Vol-07 Issue 06, June-2023 ISSN: 2456-9348
Impact Factor: 6.736

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SYSTEM STABILITY ANALYSIS USING POWER SYSTEM STABILIZERS (PSS)

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ABSTRACT
The stability of the electric power system is one of the topics that is always discussed and especially stability in generation. To maintain system stability, one of the devices used is PSS (Power System Stabilizers) where signals are injected, among others, in phase with the next power PSS output is entered into the excitation circuit. To show the design results, a simulation was carried out by increasing the load gradually, namely every 5 seconds. The simulation was carried out by determining the values of K_1, K_2, K_3, K_4, K_5, and K_6 and obtained the number $K_1 = 0.6864$; $K_2 = 1.9843$; $K_3 = 0.2995$; $K_4 = 1.7084$; $K_5 = -0.0673$; $K_6 = 0.4027$.
Keywords:
Municipal Solid Waste, Biological Treatment, Thermal Treatment, Physical Treatment

INTRODUCTION

Electric power system stability is defined as the ability of an electric power system or its component parts to maintain system synchronization and balance. In the electric power system, there are three kinds of stability controllers to get an optimal system condition and one way is the use of AVR (Automatic Voltage Regulator).
For the stability of the plant used PSS (Power System Stabilizers)[1], which is a device with a certain transfer function that can be adjusted in magnitude and phase. In order for PSS to stabilize the plant in all hazardous conditions, the value of the magnitude and phase of the PSS must be tuned taking into account hazardous loading conditions[2]. By analyzing the frequency response at a specific oscillating frequency range[3][4], a robust control for specific load changes can be devised.

Electric Power System

There are six general sources of waste generation, namely; domestic, commercial, industrial, agricultural,institutional and natural.
Electric power systems are the components of electric power that form an integrated and connected system. In general, the electric power system is divided into three parts, namely the generation system, transmission network and load.

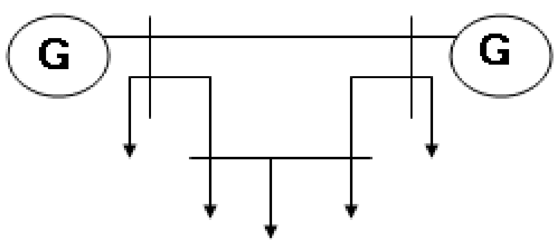

Figure 1 Electric Power System

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Figure 1 shows the transfer of electrical energy from the plant center to the load through the transmission network and figure 2 shows the process of transferring energy from natural resources into electrical quantities such as power, current and voltage.

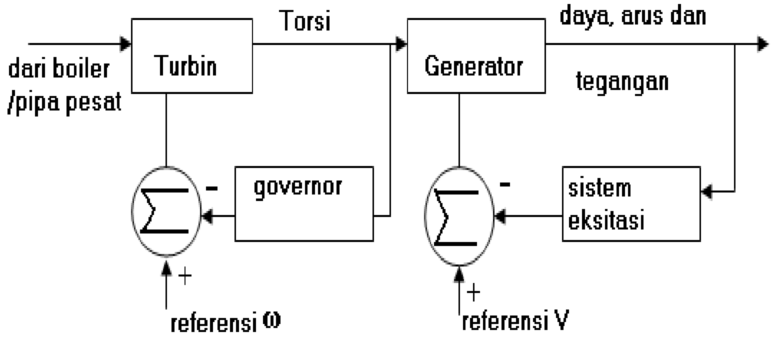

Figure 2 Electric Power Plant System

There are two settings are made to achieve system stability, namely by using the governor and using the excitation system. These two controllers, have different response times. The governor has a slow response to load changes, while the excitation system has a fast response. Therefore, in studies such as stability studies, the governor's response is often ignored

Electric Power System Stability

Electric power system stability can be defined as the ability of an electric power system or its component parts to maintain synchronization and balance in the system. Based on the nature and magnitude of the disturbance, the problem of electric power system stability can be divided into three[5], namely:

1. Steady state stability
2. Transition stability (transient)
3. Dynamic stability

In all stability studies, the aim is to determine whether the rotor of a disrupted engine can return to working state at a constant speed, or not to facilitate calculation, in all stability studies three basic assumptions are made, namely:

1. In the stator windings and power system, only synchronous frequency current and voltage are taken into account. Therefore, the dc offset current and the harmonic components are all ignored.
2. Symmetrical components are used in the representation of unbalanced disorders.
3. The voltage generated is considered not affected by changes in engine speed.

Angle-Power Equation

In the swing equation for a generator, the mechanical power input from the initial drive Pm will be considered constant. The power angle equation that then applies to pure reactance meshes is only one that we already know

$$P_e = P_{maks} \sin \delta$$

where $P_{maks} = |E_1'||E_2'|/X$ and X is the reactance transfer between E1′ and E2′.

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Electric Power System Model

In dynamic stability studies, synchronous generators are modeled as a constant voltage behind the transient reactance as shown in Figure 3.

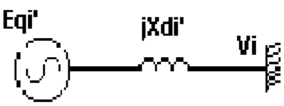

Figure 3 Synchronous Generator Model

Where: E_{qi}': Axis transient voltage q from the machine i; x_{di}': D-axis transient reactance of machine i; V_i: bus voltage.

The Role of the Voltage Regulator

In the power generation system by the generator, to keep the rotor rotation within the limits of stability is known as the excitation system and voltage regulator. Exciter as an excitation system serves to provide reinforcement to the current so that if there is a change in rotor rotation it can be synchronized again.

While the voltage regulator functions almost the same. If the exciter serves to maintain the stability of the rotor by providing field current reinforcement, then the voltage regulator (automatic) serves to maintain voltage stability at a constant normal working state[6][7].

PSS Transfer Function

As explained in the previous chapter, the PSS block diagram has been explained which has a general transfer function as follows:

$$G_F = K_{stb}\left(\frac{1+sT_1}{1+sT_2}\right)\left(\frac{1+sT_3}{1+sT_4}\right)\ldots..\left(\frac{1+sT_{k-1}}{1+sT_k}\right)\left(\frac{1+sT}{1+sT}\right)$$

K_{stab} is a gain constant for which the value can be set.

Generator Modeling

In generator modeling there are three models that can be used, namely: Simplified Model (Classical Model), Two Axis Model, Completed Model. In the final project modeling of the generator used is the Two Axis model, the equation below to express one machine with the equation is as follows

$$\tau'_{q0i}\,\dot{E}'_{di} = -E'_{di} - \left(x_{qi} - x'_i\right)I_{qi}$$

$$\tau'_{d0i}\,\dot{E}'_{qi} = -E_{FDi} - E'_{qi} + \left(x_{di} - x'_i\right)I_{di}$$

$$\tau_{ji}\,\dot{\omega}_i = -T_{mi} - \left(I_{di}E'_{di} + I_{qi}E'_{qi}\right) - D_i\omega_i$$

$$\dot{\delta}_i = \omega_i - 1$$

The derivation of the formula so that the above equations are obtained will not be discussed and is contained in the book Power System Control and Stability by Dan Fouad. If the above equations are written in a block diagram, it will be like figure 4 and figure 5.

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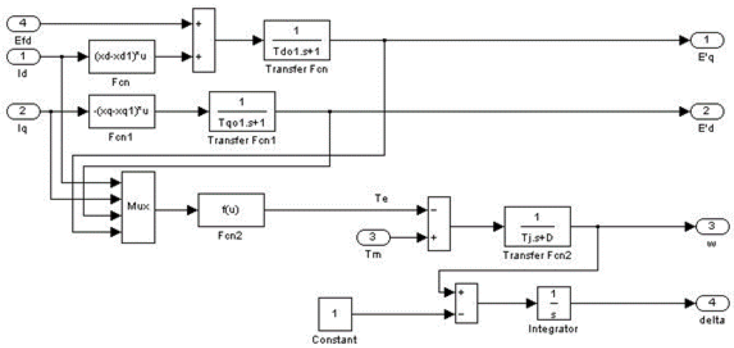

Figure 4 Two Axis Generator Model Block Diagram

Exciter Modeling

The change in voltage V_{me} dan Δ_{FD} results from V_{REF} or V_T. If it is assumed that the value of V Δ_{REF} = 0 and the

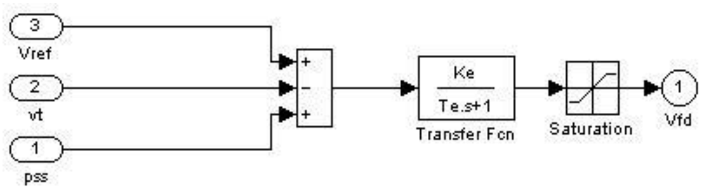

Figure 5 Excitation System Block Diagram

transducer has no time delay, then $V_{\Delta FD}$ depends only on $V_{\Delta T}$. For ease of analysis, it is assumed by simple modeling of voltage regulators and excitation systems[8][5]. The relationship of the change in voltage V $_{medan}$ Δ_{FD} and the change in input voltage of synchronous generator $V_{\Delta T}$ in the forms

$$\Delta V_{FD} = -\left[\frac{K_e}{1+\tau_e s}\right]\Delta V_T$$

which : Ke = regulator reinforcement constant

τe = Regulator amplifier time constant.

Governor Modeling

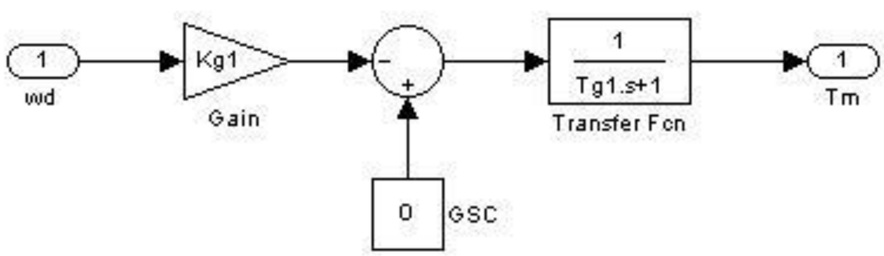

Figure 6 Governor Block Diagram

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A change from speed or load or speed reference [Governor Speed Changer (GSC)] results in a change in mechanical torque (T_m). The magnitude of the change from T_m depends on the speed that has dropped and the transfer function of the governor and power source.
From the figure 6, it is assumed that the value of GSC = 0 and the equation that expresses the change in mechanical power due to the turbine and speed in the governor is

$$\Delta P_m = -\left[\frac{K_g}{1+\tau_t s}\right]\Delta\omega$$

With: Kg = Gain constant
τg = Governor Time Constant

Network and Load Modeling

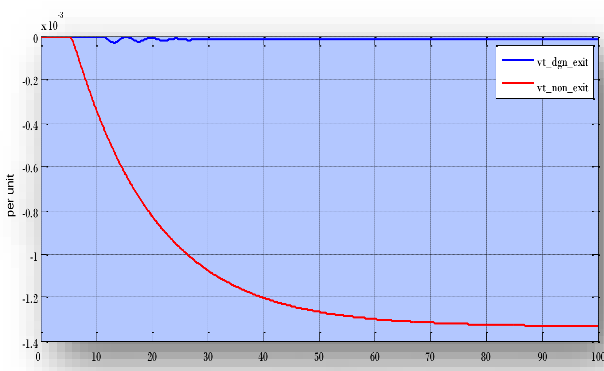
Load modeling is considered a constant impedance or static load. By considering the load as a static load, the load is considered as impedance and combined with the impedance of the network. Then network reduction is carried out so that the network matrix changes to match the number of generators

METHODOLOGY RESEARCH

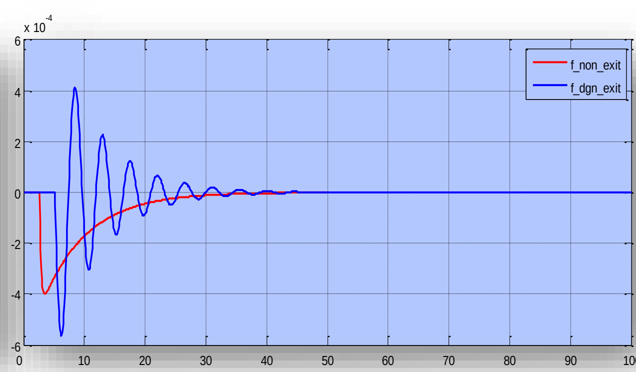
In this study, the methods used are:
1. Literature study
2. Design simulation using the MatLab compute language
3.

RESULTS AND DISCUSS

Data K_1, K2, K_3, K_4, K_5, K_6



Graph 1. Change in generator terminal voltage due to 0.01 pu load increase in the 5th second



Graph 2. Frequency change due to additional load of 0.01 pu in the 5th second

Analysis:
The additional load results in a decrease in turbine rotation. This also results in a decrease in system frequency. To achieve stability, the turbine needs to increase its mechanical power to compensate for the additional power. From graphs 1 and 2, it can be seen that there is a striking difference between the change in terminal voltage of a circuit without excitation and a circuit that uses excitation. Similarly, changes in rotor angle and frequency changes. What needs to be considered in this case is the change in voltage as the main function of the AVR. From hail simulations have shown that AVR can fix voltage when there is an increase in load.

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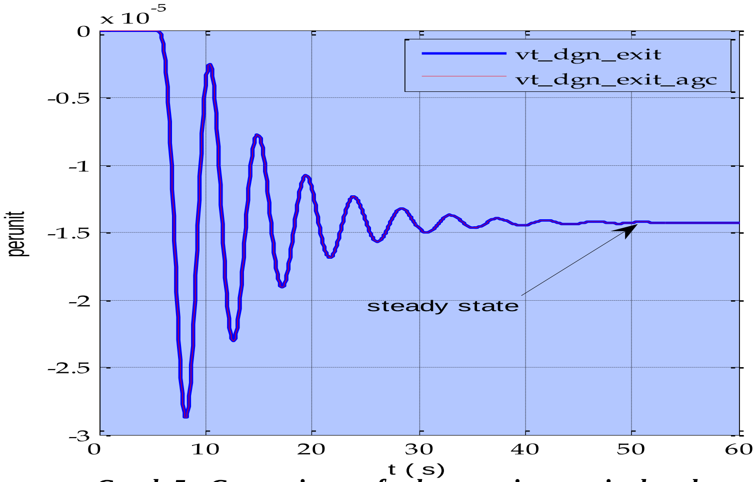
Control design added with AGC (Automatic Generator Controller)



Graph 5. Comparison of changes in terminal voltage between using K1 with AGC

Analysis:

From Graphs 3, 4, and 5, by removing K1 and replacing it with the AGC circuit, there is no change in the terminal voltage, frequency, and angle of the rotor.

Power System Stabilizer (PSS) Design

To calculate the parameters K_1 to K_6 first calculate the parameters of the machine.

Ia = P/(V_t.Pf) = 1.0/(1.0 * 0.85) = 1.176; Machine armature current.

ϕ =arc cos (0.85) = 31.788°

So: $I_r = I_a \cos\phi$ = 1.176 * 0.85 = 1.0; $I_x = - I_a \sin\phi$ = 1.176 * 0.5267 = -0.6194;

The angle between the q axis and the terminal voltage V_t is:

$\delta - \beta = \tan^{-1} [(x_qI_r + rI_x)/ (V_t + rI_r – x_qI_x)]$

$= \tan^{-1}$ [(1.22*1.0 + 0.0014*(-0.6194)/ (1.0 + 0.0014*1.0 – (1.22*-0.6194)

$= \tan^{-1}(0.6938)$ = 34.76°

And $\delta - \beta + \phi$ = 34.76° + 31.788° = 66.5480° is the angle at which Ia lag with respect to the q axis

From the above angles can be obtained currents on the d and q axes, namely:

$I_d = -I_a \sin (\delta - \beta + \phi)$ dan $I_q = I_a\cos (\delta - \beta + \phi)$

= -1.176*sin (66.5489°) I_q = 1.176*cos (66.5489°)

= -1.08 pu = 0.468 pu

The voltage on the d and q axes is

$V_d = -V_t \sin (\delta - \beta)$ = 1.0 *0.57 = -0.57 pu

$V_q = V_t \cos (\delta - \beta)$ = 1.0*0.82 = 0.82 pu

$E_{FD} = V_q + rI_q - x_dI_d$ = 0.82 + 0.0014*0.468 + 1.25*1.08 = 2.1707 pu (E_{FD} pada steady state)

$i_F = \sqrt{3}. E_{FD}/L_{AD} = \sqrt{3}.2.1707/1.55$ = 2.426 pu

To obtain the voltage on the bus (V_m) use the equation $\bar{V}_m = \bar{V}_t - \bar{Z}_e\, \bar{I}_a$

Suppose $V_a = V_a\angle\beta = 1.0\angle\beta$, so

$\bar{I}_a = I_a \angle(\beta - \phi)$ = 1.176∠(β-31.788°)

$V_m \angle\alpha$ = 1.0∠β - (0.4 ∠87.13°)*1.176∠(β-31.788°) ||| each of its corners is reduced, β so:

$V_m\angle(\alpha - \beta)$ = 1.0 – 0.4704∠55,342 = 1.0 – (0.2675 + j0.387) = 0.7325 - j0.387

= 0.828∠-27.85°

thus V_m = 0.828 pu, and (β - α) = 27.85° which V_t lead to V_m.

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The angle between the infinite bus and the q axis can be obtained as follows:

$(\delta - \alpha) = (\delta - \beta) + (\beta - \alpha) = 34.76° + 27.85° = 62.61°$

$E_{qa0} = E'_{q0} - (x_q - x'_d)\, I_{d0} = I_F{*}L_{AD} - (x_q - x'_d)\, I_{d0} = i_F{*}L_{AD}/\sqrt{3} - (x_q - x_d')\, I_{d0}$

$= 2.426{*}1.55/\sqrt{3} - (1.22 - 0.232) {*}{-1.08} = 3.421$ pu

$1/K_l = R_e^2 + (x_q + X_e)(x'_d + X_e) = 0.022 + (0.715 + 0.4)(0.232 + 0.4) = 0.7051$

$K_l = 1/0.7051 = 1.4182$

From the results of the above calculations obtained the following parameters:

I_{d0}	=	-1,08 pu	I_{q0}	=	0.468 pu
V_{d0}	=	0.57 pu	V_{q0}	=	0.82 pu
E_{FD}	=	2.1707 pu	V_m	=	0.828 pu
$(\delta 0 - \alpha)$	=	62.61°	E_{qa0}	=	3.421 pu

$K_l = 1.4182$

$K_1 = K_l V_m [E_{qa0}[R_e \sin(\delta 0 - \alpha) + (x'd + Xe)\cos(\delta 0 - \alpha)]$
$+ I_{q0}(x_q - x'_d)\,[(X_e + x_q) \sin(\delta 0 - \alpha) - R_e \cos(\delta 0 - \alpha)]]$

= 1.4182*0.282(3.421(0.02*sin (62.61°)+(0.232+0.4) *cos (62.61°))
+0.468*(1.22-0.232) ((0.4+1.22) *sin (62.61°)-0.02*cos (62.61)))

= 0.6864

$K_2 = K_l\, [R_e E_{qa0} + I_{q0}[R_e^2 + (x_q + X_e)^2]]$

= 1.4182*(0.02*3.421+0.468(0.468^2+(1.22+0.4) ^2))

= 1.9843

$K_3 = 1/\,(1 + K_l\,(x_d - x'_d)\,(x_q + X_e))$

= 1/ (1+1.4182*(1.25-0.232) *(1.22+0.4))

= 0.2995

$K_4 = V_m K_l (x_d - x'_d)[(x_q + X_e) \sin(\delta 0 - \alpha) - R_e \cos(\delta 0 - \alpha)]$

= 0.828*1.4182*(1.25-0.232) *((1.22+0.4) *sin (62.61°)-0.02*cos (62.61°))

= 1.7084

$K_5 = (K_l(v_{q0}/v_{t0})\, x'_d V_m [R_e \cos(\delta 0 - \alpha) - (x_q + X_e) \sin(\delta 0 - \alpha)]$
$-(K_l(v_{d0}/v_{t0})\, v_m)\, [(x'd + Xe)\cos(\delta 0 - \alpha) + R_e \sin(\delta 0 - \alpha)]$

= (1.4182*(0.82/1.0) *0.232*0.828) *(0.02*cos (62.61°)-(1.22+0.4) *sin (62.61°)) -(1.4182*(-0.57) *1.22*0.828) *((0.232+0.4) *cos (62.61°)+0.02*sin (62.61°))

= -0.0673

$K6 = (v_{q0}/v_{t0})\, [1 - K_l x'_d (x_q + X_e)] - (v_{d0}/v_{t0})\, K_l x_q R_e$

= (0.82/1.0) *(1-1.4182*0.232*(1.22+0.4)) +(0.57/1.0) *1.4182*1.22*0.02

= 0.4027

CONCLUSION

From the calculation results, K_1, K_2, K_3, K_4, K_5, K_6 values are obtained. These values are fed into parameters to be simulated using Simulink in MatLab.

The values are as follows:

K1 = 0.6864
K2 = 1.9843
K3 = 0.2995
K4 = 1.7084
K5 = - 0.0673
K6 = 0.4027

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ACKNOWLEDGMENT
This research was supported by State Polytechnic of Samarinda as Grant Maker partially. We thank our colleagues from Product Design Department who provided insight and expertise that greatly assisted this research, although they may not agree with all of the interpretations/conclusions of this paper. Also, to fellow lecturers in the Department of Electrical Engineering who have provided valuable input.

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