MITSUBISHI

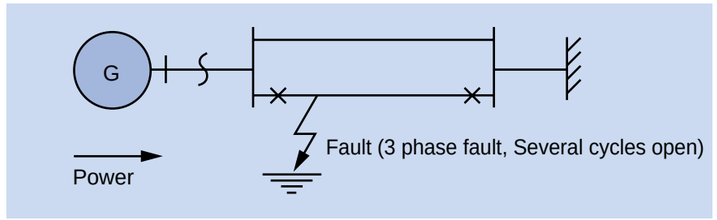
Power System Stabilizer (PSS)

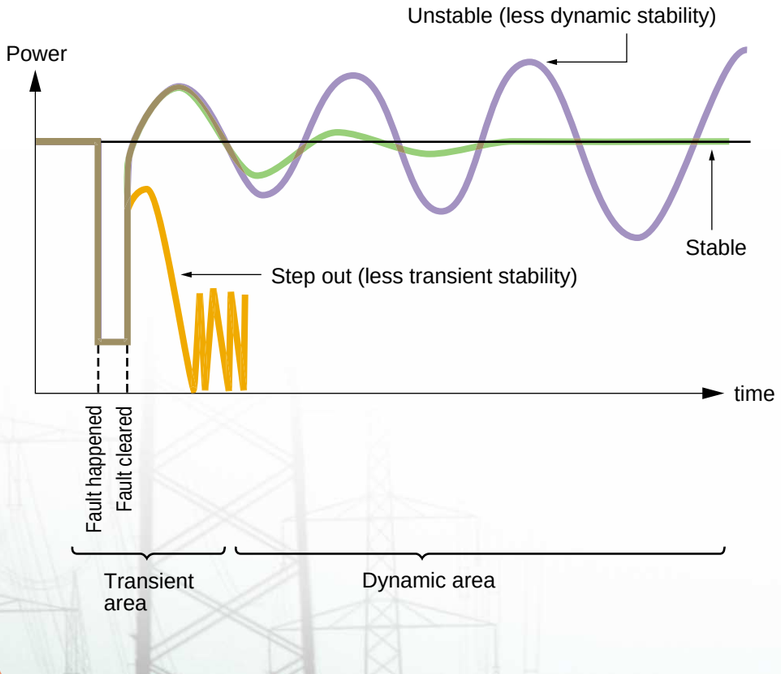
Step response

Grid one line open

A POWER SYSTEM STABILIZER (PSS) which is installed in the Automatic Voltage Regulator of the Generator, can improve the power system stability. Therefore the PSS has excellent cost performance rather than constructions of power system arrangements. MITSUBISHI PSS has various system, such as Analogue / Digital type and ΔP / Δω / Δf input type, and can respond to various customer's needs.

1 Summary of Power system stability

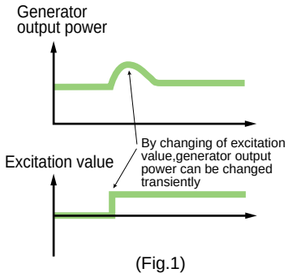




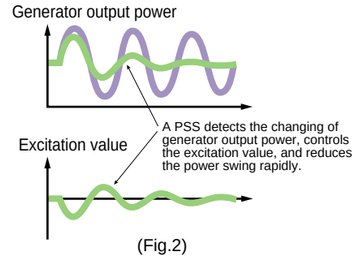
2 Theory of PSS

■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.1)
A PSS detects the changing of generator output power, controls the excitation value, and reduces the power swing rapidly. (Fig.2)

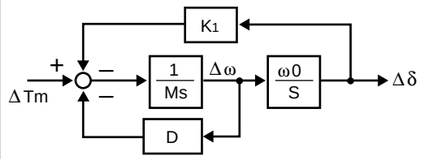
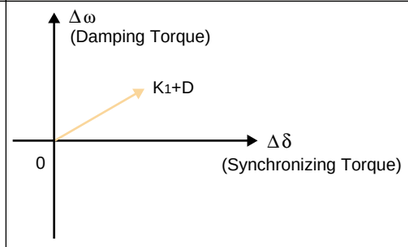
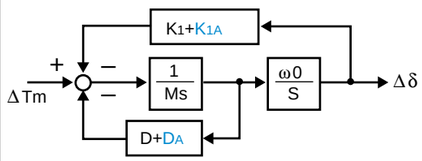
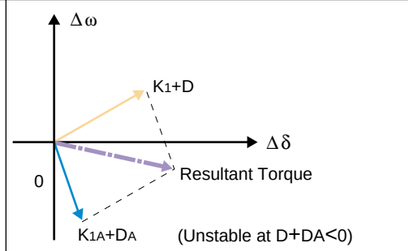
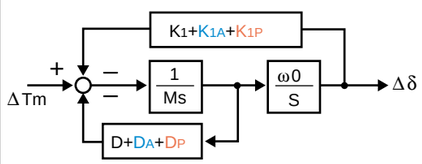
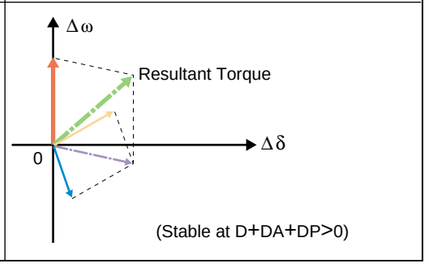


(Fig.1)



(Fig.2)

■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)

3 Type of PSS

As mentioned before, a PSS detects the changing of generator output power and controls the excitation value.
The type of PSS is identified by the detecting signal. The most simple and typical type is ΔP input type.
And, recently Δω input type and/or Δf input type PSS also adopted in order to improve a stability of inter-area mode due to the recent increase in power system and power re-routing. Each features are as follows;

Local Mode Power Oscillation

- ●Individual generator oscillates against the system.
- ●Frequency is approx. 1 Hz.

- ●PSS of single input, such as ΔP, Δω and Δf, etc.
- ●ΔP type of PSS is more effective.

Inter-area (Long Cycle)Mode Power Oscillation

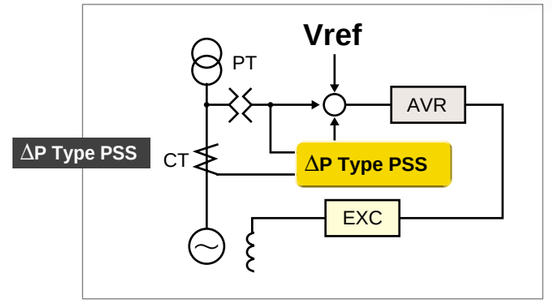
- ●The whole system oscillates with long-distance and large power transportation system connection.
- ●Frequency is 0.2 to 0.5 Hz

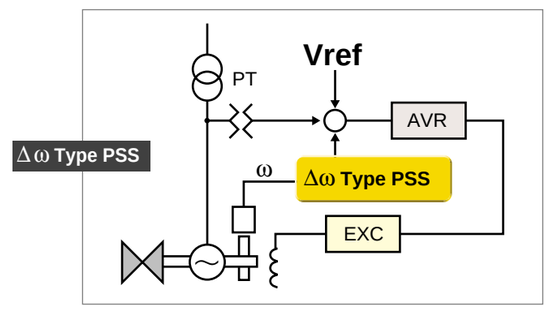
- ●PSS of single input, such as ΔP, Δω and Δf, etc.
- ●Δω or Δf type of PSS is more effective.

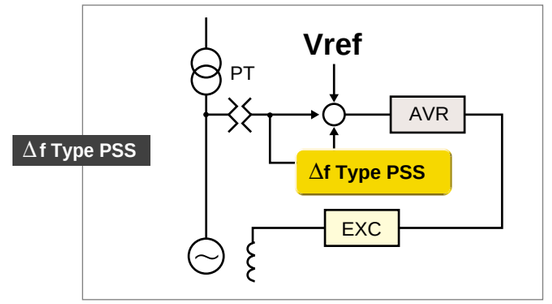
Complex Power Oscillation

- ●Complex power oscillation mode, such as local mode + inter-area mode

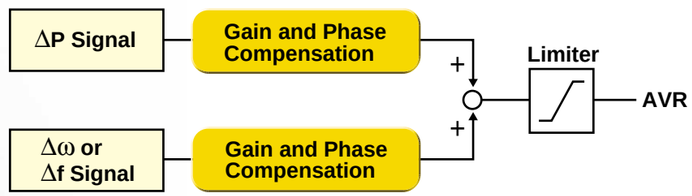
- ●Multiple input PSS is more effective.
- ●ΔP + Δω type or ΔP + Δf type of PSS.







Multiple Input Type PSS

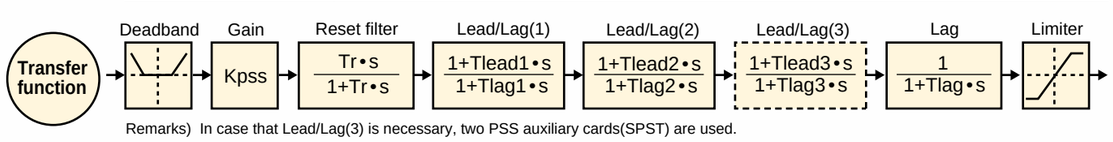


4 Hardware Configuration

Incase of Analogue type

The PSS of analogue type is composed from the PSS unit which dimension is H250 ×W680 ×D480 ㎜. This PSS unit installs following devices.

DEVICE	FUNCTION	SPECIFICATION
Power/Voltage converter	Detecting a 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
	Dead band, 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	Detecting that PSS output signal becomes over one value and time. Setting range Pick up:±0.1pu based on generator voltageTimer:0-30sec Standard setting±0.045pu, 10sec
	Changing over PSS ON/OFF	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



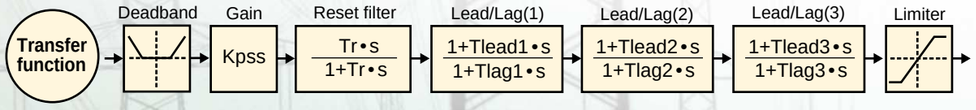
Remarks) In case that Lead/Lag(3) is necessary, two PSS auxiliary cards(SPST) are used.

Incase of Digital type

The PSS of digital type is realized its functions by the software. Generally, it is computed in same CPU of D-AVR. The basic functions are as same as analogue type. Minor differences are as follows;

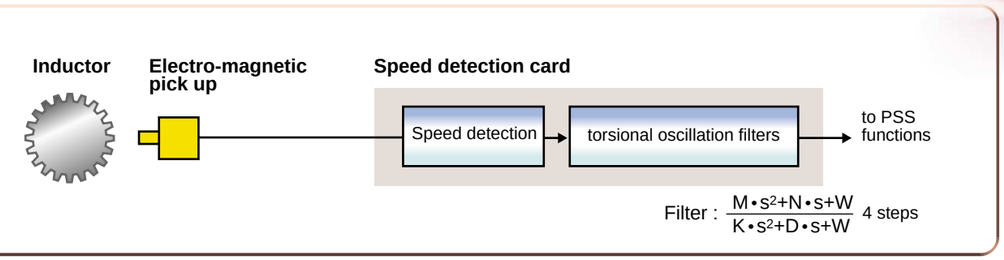
(1) Fault detection : It is detected by self diagnostic function of Digital equipment.

(2) Lag : In case of analogue type, there is a Lag function in order to cut the noise due to each circuits. However, in case of digital type, it is not necessary, because the noise is cut on input-signal-detector.



5 Speed detection in Δω input type

The generator speed is detected in Δω input type PSS. The speed detector for PSS should detect very small fluctuation of speed with high accuacy. MITSUBISHI speed detector for PSS is excellent performance(16bits, accuracy:±0.05%), and has torsional oscillation filters.



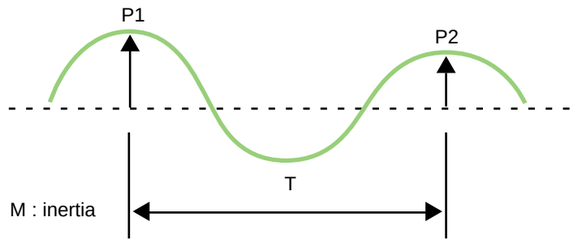
6 Design of PSS parameters

PSS parameters design is very important in order to operate PSS effectively. In general, it is designed in condition of Single machine Infinite bus model. MITSUBISHI can analysis in condition of Multi machine model with additional.

7 Site commissioning test of PSS

The reducing speed of the power swing will be compared in case of PSS OFF condition and PSS ON condition in order to confirm the PSS effect in site commissioning test. In general, the step response test will be adopted for this test. The Damping torque will be calculate from test results. In general, in case of local mode, PSS will be effective if the Damping torque would increase more than 10.

Calculation of Damping torque : $D = -\frac{2M}{T} \cdot \ell n \left(\frac{P2}{P1}\right)$



Mitsubishi Power System Stabilizer (PSS)

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

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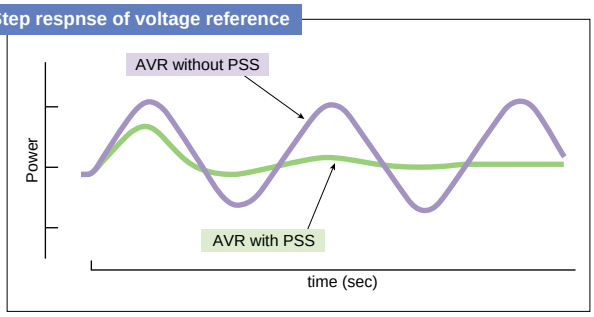
Changes for the Better

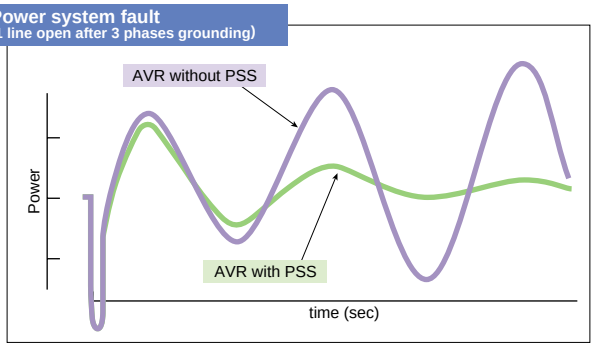
MITSUBISHI ELECTRIC

Integral of Accelerating Power Type PSS (Power System Stabilizer)

Step respnse of voltage reference



Power system fault
(1 line open after 3 phases grounding)



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.

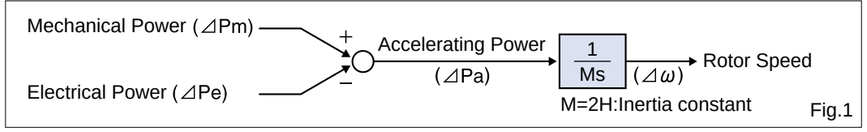


Fig.1

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

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.

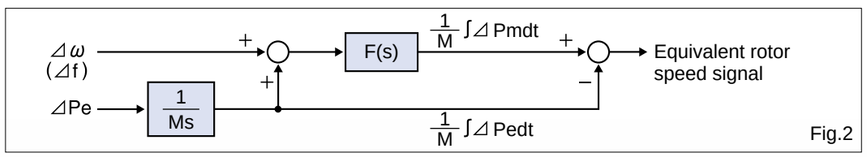
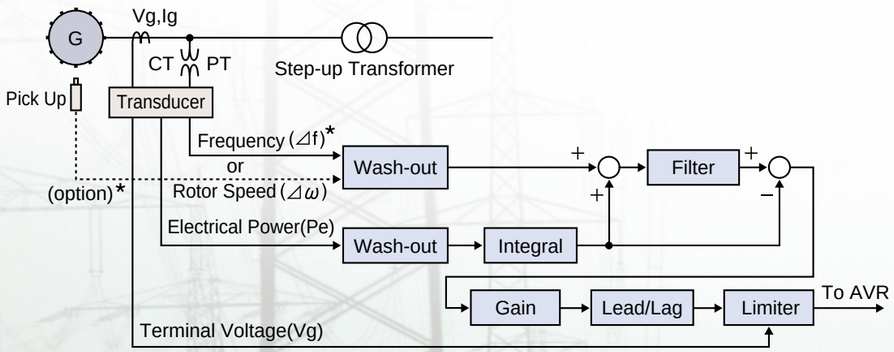


Fig.2

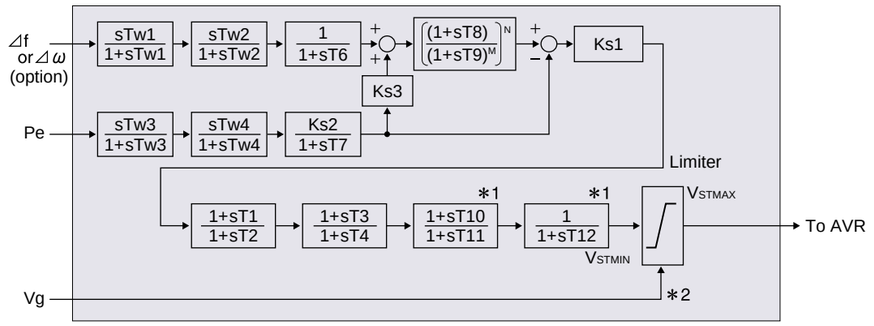
Where, F(s) is transfer function of the filter for attenuating the torsional oscillation.

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

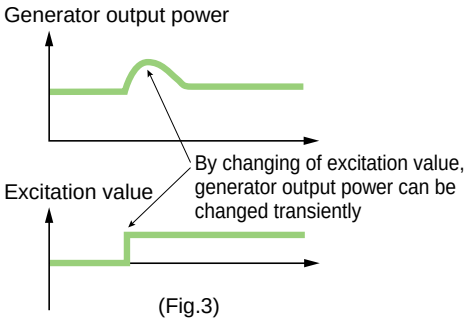
Parameter	Description	Units	Typical range	Remarks
Tw1	Wash-out Time constant-1	Sec.	1 to 10.	⊿f (⊿ω)
Tw2	Wash-out Time constant-2	Sec.	1 to 10.	⊿f (⊿ω)
Tw3	Wash-out Time constant-3	Sec.	1 to 10.	⊿Pe
Tw4	Wash-out Time constant-4	Sec.	1 to 10.	⊿Pe
T1	Lead Time constant-1	Sec.	0. & 0.02 to 2.	
T2	Lag Time 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)

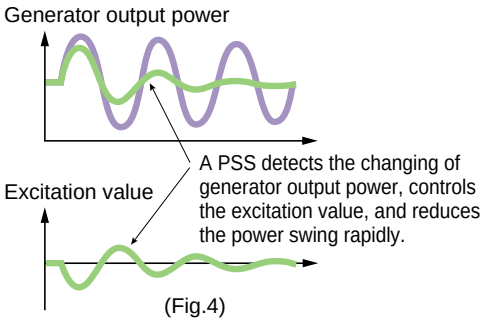
Theory of PSS

■ 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)

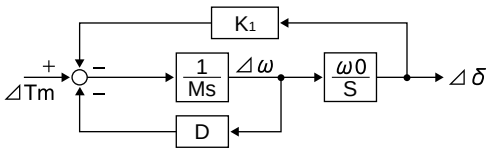
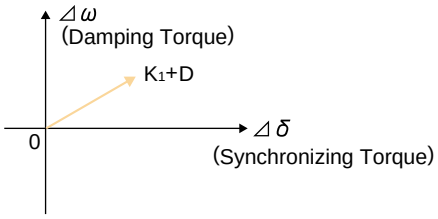
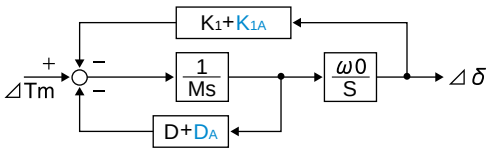
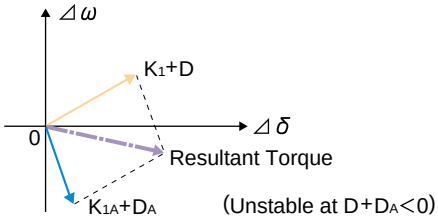
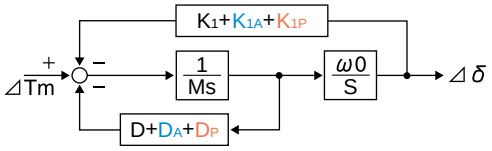
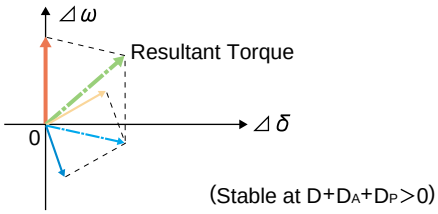


(Fig.3)



(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	
AVR + PSS	 K1P : Synchroning Torque by PSS DP : Damping Torque by PSS	

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