Redesign Integrated Control System GTG and HRSG to Reduce Loss of Electrical Production at Combined Cycle Power Plant Muara Karang

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Abstract. Combined Cycle Power Plant (CCPP) Block 1 Muara Karang control system had performance degradation since 2016-2017. Performance degradation comes from the complexity of the design architectures that are serially configured which can cause loss of electrical production. The Re-Design Method is able to simplify the architecture design by replacing hardware devices into modbus-based TCP-IP software that is compatible with the communication technology between GTG and HRSG and has a redundant path that can increase reliability. Based on the Muara Karang PLTGU Block 1 disturbance report data, redesign is able to increase reliability and better financial aspect. It shows that before the redesign there were 9 disruptions, while after the redesign there were no failures and Total saving opportunity loss of electrical production is Rp 10,792,782,094.30. This value is obtained from the unit repair time from operation failure and electricity sales price. On the corporate side, Re-Design can be applied to other generating units that have differences in technology based on open protocol.

1. Introduction

Combined Cycle Power Plant (CCPP) Block 1 Muara Karang have capacity of 500 MW, It supplies electricity needs in the center of government in Jakarta. CCPP has a main control system that is inseparable in the power generation system. The GTG use General Electric Speedtronic Mark VIE system since 2012. The HRSG use ABB infi 90 control system since 1992. The STG use General Electric Speedtronic Mark V control system since 1995. All control system must be well integrated in a system called Distributed Integrated Control System (DCIS). DCIS operates to monitor, control, and become safety tools of the engines so that it can be operated safely and reliable [1].

Based on pareto frequency failure from 2015 to 2017, there were 9 disruptions in the integration of the GTG and HRSG. The disruption occurs is due to complexity of the control system integration architecture design that is configured serially [2,3,4]. There are differences in the implementation of data communication between GTG and HRSG control system. GTG use Modbus-based data communication, while HRSG based on serial data dump. Because of the difference, it takes 4 control system integration devices that convert Modbus technology into serial technology so that data communication occurs. If 1 of the 4 devices is experiencing interference, it can cause a loss of electrical production [5,6].
Meanwhile in power generation industry, the main parameter to increase its value is reliability and availability. If loss of production occurs, the power plant may not be able to reach maximum load or derating so it may cause high cost of energy production. Furthermore, if the power plant fail to produce electricity, it may reduce availability and increase force outage rate.

Serial arrangement for devices in an integration system are considered to have weaknesses. The study conducted by Ahmad Fauzi et al [7] compared serial and serial-parallel system configurations. It was concluded that serial-parallel configuration has better reliability. It is evidenced by the production line that does not occur interruptions during corrective and preventive maintenance.

In this study, the problem was identified why failure occurred during 2015-2017 and resolve the problem by simplifying the integration of the control system. Then with the change of the control system configuration, it will have implications for the readiness and reliability of the power plant.

2. Control System Description

2.1. DCIS Architecture

Distributed Control Integrated System (DCIS) is a control system used to collect and acquire information data, as well as controlling the control process of several different control systems in a centralized system in an integrated loop [1]. Architecture design of DCIS in CCPP Muara Karang Block 1 can be seen in figure 1.

![Figure 1. Architecture Design of DCIS.](image)

The General Electric Speedtronic Mark VIE Gas Turbine Generator (GTG) control system is integrated into the DCIS system using a gateway server communication device, modulator-demodulator RS232 / 422, and an HRSG controller. The integration of the GTG control system into DCIS serves to monitor and control GTG operations through the operator station (HMI) in the central control room [8,9].

The ABB Infi 90 HRSG control system is integrated into DCIS with the controller module, network interface module (INNIS) and network processing module (INNPM) devices. The integration of the HRSG control system to DCIS also serves to monitor and control HRSG operation through operation station (HMI) in central control room [10].
2.2. Modbus Protocol

Modbus is one of the most widely used industrial communications protocols, especially in industrial control applications and energy management and building automation systems [11,12]. The implemented systems use the Modbus-RTU RS 485 serial buses to interconnect plant devices that are integrated via gateways with supervision and management systems, which operate over the Ethernet or with other communications networks that use other protocols [13].

2.3. Problem Identification

Based on pareto frequency failure from 2015 to 2017, we evaluate an integration of GTG and HRSG control system. Then, Root Cause Analysis (RCA) is applied as one of the basic methods that helps to find the cause and effect of the problem [14]. Therefore, we applied RCA to identify major system-wide failure issues as part of maintenance.

Based on RCA, the problem identification of GTG and HRSG control system can be described in the figure 2, as follows:

- The Complexity of Architecture Design
  Integration of Architecture Design of the GTG and HRSG control system is very complex. The complexity appears in architecture design because it differences between implementation of GTG and HRSG control system. The GTG control system communicate using TCP/IP modbus, while the HRSG control system communicate using serial dump data. Therefore, an additional communication technology would be needed to synchronize two different data between GTG and HRSG control system.

- The Serial Configuration of Architecture Design
  Integration of Architecture Design of the GTG and HRSG control system is configured serially. Serial configuration has low reliability because if one of the devices is experiencing interference it can cause failure of the overall system. In terms of reliability, a system is considered reliable if it could perform its intended function adequately for a specified period of time, or will operate in a defined environment without failure [15].

- Integration Device GTG and HRSG Control System
  There are 4 integration devices GTG and HRSG control system, consist of 1 unit gateway server, 2 units of serial modulator-demodulator RS232/422 (modem), and 1 unit of HRSG controller. Gateway server have functions can be used to provide data from other modbus protocol to control network [16]. Modem have functions the process of superimposing data on the carrier wave frequency to the message information signal so that it can be sent to the receiver via cable, in the form of a sine wave [17]. For most of the works have been implemented to integrate device GTG and HRSG control system. It has decreased performance in the 2015-17 period. This is due to various factors, such as software corruption and internal system hardware electronic fail caused by the device's lifetime.
Figure 2. Integration Control System GTG and HRSG.

Based on disruption report in Muara Karang Power Plant Block 1, we evaluate one of the problems with the operation disruption on September 19, 2016, a problem analysis was carried out using the STG trip trend data in the 1-1-1 configuration, as shown in figure 3.

Figure 3. Data Trend STG Failure.
The chronology of the STG trip failure can be explained in detail as follows:

- **Time 13.55.00 WIB:**
  The load value of GTG 1.1 (red colour) is 93.36 MW. The load value of STG 1.0 (blue colour) is 41.59 MW. The value of damper signal (green colour) is 101.36%. At this time, power plant operates with normally condition.

- **Time 13.55.50 WIB:**
  The load value of GTG 1.1 suddenly blank with value 0 MW, when the load value GTG blank, it causes the “GTG Master Protective” signal to be active, this signal gives a command to the damper signal to full close (0%). At this condition, when the damper condition is full close, it make HRSG Trip and a few second later STG Trip.

- **Time 13.56.20 WIB:**
  The load value of GTG 1.1 suddenly appears. However, the damper condition in process to full close (HRSG trip) and STG already trip.

2.4. **Saving Opportunity Loss of Electrical Production**

Saving opportunity loss of electrical production is obtained from the calculation of disruptions that occurred during 2015-2017 caused by disruption of the control system integration. When a disturbance occurs, each unit experiences a different downtime. The longer the downtime, the potential for saving opportunity loss of electrical production increases.

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\text{Saving Opp Production (Rp)} = \text{Loss of Production (MWH)} \times 1000 \times \text{Selling Price (Rp KWH)} \quad (1)
\]

3. **Redesign Control System**

Based on the problem identification, redesign control system is needed. Implementation in this redesign as figure 4, consists of:

- Integrating communication technology between GTG and HRSG control system using an ethernet cable (RJ45) with type cat 5e.
- Installation harmony gateway software (HGS) as a database and interface modbus from GTG to HRSG control system.
- Installation engineering work station (EWS) software as a database and interface logic from GTG to HRSG control system;
- Add to the design of integration path between the General Electric HMI Server to the process control unit redundantly, so that it can increase its reliability.
3.1 Implementation Redesign
There are several stages of implementation, as follows:

- Replace controller IMMFP02 with a redundant controller type BRC 410 and connect the GTG server hubswitch to BRC 410 with ethernet cable.
- Create databases and interface modbus in HGS, including setting data types (I/O analog or digital) & protocol address controller (IP), scaling values and verify the project to ensure there are no errors;
- Create database and interface logic, including download program from HGS file to HRSG controller module in the process control unit via the EWS;
- Testing communication and redundancy GTG and HRSG control system

3.2 The Standard References and Testing
Tests carried out include testing communication and redundancy. The communication test functions to determine the suitability of the operation data sent by the HMI GTG server to the HMI DCIS control room. Redundancy testing functions to test the reliability of the controller. The standard references used in the Redesign Integrated Control System GTG and HRSG are described in table 1.

| No  | Standard  | Description                                                  | Function                                        |
|-----|-----------|--------------------------------------------------------------|-------------------------------------------------|
| 1   | IEC 615111| Safety Instrumented Systems for Process Industry             | Determine Equipment Risk Level                  |
| 2   | IEC 61508-1| Functional Safety of Programmable Electronic Safety-Related Systems | The choice of hardware and software that has a high level of security |
| 3   | IEEE 802.3| Network technology based Fast Ethernet (100Mbps)              | Determine the type of ethernet cable that has faster data processing speeds with a maximum distance of 100 meters. |
4. Result and Discussion

Based on the Muara Karang PLTGU Block 1 disturbance report data, it shows that before the redesign there were 9 disruptions, while after the re-design there were no failures as described in table 2.

| No | Unit | Disruption Impact | Cause | Before Sum of Disruption Unit | After Sum of Disruption Unit |
|----|------|-------------------|-------|-------------------------------|------------------------------|
| 1  | GTG 1.1 | Trip | Controller | 1 Times | 0 Times |
| 2  | STG 1.0 | Derating | Controller | 1 Times | 0 Times |
| 3  | STG 1.0 | Trip | Controller | 1 Times | 0 Times |
| 4  | STG 1.0 | Trip | Modem Serial | 1 Times | 0 Times |
| 5  | GTG 1.3 | Start Failure | Modem Serial | 1 Times | 0 Times |
| 6  | STG 1.0 | Start Failure | Modem Serial | 1 Times | 0 Times |
| 7  | STG 1.0 | Trip | Controller | 1 Times | 0 Times |
| 8  | STG 1.0 | Trip | Controller | 1 Times | 0 Times |
| 9  | STG 1.0 | Trip | Controller | 1 Times | 0 Times |
| Sum of Disruption | 9 Times | 0 Times |

**Source:** Muara Karang Power Plant Block 1 Disruption Report.

This is because Redesign uses path redundant. If Component 1 is working, Component 2 is in the standby state. Then, if suddenly Component 1 fails, then Component 2 starts immediately to work.

4.1 Advantages of the redesign

Advantages of the redesign innovation of the integration of GTG and HRSG control systems are as follows:

- Redesign has a very simple architecture design, redundant type paths so that system reliability is increased and media integration is enough to use an ethernet cable.
- Modbus-based technology with open protocol type with harmony gateway software as Modbus database and engineering workstation as Modbus interface.
- Integration of communication system technology can be applied to other generating units incorporate PLN that has an open protocol based system.

4.2 Risk Mitigation

Based on the risk analysis of the implementation of the redesign of the integration of the GTG and HRSG control systems, there is a risk of control system integration disruptions caused by HRSG controller interruptions, ethernet connections, and hub switches. So, we need risk mitigation in the form of preventive maintenance (PM) by monitoring the status of the controller in the local panel and software, checking the ethernet cable connection and the hub switch.

4.3 Saving Opportunity Loss of Production

Saving opportunity Loss of Production is obtained from the calculation of disruptions that occurred during 2015-2017 caused by disruption of the Control System Integration, as described in table 3.
### Table 3: Saving Opportunity Loss of Electrical Production

| No | Date       | Unit | Loss of Production (MWH) | Selling Price (Rp /KWH) | Saving Production (Rp)       |
|----|------------|------|--------------------------|-------------------------|------------------------------|
| 1  | 12-May-16  | GTG 1.1 | 195.00                 | 1,818.50                | 354,607,500.00              |
| 2  | 12-May-16  | STG 1.0 | 8,991.30                | 934.49                  | 8,402,279,937.00            |
| 3  | 19-Sep-16  | STG 1.0 | 233.53                  | 934.49                  | 218,234,564.67              |
| 4  | 24-Apr-17  | STG 1.0 | 465.00                  | 934.49                  | 434,537,850.00              |
| 5  | 23-May-17  | GTG 1.3 | 225.00                  | 1,818.50                | 409,162,500.00              |
| 6  | 23-May-17  | STG 1.0 | 801.87                  | 934.49                  | 749,336,381.33              |
| 7  | 15-Aug-17  | STG 1.0 | 62.00                   | 934.49                  | 57,938,380.00               |
| 8  | 28-Aug-17  | STG 1.0 | 48.17                   | 934.49                  | 45,014,383.30               |
| 9  | 30-Sep-17  | STG 1.0 | 130.20                  | 934.49                  | 121,670,598.00              |

**Total Saving Opportunity Loss of Electrical Production**: Rp 10,792,782,094.30

Based on table 3. Total saving opportunity loss of electrical production is Rp 10,792,782,094.30. This value is obtained from the unit repair time from operation failure and electricity sales price. The highest loss of production is no 2 with 8,991.3 MWH. This loss was caused by the problem of the controller that can make the STG unit experience derating.

### 5. Conclusion

Conclusion of the redesign innovation of the integration of GTG and HRSG control systems are as follows:

- The redesign of the integration of the GTG and HRSG control systems has been proven and tested to have a design that is able to prevent disruption to the unit’s operation, before innovation occurs 9 times, whereas after the innovation has not failed.
- The redesign of the integration of the GTG and HRSG control systems can saving opportunity losses of electrical production Rp 10,792,782,094.30.

### Acknowledgment

The author would like to thank to the officials of Muara Karang Power Plant, PT Pembangkitan Jawa Bali for the support and assistance that have been given in this study.

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