للحمل تظهر تذبذبات في الأنظمة الكهربائية ففي بعض الاحيان تكون هذه التذبذبات شديدة و اذا ما أستمرت في الزيادة سوف تؤثر في أستقرارية المنظومة.

كرس هذا البحث لدراسة أستقرارية الشبكة الوطنية العراقية تحت شروط تشغيل متعددة (عطل :تغير كبيروتغير صغير للحمل). تغيرات الحمل تنتج ذبذبات واطئة التردد التي تمثل ظاهرة غير مستقرة ,من المهم أن تخمد هذه الذبذبات.من الممكن أضافة المسيطرات التكميلية (مثبتات نظام القدرة نوع 2 A) لمسيطرات المولدات لتحسين أخماد هذه الذبذبات.

العمل الحالي هو محاولة لتمثيل مثبتات نظام القدرة في محطة القدرة لمساعدة أخماد هذه الذبذبات.جزء من العمل يركزعلى دراسة الذبذبات على زاوية عزم المولدات في الشبكة العراقية. فقد درست ثلاث حالات، الأولى مع تغير الحمل والثانية مع
عطل خطي منفرد والثالثة مع عطل ثلاثي الطورعلى طرف المولدة.

1. Introduction

The primary function of a power system is to provide real and reactive power demanded by The various loads connected to the system. The supplied power in addition to continuity, must also meet certain minimum requirements, such as:

* General Manager in Ministry of Electricity/Baghdad
** Engineering College, University of Baghdad /Baghdad

1. Constant frequency within specified limits, ± 0.5 Hz.
2. Constant voltage within specified limits, ± 5% for 400 kV, and ±10%for 132kV.
3. High reliability.
4. Purity of sinusoidal wave form.

   The basic properties of any power system are: changes in real power affect the frequency, while changes in reactive power affect essentially the voltage of the system.

   The control of the power system is divided into two separate control schemes:

   1. The mega var voltage (QV control).
   2. The mega watt frequency (Pf control).

According to this classification, a generator is equipped with two major control systems, namely Automatic Voltage Regulator (AVR) and Automatic generation control (AGC).

The main deficiency of the conventional control system are their limited ability to respond to the Low Frequency Oscillations (LFOs), which are generated in the system due to operating conditions.

1.1 Importance of stability study

The concept of "stability" for a power system may be defined as:

"Power system stability may be broadly defined as that property of a 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"[1].

From this general definition, type of stability is derived:

1. Small Signal Stability: The ability of the system to return to a normal operating state following a small disturbance (small change in loads).
2. Transient stability: The ability of the system to return to a normal operating state following a severe disturbance, such as single or multi-phase short –circuit or generator loss.

A third term, Dynamic stability has been used to describe a separate class of stability. In general different types of power system stability.

In this dissertation, the small signal and transient stability of the Iraqi Power Grid will be investigated with regard to the LFO problem.

The power system industry is a field where there are continuous changes. Power industries are restructured to cater for more users at lower prices and better power efficiency. Power systems are more complex, as they become inter-connected. Load demand also increases linearly with increase in users. Since stability phenomena limit the transfer capability of the system, there is a need to ensure stability and reliability of the power system due to economic reason [2].

The problem of interest is one where a power system operating under a steady load condition is perturbed, causing the readjustment of the voltage angles of the synchronous machines. If such an occurrence creates an in balance between the system generation and load, it results in the establishment of a new steady-state operating condition, with the subsequent adjustment of the voltage angles. The perturbation could be a major disturbance such as the loss of a generator, a fault or the loss of a line, or a combination of such events. It could also be a small load or random load changes occurring under normal operating conditions [3].

1.2 Experimental

1.2.1) Change of load Cases

Dora Station

Case one (10% change of load)

This case was applied to Dora station, under the following operating conditions:-100MW, 60 MVAR, 132kV, (10 MW change of load).

The simulation was carried out assuming the disturbance (change of load) is applied at time =1sec, while before that, the system is operating under normal steady state conditions. The performance of the system is examined for 10 sec.

The main interest when changing the load on the generation is to examine the oscillations of the generator load angle (δ) and oscillations in active power flow in the transmission lines connecting this station to other stations.

For this case, Fig. (1.a) shows the oscillations in generator's load angle with and without PSS. The performance is slightly improved when installing the PSS:

Peak over shoot without PSS= -18.895degree, peak over shoot with PSS= -18.928 degree and overshoot difference = 0.033 degree.

As for the power deviation, the improvement is pronounced as shown in Fig. (1.b).

Peak over shoot without PSS= -76.73 degree, peak over shoot with PSS= -76.86 degree, and over shoot difference = 0. 137 p.u.

Case two (30%change of load)

This case was applied to Dora station, under the following operating conditions:-100MW, 60 MVAR, 132kV, (30MW change of load).

The simulation was carried out assuming the disturbance (change of load) is applied at time =1sec, while before that, the system is operating under normal steady state conditions. The performance of the system is examined for 10 sec.

The main interest when changing the load on the generation is to examine the oscillations of the generator load angle (δ) and oscillations in active power flow in the transmission lines connecting this station to other stations.

For this case, Fig. (2.a) shows the oscillations in generator's load angle with and without PSS. The performance is slightly improved when installing the PSS:

Peak over shoot without PSS= -18.559degree, peak over shoot with PSS= -18.641 degree and overshoot difference = 0.082 degree.

As for the power deviation, the improvement is pronounced as shown in Fig (2.b):

Peak over shoot without PSS= -76.229 degree, peak over shoot with PSS= -76.559 degree and overshoot difference = 0.33 p.u.

Case three (40% change of load)

This case was applied to Dora station, under the following operating conditions:-100MW, 60 MVAR, 132kV, (40 MW change of load).

The simulation was carried out assuming the disturbance (change of load) applied at time =1sec, while before that, the system is operating under normal steady state conditions. The performance of the system is examined for 10 sec.

The main interest when changing the load on the generation is to examine the oscillations of the generator load angle (δ) and oscillations in active power flow in the transmission lines connecting this station to other stations. For this case, Fig. (3.a) shows the oscillations in generator's load angle with and without PSS. The performance is slightly improved when installing the PSS.

Peak over shoot without PSS= -18.435 degree, peak over shoot with PSS= -18.572 degree and overshoot difference = 0.137 degree.

As for the power deviation, the improvement is pronounced as shown in Fig. (3.b):

Peak over shoot without PSS = -75.945degree, peak over shoot with PSS = -76.571 degree and overshoot difference = 0. 626 p.u.

1.2.2) Single line to ground fault Conditions:Case one: Baiji Power Station

In order to evaluate the performance of the grid under transient conditions (faults), a series of simulations were carried out on different stations for both cases with and without PSS in an attempt to study the behavior of the system under these conditions, and to investigate the effect of adding PSS to the system oscillations resulting from these conditions.

For this study case, a single line to ground fault is assumed to take place at the generation bus bar (400kV side).

The time duration for the fault is assumed to be 200 mS.

The simulation was carried out assuming the disturbance (single-line-ground) is applied at time =1sec, before that the system is operating under normal steady state conditions. The performance of the system is examined for 10 sec.

The main interest, the effect of single-line-ground fault on the one generator is to examine the oscillations of the generator angle (δ) and the oscillations in active power flow in the transmission lines connecting this station to other stations.

For this case Figs. (4) And (5) show the oscillations in generator's angle and active power respectively, with and without PSS. The performance is slightly improved when installing the PSS:

Peak over shoot without PSS= 7.722 degree, peak over shoot with PSS= 7.715 degree, and overshoot difference = 0.0007 degree.

As for the power, peak over shoot without PSS= 8.98 degree, peak over shoot with PSS= 8.84 degree and overshoot difference = 0.14 p.u.

To study the effect at other stations, due to S-L-G fault, on Baiji bus bars with PSS installed at Baiji power station, the following cases are taken:

1) Hartha power station

The oscillations in generator's angle, of Hartha power station due to a Single-Line-Ground fault on Baiji bus bar, with and without PSS. The performance is slightly improved when installing the PSS, at Baiji power station:

Peak over shoot without PSS= 61.882 degree, peak over shoot with PSS= 61.288 degree and overshoot difference = 0.594 degree.

2) Dora power station

The oscillations in generator's angle, of Dora power station due to a Single-Line-Ground fault on Baiji bus bar, with and without PSS. The performance is slightly improved when installing the PSS, at Baiji power station:

Peak over shoot without PSS= 41.587 degree, peak over shoot with PSS= 41.34 degree and overshoot difference = 0.247 degree.

3) Mosul power station

The oscillations in generator's angle, of Mosul power station due to a Single-Line-Ground fault on Baiji bus bar, with and without PSS. The performance is slightly improved when installing the PSS, at Baiji power station:

Peak over shoot without PSS= 21.342 degree, peak over shoot with PSS= 18.073 degree and overshoot difference = 3.269 degree.

1.2.3) three phase short circuit fault

Case one: Baiji power station

In order to evaluate the performance of the grid under transient conditions (faults), a series of simulations were carried out on different stations for both cases with and without PSS, in an attempt to study the behavior of the system under these conditions, and to investigate the effect of adding PSS to the system oscillations resulted from these conditions.

For this study case, a three phase short circuit fault is a assumed to take place at the generation bus bar (400kV side).

The time duration for the fault is assumed to be 200 mS.

The simulation was carried out assuming the disturbance (three phase short circuit) is applied at time =1sec, while before that, the system is operating under normal steady state conditions. The performance of the system is examined for 10 sec.

The main interest, when three phase short circuit occurs in the one generator, is to examine the oscillations of the generator angle (δ) and the oscillations in active power flow in the transmission lines connecting this station to other stations.

For this case Figs. (6) And (7) show the oscillations in generator's angle and active power, with and without PSS. The performance is slightly improved when installing the PSS:

Peak over shoot without PSS= 58.821 degree, peak over shoot with PSS= 58.028 degree and overshoot difference = 0.793 degree.

As for the power, peak over shoot without PSS= 57.948 degree, peak over shoot with PSS= 54.976 degree and overshoot difference = 2.972 p.u.

To study the effect at other stations, due to three phase short circuit fault on Baiji bus bars with PSS installed at Baiji power station, the following cases are taken:

1) Dora power station

The oscillations in generator's angle, of Dora power station due to a three phase short circuit fault on Baiji bus bar, with and without PSS. The performance is slightly improved when installing the PSS, at Baiji power station:

Peak over shoot without PSS=83.386 degree, peak over shoot with PSS= 81.405 degree and overshoot difference = 1.981 degree.

2) Hartha power station

The oscillations in generator's angle, of Hartha power station due to a three phase short circuit fault on Baiji bus bar, with and without PSS. The performance is slightly improved when installing the PSS, at Baiji power station:

Peak over shoot without PSS=112.88 degree, peak over shoot with PSS= 105.94 degree and overshoot difference = 6.94 degree.

3) Mosul power station:

The oscillations in generator's angle, of Mosul power station due to a three phase short circuit fault on Baiji bus bar, with and without PSS. The performance is slightly improved when installing the PSS, at Baiji power station:

Peak over shoot without PSS=71.3 degree, peak over shoot with PSS=

70.3 degree and overshoot difference = 1degree.

1.3 Conclusions

The conclusions from this work can be summarized as follows:

1. Change of Load:
   - A low frequency oscillations, was produced as the load of Iraqi National Grid was changed by more than 10%. This is unstable state which affect on the operation of grid and it is necessary to well damp these oscillations using power system stabilizers to reach to the stable state as listed in table (1).
   - When the changing in load increase to 30% or 40%, the oscillations were increased, and the effect of using PSS in the damping of oscillations is clear in the case of 40% more than that in 30% and 10%.
2. Single Line to Ground Fault: when the grid suffering from a S-L-G fault this leads also to oscillations of low frequency. The affect of S-L-G fault on the 400 KV stations is more than its effect on the 132 KV stations as listed in table (2).
3. Three Phase Short Circuit Fault: when a grid suffering from a three phase short circuit fault (this is a worst case that the grid suffering from), it is possible to well damp these oscillations using (PSS), which its performance on grid was clear in this case. PSS helps in well damp the oscillations that results from faults in grid and improve the stability of the synchronous machines, as listed in table (3).

The region under fault had oscillations more than those results from the neighboring stations, where the fault will effect on the regions near the station, and its effect was decreased as the stations become far from the region under fault. The PSS also helps in maintenance the reliability of grid.

1.4 References

[1]. P. Kundur, ″Power System Control and Stability″, New York: McGrew-hill, Inc., 1994.

[2]. Khai Chiat THAM, ″ Power system stability″, Msc. Thesis, The University of Queensland, October 2003.

[3]. P.M. Anderson and A.A Fouad, ″ Power System Control and Stability″, New York: Mc Grew-hill, Inc.,1997.

Table (1): Summary of results for (change of load).

Percentage Load change	percentage overshoot change due to effect of using PSS	
	Bus angle	Active power
10 %	- 0.174	- 0.169
30 %	-0.441	- 0.432
40 %	- 0.743	- 0.824

Table (2): Summary of results for Single-Line-Ground fault.

Station	**Percentage Improvement with PSS Due to effect of using PSS**	
	load angle	**line power**
1. Baiji	0.09	1.559
Dora	0.593	
Hartha	0.959	
Mosul	15.317	
2. Hartha	1.353	4.538
Baiji	3.278	
Dora	1.206	
Mosul	1.522	

Table (3): Summary of results for three phase short circuit fault.

Station	**Percentage Improvement with PSS Due to effect of using PSS**	
	load angle	line power
1. Baiji	1.348	5.128
Dora	2.375	
Hartha	6.148	
Mosul	1.402	
2. Dora	7.839	
Baiji	2.411	
Hartha	2.353	
Mosul	3.192	
3. Hartha	**4.552**	**26.438**
Baiji	4.245	
Dora	4.267	
Mosul	3.365	

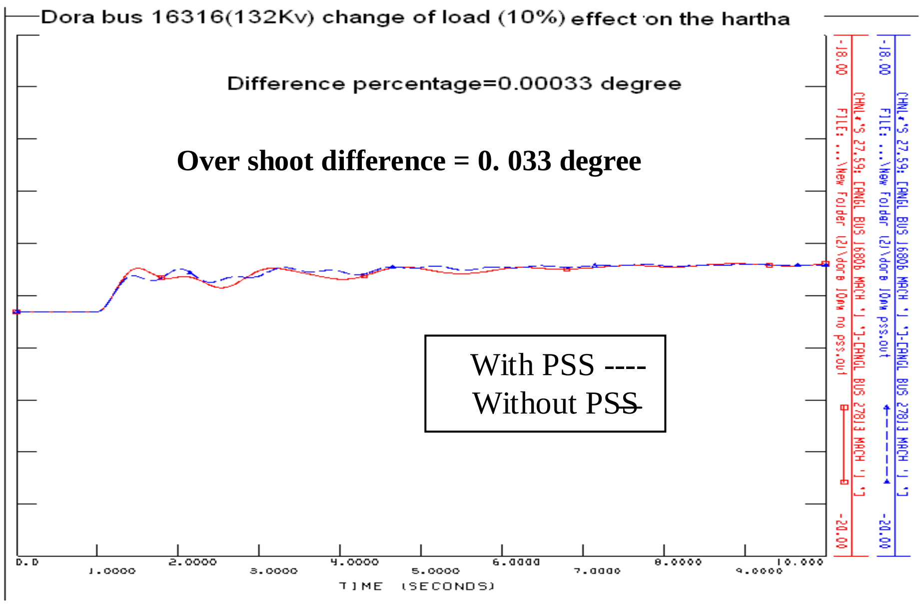

Figure (1.a) Oscillations in load angle at Dora bus bar for a 10% load change.

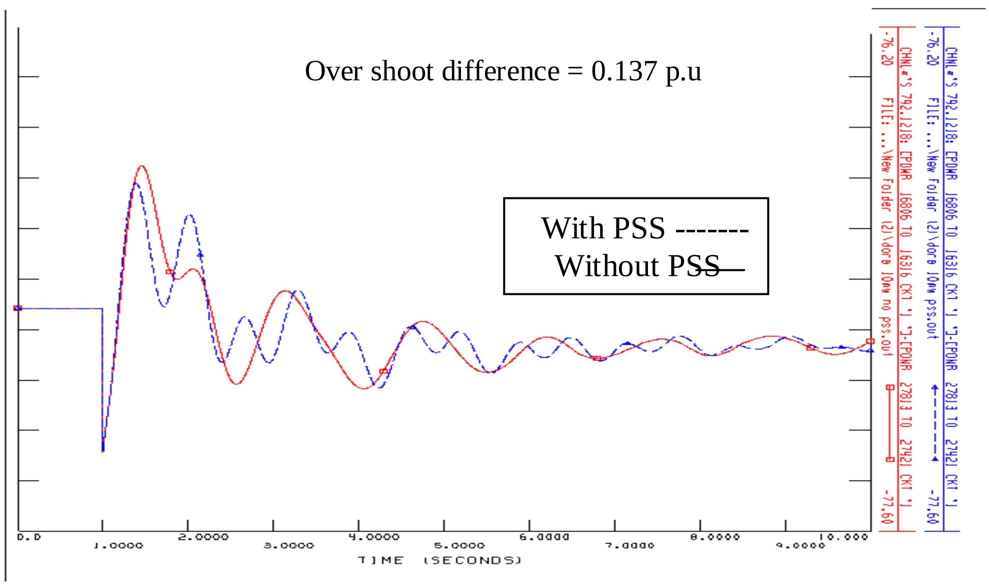

Figure (1.b) Active Power Oscillations in the line for a load change of 10%.

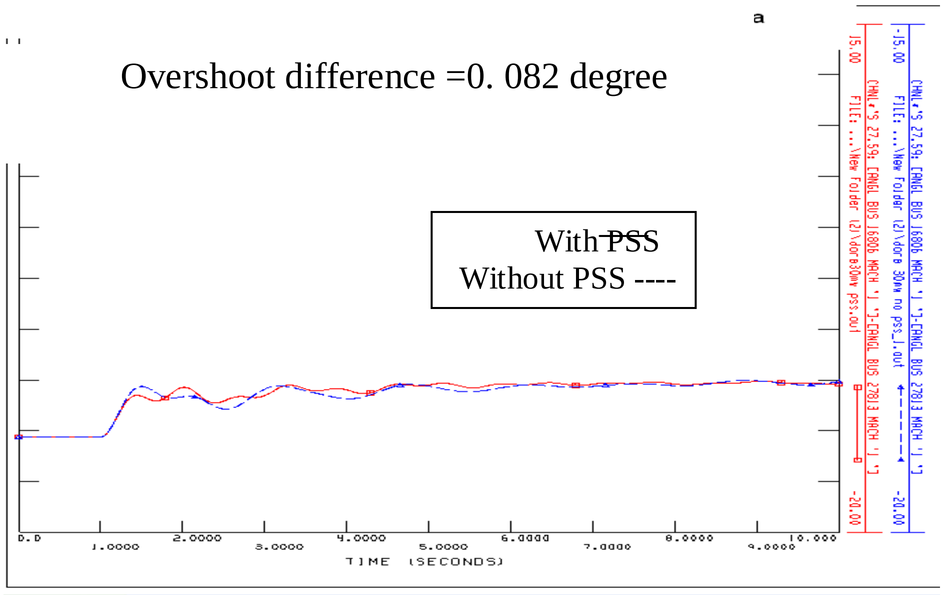

Figure (2.a) Oscillations in load angle at Dora bus bar for a 30% load change.

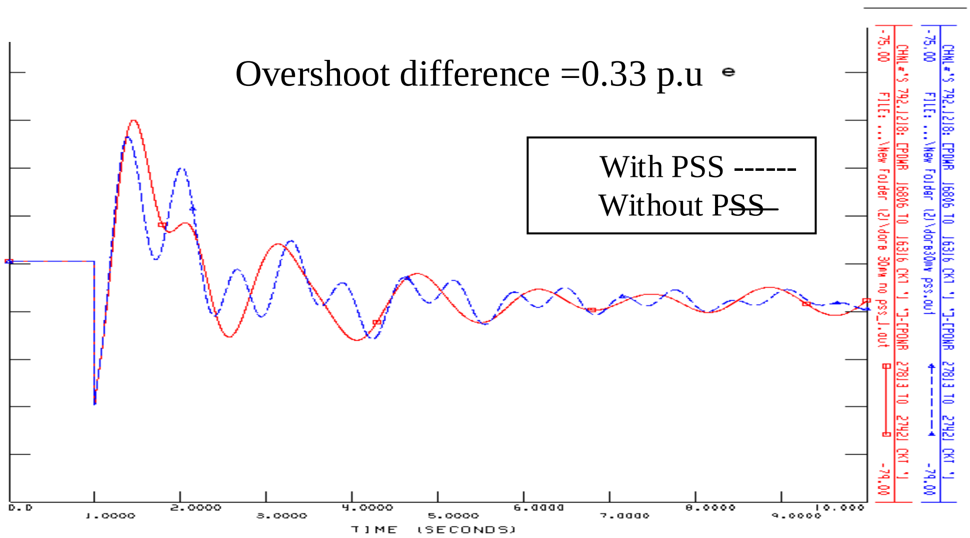

Figure (2.b) Active Power Oscillations in the line for a load change of 30%.

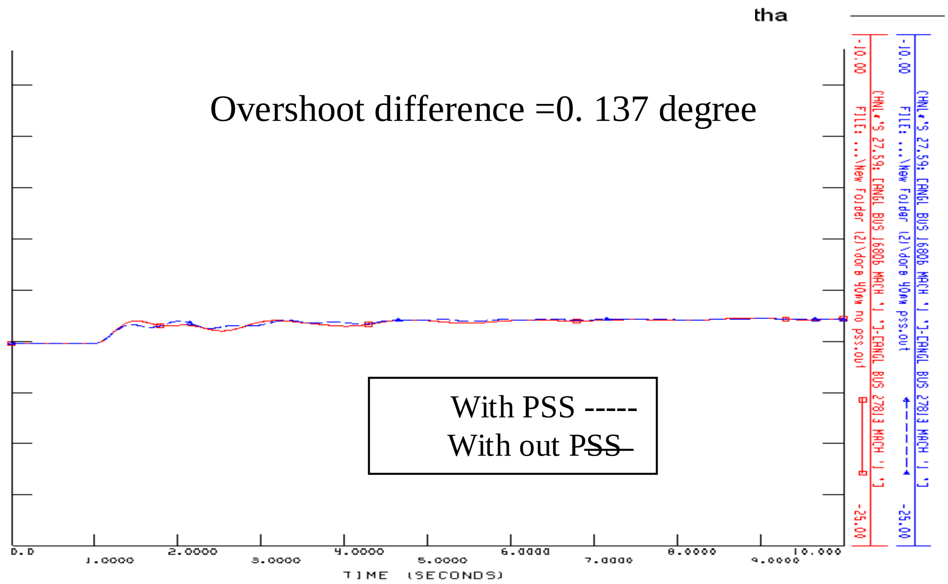

Figure (3.a) Oscillations in load angle at Dora bus bar for a 40% load change.

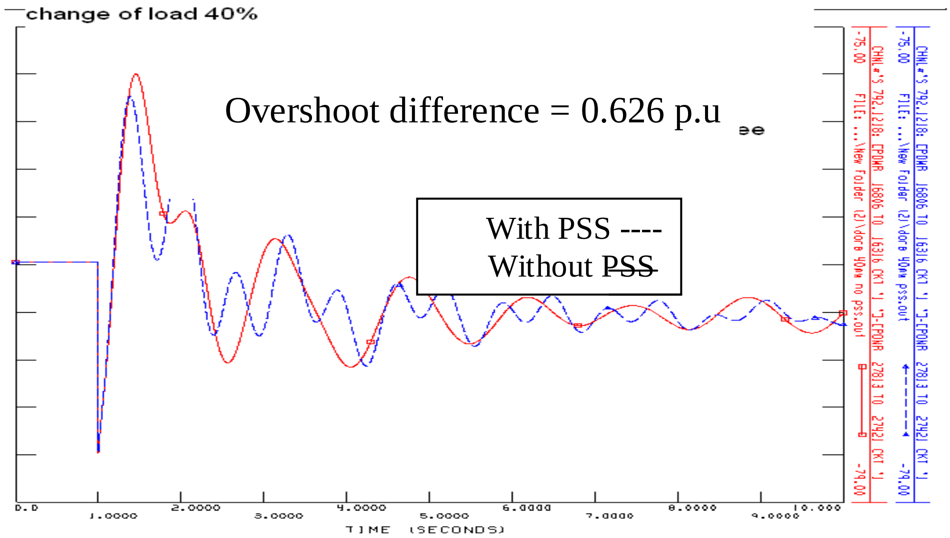

Figure (3.b) Active Power Oscillations in the line for a load change of 40%.

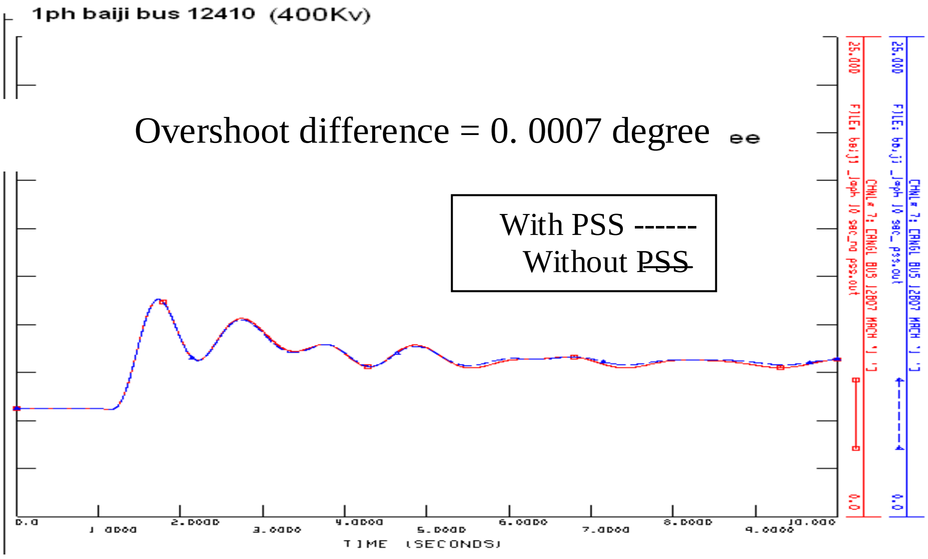

Figure (4) Oscillations in load angle at Baiji power station for S-L-G fault.

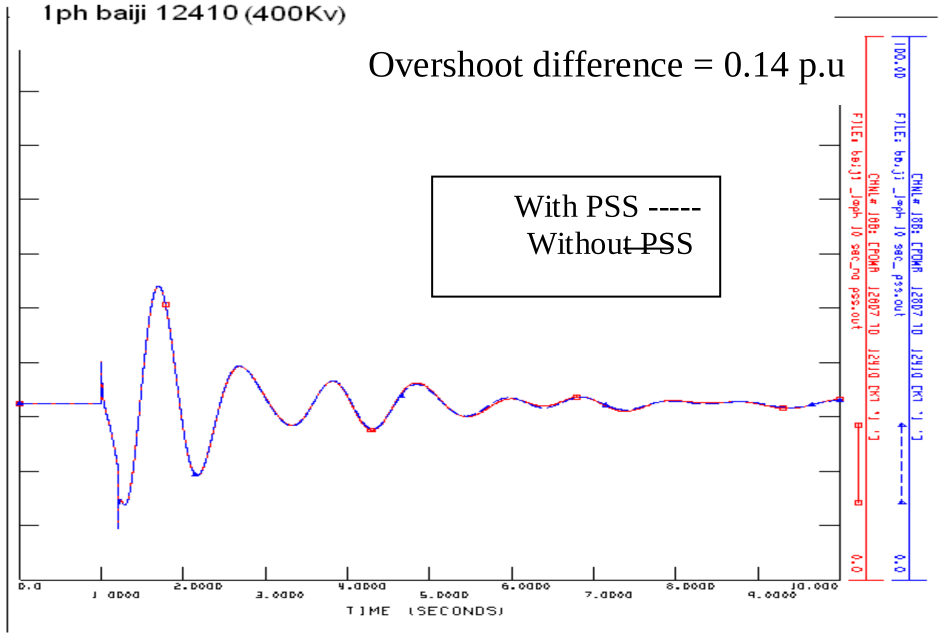

Figure (5) Power oscillations at Baiji power station due to S-L-G fault at bus bar.

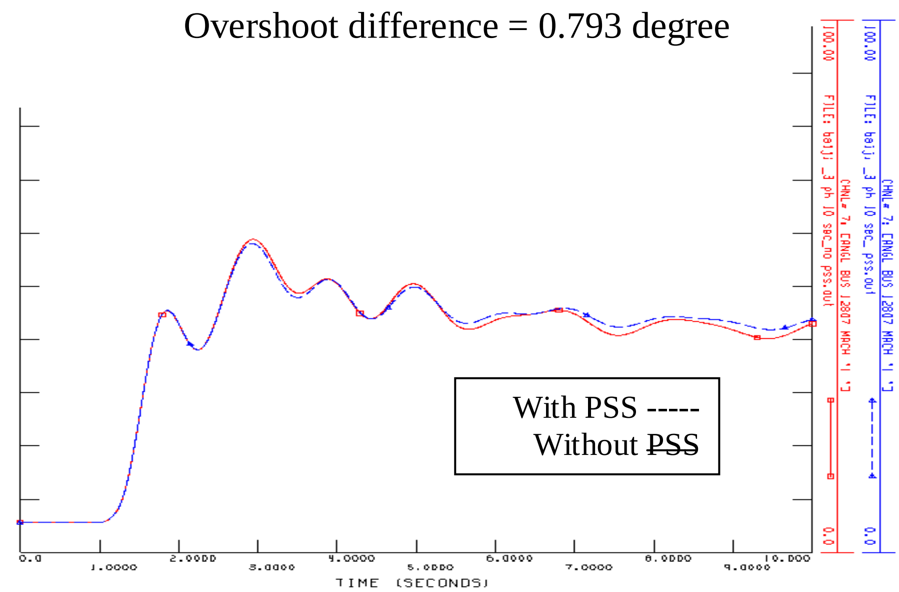

Figure (6) Oscillations in load angle at Baiji power station for three phase fault.

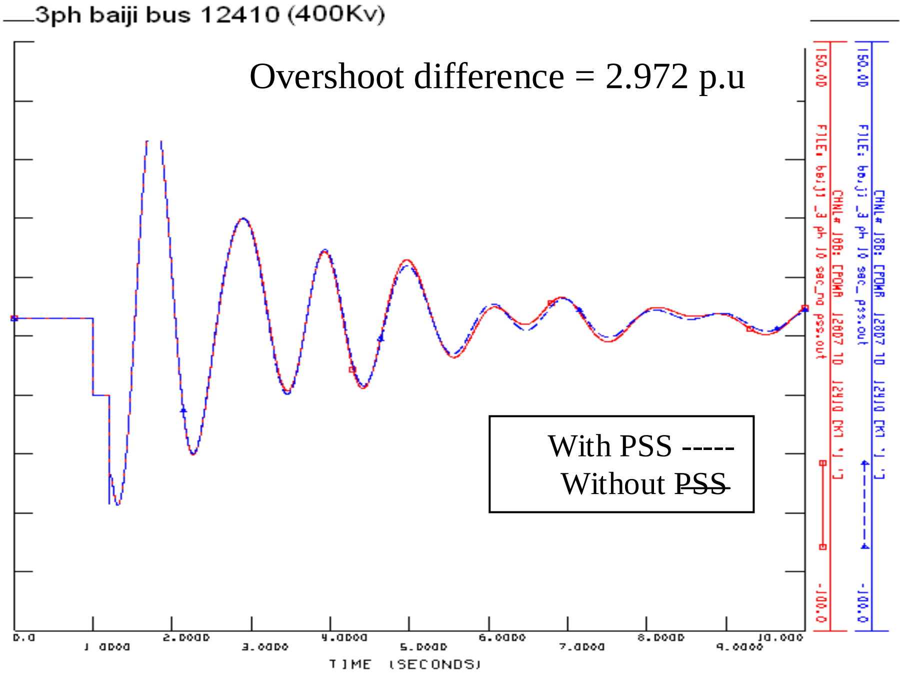

Figure (7) Power oscillations at Baiji power station due to three phase fault at bus bar.