Analysis of Communication Network Reliability Improvement SCADA Based for Pumping Wells Offshore

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Abstract*— SCADA (Supervisory Control and Data Acquisition) is one of the systems used to monitor and control ESP (Electric Submersible Pump) offshore in real time. SCADA system consists of three main parts, namely MTU (Master Terminal Unit), RTU (Remote Terminal Unit) and communication media (link). MTU or Master, functions as a communication controller by sending commands (queries) while RTU or Slave, functions to respond to the Master's command about the condition of the plant. Communication between Master and Slave uses Modbus protocol communication rules. Background of the problems faced by monitoring and control system for ESP wells offshore is the unstable quality of SCADA system communication network (intermittent), multiple delays causing data from ESP well is not fully stored in the database. In current condition, communication media on ESP controller uses serial RS-485 while in the implementation of SCADA system using Ethernet communication media. Purpose of this research is to analyze the improvement of communication network reliability by comparing technology and empirical testing on SCADA system. Results of this research have an impact on production optimization, reduction of operational and equipment maintenance costs and allow for the development of future technologies such as the Internet of Things (IoT).

***Keywords**: SCADA, Offshore, Real-time, Delay.*

I. Introduction

Pertamina Hulu Energi Offshore North West Java (PHE ONWJ) has several artificial lift production wells using ESP (Electric Submersible Pump) method to pump oil and natural gas up to the surface. The production wells which are using ESP pump are located in 2 Flow Stations, namely the Zulu Flow Station and Papa Flow Station. Previously ESP well monitoring and control system was carried out conventionally, hence the operator had to go to NUI (Normally Unmanned Installation) platform using boat transportation to monitor and operate the wells. As a solution to this problem, a system to monitor and operate ESP wells in real time and remotely was built based on SCADA (Supervisory Control and Data Acquisition).

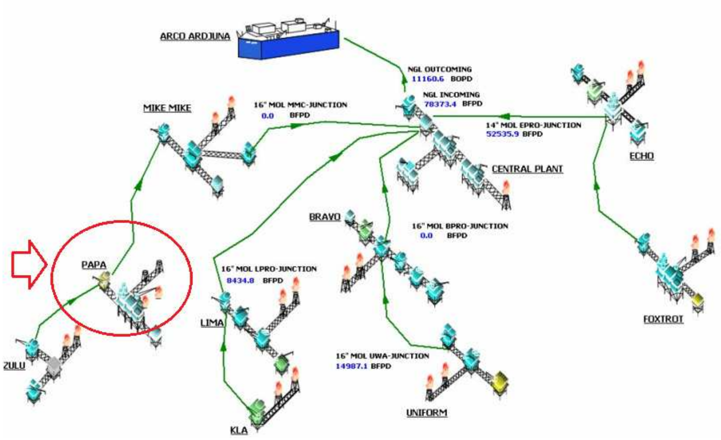


Figure 1. PHE ONWJ Production Pipeline Layout

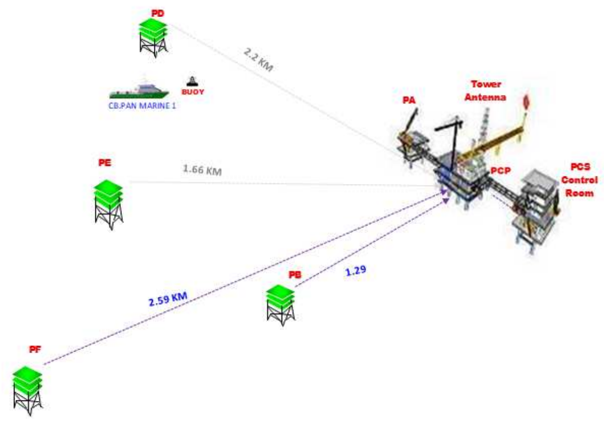


Figure 2. Papa Flow Station Pipeline Layout

From the overall production pipeline network at PHE ONWJ shown in Figure 1, it can be seen that the oil productions from Zulu, Papa, Mike-Mike, KLA, Lima, Uniform, Bravo, Foxtrot and Echo platforms are transported using subsea pipelines to NGL platform for water treatment process and subsequently transported to Arco Arjuna Floating Oil Storage Barge before being exported for sales. The place of our research is the red circle in figure 1.

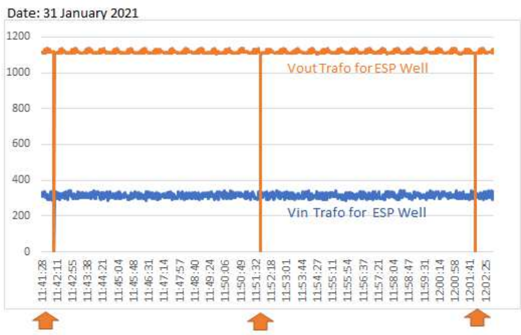
Papa flow station which consists of PCP (oil processing platform), PCS (accommodation platform), PA (well platform) and 4 NUIs (PB, PF, PE, PD) is selected to conduct this research mainly because it already has SCADA system applied into two of the NUIs which are PB and PF. Layout of Papa flow station complex and the subsea pipelines connected is shown in Figure 2 and actual photo is shown in Figure 3.

Figure 3. Papa Flow Station Platform

In order to control ESP well, VSD (Variable Speed Drive) is used. Default communication media used by ESP controller on the VSD is RS-485 serial data. Usage of this serial data has negative effect on the quality of the communication system due to time error and delay (75 µs) causing data cannot be monitored in real time.

Problems related to reliability prior to the implementation of SCADA system include delays that cause data to be disconnected, high maintenance costs due to having to replace data cable through subsea power cable facility, conventional parameter monitoring which has an impact on high operational costs, high risk of accidents for personnel visiting ESP pump wells at NUI and it is not compatible with the technology developments, namely Internet of Things (IoT).

One of the reliability problem faced by ESP well monitoring and control system is unstable or intermittent (data communication stopped, started repeatedly or with periods in between). Communication network for SCADA system from ESP well platform to control room, several times experiencing delays causing data from ESP well is not fully recorded in the database. Delay is a lateness in data transmission time from the ESP controller or RTU as the sender and MTU as the receiver in the Control Room, the unit of delay is micro second (micro second). SCADA trending data for ESP pump well parameters are shown in Figure 4.



Data is not connected (Intermittent)

Figure 4. Historical Trending SCADA Data

Figure 4 above shows that parameter data from ESP well pump was not recorded multiple times in the HMI (Human Machine Interface) located in control room during the time span from 11:41:28 to 12:02:25, January 31st 2021. If the delay is too long, it will certainly disrupt the data transmission process, so that the ESP Pump parameters cannot be read in real time. This condition can result in a decrease in the level of supervision of the condition of the ESP pump so lack of anticipation of potential pump damage.

If the ESP pump is damaged, it will have an impact on increasing production losses and maintenance costs. The increase in pump maintenance activities means that the potential for work accidents also increases.

Limitations of the discussion in this research include:

- Existing SCADA system uses RS-485 serial data communication technology and Ethernet data is applied to the new SCADA system.
- Wireless communication media uses an 802.11abg Industrial Hotspot (RLXIB-IHW) radio to connect between ESP well platform and control room.
- Reliability Analysis of the communication network on the benefits of implementing the SCADA system in terms of safety, production and the development of the latest technology (Internet of Things/ IoT).

Purpose of this research is to analyze the improvement of communication network reliability by comparing technology and empirical testing on the SCADA system applied offshore.

II. METHODOLOGY

This research is divided into several stages as shown in Figure 5:

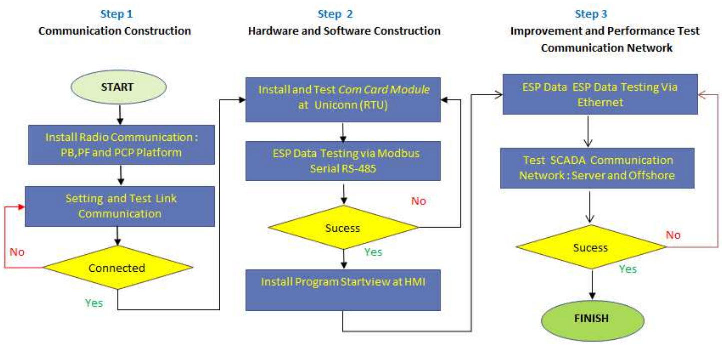


Figure 5. Flow Chart of Research SCADA Data Communication Network

Analysis to improve the communication network reliability of ESP wells offshore is carried out by comparing the communication media technology used in SCADA system. Communication media between platforms offshore used RS-485 serial data cable, radio communication and Ethernet.

At the first stage of this research, communication network was installed between the pump well platforms at PB, PF and PCP using radio communication, then proceeded with setting up and testing the wireless network to get the optimum communication signal.

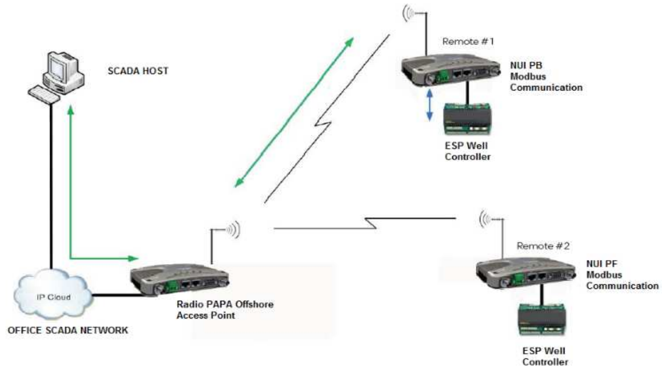


Figure 6. SCADA Communication Network Infrastructure

Figure 6 shows that data from ESP pump wells in PF and PB is transmitted to ESP wells controller remotely. In Remote #1 and Remote #2, ESP well controller uses Modbus serial RS485 protocol then converted using Modbus TCP (Ethernet) then the data is transmitted via radio communication to PAPA Offshore. Communication network from PAPA Offshore (PCP) to SCADA Host in PCS is using Modbus TCP (Ethernet). SCADA host is a device which is the center for monitoring and controlling SCADA system which consists of software (software program), MTU and HMI.

At second stage of this research, communication card module was installed and ESP data was tested via RS-485 serial Modbus, then at the third stage of this research ESP data was tested via Ethernet (Modbus TCP) so that a stable communication network met the Modbus standard with a maximum delay of 61.85µs.

III. RESULT

The radio communication network was tested using ARC Wireless to obtain maximum stability. This SCADA communication system connects the communication network of ESP well platform at PB with PCP platform through point-to-point antennas installed at each location. The distance between PCP to PB well platform is 1.29 km and the distance between PCP - PF well platform is 2.59 km. The antenna is installed at a height of 30 meters above sea level. Communication from Antenna - Radio with SCADA system uses Local Area Network (LAN) with UTP (Unshielded Twisted Pair) cable as the conductor. The results of communication system stability test are shown in Figure 7 and Figure 8.

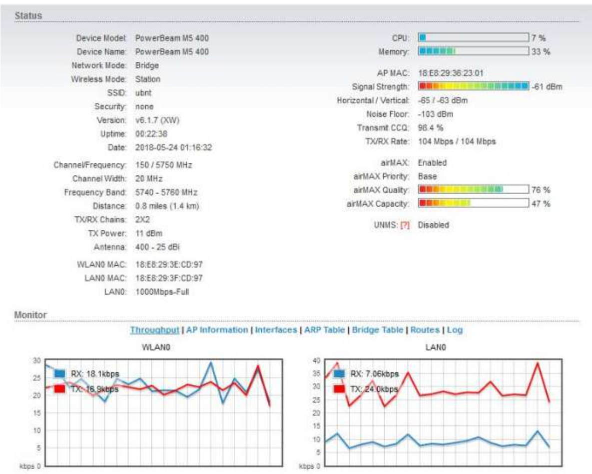


Figure 7. Communication Stability Test Results at PB

The communication between access point and subscriber is shown in Figure 7. In the picture, the signal strength value is shown in graph. The WLan0 graph shows an average receiver of 18.1 kbps and a transmitter of 16.9 kbps (as the access point). The Lan0 graph shows an average receiver of 7.06 kbps and 24.0 kbps (the graph of traffic to the device). Signal strength value resulted from the radio communication network is quite good (-61 dBm).

Quality (q) can be calculated as:

$$q = 2 * (dBm+100)$$

dBm: -100 to -50

So we get q = 2 * (-61+ 100) = 2 x 39 = 78%. Indicator Bar for signal strength category can be seen in Table 1 (Base on IEEE 802.11 system).

Table 1. Quality Radio Signal Strength Communication

Bar Indication	Signal Strength	Category
>9	>-60 dBm	Very Good
7-9	-61 until -70 dBm	Good
5-7	-71 until -80 dBm	Moderate
3-5	-81 until -90 dBm	Bad
<3	<-90 dBm	Very Bad

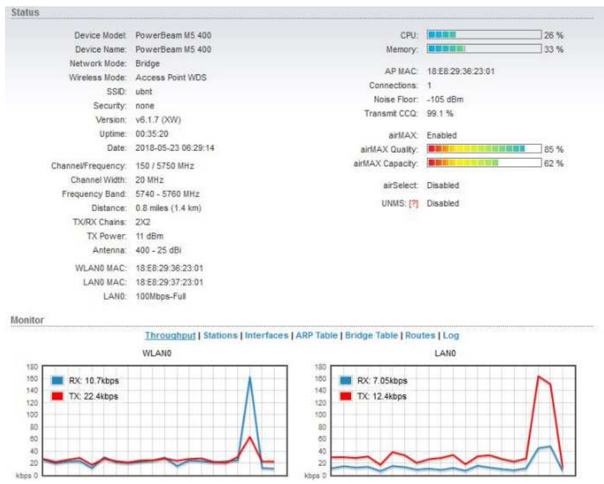


Figure 8. Communication Stability Test Results at the PCP

Figure 8 shows the communication between the subscriber and access point. The WLan0 graph shows an average receiver of 10.7 kbps and a transmitter of 22.4 kbps as subscribed. The Lan0 graph shows an average receiver of 7.05 kbps and 12.4 kbps (the graph of traffic to the device). The status of the signal strength value of the radio communication network is quite good in the subscriber direction to the access point.

Testing on delay and response time when sending data are carried out to determine the level communication network reliability. SCADA communication network using serial Modbus RS-485 and Ethernet was used for this research. The test is carried out using a Modbus Poller, as shown in Figure 9 and Figure 10.

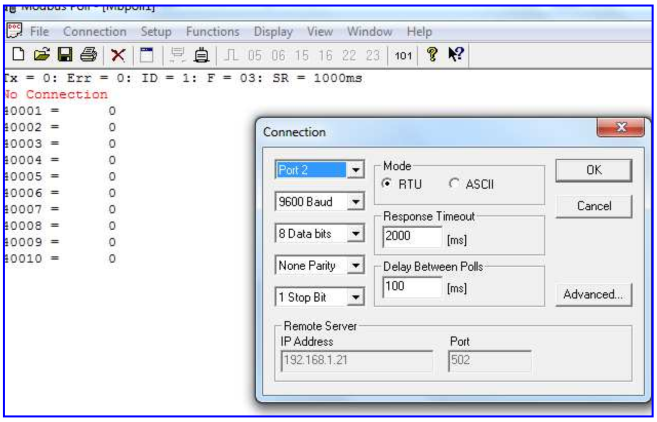


Figure 9. Modbus Poller RTU

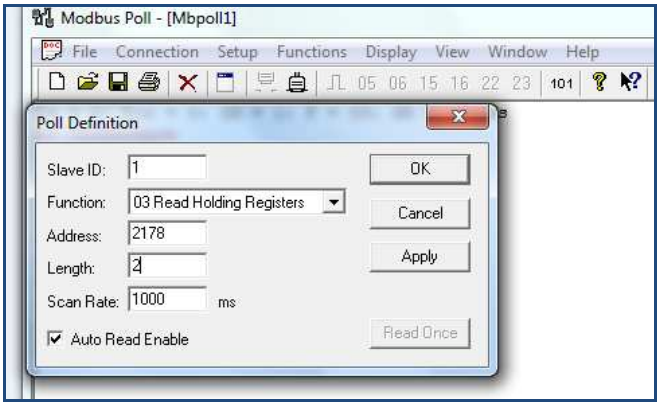


Figure 10. Modbus Poller RTU

From Figure 9 it can be seen that the Port settings are adjusted to the installed ESP controller equipment, namely Port2 using the data transfer speed (baud rate) of 9600 bps. Upon setting the response time and delay, we will know whether the ESP data is connected or not connected. Figure 10 shows a certain scan rate setting which resulted testing data from the ESP controller as shown in Table 2.

Table 2. Testing Data Communication Delay

No Register Address	Response Time (µs)	Delay (µs)	Serial RS-485	Ethernet
4-2178	2000	0	NOK	NOK
4-2178	2000	25	NOK	NOK
4-2178	2000	50	NOK	OK
4-2178	2000	75	NOK	OK
4-2178	2000	100	OK	OK
4-2178	2000	125	OK	OK
4-2178	2000	150	OK	OK
4-2178	2000	175	OK	OK

Note:
NOK = Not OK (Data Not Connected)
OK = (Data Connected)

In Table 2 it can be seen that the test using Modbus TCP (Ethernet) with response time (2000 µs) resulting a connected data (OK) at a delay time of 50 µs, while using Serial RS-485 resulted that the data is not connected (Not OK). Using the RS-485 serial Modbus, the data is well connected at a delay rate above 100 µs. Figure 10 is a graph of receiving ESP pump data after implementing SCADA using Modbus TCP (Ethernet data).

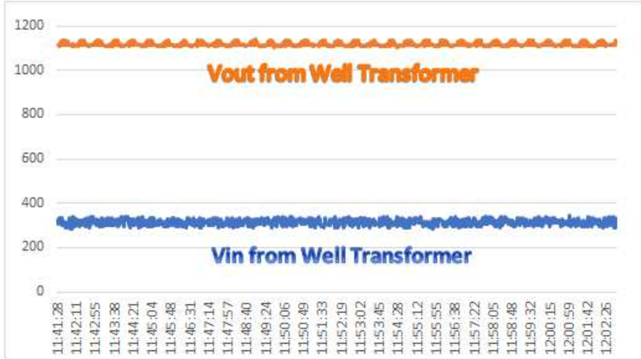


Figure 11. ESP data using Modbus TCP (Ethernet)

In Figure 11 it can be seen that the communication network is uninterrupted therefore the ESP well data can be fully monitored in real time. The implementation of SCADA using Ethernet data can be seen in Figure 12 and Figure 13.

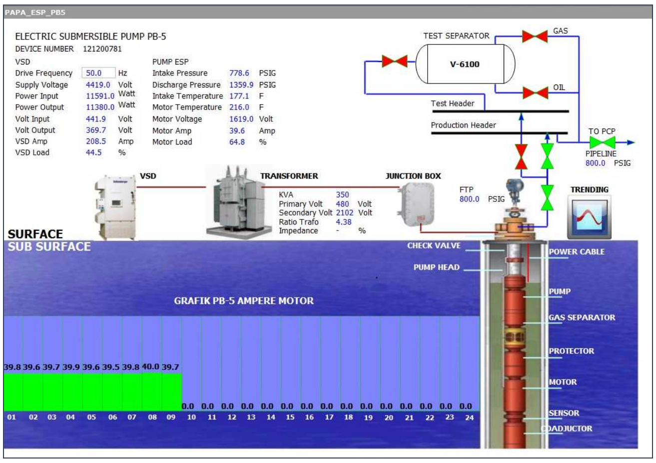


Figure 12. HMI SCADA PB-5 Well

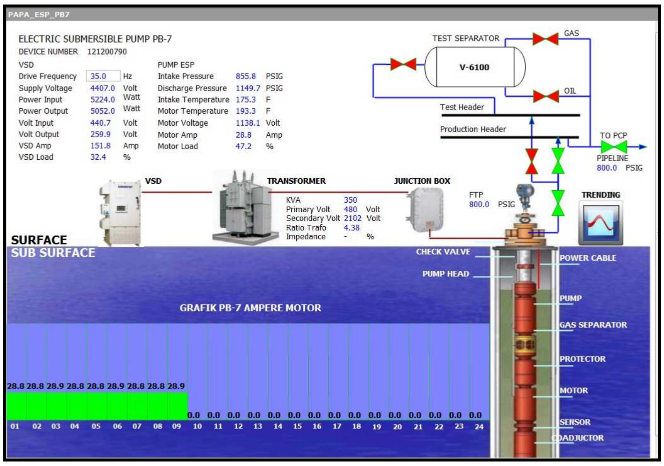


Figure 13. HMI SCADA PB-7 Well

In Figure 12 and Figure 13, it can be seen that the communication network is uninterrupted, hence the ESP well data can be fully monitored in real time. All ESP data can also be stored in the database. Table 3 and table 4 show ESP well monitoring data from well PB-5 and PF-5.

Table 3. Data Report PB-5 Well

SCADA System PHE ONWJ
Realtime Production Monitoring
Show Launch Pad | Customize — Home | Help | About | Log off
PAPA PB
1 of 76 — 75% — Find | Next — Select a format — Export

PERTAMINA PHE ONWJ — ESP Well Report
PB5

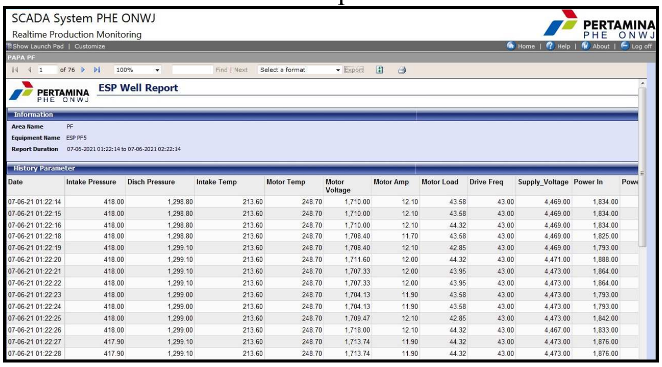
Information

Area Name: PB
Equipment Name: ESP PB5
Report Duration: 07-06-2021 01:27:35 to 07-06-2021 02:27:35

History Parameter

Date	Intake Pressure	Disch Pressure	Intake Temp	Motor Temp	Motor Voltage	Motor Amp	Motor Load	Drive Freq	Supply_Voltage	Power In	Power Out	Volt In	Volt Out	VSD Amp	VSD Load
07-06-21 01:27:35	780.80	1,381.10	177.10	216.00	1,609.78	39.60	64.81	50.00	4,420.00	11,624.00	11,319.00	442.00	367.60	208.70	44
07-06-21 01:27:36	780.80	1,381.10	177.10	216.00	1,609.78	39.60	64.81	50.00	4,420.00	11,624.00	11,319.00	442.00	367.60	208.70	44
07-06-21 01:27:37	780.80	1,381.10	177.10	216.00	1,615.04	39.70	64.97	50.00	4,418.00	11,707.00	11,449.00	441.80	368.80	209.40	44
07-06-21 01:27:38	780.80	1,381.00	177.30	216.00	1,624.07	39.70	64.97	50.00	4,417.00	11,707.00	11,449.00	441.70	371.00	209.00	44
07-06-21 01:27:39	780.00	1,381.00	177.30	216.00	1,614.00	39.70	64.97	50.00	4,417.00	11,485.00	11,202.00	441.70	368.70	209.40	44
07-06-21 01:27:40	780.80	1,381.00	177.30	216.00	1,614.80	39.70	64.97	50.00	4,417.00	11,664.00	11,440.00	441.70	368.70	209.40	44
07-06-21 01:27:41	780.80	1,381.00	177.30	216.00	1,609.40	39.60	64.81	50.00	4,421.00	11,402.00	11,276.00	442.10	368.60	208.50	44
07-06-21 01:27:42	780.70	1,381.10	177.10	216.00	1,610.22	39.60	64.81	50.00	4,417.00	11,723.00	11,480.00	441.70	367.70	209.80	44
07-06-21 01:27:43	780.70	1,381.10	177.10	216.00	1,622.52	39.70	65.13	50.00	4,419.00	11,723.00	11,480.00	441.50	370.60	209.00	44
07-06-21 01:27:44	780.70	1,381.10	177.10	216.00	1,622.82	39.70	64.97	50.00	4,419.00	11,607.00	11,223.00	441.90	370.60	209.20	44
07-06-21 01:27:45	780.70	1,381.10	177.10	216.00	1,618.04	39.70	64.97	50.00	4,422.00	11,684.00	11,449.00	442.20	368.80	209.20	44

Table 4. Data Report PF-5 Well



SCADA System PHE ONWJ
Realtime Production Monitoring
Show Launch Pad | Customize — Home | Help | About | Log off
PAPA PF
1 of 76 — 100% — Find | Next — Select a format — Export

PERTAMINA PHE ONWJ — ESP Well Report

Information

Area Name: PF
Equipment Name: ESP PF5
Report Duration: 07-06-2021 01:22:14 to 07-06-2021 02:22:14

History Parameter

Date	Intake Pressure	Disch Pressure	Intake Temp	Motor Temp	Motor Voltage	Motor Amp	Motor Load	Drive Freq	Supply_Voltage	Power In	Powe
07-06-21 01:22:14	418.00	1,298.80	213.60	248.70	1,710.00	12.10	43.58	43.00	4,469.00	1,834.00	
07-06-21 01:22:15	418.00	1,298.80	213.60	248.70	1,710.00	12.10	43.58	43.00	4,469.00	1,834.00	
07-06-21 01:22:16	418.00	1,298.80	213.60	248.70	1,710.00	12.10	44.32	43.00	4,469.00	1,834.00	
07-06-21 01:22:18	418.00	1,298.80	213.60	248.70	1,708.40	11.70	43.58	43.00	4,469.00	1,825.00	
07-06-21 01:22:19	418.00	1,299.10	213.60	248.70	1,708.40	12.10	42.85	43.00	4,469.00	1,793.00	
07-06-21 01:22:20	418.00	1,299.10	213.60	248.70	1,711.60	12.00	44.32	43.00	4,471.00	1,888.00	
07-06-21 01:22:21	418.00	1,299.10	213.60	248.70	1,707.33	12.00	43.95	43.00	4,473.00	1,864.00	
07-06-21 01:22:22	418.00	1,299.10	213.60	248.70	1,707.33	12.00	43.95	43.00	4,473.00	1,864.00	
07-06-21 01:22:23	418.00	1,299.00	213.60	248.70	1,704.13	11.90	43.58	43.00	4,473.00	1,793.00	
07-06-21 01:22:24	418.00	1,299.00	213.60	248.70	1,704.13	11.90	43.58	43.00	4,473.00	1,793.00	
07-06-21 01:22:25	418.00	1,299.00	213.60	248.70	1,709.47	12.10	42.85	43.00	4,473.00	1,842.00	
07-06-21 01:22:26	418.00	1,299.00	213.60	248.70	1,718.00	12.10	44.32	43.00	4,467.00	1,833.00	
07-06-21 01:22:27	417.90	1,299.10	213.60	248.70	1,713.74	11.90	44.32	43.00	4,473.00	1,876.00	
07-06-21 01:22:28	417.90	1,299.10	213.60	248.70	1,713.74	11.90	44.32	43.00	4,473.00	1,876.00	

IV. CONCLUSION

Based on the data testing result and analysis, authors conclude that the improvement of communication network reliability can be achieved by changing the physical layer communication media technology from RS-485 to Ethernet. The use of Ethernet technology has many advantages such as a high absorption capacity upon the application of SCADA system technology, reduce equipment maintenance costs and the ability to monitor data in real time remotely wherever we are via a smartphone. Reliability of communication network guarantees in carrying out production operations safely and efficiently.

REFERENCES

[1] Intelligent Digital Oil and Gas Fields. Concepts, Collaboration, and Right-Time Decisions. Chapter Two - Instrumentation and Measurement (2018).

[2] Salahuddin, Bakhtiar, Yusman, Fadhli " Development of a High Performance Remote Terminal Unit (RTU) of Wire-less SCADA System for Monitoring Per-formance of Micro Hydro Power Plant" IOP Conference Series: Materials Science and Engineering 854(1),012009 (2020).

[3] KAHIOMBA Sonia KIAN-GALA and Zenghui WANG " An Industry 4.0 approach to de-velope auto param-eter configuration of a bottling process in a small to medium scale industry using PLC and SCADA" Procedia Manu-facturing 35 (2019) 725–730 Published by Elsevier B.V (2019)

[4] Darko Ba-bunski, Emil Zaev, Atanas-ko Tuneski , Dejan Bo-zovic "Optimization Meth-ods for Water Sup-ply SCADA System" https://ieeexplore.ieee.org/document/8405970 (2018)

[5] Philipp Kreimel , Oliver Eign-er , Francesco Mercaldoc " Anomaly detection in substation networks" https://doi.org/10.1016/j.jisa.2020.102527 (2020)

[6] Electrical Submersible Pumps Manual (Second Edition), Design, Opera-tions, and Maintenance, Chapter 7 - Operation, Monitoring, and Surveillance of Electrical Submersible Pumping Systems (2018).

[7] B.R.Mehta, Y.J.Reddy, "Industrial Process Automation Systems", Design and Implementation, Chapter 7 Pages 237-300 – "SCADA systems", 2015.

[8] Fahmi, Yulita Salim, Ramdan Satra, "Analysis of Quality of Service Using Delay, Packet Loss, Jitter and Mean Opinon Score on Voice Over IP," Proceedings of the National Seminar on Computer Science and Information Technology , 2 December 2018.

[9] Ian Sutton "Plant Design and Operations", Chapter 6 Pages 187-212- Instru-mentation and Control, 2017.

[10] Geeta Yadav, Kolin Paul "Architecture and Security of SCADA Systems: A Review" https://doi.org/10.1016/j.ijcip.2021.100433 (2021)

[11] D. Pamela , K. Gerard Joe Nigel, P. Kingston Stanley "Monitoring and cotrol of the various process using a distributed control system" https://doi.org/10.1016/j.matpr.2020.11.976 (2020)

[12] The ISA.org website [Online], https://www.isa.org/intech-home/2017/november-december/features/isa-95-to-support-smart-manufacturing-iiot

[13] M. Taruk and A. Ashari, "Analisis Throughput Varian TCP Pada Model Jarin-gan WiMAX," IJCCS, vol. 10, no. 2, pp. 115–124, 2016.

[14] Yokogawa White Paper –e book: https://www.yokogawa.com/us/library/resources/white-papers/what-are-the-roles-of dcs-and-scada-in-digital-transformation.

[15] Bies, Lammert. "RS485 Serial Information" , Mei,2016

[16] website online, "SCADA Communication and Protocols" https://etap.com/product/SCADA-Data-Acquisition. https://instrumentationtools.com/scada-communication-and-protocols

[17] website online, Radio komunikasi. https://www.prosoft-technology.com/Products/Industrial-Wireless/Industrial-Hotspot/802.11abg-Industrial-Hotspot-FCC.Kerzner, H. *Project Management - A Systems Approach to Planning, Scheduling and Controlling.* New York: John Wiley & Sons, Inc.

[18] Mrunali Tan-del , Uday Joshi, Amit Golhani " Scripting Engine for SCADA HMI" https://ieeexplore.ieee.org/document/8226178 (2017)

[19] Astha Nagar, Prof. Sandip Mehta "Steam Turbine Lube Oil System Protec-tions using SCADA and PLC" https://ieeexplore.ieee.org/document/8250695 (2017)

[20] Oscar Natan, Chandra Wiryono, Agus Indra Gunawan " SCADA-based Au-tomation System for Steam Turbine Pro-tection and Supervi-sion" https://ieeexplore.ieee.org/document/8615466 (2017)

[21] Supriya N. Lakade, Dr. S.U. Bhandari " Development of SCADA System for Turbocharger Testing" https://ieeexplore.ieee.org/document/7860134 (2016)