Advanced Bus Transfer and Load Shedding Applications with IEC61850

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Abstract - The new communications technology and the newly developed IEC61850 standard for generic object oriented substation events (GOOSE) bring many advantages to the industrial protection and control applications. Some of the applications benefiting the most are the ones associated with the bus transfer and the load shedding schemes, together with more beneficial communication-assisted schemes, like zone-interlocking, fast bus trip, arc-flash reduction, etc. Some Intelligent electronic devices (IEDs) are equipped with more than one high-speed Ethernet channel to transmit/receive hundreds of discrete and analog values. This offers two very big advantages over the copper wired IEDs: the first - a single pair of network cable either copper of fiber, can substitute a big number of standard copper wires, and the second – using two or more network channels provide very good data exchange redundancy and hence higher reliability. The savings on substituting a big number of copper wires by a communication media like Ethernet copper twisted pair cable, or a pair of fiber optic, can be easily calculated.

Index Terms – IEC 61850 protocol, GOOSE, peer to peer communication, motor bus transfer, load shedding

I. INTRODUCTION

The technological advancements in the design of relay hardware and the development of high-speed peer-to-peer communication protocols have resulted in a new generation of intelligent electronic devices (IEDs). An efficient way to apply these devices and obtain a custom-built automatic bus transfer scheme is to use high-speed peer-to-peer IEC61850 GOOSE messaging. IEC61850 uses an Ethernet connection as the medium of communication between the protective relays. This paper takes the reader inside the design of residual voltage bus transfer scheme, as well as load shedding and other schemes, using a pair of multifunctional IEDs, where the usage of copper wires is taken down to a minimum. The paper shows clearly the areas of applications, where reliable exchange of digital and analog information between the protection and control IEDs is achieved through a direct peer-to-peer communications, IEC61850 standard and an Ethernet network.

II. APPLICATION REQUIREMENTS

The bus transfer and load shedding schemes are further discussed as applied to a medium voltage industrial plant. The application requirements for both schemes are that they be fast, reliable, and secure. In order to implement these requirements, a distributed architecture connected by IEC61850 based Generic Object Oriented Substation Event (GOOSE) over Ethernet communications is proposed. This architecture has point-to-point, point-to-multipoint, or multipoint-to-multipoint performance available. The components of a bus transfer and load shed scheme include IEC61850 enabled relays and a communication network.

A. Scheme Redundancy

Since both the bus transfer and the load shedding schemes are critical systems in an industrial plant, redundancy in the scheme is very much desired. In the utility world, this is typically achieved through complete duplication of all components. In the industrial plant environment, a good approximation of redundancy can be achieved with some component redundancy and through the use of the failure properties of the IEC61850 GOOSE.

With the logic of the schemes residing in the relays, they become the first point of redundancy. The relays are connected to a redundant Ethernet communication system (Fig.1), such that no single failure of either device or a component of the Ethernet network affects the operation of the scheme. Each device is connected through both fiber optic channels to two separate Ethernet switches, which send and receive measurements and commands securely. In order to operate the Ethernet network in a redundant ring, the IEEE Rapid Spanning Tree Protocol (RSTP) should be configured in the Ethernet switches. This algorithm detects rings and ring breaks and dynamically re-connects the communication system to re-route messages as needed.

B. Sending and Receiving IEC61850 GOOSE Data Items

The ability of each device to receive line and bus AC information and the ability to send messages is achieved through the use of the IEC61850 GOOSE. The IEC61850 GOOSE is a multicast Ethernet data frame that contains packet description information and a user-defined dataset. The GOOSE dataset can contain information such as remote measurements of Line and Bus Voltages, System Frequency, Phase Angle, Watts, Vars, Breaker status, etc., and can initiate bus transfer, and load-shed commands to the other devices in the scheme.

As a Multicast Ethernet message, the GOOSE message can be sent to multiple locations simultaneously. As such, when one monitoring / measuring device (relay) sends voltage value from one location, it is simultaneously received by the other devices connected to the same network. The time on the wire of a small GOOSE message operating on a 100MB Ethernet network is about 20 μsec.

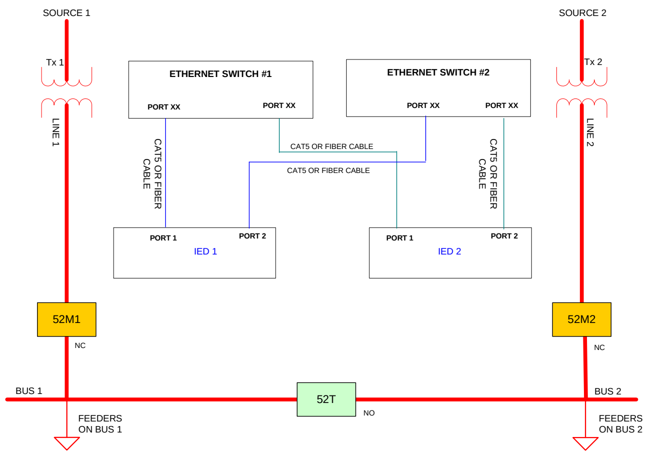

Fig.1 - Main-Tie-Main bus configuration with redundant communication networks

It should be noted that, for data security, all Ethernet physical interfaces should be implemented over fiber optic media. This implementation has a second advantage, which is that the Ethernet signal can travel up to 2km in a single span of multimode fiber. In large industrial facilities, this becomes necessary. Distances longer than 2km can be achieved through the use of an Ethernet switch as a repeater or using single mode fiber/switch ports which can then operate up to 40 km or even longer.

The GOOSE is sent several times in quick succession such that if one packet of information is missed or lost due to a communication error, a repeat of the packet is quickly re-sent. In the case of a binary-only GOOSE message (as would be used in sending the bus transfer and the load-shed commands), the first repeat time can be as little as 4ms.

Transmission of the GOOSE is triggered by either a data change of an item in the dataset being sent or by a periodic time delay. Data change in a binary value is obviously the change of the value either from 0 to 1 or 1 to 0. In the case of an analog value, data change is calculated as a user-defined percent change in the analog value from a given base. For example, if the base value for Volts was 13.8kV and the percent change detect was set at 1%, a 138 V change in the load voltage from the previous value would result in the transmission of the GOOSE containing the updated value of this data item in its dataset.

If, however, the data in the GOOSE dataset is not changing, the subscribing device cannot detect the integrity of the sending device. Detection of remote device integrity is accomplished through a data item in the header of the GOOSE message known as Time Allowed To Live or TTL. The TTL value sent from the publisher tells all the subscribers receiving the published GOOSE, such that the next GOOSE transmission from the publisher will occur in XX time where the XX is set typically in the range of 100ms to 60 seconds. If the receiving device fails to receive a new GOOSE from the publisher in the stated time period, the Subscriber can declare the sending device as "failed" and use alternate values in logic or settings for those in the expected GOOSE.

It is the ability of setting alternative values in the subscribing device for those in a missing GOOSE that enables this architecture to operate without complete redundancy of the metering. For example, if the metering device measuring the load in a facility fails, the subscriber of this load information can choose to substitute either the last known value of the load, or it can select a worst-case load value that was pre-set by the designing engineer (user selectable option). In this manner, the scheme can continue to effectively operate.

III. RESIDUAL VOLTAGE TRANSFER

One of the methods for transferring loads from one source to another source is the residual voltage transfer. This method is designed to trip the old source breaker before closing the new source breaker, whereby the voltage magnitude of the disconnected bus must fall below a predetermined level, before the close command is issued to the new breaker. For Main-Tie-Main schemes, the new source breaker would be the tie-breaker, as in normal condition the tie-breaker is normally open and the two main breakers are normally closed.

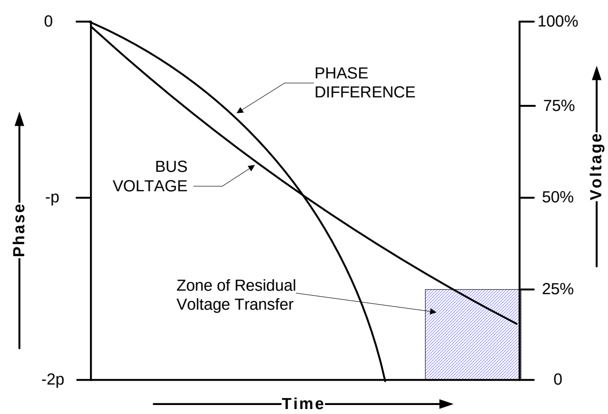

Fig.2 - Voltage decay and phase difference

Since this scheme is unsupervised as to phase angle or slip frequency, this method must prevent closure of the new source breaker until the bus voltage drops below a predetermined voltage limit (Fig.2) or usually below 25% of its nominal voltage level. This voltage level is defined safe to avoid excessive torque on the motor shaft upon connecting the disconnected motor bus to the healthy source. The transfer of big motors to the healthy bus is associated with voltage dip, which may cause the contactors from some other motors connected to this bus to drop out. Thus, some under-voltage analysis and timing coordination must be performed. The set-point accuracy and speed of response of the motor bus transfer under-voltage relay must measure and operate correctly at frequencies below nominal and with a significant rate of change in voltage decay.

During the time necessary to wait for sufficient voltage decay, it is of concern that the frequency may have already decayed past the stall point of the motors on the bus. In such cases, consideration must be given to necessary load shedding, and also in the case, where the new source cannot re-accelerate all bus motors simultaneously or the new source cannot power up all load on both buses due to its capacity limitation. Thus, a detailed analysis of plant process is required to determine the effects of such a residual voltage transfer.

IV. MTM RESIDUAL VOLTAGE TRANSFER SCHEME WITH TRADITIONAL THREE-RELAY SETUP

The traditional way (Fig.3) of providing protection, control and transfer logic in a main-tie-main substation arrangement involves the following components:

- Two multifunction relays for transformer differential protection.
- Three feeder relays for line and bus tie phase and ground over-current protection, and perform main-tie-main transfer scheme. The main-tie-main transfer can also be performed by using a separate PLC.
- Two tap changer controllers for transformers equipped with tap changers.
- Total of 7-8 devices

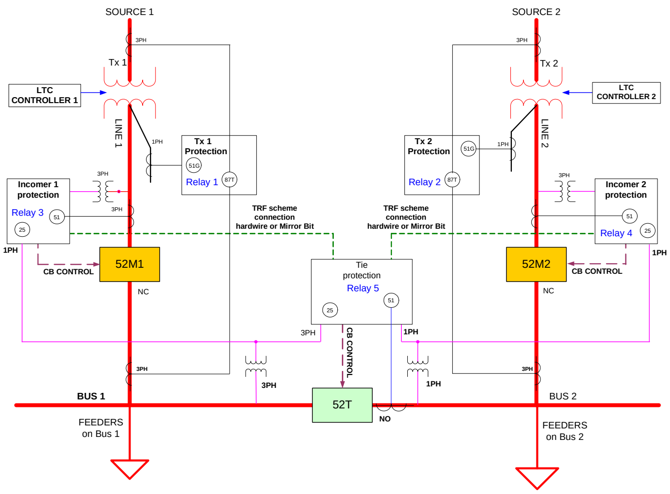

Fig.3 - Main-Tie-Main arrangement with traditionally applied protection and control devices

In this arrangement, the bus transfer is performed by Relay #3, Relay #4, and Relay #5. These three relays exchange only digital information, over copper wires. This information is further used by the specific relay to execute the proper transfer scheme logic equations. For example, one transfer scenario may include the following: A fault on Source 1 trips the Main 1 breaker 52M1. Relay #3 detects 52M1 breaker open condition, detects a line under-voltage condition lasting for amount of pre-programmed time delay, and sends a command to Relay # 5 to close the tie-breaker. At the same time Relay #5 makes its own measurements, and runs its own programmed logic to determine whether or not to send close command to the tie-breaker 52T. When conditions such as no presence of block transfer signals, disconnected bus voltage below 25% of its nominal level, and healthy voltage on the other bus exist, the tie-breaker relay sends a close command to the tie-breaker 52T. Closing the 52T effectively ends the sequence of switching bus 1 to the healthy Source 2.

In this setup, Main 1 and Main 2 relays monitor/measure the corresponding line and bus voltages, and the tie-breaker relay measures Bus 1 and Bus 2 voltages. The tie-breaker relay will not issue close command to the tie-breaker until the selected logic condition DB&DL, LL&DB, DL&LB, DL/DB, or DLxDB checks true. These logic conditions refer to Dead Line (DL), Live Line (LL), Dead Bus (DB), and Live Bus (LB), where the "&" symbolizes logical "AND", "/" stands for logical "OR", and "x" is the logical "XOR" operand. These conditions are set with reference to the both the line and bus voltage magnitudes as part of the residual voltage bus transfer scheme.

Simple main-tie-main transfer scheme logic would require that the three relays be wired and exchange the following digital information as minimum:

- Source 1(2) Breaker racked-in/racked-out status
- Source 1(2) Breaker open/close status
- Tie Breaker racked-in/racked-out status
- Transfer initiate signal from each source relay
- Tie Breaker open/closed status
- Under-voltage operation from each source
- Healthy voltage from each source
- Source Trip
- Transformer trip lockout
- Block transfer
- Trip Breaker selection
- Close from Incomer 1
- Close from Incomer 2
- Transfer Ready

The number of copper wires connected between the relays to exchange even the information from above can be high enough and can lead to a risk of making wiring and/or logic mistakes.

The proposed two-relay scheme eliminates these risks, as it provides a sound solution using advanced communication media and protocol for sending a big number of both digital and analog signals, without jeopardizing the logic.

V. MTM TRANSFER SCHEME WITH TWO RELAYS AND IEC61850 GOOSE PEER-TO-PEER COMMUNICATION

The technological advancements in the design of relay hardware and the development of high-speed peer-to-peer communication protocols have resulted in a new generation of intelligent electronic devices (IEDs). These protective and control devices have the capability to accept multiple levels of current and voltage inputs, analyze measured AC signals at significantly increased speeds, and issue commands upon solving complex logic. The main advantages of using these numerical devices are simplification of the automatic bus transfer system, component cost reduction, increased system reliability, and the availability of events for transfer analysis.

An efficient way to apply these devices and obtain a custom-built automatic bus transfer scheme is to use high-speed peer-to-peer IEC61850 GOOSE messaging. IEC61850 uses an Ethernet connection as the medium of communication between the protective relays. Remote I/Os via Ethernet communications are used in place of the traditional hard wires to exchange information. The information sent over the network might include the status of the main and tie-breakers, voltage detector status, current detector status and transfer scheme status. Modern IEC61850 implementations are able to send messages between relays at speeds of around 2-4 ms. The two relays exchange not only digital data, but also analog data over the same Ethernet media and the same IEC61850 Standard. The relays exchange their measurements and actual values. For the purpose of the residual voltage bus transfer, and more specifically for the part of restoration, the two relays need to exchange information on voltage magnitudes, phase angles and frequency over the high speed network. Figure 4 illustrates some of the digital data exchanged between the two relays.

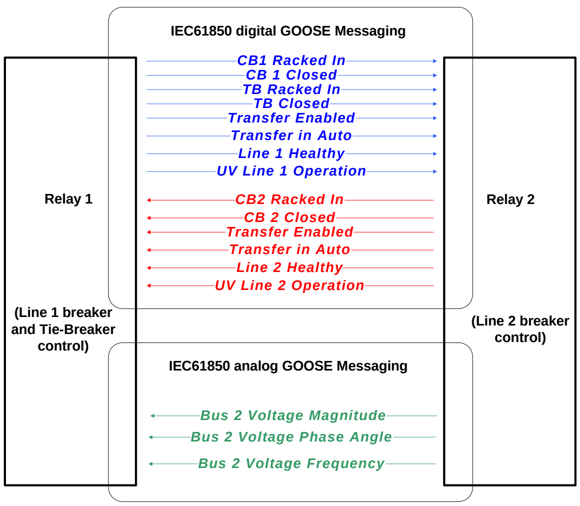

Fig.4 - Digital and analog IEC61850 GOOSE data items exchanged between the two transfer scheme relays

A. Two-Relay MTM Functionality

The careful selection of protection relays defines the digital multifunction differential protection relays as the ones providing all the required protection, control and IEC61850 communication-assisted transfer scheme flexibility. Refer to Figure 5. These two relays are set to perform the following functions:

- Relay 1 is set to send/receive digital and analog values over network communication and IEC61850 standard, provide Line 1 and Bus 1 voltage metering, control the Main 1 breaker applying sync check and voltage permissive logic, and necessary interlock, control the Tie breaker applying sync check and voltage permissive logic, and necessary interlock, protect transformer #1 by applying 87T, 50/51, and 50G/51G functions, and protect the bus tie by applying 51/51G function.
- Relay 2 is set to send/receive digital values using IEC61850 protocol, provide Line 2 and Bus 2 metering, control Main 2 breaker applying sync check and voltage permissive logic and necessary interlock, and protect transformer #2 by applying 87T, 50/51, and 50G/51G functions.

The relays are equipped with a number of hard wired inputs and outputs, for breaker monitoring and tripping, control switches, selection switches, etc. With the use of IEC61850 GOOSE messaging, these inputs and outputs can be limited to the following:

- 3 phase & ground currents
- 3 phase line voltages
- 1 auxiliary bus voltage
- 52a contact
- Breaker racked-in/racked-out contact
- 63X transformer sudden pressure
- 10-Switch breaker trip selection
- Trip output
- Close output
- Relay control power

B. MTM Auto-Transfer

The two relays execute the bus transfer in either automatic or manual mode in the following manner. The auto-transfer mode applies a Break-Before-Make sequence intended to operate when voltage from any main incoming source is dropped to a value below the transfer initiate value for a predetermined time delay, while the second incoming source remains healthy. The time delay is used to avoid nuisance automatic transfer operations caused by a voltage dip in the source. The line voltage is monitored by the relay, which produces a flag, if voltage goes below the programmed transfer initiate voltage level. This level is usually set to 0.75 per unit. After the time delay expires, the relay issues open command to the corresponding normally closed main breaker 52M1 or 52M2 and continues to monitor the residual voltage from the disconnected bus. When the residual voltage decays to the applied preset dead bus voltage level (usually 0.25pu), the relay sends a command to the tie-breaker 52T to close. To be able to send close command to the tie-breaker, the corresponding relay needs to receive information from the other relay related to the other main line such as health of the line voltage, the closed state of the main breaker, no undervoltage operation, as well as information related to the bus tie, such as the tie-breaker open status. All this data is sent through GOOSE dataset using IEC61850 standard and the dual fiber optic Ethernet channels.

C. MTM Auto-Restoration (Auto-Retransfer)

The auto-retransfer mode applies Make-Before-Break sequence intended to restore the scheme back to normal. When the voltage on the previously disconnected line comes back to normal for a predetermined time delay, the main breaker will need to close automatically, so that all three breakers are closed at that time. The main breaker closes automatically only after sync-check 25 function is performed for matching line and bus voltage magnitudes, phase and frequency. Next, the automatic operation sends open command to the tie-breaker, and puts the scheme back in normal condition.

Closing of a main breaker for scheme auto-restoration does not occur without permission of the sync-check function. Since the relay on the main breaker measures both the line and bus voltages, no analog GOOSE messaging is involved.

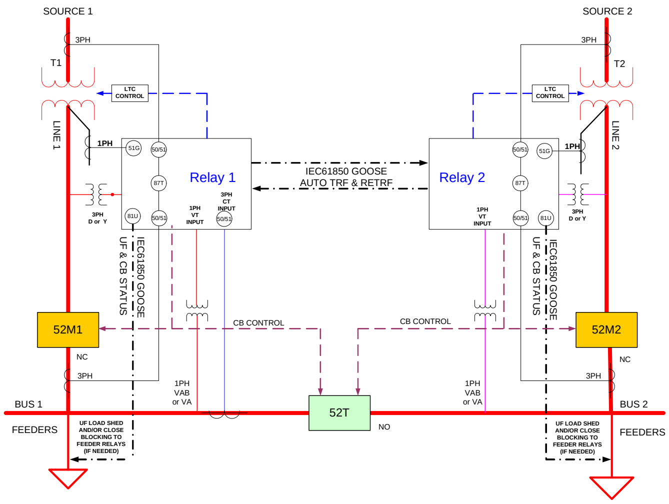

Fig.5 - Main-Tie-Main scheme with two relays performing protection, control and scheme logic

D. MTM Manual Transfer

The manual transfer and manual retransfer through 10-switch go also through Make-Before-Break sequence and is intended to transfer the loads from the two incoming sources, to one incoming source and transfer back. This transfer starts with manually closing the tie-breaker after permission from the sync-check function and opening one of the main breakers preselected using the 10-switch selection. For the described GOOSE enabled two-relay scheme, the Main 1 relay performs not only the sync-check function needed to close the 52M1 breaker during auto-restoration and manual operation mentioned above, but also performs sync-check function for the tie-breaker 52T during manual transfer. To accomplish this functionality, the Main 1 relay is set to receive bus 2 voltage - magnitude, phase and frequency through the analog IEC61850 GOOSE messaging from Main 2 relay. Further, together with the locally available bus 1 magnitude, phase and frequency metered voltage values, the received GOOSE analog values are fed into a programmable sync-check function that compares analog IEC61850 GOOSE values.

The manual transfer does not require fast tie-breaker closing action, so that it is not so important whether or not, the tie-breaker will close after a second, or after more than a second after the manually initiated close command. This implies that analog values may be originated from a separate GOOSE dataset that has a relatively slower inter-relay communication speed as compared to the fast speed digital GOOSE messaging dataset, in order to smooth the network traffic.

However, it is still important to open the Main breaker as fast as possible during the manual transfer process. Paralleled lines from a MTM arrangement is not a desired mode, as any fault on any of the two sources, or buses without applying more complicated protection scheme like 67, will lead to trip from both main breakers, leaving both motor buses disconnected. If the fault occurs at a feeder location while two lines are paralleled, the fault current may exceed the interrupting capacity of the feeder breaker.

VI. OTHER COMMUNICATION-ASSISTED SCHEMES USING TWO RELAYS AND IEC61850 GOOSE MESSAGING

A. Load Shed Schemes

Simple load shed scheme needs be fast and reliable to detect under-frequency or under-voltage conditions that may be present during system overloading. The overloading conditions are dangerous for the system, as the system components (such as transformers, lines and generators) may operate above their ratings and may overheat that result in component damages.

For radial feeders connected to the two buses from a MTM line-bus configuration, the load-shed scheme is employed using the relays from the main breakers and the feeder relays. The GOOSE messaging between these relays is used to exchange load flow values (Watts), voltage, frequency, as well as to initiate commands for opening/closing feeder breakers.

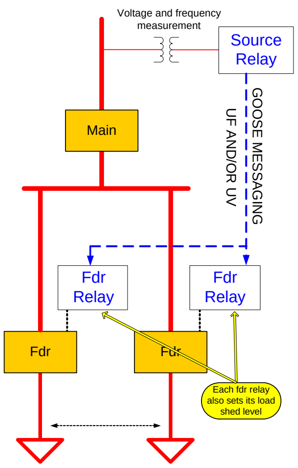

Fig.6 - Load Shed Scheme with GOOSE messaging

The two-relay transfer scheme uses the following ways to perform feeder load shed applications. All communications between the main relay and the feeder relays use IEC61850 GOOSE messaging.

<u>Normal Application</u>

For a double-ended industrial substation with main-tie-main configuration, normal scheme state is defined when the two main breakers are closed and the tie breaker is open. Figure 6 illustrates a source relay (main) which constantly detects voltage and frequency of the incoming lines, and two feeder relays. When the detected incoming line voltage or frequency, or both, are low enough, and have reached the preset thresholds, the need for feeder load shed arises. The source relay sends IEC61850 GOOSE message to pre-selected feeder relays to perform load shed tasks. Multiple levels of under frequency or under voltage signals may be sent to the feeder relays, where further logic can be performed as based on the priority level of each feeder.

<u>Transfer Process with Equal Line/Transformer Capacity</u>

The entire load on the two buses, Bus 1 and Bus 2, is supposed to be fed by two incoming lines/transformers. Each line/transformer is usually sized to handle 70-80% of the total load resided on the two buses. If the load on the two buses reached the maximum allowed value when one of the incoming sources is lost, transferring the entire load to the single healthy source will place a great overloading threat to healthy line, and transformer. In order to avoid such situation, when relay detects loss of one of incoming lines and issues a command to open the corresponding main breaker, it also sends IEC61850 GOOSE messaging to the pre-selected feeder relays as feeder load shed signals. These signals are used to automatically shed some of the feeders in order to avoid single incoming line/transformer overload. These signals are not only used to trip the pre-selected feeder breaker, but also used to block them from closing. The tie breaker will not be allowed to close unless the main relay receives all confirmation signals from the feeder relays (Also IEC61850 GOOSE) that the feeders are load shed and feeder breakers are blocked from closing. These load shed signals will be withdrawn after the previously lost line returns back.

<u>Transfer Process with Unequal Line/Transformer Capacity</u>

Similar to the first point from above, automatic feeder load shedding is also performed to prevent source overloading when the transformers from the two lines are of different size (ratings), particularly transferring the load from two sources to a single source with smaller-size of power transformer. The GOOSE messages are sent to some of the pre-selected feeder relays, to shed loads automatically and block them from closing. This prevents overloading of the transformer.

B. Fast Bus Trip Scheme

Fast bus trip scheme using GOOSE messaging is performed by the relays from the main breakers without the need of adding a bus differential relay. In such cases relays from the main breakers are connected via fiber optic or copper twisted pair Ethernet cables to all of the feeder relays to exchange GOOSE data. Any of the two relays from the Main 1 and Main 2 breakers can trip the corresponding bus, if during bus fault, the main relay detects the 50 function operation, and none of the bus feeders detects overcurrent conditions. As the fault must be on the bus, depending on the need of various applications, the main relay would either trip all the beakers in the zone and block them from closing, or would just trip the main breaker and block it from closing.

C. Zone Interlocking Scheme

Trip zone interlocking through GOOSE messaging can be implemented between the main relay and the feeder relays. By using trip zone interlocking, the main relay can also use 50 function, instead of 51, that would reduce CTI (coordination time interval) from at least 200ms to less than 100ms (for 5 cycle breaker), to speed up the trip operation, simplify relay protection coordination study and reduce arc flash hazard.

VII. AUTOMATIC TRANSFER APPLICATIONS FOR OTHER SUBSTATION CONFIGURATIONS

By expanding the same principles and concepts described above, the other substation configurations can easily adopt the IEC61850 GOOSE applications. These applications include:

- Two generators as the power sources. The relay selected to perform the automatic transfer must have generator protection as the major protection element.
- Instead of using two incoming power transformers, substations that use one generator and one transformer to/from two different power sources. The relay selected to perform the automatic transfer must have generator protection, 87G, 50/51, 64, 46, 47, etc. for the generator source and must have transformer protection, 87T, 50/51, etc. for the transformer source as the major protection elements.
- The use of a second, functional tie-breaker has been gaining greater acceptance in industry to facilitate safe equipment maintenance without sacrificing production. This can be as a variant of normal main-tie-main substation but can also be accommodated with the two-relay transfer scheme using IEC61850 GOOSE.
- Industrial substations that have only two main breakers, but do not have tie breaker as a primary-secondary source configuration.

VIII. CONCLUSIONS

Reduction in wiring is attractive to the switchgear builder and allows them to limit the wiring across shipping splits. The advantages of using two protective relays and IEC61850 GOOSE communications are:

- Significant reduction in hardwiring as compared to that between traditional bus transfer schemes.
- Transmitting and receiving digital status and analog values between two main protective relays, as well as between main relays and feeder relays, at high speed via Ethernet port.
- The use of programmable logic functions such as protection and logic flags, timers, Boolean gates, provides flexibility to implement a custom bus transfer scheme to best meet the needs of the application.
- Selector switch functions (select to trip, auto transfer on/off) can be traditionally wired switches, or implemented via protective relay faceplate programmable pushbuttons, eliminating components and installation costs.
- Interlocking (bus protection) with downstream and upstream relays, trip-zone interlocking to reduce arc-flash hazard can be accomplished with IEC61850 GOOSE messaging.

- Scheme alarms when either protective relay is off-line or not communicating.
- Reconfiguration of scheme without time and expense of additional wiring.

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Benefits to the conference attendees:

- Gain knowledge of IEC61850 GOOSE peer-to-peer communication between IEDs through Ethernet
- Gain knowledge of how IEC61850 GOOSE can play an important role of relay to relay communications for different applications related to bus transfer schemes.
- Gain knowledge of how IEC61850 GOOSE can reduce number of components and hard wire connection to save cost in bus transfer schemes in substations.
- Gain knowledge of how IEC61850 GOOSE can be used in different substation configurations for communication-assisted relay schemes.
- Reduce cost for bus transfer scheme for different configurations and implement of other communication-assisted relay applications all together

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X. BIOGRAPHIES

Tony W. Zhao received AS degree in Electronic Engineering from Beijing University of Broadcasting and Television in 1982 and in 1986 he received M.Sc. degree in High Voltage Engineering from China Electric Power Research Institute (CEPRI). After working for CEPRI for three years as a testing engineer, he joined Shenzhen Nanshen Power Station Company in China as an electrical and control maintenance manager for gas-turbine generator sets. In 1997 he started with GE Instrument Transformer Inc. USA as an applications engineer. In 2001, he jointed Powell Electrical Systems Inc. as an R&D engineer. Currently he works as a senior power control systems engineer for relay programming, relay protection, system automation and integration. He is a contributing and active member in the IEEE Houston Section's Continuing Education on Demand seminars.

Lubomir Sevov received his M.Sc. degree from Technical University of Sofia, Bulgaria in 1990. After graduation, he worked as a protection and control engineer for National Electric Company (NEC) Bulgaria. Mr. Sevov joined GE Multilin in 1998 as a relay test design engineer and in 2001 he was promoted to an application engineer. Mr. Sevov is a Senior Applications Engineer in charge of the design and development of industrial type GE protective relays. In 2004 he became a member of the association of professional engineers Ontario, Canada. He is a member of the IEEE – Power Engineering Society since 1999. He is an IEEE senior member.

Craig Wester is the southeast US regional sales manager for GE Digital Energy Multilin in Norcross, Georgia. He was born in Belgium, Wisconsin, and received a B.S. in Electrical Engineering with a strong emphasis on power systems from the University of Wisconsin-Madison in 1989. Craig joined General Electric in 1989 as a utility transmission & distribution application engineer. He is a member of the IEEE