IEC 61850 Multivendor Station and Process Bus Substation Design

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1 ABSTRACT

This paper presents the experience on how Entergy Transmission Engineering Group started the IEC 61850 effort together with collaborators such as vendors, research institutes, utility companies, and standard committee. The project was initially started with the intension to learn about the technology and had gradually evolved into an open platform testbed for multivendor interoperability of their Intelligent Electronics Devices (IED), which eventually had gained support and interest to start a pilot project to deploy a parallel IEC 61850 process bus system into one of the substations in New Orleans – Joliet Sub. This paper will share the goals and the design of the pilot substation and future design concepts of a digital substation will be discussed in this paper.

2 INTRODUCTION

Entergy's dive into the world of IEC 61850 began with a passionate group of people, a few IEDs, and a file room deemed "lab". Through strong support and leadership of Entergy management and the vision of Dr. Chan Wong, our efforts and collaborations have led to an implementation of an IEC 61850 process bus system operating in parallel with Entergy's traditional copper system at Joliet Substation. This paper will discuss the design philosophies behind the digital deployment at Joliet and Entergy's next step in their research and design for their next digital/copper substation.

3 ENTERGY PILOT SUBSTATION – JOLIET

Joliet 230kV Substation is located close to the city of New Orleans, Louisiana and it is tied to two substations through a 230kV Transmission line. It has two distribution transformers rated at 100 MVA 230/24kV. Both the transformers have a motor operated switch on the high side. In the event of a fault on one of the Transmission lines, the 230kV bus has a tie breaker which can be used to isolate either of the two lines and maintain supply to the distribution side. On the 24kV side there are two main buses and two auxiliary buses. There are 13 feeder breakers feeding 13 underground distribution lines.

3.1 IEC 61850 Pilot Process Bus

The objective of the Entergy IEC 61850 Multivendor Process Bus Pilot at Joliet was to perform validation and verification of the IEC 61850's protection and communication system are comparable with the existing copper wire system. Thus, the test system was connected in parallel to the existing copper system allowing for data and operation occurrences to be recorded. Using the acquired data, a comparison can be drawn between the two protection systems that will be used to evaluate the pilot. In addition, the test system will not be allowed to operate the breaker once fault conditions are met. Instead the trip initiates of all the IEDs will be stored in the Sequence of Event Record (SER). With this setup, the reliability, dependability and accuracy of both systems can be analyzed.

The pilot design consists of separate vendors' protection/HMI racks installed within the control house, which communicate via fiber to the merging units installed in the breaker cabinet. In order to avoid any misoperations, a spare set of CTs from the breaker were used to supply currents to the two merging units. Schematic representation of the CT and PT circuits are shown in Figure 1.

Figure 5 depicts Entergy's standard protection panel as well as a Field fabricated swing panel which houses the two merging units.

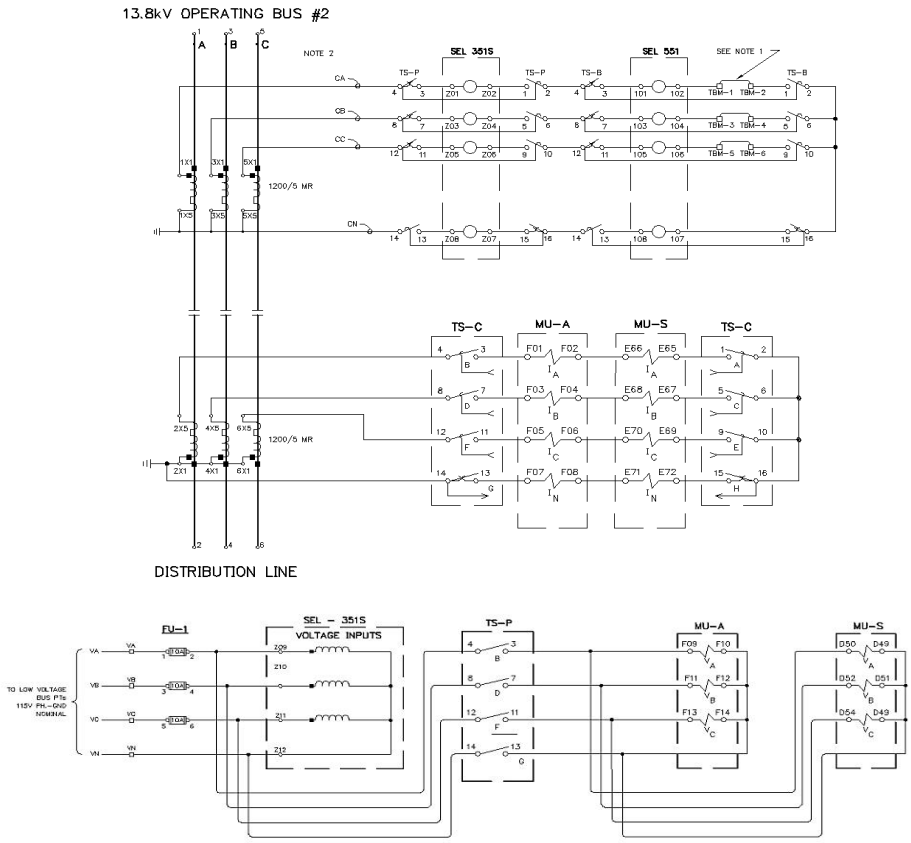

Figure 1: Merging units Schematic

Figure 2: Merging units rack installed in breaker cabinet

The main focus of the pilot at Joliet was to implement a multivendor station and process bus system without affecting or reducing reliability of the existing copper system. In addition to aquiring data from each merging unit, features from Entergy's standard protection scheme were chosen to similate. An output from each merging unit is sent to the standard relay in order to indicate once ground trip has been disabled. In addition, each merging unit was wired to accept a 52A and B contact for breaker status. Figure 3 shows schematic representation.

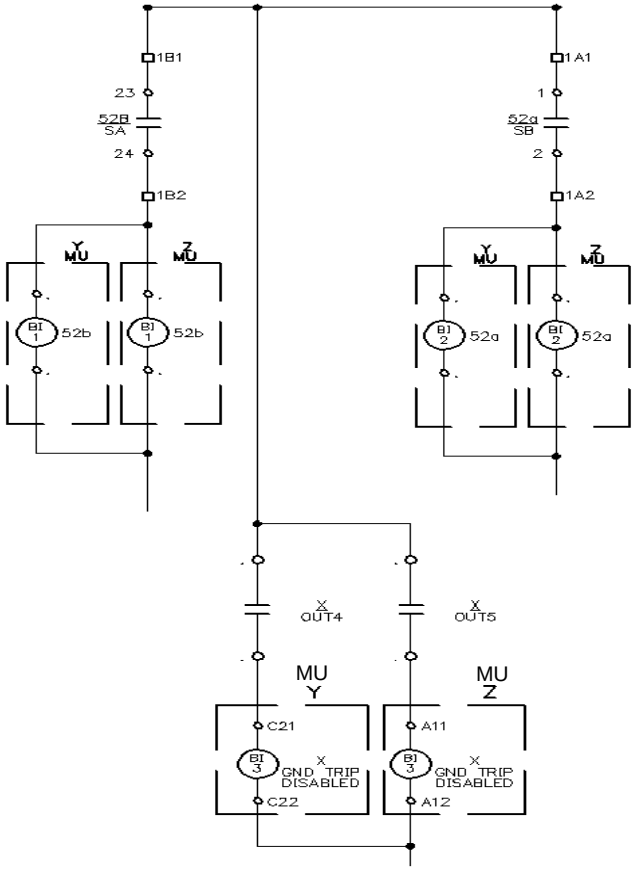

Figure 3: Ground Trip synchronization between two systems

Further, The binary outputs from each merging unit are wired to inputs of the existing relay, which allows for an accurate and direct comparison of trip pick up times. By investigation of the standard relay's Sequence of Event Record (SER), a comparison of when each device initiated a trip compand to the breaker can be drawn. Parital trip circuit are illistrated in Figure 4.

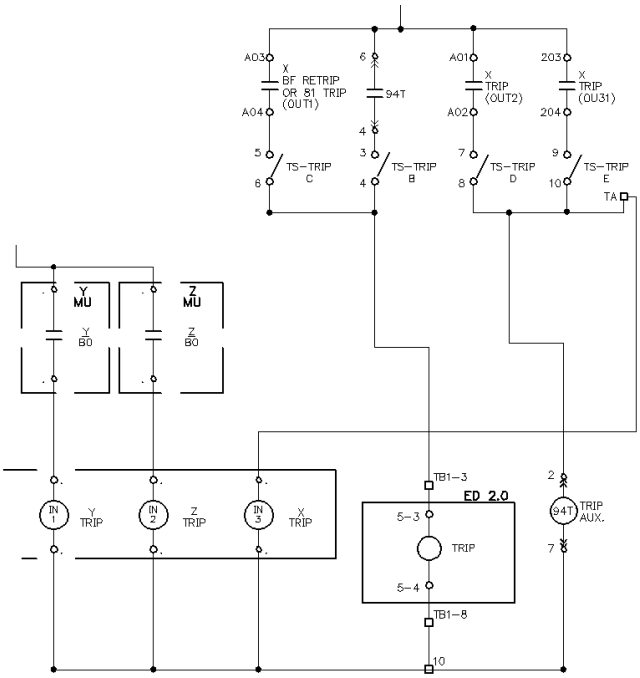

Figure 4: Partial trip circuit

To sum up the Joliet project, The IEC 61850 Pilot has been installed in one feeder and is currently reporting data to the vendor's HMIs via the two merging units installed in the breakers cabinet. Comparisons of tripping times have yet to be drawn due to the lack of operations of the breaker. Through the design, testing, construction, and energization of the IEC 61850 pilot at Joliet, Entergy has decided to move forward with their next implementation of the technology.

4 ENTERGY SUBSTATION – CULICCHIA

Arabi 230kV Substation is currently located in an unprotected marshy area that is susceptible to flooding. In the near future, Entergy plans to rebuild the substation on the opposite side of a levee for increase protection from the elements. Due to its location, Arabi Substation, which is to be renamed Culicchia Substation, has been targeted to succeed Joliet as an IEC 61850 deployment. Entergy's design for Culicchia Substation will be the next step in testing the reliability, dependability, accuracy, and in the event of a flood, recovery speed of an IEC 61850 station and process bus system.

4.1 Culicchia Equpiment Design

Although the exact ratings for the equipment have not been determined, Culicchia Substation is planned to comprise of two 230kV to 13.8kV distribution transformers. On the 230kV side, each transformer will have a circuit switcher and motor operated switch while the 13.8kV side will consist of two main breakers, six to eight feeders, and a bus tie breaker which will allow one transformer to feed all six to eight distribution feeds. The following section will discuss the protection schemes and devices needed to implement Entergy's first non-Pilot digital substation.

4.2 Culicchia Protection Design

Culicchia Substation will differ from Entergy's Multivendor Pilot project at Joliet Substation in a number of ways. Joliet's digital system was strictly intended for data acquisition, IEC 61850 9-2LE evaluation, and an introduction of the technology to the Entergy organization. Moving forward in the design and deployment for Culicchia Substation, Entergy will implement all primary protection using IEC 61850

Goose messaging and IEC 61850 9-2 Sample Values. Below, Figure 7 shows an oneline representation of the transformer's primary and backup differential protection. Due to the number of CT inputs each merging unit can accept, the protection scheme will consist of two merging units installed in the transformer cabinet. Merging unit 1 will provide sample values of the high-side set of CTs to the relaying within the Control House. The second merging unit will complete the protection zone wrapping the transformer by supplying a low side set of CTs to the differential protection relay. In the event of ground overcurrent fault, merging unit 2 will also pass the fault current from the neutral X0 winding of the transformer. In addition, Figure 7 represents, backup protection will consist of a differential zone wrapping the high-side of the transformer to the low-side of the main breaker. This backup protection scheme will be implemented entirely by a traditional copper system and not a digital one.

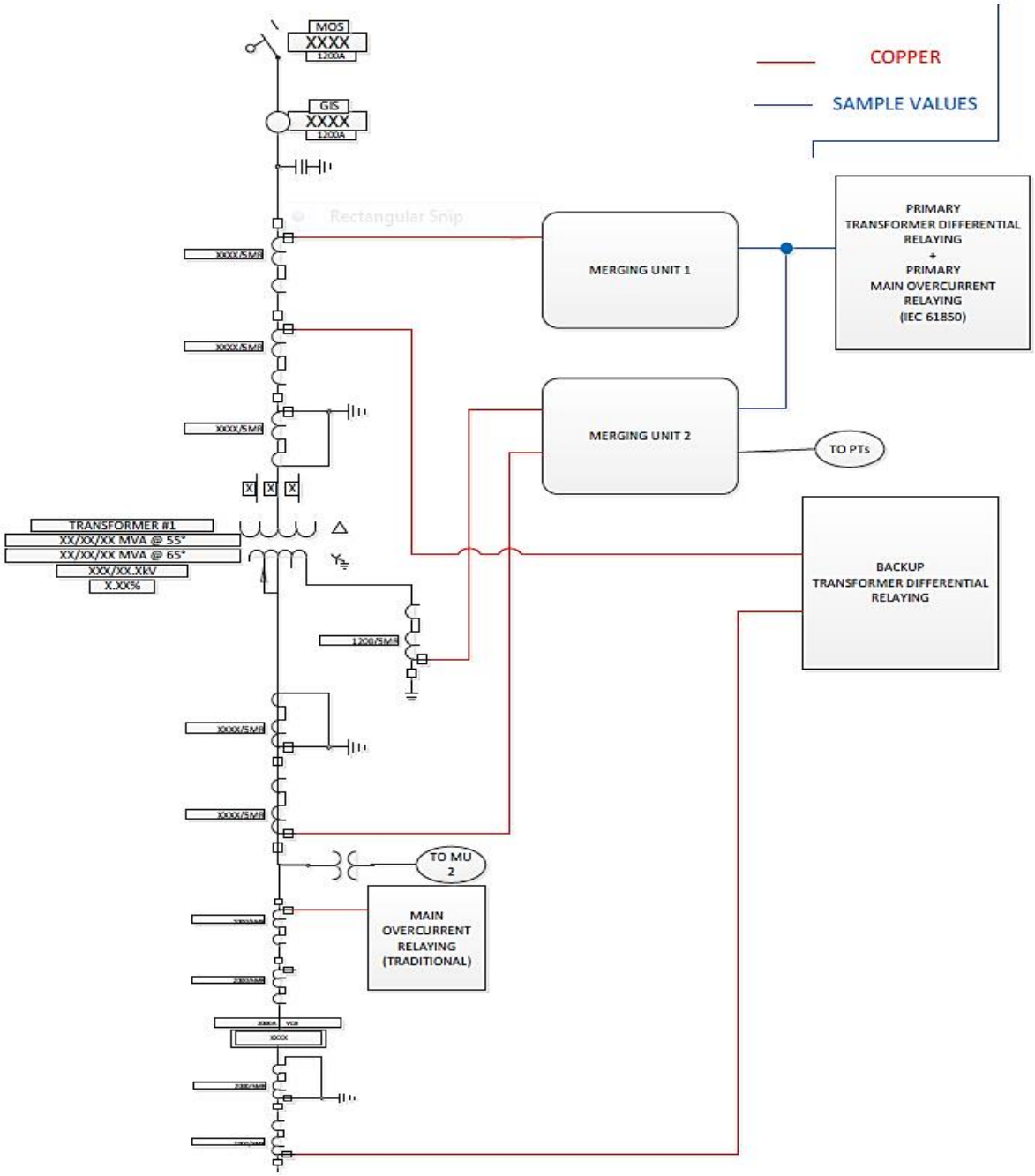

Figure 7: Transformer Relaying Oneline

Continuing to the feeders, Figure 8 illustrates a partial representation of Entergy's feeder protection scheme. Along with Entergy's standard relay, each feeder will include a merging unit within its yard cabinet. The feeder's current outputs will be supplied to the standard relay and merging unit, which are wired in series. Within the control house, a primary and secondary IEC 61850 9.2 compatible relay will accept the sample values from the field installed merging units. In summary, a single relay will protect three individual feeders and with the inclusion of an identical secondary relay, a redundant protection scheme will be in place. By designing for this level of redundancy, one relay, whether out of service due to failure or maintenance, will not jeopardize protection of three feeders.

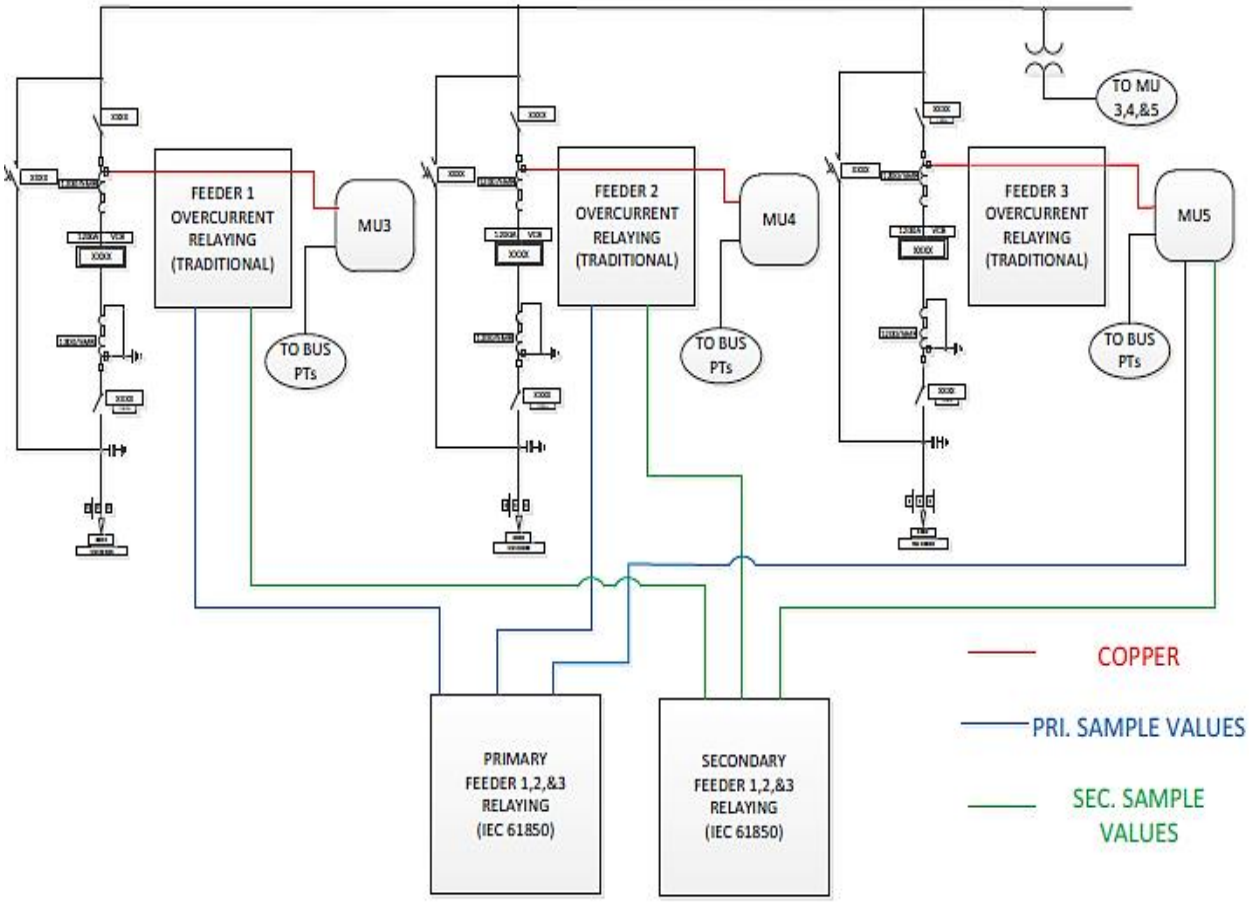

Figure 8: Partial Feeder Relaying Oneline

As discussed above, primary protection schemes are solely implemented using IEC 61850 Goose messaging and Sample Values. Backup protection will require a traditional copper system. The decision to not "take the leap" to a fully digital system was made at the request of Entergy's Field personnel. As with any significant change, questions and concerns arise. Entergy's Engineering Group has taken small steps in order to familiarize the Field with the technology and gauge their comfort level for future implementations. As with Joliet, Culicchia's protection and control design will be constructed within a lab environment. This approach will allow complete testing of the system and training of field personnel before actual deployment to the substation.

Refer to Figure 9 for a full oneline illustration of the digital protection system, including transformer, main, bus tie, and eight feeders for Culicchia Substation.

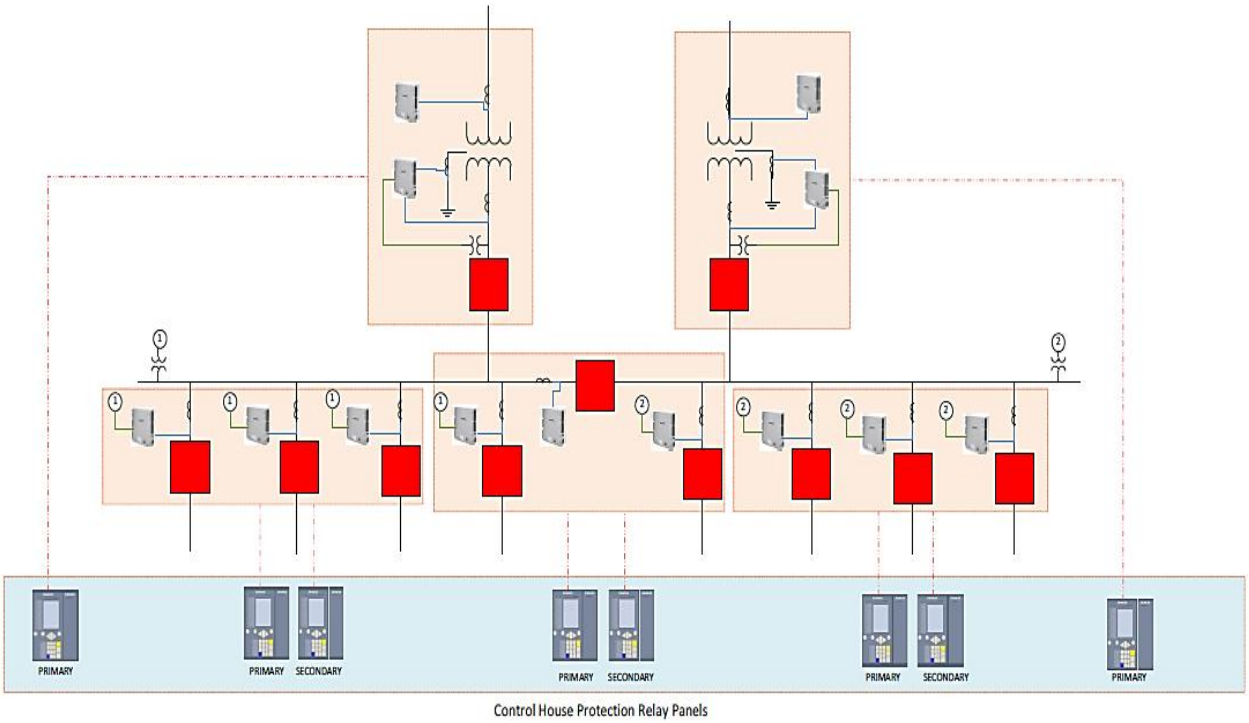

Figure 9: Full Digital Protection Oneline

5 CONCLUSION

As this paper presents, Entergy's Transmission Engineering group, along with its many collaborators such as vendors, research institutes, utility companies, and standard committees, has successfully designed and deployed a Multivendor IEC 61850 station and process bus system. Based on the efforts and lessons learned throughout the design, testing, and deployment of Joliet's Pilot system, Entergy has agreed to move forward with designing a digital primary protection and copper backup protection system for Culicchia Substation.

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7 AUTHORS

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Chan Wong is a Senior Engineer at the Entergy Transmission Design Basis based in New Orleans, Louisiana primarily involved in Transmission Protection Standard and Substation Automation. Prior to this position, Chan had experience working on projects related with NERC CIP, RTU configuration, relay automation and process improvement. Since 2014, he has been leading the Entergy Multi-vendors IEC 61850 effort and developed an integration lab to explore and learn about the state of the art of vendors' IED and IEC 61850. Chan received his Ph.D degree in Automotive Engineering from Clemson University International Center for Automotive Research (CU ICAR) focusing in automation, instrumentation, precision engineering and control theory. Chan currently serve on the Entergy Technology Council and Tulane University Board of Advisor for the Physic and Engineering Physics Department. He is an active member of IEEE, participant of IEEE Power System Relaying Committee, New Orleans IEEE PES Chair, and IEEE Region 5 Young Professional Coordinator

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