SIPROTEC 5 Application Note

Breaker-and-a-half solutions

SIP5-APN-002, Edition 2

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1 Breaker-and-a-half solutions

1.1 Introduction
This application describes the requirements for the protection and control of breaker-and-a-half systems and introduces an efficient and innovative solution concept with SIPROTEC 5.

1.2 Properties of a breaker-and-a-half application
- Each line is delimited by two circuit breakers and the associated current transformers. These currents have to be supersized and processed.
- Each diameter contains two feeders (two lines or line and transformer). The central circuit breaker is used jointly by both feeders. Only 3 circuit breakers are consequently available for 2 feeders. Hence the designation breaker-and-a-half application.
- Different voltages have to be selected for synchronizing the switching command depending on the switch position.

1.3 Terminology
The following terminology is used in the context of breaker-and-a-half:
- Breaker-and-a-half: Term used for the plant configuration shown in the single line diagram, figure 1.
- Diameter: Term used to describe the three circuit breakers and associated equipment in the diagram below. A number of such “diameters” in parallel are applied to the two busbars.
- Stub Protection: In this application this is a special protection that covers the zone between the breakers and the line isolator when the line isolator is open.
- Tie-CB: The central circuit breaker, between the two feeders, in the breaker-and-a-half configuration is referred to as the Tie-CB.
- Leader/Follower: The Leader/Follower logic is associated with the auto re-close function in the breaker-and-a-half configuration. It determines the sequence of re-closing of the two circuit breakers that trip to clear a fault on the OHL.
- Application Template: Predefined device configuration in DIGSI 5 (e.g. DIS overhead line, grounded systems). The application templates contain the basic configurations, required functions groups and function as well as default settings.
- Function Group: Functional groups (FG) correspond to the primary components (protection object: line; transformer, circuit breaker, disconnector), thereby simplifying the direct reference to the actual system. For example, if the switchgear includes 2 circuit breakers, this is also represented by 2 “circuit breaker” functional groups – a schematic map of the actual system.

1.4 Requirements for the system solution
- Feeder protection (main protection and backup protection)
- Circuit-breaker failure protection
1.5 Solution concept with SIPROTEC 5 for two feeders

- Main protection and backup protection devices for each line
- 1 central control unit for the entire diameter/bay
- All devices of a diameter are connected by a so called a diameter bus.
- Distribution of the functions between the devices using the flexibility of SIPROTEC 5:
  - Control unit: control, synchrocheck
  - Protection devices: protection, tripping, AR, circuit-breaker failure protection
- Flexible expansion of IOs using the modular quantity structure or connected IO units (diameter bus)

Figure 1: Overall concept for protection and control of breaker-and-a-half systems
1.6 Description of the individual system components

Diameter bus
The diameter bus is implemented in order to ensure the proper data exchange among the devices belonging to the diameter. This provides the following system benefits:

- fast data exchange between the devices
- isolated signal exchange (optical fiber)
- enhanced security compared to wire connections through monitoring of the signal links
- easy implementation of group indications and additional automation functions (e.g. common start of fault records, coordination of protection functions that run parallel)
- It is possible to implement communication and function redundancy
- easy integration of redundant devices and/or additional devices
- reduced wiring and engineering effort
- more flexibility for future modifications
- less space required

There is several options for such a diameter bus:

1. Using Protection Data Interfaces (PDI) - Modules USART-xx-yFO
2. Using a dedicated IEC61850 GOOSE Network by adding an ETH-xx-2FO Module, preferably using HSR configuration.

Controlling equipment
The switching equipment, circuit breakers and disconnector, is operated from a central bay controller.

- clearly arranged operation owing to representation on the device display
- The diameter bus provides the central bay controller with all the information that is relevant to assume the control task. (e.g. interlocking)
- It is possible to activate backup protection functions in the central bay controller if no line backup protection is used.

Synchrocheck
The synchrocheck is realized centrally in the bay controller for the entire diameter. All voltages are acquired directly and independently by the bay controller and applied to the synchrocheck function depending on the diameter current configuration.

- enhanced security and reduced wiring effort because no external coupling relays are needed to select the voltage
- monitoring of all voltage transformers (fuse failure monitor)

Line protection
The protection scheme can be implemented with a single device. Redundancy can be achieved by using the protection device of one feeder as the backup protection of the other.

- Line differential protection and distance protection in one device (7SL8). Alternatively, can be also distributed on two devices (7SD8 and 7SA8)
- integrated stub protection (87Stub) when line disconnectors are open
- increased sensitivity of the line differential protection through separate transformer acquisition
1.7 Description of the selected device hardware

The following devices are selected for this solution:

- 7SL8 Line Differential and Distance Protection (Line 1 Main 1)
- 7SL8 Line Differential and Distance Protection (Line 2 Main 1)
- 6MD8 Bay Controller (Control of switching devices of the diameter)

2 x 7SL87 for Line 1 and 2: Product code P1C107747 *

- **7SL8** Line Differential and Distance Protection (Line 1 Main 1)
- **7SL8** Line Differential and Distance Protection (Line 2 Main 1)
- **6MD8** Bay Controller (Control of switching devices of the diameter)

* Diameter Bus with PDI

- Housing width: 5/6 x 19"
- Housing type: Flush mounting
- Binary inputs: 47**
- Binary outputs: 36 Relays (22 Standard, 14 Fast, 0 High-Speed, 0 Power)**
- Current transformers: 8 for protection, 0 for measurement and sensitive ground-current detection**
- Voltage transformers: 8**
- Modules in 19" row 1: IO202, PS201, IO208, IO207, IO207

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** Additional stability of the direction determination for the distance protection
** Saturation detection for each transformer
Number of LEDs: 32
Display type: Small display
Power Supply: DC 60 V-250 V, AC 100 V-230 V

Communication:
- Communications encryption: Normal
- Integrated Ethernet port: for DIGSI 5
- Plug-in module position E:
  USART-AE-2FO: 2 x optic 1.5 km, 820 nm, ST connector, for serial protocols, e.g. IEC60870-5-103, DNP3.0 etc. and protection interface
- Plug-in module position F:
  ETH-BB-2FO: 2 x optic Ethernet, Ethernet 100 Mbit/s, 1300 nm, LC-Duplex connector, 2 km over 50/125 m or 62.5/125 m multimode - fiber

Functions:
Function points class: Base + 425 function points

** The amount of binary/analog inputs and outputs can be adjusted by adding, reducing, changing the IO Modules.

1 x 6MD86 for Control of switching equipment of the diameter: Product code P1G93301*

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### 6MD8

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>U</th>
<th>BI</th>
<th>BO</th>
</tr>
</thead>
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<td>PS 201</td>
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<td>2</td>
<td></td>
<td></td>
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<tr>
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<td>4</td>
<td>8</td>
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</tr>
<tr>
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<td>-</td>
<td>-</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>I/O 231</td>
<td>-</td>
<td>-</td>
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<td>24</td>
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<tr>
<td>PS 203</td>
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<tr>
<td>I/O 231</td>
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<td>-</td>
<td>24</td>
<td>24</td>
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<tr>
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<td>-</td>
<td>-</td>
<td>48</td>
<td>0</td>
</tr>
<tr>
<td>CB 202</td>
<td>Optional – not included</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>147</td>
<td>93</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Diameter Bus with PDI

- Housing width: 9/6 x 19*
- Housing type: Flush mounting
- Binary inputs: 147**
- Binary outputs: 93 Relays (75 Standard, 18 Fast, 0 High-Speed, 0 Power)**
- Current transformers: 0 for protection, 12 for measurement and sensitive ground-current detection**
- Voltage transformers: 8**

* Diameter Bus with PDI

** The amount of binary/analog inputs and outputs can be adjusted by adding, reducing, changing the IO Modules.

- Modules in 19" row 1: IO202, PS201, IO202, IO201, IO231, IO231
- Modules in 19" row 2: PS203, IO231, IO230
- Number of LEDs: 64
- Key switch: With
- Display type: Large display
- Power Supply: DC 60 V-250 V, AC 100 V-230 V

Communication:
- Communications encryption: Normal
- Integrated Ethernet port: for DIGSI 5
- Plug-in module position E: ETH-BA-2EL: 2 x electric Ethernet, RJ45, applicable for DIGSI, IEC61850, DNP, etc.
  
Plug-in module position F:
- USART-AD-1FO: 1 x optic 1.5 km, 820 nm, ST connector, for serial protocols, e.g. IEC60870-5-103, DNP3.0 etc. and protection interface

Functions:
- Function points class: Base
1.8 SIPROTEC 5 Function Groups for Breaker-and-a-half

In the SIPROTEC 5 platform was introduced the "Function Group" concept. A "Function group", FG, is the representation of a primary object like a line, circuit breaker, transformer, disconnector, or generic V-I groups, among others. The protection functions are assigned to the corresponding Function Groups where the protection functionality is to operate, providing a clear interface and separation of tasks between the various functions in a complex application. The following example shows the allocation of the required Function Groups and Protection Functions for this application:

Distribution of Protection Functions in the corresponding Function Groups:

<table>
<thead>
<tr>
<th>Protection Devices</th>
<th>Control Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>FG Line</td>
<td>FG Circuit Breaker A_Q0</td>
</tr>
<tr>
<td>Distance Protection x</td>
<td>x</td>
</tr>
<tr>
<td>Line Differential  x</td>
<td>x</td>
</tr>
<tr>
<td>Over Current       x</td>
<td>x</td>
</tr>
<tr>
<td>Over Voltage       x</td>
<td>x</td>
</tr>
<tr>
<td>Auto Reclose       x</td>
<td>x</td>
</tr>
<tr>
<td>Sync Check         x</td>
<td>x</td>
</tr>
<tr>
<td>Breaker Failure    x</td>
<td>x</td>
</tr>
</tbody>
</table>

Figure 2: Functional allocation

1.9 Protection and (optional) control functions

Several protection functions shall be normally enabled in a diameter in order to cover all possible fault scenarios. The table below shows an example for overhead lines OHL, indicating the type of IED that can be used with information about the applicable Function group and Protection functions, as well as the corresponding SIPROTEC 5 Application Note if available:

<table>
<thead>
<tr>
<th>Function</th>
<th>Function Group</th>
<th>Description</th>
<th>Protection IED</th>
<th>Detailed App Instr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance Protection</td>
<td>Line</td>
<td>Main and / or back up protection in OHL</td>
<td>7SA86, 7SA87, 7SL86 and 7SL87</td>
<td>SIP5-APN0016</td>
</tr>
<tr>
<td>Differential protection</td>
<td>Line</td>
<td>Main and / or back up protection in OHL</td>
<td>7SD86, 7SD87, 7SL86 and 7SL87</td>
<td></td>
</tr>
<tr>
<td>Earth Fault Protection</td>
<td>Line</td>
<td>Back up protection in OHL</td>
<td>7SA86, 7SA87, 7SD86, 7SD87, 7SL86 and 7SL87</td>
<td></td>
</tr>
<tr>
<td>Voltage / frequency Protection</td>
<td>Line</td>
<td>Additional protection in OHL</td>
<td>7SA86, 7SA87, 7SD86, 7SD87, 7SL86 and 7SL87</td>
<td></td>
</tr>
<tr>
<td>Stub</td>
<td>Line</td>
<td>Protection to cover the zone</td>
<td>7SA86, 7SA87</td>
<td>SIP5-APN017</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>protection</th>
<th>between circuit breakers and line isolator</th>
<th>7SD86, 7SD87, 7SL86 and 7SL87</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Busbar protection</strong></td>
<td>Busbar</td>
<td>7SS85</td>
</tr>
<tr>
<td><strong>Breaker failure protection</strong></td>
<td>Circuit Breaker</td>
<td>7SA86, 7SA87, 7SD86, 7SD87, 7SL86 and 7SL87</td>
</tr>
<tr>
<td></td>
<td>Local back-up protection for breaker fail scenarios after a protection trip</td>
<td>7VK86 7VK87 and 6MD8x</td>
</tr>
<tr>
<td><strong>Auto reclose</strong></td>
<td>Circuit Breaker</td>
<td>7SA86, 7SA87, 7SD86, 7SD87, 7SL86 7SL87, 7VK86 7VK87 and 6MD8x</td>
</tr>
<tr>
<td>Incl. leader follower function</td>
<td></td>
<td>SIP5-APN-018</td>
</tr>
<tr>
<td><strong>Sync Check</strong></td>
<td>Circuit Breaker</td>
<td>7SA86, 7SA87, 7SD86, 7SD87, 7SL86 and 7SL87</td>
</tr>
<tr>
<td></td>
<td>Provides sync check prior to closing of CB (after AR or control command)</td>
<td>7VK86 7VK87 and 6MD8x</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SIP5-APN-004</td>
</tr>
</tbody>
</table>

Figure 3: Function and function group overview of a diameter

### 1.10 Summary

The solution concept introduced above uses the multiple features of the SIPROTEC 5 series. It is based on a distributed system solution approach whose components are merged to a total solution using highly efficient and reliable communication options. The individual functions can be adjusted flexibly to customer requirements and to the individual device within the overall solution.
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