# Reducing System Losses and Implementing Self-Healing to Minimize Impact of Faults in Distribution Networks

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***Abstract -*** Greater emphasis on reliability and efficiency of the electric distribution network is taking place through regulation at the federal and state level. Utilities have identified investments for self-healing networks and volt var optimization to improve distribution grid reliability and efficiency to comply with the regulations. When faults occur on the system, fault detection and isolation techniques now available rarely consider the power quality and VAR impact to non-isolated customers. However, new technologies now make this possible.

## INTRODUCTION

As distribution grid modernization accelerates in North America, relay engineers require a greater knowledge of system operation influences on power availability, power quality and power factor. Past system coordination considerations focused protection on assets within the power system and less consideration was given to power factor and power quality. As microprocessor relays continue to integrate service functions, the knowledge of relay protection engineers had to increase to optimize application of protection functions. For applications of both self-healing and voltage regulation, a better understanding of information is necessary to coordinate power system loads. This includes location and types of generation, VARs, and control elements brought into the system. For distribution networks, the control elements include capacitor banks, regulators, and load tap changers. The interaction of self-healing logic with VAR control and voltage regulation has a substantial impact on load balance, power quality and power factor. Initiatives by utilities and industrials to improve power factor and power quality are achieved through addition of capacitor banks and regulators, coordinating meter data with these devices to enable better system voltage control. When faults occur on the system, fault detection and isolation techniques now available rarely consider the power quality and VAR impact to non-isolated customers. Using advanced computer logic, wireless and wired communication mediums, protection relays, and capacitor bank and regulator controls, the coordination of applications for self-healing networks, voltage regulation (conservation voltage reduction), and volt var optimization has become a viable solution.

## POWER QUALITY AND POWER FACTOR IMPROVEMENTS

The first consideration for coordinating self-healing networks with VAR optimization is the protection elements necessary for protection of transformers, switches, and conductors. This process is consistent with current protection relay engineering practices in determining protection elements for an asset on, or a segment of the circuit. Once the self-healing logic is completed (protection devices on the distribution network connected), and coordination of load tap changers, capacitor banks and regulators is accomplished, then developing the logic to combine both self-healing and voltage regulation is possible.

A breakdown of recommended elements for protection of assets within the substation and feeder protection elements is shown below.

Feeder protection elements:

| **Recloser protection elements** | |
|---|---|
| 51P&51N | Phase & Ground Time-Overcurrent (Slow Curve) |
| 50P&50N | Phase & Ground instantaneous (“fast phase curve”) |
| 46 | Negative Sequence Time Overcurrent |
| 67P&67N | Directional Phase & Ground Time Overcurrent |
| 81 | Frequency Load Shed and Restoration |
| 27 | Undervoltage |
| 59 | Overvoltage |
| 32P&32N | Positive Directional Power & Negative Directional Power |
| 79 | Auto reclosing |
| 25 | SYNC check |

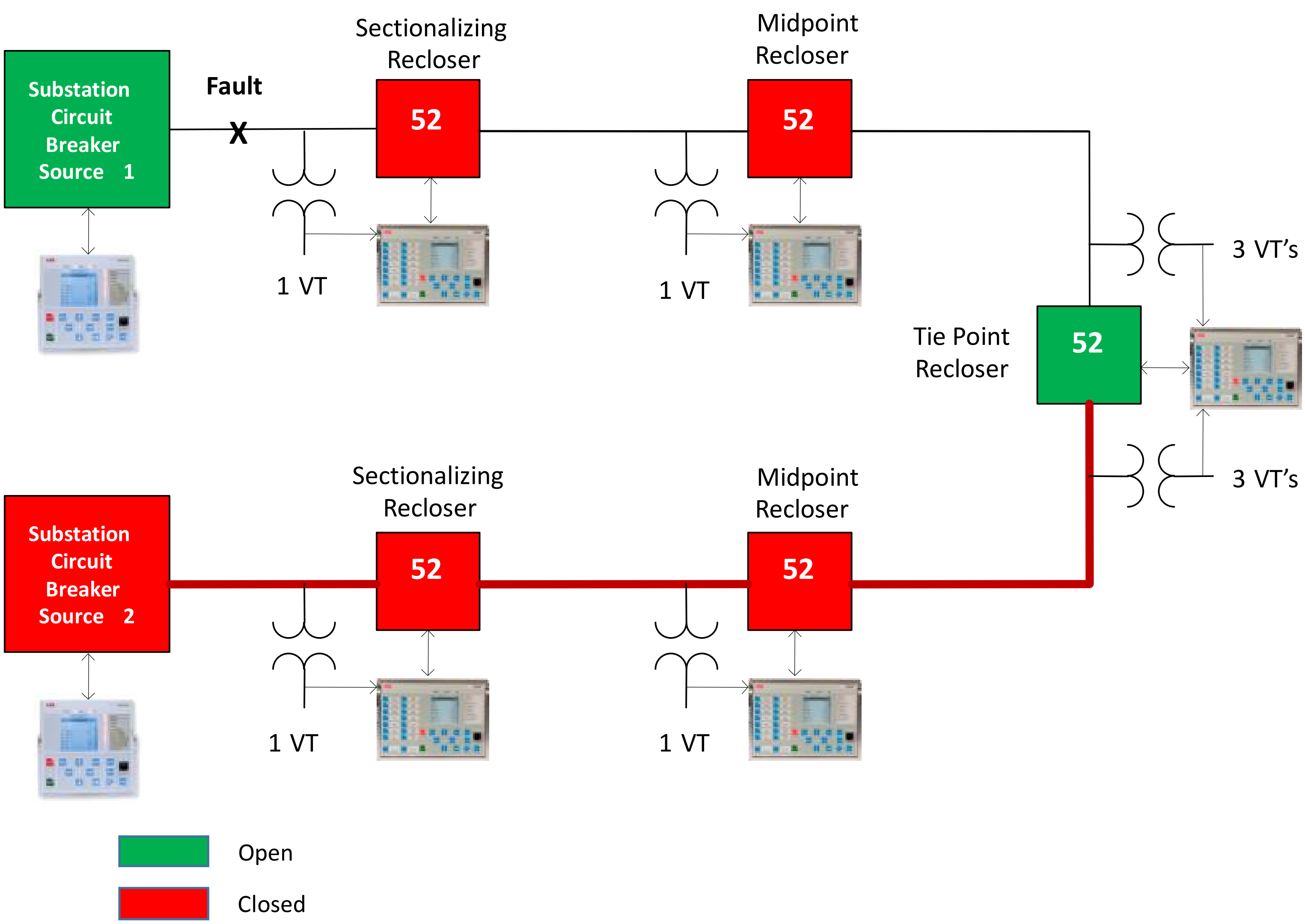
Substation breaker protection elements:

| **CB feeder protection elements** | |
|---|---|
| 51P&51N | Phase & Ground Time-Overcurrent |
| 50P&50N | Phase & Ground instantaneous |
| 27 | Undervoltage |
| 59 | Overvoltage |
| 81 | Frequency Load Shed and Restoration |
| 47 | Positive sequence |
| 67 | 3 Phase directional Overcurrent |
| 79 | Auto reclosing |
| 49F | 3 phase thermal overload (feeder and cable) |
| 25 | SYNC check/voltage check |
| 87L | Line differential protection |
| 60 | Fuse failure supervision |

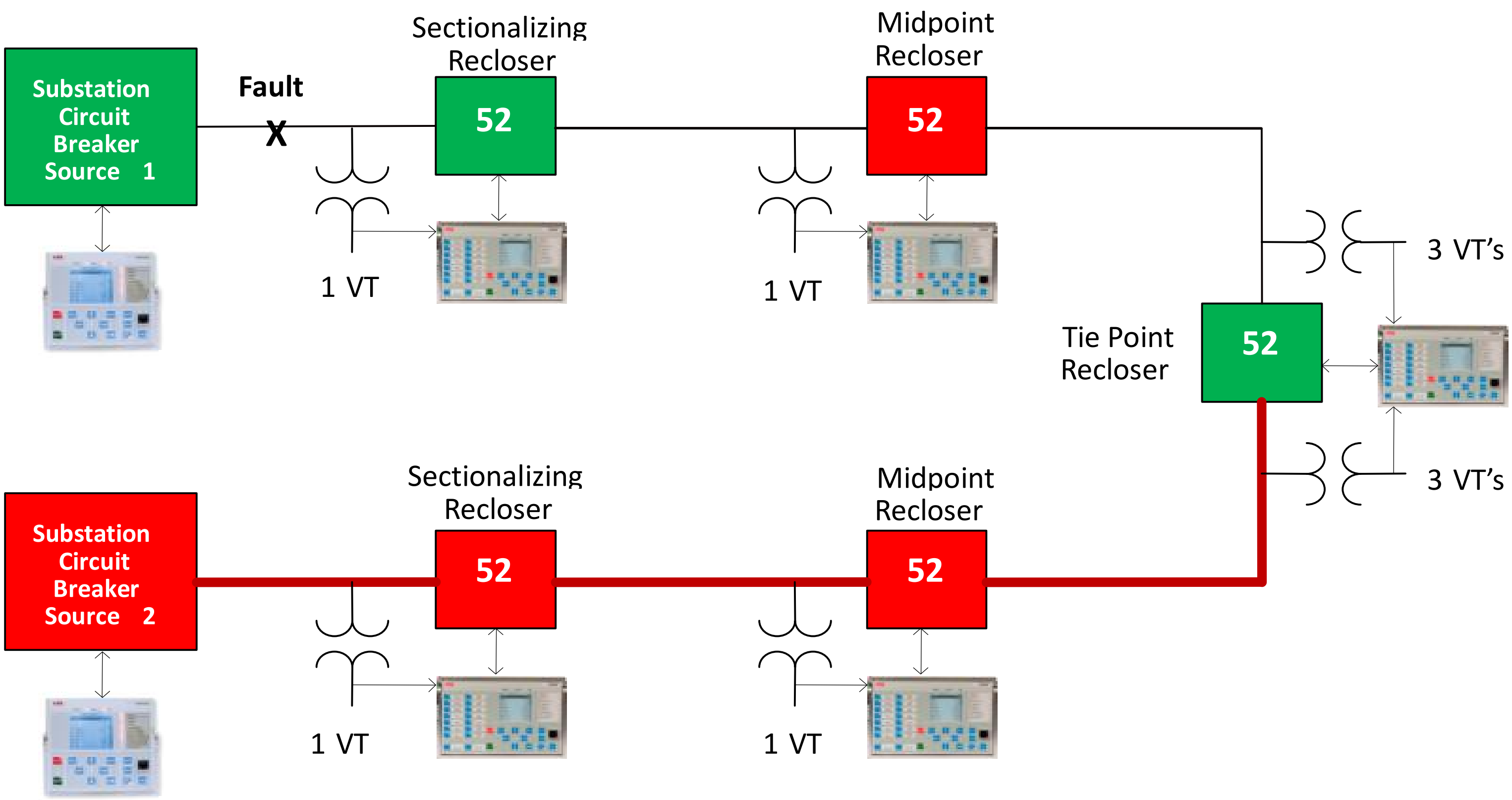
Once the protection elements are defined, coordination between devices is necessary to perform the circuit self-healing. There are generally recognized methods for collection of data, analysis and issuance of control actions. The three locations for assimilation of data and command actions are: centralized, distributed, and peer to peer. Each method requires similar inputs, each has advantages/disadvantages but all are capable of performing self-healing (fault detection, isolation and restoration).

Once selection and deployment of the method to perform self-healing is complete, the capability exists for the fault to be located and a segment of the circuit isolated through opening of reclosers, switches or breakers. A fault location, isolation and restoration example is shown using the four diagrams below.

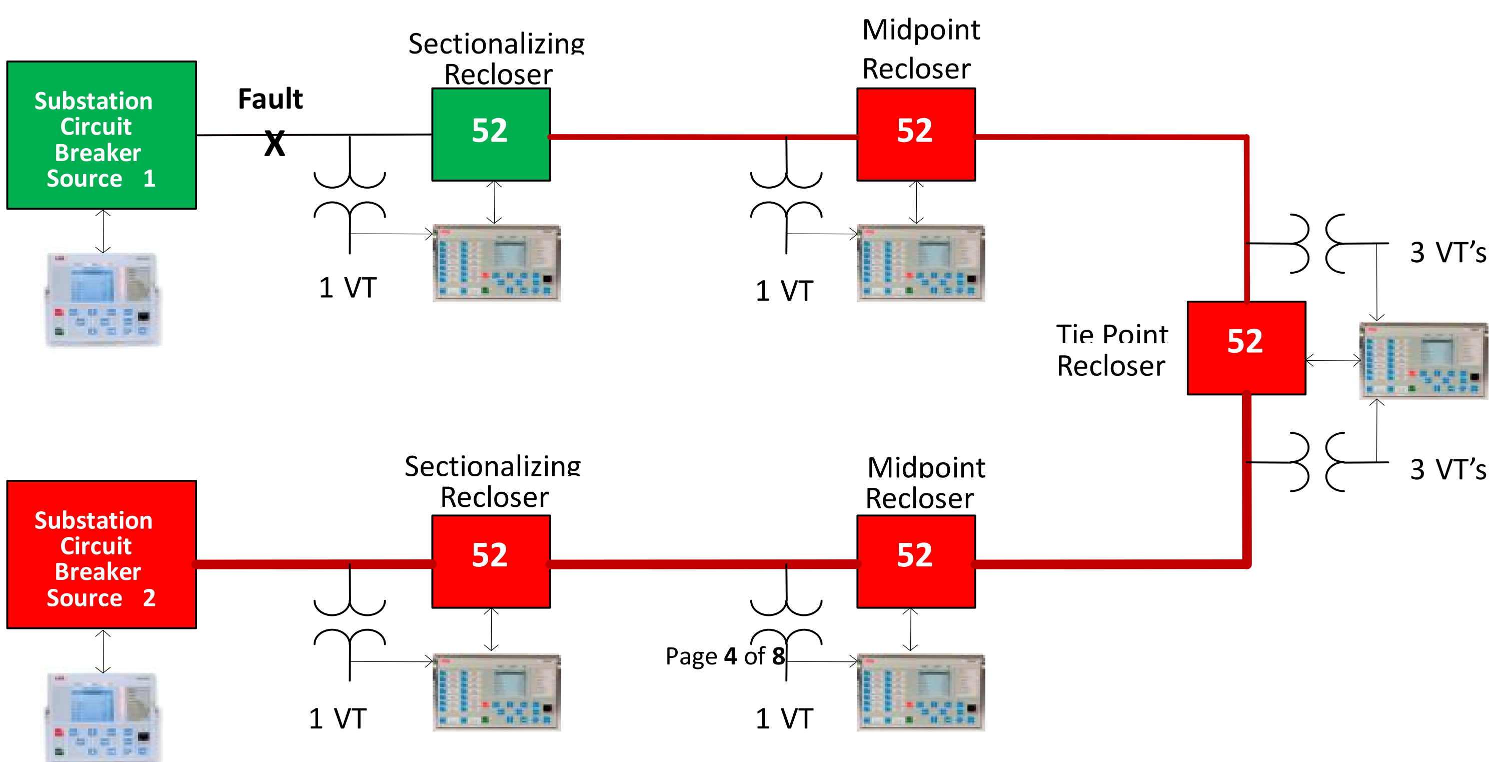
Identification of a fault is shown in the segment leaving substation 1, on the segment between the substation breaker and the first downstream recloser.



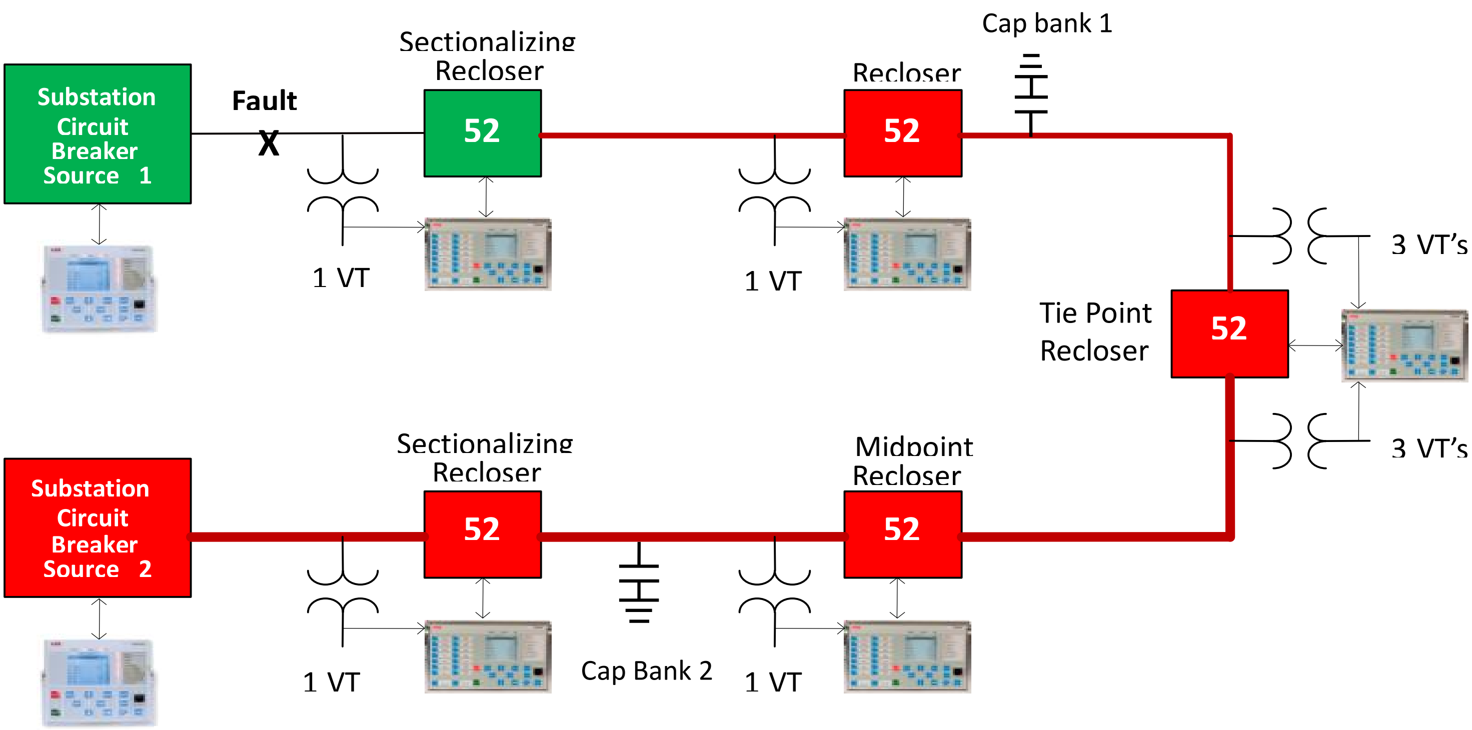
Isolation of a circuit segment is required next in preparation for restoration of power to the un-faulted segments. The downstream (from breaker) sectionalizing recloser opens to isolate the faulted segment.




In the diagram below, the power is applied from the Source 2 by closing the tie point, providing power to the non-faulted section of the circuit. This is the system configuration until the fault is removed and the system can be restored to pre-fault conditions.

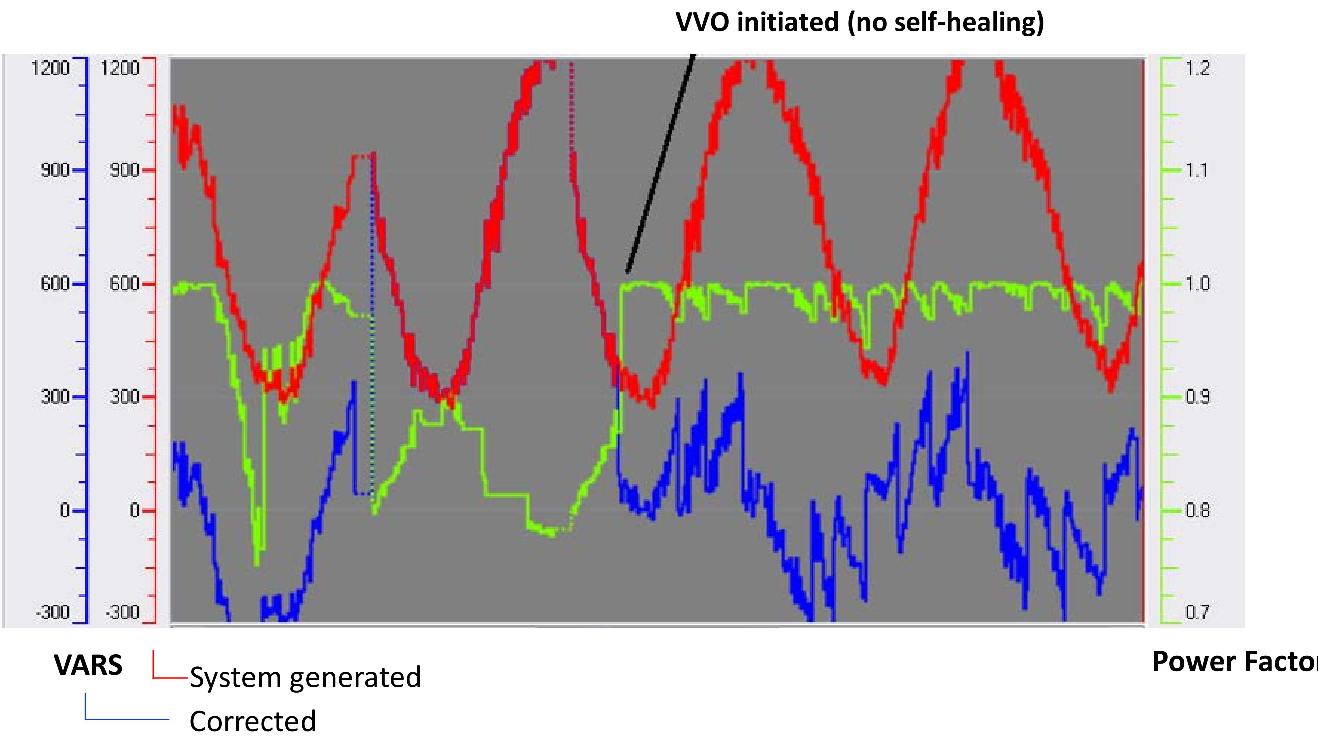


Once the self-healing scheme has been designed it is appropriate to assess the locations of devices for volt var optimization (VVO). Using capacitors and voltage regulators can hurt or help the system during self-healing events.

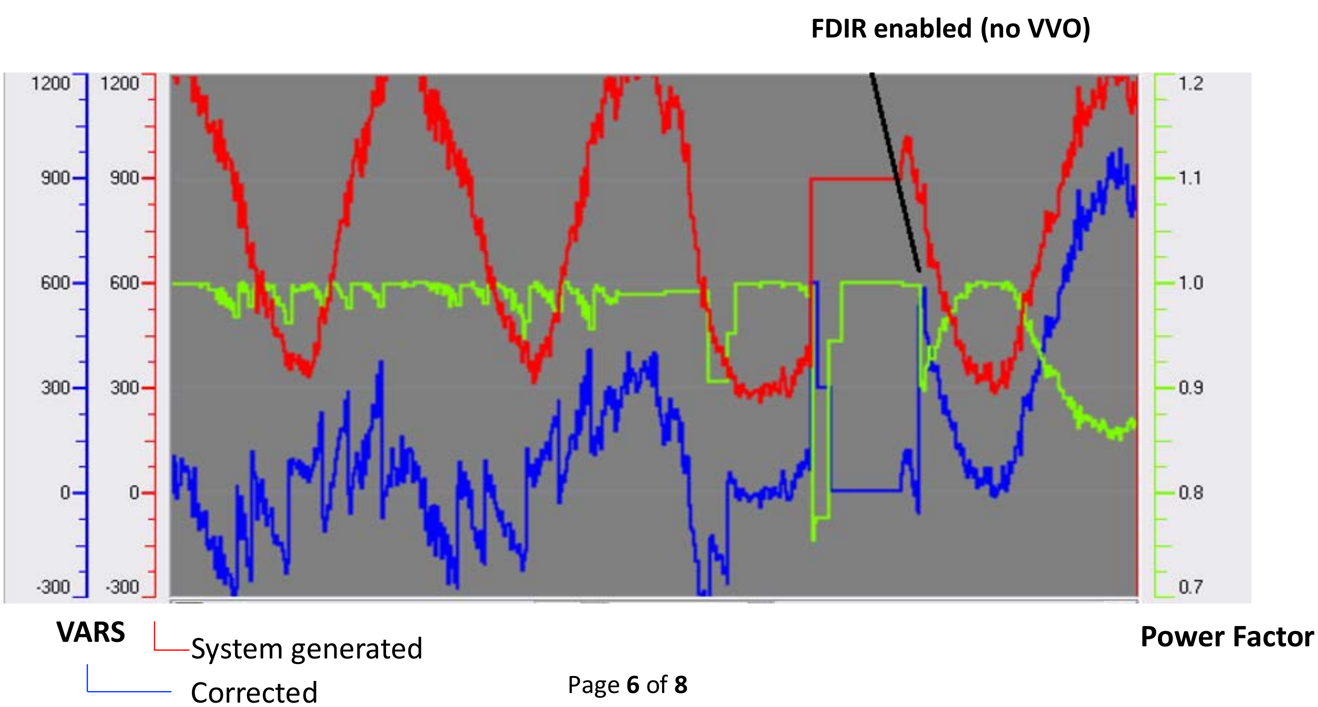



Two capacitor banks are shown on the diagram and each will be impacted by the self-healing actions. Depending on location of capacitor banks and regulators on the system, VARS may be required after power is restored to the non-faulted segments. However, which capacitor(s) and how many VARS necessary to put onto the system is important to consider before reactivating or deactivating capacitor controls. In the diagram above, source 2 is providing all the power for the circuit and two capacitor banks are available. Power flow in Cap Bank 1 is reversed so adding VARS may not be necessary or recommended. Turning this off or on is possible when volt var optimization algorithms are linked with self-healing automation.

Shown below is the application of volt var optimization algorithm without deploying a self healing scheme. Improvement in power factor improvement is shown when the VVO automation is enabled.

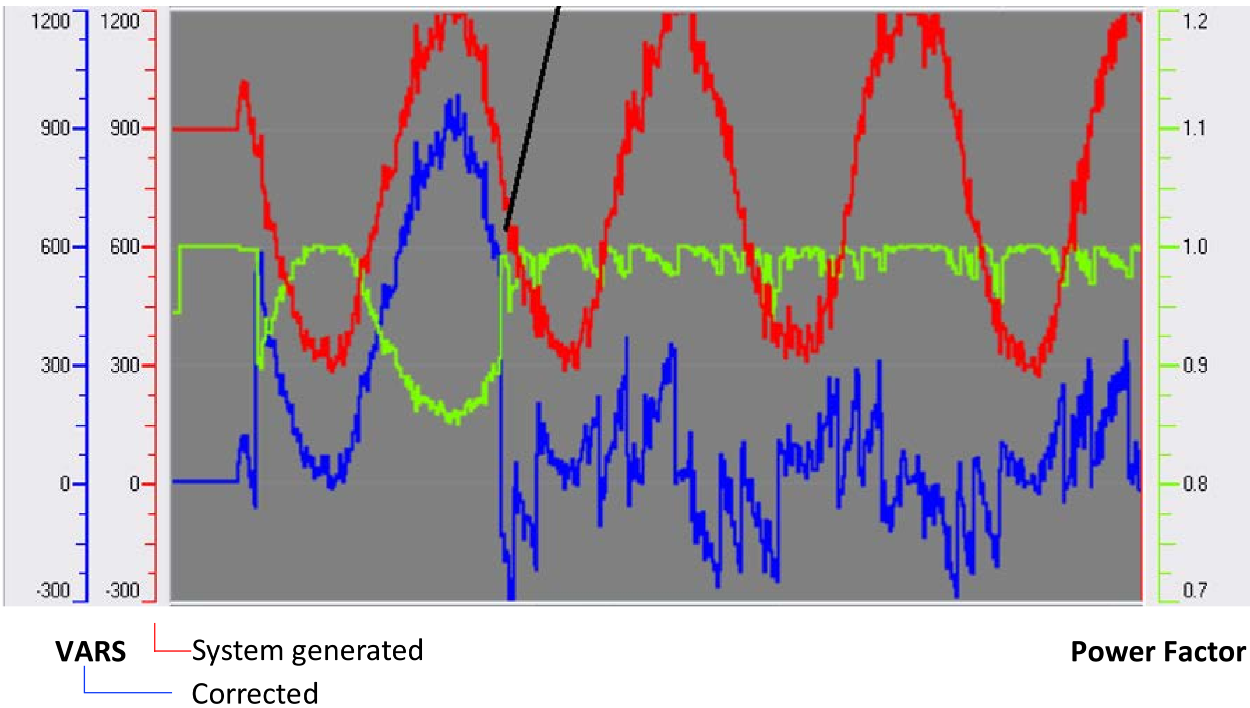



When a self-healing scheme is deployed without coordination with voltage control power factor declines after enabling the self-healing (FDIR) function.



When self-healing schemes are coordinated with voltage optimization control, the system is optimized for the conditions present on the circuit.  It is possible to perform self-healing schemes with volt var optimization simultaneously, yielding improved SAIDI, SAIFI and power factor performance.

**FDIR & VVO performed simultaneously**




CONCLUSION

Efforts to deploy self-healing networks have been successful and are beneficial to both the customer and the utility.  Voltage regulation and optimization is possible when utilities deploy accurate sensors on distribution circuits and coordinate information with available meter data.  Combining applications for self-healing networks and volt var optimization provide the optimal circuit performance during normal operating conditions and when faulted conditions exist on the network.

## BIOGRAPHIES

**Doug Voda** is Global Segment Leader for Medium Voltage Smart Grid, at ABB. He is responsible for developing and delivering solutions to utilities and industrial customers around the world. Doug has held senior management or engineering management positions at SEL, Compaq, Motorola, and has over 16 years' experience in electric power products and solutions. Doug holds a B.S.M.E from the University of Nebraska and an MBA from HBU in Texas.

**David Frame** is a member of the ABB North America Grid Automation Solutions team. Starting in 1978, he worked for 26 years as a systems integration engineer in process automation specializing in logic controls and SCADA for steam generation, turbine, water and wastewater control. Dave joined ABB in 2004 as electrical distribution automation and SCADA specialist.

**Wei Huang** received his B.S in Electrical Engineering and M.S. in Process Automation from Zhejiang University, and M.S. in Computer Science from Florida Atlantic University. Wei is currently the ABB Regional Technical Manager with emphasis on communications. He has extensive experience of design, development and system integration of process automation and power distribution automation system. He has worked for ABB as a software developer, product specialist and technical manager of communication. Prior to joining ABB, he worked for Elsag Bailey Pte Ltd and RTP Corp as automation system developer and integrator. He is a member of IEEE.

**Alfredo Romero** received his B.S. in Electrical Engineering from the University of Florida. He has broad experience in the electrical and power industry, starting his career at Southern Company where he worked as an Engineering Co-Op. Alfredo joined ABB in 2007 and has held several roles in marketing and sales and application engineering for medium voltage products and power distribution components. He has worked with electric utilities in North America to develop feeder automation and grid modernization solutions to improve system reliability and operational efficiency. He is currently the Marketing and Sales Manager for Medium Voltage Outdoor products in the US.

**Harsh Karandikar** received his B.Tech. in Mechanical Engineering from the Indian Institute of Technology and a Ph.D. in Mechanical Engineering from the University of Houston. He is currently the VP of Product Management for the North American medium voltage business unit and coordinates the product strategy for protection & control relays, instrument transformers & sensors, indoor & outdoor apparatus, switchgear and service. Prior to his current position he was the head of engineering for the same business. Harsh has written extensively on the topic of effective & efficient management of product development including the role of product platforms, global teams and emerging country sourcing. He is a Senior Member of IEEE and a Fellow of ASME.