Design and Implementation of SCADA Wireless Communication System for Monitoring the Performance of Microhydro Power Plant Based on Protocol AX.25

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Abstract

Purpose – This study aims to design and build a wireless supervisory control and data acquisition (SCADA) system based on Protocol AX.25 with the aim of monitoring the performance of several parameters in Microhydro Power Plant (MHPP). This system can monitor several MHPP parameters such as voltage, current, frequency, and turbine rotation so that it can be accessed directly at one central location.

Design/Methodology/Approach – The design is done by taking into account the real parameters that exist in the MHPP. Some parameters that become the main object to see the performance of MHPP are voltage, current, frequency, and turbine rotation. The voltage generated by the MHPP must be adjusted to the voltage supplied by State Electricity Company to the consumer, including the phase used. The resulting stream should also be monitored for power to be adjusted to the turbine spin. The generator frequency is kept stable according to the standard frequency of the State Electricity Company generator.

Findings – The remote terminal unit (RTU) system has been simulated using 2 ACS712 current sensors, voltage sensor, zero crossing point, frequency sensor, and rotation sensor functionalized to monitor MHPP parameters. The AX.25 protocol has been applicable in the wireless SCADA network for monitoring the performance of MHPP by embedding in KYL-1020UA transceiver radio using the 433 MHz frequency and the audio frequency shift keying modulation system. Radio transmitter KYL-1020UA has been successfully simulated to send data from sensors to display on the computer through SCADA built applications. The data changes in the RTU section can be displayed properly on the graphic user interface in accordance with the existing display at the MHPP location.

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Research Limitations/Implications – There are only two RTUs that will be connected to communicate, in this case MHPP-1 with callsign "RTU-001" and MHPP-2 with callsign "RTU-002." While the existing devices in the data access section parameters MHPP as master station with callsign "MSSCADA" monitoring the performance of parameters sent from the RTU. There is no collision or error in data transmission. Baudrate is varied at 1,200 bps, 2,400 bps, 4,800 bps, and 9,600 bps for effective throughput calculation and AX.25 protocol efficiency. The transmission distance is varied at 100 m, 200 m, 300 m, and 500 m to see the bit error rate with baudrate 1,200 bps and 9,600 bps.

Practical Implications – This product is expected to be applied to several MHPP locations in Aceh Province so that its monitoring system is more centralized and efficient.

Originality/Value – This research if for the efficient monitoring of several MHPP located far apart and can be monitored in one central location so that operators do not have to be located at the plant site.

Keywords Design of prototype, system modeling, protocol AX.25, microhydro power plant, SCADA wireless communication network

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1. Introduction

Monitoring of the performance of the microhydro power plant (MHPP) system is carried out directly at the plant site. Conventional monitoring system is ineffective if there are many MHPP that are to be monitored and controlled centrally and located in remote areas. This research has designed a system to monitor MHPP wirelessly by utilizing AX.25 communication protocol. Some MHPP parameters such as turbine rotation, voltage, frequency, and current can be accessed directly at one central location using this system. The data transmitted by the sensors contained in the remote terminal unit (RTU) can be a guide for the operator to decide on further steps if any monitored MHPP parameters change from a predetermined standard. The objective of the research is to design the model wireless monitoring system based on protocol AX.25 with the aim of monitoring MHPP performance.

2. Literature review

2.1. Protocol AX.25

The AX.25 protocol is a protocol for synchronous network access between data terminal equipment (DTE) on the user side and data circuit terminating equipment which is a device located on the network side directly related to the user side (Zieliński, 2013). Protocol AX.25 has three layers that have different functions. The first layer, namely, *physical level* that will be related to the problem of the procedure of interaction with the modem physical media. While in practical terms it deals with the electrical and mechanical problems of the interface with an intermediate medium. One example of a technical specification about this layer is the connector (Ronan *et al.*, 2010). This connector connects directly between the computer and the modem and consists of several pins that pass data of different functions. Figure 1 shows an example of multiple links to the radio port. The link multiplexer described in this standard multiplexes multiple data-link connections into one physical connection.

2.2. Microhydro power plant

The MHPP principally exploits the height difference and the amount of water discharge per second in the irrigation channel, river, or waterfall. This water flow will rotate the turbine shaft to produce mechanical energy (Sobhan, 2016). This energy then drives the generator and generates electricity.

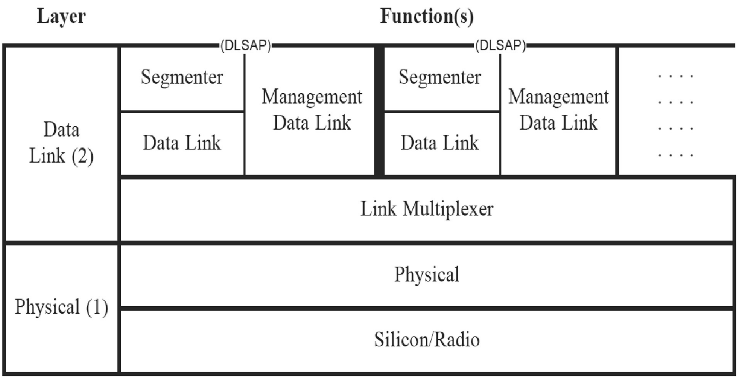

Figure 1.
AX.25 Model for Multiple Link

2.3. SCADA
Supervisory control and data acquisition (SCADA) is a system that collects data from various sensors in remote locations and then sends this data to a central computer which then manages and controls the data. Due to the increasing scope of its use, the use of these communication lines became impractical, as it introduced an integrated wireless communication system for SCADA (Kim, 2010; Bardzadeh *et al.*, 2012; Daniel *et al.*, 2014). Specifically SCADA systems include several parts of them, operating equipment such as pumps, valves, conveyors, and branch breakers that can be controlled by actuators or relays. Instruments in the field or facilities that are sensitive to conditions such as pH, temperature, pressure, power level and flow rate.Then a close-range communication network between a local processor with instruments and equipment operation. This section includes Programmable Logic Controller (PLC), Remote Terminal Unit (RTU), Intelligent Electronic Device (IED) and Process Automation Controller (PAC).(Rosslin and Kim, 2010).

2.4. Terminal node controller
Terminal Node Controller (TNC) is a microprocessor-based device that is often used in data communications on an amateur radio package network. The main function of TNC is to establish a connection between the radiofrequency (RF) transceiver and a computer that serves the device as a DTE such as a programmable logic controller or weather station. The TNC function consists of assembling and disassembling the frame and modulation and demodulation to adjust the format of the data transmitted through the computer serial port according to the requirements of the wireless transmission line (Ronan, et.al., 2010; Zieliński, 2013).

3. Research and design method
The design of SCADA wireless communication system based on protocol AX.25 for monitoring of MHPP in general has several stages, namely:

- *Design stage by considering the real condition in the field*: monitored parameters and monitoring method already exist. The results of this monitoring serve as a basis in designing hardware on the part of RTU that serves to acquire, collect, and mengrim existing data on the generator, then the main terminal unit (MTU) that serves to receive, demodulate, and decode data Sent RTU to be displayed on the SCADA graphic user interface (GUI).

- *Preparation of simulation software*: this stage aims to produce a simulation model of MHPP performance monitoring system wirelessly. AX.25 software development for packet data transmission from MHPP and software creation for human machine interface (HMI) SCADA display are required.
- *Analysis and evaluation*: this stage is completed after collecting data either based on literature study or field study.

3.1. System performance standards

Generally, the system must be able to establish a link connection between DTE MHPP circuit blocks with DCM (data terminating circuit equipment) HMI SCADA on master station, transferring information, transmits data to the monitoring center, and may disconnect if there is any disturbance to the monitored MHPP parameters. In addition, the system is able to interactively interact with the user through a GUI app that serves as HMI, or at least using hyperterminal. The system to be built has several performance standards to be a reference in the implementation and testing system that has been made. Some standard MHPP parameters that are expected to be implemented are as follows:

- *Current*. The current in the generator changes rapidly with the changes in the installed load, it is necessary to observe that these fluctuations do not cause damage to both the generator and the load.
- *Voltage*. Voltage on the generator needs to be observed to remain stable in accordance with the standard voltage required by the load that is equal to 220 V with a difference of tolerance of 10%.
- *Temperature*. The temperature parameter is the temperature of the generator and is kept under normal conditions.

3.2. Design method

The design is done by taking into account the real parameters that exist in the MHPP. Some parameters that become the main object to see the performance of MHPP are turbine rotation, voltage, current, and frequency. MHPP parameters consisting of turbine rotation, voltage, current, and frequency in the form of analog data are extracted using sensors which are then converted by analog-to-digital converter and transmitted to the microcontroller into digital data. The data are packed in several groups and packed in frames available on the AX protocol. The data packets that have been entered in the frame on the AX.25 protocol are then sent using KYL-500S as RF transmitters after going through the modulation stage. The data packet is then received by the RF receiver which then demodulates to be readable by the AX.25 protocol at the receiving end.

3.3. System design

The developed hardware has a block as shown in Figure 2. On the hardware, it has four blocks. Sensors serve to hold variables to be monitored at MHPP and adjusted to the input voltage for the microcontroller. Microcontroller functions as the main component in this device. Its main task is to organize data from the MHPP, forming the AX.25 protocol and set the correct timing to obtain a signal with a frequency corresponding to the desired audio frequency shift keying (AFSK) modulation. The software created is the one that runs inside the microcontroller. The voltage of the sensor is then taken according to the voltage level required to be converted into data relating to turbine rotation, voltage, current, and temperature information. The data are then set with the AX.25 protocol format. Data that have been formatted in the AX protocol 25 is then transmitted using AFSK modulation.

4. Result and discussion

4.1. RTU and MTU

RTU circuit is an existing system in the MHPP section that serves to collect data from the installed sensors to observe the parameters to be controlled. RTU circuit is built as many as two units in accordance with the number of MHPP to be monitored. Each RTU is coded according to the location of MHPP, that is, RTU_MHPP_1 for MHPP-1 and RTU_MHPP_2 for MHPP-2. Figure 3 shows the display of the simulation circuit for RTU and MTU MHPP. The MTU circuit serves to receive data from RTU_MHPP_1 and RTU_MHPP_2, the data will be selected according to the data input of each PLTMh. The MTU is then connected to a computer through software that serves to convert serial data to be displayed on the GUI as a SCADA interface.

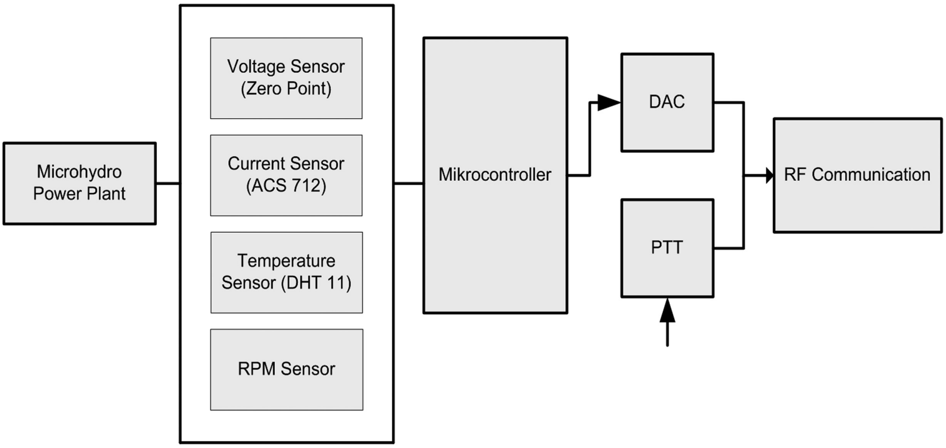

Figure 2. Hardware Block Diagram

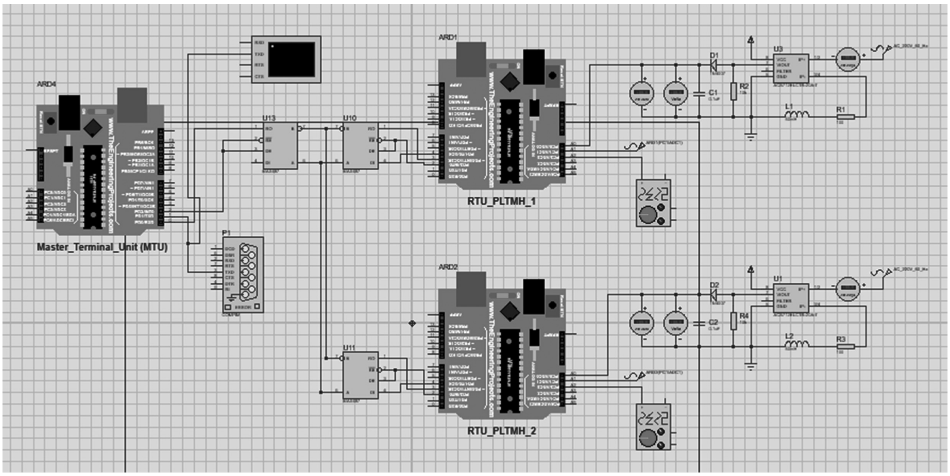

Figure 3. Simulation Circuit of RTU and MTU MHPP

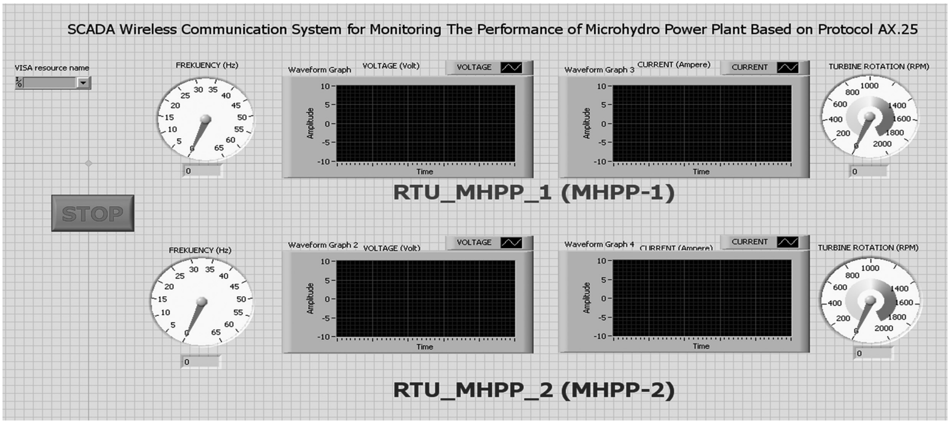

Figure 4.
Design of Display for GUI SCADA

4.2. HMI SCADA (GUI)

HMI is a display for RTU parameter monitoring which is a collection of sensor data in the form of GUI. This GUI will display the current data, voltage, frequency, and turbine rotation of which the data are taken from each of the monitored MHPP. This view allows the user to observe the state of all parameters so there is no need to look directly at the MHPP location. Figure 4 shows the appearance of the GUI design for monitoring data parameter from each RTU.

5. Conclusion

After simulation design of SCADA wireless communication system based on AX.25 protocol the following conclusions can be drawn:

- The RTU system has been successfully simulated using two ACS712 current sensors, voltage sensor, zero crossing point, frequency sensor, and rotation sensor functionalized to monitor the parameters of MHPP.
- The AX.25 protocol has been applicable in the wireless SCADA network for monitoring the performance of MHPP by embedding in KYL-500S transceiver radio using 433 MHz frequency switch and AFSK modulation system.
- Radio transmitter KYL-500S has been successfully simulated to send data from sensor to display on computer through SCADA-built application.
- Changes in data on the RTU can be displayed properly on the GUI in accordance with the existing view on the location of the MHPP.

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