PARALLEL FEEDER OPERATION SCHEME BASED ON DISTRIBUTED AUTOMATION LOGIC

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ABSTRACT

Conventional distribution system supplies loads radially, and often relies on tied adjacent feeders to provide alternative supply during outage. This results in customer outages of varying duration while the fault is located and isolated and restored, which can be very costly to the impacted customers. This paper describes one unique distribution automation scheme implemented in BC Hydro which provides uninterruptable power service to connected customers. With the implemented networked feeder DA scheme based on distributed automation logic, the critical customer loads are supplied from two parallel feeders from neighbouring substations with the two feeders are normally tied together and operated in parallel continuously. Based on sophisticated protection and telecommunications scheme, when either of the feeders experiences a fault, fault interrupters quickly isolate the critical customers from the fault based on preset automation logic and the load remains continuously supplied from the alternate feeder. Instead of experiencing an outage, the customers' service will be maintained uninterrupted but only experience a momentary voltage dip while the fault is cleared in 3 to 5 cycles. The DA system configuration, telecommunication and SCADA functionalities and detail protection logics are described in this paper. Practical considerations for voltage control to minimize the distribution tie current are introduced as well.

INTRODUCTION

Digital economy requires high reliable power and reliability improvement has been one key business driver for advanced distribution automation (DA). Considering the fact the conventional distribution system are designed to serve load radially, utilities often implement open loop type of distribution automation scheme to achieve this goal. While this does reduce the customer outage interruption duration to the level of minutes, customers affected still experience power supply interruption. This may not be acceptable for customers need higher system supply reliability. This paper describes one unique distribution automation scheme [1-3] implemented in BC Hydro, which is designed to operate in a parallel feeder operation configuration. Equipped with distributed automation intelligence, it provides uninterruptable power service to downstream customers.

DV2010 DA SCHEME

The project was initiated as a result of BC Hydro's membership in the Distribution Vision 2010 LLC (DV2010) research consortium[4]. DV2010 is a utility research and development alliance formed in 2001 which aims to develop the advanced distribution automation solution that can be employed to meet the future customer reliability requirements. Advocating the idea for utilities to proactively (instead reactively) improve the supply reliability, it proposed one 4-tier distribution automation design[5]:

- Tier-1: autonomous protection
- Tier-2: distributed automation logic
- Tier-3: substation local area control
- Tier-4: regional wide area controls

Each tier provides independent automation features. DA systems can be designed with one or all tiers of automation to customize the system performance and optimize customer reliability. It worth noting that DV2010 defines DA as the solution which can react to outage as first response without human intervention, so operations require operator's involvement such as operators' remote control and outage restoration via traditional SCADA system are not considered as part of DA solution.

Detailed in this paper, is a tier-two DA scheme based on distributed automation logic, which has been operating at BC Hydro since 2006.

PARALLEL FEEDERS SOLUTION

Conventional distribution system supplies loads radially, which means that every loading point on distribution feeders only connected to one supply source at any time. To maintain the supply reliability, distribution feeders are often sectionalized and normally open tie switches are installed between feeders to provide alternative supply sources when one of the feeder supplies is lost. This results in customer outages of varying duration while the fault is located and isolated and restored, which can be very costly to the impacted customers. Distribution automation or supervised remote control/switching often is implemented to speedup the restoration process and reduce the customer interruption duration. However, the customer will experience service interruption due to the outage.

Unlike the conventional radial supply, the DA scheme based on distributed automation logic employs networked feeder topology to serve the critical customer loads, in which two 12kv feeders from neighboring substations are normally tied together and operated in parallel continuously to supply downstream customers (here it is shopping centre load). The networked feeder topology can be found in

Figure 1.

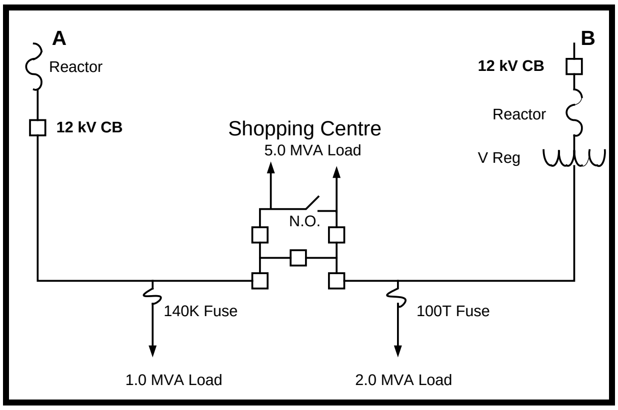

Figure 1 Networked Feeder Supply

The DA system integrates two custom designed pad mounted Loop Tap Switches (LTSs) with sophisticated protection and telecommunications scheme. Each LTS is an assembly with three Cooper Power Vacuum Fault Interrupters (VFI) switchgears. The LTS layout and site configuration is shown schematically in Figure 2.

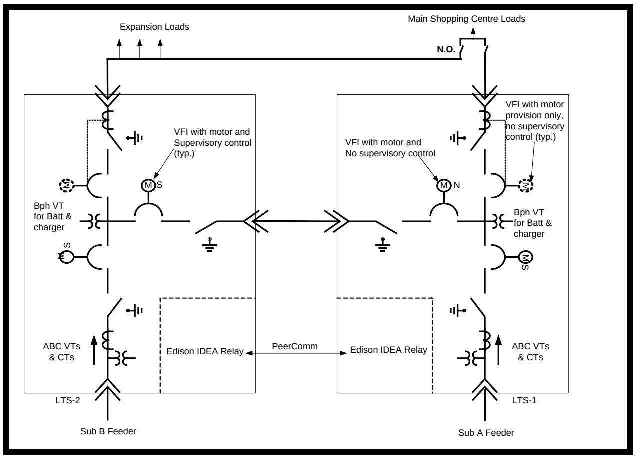

Figure 2 Loop Tap Switches Configuration

As shown in Figure 2, all six VFIs are in Normal Closed status during normal operation so provide the downstream load (shopping centre) with high availability service. Sufficient spare capacity is retained in the feeders to supply the shopping centre load from either feeder. When either of the feeders experiences a fault, fault interrupters inside the LTSs quickly isolate the critical customers from the fault based on preset automation logic and the load remains continuously supplied from the alternate feeder. Instead of experiencing an outage, the customers' service will be maintained uninterrupted but only experience a momentary voltage dip while the fault is cleared in 3 to 5 cycles.
The following shows a site picture of the two LTSs installed on site of the shopping center. It demos the modular design of this DA solution which can be easily deployed for other major customers who need similar reliability.

Figure 3 Loop Tap Switches on Site

While short duration temporary parallels in distribution primaries are often permitted for operations and for system expansion projects, operating with feeders normally tied at the primary voltage level is unusual due to increased fault levels. Fault studies were conducted to determine fault levels at all buses during various transmission and distribution configurations which resulted in various system upgrading, such as cutout upgrade, current limiting fuse installation, etc. Current limiting reactors are installed on each feeder at station side as well to restrict downstream fault levels.

It worth mentioning that the two stations are also directly tied in upper transmission voltage level 69kv system. Careful consideration has been also given to voltage regulation. Since both substations have 60/12.5 kV transformers which are normally operated in parallel with closed CBs on both the 60 kV and 12.5 kV sides, Station A transformers' Load Tap-Changers (LTCs) are set to operate in unison so that both are on the same tap position in the normal configuration. Station B transformers have fixed taps, feeder voltage regulators are used to adjust the sending voltage. In normal operation, there is current flow through the distribution tie, but no current will flow back to either station.

DISTRIBUTED AUTOMATION LOGIC

The communications and control system used is shown in Figure 4. The physical layer is a mixture of 2400 bps leased telephone, fibre, and OC-1 microwave to the Area Control Centre. Communications protocols used are SEL Mirrored Bits between the two SEL-351S relays and a SEL-2100 Logic Processor on site, CPS PeerComm between the two IDEA relays, DNP 3.0 between the IDEA relays and a GE D25 data concentrator on site, and DNP3.0 between the D25 and the Area Control Centre. Twisted pairs are used for hardwired outputs from the SEL-2100 to the IDEA relays.

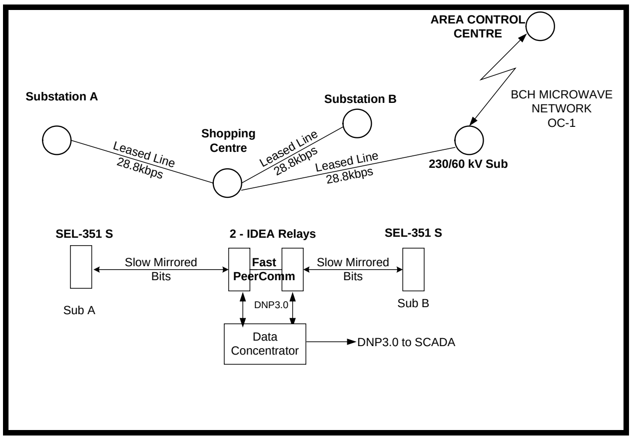

Figure 4 Communication Networks and SCADA Links

The heart of the solution is the protection coordination based on preset automation logic. The key components consist of SEL 351S relays in the substation feeder Circuit Breaker (CB) positions and the six VFIs in the two LTSs in ahead of the shopping centre.

Incoming VFIs on each LTS assembly are controlled by Cooper IDEA relays. IDEA relays exchange information every 4ms by high speed PeerComm telecommunications via fibre, which enables VFIs to response to any outage situation than with conventional relays. The IDEA relays will use directional elements to clear upstream faults on either feeder as well as to provide control, indication and telemetry to the Area Control Centre. If either loop tap switch is required to be de-energized, load can be safely transferred to the other unit.

This secition details the protection considerations and automation logics based on enumerated outage scenarios.

Scenario 1 – Fault between Substation and LTS

The most frequently occurring outage scenario is a fault occurring between either substation feeder CB and the LTSs as these feeder segments are mostly overhead construction. In this case, fault current is supplied from the main source from the substation closest to the fault and the second source from another substation which provides fault current through the distribution loop connected by LTSs. Protection operation is described as follows.

- IDEA relays detect reverse fault current in either of the incoming positions and quickly clear the fault via tripping VFI in the incoming position of the faulted feeder, typically in 3 to 5 cycles. Note that Only the VFI closest to the fault trips. This step isolates shopping centre loads from the fault and transfers the full load to the un-faulted supply feeder.
- SEL-351S relay in the station with the faulted feeder trips the feeder CB, typically in 8 to 10 cycles; no directional capability is required. A single automatic reclose of this CB is allowed, provided reclosing is not blocked. However, reclosing is typically disabled whenever a Live Line Permit is issued for worker protection.
- IDEA relays monitor the source side of the open VFI for voltage restoration. If voltage is restored, the IDEA permissively closes the incoming VFI to restore the primary loop and resets the voltage timer. Otherwise, the fault is permanent and field staffs are dispatched to patrol the line.

In the case only where a permanent fault occurs between Station A and upstream of LTS, the Station B feeder voltage regulator is automatically enabled to compensate for line drop to shopping centre. The shopping centre loads may experience low voltage temporarily while the regulator moves to the appropriate tap position.

In this outage scenario, customer will experience no interruption but just several cycles of voltage dip while the fault is cleared.

Scenario 2 – Fault on Radial Cables Downstream of LTSs

A fault occurring downstream of either LTS in the shopping centre side will be cleared by the corresponding VFI closest to the fault. These VFIs rely on time overcurrent coordination with downstream devices. The IDEA relays monitor incoming and outgoing fault currents to the LTSs, and inhibit any protection mis-operation by only tripping the appropriate downstream VFIs.

This is considered low probability outage since the underground cables downstream the LTSs in the shopping centre side are recently replaced and reasonably short. While if this does occur, the shopping centre load within the faulted feeder section will be out of power. Manual restoration is required by the crew visit to manually operate the normal open tie switch which separates the shopping centre load into to portions.

Scenario 3 – Internal Fault on Distribution Tie Cables

When an internal fault occurs on the short tie cables between them, the IDEA relays detect incoming fault current in both source positions, but on neither of the tap positions. There is no way of detecting if the tie positions see the fault as there are no CTs on the tie positions. The most likely location is presumed to be on the tie cables or their terminations. In this case, the IDEA relays quickly trip both VFIs in either side of the distribution tie. This simultaneously breaks the distribution loop tie between the substations.

In this case, the shopping centre load is supplied by two separate feeders without distribution loop. Customer will experience no service interruption.

Scenario 4 – Internal Fault in LTS Switchgear

When an internal fault occurs in either of the LTSs, the IDEA relays detect incoming fault current in both source positions, but on neither of the tap positions. The IDEA relays quickly trip both VFIs in either side of the distribution tie, which breaks the distribution loop tie between the substations.

This time, the IDEA relay still sees the fault current in the incoming VFI, so it knows the fault is in the LTS tank, and the incoming VFI is tripped.

If this action still fails to clear the fault, then the feeder CB at the substation will trip. All of the above is monitored from the control centre.

In this case, shopping centre load downstream the faulted LTS will lose power, while other portion will be uninterrupted and supplied via another feeder.

Scenario 5 – Fault on Transmission Tie

Initially consideration was that whenever a fault occurring in the 69 kV transmission tie between station A and B, the trip of the transmission loop will send signals to the IEDA relays to break the distribution loop thereby splitting the load between the two supplying feeders. This was intended to minimize the risk of reverse circulating current into stations.

This is revised after one second contingency fault which occurred on December 2006 when outages occurred on both transmission tie and one distribution feeder during storm, although normally a second contingency fault is excluded from the regular distribution planning criteria as the probability is low. The revised protection logic is as follows:

- When a fault occurs on the 69 kV transmission circuit connecting both stations A and B, transmission CBs in both station will trip to transmission loop.
- Distribution loop will be tripped if reverse circulating current at any feeder CB at station side is detected.
- In case any coincidental outage on any distribution feeder, it will be cleared by the incoming VFI and the feeder CB in the station

In this case of only transmission circuit outage, shopping centre service will keep uninterrupted. If the distribution loop exists, depends on the situation that time. While if a coincidental feeder outage occurs the same time, distribution loop will be broken and portion of shopping centre load will be interrupted.

SUMMARY

This paper details one unique distribution automation solution deployed at BC Hydro. Unlike the conventional radial supply for distribution customers, it supplies the downstream customers by continuously running two parallel feeders which are normally tied together. This high availability design provides uninterrupted service to customers when fault occurs in either feeder. Sophisticated distributed automation logics are employed in this solution. The DA system configuration, telecommunication/SCADA functionality design, and detail protection logics are described. Practical considerations for voltage control to minimize the distribution tie current are introduced as well.

The parallel networked feeder solution has provided superior supply reliability to customers based on site experience in last several years, and its modular design makes it easy to be deployed for other important commercial customers who require similar level of reliability.

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