EVALUATION OF A SELF HEALING DISTRIBUTION AUTOMATION SCHEME ON THE ISLE OF WIGHT

David MACLEMAN  Scottish and Southern Energy – UK  David.MacLeman@scottish-southern.co.uk
Witold BIK  S&C Electric - US  WBik@Sandc.com
Andrew JONES  S&C Electric Europe - UK  andrew.jones@sandc.com

ABSTRACT

The paper will describe the challenges and implementation of self healing distribution automation scheme implemented by Scottish and Southern Energy on the Isle of Wight in 2008. This involved the supply of equipment by S&C Electric Europe Ltd covering several 11KV feeder and substations. It will describe the equipment used that when combined offered a self healing real time solution to distribution networks and how this improves network reliability.

It will discuss the products being used and the features chosen by Scottish and Southern energy to introduce a self healing real time alternative solution to conventional centralised Scada control to improve network performance. The S&C IntelliRupter pulse closer will be discussed along with how the patented pulse closing can be used to extend network life and restore networks even when there is a loss of communication. IntelliTEAM ii peer to peer communications and universal interface modules and their benefits and interface with existing equipment and Scada will be covered.

INTRODUCTION


IntelliTEAM II fully supports SCADA operation, and automatically sectionalizes to isolate a faulted line section and will restore power in significantly less than the 3-minute restoration target set by OFGEM. The S&C IntelliRupter® PulseCloser was chosen because its patented pulseclosing will extend network service life, and the IntelliTEAM II Universal Interface Module allows existing substation breakers to also function as IntelliTEAM II team members. It also consists of stainless steel construction to resist corrosion in exposed coastal environments.

TEST SYSTEM

The Isle of Wight was chosen for this pilot project because it is representative of typical SSE network layouts, and the area is subject to severe weather conditions that will test IntelliTEAM II performance.

The 11 kV feeders comprise a mixed network of underground and overhead feeders. The existing conventional reclosers and air-break load switches were moved to alternative locations as they were replaced by IntelliRupters.

DEVICE LOCATION

S&C and SSE jointly developed a spreadsheet to determine device location based on the most cost effective reliability improvement. The following information helped evaluate the switching device location impact on customer minutes lost, total load lost, and customer interruptions –

- Fault rate
- Average time to switch
- Average time to complete a repair
- Underground / overhead split

INTELLIRUPTER PULSE CLOSERS

32 S&C IntelliRupters were installed on 9 feeders. The visible disconnect model has control power supplied by two integral power modules fed by a different phase on each side of the device. Three-pole vacuum fault-interrupters are individually operated by magnetic latching actuators capable of 2-millisecond close-open (pulse) operation and have integral voltage and current sensors. The communication module has a Radius PRD121 VHF radio. The control module and the communication modules are mounted in the unitized stainless-steel IntelliRupter base and are easily accessible. The self-contained IntelliRupter is put on the pole with a single-point lift, and the only site wiring is to connect the IntelliRupter to the power line.

Due to their accuracy and speed of response, often more IntelliRupters can be coordinated in series than conventional reclosers. An IntelliRupter measures current in both directions and can coordinate in either direction. Protection capabilities include simultaneous independent directional phase, ground, and negative-sequence time-overcurrent elements; simultaneous independent directional phase, ground, and negative-sequence definite-time elements; directional blocking overcurrent elements, intelligent fuse saving overcurrent elements; over voltage/under voltage elements, and sensitive earth faults.

IntelliRupter pulseclosing tests fault persistence by injecting
a minor loop of energy after the initial interruption. Conventional reclosers must test by reclosing into the fault, which produces high-asymmetrical current and stresses all system components.

**Fig 1a**

Shows the fault current that exists when a recloser or breaker is closed into a permanent fault and the impact on the un-faulted phases when this is done.

**Fig 1b**

Clearly shows the improvement when Pulseclosing Technology is used to test a permanent fault.

Low-current Pulseclosing Technology as seen in fig 2 above can safely test as many times as required to determine if a fault is permanent. It also will improve conductor life, conductor accessory life, and transformer life – compared to the hard reclose used by a conventional recloser for fault-persistence testing.

**Fig 2.**

Pulseclosing a string of devices also allows safe restoration if communication is lost. Pulseclosing can also be used to get more devices in series on a network when the devices share the same curves. In the sequence below, Devices 2 to 5 share the same A3 protection curve, to illustrate how pulseclosing works.

**Fig 3a**

Initial circuit with 5 IntelliRupters in sequence.

**Fig 3b**

Fault occurs between devices 4 and 5, and devices 2 to 4 open.

**Fig 3c**

After 1 sec (can be preset to various values) device 2 pulses to check if the fault is located between it and device 3.

**Fig 3d**

Device 2 closes because it has confirmed no fault between it and device 3.
**Fig 3c**

Pulse-closing is repeated so that every 0.5 second the next device in series pulses to check if the fault exists between it and the next device. This shows the final status of the feeder, which is achieved after 2 seconds – and no communication was used.

**INTELLITEAM II UNIVERSAL INTERFACE MODULE**

Universal Interface Modules (UIM) were installed at the substation breaker controls on the 11 kV system, so that the existing substation breakers could also operate as IntelliTEAM II team members. The UIM takes information from the existing breaker relay and supplies real-time feeder loading information to its team. For the system on the Isle of Wight, UIM devices will also be installed at the 33 kV breaker-control relays to communicate possible load constraints on the 33 kV network.

The UIM enables Intelligent Electronic Devices (IED) not of S&C manufacture, such as breaker relays, to function as team members in an IntelliTEAM II system. A UIM does not add new features to its host IED, its function is to enable the host device to communicate with other team members and implement the restoration scheme. Fault interrupting and protective functions remain under control of the host IED. The UIM connects to the protective relay or recloser control with a serial or Ethernet cable. IntelliTEAM II can then acquire status information and analogue data from the IED and the IED can respond to team commands. The UIM also supports DNP 3.0 Protocol for communication with the SCADA master or substation RTU. All UIM DNP points are configurable, and consist of all of the DNP points normally scanned by the SCADA master, and all IntelliTEAM II DNP points.

**INTELLITEAM II AUTOMATIC RESTORATION SYSTEM**

In this pilot project, IntelliTEAM II works with IntelliRupters and Universal Interface Modules to improve network reliability for critical areas of the distribution system. It is scaleable, and can be expanded to work on the entire network, and is ideal for a pilot system test. IntelliTEAM II requires no central monitoring or SCADA control, though SCADA is fully supported. With IntelliTEAM II, restoration proceeds without the delays inherent in a dispatcher-operated or centrally controlled system. It monitors real-time current and voltage throughout the system and uses this information to make smart switching decisions, and it acts locally before breakers or reclosers lock-out.

Unlike time-coordinated restoration systems that must be carefully pre-programmed, sophisticated IntelliTEAM II operating logic can automatically restore service during multiple-event contingencies. During storms or major outages, it quickly returns service to as many customers as possible, freeing utility personnel to deal with system repairs. IntelliTEAM II minimizes “Customer Minutes of Interruption” and “Customer Interruptions”, improving system reliability ratings. And when IntelliRupters are installed, “Short Interruptions” are eliminated for upstream customers.

IntelliTEAM II supports complex systems of virtually any size and accommodates tie points from multiple sources. It can handle as many teams of switches as line loading will allow. Restoration capacity is based on real-time loading and actual feeder capacity, with the result that it prevents overloading during restoration, which was critical for the pilot system due to the limited capacity of some feeders. The excess capacity of adjacent sources is used to restore service to un-faulted segments, helping defer the need for system upgrades and allowing tie circuits that traditional planning criteria wouldn’t permit. In the pilot system, IntelliTEAM II uses DNP 3.0 Protocol and peer-to-peer communication with Radius VHF radios. SCADA communication is implemented with a gateway at each substation.

Team and coach metaphors describe IntelliTEAM II operation. Each team is a line segment bounded by up to eight switching points, each of which can be an alternate power source. The software coach continually monitors real-time voltage and current at each team member and shares this information with coaches of adjacent teams. When an outage or line fault occurs, the coach of each affected team uses the real-time data, plus voltage and current prior to the system event, to develop a restoration strategy.

IntelliTEAM II operating principles are simple:

- The mission of each team is to maintain power on its line segment, using the normal power source whenever possible.
- Each team communicates with neighbouring teams through controls they share in common. The excess capacity of a neighbouring team is a
possible restoration source that is available at the shared switch.

- Each switch control monitors the current and voltage at its switches. If a fault occurs, the coach of the faulted team recognises that the fault is located in its team because fault current was sensed at only one team switch. The coach of the faulted team prevents the automated devices bounding the segment from closing, which isolates the fault.

- If an un-faulted team experiences extended loss of voltage, its coach evaluates the excess capacity of neighbouring teams and transfers load to the first team that has sufficient excess capacity. The alternate source can be more than one team away, and inter-team data exchange ensures the sharing of excess capacity and coordination of restoration decisions. The order in which alternate sources are specified can be prioritized.

- When normal power has been restored or the fault has been corrected, the system returns to its normal configuration, either manually, automatically, or via SCADA control. If another event takes place after the team has transferred to an alternate source, the team will seek a different alternate source to keep its line segment energized. The ability to respond to multiple contingencies makes it a much more effective tool than other restoration systems.

CONCLUSION

When this paper was written, about half the devices had been installed, and IntelliTEAM II has not been commissioned. By the conference date, we expect that SSE has commissioned IntelliTEAM II and evaluated the actual system performance improvements. Currently the expectation is that the pilot will prove the concept of self-healing networks that achieve significant improvements in network reliability.