MBSPS and FRSNS Systems Result Comparative to Monitoring Step-Down Power Transformer in 33/11 KV Distribution Substation

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Abstract:

In electrical power system transformers consider the most important and expensive equipment. Monitoring and controlling these devices in a reliable manner is essential.in this paper two systems were designed to monitoring the parameters of step-down power transformer based on ZIGBEE technology theses parameters are: current, voltage, temperature and oil level. One of these systems work with the help of microcontroller (Arduino mega) is microcontroller-based sensor pooling system (MBSPS) and the other depends on XBEE alone is free running sensor node system (FRSNS) then integrated the work with SUPERVISORY CONTROL AND DATA AQUISETION (SCADA) system by reaching the parameters by XBEE to the remote terminal unit (RTU) using one of the most popular SCADA protocol (MODBUS). The results obtained unevenly depending on the function of each system.the time consumed for processing one packet in free running is triple than in pooling and required double time to receiving one packet. microprocessor assisted consume more power with a difference of 29.0037J.

Keyword: power system, transformer, XBEE, Arduino, SCADA, RTU, MODBUS.

1.Introduction

In Iraq at 33/11 kV distribution substation the process of monitoring and transferring transformer signals is still on the wired system. With the developments of industrial automation technology, limitation of traditional cable control network has become increasingly. For this, establishing a reliable data transmission network in industry becomes an important demand. To this day، wired networks are still used to connect sensors to move sampled process data to control system. Wired networks are very stable and reliable communication systems for controls and instruments. However, the cabling engineering necessary is cost a lot. so, recently costless wireless networks are strongly required by customers. Many research institutions and foreign companies and domestic start studying how to formulate wireless measure and control systems in industries [1]. Wireless Sensor Network (WSN) means a group of spatially dispersed and dedicated sensors that used for monitoring and recording the physical conditions of the environment then organizing the collected data in a central location [2]. wireless sensor network (WSN) technology has been proved a great potential for commercial, industrial and consumer application, especially in monitoring and control. Adopting WSN for process monitoring and control adds major advantage over the traditional wired system. these advantages are [3]:

- No wiring constraints
- Easy maintenance
- Reduced cost
- Better performance

In power system the Power transformers are important part which are used to step down and step up the power to make usable for electricity consumers. Transformers are vulnerable to failure and that for several seasons like internal fault, external fault or general ageing of parts which can lead to serious damage and results in replace the parts due to which the consumer suffers from longer power outage and the high replacement of the part; it can also cause fire and explosion which is threatening property and lives[4]. ZIGBEE is a WSN technology, this technology is a type of low power-consuming communication technique for coverage area surrounded by 200m, with data rate from 20Kbps to 250Kpbs [5]. this work is based on this technology to monitoring step-down power transformer at 33/11 kV distribution substation. FRNSN and MBSPS systems designed to monitoring transformers wirelessly.

2.Realted Work

1.Drasko Furundzicet al.2012,[6] The paper discusses how to identify casual relation of dissolved gases in transformer oil and current state of transformer health using neural networks that are considered a widespread technique for transformer health monitoring system, and improve the reliability and accuracy in transformer health and failure prognosis.

2. Mallikarjun Sarsambaet al.2013,[7]. This paper discussion about monitoring the load and power lines using GSM wireless technology to provides flexible control of load and provides information about any abnormality in power lines. This methodology is design and implemented by using embedded system for monitor and record load changes with respect to voltage and current in power lines and how to breaks the power lines when the load become high.

3. Ravishankar Tularam Zanzad et al.2016,[8]. The idea of this paper is design and implementation wireless system based on ZIGBEE to monitor and record parameters of distribution transformer: temperature, over current, over voltage and oil level. The aim of measuring the above parameters is to optimize transformer and identify problem before it occurs to avoid failure.

3.ZIGBEE Technology

ZIGBEE is one of the most widely used wireless sensor network standards with low data rate, low cost, low power and short time delay characteristics, easy to develop and deploy and provide high data reliability and robust security [9]. ZIGBEE name came from zigzagging movement of honey bees between flowers; show the communication between nodes in a mesh network [10].

4. ZIGBEE in Power System

ZigBee technology is suitable for applications in power monitoring system, it can provide reliable protection for the operation of electric power systems. The Following points justify this statement.[11]

- Data rate: maximum transfer rate can be up to 250 kbps which compatible with data rate needed in the power monitoring system.
- Large capacity: ZIGBEE is suitable for the complex structure of power system because network support up to 65,000 nodes.
- Low-cost: The installation costs are low, and the maintenance is simple.
- Strong anti-interference: For the interferences from environments like, mobile, cars, generators, transformers, power distribution room, etc., this technology can prevent well.
- Short time delay: The delay usually from 15 - 20 ms, so it is very suitable for industrial system that need real-time data transmission.
- Low power-cost. In low power standby mode, two normal ordinary dry-cell batteries can be used for 6 months to 2 years. This consider the major advantage of ZigBee to ensure that the monitoring system continue working in the event of the power failure.
- Strong safety: Zigbee technology use the encryption algorithm AES-128 which provides functions of integrity data checking and authentication.

5.Systems Design

5.1 Microprocessor-Based Sensor Pooling System (MBSPS).

This proposal works to monitor the parameters of two transformer these parameters are: core temperature, current, voltage and oil level transformer side consist of sensors, microcontroller Arduino board and XBEE module (end node) that provide a wireless communication. RTU side consist of Arduino board and XBEE module(coordinator). in this proposal the monitoring terminal interrogates all available nodes for sensors values. Each node equipped with XBEE for wireless communication and a microprocessor to process sensors values and to respond to monitoring terminal interrogation. Node processor is also responsible for some miner decisions and interpret control commands received from the monitoring terminal like (turn on and off the transformer using relay in the case of temperature limits exceeded). In this proposal system the microprocessor driven nodes, must recognizing certain commands to read sensors values and to control different activates. Hence multiple sensors can be asserted in a single node to measured different phenomena. The system should have its monitoring terminal to interrogates all available nodes continuously in sequence. The monitoring terminal should be capable to deliver all measurements to RTU**.**

Figure 1 shows the block diagram of MBSPS

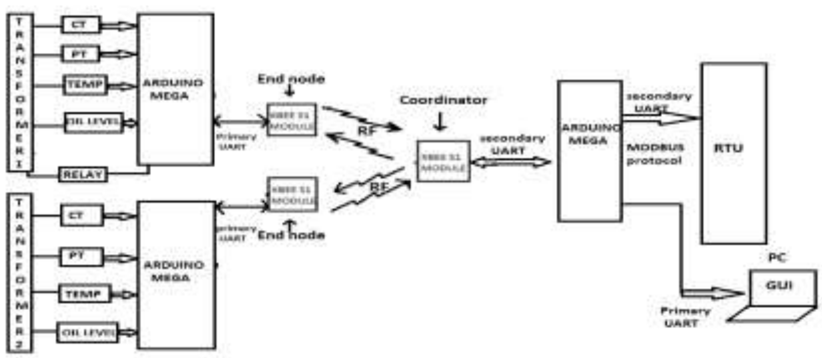

Figure 1. MBSPS block diagram.

In this method the packet is designed according to certain criteria this packet sends from end node to the coordinator responded to the coordinator request contains the node number and information about this node the following figure (3.) shows the packet send from sender to the receiver. Then this packet encoded to text-based packet that send to MATLAB to be displayed on the GUI (graphical user interface). This GUI considered a small SCADA to monitor the status of the equipment.

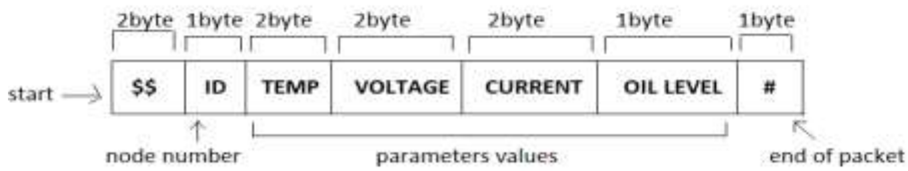

Figure 3. packet design.

5.2 Free Running Sensor Node System (FRSNS).

The aim of this proposal the same in proposal one, woks to monitoring the parameters of two transformers. The difference is this proposal depends on XBEE capability to read sensors values and transmit them periodically. Monitoring terminal received sampled data (sensors values) from all node available. This proposed system composed of free running measurement nodes (measurement is taken in a periodic fashion). Measurement is provided by XBEE node logic circuits. coordinator is also an XBEE node connected to the monitoring computer through UART-USB adapter **see figure 2 (block diagram of FRSNS)**. Same monitoring program written for first proposal is modified to host code necessary to run this proposal.

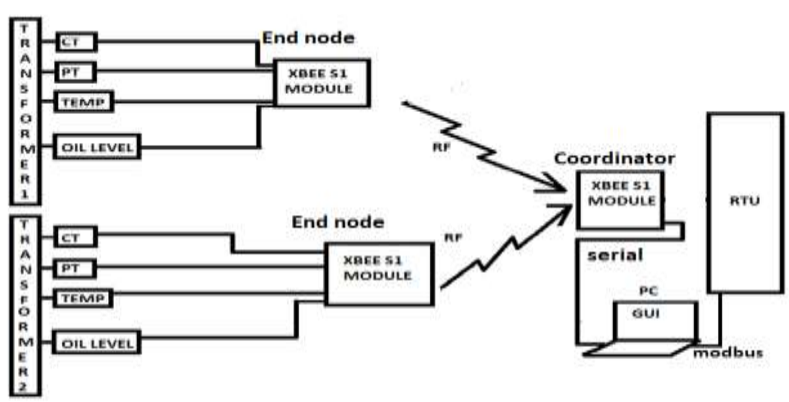

Figure 2. FRSNS block diagram.

End node XBEE and coordinator should be configured to use (API) mode rather than AT command mode**.** The reason is to control all the nodes swiftly without changing from data to command mode back and forth. To be able to send values of I/O and ADCs periodically, the XBEE should be configured using command AT IR= 2AF8. This command shall sample all input and ADC and send them in one packet. Packet type sent voluntary from XBEE is 16 bit I/O frame coded as (0X 83) type. This frame contains source address which can be used to determine which node who sent. Also, it contains all status of I/O and used (ADC)s, the packet has a specific format figure (4.) shows the API frame

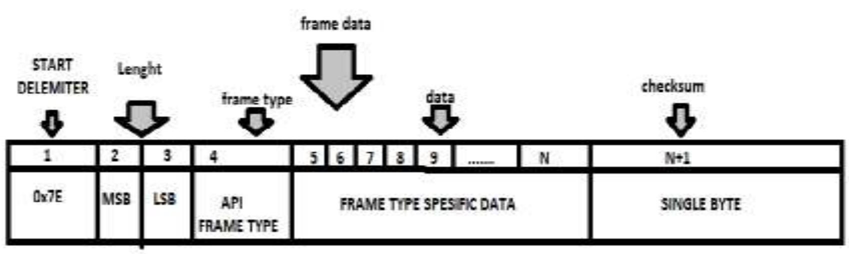

Figure 4. API frame structure

5.3 Circuit Operation

Because of very high voltage component 33/11kv no sensor available can be experiment with, for this reason an example of a simple load was applied, as a **Lamp 25 w**. it is considered as transformer (primary or secondary winding). Public source, **AC (alternating current) 220 V** was used for power supply. The temperature is measured on the lamp's glow and the current is measured on a lamp resistor. **Relay** the benefit of it here is turning on and off the lamp connected to ARDUINO (Pin7). Now the measurement method will be clarified: - **Current transformer** is the same as the transformer. Since it is used to measure (AC), In order to measure it, it must be converted to direct current (DC) so the **Full bridge rectifier** was used to rectifies AC current to DC considering both polarities from (0- +amplitude) of the current and the other half from (0- -amplitude) thus considering whole the power and convert it to equivalent RMS. In parallel, **Capacitor** used works as a filter to allow passes only (DC). As a precautionary measure, in parallel **Zener diode** was connected in value 5V which represents the maximum volt possible to enter the measuring circuit (ADC ATMEGA 2560 Arduino microcontroller). **Operation Amplifier**: to amplify current circuit output(voltage) an operation amplifier has been used in non-inverting type. For the **Voltage sensor**, it is a transformer that step-down the voltage from 220V to range from (0-5V). The output from this sensor is fed to XBEE/Arduino ADC. The **Drive** in this circuit works to enable the XBEE module or the microcontroller with limited low current to energize and de energize the relay with suitable current. A 100 k **Resistor** was used for low current consumption for measurement purposes (5V/100.00R=0.00005I) according to ohm’s law (section 2.8) **V= I * R**. The temperature has been measured using **LM35 Temperature sensor**. The temperature is translated with this semiconductor sensor to voltage, the sensor is connected inside the package to a linear converter circuit it provides according to the data sheet (10mV per C°) from load converted to multiple 10mV. Also, the out from this sensor fed to XBEE /Microcontroller ADC. **Divider:** used to make the voltage value from sensors suit to the XBEE internal reference voltage =1.8, so two resistors was used one ١kΩ and the other 3300 Ω to obtain one third of the voltage. that came from sensor. **Switches:** the normal operation of oil tank there is two floating switches (on/off) one in the button and the other on the top. Normally when almost full lower floating switch is on while top floating switch is off, it will be on when the oil is over flow. To simulate this status lower floating switch is represented with a normally closed microswitch. Upper floating switch represented with a normally open microswitch. Because the normal operation of floating switches when it is in good condition the lower is (on) and the upper is (off). If both of them on this indicate overflow case else if both off this indicate under flow case.

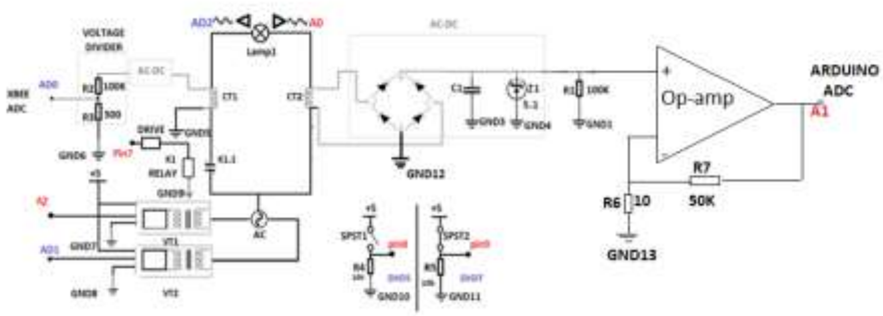

Figure 5. circuit operation

6.Result

-packet rate test.

Table 1. indicates the results of packet rate to the two systems in single/double node for five, ten and fifteen minutes

	PRSNM1	PRDNM1	PRSNM2	PRDNM2
5	0.15488	0.30185	0.10276	0.19829
10	0.1532	0.30038	0.096284	0.18599
15	0.15264	0.29976	0.094167	0.18214

Table 1. results of packet rate

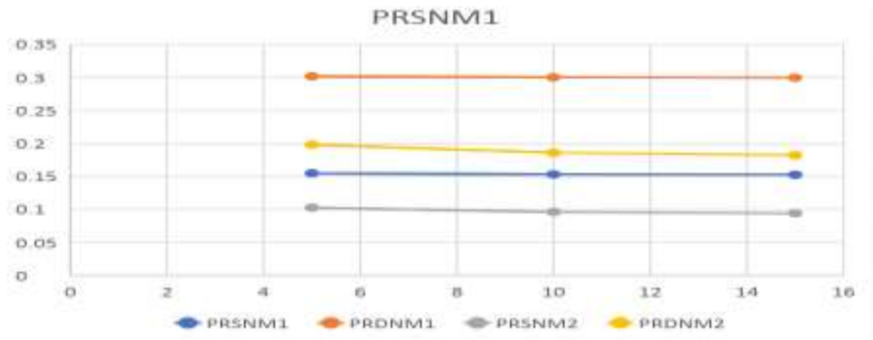

Figure 6. packet rate test chart.

Figure (6.) shows four sets of data the lower are data taken from pooling system the most upper two represents measurement taken from free running system. the time span between the two set from the same system shows large time consumed during reception in free running while in pooling it takes less. This behavior is caused by the fixed length and higher possibility of collision since each node sends its packet freely without coordination with the other node. In free running channel is occupied most of the time as the number of nodes increases on contrary pooling system tends to clear the channel most of the time. So, the channel is always available and collision is avoided also the length of the packet is shortest because it doesn't need any counter measure for collision avoidance.

-power consumption test.

In this test power consumption is calculated using current drawn by normal operation and idle of node in the pooling method; transmission and reception in free running method. Normal operation of node in the pooling method consumes current during the processing of the received packet. Hence XBEE powered from the same circuit is not transmitting (receiving) the rest of the time is shared between idle and transmission. Idle state when processor is waiting to end transmission and start a new round of answering a pool question. (**Total operation time = normal time + transmission time + idle time**). since normal time is none and transmission time is I the reverse of packet rate, then idle time can be calculated. Total power consumption is consumption during the three times: during normal time, transmission and idle. Hence power can be calculated.

In free running no hardware is connected to control the nodes so only transmission and receiving current is measured. Power consumption is calculated considering total operation time and transmission time (calculated from packet rate) hence receiving time can be calculated.

To compute the power consumption **for pooling system** After we loaded the receiver with an empty program (idle) the power from ARDUINO and XBEE is **240 milli ampere**, after loaded the original program the power is in **range (240-250) milli ampere** measured by ammeter. The difference is 10 milli amber.

240 milli amber * 12 v = 2.8 watt in idle case.

250 milli amber * 12v = 3 watt in normal case (the power during processing).

In idle case the power consumption is less. To calculate it for one hour (**Note):**

79.86: is the transmission cost for one hundred read request.

11s: is the time for requesting nodes periodically in polling

1st proposal	**٢nd proposal**
Packet rate faster (1٥%percent of the second to receive one packet)	Packet rate slower (30%percent of the second to received one packet)
Power consumption more 30.816J	Power consumption less 1.8123J
Hardware cost more	Hardware cost less

3 watt * 79.86s = 0.24j. (the cost of power for one packet)

11s – 79.86s= 10.92s. (idle time)

2.8 watt * 10.92s =30.576J

0.24J + 30.576J= 30.816 J

In free running method according to the data sheet XBEE consume max 45 milli amber in transmitting and max 50 milli amber in receiving to calculate the power consumption in this method:

11s:is the time for sending packet periodically in free running.

20byte (packet length) * 8 bit per byte= 160 bit

160 bit / 9600 (Baud rate) = 0.0167 s the transmission time per packet.

45 ma *3.3 V= 148.5 mW → 0.1485 W.

0.0167 * 0.1485 = 0.0025 J (during transmission)

11s - 0.0167s = 10.98334 s idle time.

50 * 3.3 = 165 Mw → 0.165 W.

10.98334 s * 0.165W = 1.8123 J

0.0025 J + 1.8123 J = 1.8148 J energy consumed per packet

7. Conclusion

- performance of microcontroller assisted nodes operating in pooling method is better than free running that required double time to receiving one packet. Also the processing speed is affected by the complexity of packet in free running.
- Microprocessor assisted consume more power with a difference of 29.0037J.

8. Future Work

- testing nodes combining free running and pooling with much greater number of nodes.
- combination of two methods distributed in smart way with different time to preserve power and processing time.

9. References

[1] Archana, R. , Malik, L. G. (2011). Zigbee In Building Industrial Control and Automation, International Journal of Wireless Communications and Networking.

[2] Jafaru, I., Tonga, A.D., Musefiu, A. (2017). Comparative Analysis Between Wired And Wireless Technologies In Communication: Review ,The IIER International Conference, Mecca, Saudi Arabia, 23rd-24th March 2017, ISBN: 978-93-86291-88-2

[3] Gang Zhao, (2011). Wireless Sensor Networks For Industrial Process Monitoring And Control: A survey, Macro Think Institute Network Protocols and Algorithms, VOL. 3, ISSN: [1943-3581].

[4] Shreyansh, L. (2017). Power transformer monitoring system. Columbia undergraduate science journal, Chameli Devi Group of Institutions, Electrical and Electronics Engineering.

[5] Javaid , N. , Sharif , A., Mahmood , A. , Ahmed , S. Qasim , U . , & Khan ,Z. A. (2012) . Monitoring and controlling power using zigbee communications. 2012. Seventh international conference on broadband , wireless computing ,communication and applications.

[6] Furndzic, D. , Djurovic, Z. , Celebic, V., & Salom , I.(2012). Neural Network Ensemble for Power Transformers Fault Detection. 11 th symposium on neural network applications in electrical engineering. Dio:10.1109/ neural .2012.6420027.

[7] Sarsamba, M. , Sangulagi, P. ,& Yanamshetty, R.(2013). The load monitoring and protection on electricity power lines using GSM network. International journal advanced research in computer science and software

engineering (IJARCSSE),VOL.3 , issue 9, ISSN:2277-128X.

[8] Zazad, R. S. , Umare, N. , Patle, G. (2016). ZIGBEE Wireless Transformer Monitoring, Protection and Control System. International Journal of Innovative Research in Computer and Communication Engineering(IJIRCCE), vol 4, issue 2 , ISSN:2320-9789.

[9] Ramya, C. M., Shanmugaraj, M., & Prabakaran, R. (2011). Study on zigbee technology. 2011 3rd international conference on electronics computer technology.

[10] www.zigbee.org.

[11] Archana, R. , Malik, L. G. (2011). Zigbee In Building Industrial Control and Automation, International Journal of Wireless Communications and Networking.