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SCADA APPLICATION FOR GEOTHERMAL POWER PLANT

DADANG LUKMAN HAKIM, ADE GAFAR ABDULLAH, YADI MULYADI

Department of Electrical Engineering, Faculty of Technical and Vocational Education,
Universitas Pendidikan Indonesia,
Jl. Dr. Setiabudhi 229 Bandung, 40154, Bandung, Indonesia
*Corresponding Author: ade_gaffar@upi.edu

Abstract

Device process and control in industries need a fast response to the existing situation or changes occurring in doing such as activities as supervision, control, and data recording simultaneously. The advancement of computer network technology gives a strong impact in the revolution of real time control system. Nowadays, almost all modern industries in the world use SCADA-based control system for supervising industrial process performance. Visualization of geothermal power plant (GPP) principles are presented in this study. The SCADA system application is designed using Wonderware Intouch version 10 software, which also presents the cooling and generating systems of the GPP. There are 162 components being controlled equipped with security system, real-time trend, historical trend, and real-time alarm features. The application developed gives comprehensive information on the status of the GPP control process devices. In addition, the status of temperature, pressure, and fluid mass flow from the data fluid can also be acquired in real-time. The SCADA system application in GPP is expected to be able to give a lot of benefits for engineers in need of in-depth understanding on the process of energy flow in the GPP.

Keywords: Geothermal power plant, Real-time control, SCADA systems, Wonderware intouch.

1. Introduction

Supervisory Control and Data Acquisition (SCADA) plays an important part in controlling and monitoring industrial infrastructure functions such as power generators, transmission tools, water purification, manufacturing facilities, and traffic [1-5]. It also functions to control and obtain real time data from such remote devices as motors, valves, pumps, relays, and sensors, as well as gives comprehensive remote control through human-machine interface (HMI) to be able to be viewed by operators [6].

Roop [7] mentioned that there are basically two main activities involved in SCADA including data acquisition of a certain device and process supervision leading to complete automation. A modern SCADA system is centralized in an advanced computer controlling and supervising all the tasks including data collection for displaying graphics and saving historical data and other data [8]. The primary principles of SCADA system are to collect information, transfer the information back to the control centre, display what has happened, and perform an analysis to be able to proceed to controlling or other actions and present information logically and in a well-organized way [9]. The supervision and control system are carried out by collecting and analysing the data in real time [10, 11].

According to Ostojic and Rajakovic [12], SCADA systems are widely used for processing, controlling, and supervising acts in power generator centres, for instance to monitor the performance of photovoltaic energy components [13], control the process of water treatment on electric steam power plant [14], and acquire data of electric field control of central heating on a thermal power plant [15]. SCADA system has also been proven to be able to deal with inter-probability issues among products of control system devices on hydroelectric power plant [16]. Lately, applications on data acquisition using SCADA system for wind power generation have been developed [17]. More specifically, the system has been widely used for fault detection [18, 19], monitoring wind turbine performance [20, 21], and measuring the wind and its vibration wave capacity [22].

Results of studies on SCADA application on control and supervision systems of power plants have been published yet there are limited studies in related to the processes and principles of SCADA-based control and supervision system for geothermal power plant. Therefore, this study is trying to fill a research gap on the importance of introducing a SCADA-based fundamental technology on geothermal power plant. The application offers a lot of benefits to be introduced to the learning processes of control system either in universities or engineering courses.

2. GPP Description

Geothermal power plant (GPP) basically shares the same principles with those of electric steam power plant; the only difference lies on the components producing the water vapor. The water vapor on the electric steam power plant is produced through the water boiling process while that on the GPP is obtained from the geothermal reservoir. The heat energy derives from the core of the earth, which is around 4,000 miles below the earth surface. The core of the earth consists of melted rocks. There is very high temperature produced within the core of the earth with the existence of slow decay of radioactive particles [23]. Most of the existing power plants widely used use single flash power plant type, which utilizes fluid on the reservoir within saturated liquid. The fluid is then streamed into a flasher to come up with separation between liquid-phased and stream-phased fluids. The amount of the stream produced depends on the flasher pressure. The stream then turns into mechanical energy and turns a stream turbine [24, 25]. The schematic diagram of steam power plant can be viewed in Fig. 1.

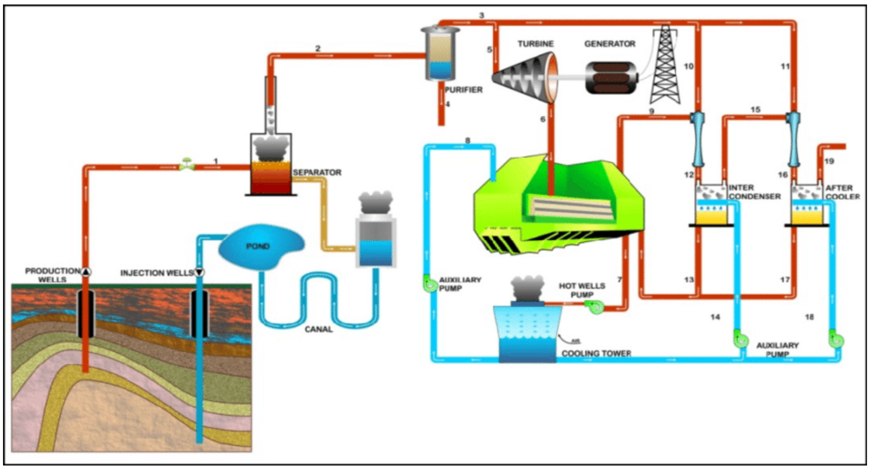

Fig. 1. Single flash steam power plant principles [26].

The steam used to turn the turbine on the GPP is a dry one. The well of the dry steam is naturally formed and is beneficial in comparison with the other reservoir. The dry steam coming from the reservoir is then streamed into the steam turbine installed with the shaft generator so that it results in electrical power. To be able to work efficiently, the exhaust steam header from the turbine should be in a vacuum condition (0.10 bar) by condensing the previously turned steam in a condenser installed under the turbine. The exhaust steam of the turbine comes from the top of the condenser, which will be condensed due to the heat absorption by cooling water injected through spray-nozzle. The level of the water condensate is maintained in a normal condition by a pump to be chilled by cooling water before getting back to circulation [27].

Reservoir classified into dry steam one has no certainty of creating fluids in form of steam; it is sometimes likely to be a combination of both steam and water. However, the reservoir has a temperature > 225 ^{o}C, while the minimum temperature of the geothermal steam suitable for GPP is 125 ^{o}C [28]. Even though the reservoir is categorized into dry steam, some of the power plants do not directly use dry steam to spin the turbine. Based on a study by Setyawan et al. [29], there are other components used as steam receiving headers, demisters and separators to control and filter the steam to minimize damages on the turbine such as vibration, erosion, and scale formation of the turbine.

3. Material and Methods

The application using the GPP performance principles was designed using a software namely Wonderware in Touch. The simulated data referred to the profile of GPP in Kamojang, Indonesia. The dry steam resulted in Kamojang Power Plant (KPP) was one of the best steams in the world since it is a high-pressure dry steam.

KPP used geothermal steam flow supplied from PT Pertamina Indonesia. The steam from the core of the earth was streamed on the receiving header (see Fig. 2(a)), which was a cylinder tube whose diameter was 1,800 mm and functioned as a vaporizer to make sure the steam coming through the turbine stable even through there were changes from the producing well. In addition, the steam pressure on the receiving header was also kept constant on 6.5 bar with vent structure. Vent structure worked to heat up on the pipe line system, and the safety valve on it would throw more pressure in case there is a sudden trip in the receiving header steam. It also kept the pressure coming into the turbine constant. If there is disturbance on the unit causing a sudden trip, the unstoppable stream of steam from the nature would be disposed through this tool.

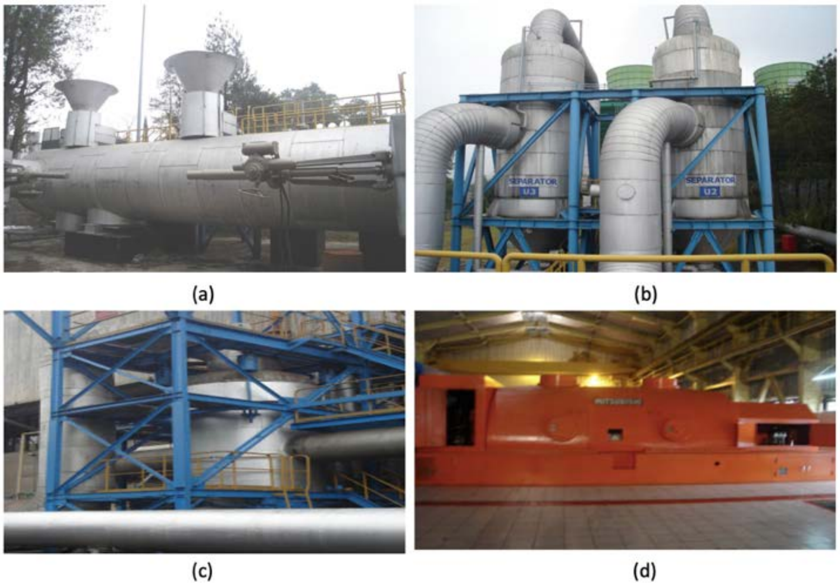

Fig. 2. The main components of KPP:
(a) Receiving header, (b) Separator, (c) Demister, and (d) Turbine.

The steam flow would go through a flow meter to measure the amount of steam coming into the receiving header. The steam would come to the separator (see Fig. 2(b)) working to separate solid, silica, water spots, and other substances mixed with the steam within the separator. Some waste and other substances contained in the steam getting into the separator would automatically be separated down under. The separator used was a cyclone type, which was an upright cylinder where the pipe for the steam to get through was designed following the centrifugal flow.

The filtered steam on the separator was then flowed into the demister (see Fig. 2(c)). The demister functioned as a final separator eliminating water spots and solid slipping off the separator. The steam from the demister had to be dry and clean steam to avoid vibration, erosion, and scale formation on the turbine blade and nozzle. The dry and clean steam from the demister was finally flowed into the turbine (see Fig. 2(d)). Before the steam came into the turbine, it would go through a process namely main steam valve (MSV) and governor valve. The valve worked to control the amount of steam coming through the turbine. The turbine used in

KPP was single cylinder double flow type, which was a combination of action and reaction turbines. The speed of the turbine was constantly maintained at 3,000 rpm and was installed with the generator to result in electrical power. The generator used in KPP was a direct generator type with two poles, three phases, 50Hz and 3,000 rpm. The excitation system used was rotating brushless type AC with a rectifier. The voltage was controlled using Automatic Voltage Regulator (AVR) and the electrical power could be generated by unit 2 with 55 MW and 11.8 kV. Using a transformer step up, we escalated the voltage into 150 kV.

Figure 3 shows the cooling system in KPP using the system with closed circulation from the water resulted from steam condensation. There are two types of circulation including first, main cooling water consisting of condenser, cooling tower, main cooling water pump and second, secondary cooling water cooling water system as shown in Fig. 3(a) consisting of supporting devices such as oil cooler, generator air cooler, and compressor air cooler. The cooling system maintained the steam from the turbine to be constantly in a vacuum condition at 0.10 bar by condensing the steam using the condenser as presented in Fig. 3(b) installed under the turbine. This was to keep the turbine work efficiently. For vacuum maintenance, the non-condensable gas (NCG) on the condenser should be continuously disposed. However, the NCG was not directly disposed; it was extracted before to reduce environmental pollution.

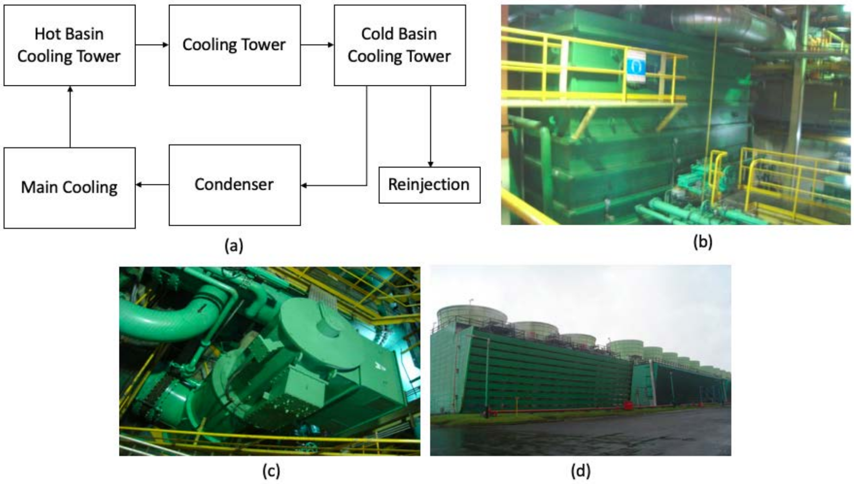

Fig. 3. Cooling system in: (a) Cooling process diagram, (b) Condenser, (c) Main cooling water pump and (d) Cooling tower.

The extraction system of the NCG contained two phases, which were first steam ejector and second steam ejector. The NCG was then sucked by the first steam ejector to be flowed into the inter-condenser. The NCG within the inter-condenser was sucked back by the second steam injector to be flowed to after-condenser. The water from the NCG condensation was sent back to the condenser and the rest of the non-condensable gas was disposed into the air. The rest of the steam from the turbine was coming from the top of the condenser and got condensed as a result of heat absorption by the cooling water injected through the spray or nozzle. The condensed water with temperature less than 49 ^{o}C was pumped with two big pumps namely main cooling water pump (see Fig. 3(c)) to be flowed to hot basin cooling water on top of the cooling tower (see Fig. 3(d)).

The cooling tower worked to exchange huge heat so that here is an exchange between heat and free air. The water from the hot basin cooling tower was then dropped to the cooling tower so that there was an exchange of water heat and free air with the help of cooling tower suction fan. The dropped water had a temperature decrease into 27 ^{o}C when arriving at the cold basin cooling tower under the cooling tower. Some of the water inside the cold basin cooling tower was flowed into the condenser for condensation and some other was pumped by the primary pump for cooling media in intercooler, inter-condenser, and after condenser, and the other was injected aiming to reduce environmental pollution, ground subsidence, maintain the pressure, and fill and add reservoir. The entire processes of the energy flow and conversion on the geothermal power plant was visualized using a human-machine interface (HMI) with a software namely Wonderware in Touch ver. 10.0.

4. Results and Discussion

SCADA system application for GPP has been synchronized with the KPP's operational standards. There are two parts visualized, which are generating system and cooling system. Using a software namely Wonderware Intouch, devices which will be controlled are taken from special wizard tool. However, in the special wizard, there are four figure objects not available including university logos, alarm, historical trends and real time trends. On the top part there is a blue box presenting the generator performance indicators. The parameter shows the active and reactive power output and also frequency. The university logos on the top right corner indicate the identity of the KPP researchers and simulator designers' affiliation. On the top left corner, there is a box labelled OPR, which will display operator's names input through "LOG IN". In addition, there is also a box labelled "TIME" and "DATE", which shows real time and date. The "LOG IN" button is used by the operators to input a correct username and password. In the meantime, the "LOG OUT" button is to disable the system so that somebody with no access cannot operate it. A button with a bell symbol will blink where there is disruption on the system. The button will also show popup window real-time alarm. Under it, there is an "ACT ALARM" button to acknowledge the alarm. The GPP interface is illustrated in Fig. 4.

There are two versions of buttons "START", "STOP", "HT", "RT", and "CONTROL"; one is for the generating system and the other one is for the cooling system. When a user logs in correctly, the START button is functional to run the GPP simulator system. When the username and password are incorrect, the START button is not functional. This is the security system on SCADA simulator. The HT and RT buttons will display popup window historical trend and real-time trend. The CONTROL button is to input the parameter of every component by presenting the popup window control.

Every device controlled will be given a unique tag name to differentiate one component to another. There are two types of tags, which is "memory" for simulation not connected to PLC and other controlling devices, and "I/O" for simulation connected to PLC and other devices. The design of HMI uses tag memory type since every device is connected to the PLC. There are several types of memory including memory discrete in need of input 1 and 0, memory integer for analog-valued objects using integers and memory real for analog-valued objects using real numbers. All devices are given an animation link when it has a tag name. The animation link aims to give visual signs when the controlled device is working. The link is also divided into two parts comprising touch link and display link. In this application, there are 162 devices to be controlled. The examples of tag name giving on each device is presented in Table 1.

Every device, which will be controlled certainly has a performance parameter and operating limit. Information of the operating limit values can be used to design an alarm system. The alarm system is set into several conditions and priorities, in which, the system should be able to act out or respond to prioritized actions. The alarm condition consists of “Hi Hi”, “High and Low”, and “Lo Lo”. “Hi Hi” and “Lo Lo” indicate main priorities, where disruption is getting critical. Meanwhile, “High and Low” shows second priority, where disruption exceeds the operating limit yet is not critical. The operating limit of each main component is presented in Table 2.

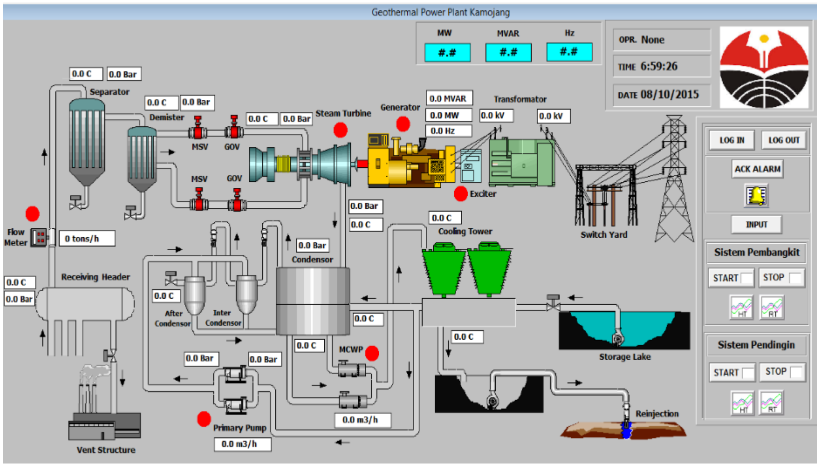

Fig. 4. Human machine interface on GPP.

Table 1. Examples of tag name giving on the devices to be controlled.

Object name	Tag name	Type memory	Animation link
Receiving header	Receiving/animation	Memory integer	Display link/percent fill
	Receiving/temp	Memory real	Display link/value display
	Receiving/press	Memory real	Display link/value display
Flow meter	Flowmeter/animation	Memory integer	Display link/percent fill
	Flowmeter/amount of steam	Memory real	Display link/value display
Separator	Separator/animation	Memory integer	Display link/percent fill
	Separator/temp	Memory real	Display link/value display
	Separator/press	Memory real	Display link/value display
Demister	Demister/animation	Memory integer	Display link/percent fill
	Demister/temp	Memory real	Display link/value display
	Demister/press	Memory real	Display link/value display
Turbine	Turbine/animasi	Memory discrete	Display link/fill color
	Turbine/tempin	Memory real	Display link/value display
	Turbine/pressin	Memory real	Display link/value display
	Turbine/tempout	Memory real	Display link/value display
	Turbine/pressout	Memory real	Display link/value display

Table 2. Operating limit of GPP main components.

Parameter	Operating values	Operating limit	
		Low	High
Temperature receiving	161.9 ˚C	150 ˚C	175 ˚C
Pressure receiving	6.5 bar	4 bar	6.8 bar
Flowmeter steam volume	400 ton/hours	350 ton/hours	450 ton/hours
Temperature separator	161.9 ˚C	150 ˚C	175 ˚C
Pressure separator	6.5 bar	4 bar	6.8 bar
Temperature demister	161.9 ˚C	150 ˚C	175 ˚C
Pressure demister	6.5 bar	4 bar	6.8 bar
Temperature in turbine	161.9 ˚C	150 ˚C	175 ˚C
Pressure in turbine	6.5 bar	4 bar	6.8 bar
Temperature out turbine	90 ˚C	80 ˚C	130 ˚C
Pressure out turbine	0.1 bar	0.07 bar	0.211 bar
Power active generator	55 MW	50 MW	57.75 MW
Power reactive generator	27 MVAR	20 MVAR	40 MVAR
Frequency of generator	50 Hz	48 Hz	53 Hz
Voltage in transformator	11.8 kV	9.8 kV	13.8 kV
Voltage out transformator	150 kV	130 kV	170 kV
Pressure condenser	0.1 bar	0.07 bar	0.211 bar
Temperature in condenser	27 ˚C	20 ˚C	35 ˚C
Temperature out condenser	45.8 ˚C	40 ˚C	51 ˚C
Temperature in cooling tower	43 ˚C	35 ˚C	50 ˚C
Temperature out cooling tower	27 ˚C	20 ˚C	35 ˚C
Mcwp water volume	11500 m^3/hours	11000 m^3/hours	13000 m^3/hours
Primary pump water volume	680 m^3/hours	600 m^3/hours	760 m^3/hours
Pressure in primary pump	0.7 bar	0.34 bar	1 bar
Pressure out primary pump	3.5 bar	3 bar	4 bar
Temperature out after condenser	68 ˚C	60 ˚C	72 ˚C

Figure 5 shows visualization of cooling system on GPP. The cooling flow is visually shown in blue. When a user pushes the START button, the visual cooling water flow from storage lake, cooling tower, primary pump, and condenser can be seen. Information related to water temperature, water discharge, and water pressure can be clearly viewed. Figure 6 shows the visualization of energy flow process in GPP. The animation link is red, indicating that such devices as receiving header, flow meter, separator, valve, and demister are working. On the SCADA application, information on fluid temperature, pressure, and fluid mass flow is presented accurately.

The SCADA application in GPP is equipped with real-time trends functioning to show the device conditions operating in real time. The maximum time range displayed in one trend is 60 seconds with update rate per one second. To show popup window real time trend, users only need to push the RT button and graphics telling real time conditions of controlled devices are shown as presented by Fig. 7.

The quantity of power generators, turbine temperature and pressure, demister temperature and pressure, the quality of steam, and others are analysed real time. To find out previous occurrences, the application is equipped with such features as historical trends as shown in Fig. 8. To present popup window historical trends, users only need to push the HT button and graphics of historical parameters on the controlled GPP devices will be displayed. To find out the historical data based on the time interval, users need to push buttons under the graphics as they wish.

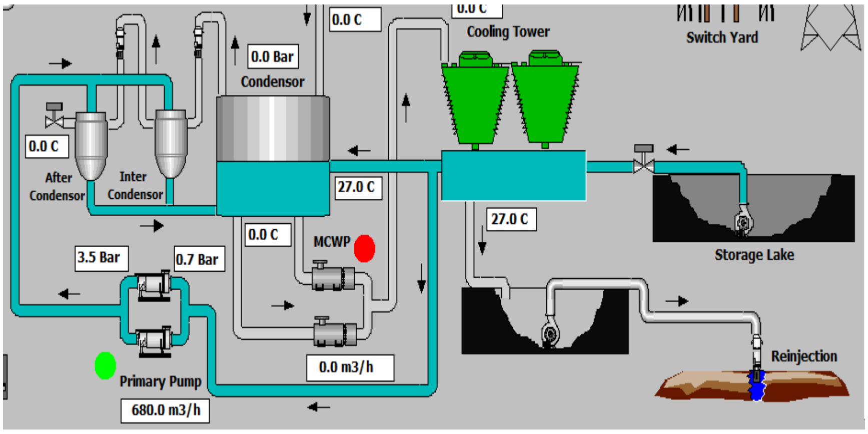

Fig. 5. Visualization of cooling water flow in GPP.

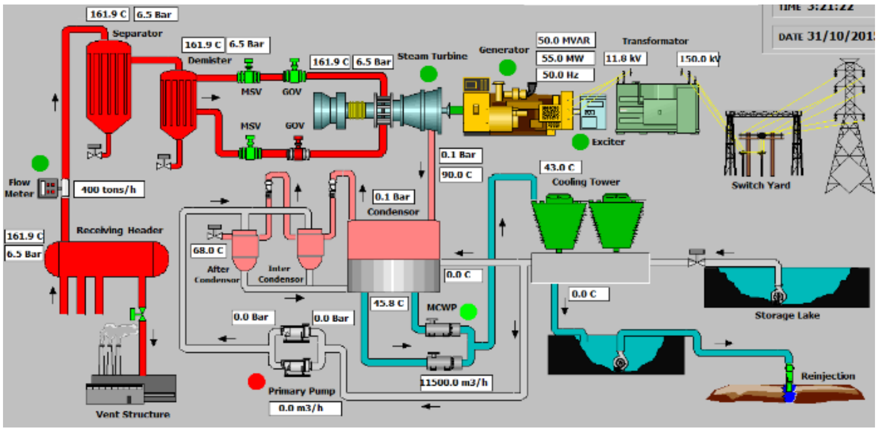

Fig. 6. Visualization of energy flow process in GPP.

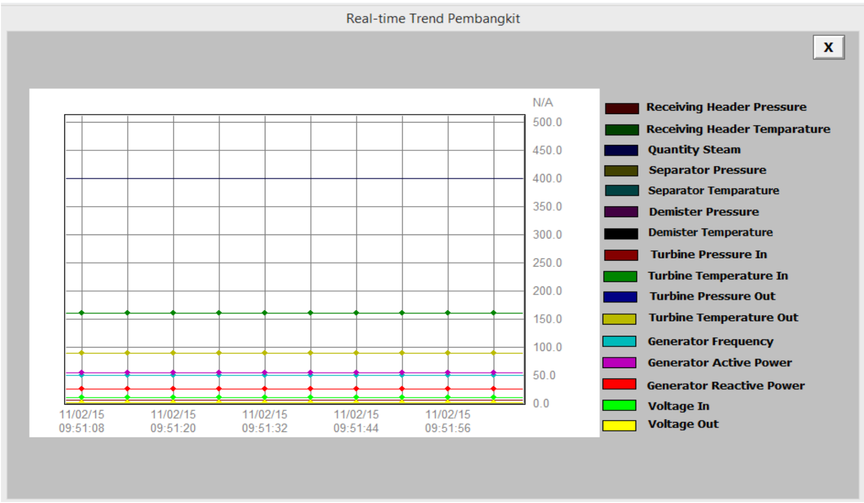

Fig. 7. Real-time trend of GPP.

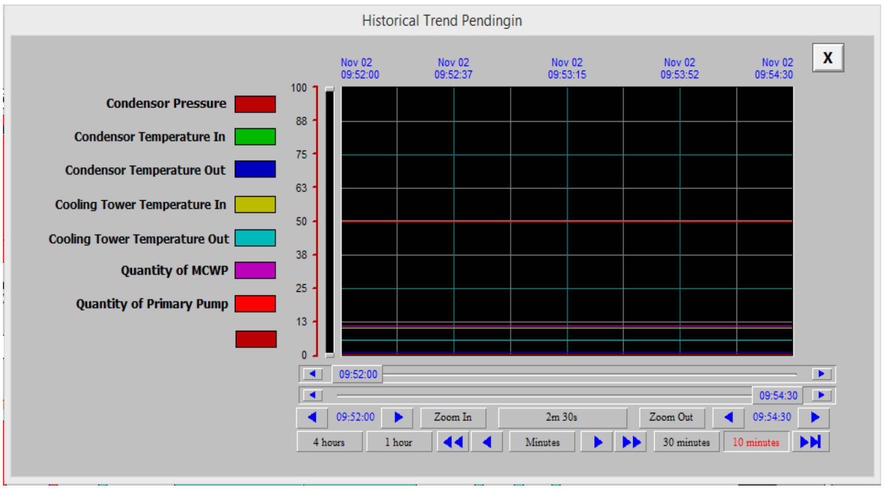

Fig. 8. Historical trend of GPP cooling system.

To monitor and identify the abnormal condition of GPP devices, there needs to be a real time alarm feature. Abnormalities usually happen when users change their parameter exceeding the operating limit. For instance, when a device exceeds its operating limit, the bell button will blink to indicate abnormalities. The visualization of real-time alarm on the application is presented in Fig. 9. Annunciator alarm will ease the operators to identify what kinds of devices having disruption. The disrupted devices will be identified by repeated blinks. To find out the causes of disruption, users need to push the blinking component. When pressing it, there will be popup window real time alarm as shown in Fig. 9. One of the most important information is priority showing, which components to prioritized.

Operators can press the ACT ALARM when they know there is disruption. The information on real time alarm will turn into black, which indicates that the alarm has been acknowledged by the operators. After knowing the disruption, operators are to press the CONTROL button to take control of the system back into normal by swiping the sliders to reach the parameter values in accordance with the operating limit set before. Figure 10 shows the control system used in SCADA application in GPP.

Real time control of GPP using SCADA application is a quite complicated task since the components to be controlled in the industry come with complexity and huge number. In fact, there are thousands of devices to supervise and control. An operator of GPP can control and monitor the plant process through an HMI-based control system. SCADA is a modern control system based on HMI used to control and monitor a plant through a computer within a centralized room [30]. The data of the HMI on the SCADA systems are going to be processed and presented to be able to be viewed and monitored by operators (dispatchers) [31]. Prior to the actual implementation, a steam power plant operator should understand the SCADA system and the process of electricity generation on the steam power plant so that fatal errors in the field are avoidable. An industry of power plant should also have a function as a laboratory, which can give experiences to students and engineers to train and obtain knowledge on the SCADA system directly through the supervision and control systems in real time. Such SCADA components as master station, RTU, communication lines, and field equipment should be available in the laboratory [32].

Security is an absolute requirement on a SCADA system in GPP. The scheme used on the SCADA system in GPP should also support the message sending and communication network with safety by distributing high voltage nodes equally to the master terminal unit (MTU) protocols to avoid the additional potentials of the system performance. It is commonly known that SCADA systems should have secure message delivery and communication networking. In fact, most of the systems have secure communication network yet it does not support secure message delivery [33]. The SCADA system in GPP should also be economical, flexible, reliable, and able to run processes real time. In addition, further analysis is required, especially for applying this system for the simple practical processes, which indeed uses commercially available apparatus [34].

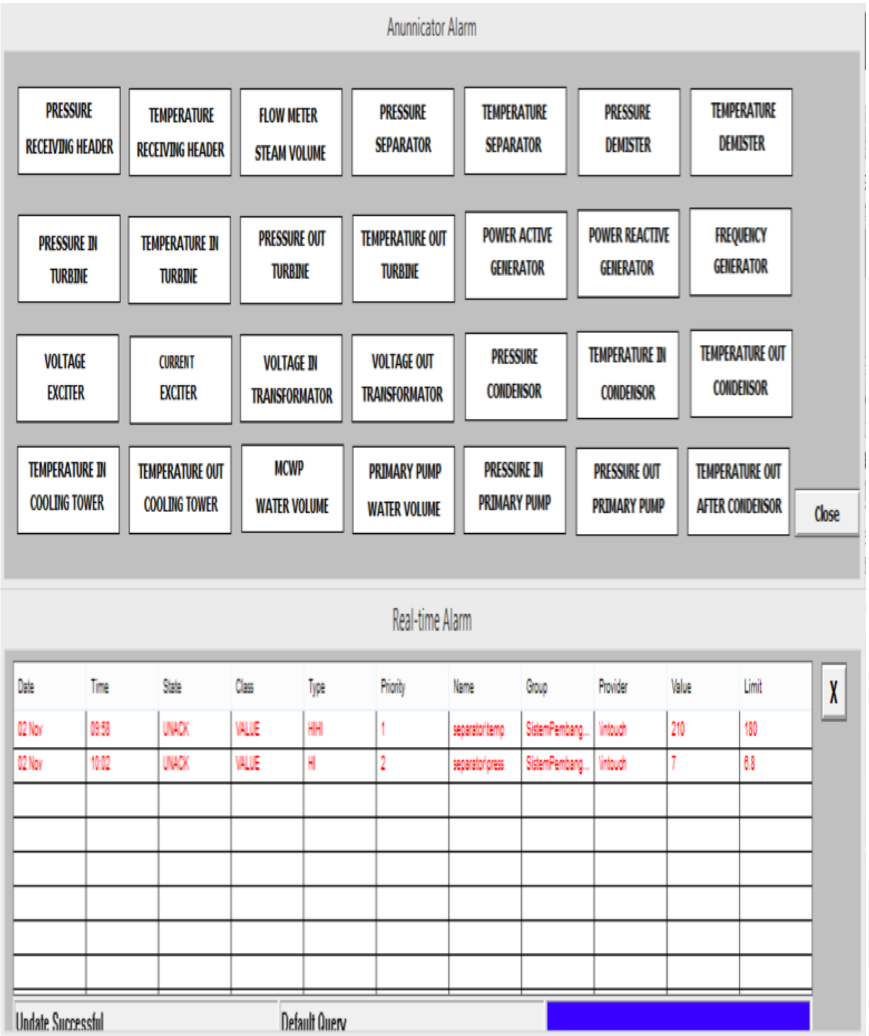

Fig. 9. Visualization of real-time alarm.

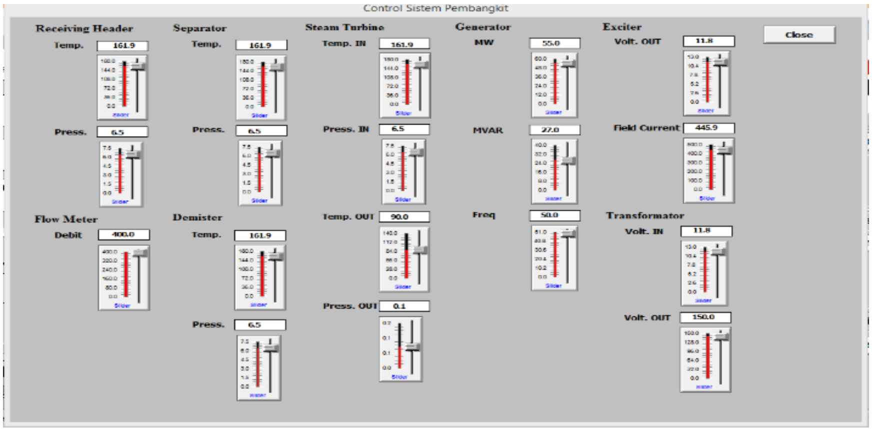

Fig. 10. Control panel of GPP main components.

5. Conclusions

This study presented the practical application of SCADA system to monitor the pressure parameter, temperature, fluid discharge, and fluid traffic on geothermal power plant. This paper also offered a solution for engineers interested in energy who want to learn energy flow principles of GPP. SCADA system application in GPP had to have an ability to respond to the system behaviours fast since there will be an impact to the stability of geothermal power plant performance. SCADA application in GPP also enabled users to perform certain actions real time for instance dealing with issues with power plant devices exceeding their operating limit or documenting performance behaviours of the system in the past. Since the real time control system in GPP required skilled operators, the application was proven to be suitable to be a training device for university students and engineers. In terms of implementation, the application gave an actual description on the process of GPP control and supervision.

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References

1. Long, H.; Wang, L.; Zhang, Z.; Song, Z.; and Xu, J. (2015). Data-driven wind turbine power generation performance monitoring. *IEEE Transactions on Industrial Electronics*, 62(10), 6627-6635.
2. Wang, Y.; Xu, W.; and Shen, J. (2015). Online tracking of transmission-line parameters using SCADA data. *IEEE Transactions on Power Delivery*, 31(2), 674-682.
3. Akdeniz, T.; and Muhammetoğlu, H. (2017). Chlorine residual management for water utilities using GIS, SCADA and modeling tools. *Desalination and Water Treatment*, 59, 135-143.
4. Tisza, M.; and Czinege, I. (2018). Comparative study of the application of steels and aluminium in lightweight production of automotive parts. *International Journal of Lightweight Materials and Manufacture*, 1(4), 229-238.

5. Qi, L.; Zhou, M.; and Luan, W. (2016). A two-level traffic light control strategy for preventing incident-based urban traffic congestion. *IEEE Transactions on Intelligent Transportation Systems*, 19(1), 13-24.
6. Humoreanu, B.; and Nascu, I. (2012). Wastewater treatment plant SCADA application. *Proceedings of the IEEE International Conference on Automation, Quality and Testing, Robotics*. Cluj-Napoca, Romania, 575-580.
7. Roop, D.W. (2015). Power system SCADA and smart grids [book reviews]. *IEEE Power and Energy Magazine*, 14(1), 115-116.
8. Soete, N.; Claeys, A.; Hoedt, S.; Mahy, B.; and Cottyn, J. (2015). Towards mixed reality in SCADA applications. *IFAC-PapersOnLine*, 48(3), 2417-2422.
9. Figueiredo, J.; and da Costa, J.S. (2012). A SCADA system for energy management in intelligent buildings. *Energy and Buildings*, 49, 85-98.
10. Abimanyu, A.; Jumari, Yuliansari, D.; Kusuma, G., and Sukarman. (2013). Design mini SCADA for furnace induction reactor of kernel coating. *Proceedings of the International Conference on Computer, Control, Informatics and its Applications (IC3INA)*. Jakarta, Indonesia, 195-200.
11. Dhend, M.H.; and Chile, R.H. (2015). Innovative scheme for smart grid distribution SCADA system. *Proceedings of the IEEE 2nd International Future Energy Electronics Conference (IFEEC)*. Taipei, Taiwan, 1-6.
12. Ostojic, D.; and Rajakovic, N. (1993). Application of distributed SCADA system in electric power plant. *Proceedings of the Joint International Power Conference Athens Power Tech*. Athens, Greece, 372-376.
13. Moreno-Garcia, I.M.; Palacios-Garcia, E.J.; Palates-Lopez, V.; Santiago, I.; Gonzalez-Redondo, M.J.; Varo-Martinez, M.; and Real-Calvo, R.J. (2016). Real-time monitoring system for a utility-scale photovoltaic power plant. *Sensors*, 16(6), 25 pages.
14. Lihou, M.N. (2013). SCADA application of a water steam cycle of a thermal power plant. *Proceedings of the 5th International Conference on Modeling, Simulation and Applied Optimization (ICMSAO)*. Hammamet, Tunisia, 1-5.
15. lacob, M.; Andreescu, G.-D.; and Muntean, N. (2009). SCADA system for a central heating and power plant. *Proceedings of the 5th International Symposium on Applied Computational Intelligence and Informatics*. Timisoara, Romania, 159-164.
16. Villacorta, C.A.; Jardini, J.A.; and Magrini, L.C. (2003). Applying object-oriented technology to project hydroelectric power plant SCADA systems. *IEEE Power Engineering Society General Meeting*. Toronto, Ontorio, Canada, 1075-1080.
17. Badrzadeh, B.; Bradt, M.; Castillo, N.; Janakiraman, R.; Kennedy, R.; Klein, S.; and Vargas, L. (2011). Wind power plant SCADA and controls. *IEEE Power and Energy Society General Meeting*. Detroit, Michigan, United States of America, 1-7.
18. Zaher, A.; McArthur, S.D.J.; Infield, D.G.; and Patel, Y. (2009). Online wind turbine fault detection through automated SCADA data analysis. *Wind Energy: An International Journal for Progress and Applications in Wind Power Conversion Technology*, 12(6), 574-593.
19. Kim, K.; Parthasarathy, G.; Uluyol, O.; Foslien, W.; Sheng, S.; and Fleming, P. (2011). Use of SCADA data for failure detection in wind turbines.

Proceedings of the Energy Sustainability Conference and Fuel Cell Conference. Washington, D.C., United States of America, 9 pages.

20. Yang, W.; Court, R.; and Jiang, J. (2013). Wind turbine condition monitoring by the approach of SCADA data analysis. *Renewable Energy,* 53, 365-376.
21. Yang, W.; Tavner, P.J.; Crabtree, C.J.; Feng, Y.; and Qiu, Y. (2014). Wind turbine condition monitoring: Technical and commercial challenges. *Wind Energy,* Special Issue: Condition Monitoring, 17(5), 673-693.
22. Zhang, Z.; and Kusiak, A. (2012). Monitoring wind turbine vibration based on SCADA data. *Journal of Solar Energy Engineering,* 134(2), 021004-1-021004-12.
23. Tousif, S.M.R.; and Taslim, S.M.B. (2011). Producing electricity from geothermal energy. *Proceedings of the 10th International Conference on Environment and Electrical Engineering.* Rome, Italy, 1-4.
24. Bronicki, L.Y. (2015). *Geothermal power conversion technology*. New York, United States of America: Springer Science + Business Media.
25. Williamson, K.H.; Gunderson, R.P.; Hamblin, G.M.; Gallup, D.L.; and Kitz, K. (2001). Geothermal power technology. *Proceedings of the IEEE,* 89(12), 1783-1792.
26. Pambudi, N.A.; Itoi, R.; Jalilinasrabady, S.; and Jaelani, K. (2015). Performance improvement of a single-flash geothermal power plant in Dieng, Indonesia, upon conversion to a double-flash system using thermodynamic analysis. *Renewable Energy,* 80, 424-431.
27. DiPippo, R. (2015). Geothermal power plants: Evolution and performance assessments. *Geothermics*, 53, 291-307.
28. Franco, A. (2011). Power production from a moderate temperature geothermal resource with regenerative Organic Rankine Cycles. *Energy for Sustainable Development,* 15(4), 411-419.
29. Setyawan, N.D.; Pambudi, N.A.; Utomo, F.; Saputro, H.; Adiprana, R.; Saw, L.H.; and Rudiyanto, B. (2018). Energy and exergy analysis of dry-steam geothermal power plant: Case study in Kamojang Geothermal Power Plant unit 2. *MATEC Web of Conferences,* 197, 08018.
30. Wijaksono, U.; Abdullah, A.G.; and Hakim, D.L. (2016). Design of virtual SCADA simulation system for pressurized water reactor. *AIP Conference Proceedings,* 1708(1), 050005.
31. Nugraha, E.; Abdullah, A.G.; and Hakim, D.L. (2016). Designing a SCADA system simulator for fast breeder reactor. *IOP Conference Series: Materials Science and Engineering,* 128(1), 012006.
32. Thomas, M.S.; Kumar, P.; and Chandna, V.K. (2004). Design, development, and commissioning of a supervisory control and data acquisition (SCADA) laboratory for research and training. *IEEE Transactions on power systems,* 19(3), 1582-1588.
33. Choi, D.-H.; Lee, S.-J.; Jeong, H.; Kang, D.J.; Kim, H.-M.; Kim, K.-S.; Won, D.; and Kim, S. (2009). Advanced key management architecture based on tree structure for secure SCADA communications. *The KIPS Transactions: Part C,* 16C(1), 37-50.
34. Nandiyanto, A.B.D.; Sukmafitri, A.; Ragadhita, R.; Oktiani, R.; Haristiani, N.; and Hamidah, I. (2019). Conventional filter for the water treatment system in rural area. *Journal of Engineering Science and Technology,* 14(4), 2090-2097.