Reliability and Safety Assessment of SCADA Project Implementation of Peninsula Electric Cooperative

Nelson S. Andres[1,2], Christopher V. Maglaque[1,2], Ira C. Valenzuela[1,3]

Abstract

This study assesses the three (3) phases of the three-year implementation of the Supervisory Control and Data Acquisition (SCADA) project for twenty-seven (27) substations of Peninsula Electric Cooperative in its pursuit of reliability and safety of power system for better electric service. The assessment aims to measure the degree of improvement in terms of reliability and safety for the accomplished Phase 1, Phase 2, and Phase 3 of the project implementation. The data on power interruption occurrence before and after the implementation of SCADA was presented to show the improvement in reliability. Furthermore, the data on the response of protection in the substations were also collected and interpreted to see the improvement in safety structures of acquired SCADA. Given the initial findings, PENELCO may use the results of the study as guide in assessing the succeeding phases of the project implementation.

***Keywords*: SCADA, Substation, IED, Fiber Optics, RFN**

I. Introduction

Peninsula Electric Cooperative, Inc. (PENELCO) has twenty-seven (27) substations within its franchise area that distributes electricity to the province of Bataan. These substations namely Mariveles, Alasasin 13.2kV, Alasasin 23kV, Cabcaben, Limay, Orion, Pilar, Cupang, Balanga New, Balanga Mirror, Balanga Main, Abucay, Samal, Orani, Hermosa, Palihan, Dinalupihan, Pinulot, Bagac, Morong, Sabang, Balanga 20 MVA, Samal 20 MVA, Dinalupihan 20 MVA, Orion 20 MVA, Orani 20 MVA, and Hermosa 20 MVA were typically designed and equipped with devices for the protection, metering, and operation of the substation [5].

To further improve reliability and safety, automation of the power system is vital. Hence, PENELCO formulated and implemented the Supervisory Control and Data Acquisition (SCADA) Project. PENELCO has its pilot operational SCADA system installed at its main office for the Balanga Main Substation with only one (1) server and one (1) client workstation. Currently, PENELCO is establishing its own fiber optics communication within the province. PENELCO also opts to embrace the wireless communication technology that will also serve as a backup for the main fiber optic communication once completed [1].

The integration and automation of different protection equipment and intelligent electronic devices (IED) installed on PENELCO's twenty-seven (27) substations, sub-transmission, and distribution lines will provide control, data acquisition, and monitoring capability from the main station through fiber optic and wireless communication [2]. The new system will provide upgrades and compatibility with the existing SCADA system. The said project will also include additional devices, upgrading, and replacement of protection and metering equipment.

The objective of the study is to assess the extent of improvement in the present power system of PENELCO after incorporating the SCADA system in terms of reliability and safety. This study gives the PENELCO a preview of the performance of the SCADA system even at its halfway of implementation. Furthermore, a high

[1]Polytechnic Univesity of the Philippines
[2]Bataan Peninsula State University
[3]De La Salle University
Balanga City, Bataan, Philippines
nsandres@bpsu.edu.ph

level of reliability and safety in electric service benefits the consumers the most in terms of comfort, business revenue, work efficiency, connectivity, and others.

II. Methodology

A. Project Requirements

The SCADA system must provide secured control of protection and switching equipment, capable of real-time monitoring, transfer of data from relays, kWh meters, etc. installed at remote stations to the main station, remotely and locally configurable settings, easy to understand interface and archive data for engineering purposes which also includes event logs and usage report [8]. The system must also provide spare connections for PENELCO expansion projects and cater to additional IEDs. The system must capable of integrating the following: control and status indication of sub-transmission, substation and distribution system, protection and switching equipment in a single line diagram representation [9]; monitoring of distribution system with real-time parameters such as but not limited to voltage, current, power, frequency, and power factor; condition monitoring of power transformers such as but not limited to oil temperature, oil level, winding temperature, online tap changer and dissolved gasses measured by an online analyzer; acquisition of data from protection relays, re-closers, kWh meters, and other devices which also includes setting, programming, diagnostic and other feature of the equipment; a status indication of faulted circuit indicator installed in PENELCO electrical lines in a geographical representation; and Monitoring of substation AC and DC power supply [3].

The SCADA system must be linked to the remote twenty-seven (27) stations located within the province of Bataan to the main (central) station which is located at the SCADA Room in the Engineering Building of the PENELCO Main Office which is located in Roman Superhighway, Tuyo, Balanga. The geographical locations of the said twenty-seven (27) substations are illustrated in Figure 1 [10].

There are two (2) means of communication used for the PENELCO SCADA System. Figure 2 shows the network topology for all the substations of PENELCO. The system is linked through fiber optic and wireless communication. The SCADA system is configured and wired with fiber optic while the wireless communication is done via of radiofrequency network [4].

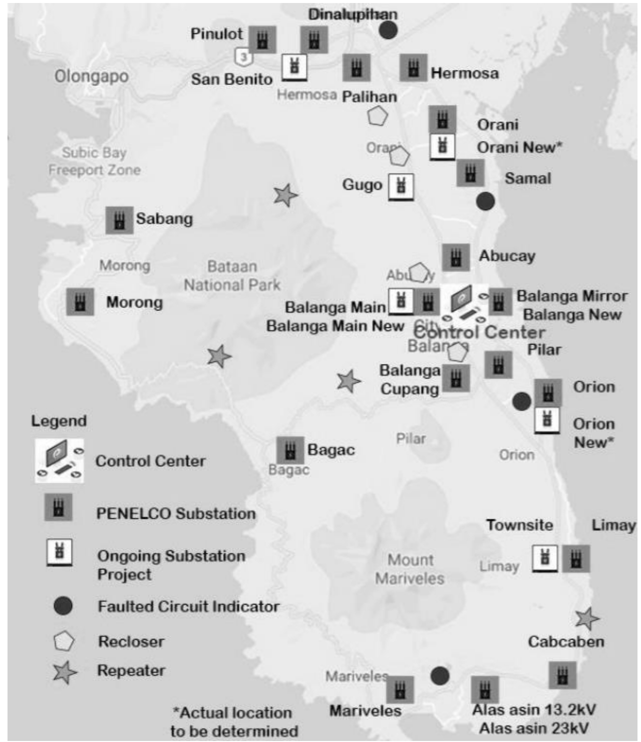

Figure 1. Geographical Locations of Substations [10]

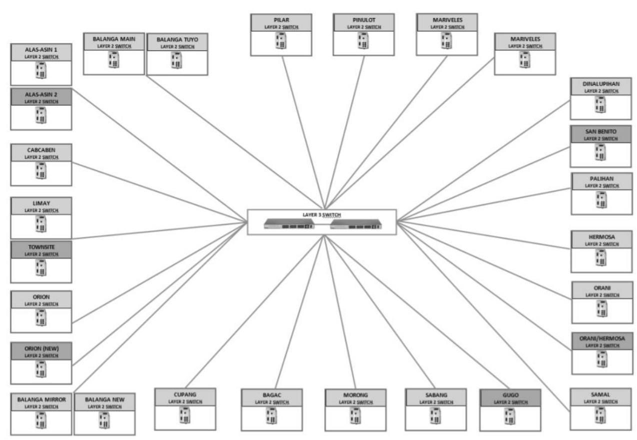

Figure 2. Network Topography of Fiber Optics for all the PENELCO Substations

The supplier adopted the minimum requirements of a radiofrequency communication system for PENELCO SCADA indicated in this Terms of Reference. The communication system required the installation and configuration of radiofrequency communication which also includes the supply of its hardware and software [7]. The supplier also guaranteed the strength of the signal in the entire province for the twenty-seven (27) remote stations and remote IEDs to the central/main station. The supplier conducted its own radio path study. PENELCO required the supplier to conduct actual testing to verify the radio path study which was conducted and provided by the supplier.

The project has six (6) phases before the completion. The completion of this project as a whole system must be on/or before the end of the third quarter of 2022. As agreed by both parties, any delay on the part of the supplier will be subjected to penalties/liquidated damages or termination of the contract as specified in this bidding document. Table 1 - 6 are the project status per phase, each of which has supply requirements and scope of work. The minimum specification and technical requirements of software and hardware (SCADA Software Requirement and Hardware and Equipment Technical Specification) are indicated in the Terms of Reference submitted by the supplier to PENELCO.

Table 1
Project Implementation Phase 1

SCOPE	PROJECT NAME	STATUS
1	Upgrading of existing PENELCO SCADA system for main station	Completed
2	Establishing of SCADA communication network at main station	Completed
3	Upgrading of SCADA System for Balanga Main Substation	Completed
4	SCADA System for Balanga New Substation	Completed
5	SCADA System for Balanga Mirror Substation	Completed
6	SCADA System for Pilar Substation	Completed
7	SCADA System for other PENELCO IED's	Completed

Table 2
Project Implementation Phase 2

SCOPE	PROJECT NAME	STATUS
1	SCADA System for Cupang Substation	Completed
2	SCADA System for Bagac Substation	Completed
3	SCADA System for Morong Substation	Completed
4	SCADA System for Sabang Substation	Completed

Table 3
Project Implementation Phase 3

SCOPE	PROJECT NAME	STATUS
1	SCADA System for Abucay Substation	Completed
2	SCADA System for Samal Substation	Completed
3	SCADA System for Orani Substation	Completed
4	SCADA System for Hermosa Substation	Completed
5	SCADA System for Palihan Substation	Completed

Table 4
Project Implementation Phase 4

SCOPE	PROJECT NAME	STATUS
1	SCADA System for Dinalupihan Substation	March 2021 To September 2021
2	SCADA System for Pinulot Substation	
3	SCADA System for Orion Substation	
4	SCADA System for Limay Substation	
5	SCADA System for Townsite Substation	

Table 5
Project Implementation Phase 5

SCOPE	PROJECT NAME	STATUS
1	SCADA System for Cabcaben Substation	October 2021 to March 2022
2	SCADA System for Alasasin 13.2kV Substation	
3	SCADA System for Alasasin 23kV Substation	
4	SCADA System for Mariveles Substation	
5	SCADA System for Balanga Tuyo Substation	

Table 6
Project Implementation Phase 6

SCOPE	PROJECT NAME	STATUS
1	SCADA System for Gugo Substation	April 2022 to September 2022
2	SCADA System for San Benito Substation	
3	SCADA System for new Substation in Orion	
4	SCADA System for new Substation in Orani/Hermosa	
5	SCADA System for Balanga Tuyo Substation	

B. Project implementation of phases 1 to 3

The assessment procedures shall only be carried out for Phases 1, 2, and 3 of the projects since phases 4, 5, and 6 have not yet started. In Phase 1 of the project, the upgrading of the existing PENELCO SCADA system for the main station was carried out through the upgrading of the program/ software of existing SCADA in the workstation and server in the Main office. Figure 3 shows the configuration of the upgraded SCADA Main Control System.

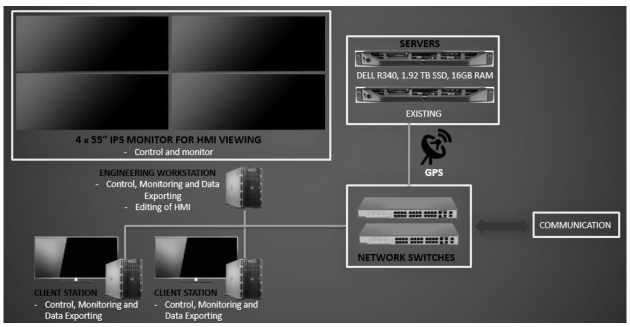

Fig. 3. Configuration of the PENELCO SCADA Main Control System

The installation of a display monitor for SCADA Human Machine Interface (HMI), the integration and mapping of all IEDs in 27 substations both for 69kV and 13.2kV lines is reflected in Figure 4. The HMI of the substations and re-closers in a single line diagram and faulted circuit indicator in a geographical representation were then configured.

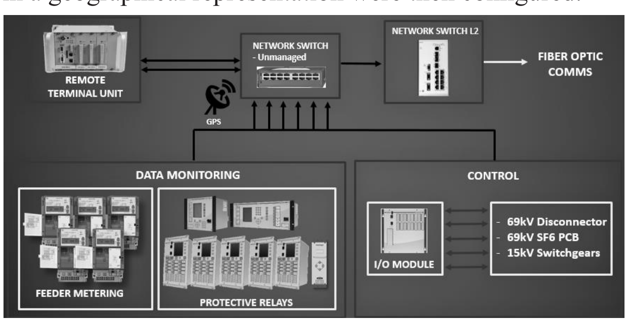

Fig. 4. PENELCO SCADA Topology in every Substation

For the radio frequency communication, the permit was applied to NTC to secure the frequency channel. The EXI Systems with a total of 22 units radio modem, 10 units for Main plus Repeater, 4 units for 4 substations (Balanga main, Balanga New, Balanga Mirror and Pilar), 8 units for re-closers and smart navigators were installed by the supplier while PENELCO provided the antenna of the radio with the supervision of supplier personnel.

For Phase 2 of the project, necessary devices and equipment were again installed in four (4) substations namely Cupang, Bagac, Morong, and Sabang. Aside from SCADA hardware and communication devices, network switches, remote terminal unit, GPS time synchronizer, relay, meters, other IEDs, radiofrequency modem, and power supply with overcurrent and surge protection were installed and configured in each of the four substations. These substation devices were linked to Main Station through radio frequency communication.

The same scope of works was implemented for Phase 3, however, the works were implemented in Abucay, Samal, Orani, Hermosa, and Palihan substations. In this study which only covers Phases 1-3 of the whole project, only the implementation on twelve (12) out of twenty-seven (27) substations were taken into consideration.

For the assessment procedure, the test results of the cited completed projects (Phase 1-3) of PENELCO on SCADA were compared to two local Electric Cooperatives with working and completed of same scope and supplier. The SCADA system was tested for remote operation (open/close) through SCADA HMI for primary disconnect switch, primary power circuit breaker, feeder breakers, and re-closers. The system must be able to monitor real-time parameters at SCADA HMI for protection relays, electrical parameters such as voltage, frequency, power factor, transformer and per feeder loading (kW, kVA, Ampere, etc.), transformer condition (temperature, online dissolved gas analysis), breaker and disconnect switch status (trip/ close), substation power supply (AC/DC) and others. The IEDs must also have alert tests for tripping and limits. While for Communication and signal, its strength was tested. For data acquisition, the system was tested for data retrieving and gathering for relay data and kWh meter data.

III. Results and Discussions

The annual unscheduled power interruption occurrences, in substations under survey per phase, were collected from the year 2015 to 2020. The year 2015 to 2017 is considered as the pre-implementation period while from the year 2018 to 2020 is the post-implementation period. Fault occurrences in the system cause power interruption. Frequent occurrences of power interruption because of an equipment failure is a manifestation of poor reliability. Power interruption caused by human error and nature is inevitable in any power system but can be minimized. Table 7 depicts data on the unscheduled power interruptions that occurred from the year 2015 to 2020. It is evident that the equipment failure contributes mostly to the occurrence of unscheduled power interruption, whereas the human error and nature as causes of power interruption are almost constant every year in substations as grouped per phase. This manifests the improvement in reliability brought by integrating the

Table 7
Unscheduled Power Interruption from 2015-2020

	PHASE 1 (Main/Balanga/Pilar)			PHASE 2 (Cupang/Bagac/ Morong/Sabang)			PHASE 3 (Abucay/Samal/ Orani/ Hermosa/ Palihan)		
YEAR	Equipment Failure	Human Error	Nature	Equipment Failure	Human Error	Nature	Equipment Failure	Human Error	Nature
2020	9	3	6	6	4	6	9	6	6
2019	17	5	7	9	5	7	13	6	7
2018	21	8	12	11	6	12	17	10	12
2017	31	8	10	25	7	10	26	11	10
2016	26	10	12	29	6	12	31	9	12
2015	28	11	11	24	8	11	35	8	11

SCADA system into the power system of PENELCO since 2018. The occurrence of unscheduled interruptions for phases 1, 2, and 3 decreased tremendously. This may be attributed to the real-time monitoring and control capabilities of SCADA that several interruptions became momentary.

The detection of fault occurrence in substations under survey per phase were also collected from the year 2015 to 2020. From the unscheduled interruption occurrences, the data to which interruptions were detected by relays and sensors signify safety in the power system. It means that the system is protected from the occurrence of any fault in the system because protective equipment activated by relays and sensors isolates the faulty system. Thus, further damage to the system is controlled, whereas, the undetected fault occurrence in the system indicates poor safety. Table 8 depict the data collected on the fault detection by protective equipment and devices during the unscheduled power interruptions from the year 2015 to 2020. The fault that causes the interruption must be detected by the system as soon as possible to be able to protect the power system from further damage or harm to humans and properties. This constitutes safety in the power system.

Table 8
Fault Detection of Protective Equipment Phase 1

	PHASE 1 (Cupang/Bagac/ Morong/Sabang)				PHASE 2 (Cupang/Bagac/ Morong/Sabang)				PHASE 3 (Abucay/Samal/ Orani/Hermosa/ Palihan)			
YEAR	Interruption	Detected	Undetected	Sensitivity	Interruption	Detected	Undetected	Sensitivity	Interruption	Detected	Undetected	Sensitivity
2020	18	17	1	94.44%	16	14	2	87.50%	21	17	4	80.95%
2019	29	26	3	89.66%	21	17	4	80.95%	26	22	4	84.62%
2018	41	35	6	85.37%	29	21	8	72.41%	39	31	8	79.49%
2017	49	36	13	73.47%	42	26	16	61.90%	47	30	17	63.83%
2016	48	35	13	72.92%	47	32	15	68.09%	52	29	23	55.77%
2015	50	34	16	68.00%	39	21	18	53.85%	44	32	12	72.73%

Improved safety of the power system after implementing and incorporating the SCADA can be observed. Since the implementation of SCADA in 2018, the detection of faults or the sensitivity of the protective equipment on detecting faults has increased from 2018 to 2020 as depicted in Figure 10.

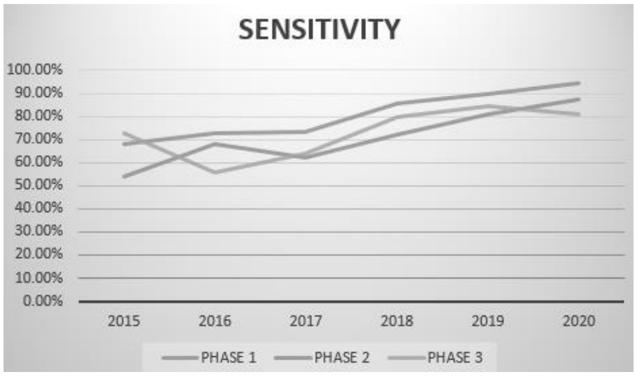

Fig.5. Percent Sensitivity of Protective Equipment

IV. Conclusion

The study was able to assess the improvement brought by the SCADA system into the power system of PENELCO in terms of reliability and safety. The unscheduled power interruptions had appreciatively decreased when the SCADA system was incorporated into the power system of PENELCO which denotes the improvement in the system's reliability. Safety in the power system was also improved when PENELCO adapted the SCADA system because the occurrence of undetected faults was minimized due to its real-time monitoring and control capabilities. SCADA as a technological intervention to the electric power system is essential for better reliability and safety which is achieved through real-time monitoring, control, and data acquisition. The methods of the conducted assessment may be used by PENELCO as a guide in assessing the whole implementation of the SCADA system. It is recommended to mobilize the completion of Phases 4, 5, and 6 of the implementation of the SCADA system to further improve reliability and safety in PENELCO electric service for the benefit of the consumers.

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