IDA Restoration- The Transmission Engineering Efforts

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***Abstract*—Hurricane IDA left huge impacts on the electric systems in Southern Louisiana. One of the major impacts of IDA is the destruction of 230kV Mississippi river-crossing line in between Avondale and Harahan which resulted in the radial configuration of transmission systems for Harahan, Kenner, and Destrehan area. Around 25k customers which includes several major industries were getting power through a single source 230kV line from Little Gypsy. In those circumstances, any outage of that single source line could cause blackout of 25k customers. To mitigate that reliability issue within a short time, transmission owner utility planned to build a short line to connect Destrehan-Harahan and Snakefarm-Labarre 230kV lines which resulted in a multi-terminal transmission line. The protection and relaying of the unconventional multi-terminal transmission line is a complex problem. This paper presents the protection challenges of the multi-terminal transmission line, the implemented solution, and its benefits.**

I. Introduction

On August 29, 2021 Hurricane IDA made landfall near Port Fourchon (south Louisiana) as category 4 major hurricane, with maximum sustain speed 150 mph and gusts recorded reaching 172 mph. The fierce storm came ashore on the 16th anniversary of Hurricane Katrina. Its fury resulted in some communities deemed as uninhabitable, storm surge over 15 feet, heavy rain, tornadoes, flooding, and loss of life. IDA left around 1 million people out of power in Louisiana and Mississippi. IDA completely destroyed the Mississippi river crossing section of the Avondale-Harahan 230kV transmission line (Fig. 1). The damage resulted in the radial configuration of transmission systems for approximately 25k customers, including several major industries. This paper describes a temporary three-terminal line solution implemented by Entergy for immediate reliability risk mitigation.

Section II of this paper describes the project summary. Section III presents relay impact study and the challenges of three-terminal line protection. The solutions and implementation including testing are illustrated in Section IV. Discussion and concluding remarks are presented in Section V.

II. Project Summary

Entergy transmission planned to build an immediate second transmission source for the affected area. Several alternatives were considered including a possible three-terminal line by connecting Kenner-Harahan line to Snakefarm-Labarre line. The above-mentioned lines run near each other at one point as shown in Fig. 2. Considering the implementation time and cost, Entergy decided to build the three-terminal line by connecting Kenner-Harahan line to Snakefarm-Labarre line as shown in Fig. 3 to facilitate a source from the Ninemile generating station via Labarre and Southport. The three terminals of the line were because Destrehan, Snakefarm, and Labarre. Harahan also had protection and breaker but it was decided to operate Harahan as a tap station to reduce the complexity.

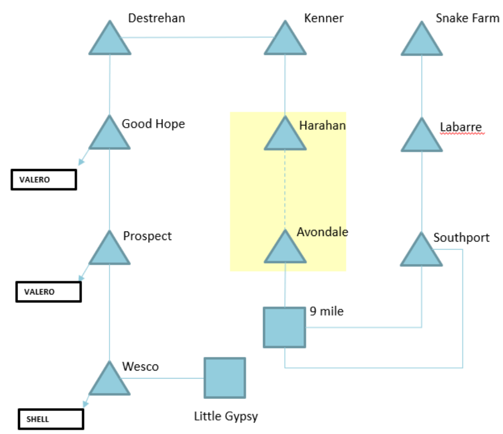

Fig. 1. Damaged Avondale-Harahan line (highlighted)

III. Relay Impact Study And Challenges

The relay impact study was conducted to re-evaluate the existing protection schemes at Destrehan, Snakefarm, Labarre, and the adjacent stations for the proposed three-terminal line. Destrehan, Snakefarm, and Labarre had distance element-based protection schemes. During the relay impact study, multiple challenges were identified related with the existing distance element-based protection scheme to protect the three-terminal line. All the challenges are discussed below.

A. Under-reaching of distance elements due to in-feed

The distance element at each terminal can under reach when the relays at corresponding terminals see the faults beyond

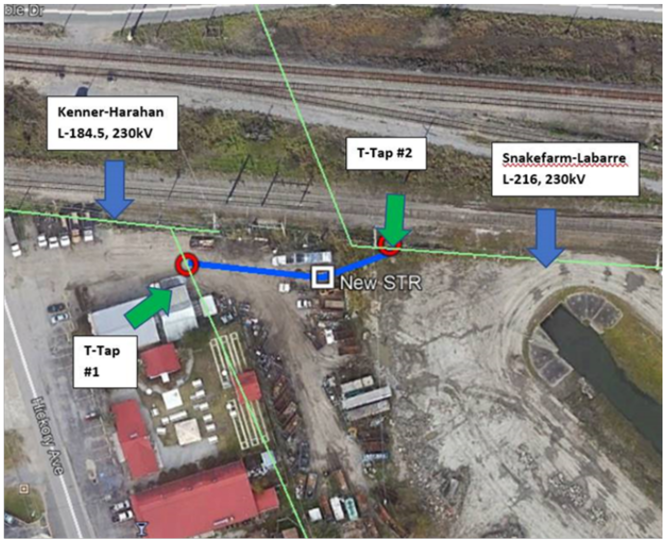

Fig. 2. Physical interconnection point

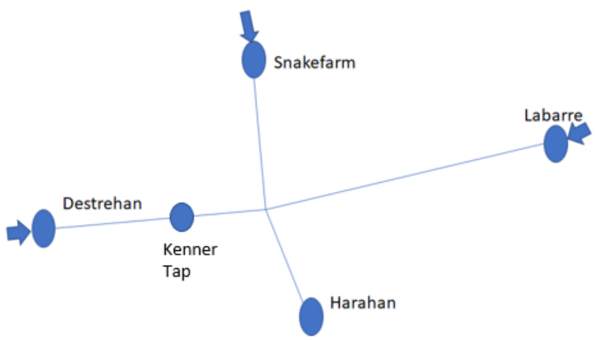

Fig. 3. 3-terminal line configuration

three-terminal junction point. An example is shown in Fig. 4. The actual impedance of the line A-B is 3.0 Ohms; however, the relays at terminal A see 4.0 Ohms for the close-in fault at terminal B because of in-feed from terminal C. Zone2 reach is 3.6 Ohms in this example (120% of the actual line impedance) so it will not be able to see the fault. The typical solution for this problem is to set the Zone2 reach to 120% of the longest remote bus impedance with in-feed. However, this solution causes other issues mentioned below:

- Overreaching miscoordination when in-feed is minimal due to system contingency conditions
- Violation of NERC loading compliance due to high reach
- Relay setting range limitation

B. Overreaching of distance element due to out-feed

Depending on system condition, the distance element at each terminal can overreach due to out-feed when the relays at corresponding terminals see the faults beyond remote

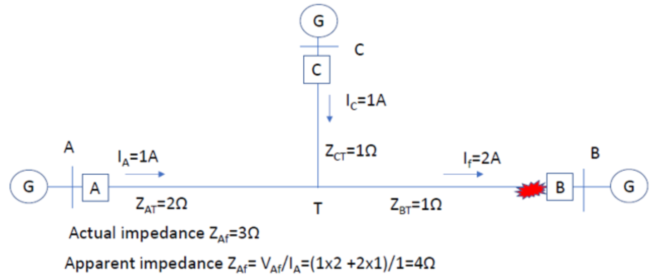

Fig. 4. Distance element under-reaching issue due to in-feed

terminal. An example is shown in Fig. 5 for a bus fault at terminal B. The actual impedance of the line A-B is 3.0 Ohms; however, the relays at terminal A see 2.67 Ohms for the close-in fault at terminal B because of out-feed from terminal C to B. Zone1 reach is 2.7 Ohms for this example (90% of the actual line impedance) so it will overreach the remote bus fault. The typical solution for this problem is to set the Zone1 reach to 80% of the shortest remote bus impedance with out-feed. However, the reduced Zone1 may not cover the whole line as shown in Fig. 6.

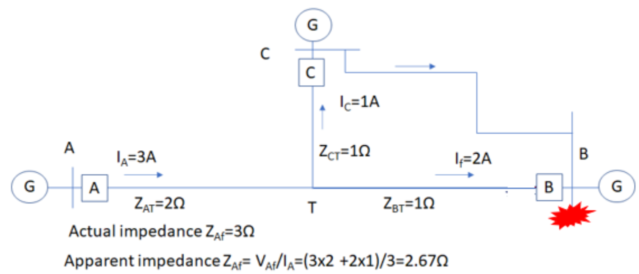

Fig. 5. Distance element overreaching issue due to out-feed

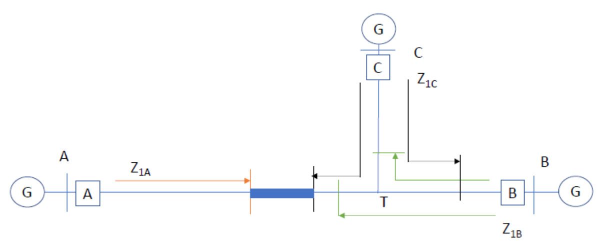

Fig. 6. Under-reach Zone1 element due to reduced reach

C. Limitations of Permissive Overreach Transfer Trip (POTT) Scheme

Destrehan, Snakefarm, and Labarre had SEL-421 and SEL-311C relays. The built-in POTT scheme for the SEL-421 and SEL-311C relays is configured for two-terminal line protection. The above-mentioned relays can be configured for a three-terminal line [1]. However, typical POTT scheme will not be able to communicate properly with both remote ends if the communication path is opened between two terminals as shown in Fig. 7. The security of this scheme is channel dependent; therefore, this logic will only allow a permit to pass through Normal Direct channel. A complex and customized logic scheme is required for the secondary pass through channel to allow the POTT scheme to operate normally even if a single channel has failed. Moreover, the performance of the POTT scheme can be affected by a weak feed condition during various system contingency cases.

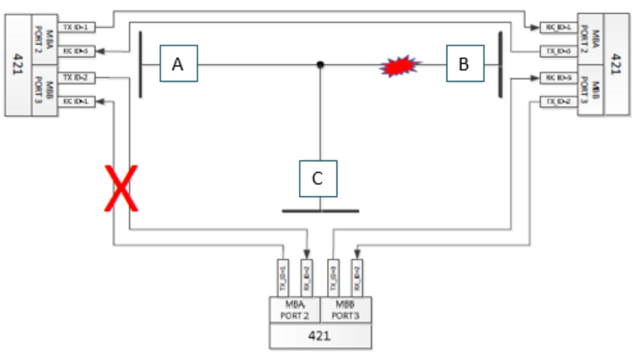

Fig. 7. Three-terminal POTT scheme with open-circle communication.

IV. Implementation

A. Implemented Solutions

Due to the challenges of the existing protection schemes discussed in the previous section, Entergy decided to replace the existing panels at Destrehan, Snakefarm, and Labarre with redundant line differential protection (87L). Not only are the deficiencies of impedance-based relaying hidden by differential relaying, but so is the weak feed condition. Furthermore, the weak feed condition has no impact on differential relaying because of the increased sensitivity of differential elements and the differential scheme's security [2], [3]. One of the main differences between applying the differential scheme in a three-terminal line and a two-terminal line is the way the alpha plane values are calculated [4]. In the three-terminal line the remote current is produced by vector summation of two terminal currents and the uncombined current becomes the local current. Fig. 8 shows the three possible combinations that are used to calculate the alpha plane ratio of remote to local current at terminal A. Line differential relay uses the trip/restrain decision from the 87L elements, which uses the maximum terminal current as the "local" current [5].

The identified line panels on the three terminals were designed to incorporate dual SEL-411L relays with two redundant fiber channels. Additionally, each line protection scheme was designed with one additional fiber channel per relay to be used for the SEL Mirror Bit Protocol. Furthermore, the

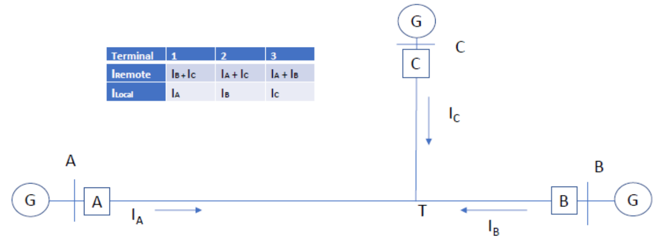

Fig. 8. Three-terminal 87L scheme current combinations

SEL Mirror Bit communications were designed to perform direct transfer trip (DTT) in the case of a breaker failure and to communicate breaker and line switch statuses. Once the design was implemented, each line would have two redundant differential relays on each terminal to make a total of four redundant differential channels.

In addition to the implementation of differential relaying, there were other standard relay functions that needed to be disabled or modified to account for the protection issues caused by the three-terminal line. POTT scheme was implemented with customized pass-through mirror bit. Due to high SIR value at Labarre and Snakefarm, Zone1 distance element was disabled. Zone2-short and Zone2-long distance elements were used for coordination. The deployed protection functions for each panel are presented below.

1) Panel at Destrehan:

- Dual line differential with redundant channel
- POTT scheme with customized pass-through mirror bit
- Zone1 was set to 80% of the shortest remote bus impedance with out-feed.
- Zone2-short was set to 120% of the shortest remote bus impedance without in-feed. Time delay was 10 cycles. Zone2-short was also supervised by communication scheme failure which means Zone2-short will be enabled only if both 87L and POTT were disabled.
- Zone2-long was set to 120% of the longest remote bus impedance with in-feed. Time delay was 30 cycles. Zone2-long was also supervised by communication scheme failure which means Zone2-long will be enabled only if both 87L and POTT were disabled.
- Zone3 forward was delayed 60 cycles
- DTT scheme for breaker failure

2) Panel at Snakefarm:

- Dual line differential with redundant channel
- POTT scheme with customized pass-through mirror bit
- Zone1 was was disabled due to high SIR.
- Zone2-short was set to 120% of the shortest remote bus impedance without in-feed. Time delay was 10 cycles. Zone2-short was also supervised by communication scheme failure which means Zone2-short will be enabled only if both 87L and POTT were disabled.

- Zone2-long was set to 120% of the longest remote bus impedance with in-feed. Time delay was 30 cycles. Zone2-long was also supervised by communication scheme failure which means Zone2-long will be enabled only if both 87L and POTT were disabled.
- Zone3 forward was delayed 60 cycles
- DTT scheme for breaker failure

3) Panel at Labarre:

- Dual line differential with redundant channel
- POTT scheme with customized pass-through mirror bit
- Zone1 was was disabled due to high SIR.
- Zone2-short was set to 120% of the shortest remote bus impedance without in-feed. Time delay was 10 cycles. Zone2-short was also supervised by communication scheme failure which means Zone2-short will be enabled only if both 87L and POTT were disabled.
- Zone2-long was set to 120% of the longest remote bus impedance with in-feed. Time delay was 30 cycles. Zone2-long was also supervised by communication scheme failure which means Zone2-long will be enabled only if both 87L and POTT were disabled.
- Zone3 forward was delayed 60 cycles
- DTT scheme for breaker failure

B. Testing

All the above-mentioned line protection functions were tested during commissioning to ensure the expected functionality. For each line panel two separate methodologies were applied as mentioned below.

- Relay element calibration testing: Each function of the relay including protections and alarms were tested to ensure pick-up values. The calculated currents and voltages were simulated from power system simulator to inject into the relay [6].
- End-to-End Testing: End-to-End test was conducted to check the functionality of the communication aided schemes (line differential, POTT, and DTT). Various faults (internal and external) were simulated in the customized test system based on fault analysis software, power system simulator, and GPS.

V. Conclusions

The successful commissioning of the line resolved the reliability concern created by the river crossing tower failure during IDA. As a premier utility, customers are Entergy's first priority. The described transmission engineering efforts are aligned with Entergy's customer-centric values. The customers of the Harahan, Kenner, and Destrehan area were greatly benefited from the efforts. As an example, there was a fault event that occurred on January 4, 2022 on the Good Hope-Destrehan 230kV line. The event tripped the Good Hope-Destrehan section of the line. However, Harahan, Kenner, and Destrehan substations were energized from Snakefarm and Labarre. Without the three-terminal line, about 22k customers would have been out of service in that event.

References

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