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SCADA IMPLEMENTATION IN MICROHYDRO POWER PLANT CONTROL AND MONITORING SYSTEMS OF SCREW TURBINE TYPE

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ABSTRACT

Screw turbine-type micro-hydro power plants are still controlled manually by humans when there is a change in the electrical load on the generator output. If there is a change in the electrical load, the generator output voltage will change, thus affecting the rotation of the turbine being used. In this case, humans are needed to manually regulate the flow of water entering the turbine to maintain the stability of the generator output voltage by controlling the sluice gate. The water discharge entering the screw turbine will rotate the generator through a belt/gearbox pulley transmission, thus producing an electrical voltage at the generator output. To maintain the stability of the generator output voltage, it is necessary to control the water discharge entering the screw turbine. The expected goal of this research is to design a control system for a screw turbine type microhydro power plant to stabilize the generator output voltage and monitor the output of a screw turbine type generator using a SCADA (Supervisory Control, and Data Aquisition) system. The method used is the research and development method, namely the system design stage based on secondary data that has been collected, where the system design includes hardware design and software design, followed by making hardware such as control panels and devices. Software, which includes display design and leader diagrams and testing, is carried out by testing the system on software, hardware, and overall system testing. From the results of the discussion and analysis, the screw turbine type microhydro power plant control design system was created, a load control system consisting of 6 groups and sluice gate opening control that uses an ultrasonic sensor to determine the water level. With the results of controlling the sluice gate at a door opening of 30 mm, the generator voltage is 18.42 Volts DC, DC current is 0.0 Ampere at a load of 0 watts, when the load is 30 watts the generator voltage decreases by 18.40 volts, current is 1.37 Ampere. Through the on-line monitoring system, electrical parameters are obtained which are displayed on the SCADA system by looking in real-time at the history of DC voltage and DC current, DC power, and DC energy generated by the screw turbine-type DC generator. The voltage read is 18. 57 volts, current 1.37 Amperes, DC electrical power is 25.4 watts with a DC light load of 30 watts.

Keywords: SCADA, PLC, HMI, screw turbine.

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INTRODUCTION

A screw turbine is a turbine that is used to utilize the potential energy of water flows that have a low head, which experiences changes in water elevation, namely the change in the potential energy of water into kinetic energy of water which is utilized by the blades (screw-shaped) to rotate the turbine. Utilization of water flow energy is possible due to the high mass density of water (998 kg/m3) so that it is able to provide compressive force (perpendicular to the thread surface) and shear force (tangential to the thread surface) [1]. The resultant compressive force and shear force acting on the surface of the turbine thread will produce torque about the turbine axis.

The results of laboratory scale screw turbine performance tests reported by [2, 3] Saroinsong Tineke, *et al* (2016), the lower the inclination of the turbine shaft, the higher the efficiency. If the inclination of the shaft is increased, a vortex will occur between the screw turbine blades which reduces turbine efficiency. However, the turbine power will increase if the shaft inclination is increased. The best Archimedes water turbine efficiency occurs at a shaft inclination of 25°, an inflow head of 0.055 m and a flow speed of 0.5 m/s producing 1.35 Watt power and 89% efficiency. Meanwhile, the highest turbine power of 5.01 Watt occurs at a shaft inclination of 45° with an efficiency of 72%.

SCADA (Supervisory Control and Data Acquisition) is a combination of data acquisition and telemetry, which functions to retrieve data which is then analyzed and sent back to main control. The data is then converted into data that is easy to read by the operator and can be seen via the HMI display [4]. SCADA is now often found in the industrial world where it is used to control and supervise the work of each tool. Maintenance is also easier to do if an error or mistake occurs in the work.

The entire system in a plant can be managed and configured freely because it can be controlled and monitored in one place. With the real-time feature in the SCADA system, ongoing operations at a plant can be monitored quickly and accurately. In a SCADA system, the "brain" or controller is the PLC. The SCADA system has several main parts, including: Field Instrumentation / Field device, RTU / PLC, HMI and MTU. In other words, operators can run this system by using a computer (MTU) or HMI to give commands to the PLC/RTU to read data and control equipment in the field (Field devices).

The SCADA (Supervisory Control, and Data Acquisition) system works through local control of the RTU via wired or wireless communications. SCADA receives and stores all information and data originating from field equipment which is then sent to the control center. This system has several sub systems that make up [5], including: HMI (Human Machine Interface), MTU (Master Terminal Unit) RTU (Remote Terminal Unit), Field Devices, and Communication System.

HMI is a device in a system that is used to connect or bridge between machines and humans. Currently, we can find HMI in almost every industry that exists, both large and small scale industries. HMI has a shape like an ATM (Automatic Teller Machine) with a smaller monitor display and generally has a touch screen feature. [5]. MTU has functions as a master unit that works to store data from feedback originating from the slave after a command is sent. Command signals can be sent remotely to each scattered plant. The MTU can also communicate with the HMI to present data to the operator.

The RTU works as a slave unit that receives commands from the master and then sends control signals to field devices/equipment in the field, to extract data and then present the data to the master (MTU). Currently, PLCs are used more often than RTUs themselves. Field Devices is equipment in the field that is directly connected to machine technology which can then be controlled by the RTU via commands originating from the MTU. Field devices that are often used can be sensors to measure parameters and can be actuators that function to move equipment parts in machine technology. The communication system used to connect the HMI and MTU is in the form of Ethernet or Wi-Fi (Wireless), for the MTU to the RTU using Ethernet, while for the RTU to the Field Device it uses the RS-485 (Modbus) serial communication protocol.

SCADA system is a system that allows users or operators to monitor (supervision), which is used to collect information regarding system conditions and operating indications, then display it at the control center on the SCADA display that has been created. To Control, which is used to operate hardware equipment such as PLC. Data Acquisition (data retrieval and recording), which is used to retrieve data on all controlled systems. Finally, as a process alarms and events that inform you if changes occur in the system [6].

PLC (Programmable Logic Controller) is an electronic device used to replace old control systems that use relays. With increasingly affordable market prices, PLCs have become an option and are often used in industry as part of control systems. The PLC can be programmed via application/software which is then inserted by downloading it. With the downloaded program, the PLC can control or control the machine technology in a plant. The working system of the PLC is to receive commands from the input section which are then executed through the output to control the machine [7].

PLC has memory that can store all instructions that have been made. The input device on a PLC can be a push button, limit switch, sensor or other equipment that can send signals to the input section of the PLC. In the PLC output section, relays are often used to control lighting systems or contactors for machines or motors with relatively large power. The advantage of a PLC is that it is programmed in software which has various types of logic such as timing, arithmetic and sequential which can control machine technology in a plant according to the wishes and needs of the operator.

Each input and output from the PLC has a different address depending on the PLC brand, such as Omron with input addresses I: 0.00, I: 0.01, etc. and output O: 100.00, 100.01 etc. while the Haiwell brand has different input output addresses, namely X1, X2, etc. for input and Y1, Y2 etc. for output. To create a ladder program on a PLC, special software is needed which is usually the same as the PLC brand used, for example CX-Programmer for Omron PLCs and Haiwell Happy for Haiwell PLCs

Screw turbines are used as hydroelectric power plants, designing a monitoring system for generator output parameters and water flow based on Supervisory Control and Data Acquisition SCADA is important to maximize the needs for electricity generation. With component circuit schematics and some logical programming, accurate information can be obtained in real-time. This data can then be accessed via a centralized SCADA interface, allowing managers for Real-time monitoring: With regularly updated data, managers can see changes in generator output to inform generation needs in real-time. This allows rapid response to changing conditions that may affect screw turbine power generation.

SCADA technology has experienced rapid development in recent years. SCADA is a system consisting of hardware and software that functions to collect, analyze and control data in real-time from various equipment in the field. With SCADA, managers can monitor and control the system more efficiently and on time.

In the context of water resources management, designing a SCADA-based generator output and water flow monitoring system is important to maximize electricity generation needs. With component circuit schematics and some logical programming, accurate information can be obtained in real-time. This data can then be accessed via a centralized SCADA interface, allowing managers for Real-time monitoring: With regularly updated data, managers can see changes in generator output to inform generation needs in real-time. This allows rapid response to changing conditions that may affect water resource management.

Historical data accumulated in a SCADA system can help in long-term analysis. This enables better decision making in water resource management planning over longer periods of time. With a better understanding of the behavior of water levels and flows, managers can optimize operations such as sluice gate settings, water flow, and more to avoid potential losses.

The SCADA system can be used to detect sudden changes in water level which can indicate the potential for water supply to the turbine so that the turbine can rotate stably according to the electrical current required to rotate the screw turbine. If something undesirable happens, such

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as a sluice gate that is too oversupplied and cannot maintain the turbine rotation as needed, in this case it experiences a drop, which allows the authorities to take preventative action earlier in the monitoring process.

The purposes of this research is firstly to design a control system for a screw turbine type microhydro power plant to stabilize the generator output voltage. And secondly to monitor the output of the screw turbine type generator with a SCADA system. On other hand, the benefit of this research is to detect disturbances quickly so as to minimize damage to the generation system.

EXPERIMENTAL METHOD

Conceptual Research

The process of this research is shown in a flow diagram in the form of a conceptual framework.

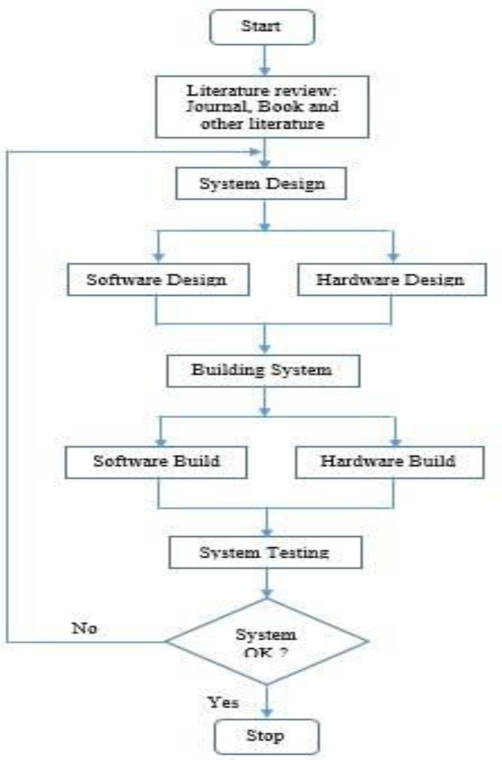

Figure-1. Conceptual research flow diagram.

System design stage, at this stage the author collects data. Makes observations to collect existing data directly into the screw turbine type power generating equipment to obtain primary and secondary data.

System design stage, at this stage a system design is carried out based on secondary data that has been collected, where the system design includes hardware design and software design. The most important thing in choosing the hardware in making the PLC system is the Haiwell AC16SOR PLC and HMI type C7S-W and the PZEM 003 DC power meter.

System creation stage, at this stage the hardware is made such as the control panel and software such as the PLC leader, HMI and SCADA display design. Testing stage, testing is carried out by testing the system on software, hardware and testing the entire system that has been created, and if the system does not work according to its function then it is necessary to check the software and hardware design again.

If the system is OK, this final stage has produced a control and monitoring system as planned and can be further identified for data retrieval based on the data displayed on the SCADA system.

System Layout

The first thing to do in designing this system is to make a site plan for the project by containing the electrical loads in the microhydro power plant with a screw turbine. This is done to determine the placement of the sensors. The design layout is:

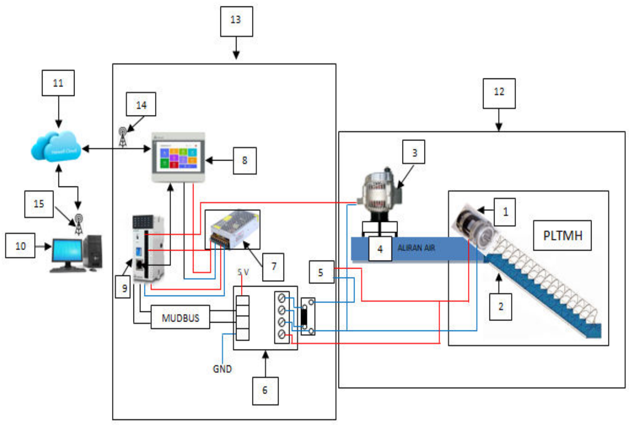

Figure-2. Layout of the SCADA system in a screw turbine.

Screw Turbine SCADA System Design

In hardware design, a description of the system that will be created will be needed to make it easier for the writer to create the system. The description of the system that will be created is in the form of a block diagram of the entire system. The system block diagram is shown in Figure-4.

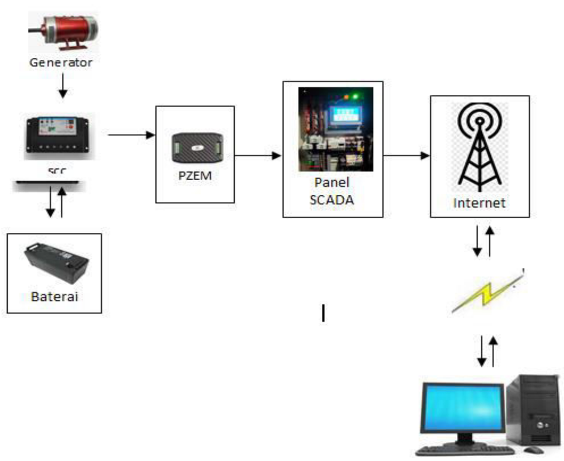

Figure-3. SCADA system design.

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The explanation of Figure-3 is as follows:

a. DC Generators

A DC generator is a device used on a screw turbine to produce voltage.

b. Battery

The battery is a DC voltage source that is charged from a DC generator.

c. Inverters

An inverter is a tool used to change DC voltage into AC voltage from a battery.

RESULT AND DISCUSSIONS

After designing the system for the HMI and Leader PLC, it was continued by testing the SCADA system online using the Claud SCADA application. From several stages of testing, the following are obtained:

The control system displayed on the SCADA system is the same as that displayed on the HMI as in Figure-4. If you turn on and turn off the load via a PC or on a smartphone, it will appear as in Figure-5.

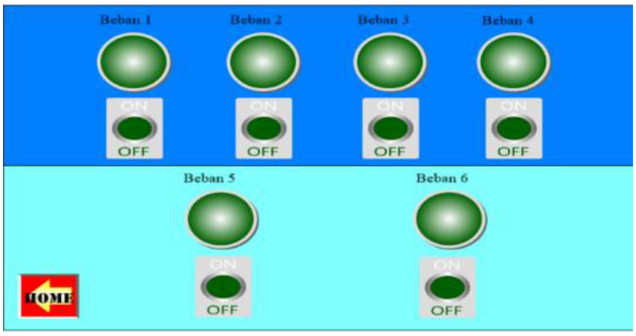


Figure-4. SCADA system load control.

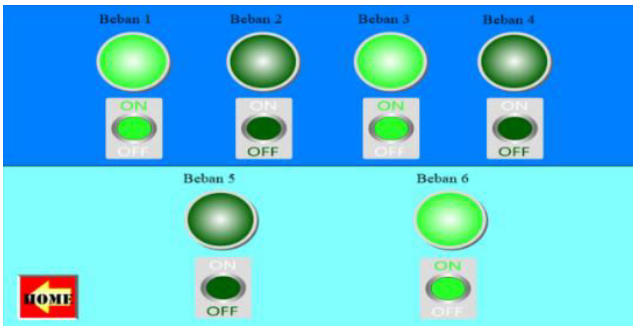
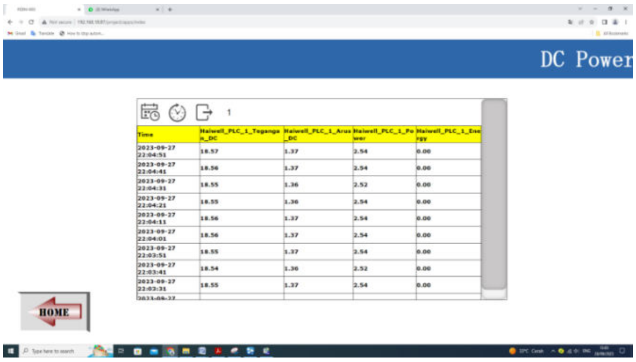


Figure-5. Load 1, load 3 and load 6 controls are turned on online.

The electrical parameters are displayed on the SCADA system by looking in real-time at the history of DC voltage and DC current, DC Power, and DC energy generated by a screw turbine type DC generator as in Table-1 using a cloud where the voltage read is 18, 57 volts, current 1.37 Amperes, DC electrical power is 25.4 watts with a DC light load of 30 watts.

Table-1. Historical DC electricity parameter data.



Time	Haiwell_PLC_1_Tegangan_DC	Haiwell_PLC_1_Arus_DC	Haiwell_PLC_1_Power	Haiwell_PLC_1_Energy
2023-09-27 22:04:51	18.57	1.37	2.54	0.00
2023-09-27 22:04:41	18.56	1.37	2.54	0.00
2023-09-27 22:04:31	18.55	1.36	2.52	0.00
2023-09-27 22:04:21	18.55	1.36	2.54	0.00
2023-09-27 22:04:11	18.56	1.37	2.54	0.00
2023-09-27 22:04:01	18.56	1.37	2.54	0.00
2023-09-27 22:03:51	18.55	1.37	2.54	0.00
2023-09-27 22:03:41	18.54	1.36	2.52	0.00
2023-09-27 22:03:31	18.55	1.37	2.54	0.00

The monitoring system displayed on this screen is the same as the one in Table-1, however, the measured parameters cannot be seen when these measurements are measured when they are displayed. The measured voltage as per monitoring results is 18.55 volts, current 1.36 Ampere, DC power 25.2 watts. As in Figure-6.

Figure-6. Monitoring DC electrical parameters.

The measured electrical parameters can be seen on a graph in real-time as in Figure-7.

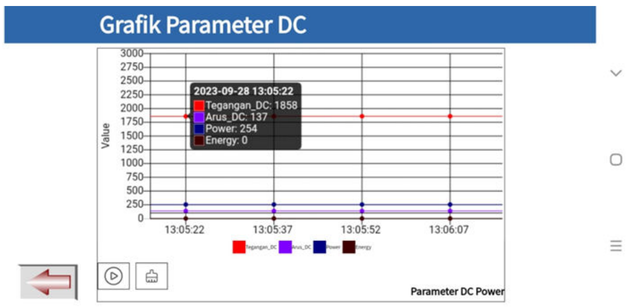


Figure-7. DC parameter graph.

CONCLUSIONS

The conclusions of this study are:

a) The control system design for the screw turbine type micro-hydro power plant is a load control system consisting of 6 groups and a sluice gate opening control that uses an ultrasonic sensor to determine the water level. With the results of controlling the sluice gate at a door opening of 30 mm, the generator voltage is 18.42 Volts DC, DC current is 0.0 Ampere at a load of 0 watts, when the load is 30 watts the generator voltage decreases by 18.40 volts, current is 1.37 Ampere.

b) Through the on-line monitoring system, the electrical parameters displayed on the SCADA system are obtained by looking in real-time at the history of DC voltage and DC current, DC power and DC energy generated by the screw turbine type DC generator, the voltage that is read is 18.57 volts, current 1.37 Amperes, DC electrical power is 25.4 watts with a DC light load of 30 watts.

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