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Reducing system losses and implementing self healing to minimize impacts of Faults on Distribution Networks

Agenda



- Foundation of Distribution Grid Modernization
- Protection Impact
- Performance measures
- Selecting Protection Elements
- Architecture for Self Healing Networks

Distribution grid modernization

Foundation is based on five objectives

| | |
|----------------|--|
| Capacity | Upgrade/install capacity economically Provide additional infrastructure (PHEVs, Renewables) |
| Reliability | Stabilize the system and avoid outages Provide high quality power all the time |
| Efficiency | Improve efficiency of power generation Reduce losses in transport and consumption |
| Sustainability | Connect renewable energy to the grid Extend life of products as technology changes |
| Safety | Eliminate or reduce risk of harm or injury |

Challenges for Utility and Industrials

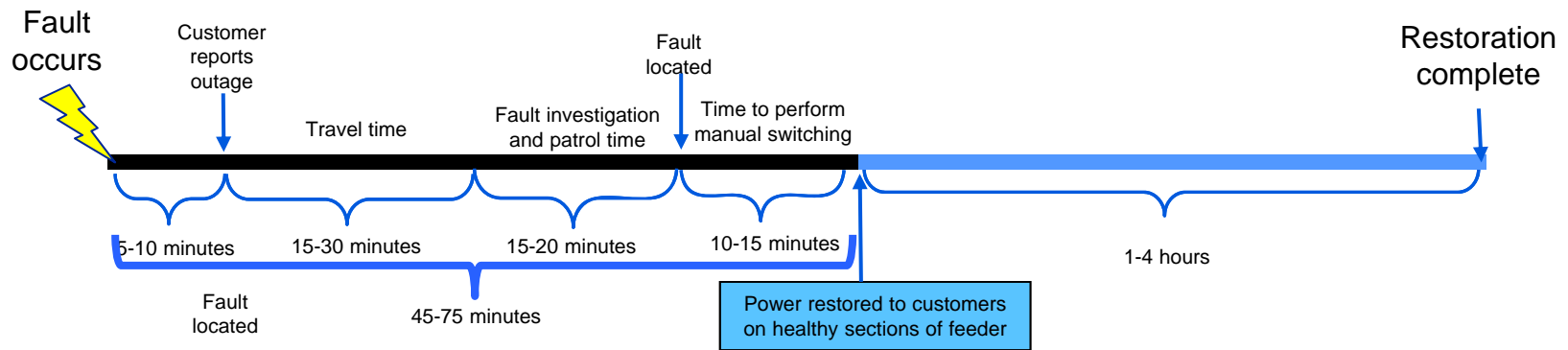
Driving investment in Outage Restoration

| 1 Capacity | 2 Reliability | 3 Efficiency | 4 Communi- cations. | 5 Aging Workforce |
|---|---|---|--|--|
| Installation of renewable generation reduces system Inertia (especially PV) | Growing energy dependency has resulted in a reduced tolerance for interruptions of service. | Frequency and cost of major outage events is increasing, utilities need to reduce occurrences and response costs. | Proactive communication about outages is a must. | Knowledge loss from retiring workforce needs to be replaced with system automation and workflows |

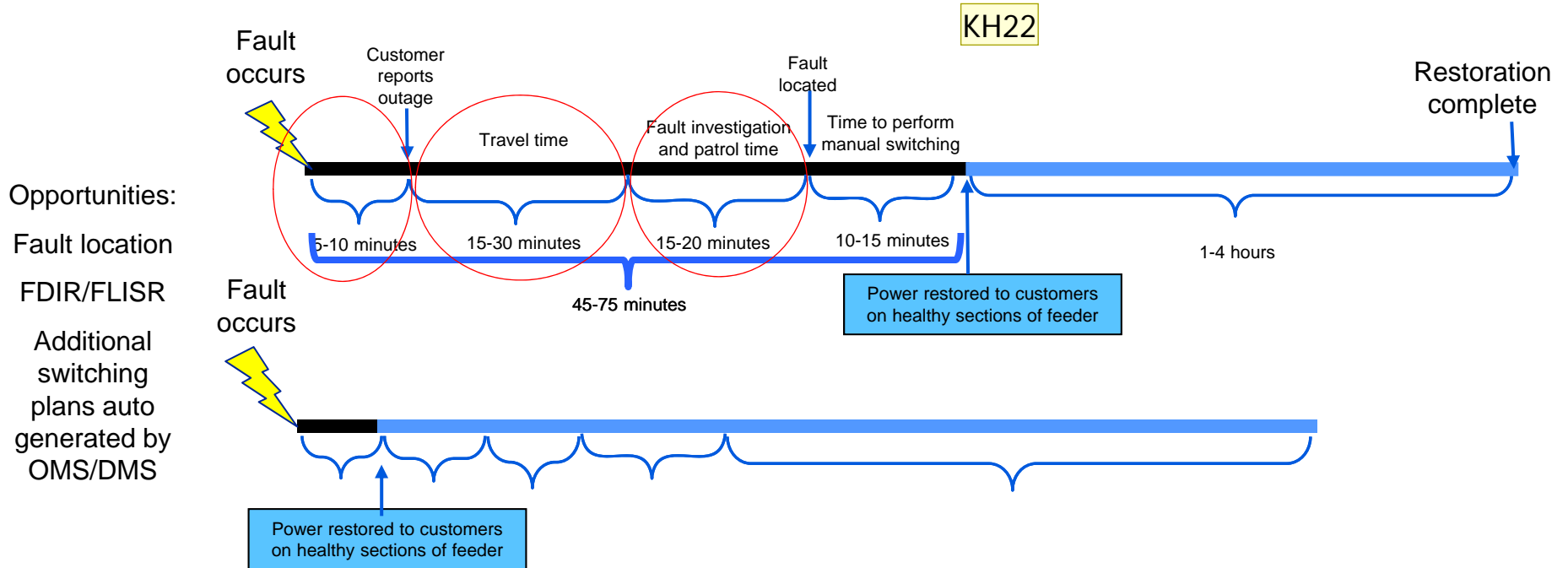
The bottom line:

Utilities are being required to not only prevent or minimize outage occurrences, but also restore service as quickly as possible, improve reliability and safety, avoid penalties or fines, and run their operations more efficiently.

Restoration enhancement opportunities



Restoration enhancement opportunities



One utility estimated a 21 percent reduction in SAIDI with Self Healing

Slide 6

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Keith Herreman, 10/30/2014

Restoration enhancement opportunities

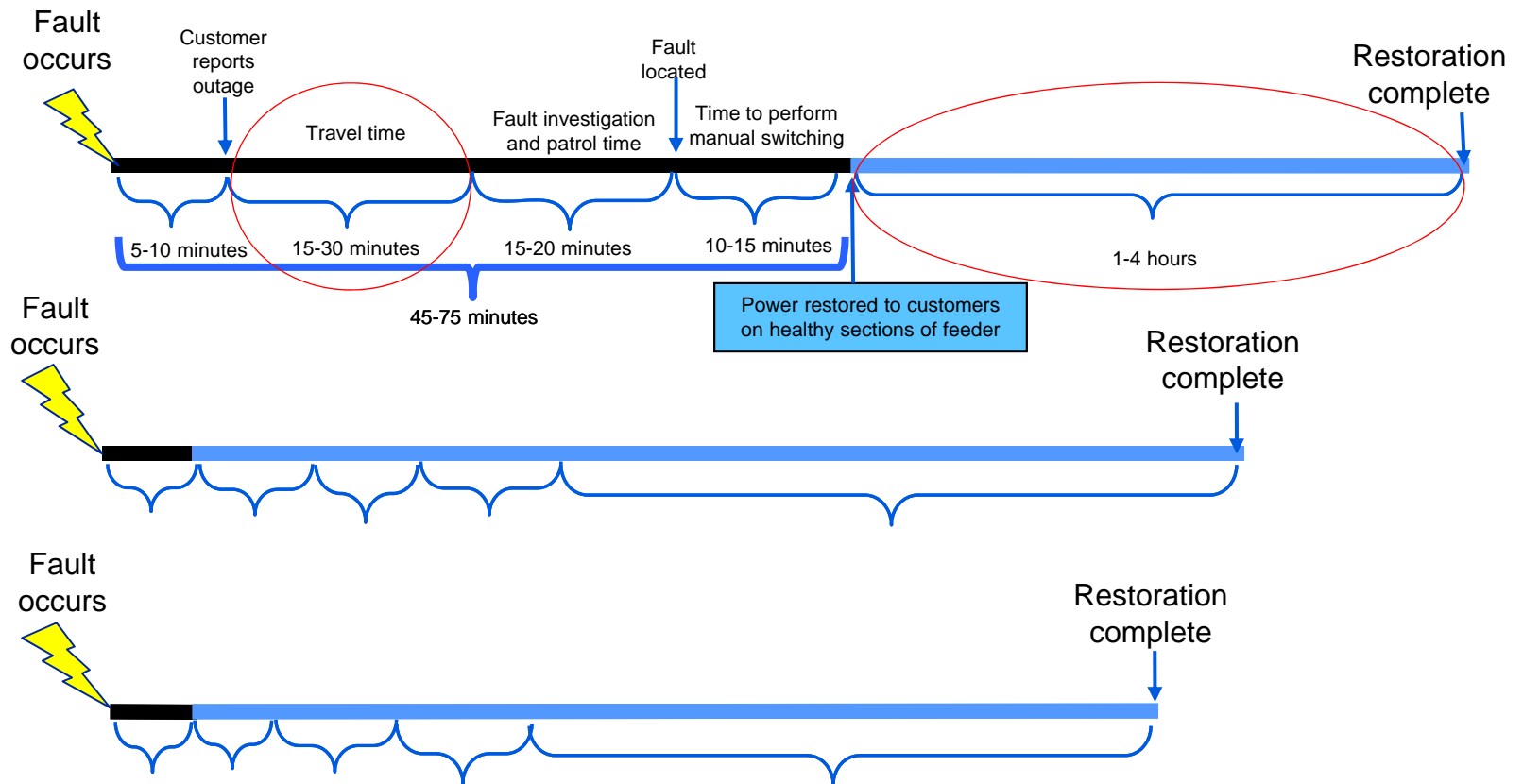
Opportunities:

Fault location

FDIR/FLISR

Additional
switching
plans auto-
generated by
OMS/DMS

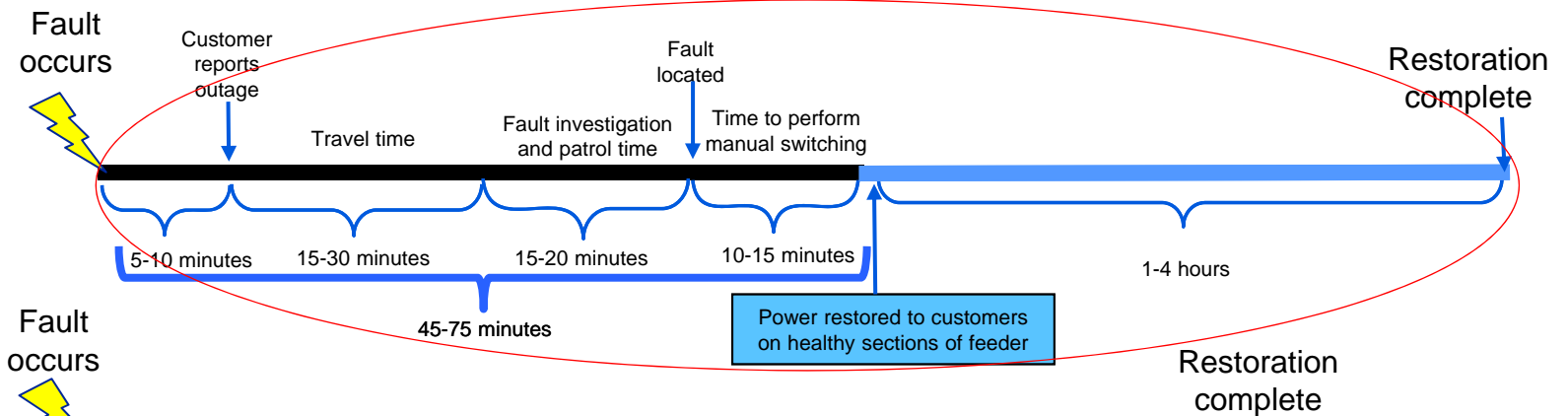
Automated
dispatch with
work
optimization
and routing



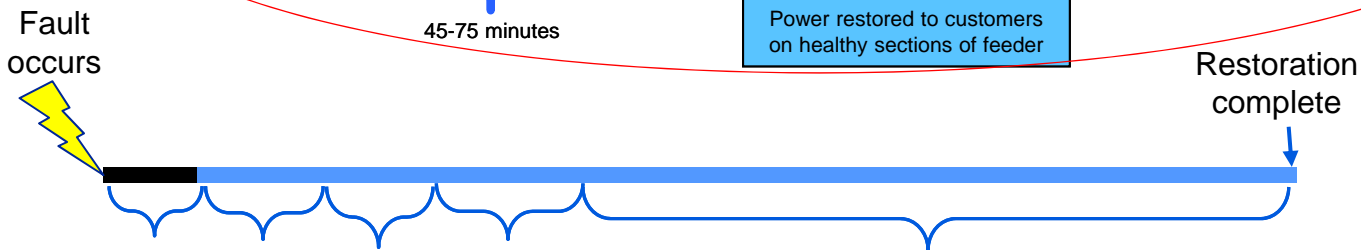
A major utility estimated a 50% reduction in dispatcher time with auto-dispatch

Restoration enhancement opportunities

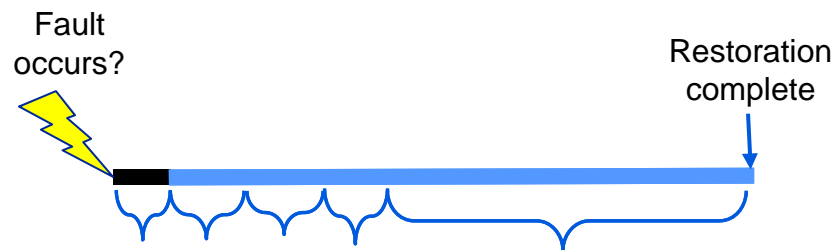
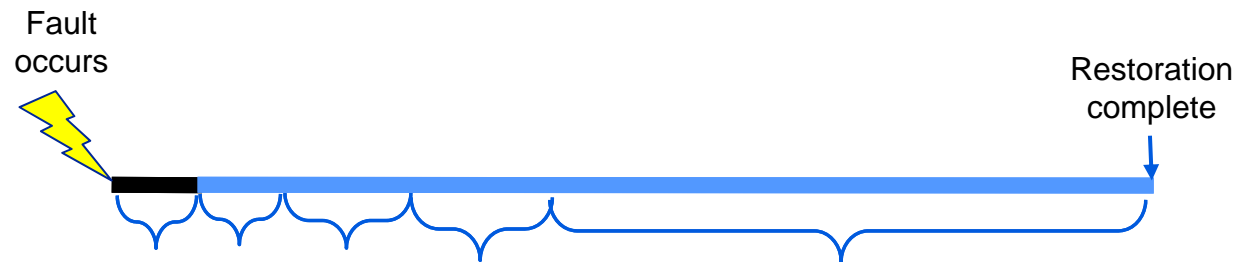
Opportunities:
Fault location
FDIR/FLISR
Additional
switching plans
auto-generated



Automated
dispatch with
work
optimization
and routing



Storm planning,
logistics and
grid hardening
via analytics,
network
management



Relay Settings for Self Healing Circuits

Relay protection elements for self healing circuits

Feeder protection elements:

| Recloser protection elements | Protection function |
|------------------------------|---|
| 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 |

Relay protection elements for self healing networks

Substation breaker protection elements:

| CB feeder protection elements | Protection function |
|-------------------------------|---|
| 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 |

Examples of a Self Healing Circuit

Grid Modernization – Self Healing Architecture

Layers of control



Self Healing – FDIR

Device level
and/or peer-
to-peer

- A group of reclosers, load break switches, and circuit breakers on a feeder operate together to restore power in the most optimal manner

Substation
level

- Coordinated control between groups of reclosers, load break switches, and substation circuit breakers within a substation and possibly with adjacent substations

Centralized

- Coordinated control between groups of reclosers, load-break switches, and substation circuit breakers across the distribution grid



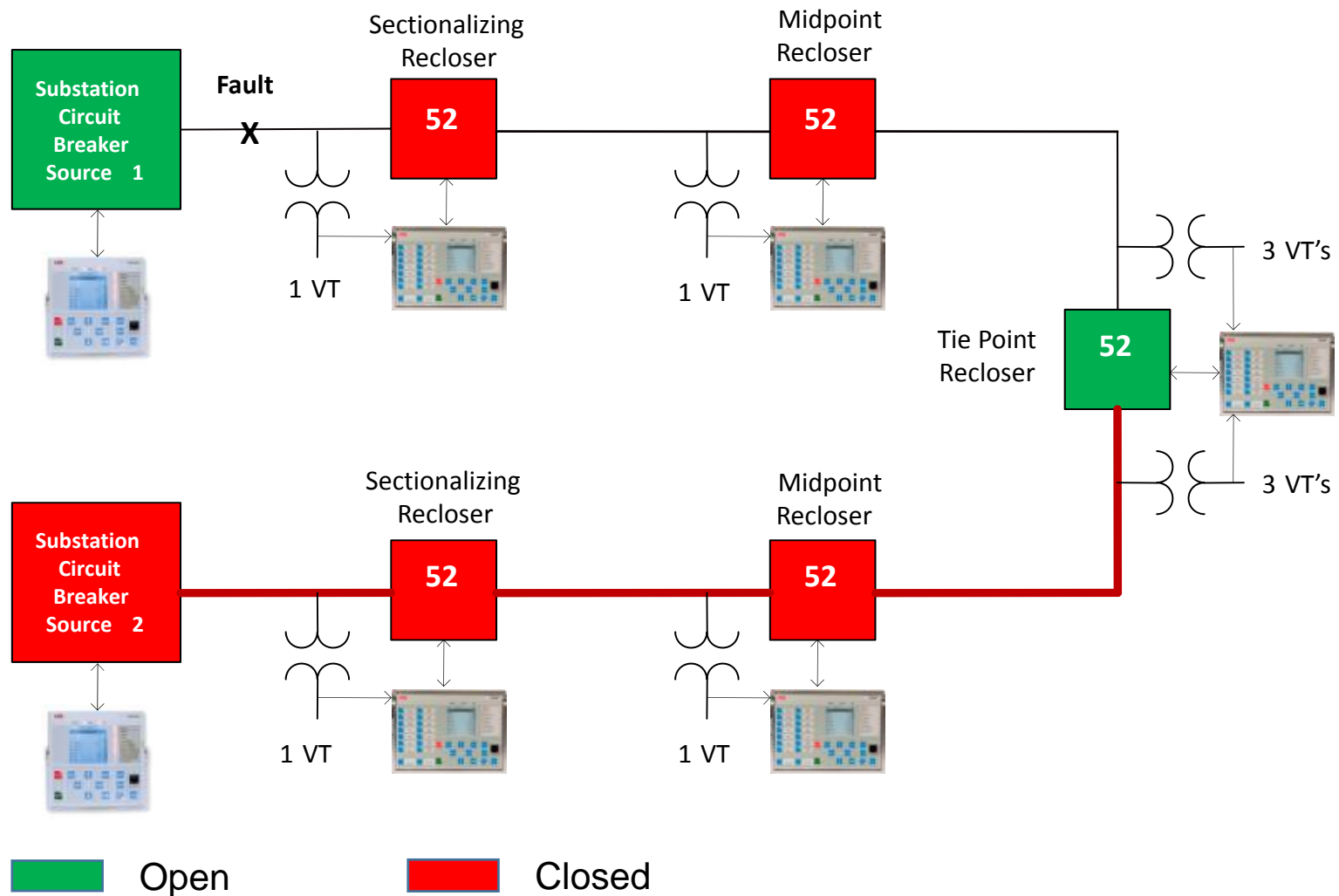
Efficiency – Volt/VAr control

- Manually or remotely control capacitors at the local level utilizing settings based on historic metrics of customer power usage

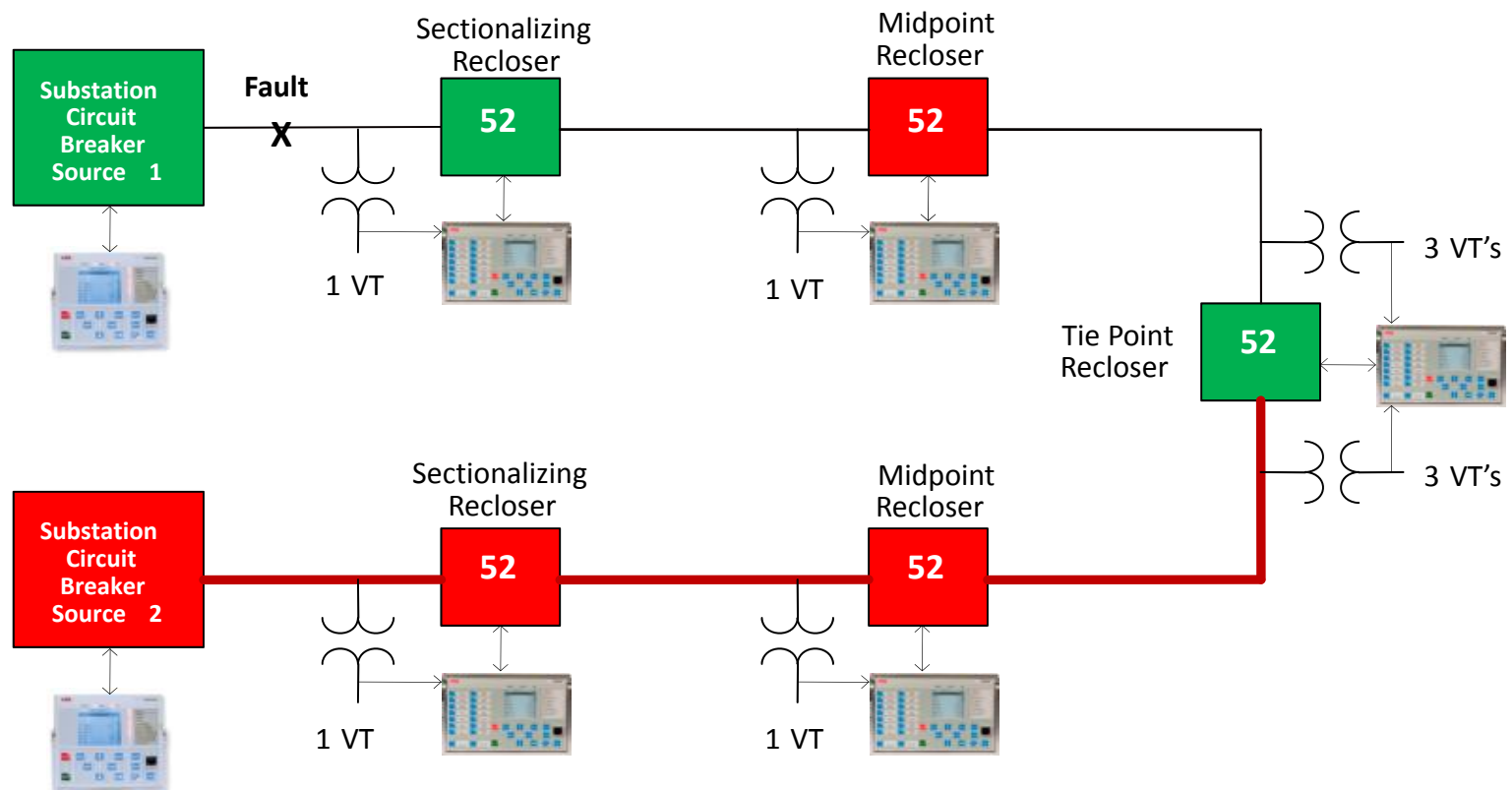
- Adding two-way communications and Volt/VAr control software to coordinate and control capacitors, voltage regulators and load tap changers in real time

- Utilizing network management software and an impedance model of the distribution system to optimize the reduction in energy losses and demand

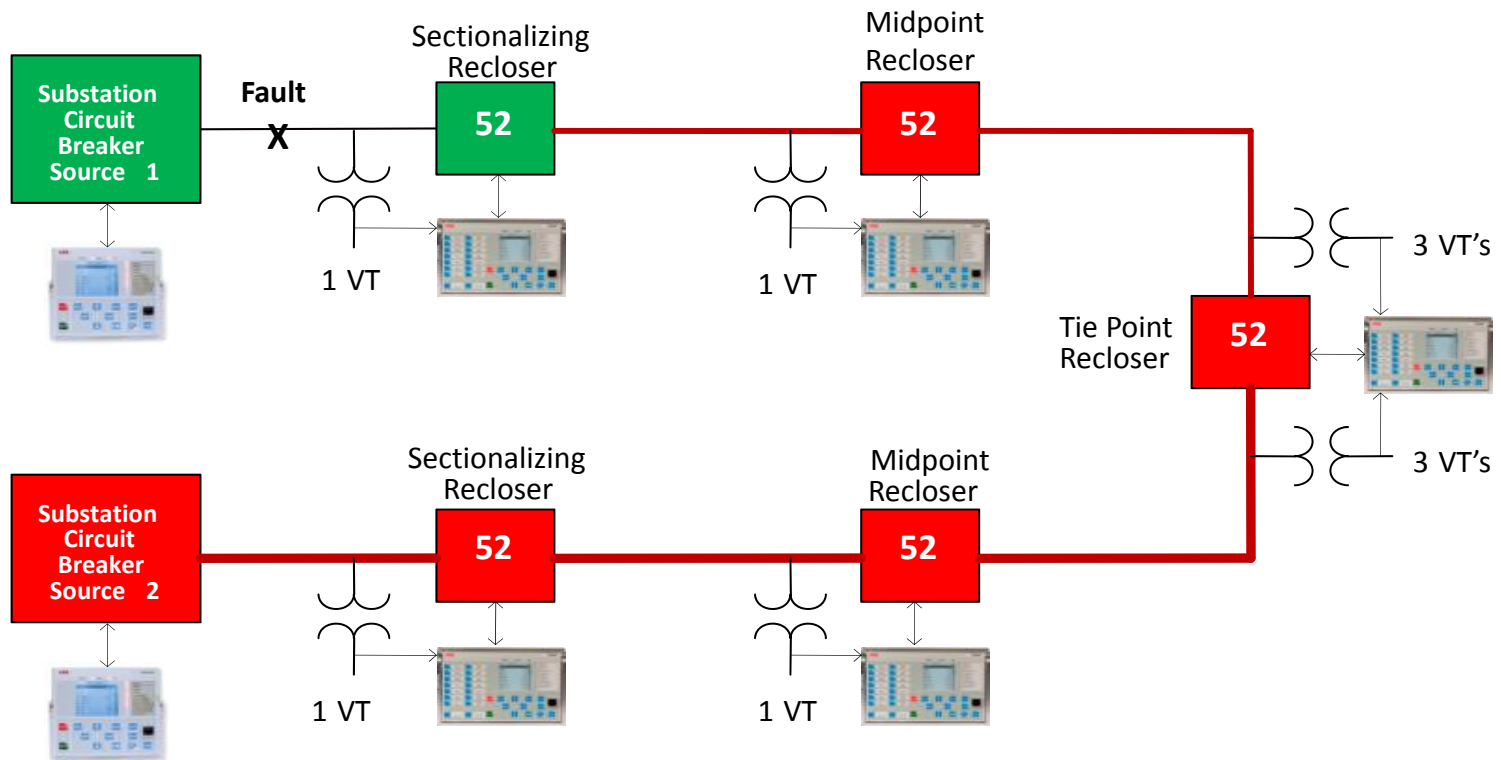
Distribution Circuit Self Healing – Fault Detection



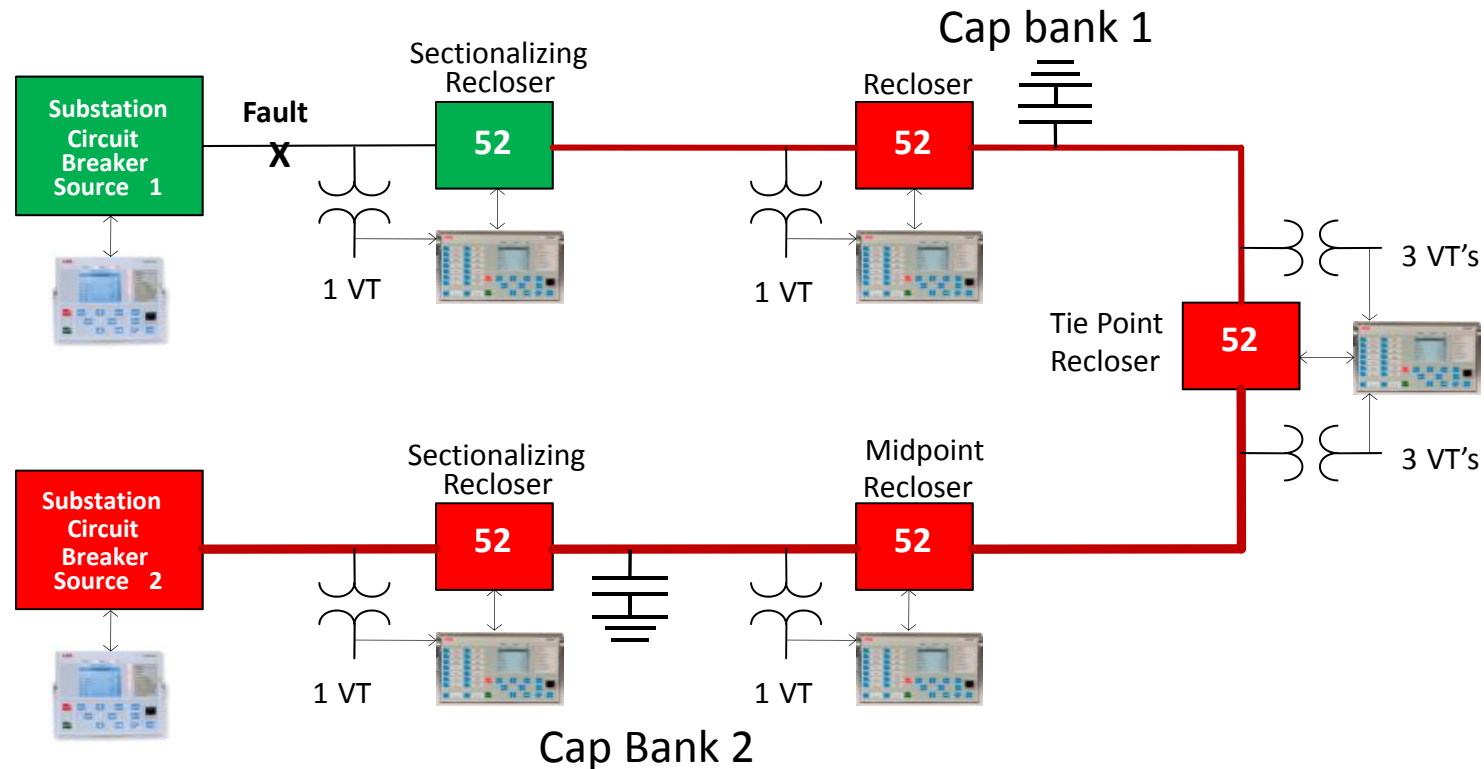
Isolation



Restoration



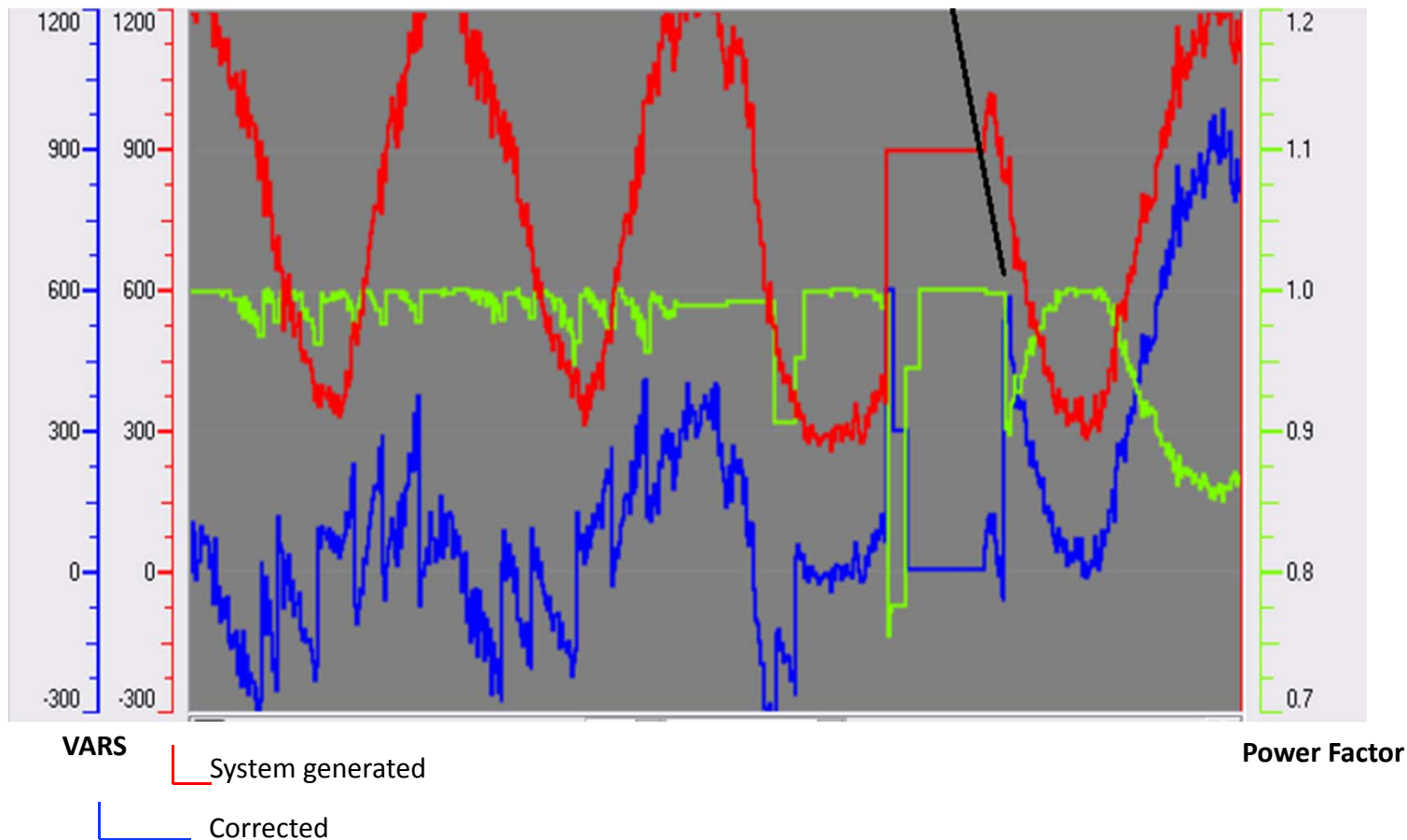
During circuit reconfiguration, what happens to power factor? Power quality?



Impact when Coordinating Protection and Voltage Regulation

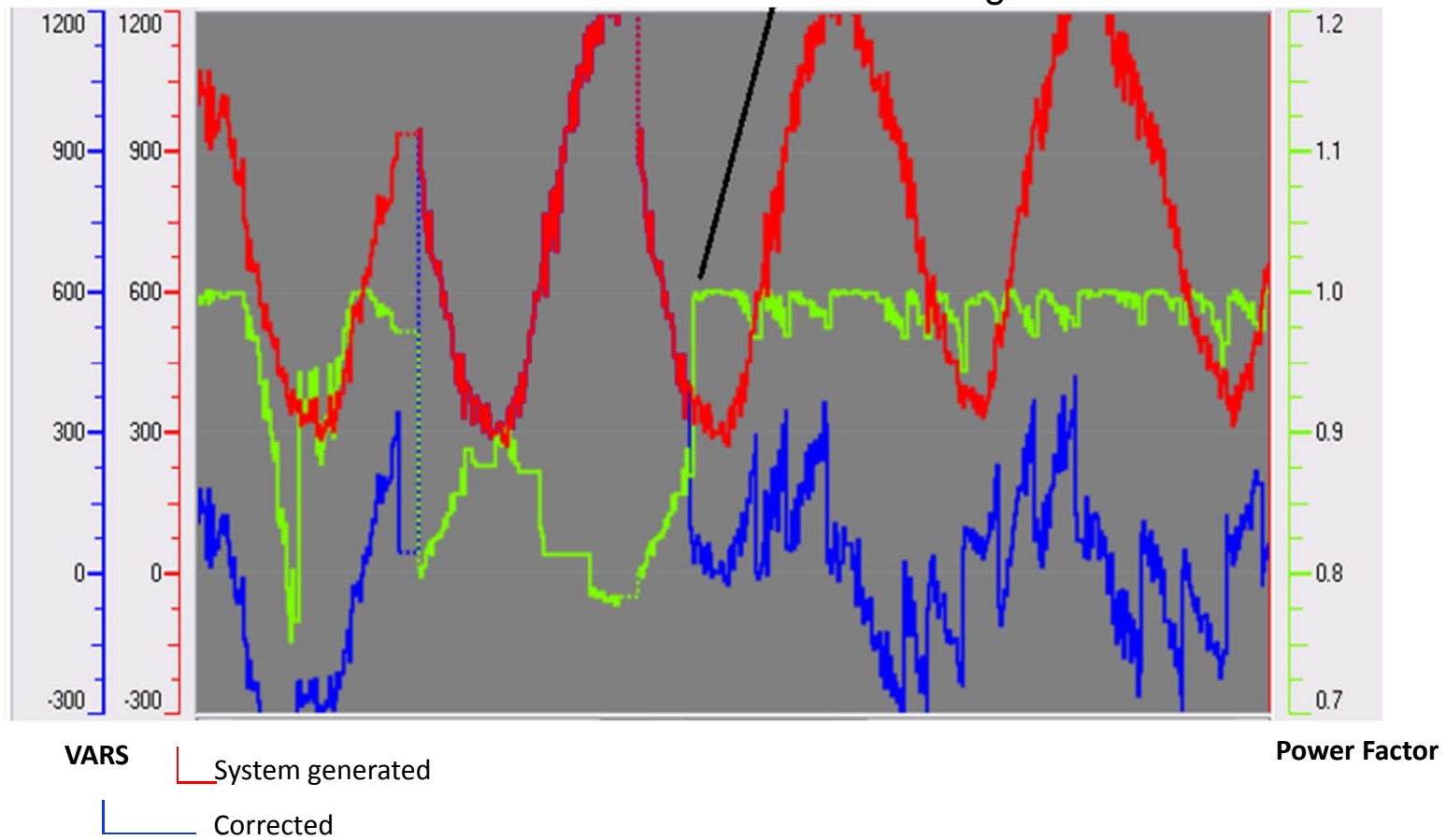
Successful Fault Location Isolation, Restoration without Voltage Optimization

Self Healing – No VVO



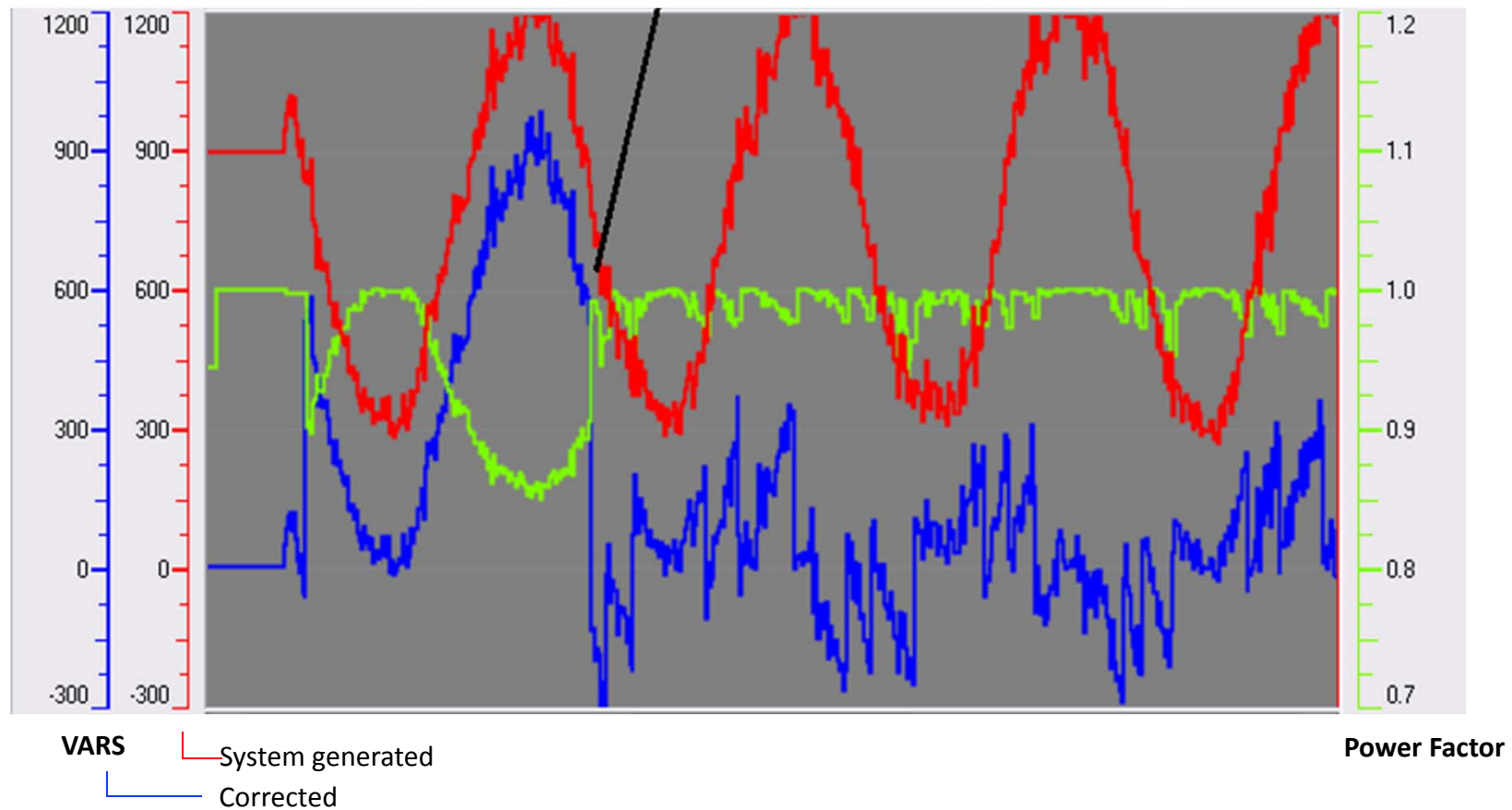
Voltage Optimization

VVO without self healing automation



Successful Fault Location, Isolation, Restoration AND Optimized Voltage Control

Self Healing and VVO Coordinated



Successful Self Healing



Key takeaways



Manage outage restoration from event through restoration to return to normal



Improve power quality and reduce customers impact of faults



Improve safety of line crews by providing the accurate information about the fault location and affected assets



Platform for pre-preparation and modeling that can be used to communicate with media, regulators, customers & employees

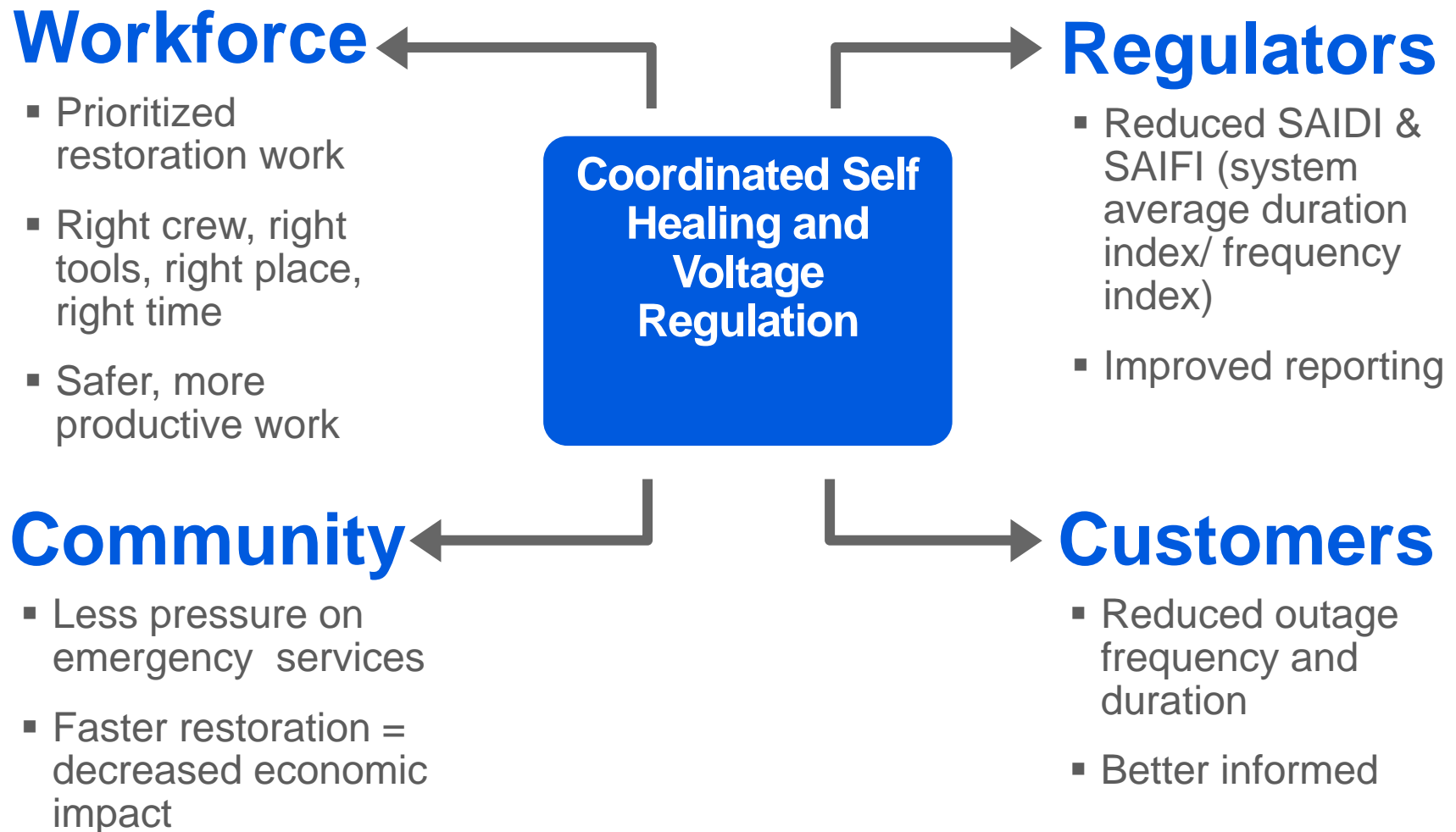


Increase stakeholder satisfaction by providing timely, accurate and usable information on a timely basis, improve power quality and reliability



Ensure compliance with regulatory requirements such as system and customer average interruption and duration indices

Coordinating Protection and Voltage Control benefits all stakeholders



Thank You

Performance-based measures

IEEE Std 1366

SAIFI

System Average Interruption Frequency

$$= \frac{\text{Total number of customer interrupted}}{\text{Total number of customers served}}$$

SAIDI

System Average Interruption Duration

$$= \frac{\text{Sum of customer interruption duration}}{\text{Total number of customers served}}$$

CAIDI

Customer Interruption Duration

$$= \frac{\text{Sum of customer interruption duration}}{\text{Total number of customers interrupted}}$$

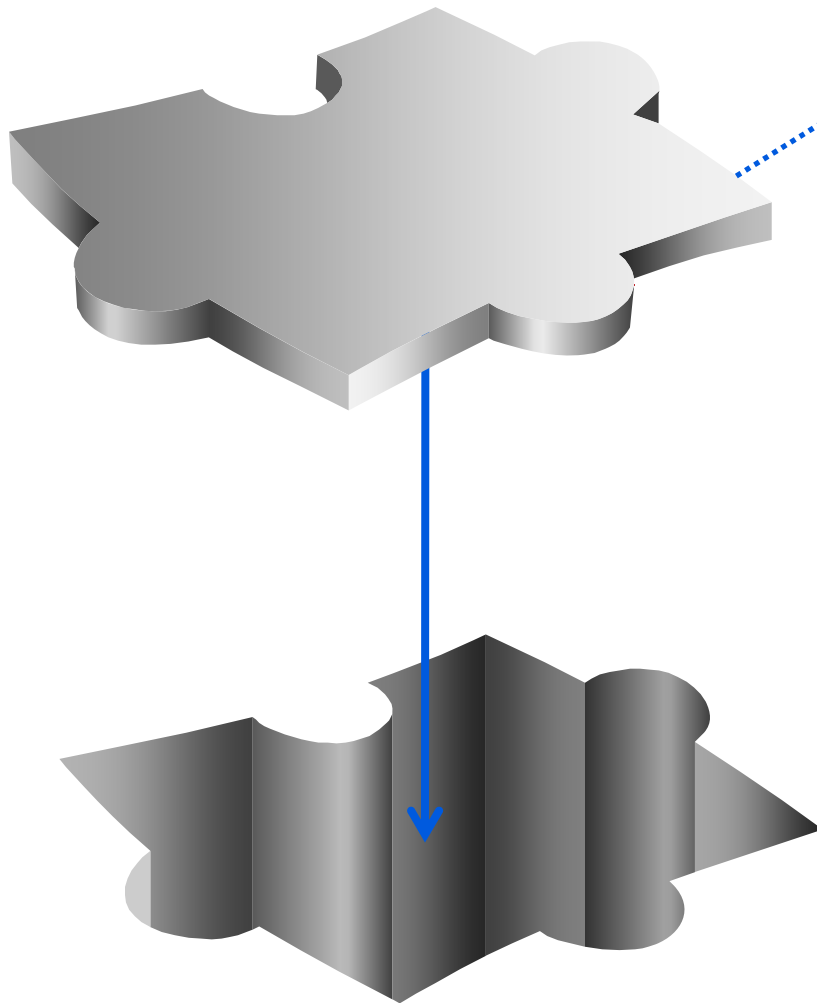
MAIFI

Momentary Ave. Interruption Frequency

$$= \frac{\text{Total number of customer momentary interruptions}}{\text{Total number of customers served}}$$

Ranking priorities in smart grid

Improving reliability



Solutions offered

- Fault detection isolation and restoration (FDIR)
- Distribution/outage mgt system (DMS/OMS)

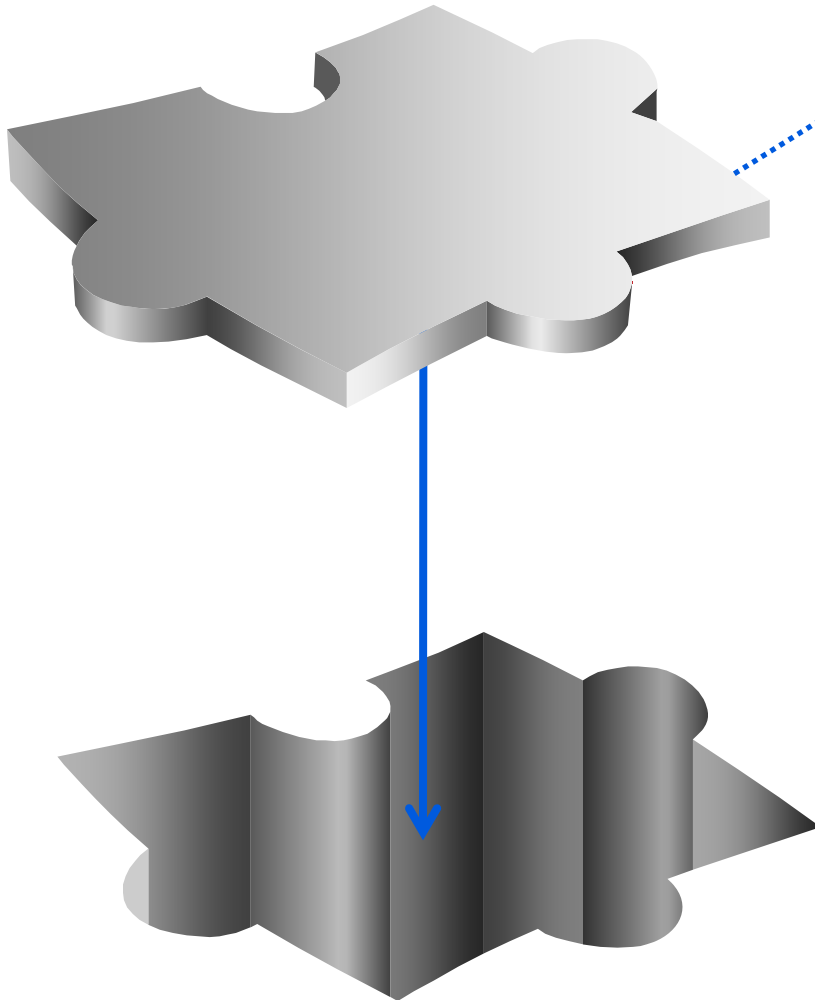
Benefits observed

- Improved SAIDI, SAIFI, etc.
- Up to 30% reduced outage
- Faster restoration: from hours to seconds

Advanced applications to optimize power distribution

Ranking priorities in smart grid

Improving efficiency



Solutions offered

- Volt-VAr optimization (VVO)
- Conservation voltage reduction (CVR)

Benefits observed

- Reduced carbon emissions
- Reduced line losses
 - Up to 7% reduction
- Improved power factor
 - Up to 0.98
- Decrease power purchase
 - Up to 3% MWh reduction