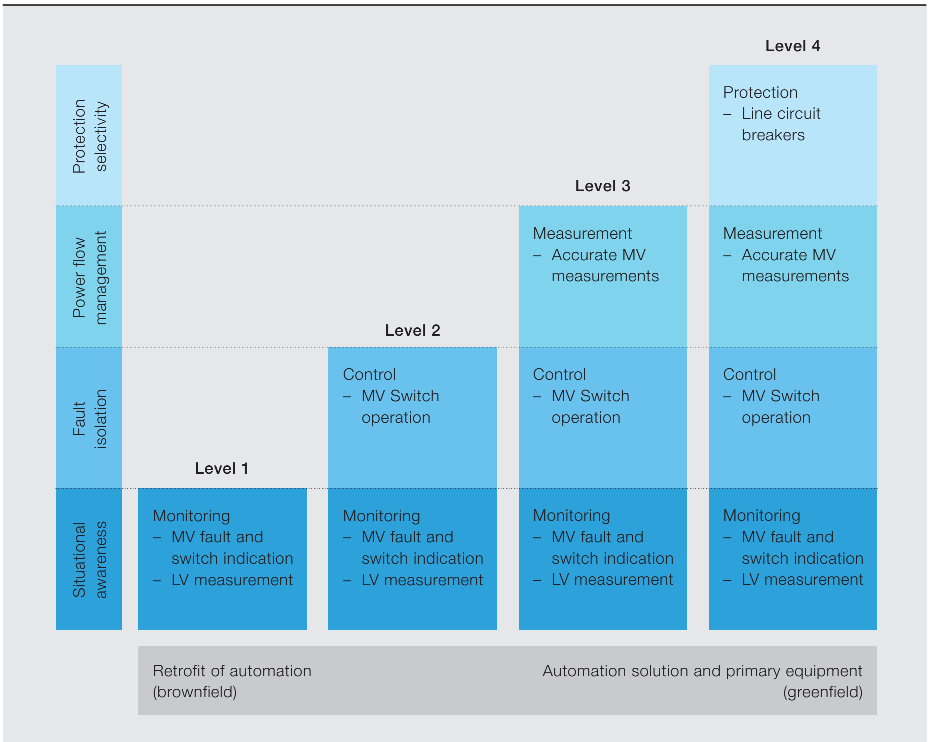
Break free

Outages can be reduced by handling faults in an intelligent way

VINCENZO BALZANO – The permeation of intelligence into the medium-voltage network is continuing apace, bringing the reality of the smart grid ever closer. One target of the smart grid is to improve service continuity by recognizing, locating and isolating faults as quickly as possible. At the same time, the amount of equipment taken out of service should be minimized in order to keep energy provision to the consumer at a maximum. Although faults and outages have always occurred in the power network, their frequency has increased with the growth of renewable energy sources connecting to the grid. To mitigate the effects of faults and outages, improve continuity and quality of electrical service, and increase the network energy efficiency while minimizing losses, it becomes necessary for network monitoring equipment to work in real time and intelligently.

If a fault occurs at any point in an electrical distribution circuit, it is essential that it is recognized, located and isolated in the shortest possible time.

1 Automation equipment can be classed in four logical levels



If a fault occurs at any point in an electrical distribution circuit, it is essential that the fault is recognized, located and isolated in the shortest possible time. Circuit breakers (CBs) are used to isolate the faulty section and the extent of this has to be minimized in order to reduce disruption to consumers. In parallel, power should be quickly restored to the maximum number of consumers possible by rerouting the power flow through unaffected areas.

Apart from consumer inconvenience, these failures give rise to significant costs and negatively impact resource planning, efficiency and profitability for utilities. In addition, utilities now come under intense scrutiny from overseeing bodies, like public ombudsmen, who have the power to administer penalties and levy fines. Therefore, utilities are highly motivated to avoid outages.

Logic selectivity is used when it is necessary to drastically reduce the number of outages, and their duration.

Metrics that matter

Utility performance is measured using a number of metrics. Two primary measurements are SAIDI (system average interruption duration index) and SAIFI (system average interruption frequency index). Government agencies and public utility commissions (PUCs) use these metrics to help them make various decisions – eg, whether or not to levy fines, or how high these should be.

The calculations for SAIDI and SAIFI are similar, and both metrics are related to unplanned outages. Short-term outages, called momentary disruptions, do not affect these indices, but the permissible disruption length is set by the local agencies and may vary from place to place.

SAIDI deals with the duration of the outage, that is, how long the customer is without power. Once a customer calls the utility to report an outage and the outage exceeds a set maximum time, the clock starts ticking on this metric. SAIDI is the annual outage duration per customer.

Title picture
To keep power flowing to as many customers as possible during fault conditions, it is necessary to minimize the section taken out of service. What products and strategies are available to do this?

2 The REC615 is a dedicated grid automation IED designed for remote control and monitoring, protection, fault indication, power quality analysis and automation.

SAIFI is concerned with the frequency of unplanned outages. In this case, each new outage that exceeds a set time affects this metric regardless of how long the customer is eventually without power. SAIFI is the annual number of interruptions per customer.

CAIDI (customer average interruption duration index) is a reliability index arrived at by dividing SAIDI by SAIFI.

To put these metrics in perspective: They are the basis of the decisions by some major utilities to budget several million dollars a year for fines arising from non-compliance.

Proper management of faults and outages provides a way to improve these metrics and reduce the risk of incurring large fines.

FDIR and logic selectivity

In general, there are two approaches to tackling faults and outages to improve service continuity:

- Fault detection isolation and restoration (FDIR)
- Logic selectivity

FDIR allows utilities to increase grid reliability mainly by decreasing the duration of outages for customers affected by unplanned incidents. Benefits of FDIR include improved customer service and increased revenues. FDIR reduces the cost of restoration as well as the risk of fines and lawsuits.

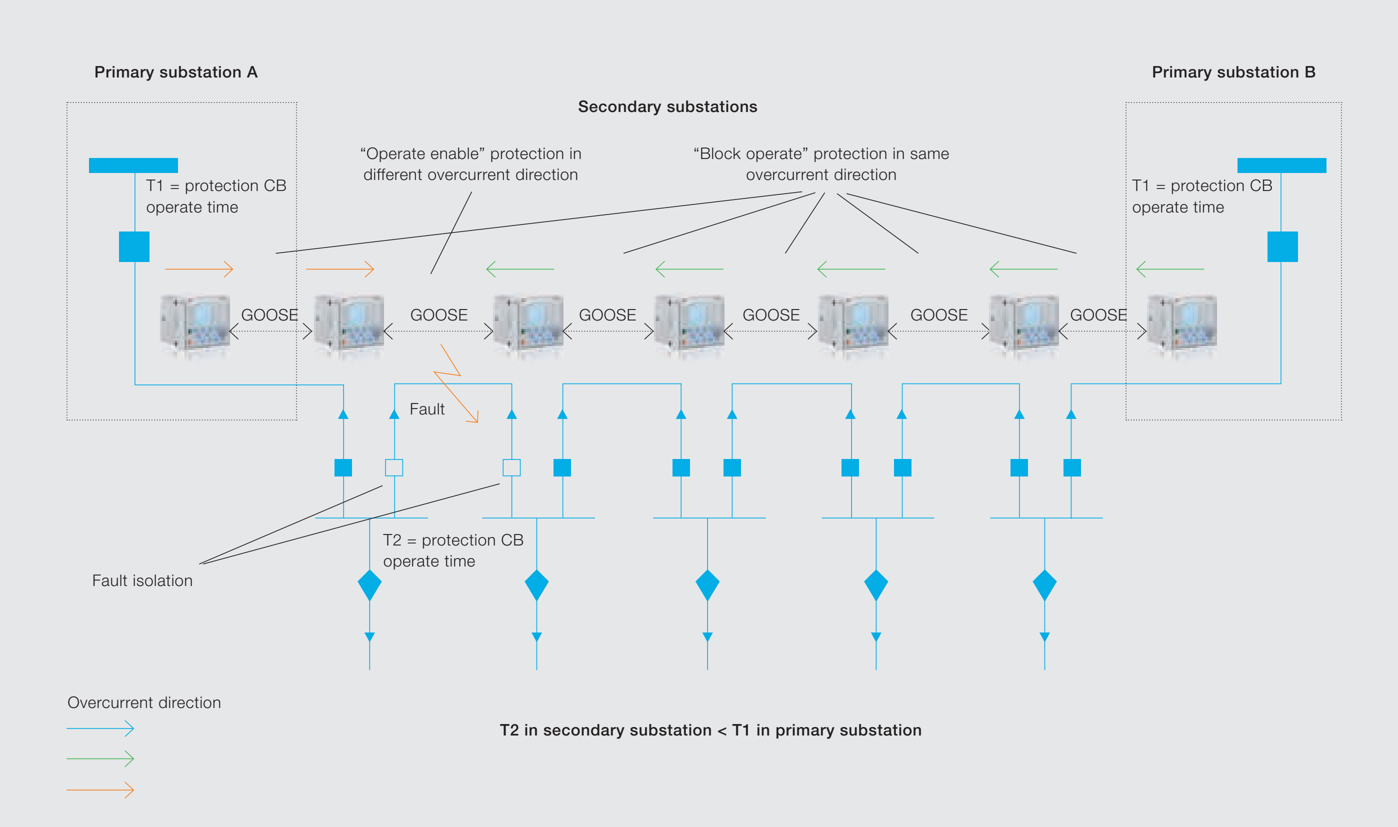
Logic selectivity is used when it is necessary to drastically reduce the number of outages, and their duration. The logic selectivity system allows rapid fault isolation. The system has the great benefit of isolating the fault without users other than those directly affected seeing any effect. Investment in primary equipment and communication network infrastructure might be required to accommodate the logic selectivity system – eg, circuit breakers and IEC 61850-protocol-enabled protection in secondary substations, or pole-mounted reclosers, in combination with a high-performance communication network that can provide the low latency necessary.

Remedial strategies for both FDIR and logic selectivity can occur on a number of levels:

- Peer-to-peer, where a group of switchgear or outdoor equipment operates in unison to restore power in the most optimal manner, and at substation level, where a coordinated control between switchgear or outdoor equipment is performed

Apart from consumer inconvenience, power failures cause a significant expense and negatively impact resource planning, efficiency and profitability for utilities.

3 Isolating the fault in an intelligent manner minimizes disruption.



> Metrics like CAIDI are the basis of the decisions by some major utilities to budget several million dollars a year for the fines arising from noncompliance.

within a substation or with adjacent substations.
- Centralized level, where coordinated control extends across the distribution grid.

These strategies bring further advantages, such as reduced revenue loss and improvement of the utility's reputation in the eyes of customers, stockholders and regulators.

Grid automation

To successfully monitor and rectify grid outages, intelligent grid automation equipment is necessary. ABB has a wide variety of intelligent grid automation products, such as UniGear Digital for primary substations; SafeRing/SafePlus gas-insulated ring main units and UniSec air-insulated switchgear for secondary substations; Sectos and OVR reclosers for outdoor apparatus; UniPack-G for compact substations; RER/REC 601, 603, 615 and RIO600 for intelligent electronic devices (IEDs); and GAO and GAI intelligent low-voltage cabinets for outdoor and indoor retrofits.

Numerous investigations have shown that, as far as grid automation products are concerned, a "one size fits all" approach does not work – so ABB has defined four levels that correspond to the different functional levels of automation → 1.

Level 1 is the basic solution, which includes monitoring of the entire secondary substation, and current, voltage and energy measurement on the low-voltage side.

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Level 2 adds control of medium-voltage and low-voltage primary apparatus to level 1. FDIR is enabled on this level by devices such as the ABB REC603 wireless controller – a device for the remote control and monitoring of secondary substations, such as ring main units with switch disconnectors in distribution networks.

Level 3 adds to level 2 accurate current, voltage and energy measurement on the medium-voltage side: Power flows can be managed with proper instrumentation and IEDs, which is important when distributed generation is connected to the distribution grid.

When a failure occurs, only the breakers in the substations immediately upstream and downstream of the fault are opened.

Level 4 is the most technically complete solution. Here, the circuit breaker and protection relay are essential in order to manage the logic selectivity and increase performance in topologies ranging from a simple radial topology up to a complex meshed solution. Level 4 adds to level 3 protection functions utilizing breakers on incoming and/or outgoing feeders.

This level features products such as the REC615 → 2. With the REC615, grid reliability can be enhanced as it can provide functionality ranging from basic, nondirectional overload protection all the way up to extended protection functionality with power quality analysis. Thus, it supports the protection of overhead line and cable feeders in isolated neutral, resistance-earthed, compensated and solidly earthed networks. In addition to the essential protection functionality, it can also handle applications where multiple objects are controlled, based on either traditional or sensor technology. REC615 is freely programmable with horizontal GOOSE (generic object-oriented substation events) communication, thus enabling sophisticated interlocking functions. It supports also specific protocol communication such as IEC 60870-5-101 and IEC 60870-5-104.

Logic selectivity

At level 4, the logic selectivity approach can reduce the number of outages without isolating users that are not directly affected by the fault. It can also accurately isolate the fault branch by quickly opening the adjacent circuit breaker(s) and reduce the fault time to hundreds of milliseconds, as opposed to the minutes associated with the FDIR approach.

The high performance of logic selectivity requires high-speed communication – usually using a protocol based on IEC 61850, which can perform peer-to-peer multicast. Generic substation events (GSE) is a control model defined by IEC 61850 that provides a fast and reliable way to transfer data over the substation network. GSE ensures the same event message is received by multiple devices. GOOSE is a subdivision of GSE. For good performance, it must be guaranteed that communication between two nodes of the network be accomplished inside tens of milliseconds.

In fact, the selectivity algorithm normally assumes that this high speed of communication does exist between the substations on the medium-voltage line involved and the relevant protection relays. When a failure occurs, the protection relays related to the area concerned communicate with each other and then only the substations immediately upstream and downstream of the fault are signaled to open the appropriate breakers. The selection algorithm must terminate and extinguish the fault conditions within the delay times set in the primary substation, ie, within the time after which the circuit breaker opens in the primary substation → 3.

The use of circuit breakers, devices based on IEC 61850 and the widespread introduction of a communication network with low latency enable the implementation of massive selectivity logic on the secondary distribution network. This results in early detection and quick restoration – meaning a reduced number of outages and reduced average interruption duration for the customer. This is welcomed by utilities at a time when PUCs and government agencies are increasing their scrutiny of SAIDI, SAIFI and other related metrics.

As growing demand for power and a growing number of renewable sources puts additional burdens on the grid, the scrutiny of unplanned outages is expected to continue to increase. The smart utility will leverage technology to better manage faults and outages – and thus cut operating expenses and improve service reliability to ready themselves for the energy industry dynamics of the future.

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