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Optimization of Power System Stabilizers in the Electrical Energy System

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ABSTRACT

Stability in electrical energy system is very needed in giving guarantee of available electrical energy. Generally, improvement of stability uses Power System Stabilizer (PSS) as a media for improving the stability by giving stability on the osilator of sincronize machine rotor. This fact has legitimated by previous studies as follow: 1) The using of PSS could help the system returning to stabil condition though in the other balancing point; 2) The using of PSS dis not give meaningful impact on the angle size of generator rotor and frequency but it very influenced the magnitude value of bus voltage (V); and 3) Type PSS of IEEE-1 has increased the system of stability by controlling electrical power or reactive power (VAR). Therefore, the using of PSS in electrical energy system was very needed on using the single machine or multi one.
Keywords: electrical energy, stability, PSS.

INTRODUCTION

Stability of electrical energy system is defined as the ability of a electrical energy system or part of component for holding the sincronization and balancing of the system in process of input and output. It means that the operated electrical energy system in stabil condition has the balancing between mechanical input power (prime-mover) and electrical output power. In this condition, the whole generator turns in sincronized speed, every riding or removal of load will be followed by mechanical power change of prime mover generator. If mechanical power can not fit with load power and system losses, so the generator rotor speed (system frequency) and voltage will deviate from normal condition. It means that there are the balancing between mechanical input power on prime mover and electrical output power of system due to stabil operational condition of electrical energy system, so that in this condition the whole generators turn in sincronized condition.

The using of Power System Stabilizers (PSS) with high strength can increase the stability of electrical energy system in operated condition. In this condition, the stability of electrical energy system is said stabil if it has fulfilled the reliability, quality, and stability. Reliability involves the aspect of a system ability to flow the power or energy continuously. Quality means the ability of electrical energy system to produce the dimensions due to the hoped frequency. Stability invloves the aspect of system ability to work normally again after having a standard obstruction which is conditioned for the system to return. PSS is an utility with the certain transfer function which can be arranged of the dimension and phase. Then the output of PSS is entered to the series of exitation. By arranging the phase of PSS, the output signal of exitation will produce positive stability which is functioned for compansating the negative stability. Amplifier in PSS has to be arranged so that the positive stability is enough to compensate the negative stability [1]. Even though it also says that in power system generation, power system stabilizer (PSS) is used to damp the mechanic electro oscillation. This oscillation is a disturbance of system [2].

Signal that is injected to the PSS has the same phase with the power and appearing the dynamic stability such as an ability form of electrical energy system for returning to the balancing point after suddently there is small obstruction in a long time. In the study of stability, to know what the electrical energy system is stabil or not after being obstruction, it is observed through the variables of system condition by stability indicator such as rotor angle of δ, rotor angular speed of ω, and generator terminal voltage of v_t.. If the load changes at electrical energy system, voltage change and frequency of system cause the controlling as well as back regulator of input dimensions for reaching balancing point will reach the new balancing point [3].

MATERIALS AND METHODS

Stability of electrical network

Since 1920, the stability of electrical energy system has been assumed as the important problem for safing the system operation of electrical energy. There are many problem of total turning off electric is caused by unstable of energy system. This condition has indicated that the stability of energy system becomes as important phenomenon. Based on the some conditions, unstability of transient has become as the most special stability and it becomes the main attention in the system stability. System stability of electrical energy is as a

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system characteristic which enable the machine moving together in the system for giving the reaction to obstruction in normal work condition, and turn again to the beginning condition when the condition becomes normal again.

Stability in such urgent of electrical network system, jn some research take place the stability as the main factor because the obstruction in system can cause unstable condition. There are two types stability in electrical energy system such as steady state and transient stability [3][4]. The dynamic change of load in electrical energy system enables frequently occuring ossilation in system, even illustratively describe this condition that an electrical energy system is said in stabil condition if the whole variables are stabil as well as bus voltage, generator angle or system frequency. If the system becomes unstable, so the unstability can be realized through the different manners and it depends on the characteristic of system, operational condition, and on the characteristic and location where becomes the obstruction. The unstability system which is realized in the form of voltage in some bus go down far under the normal condition and enable occuring voltage failure, so this condition can be said as the phenomenon of voltage unstability [5].

The factors which can cause unstability of system are as follow: 1) generator loading or channel relation; 2) power transfer ability of transmission channel; 3) power factor; and 4) amplifier of AR (Automatic Voltage Regulator) or the other controller. Analysis can be carried out by linearing the equation system in surround of operational point by the condition of $x = x(0)$, $y = y(0)$, $z = z(0)$ which is described in the equation and ΔA, Δx will be obtained in state space equation which Δx is the variable system which has dimension of n x 1 and ΔA is as matrix system.

Therefore, there is formal definition of electrical energy system which is suggested as that "electrical energy system stability" is the ability of energy system for, based on the certain initial operation condition, gets again a balancing condition of operation after experiencing physical obstruction, by some limited system variables in such a way so in practically the whole system remains intact. Therefore, stability problem is very depended on the system ability for holding firm voltage condition at the whole bus in normal operation condition as well as after occuring obstruction. A system is said in unstable condition if there is over estimation of system change [5]

There are two kinds of stability in electrical energy system such as steady and transient. Steady state stability is the ability of energy system to reach stabil condition on the same or identic of new operation condition with the condition before obstruction and after the system has small obstruction. Analysis of steady state stability uses linear model approach. Steady state stability on energy system can be mentioned as small signal stability. Steady state stability is as a function of operation condition, but transient stability is energy system ability for reaching stabil condition of new operation which can be accepted after the system experiences big obstruction. Analysis of transient stability uses non linear model approach. Transient stability on energy system is output response which reaches the condition of steady state operation and as a system which can turns back to the beginning position when the system experiences obstruction. Transient stability is as the function of operation condition and obstruction.

Besides the two categories as above, William D. Stevenson [6] added a category such as dynamic stability. Conceptually, state steady and dynamic stability are the same. The other important thing which has to be noted is though the system is operating transiently in unstable condition, but small signal stability on the system is nacessary to be maintained any time. Generally, stability is depended on the load system. The increasing of load can cause unstability. It indicated that maintaining system stability is as an important thing though it is under weight load condition [6].

Power System Stabilizer (PSS)

Dynamic stability in the electrical power system is determined by the ability of some generator components in giving the transfer response to the occured load change. The suddent and periodical load change can not be well responsed by generator so that can influence the dynamic system stability. Not too good response can make frequency of osilision is rising in long period. It can cause the decreasing of power tranfer strength which can be fulfilled using the additional utility which is called as Power System Stabilizer {PSS)

Power System Stabilizer (PSS) is as an utility which is used to improve the stability by giving stability on osiliation of sincronized mechanic rotor. The stability is PSS produces electrical torsi component but output of PSS which is suitable with rotor speed deviation. Input signal of PSS is as the rotor speed change but the output is as voltage signal which is functioned as additionl control signal on the exiter. Block diagram of gain (K_{pss}), washout (T_s), and lead-lag (T_A-T_D) can be presented as in Figure 1 below.

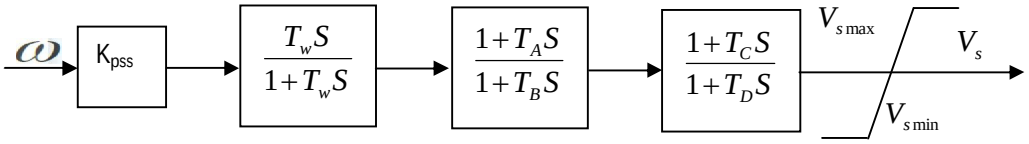

Figure 1. Block Diagram of PSS

Therefore, PSS is an utility which produces control signal for being lured to the exitation system. But in the newer approach, control signal as the output of PSS is also lured to the turbine side. The base function of PSS is to increase the stability limit by arranging generator exitation for giving the stability to rotor ossilation of sincronized machine. Inability on stabilizing the ossilation can restrict the ability of power transfer, so that occurs obstruction in exitation system which causes obstruction and unstability of electrical dynamic system.

This relative stabil condition in electrical system energy is known as stability of electrical energy system which is defined as the ability of electrical energy system or part of component for holding the sincronization and system balancing [7]. In stability study, there is a base equation which arranges dynamic (moving) of mechanic cycle together. The base equation is mechanic swing formula as follow:

$$\frac{H}{180 f}.\frac{d^2\delta}{dt^2} = P_a = P_m - P_e \quad \text{.....} \quad (1)$$

Note:

H : constant of Inersia
P_a : accelaration power
f : frequency (Hz)
P_m : input of as power to machine
δ : rotor angle to rotor
P_e : electrical power

The formulation is as an equation for knowing the stability level of electrical energy system after being obstruction. The aspects which are nacessary to be observed through variables of the system with the stability indicator is electrical power of *Pe* which is measured from generator terminal voltage of *vt*, rotor angle of δ, and frequency of f or rotor cycle speed of ω.

In addition, in stabil operational condition on electrical energy system, there is the balancing between mechanical input power on prime mover and electrical output power on the system. In this condition, it can be fulfilled by implementing a PSS on the power system which is connected through ΔVp to the port stabilizer. Simultaneously, the implementation can be showed as in Figure 2 below.

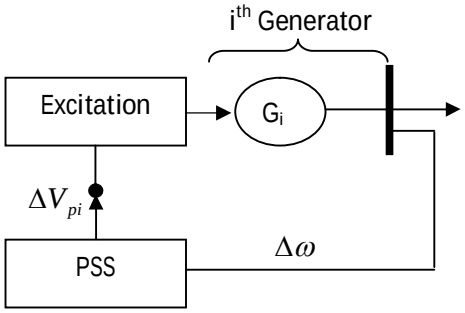

Figure 2: Implemetation of PSS on the power system

The PSS ia also nacessary or even though has to be used on electrical energy system of multi machine as a reliable controller in fulfilling some problems on performance improvement of dynamic system. In the energy system of multi machine, the condition change of a machine will influence the other machine, because between one to the other machine is connected through transmission channel. If the observed machine is expressed with machine-i and the other one is machine-j, so the change of rotor angle of machine-i will influence machine-j as rotor angle, rotor speed, and terminal voltage and thus on the contrary condition [8]. This condition is graphically presented as in Figure 3 below.

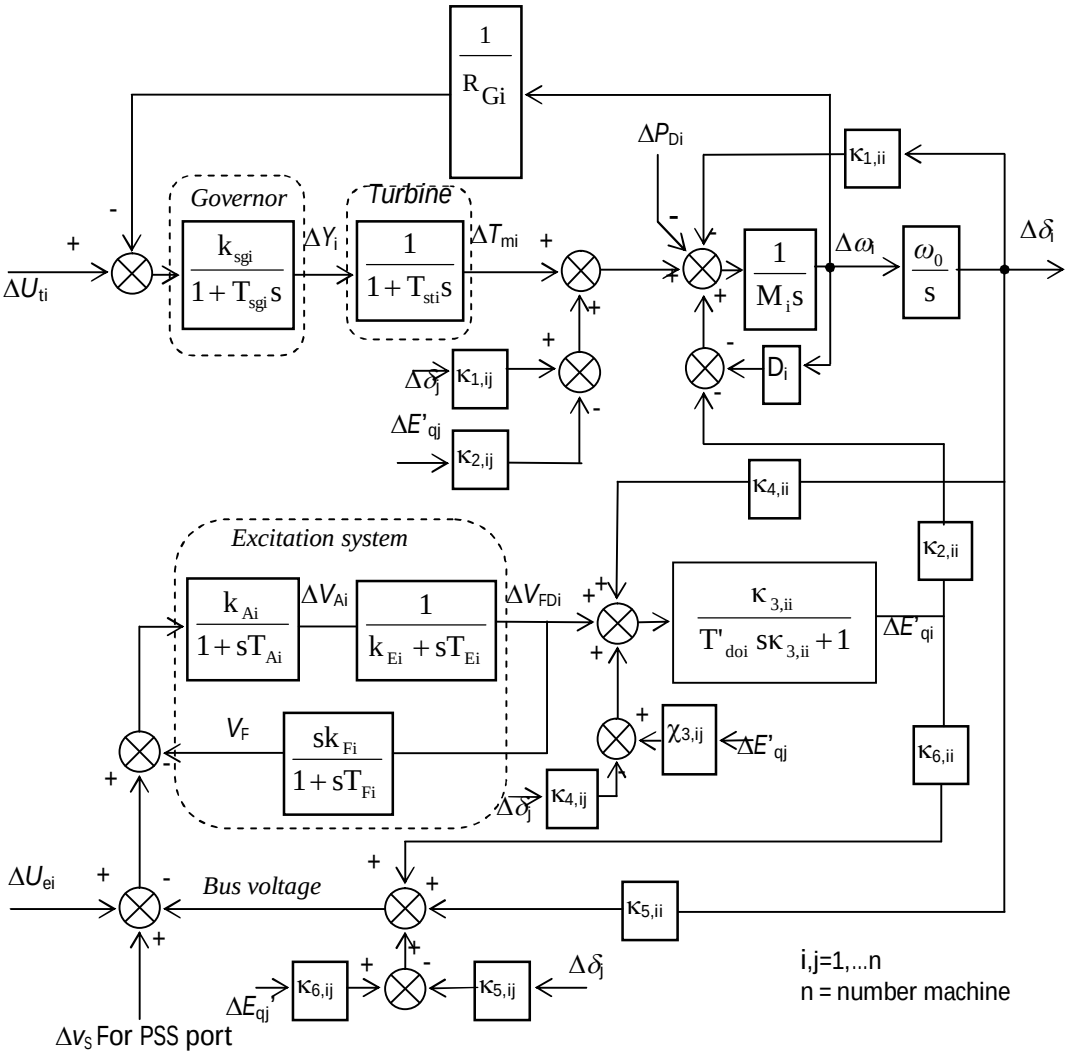

Figure 3: Implementation of PSS in multi machine generator

However, implementation of the utility is very nacessary for a big enough of system. In the other side, the optimal combination of an optimal control and efefective gains which are produced by controller system will become as stabilizer of an electrical energy system. PSS is one of optimal control which installs on machine system as single machine as well as multi machine. Generally, change function from PSS can be described in the linear model as follow:

$$\Delta V_{Pi} S = K_{PSS} \frac{T_w S}{1+T_w S}\left[\frac{(1+T_a S)(1+T_b S)}{(1+T_c S)(1+T_d S)}\right]\Delta\omega_i(s) \quad \text{..... .....} \qquad (2)$$

$T_wS/(1+T_wS)$ is a factor of washout which works as high-pass with time lag of $T\omega$. The factor of $(1+T_wS)$ is lead compensation for improving phase of lag trough the system. The parameters T_a, T_b, T_c, T_d, and K_{PSS} is tuned as unchanged value.

RESULTS AND DISCUSSION

The main aim of installing PSS in the system is for stability system. It means that when the generator is operating in stabil condition with electrical output power, the frequency is remained, so that the urgent study is on the exonerating of obstruction side on the electrical network. Updated studies present that: 1) The using of PSS can help the system to turn back to stabil condition though in the other balancing point; 2) The using of PSS do not give meaningfull impact on the size of generator rotor angle and frequency but it very influences the magnitude value of bus voltage (V); and 3) PSS type IEEE-1 is presented as in Figure 4 below.

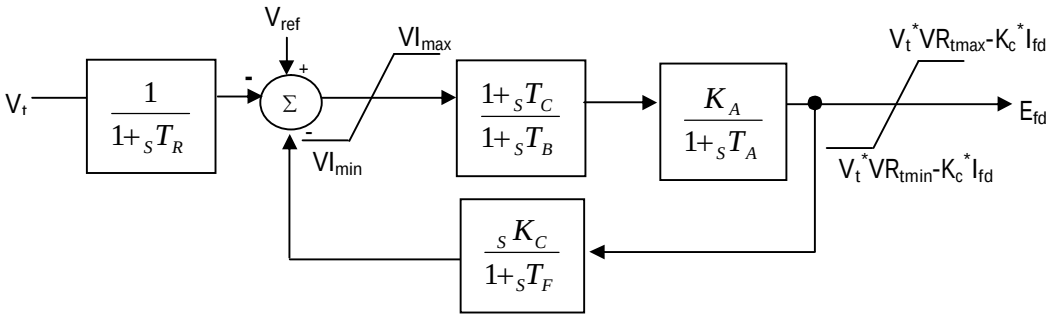

Figure 4: PSS Tipe IFEE-1

In inter-connection of electrical energy system, frequency and voltage are as very important output variables, because both of the variables are as imaging of a system performance. The performance of frequency and voltage are influenced by system operation condition, especially the load change. The load change any time cause the variables of voltage and frequency experience fluctuation so that the system is ossilating and cause an impact of energy losses. To pursue the energy losses, stability system has to be maintained and one of the manners is by installing the Power System Stabilizer (PSS) [9]. In fact, there is obstruction in the electrical network such as small and big obstruction. Small obstruction is as one of the dynamic system elements which can be analyzed by using linear equation (small signal analysis). Small obstruction included load change in the side of load or randomly, slowly, and gradually of generator. Obstruction which produces suddent surprice on the bus voltage is the type of big obstruction which has to be fastly exonerated. If it does not been fastly exonerated, the obstruction will very influence the stability system, not only the size of obstruction, but time of obstruction also influences the stability system. Particularly to see the other main problem being experienced by energy system now that enters in the problem of dropped or unstability voltage which is produced from firm condition unstability. The history has noted that unstability of steady state is related with unstability of power angle and the missing of slowly sincronization inter generator. Dropping of load bus voltage is under condition of high load and slowly limited reactive power.

Optimal Control

The quality of power in electrical energy system is an important thing for maintaining the stability of electrical energy system, but the general problem in designing of control system is the reaching of spesific design which has been determined. The other thing which is naccessary to be attented is how the spesific design can be reached. Good control system is the control system which has fast and stabil response power, but it does not need more energy. The control system like that can be reached through the arranging of accurate index performance. Control system which is designed based on the optimization of index performance is called as optimal control system.

Therefore, the study which is still relevant to PSS is the research which is developed by considering the stability of single machine system which is related with infinite bus (as in Figure 4). The relevant equation is Riccati formula which can be used for finding the available gains. Obstruction input of ΔP_D can be obtained from some values of optimal gain. The value of optimal gains are as the gains which has integral and proportional characterstic such as $\mathbf{K}_I$ and $\mathbf{K}_P$ which is obtained through optimal solution of Riccati formula. Integral gain of $\mathbf{K}_I$ is installed on the side of exitation and proportional gain of $\mathbf{K}_P$ is installed on the side of turbine from generator (as in Figure 5).

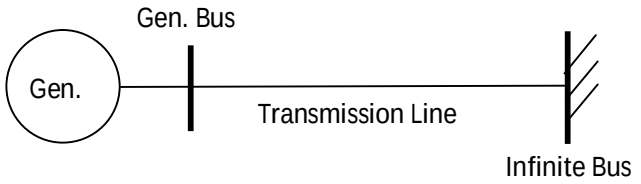

Figure 5: System of single machine with Infinite Bus

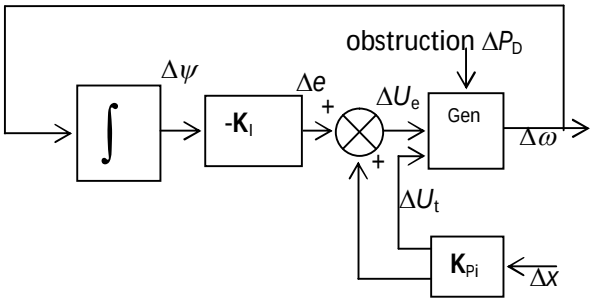

Figure 6. Proportional and Integral Gain on single machine

The detail procedure of optimization process (Figure 5) is presented as in Figure 6 below.

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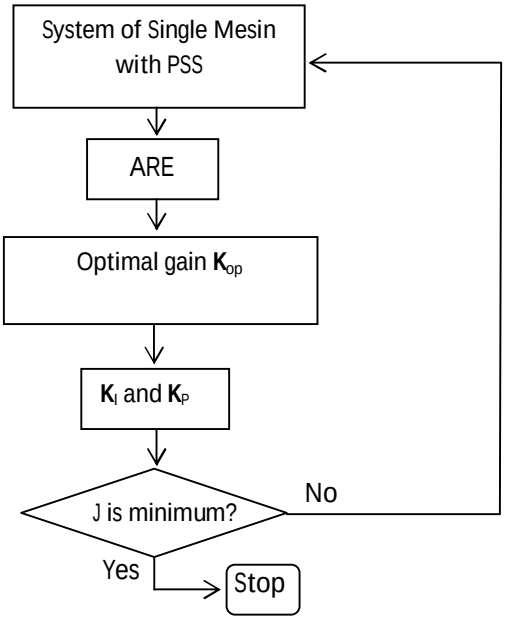

Figure 7: Flowchart for single machine

Through optimization process which involves 2 inputs such as the change of anguler speed of $\Delta\omega$ and the change of ΔP which is directly obtained from the scheduled system (as in Figure 4) and it will also produce optimal gain. The two inputs are processed to produce the scheduled optimal gain of $\mathbf{K}_{op\text{-}s}$ as in Figure 8 below

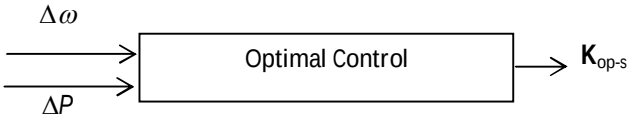

Figure 8: Block diagram of optimization control

To measure the valid dimension level, there is used the formula as follow:

$$\mathbf{K}_{op-s} = \frac{\sum_{i=1}^{49} w^i \mathbf{K}_{op}}{\sum_{i=1}^{49} w^i}, \text{ with } w^i = \min(\mu(A_1^i), \mu(A_2^i)) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

CONCLUSION

Power System Stability (PSS) is an utility which has been widely used for improving osilation stabilizer of low frequency. The stabilizer generates additional signal to the system of exitation orAutomatic Voltage Regulator (AVR). Therefore, the main function of additional control such as Power System Stabilizer (PSS) is to arrange globally the frequency and terminal voltage on each generator as the response of occured deviation of variable which has been set. In addition, the main usage of energy system control is to arrange the deviation between real power value and reaction of generator which is sent from the system. The generator system can be also carried out by arranging active utility which supplies energy into transmission network to the work point so that forms opened loop. The work process of opened loop system very influences the control of generator and turbine.

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