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Frequency Control System Design of Turbine Gas using Electro-Hydraulic Converter

Fitria Hidayanti, Ajat Sudrajat, Gamal Fiqih Handono Warih

***Abstract:** In controlling the electric power system, it requires Load Control Frequency (LFC) to control load in MW and frequency (Hz) in the nominal range of 50Hz. The nominal parameter for the controller is the opening of the fuel valve, which is driven by the Electro-Hydraulic Converter (EHC). The control variable contained in the gas turbine system itself is the deviation between the setpoint and the feedback does not exceed 5% if the value exceeds the set value, it will produce a deviation, that means playing the error control. If the backup control system is active at startup, this system will result in not being able to synchronize because variable input from the network can only be controlled by frequency and active power control. It can also result in travel due to synchronous failure. If an error occurs during the operation of the backup controller load will be on, it will cause more speed or a maximum of 147 MW and of course, it will be dangerous for the gas turbine generator system. This paper will analyze the protection system from main control errors due to deviations between feedback and the setpoint set at 5% to 10% and see the system's response when there is a system change in the turbine gas. The control system design produces the largest error value at 7.2% valve opening with the control parameter Kp 12, Ti 1.9, Td 2. With simulations and data were taken through POS Simponi S+ and logic data analysis on PDDS (Programming Diagnostic Display System). The speed droop response value affects how much speed regulation is set, the smaller speed droop response value the faster the response to frequency changes and the greater speed droop response value the slower the response received by the system. In this study, the rise time value was 0.26 s and the settling time was 17.9 s.*

***Keywords:** frequency, turbine gas, PID, control system, electro-hydraulic converter*

I. INTRODUCTION

The automatic control is a closed control system that does not require any action from the operator. In the control automation system, there are two interrelated process variables, controlled variables, and manipulated variables. The controlled variable is a variable process that can be adjusted to a certain value or with a specific range as well as from the EHC system that works automatically to maintain stability both for combustion or stability to maintain frequency when fluctuating load changes occur.

With this critical part, special attention is needed to treat the equipment to remain reliable. Today many failures due to damage to the EHC have an impact on the trip unit from the data we get from Maximo which shows failure due to EHC as much as 5 times in 2018 and early 2019 occurred 5 times. Failure which can be indicated to the controller that is unable to maintain the stability of the EHC which results in material fatigue contained in the EHC itself includes slide valve, moving coil, spring and Linear Variable Differential Transformer (LVDT). When we do the calibration, we often adjust the PID parameters, Kp, Ti, and Td, which affect the stability of the response time of the equipment on the E715 card which can have an impact on the reliability of a device. In this study, analysis and tuning of a control system will be carried out specifically in systems that affect the performance of the EHC. Gas and Steam Power Plant, Tanjung Priok, Indonesia with a total capacity of 1180 MW consists of two blocks, i.e. Block 1 consisting of 3 pieces of a gas turbine of 130 MW and 1 steam turbine 200 MW and Block 2 consists of three gas turbines of 130 MW and 1 steam turbine 200 MW. Gas and Steam Power Plant, Tanjung Priok combined power cycle gas turbine combined with GSD turbine with fuel valve governor and exhaust gas from the gas turbine is used to obtain steam with HRSG. The steam turbine valve governor regulates the steam output. The type of gas turbine is ABB GT13E1 has a capacity of 130 MW, which has a silo type with a double burner and a single combustor with turbine inlet temperature (TIT) 1,070 ^{0}C and turbine output temperature (TOT) 545 ^{0}C. In the primary setting in Gas and Steam Power Plant, Tanjung Priok, Indonesia, the control system has government equipment, excitation systems, and Automatic Voltage Regulators. Speeddroop settings for gas turbines are 4%. In gas turbines, there are frequency controllers and temperature controllers. Meanwhile, the secondary settings are equipped with a Load Frequency Controller (LFC). Gas and Steam Power Plant, Tanjung Priok, Indonesia is connected to a 150 KV infinite bus in the Priok which bears the burden of the Jakarta-Bekasi area of 750 MW at the lowest frequency setting of 48.3 Hz [1].

EHC (Electro Hydraulic Converter)

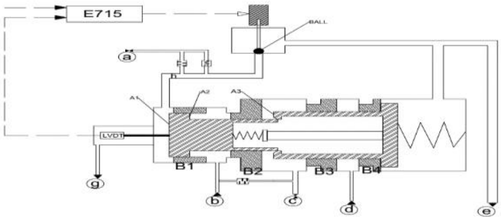

Fig. 1. Force View for Moving Piston EHC, (a) Safety System, (b) H.P Hydraulic system, (c) Control System, (d) Drain, (e) Leakage, (g) Leakage [2]

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***** Correspondence Author

Fitria Hidayanti*, Engineering Physics Department, Universitas Nasional, Jakarta 12520, Indonesia. Email: fitriahidayanti@gmail.com

Ajat Sudrajat, Engineering Physics Department, Universitas Nasional, Jakarta, Indonesia.

Gamal Fiqih Handono Warih, Engineering Physics Department, Universitas Nasional, Jakarta, Indonesia.

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When the signal from the E715 position controller (Fig. 1) is transmitted to the electrodynamic driver/moving coil, an electromagnetic force will occur which causes the movement of the rod so that the ball in the pilot control system will control the pressure. Oil flow originating from a line a will pass through two components, namely the orifice and check valve, the output of the orifice will be forwarded to the surface of A1 and Ball which passes through the pilot control line which will later give the effect of shifting the slide valve control. Line b gets pressure from the header power oil with higher pressure than in line a, this pressure will operate on the surface A2 and will be in the opposite direction to the compression spring force. Slide control valve will stop shifting/moving when the total amount of force produced is in equilibrium. If there is a change again, it will immediately adjust to achieve a force balance under Newton's third law. LVDT Position Transmitter will send a signal in the form of 4-20 mA which represents the position of the slide valve control. The position controller (E715) will make a comparison between the setpoint and the feedback from the position transmitter. If there are still differences, it will condition the condition immediately. On line c the pressure is supplied from the power oil header after passing the Orifice Feed component, which will go both ways, the direction to the servo valve and the direction to the control piston to provide thrust to the A3 surface and partly to the drain so that the amount of pressure can fluctuate slide valve control movement. If the pressure on the system a collapse (such as turbine trip), the pilot control system will experience a drastic decrease in pressure because the check valve on the line will open which aims to dispose of fluid in the line. Pressure line b will push surface A2 and control spring (spring on the control slide valve) to the left position until it stops with the intermediate housing. The control slide valve is fully open so that pressure on line C will drop and the actuator is in the safe end position. Compression spring will push the control piston to the left until it stops. Leak oil will run into the drain on line D so the pressure is gone.

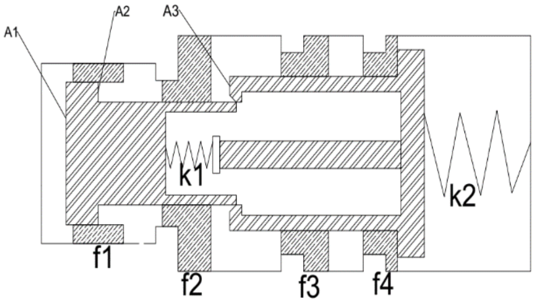

Fig. 2.Force Description, (f_1) Safety System, (f_2) H.P. Hydraulic system, (f_3) Control System, (f4) Drain, (k_2) Spring (k_1) Spring [2]

The force (Fig. 2) affecting the change of the slide valve control that allows giving a problem is the kinetic friction force (f_k) with a high coefficient of friction can result in a force k = friction into a static friction force (f_s). The change from kinetic friction to static friction is influenced by lube oil content in the form of particle.

System Gas Turbine

The control system in the turbine gas system generally consists of the main part of the gas turbine and governor and the excitation system. The combination of the two systems is connected to the generator to form a control system for Gas Power Plants. The control system is intended to maintain stability so that the frequency is in the desired area so that it can return the rotor rotation to synchronous rotation and voltage is at the desired nominal voltage.

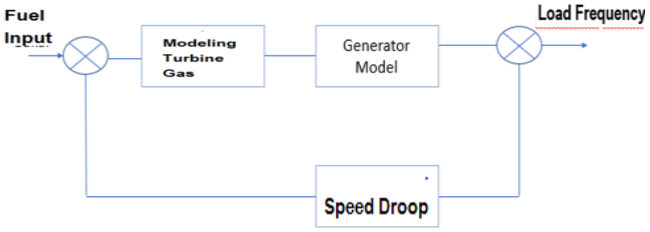

Fig. 3.Closed-Loop System Governor [2]

The mathematical model of the turbine gas system was developed using the gas flow model approach through a vessel as shown in Fig. 3. This model was as proposed in [3], which was mainly based on the modelling proposed in Fig.4 [4].

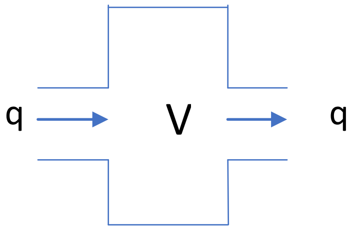

Fig. 4.Illustration of Turbine like a Vessel [2]

Governor Control System

The governor system used in this plant is an EHC governor system consists of electronic parts that get input from the speed and load (MW) signals. The output of this electronic part is a voltage signal that is converted into hydraulic pressure by an EHC. Furthermore, the pressurized hydraulic fluid will drive the high-pressure servo control valve. The governor will act to prevent changes in frequency. This governor rotation speed sensor can be a flyball assembly or frequency transducer. The output of the speed sensor and load sensor (MW) passes through the signal conditioner and amplifier (amplifier) in the form of a combination of mechanical, hydraulic elements, electronic circuits and software. Fig. 4 shows the governor system. In systems connected to two or more power plants, a speed droop governor is needed with the aim that if an interruption occurs that causes a change.

Fig. 5 show the generator response to load changes. In settings using a speed-droop, the governor did not return the turbine rotation rate to nominal frequency but in a range in accordance with the choice of the speed-droop constant.

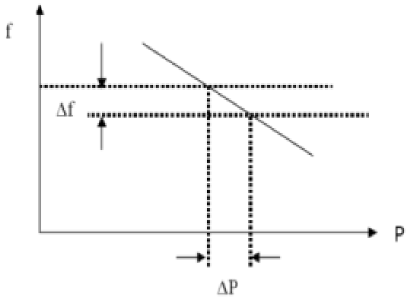

Fig. 5.Generator response in speed droop

II. MATERIALS AND METHOD

Flowchart for this research follows Fig. 6. Data Retrieval Specifications EHC (Electro-Hydraulic Converter), Sensors and actuators include data on the amount of input and output on gas turbines, sensors and actuators. Data was collected at Gas and Steam Power Plant, Tanjung Priok, Indonesia. Modelling of governor control systems, sensors and actuators EHC are obtained from the data specifications that have been taken, and modelling is taken manual book reference. Model validation using E715 specification data for real power, temperature, and frequency during operating conditions with a nominal load of 25%, 50%, 75%, 100% of net capacity and data retrieval when changes occur Frequency to determine system response. The design of the PID control gain to get the Kp, Ti, and Td parameter values to get a maximum overshoot value of 3.03%, steady-state error 7.2%, and a settling time of 75 s and disturbance with a maximum overshoot of 0.75% and settling time 1102 s.

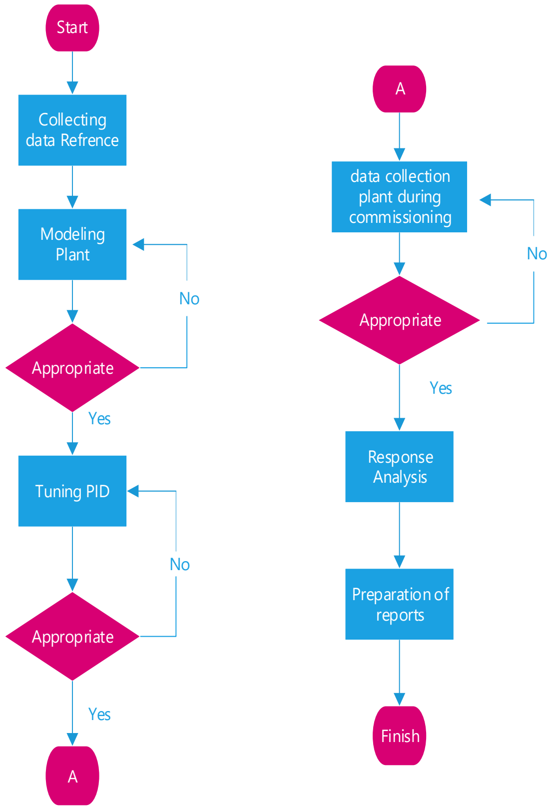

Fig. 6.Research Flowchart

III. RESULTS AND DISCUSSION

The simulation results from modelling the EHC (Electro-Hydraulic Converter) as follows.

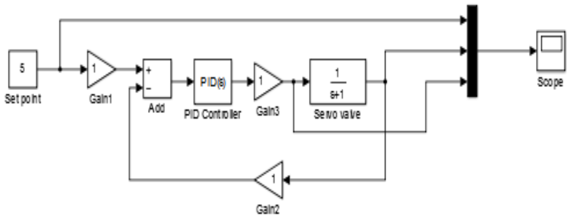

Fig. 7.Governor control loop system

From Fig. 7, we get the system modelling by referring to the E715 manual book that uses the PID control parameter tuning (Table 1).

Table- I: Data Card E715

Variable Reference	Value (VDC)	Adjust Reference
MP1	1.9882	2 VDC (SP from 83SR51 to moving coil)
MP2	0.0042	P1 (offset SetPoint)
MP3	0.0037	P2 (Gain SetPoint)
MP4	2.1056	2 VDC (from LVDT)
MP5	1.8884	P3 (Offset Actual)
MP6	-4.2138	P4 (Gain Actual)
MP7	12.719	P5 (Proportional)
MP8	1.0511	P7 (Integral) and I Part (Ki)
MP9	1.017	Limit Control Deviasi (jumper) B51& B52
MP10	-11.572	SUM signal P-I & D-part + Dither
MP11	0.929	Servo valve Current (P10)

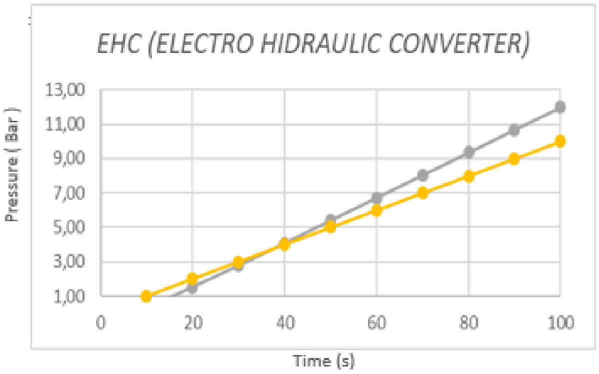

Fig. 8. Characteristics EHC

The data obtained to determine the character of the EHC system (Fig. 8) are as follows the data obtained when tuning the EHC on the Gas Turbine Unit 1.3 by taking data on the control system/card controller type E715 and the response obtained by entering the Linear Variable Differential Transformer (LVDT) 2 Volt feedback parameter with a constant setpoint input of 1.9 VDC, with proportional parameters of Kp = 12, Ti = 1.9, Td = 2 by taking as many samples.

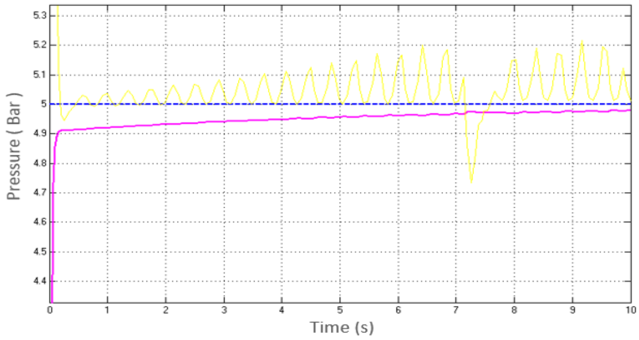

Fig. 9. Response Setpoint on 5% Opening

Fig. 9 showed the dynamics of the output signal stability due to changes in the control system in seconds 7 to 8 s occurs a maximum deviation of the range 4.8 to 5.1% which if this happens can result in failure on the EHC system.

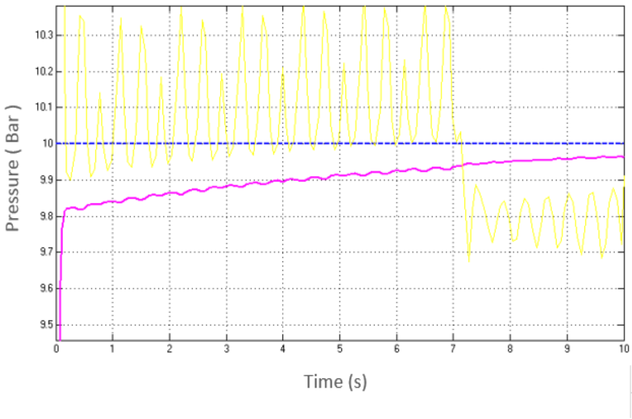

Fig. 10. Response Setpoint on 10% Opening

Fig. 10 shows the dynamics of the output signal stability due to changes in the control system in seconds 7 s to 7.2 s occurs a maximum deviation of the range of 9.8% to 10.3% which if this happens can fail the EHC.

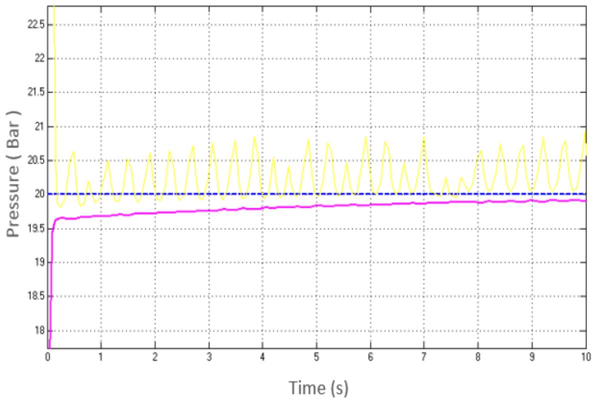

Fig. 11. Response Setpoint on 20% Opening

Fig. 11 shows the dynamics of 20% output signal stability due to changes in the control system in seconds to 0.2-10 s occurs a maximum deviation of the range of 20% to 20.5% which if this happens can fail the EHC system.

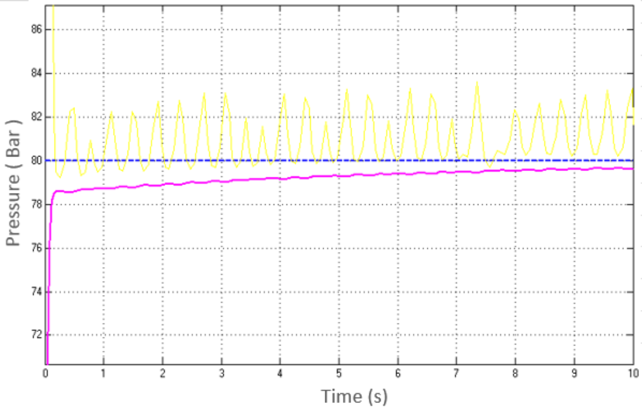

Fig. 12. Response Setpoint on 80% Opening

Fig. 12 shows the dynamics of 20% output signal stability due to changes in the control system in seconds to 0.2 s to 10 s, the maximum deviation occurs from the range of 20% to 20.5%, which if this happens can fail the EHC system. The implementation of error signal replacement in the EHC system.

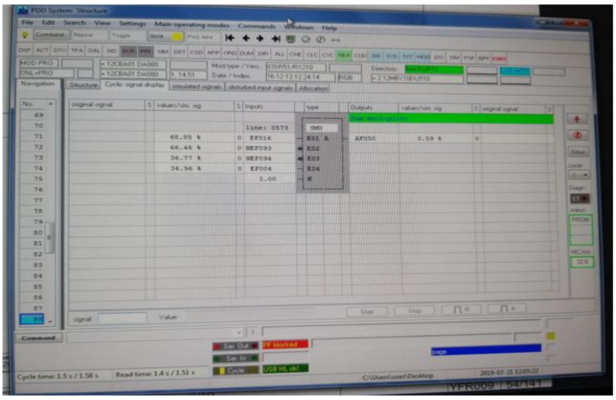

Fig. 13. Signal set value and actual signal on PDDS

Fig. 13 shows the deviation parameter which the value of the feedback and commands contained in the DCS (Distributed Control System).

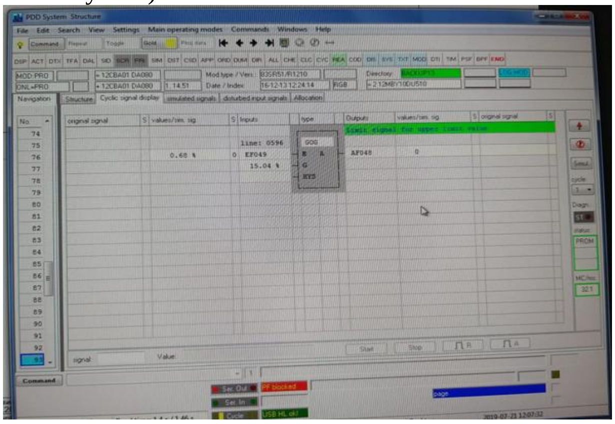

Fig. 14. Signal Parameters changed by GOG

In Fig. 14, the result of 15% as a result of the simulation that occurs due to the dynamics of frequency changes and changes in system fluctuations we change the maximum gain of this deviation to cope with the system so that no trip occurs when the load fluctuates [5].

System Test Results as shown in Fig. 15.

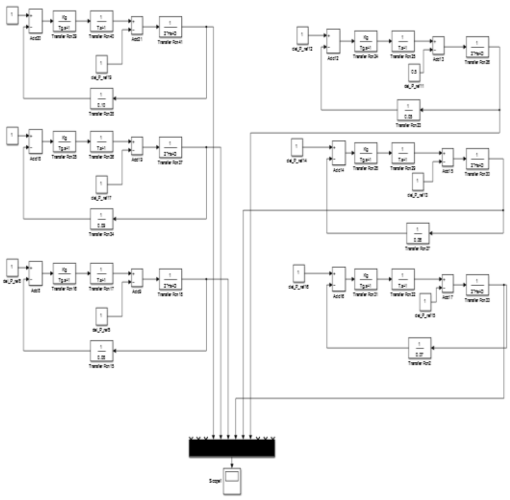

Fig. 15. LFC (Load Frequency Control) Simulation

In Gas and Steam Power Plant, Tanjung Priok, Indonesia Block 1 and Block 2, the frequency setting uses free governor. In other words, free governor auto will follow the frequency change if there is a frequency change so that the decrease or increase in load due to frequency changes is limited in value. For units 1 and 2 use a free governor and a speed droop of 4%, so it is fast in responding to changes in frequency that occur based on the manual book because Block 1 and Block 2 uses EHC. The system response to the free governor block as Fig. 16.

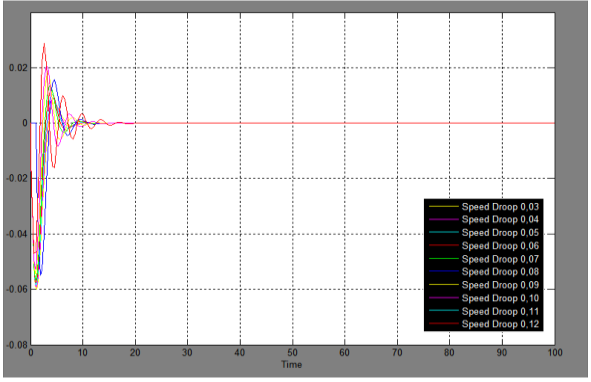

Fig. 16. Simulation Chart with free Gov data with Speed droop between 2% and 10%.

From the results of the simulation image above, it appears that the governor with a value of R = 2% responds more quickly to changes in load and the decrease in frequency is not too large compared to the governor with a value of R = 12%. This is because when there is a sudden increase in the load of 0.05 p.u., the system frequency decreases. Then the output of this frequency decrease is responded back by the governor, so the valve in the generator opens up so that more steam enters the turbine. Then the speed will increase, followed by an increase in frequency. In the field at Priok Block 1 and 2 uses 4% Speed Drop as 49 MW/Hz.

This means that every 0.1 Hz change will result in load changes of 4.9 MW. Seen from the graph 1 Condition is during Governor Control operation, set load limit is set manually adjusting to Temperature After Turbine conditions. The free governor's condition is locked, so the governor should be able to follow load changes can not work optimally. The governor is locked at a 100% load limit, so when there is a decrease in the frequency of the addition of steam in the turbine, the operator changed it manually. So, it can be said that when a governor has a large speed droop, the governor acts "slow" because it is slower in responding to changes in frequency that occur. Vice versa, if the governor has a small speed droop, the governor is said to be "responsive" because it responds more quickly to changes in frequency [5].

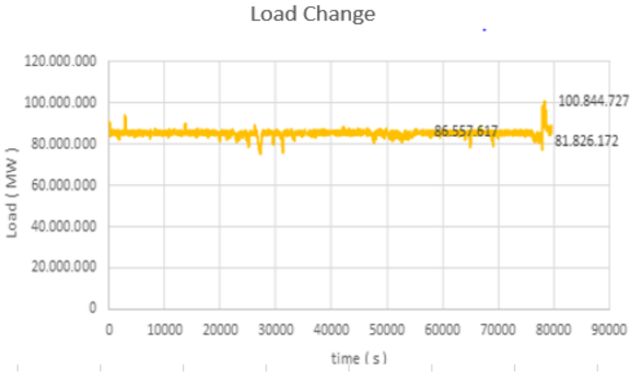

Fig. 17. Response of Free Governor

Fig. 17 shows the actual few-frequency response when a trip incident one of the power plant units in the Java-Bali electricity system resulted in a frequency drop during the frequency change.

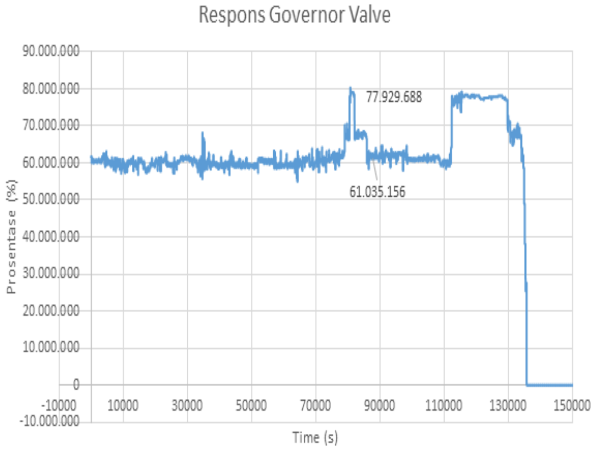

Fig. 18. Changes in stroke/valve response

The response on Fig. 18 shows the response when a frequency change occurs from the percentage of 61.035-77.929%, which shows the dynamic response.

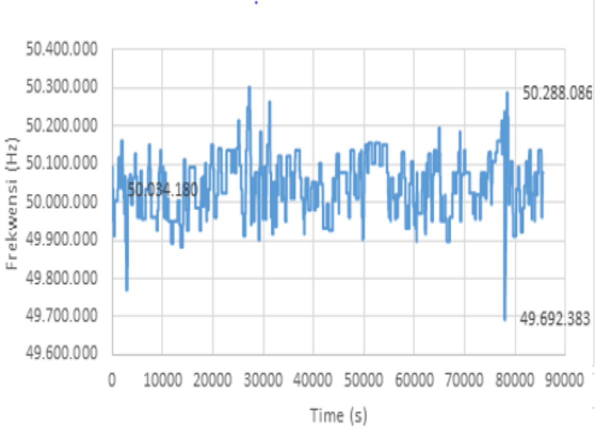

Fig. 19. Frequency Response

Fig. 19 explains that there is a decrease in frequency when there is interference or decrease in nominal frequency due to blackout from a range of 50 Hz to 49.692 Hz.

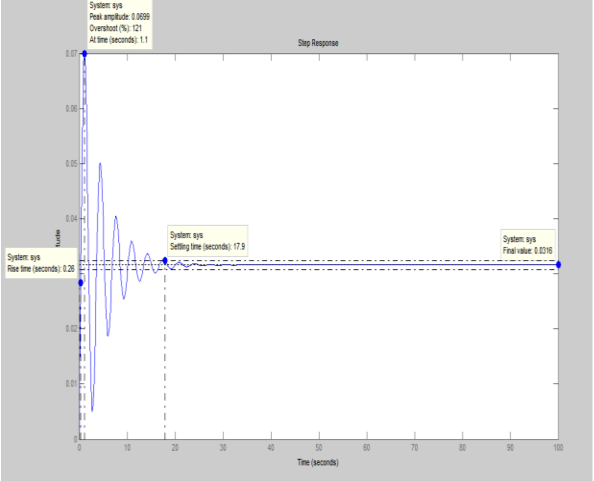

Fig. 20. Graph of response changes when given a load

Fig. 20 stated that a rise time condition of 2.6 s and settling time of 17.9 s. A change of 0.04 yields a maximum result of 0.1 p.p.u although after it is steady within 20 seconds.

IV. CONCLUSION

The conclusions obtained from this study are as follows:

a. The governor's ability largely determines the performance of frequency control, the value of R varies between 2% to R 12% showing results that have different responses to changes in load from the turbine and generator system, the smaller the value of R given, the higher the load (MW) produce.
b. Deviation of the EHC (Electro-Hydraulic Converter) can cause an abnormal control system.
c. The response of the Gas and Steam Power Plant, Tanjung Priok frequency control system is influenced by the performance of the speed drop having a rise time condition of 0.26 s and the settling time of 17.9 s.

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AUTHORS PROFILE

Fitria Hidayanti Doctoral student at Faculty of Engineering, University of Indonesia. She is an Assistant Professor at Engineering Physics Department, Universitas Nasional.

Ajat Sudrajat Doctoral student at Universiti Teknikal Malaysia Melaka. He is an Associate Professor at Engineering Physics Department, Universitas Nasional.

Gamal Fiqih Handono Warih Bachelor Degree at Engineering Physics Department, Universitas Nasional.