MITSUBISHI ELECTRIC CORPORATION
HEAD OFFICE: TOKYO BUILDING, 2-7-3, MARUNOUCHI, CHIYODA-KU, TOKYO 100-8310, JAPAN

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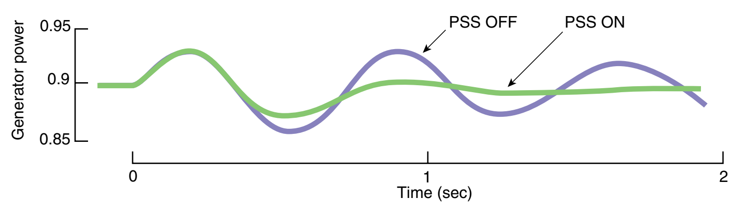
Changes for the Better

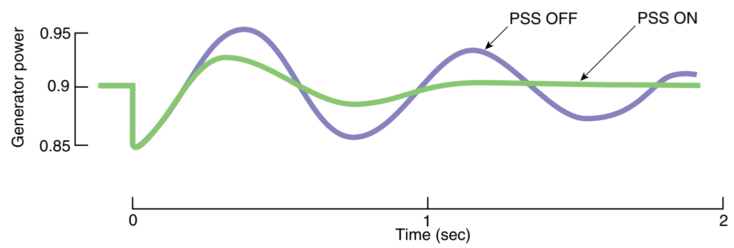
MITSUBISHI ELECTRIC

Power System Stabilizer (PSS)

Step response

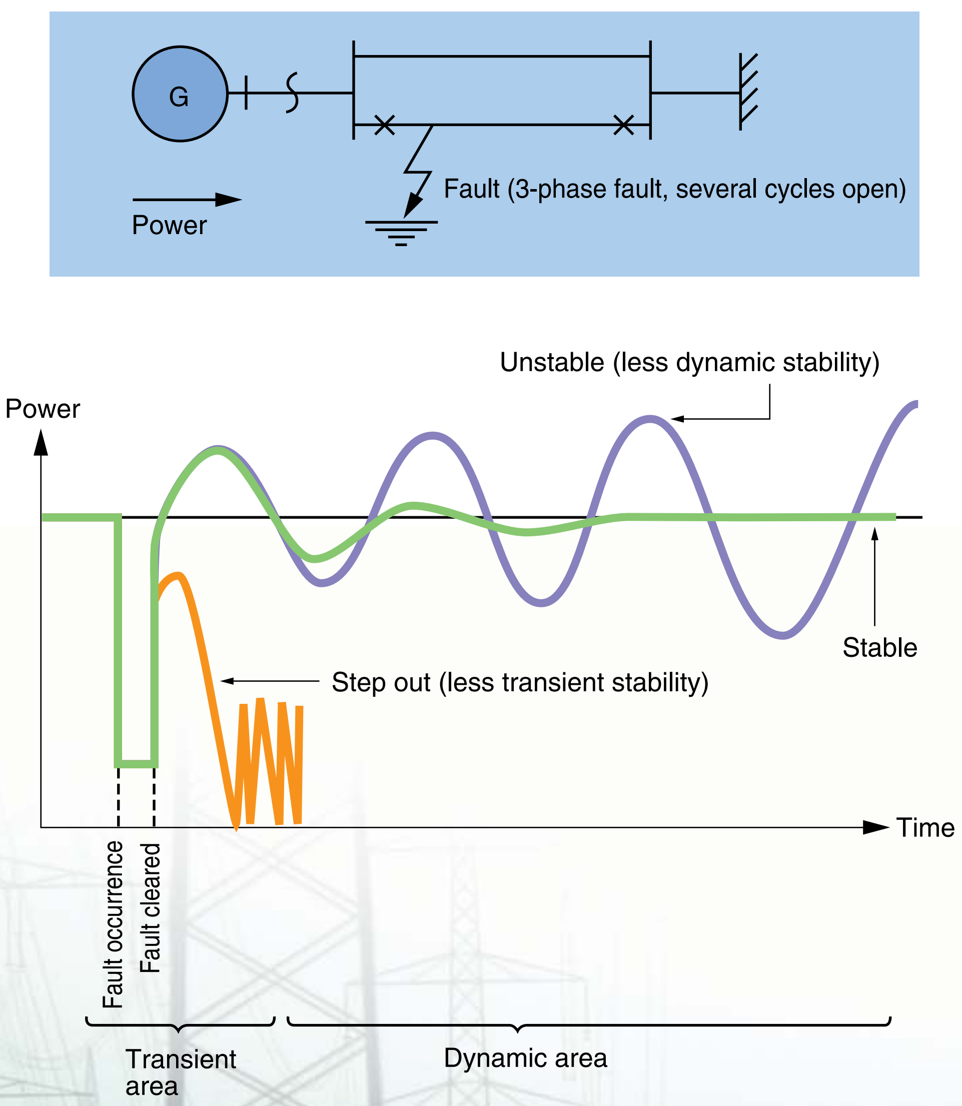


Grid one line open



The power system stabilizer (PSS) is a device that measures improvements in system stability when added to a generator's automatic voltage regulator (AVR). Therefore, compared to system reconstruction or enhancement, it offers overwhelmingly superior cost performance. With an abundant system line-up including analogue, digital and ⊿P/⊿ω/⊿f input type models, Mitsubishi Electric is ready to respond to the diversified needs of its customers.

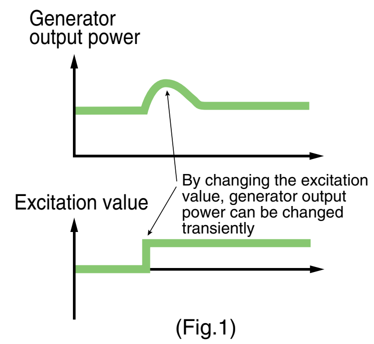
1 Summary of Power System Stability



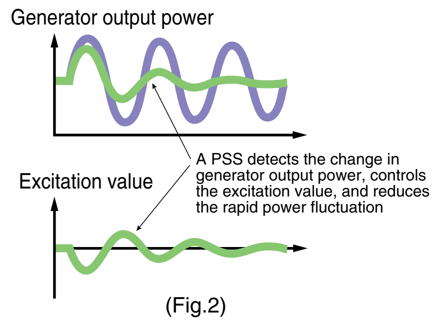
2 Theory of PSS

■Summary

Though generator output power is decided by a turbine's mechanical torque, it can be changed by transiently changing the excitation value (Fig.1).
A PSS detects the change in generator output power, controls the excitation value, and reduces the rapid power fluctuation (Fig.2).

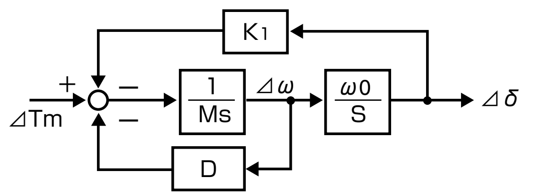
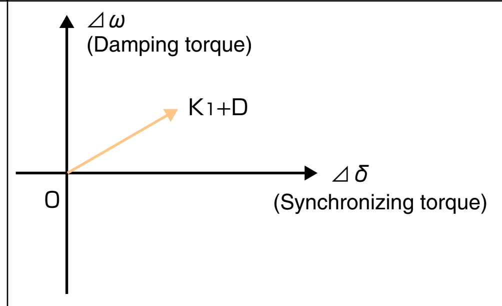
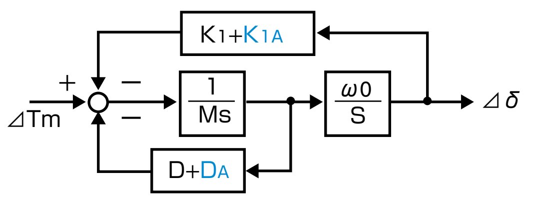
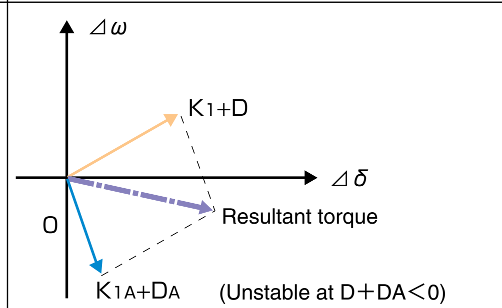
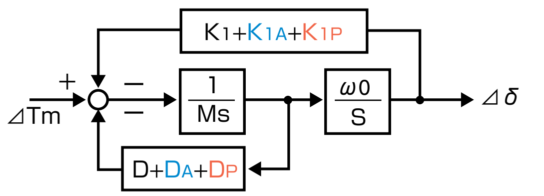
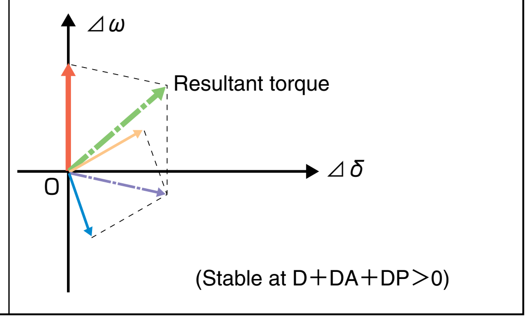


(Fig.1)



(Fig.2)

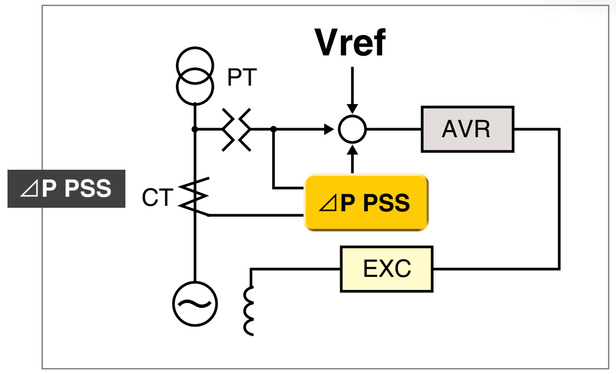
■Explanation of torque vector

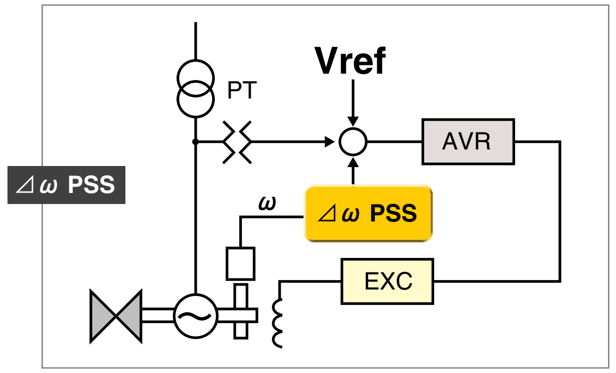
	Block diagram	Torque characteristics
Constant excitation	 K1 : Synchronizing torque D : Damping torque M : Inertia	
AVR	 K1A : Synchronizing torque by AVR DA : Damping torque by AVR	
AVR + PSS	 K1P : Synchronizing torque by PSS DP : Damping torque by PSS	

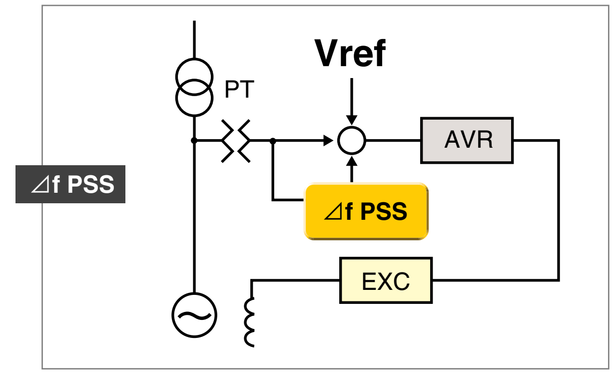
3 Types of PSS

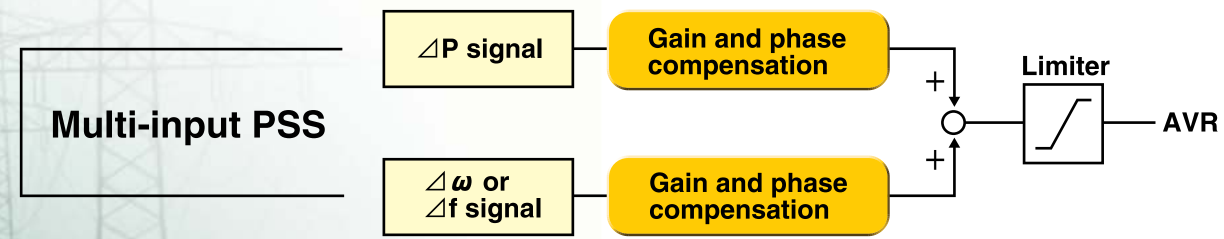
As previously mentioned, the PSS detects fluctuations in generator output power and controls the excitation. The type of PSS is distinguished by its detection signal. The simplest and most typical type is the ⊿P input type unit; however, ⊿ω and ⊿f input type units have been introduced to improve the stability of the intra-system oscillation mode (i.e., long-term or interface mode) in view of the large increase in power systems and power re-routing in recent years. Each of the features is outlined below.

Local Mode Power Oscillation	● Individual generator oscillates against the system ● Frequency is approx. 1Hz	● Single-frequency PSS, such as ⊿P, ⊿ω or ⊿f ● ⊿P type PSS is more effective
Inter-area (Long-cycle) Mode Power Oscillation	● The whole system oscillates as a result of long-distance, large-capacity power transmission ● Frequency is 0.2 to 0.5Hz	● Single-frequency PSS, such as ⊿P, ⊿ω or ⊿f ● ⊿ω or ⊿f type PSS is more effective
Complex Power Oscillation	● Complex power oscillation mode, such as local mode +inter-area mode	● Multi-input PSS is more effective ● ⊿P+⊿ω type or ⊿P+⊿f type







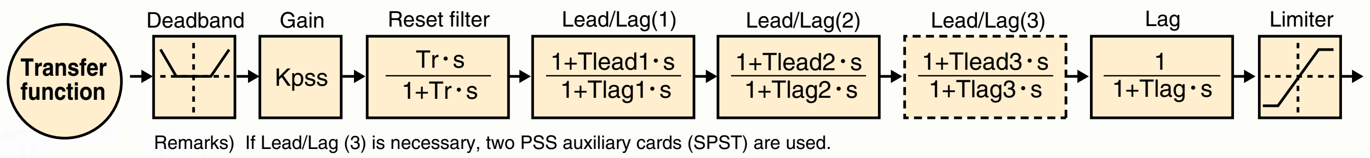


4 Hardware Configuration

Analogue

The dimensions of the analogue PSS are 250 x 680 x 480mm (LxWxD). Each unit is equipped with the following devices:

Device	Function	Specification
Power/Voltage converter	Detects generator power and voltage from PT, CT signal	Power converter: 0-1kW/0-30mV, response time: less than 10msec, voltage converter: 0-150VAC/0-5VDC
PSS main card (SPMT)	Amplifier (Gain) [Kpss]	Kpss=0.1〜3.0pu/pu (typical range)
	Reset filter [Tr]	Tr=1〜20sec
	Lag [Tlag]	Tlag=0.01〜1sec
	Limiter	Setting range ±0.1pu based on generator voltage Standard setting ±0.05pu
PSS auxiliary card (SPST)	Lead/Lag1 [Tlead1,Tlag1]	Tlead 1=0.08〜2.2sec, Tlag 1=0.07〜2.2sec
	Lead/Lag2 [Tlead2,Tlag2]	Tlead 2=0.008〜0.22sec, Tlag 2=0.007〜0.22sec
	Deadband, absolute	Setting range 0-1pu based on generator output Standard setting 0.3pu
PSS protection card (SPPT)	Low-power detection	Setting range 0-1pu based on generator output Standard setting 0.3pu
	Generator over-and under-voltage detection	Setting range 0-1.3pu based on generator voltage Standard setting over voltage: 1.1pu, under-voltage: 0.9pu
	Fault detection	Detects PSS output that is over a set value/time Setting range pick up: ±0.1pu based on generator voltagetimer: 0-30sec Standard setting±0.045pu, 10sec
	PSS ON/OFF switching circuit	Automatic lock (OFF) and automatic reset (ON) by low power detection, Generator over- and under-voltage detection Automatic lock (OFF) and manual reset (ON) by fault detection



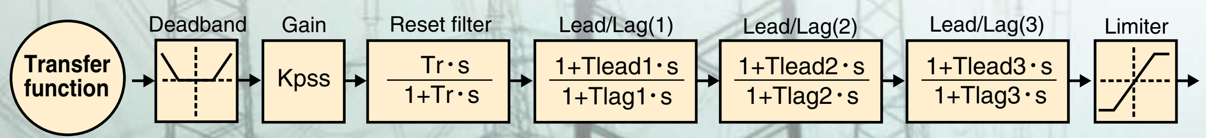
Remarks) If Lead/Lag (3) is necessary, two PSS auxiliary cards (SPST) are used.

Digital

The functions of the digital PSS are realized through the software. Generally, computations are performed in the same CPU as the digital AVR. The basic functions are the same as for analogue. Minor differences are as follows:

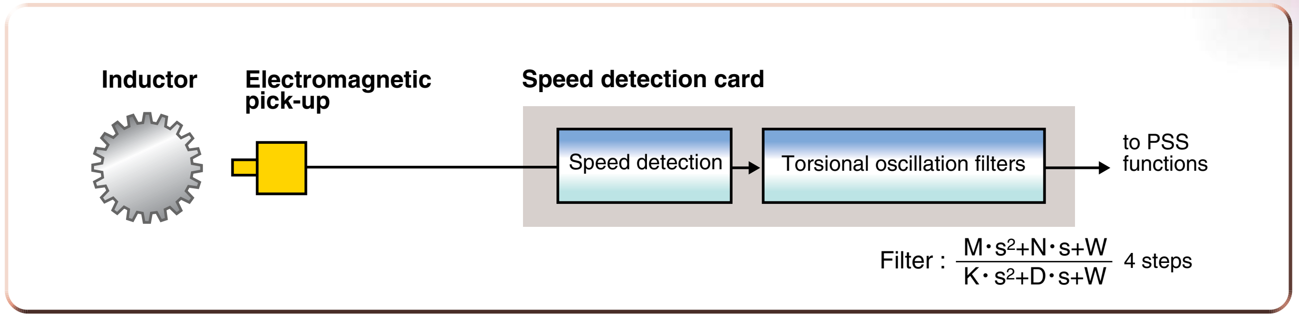
(1) Fault detection: for analogue, excessive PSS output is detected. However, in the case of the digital unit, a fault occurring in individual parts (e.g., reset filter) is not realistic. Therefore, rather than basing fault detection on computation results, a self-diagnostics function is built into the hardware and software to detect faults.

(2) Lag: analogue units have a lag circuit at the final stage that suppresses the noise signal. Generally, this is not incorporated in digital units since noise suppression is carried out at the point of input-signal detection.



5 Speed Detection in ⊿ω Input Type

The generator speed is detected by the ⊿ω input type PSS. It is necessary for the PSS speed detector to be able to detect very small fluctuations with high accuracy. Mitsubishi Electric developed a highly accurate, high-performance speed detector (16-bit resolution, ±0.05% accuracy) and a filter to eliminate torsional oscillation in the spinning component.

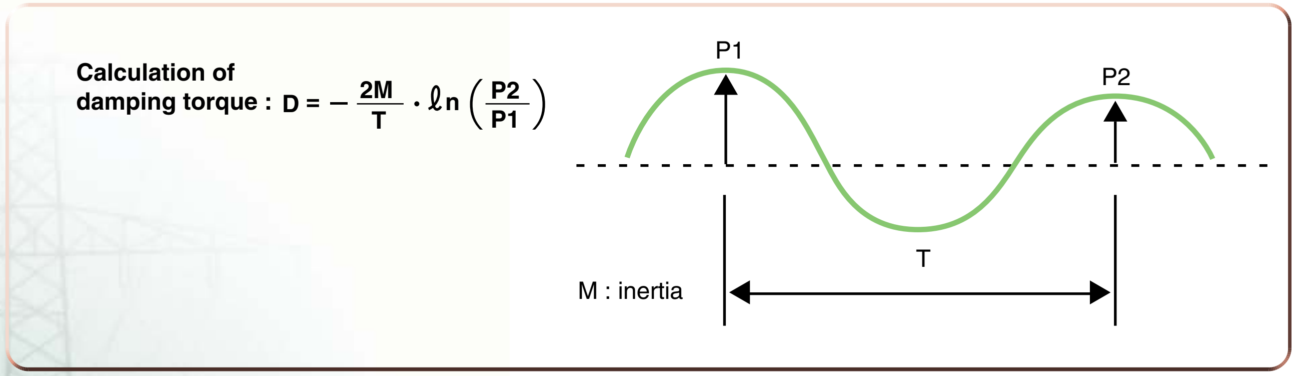


6 Design of PSS Parameters

An appropriate parameter design is very important in order for a PSS to operate effectively. In general, these parameters are set with the single machine infinite bus model; however, on request, analysis using a multi-system model is also available.

7 Site Commissioning test of PSS

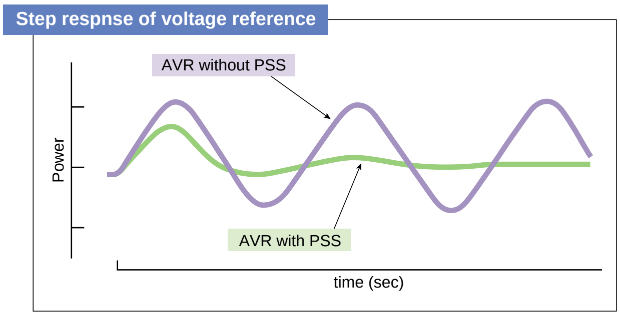
During site examination, to confirm the effectiveness of the PSS, power fluctuations are generated when the PSS is in use and when it is not in use, and damping measurements are compared. As a common method for generating power fluctuations, a generator voltage transient response test, is applied. In order to quantify the effectiveness of the PSS, the damping torque is calculated from the test results. Generally, in the case of applying a local mode, the PSS is judged to be sufficiently effective if the damping torque is tenfold higher as a result of using the PSS.

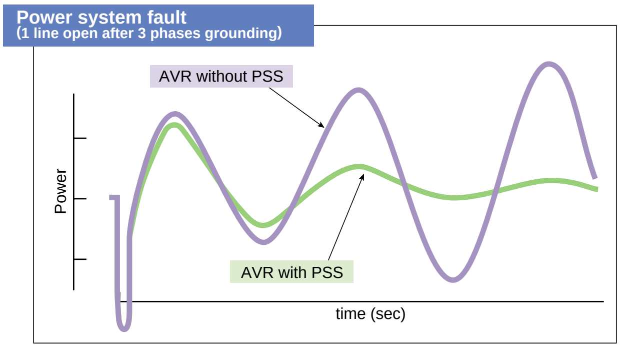


Changes for the Better

MITSUBISHI ELECTRIC

Integral of Accelerating Power Type PSS
(Power System Stabilizer)





A POWER SYSTEM STABILIZER (PSS), which is installed in the Automatic Voltage Regulator of a Generator, can improve power system stability. The PSS has excellent cost performance compared to other power system modifications or additions.
MITSUBISHI "Integral of Accelerating Power Type PSS" conforms to Type PSS2A in "IEEE Std. 421.5-1992".

Integral of Accelerating Power Type PSS

The relation of change among mechanical power, electrical power, accelerating power and rotor speed can be illustrated as Fig.1 from the swing equation where the integral of accelerating power is equal to rotor speed.

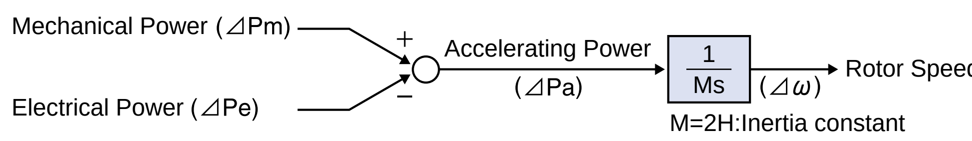


Fig.1

Thus, Integral of mechanical power is derived as the following equation from measured electrical power and rotor speed (or frequency). $\int \Delta Pm\,dt = \int \Delta Pe\,dt + M\Delta\omega$

The resultant block diagram of sensing input signal can be illustrated as Fig.2. Thus, the input signal of "Integral of Accelerating Power Type PSS" is equivalent to rotor speed.

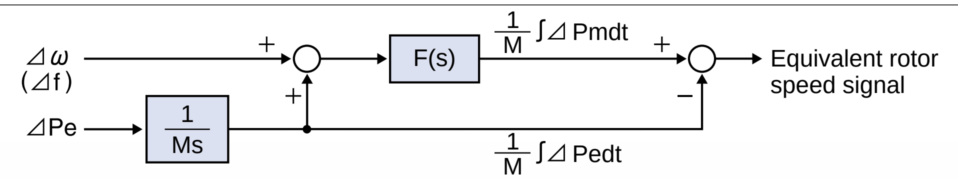
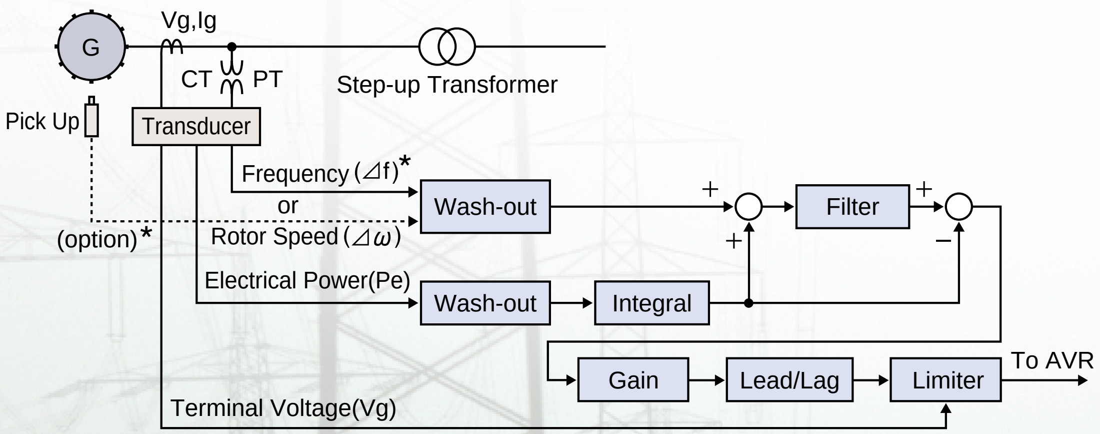


Fig.2

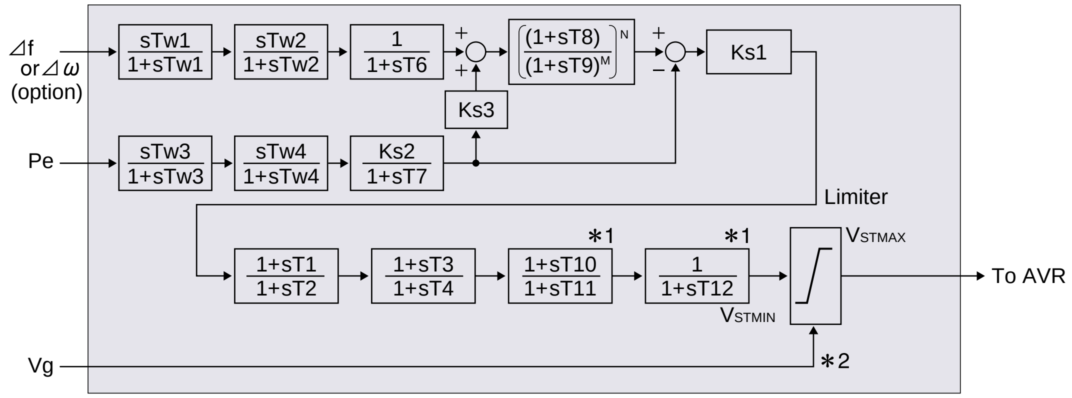
Where, F(s) is transfer function of the filter for attenuating the torsional oscillation.

Configuration of PSS Function



***Kinds of Speed signal**
(1) Frequency of terminal voltage·····only terminal voltage
(2) Frequency of internal voltage calculated from terminal voltage and current (Vi=Vg+xd Ig)·····(option)
(3) Actual rotor speed·····required speed detector, toothed wheel mounted on generator shaft and pickup (option)

Transfer Function of PSS



*1 : Added to PSS2A model
*2 : If generator voltage is continuosly kept higher than 105% or lower than 95% of rated voltage, generator voltage is automatically reduced within 95 to 105% by changing limit value after time delay.

Parameters

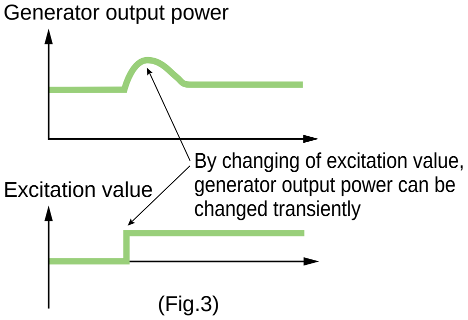
Parameter	Description	Units	Typical range	Remarks
Tw1	Wash-out Time constant-1	Sec.	1 to 10.	⊿f (⊿ω)
Tw2	Wash-out Time constant-2	Sec.	1 to 10.	⊿f (⊿ω)
Tw3	Wash-out Time constant-3	Sec.	1 to 10.	⊿Pe
Tw4	Wash-out Time constant-4	Sec.	1 to 10.	⊿Pe
T1	Lead Time constant-1	Sec.	0. & 0.02 to 2.	
T2	Lag Time constant-1	Sec.	0. & 0.02 to 2.	
T3	Lead Time constant-2	Sec.	0. & 0.02 to 2.	
T4	Lag Time constant-2	Sec.	0. & 0.02 to 2.	
T6	Lag Time constant	Sec.	0. & 0.02 to 2.	
T7	Integral Time constant	Sec.	0.5 to 10.	Integral of Pe
T8	Ramp-tracking time constant	Sec.	0. & 0.02 to 2.	
T9	Filter time constant	Sec.	0. & 0.02 to 2.	
T10	Lead Time constant-3	Sec.	0. & 0.02 to 2.	
T11	Lag Time constant-3	Sec.	0. & 0.02 to 2.	
T12	Lag Time constant-4	Sec.	0. & 0.02 to 2.	
Ks1	PSS Gain	pu/pu	0.2 to 20.	
Ks2	Gain	pu/pu	0.1 to 5.	Normally = T7/2H(Inertia)
Ks3	Gain	pu/pu	0.5 to 2.	Normally = 1
M	Integer filter constant	Integer	1 to 5	
N	Integer filter constant	Integer	1 to 5	
V_{STMAX}	PSS output limiter "max"	pu	0. to 0.2	
V_{STMIN}	PSS output limiter "min"	pu	0. to -0.1	

Mitsubishi Integral of Accelerating Power Type PSS (Power System Stabilizer)

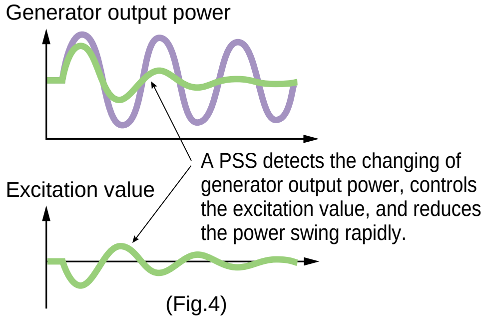
Theory of PSS

■Summary

Though a generator output power is decided by the turbine mechanical torque, a generator output power also can be changed by changing excitation value transiently. (Fig.3)
A PSS detects the changing of generator output power, controls the excitation value, and reduces the power swing rapidly. (Fig.4)

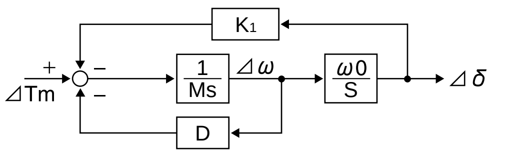
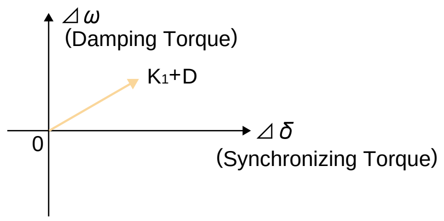
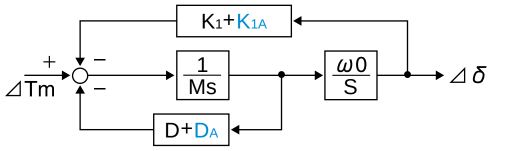
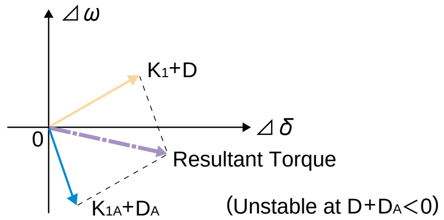
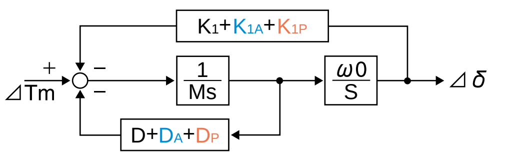
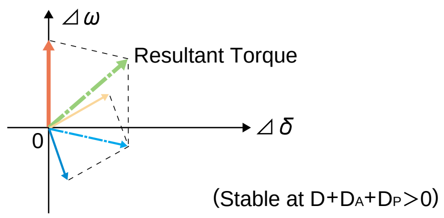


(Fig.3)



(Fig.4)

■Explanation on torque vector

	Block Diagram	Torque Characteristics
Constant Excitation	 K1 : Synchronizing Torque D : Damping Torque M : Inertia	
AVR	 K1A : Synchronizing Torque by AVR DA : Damping Torque by AVR	 (Unstable at D+DA<0)
AVR + PSS	 K1P : Synchroning Torque by PSS DP : Damping Torque by PSS	 (Stable at D+DA+DP>0)

MITSUBISHI ELECTRIC CORPORATION
HEAD OFFICE: MITSUBISHI DENKI BLDG., MARUNOUCHI, TOKYO 100-8310. TELEX: J24532 CABLE: MELCO TOKYO

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