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Design of SCADA Wireless System Protocol-Based AX.25 for Monitoring Micro hydro Power Plants

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With a range of long distances or depths and areas beyond the reach of the internet it is necessary to design a wireless SCADA system based on the AX.25 protocol for the purpose of monitoring Micro hydro power generation and forming a prototype in a model of a micro hydro power plants (Micro hydro power plant) wirelessly monitoring system. The method used in this research is quantitative method, by designing a system to monitor Micro hydro power plant wirelessly by utilizing AX.25 protocol. This system can monitor several Micro hydro power plant parameters such as voltage, current and frequency and turbine rotation so that it can be accessed directly at one central location. Data transmitted by Remote Terminal Units (RTUs) may serve as a reference for operators to decide on further steps if any monitored Micro hydro power plant parameters change from a predetermined standard. This prototype has been simulated using the Proteus 8.6 and LabView 2012 software. Data from the sensors transmitted over radio frequency using KYL 1020 from each RTU to MTU and connected to the computer using LabView software and displayed on the computer with taking into account the operating parameters, characteristics and workings of the AX protocol. The RTU system has been successfully simulated using 2 ACS712 current sensors, voltage sensor, zero crossing point, frequency sensor and rotation sensor functional for monitoring Micro hydro power plant parameters. The AX.25 protocol has been applicable in the wireless SCADA network for monitoring the performance of the Micro hydro power plant by embedding in a KYL-1020UA transceiver radio using the 433 MHz frequency and the AFSK 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 GUI in accordance with the existing display at the Micro hydro power plant location.

Keywords: Design of prototype, system model, Protocol AX.25, Micro hydro power plant, and SCADA wireless communication network.

1. INTRODUCTION

Monitoring of the performance of the Micro hydro power plant system is carried out directly at the plant site. Such monitoring is ineffective if there are Micro hydro power plant that want to be monitored and controlled centrally and located in remote areas. This research has designed a system to monitor Micro hydro power plant wirelessly by utilizing AX.25 protocol. This system can monitor several Micro hydro power plant parameters such as frequency, voltage and current and can be accessed directly at one central location. Data transmitted by Remote Terminal Units (RTUs) may serve as a reference for operators to decide on further steps if any monitored Micro hydro power plant parameters change from a predetermined standard.

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Considering the cost, the AX.25 Protocol is expected to be an alternative to wireless SCADA communications in monitoring the performance of the Micro hydro power plant. There are several problems found in the Micro hydro power plant system: How the system is implemented online, how to build AX.25 protocol based wireless SCADA system for monitoring micro hydro power generation. The objective of the research is to design the model of Micro hydro power plant performance monitoring system wirelessly by using software and simulation to produce simulation product and remote monitoring system with some important parameters of Micro hydro power plant such as voltage, current, frequency and turbine rotation so that it can be monitored centrally. The benefits of this research are for the efficient monitoring of several Micro hydro power plant located far apart and can be monitored in one central

location so that operators do not have to be located at the plant site. Saves time and cost, when compared to doing it manually and not centralized. This product is expected to be applied to several Micro hydro power plant locations in Aceh Province so that its monitoring system is more centralized and efficient.

2. LITERATURE REVIEW

a. Protocol AX.25

The AX.25 protocol is a protocol for synchronous network access between DTE (Data Terminal Equipment) on the user side and DCE (Data Circuit Terminating Equipment) which is a device located on the network side directly related to the user side). Protocol AX.25 has 3 layers / layers that have different functions, namely:

Physical level:

This layer is seen from its name, will be related to the problem of the procedure of interaction with the modem physical media. In practical terms, the dealing with interface electrical and mechanical problems are reached intermediate medium. One example of a technical specification about this layer is the connector. This connector connects directly between the computer and the modem and consists of several pins that pass data of different functions.

Link level:

This layer has rules for exchanging data called data link control. The protocol used in this layer by ISO is called HDLC (High Level Data Link Control) performs several things such as, establishing logical relationships through existing media such as cables or atmosphere, providing information about moving data to keep the data in sequence, performing error detection and closing Logical connection that has been completed.

Packet level:

The main purpose of the packet level protocol is to multiplex a number of logical information flows in a single medium. At this level, data is broken down into packets that have a certain size. The logic relationship built is a virtual circuit whose transport mechanism is a full-duplex point to point. The logical relationship consists of 2 types, namely Permanent Virtual Circuit (PVC) which is a relationship between 2 DTE that does not require initialization procedure at the beginning of connection. This type is usually used for leased lines where both modems are connected and never disconnected. Another logical relationship is the Virtual Circuit (VC) also the relationship between 2 DTE and using the connection and disconnection procedures.

b. AFSK Modulation

One of the data communication techniques for sending data using HT is utilizing Audio Frequency Shift Keying (AFSK) modulation technique is a digital modulation system that converts digital data into analog waves at sound frequency. These AFSK cues modulate digital signals in NRZI (Non Return to Zero Inverted) format, which means that if digital data is '1', then there is no tone change, for digital data '0' there is a tone change. This is shown in figure 1. In general the AFSK used can be expressed as follows.

$$ft = \begin{matrix} A\ sin 2\pi f_1 t, & F(n) = 0 \\ A\ sin\ 2\pi f_2 t, & F(n) = 0 \end{matrix} \quad (1)$$

where, A is amplitude of the analogue signal, *f(t)* is FSK signal, and *F(n)* is digital data.

c. Micro hydro Power Plant

Micro hydro power plant 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. This energy then drives the generator and generates electricity. The illustration of Micro hydro power plant can be seen in Figure 1.

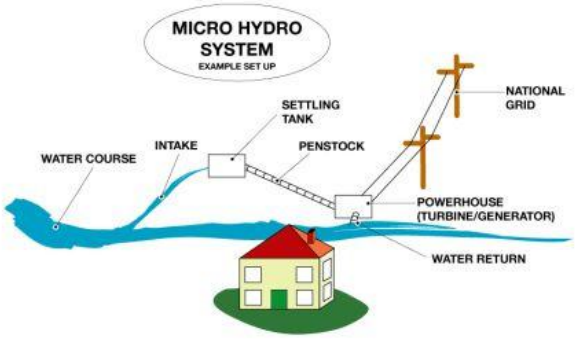

Figure 1. Illustration of Micro hydro power plant

The development of Micro hydro power plant needs to start with the construction of a dam to regulate the flow of water that will be used as a driving force Micro hydro power plant. Dams need to be equipped with sluice gates and filters to prevent entry of dirt or mud sediment. Near the dam built intake building (intake). Then proceed with the creation of a conductor channel that serves to drain the water from the intake. At the end of the overflow channel is built a settling pond. This pool serves to precipitate the sand and filter out the dirt so that the water coming into the turbine is relatively clean. The channel is constructed with concrete construction and is as close as possible to the turbine house to save on the pipe. Rapid pipeline works to drain the water before entering the turbine usually made of steel pipes that drill then welded for inter-pipe connections used flange.

d. SCADA

SCADA is a system that collects data from various sensors in a factory, generator or at other remote locations and then sends this data to a central computer which then manages and controls the data. Initially, SCADA was designed to be on a private network using a communication path. 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. 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 in facilities 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 must put into consideration. This section includes Programmable Logic Controller (PLC), Remote Terminal Unit (RTU), Intelligent Electronic Device (IED) and Process Automation Controller (PAC).

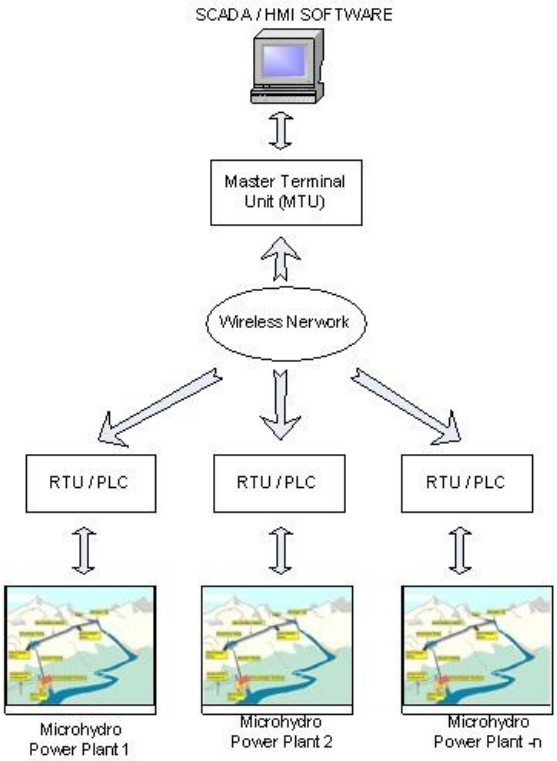

Figure 2. Typical wireless SCADA system for Micro hydro power plant

3. METHODOLOGY

The design of SCADA wireless communication system based on protocol AX.25 for monitoring of Micro hydro power plant in general done several stages, namely:

1. Design method is 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 (remote terminal unit) that serves to acquire, collect and send existing data on the generator, then the MTU (main terminal unit) that serves to receive, demodulate and decode data Sent RTU to be displayed on the SCADA GUI (graphic user interface).
2. Preparation of simulation software, this stage aims to produce a simulation model of Micro hydro power plant performance monitoring system wirelessly. AX.25 software development for packet data transmission from Micro hydro power plant and software creation for HMI SCADA display.
3. Analysis and Evaluation, after collecting data either based on literature study or field study (see Figure 3).

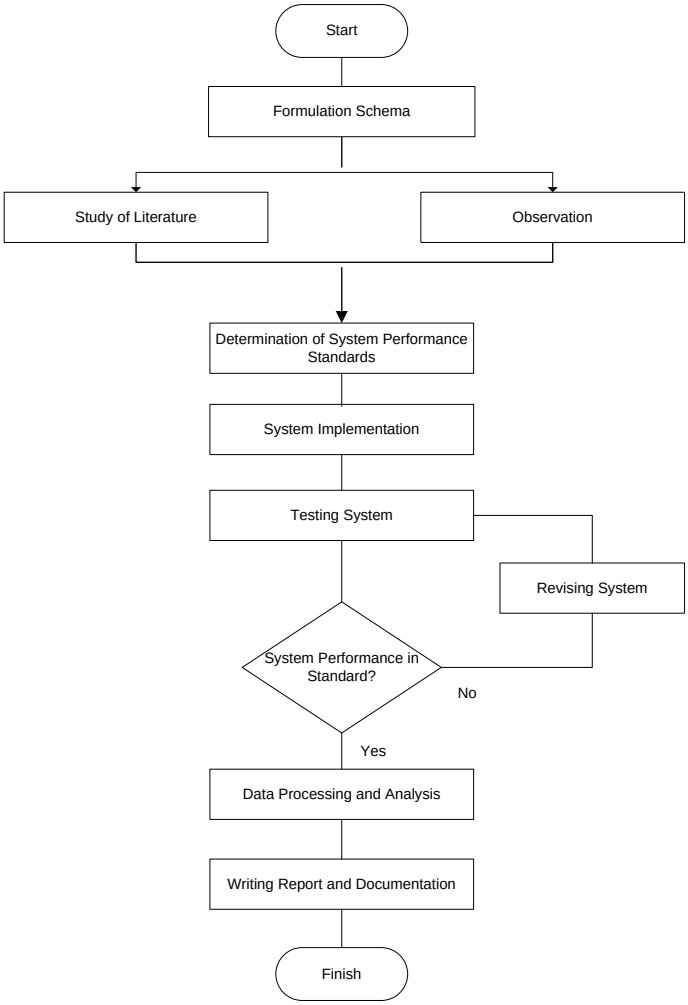

Figure 3. Flowchart diagram study

In general, the system must be able to establish a link connection between DTE (Data Terminal Equipment) Micro hydro power plant circuit blocks in this case as RTU (Remote Terminal Unit) with DCE (Data Terminating Circuit Equipment) HMI SCADA on MS (Master Station), can transfer information, Transmits data to the monitoring center and may disconnect if there is any disturbance to the monitored PLMTh 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. System features consist of 1200 bps baud rate, KISS mode only baseband, using FSK modem for packet radio applications using KYL 1020-UA as RF Transceiver. 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 Micro hydro power plant parameters that are expected to be implemented are:

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 volts with a difference of tolerance of 10%.

Temperature. The temperature parameter is the temperature of the generator and is kept under normal conditions. There are only two RTUs (remote terminal units) that will be connected to communicate, in this case Micro hydropower plant-1 with call sign "RTU-001" and Micro hydro power plant-2 with call sign "RTU-002". While the existing devices in the data access section parameters Micro hydro power plant as MS (master station) with call sign "MSSCADA" monitor the performance of parameters sent from the RTU. There is no collision or error in data transmission. Baud rate is varied at 1200 bps, 2400 bps, 4800 bps, and 9600 bps for effective throughput calculation and AX.25 protocol efficiency. The transmission distance is varied at 100 meters, 200 meters, 300 meters and 500 meters to see the BER (bit error rate) with baud rate 1200 bps and 9600 bps.

b. Design Method

The design is done by taking into account the real parameters that exist in the Micro hydro power plant power plant. Some parameters that become the main object to see the performance of Micro hydro power plant are voltage, current, frequency and turbine rotation. The voltage generated by the Micro hydro power plant plant 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. The simulation circuit is built using proteus software with the components used adapted to the real conditions of the field. After designing the simulation using proteus software is completed, and then the activity that followed is the manufacture of the product. Micro hydro power plant parameters consisting of voltages, currents and temperatures in the form of analog data are extracted using sensors which are then converted by Analog to Digital Converter (ADC) and transmitted to the microcontroller into digital data. The data is packaged in several groups and packaged in frames available on the AX protocol. The data packets that have been entered in the frame on the AX protocol 25 are then sent using KYL 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. The data still packaged in the frame is then broken back into the form of initial data sent through the serial port computer that can be read through the existing GUI display, or by using Hyper terminal. Figure 4 shows the working principle and system design of the system design plan (see Figure 4).

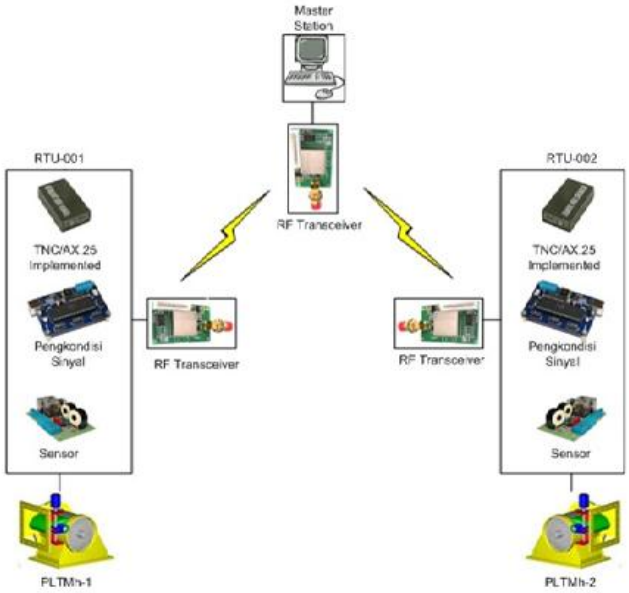

Figure 4. System design plan

c. Hardware Design

The hardware development is shown in Figure 5. On the hardware, it has four blocks. Temperature sensor, current sensor and voltage sensor serves to collect variables to be monitored at Micro hydro power plant 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 Micro hydro power plant, forming the AX.25 protocol and set the correct timing to obtain a sine wave signal with a frequency corresponding to the desired AFSK modulation.

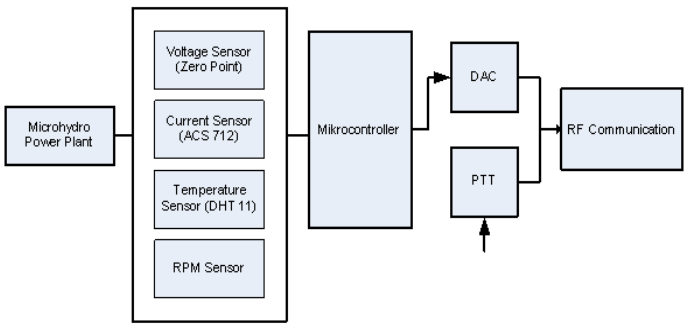

Figure 5. Hardware block diagram

d. Designing Software

The software created is software that runs inside the microcontroller. This software is in charge of organizing the work of the microcontroller as the receiver of data from the sensor-sensior installed on the Micro hydro power plant, AX.25 protocol controller and generate the right frequency for AFSK modulation. In addition, the microcontroller can also receive data from the computer

when it will be done changing the configuration of the shipping address and delivery time on the hardware. Figure 6 shows the flowchart of the AX.25 protocol implementation process. Inside this software an introduction to the sensor data is received. The voltage of the sensor is then taken according to the voltage level required to be converted into data relating to voltage, current and temperature information. The data is then set with the AX.25 protocol format. Data that has been formatted in the AX protocol 25 is then transmitted using AFSK modulation. This modulation is generated by microcontroller by generating sine wave with exact frequency that is 1200Hz and 2200Hz. The process of forming a sine wave is performed using a lookup table method by extracting digital data to be converted to analog using the DAC previously described. Frequency is set by setting the clock output digital data. Another software is on the receiving end. On the receiver side the voice signal from HT goes into the computer via the mic line on the sound card to do the demodulation, is used using sound modem software or by using hyper terminal application which is the default window application to communicate with existing I/O terminals On computer hardware. After the installation of the software, configured to work properly (see Figure 6).

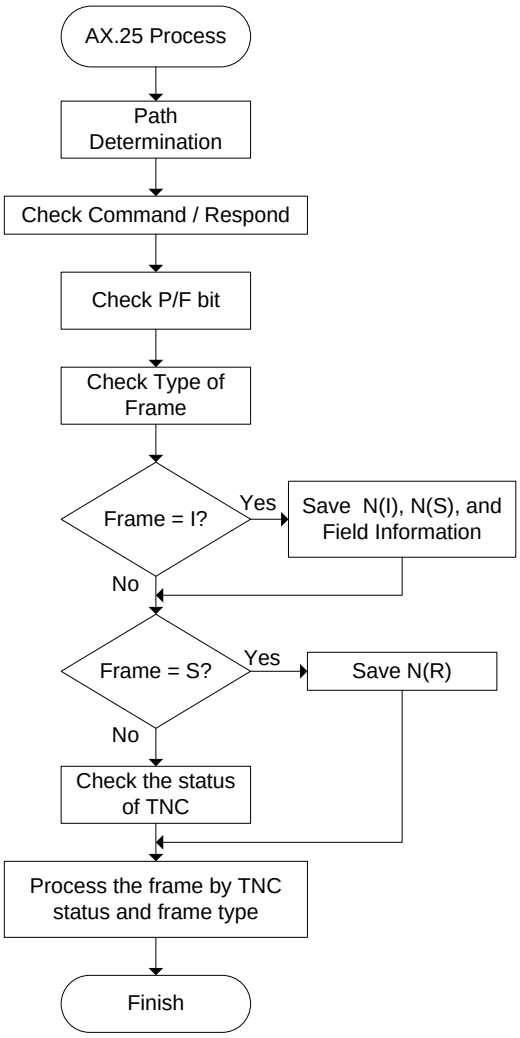

Figure 6. Flow chart of AX 25 protocol process

c. Arduino Pro mini 328

Arduino is a microcontroller board based on ATmega328. Arduino has 14 input / output pins which 6 pins can be used as PWM output, 6 analog input, 16 MHz crystal oscillator, USB connection, power jack, ICSP head, and reset button. Arduino able to support microcontroller; Can be connected to a computer using a USB cable.

Figure 7. Arduino pro mini 328

Arduino can be given power via USB connection or power supply. The Power selected automatically. Power supply can use DC adapter or battery. The adapter can be connected by plugging the adapter jack on the input supply port connection. The arduino board can be operated using an external supply of 6-20 volts. If supply is less than 7V, sometimes 5V pin will supply less than 5 volt and board can become unstable. If it uses more than 12 V, the voltage across the regulator can get very hot and cause damage to the board. The recommended voltage is at 7 to 12 volts.

d. RF Data Transceiver YS-1020UA

RF data transceiver YS-1020UA is a device that can transmit serial data through air media. The device performs the process of laying digital serial data into a carrier frequency with a higher frequency to be transmitted into the air by the transmitter. At the carrier frequency receiver containing the data is captured and separated from the carrying data. YS-1020UA module The Wireless Data Transceiver can transmit and receive serial data through aerial media, with 433MHz ISM band frequency and 9600 bps of water baud rate. The use of the module is quite practical because in terms of size is small enough and directly connected with RS232. The module works with a supply between 3.3 to 5 VDC. In one module can be used as both sender and receiver. The physical form of the YS-1020UA module is as shown in Figure 10. Serial data to be transmitted via RF is fed to the YS-1020 module by the microcontroller in series. Similarly, data received, will be taken by the microcontroller in serial.

Figure 8. Physical Form of Module YS-1020UA

The signal emitted by the antenna must be of high frequency, so that the transmitting antenna used has a dimension not too large to make. This is related to the effectiveness of an antenna to be able to emit the signal. An antenna will only emit electrical signals efficiently, if the length of the antenna is proportional to the wavelength of the signal to be emitted. To enable the transmission of such signals to the length of the antenna possible, before the signal is sent to the antenna, a modulation process is performed. Modulation is the process of moving the spectrum / frequency of a (usually low) signal to a higher spectrum. In the process of modulation is done mixing between information signal (which is usually relatively low frequency) with a signal with higher frequency.

c. AX.25 Protocol Software

Software created is run in arduino pro mini 328. This software is tasked with arranging arduino work as data recipient of sensors installed in Micro hydro power plant, AX.25 protocol controller and arranging communication with RF transceiver as sender of data. In addition, arduino can also receive data from the computer when it will be done changing the configuration of the address and delivery time on the hardware. In this software an introduction to the sensor data is received. The voltage of the sensor is then taken according to the voltage level required to be converted into data relating to voltage, current and temperature information. The data is then set with the AX.25 protocol format. Data that has been formatted in protocol AX.25 is then transmitted using RF Transceiver. Another software is on the receiving end. At the receiving end of the signal from the RF Transceiver goes into the computer through the USB path for later display via the created GUI or by using the hyper terminal application which is the default window application to communicate with existing I / O terminals on the computer hardware. After the installation of the software, configured to work properly.

d. ACS 712 Current Sensor

Current measurements usually require a shunt resistor which is a resistor connected in series at the load and converts the current into voltage. The voltage is usually fed to the current transformer first before entering the signal conditioning circuit. Hall effect technology applied by Allegro replaces the function of resistor shunt and current transformer into a sensor with a relatively much smaller size. An electric current flow resulting in a magnetic field induced the dynamic offset portion of the ACS712 cancellation. This sensor has been calibrated by the manufacturer. Block diagram of ACS 712 current sensor (see in Figure 9).

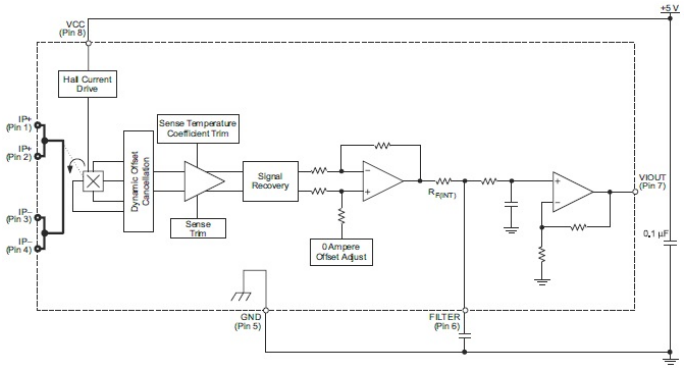

Figure 9. Block diagram of ACS 712 current sensor

4. RESULTS AND DISCUSSION

The output of this sensor is (> VIOUT (Q)) when the current increases in the current conductor (from pin 1 and pin 2 to pins 3 and 4), which is used for detecting or sensing currents. The resistance in the sensor carrier is 1.2 mΩ with low power. Electronically conductive terminals are isolated from the lead / lead sensor (pins 5 through pin 8). This enables ACS712 current sensors to be used in applications that require electrical isolation without the use of opto-isolators or other expensive isolation techniques. The current-carrying thickness inside the sensor is three times overcurrent. This sensor has been calibrated by the manufacturer. ACS 712 current sensor simulation circuit can be seen in Figure 10:

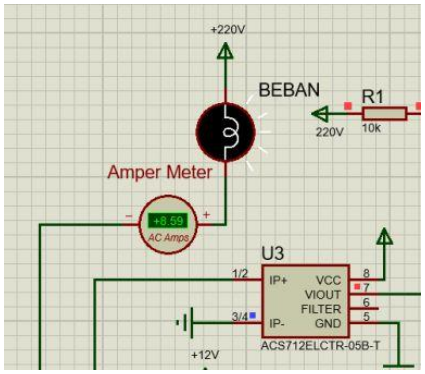

Figure 10. ACS 712 current sensor simulation circuit

RTU circuit is an existing system in the Micro hydro power plant section that serves to collect data from the installed sensors to observe the parameters to be controlled the parameters are voltage magnitude, frequency, current and turbine rotation. RTU circuit is built as many as two units in accordance with the number of Micro hydro power plant (MHP) to be monitored. Each RTU is coded according to location of Micro hydro power plant that is RTU-1 for Micro hydro power plant -1 and RTU-2 for Micro hydro power plant -2.

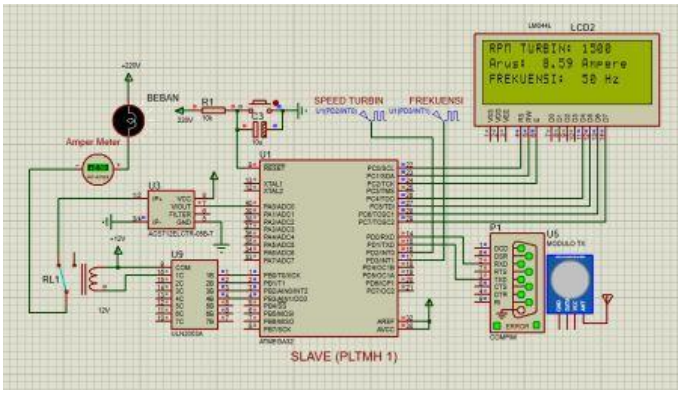

Figure 11. RTU-1 simulation circuit (MhPP-1)

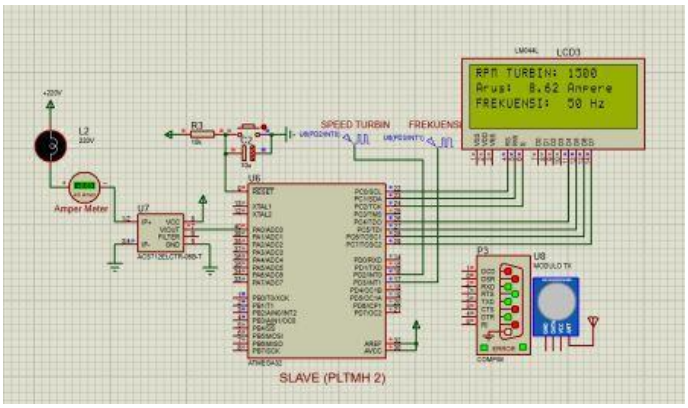

Figure 12. RTU-2 simulation circuit (MhPP-2)

The MTU circuit serves to receive data from RTU-1 and RTU-2, the data will be selected according to the data input of each Micro hydro power plant. The MTU is then connected to the computer through software that serves to convert serial data to be displayed on the GUI (Graphical User Interface) as the SCADA interface.

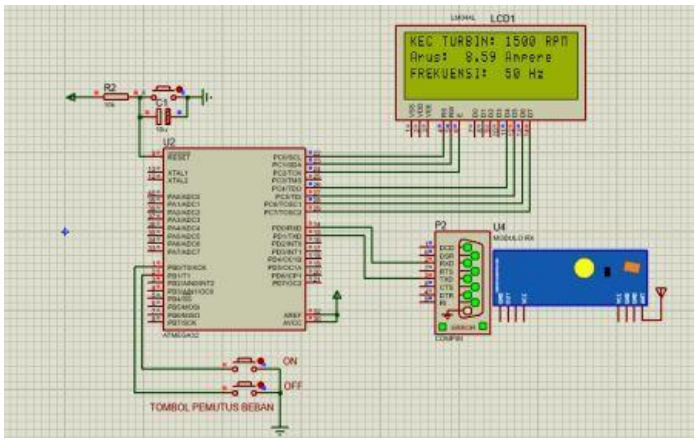

Figure 13. MTU simulation circuit (Master Terminal Unit)

HMI (Human Machine Interface) is a display for RTU parameter monitoring which is a collection of sensor data in the form of GUI (Graphical User Interface). This GUI will display the current data, voltage, frequency and turbine rotation of which data are extracted from each monitored Micro hydro power plant. This view allows the user to observe the state of all parameters so there is no need to look directly at the Micro hydro power plant location.

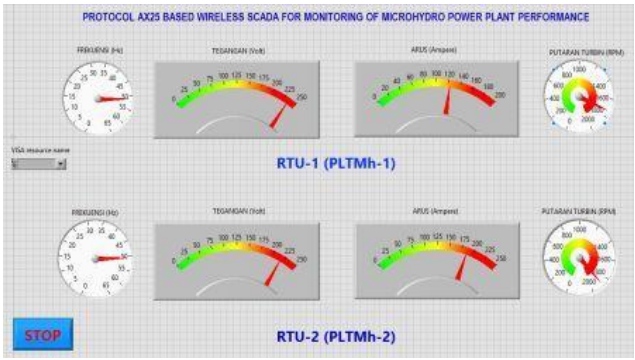

Figure 14. Display of HMI-SCADA

5. CONCLUSIONS

After simulation design of SCADA wireless communication system based on AX.25 protocol can be drawn into four point conclusions as follows:

1. 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 Micro hydro power plant,
2. The AX.25 protocol has been applicable in the wireless SCADA network for monitoring the performance of Micro hydro power plant by embedding in KYL-1020UA transceiver radio using frequency 433 MHz and AFSK modulation system.
3. Radio transmitter KYL-1020UA has been successfully simulated to send data from sensor to display on computer through SCADA application built.
4. Changes in data on the RTU can be displayed properly on the GUI in accordance with the existing view on the location of the Micro hydro power plant is located.

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