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Governor Control Valve Monitoring System to Keep Stability of Steam Turbine Rotation

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***Abstract**: This One of the important components in the Steam Power Plant system is the Governor Control Valve system. In this system, the control valve is used to adjust the volume of steam in the pipe before going to the steam turbine. To determine the size of the valve opening, the control valve gets an order from a controller called the governor. Power plants usually use a Safety Instrumented System (SIS), the Tri-GP SIS Logic Solver as the governor. In controlling it, a control module is used which is called the Steam Turbine Generator Control, Turbine Control System (TCS). The steam turbine will be adjusted gradually so that the steam turbine rotation reaches a speed of 3000 rpm and remains stable. For this reason, it is necessary to control the control valve so that the steam flow to the turbine is always stable.*

Keywords—governor control valve; SIS ; Steam Turbine Generator Control; TCS

1. INTRODUCTION

Population growth in Indonesia is currently very fast with a population of 265 million people. With this amount, the need for more electricity sources. To overcome this, the government has built a power generation system by utilizing natural resources to meet electrical energy needs. Utilizing geothermal energy as a renewable and environmentally friendly energy is a brilliant solution.

The government manages geothermal energy and uses it as a source of power for electricity generation. The scope of activities he undertakes starts from the exploration stage, exploitation of geothermal producing land, construction of generating facilities to channeling processed geothermal products into electrical energy to the interconnected power transmission network.

In the Power Plant Area, there is a process of generating electricity using steam from geothermal energy. The steam regulation that enters the turbine is controlled by the governor control valve so that the turbine rotates stably and in accordance with the predetermined set point, so that the output on the generator will be as expected.[1]

A governor is an equipment that functions to control speed (speed) and output power (power) based on power-frequency characteristics. To control the amount of energy produced by the generator, the amount of fluid entering the turbine must be controlled. The amount of fluid that enters, depends on the valve opening (valve), where this valve is controlled by the governor. To determine the size of the valve opening, the governor will get an input signal in the form of setting power (Preff), the actual power output of the generator (P), frequency (f), or turbine rotation (ω).[2]

2. METHODOLGY

2.1 Power Plan

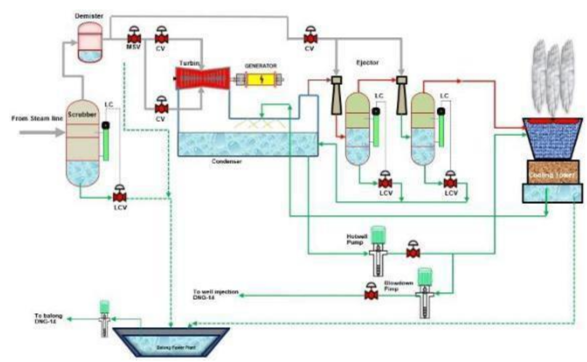

Figure 1: Power plan process

In a steam power plant. Steam with a pressure of 9 bars will go through 2 times filtering, namely through the scrubber then demister. Scrubber functions to filter water contained in steam. Meanwhile, the function of the demister is to filter steam from particles such as sand which is still carried away so that it is expected that the steam entering the turbine will be completely dry and clean. After leaving the demister, the steam will flow in 2 directions with 2 different functions, namely through the MSV (Main Stop Valve) to drive the turbine and the ejector valve to obtain a vacuum in the condenser.[3]

After that, MSV will pass the pressurized steam to enter the turbine, then to CV (Control Valve) 1 and 2 then SV (Stop Valve) 1 and 2.MSV and SV function as safety vapors that enter the turbine, while CV functions to control the amount. the steam used to turn the turbines. Steam is used to drive a turbine that has been coupled with a generator with a capacity of 60 MW with a voltage of 15 kV and a frequency of 50 Hz. The steam that has been used to drive the turbine will condense and change phase into water which has a temperature of around 33 ° C and will flow into the condenser. Inside the condenser must be in a vacuum with a water level of about 40% of the total condenser capacity. Inside the condenser there is NCG (Non-Condensable Gas) or gas that cannot be condensed which also comes from and processes the vacuum through the ejector. The gas will be discharged through the intercondenser and aftercooler to the cooling tower.[4]

2.2 Governor Control Valve

The steam that has gone through the demister will flow in 2 directions with 2 different functions, namely through the Main Stop Valve (MSV) to move the turbine and enter the ejector to obtain a vacuum condenser condition.

After the vacuum condenser is obtained, MSV passes the pressurized steam into the turbine through Control Valve (CV) 1 and 2 to control the valve opening, then passes through Stop Valve (SV) 1 and 2. MSV and SV are useful as protection for steam entering the turbine, while CV is useful as a controller for the amount of steam that enters to turn the turbine. The turbine here has been coupled with a generator with a capacity of 60 MW with a voltage of 15 KV and a frequency of 50 Hz.

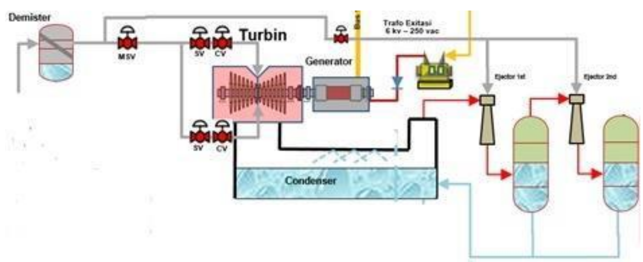

Figure 2: Turbine Generator

The measured speed signal in the steam turbine is sent back to the PID speed control and then compared with the speed signal sent through the speed set point block. The PID speed control will control the output according to the error calculated between the speed set point and the actual turbine speed. The output from the PID will be used to control the position for control valves CV1 and CV2. After the turbine generator has synchronized and the generator breaker is closed, the turbine rotational speed is locked to the grid frequency. Speed can no longer be affected / changed.[5]

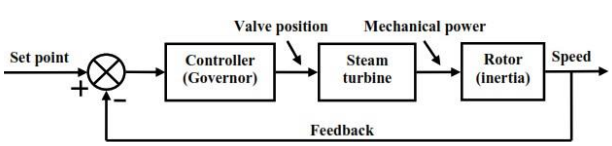

Figure 3: Governor control block diagram

When both the generator breaker and grid breaker are closed. Power control can be activated on the HMI. In power control mode (MW), the operator sets the power setpoint (MW) in HMI. The TCS will read the current power from the power transducer. TCS will give commands to CV1 and CV2 to match the current rated power (MW) with the power setpoint value (MW) in HMI. Power control can only be activated after the generator is synchronized to the network. The control valve governor system works based on commands or setting points that have been determined by the Turbine Control System (TCS).[6]

In the governor control, TCS is the receiver of data from the sensors in the turbine, then TCS will process the information obtained and then execute the action according to the information obtained. For example, when determining the turbine speed. When the speed has not reached the specified set point, TCS will receive signal information from the speed transmitter to provide a larger current to the solenoid (-16 mA to +16 mA) so that more oil enters and the valve will open wider. When the valve opens wider, the more steam flow will enter. But when the turbine rotation speed has reached 3000 rpm, the valve will adjust, because the standard speed of the turbine is 3000 rpm. Then the grid function will move to adjust the generator frequency.[7]

3. Result

The governor control valve is used as a regulator of incoming steam to control the turbine rotation so that it is stable and according to the desired set point. Currently, the control of the governor control valve is controlled in the TCS (Turbine Control System) which also functions as a SIS (Safety Instrumented System).

Safety Instrumented System (SIS) is an instrumentation system used to implement one or more safety functions by instrumentation / Safety Instrumented Function (SIF). SIS consists of a combination of sensors, logic solver, and final elements. SIS functions to monitor process variables and initiate security measures if needed. In this study using the Tri-GP (Triconex - General Purpose), Schneider Electric output as a Safety Instrumented System (SIS).

3.1 TRI-GP SIS LOGIC SOLVER

Tri-GP controller is an advanced, high integrity programmable logic controller with Fault-Tolerant Control via Triple-Modular Redundant (TMR) architecture. TMR integrates three isolated parallel control systems and extensive diagnostics in one control system. Fault-Tolerant Control means fault-tolerance in the control system to identify and compensate for failed system elements and to enable improvement while continuing to control industrial processes without interruption.

Tri-GP uses 3 identical channels. Each channel independently executes the application in parallel with the other two channels. Because each channel is isolated from the others, not a single failure on any channel can switch to the other. If a hardware failure occurs on one channel, the other channel will take over the job. Meanwhile, the failed module can be easily removed and replaced when the controller is online without interrupting the control process.

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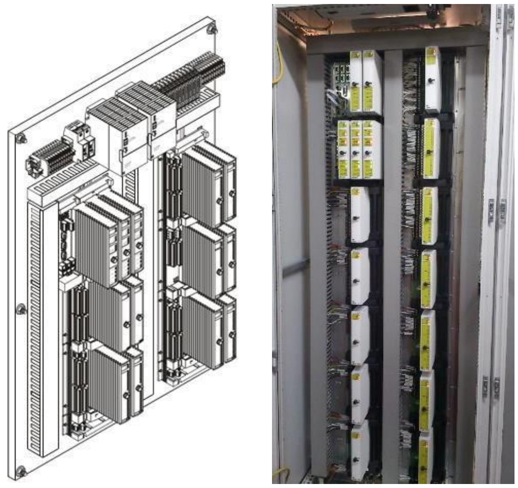

Figure 4: Pre-installed Tri-GP system

The Tri-GP system of 3 main processor modules controls separate channels and operates in parallel with the other two modules. They communicate with each other by using TriBus, which is a high-speed, fault-tolerant communication bus. The special I/O control processor on each main processor manages the exchange of data between the main processor and the I/O module.[8]

The target speed selection is determined by the turbine operation mode. Each mode has a target speed, minimum speed, maximum speed.

Table 1: Target Speed Setpoint, Minimum Limit & Maximum Limit

Sequence Mode	*Speed Target* (RPM)	*Min Limit* (RPM)	*Max Limit* (RPM)
Shutdown (Mode 0)	0	0	0
Ready to Start (Mode 1)	0	0	0
Idle Speed 1 (Mode 2)	1000	0	1050
Idle Speed 2 (Mode 3)	2000	950	2050
Rated Speed (Mode 4)	3000	1950	3050
FSNL (Mode 5)	-	2940	3150
Overspeed Trip Test (Mode 6)	3000	2900	3360
Online (Mode 7)	3000	-	-
Normal Stop (Mode 8)	0	0	3000

3.2 MW Control

The MW Control is activated only when the generator breaker (dIN_PARALLEL) and grid breaker (dEESGI) are closed. MW Control will be turned off when the grid is open.MW setpoint signal is clamped between 0- 60MW in TriGP control system, can be increased / decreased from HMI or DCS. The operator can change the MW control between on & off of the HMI. The output of the MW controller flows to the Droop block (module 5).

Table 2: Configure MW Setpoint & PID Controller

Tagname	*Value*	*Description*
rMW_TGT	0 to 60 MW	*Target Setpoint*
rMW_SP	0 to 60 MW	*Ramp Setpoint*
kMWRR	0.1 MW/sec	*Ramp Rate*
kMWMANRR	0.5 %/sec	*Manual Raise Ramp Rate*
rGEN_MW	0 to 60 MW	*Controller Measurement*
rMW_OUT	0 to 100%	*Controller Output*
rMW_MAN	0 to 100%	*Controller Manual Demand*
fMW_ENB	-	*Enable/Disable (Enable=1)*
fMW_AUTO	-	*Auto/Manual (Auto=1)*
dLOADR		*MW Setpoint / Manual Raise*
dLOADRL	-	*MW Setpoint / Manual Lower*
kMaxMW	60 MW	*Maximum MW*
kMinMW	0 MW	*Minimum MW*
kMW_GAIN	<1.7>	*Controller Gain*
kMW_RST	<2.0>	*Controller Reset (repeat/min)*
kMW_DFR	<0.0>	*Controller Derivative (%/sec)*
-	Reverse	*Controller Action*
-	True	*Setpoint tracking in Manual*

3.3 Speed ramp rate

The Speed ramp rate Selector block is used to select the ramp rate based on Start Mode (Hot / Cold) and Operation Mode (iMode). This ramp rate will move various actual setpoints to the corresponding target setpoints with stable and smooth rates. The resulting Speed Ramp Rate and Speed Target will be used by the Speed Generator Block to generate the actual speed setpoint.

Table 3: Speed ramp rate

Speed Zone	***Ramp Rate* (RPM/min)**
Normal Hot* (kHOTNORRS) *during start up	300
Normal Cold* (kCOLNORRS) *during start up	100
Fast ramping speed* (kCRTNORRS) *during critical band	300 (TBC)
Normal* (kNORRR) *during full speed no load	30
***Critical Speed Zone* (TBC ~ TBC rmp)**	300 (TBC)

3.4 Speed PID

The Speed PID uses a standard PID controller. With an algorithm that compares the process variable (PV) and setpoint (SP), increases or decreases the output at a level determined by the tuning constant (Gain, Reset) to minimize errors between inputs.

The speed controller is activated and put in automatic mode when not in online mode. The direction of the controller action is set to reverse action, which means that as the measurement increases, the PID output will decrease.

Table 4: Configure Speed Setpoint & PID Controller

Tagname	*Value*	*Description*
rSPD_TGT	0 to 3360 RPM	*Target Setpoint*
rSPD_SP	0 to 3360 RPM	*Ramp Setpoint*
rSPEED	0 to 3360 RPM	*Controller Measurement*
rSPD_OUT	0 to 100%	*Controller Output*
kSPD_GAIN_S *kSPD_GAIN_R*	<2.7> <0.7>	*Controller Gain*
kSPD_RST_S *kSPD_RST_R*	<4.0> <2.0>	*Controller Reset (repeat/min)*
kSPD_DER	<0.0>	*Controller Derivative (%/sec)*
-	*Reverse*	*Controller Action*
-	*True*	*Setpoint tracking in Manual*

3.5 Speed PID

When starting the turbine, CV1 will start to open and integrate with the output speed / Load PID request. After the start-up sequence is complete, synchronization is performed and the turbine has reached its configurable load request limit (initially set to 20% on the CV1 limit). CV2 will start to open while CV1 will be closed until it reaches zero equalization.

The AO signal to control the CV1 and CV2 valves will be converted in the axiomatic signal converter. This converter unit will convert the AO signal from the AO module (4 - 20 mA) to -16 - 16mA. The block diagram above shows the valve control process.

In turbine control logic, servo coil null drive is 12mA (with Null current setting), the output of the axiomatic signal converter will be 0 mA. Typical & integral driver moves the servo coil to achieve the desired valve opening position. Position feedback is used in integral driver logic for position feedback. If there is a small or large deviation, the control system will issue a mismatch alarm.

For example, the valve position of the two valve algorithms changes from 30% to 35%, the output current increases to 20 mA at the TRIGP output (the axiomatic signal converter output will be 16 mA) the valve will move to 35% valve position and at the same time, the RVDT will feedbacks the position until it reaches the desired position then the null current returns at 12mA.

Figure 5 : *Set point & actual data*

In this research, the turbine is a double flow type, so it uses 2 CV (Control Valves) to drive the turbine. From the picture above, CVI opens the valve by 24.66% while CV2 opens the valve by 14.67% when Load Reference is 19.67%; Speed Set point 3000 rpm; MW Set point 44.82 MW. CV1 and CV2 adjust aperture by looking at the Load Reference, MW Set point, and Speed Set point specified.

4. Conclusion

All governor control valve systems must use modern devices that have optimization features. The power plant also keeps updating technology continuously. This research was carried out by updating the governor by replacing the old system with the Tri-GP SIS Logic Solver. With this technology replacement, the turbine speed control process will have a faster, safer troubleshooting process because the Tri-GP SIS is equipped with Fault-Tolerant Control via Triple-Modular Redundant (TMR) architecture..

5. References

[1] Lopez Research, "An Introduction to the Internet of Things (IoT)," *Lopez Res. Llc*, vol. Part 1. of, no. November, pp. 1–6, 2013.

[2] H. F. Wang, Y. S. Hao, B. W. Hogg, and Y. H. Yang, "Stabilization of power systems by governor-turbine control," *Int. J. Electr. Power Energy Syst.*, vol. 15, no. 6, pp. 351–361, 1993, doi: https://doi.org/10.1016/0142-0615(93)90003-6.

[3] G. R. Ahmadi and D. Toghraie, "Energy and exergy analysis of Montazeri Steam Power Plant in Iran," *Renew. Sustain. Energy Rev.*, vol. 56, pp. 454–463, 2016, doi: https://doi.org/10.1016/j.rser.2015.11.074.

[4] A. Tio, D. Hill, and J. Ma, "Towards planning for flexible future grids under high power injection diversity," *Electr. Power Syst. Res.*, vol. 189, p. 106687, 2020, doi: https://doi.org/10.1016/j.epsr.2020.106687.

[5] K.-I. Min, C.-H. Jung, K. Hur, I.-Y. Jeon, and Y.-H. Moon, "Output Feedback PID Based Governor Control to improve Generator Damping for Power System Stabilization," *IFAC Proc. Vol.*, vol. 44, no. 1, pp. 4964–4970, 2011, doi: https://doi.org/10.3182/20110828-6-IT-1002.01594.

[6] Y. Wang, J. Wang, Z. Cheng, Q. Sun, P. Zhao, and Y. Dai, "Dynamic performance of an organic Rankine cycle system with a dynamic turbine model: A comparison study," *Appl. Therm. Eng.*, vol. 181, p. 115940, 2020, doi: https://doi.org/10.1016/j.applthermaleng.2020.115940.

[7] G. R. Frey, C. D. Petersen, F. A. Leve, E. Garone, I. V Kolmanovsky, and A. R. Girard, "Time Shift Governor for Coordinated Control of Two Spacecraft Formations," *IFAC-PapersOnLine*, vol. 49, no. 18, pp. 296–301, 2016, doi: https://doi.org/10.1016/j.ifacol.2016.10.180.

[8] Z. Xu, "Tuning method for governor control parameters of hydropower generator in isolated grid considering primary frequency performance and small-signal stability," *Glob. Energy Interconnect.*, vol. 1, no. 5, pp. 568–575, 2018, doi: https://doi.org/10.14171/j.2096-5117.gei.2018.05.006.