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Restoring Power Outages Caused by Voltage Events with DMS FLISR

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INTRODUCTION

Unplanned power outages are the most challenging to restore because of their unpredictable nature. The fault that causes an unplanned interruption is usually categorized as either a shunt or a series fault. While shunt faults are unbalances between phases or between phases and neutral or ground, series faults are unbalances in the series impedances where one, two, or three phases are open circuits. Due to this unbalance, series faults are also referred to as open-phase or voltage events. When a series fault takes place upstream of the distribution substation feeder breaker, the event is also referred to as feeder loss of potential (LOP). In this scenario, the downstream feeder is de-energized due to an upstream event, which the distribution system may not be aware of. The differences between shunt and series faults make the process of locating, isolating, and restoring their sustained outages different. Additionally, due to the size and complexity that distribution systems commonly have, potential transformers (PTs) are usually only available on specific switching devices, rather than all, as shown in Figure 1.

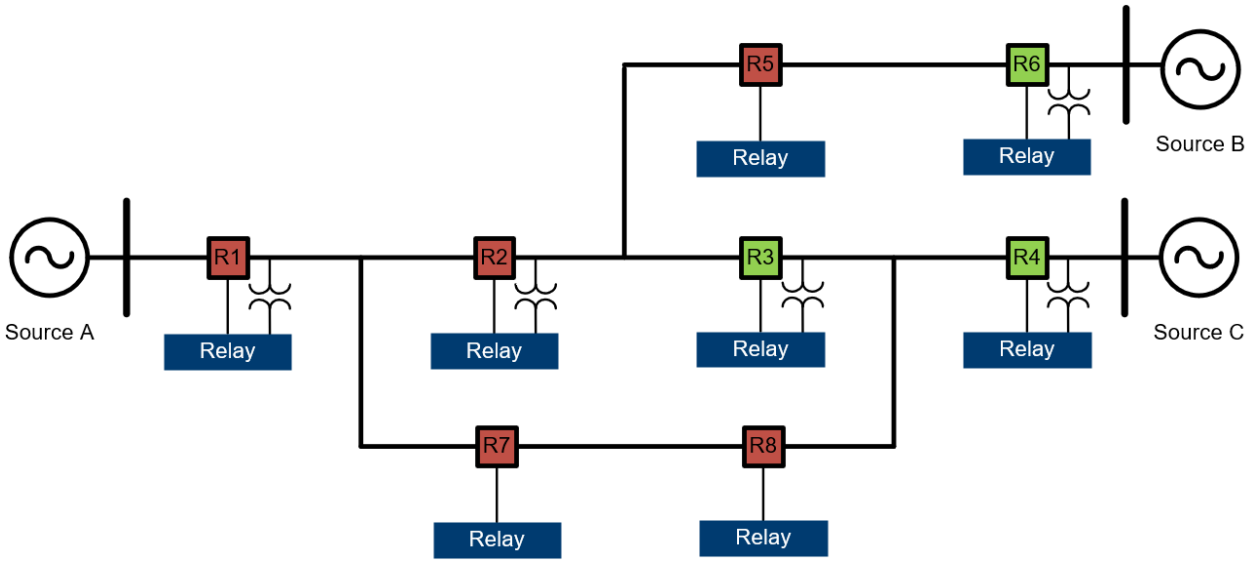

Figure 1 Typical Distribution System Topology, Control, and Instrumentation.

The concern of identifying, locating, and isolating shunt and series faults is not only related to improving reliability indices but also highly related to public, personal, and system safety. While shunt faults usually create short-circuit currents that can be identified and responded to, the series faults are usually caused by connectivity issues, such as broken and hanging conductors that are not as easy to identify.

SEL Solution

SEL Blueframe® ecosystem includes the Distribution Management System (DMS), which is a suite of applications capable of facilitating and supporting the operation of distribution systems. Fault location, isolation, and service restoration (FLISR) is one of the DMS applications that is responsible for automating power outage restorations caused by shunt faults or voltage events. With different types of faults that can lead to a sustained power outage and the likely limitation of measurements in distribution systems, DMS FLISR is designed to address the peculiarities of each type of event, under any level of available instrumentation.

To achieve this function, DMS FLISR monitors the system for conditions that define a power outage. Once a sustained outage event is confirmed and temporized to allow any additional protection and control actions, the most likely fault location is computed and then isolated by opening remote-controlled switching devices bounding the area. Once the physical damage is de-energized and safely isolated, a network reconfiguration is performed to optimally restore the remainder of impacted customers and improve system reliability while the damage is repaired.

Series Faults

A single-phase series fault between two points, x and y, provides unhealthy voltage to the devices downstream of this event, while the upstream devices experience healthy measurements. Consider that there is an open-phase event between R7 and R8 on the typical distribution system illustrated in Figure 1. In this instance, R1 and R2 sense healthy voltage levels and the PT for R3 becomes the next downstream instrumentation capable of sensing and reporting unhealthy voltage measurement, as R7 and R8 do not have voltage instrumentation. By receiving the system voltage telemetry and computing the measurements based on the system topology and configuration, DMS FLISR identifies the most likely fault location. Due to the lack of voltage instrumentation in R7 and R8, conservative isolation actions are taken by opening R1 and R2 and keeping R3 and R4 in open state. Once isolation is achieved, there may still be de-energized customers outside the damaged area, so DMS FLISR performs additional reconfiguration actions to restore as many of these remaining customers as possible, such as by closing R6, as shown in Figure 2.

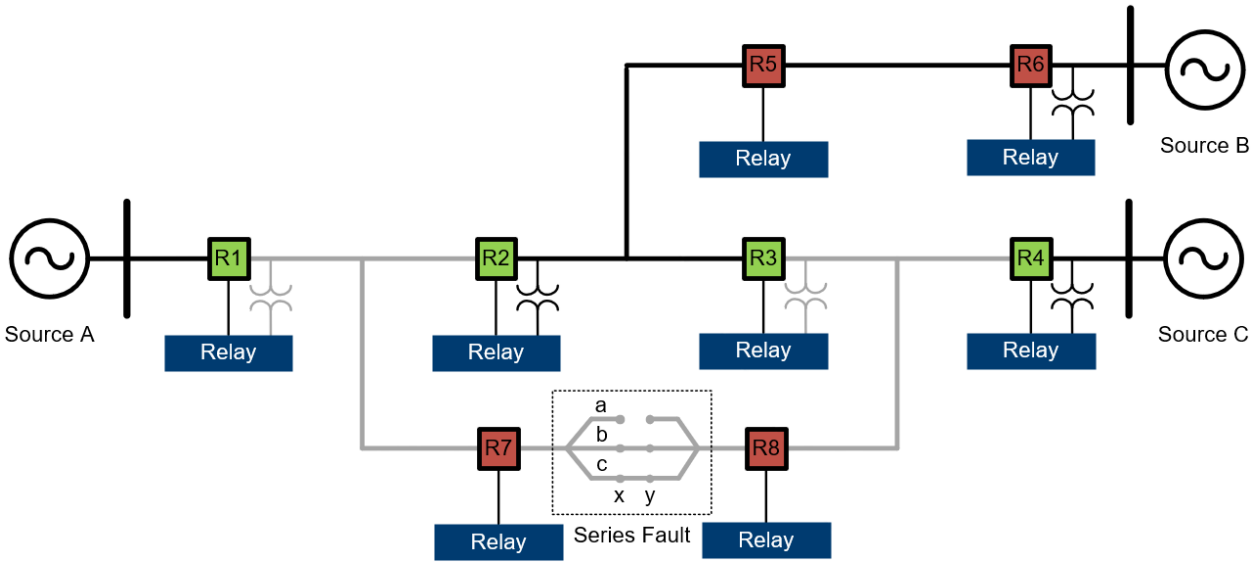

Figure 2 Power Outage Restoration From a Single-Phase Series Fault Event.

LOP

A feeder LOP event takes place at the substation or the upstream system and can impact single, two, or three-phases. For the system shown in Figure 1, a three-phase LOP event at Source A causes the entire feeder to be de-energized, while Source B and C remain energized. By receiving the voltage telemetry from R1, R2, R3, R4, and R6, DMS FLISR is capable of identifying an LOP at Source A. From this identification, R1 must be open to isolate the upstream event, and the adjacent sources, B and C, are used to transfer load, based on available capacities. The load transfer is achieved with network reconfiguration, where the configuration is rearranged as needed to maximize the number of restored customers. As shown in Figure 3, R1 is opened as an isolation action, while R4 and R6 are closed and R7 is open to achieve restoration.

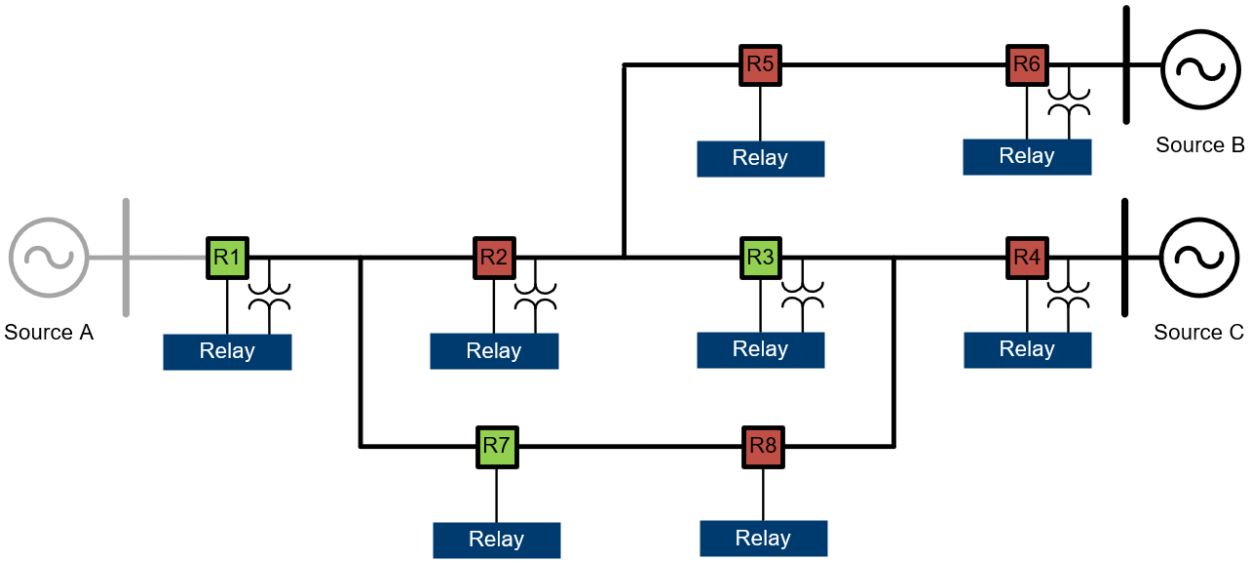

Figure 3 Power Outage Restoration from an LOP Event.

SOLUTION FLEXIBILITY

DMS FLISR is designed with flexibility, making it easy for users to select which type of event the solution should respond to, if not for both shunt and voltage events. Additionally, DMS FLISR allows configuring the LOP condition in which the system should respond to, whether it responds only to three-, two-, or single-phase events or to any combination of phase events. Such flexibility is especially valuable when the system is not expected to react to a single- or two-phase LOP, which are commonly caused by blown fuses, but the system should respond to a three-phase LOP, which may be an actual upstream outage.

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