

# AQ-SAS™ MV Standard Arc Schemes

Instruction manual

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# 1 Document information

## 1.1 Version 2 revision notes

Table. 1.1 - 1. Version 2 revision notes

|          |  |
|----------|--|
| Revision | 2.00   |
| Date     | 18.12.2023   |
| Changes  | <ul style="list-style-type: none"><li>- New more consistent look.</li><li>- More descriptions to schemes.</li><li>- Drawings redone.</li><li>- Added new schemes with AQ-103.</li><li>- Rearranged order of schemes.</li></ul> |
| Revision | 2.01   |
| Date     | 7.11.2024  |
| Changes  | <ul style="list-style-type: none"><li>- Fixed AQ-110P SS:7a binary input connection descriptions.</li><li>- Revised connection drawings for application with one tie breaker and multiple incoming feeders.</li></ul>          |
| Revision | 2.02   |
| Date     | 20.12.2024   |
| Changes  | <ul style="list-style-type: none"><li>- Additional details in the detailed application drawings included in the zip package.</li></ul>   |

## 1.2 Version 1 revision notes

Table. 1.2 - 2. Version 1 revision notes

|          |  |
|----------|--|
| Revision | 1.00   |
| Date     | 1.10.2010  |
| Changes  | <ul style="list-style-type: none"><li>- First revision.</li></ul>                                |
| Revision | 1.01   |
| Date     | 1.8.2011   |
| Changes  | <ul style="list-style-type: none"><li>- Added more information and selectable schemes.</li></ul> |
| Revision | 1.02   |
| Date     | 1.9.2011   |
| Changes  | <ul style="list-style-type: none"><li>- Added more information and selectable schemes.</li></ul> |
| Revision | 1.03   |
| Date     | 1.11.2011  |

|          |  |
|----------|--|
| Changes  | - Corrected information.               |
| Revision | 1.04                                   |
| Date     | 1.8.2012                               |
| Changes  | - Corrected information.               |
| Revision | 1.05                                   |
| Date     | 1.8.2017                               |
| Changes  | - Add new schemes and layouts.         |
| Revision | 1.06                                   |
| Date     | 1.8.2020                               |
| Changes  | - Revised AQ-101S connection diagrams. |

### 1.3 Safety information

This document contains important instructions that should be saved for future use. Read the document carefully before installing, operating, servicing, or maintaining this equipment. Please read and follow all the instructions carefully to prevent accidents, injury and damage to property.

Additionally, this document may contain four (4) types of special messages to call the reader's attention to useful information as follows:



#### NOTICE!

"Notice" messages indicate relevant factors and conditions to the the concept discussed in the text, as well as to other relevant advice.



#### CAUTION!

"Caution" messages indicate a potentially hazardous situation which, if not avoided, **could** result in minor or moderate personal injury, in equipment/property damage, or software corruption.



#### WARNING!

"Warning" messages indicate a potentially hazardous situation which, if not avoided, **could** result in death or serious personal injury as well as serious damage to equipment/property.



#### DANGER!

"Danger" messages indicate an imminently hazardous situation which, if not avoided, **will** result in death or serious personal injury.

These symbols are added throughout the document to ensure all users' personal safety and to avoid unintentional damage to the equipment or connected devices.

Please note that although these warnings relate to direct damage to personnel and/or equipment, it should be understood that operating damaged equipment may also lead to further, indirect damage to personnel and/or equipment. Therefore, we expect any user to fully comply with these special messages.

## 1.4 Abbreviations

AQD – Arc quenching device

BI – Binary input

BO – Binary output

CBFP – Circuit breaker failure protection

HSO – High-speed output

L> – Arc light signal

Lext> – Arc light signal received from an external device

I> – Overcurrent detected by the device i.e. internal overcurrent.

Iext> – Overcurrent signal received from an external device.

MT – Master trip

SS – Standard Scheme. Operation logic of the arc protection device. Selectable by the user.

## 2 General

Arcteq's AQ 100 series offers a complete solution for arc flash protection focusing on simplicity while maintaining both flexibility and function. The devices are built for a single purpose: to provide effective arc flash protection for low-voltage or medium-voltage applications. This MV Standard Arc Schemes (AQ-SAS™) instruction manual includes a collection of pre-engineered, fully tested, and fully documented protection schemes which ensure correct operation in all conditions. The schemes are suitable for various typical switchgear layouts.

This document includes:

- Both simplified and detailed descriptions of each application
- Comparison of each solution (advantages and disadvantages)
- Example single line diagram of the application
- Required AQ 100 series arc protection devices for each application
- Trip and I/O operation logic
- Setting instructions
- Wiring diagram of each of the devices
- Ways to make modifications to typical applications.

This document is distributed as a zip package. In addition to this PDF document, the package includes application drawings of each scheme with higher detail than what you can find in this document.

For detailed information about AQ 100 series devices refer to their manuals at <https://www.arcteq.fi/documents-and-software/>.

## 3 Without a tie breaker

This chapter lists various typical arc protection application solutions for substations without tie breakers. The device types, used logic schemes and wiring vary between the solutions, but the basic operation logic is the same in all of them. Suggested schemes in this chapter are completely selective. Later chapters explain the design and operation of each suggested solution in higher detail.

Figure. 3 - 1. Position of each point sensor in a substation.

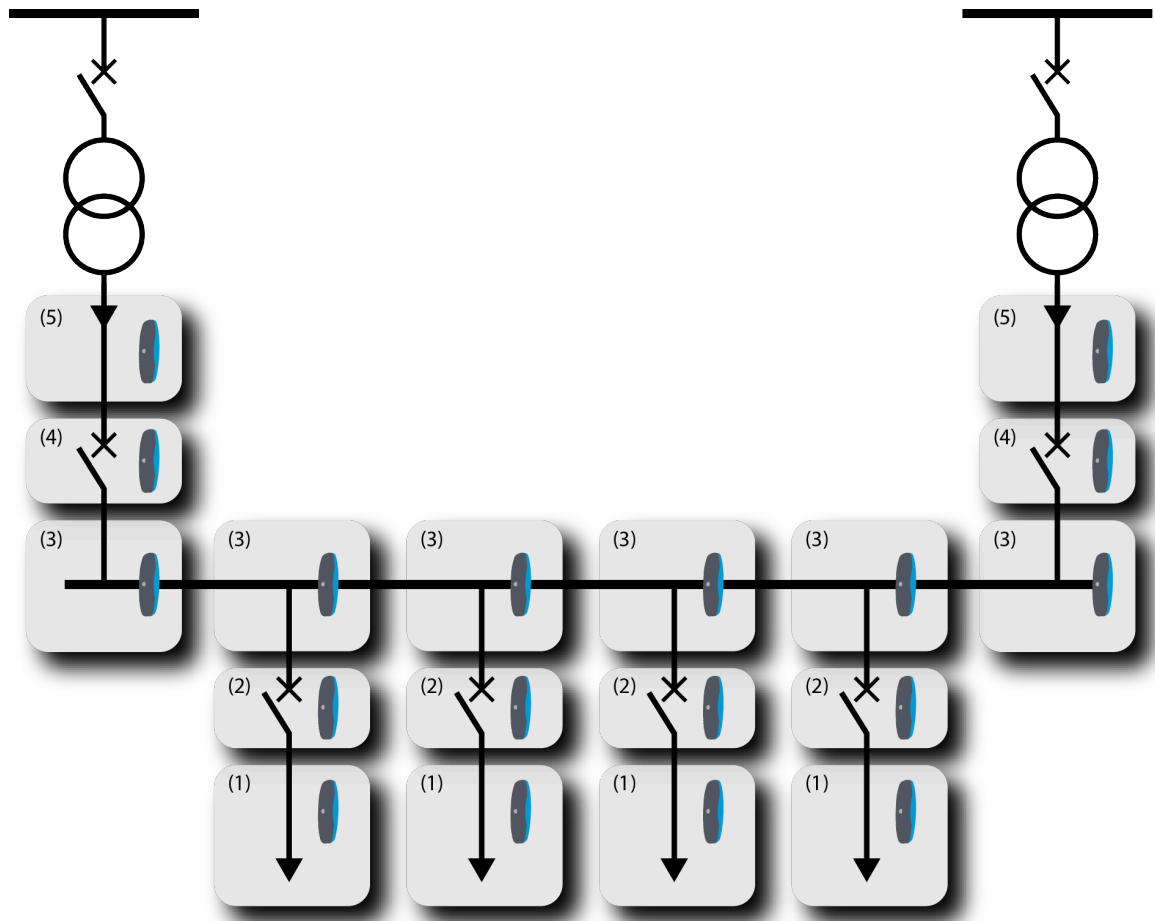


Table. 3 - 3. Simplified arc protection operation logic in a substation without tie breakers.

| # | Fault location                              | Circuit breaker to trip  | CBFP trip  |
|---|---|--|--|
| 1 | Outgoing feeder cable compartment           | <ul style="list-style-type: none"> <li>The outgoing feeder with the fault</li> </ul>               | <ul style="list-style-type: none"> <li>Incoming feeder(s)</li> <li>All outgoing feeders</li> </ul> |
| 2 | Outgoing feeder circuit breaker compartment | <ul style="list-style-type: none"> <li>Incoming feeder(s)</li> <li>All outgoing feeders</li> </ul> | <ul style="list-style-type: none"> <li>HV side of incoming feeder(s)</li> </ul>                    |
| 3 | Busbar compartment                          |  |  |



| # | Fault location                              | Circuit breaker to trip   | CBFP trip  |
|---|---|---|--|
| 4 | Incoming feeder circuit breaker compartment | <ul style="list-style-type: none"> <li>Incoming feeder(s)</li> <li>HV side of incoming feeder with the fault</li> <li>All outgoing feeders</li> </ul> | <ul style="list-style-type: none"> <li>HV side of other incoming feeders</li> </ul>                    |
| 5 | Incoming feeder cable compartment           | <ul style="list-style-type: none"> <li>The incoming feeder with the fault</li> <li>HV side of the incoming feeder with the fault</li> </ul>           | <ul style="list-style-type: none"> <li>All outgoing feeders</li> <li>Other incoming feeders</li> </ul> |

### Incoming feeder protection

Each suggested incoming feeder protection solution has point sensors installed to cable compartments, circuit breaker compartments and busbar compartments. Incoming feeder devices exchange information (light, master trip and current signals) with outgoing feeder devices and other incoming feeder devices with I/O.

Figure. 3 - 2. Typical point sensor positions in incoming feeders with suggested devices and schemes.

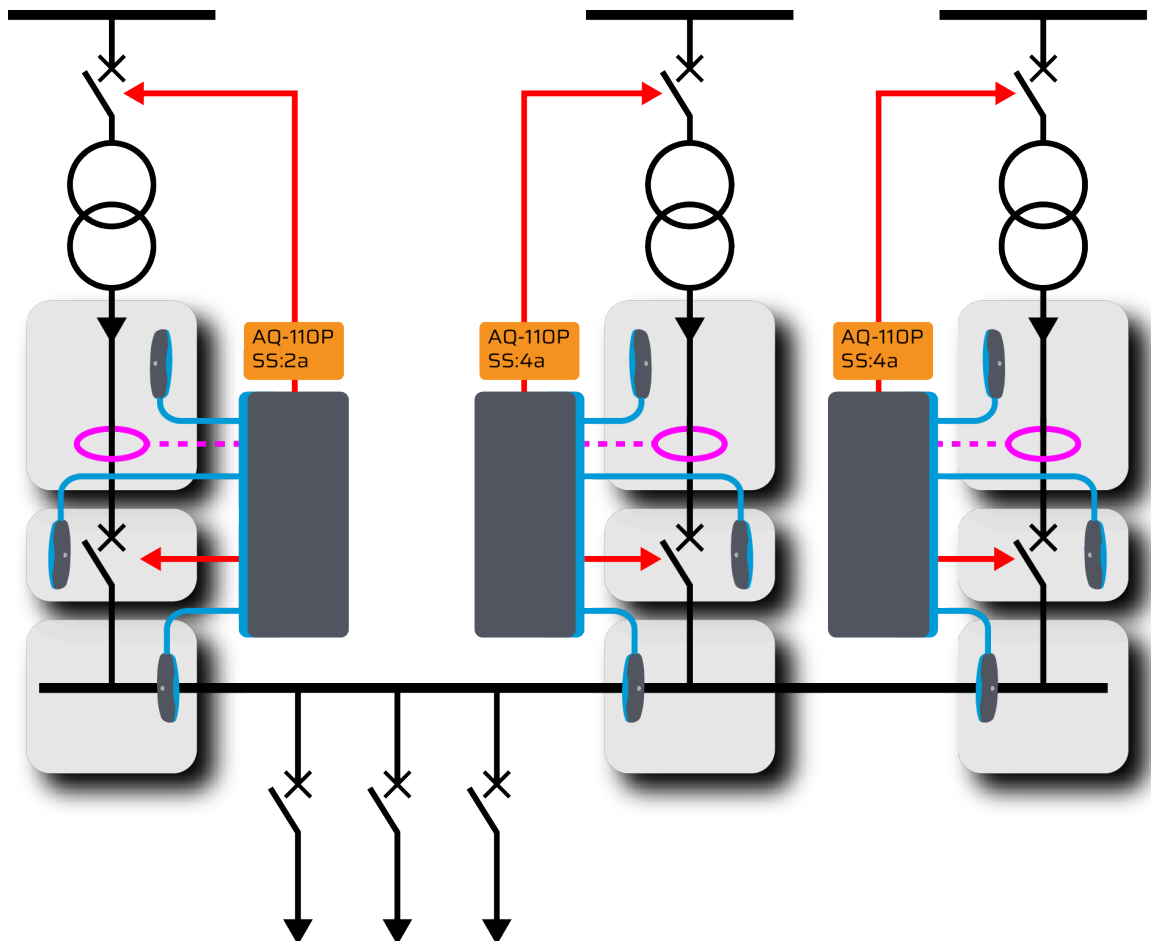


Table. 3 - 4. Devices installed to incoming feeders.

| Device (scheme)    | Description  |
|--------------------|--|
| AQ-110P<br>(SS:2a) | <ul style="list-style-type: none"> <li>• "Master incoming feeder" device.</li> <li>• Can detect overcurrents and earth faults and share this information it with other devices in the system.</li> <li>• Sends master trip and current signals to outgoing feeder devices.</li> <li>• Sends master trip signals to "Follower incoming feeder" devices.</li> <li>• At most 20 external devices can be connected to this device with I/O.</li> </ul> |
| AQ-110P<br>(SS:4a) | <ul style="list-style-type: none"> <li>• "Follower incoming feeder" device.</li> <li>• Used if there is more than one incoming feeder in the substation.</li> <li>• Up to five (5) "Follower incoming feeder" devices can be connected to the "Master incoming feeder" device.</li> <li>• Sends light and overcurrent signals to "Master incoming feeder" device.</li> </ul>   |

## Outgoing feeder protection

Each suggested outgoing feeder protection solution has point sensors installed to cable compartments, circuit breaker compartments and busbar compartments. Outgoing feeder protection devices exchange information (light, master trip and current signals) with "Master incoming feeder" device with I/O.

Figure. 3 - 3. Typical point sensor positions in outgoing feeders with suggested devices and schemes.

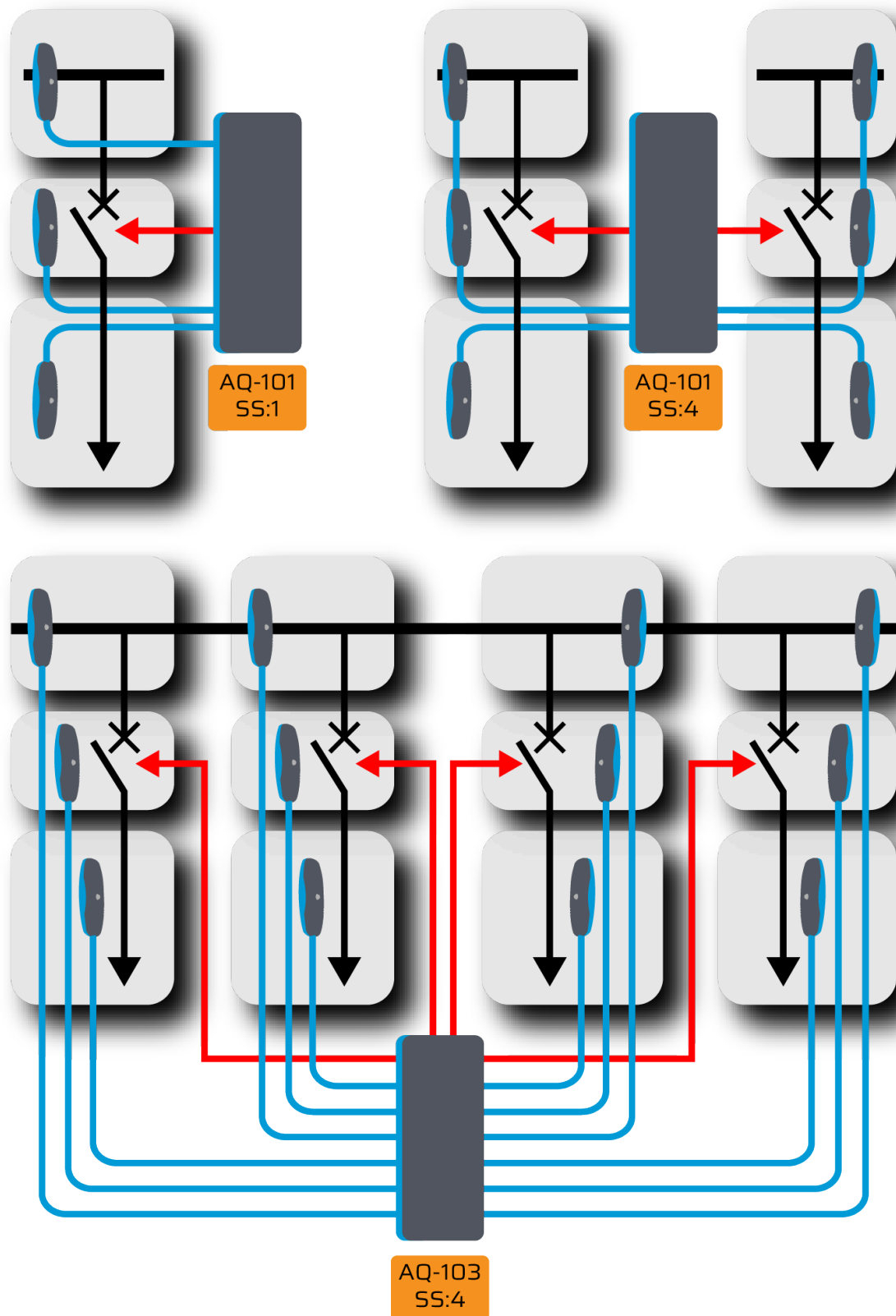


Table. 3 - 5. Devices installed to outgoing feeders.

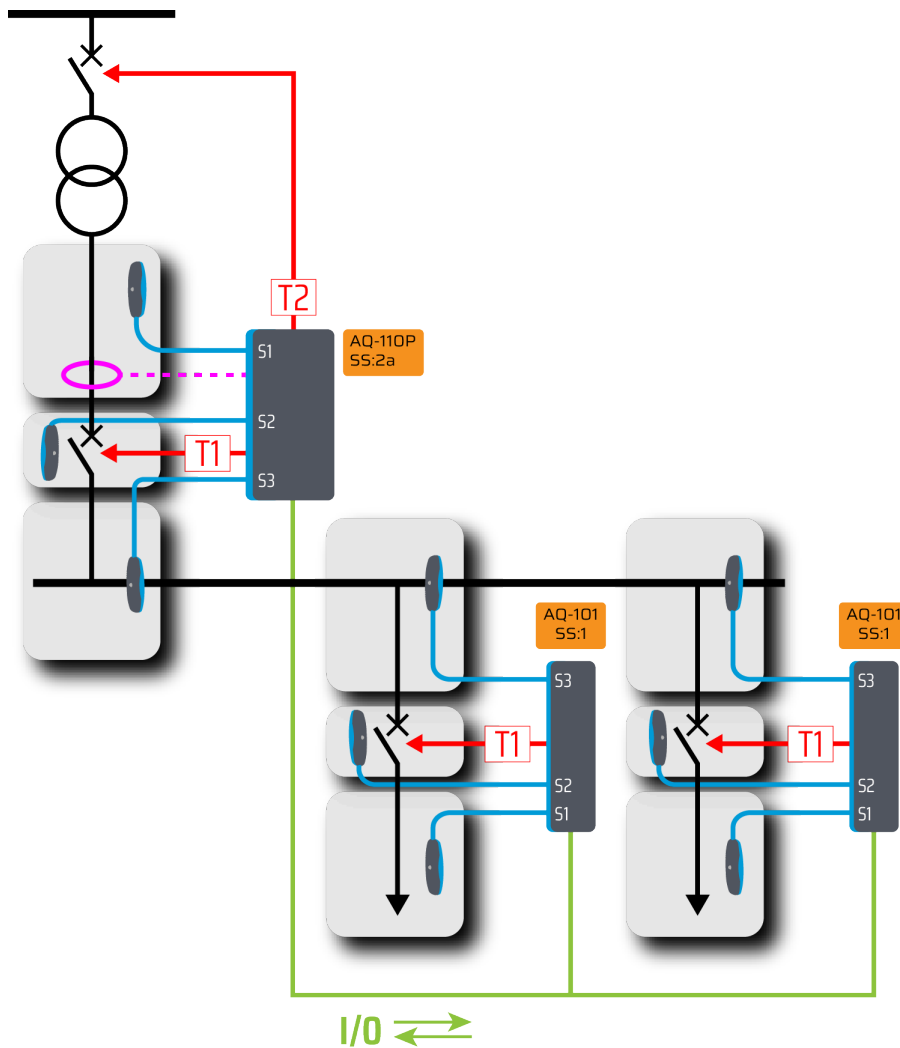
| Device (scheme) | Description  |
|-----------------|--|
| AQ-101 (SS:1)   | <ul style="list-style-type: none"> <li>Monitors one outgoing feeder per device.</li> <li>Max. 20 outgoing feeders per substation.</li> </ul>   |
|                 | Advantages: <ul style="list-style-type: none"> <li>Fault location can be indicated with high accuracy with LEDs.</li> <li>Less feeders unprotected in case of device failure.</li> </ul>   |
|                 | Disadvantages: <ul style="list-style-type: none"> <li>Lower maximum number of outgoing feeders compared to other schemes.</li> <li>More devices to install.</li> </ul>   |
| AQ-101 (SS:4)   | <ul style="list-style-type: none"> <li>Monitors max. two outgoing feeders per device.</li> <li>Max. 40 outgoing feeders per substation.</li> </ul>   |
|                 | Advantages: <ul style="list-style-type: none"> <li>Fewer protection devices needed for outgoing feeders compared to AQ-101 (SS:1).</li> <li>Less wires to install for I/O.</li> <li>Less cables to wire for point sensors.</li> </ul>  |
|                 | Disadvantages: <ul style="list-style-type: none"> <li>If a fault occurs either in the outgoing feeder circuit breaker compartment or in the busbar compartment the location is not indicated with LEDs as accurately as with other options.</li> <li>Two outgoing feeders are left unprotected at once in case of device failure.</li> </ul> |
| AQ-103 (SS:4)   | <ul style="list-style-type: none"> <li>Monitors max. four outgoing feeders per device.</li> <li>Max. 80 outgoing feeders per substation.</li> </ul>  |
|                 | Advantages: <ul style="list-style-type: none"> <li>Fewest number of devices to install to outgoing feeders.</li> <li>Fault location can be indicated with high accuracy with LEDs.</li> <li>Fewest number of I/O to wire.</li> <li>Ability to report signals to SCADA with Modbus connection (order option).</li> </ul>                      |
|                 | Disadvantages: <ul style="list-style-type: none"> <li>Four outgoing feeders are left unprotected at once in case of device failure.</li> <li>One point sensor per channel. More sensor cables to run for the same protection capability.</li> </ul>  |

**NOTICE!**



Up to 20 devices can be connected to "Master device". "Maximum number of outgoing feeders per substation" for each solution assumes that the substation has only one incoming feeder per busbar section. Each additional incoming feeder deducts from maximum number of outgoing feeder protection devices that can be connected. When designing arc protection solution for a very large substation, please contact your nearest Arcteq representative for more information.

### 3.1 One incoming feeder — one outgoing feeder per device



This is a fully selective scheme for protecting substations with one (1) incoming feeder and up to 20 outgoing feeders. The scheme uses the following basic logic:

Table. 3.1 - 6. Simplified operation logic description.

| Fault location  | Circuit breaker to trip   | CBFP trip   |
|---|---|---|
| <ul style="list-style-type: none"> <li>Outgoing feeder cable compartment</li> </ul>                                       | <ul style="list-style-type: none"> <li>The outgoing feeder with the fault</li> </ul>  | <ul style="list-style-type: none"> <li>Incoming feeder</li> <li>All outgoing feeders</li> </ul> |
| <ul style="list-style-type: none"> <li>Outgoing feeder circuit breaker compartment</li> <li>Busbar compartment</li> </ul> | <ul style="list-style-type: none"> <li>Incoming feeder</li> <li>All outgoing feeders</li> </ul>   | <ul style="list-style-type: none"> <li>HV side of the incoming feeder</li> </ul>                |
| <ul style="list-style-type: none"> <li>Incoming feeder circuit breaker compartment</li> </ul>                             | <ul style="list-style-type: none"> <li>Incoming feeder</li> <li>HV side of the incoming feeder</li> <li>All outgoing feeders</li> </ul> | <ul style="list-style-type: none"> <li>N/A</li> </ul>   |

| Fault location  | Circuit breaker to trip   | CBFP trip  |
|---|---|--|
| <ul style="list-style-type: none"> <li>Incoming feeder cable compartment</li> </ul> | <ul style="list-style-type: none"> <li>Incoming feeder</li> <li>HV side of the incoming feeder</li> </ul> | <ul style="list-style-type: none"> <li>All outgoing feeders</li> </ul> |

### 3.1.1 Incoming feeder AQ-110P (SS:2a)

Table. 3.1.1 - 7. Outputs of incoming feeder AQ-110P (SS:2a) device.

| Output | Connects to                                   | Action                                     |
|--------|---|--|
| T1     | Incoming feeder circuit breaker.              | Opens circuit breaker.                     |
| T2     | Incoming feeder HV side circuit breaker.      |  |
| T3     | (Not usable in this application)              | (Not usable in this application)           |
| T4     | Alarming unit (optional).                     | Trip alarm signal.                         |
| BO1    | (Not usable in this application)              | (Not usable in this application)           |
| HSO1   | BI1 of outgoing feeder AQ-101 (SS:1) devices. | Sends overcurrent and earth fault signals. |
| HSO2   | BI2 of outgoing feeder AQ-101 (SS:1) devices. | Sends master trip signal.                  |

Table. 3.1.1 - 8. Inputs of incoming feeder AQ-110P (SS:2a) device.

| Input               | Connects to  | Action   |
|---------------------|--|--|
| IL1,<br>IL2,<br>IL3 | <ul style="list-style-type: none"><li>Incoming feeder.</li></ul>                             | <ul style="list-style-type: none"><li>Sensor channels and external light signal (BI2) can be set up to use overcurrent and earth fault signal as an additional criteria for tripping.</li><li>Overcurrent and earth fault signal can be sent to outgoing feeder AQ-101 (SS:1) devices with <b>HSO1</b>.</li></ul>  |
| I <sub>0</sub>      |  |  |
| S1                  | <ul style="list-style-type: none"><li>Incoming feeder cable compartment.</li></ul>           | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with <b>T1</b> relay.</li><li>Trips incoming feeder HV side circuit breaker with <b>T2</b> relay.</li><li>Sends master trip signal with <b>HSO2</b> to outgoing feeder AQ-101 (SS:1) devices after CBFP time delay.</li><li><b>This channel must be set to "Light only" mode if current measurement point is located after the sensor.</b></li></ul> |
| S2                  | <ul style="list-style-type: none"><li>Incoming feeder circuit breaker compartment.</li></ul> | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with <b>T1</b> relay.</li><li>Trips incoming feeder HV side circuit breaker with <b>T2</b> relay.</li><li>Sends master trip signal with <b>HSO2</b> to outgoing feeder AQ-101 (SS:1) devices.</li></ul>  |
| S3                  | <ul style="list-style-type: none"><li>Busbar compartment.</li></ul>                          | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker <b>T1</b>.</li><li>Sends master trip signal with <b>HSO2</b> to outgoing feeder AQ-101 (SS:1) devices.</li><li>Trips incoming feeder HV side circuit breaker with <b>T2</b> relay after CBFP time delay.</li></ul>   |
| S4                  | <ul style="list-style-type: none"><li>Optional</li></ul>                                     |  |
| S5                  |  |  |

| Input | Connects to   | Action  |
|-------|---|---|
| BI2   | <ul style="list-style-type: none"> <li>BO1 of outgoing feeder AQ-101 (SS:1) devices.</li> <li>Receives light signal.</li> </ul> |   |
| BI1   | <ul style="list-style-type: none"> <li>N/A</li> </ul>   | <ul style="list-style-type: none"> <li>N/A</li> </ul> |

Figure. 3.1.1 - 4. Logic matrix of incoming feeder AQ-110P (SS:2a) device.

| SS:2a  |                        | OUTPUTS        |                   |                |      |                   |                |
|--------|------------------------|----------------|-------------------|----------------|------|-------------------|----------------|
|        |                        | T1             | T2                | T4             | HSO1 | HSO2              | AQD            |
| INPUTS | S1                     | x <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |      | CBFP <sup>1</sup> |                |
|        | S2                     | x <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | S3,S4,S5               | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup> |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | Lext> (BI2)            | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup> |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | I> (phase currents)    |                |                   |                | x    |                   |                |
|        | Io> (residual current) |                |                   |                | x    |                   |                |

1. Activates only if channel has been set to light only mode or if any overcurrent signal (I> or Io>) is ON.
2. Activates only if phase overcurrent signal (I>) is ON.

### 3.1.2 Outgoing feeders AQ-101 (SS:1)

Table. 3.1.2 - 9. Outputs of an outgoing feeder AQ-101 (SS:1) device.

| Output | Connects to                                    | Action                 |
|--------|--|------------------------|
| T1     | Outgoing feeder circuit breaker.               | Opens circuit breaker. |
| T2     | N/A  | N/A                    |
| T3     | N/A  | N/A                    |
| T4     | Alarming unit (optional).                      | Trip alarm signal.     |
| BO1    | BI2 of incoming feeder AQ-110P (SS:2a) device. | Sends light signal.    |

Table. 3.1.2 - 10. Inputs of an outgoing feeder AQ-101 (SS:1) device.

| Input | Connects to  | Action  |
|-------|--|---|
| BI1   | <ul style="list-style-type: none"> <li>HSO1 of incoming feeder AQ-110P (SS:2a) device.</li> <li>Receives overcurrent or earth fault signal.</li> </ul> | <ul style="list-style-type: none"> <li>If a sensor channel has been set to "Light and current" mode, this input must be active for the sensor channel to trip.</li> </ul> |

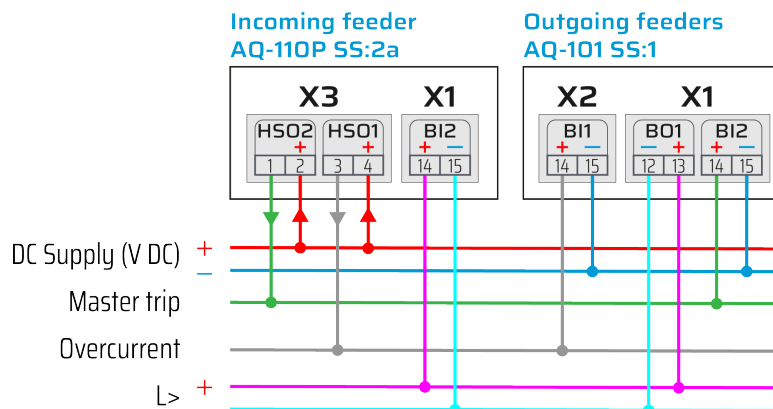
| Input | Connects to  | Action  |
|-------|--|---|
| BI2   | <ul style="list-style-type: none"><li>• HSO2 of incoming feeder AQ-110P (SS:2a) device.</li><li>• Receives master trip signal.</li></ul> | <ul style="list-style-type: none"><li>• Trips outgoing feeder with T1 relay.</li></ul>  |
| S1    | <ul style="list-style-type: none"><li>• Outgoing feeder cable compartment.</li></ul>   | <ul style="list-style-type: none"><li>• Trips outgoing feeder with T1 relay.</li><li>• Sends light signal to incoming feeder AQ-110P (SS:2a) device with BO1 after CBFP time delay.</li></ul> |
| S2    | <ul style="list-style-type: none"><li>• Outgoing feeder circuit breaker compartment.</li></ul>   | <ul style="list-style-type: none"><li>• Sends light signal to incoming feeder AQ-110P (SS:2a) device with BO1.</li></ul>  |
| S3    | <ul style="list-style-type: none"><li>• Busbar compartment.</li></ul>  |   |
| S4    | <ul style="list-style-type: none"><li>• Optional</li></ul>   |   |
| S5    |  |   |

Figure. 3.1.2 - 5. Logic matrix of an outgoing feeder AQ-101 (SS:1) device.

| SS:1   |                   | OUTPUTS        |                   |      |
|--------|-------------------|----------------|-------------------|------|
|        |                   | T1             | T4                | BO1  |
| INPUTS | S1                | x <sup>1</sup> | x <sup>1</sup>    | CBFP |
|        | S2, S3, S4, S5    |                | CBFP <sup>1</sup> | x    |
|        | Master Trip (BI2) | x              | x                 |      |

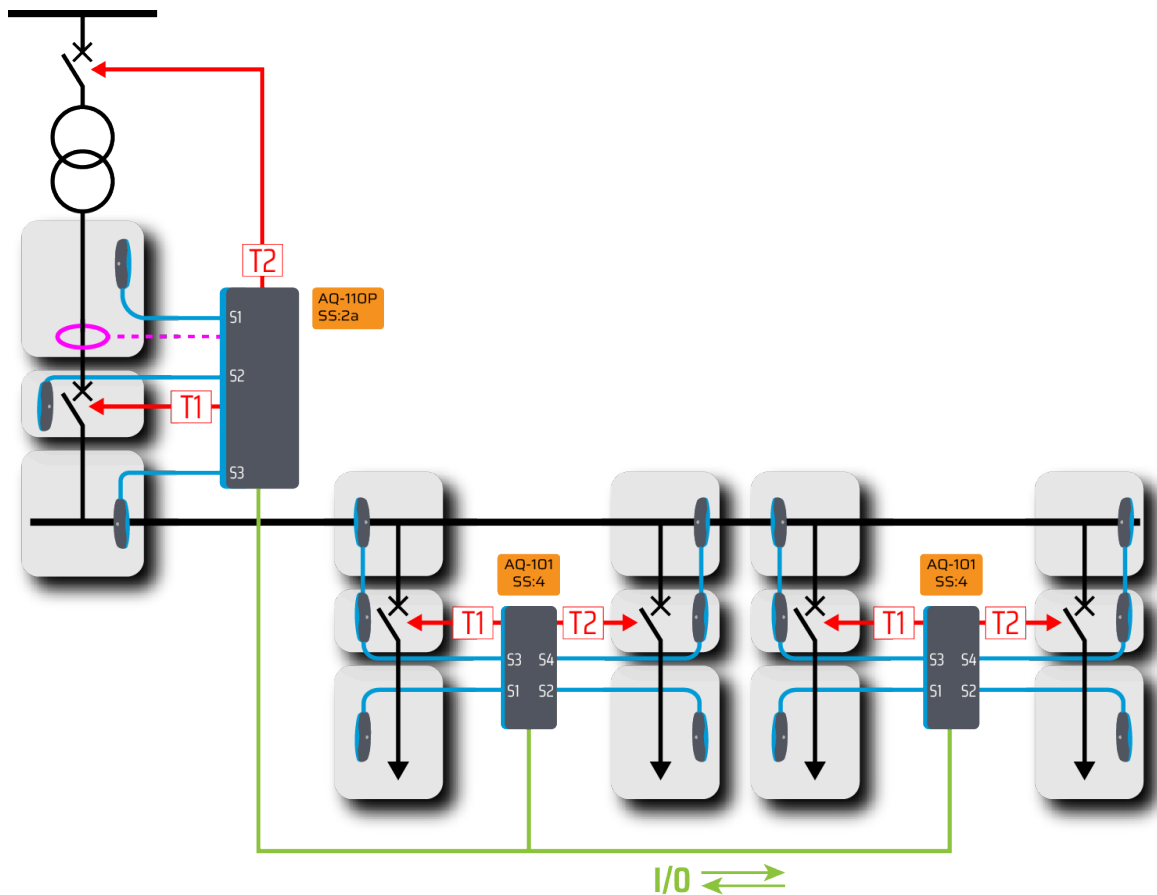
1. Activates only if channel has been set to light only mode or overcurrent signal (BI1) is ON.

### 3.1.3 Connections





### 3.2 One incoming feeder — two outgoing feeders per device



This is a fully selective scheme for protecting substations with one (1) incoming feeder and up to 40 outgoing feeders. The scheme uses the following basic logic:

Table. 3.2 - 11. Simplified operation logic description.

| Fault location  | Circuit breaker to trip   | CBFP trip   |
|---|---|---|
| <ul style="list-style-type: none"> <li>Outgoing feeder cable compartment</li> </ul>                                       | <ul style="list-style-type: none"> <li>The outgoing feeder with the fault</li> </ul>  | <ul style="list-style-type: none"> <li>Incoming feeder</li> <li>All outgoing feeders</li> </ul> |
| <ul style="list-style-type: none"> <li>Outgoing feeder circuit breaker compartment</li> <li>Busbar compartment</li> </ul> | <ul style="list-style-type: none"> <li>Incoming feeder</li> <li>All outgoing feeders</li> </ul>   | <ul style="list-style-type: none"> <li>HV side of the incoming feeder</li> </ul>                |
| <ul style="list-style-type: none"> <li>Incoming feeder circuit breaker compartment</li> </ul>                             | <ul style="list-style-type: none"> <li>Incoming feeder</li> <li>HV side of the incoming feeder</li> <li>All outgoing feeders</li> </ul> | <ul style="list-style-type: none"> <li>N/A</li> </ul>   |
| <ul style="list-style-type: none"> <li>Incoming feeder cable compartment</li> </ul>                                       | <ul style="list-style-type: none"> <li>Incoming feeder</li> <li>HV side of the incoming feeder</li> </ul>                               | <ul style="list-style-type: none"> <li>All outgoing feeders</li> </ul>                          |

### 3.2.1 Incoming feeder AQ-110P (SS:2a)

Table. 3.2.1 - 12. Outputs of incoming feeder AQ-110P (SS:2a) device.

| Output | Connects to                                   | Action                                     |
|--------|---|--|
| T1     | Incoming feeder circuit breaker.              | Opens circuit breaker.                     |
| T2     | Incoming feeder HV side circuit breaker.      |  |
| T3     | N/A   | N/A  |
| T4     | Alarming unit (optional).                     | Trip alarm signal.                         |
| BO1    | N/A   | N/A  |
| HSO1   | BI1 of outgoing feeder AQ-101 (SS:4) devices. | Sends overcurrent and earth fault signals. |
| HSO2   | BI2 of outgoing feeder AQ-101 (SS:4) devices. | Sends master trip signal.                  |

Table. 3.2.1 - 13. Inputs of incoming feeder AQ-110P (SS:2a) device.

| Input               | Connects to   | Action   |
|---------------------|---|--|
| IL1,<br>IL2,<br>IL3 | <ul style="list-style-type: none"><li>Incoming feeder.</li></ul>  | <ul style="list-style-type: none"><li>Sensor channels and external light signal (BI2) can be set up to use overcurrent and earth fault signal as an additional criteria for tripping.</li><li>Overcurrent and earth fault signal can be sent to outgoing feeder AQ-101 (SS:4) devices with <b>HSO1</b>.</li></ul>  |
| I <sub>0</sub>      |   |  |
| S1                  | <ul style="list-style-type: none"><li>Incoming feeder cable compartment.</li></ul>  | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with <b>T1</b> relay.</li><li>Trips incoming feeder HV side circuit breaker with <b>T2</b> relay.</li><li>Sends master trip signal with <b>HSO2</b> to outgoing feeder AQ-101 (SS:4) devices after CBFP time delay.</li><li><b>This channel must be set to "Light only" mode if current measurement point is located after the sensor.</b></li></ul> |
| S2                  | <ul style="list-style-type: none"><li>Incoming feeder circuit breaker compartment.</li></ul>  | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with <b>T1</b> relay.</li><li>Trips incoming feeder HV side circuit breaker with <b>T2</b> relay.</li><li>Sends master trip signal with <b>HSO2</b> to outgoing feeder AQ-101 (SS:4) devices.</li></ul>  |
| S3                  | <ul style="list-style-type: none"><li>Busbar compartment.</li></ul>   | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with <b>T1</b> relay.</li><li>Sends master trip signal with <b>HSO2</b> to outgoing feeder AQ-101 (SS:4) devices.</li><li>Trips incoming feeder HV side circuit breaker with <b>T2</b> relay after CBFP time delay.</li></ul>  |
| S4                  | <ul style="list-style-type: none"><li>Optional</li></ul>  |  |
| S5                  |   |  |
| BI2                 | <ul style="list-style-type: none"><li><b>BO1</b> of outgoing feeder AQ-101 (SS:4) devices.</li><li>Receives light signal.</li></ul> |  |
| BI1                 | <ul style="list-style-type: none"><li>N/A</li></ul>   | <ul style="list-style-type: none"><li>N/A</li></ul>  |

Figure. 3.2.1 - 6. Logic matrix of incoming feeder AQ-110P (SS:2a) device.

| SS:2a  |                        | OUTPUTS        |                   |                |      |                   |                |
|--------|------------------------|----------------|-------------------|----------------|------|-------------------|----------------|
|        |                        | T1             | T2                | T4             | HSO1 | HSO2              | AQD            |
| INPUTS | S1                     | x <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |      | CBFP <sup>1</sup> |                |
|        | S2                     | x <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | S3,S4,S5               | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup> |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | Lext> (BI2)            | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup> |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | I> (phase currents)    |                |                   |                | x    |                   |                |
|        | Io> (residual current) |                |                   |                | x    |                   |                |

1. Activates only if channel has been set to light only mode or if any overcurrent signal (I> or Io>) is ON.
2. Activates only if phase overcurrent signal (I>) is ON.

### 3.2.2 Outgoing feeders AQ-101 (SS:4)

Table. 3.2.2 - 14. Outputs of an outgoing feeder AQ-101 (SS:4) device.

| Output | Connects to                                    | Action                 |
|--------|--|------------------------|
| T1     | "Left side" outgoing feeder circuit breaker.   | Opens circuit breaker. |
| T2     | "Right side" outgoing feeder circuit breaker.  |                        |
| T3     | N/A  | N/A                    |
| T4     | Alarming unit (optional).                      | Trip alarm signal.     |
| BO1    | BI2 of incoming feeder AQ-110P (SS:2a) device. | Sends light signal.    |

Table. 3.2.2 - 15. Inputs of an outgoing feeder AQ-101 (SS:4) device.

| Input | Connects to  | Action  |
|-------|--|---|
| BI1   | <ul style="list-style-type: none"> <li>• HSO1 of incoming feeder AQ-110P (SS:2a) device.</li> <li>• Receives overcurrent or earth fault signal.</li> </ul> | <ul style="list-style-type: none"> <li>• If a sensor channel has been set to "Light and current" mode, this input must be active for the sensor channel to trip.</li> </ul>                                   |
| BI2   | <ul style="list-style-type: none"> <li>• HSO2 of incoming feeder AQ-110P (SS:2a) device.</li> <li>• Receives master trip signal.</li> </ul>                | <ul style="list-style-type: none"> <li>• Trips both outgoing feeder circuit breakers with T1 and T2.</li> </ul>   |
| S1    | <ul style="list-style-type: none"> <li>• "Left side" outgoing feeder cable compartment.</li> </ul>   | <ul style="list-style-type: none"> <li>• Trips "left side" outgoing feeder with T1 relay.</li> <li>• Sends light signal to incoming feeder AQ-110P (SS:2a) device with BO1 after CBFP time delay.</li> </ul>  |
| S2    | <ul style="list-style-type: none"> <li>• "Right side" outgoing feeder cable compartment.</li> </ul>  | <ul style="list-style-type: none"> <li>• Trips "right side" outgoing feeder with T2 relay.</li> <li>• Sends light signal to incoming feeder AQ-110P (SS:2a) device with BO1 after CBFP time delay.</li> </ul> |

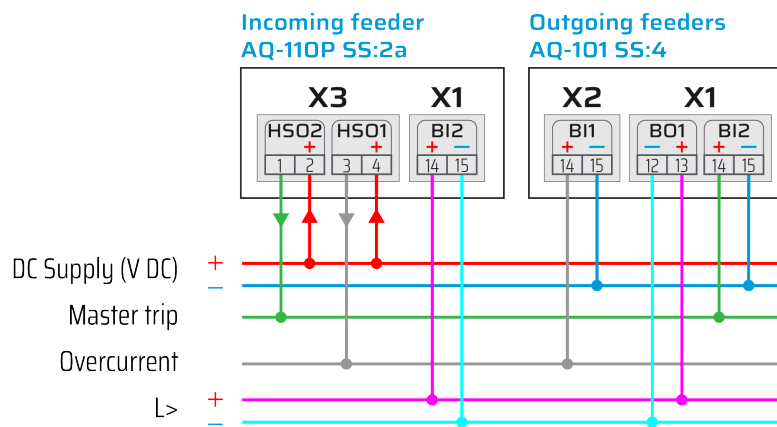
| Input | Connects to  | Action   |
|-------|--|--|
| S3    | <ul style="list-style-type: none"> <li>"Left side" outgoing feeder circuit breaker compartment</li> <li>Busbar compartment</li> </ul>  | <ul style="list-style-type: none"> <li>Sends light signal to incoming feeder AQ-110P (SS:2a) device with BO1.</li> </ul> |
| S4    | <ul style="list-style-type: none"> <li>"Right side" outgoing feeder circuit breaker compartment</li> <li>Busbar compartment</li> </ul> |  |
| S5    | <ul style="list-style-type: none"> <li>Optional</li> </ul>   |  |

Figure. 3.2.2 - 7. Logic matrix of an outgoing feeder AQ-101 (SS:4) device.

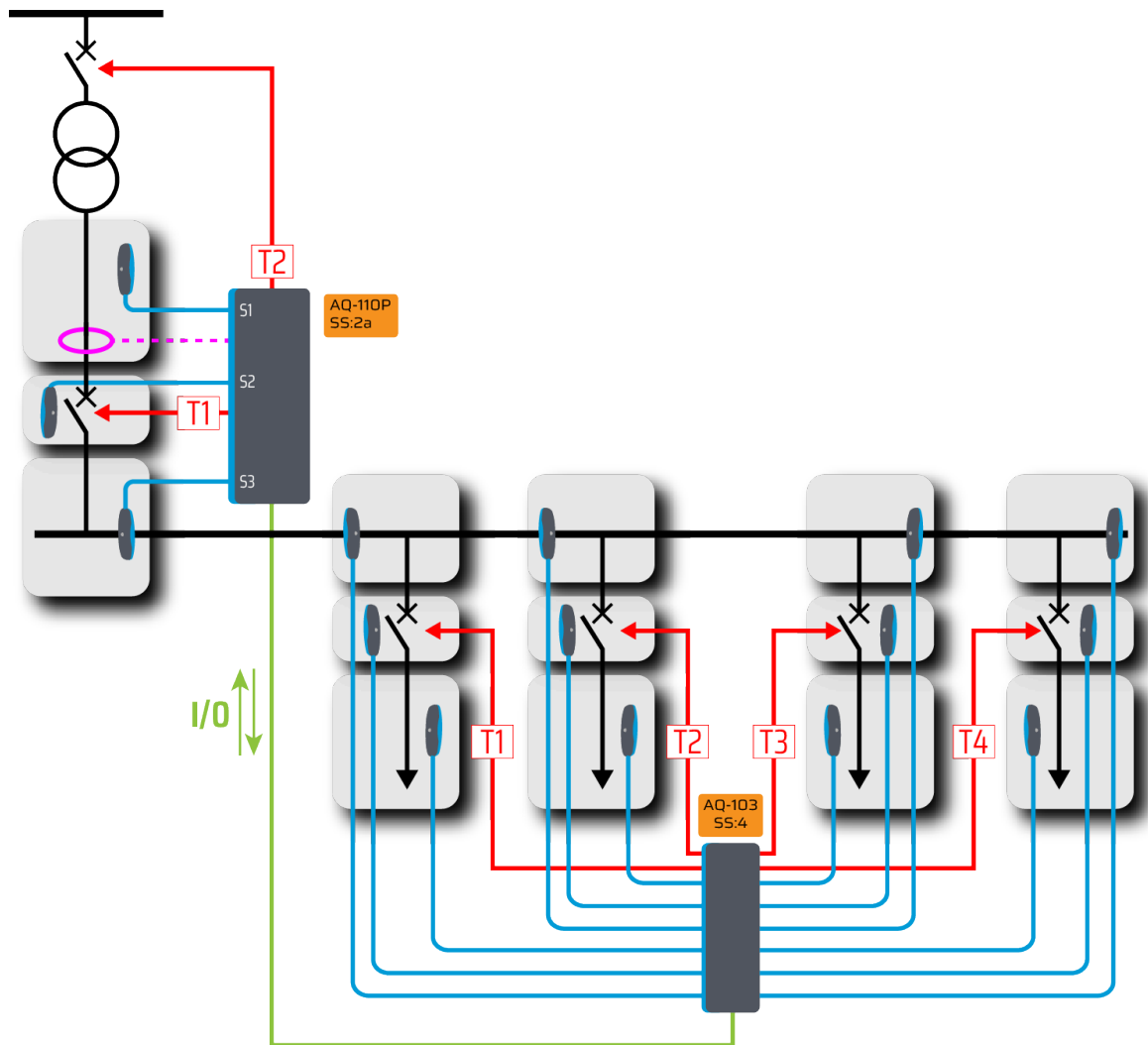
| SS:4   |                   | OUTPUTS        |                |                |      |
|--------|-------------------|----------------|----------------|----------------|------|
| INPUTS | S1                | x <sup>1</sup> |                | x <sup>1</sup> | CBFP |
|        | S2                |                | x <sup>1</sup> | x <sup>1</sup> | CBFP |
|        | S3, S4, S5        |                |                | x <sup>1</sup> | x    |
|        | Master Trip (BI2) | x              | x              | x              |      |

1. Activates only if channel has been set to light only mode or overcurrent signal (BI1) is ON.

### 3.2.3 Connections



### 3.3 One incoming feeder — four outgoing feeders per device



This is a fully selective scheme for protecting substations with one (1) incoming feeder and up to 80 outgoing feeders. The scheme uses the following basic logic:

Table. 3.3 - 16. Simplified operation logic description.

| Fault location  | Circuit breaker to trip   | CBFP trip   |
|---|---|---|
| <ul style="list-style-type: none"> <li>Outgoing feeder cable compartment</li> </ul>                                       | <ul style="list-style-type: none"> <li>The outgoing feeder with the fault</li> </ul>  | <ul style="list-style-type: none"> <li>Incoming feeder</li> <li>All outgoing feeders</li> </ul> |
| <ul style="list-style-type: none"> <li>Outgoing feeder circuit breaker compartment</li> <li>Busbar compartment</li> </ul> | <ul style="list-style-type: none"> <li>Incoming feeder</li> <li>All outgoing feeders</li> </ul>   | <ul style="list-style-type: none"> <li>HV side of the incoming feeder</li> </ul>                |
| <ul style="list-style-type: none"> <li>Incoming feeder circuit breaker compartment</li> </ul>                             | <ul style="list-style-type: none"> <li>Incoming feeder</li> <li>HV side of the incoming feeder</li> <li>All outgoing feeders</li> </ul> | <ul style="list-style-type: none"> <li>N/A</li> </ul>   |

| Fault location  | Circuit breaker to trip   | CBFP trip  |
|---|---|--|
| <ul style="list-style-type: none"> <li>Incoming feeder cable compartment</li> </ul> | <ul style="list-style-type: none"> <li>Incoming feeder</li> <li>HV side of the incoming feeder</li> </ul> | <ul style="list-style-type: none"> <li>All outgoing feeders</li> </ul> |

### 3.3.1 Incoming feeder AQ-110P (SS:2a)

Table. 3.3.1 - 17. Outputs of incoming feeder AQ-110P (SS:2a) device.

| Output | Connects to                                   | Action                                     |
|--------|---|--|
| T1     | Incoming feeder circuit breaker.              | Opens circuit breaker.                     |
| T2     | Incoming feeder HV side circuit breaker.      |  |
| T3     | N/A   | N/A  |
| T4     | Alarming unit (optional).                     | Trip alarm signal.                         |
| BO1    | N/A   | N/A  |
| HSO1   | BI1 of outgoing feeder AQ-103 (SS:4) devices. | Sends overcurrent and earth fault signals. |
| HSO2   | BI2 of outgoing feeder AQ-103 (SS:4) devices. | Sends master trip signal.                  |

Table. 3.3.1 - 18. Inputs of incoming feeder AQ-110P (SS:2a) device.

| Input               | Connects to  | Action   |
|---------------------|--|--|
| IL1,<br>IL2,<br>IL3 | <ul style="list-style-type: none"><li>Incoming feeder.</li></ul>                             | <ul style="list-style-type: none"><li>Sensor channels and external light signal (BI2) can be set up to use overcurrent and earth fault signal as an additional criteria for tripping.</li><li>Overcurrent and earth fault signal can be sent to outgoing feeder AQ-103 (SS:4) devices with HSO1.</li></ul>   |
| I <sub>0</sub>      |  |  |
| S1                  | <ul style="list-style-type: none"><li>Incoming feeder cable compartment.</li></ul>           | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with T1 relay.</li><li>Trips incoming feeder HV side circuit breaker with T2 relay.</li><li>Sends master trip signal with HSO2 to outgoing feeder AQ-103 (SS:4) devices after CBFP time delay.</li><li>This channel must be set to "Light only" mode if current measurement point is located after the sensor.</li></ul> |
| S2                  | <ul style="list-style-type: none"><li>Incoming feeder circuit breaker compartment.</li></ul> | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with T1 relay.</li><li>Trips incoming feeder HV side circuit breaker with T2 relay.</li><li>Sends master trip signal with HSO2 to outgoing feeder AQ-103 (SS:4) devices.</li></ul>   |
| S3                  | <ul style="list-style-type: none"><li>Busbar compartment.</li></ul>                          | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with T1 relay.</li><li>Sends master trip signal with HSO2 to outgoing feeder AQ-103 (SS:4) devices.</li><li>Trips incoming feeder HV side circuit breaker with T2 relay after CBFP time delay.</li></ul>   |
| S4                  | <ul style="list-style-type: none"><li>Optional</li></ul>                                     |  |
| S5                  |  |  |

| Input | Connects to   | Action  |
|-------|---|---|
| BI2   | <ul style="list-style-type: none"> <li>BO1 of outgoing feeder AQ-103 (SS:4) devices.</li> <li>Receives light signal.</li> </ul> |   |
| BI1   | <ul style="list-style-type: none"> <li>N/A</li> </ul>   | <ul style="list-style-type: none"> <li>N/A</li> </ul> |

Figure. 3.3.1 - 8. Logic matrix of incoming feeder AQ-110P (SS:2a) device.

| SS:2a  |                        | OUTPUTS        |                   |                |      |                   |                |
|--------|------------------------|----------------|-------------------|----------------|------|-------------------|----------------|
|        |                        | T1             | T2                | T4             | HSO1 | HSO2              | AQD            |
| INPUTS | S1                     | x <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |      | CBFP <sup>1</sup> |                |
|        | S2                     | x <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | S3,S4,S5               | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup> |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | Lext> (BI2)            | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup> |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | I> (phase currents)    |                |                   |                | x    |                   |                |
|        | Io> (residual current) |                |                   |                | x    |                   |                |

1. Activates only if channel has been set to light only mode or if any overcurrent signal (I> or Io>) is ON.
2. Activates only if phase overcurrent signal (I>) is ON.

### 3.3.2 Outgoing feeders AQ-103 (SS:4)

Table. 3.3.2 - 19. Outputs of an outgoing feeder AQ-103 (SS:4) device.

| Output | Connects to                                  | Action                 |
|--------|--|------------------------|
| T1     | Outgoing feeder circuit breaker #1.          | Opens circuit breaker. |
| T2     | Outgoing feeder circuit breaker #2.          |                        |
| T3     | Outgoing feeder circuit breaker #3.          |                        |
| T4     | Outgoing feeder circuit breaker #4.          |                        |
| BO1    | BI2 of incoming feeder AQ-110P SS:2a device. | Sends light signal.    |
| HSO    | N/A  | N/A                    |

Table. 3.3.2 - 20. Inputs of an outgoing feeder AQ-103 (SS:4) device.

| Input | Connects to  | Action   |
|-------|--|--|
| BI1   | <ul style="list-style-type: none"> <li>HSO1 of incoming feeder AQ-110P (SS:2a) device.</li> <li>Receives overcurrent or earth fault signal.</li> </ul> | <ul style="list-style-type: none"> <li>If the AQ-103 device has been set to "Light and current" mode, this input must be active for the sensor channel to trip.</li> </ul> |

| Input | Connects to   | Action  |
|-------|---|---|
| BI2   | <ul style="list-style-type: none"> <li>HSO2 of incoming feeder AQ-110P (SS:2a) device.</li> <li>Receives master trip signal.</li> </ul> | <ul style="list-style-type: none"> <li>Trips all four outgoing feeders with T1, T2, T3 and T4 relays.</li> </ul>  |
| S1-S4 | <ul style="list-style-type: none"> <li>Busbar compartment</li> </ul>  | <ul style="list-style-type: none"> <li>Sends light signal to incoming feeder AQ-110P (SS:2a) device with BO1.</li> </ul>  |
| S5    | <ul style="list-style-type: none"> <li>Optional</li> </ul>  |   |
| S6-S9 | <ul style="list-style-type: none"> <li>Outgoing feeder circuit breaker compartments #1 to 4.</li> </ul>                                 |   |
| S10   | <ul style="list-style-type: none"> <li>Optional</li> </ul>  |   |
| S11   | <ul style="list-style-type: none"> <li>Outgoing feeder cable compartment #1.</li> </ul>   | <ul style="list-style-type: none"> <li>Trips outgoing feeder #1 with T1 relay.</li> <li>Sends light signal to incoming feeder AQ-110P SS:2a device with BO1 after CBFP time delay.</li> </ul> |
| S12   | <ul style="list-style-type: none"> <li>Outgoing feeder cable compartment #2.</li> </ul>   | <ul style="list-style-type: none"> <li>Trips outgoing feeder #2 with T2 relay.</li> <li>Sends light signal to incoming feeder AQ-110P SS:2a device with BO1 after CBFP time delay.</li> </ul> |
| S13   | <ul style="list-style-type: none"> <li>Outgoing feeder cable compartment #3.</li> </ul>   | <ul style="list-style-type: none"> <li>Trips outgoing feeder #3 with T3 relay.</li> <li>Sends light signal to incoming feeder AQ-110P SS:2a device with BO1 after CBFP time delay.</li> </ul> |
| S14   | <ul style="list-style-type: none"> <li>Outgoing feeder cable compartment #4.</li> </ul>   | <ul style="list-style-type: none"> <li>Trips outgoing feeder #4 with T4 relay.</li> <li>Sends light signal to incoming feeder AQ-110P SS:2a device with BO1 after CBFP time delay.</li> </ul> |
| S15   | <ul style="list-style-type: none"> <li>Optional</li> </ul>  | <ul style="list-style-type: none"> <li>Sends light signal to incoming feeder AQ-110P (SS:2a) device with BO1.</li> </ul>  |

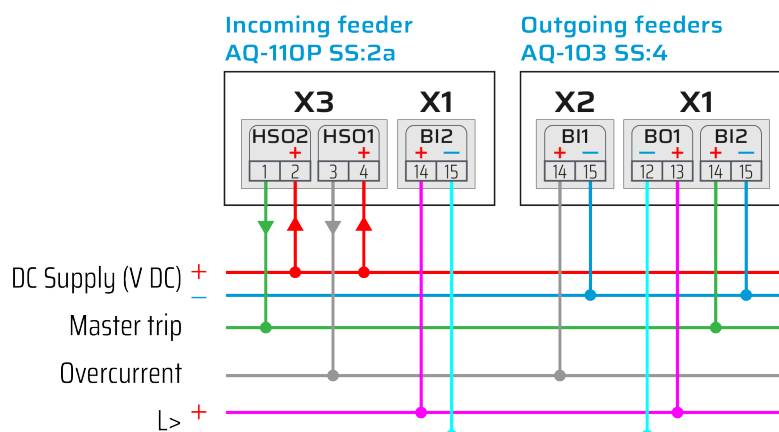
Figure. 3.3.2 - 9. Logic matrix of an outgoing feeder AQ-103 (SS:4) device.

| SS:4   |                   | OUTPUTS        |                |                |                |      |
|--------|-------------------|----------------|----------------|----------------|----------------|------|
|        |                   | T1             | T2             | T3             | T4             | BO1  |
| INPUTS | S1-S10            |                |                |                |                | x    |
|        | S11               | x <sup>1</sup> |                |                |                | CBFP |
|        | S12               |                | x <sup>1</sup> |                |                | CBFP |
|        | S13               |                |                | x <sup>1</sup> |                | CBFP |
|        | S14               |                |                |                | x <sup>1</sup> | CBFP |
|        | S15               |                |                |                |                | x    |
|        | Master Trip (BI2) | x              | x              | x              | x              |      |

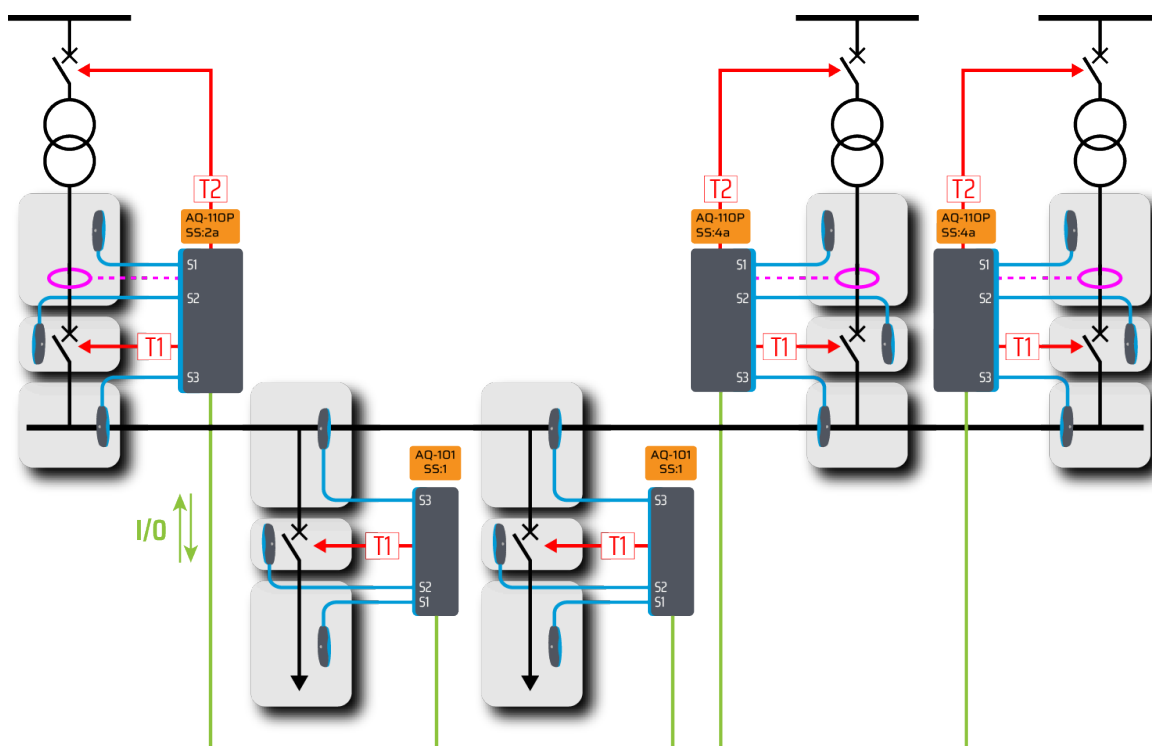
1. Activates only if channels have been set to light only mode or overcurrent signal (BI1) is ON.



### 3.3.3 Connections



### 3.4 Multiple incoming feeders — one outgoing feeder per device



This is a fully selective scheme for protecting substations with two or more incoming feeders. The operation logic is identical to previous schemes with one incoming feeder.

While this chapter uses AQ-101 with SS:1 for the outgoing feeders, it is possible to use AQ-101 with SS:4 or AQ-103 with SS:4 instead to increase the maximum number of outgoing feeders. Up to 20 devices can be connected to the "Master device". Each additional incoming feeder deducts from maximum number of outgoing feeder protection devices that can be connected. When designing arc protection solution for a very large substation, please contact your nearest Arcteq representative for more information.

Table. 3.4 - 21. Simplified operation logic description.

| Fault location  | Circuit breaker to trip   | CBFP trip  |
|---|---|--|
| <ul style="list-style-type: none"> <li>Outgoing feeder cable compartment</li> </ul>                                       | <ul style="list-style-type: none"> <li>The outgoing feeder with the fault</li> </ul>  | <ul style="list-style-type: none"> <li>All incoming feeders</li> <li>All outgoing feeders</li> </ul>   |
| <ul style="list-style-type: none"> <li>Outgoing feeder circuit breaker compartment</li> <li>Busbar compartment</li> </ul> | <ul style="list-style-type: none"> <li>All incoming feeders</li> <li>All outgoing feeders</li> </ul>  | <ul style="list-style-type: none"> <li>HV side of incoming feeders</li> </ul>                          |
| <ul style="list-style-type: none"> <li>Incoming feeder circuit breaker compartment</li> </ul>                             | <ul style="list-style-type: none"> <li>All incoming feeders</li> <li>HV side of incoming feeder with the fault</li> <li>All outgoing feeders</li> </ul> | <ul style="list-style-type: none"> <li>HV side of other incoming feeders</li> </ul>                    |
| <ul style="list-style-type: none"> <li>Incoming feeder cable compartment</li> </ul>                                       | <ul style="list-style-type: none"> <li>The incoming feeder with the fault</li> <li>HV side of the incoming feeder with the fault</li> </ul>             | <ul style="list-style-type: none"> <li>All outgoing feeders</li> <li>Other incoming feeders</li> </ul> |

Table. 3.4 - 22. Scheme characteristics

| Device role                      | Device type     | Number of devices | Number of incoming feeders / outgoing feeders protected |
|----------------------------------|-----------------|-------------------|---|
| Master incoming feeder device    | AQ-110P (SS:2a) | 1                 | 1   |
| Follower incoming feeder devices | AQ-110P (SS:4a) | 1...5             | 1...5   |
| Outgoing feeder device options   | AQ-101 (SS:1)   | 1...19            | 1...19  |
|                                  | AQ-101 (SS:4)   | 1...19            | 2...38  |
|                                  | AQ-103 (SS:4)   | 1...19            | 4...76  |

### 3.4.1 Master incoming feeder AQ-110P (SS:2a)

Table. 3.4.1 - 23. Outputs of master incoming feeder AQ-110P (SS:2a) device.

| Output | Connects to                                   | Action                                     |
|--------|---|--|
| T1     | Incoming feeder circuit breaker.              | Opens circuit breaker.                     |
| T2     | Incoming feeder HV side circuit breaker.      |  |
| T3     | N/A   | N/A  |
| T4     | Alarming unit (optional).                     | Trip alarm signal.                         |
| BO1    | N/A   | N/A  |
| HSO1   | BI1 of outgoing feeder AQ-101 (SS:1) devices. | Sends overcurrent and earth fault signals. |

| Output | Connects to  | Action                    |
|--------|--|---------------------------|
| HSO2   | BI2 of outgoing feeder AQ-101 (SS:1) devices.            | Sends master trip signal. |
|        | BI1 of follower incoming feeder AQ-110P (SS:4a) devices. |                           |

Table. 3.4.1 - 24. Inputs of master incoming feeder AQ-110P (SS:2a) device.

| Input               | Connects to  | Action   |
|---------------------|--|--|
| IL1,<br>IL2,<br>IL3 | <ul style="list-style-type: none"><li>Incoming feeder.</li></ul>   | <ul style="list-style-type: none"><li>Sensor channels and external light signal (BI2) can be set up to require overcurrent, earth fault or external current signal as an additional criteria for tripping.</li><li>Current signals are sent to outgoing feeder AQ-101 (SS:1) devices with HSO1.</li></ul>  |
| I <sub>0</sub>      |  |  |
| BI1                 | <ul style="list-style-type: none"><li>HSO1 of follower incoming feeder AQ-110P (SS:4a) devices.</li><li>External overcurrent or earth fault signal.</li></ul>                                |  |
| S1                  | <ul style="list-style-type: none"><li>Incoming feeder cable compartment.</li></ul>   | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with T1 relay.</li><li>Trips incoming feeder HV side circuit breaker with T2 relay.</li><li>Sends master trip signal with HSO2 to outgoing feeder AQ-101 (SS:1) devices after CBFP time delay.</li><li>Sends master trip signal with HSO2 to follower incoming feeder AQ-110P (SS:4a) devices after CBFP time delay.</li><li>This channel must be set to "Light only" mode if current measurement point is located after the sensor.</li></ul> |
| S2                  | <ul style="list-style-type: none"><li>Incoming feeder circuit breaker compartment.</li></ul>   | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with T1 relay.</li><li>Trips incoming feeder HV side circuit breaker with T2 relay.</li><li>Sends master trip signal with HSO2 to outgoing feeder AQ-101 (SS:1) devices.</li><li>Sends master trip signal with HSO2 to follower incoming feeder AQ-110P (SS:4a) devices.</li></ul>   |
| S3                  | <ul style="list-style-type: none"><li>Busbar compartment.</li></ul>  | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with T1 relay.</li><li>Sends master trip signal with HSO2 to outgoing feeder AQ-101 (SS:1) devices.</li><li>Sends master trip signal with HSO2 to follower incoming feeder AQ-110P (SS:4a) devices.</li><li>Trips incoming feeder HV side circuit breaker with T2 relay after CBFP time delay.</li></ul>   |
| S4                  | <ul style="list-style-type: none"><li>Optional</li></ul>   |  |
| S5                  |  |  |
| BI2                 | <ul style="list-style-type: none"><li>BO1 of outgoing feeder AQ-101 (SS:1) devices.</li><li>BO1 of follower incoming feeder AQ-110P (SS:4a) device.</li><li>Receives light signal.</li></ul> |  |

Figure. 3.4.1 - 10. Logic matrix of master incoming feeder AQ-110P (SS:2a) device.

| SS:2a  |                        | OUTPUTS        |                   |                |      |                   |                |
|--------|------------------------|----------------|-------------------|----------------|------|-------------------|----------------|
|        |                        | T1             | T2                | T4             | HSO1 | HSO2              | AQD            |
| INPUTS | S1                     | x <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |      | CBFP <sup>1</sup> |                |
|        | S2                     | x <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | S3,S4,S5               | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup> |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | Lext> (BI2)            | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup> |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | Iext> (BI1)            |                |                   |                | x    |                   |                |
|        | I> (phase currents)    |                |                   |                | x    |                   |                |
|        | Io> (residual current) |                |                   |                | x    |                   |                |

1. Activates only if channel has been set to light only mode or if any overcurrent signal (I>, Io> or BI1) is ON.
2. Activates only if phase overcurrent signal (I>) is ON.

### 3.4.2 Follower incoming feeders AQ-110P (SS:4a)

Table. 3.4.2 - 25. Outputs of follower incoming feeder AQ-110P (SS:4a) device.

| Output | Connects to   | Action                                     |
|--------|---|--|
| T1     | Incoming feeder circuit breaker.  | Opens circuit breaker.                     |
| T2     | Incoming feeder HV side circuit breaker.  |  |
| T3     | N/A   | N/A  |
| T4     | Alarming unit (optional).   | Trip alarm signal.                         |
| BO1    | BI2 of master incoming feeder AQ-110P (SS:2a) device.   | Sends light signals.                       |
| HSO1   | BI1 of master incoming feeder AQ-110P (SS:2a) device.<br>BI2 of follower incoming feeder AQ-110P (SS:4a) devices. | Sends overcurrent and earth fault signals. |
| HSO2   | N/A   | N/A  |

Table. 3.4.2 - 26. Inputs of follower incoming feeder AQ-110P (SS:4a) device.

| Input               | Connects to  | Action   |
|---------------------|--|--|
| IL1,<br>IL2,<br>IL3 | <ul style="list-style-type: none"> <li>Incoming feeder.</li> </ul>   | <ul style="list-style-type: none"> <li>Sensor channels and external light signal (BI2) can be set up to require overcurrent or earth fault signal as an additional criteria for tripping.</li> <li>Overcurrent and earth fault signals are sent to all incoming feeder AQ-110P devices with HSO1.</li> </ul> |
| Io                  |  |  |
| BI2                 | <ul style="list-style-type: none"> <li>HSO1 of follower incoming feeder AQ-110P (SS:4a) devices.</li> <li>External overcurrent or earth fault signal.</li> </ul> | <ul style="list-style-type: none"> <li>Sensor channels can be set up to require overcurrent signal as an additional criteria for tripping.</li> </ul>  |

| Input | Connects to   | Action  |
|-------|---|---|
| S1    | <ul style="list-style-type: none"><li>Incoming feeder cable compartment.</li></ul>  | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with T1 relay.</li><li>Trips incoming feeder HV side circuit breaker with T2 relay.</li><li>Sends light signal with BO1 to master incoming feeder AQ-110P (SS:2a) device after a CBFP time delay.</li><li>This channel must be set to "Light only" mode if current measurement point is located after the sensor.</li></ul> |
| S2    | <ul style="list-style-type: none"><li>Incoming feeder circuit breaker compartment.</li></ul>  | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with T1 relay.</li><li>Trips incoming feeder HV side circuit breaker with T2 relay.</li><li>Sends light signal with BO1 to master incoming feeder AQ-110P (SS:2a) device.</li></ul>   |
| S3    | <ul style="list-style-type: none"><li>Busbar compartment.</li></ul>   | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with T1 relay.</li><li>Sends light signal with BO1 to master incoming feeder AQ-110P (SS:2a) device.</li><li>Trips incoming feeder HV side circuit breaker with T2 relay after CBFP time delay.</li></ul>   |
| S4    | <ul style="list-style-type: none"><li>Optional</li></ul>  |   |
| S5    |   |   |
| BI1   | <ul style="list-style-type: none"><li>HSO2 of master incoming feeder AQ-110P (SS:2a) device.</li><li>Receives master trip signal.</li></ul> | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with T1 relay.</li><li>Trips incoming feeder HV side circuit breaker with T2 relay after CBFP time delay. This requires overcurrent or earth fault to be detected.</li></ul>  |

Figure. 3.4.2 - 11. Logic matrix of follower incoming feeder AQ-110P (SS:4a) device.

| SS:4a  |                        | OUTPUTS        |                   |                |                |      |
|--------|------------------------|----------------|-------------------|----------------|----------------|------|
| INPUTS |                        | T1             | T2                | T4             | BO1            | HSO1 |
|        | S1                     | x <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> | x <sup>1</sup> |      |
|        | S2                     | x <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> | x              |      |
|        | S3,S4,S5               | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup> | x              |      |
|        | Master trip (BI1)      | x              | CBFP <sup>2</sup> | x              |                |      |
|        | I> (phase currents)    |                |                   |                |                | x    |
|        | Io> (residual current) |                |                   |                |                | x    |

1. Activates only if channel has been set to light only mode or if any overcurrent signal (I>, Io> or BI2) is ON.
2. Activates only if any overcurrent signal (I>, Io> or BI2) is ON.

### 3.4.3 Outgoing feeders AQ-101 (SS:1)

Table. 3.4.3 - 27. Outputs of an outgoing feeder AQ-101 (SS:1) device.

| Output | Connects to   | Action                 |
|--------|---|------------------------|
| T1     | Outgoing feeder circuit breaker.                      | Opens circuit breaker. |
| T2     | N/A   | N/A                    |
| T3     | N/A   | N/A                    |
| T4     | Alarming unit (optional).                             | Trip alarm signal.     |
| BO1    | BI2 of master incoming feeder AQ-110P (SS:2a) device. | Sends light signal.    |

Table. 3.4.3 - 28. Inputs of an outgoing feeder AQ-101 (SS:1) device.

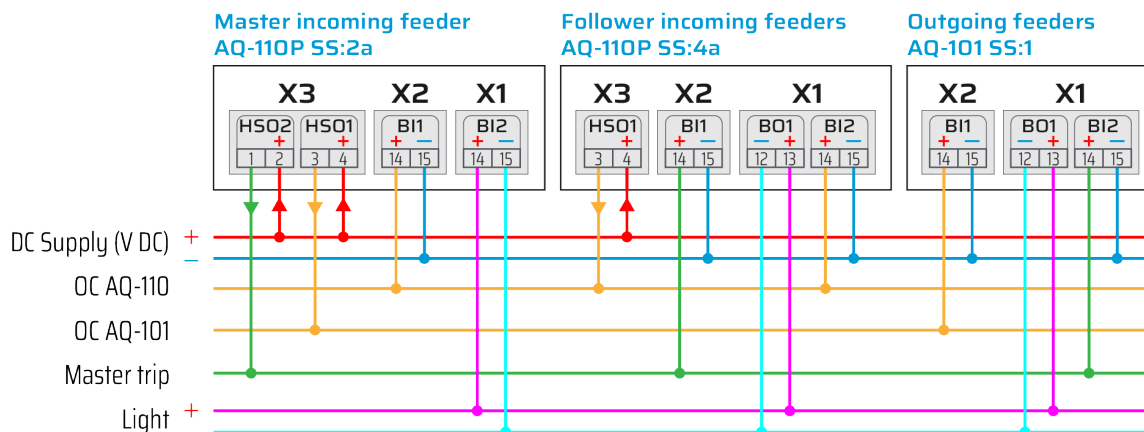
| Input | Connects to  | Action   |
|-------|--|--|
| BI1   | <ul style="list-style-type: none"><li>• HSO1 of master incoming feeder AQ-110P (SS:2a) device.</li><li>• Receives overcurrent or earth fault signal.</li></ul> | <ul style="list-style-type: none"><li>• If a sensor channel has been set to "Light and current" mode, this input must be active for the sensor channel to trip.</li></ul>                            |
| BI2   | <ul style="list-style-type: none"><li>• HSO2 of master incoming feeder AQ-110P (SS:2a) device.</li><li>• Receives master trip signal.</li></ul>                | <ul style="list-style-type: none"><li>• Trips outgoing feeder with T1 relay.</li></ul>   |
| S1    | <ul style="list-style-type: none"><li>• Outgoing feeder cable compartment.</li></ul>   | <ul style="list-style-type: none"><li>• Trips outgoing feeder with T1 relay.</li><li>• Sends light signal to master incoming feeder AQ-110P (SS:2a) device with BO1 after CBFP time delay.</li></ul> |
| S2    | <ul style="list-style-type: none"><li>• Outgoing feeder circuit breaker compartment.</li></ul>   | <ul style="list-style-type: none"><li>• Sends light signal to master incoming feeder AQ-110P (SS:2a) device with BO1.</li></ul>  |
| S3    | <ul style="list-style-type: none"><li>• Busbar compartment.</li></ul>  |  |
| S4    | <ul style="list-style-type: none"><li>• Optional</li></ul>   |  |
| S5    |  |  |

Figure. 3.4.3 - 12. Logic matrix of an outgoing feeder AQ-101 (SS:1) device.

| SS:1   |                   | OUTPUTS        |                   |      |
|--------|-------------------|----------------|-------------------|------|
| INPUTS |                   | T1             | T4                | BO1  |
|        | S1                | x <sup>1</sup> | x <sup>1</sup>    | CBFP |
|        | S2, S3, S4, S5    |                | CBFP <sup>1</sup> | x    |
|        | Master Trip (BI2) | x              | x                 |      |

1. Activates only if channels have been set to light only mode or overcurrent signal (BI1) is ON.

### 3.4.4 Connections



## 4 With one tie breaker

This chapter lists various typical arc protection application solutions for substations with one tie breaker and explains their differences (advantages, disadvantages, hardware used etc.). The device types, used logic schemes and wiring vary between the solutions, but the basic operation logic is the same in all of them. Suggested schemes in this chapter are completely selective. Later chapters explain the design and operation of each suggested solution in higher detail. At the end of this document you can find available modifications to these typical setups.

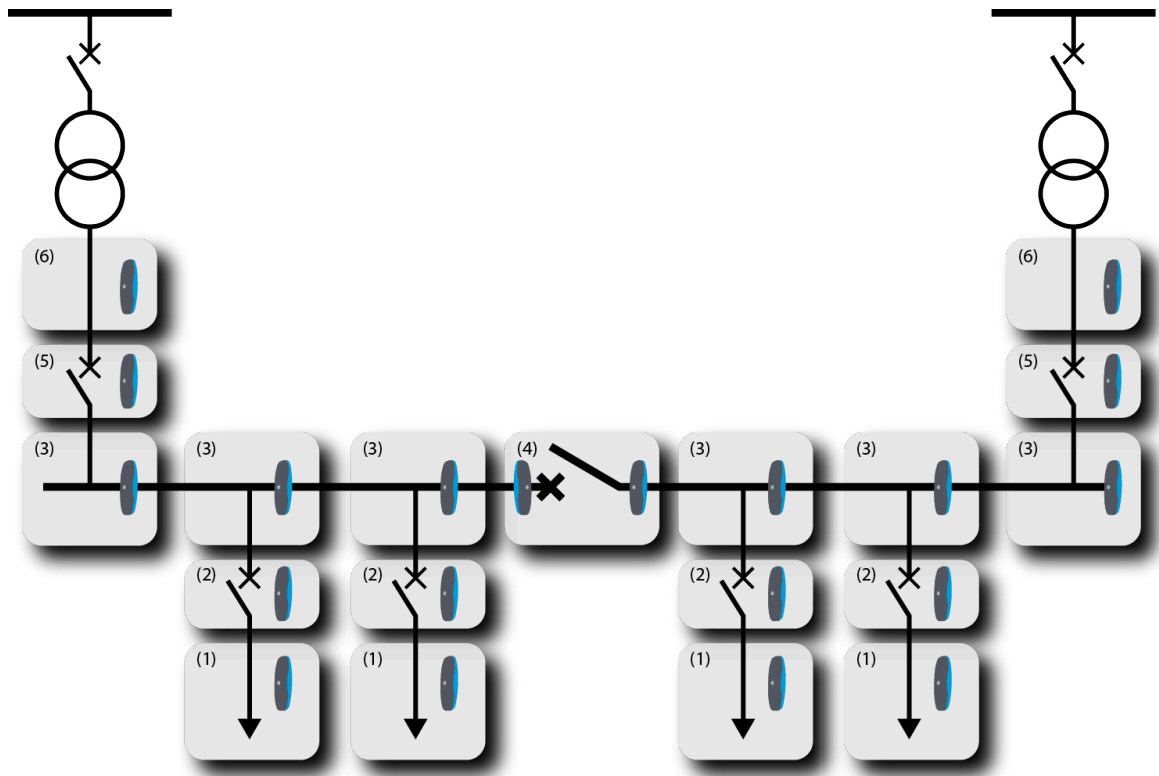


Table. 4 - 29. Simplified arc protection operation logic in a substation without tie breakers.

| # | Fault location                              | Circuit breaker to trip  | CBFP trip  |
|---|---|--|--|
| 1 | Outgoing feeder cable compartment           | <ul style="list-style-type: none"> <li>The outgoing feeder with the fault</li> </ul>   | <ul style="list-style-type: none"> <li>Incoming feeder in the same busbar section</li> <li>Outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul> |
| 2 | Outgoing feeder circuit breaker compartment | <ul style="list-style-type: none"> <li>Incoming feeder in the same busbar section</li> <li>Outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul> | <ul style="list-style-type: none"> <li>HV side of the incoming feeder</li> </ul>   |
| 3 | Busbar compartment                          |  |  |
| 4 | Tie breaker compartment                     | <ul style="list-style-type: none"> <li>All incoming feeders</li> <li>Tie breaker</li> <li>All outgoing feeders</li> </ul>  | <ul style="list-style-type: none"> <li>HV side of incoming feeders</li> </ul>  |

| # | Fault location                              | Circuit breaker to trip  | CBFP trip  |
|---|---|--|--|
| 5 | Incoming feeder circuit breaker compartment | <ul style="list-style-type: none"> <li>Incoming feeder with the fault</li> <li>HV side of the incoming feeder</li> <li>Tie breaker</li> <li>Outgoing feeders in the same busbar section</li> </ul> | <ul style="list-style-type: none"> <li>N/A</li> </ul>  |
| 6 | Incoming feeder cable compartment           | <ul style="list-style-type: none"> <li>The incoming feeder with the fault</li> <li>HV side of the incoming feeder</li> </ul>   | <ul style="list-style-type: none"> <li>Outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul> |

### Incoming feeder protection

Each suggested incoming feeder protection solution has point sensors installed to cable compartments, circuit breaker compartments and busbar compartments. One channel can be used for monitoring each the tie breaker compartment. Incoming feeder devices exchange information (light, master trip and current signals) with outgoing feeder devices and other incoming feeder devices with I/O. Up to six incoming feeders can be protected.

Figure. 4 - 13.

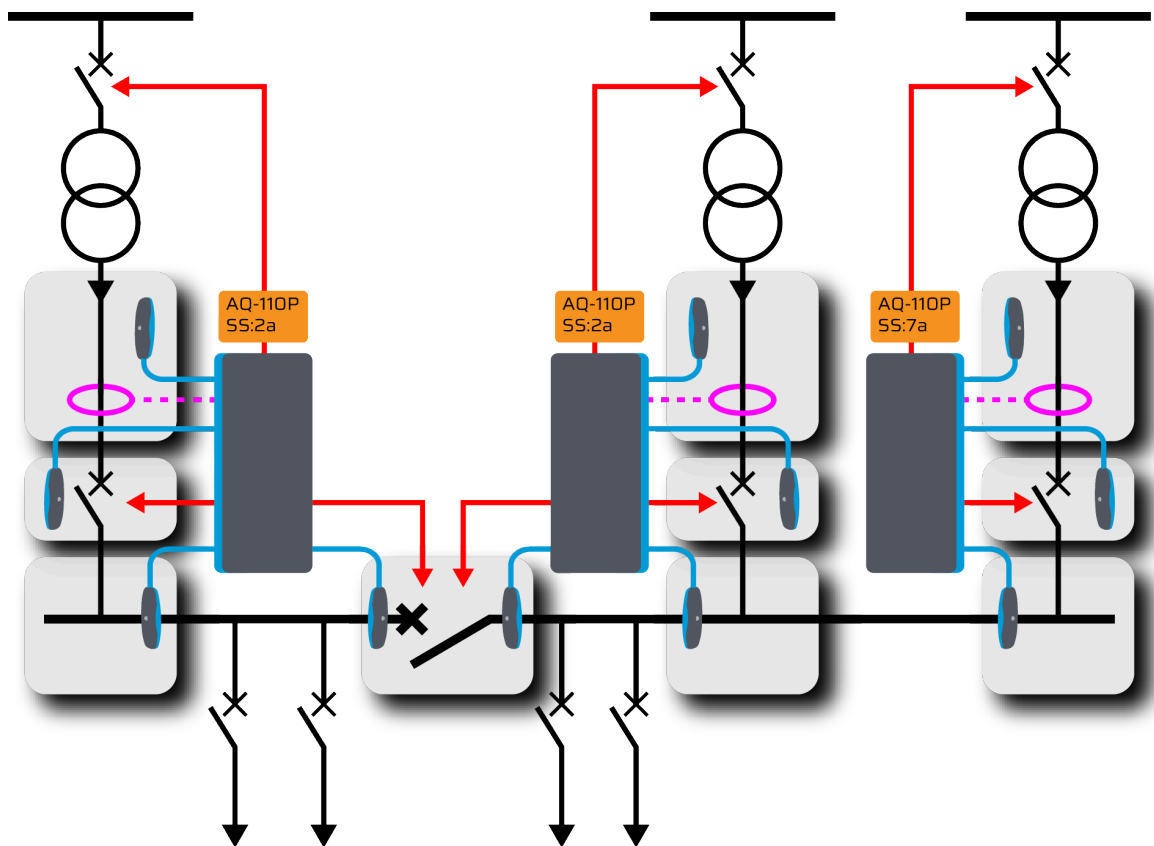




Table. 4 - 30. Devices installed to incoming feeders.

| Device type (scheme number) | Description  |
|-----------------------------|--|
| AQ-110P (SS:2a)             | <ul style="list-style-type: none"> <li>Both busbar sections have their own "Master incoming feeder" device.</li> <li>Can detect overcurrents and earth faults. Can share current signals with other devices.</li> <li>"Master incoming feeders" devices exchange signals with I/O.</li> <li>Sends master trip and current signals to outgoing feeder devices <b>in the same busbar section</b>.</li> <li>At most 20 external devices can be connected to this device with I/O.</li> <li>Tie breaker compartment can be monitored with one of the light sensor channels.</li> </ul> |
| AQ-110P (SS:7a)             | <ul style="list-style-type: none"> <li>"Follower incoming feeder" device.</li> <li>Used if there is more than one incoming feeder <b>in the same busbar section</b>.</li> <li>Up to four (4) "Follower incoming feeder" devices can be installed into a substation.</li> <li>Sends light and overcurrent signals to "Master incoming feeder" devices.</li> </ul>   |

### Outgoing feeder protection

Each suggested outgoing feeder protection solution has point sensors installed to cable compartments, circuit breaker compartments and busbar compartments. Outgoing feeder protection devices exchange information (light, master trip and current signals) with "Master incoming feeder" device with I/O.

Figure. 4 - 14. Typical point sensor positions in outgoing feeders with suggested devices and schemes.

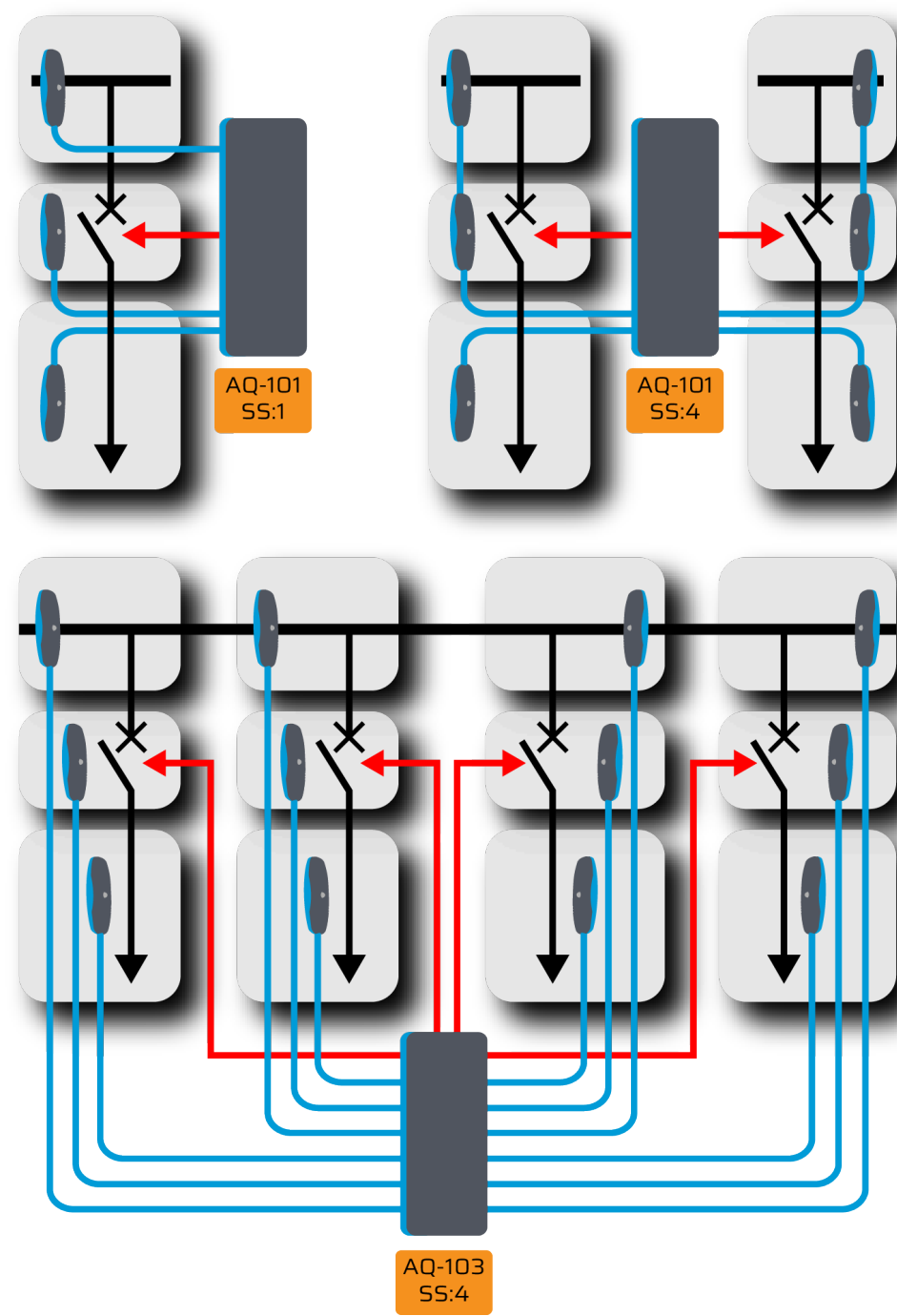


Table. 4 - 31. Devices installed to outgoing feeders.

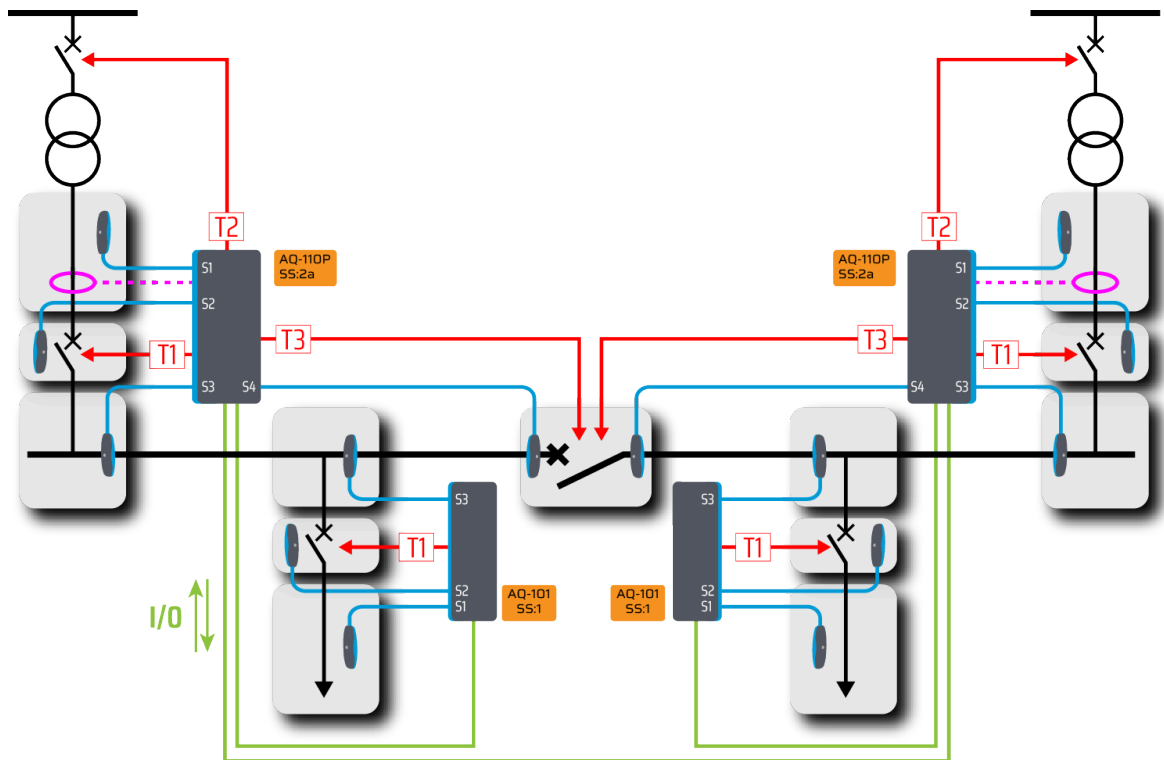
| Device type<br>(scheme<br>number) | Description   |
|-----------------------------------|---|
| AQ-101 (SS:1)                     | <ul style="list-style-type: none"><li>• Monitors one outgoing feeder per device.</li><li>• Max. 38 outgoing feeders per substation.</li></ul> |

| Device type<br>(scheme number) | Description  |
|--------------------------------|--|
|                                | <p>Advantages:</p> <ul style="list-style-type: none"> <li>• Fault location can be indicated with high accuracy with LEDs.</li> <li>• Only one outgoing feeder is unprotected in case of device failure.</li> </ul> <p>Disadvantages:</p> <ul style="list-style-type: none"> <li>• Lower maximum number of outgoing feeders compared to other schemes.</li> <li>• More devices to install.</li> </ul>   |
| AQ-101 (SS:4)                  | <ul style="list-style-type: none"> <li>• Monitors max. two outgoing feeders per device.</li> <li>• Max. 76 outgoing feeders per substation.</li> </ul> <p>Advantages:</p> <ul style="list-style-type: none"> <li>• Fewer protection devices needed for outgoing feeders compared to AQ-101 (SS:1).</li> <li>• Less wires to install for I/O.</li> <li>• Less cables to wire for point sensors.</li> </ul> <p>Disadvantages:</p> <ul style="list-style-type: none"> <li>• If a fault occurs either in the outgoing feeder circuit breaker compartment or in the busbar compartment the location is not indicated as accurately with LEDs as with other options.</li> <li>• Two outgoing feeders are unprotected at once in case of device failure.</li> </ul> |
| AQ-103 (SS:4)                  | <ul style="list-style-type: none"> <li>• Monitors max. four outgoing feeders per device.</li> <li>• Max. 152 outgoing feeders per substation.</li> </ul> <p>Advantages:</p> <ul style="list-style-type: none"> <li>• Fewest number of devices to install to outgoing feeders.</li> <li>• Fault location can be indicated with high accuracy with LEDs.</li> <li>• Fewest number of I/O to wire.</li> <li>• Ability to report signals to SCADA with Modbus connection (order option).</li> </ul> <p>Disadvantages:</p> <ul style="list-style-type: none"> <li>• Four outgoing feeders are unprotected at once in case of device failure.</li> <li>• One point sensor per channel. More point sensor cables to run.</li> </ul>                                 |

**NOTICE!**

Up to 20 devices can be connected to one "Master device". "Maximum number of outgoing feeders per substation" stated for each solution assumes that the substation has only one incoming feeder per busbar section that the outgoing feeders are divided evenly between the two busbar sections. Each additional incoming feeder deducts from maximum number of outgoing feeder protection devices that can be connected. When designing arc protection solution for a very large substation, please contact your nearest Arcteq representative for more information.

## 4.1 Two incoming feeders — one outgoing feeder per device



This is a fully selective scheme for protecting substations with one (1) incoming feeder per busbar section and up to 20 outgoing feeders per busbar section. The scheme uses the following basic logic:

Table. 4.1 - 32. Simplified operation logic description.

| Fault location  | Circuit breaker to trip  | CBFP trip  |
|---|--|--|
| <ul style="list-style-type: none"> <li>Outgoing feeder cable compartment</li> </ul>                                       | <ul style="list-style-type: none"> <li>The outgoing feeder with the fault</li> </ul>   | <ul style="list-style-type: none"> <li>Incoming feeder in the same busbar section</li> <li>Outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul> |
| <ul style="list-style-type: none"> <li>Outgoing feeder circuit breaker compartment</li> <li>Busbar compartment</li> </ul> | <ul style="list-style-type: none"> <li>Incoming feeder in the same busbar section</li> <li>Outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul>                             | <ul style="list-style-type: none"> <li>HV side of the incoming feeder</li> </ul>   |
| <ul style="list-style-type: none"> <li>Tie breaker compartment</li> </ul>   | <ul style="list-style-type: none"> <li>Both incoming feeders</li> <li>Tie breaker</li> <li>All outgoing feeders</li> </ul>   | <ul style="list-style-type: none"> <li>HV side of both incoming feeders</li> </ul>   |
| <ul style="list-style-type: none"> <li>Incoming feeder circuit breaker compartment</li> </ul>                             | <ul style="list-style-type: none"> <li>Incoming feeder with the fault</li> <li>HV side of the incoming feeder</li> <li>Tie breaker</li> <li>Outgoing feeders in the same busbar section</li> </ul> | <ul style="list-style-type: none"> <li>N/A</li> </ul>  |

| Fault location  | Circuit breaker to trip  | CBFP trip  |
|---|--|--|
| <ul style="list-style-type: none"> <li>Incoming feeder cable compartment</li> </ul> | <ul style="list-style-type: none"> <li>The incoming feeder with the fault</li> <li>HV side of the incoming feeder</li> </ul> | <ul style="list-style-type: none"> <li>Outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul> |

### 4.1.1 Incoming feeders AQ-110P (SS:2a)

Table. 4.1.1 - 33. Outputs of incoming feeder AQ-110P (SS:2a) device.

| Output | Connects to  | Action   |
|--------|--|--|
| T1     | Incoming feeder circuit breaker.   | Opens circuit breaker.   |
| T2     | Incoming feeder HV side circuit breaker.                                 |  |
| T3     | Tie breaker.   |  |
| T4     | Alarming unit (optional).  | Trip alarm signal.   |
| BO1    | BI1 of the other incoming feeder AQ-110P (SS:2a) device.                 | Sends overcurrent and earth fault signals.                             |
| HSO1   | BI1 of outgoing feeder AQ-101 (SS:1) devices in the same busbar section. | Sends overcurrent, earth fault and external overcurrent (BI1) signals. |
| HSO2   | BI2 of outgoing feeder AQ-101 (SS:1) devices in the same busbar section. | Sends master trip signal.  |

Table. 4.1.1 - 34. Inputs of incoming feeder AQ-110P (SS:2a) device.

| Input               | Connects to  | Action   |
|---------------------|--|--|
| IL1,<br>IL2,<br>IL3 | <ul style="list-style-type: none"> <li>Incoming feeder.</li> </ul>   | <ul style="list-style-type: none"> <li>Sensor channels and external light signal (BI2) can be set up to require overcurrent or earth fault signal as an additional criteria for tripping.</li> <li>Overcurrent and earth fault signals are sent to outgoing feeder AQ-101 (SS:1) devices in the same busbar section with <b>HSO1</b>.</li> <li>Overcurrent and earth fault signals are sent to the other AQ-110P (SS:2a) device with <b>BO1</b>.</li> </ul>  |
| I <sub>0</sub>      |  |  |
| BI1                 | <ul style="list-style-type: none"> <li><b>BO1</b> of the other incoming feeder AQ-110P (SS:2a) device.</li> <li>External overcurrent or earth fault signal.</li> </ul> | <ul style="list-style-type: none"> <li>Sensor channels and external light signal (BI2) can be set up to require overcurrent signal as an additional criteria for tripping.</li> <li>External current signal is sent forward to outgoing feeder AQ-101 (SS:1) devices in the same busbar section with <b>HSO1</b>.</li> </ul>   |
| S1                  | <ul style="list-style-type: none"> <li>Incoming feeder cable compartment.</li> </ul>   | <ul style="list-style-type: none"> <li>Trips incoming feeder circuit breaker with <b>T1</b> relay.</li> <li>Trips incoming feeder HV side circuit breaker with <b>T2</b> relay.</li> <li>Trips the tie breaker with <b>T3</b> relay after CBFP time delay.</li> <li>Sends master trip signal with <b>HSO2</b> to outgoing feeder AQ-101 (SS:1) devices in the same busbar section after CBFP time delay.</li> <li>This channel must be set to "Light only" mode if current measurement point is located after the sensor.</li> </ul> |

| Input | Connects to  | Action  |
|-------|--|---|
| S2    | <ul style="list-style-type: none"> <li>Incoming feeder circuit breaker compartment.</li> </ul>   | <ul style="list-style-type: none"> <li>Trips incoming feeder circuit breaker with <b>T1</b> relay.</li> <li>Trips incoming feeder HV side circuit breaker with <b>T2</b> relay.</li> <li>Trips the tie breaker with <b>T3</b> relay.</li> <li>Sends master trip signal with <b>HSO2</b> to outgoing feeder AQ-101 (SS:1) devices in the same busbar section.</li> </ul>                       |
| S3    | <ul style="list-style-type: none"> <li>Busbar compartment.</li> </ul>  | <ul style="list-style-type: none"> <li>Trips incoming feeder circuit breaker with <b>T1</b> relay.</li> <li>Trips the tie breaker with <b>T3</b> relay.</li> <li>Sends master trip signal with <b>HSO2</b> to outgoing feeder AQ-101 (SS:1) devices in the same busbar section.</li> <li>Trips incoming feeder HV side circuit breaker with <b>T2</b> relay after CBFP time delay.</li> </ul> |
| S4    | <ul style="list-style-type: none"> <li>Tie breaker compartment.</li> </ul>   |   |
| S5    | <ul style="list-style-type: none"> <li>Optional.</li> </ul>  |   |
| BI2   | <ul style="list-style-type: none"> <li>BO1 of outgoing feeder AQ-101 (SS:1) devices in the same busbar section.</li> <li>Receives light signal.</li> </ul> |   |

Figure. 4.1.1 - 15. Logic matrix of incoming feeder AQ-110P (SS:2a) device.

| SS:2a  |                        | OUTPUTS        |                   |                   |                |     |      |                   |                |
|--------|------------------------|----------------|-------------------|-------------------|----------------|-----|------|-------------------|----------------|
| INPUTS |                        | T1             | T2                | T3                | T4             | BO1 | HSO1 | HSO2              | AQD            |
|        | S1                     | x <sup>1</sup> | x <sup>1</sup>    | CBFP <sup>1</sup> | x <sup>1</sup> |     |      | CBFP <sup>1</sup> |                |
|        | S2                     | x <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup>    | x <sup>1</sup> |     |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | S3,S4,S5               | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |     |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | Lext> (BI2)            | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |     |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | Iext> (BI1)            |                |                   |                   |                |     | x    |                   |                |
|        | I> (phase currents)    |                |                   |                   |                | x   | x    |                   |                |
|        | Io> (residual current) |                |                   |                   |                | x   | x    |                   |                |

1. Activates only if channel has been set to light only mode or if any overcurrent signal (I>, Io> or Iext>) is ON.
2. Activates only if phase overcurrent signal (I>) is ON.

## 4.1.2 Outgoing feeders AQ-101 (SS:1)

Table. 4.1.2 - 35. Outputs of an outgoing feeder AQ-101 (SS:1) device.

| Output | Connects to   | Action                 |
|--------|---|------------------------|
| T1     | Outgoing feeder circuit breaker.  | Opens circuit breaker. |
| T2     | N/A   | N/A                    |
| T3     | N/A   | N/A                    |
| T4     | Alarming unit (optional).   | Trip alarm signal.     |
| BO1    | BI2 of incoming feeder AQ-110P (SS:2a) device in the same busbar section. | Sends light signal.    |

Table. 4.1.2 - 36. Inputs of an outgoing feeder AQ-101 (SS:1) device.

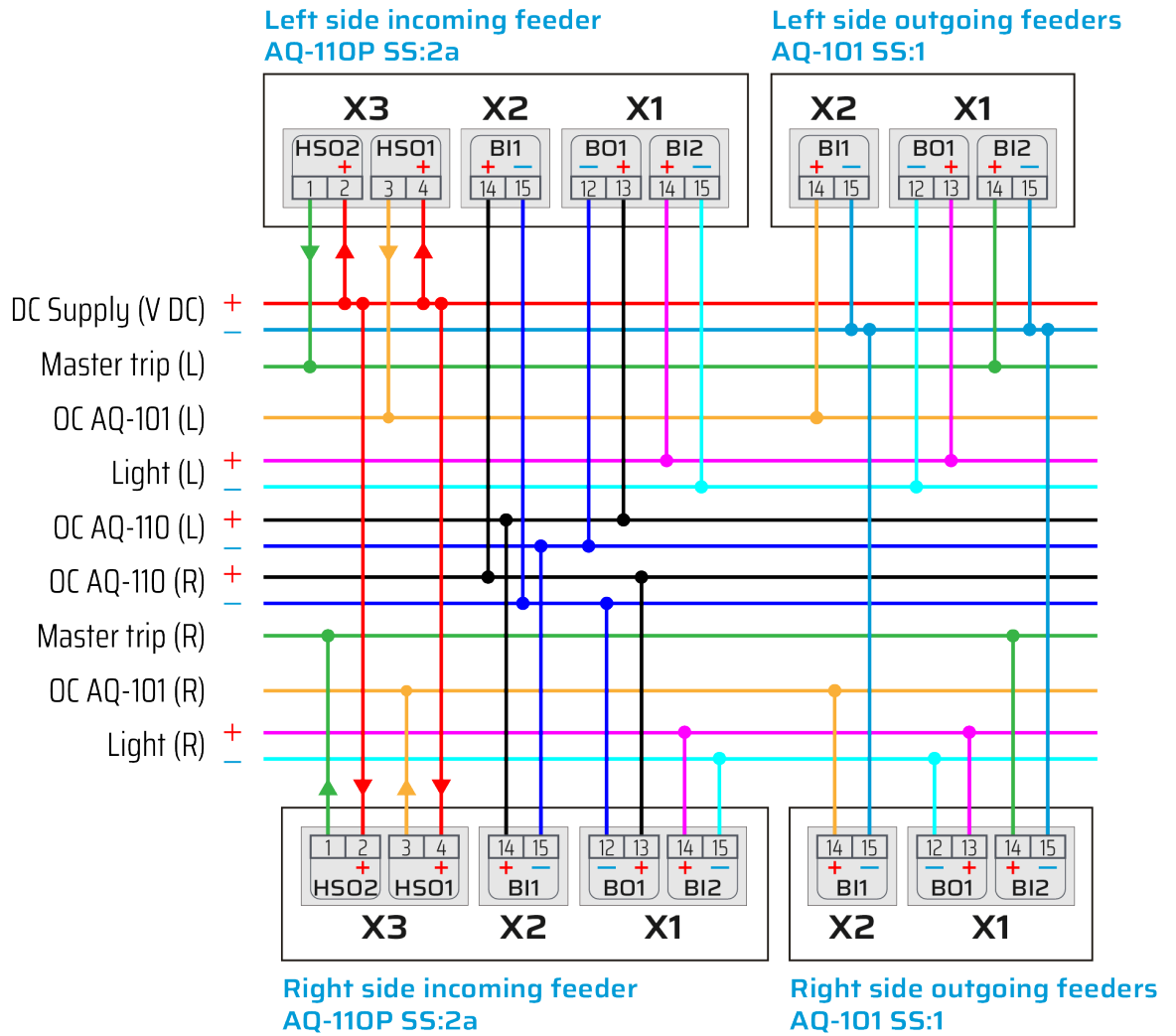
| Input | Connects to   | Action   |
|-------|---|--|
| BI1   | <ul style="list-style-type: none"><li>• <b>HSO1</b> of incoming feeder AQ-110P (SS:2a) device in the same busbar section.</li><li>• Receives overcurrent or earth fault signal.</li></ul> | <ul style="list-style-type: none"><li>• If a sensor channel has been set to "Light and current" mode, this input must be active for the sensor channel to trip.</li></ul>  |
| BI2   | <ul style="list-style-type: none"><li>• <b>HSO2</b> of incoming feeder AQ-110P (SS:2a) device in the same busbar section.</li><li>• Receives master trip signal.</li></ul>                | <ul style="list-style-type: none"><li>• Trips outgoing feeder with T1 relay.</li></ul>   |
| S1    | <ul style="list-style-type: none"><li>• Outgoing feeder cable compartment.</li></ul>  | <ul style="list-style-type: none"><li>• Trips outgoing feeder with <b>T1</b> relay.</li><li>• Sends light signal to incoming feeder AQ-110P (SS:2a) device in the same busbar section with <b>BO1</b> after CBFP time delay.</li></ul> |
| S2    | <ul style="list-style-type: none"><li>• Outgoing feeder circuit breaker compartment.</li></ul>  | <ul style="list-style-type: none"><li>• Sends light signal to incoming feeder AQ-110P (SS:2a) device in the same busbar section with <b>BO1</b>.</li></ul>   |
| S3    | <ul style="list-style-type: none"><li>• Busbar compartment.</li></ul>   |  |
| S4    | <ul style="list-style-type: none"><li>• Optional.</li></ul>   |  |
| S5    |   |  |

Figure. 4.1.2 - 16. Logic matrix of an outgoing feeder AQ-101 (SS:1) device.

| SS:1   |                   | OUTPUTS        |                   |      |
|--------|-------------------|----------------|-------------------|------|
|        |                   | T1             | T4                | BO1  |
| INPUTS | S1                | x <sup>1</sup> | x <sup>1</sup>    | CBFP |
|        | S2, S3, S4, S5    |                | CBFP <sup>1</sup> | x    |
|        | Master Trip (BI2) | x              | x                 |      |

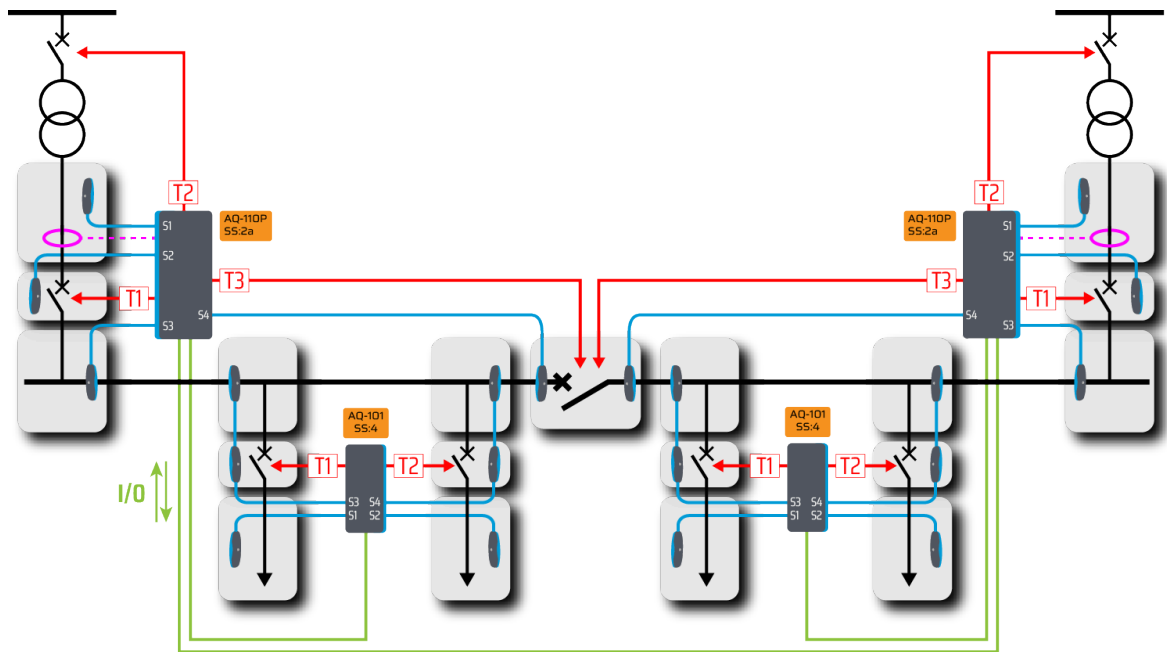
1. Activates only if channel has been set to light only mode or overcurrent signal (BI1) is ON.

### 4.1.3 Connections





## 4.2 Two incoming feeders — two outgoing feeders per device



This is a fully selective scheme for protecting substations with one (1) incoming feeder per busbar section and up to 40 outgoing feeders per busbar section. The scheme uses the following basic logic:

Table. 4.2 - 37. Simplified operation logic description.

| Fault location  | Circuit breaker to trip  | CBFP trip  |
|---|--|--|
| <ul style="list-style-type: none"> <li>Outgoing feeder cable compartment</li> </ul>                                       | <ul style="list-style-type: none"> <li>The outgoing feeder with the fault</li> </ul>   | <ul style="list-style-type: none"> <li>Incoming feeder in the same busbar section</li> <li>Outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul> |
| <ul style="list-style-type: none"> <li>Outgoing feeder circuit breaker compartment</li> <li>Busbar compartment</li> </ul> | <ul style="list-style-type: none"> <li>Incoming feeder in the same busbar section</li> <li>Outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul>                                 | <ul style="list-style-type: none"> <li>HV side of the incoming feeder</li> </ul>   |
| <ul style="list-style-type: none"> <li>Tie breaker compartment</li> </ul>   | <ul style="list-style-type: none"> <li>Both incoming feeders</li> <li>All outgoing feeders</li> <li>Tie breaker</li> </ul>   | <ul style="list-style-type: none"> <li>HV side of the incoming feeders</li> </ul>  |
| <ul style="list-style-type: none"> <li>Incoming feeder circuit breaker compartment</li> </ul>                             | <ul style="list-style-type: none"> <li>The incoming feeder with the fault</li> <li>HV side of the incoming feeder</li> <li>Outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul> | <ul style="list-style-type: none"> <li>N/A</li> </ul>  |
| <ul style="list-style-type: none"> <li>Incoming feeder cable compartment</li> </ul>                                       | <ul style="list-style-type: none"> <li>The incoming feeder with the fault</li> <li>HV side of the incoming feeder with the fault</li> </ul>  | <ul style="list-style-type: none"> <li>All outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul>   |

## 4.2.1 Incoming feeders AQ-110P (SS:2a)

Table. 4.2.1 - 38. Outputs of incoming feeder AQ-110P (SS:2a) device.

| Output | Connects to  | Action   |
|--------|--|--|
| T1     | Incoming feeder circuit breaker.   | Opens circuit breaker.   |
| T2     | Incoming feeder HV side circuit breaker.                                 |  |
| T3     | Tie breaker.   |  |
| T4     | Alarming unit (optional).  | Trip alarm signal.   |
| BO1    | BI1 of the other incoming feeder AQ-110P (SS:2a) device.                 | Sends overcurrent and earth fault signals.                             |
| HSO1   | BI1 of outgoing feeder AQ-101 (SS:4) devices in the same busbar section. | Sends overcurrent, earth fault and external overcurrent (BI1) signals. |
| HSO2   | BI2 of outgoing feeder AQ-101 (SS:4) devices in the same busbar section. | Sends master trip signal.  |

Table. 4.2.1 - 39. Inputs of incoming feeder AQ-110P (SS:2a) device.

| Input               | Connects to   | Action   |
|---------------------|---|--|
| IL1,<br>IL2,<br>IL3 | <ul style="list-style-type: none"> <li>Incoming feeder.</li> </ul>  | <ul style="list-style-type: none"> <li>Sensor channels and external light signal (BI2) can be set up to require overcurrent or earth fault signal as an additional criteria for tripping.</li> <li>Overcurrent and earth fault signals are sent to outgoing feeder AQ-101 (SS:4) devices in the same busbar section with HSO1.</li> <li>Overcurrent and earth fault signals are sent to the other AQ-110P (SS:4) device with BO1.</li> </ul>   |
| I <sub>0</sub>      |   |  |
| BI1                 | <ul style="list-style-type: none"> <li>BO1 of the other incoming feeder AQ-110P (SS:2a) device.</li> <li>External overcurrent or earth fault signal.</li> </ul> | <ul style="list-style-type: none"> <li>Sensor channels and external light signal (BI2) can be set up to require overcurrent signal as an additional criteria for tripping.</li> <li>External current signal is sent forward to outgoing feeder AQ-101 (SS:4) devices in the same busbar section with HSO1.</li> </ul>  |
| S1                  | <ul style="list-style-type: none"> <li>Incoming feeder cable compartment.</li> </ul>  | <ul style="list-style-type: none"> <li>Trips incoming feeder circuit breaker with T1 relay.</li> <li>Trips incoming feeder HV side circuit breaker with T2 relay.</li> <li>Trips the tie breaker with T3 relay after CBFP time delay.</li> <li>Sends master trip signal with HSO2 to outgoing feeder AQ-101 (SS:4) devices in the same busbar section after CBFP time delay.</li> <li>This channel must be set to "Light only" mode if current measurement point is located after the sensor.</li> </ul> |
| S2                  | <ul style="list-style-type: none"> <li>Incoming feeder circuit breaker compartment.</li> </ul>  | <ul style="list-style-type: none"> <li>Trips incoming feeder circuit breaker with T1 relay.</li> <li>Trips incoming feeder HV side circuit breaker with T2 relay.</li> <li>Trips the tie breaker with T3 relay.</li> <li>Sends master trip signal with HSO2 to outgoing feeder AQ-101 (SS:4) devices in the same busbar section.</li> </ul>  |

| Input | Connects to  | Action  |
|-------|--|---|
| S3    | • Busbar compartment.  | <ul style="list-style-type: none"> <li>Trips incoming feeder circuit breaker with T1 relay.</li> <li>Trips the tie breaker with T3 relay.</li> <li>Sends master trip signal with HSO2 to outgoing feeder AQ-101 (SS:4) devices in the same busbar section.</li> <li>Trips incoming feeder HV side circuit breaker with T2 relay after CBFP time delay.</li> </ul> |
| S4    | • Tie breaker compartment.   |   |
| S5    | • Optional   |   |
| BI2   | <ul style="list-style-type: none"> <li>BO1 of outgoing feeder AQ-101 (SS:4) devices in the same busbar section.</li> <li>Receives light signal.</li> </ul> |   |

Figure. 4.2.1 - 17. Logic matrix of incoming feeder AQ-110P (SS:2a) device.

| SS:2a  |                          | OUTPUTS        |                   |                   |                |   |   |                   |                |
|--------|--------------------------|----------------|-------------------|-------------------|----------------|---|---|-------------------|----------------|
| INPUTS | S1                       | x <sup>1</sup> | x <sup>1</sup>    | CBFP <sup>1</sup> | x <sup>1</sup> |   |   | CBFP <sup>1</sup> |                |
|        | S2                       | x <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup>    | x <sup>1</sup> |   |   | x <sup>1</sup>    | x <sup>2</sup> |
|        | S3,S4,S5                 | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |   |   | x <sup>1</sup>    | x <sup>2</sup> |
|        | l <sub>ext</sub> > (BI2) | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |   |   | x <sup>1</sup>    | x <sup>2</sup> |
|        | l <sub>ext</sub> > (BI1) |                |                   |                   |                |   | x |                   |                |
|        | l> (phase currents)      |                |                   |                   |                | x | x |                   |                |
|        | lo> (residual current)   |                |                   |                   |                | x | x |                   |                |

1. Activates only if channel has been set to light only mode or if any overcurrent signal (l>, lo> or l<sub>ext</sub>>) is ON.
2. Activates only if phase overcurrent signal (l>) is ON.

## 4.2.2 Outgoing feeders AQ-101 (SS:4)

Table. 4.2.2 - 40. Outputs of an outgoing feeder AQ-101 (SS:4) device.

| Output | Connects to   | Action                 |
|--------|---|------------------------|
| T1     | "Left side" outgoing feeder circuit breaker.                              | Opens circuit breaker. |
| T2     | "Right side" outgoing feeder circuit breaker.                             |                        |
| T3     | N/A   | N/A                    |
| T4     | Alarming unit (optional).   | Trip alarm signal.     |
| BO1    | BI2 of incoming feeder AQ-110P (SS:2a) device in the same busbar section. | Sends light signal.    |

Table. 4.2.2 - 41. Inputs of an outgoing feeder AQ-101 (SS:4) device.

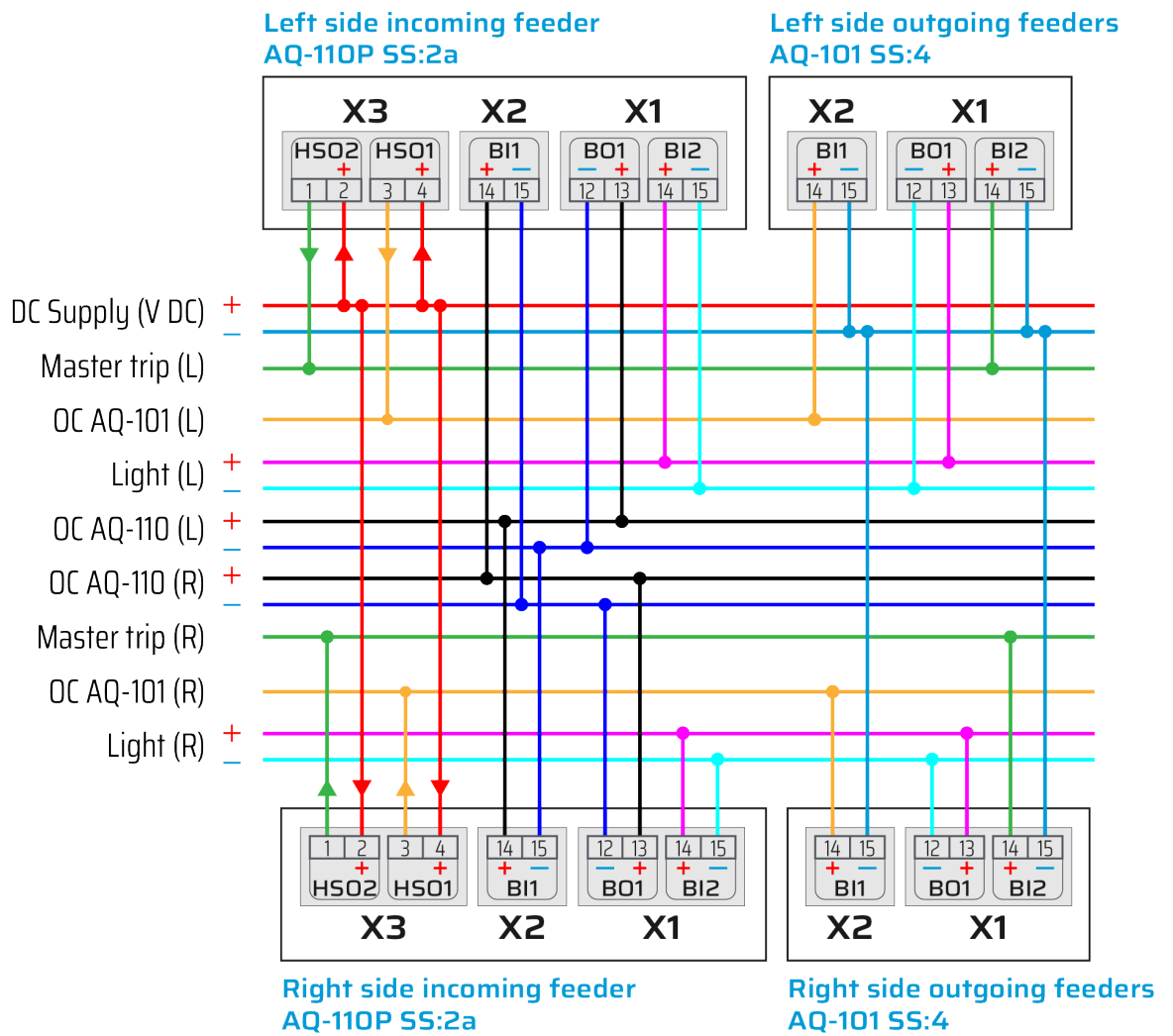
| Input | Connects to   | Action  |
|-------|---|---|
| BI1   | <ul style="list-style-type: none"> <li>HSO1 of incoming feeder AQ-110P (SS:2a) device in the same busbar section.</li> <li>Receives overcurrent or earth fault signal.</li> </ul> | <ul style="list-style-type: none"> <li>If a sensor channel has been set to "Light and current" mode, this input must be active for the sensor channel to trip.</li> </ul>                                 |
| BI2   | <ul style="list-style-type: none"> <li>HSO2 of incoming feeder AQ-110P (SS:2a) device in the same busbar section.</li> <li>Receives master trip signal.</li> </ul>                | <ul style="list-style-type: none"> <li>Trips both outgoing feeder circuit breakers with T1 and T2.</li> </ul>   |
| S1    | <ul style="list-style-type: none"> <li>"Left side" outgoing feeder cable compartment.</li> </ul>  | <ul style="list-style-type: none"> <li>Trips "left side" outgoing feeder with T1 relay.</li> <li>Sends light signal to incoming feeder AQ-110P (SS:2a) device with BO1 after CBFP time delay.</li> </ul>  |
| S2    | <ul style="list-style-type: none"> <li>"Right side" outgoing feeder cable compartment.</li> </ul>   | <ul style="list-style-type: none"> <li>Trips "right side" outgoing feeder with T2 relay.</li> <li>Sends light signal to incoming feeder AQ-110P (SS:2a) device with BO1 after CBFP time delay.</li> </ul> |
| S3    | <ul style="list-style-type: none"> <li>"Left side" outgoing feeder circuit breaker compartment.</li> <li>Busbar compartment.</li> </ul>   | <ul style="list-style-type: none"> <li>Sends light signal to incoming feeder AQ-110P (SS:2a) device with BO1.</li> </ul>  |
| S4    | <ul style="list-style-type: none"> <li>"Right side" outgoing feeder circuit breaker compartment.</li> <li>Busbar compartment.</li> </ul>  |   |
| S5    | <ul style="list-style-type: none"> <li>Optional</li> </ul>  |   |

Figure. 4.2.2 - 18. Logic matrix of an outgoing feeder AQ-101 (SS:4) device.

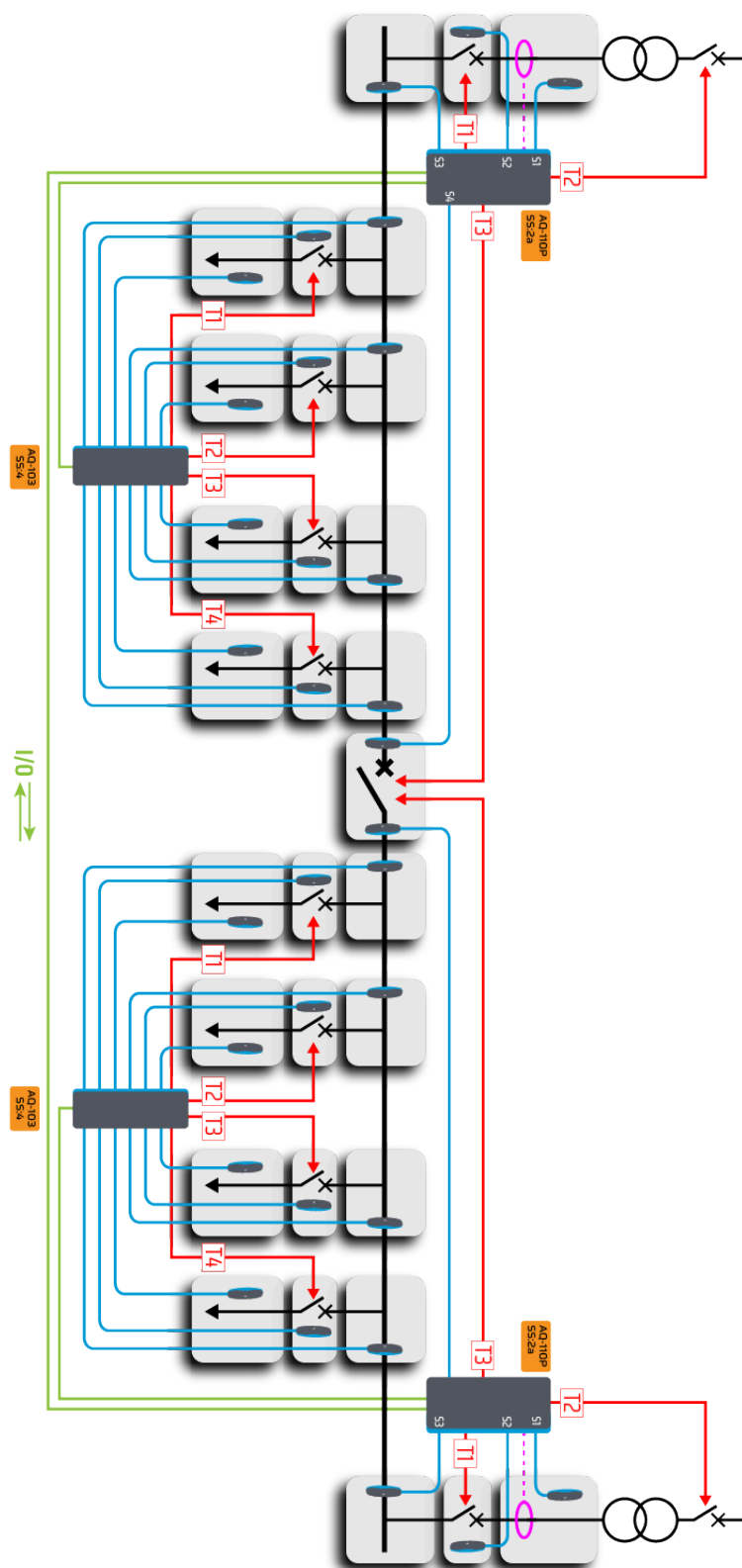
| SS:4   |                   | OUTPUTS        |                |                |      |
|--------|-------------------|----------------|----------------|----------------|------|
| INPUTS | S1                | T1             | T2             | T4             | BO1  |
|        | S2                | x <sup>1</sup> |                | x <sup>1</sup> | CBFP |
|        | S3, S4, S5        |                | x <sup>1</sup> | x <sup>1</sup> | CBFP |
|        | Master Trip (BI2) |                |                | x <sup>1</sup> | x    |
|        |                   | x              | x              | x              |      |

1. Activates only if channel has been set to light only mode or overcurrent signal (BI1) is ON.

## 4.2.3 Connections



### 4.3 Two incoming feeders — four outgoing feeder per device



This is a fully selective scheme for protecting substations with one (1) incoming feeder per busbar section and up to 80 outgoing feeders per busbar section. The scheme uses the following basic logic:

Table. 4.3 - 42. Simplified operation logic description.

| Fault location  | Circuit breaker to trip  | CBFP trip  |
|---|--|--|
| <ul style="list-style-type: none"> <li>Outgoing feeder cable compartment</li> </ul>                                       | <ul style="list-style-type: none"> <li>The outgoing feeder with the fault</li> </ul>   | <ul style="list-style-type: none"> <li>Incoming feeder in the same busbar section</li> <li>Outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul> |
| <ul style="list-style-type: none"> <li>Outgoing feeder circuit breaker compartment</li> <li>Busbar compartment</li> </ul> | <ul style="list-style-type: none"> <li>Incoming feeder in the same busbar section</li> <li>Outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul>                                 | <ul style="list-style-type: none"> <li>HV side of incoming feeder</li> </ul>   |
| <ul style="list-style-type: none"> <li>Tie breaker compartment</li> </ul>   | <ul style="list-style-type: none"> <li>Both incoming feeders</li> <li>Tie breaker</li> <li>All outgoing feeders</li> </ul>   | <ul style="list-style-type: none"> <li>HV side of both incoming feeders</li> </ul>   |
| <ul style="list-style-type: none"> <li>Incoming feeder circuit breaker compartment</li> </ul>                             | <ul style="list-style-type: none"> <li>The incoming feeder with the fault</li> <li>HV side of the incoming feeder</li> <li>Outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul> | <ul style="list-style-type: none"> <li>N/A</li> </ul>  |
| <ul style="list-style-type: none"> <li>Incoming feeder cable compartment</li> </ul>                                       | <ul style="list-style-type: none"> <li>The incoming feeder with the fault</li> <li>HV side of the incoming feeder with the fault</li> </ul>  | <ul style="list-style-type: none"> <li>All outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul>   |

### 4.3.1 Incoming feeders AQ-110P (SS:2a)

Table. 4.3.1 - 43. Outputs of incoming feeder AQ-110P (SS:2a) device.

| Output | Connects to  | Action                                     |
|--------|--|--|
| T1     | Incoming feeder circuit breaker.   | Opens circuit breaker.                     |
| T2     | Incoming feeder HV side circuit breaker.                                 |  |
| T3     | Tie breaker.   |  |
| T4     | Alarming unit (optional).  | Trip alarm signal.                         |
| BO1    | BI1 of the other incoming feeder AQ-110P (SS:2a) device.                 | Sends overcurrent and earth fault signals. |
| HSO1   | BI1 of outgoing feeder AQ-103 (SS:4) devices in the same busbar section. | Sends overcurrent and earth fault signals. |
| HSO2   | BI2 of outgoing feeder AQ-103 (SS:4) devices in the same busbar section. | Sends master trip signal.                  |

Table. 4.3.1 - 44. Inputs of incoming feeder AQ-110P (SS:2a) device.

| Input               | Connects to   | Action   |
|---------------------|---|--|
| IL1,<br>IL2,<br>IL3 | <ul style="list-style-type: none"> <li>Incoming feeder.</li> </ul>  | <ul style="list-style-type: none"> <li>Sensor channels and external light signal (BI2) can be set up to require overcurrent or earth fault signal as an additional criteria for tripping.</li> <li>Overcurrent and earth fault signals are sent to outgoing feeder AQ-103 (SS:4) devices in the same busbar section with HSO1.</li> <li>Overcurrent and earth fault signals are sent to the other incoming feeder AQ-110P (SS:2a) device with BO1.</li> </ul>  |
| I <sub>0</sub>      |   |  |
| BI1                 | <ul style="list-style-type: none"> <li>BO1 of the other incoming feeder AQ-110P (SS:2a) device.</li> <li>External overcurrent or earth fault signal.</li> </ul> | <ul style="list-style-type: none"> <li>Sensor channels and external light signal (BI2) can be set up to require overcurrent signal as an additional criteria for tripping.</li> <li>External current signal is sent forward to outgoing feeder AQ-103 (SS:4) devices in the same busbar section with HSO1.</li> </ul>  |
| S1                  | <ul style="list-style-type: none"> <li>Incoming feeder cable compartment.</li> </ul>  | <ul style="list-style-type: none"> <li>Trips incoming feeder circuit breaker with T1 relay.</li> <li>Trips incoming feeder HV side circuit breaker with T2 relay.</li> <li>Trips the tie breaker with T3 relay after CBFP time delay.</li> <li>Sends master trip signal with HSO2 to outgoing feeder AQ-103 (SS:4) devices in the same busbar section after CBFP time delay.</li> <li>This channel must be set to "Light only" mode if current measurement point is located after the sensor.</li> </ul> |
| S2                  | <ul style="list-style-type: none"> <li>Incoming feeder circuit breaker compartment.</li> </ul>  | <ul style="list-style-type: none"> <li>Trips incoming feeder circuit breaker with T1 relay.</li> <li>Trips incoming feeder HV side circuit breaker with T2 relay.</li> <li>Trips the tie breaker with T3 relay.</li> <li>Sends master trip signal with HSO2 to outgoing feeder AQ-103 (SS:4) devices in the same busbar section.</li> </ul>  |
| S3                  | <ul style="list-style-type: none"> <li>Busbar compartment.</li> </ul>   | <ul style="list-style-type: none"> <li>Trips incoming feeder circuit breaker with T1 relay.</li> <li>Trips the tie breaker with T3 relay.</li> <li>Sends master trip signal with HSO2 to outgoing feeder AQ-103 (SS:4) devices in the same busbar section.</li> <li>Trips incoming feeder HV side circuit breaker with T2 relay after CBFP time delay.</li> </ul>  |
| S4                  | <ul style="list-style-type: none"> <li>Tie breaker compartment.</li> </ul>  |  |
| S5                  | <ul style="list-style-type: none"> <li>Optional</li> </ul>  |  |
| BI2                 | <ul style="list-style-type: none"> <li>BO1 of outgoing feeder AQ-103 (SS:4) devices in the same busbar section.</li> <li>Receives light signal.</li> </ul>      |  |



Figure. 4.3.1 - 19. Logic matrix of incoming feeder AQ-110P (SS:2a) device.

| SS:2a  |                        | OUTPUTS        |                   |                   |                |     |      |                   |                |
|--------|------------------------|----------------|-------------------|-------------------|----------------|-----|------|-------------------|----------------|
|        |                        | T1             | T2                | T3                | T4             | BO1 | HSO1 | HSO2              | AQD            |
| INPUTS | S1                     | x <sup>1</sup> | x <sup>1</sup>    | CBFP <sup>1</sup> | x <sup>1</sup> |     |      | CBFP <sup>1</sup> |                |
|        | S2                     | x <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup>    | x <sup>1</sup> |     |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | S3,S4,S5               | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |     |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | Iext> (BI2)            | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |     |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | Iext> (BI1)            |                |                   |                   |                |     | x    |                   |                |
|        | I> (phase currents)    |                |                   |                   |                | x   | x    |                   |                |
|        | Io> (residual current) |                |                   |                   |                | x   | x    |                   |                |

1. Activates only if DIP-switch has been set to light only mode or if any overcurrent signal (I>, Io> or Iext>) is ON.
2. Activates only if phase overcurrent signal (I>) is ON.

### 4.3.2 Outgoing feeders AQ-103 (SS:4)

Table. 4.3.2 - 45. Outputs of an outgoing feeder AQ-103 (SS:4) device.

| Output | Connects to   | Action                 |
|--------|---|------------------------|
| T1     | Outgoing feeder circuit breaker #1  | Opens circuit breaker. |
| T2     | Outgoing feeder circuit breaker #2  |                        |
| T3     | Outgoing feeder circuit breaker #3  |                        |
| T4     | Outgoing feeder circuit breaker #4  |                        |
| BO1    | BI2 of incoming feeder AQ-110P (SS:2a) device in the same busbar section. | Sends light signal.    |

Table. 4.3.2 - 46. Inputs of an outgoing feeder AQ-103 (SS:4) device.

| Input | Connects to   | Action  |
|-------|---|---|
| BI1   | <ul style="list-style-type: none"> <li>• HSO1 of incoming feeder AQ-110P (SS:2a) device in the same busbar section.</li> <li>• Receives overcurrent or earth fault signal.</li> </ul> | <ul style="list-style-type: none"> <li>• If a sensor channel has been set to "Light and current" mode, this input must be active for the sensor channel to trip.</li> </ul> |
| BI2   | <ul style="list-style-type: none"> <li>• HSO2 of incoming feeder AQ-110P (SS:2a) device in the same busbar section.</li> <li>• Receives master trip signal.</li> </ul>                | <ul style="list-style-type: none"> <li>• Trips all four outgoing feeders with T1, T2, T3 and T4 relays.</li> </ul>  |
| S1-S4 | <ul style="list-style-type: none"> <li>• Busbar compartment</li> </ul>  | <ul style="list-style-type: none"> <li>• Sends light signal to incoming feeder AQ-110P (SS:2a) device in the same busbar section with BO1.</li> </ul>                       |
| S5    | <ul style="list-style-type: none"> <li>• Optional</li> </ul>  |   |
| S6-S9 | <ul style="list-style-type: none"> <li>• Outgoing feeder circuit breaker compartments #1 to 4.</li> </ul>   |   |

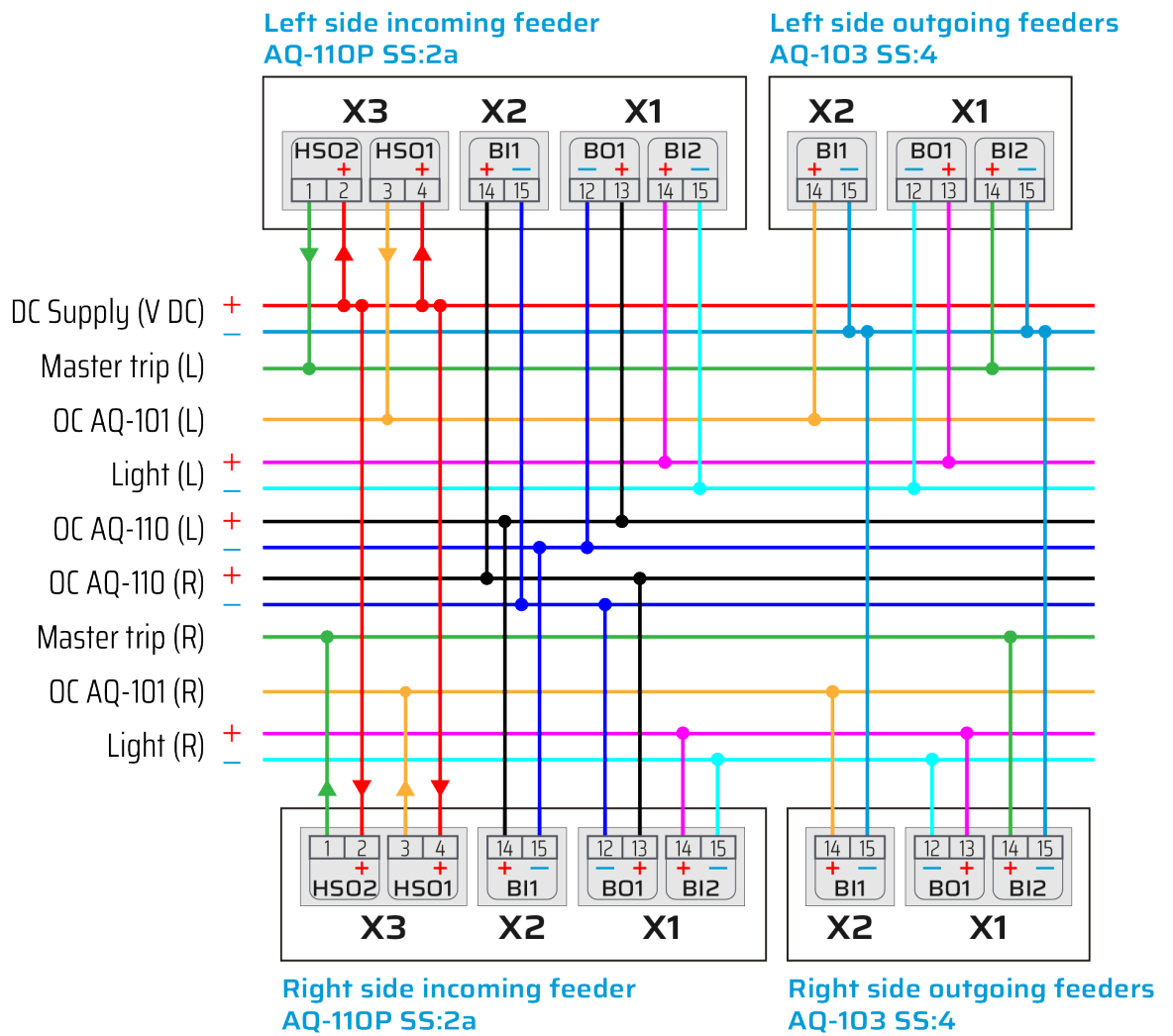
| Input | Connects to   | Action   |
|-------|---|--|
| S10   | <ul style="list-style-type: none"> <li>Optional</li> </ul>                              |  |
| S11   | <ul style="list-style-type: none"> <li>Outgoing feeder cable compartment #1.</li> </ul> | <ul style="list-style-type: none"> <li>Trips outgoing feeder #1 with T1 relay.</li> <li>Sends light signal to incoming feeder AQ-110P (SS:2a) device in the same busbar section with BO1 after CBFP time delay.</li> </ul> |
| S12   | <ul style="list-style-type: none"> <li>Outgoing feeder cable compartment #2.</li> </ul> | <ul style="list-style-type: none"> <li>Trips outgoing feeder #2 with T2 relay.</li> <li>Sends light signal to incoming feeder AQ-110P (SS:2a) device in the same busbar section with BO1 after CBFP time delay.</li> </ul> |
| S13   | <ul style="list-style-type: none"> <li>Outgoing feeder cable compartment #3.</li> </ul> | <ul style="list-style-type: none"> <li>Trips outgoing feeder #3 with T3 relay.</li> <li>Sends light signal to incoming feeder AQ-110P (SS:2a) device in the same busbar section with BO1 after CBFP time delay.</li> </ul> |
| S14   | <ul style="list-style-type: none"> <li>Outgoing feeder cable compartment #4.</li> </ul> | <ul style="list-style-type: none"> <li>Trips outgoing feeder #4 with T4 relay.</li> <li>Sends light signal to incoming feeder AQ-110P (SS:2a) device in the same busbar section with BO1 after CBFP time delay.</li> </ul> |
| S15   | <ul style="list-style-type: none"> <li>Optional</li> </ul>                              | <ul style="list-style-type: none"> <li>Sends light signal to incoming feeder AQ-110P (SS:2a) device in the same busbar section with BO1.</li> </ul>  |

Figure. 4.3.2 - 20. Logic matrix of an outgoing feeder AQ-103 (SS:4) device.

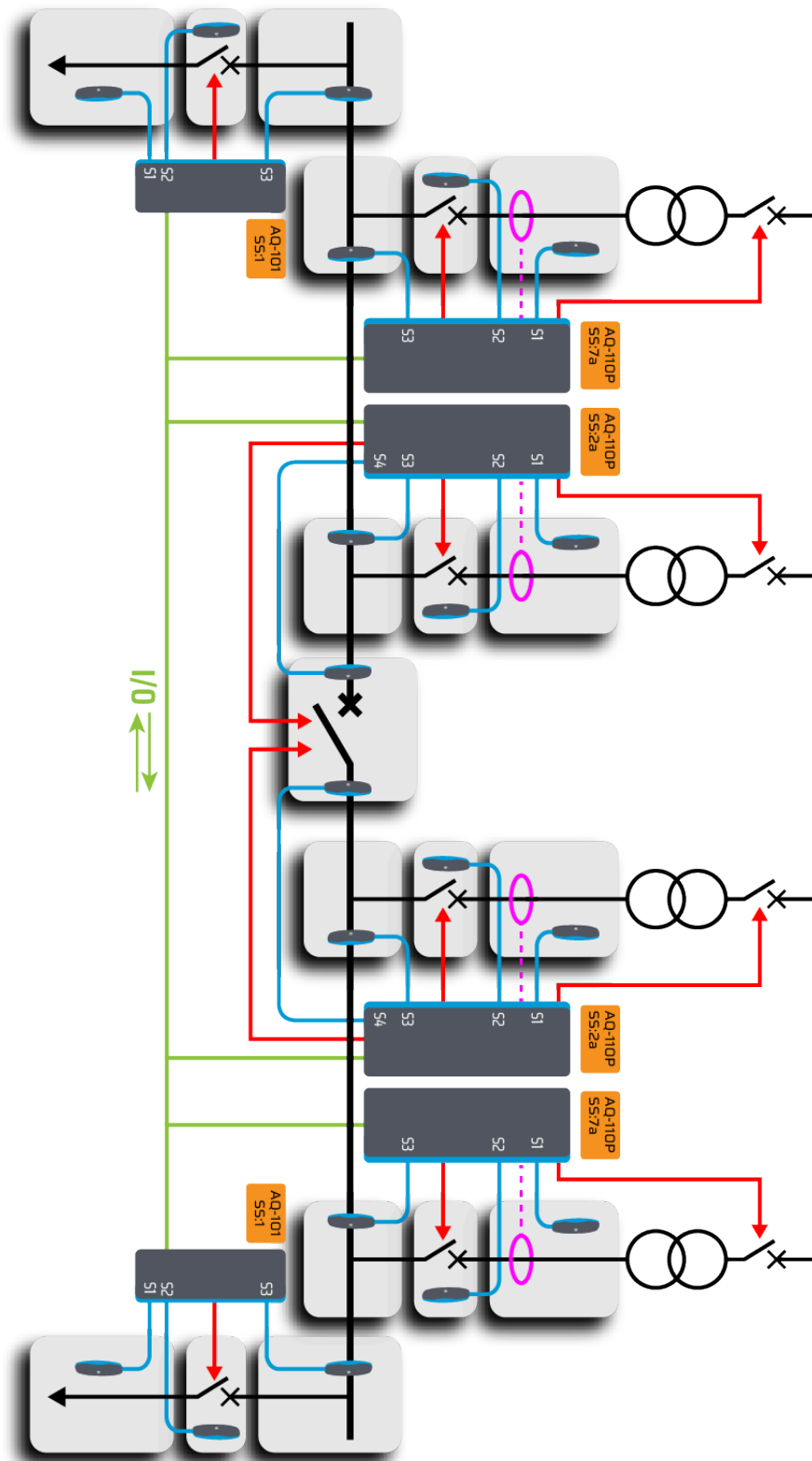
| SS:4   |                   | OUTPUTS        |                |                |                |      |
|--------|-------------------|----------------|----------------|----------------|----------------|------|
|        |                   | T1             | T2             | T3             | T4             | BO1  |
| INPUTS | S1-S10            |                |                |                |                | x    |
|        | S11               | x <sup>1</sup> |                |                |                | CBFP |
|        | S12               |                | x <sup>1</sup> |                |                | CBFP |
|        | S13               |                |                | x <sup>1</sup> |                | CBFP |
|        | S14               |                |                |                | x <sup>1</sup> | CBFP |
|        | S15               |                |                |                |                | x    |
|        | Master Trip (BI2) | x              | x              | x              | x              |      |

1. Activates only if channels have been set to light only mode or overcurrent signal (BI1) is ON.

## 4.3.3 Connections



## 4.4 Multiple incoming feeders — one outgoing feeder per device



This is a fully selective scheme for protecting substations with two or more incoming feeders per busbar section. The operation logic is identical to previous schemes with two incoming feeders.

While this chapter uses AQ-101 with SS:1 for the outgoing feeders, it is possible to use AQ-101 with SS:4 or AQ-103 with SS:4 instead to increase the maximum number of outgoing feeders. Up to 20 devices can be connected to a "Master device". Therefore each additional incoming feeder deducts from maximum number of outgoing feeder protection devices that can be connected. When designing arc protection solution for a very large substation, please contact your nearest Arcteq representative for more information.

Table. 4.4 - 47. Simplified operation logic description.

| Fault location  | Circuit breaker to trip   | CBFP trip   |
|---|---|---|
| <ul style="list-style-type: none"> <li>Outgoing feeder cable compartment</li> </ul>                                       | <ul style="list-style-type: none"> <li>The outgoing feeder with the fault</li> </ul>  | <ul style="list-style-type: none"> <li>Incoming feeders in the same busbar section</li> <li>Outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul>       |
| <ul style="list-style-type: none"> <li>Outgoing feeder circuit breaker compartment</li> <li>Busbar compartment</li> </ul> | <ul style="list-style-type: none"> <li>Incoming feeders in the same busbar section</li> <li>Outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul>   | <ul style="list-style-type: none"> <li>HV side of incoming feeders</li> </ul>   |
| <ul style="list-style-type: none"> <li>Tie breaker compartment</li> </ul>   | <ul style="list-style-type: none"> <li>All incoming feeders</li> <li>Tie breaker</li> <li>All outgoing feeders</li> </ul>   | <ul style="list-style-type: none"> <li>HV side of both incoming feeders</li> </ul>  |
| <ul style="list-style-type: none"> <li>Incoming feeder circuit breaker compartment</li> </ul>                             | <ul style="list-style-type: none"> <li>Incoming feeders in the same busbar section</li> <li>HV side of incoming feeders in the same busbar section</li> <li>Outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul> | <ul style="list-style-type: none"> <li>N/A</li> </ul>   |
| <ul style="list-style-type: none"> <li>Incoming feeder cable compartment</li> </ul>                                       | <ul style="list-style-type: none"> <li>The incoming feeder with the fault</li> <li>HV side of the incoming feeder with the fault</li> </ul>   | <ul style="list-style-type: none"> <li>Other incoming feeders in the same busbar section</li> <li>Outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul> |

Table. 4.4 - 48. Scheme characteristics

| Device role                     | Device type     | Number of devices           | Number of incoming feeders / outgoing feeders protected |
|---------------------------------|-----------------|-----------------------------|---|
| Master incoming feeder device   | AQ-110P (SS:2a) | 2                           | 2   |
| Follower incoming feeder device | AQ-110P (SS:7a) | 1...20 (per busbar section) | 1...4   |
| Outgoing feeder device options  | AQ-101 (SS:1)   |                             | 1...20  |
|                                 | AQ-101 (SS:4)   |                             | 2...40  |
|                                 | AQ-103 (SS:4)   |                             | 4...80  |

## 4.4.1 Master incoming feeders AQ-110P (SS:2a)

Table. 4.4.1 - 49. Outputs of incoming feeder AQ-110P (SS:2a) device.

| Output | Connects to   | Action   |
|--------|---|--|
| T1     | Incoming feeder circuit breaker.  | Opens circuit breaker.   |
| T2     | Incoming feeder HV side circuit breaker.  |  |
| T3     | Tie breaker.  |  |
| T4     | Alarming unit (optional).   | Trip alarm signal.   |
| BO1    | BI2 of the follower incoming feeder AQ-110P (SS:7a) devices in the same busbar section.   | Sends overcurrent and earth fault signals.                             |
| HSO1   | BI1 of outgoing feeder AQ-101 (SS:1) devices in the same busbar section.  | Sends overcurrent, earth fault and external overcurrent (BI1) signals. |
| HSO2   | BI2 of outgoing feeder AQ-101 (SS:1) devices in the same busbar section.<br>BI1 of the follower incoming feeder AQ-110P (SS:7a) devices in the same busbar section. | Sends master trip signal.  |

Table. 4.4.1 - 50. Inputs of incoming feeder AQ-110P (SS:2a) device.

| Input               | Connects to   | Action  |
|---------------------|---|---|
| IL1,<br>IL2,<br>IL3 | <ul style="list-style-type: none"> <li>Incoming feeder.</li> </ul>  | <ul style="list-style-type: none"> <li>Sensor channels and external light signal (BI2) can be set up to require overcurrent or earth fault signal as an additional criteria for tripping.</li> <li>Overcurrent and earth fault signals are sent to outgoing feeder AQ-101 (SS:1) devices in the same busbar section with HSO1.</li> <li>Overcurrent and earth fault signals are sent to the follower incoming feeder AQ-110P (SS:7a) devices with BO1.</li> </ul>   |
| I <sub>0</sub>      |   |   |
| BI1                 | <ul style="list-style-type: none"> <li>HSO2 of all of the follower incoming feeder AQ-110P (SS:7a) devices on both busbar sections.</li> <li>Receives overcurrent or earth fault detected by any of the incoming feeder devices.</li> </ul> | <ul style="list-style-type: none"> <li>Sensor channels and external light signal (BI2) can be set up to require overcurrent signal as an additional criteria for tripping.</li> <li>External current signal is sent forward to outgoing feeder AQ-101 (SS:1) devices in the same busbar section with HSO1.</li> </ul>   |
| S1                  | <ul style="list-style-type: none"> <li>Incoming feeder cable compartment.</li> </ul>  | <ul style="list-style-type: none"> <li>Trips incoming feeder circuit breaker with T1 relay.</li> <li>Trips incoming feeder HV side circuit breaker with T2 relay.</li> <li>Trips the tie breaker with T3 relay after CBFP time delay.</li> <li>Sends master trip signal with HSO2 to outgoing feeder AQ-101 (SS:1) devices and follower incoming feeder AQ-110P (SS:7a) devices in the same busbar section after CBFP time delay.</li> <li>This channel must be set to "Light only" mode if current measurement point is located after the sensor.</li> </ul> |

| Input | Connects to   | Action   |
|-------|---|--|
| S2    | <ul style="list-style-type: none"> <li>Incoming feeder circuit breaker compartment.</li> </ul>  | <ul style="list-style-type: none"> <li>Trips incoming feeder circuit breaker with T1 relay.</li> <li>Trips incoming feeder HV side circuit breaker with T2 relay.</li> <li>Trips the tie breaker with T3 relay.</li> <li>Sends master trip signal with HSO2 to outgoing feeder AQ-101 (SS:1) devices and follower incoming feeder AQ-110P (SS:7a) devices in the same busbar section.</li> </ul>                       |
| S3    | <ul style="list-style-type: none"> <li>Busbar compartment.</li> </ul>   | <ul style="list-style-type: none"> <li>Trips incoming feeder circuit breaker with T1 relay.</li> <li>Trips the tie breaker with T3 relay.</li> <li>Sends master trip signal with HSO2 to outgoing feeder AQ-101 (SS:1) devices and follower incoming feeder AQ-110P (SS:7a) devices in the same busbar section.</li> <li>Trips incoming feeder HV side circuit breaker with T2 relay after CBFP time delay.</li> </ul> |
| S4    | <ul style="list-style-type: none"> <li>Tie breaker</li> </ul>   |  |
| S5    | <ul style="list-style-type: none"> <li>Optional</li> </ul>  |  |
| BI2   | <ul style="list-style-type: none"> <li>BO1 of outgoing feeder AQ-101 (SS:1) devices in the same busbar section.</li> <li>BO1 of follower incoming feeder AQ-110P (SS:7a) devices in the same busbar section.</li> <li>Receives light signal.</li> </ul> |  |

Figure. 4.4.1 - 21. Logic matrix of incoming feeder AQ-110P (SS:2a) device.

| SS:2a  |                        | OUTPUTS        |                   |                   |                |     |      |                   |                |
|--------|------------------------|----------------|-------------------|-------------------|----------------|-----|------|-------------------|----------------|
|        |                        | T1             | T2                | T3                | T4             | BO1 | HSO1 | HSO2              | AQD            |
| INPUTS | S1                     | x <sup>1</sup> | x <sup>1</sup>    | CBFP <sup>1</sup> | x <sup>1</sup> |     |      | CBFP <sup>1</sup> |                |
|        | S2                     | x <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup>    | x <sup>1</sup> |     |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | S3,S4,S5               | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |     |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | Lext> (BI2)            | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |     |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | Iext> (BI1)            |                |                   |                   |                |     | x    |                   |                |
|        | I> (phase currents)    |                |                   |                   |                | x   | x    |                   |                |
|        | Io> (residual current) |                |                   |                   |                | x   | x    |                   |                |

1. Activates only if channel has been set to light only mode or if any overcurrent signal (I>, Io> or Iext>) is ON.
2. Activates only if phase overcurrent signal (I>) is ON.

#### 4.4.2 Follower incoming feeders AQ-110P (SS:7a)

Table. 4.4.2 - 51. Outputs of incoming feeder AQ-110P (SS:7a) device.

| Output | Connects to                              | Action                 |
|--------|--|------------------------|
| T1     | Incoming feeder circuit breaker.         | Opens circuit breaker. |
| T2     | Incoming feeder HV side circuit breaker. |                        |
| T3     | N/A                                      | N/A                    |
| T4     | Alarming unit (optional).                | Trip alarm signal.     |

| Output | Connects to  | Action   |
|--------|--|--|
| BO1    | BI2 of the master incoming feeder AQ-110P (SS:2a) device in the same busbar section. | Sends light signals.   |
| HSO1   | N/A  | N/A  |
| HSO2   | BI1 of both master incoming feeder AQ-110P (SS:2a) devices.                          | Sends overcurrent, earth fault and external overcurrent (BI1) signals. |

Table. 4.4.2 - 52. Inputs of incoming feeder AQ-110P (SS:7a) device.

| Input               | Connects to   | Action   |
|---------------------|---|--|
| IL1,<br>IL2,<br>IL3 | <ul style="list-style-type: none"><li>Above incoming feeder circuit breaker.</li></ul>  | <ul style="list-style-type: none"><li>Sensor channels can be set up to require overcurrent or earth fault signal as an additional criteria for tripping.</li><li>Overcurrent and earth fault signals are sent to both master incoming feeder AQ-110P (SS:2a) devices with <b>HSO2</b>.</li></ul>   |
| I <sub>0</sub>      |   |  |
| BI2                 | <ul style="list-style-type: none"><li><b>BO1</b> of the master incoming feeder AQ-110P (SS:2a) device in the same busbar section.</li><li>Receives overcurrent or earth fault detected by master incoming feeder AQ-110P (SS:2a) device in the same busbar section.</li></ul> | <ul style="list-style-type: none"><li>Sensor channels can be set up to require overcurrent signal as an additional criteria for tripping.</li><li>This signal is sent to both master incoming feeder AQ-110P (SS:2a) devices with <b>HSO2</b>.</li></ul>   |
| S1                  | <ul style="list-style-type: none"><li>Incoming feeder cable compartment.</li></ul>  | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with <b>T1</b> relay.</li><li>Trips incoming feeder HV side circuit breaker with <b>T2</b> relay.</li><li>Sends light signal with <b>BO1</b> to master incoming feeder AQ-110P (SS:2a) device in the same busbar section after CBFP time delay.</li><li><b>This channel must be set to "Light only" mode if current measurement point is located after the sensor.</b></li></ul> |
| S2                  | <ul style="list-style-type: none"><li>Incoming feeder circuit breaker compartment.</li></ul>  | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with <b>T1</b> relay.</li><li>Trips incoming feeder HV side circuit breaker with <b>T2</b> relay.</li><li>Sends light signal with <b>BO1</b> to master incoming feeder AQ-110P (SS:2a) device in the same busbar section.</li></ul>  |
| S3                  | <ul style="list-style-type: none"><li>Busbar compartment.</li></ul>   | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with <b>T1</b> relay.</li><li>Sends light signal with <b>BO1</b> to master incoming feeder AQ-110P (SS:2a) device in the same busbar section.</li><li>Trips incoming feeder HV side circuit breaker with <b>T2</b> relay after CBFP time delay.</li></ul>  |
| S4                  | <ul style="list-style-type: none"><li>Optional</li></ul>  |  |
| S5                  |   |  |
| BI1                 | <ul style="list-style-type: none"><li><b>HSO2</b> of master incoming feeder AQ-110P (SS:2a) device in the same busbar section.</li><li>Receives master trip signal.</li></ul>   | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with <b>T1</b> relay.</li><li>Trips incoming feeder HV side circuit breaker with <b>T2</b> relay after CBFP time delay.</li></ul>  |



Figure. 4.4.2 - 22. Logic matrix of incoming feeder AQ-110P (SS:7a) device.

| SS:7a  |                        | OUTPUTS        |                   |                |                   |      |
|--------|------------------------|----------------|-------------------|----------------|-------------------|------|
|        |                        | T1             | T2                | T4             | BO1               | HSO2 |
| INPUTS | S1                     | x <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> | CBFP <sup>1</sup> |      |
|        | S2                     | x <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> | x                 |      |
|        | S3,S4,S5               | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup> | x                 |      |
|        | Master trip (BI1)      | x              | CBFP              | x              |                   |      |
|        | Iext> (BI2)            |                |                   |                |                   | x    |
|        | I> (phase currents)    |                |                   |                |                   | x    |
|        | Io> (residual current) |                |                   |                |                   | x    |

1. Activates only if channel has been set to light only mode or if any overcurrent signal (I>, Io> or Iext>) is ON.

### 4.4.3 Outgoing feeders AQ-101 (SS:1)

Table. 4.4.3 - 53. Outputs of an outgoing feeder AQ-101 (SS:1) device.

| Output | Connects to  | Action                 |
|--------|--|------------------------|
| T1     | Outgoing feeder circuit breaker.   | Opens circuit breaker. |
| T2     | N/A  | N/A                    |
| T3     | N/A  | N/A                    |
| T4     | Alarming unit (optional).  | Trip alarm signal.     |
| BO1    | BI2 of master incoming feeder AQ-110P (SS:2a) device in the same busbar section. | Sends light signal.    |

Table. 4.4.3 - 54. Inputs of an outgoing feeder AQ-101 (SS:1) device.

| Input | Connects to  | Action   |
|-------|--|--|
| BI1   | <ul style="list-style-type: none"> <li>HSO1 of master incoming feeder AQ-110P (SS:2a) device in the same busbar section.</li> <li>Receives overcurrent or earth fault detected by any of the incoming feeders in the same busbar section.</li> </ul> | <ul style="list-style-type: none"> <li>If a sensor channel has been set to "Light and current" mode, this input must be active for the sensor channel to trip.</li> </ul>  |
| BI2   | <ul style="list-style-type: none"> <li>HSO2 of master incoming feeder AQ-110P (SS:2a) device in the same busbar section.</li> <li>Receives master trip signal.</li> </ul>  | <ul style="list-style-type: none"> <li>Trips outgoing feeder with T1 relay.</li> </ul>   |
| S1    | <ul style="list-style-type: none"> <li>Outgoing feeder cable compartment.</li> </ul>   | <ul style="list-style-type: none"> <li>Trips outgoing feeder with T1 relay.</li> <li>Sends light signal to master incoming feeder AQ-110P (SS:2a) device in the same busbar section with BO1 after CBFP time delay.</li> </ul> |

| Input | Connects to  | Action   |
|-------|--|--|
| S2    | <ul style="list-style-type: none"><li>Outgoing feeder circuit breaker compartment.</li></ul> | <ul style="list-style-type: none"><li>Sends light signal to master incoming feeder AQ-110P (SS:2a) device in the same busbar section with BO1.</li></ul> |
| S3    | <ul style="list-style-type: none"><li>Busbar compartment.</li></ul>                          |  |
| S4    | <ul style="list-style-type: none"><li>Optional</li></ul>                                     |  |
| S5    |  |  |

Figure. 4.4.3 - 23. Logic matrix of an outgoing feeder AQ-101 (SS:1) device.

| SS:1   |                   | OUTPUTS        |                   |      |
|--------|-------------------|----------------|-------------------|------|
|        |                   | T1             | T4                | BO1  |
| INPUTS | S1                | x <sup>1</sup> | x <sup>1</sup>    | CBFP |
|        | S2, S3, S4, S5    |                | CBFP <sup>1</sup> | x    |
|        | Master Trip (BI2) | x              | x                 |      |

1. Activates only if channel has been set to light only mode or overcurrent signal (BI1) is ON.

## 4.4.4 Connections

Figure. 4.4.4 - 24. Overcurrent signal connection between the two sides of the tie breaker.

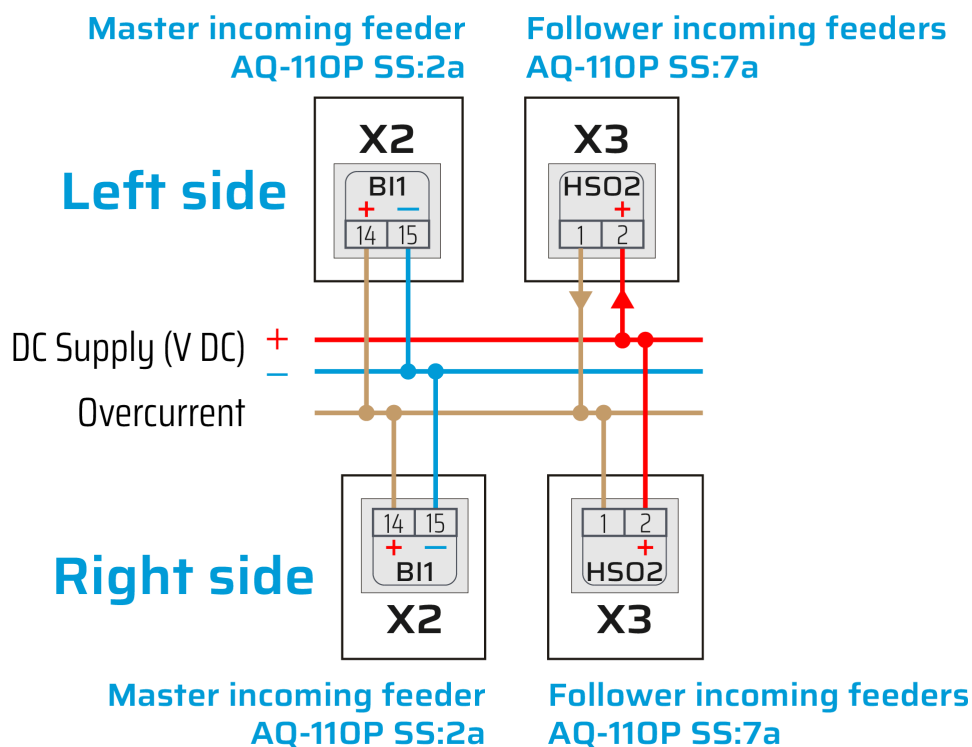


Figure. 4.4.4 - 25. I/O connection on the left side of the tie breaker.

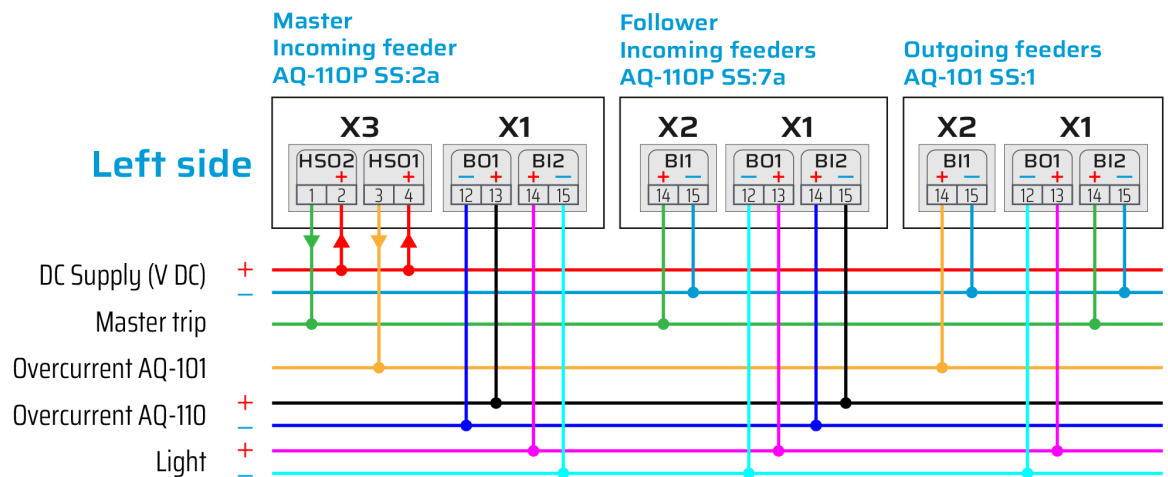
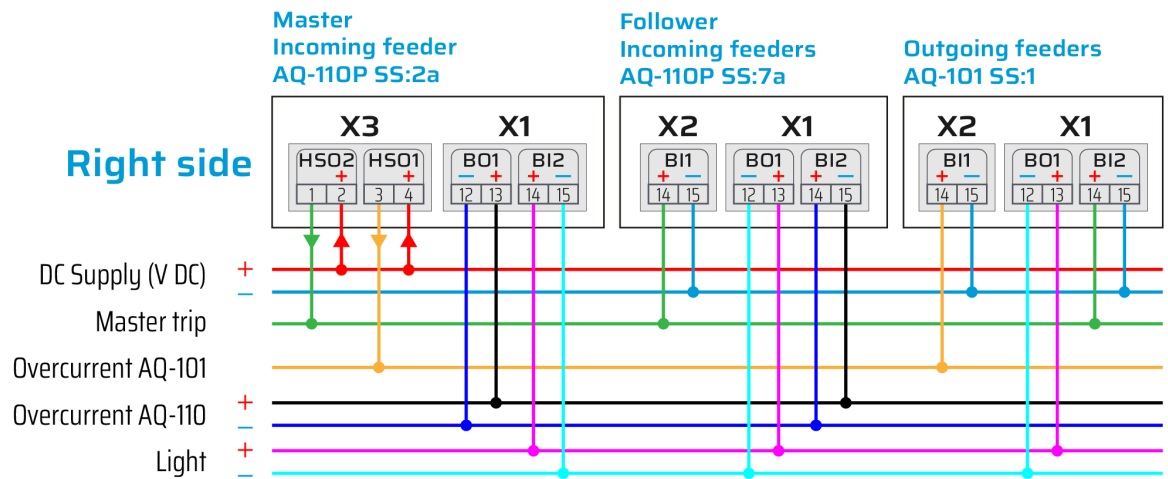
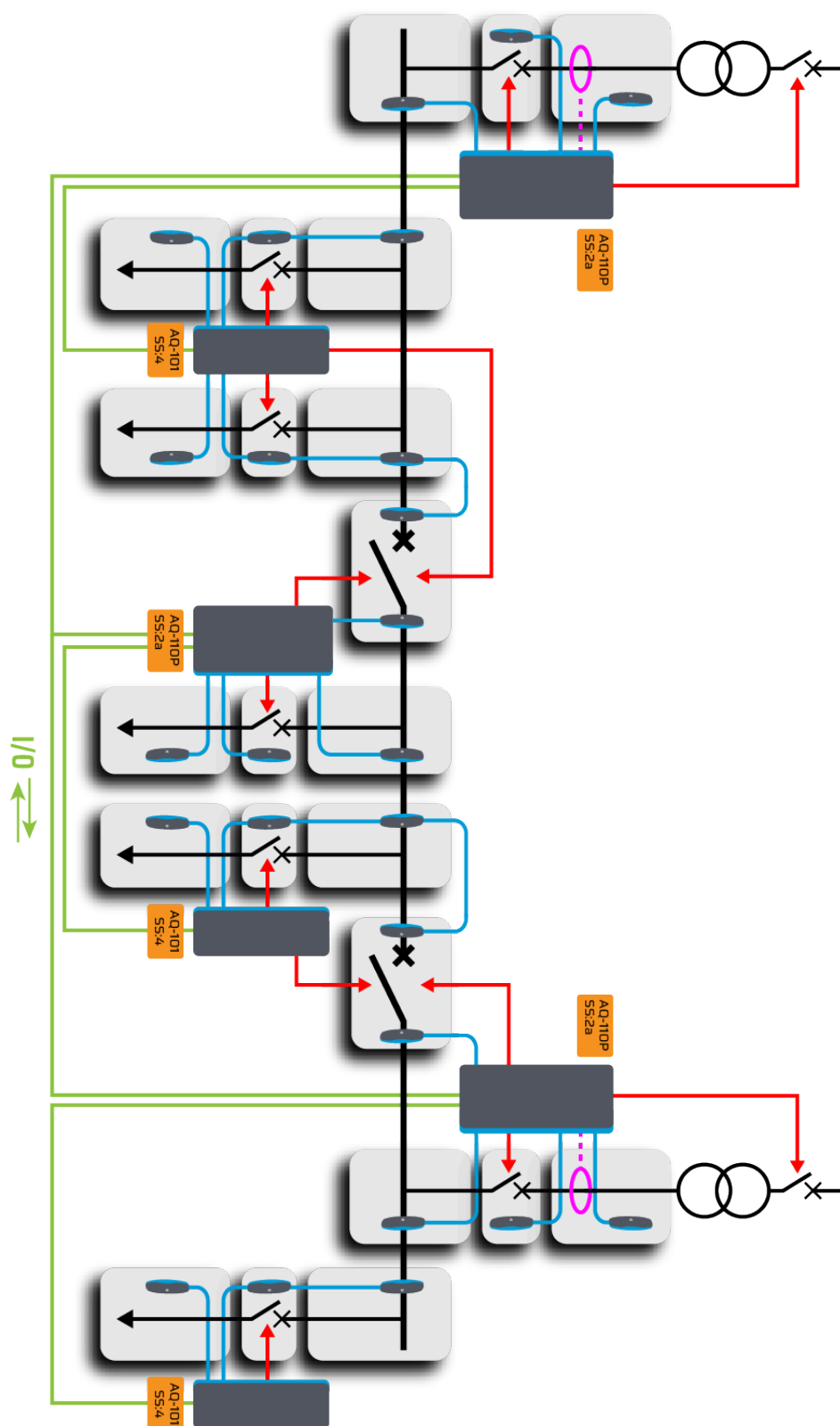


Figure. 4.4.4 - 26. I/O connection on the left side of the tie breaker.



## 5 Other schemes

### 5.1 Multiple sections - single incoming feeder per section



This is a fully selective scheme for protecting substations with max. six (6) busbar sections and up to 30 outgoing feeders per section. If the busbar section has an incoming feeder, AQ-110P (SS:2a) device will be installed to the incoming feeder. If there are no incoming feeders in a busbar section, AQ-110P (SS:2a) device will be installed to one of the outgoing feeders in the section.

Table. 5.1 - 55. Simplified operation logic description.

| Fault location  | Circuit breaker to trip   | CBFP trip  |
|---|---|--|
| <ul style="list-style-type: none"> <li>Outgoing feeder cable compartment</li> </ul>                                       | <ul style="list-style-type: none"> <li>The outgoing feeder with the fault</li> </ul>  | <ul style="list-style-type: none"> <li>Incoming feeder in the same busbar section (if applicable)</li> <li>Outgoing feeders in the same busbar section</li> <li>Tie breakers in the same busbar section</li> </ul> |
| <ul style="list-style-type: none"> <li>Outgoing feeder circuit breaker compartment</li> <li>Busbar compartment</li> </ul> | <ul style="list-style-type: none"> <li>Incoming feeder in the same busbar section (if applicable)</li> <li>Outgoing feeders in the same busbar section</li> <li>Tie breakers in the same busbar section</li> </ul>  | <ul style="list-style-type: none"> <li>HV side of the incoming feeder (if applicable)</li> </ul>   |
| <ul style="list-style-type: none"> <li>Tie breaker compartment</li> </ul>   | <ul style="list-style-type: none"> <li>Incoming feeders on both sides of the tie breaker</li> <li>Tie breaker with the fault</li> <li>Tie breakers at the end of both busbar sections (if applicable)</li> <li>Outgoing feeders on both sides of the tie breaker</li> </ul> | <ul style="list-style-type: none"> <li>HV side of incoming feeders on both sides of the tie breaker (if applicable)</li> </ul>   |
| <ul style="list-style-type: none"> <li>Incoming feeder circuit breaker compartment</li> </ul>                             | <ul style="list-style-type: none"> <li>Incoming feeder with the fault</li> <li>HV side of the incoming feeder</li> <li>Tie breakers in the same busbar section</li> <li>Outgoing feeders in the same busbar section</li> </ul>  | <ul style="list-style-type: none"> <li>N/A</li> </ul>  |
| <ul style="list-style-type: none"> <li>Incoming feeder cable compartment</li> </ul>                                       | <ul style="list-style-type: none"> <li>The incoming feeder with the fault</li> <li>HV side of the incoming feeder</li> </ul>  | <ul style="list-style-type: none"> <li>Outgoing feeders in the same busbar section</li> <li>Tie breakers in the same busbar section</li> </ul>   |

### 5.1.1 Section master device AQ-110P (SS:2a)

If the busbar section has an incoming feeder, AQ-110P (SS:2a) device will be installed to the incoming feeder. If there are no incoming feeders in the busbar section, AQ-110P (SS:2a) device will be installed to one of the outgoing feeders in the section.

Table. 5.1.1 - 56. Outputs of busbar section master device AQ-110P (SS:2a) device.

| Output | Connects to                              | Action                 |
|--------|--|------------------------|
| T1     | Feeder circuit breaker.                  | Opens circuit breaker. |
| T2     | HV side circuit breaker (if applicable). |                        |

| Output | Connects to  | Action   |
|--------|--|--|
| T3     | Tie breaker (if applicable).   |  |
| T4     | Alarming unit (optional).  | Trip alarm signal.   |
| BO1    | BI1 of all AQ-110P (SS:2a) devices.                                      | Sends overcurrent and earth fault signals.                             |
| HSO1   | BI1 of outgoing feeder AQ-101 (SS:4) devices in the same busbar section. | Sends overcurrent, earth fault and external overcurrent (BI1) signals. |
| HSO2   | BI2 of outgoing feeder AQ-101 (SS:4) devices in the same busbar section. | Sends master trip signal.  |

Table. 5.1.1 - 57. Inputs of section master device AQ-110P (SS:2a) device.

| Input               | Connects to   | Action  |
|---------------------|---|---|
| IL1,<br>IL2,<br>IL3 | <ul style="list-style-type: none"> <li>Incoming feeder (if applicable).</li> </ul>  | <ul style="list-style-type: none"> <li>Sensor channels and external light signal (BI2) can be set up to require overcurrent or earth fault signal as an additional criteria for tripping.</li> <li>Overcurrent and earth fault signals are sent to AQ-101 (SS:4) devices with <b>HSO1</b>.</li> <li>Overcurrent and earth fault signals are sent to other AQ-110P (SS:2a) devices with <b>BO1</b>.</li> </ul>   |
| I <sub>0</sub>      |   |   |
| BI1                 | <ul style="list-style-type: none"> <li><b>BO1</b> of all AQ-110P (SS:2a) devices.</li> <li>External overcurrent or earth fault signal.</li> </ul>                 | <ul style="list-style-type: none"> <li>Sensor channels and external light signal (BI2) can be set up to require overcurrent signal as an additional criteria for tripping.</li> <li>External current signal is sent forward to AQ-101 (SS:4) devices in the same busbar section with <b>HSO1</b>.</li> </ul>  |
| S1                  | <ul style="list-style-type: none"> <li>Cable compartment.</li> </ul>  | <ul style="list-style-type: none"> <li>Trips feeder circuit breaker with <b>T1</b> relay.</li> <li>Trips incoming feeder HV side circuit breaker with <b>T2</b> relay (if applicable).</li> <li>Trips the tie breaker with <b>T3</b> relay after CBFP time delay.</li> <li>Sends master trip signal with <b>HSO2</b> to outgoing feeder AQ-101 (SS:4) devices after CBFP time delay.</li> <li><b>This channel must be set to "Light only" mode if current measurement point is located after the sensor.</b></li> </ul> |
| S2                  | <ul style="list-style-type: none"> <li>Circuit breaker compartment.</li> </ul>  | <ul style="list-style-type: none"> <li>Trips feeder circuit breaker with <b>T1</b> relay.</li> <li>Trips incoming feeder HV side circuit breaker with <b>T2</b> relay (if applicable).</li> <li>Trips the tie breaker with <b>T3</b> relay.</li> <li>Sends master trip signal with <b>HSO2</b> to outgoing feeder AQ-101 (SS:4) devices.</li> </ul>   |
| S3                  | <ul style="list-style-type: none"> <li>Busbar compartment.</li> </ul>   | <ul style="list-style-type: none"> <li>Trips feeder circuit breaker with <b>T1</b> relay.</li> <li>Trips the tie breaker with <b>T3</b> relay.</li> <li>Sends master trip signal with <b>HSO2</b> to outgoing feeder AQ-101 (SS:4) devices.</li> <li>Trips incoming feeder HV side circuit breaker with <b>T2</b> relay after CBFP time delay (if applicable).</li> </ul>   |
| S4                  | <ul style="list-style-type: none"> <li>Tie breaker compartment.</li> </ul>  |   |
| S5                  | <ul style="list-style-type: none"> <li>Optional.</li> </ul>   |   |
| BI2                 | <ul style="list-style-type: none"> <li><b>BO1</b> of outgoing feeder AQ-101 (SS:4) devices in the same busbar section.</li> <li>Receives light signal.</li> </ul> |   |

Figure. 5.1.1 - 27. Logic matrix of busbar section master device AQ-110P (SS:2a) device.

| SS:2a  |                        | OUTPUTS        |                   |                   |                |     |      |                   |                |
|--------|------------------------|----------------|-------------------|-------------------|----------------|-----|------|-------------------|----------------|
|        |                        | T1             | T2                | T3                | T4             | BO1 | HSO1 | HSO2              | AQD            |
| INPUTS | S1                     | x <sup>1</sup> | x <sup>1</sup>    | CBFP <sup>1</sup> | x <sup>1</sup> |     |      | CBFP <sup>1</sup> |                |
|        | S2                     | x <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup>    | x <sup>1</sup> |     |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | S3,S4,S5               | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |     |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | Iext> (BI2)            | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |     |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | Iext> (BI1)            |                |                   |                   |                |     | x    |                   |                |
|        | I> (phase currents)    |                |                   |                   |                | x   | x    |                   |                |
|        | Io> (residual current) |                |                   |                   |                | x   | x    |                   |                |

1. Activates only if channel has been set to light only mode or if any overcurrent signal (I>, Io> or Iext>) is ON.
2. Activates only if phase overcurrent signal (I>) is ON.

## 5.1.2 Outgoing feeders AQ-101 (SS:4)

Table. 5.1.2 - 58. Outputs of an outgoing feeder AQ-101 (SS:4) device.

| Output | Connects to  | Action                 |
|--------|--|------------------------|
| T1     | "Left side" outgoing feeder circuit breaker.                             | Opens circuit breaker. |
| T2     | "Right side" outgoing feeder circuit breaker.                            |                        |
| T3     | Tie breaker.   |                        |
| T4     | Alarming unit (optional).  | Trip alarm signal.     |
| BO1    | BI2 of busbar section master AQ-110P (SS:2a) device on the same section. | Sends light signal.    |

Table. 5.1.2 - 59. Inputs of an outgoing feeder AQ-101 (SS:4) device.

| Input | Connects to   | Action   |
|-------|---|--|
| BI1   | <ul style="list-style-type: none"> <li>• HSO1 of busbar section master device AQ-110P (SS:2a) in the same busbar section.</li> <li>• Receives overcurrent or earth fault signal.</li> </ul> | <ul style="list-style-type: none"> <li>• If a sensor channel has been set to "Light and current" mode, this input must be active for the sensor channel to trip.</li> </ul>  |
| BI2   | <ul style="list-style-type: none"> <li>• HSO2 of busbar section master device AQ-110P (SS:2a) device in the same busbar section.</li> <li>• Receives master trip signal.</li> </ul>         | <ul style="list-style-type: none"> <li>• Trips both outgoing feeder circuit breakers with T1 and T2.</li> <li>• Trips the tie breaker with T3 relay.</li> </ul>  |
| S1    | <ul style="list-style-type: none"> <li>• "Left side" outgoing feeder cable compartment.</li> </ul>  | <ul style="list-style-type: none"> <li>• Trips "left side" outgoing feeder with T1 relay.</li> <li>• Trips the tie breaker with T3 relay after CBFP time delay.</li> <li>• Sends light signal to busbar section master AQ-110P (SS:2a) device with BO1 after CBFP time delay.</li> </ul> |

| Input | Connects to   | Action  |
|-------|---|---|
| S2    | <ul style="list-style-type: none"> <li>"Right side" outgoing feeder cable compartment.</li> </ul>   | <ul style="list-style-type: none"> <li>Trips "right side" outgoing feeder with T2 relay.</li> <li>Trips the tie breaker with T3 relay after CBFP time delay.</li> <li>Sends light signal to busbar section master AQ-110P (SS:2a) device with BO1 after CBFP time delay.</li> </ul> |
| S3    | <ul style="list-style-type: none"> <li>"Left side" outgoing feeder circuit breaker compartment.</li> <li>Busbar compartment.</li> <li>(Tie breaker)</li> </ul>  | <ul style="list-style-type: none"> <li>Trips the tie breaker with T3 relay.</li> <li>Sends light signal to busbar section master AQ-110P (SS:2a) device with BO1.</li> </ul>  |
| S4    | <ul style="list-style-type: none"> <li>"Right side" outgoing feeder circuit breaker compartment.</li> <li>Busbar compartment.</li> <li>(Tie breaker)</li> </ul> |   |
| S5    | <ul style="list-style-type: none"> <li>Optional.</li> </ul>   |   |

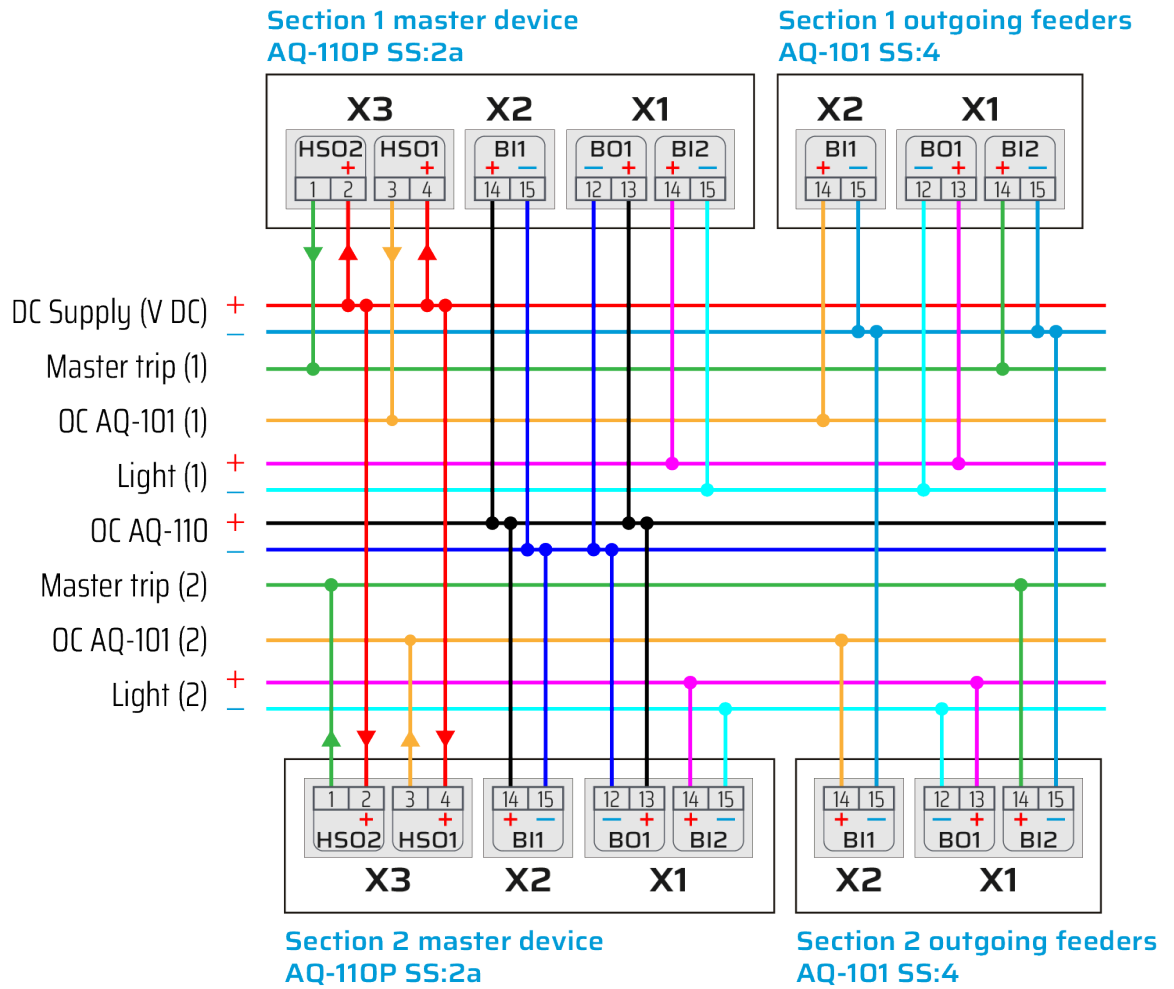
Figure. 5.1.2 - 28. Logic matrix of an outgoing feeder AQ-101 (SS:4) device.

| SS:4   |                   | OUTPUTS        |                |                   |                |      |
|--------|-------------------|----------------|----------------|-------------------|----------------|------|
|        |                   | T1             | T2             | T3                | T4             | BO1  |
| INPUTS | S1                | x <sup>1</sup> |                | CBFP <sup>1</sup> | x <sup>1</sup> | CBFP |
|        | S2                |                | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup> | CBFP |
|        | S3, S4, S5        |                |                | x <sup>1</sup>    | x <sup>1</sup> | x    |
|        | Master Trip (BI2) | x              | x              | x                 | x              |      |

1. Activates only if channel has been set to light only mode or overcurrent signal (BI1) is ON.



## 5.1.3 Connections



## 6 Modifications to suggested designs

### 6.1 Two incoming feeders with a dedicated tie breaker protection device

It is possible to install a dedicated arc protection device AQ-101S to the tie breaker to improve fault location indication and improve protection selectivity for faults close to the tie breaker. In this example design AQ-101 (SS:1) devices have been used for outgoing feeders but other options can be used as well.

Figure. 6.1 - 29. Point sensor positions in tie breaker with optional AQ-101S device.

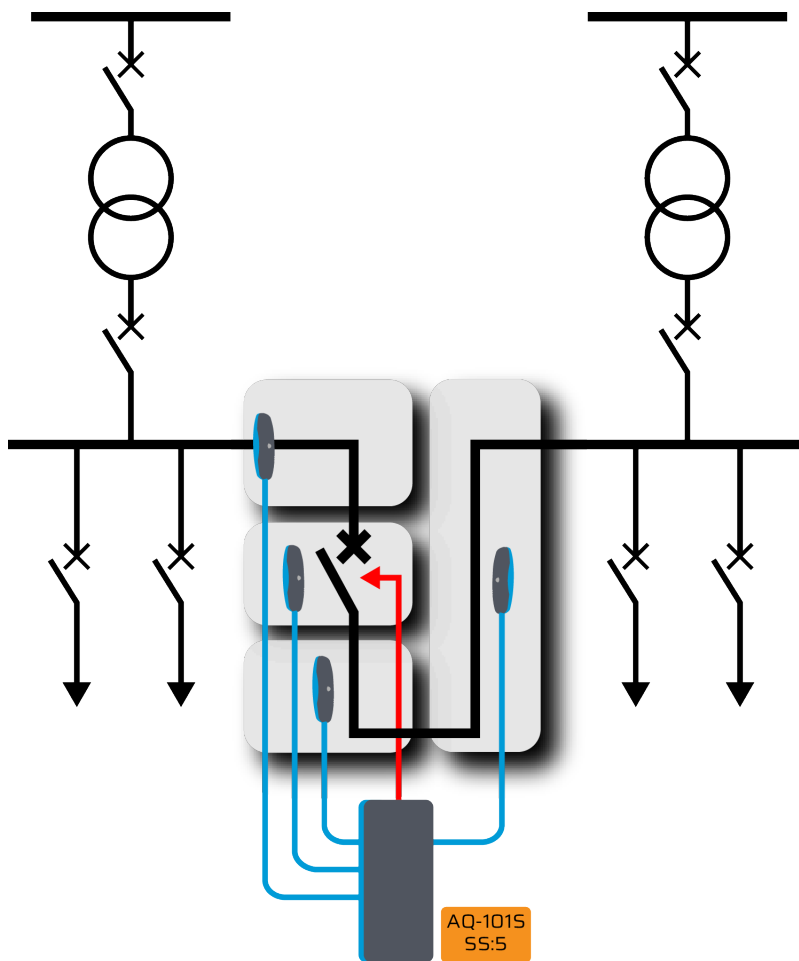


Table. 6.1 - 60. Optional device dedicated for tie breaker compartment monitoring.

| Device type<br>(scheme number) | Description   |
|--------------------------------|---|
| AQ-101S (SS:5)                 | <ul style="list-style-type: none"> <li>Optional device dedicated for tie breaker compartment monitoring.</li> <li>Location of fault in the tie breaker compartment can be detected with more accuracy.</li> <li>Indicates with LEDs if the fault was in the tie breaker compartment or on either side of the tie breaker in the busbar compartment.</li> <li>Trips the tie breaker when fault is detected.</li> <li>Sends light information to incoming feeder AQ-110P devices on either or both sides of the tie breaker depending on the fault location.</li> </ul> |

| Device type<br>(scheme number) | Description  |
|--------------------------------|--|
|                                | <b>Advantages:</b> <ul style="list-style-type: none"> <li>Increases the accuracy of fault location indication.</li> <li>Increases fault clearing selectivity around the tie breaker.</li> </ul>          |
|                                | <b>Disadvantages:</b> <ul style="list-style-type: none"> <li>Decreases the maximum number of devices that can be installed into the substation.</li> <li>One more device to install and wire.</li> </ul> |

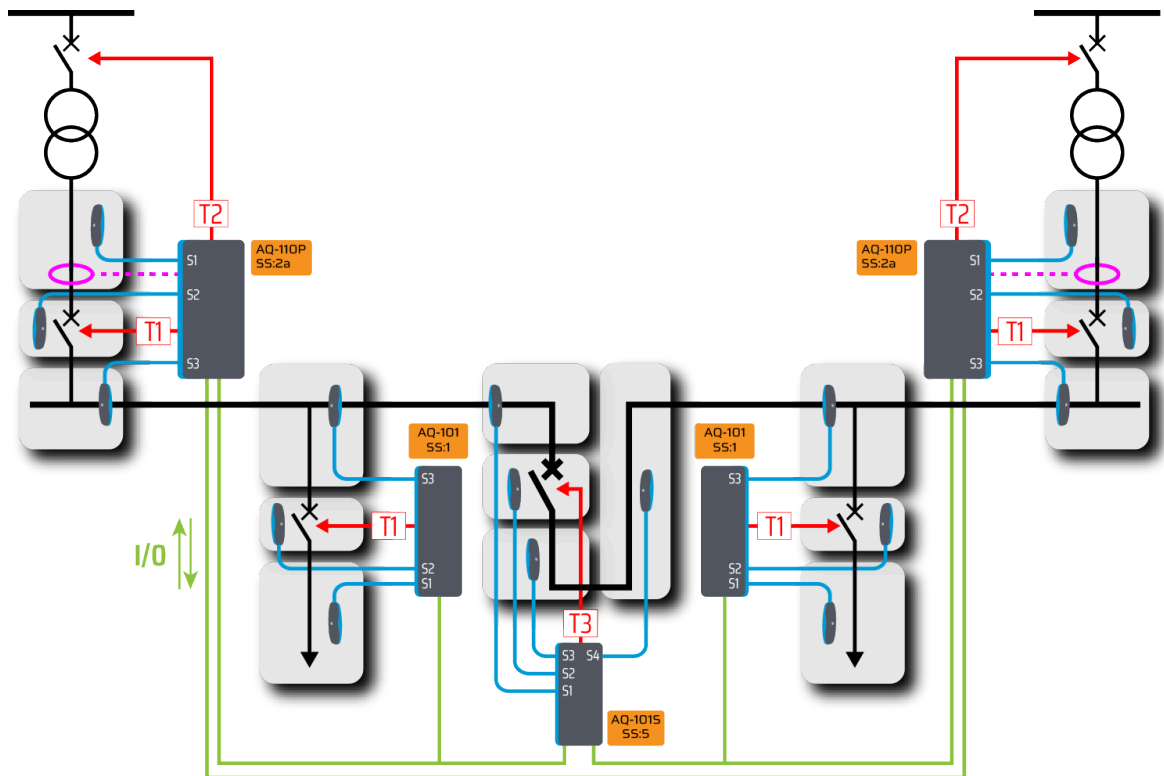


Table. 6.1 - 61. Simplified operation logic description.

| Fault location  | Circuit breaker to trip  | CBFP trip  |
|---|--|--|
| <ul style="list-style-type: none"> <li>Outgoing feeder cable compartment</li> </ul>                                       | <ul style="list-style-type: none"> <li>The outgoing feeder with the fault</li> </ul>   | <ul style="list-style-type: none"> <li>Incoming feeder in the same busbar section</li> <li>Outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul> |
| <ul style="list-style-type: none"> <li>Outgoing feeder circuit breaker compartment</li> <li>Busbar compartment</li> </ul> | <ul style="list-style-type: none"> <li>Incoming feeder in the same busbar section</li> <li>Outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul> | <ul style="list-style-type: none"> <li>HV side of incoming feeder</li> </ul>   |
| <ul style="list-style-type: none"> <li>Tie breaker compartment</li> </ul>   | <ul style="list-style-type: none"> <li>Both incoming feeders</li> <li>Tie breaker</li> <li>All outgoing feeders</li> </ul>   | <ul style="list-style-type: none"> <li>HV side of both incoming feeders</li> </ul>   |

| Fault location  | Circuit breaker to trip  | CBFP trip   |
|---|--|---|
| <ul style="list-style-type: none"> <li>Incoming feeder circuit breaker compartment</li> </ul> | <ul style="list-style-type: none"> <li>The incoming feeder with the fault</li> <li>HV side of the incoming feeder</li> <li>Outgoing feeders in the same busbar section</li> <li>Tie breaker</li> </ul> | <ul style="list-style-type: none"> <li>N/A</li> </ul>                                       |
| <ul style="list-style-type: none"> <li>Incoming feeder cable compartment</li> </ul>           | <ul style="list-style-type: none"> <li>The incoming feeder with the fault</li> <li>HV side of the incoming feeder with the fault</li> </ul>  | <ul style="list-style-type: none"> <li>All outgoing feeders</li> <li>Tie breaker</li> </ul> |

Table. 6.1 - 62. Scheme characteristics

|                            |                                   |
|----------------------------|-----------------------------------|
| Number of incoming feeders | 2                                 |
| Number of outgoing feeders | 1...18 (per busbar section)       |
| Devices used               | Incoming feeders: AQ-110P (SS:2a) |
|                            | Outgoing feeders: AQ-101 (SS:1)   |
|                            | Tie breaker: AQ-101S (SS5)        |



**NOTICE!**

If the application has a big number of outgoing feeders, AQ-101 (SS:1) can be changed to AQ-101 (SS:4) or AQ-103 (SS:4) to increase the maximum number of outgoing feeders that can be installed.

## 6.1.1 Incoming feeders AQ-110P (SS:2a)

Table. 6.1.1 - 63. Outputs of incoming feeder AQ-110P (SS:2a) device.

| Output | Connects to   | Action                                     |
|--------|---|--|
| T1     | Incoming feeder circuit breaker.  | Opens circuit breaker.                     |
| T2     | Incoming feeder HV side circuit breaker.                                  |  |
| T3     | N/A   | N/A  |
| T4     | Alarming unit (optional).   | Trip alarm signal.                         |
| BO1    | BI1 of the other incoming feeder AQ-110P (SS:2a) device.                  | Sends overcurrent and earth fault signals. |
| HSO1   | BI1 of outgoing feeder AQ-101 (SS:1) devices in the same busbar section.  | Sends overcurrent signal.                  |
|        | Left side incoming feeder: BI3 of tie breaker AQ-101S (SS:5) device.      |  |
|        | Right side incoming feeder: BI4 of the tie breaker AQ-101S (SS:5) device. |  |

| Output | Connects to   | Action                    |
|--------|---|---------------------------|
| HSO2   | BI2 of outgoing feeder AQ-101 (SS:1) devices in the same busbar section.  | Sends master trip signal. |
|        | Left side incoming feeder: BI1 of the tie breaker AQ-101S (SS:5) device.  |                           |
|        | Right side incoming feeder: BI2 of the tie breaker AQ-101S (SS:5) device. |                           |

Table. 6.1.1 - 64. Inputs of incoming feeder AQ-110P (SS:2a) device.

| Input               | Connects to   | Action  |
|---------------------|---|---|
| IL1,<br>IL2,<br>IL3 | <ul style="list-style-type: none"><li>Incoming feeder.</li></ul>  | <ul style="list-style-type: none"><li>Sensor channels and external light signal (BI2) can be set up to require overcurrent or earth fault signal as an additional criteria for tripping.</li><li>Overcurrent and earth fault signals are sent to the other incoming feeder AQ-110P (SS:2a) device with <b>BO1</b>.</li><li>Overcurrent and earth fault signals are sent to AQ-101 (SS:1) in the same busbar section and AQ-101S (SS:5) devices with <b>HSO1</b>.</li></ul>                            |
| I <sub>0</sub>      |   |   |
| BI1                 | <ul style="list-style-type: none"><li><b>BO1</b> of the other incoming feeder AQ-110P (SS:2a) device.</li><li>External overcurrent or earth fault signal.</li></ul>   | <ul style="list-style-type: none"><li>Sensor channels and external light signal (BI2) can be set up to require overcurrent signal as an additional criteria for tripping.</li><li>External current signal is sent forward to AQ-101 (SS:1) in the same busbar section and AQ-101S (SS:5) devices with <b>HSO1</b>.</li></ul>  |
| S1                  | <ul style="list-style-type: none"><li>Incoming feeder cable compartment.</li></ul>  | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with <b>T1</b> relay.</li><li>Trips incoming feeder HV side circuit breaker with <b>T2</b> relay.</li><li>Sends master trip signal with <b>HSO2</b> to outgoing feeder AQ-101 (SS:1) devices and the tie breaker AQ-101S (SS:5) device in the same busbar section after CBFP time delay.</li><li><b>This channel must be set to "Light only" mode if current measurement point is located after the sensor.</b></li></ul> |
| S2                  | <ul style="list-style-type: none"><li>Incoming feeder circuit breaker compartment.</li></ul>  | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with <b>T1</b> relay.</li><li>Trips incoming feeder HV side circuit breaker with <b>T2</b> relay.</li><li>Sends master trip signal with <b>HSO2</b> to outgoing feeder AQ-101 (SS:1) devices and the tie breaker AQ-101S (SS:5) device in the same busbar section.</li></ul>  |
| S3                  | <ul style="list-style-type: none"><li>Busbar compartment.</li></ul>   | <ul style="list-style-type: none"><li>Trips incoming feeder circuit breaker with <b>T1</b> relay.</li><li>Sends master trip signal with <b>HSO2</b> to outgoing feeder AQ-101 (SS:1) devices in the same busbar section and the tie breaker AQ-101S (SS:5) device.</li><li>Trips incoming feeder HV side circuit breaker with <b>T2</b> relay after CBFP time delay.</li></ul>  |
| S4                  | <ul style="list-style-type: none"><li>Optional.</li></ul>   |   |
| S5                  |   |   |
|                     |   |   |
| BI2                 | <ul style="list-style-type: none"><li><b>BO1</b> of outgoing feeder AQ-101 (SS:1) devices in the same busbar section.</li><li>Left side incoming feeder: <b>BO1</b> of tie breaker AQ-101S (SS:5) device.</li><li>Right side incoming feeder: <b>BO3</b> of tie breaker AQ-101S (SS:5) device.</li><li>Receives light signal.</li></ul> |   |

Figure. 6.1.1 - 30. Logic matrix of incoming feeder AQ-110P (SS:2a) device.

| SS:2a  |                        | OUTPUTS        |                   |                   |                |     |      |                   |                |
|--------|------------------------|----------------|-------------------|-------------------|----------------|-----|------|-------------------|----------------|
|        |                        | T1             | T2                | T3                | T4             | BO1 | HSO1 | HSO2              | AQD            |
| INPUTS | S1                     | x <sup>1</sup> | x <sup>1</sup>    | CBFP <sup>1</sup> | x <sup>1</sup> |     |      | CBFP <sup>1</sup> |                |
|        | S2                     | x <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup>    | x <sup>1</sup> |     |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | S3,S4,S5               | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |     |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | Lext> (BI2)            | x <sup>1</sup> | CBFP <sup>1</sup> | x <sup>1</sup>    | x <sup>1</sup> |     |      | x <sup>1</sup>    | x <sup>2</sup> |
|        | Iext> (BI1)            |                |                   |                   |                |     | x    |                   |                |
|        | I> (phase currents)    |                |                   |                   |                | x   | x    |                   |                |
|        | Io> (residual current) |                |                   |                   |                | x   | x    |                   |                |

1. Activates only if DIP-switch has been set to light only mode or if any overcurrent signal (I>, Io> or Iext>) is ON.
2. Activates only if phase overcurrent signal (I>) is ON.

## 6.1.2 Outgoing feeders AQ-101 (SS:1)

Table. 6.1.2 - 65. Outputs of an outgoing feeder AQ-101 (SS:1) device.

| Output | Connects to   | Action                 |
|--------|---|------------------------|
| T1     | Outgoing feeder circuit breaker.  | Opens circuit breaker. |
| T2     | N/A   | N/A                    |
| T3     | N/A   | N/A                    |
| T4     | Alarming unit (optional).   | Trip alarm signal.     |
| BO1    | BI2 of incoming feeder AQ-110P (SS:2a) device in the same busbar section. | Sends light signal.    |

Table. 6.1.2 - 66. Inputs of an outgoing feeder AQ-101 (SS:1) device.

| Input | Connects to   | Action  |
|-------|---|---|
| BI1   | <ul style="list-style-type: none"> <li>• HSO1 of incoming feeder AQ-110P (SS:2a) device in the same busbar section.</li> <li>• Receives overcurrent or earth fault signal.</li> </ul> | <ul style="list-style-type: none"> <li>• If a sensor channel has been set to "Light and current" mode, this input must be active for the sensor channel to trip.</li> </ul>   |
| BI2   | <ul style="list-style-type: none"> <li>• HSO2 of incoming feeder AQ-110P (SS:2a) device in the same busbar section.</li> <li>• Receives master trip signal.</li> </ul>                | <ul style="list-style-type: none"> <li>• Trips outgoing feeder with T1 relay.</li> </ul>  |
| S1    | <ul style="list-style-type: none"> <li>• Outgoing feeder cable compartment.</li> </ul>  | <ul style="list-style-type: none"> <li>• Trips outgoing feeder with T1 relay.</li> <li>• Sends light signal to incoming feeder AQ-110P (SS:2a) device in the same busbar section with BO1 after CBFP time delay.</li> </ul> |

| Input | Connects to  | Action   |
|-------|--|--|
| S2    | <ul style="list-style-type: none"><li>Outgoing feeder circuit breaker compartment.</li></ul> | <ul style="list-style-type: none"><li>Sends light signal to incoming feeder AQ-110P (SS:2a) device in the same busbar section with <b>BO1</b>.</li></ul> |
| S3    | <ul style="list-style-type: none"><li>Busbar compartment.</li></ul>                          |  |
| S4    | <ul style="list-style-type: none"><li>Optional</li></ul>                                     |  |
| S5    |  |  |

Figure. 6.1.2 - 31. Logic matrix of an outgoing feeder AQ-101 (SS:1) device.

| SS:1   |                   | OUTPUTS        |                   |      |
|--------|-------------------|----------------|-------------------|------|
| INPUTS |                   | T1             | T4                | BO1  |
|        | S1                | x <sup>1</sup> | x <sup>1</sup>    | CBFP |
|        | S2, S3, S4, S5    |                | CBFP <sup>1</sup> | x    |
|        | Master Trip (BI2) | x              | x                 |      |

1. Activates only if channel has been set to light only mode or overcurrent signal (BI1) is ON.

### 6.1.3 Tie breaker AQ-101S (SS:5)

Table. 6.1.3 - 67. Outputs of tie breaker AQ-101S (SS:5) device.

| Output | Connects to  | Action                |
|--------|--|-----------------------|
| T1     | N/A  | N/A                   |
| T2     | N/A  | N/A                   |
| T3     | Tie breaker.   | Open circuit breaker. |
| BO1    | BI2 of "left side" incoming feeder AQ-110P (SS:2a).  | Sends light signal.   |
| BO2    | N/A  | N/A                   |
| BO3    | BI2 of "right side" incoming feeder AQ-110P (SS:2a). | Sends light signal.   |

Table. 6.1.3 - 68. Inputs of tie breaker AQ-101S (SS:5) device.

| Input | Connects to   | Action   |
|-------|---|--|
| BI1   | <ul style="list-style-type: none"> <li>HSO2 of "left side" incoming feeder AQ-110P (SS:2a).</li> </ul>  | <ul style="list-style-type: none"> <li>External light signal.</li> <li>Trips the tie breaker with T3 relay.</li> <li>Requires either of the external overcurrent signals (BI3 or BI4) to be active.</li> </ul> |
| BI2   | <ul style="list-style-type: none"> <li>HSO2 of "right side" incoming feeder AQ-110P (SS:2a).</li> </ul> |  |
| BI3   | <ul style="list-style-type: none"> <li>HSO1 of "left side" incoming feeder AQ-110P (SS:2a).</li> </ul>  | <ul style="list-style-type: none"> <li>Receives overcurrent signals.</li> <li>Sensor channels can be set up to require overcurrent signal as an additional criteria for tripping.</li> </ul>                   |

| Input | Connects to   | Action  |
|-------|---|---|
| BI4   | <ul style="list-style-type: none"> <li>HSO1 of "right side" incoming feeder AQ-110P (SS:2a).</li> </ul> |   |
| BI5   | <ul style="list-style-type: none"> <li>N/A</li> </ul>   | <ul style="list-style-type: none"> <li>N/A</li> </ul>   |
| BI6   |   |   |
| S1    | <ul style="list-style-type: none"> <li>"Left side" Busbar compartment.</li> </ul>                       | <ul style="list-style-type: none"> <li>Trips tie breaker with T3 relay.</li> <li>Sends light signal to "left side" incoming feeder AQ-110P (SS:2a) with BO1.</li> </ul>   |
| S2    | <ul style="list-style-type: none"> <li>Monitoring tie breaker.</li> </ul>                               | <ul style="list-style-type: none"> <li>Trips tie breaker with T3 relay.</li> <li>Sends light signal to "left side" incoming feeder AQ-110P (SS:2a) with BO1.</li> <li>Sends light signal to "right side" incoming feeder AQ-110P (SS:2a) with BO3.</li> </ul> |
| S3    | <ul style="list-style-type: none"> <li>"Right side" Busbar compartment.</li> </ul>                      | <ul style="list-style-type: none"> <li>Trips tie breaker with T3 relay.</li> <li>Sends light signal to "right side" incoming feeder AQ-110P (SS:2a) with BO3.</li> </ul>  |
| S4    |   |   |
| S5    | <ul style="list-style-type: none"> <li>Optional</li> </ul>  |   |

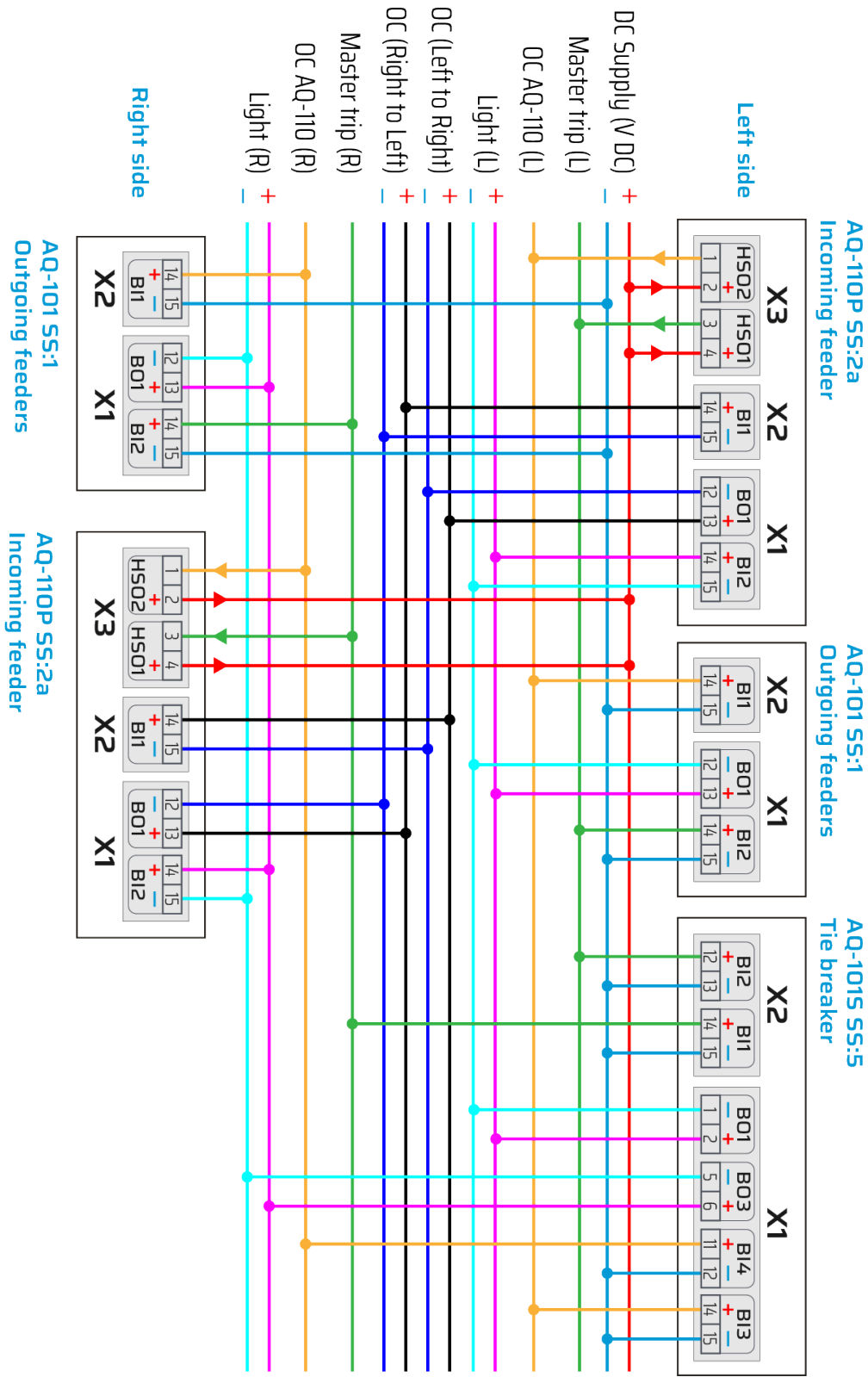
Figure. 6.1.3 - 32. Logic matrix of tie breaker AQ-101S (SS:5) device.

| SS:5   |                  | T3             | BO1 | BO3 |
|--------|------------------|----------------|-----|-----|
| INPUTS | S1               | x <sup>1</sup> | x   |     |
|        | S2               | x <sup>1</sup> | x   | x   |
|        | S3, S4           | x <sup>1</sup> |     | x   |
|        | BI1 MT Incomer 1 | x <sup>2</sup> |     |     |
|        | BI2 MT Incomer 2 | x <sup>2</sup> |     |     |
|        | BI3 I> Incomer 1 |                |     |     |
|        | BI4 I> Incomer 2 |                |     |     |

1. Activates only if channel has been set to light only mode or overcurrent signal (BI3 or BI4) is ON
2. Activates only if overcurrent signal (BI3 or BI4) is ON



6.1.4 Connections



## 7 Contact and reference information

### Manufacturer

Arcteq Relays Ltd.

### Visiting and postal address

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65300 Vaasa, Finland

### Contacts

|                    |   |
|--------------------|---|
| Phone:             | +358 10 3221 370  |
| Website:           | <a href="http://arcteq.com">arcteq.com</a>  |
| Technical support: | <a href="http://arcteq.com/support-login">arcteq.com/support-login</a><br>+358 10 3221 388 (EET 9:00 – 17.00) |
| E-mail (sales):    | <a href="mailto:sales@arcteq.fi">sales@arcteq.fi</a>  |