Bus Bar Protection Applications Seminar

April 3, 2006 – College Station TX
Presentation Outline

- Introduction to Bus Bar Protection
- GE Multilin Bus Protection Offerings
- B30 & B90 Low Impedance Operating Principles
- CT Saturation
- Example Configurations
- B30 & B90 Application Considerations
- Advanced Topics
Presentation Outline (continued)

- B90 Application Examples
- B30 & B90 User Software
- B90 Settings Example
- Conclusions
- Q & A
Introduction to Bus Protection
Challenges to Bus Zone Protection

- **High Fault Current Levels**
  - Large dynamic forces can place mechanical stress on bus bars and result in physical damage to equipment. Therefore, fast clearing times are required.
  - High fault currents can lead to CT saturation, particularly due to external faults, which may lead to mis-operation of the bus protection.

- **Mis-Operation of Bus Protection Has Significant Impact**
  - Loss of customer loads may damage customer assets as well as customer perception of the utility
  - Detrimental impact on industrial processes
  - System voltage levels and corresponding system stability may be adversely affected
    - Best Case: Remedial Action Schemes (load shedding)
    - Worst Case: Partial or Total System Collapse (wide-spread blackout)

**Bus Protection Must be Dependable and Secure, With Emphasis on Security...**
Challenges to Bus Zone Protection Continued...

- Many Different Bus Topologies
  - Many configurations possible
  - Many different CT placements possible.
  - Single Bus, Double Bus (Single and Double Breaker), Main and Transfer Bus, Breaker-and-a-Half and hybrids

- Bus Reconfiguration
  - Different apparatus may be connected/disconnected from a given bus
  - Switching may happen from any number of sources
    - Manually from human operator action (e.g. equipment maintenance)
    - Automatically from other protection, Wide-Area Special Protection, Remedial Action Schemes, Auto-Restoration/Auto-Transfer Schemes

**Bus Protection Schemes Must Adapt Automatically (No User Intervention) and in Real-Time, Based on Bus Configuration...**
Bus Zone Protection Techniques

• All Bus Zone protections essentially operate based on Kirchoff’s Law for Currents:
  – ‘The sum of all currents entering a node must equal zero.’
  – The only variation is on how this is implemented

• Various existing implementations:
  – Unrestrained Differential
  – Interlocking/Blocking Schemes
  – High Impedance Differential
  – Low Impedance Percent Differential
Unrestrained Differential (Overcurrent)

- Differential current created by physically summing CT inputs
- CT ratio matching required (auxiliary CTs)
- External faults may cause CT saturation, leading to spurious differential currents in the bus protection
  - Intentional time delay added to cope with CT saturation effects
- Unrestrained differential function useful for microprocessor-based protections (check zone)

Intentional Time Delay means No Fast Zone Clearance
Interlocking/Blocking Schemes

- Blocking signals generated by downstream protection (usually instantaneous overcurrent)
- Simple IOC protection with short intentional time delay
  - Depends on blocking signal(s)
  - Usually inverse timed backup provided
- Timed backup may be “tricked” by slow clearance of downstream faults.
- Blocking can be done via hardwire or communication channels (e.g. GSSE/GOOSE, dedicated communications)

Technique Limited to Radial Circuits with Negligible Backfeed
High Impedance Differential (Overvoltage)

- Operating signal created by connecting all CT secondaries in parallel
  - CTs must all have the same ratio
  - Must have dedicated CTs
- Overvoltage element operates on voltage developed across resistor connected in secondary circuit
  - Requires varistors or AC shorting relays to limit energy during faults
- Accuracy dependent on secondary circuit resistance
  - Usually requires larger CT cables to reduce errors → higher cost

Cannot Easily be Applied to Reconfigurable Buses and Offers no Advanced Functionality (Oscillography, Breaker Fail).
Low Impedance Percent Differential

- Individual currents sampled by protection and summated digitally
  - CT ratio matching done internally (no auxiliary CTs required)
  - Dedicated CTs not necessary
- Additional algorithms improve security of percent differential characteristic during CT saturation
- “Dynamic bus replica” allows application to reconfigurable buses
  - Done digitally with logic to add/remove current inputs from differential computation
  - Switching of CT secondary circuits not required
- Low secondary burdens
- Additional functionality available without additional devices
  - Digital oscillography
  - Time-stamped event recording
  - Breaker Failure

Can be Applied to Reconfigurable Buses and Secure from CT Saturation, with Additional Useful Functionality
Low Impedance Percent Differential

Summing External Currents
Not Recommended!

- Relay becomes combination of restrained and unrestrained elements
- In order to parallel CTs:
  - CT performance must be closely matched
  - Any errors will appear as differential currents
  - Associated feeders must be radial
  - Pickup setting must be raised to accommodate any errors

\[ I_{DIFF} = \text{Error} \]
\[ I_{REST} = \text{Error} \]

Maloperation if Error > PICKUP
Low Impedance Percent Differential

Digital Differential Algorithm Advantages

- Improvement of the main differential algorithm operation
  - Better filtering
  - Faster response
  - Better restraint techniques
  - Switching transient blocking
- Provides dynamic bus replica for reconfigurable bus bars
- Dependably detect CT saturation in a fast and reliable manner, especially for external faults
- Apply additional security to the main differential algorithm to prevent incorrect operation
  - External faults with CT saturation
  - CT secondary circuit trouble (e.g. short circuits)
Other Bus Protection Schemes (in limited use)

- **Partial differential ("bus overload")**
  - Combines time-delayed bus protection w/ feeder backup protection
  - High-set OC relay w/ time delay
  - Poor sensitivity and speed

- **Directional comparison**
  - Uses directional OC relays on sources and IOC relays on feeders
  - Intentional time delay required

- **Fault Bus (used for ground-fault protection only)**
  - All bus structure interconnected to only one connection to ground
  - OC relay connected to ground path
  - Special construction, high cost
GE Multilin Bus Protection Offerings
GE Multilin Bus Differential Relays

• High Impedance Differential
  - PVD (Electromechanical)
  - MIB II (single function digital relay)
  - HID (high impedance module with OC relay)

• Low Impedance Digital Differential
  - B30
  - B90
  - Both the B30 and B90 have a great deal in common, but have some differences
B30 & B90 – What is the Same

• Both are members of the Universal Relay (UR) family
  – Common hardware & software
  – Common features
  – Common communications interfaces & protocols
  – User Programmable Logic (FlexLogic™)

• High Performance
  – Typical Response Time: 12 msec + output contact
  – Max. Response Time: 16 msec + output contact
  – Secure for external faults with severe CT saturation

• High speed operation can minimize arc flash concerns

• Both use the same proven algorithms for ratio compensation, dynamic bus replication, differential calculations, CT saturation detection and differential element security

Proven Hardware. Proven Algorithms.
B30 & B90 – What is Different

• B30 provides three-phase bus differential protection in a single hardware chassis
  - All three phase currents from all feeders are connected to a single chassis with multiple DSPs (1 zone), with phase segregation done in software only
  - Limited to 6 three-phase current sources (or five current sources and one three-phase voltage source)

• B90 provides hardware-segregated bus differential protection in one or more hardware chassis
  - DSP modules configured for up to 8 currents (7 currents & 1 voltage) for a single phase
  - Phase segregation by hardware and software configuration
  - Minimum configuration: 8 feeders in a single chassis with three DSP modules (4 zones)
  - Maximum configuration: 24 feeders in three chassis, each with 3 DSPs (4 zones)
  - Additional I/O, additional Logic, optional breaker failure available
  - Built-in logic for isolator position and monitoring

B30 – Cost effective protection & metering.
B90 – Comprehensive and scalable protection.
B30 & B90
Low Impedance Operating Principles
**Bus Differential Adaptive Approach**

- Region 1
  - low currents
  - saturation possible due to dc offset
  - saturation very difficult to detect
  - more security required

- Region 2
  - large currents
  - quick saturation possible due to large magnitude
  - saturation easier to detect
  - security required only if saturation detected
Bus Differential Adaptive Approach

The differential and restraining signals are as follows:

\[
I_D = I_8 - I_7 - I_6 - I_5 - I_4 - I_3 - I_2 - I_1
\]

\[
I_R = I_{MAX}
\]
Bus Differential Adaptive Logic Diagram

\[
\text{DIF}_L \quad \text{AND} \quad \text{OR} \quad \text{AND} \quad \text{OR} \quad \text{87B BIASED OP}
\]

\[
\text{DIR} \quad \text{AND} \quad \text{OR} \quad \text{AND} \quad \text{OR} \quad \text{AND} \quad \text{OR}
\]

\[
\text{SAT} \quad \text{AND} \quad \text{OR} \quad \text{AND} \quad \text{OR} \quad \text{AND} \quad \text{OR}
\]

\[
\text{DIF}_H \quad \text{AND} \quad \text{OR} \quad \text{AND} \quad \text{OR} \quad \text{AND} \quad \text{OR}
\]
Bus Differential Adaptive Approach

Region 1
(low differential currents)

Region 2
(high differential currents)
Directional Principle

- **Internal Faults:** All fault ("large") currents are approximately in phase
  
  \[ \text{BUS DIR = "On" or 1 for angles close to 0 (actually less than 80 degrees)} \]

- **External Faults:** One fault ("large") current will be out of phase
  
  \[ \text{BUS DIR = "Off" or 0 for angles close to 180} \]

  - No Voltages are required
Directional Principle Continued...

For External Fault Conditions:

- \( \text{img}\left(\frac{I_p}{I_D - I_p}\right) \)
- \( I_D - I_p \)
- OPERATE

For Internal Fault Conditions:

- \( \text{img}\left(\frac{I_p}{I_D - I_p}\right) \)
- \( I_D - I_p \)
- OPERATE

\( \text{real}\left(\frac{I_p}{I_D - I_p}\right) \)
“Sum Of” Versus “Maximum Of” Restraint Methods

“Sum Of” Approach
- More restraint on external faults; less sensitive for internal faults
- “Scaled-Sum Of” approach takes into account number of connected circuits and may increase sensitivity
- Breakpoint settings for the percent differential characteristic more difficult to set

“Maximum Of” Approach
- Less restraint on external faults; more sensitive for internal faults
- Breakpoint settings for the percent differential characteristic easier to set
- Better handles situation where one CT may saturate completely (99% slope settings possible)

B30 and B90 Use the “Maximum Of” Definition for Restraint
CT Saturation
CT Saturation Concepts

- CT saturation depends on a number of factors
  - Physical CT characteristics/class (size, rating, winding resistance, saturation voltage)
  - Connected CT secondary burden (wires + relays)
  - Primary fault current magnitude, DC offset (system X/R) (Independent of voltage class/level)
  - Residual flux in CT core

- Actual CT secondary currents may not behave in the same manner as the ratio (scaled primary) current during faults

- End result is spurious differential current appearing in the summation of the secondary currents which may cause differential elements to operate if additional security is not applied
CT Saturation

No DC Offset
- Waveform remains fairly symmetrical

With DC Offset
- Waveform starts off being asymmetrical, then symmetrical in steady state
CT Saturation – External Fault with Ideal CTs

- Fault starts at $t_0$
- Steady-state fault conditions occur at $t_1$

Ideal CTs have no saturation or mismatch thus produce no differential current
CT Saturation – External Fault with Actual CTs

- Fault starts at $t_0$
- Steady-state fault conditions occur at $t_1$

Actual CTs introduce errors, thus produce some differential current (without CT saturation)
CT Saturation – External Fault with CT Saturation

- Fault starts at $t_0$, CT begins to saturate at $t_1$
- CT fully saturated at $t_2$

CT saturation causes increasing differential current that may enter the differential element operate region.
CT Saturation Detector - Examples

- The oscillography records on the next two slides were captured from a B30 relay under test on a real-time digital power system simulator.
- First slide shows an external fault with severe CT saturation (~1.5 msec of good CT performance):
  - SAT saturation detector flag asserts prior to BIASED PKP bus differential pickup
  - DIR directional flag does not assert (one current flows out of zone), so even though bus differential picks up, no trip results
- Second slide shows an internal fault with mild CT saturation:
  - BIASED PKP and BIASED OP both assert before DIR asserts
  - CT saturation does not block bus differential
The bus differential protection element picks up due to heavy CT saturation. The CT saturation flag is set safely before the pickup flag. The directional flag is not set. The element does not maloperate. Despite heavy CT saturation, the external fault current is seen in the opposite direction.
The bus differential protection element picks up. The saturation flag is not set - no directional decision required. The element operates in 10ms. The directional flag is set. All the fault currents are seen in one direction.
Example Configurations
B30 Bus Differential Protection

6-Circuit Applications

- 18 Current Inputs
- 3 Phase Protection in Single Chassis
- 1 Zone
- Different CT Ratio Capability for Each Circuit
- Largest CT Primary is Base in Relay
B90 Bus Differential Protection

8-Circuit Applications

- 24 Current Inputs
- 4 Zones
  - Zone 1 = Phase A
  - Zone 2 = Phase B
  - Zone 3 = Phase C
  - Zone 4 = Not used

- Different CT Ratio Capability for Each Circuit
- Largest CT Primary is Base in Relay
B90 Bus Differential Protection

12-Circuit Applications

- Relay 1 - 24 Current Inputs
  - 4 Zones
    - Zone 1 = Phase A (12 currents)
    - Zone 2 = Phase B (12 currents)
    - Zone 3 = Not used
    - Zone 4 = Not used

- Relay 2 - 24 Current Inputs
  - 4 Zones
    - Zone 1 = Not used
    - Zone 2 = Not used
    - Zone 3 = Phase C (12 currents)
    - Zone 4 = Not used

- Different CT Ratio Capability for Each Circuit
- Largest CT Primary is Base in Relay
B90 Architecture (13 to 24 Circuits)

- Phase-segregated multi-IED protection system built on UR platform
- Up to 24 AC Inputs per chassis
  - Up to 24 single phase currents
  - 12 single phase currents & 12 single phase voltages per chassis
- Variety of digital inputs and output contacts available via modular configuration
- Digital communications between IEDs for sharing digital states of 4th to 8th box(s)...if used
B90 Applications for Large Busbars

Single Bus Single Breaker

Double Bus Single Breaker
B90 Applications for Large Busbars (continued)

Single Bus Single Breaker with Bus Tie

Double Bus Double Breaker
B90 Components: Protection

- Up to 24 AC inputs per chassis with 3 DSP modules
- Up to 3 digital I/O modules per chassis for contact outputs and digital inputs
- Analog signal processing: Differential calculations, IOC, TOC, UV, BF current supervision

Three-phase protection for bus bars with up to 8 feeders or single-phase protection for bus bars with up to 24 feeders
B90 Components: Logic

- Up to 96 digital inputs or
- Up to 48 output contacts or
- Any combination of the above
- Breaker failure “elements” for the associated bus zone
- Logic processing: Breaker Failure logic and timers, isolator monitoring and alarming for dynamic bus replication
B90 Architecture for Large Busbars

Dual (redundant) fiber with 3msec delivery time between neighbouring URs. Up to 8 B90s/URs in the ring.

Phase A: AC signals and trip contacts

Phase B: AC signals and trip contacts

Phase C: AC signals and trip contacts

Digital Inputs for isolator monitoring and BF
B90 Architecture – Dynamic Bus Replica and Isolator Position

Phase A AC signals wired here, bus replica configured here

Phase B AC signals wired here, bus replica configured here

Phase C AC signals wired here, bus replica configured here

Up to 96 auxiliary switches wired here; Isolator Monitoring function configured here

Isolator Position
B90 Architecture – BF Initiation & Current Supervision

Phase A AC signals wired here, current status monitored here

Phase B AC signals wired here, current status monitored here

Phase C AC signals wired here, current status monitored here

Up to 24 BF elements configured here
B90 Architecture – Breaker Failure Tripping

Phase A AC signals wired here, current status monitored here

Phase B AC signals wired here, current status monitored here

Phase C AC signals wired here, current status monitored here

Breaker Fail Op command generated here and send to trip appropriate breakers
B30 & B90 Application Considerations
Applying the B30 or B90 for Bus bar Protection

**Basic Topics**
- Configure physical CT Inputs
- Configure Bus Zone and Dynamic Bus Replica
- Calculating Bus Differential Element settings

**Advanced Topics**
- Isolator Monitoring
- More on Dynamic Bus Replica – Blind Spots & End Fault Protection
- Differential Zone CT Trouble
- Additional Security for the Bus Differential Zone
- B90 Application Examples
Configuring CT Inputs

- For each connected CT circuit enter Primary rating and select Secondary rating
- For the B30, each 3-phase bank of CT inputs must be assigned to a Signal Source (SRC1 through SRC6) which is then assigned to the Bus Zone and Dynamic Bus Replica
- For the B90, the CT channels are assigned directly to the Bus Zone and Dynamic Bus Replica (no Signal Sources)

Both the B30 and B90 define 1 p.u. as the maximum primary current of all of the CTs connected in the given Bus Zone
### B90 Per-Unit Current Definition - Example

<table>
<thead>
<tr>
<th>DSP Channel</th>
<th>Primary</th>
<th>Secondary</th>
<th>Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT-1</td>
<td>F1</td>
<td>3200 A</td>
<td>1</td>
</tr>
<tr>
<td>CT-2</td>
<td>F2</td>
<td>2400 A</td>
<td>1</td>
</tr>
<tr>
<td>CT-3</td>
<td>F3</td>
<td>1200 A</td>
<td>1</td>
</tr>
<tr>
<td>CT-4</td>
<td>F4</td>
<td>3200 A</td>
<td>2</td>
</tr>
<tr>
<td>CT-5</td>
<td>F5</td>
<td>1200 A</td>
<td>2</td>
</tr>
<tr>
<td>CT-6</td>
<td>F6</td>
<td>5000 A</td>
<td>2</td>
</tr>
</tbody>
</table>

- For Zone 1, 1 p.u. = 3200 A pri
- For Zone 2, 1 p.u. = 5000 A pri
Configuration of Bus Zone (Dynamic Bus Replica)

- Dynamic Bus Replica associates a status signal with each current in the Bus Differential Zone
- Status signal can be any FlexLogic™ operand
  - Status signals can be developed in FlexLogic™ to provide additional checks or security as required
  - Status signal can be set to ‘ON’ if current is always in the bus zone or ‘OFF’ if current is never in the bus zone
- For the B30, each Signal Source (SRC1 – SRC6) must be assigned a status signal to be included in the three-phase Bus Zone
- For the B90, the CT channels are assigned status inputs directly in the respective Bus Zone(s) and the CT direction must also be configured for all current inputs in each bus zone
  - In or Out, depending on CT polarity
Bus Differential Characteristic

Bus Zone 1 Graph // B30_Temp.urs : Grouped Elements: Group 1

- High Set (Unrestrained)
- Low Slope
- High Slope
- Low Breakpoint
- High Breakpoint

Differential (pu) vs. Restraint (pu)
Advanced Topics
Advanced Topics

- Isolators and Isolator Monitoring (Dynamic Bus Replica)
- More on Dynamic Bus Replicas
  - Blind Spots
  - End Fault Protection
- Differential Zone CT Trouble
- Examples of Additional Security for the Bus Differential Zone
  - External Check Zone
  - Undervoltage Supervision
- B90 Application Examples
Re-Configurable Bus Zones

Different Currents May Need to be Added/Removed from Each Bus Zone Dynamically, Depending on Switch Status
The Dynamic Bus (Example 1)
Isolators

• Reliable “Isolator Closed” signals are needed for the Dynamic Bus Replica
• In simple applications, a single normally closed contact may be sufficient
• For maximum safety:
  – Both N.O. and N.C. contacts should be used
  – Isolator Alarm should be established and invalid contact states (open-open, closed-closed) should be sorted out
  – Switching operations should be inhibited until bus image is recognized with 100% accuracy
  – Optionally block 87B operation using Isolator Alarm
• Each isolator position signal decides:
  – Whether or not the associated current is to be included in the differential calculations
  – Whether or not the associated breaker is to be tripped
Full-Featured Isolator Monitoring

<table>
<thead>
<tr>
<th>Isolator Open Aux. Contact</th>
<th>Isolator Closed Aux. Contact</th>
<th>Isolator Position</th>
<th>Isolator Alarm</th>
<th>Block Switching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off</td>
<td>On</td>
<td>CLOSED</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Off</td>
<td>Off</td>
<td>LAST VALID</td>
<td>After time delay until reset</td>
<td>Until isolator position valid</td>
</tr>
<tr>
<td>On</td>
<td>On</td>
<td>CLOSED</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>On</td>
<td>Off</td>
<td>OPEN</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

- For the B30, this feature needs to be implemented using FlexLogic™
- For the B90 (Logic), there are 48 dedicated Isolator Position monitoring elements
Switching An Isolator – Closing Sequence

Isolator position valid
(isolator opened)

Isolator position invalid

Isolator position valid
(isolator opened)

ISOLATOR 1 OPEN

ISOLATOR 1 CLOSED

ISOLATOR 1 POSITION

ISOLATOR 1 BLOCK

alarm time
delay

blocking signal resets when
isolator position valid

ISOLATOR 1 ALARM

alarm acknowledged

ISOLATOR 1 RESET

alarm acknowledging signal
Isolator Monitoring Scheme – B90 Element Logic
Dynamic Bus Replica – Changing the Bus Zone

Bus Tie Breaker with Two CTs

- Overlapping zones – no blind spots
- Both zones trip the Tie-Breaker
- No special treatment of the TB required in terms of its status for Dynamic Bus Replica (treat as regular breaker)
Dynamic Bus Replica – Changing the Bus Zone

Bus Tie Breaker with Single CTs

- Both zones trip the Tie-Breaker
- Blind spot between the TB and the CT
- Fault between TB and CT is external to Z2
- Z1: no special treatment of the TB required (treat as regular CB)
- Z2: special treatment of the TB status required:
  - The CT must be excluded from calculations after the TB is opened
  - Z2 gets extended (opened entirely) onto the TB
Sequence of events:
1. Z1 trips and the TB gets opened
2. After a time delay the current from the CT shall be removed from Z2 calculations
3. As a result Z2 gets extended up to the opened TB
4. The Fault becomes internal for Z2
5. Z2 trips finally clearing the fault
Dynamic Bus Replica – Changing the Bus Zone

- Blind spot exists between the CB and CT
- CB is going to be tripped by line protection
- After the CB gets opened, the current shall be removed from differential calculations (expanding the differential zone up to the opened CB)
- Identical to the Single-CT Tie-Breaker
Dynamic Bus Replica – Changing the Bus Zone

- “Over-trip” spot between the CB and CT when the CB is opened.
- When the CB opens, the current shall be removed from differential calculations (contracting the differential zone up to the opened CB).
- Identical as for the Single-CT Tie-Breaker, but...
Dynamic Bus Replica – Changing the Bus Zone

- but...
- A blind spot created by contracting the bus differential zone
- End Fault Protection is required to trip remote end circuit breaker(s)
End Fault Protection (EFP)

- Instantaneous overcurrent element enabled when the associated CB is open to cover the blind spot between the CB and line-side CT
- Pickup delay should be long enough to ride-through the ramp down of current interruption (1.3 cycles maximum)
- EFP inhibited from circuit breaker manual close command

- For the B30, the End Fault Protections need to be implemented using FlexLogic™
- For the B90, there are 24 dedicated End Fault Protection elements
End Fault Protection – B90 EFP Element Logic

1. The EFP gets armed after the breaker is open.

2. Excessive current ...

3. Causes the EFP to operate.

B90 FUNCTION:
- Logic = 0
- Protection = 1

EFP 1 FUNCTION:
- Disabled = 0
- Enabled = 1

EFP 1 BLOCK:
- Off = 0

EFP 1 CT:
- Current Magnitude, |I|

EFP 1 MANUAL CLOSE:
- Off = 0

EFP 1 BREAKER OPEN:
- Off = 0

EFP 1 PICKUP:
- |I| > PICKUP

EFP 1 PICKUP DELAY:
- tP KP

FLEXLOGIC OPERANDS
- EFP 1 OP
- EFP 1 DPO
- EFP PKP
End Fault Protection – Special Consideration

- High currents may not be caused by a fault in the EFP “dead zone”
- With By-pass Isolator closed, a fault on the transfer bus will cause current to flow through the EFP CT
- EFP element must be disabled (Blocked) when the By-pass Isolator is closed.
Differential Zone CT Trouble

- Each Bus Differential Zone (1 for the B30, 4 for the B90) has a dedicated CT Trouble Monitor
- Definite Time Delay overcurrent element operating on the zone differential current, based on the configured Dynamic Bus Replica
- Three strategies to deal with CT problems:
  1. Trip the bus zone as the problem with a CT will likely evolve into a bus fault anyway
  2. Do not trip the bus, raise an alarm and try to correct the problem manually
  3. Switch to setting group with 87B minimum pickup setting above the maximum load current.
Differential Zone CT Trouble

• Strategies 2 and 3 can be accomplished by:
  – Using undervoltage supervision to ride through the period from the beginning of the problem with a CT until declaring a CT trouble condition
  – Using an external check zone to supervise the 87B function
  – Using CT Trouble to prevent the Bus Differential tripping (2)
  – Using setting groups to increase the pickup value for the 87B function (3)

• **DO NOT** use the Bus Differential element BLOCK input:
  – The element traces trajectory of the differential-restraining point for CT saturation detection and therefore must not be turned on and off dynamically
  – Supervise the trip output operand of the 87B in FlexLogic™ instead
Differential Zone CT Trouble – Strategy #2 Example

- CT Trouble operand is used to rise an alarm
- The 87B trip is inhibited after CT Trouble element operates
- The relay may misoperate if an external fault occurs after CT trouble but before the CT trouble condition is declared (double-contingency)
Undervoltage Supervision

Principle:
- Supervise all differential trips with undervoltage
- Set high (0.85-0.90pu) for speed and sensitivity
- Need 3 UV elements per bus per phase (undervoltage functions AG, AB, CA supervise differential trip for phase A)
- Alarm on spurious differential

Guards against:
- CT problems
- AC wiring problems
- Problems with aux switches for breakers and disconnectors
- DC wiring problems for dynamic bus replica
- Failures of current inputs
Application of Undervoltage Supervision to the B90

**Version 1**

- Place the supervising voltage inputs in a different chassis
- Guards against relay problems and bus replica problems
- Does not need any extra ac current wiring
- Use fail-safe output to substitute for the permission if the supervising relay fails / is taken out of service
Application of Undervoltage Supervision to the B90

**Version 2**

- Place the supervising voltage inputs in the same chassis
- Guards against relay problems and bus replica problems
- Does not need any extra ac current wiring
- No inter chassis wiring needed
B90 Application Examples
B90 Example – Reconfigurable Bus

- Double bus, single breaker with bus-tie
- 10 feeders with single CT
- Circuit breaker bypass switches per feeder CB
- Current inclusion in bus zone depends on isolator switch position (ISO x)
Bus & Backup Feeder/Main Protection

Using B90 Low Impedance Bus Relays

Using the B90 relay system, each main could have up to 22 feeders
## B90 - Direct I/O Communications Configuration

### Raw Text:

**B90-5 BKR FAIL**

**B90-4 STATUS**

**B90-1 A PHASE**

**B90-2 B PHASE**

**B90-3 C PHASE**

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**Isolators and breakers positions**

**Fiber Optic channels**

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**Direct outputs on IED4**

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>DO 1</th>
<th>DO 2</th>
<th>DO 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone Status A</td>
<td>F1</td>
<td>F1</td>
<td>F1</td>
</tr>
<tr>
<td>Zone Status B</td>
<td>Direct Input 1 On</td>
<td>Direct Input 15 On</td>
<td>ON</td>
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**Direct inputs on IED1, 2, and 3**

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**Differential zones configuration on IED1, 2, and 3**

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**Imagination at work**

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**GE Multilin 81**
B30 & B90 User Software
B30 & B90 – Software

- EnerVista UR Setup – Universal configuration software for the entire Universal Relay (UR) family
  - Free download from www.GEMultilin.com
- B30 Differential Phasor Model Simulator – Simulate B30 operation offline using virtual B30 model
  - Free download from www.GEMultilin.com
- Enervista Viewpoint Software Suite:
  - *Engineer* – Graphical Logic Designer, Real-Time Logic Monitor, Advanced COMTRADE Viewer
  - *Monitoring* – Simplified Monitoring, Data Logging & Event Retrieval for Small Systems
  - *Maintenance* – Automatic report generation for Relay Health and Relay & Settings Security
EnerVista UR Setup – Universal Relay Configuration Software
EnerVista UR Setup – COMTRADE Viewer
B30 Differential – Phasor Display
B30 Differential – Operating Characteristic
EnerVista Viewpoint Engineer
Graphical FlexLogic™ Designer

Design Control Logic in this intuitive, easy to use IEC 1131 Graphical Logic Designer

- Simplify the process of creating complex control logic for Substation Automation such as advanced Tripping, Reclosing and Transfer Schemes.
- Design Logic with drag and drop ease using a library of inputs, outputs, logic gates, symbols and configuration tools
- Document actual setting file with text to make it easier for others to understand
- Create settings offline without having to communicate with the relay

Powerful Intuitive Logic Compiler

Analyses logic for potential problems in logic such as:
- detecting infinite loops in logic
- using inputs and outputs, or protection, control and monitoring elements that have not been configured properly
- using Virtual Outputs that have not been assigned
- using inputs for hardware or features that is not available on your relay

Optimizes control logic equations to obtain maximum efficiency and to use the fewest possible lines of logic
B90 Settings Example

8-Circuit Applications

- 24 Current Inputs
- 4 Zones
  - Zone 1 = Phase A
  - Zone 2 = Phase B
  - Zone 3 = Phase C
  - Zone 4 = Not used

- Different CT Ratio Capability for Each Circuit
- Largest CT Primary is Base in Relay

CT-1 2000:5
CT-2 2000:5
CT-3 1200:5
CT-4 1200:5
CT-5 1200:5
CT-6 1200:5
CT-7 1200:5
CT-8 1200:5
Conclusions

**B30**
- For smaller busbars (up to 6 feeders)
- Single chassis providing three-phase bus differential protection, logic and I/O capabilities
- Isolator monitoring may be done in FlexLogic™ if required
- End Fault Protection may be provided using FlexLogic™ if required
- Inter-relay communications supported for additional I/O

**B90**
- For large, complex busbars (up to 24 feeders)
- Multiple chassis for single-phase bus differential, plus extra IEDs for dynamic bus replica, breaker fail
- Internal full-feature isolator monitoring provided (B90-Logic)
- 24 End Fault Protection elements provided (B90-Protection)
- Inter-relay communications supported for additional I/O
Conclusions

- B30 is designed for smaller bus bars, therefore application is fairly simple and straightforward
- B90 is designed to be applied to large complex bus bars, therefore application can be advanced
  - Multiple B90s:
    - Protection Algorithm processing
    - Dynamic Bus Replica logic
    - Isolator monitoring
    - Breaker Failure Protection
  - Inter-relay Communication schemes for I/O transfer, inter-tripping
- GE Multilin can provide a complete engineered B90 System Solution, based on specific customer application & requirements
Q & A
Thanks for the time

imagination at work