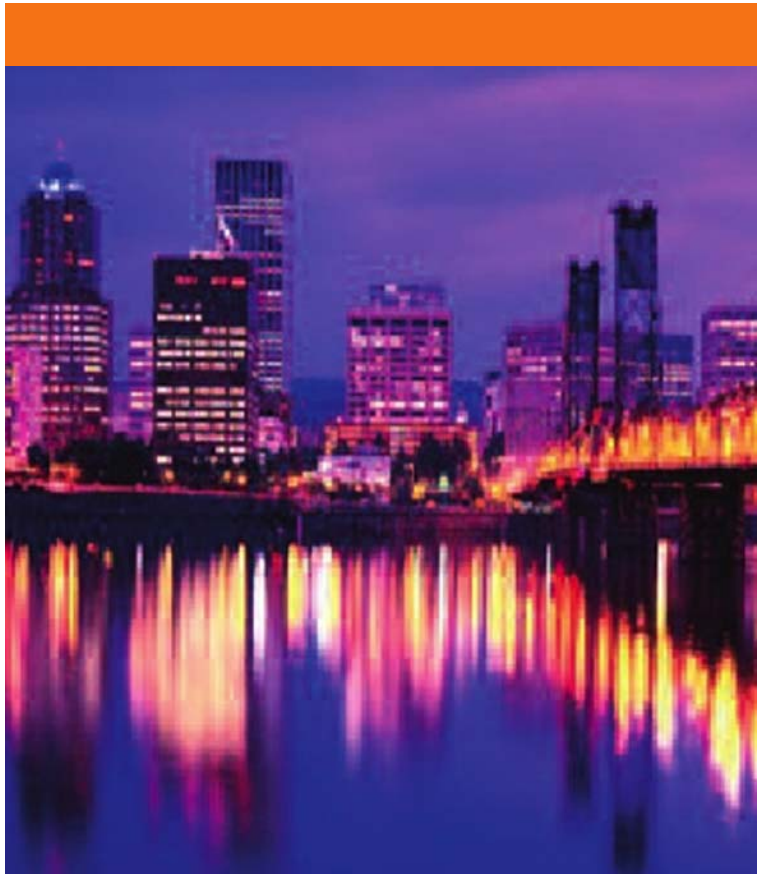
Relay Applications for the Main & Transfer Bus Configuration



Western Protective Relay Conference

Date: Wednesday October 15, 2014

Presenter: David Beach

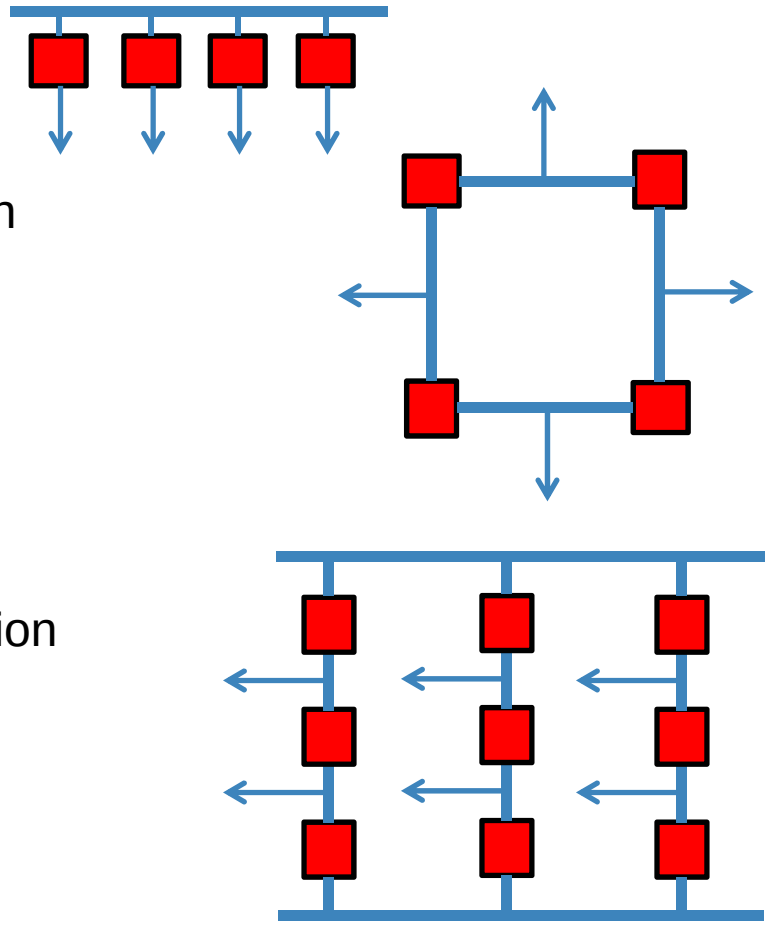
Portland General Electric

Outline

- Background
- Earlier Approaches
- Implementation
- An Alternate Approach
- What's a Bus, What's a Line?
- A Misadventure Along the Way
- Some Other Quirks
- Conclusions
- Recommendations for the Manufacturers

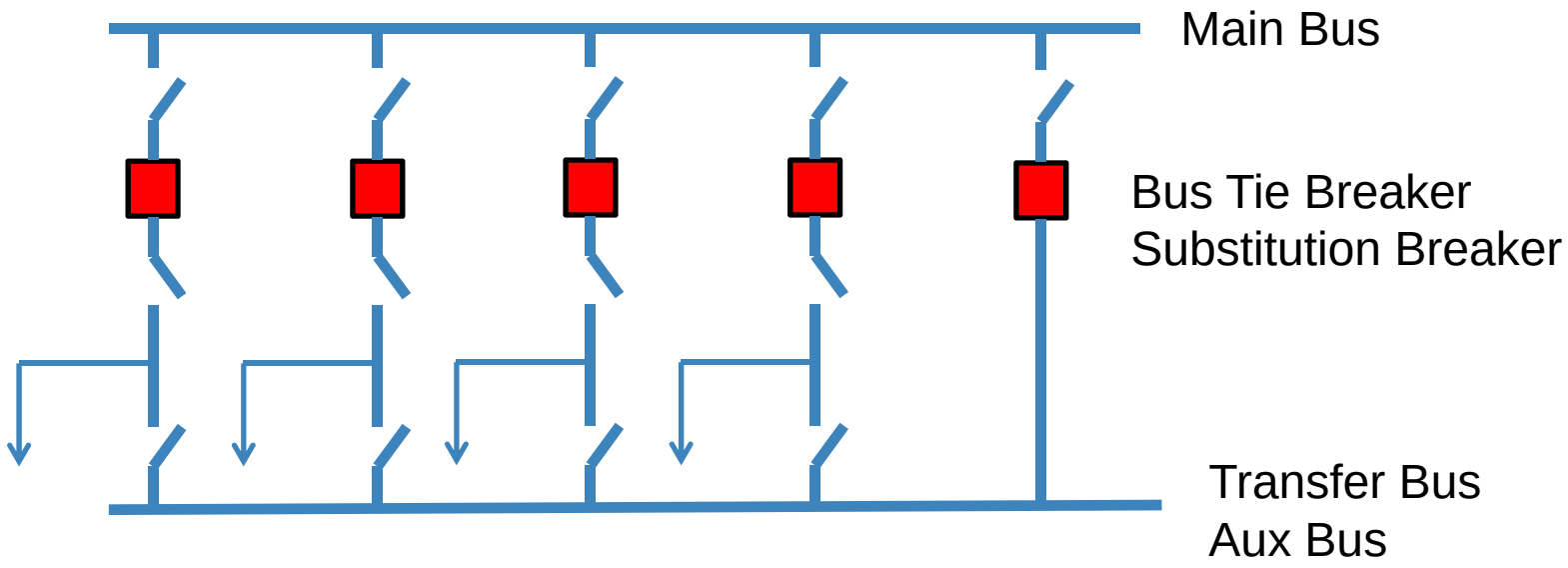
Bus Configurations

- Simple Bus, Straight Bus
  - Breaker count = position count
  - “Single Breaker” application
- Ring Bus
  - Breaker count = position count
  - “Dual Breaker” application
- Breaker-and-a-half
  - Breaker count = 1.5 * position count
  - “Dual Breaker” application



Main and Transfer Bus

- aka Main and Aux Bus
- Breaker count = position count + 1
- Single or Dual Breaker application?
  - Historically treated as single breaker plus
  - “The Other Dual Breaker Application”

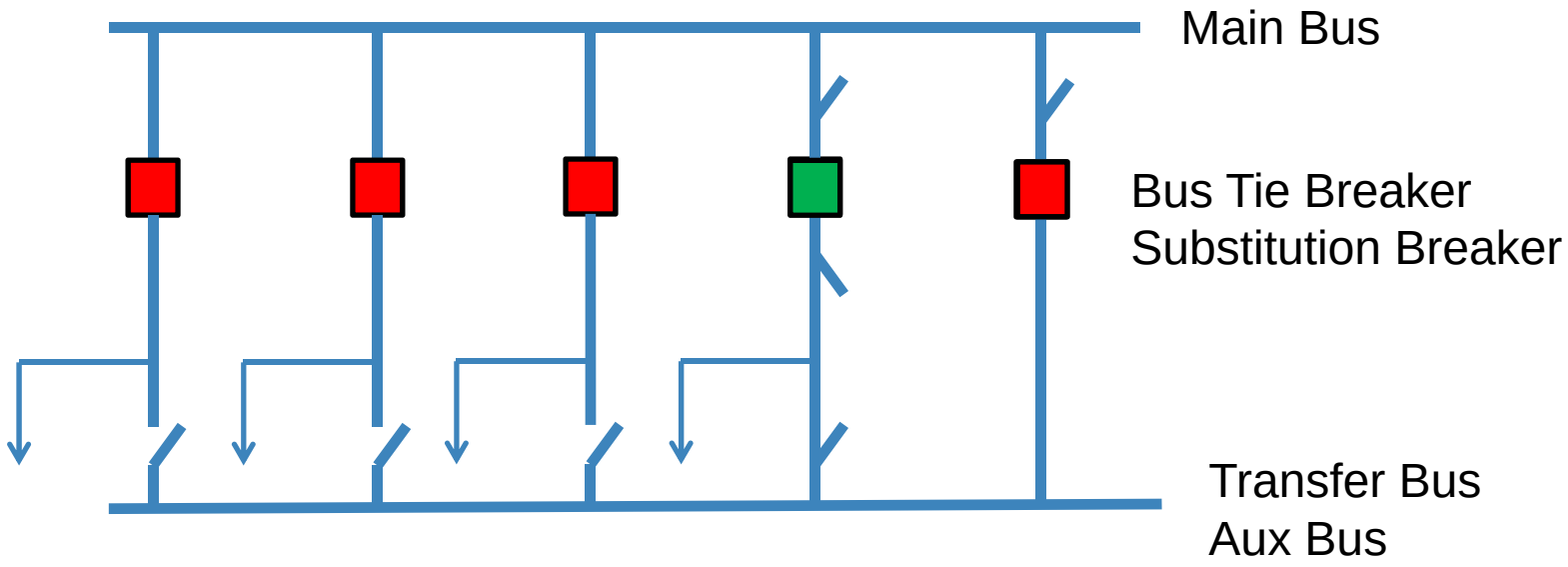


Why Main & Transfer?

- More flexibility than Simple Bus
- Far less complex than Ring Bus or Breaker-and-a-half when protected with Electro-mechanical relays.
  - With one trip contact per relay, tripping more than one breaker requires aux tripping relays.

Main and Transfer Switching

- Normal Configuration
- Close Bus Tie Switch, Close Bus Tie Breaker
- Close Aux Bus Disconnect
- Open Normal Breaker
- Open Breaker Disconnects



Protecting the Bus Tie Breaker

- Two different approaches
  - Dedicated Bus Tie Relays
    - More relays
    - Change settings for every position placed on Bus Tie or use compromised settings
      - Much easier with numeric relays with multiple setting groups
    - Works for line positions, transformer positions still require CT switching
  - Position Relays Switched to Bus Tie
    - Requires Relay Transfer Switch (RTS) that switches currents and trip circuits
    - Tripping is one breaker or the other
      - Remote back-up clearing required when both breakers closed during switching
    - Relay only sees currents from (at most) one breaker
      - No currents while RTS is between Normal and Bus Tie positions
    - Requires Bus Tie Breaker CT circuit routed to all positions for RTS switching

RTS Switching

- RTS with 5 positions (3 Labeled)
  - Normal
  - Between Normal and Off
  - Off
  - Between Off and Bus Tie
  - Bus Tie
- Handle can be inserted/removed only in Normal position.

RTS Switching – CT & Trip

	Normal		OFF		Bus Tie
Normal Breaker CT to Relay	X	X			
Normal Breaker CT Shorted		X	X	X	X
Bus Tie Breaker CT to Relay				X	X
Bus Tie Breaker CT Shorted	X	X	X	X	
Trip to Normal Breaker	X	X			
Trip to Bus Tie Breaker				X	X

Application History at PGE

- All M&T applications originally protected w/ electro-mechanical (EM) relays
- First numeric relays applied identically to the EM relays they replaced
- With 1992 numeric line relay + 1993 dual breaker reclosing relay PGE started building Ring and Breaker-and-a-half stations.
- That same 1992 numeric line relay used in a few M&T applications with few changes from the EM days
- 1999 brought an updated numeric line relay
  - Line differential added in 2001.
  - Dual Breaker application refined.
  - M&T applications with separate relay on Bus Tie Breaker

Separate Relay on Bus Tie Breaker

- Line positions have dedicated line protection
  - Can operate in parallel with Normal Breaker relaying
  - With digital transfer trip requires switching comm circuits
  - Setting group switching allows duplicate settings between Normal and Bus Tie relays
    - But with only two of those it is easy to forget to update the Bus Tie relay settings.
  - Still need to switch CT circuit when using Bus Tie for a transfomer.

Meanwhile, Back at the Ranch…

- 2001 introduction of line distance relay with 2 sets of 3-phase CTs and reclosing for 2 breakers
  - Lots and Lots of settings
    - Prior Distance relay (considering just one setting group) has about 600 settings
    - New relay had over 6700 settings
    - Functions that had been based on fixed settings now had to be created in free-form logic
- Relay pushed by vendor as the “ideal” relay for the “Dual Breaker” applications.
  - Lots of application guidance for Ring and Breaker-and-a-half
  - No mention of Main & Transfer in the application guides
- 2008 a transformer differential relay in the family is introduced
- 2011 a line differential relay in the family is introduced

… the Status Quo Reigned

- The Protection Group decided that the new relay would be more trouble than it would be worth
  - The dual breaker applications with each relay providing synch check/voltage based close supervision for one breaker seemed to work well.
  - M&T was still rather unsettled, but most new relays weren't going into M&T application
  - In other words, don't go looking for trouble

Paradise Interrupted …

- In 2008 a certain rookie member of the group was given grudging permission to explore the new dual breaker relay in a Ring Bus station.
- While studying the relay manual, said rookie engineer happened upon a critical insight
  - M&T is just another Dual Breaker application

M&T as Dual Breaker

- The relay settings allowed a certain level of CT selection control
- NUMBK – the number of breakers in the scheme
  - Ring, Breaker-and-a-half, M&T all use NUMBK = 2
- ESS – the source selection
  - Ring, Breaker-and-a-half use ESS = 3
  - M&T uses ESS = Y
- LINEI – Current for the protected line
  - Ring, Breaker-and-a-half use LINEI = COMB
  - M&T uses LINEI = IW, the breaker 1 (Normal Breaker) current
- ALINEI – the alternate current source
  - For Ring and Breaker-and-a-half this setting is unavailable
  - For M&T ALINEI = IX, the breaker 2 (Bus Tie Breaker) current

The Initial Limitation

- No combination of settings allow COMB, IW, and IX in the same application
  - The transformer differential relay allows inclusion of individual CT inputs in the differential dynamically by logic equation
    - REF configuration is not dynamic
  - The line current differential relay allows inclusion of individual CT inputs in the differential dynamically by logic equation
    - Distance element current have the same limitations as the distance only relay

First Approach

- Logical Control Using
  - RTS in Normal
  - RTS in Bus Tie

- Result is RTS in OFF = Neither
  - Just like the Electro-mechanical days

A Better Approach

- Actual Implementation based on:
  - Normal Breaker functions controlled by RTS Not in Bus Tie
  - Bus Tie Breaker functions controlled by RTS Not in Normal

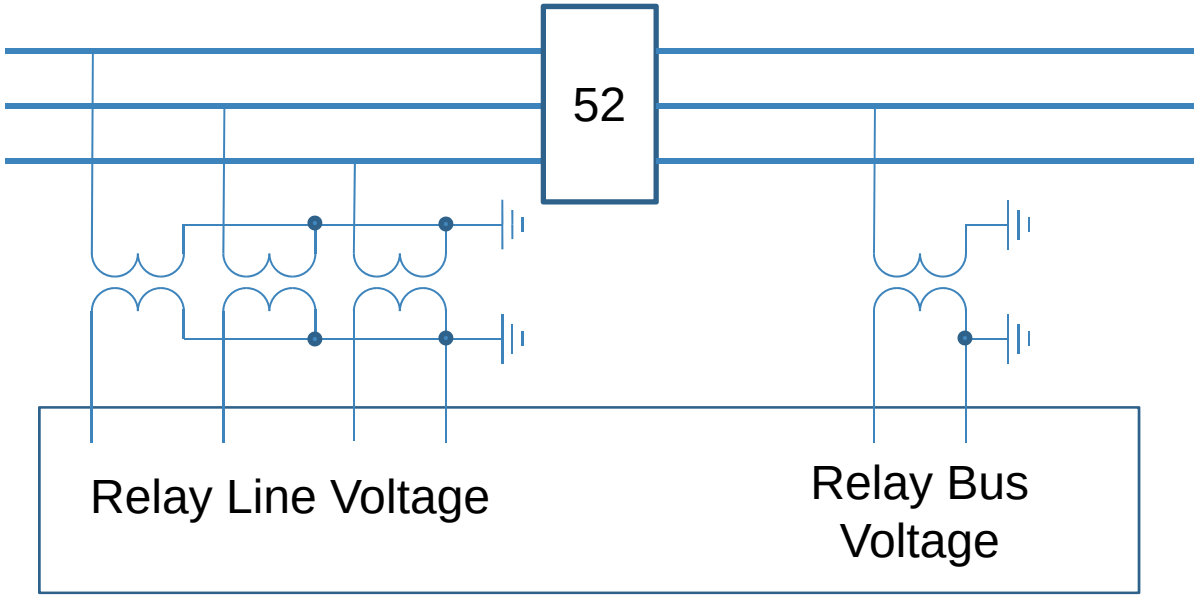
- Result is RTS in OFF = Both

Better Yet?

- Travel down the Rabbit Hole with Alice
  - One allowed combination is LINEI = COMB and ALINEI = IX (Breaker 2)
- So, make everything backward:
  - Normal Breaker wired to IX as Breaker 2
  - Bus Tie Breaker wired to IW as Breaker 1
  - RTS in Normal activates the alternate current ALINEI
  - RTS other than in Normal uses COMB, the internal current summation as the "Normal" current input.
- The downside risk is stray Normal Breaker currents while on the Bus Tie Breaker
  - Easily avoided by opening Normal Breaker test switches while doing any Normal Breaker maintenance with the position on the Bus Tie Breaker

More of Alice's World

- Consider the voltages used by the relay.
  - 3-phase voltage source – used by the distance elements as the protection voltage
  - Two 1-phase voltage sources (1 shown) – used for synch check and live/dead determinations



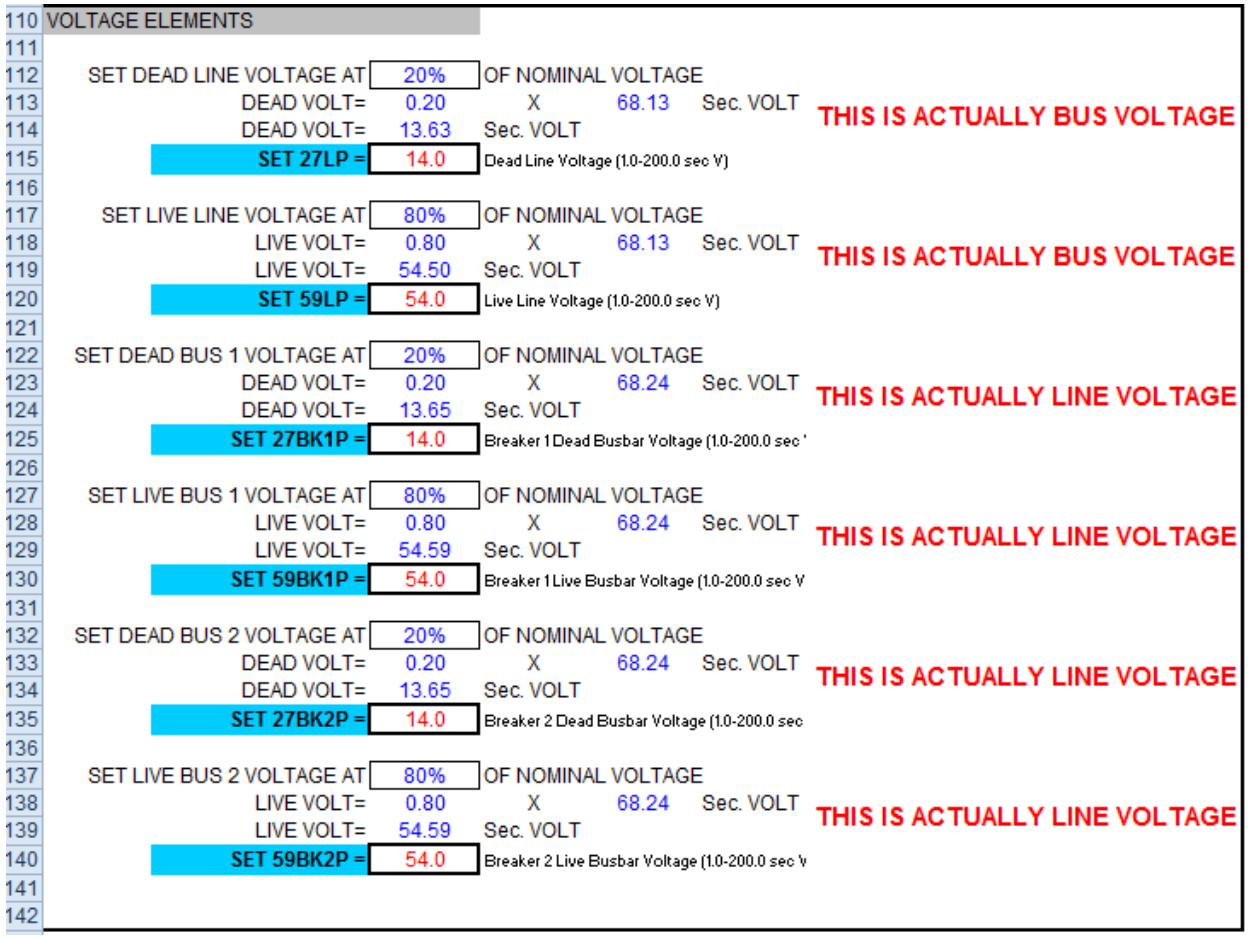
Voltages

- 3-Phase Voltage = Line
- 1-Phase Voltage = Bus
- Relay Values include such as:
  - Live Line-Dead Bus1 (LLDB1)
  - Dead Line-Live Bus1 (DLLB1)
- Ring, Breaker-and-a-half
  - 3-Phase Voltage from line side of breakers
  - 1-Phase Voltage from opposite side of each breaker
- Main & Transfer
  - 3-Phase Voltage from Bus
  - 1-Phase Voltage from line side of each breaker

Line vs. Bus Construction, per the Relay

- Ring, Breaker-and-a-half
  - Line – Uses the 3-phase VTs
    - Looks like – Spindly conductors, long spans, hung from poles or towers
  - Bus – Uses 1-phase VTs
    - Looks like – Large, often pipe, conductors, short spans, post insulators
- Main & Transfer
  - Line – Uses the 3-phase VTs
    - Looks like – Large, often pipe, conductors, short spans, post insulators
  - Bus – Uses 1-phase VTs
    - Looks like – Spindly conductors, long spans, hung from poles or towers

Setting Spreadsheet



110	VOLTAGE ELEMENTS						
111							
112	SET DEAD LINE VOLTAGE AT	20%	OF NOMINAL VOLTAGE				
113	DEAD VOLT=	0.20	X	68.13	Sec. VOLT		THIS IS ACTUALLY BUS VOLTAGE
114	DEAD VOLT=	13.63	Sec. VOLT				
115	SET 27LP =	14.0	Dead Line Voltage (1.0-200.0 sec V)				
116							
117	SET LIVE LINE VOLTAGE AT	80%	OF NOMINAL VOLTAGE				
118	LIVE VOLT=	0.80	X	68.13	Sec. VOLT		THIS IS ACTUALLY BUS VOLTAGE
119	LIVE VOLT=	54.50	Sec. VOLT				
120	SET 59LP =	54.0	Live Line Voltage (1.0-200.0 sec V)				
121							
122	SET DEAD BUS 1 VOLTAGE AT	20%	OF NOMINAL VOLTAGE				
123	DEAD VOLT=	0.20	X	68.24	Sec. VOLT		THIS IS ACTUALLY LINE VOLTAGE
124	DEAD VOLT=	13.65	Sec. VOLT				
125	SET 27BK1P =	14.0	Breaker 1 Dead Busbar Voltage (1.0-200.0 sec '				
126							
127	SET LIVE BUS 1 VOLTAGE AT	80%	OF NOMINAL VOLTAGE				
128	LIVE VOLT=	0.80	X	68.24	Sec. VOLT		THIS IS ACTUALLY LINE VOLTAGE
129	LIVE VOLT=	54.59	Sec. VOLT				
130	SET 59BK1P =	54.0	Breaker 1 Live Busbar Voltage (1.0-200.0 sec V				
131							
132	SET DEAD BUS 2 VOLTAGE AT	20%	OF NOMINAL VOLTAGE				
133	DEAD VOLT=	0.20	X	68.24	Sec. VOLT		THIS IS ACTUALLY LINE VOLTAGE
134	DEAD VOLT=	13.65	Sec. VOLT				
135	SET 27BK2P =	14.0	Breaker 2 Dead Busbar Voltage (1.0-200.0 sec				
136							
137	SET LIVE BUS 2 VOLTAGE AT	80%	OF NOMINAL VOLTAGE				
138	LIVE VOLT=	0.80	X	68.24	Sec. VOLT		THIS IS ACTUALLY LINE VOLTAGE
139	LIVE VOLT=	54.59	Sec. VOLT				
140	SET 59BK2P =	54.0	Breaker 2 Live Busbar Voltage (1.0-200.0 sec V				
141							
142							

Switching Mode – the Need

- The previously mentioned use of Not on Normal and Not on Bus Tie solved many problems but it wasn't a complete solution
- How to finish switching?
  - Switch RTS then open Breaker
    - Breaker being taken out of service would still be closed, but removed from tripping
  - Open the Breaker then switch RTS
    - For a moment all of the current would be through the breaker being put in service but the relay would still be using the currents from the other, open, breaker
- Need a Logical "Switching Mode" that would retain tripping of both breakers later in the process

Switching Mode – Line Relays

- Enter Switching Mode when the RTS is switched to OFF
  - Trip both breakers
  - No reclosing
- Change Current Selection when RTS is switched from OFF
- Exit Switching Mode when the RTS is not in OFF and the other breaker opens
  - Switching from Normal to Bus Tie, exit Switching mode when RTS is in Bus Tie and Normal Breaker is open
  - Switching from Bus Tie to Normal, exit Switching mode when RTS is in Normal and Bus Tie Breaker is open
- Exits properly whether the switching sequence is completed or the switching is aborted and returned to prior state

Switching Mode – Transformer Relays

- As the Transformer Relay application was being developed, a standardized I/O was developed.
  - The first pass only had room for one RTS input on the high-side and one RTS input on the low-side
  - No problem – the relay had programmable push buttons on the front panel – we could use push buttons to enter and exit Switching Mode.
- OOPS
  - The relays for one transformer were placed in Switching Mode between the completion of functional testing and when the relays were placed in service.
  - Months later when a line position was on the Bus Tie Breaker, the inclusion of the Bus Tie Breaker currents resulted in a transformer differential trip
- I/O has been reallocated to allow both RTS inputs on each side of the transformer and the elimination of the push buttons

Other Quirks

- REF – Because the REF is not dynamically assigned, REF has to be turned off when entering Switching Mode and may be turned back on when exiting Switching Mode.
  - The relay has 3 REF configurations, but there are 4 configurations necessary with M&T on both high-side and low-side
  - Using both Bus Tie Breakers at the same time is seen as very unlikely, so no REF for this configuration
- Back-up Overcurrent Elements
  - PGE uses definite time overcurrent as backup against uncleared system faults
  - Relay doesn't dynamically combine currents into overcurrent elements
  - Overcurrent elements had to be created in logic to include or exclude CT inputs based on switching process

Line Relay Reclosing

- The relay manufacturer defines reclose lockout as:
  - Any condition for which the relay will not attempt a reclose
    - Reclosing blocked
    - Final shot has occurred
    - Breaker manually opened and removed from reclose scheme
- PGE defines reclose lockout as:
  - Relay trip followed by the relay not issuing a reclose
    - Trip while reclosing is blocked
    - Trip following final reclosing shot
  - Logically:
    - Trip with the Reclose Enable input deasserted
    - Relay state transition from reclose cycling to reclose lockout

Reclosing during Switching

- It is assumed that any fault during the switching process is likely to be the result of the switching
  - Reclosing is not desired during switching
  - Fault likely to be over the head of the operator doing the switching
- How to Not Reclose
  - First thought was to not initiate reclosing during switching mode
    - Would work, but
    - Wouldn't provide Reclose Lockout signal to the System Control Center
  - Allow reclose initiate, but then block reclose in the supervision logic
    - Reclose will time out and the relay will transition from cycling to lockout, providing the transition that provides the Reclose Lockout signal.

Conclusions

- The family of “Two Breaker” applications is larger than just those applications where both breakers are normally in service together
- When contemplating a relay for an application where the manufacturer has not provided application guidelines it is necessary to have a thorough understanding of the assumptions made by the manufacturer in the design of the relay.
  - Line vs. Bus Voltage
- When implementing a new scheme such as this expect operational surprises as field conditions produce unanticipated situations.
- If the scheme relies on specific steps happening in a specific order, be prepared to see those steps happen in a different order.
- “Unconventional” relay applications can solve long standing protection problems

Recommendations to the Manufacturers

- Don’t make assumptions about system configurations such as those that result in “Bus” voltages coming from the line and “Line” voltages coming from the bus.
- In any case where it is possible to include, or exclude, a CT (or VT) set in a calculation, make the selection on a set-by-set basis rather than a normal-alternate type selection.
- When some features of the relay allow dynamic inclusion/exclusion of CT (or VT) sets, include that capability for all functions

Questions?