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The Integration of Supervisory Control and Data Acquisition (SCADA) on the Crushing and Barge Loading Conveyor Systems

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***Abstract*—The utilization of the Crushing and Barge Loading Conveyor (BLC) systems is important in coal processing. A crushing system is required as a tool for the process of crushing coal into smaller sizes and then transferring it to the stockpile. While a BLC system is needed to transport coal from the stockpile to the barge. In general, the control and supervision systems for crushing and BLC systems are carried out separately by two operators. However, the distance between two operators causes a time lag information. In this research, we create a Supervisory Control and Data Acquisition (SCADA) system with the type of Multiple Programmable Logic Controller (PLC) on the Crushing and BLC systems using Profinet communication integrated by two PLCs with one Human Machine Interface (HMI) and WinCC. The system is equipped with real-time data, automatic control, and online surveillance with smartphones *via* the S7APP application. The error resulting from the reading of each component by the HMI and smartphone reaches 0%, while for automatic control, the system works very well, having a success rate of 100%.**

Keywords— Barge Loading Conveyor (BLC), crushing, Human Machine Interface (HMI), profinet, Supervisory Control and Data Acquisition (SCADA)

I. INTRODUCTION

In the world of the coal industry, coal processing is generally carried out through several stages. The most important stage is the preparation stage, namely the reduction process of the grain size of the coal with crushers in order to meet the size requirement for its use [3]. At the preparation stage, there is a crushing system which is required as a tool for the process of crushing and moving coal to the stockpile as well as a Barge Loading Conveyor (BLC) system which is needed as a means of transporting coal from the stockpile to the barge. In general, the Crushing and BLC systems are in the same place with not too far away.

The automation system in the coal industry is important [5][11], one of them is crushing and BLC systems. In general, the control and supervision system on the Crushing and BLC system was carried out separately by two operators on each system. However, the distance between the two operators causes a time lag during the process of transferring information. This of course generates a delay in action when a problem occurs that requires both systems to be stopped. For example, when the BLC system has a problem that causes the system to stop, the crushing system must also be stopped. Indeed, this is necessary to avoid overloading the stockpile. However, with the time lag for the crushing system to stop, it is still prone to material build-up. SCADA is known as a system that can allow users to monitor, control and retrieve and record data. There is also a Programmable Logic Controller (PLC) as one of the control equipment that is widely used in the industry.

The PLC itself is designed to replace a sequential relay circuit in a control system. PLC also has a programming language that is easy to understand. NEMA (The National Electrical Manufacturers Association) defines PLC as a digital electronic device that uses programmable memory as the internal storage of a set of instructions by implementing certain functions, such as logic, sequential, timing, computation, and arithmetic, to control various types of machines or processes through digital and analog I/O modules [9][13]. From the above mentioned description, we design and create a project to design the SCADA integration on crushing and BLC Systems. This system will be integrated with two PLCs and one Human Machine Interface (HMI) which will be built with WinCC. Thus, from this system, we expect real-time data and automatic control of the Crushing and BLC system. This system only requires one operator for control and supervision of both systems, this aims to eliminate communication lags between operators. There are also additional facilities that can be controlled and supervised online via a smartphone, which nowadays become a research trend in automation systems [1][4][6], therefore, it can make the coal processing system easier.

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II. METHOD

A. SCADA

As shown in Figure 1, the SCADA system is a system consisting of several Remote Terminal Units (RTU) whose function is to collect data and then send it to the Master Station (MS) through a communication system. This scheme more simple than the monitoring node (controller) reads the information from sensors and transmits it directly to the Web SCADA system via the Internet using a REST-request. There can be several options to connect to the Internet (WiFi / Ethernet). Also, the node can receive commands from the Web SCADA system and perform device management [12].

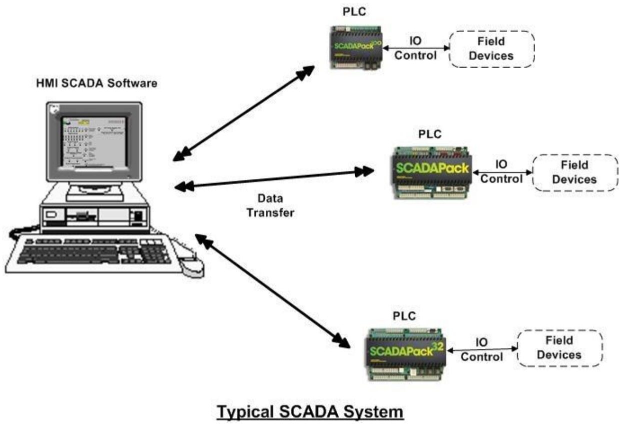

Figure 1 The schematic of the modern SCADA system.

B. PLC S7-1200

PLC S7-1200 supports Profinet communication using a standard TCP/IP connection, and can be used for communication with HMI and other devices. The communication interface has an RJ45 connector with an Auto-Cross-Over function, which supports Ethernet networks for data transmission up to 10/100 Mbps. Profinet is an Ethernet-based industrial communication protocol that uses the TCP/IP standard.

The proximity sensor as depicted in Figure 2 is a sensor to detect the presence of objects without a physical box [2]. Proximity is required in this design as a substitute for block chute switches in the crushing system. The function of proximity as a substitute for block chute switches is as a safety device when there is a pile of material on the crusher machine. So that when proximity is active, the previous process, namely the feeder motor that carries the material into the crusher machine will shut down.

C. Limit Switch

The Limit Switch device that has functions to disconnect and connect electric current in a circuit [10]. In this design, Limit Switch is used as a substitute for the belt drift switch and pull wire switch in the Crushing and BLC systems. The function of the limit switch as a substitute for a belt drift switch is as a conveyor safety device, namely when the conveyor belt shifts, the limit switch will be active. While the function of the limit switch as a substitute for a pull-wire switch is as a safety device located along the conveyor and can be activated manually in an emergency so that the conveyor will shut down.

D. Rotary Encoder

A rotary encoder is an electromechanical device that can monitor movement and position. A rotary encoder is needed in this design as a speed sensor conveyor in the crushing system and BLC which will function as a conveyor safety device. When the motor speed decreases, the conveyor will shut down.

Figure 2 The Proximity Sensor

E. Router

Figure 3 shows a router device that enables sending data packets through a network or internet to their destination [7]. The router also functions as a liaison between 2 or more networks to forward data from one network to another. In this design, it is used as an intermediary for PLC communication with the S7APP application.

Figure 3 Router

F. Motor DC

A direct current motor is an electric machine that converts electrical energy into mechanical energy [8]. A DC motor is needed in this design as a driving motor for the conveyor, feeder, and crusher in the Crushing system and as a driving motor for the conveyor and on-ground feeder in the BLC system.

III. Results and Discussion

A. HMI Interface Testing

HMI interface testing is carried out to ensure that the designed HMI can be run and easy to understand. The HMI display result when all systems are active. The red indicator indicates the component is off and the green indicator indicates the component is on. The "START AUTO" and "STOP AUTO" buttons are used to start and stop the crushing system, then the "RESET" button is used to reset the safety device system. Only one HMI to control and monitor 2 systems running concurrently, making it more effective than the previous system. The liquid level monitoring of lubricating System, crushers start, crushers speed monitoring, crushers speed transformation and protection design of crushers stall. Then we simulated the functions which the system can achieve, and got the monitoring chart in the human-machine interface [14]. The previous system have two conveyor belts, one of which delivers coal to the reduction area from the coal heaps to the motorized crushers. The crushed coal then passes through a filter and goes to a second conveyor belt. The second conveyor belt then takes the coal to the next stage for combustion [15].

B. Testing Interface S7APP

The interface S7APP test is carried out to ensure the designed application was work and is easy to understand. Figure 4 (a) and (b) show the screen appearance of S7APP in an active system. “TRUE” and ”FALSE” indicate the “on” and “off” conditions of the component, respectively. The change of the “FALSE” condition into “TRUE” in the row of “Start/Stop Crushing” is used in starting or stopping the system, while the row of “Reset SD Crushing” is used to reset the safety device system. Tag list indicates all condition of the component, the value of start/stop crushing, reset SD crushing, motor conveyor, motor crusher and motor feeder.

C. Crushing and BLC System Function Testing

Testing the function of the crushing system is carried out by placing charcoal in the feeder to be brought into the crusher machine and then transferred to the stockpile by a conveyor. While testing the function of the BLC system is carried out by placing the charcoal fragments from the stockpile on the ground feeder to be brought to the conveyor, then the conveyor carries the charcoal

Figure 4 (a) S7APP Crushing System Monitor, (b) S7APP BLC System Monitor

fragments to the barge. The size of the coal can be controlled by reducing or widening the distance of the coal crusher plate on the crusher machine. based on the size of the coal produced by the crushing system, this size has met the criteria for the coal industry so that this system can be used in the real world. Figure 8 shows the testing result from five samples. It is also shown in Figure 5 (a)-(c) which indicates the size of the charcoal before entering the crushing system is about 2.5 cm, thus the size of the largest charcoal shard after entering the crushing system is about 1 cm, and the smallest charcoal shard size after entering the crushing system is about 1 mm, respectively.

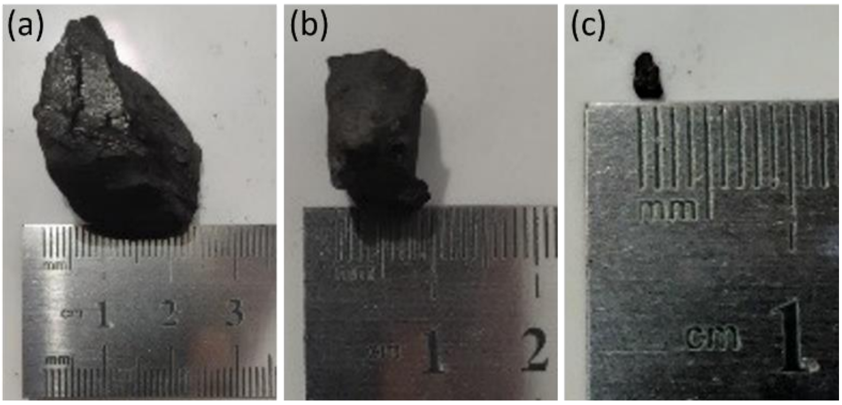

Figure 5 (a) The size of the charcoal before entering the crushing system (2.5 cm), while (b) and (c) are the size of the largest and smallest charcoal shard after entering the crushing system (1 cm and 1mm, respectively).

D. SCADA Integration Testing

The SCADA integration test is carried out by providing conditions that affect both systems, namely the crushing system and the BLC system when all systems are active. The system is said to be inactive if one or all of the motors in the system are stopped. It is better than understanding the normal response of equipment sourced from the PLC and displaying it in a desktop application. In a concept that has been developed, an example is the use of temperature sensors on PLCs, recording data from PLCs when conditions are normal or when there is a disturbance. These data were analyzed and displayed on an analysis desktop application [17].

From Figures 6, 7, and 8, it can be seen that when a problem occurs in the crushing system which causes the motor to stop, the BLC system continues to run making the BLC system still enables to carry the remaining material in the stockpile to the barge. However, when a problem occurs in the BLC system that causes the motor to stop, the crushing system also stops. This aims to avoid piles of material or overload on the stockpile making it more effective than the previous system. The liquid level monitoring of lubricating System, crushers start, crushers speed monitoring, crushers speed transformation and protection design of crushers stall. Then we simulated the functions which the system can achieve, and got the monitoring chart in the human-machine interface [14][16]. The regulator implements control of the change in the supply of stone material to prevent the crusher blockage in the event of interruptions

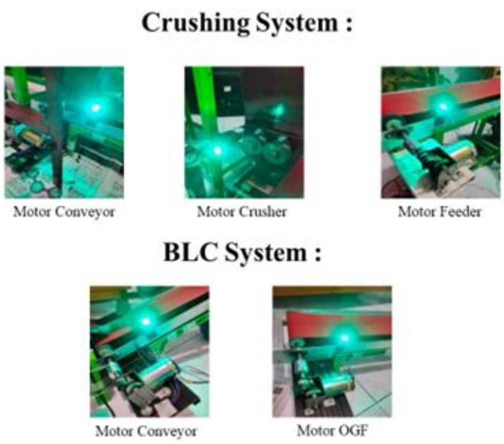

Figure 6 Conditions When Crushing System and BLC are active.

in the supply of material on the conveyor according to the following algorithm: in the case of a sharp decrease in the supply of ore (more than 70% of the steady-state value for 3 seconds), not due to the formation any control action from the control system, the set point of the material feed task is reduced [18]. A A database for oil storage and oil transportation has been created to provide experimental data for further research. In addition, these activities can be the basis for the discovery of more sophisticated methods and technologies [19].

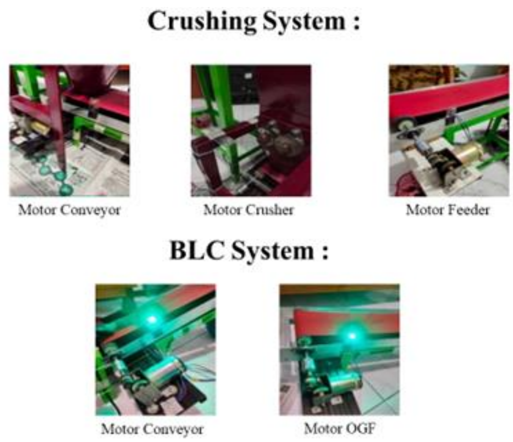

Figure 7

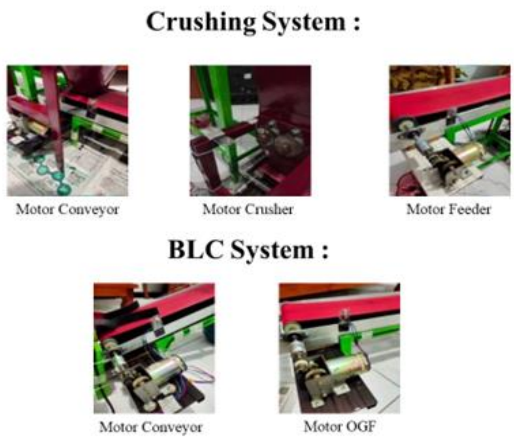

Figure 8

IV. Conclusion

Based on the results of testing and system analysis, it can be concluded as follows:

(i) The successful implementation of SCADA on the Crushing and BLC system has reached 100%, where the condition of each component can be controlled and monitored to make the system more efficient.

(ii) The SCADA system with HMI and online monitoring using a smartphone can run well in real-time with a sensor reading error of 0%.

The implementation of SCADA integration on the Crushing and BLC systems works very well with a 100% success rate, where when the BLC system stops, the Crushing system automatically stops as well. This eliminates the lag that occurred previously when taking actions manually.

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