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Increase of Transient Stability of Thermal Power Plant with Power System Stabilizer

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ABSTRACT: This paper describes the effect of Power System Stabilizers (PSS) on transient stability of thermal power plant power system after occurrence of disturbance in power system. Studies have been carried out for a thermal power plant having 2 nos. identical generating units. A dynamic model of the Kawai Super Critical Thermal Power Plant situated in the Southern Rajasthan is adopted to simulate the effect of PSS for damping of power system oscillations. Simulation studies indicate that AVR having supplementary control signal from PSS, transient stability of power system increase. Power oscillations damp out faster. Frequency of generators rapidly reach in steady state condition.

Key words: Power system stabilizers (PSS), Automatic voltage regulator (AVR).

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1.0 INTRODUCTION

Power System Stabilizers (PSS) are the most well-known and efficient devices to damp the power system oscillations caused by interruptions. The transient stability of a system can be improved by providing suitably tuned power system stabilizers on selected generators to provide damping to critical oscillatory modes. Suitably tuned Power System Stabilizers (PSS), will introduce a component of electrical torque in phase with generator rotor speed deviations resulting in damping of low frequency power oscillations in which the generators are participating. The input to stabilizer signal may be one of the locally available signals such as changes in rotor speed, rotor frequency, accelerating power, electrical power output of generator or any other suitable signal. This stabilizing signal is compensated for phase and gain to result in adequate component of electrical torque that results in damping of rotor oscillations and thereby enhance power transmission and generation capabilities. Constantly increasing intricacy of electric power systems, has enhanced interests in developing superior methodologies for Power System Stabilizers (PSS). Transient and dynamic stability considerations are among the main issues in the reliable and efficient operation of power systems. Low Frequency Oscillation (LFO) modes have been observed when power systems are interconnected by weak tie-lines. The LFO mode, with weak damping, is also called the electromechanical oscillation mode, and it usually happens in the frequency range of 0.1 to 2 Hz. PSSs are the most efficient devices for damp out these oscillations.

2.0 POWER SYSTEM DATA

2×660 MW Coal based Kawai power plant is situated in Baran District of Rajasthan. Both the units are generating power at 22 kV voltage level and stepped up to 400 kV voltage level through 2x850 MVA, 22/400 kV generating transformers. Following are the major interconnections with the Kawai power plant to the Rajasthan grid:-

- 400 kV S/C twin moose conductor line from Kawai power plant to Chhabra power plant with a line length of 45 km.
- 400 kV D/C quad moose conductor line from Kawai power plant to Anta 765 kV GSS with a line length of 50 km.

Rajasthan power system power map is placed in Fig-1.

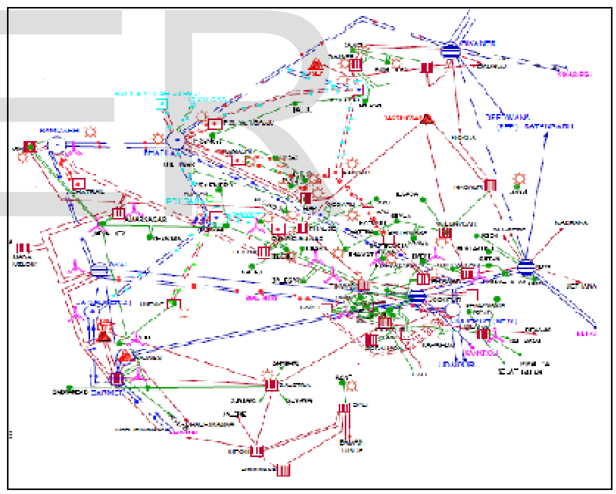

Fig-1: Rajasthan Power System

Single line diagram of power system network in the vicinity of Kawai Power plant with load flow study results is placed in figure-2.

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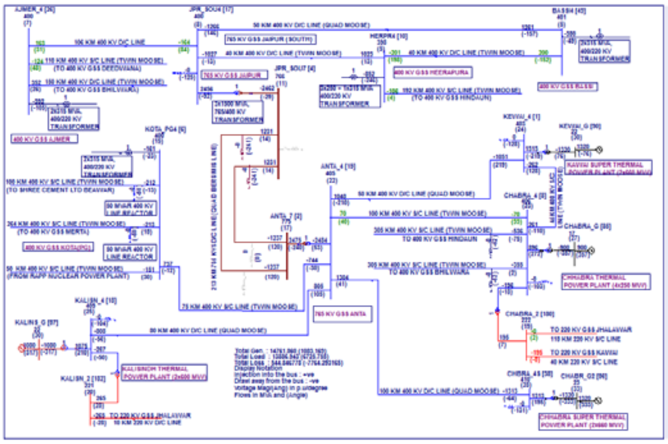

Figure-2: Single line diagram of power system for simulation

Transmission line parameters

Based on data available on transmission design followed by RRVPNL, per kilometer per circuit line parameters in ohm are given in Table-1

Table-2: Transmission Line Parameter

Description	Conductor type			
Conductor type	Quad Bersmis	Quad Moose	Twin Moose	Zebra
Voltage Rating	765	400	400	220
Positive sequence resistance	0.0114	0.0168	0.0297	0.07487
Positive sequence reactance	0.2618	0.266	0.332	0.399
Positive sequence half line charging susceptance in mho/km/ckt	2.05e-06	2.5 e-06	1.73 e-06	1.46e-06
Zero sequence resistance	0.2633	0.16192	0.16192	0.219976
Zero sequence reactance	1.0534	1.24	1.24	1.339228
Zero sequence half line charging susceptance in mho/km/ckt	1.20e-06	1.16e-06	1.12e-06	9.20e-007

Generator Parameters

There are 2 units of 660 MW rating at the Kawai power plant. Generator parameters are same for both generators. Generator parameter are given in Table-2.

Table-2: Generator Parameters

S. No.	Parameter Description	**Value**
1	MW rating	660
2	MVA rating	775
3	No. of units	2
4	Rated voltage in kV	22
5	Rated power factor	0.85 (Lag)
6	Armature Resistance (Ra) in pu (Stator Resistance per phase at 75 C)	0.0026 pu
7	Negative Sequence Reactance (Unsaturated)	0.21295 pu
8	Potier Reactance	0.126 pu
9	Zero Sequence Reactance (Unsaturated)	0.10131 pu
10	Direct Axis Reactance (Xd) (unsaturated)	2.40313 pu
11	Direct Axis Transient Reactance (Xd') (Unsaturated)	0.28281 pu
12	Direct Axis Sub- Transient Reactance (Xd") (Unsaturated)	0.21582 pu
13	Quadrature Axis Reactance (Xq) (unsaturated)	2.33924 pu
14	Quadrature Axis Transient Reactance (Xq') (Unsaturated)	0.40802 pu
15	Direct Axis Sub- Transient Reactance (Xq") (Unsaturated)	0.21007 pu
16	Direct Axis Transient Open Circuit Time Constant (T'do) (Unsaturated)	8.724 s
17	Direct Axis Sub – Transient Open Circuit Time Constant (T"do) (Unsaturated)	0.046 s
18	Quadrature Axis Transient Open Circuit Time Constant (T'qo) (Unsaturated)	0.969 s
19	Quadrature Axis Sub – Transient Open Circuit Time Constant (T"qo) (Unsaturated)	0.068 s
20	Generator Inertia Constant H (Generator +turbine + governor +excitation system) in MJ/MVA	2.70

Exciter System Details

The main function of AVR is to automatically adjust the field current of the synchronous generator to maintain the terminal voltage within continuous capability of the generator. Both the generating units have the identical excitation systems i.e. AC excitation system (Field controlled alternator rectifier excitation system). The rectifier in this excitation system is stationary and is fed from the generator terminal. The voltage regulator controls the firing angles of the thyristors and converts AC in to appropriate DC. This DC supply is fed to field winding of the alternator through slip rings. The block diagram of the excitation system in the Fig-3.

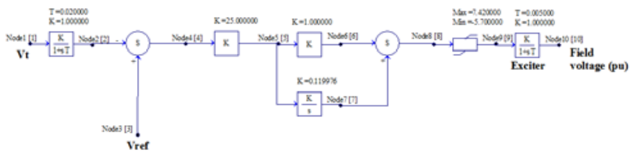

Figure-3: Block diagram of Excitation System

The Excitation system parameters are same for both units. Excitation parameters are given in table-3.

Table 3: Excitation system Parameters

Constant	Name	Parameter Value
KA	Exciter Gain	25
TR	Amplifier time constant in s	0.02
TA	Integral Time Constant	8.335
TS	Gate Control Unit and Converter Time Constant	0.005
Ukmax	Maximum voltage in pu	7.42
Ukmin	Minimum voltage in pu	-5.7

Power system Stabilizer

High performance excitation systems are essential for maintaining steady state and transient stability of modern synchronous generators, apart from providing fast control of the terminal voltage. But the fast acting exciters with high AVR gain can contribute to oscillatory instability in the power systems. This type of instability is characterized by low frequency (0.1 to 3 Hz) power oscillations which can persist (or even grow in magnitude) for no apparent reasons. This type of instability can endanger system security and limit power transfer. The major factors that contribute to the instability are

- Loading of the generator or Tie line
- Power transfer capability of transmission lines
- Power factor of the generators (Leading power factor operation is more problematic than the lagging power factor)
- AVR gain

A cost effective and satisfactory solution to the problem of oscillatory instability is to provide damping for generator rotor oscillations. This is conveniently done by providing Power System Stabilizers (PSS) which are supplementary controllers in the excitation systems. This supplementary signal is derived from rotor velocity, frequency, electrical power or combination of these variables.

PSS Block Diagram

The block diagram of PSS used in the Kawai power plant is shown in Fig-4. Both the units in power plant have the same type of PSS.

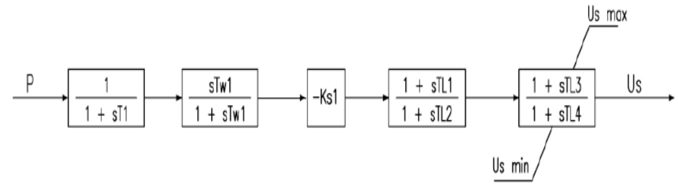

Fig 4: PSS Block Diagram

The input to the PSS is electrical power (active) which is derived from the terminal of the generator. Each synchronous generator has the same input arrangement and the output of the PSS will act as a supplementary signal to AVR as shown in Fig-5. The PSS block diagram consists of Wash out circuit, dynamic lead lag compensators, and a limiter to limit the absolute value of PSS output.

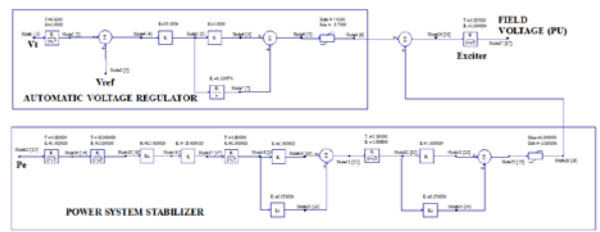

Fig-5: AVR with PSS Block Diagram

Washout Circuit

The washout circuit is provided to eliminate steady state bias in the output of PSS which will modify the generator terminal voltage. The PSS is expected to respond only to transient variations in the input signal and not to the DC offsets in the signal. The washout circuit acts essentially as a high pass filter and it must pass all frequencies that are of interest.

Dynamic Compensator

The dynamic compensator consists of lead lag (phase) compensator blocks. The phase compensation block provides the appropriate phase lead characteristic to compensate for the phase lag between exciter input and the generator electrical (air-gap) torque. The dynamic compensator as shown in Fig-4 has two lead lag stages. The time constants, T1 to T4 in the lag lead circuit are to be chosen from the requirements of the phase compensation to achieve desired damping torque. The gain of the PSS is to be chosen to provide adequate damping of all critical modes under various operating conditions. It is to be noted that PSS is tuned at a particular operating condition (full load condition with strong or weak AC system) which is most critical. Although PSS may be tuned to give optimum damping under such condition, the performance will not be optimal under other conditions.

Limiter

The output of the PSS must be limited to prevent the PSS acting to counter the action of the AVR. For example, when load rejection takes place, the AVR acts to reduce the terminal voltage

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when PSS action calls for higher value of the terminal voltage. It may be desirable to trip the PSS in case of load rejection. The negative limit of PSS output is of importance during back swing of the rotor (after initial acceleration is over). The AVR action is required to maintain the voltage (and thus prevent loss of synchronism) after the angular separation has increased. The PSS action in the negative direction must be curtailed more than in the positive direction. PSS available at the Kawai Power plant has the following setting limits with actual settings.

Table 4: PSS parameter settings range with actual settings

Parameter	Description	Unit	Range	Actual Settings
T1	Filter Time constant	s	0.003~0.02	0.02
TW1	Washout Time Constant	s	0.01~15	15
Ks1	PSS Gain Factor	pu	0.1~100	-50
TL1	Time constant of conditioning network	s	0.01~10	0.05
TL2	Time constant of conditioning network	s	0.01~10	0.1
TL3	Time constant of conditioning network	s	0.01~10	0.05
TL4	Time constant of conditioning network	s	0.01~10	0.1
Usmax	Upper limit of stabilizing Value	pu	100%	+1.0
Usmin	Lower limit of stabilizing Value	pu	100%	-1.0

3.0 SIMULATION RESULTS

Faults of varying severity are simulated and stability of Kawai plant generators is investigated without and with PSS. Plots of following parameters of generators are analyzed :-

- Electrical power output
- Swing curve
- Frequency variation
- Terminal voltage
- Field voltage
- Power flow on 400 kV D/C Kawai –Anta line
- Power flow on 765 kV S/C Anta – Jaipur line

Case 1: Three phase fault at Anta 400 kV bus created at 1.0 sec and cleared at 1.1 sec

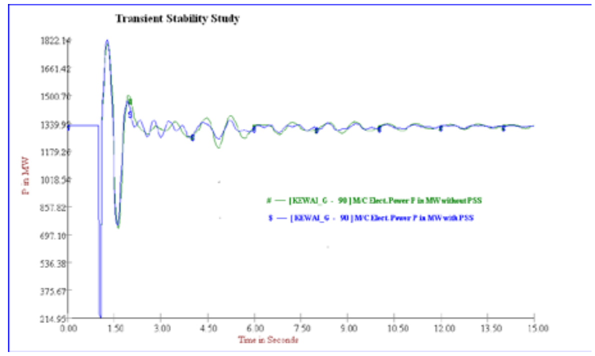

Fig-6: Electric power variation of Generators

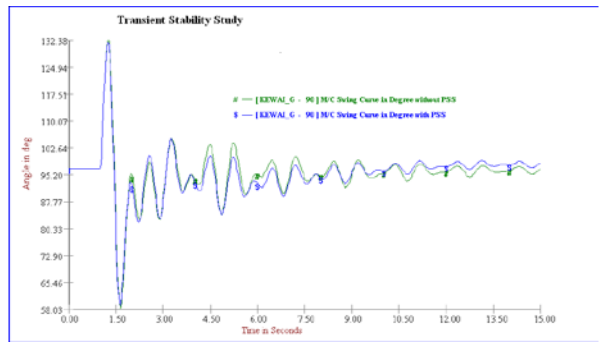

Fig-7: Swing curve of Generators

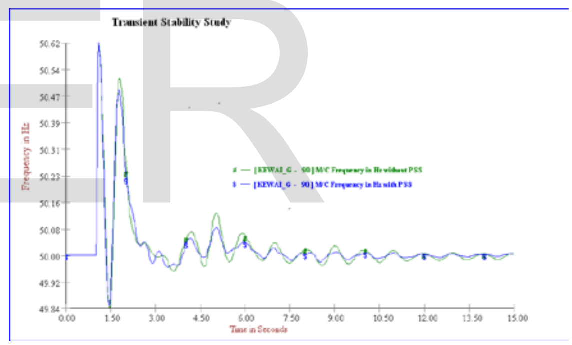

Fig-8: Frequency variation of Generators

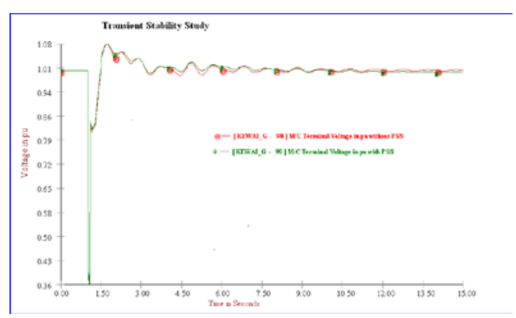

Fig-9: Terminal voltage variation of Generators

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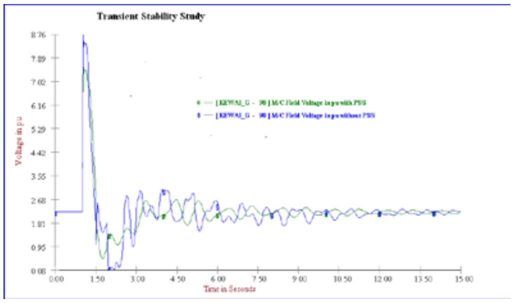

Fig-10: Electric field voltage variation of Generators

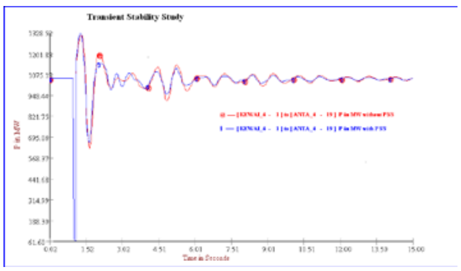

Fig-11: Power flow on 400 kV D/C Kawai – Anta line

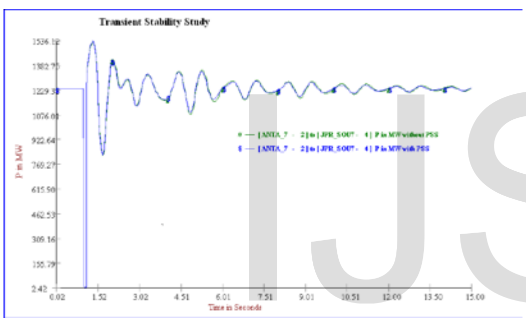

Fig-12: Power flow on 765 kV S/C Anta-Jaipur line

Case 2: Three Phase to ground fault at Anta 400 kV bus created at 1.0 sec and cleared at 1.1 sec

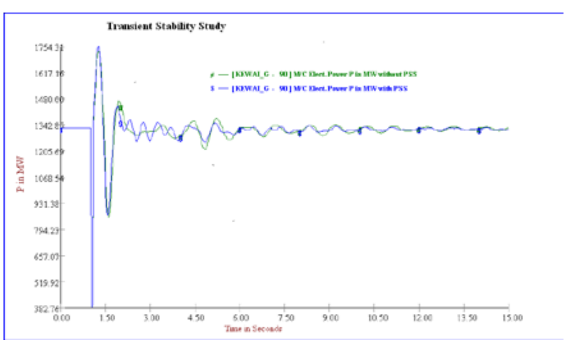

Fig-13: Electric power variation of Generators

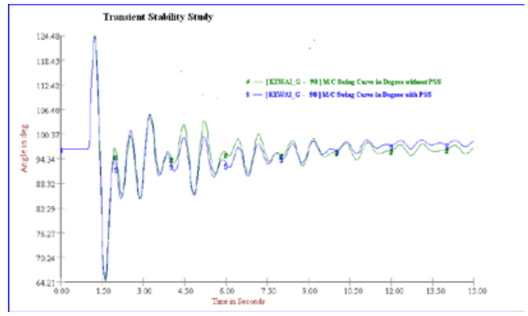

Fig-14: Swing curve of Generators

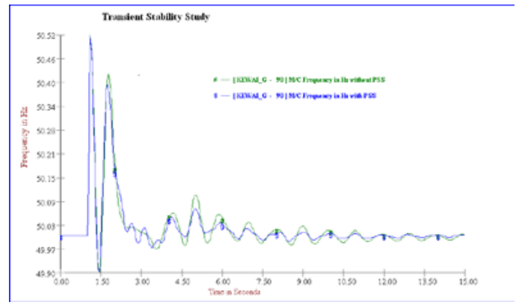

Fig-15: Frequency variation of Generators

Fig-16: Terminal voltage variation of Generators

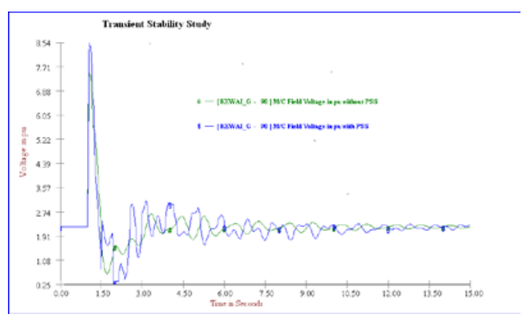

Fig-17: Electric field voltage variation Generators

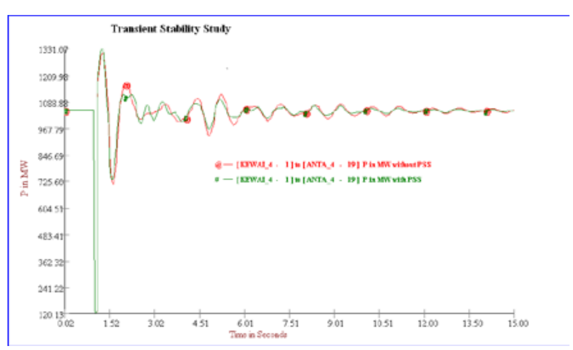

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Fig-18: Power flow on 400 kV D/C Kawai – Anta line

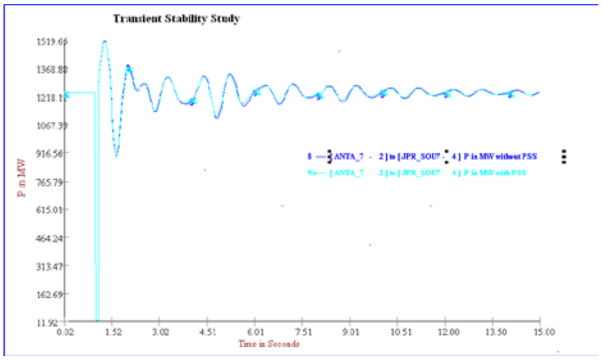

Fig-19: Power flow on 765 kV S/C Anta-Jaipur line

Case 3 : Three Phase to ground fault at Jaipur 765 kV bus created at 1.0 sec and cleared at 1.1 sec

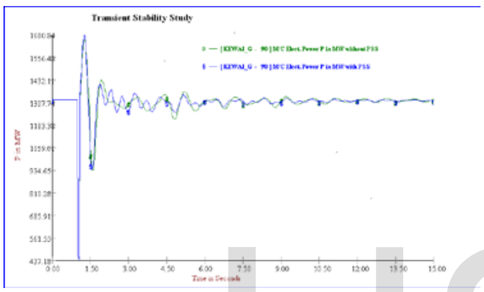

Fig-20: Electric power variation of Generators

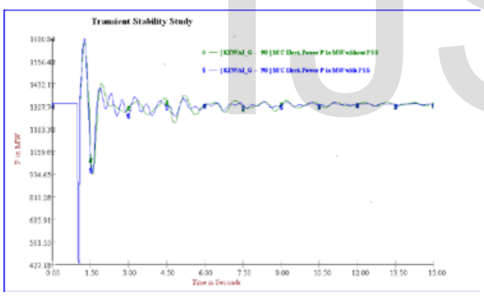

Fig-21: Swing curve of Generators

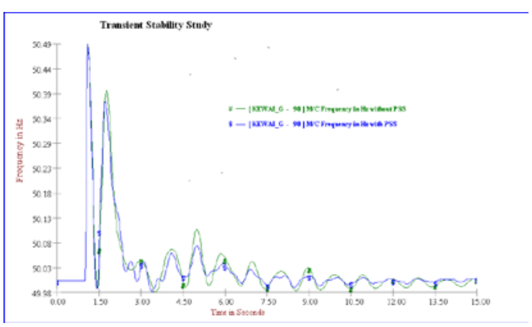

Fig-22: Frequency variation of Generators

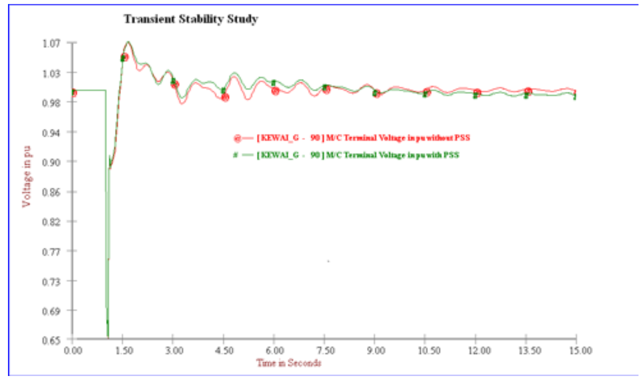

Fig-23: Terminal voltage variation of Generators

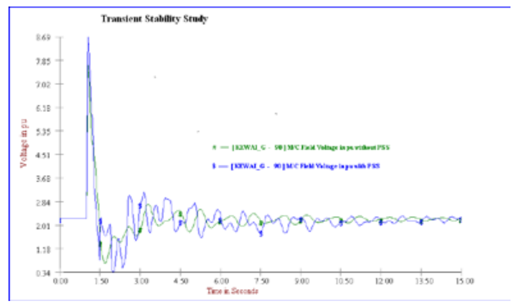

Fig-24: Electric field voltage variation of Generators

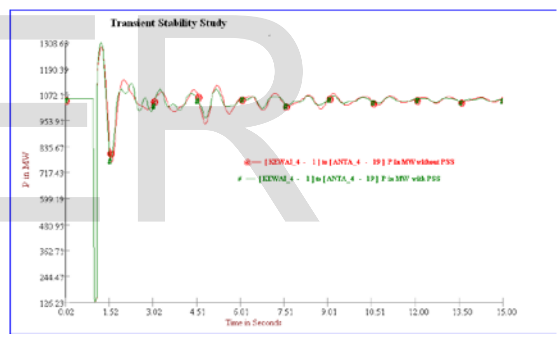

Fig-25: Power flow on 400 kV D/C Kawai – Anta line

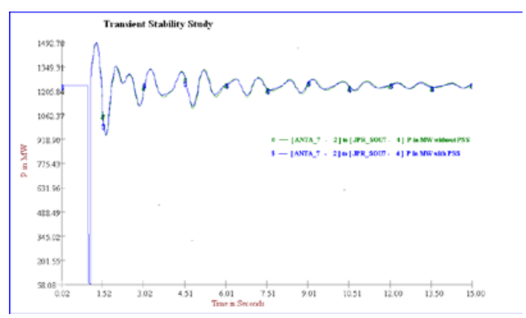

Fig-26: Power flow on 765 kV S/C Anta-Jaipur line

4.0 OBSERVATIONS

1. With PSS, initial peak in the electrical power output is slightly more than without PSS due to the fact that under faulty condition, the voltage is reduced and at the same time active power output also reduces. Since the AVR and PSS action under this condition is to increase the power output of the generator. This is due to the peculiar design of the AVR-PSS module where in the output

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signal of the PSS is added at the field voltage rather than at the generator reference voltage. But it is also noted that, the oscillations in the electrical power output subsequent to the first peak are better damped. The oscillations in the electrical power are rapidly damped with PSS.

2. Swing curves indicate that with PSS, maximum oscillation in power angle of generators are reduce in first as well as subsequent swings. The oscillations in the generators power angle are rapidly damped with PSS as compared to without PSS.
3. Frequency curves indicate that oscillations in the generators frequency is reduce in first as well as subsequent swings. The oscillations in the generators frequency are rapidly damped with PSS.
4. With PSS, generator field voltage is increase due to addition of PSS output in the AVR output so that oscillations in the generator speed can be damped out.
5. Reduction in generators terminal voltage is less with PSS as compared to without PSS.
6. Power oscillations in transmission lines are less with PSS as compared to without PSS.

5.0 CONCLUSION

In this paper simulation studies have been carried out for a thermal power plant having 2 nos. identical units for different types of faults to find out the effect of power system stabilizers on transient stability of power system. Studies have been performed without and with PSS for different types of faults in the power system. Simulation studies indicate that AVR having supplementary control signal from PSS, transient stability of power system increase. Power oscillations damp out faster. Frequency of generators rapidly reach in steady state condition. Maximum swing in power angle and power swing in transmission lines are also reduced.

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