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Relion. Thinking beyond the box.

Designed to seamlessly consolidate functions, Relion relays are smarter, more flexible and more adaptable. Easy to integrate and with an extensive function library, the Relion family of protection and control delivers advanced functionality and improved performance.

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ABB Protective Relay School Webinar Series

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ABB Protective Relay School Webinar Series

Underground feeder protection
Mike Kockott
November 5, 2015

Power and productivity
for a better world™

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Presenter

Mike Kockott

Mike is a Senior Engineer, Product Specialist for the Relion family 670 and 650 product series. He is located in Raleigh, North Carolina. Mike has been part of the NAM SA Products team since December 2011. Prior to this he worked as a Senior Applications Specialist / Senior Regional Technical Manager for 12 years at the SA Product factory in Västerås, Sweden.

Prior to joining ABB SAP in Sweden in 2000, Mike was Chief Consultant, Protection (Transmission) at Eskom (national power utility, South Africa). Mike joined Eskom as a training engineer in 1983.

Mike graduated from the University of Cape Town with BSc (electrical engineering) degree (with honors) in 1980.

ABB

Layout

- Introduction
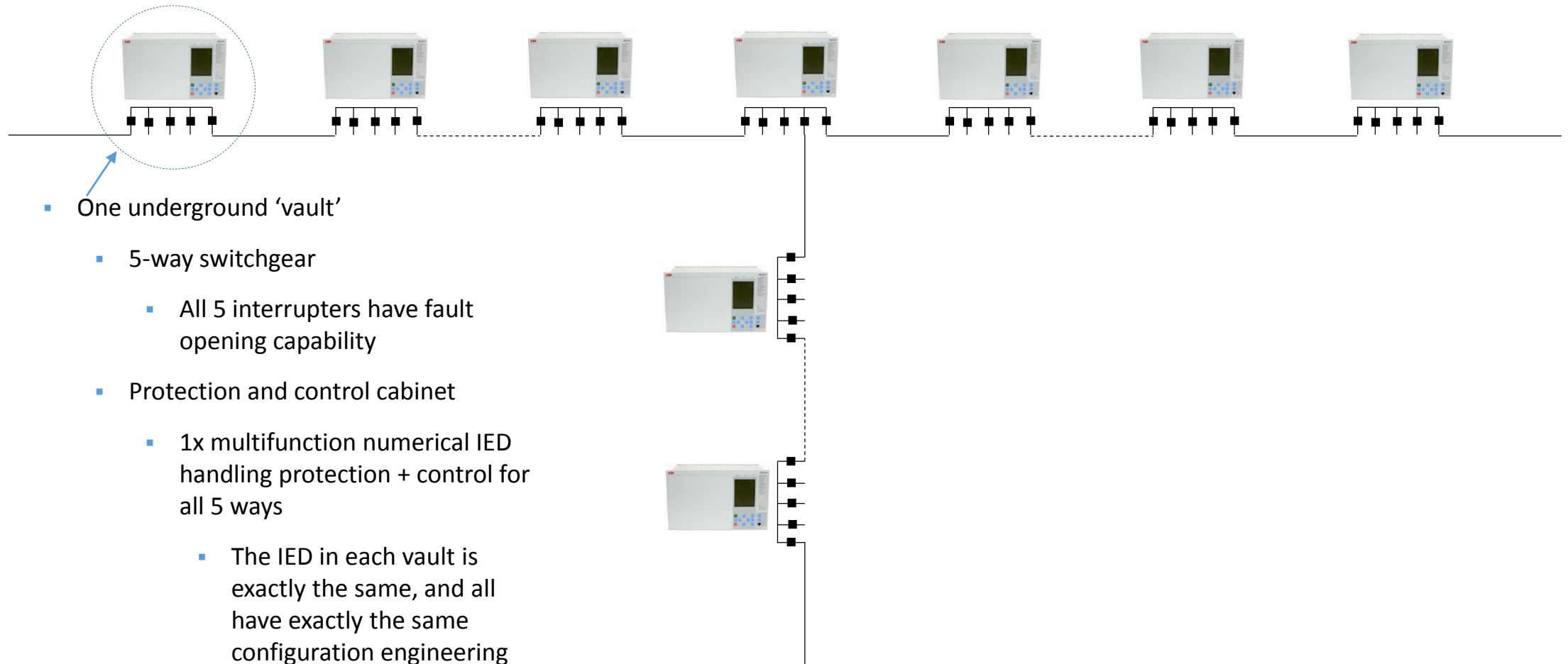
- One underground 'vault'

   - 5-way switchgear

        - All 5 interrupters have fault opening capability

    - Protection and control cabinet

        - 1x multifunction numerical IED handling protection + control for all 5 ways

            - The IED in each vault is exactly the same, and all have exactly the same configuration engineering

        - Switch, dc power source, etc.

ABB

Layout

- Main branch + alternate branch

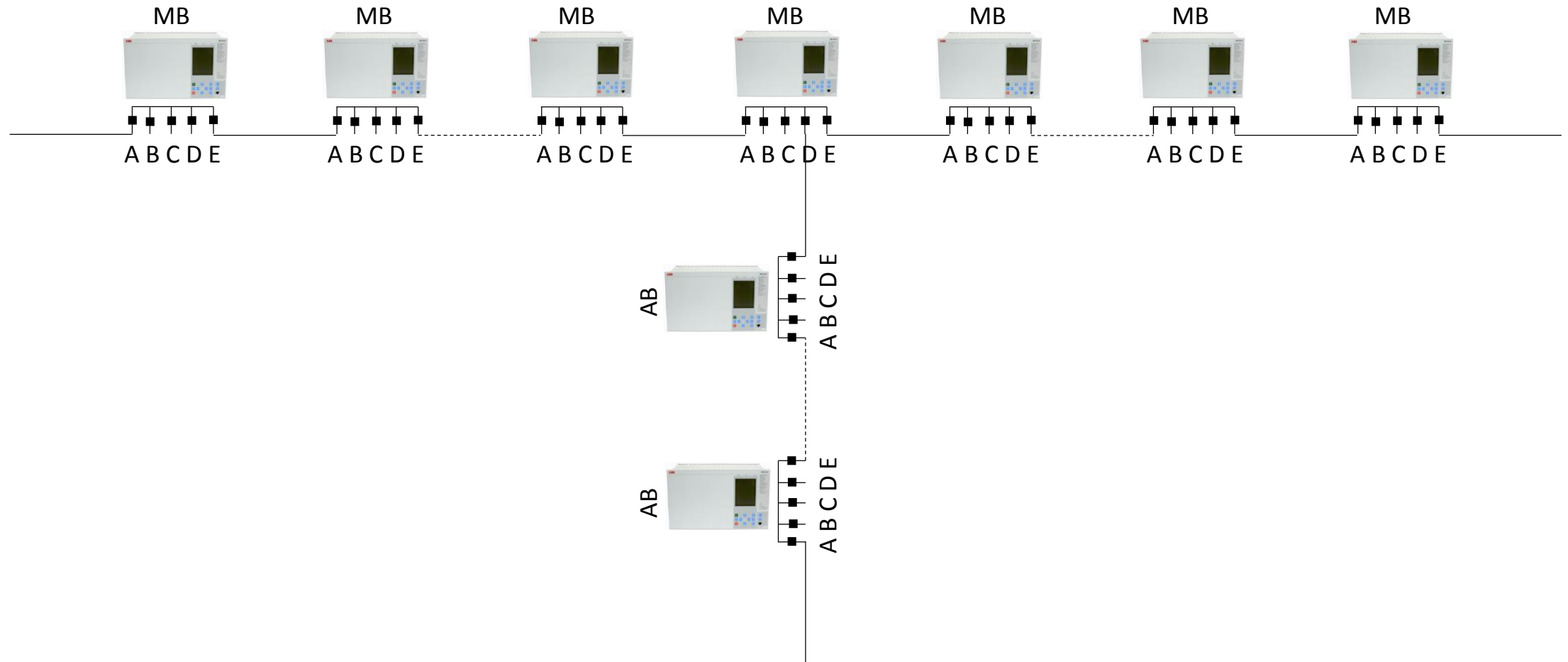Substation 1 — MB — MB — MB — MB — MB — MB — MB — Substation 2

AB — AB → Substation 3
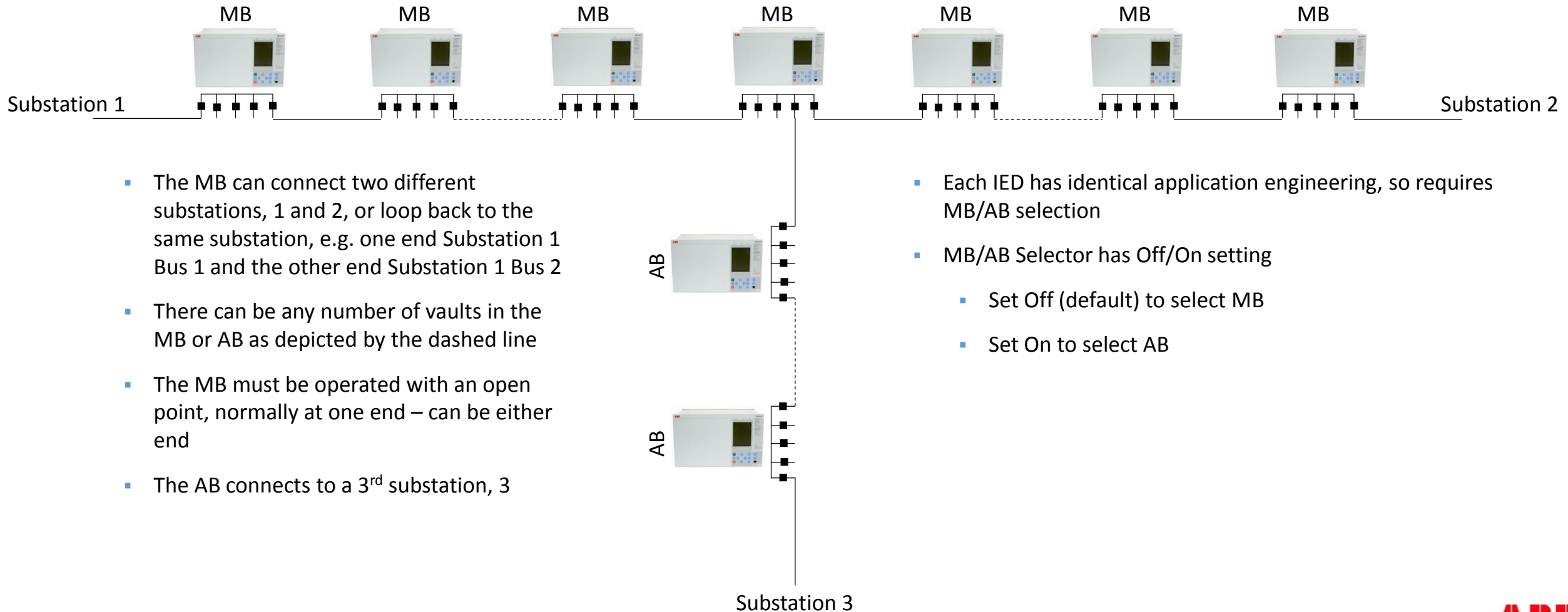
- The MB can connect two different substations, 1 and 2, or loop back to the same substation, e.g. one end Substation 1 Bus 1 and the other end Substation 1 Bus 2

- There can be any number of vaults in the MB or AB as depicted by the dashed line

- The MB must be operated with an open point, normally at one end – can be either end

- The AB connects to a 3rd substation, 3

- Each IED has identical application engineering, so requires MB/AB selection

- MB/AB Selector has Off/On setting

  - Set Off (default) to select MB
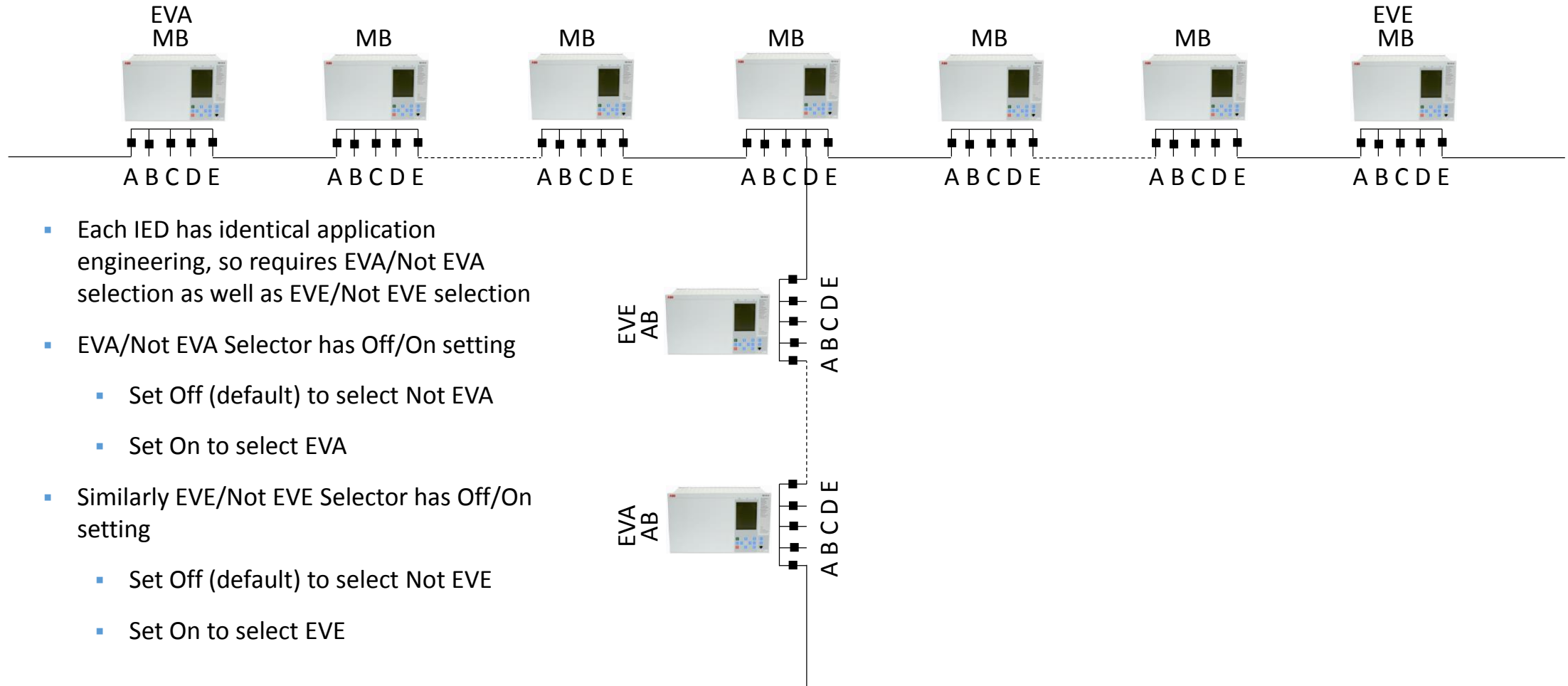
  - Set On to select AB

Layout

- Way naming and connection standards

Layout

- End vault WayA-side (EVA); end vault WayE-side (EVE)

EVA MB   MB   MB   MB   MB   MB   EVE MB

A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E

EVE AB — A B C D E

EVA AB — A B C D E

- Each IED has identical application engineering, so requires EVA/Not EVA selection as well as EVE/Not EVE selection

- EVA/Not EVA Selector has Off/On setting

  - Set Off (default) to select Not EVA

  - Set On to select EVA

- Similarly EVE/Not EVE Selector has Off/On setting

  - Set Off (default) to select Not EVE

  - Set On to select EVE
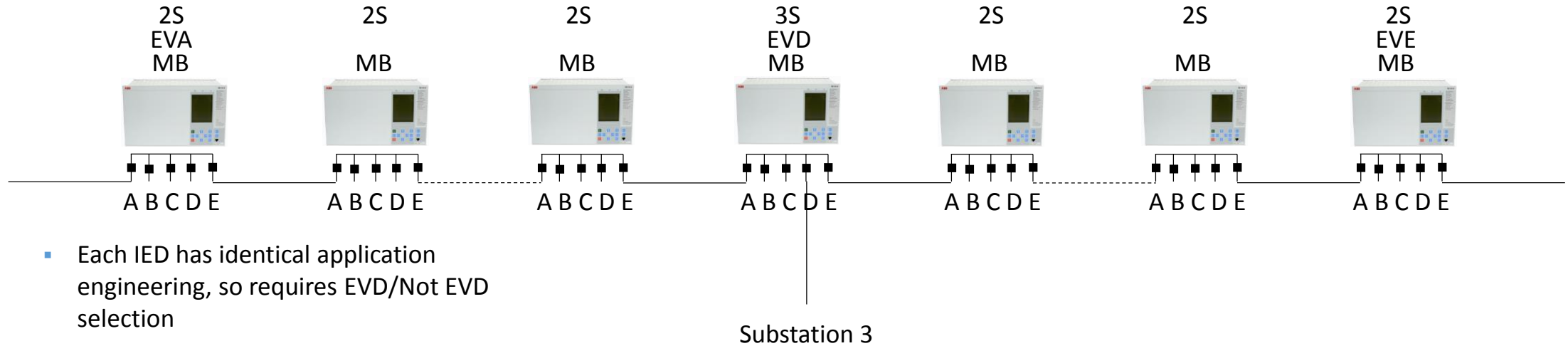
Layout

- **3-source vault**
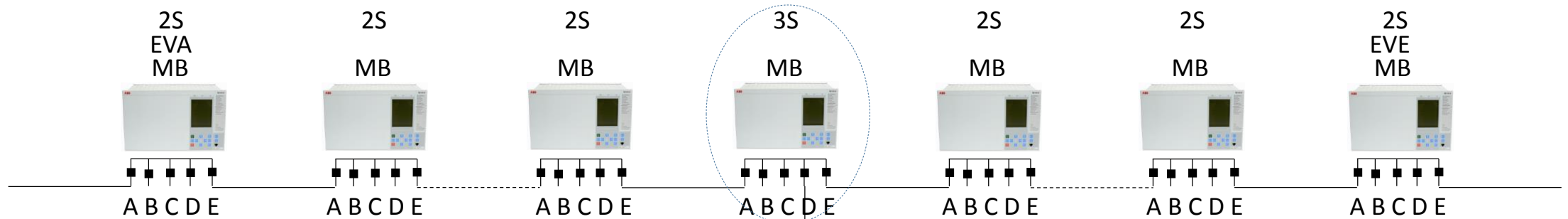
- The MB will have maximum one 3-source vault for connection to the AB at WayD, which must be connected to either WayE of the last AB vault, or directly to the 3rd source substation

- The 3-source vault can be anywhere along the MB, from EVA to EVE

- The 3-source vault WayD will operate normally open

- The AB will operate normally closed (AB EVA WayA closed) at the substation (source) end
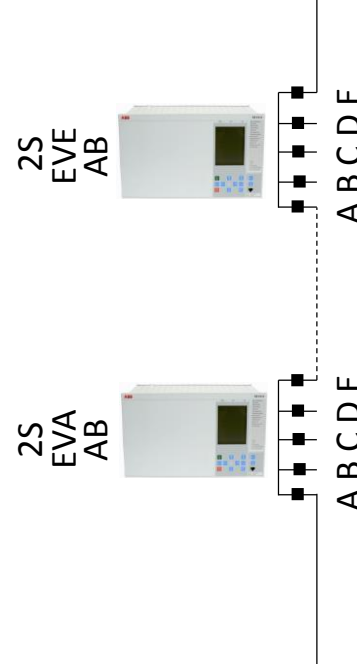
- Each IED has identical application engineering, so requires 2S/3S selection

- 2S/3S Selector has Off/On setting

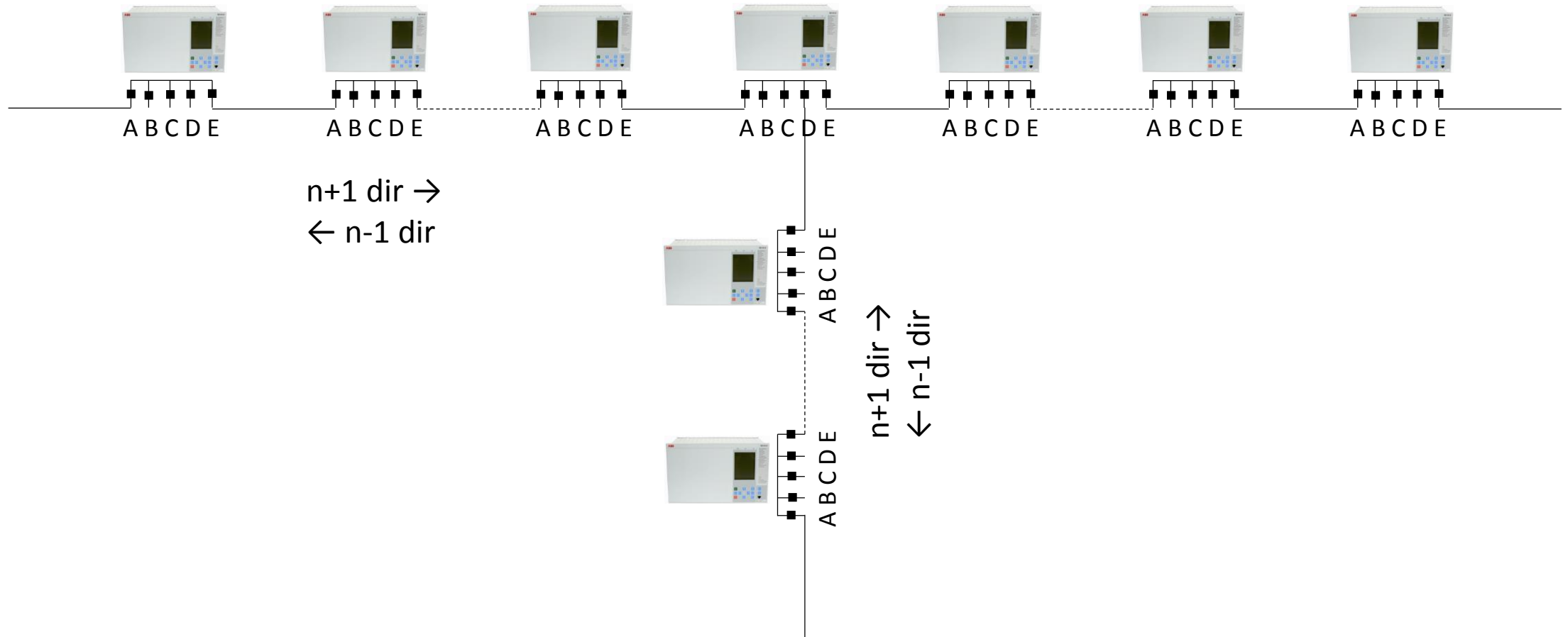 - Set Off (default) to select 2S

  - Set On to select 3S

Layout

- **End vault WayD-side (EVD)**

2S EVA MB	2S MB	2S MB	3S EVD MB	2S MB	2S MB	2S EVE MB
A B C D E	A B C D E	A B C D E	A B C D E	A B C D E	A B C D E	A B C D E

Substation 3

- Each IED has identical application engineering, so requires EVD/Not EVD selection

- Only select EVD at the 3-source IED when the 3-source vault WayD is connected directly to substation 3

- EVD/Not EVD Selector has Off/On setting

  - Set Off (default) to select Not EVD
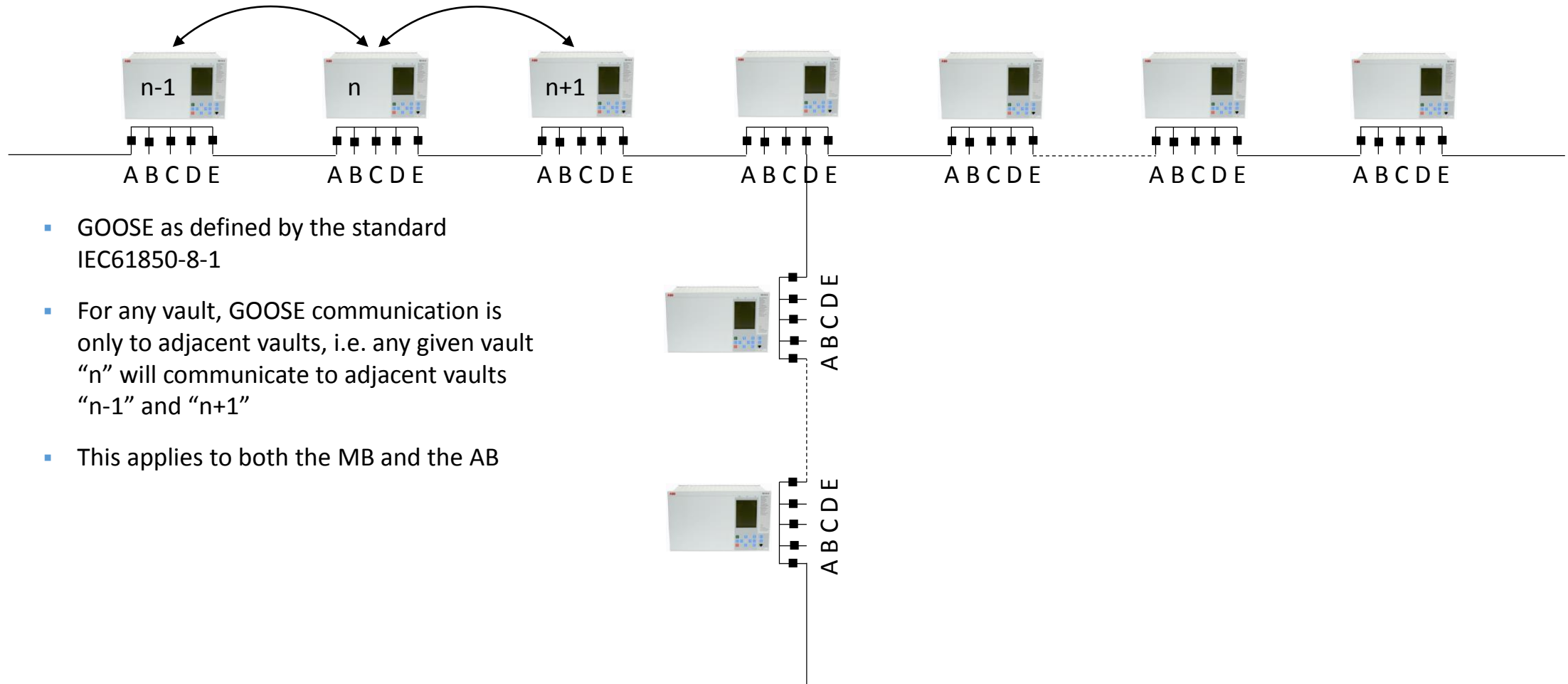
  - Set On to select EVD

Layout

- Direction reference

n+1 dir →
← n-1 dir

A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E
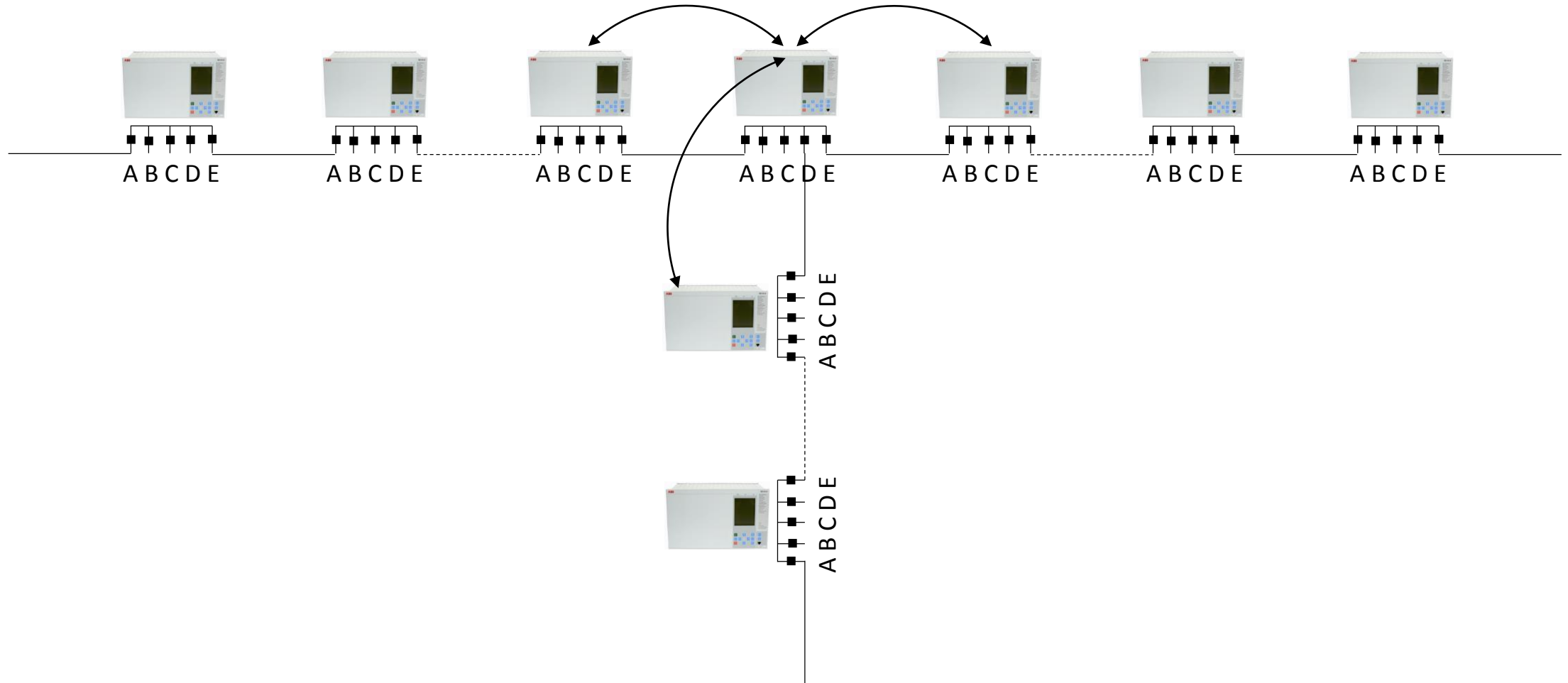
n+1 dir →
← n-1 dir

Layout

- Between vault communication

- GOOSE as defined by the standard IEC61850-8-1

- For any vault, GOOSE communication is only to adjacent vaults, i.e. any given vault "n" will communicate to adjacent vaults "n-1" and "n+1"

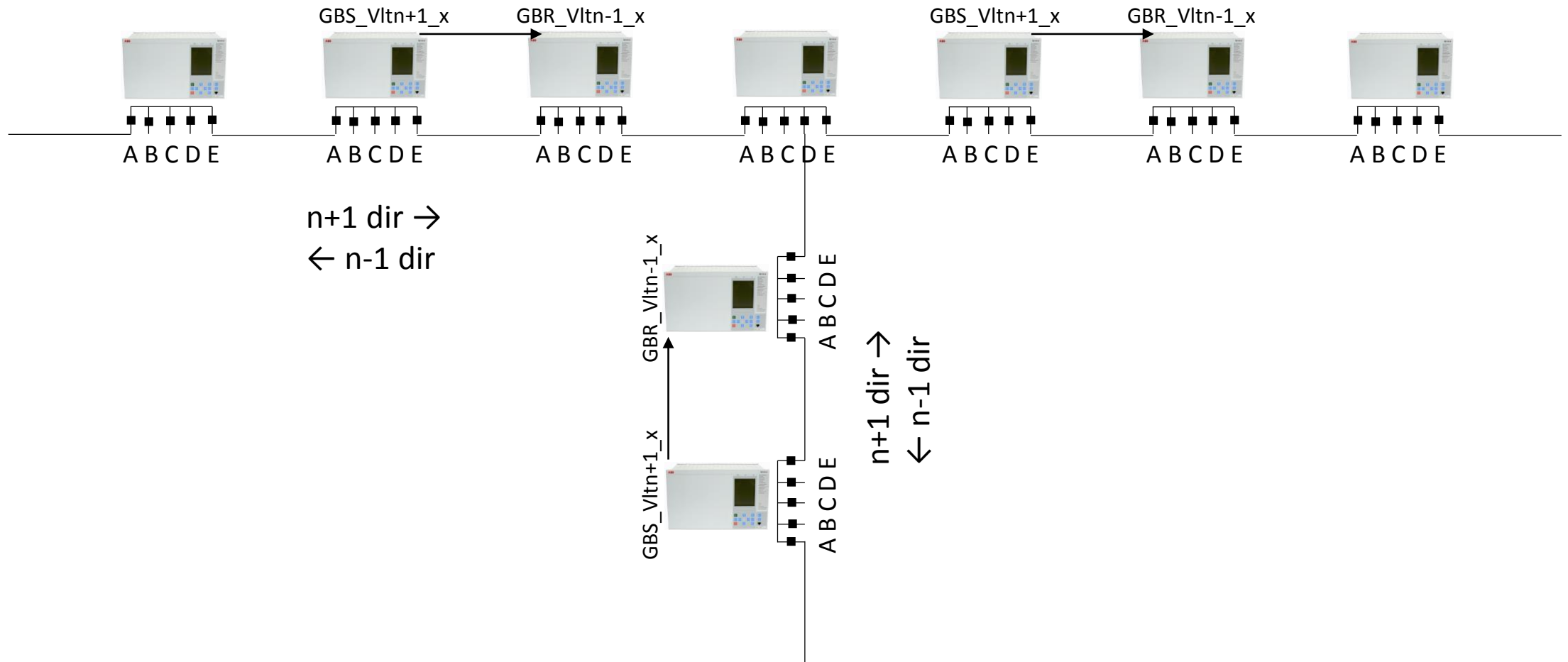- This applies to both the MB and the AB
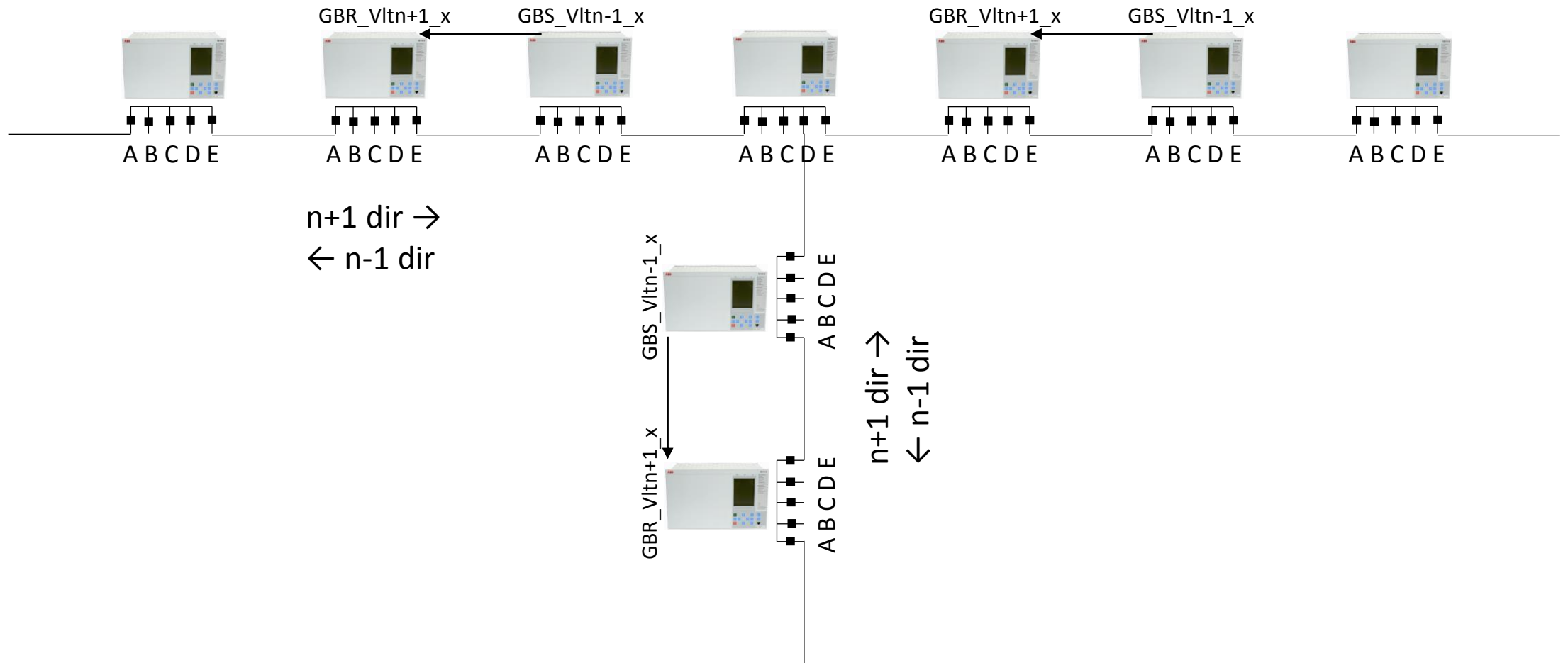
Layout

- Between vault communication – 3-source vault
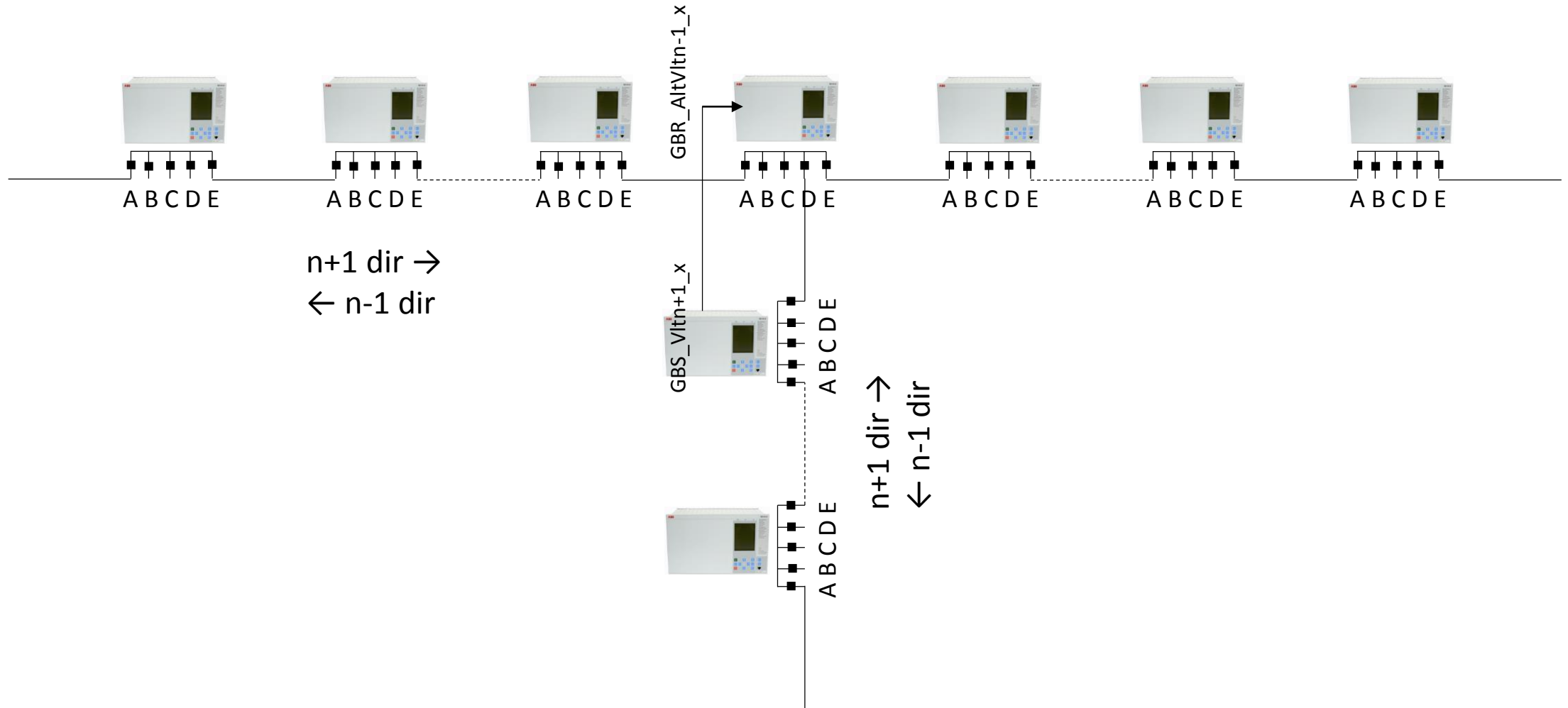
Layout

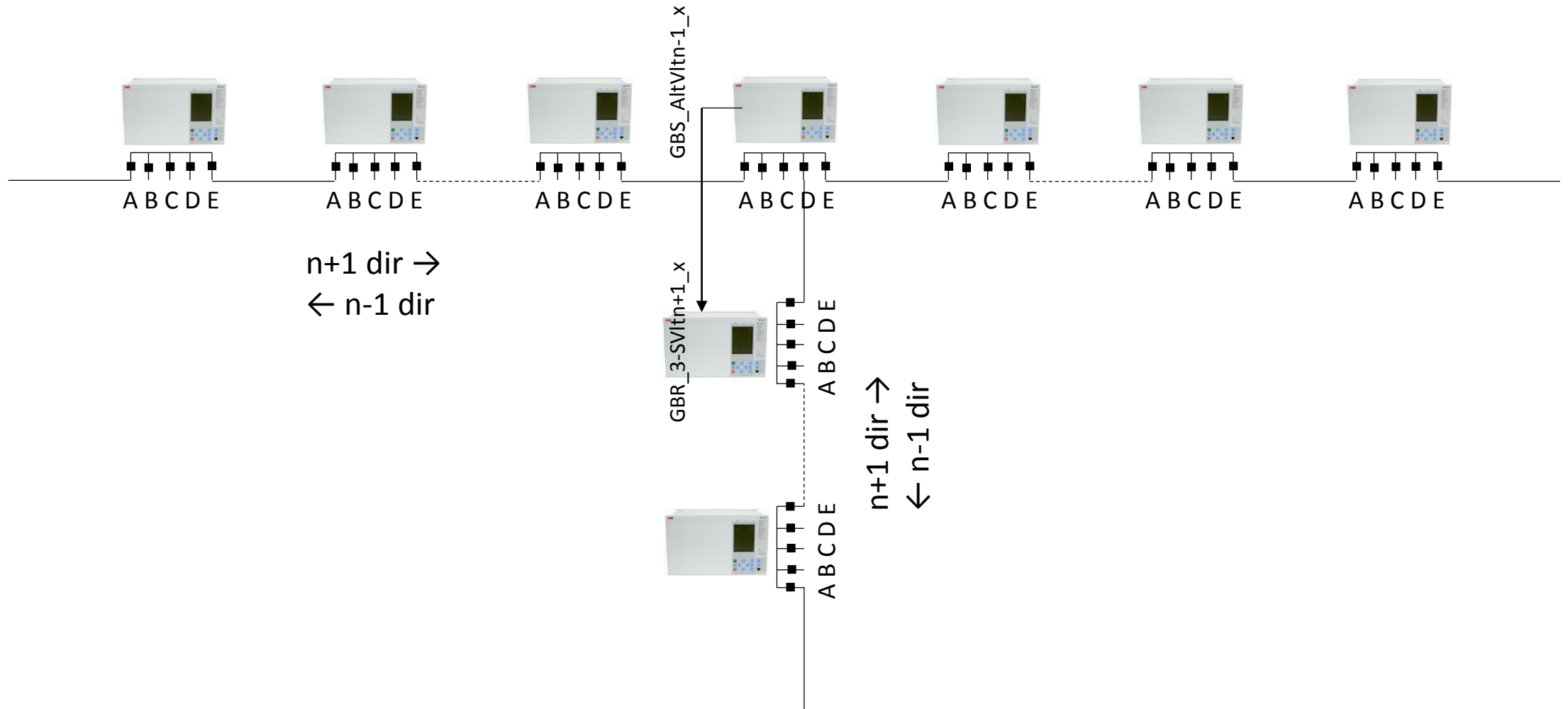- GOOSE reference

Layout

- GOOSE reference

Layout

- GOOSE reference

Layout

- GOOSE reference

Protection

- Within the vault (bounded by the CTs)

  - 87 / 87N; high set (unrestrained), lower set (2nd harmonic restrained, if required)

- WayA-connected line, WayE-connected line

  - 51 / 51N; in conjunction with 'trip enable' and 'trip block' signals (GOOSE) from adjacent vaults

- WayB-connected load, WayC-connected load, 2-source WayD-connected load

  - 50 / 50N; in conjunction with 'trip block' signal (GOOSE) from downstream load-side protection
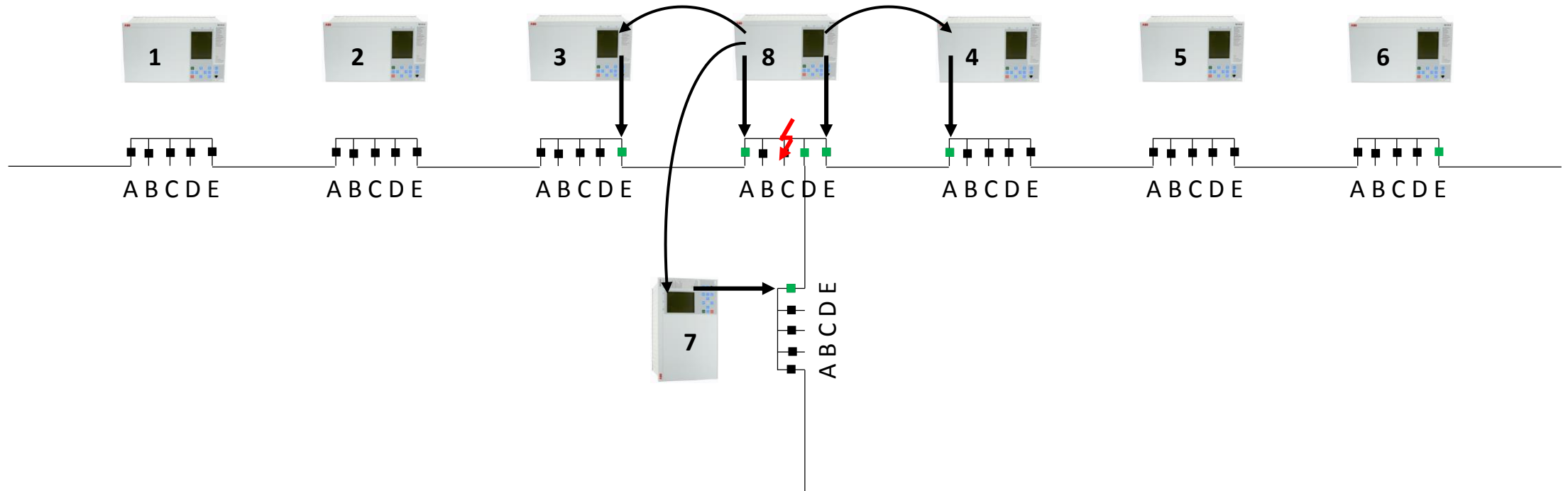
- 50BF for all Ways

87 / 87N

- Summation (per phase) of all (5) Way currents → 50 / 50N high set unrestrained, lower set 2nd harmonic restrained
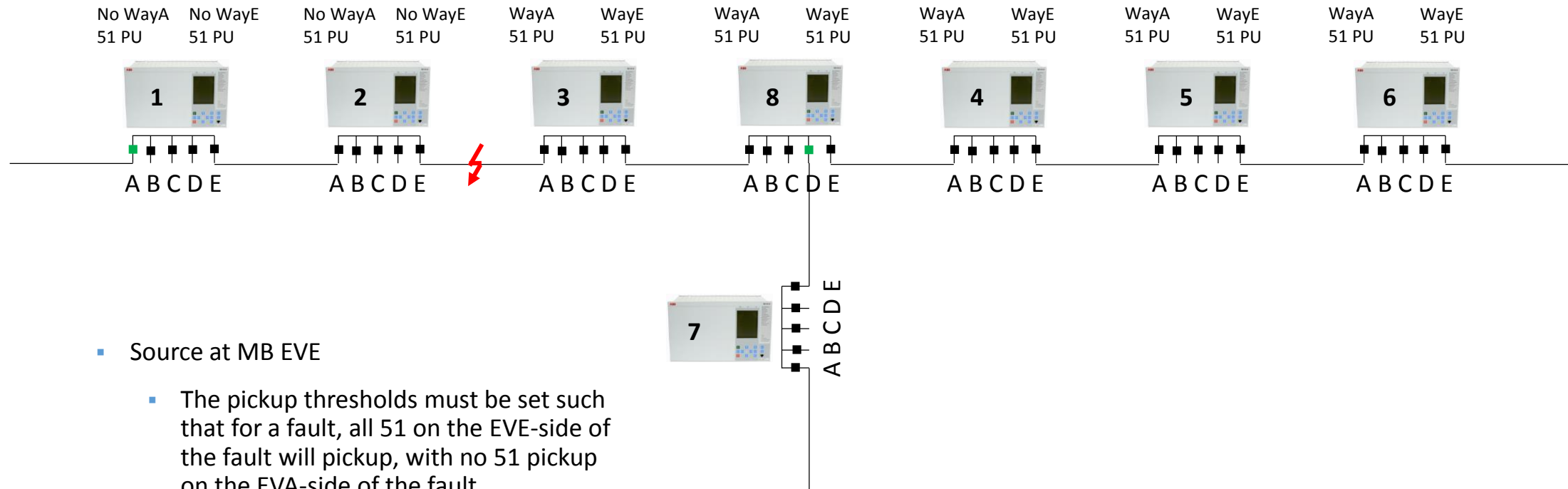
- E.G. Vault 2 internal fault
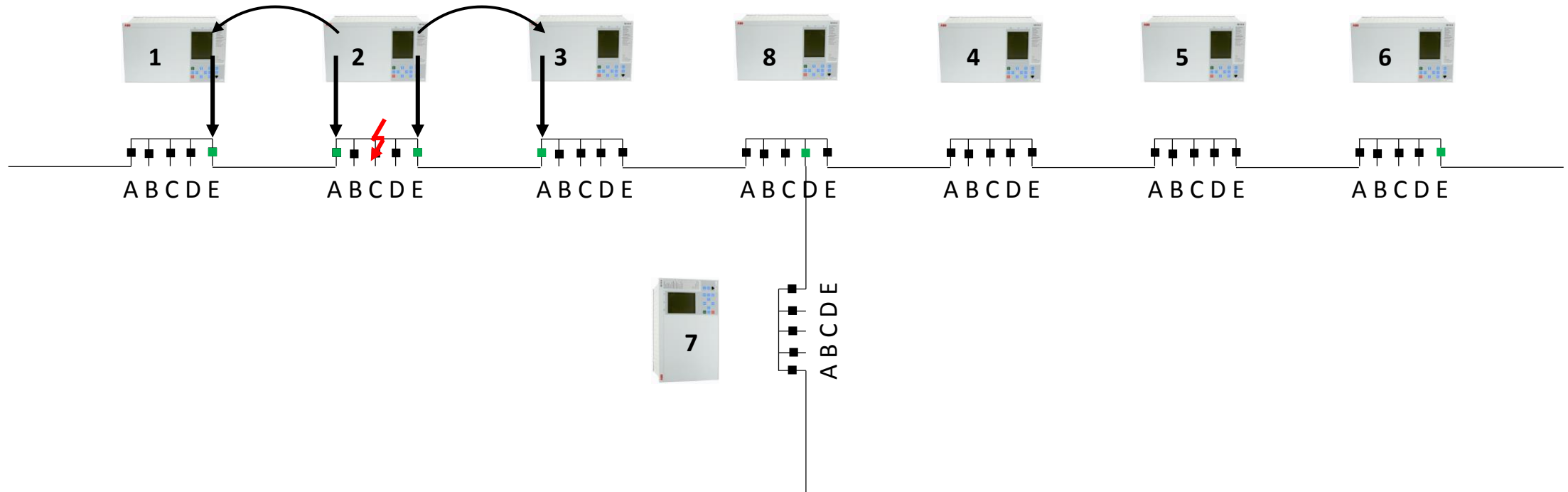
87 / 87N

- E.G. Vault 8 internal fault (3-source vault)

51 / 51N – "Line" Protection
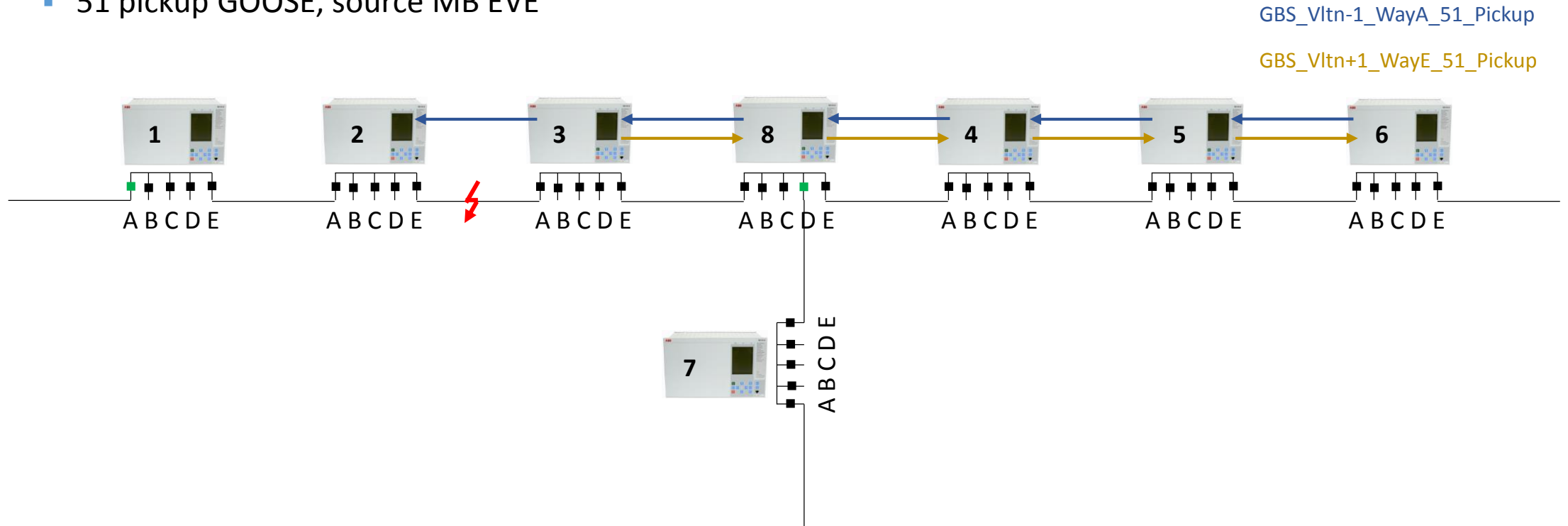
- 51 required pickup coordination

- Source at MB EVE
  - The pickup thresholds must be set such that for a fault, all 51 on the EVE-side of the fault will pickup, with no 51 pickup on the EVA-side of the fault
- Source at EVA
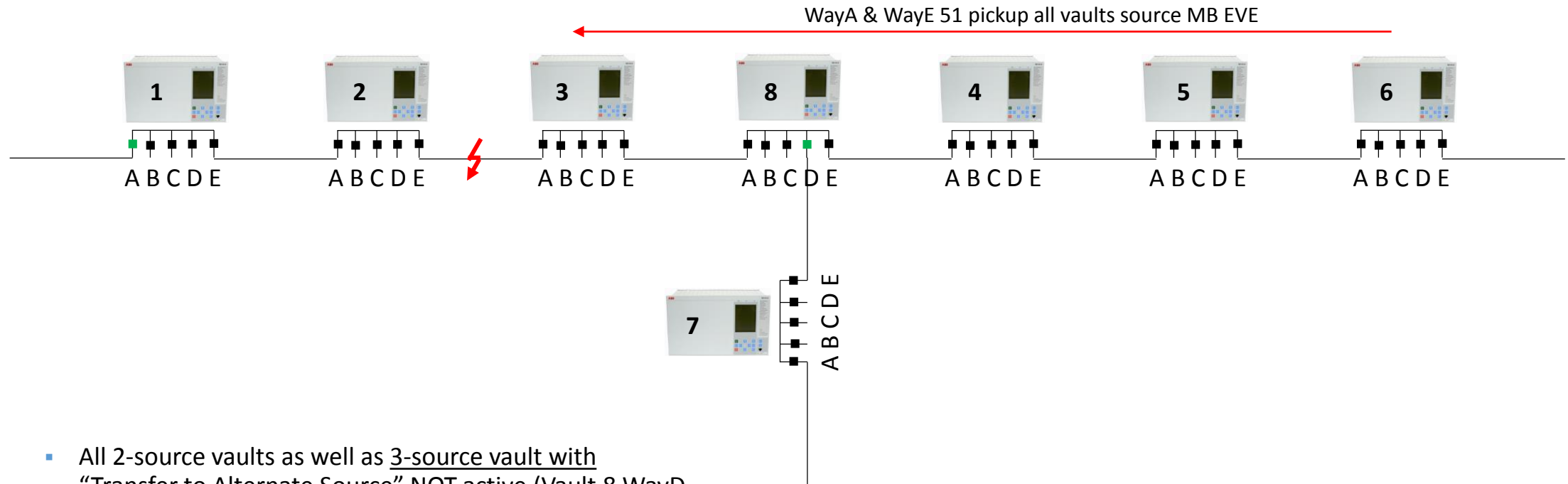 - Vice versa the above
- MB or AB

51 / 51N – "Line" Protection

- 51 pickup GOOSE, source MB EVE

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup

51 / 51N – "Line" Protection

- 51 detection of external 'line' fault

WayA & WayE 51 pickup all vaults source MB EVE

| 1 | 2 | 3 | 8 | 4 | 5 | 6 |

A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E
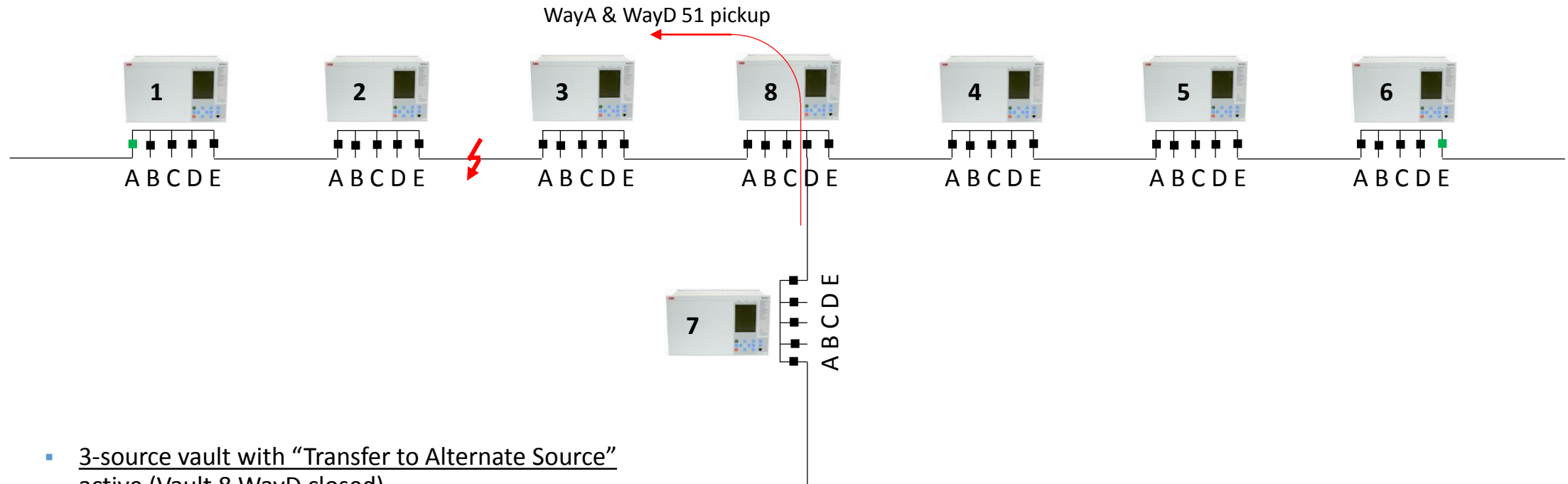
| 7 |

A B C D E

- All 2-source vaults as well as <u>3-source vault with "Transfer to Alternate Source" NOT active</u> (Vault 8 WayD open)
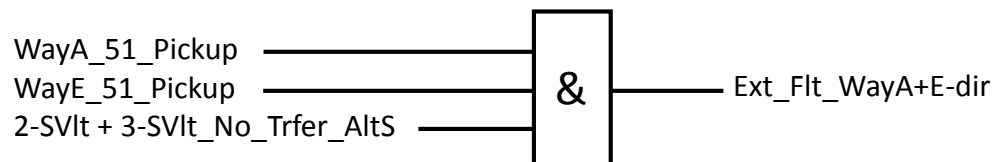
WayA_51_Pickup ─────┐
WayE_51_Pickup ─────┤ & ──── Ext_Flt_WayA+E-dir
2-SVlt + 3-SVlt_No_Trfer_AltS ─┘

51 / 51N – "Line" Protection

- 51 detection of external 'line' fault, source AB EVA

WayA & WayD 51 pickup

| 1 | 2 | 3 | 8 | 4 | 5 | 6 |

A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E

7

A B C D E

- <u>3-source vault with "Transfer to Alternate Source" active</u> (Vault 8 WayD closed)

WayA_51_Pickup ———|
WayD_51_Pickup ———| & |——— 3-SVlt_Ext_Flt_WayA-dir
3-SVlt_Trfer_AltS ———|

51 / 51N – "Line" Protection

- 51 detection of external 'line' fault, source AB EVA

WayE & WayD 51 pickup

1	2	3	8	4	5	6

A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E

7

A B C D E

- <u>3-source vault with "Transfer to Alternate Source" active</u> (Vault 8 WayD closed)

WayE_51_Pickup ─┐
WayD_51_Pickup ─┤ & ── 3-SVlt_Ext_Flt_WayE-dir
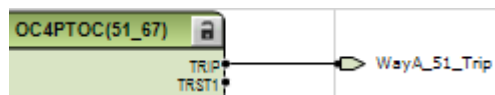3-SVlt_Trfer_AltS ─┘

ABB
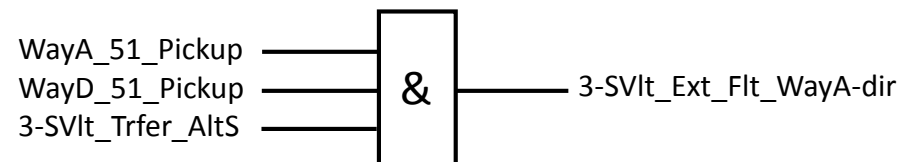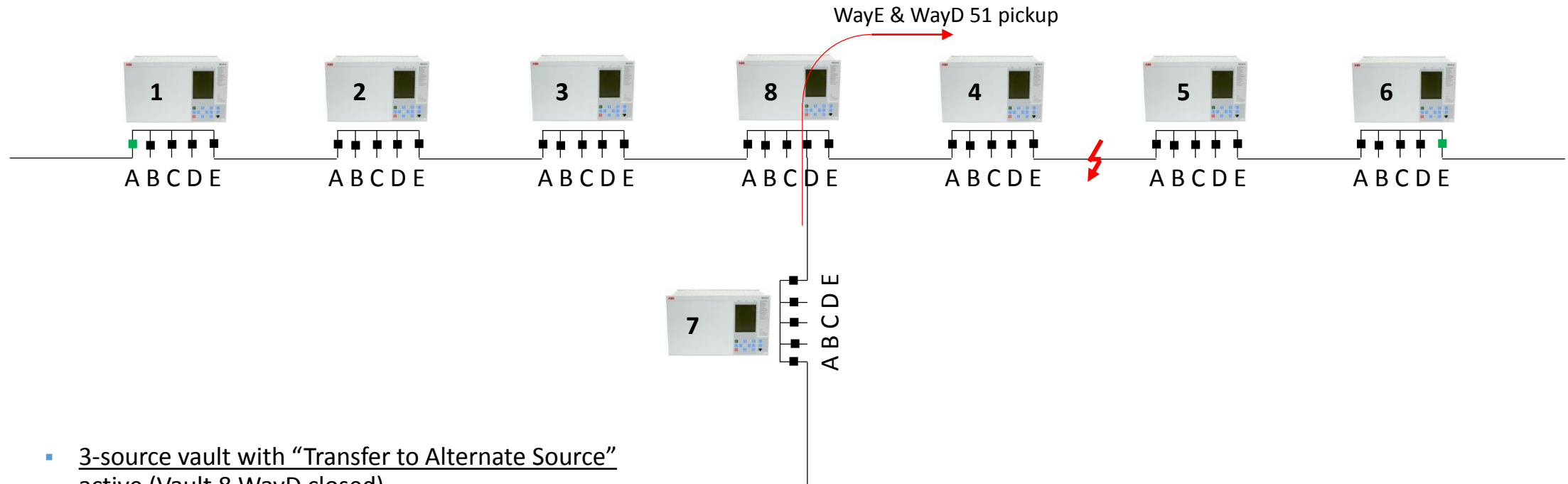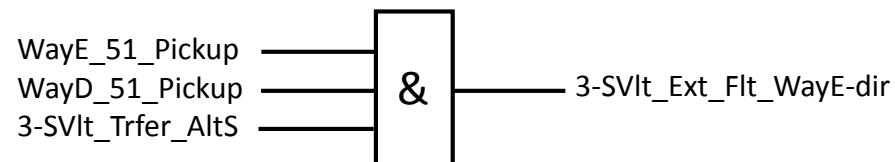
51 / 51N – "Line" Protection

- 51 operating logic
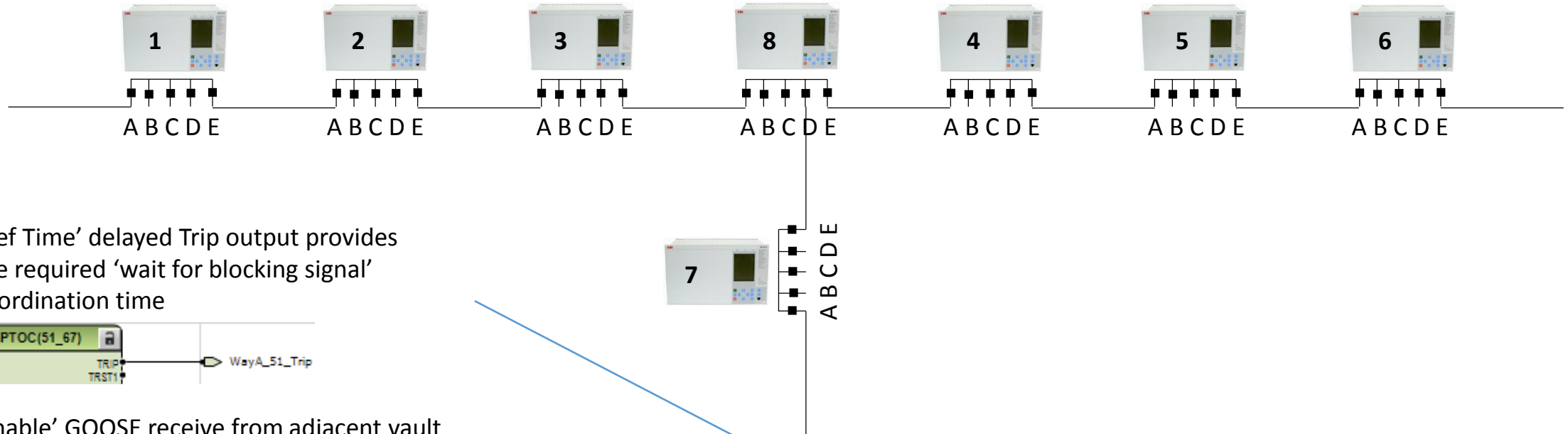
'Def Time' delayed Trip output provides the required 'wait for blocking signal' coordination time

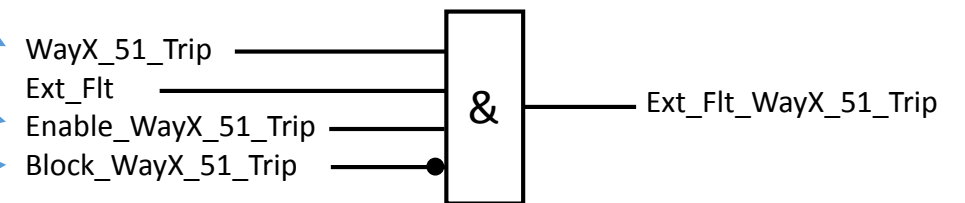'Enable' GOOSE receive from adjacent vault

    Enable Vltn WayA: receive Vltn+1 WayA Pickup

    Enable Vltn WayE: receive Vltn-1 WayE Pickup

'Block' GOOSE receive from adjacent vault

    Block Vltn WayA: receive Vltn-1 WayE Pickup

    Block Vltn WayE: receive Vltn+1 WayA Pickup

WayX_51_Trip
Ext_Flt
Enable_WayX_51_Trip
Block_WayX_51_Trip

&

Ext_Flt_WayX_51_Trip

51 / 51N – "Line" Protection

- 51 'line' (external) fault – source MB EVE

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup

1   2   3   8   4   5   6

A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E

- Vault 1

  - No WayA 51 pickup and no WayE 51 pickup = no 'line' (external) fault detected = no trip

A B C D E

7

WayX_51_Trip

Ext_Flt

Enable_WayX_51_Trip

Block_WayX_51_Trip

&

Ext_Flt_WayX_51_Trip

51 / 51N – "Line" Protection

- 51 'line' (external) fault – source MB EVE

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup

| 1 | 2 | 3 | 8 | 4 | 5 | 6 |

A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E

- Vault 2

  - No WayA 51 pickup and no WayE 51 pickup = no 'line' (external) fault detected = no trip

A B C D E

WayX_51_Trip
Ext_Flt
Enable_WayX_51_Trip
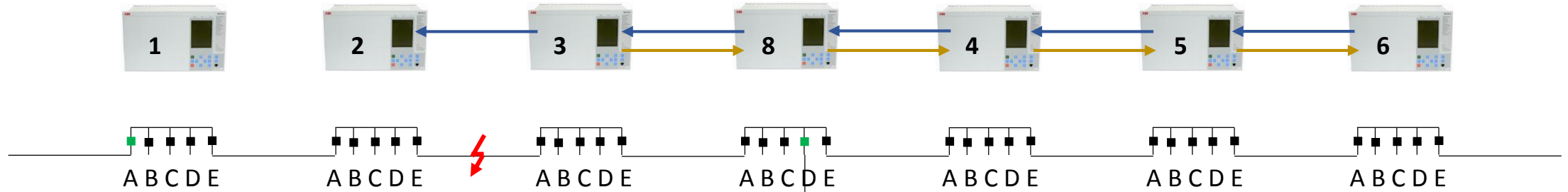Block_WayX_51_Trip

&

Ext_Flt_WayX_51_Trip

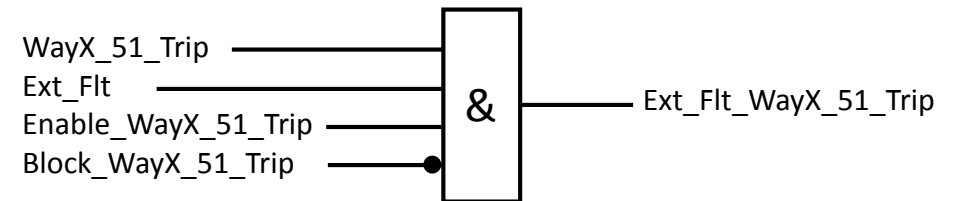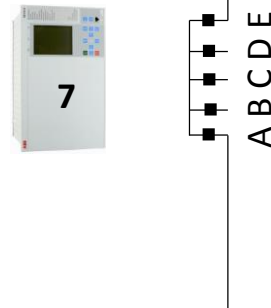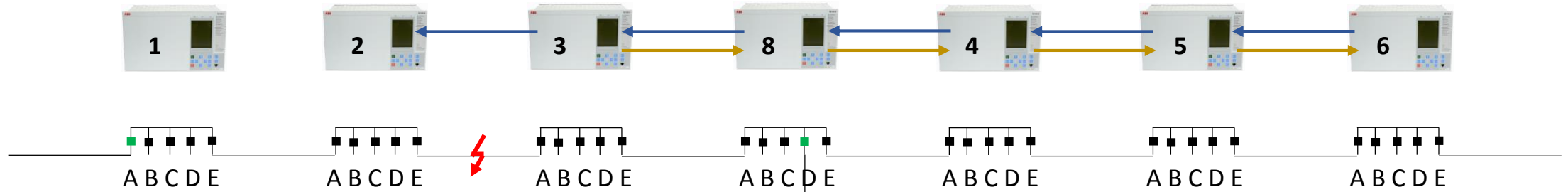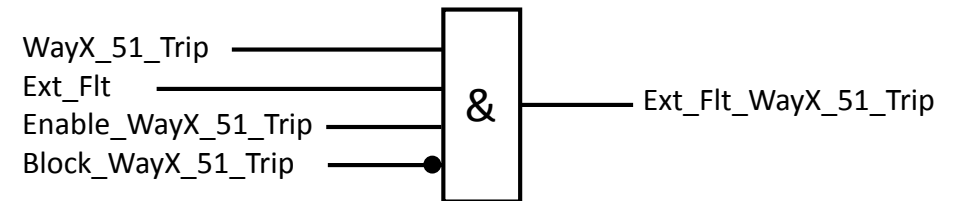# 51 / 51N – "Line" Protection

- 51 'line' (external) fault – source MB EVE

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup

- Vault 3

  - WayA 51 pickup and WayE 51 pickup = 'line' (external) fault detected

  - WayA

    - GBR_Vlt8_WayA_51_Pickup = enable

    - No GBR_Vlt2_WayE_51_Pickup = no block

    - Ext Flt WayA trip after DT delay

51 / 51N – "Line" Protection

- 51 'line' (external) fault – source MB EVE

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup

A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E

- Vault 3

  - WayA 51 pickup and WayE 51 pickup = 'line' (external) fault detected

  - WayE

    - No GBR_Vlt2_WayE_51_Pickup = no enable

    - GBR_Vlt8_WayA_51_Pickup = block

    - No Ext Flt WayE trip

WayE_51_Trip

Ext_Flt

Enable_WayE_51_Trip

Block_WayE_51_Trip

&

Ext_Flt_WayE_51_Trip

51 / 51N – "Line" Protection

- 51 'line' (external) fault – source MB EVE

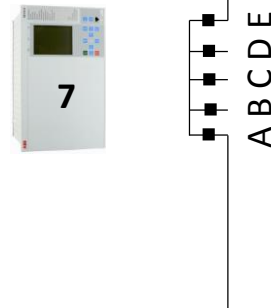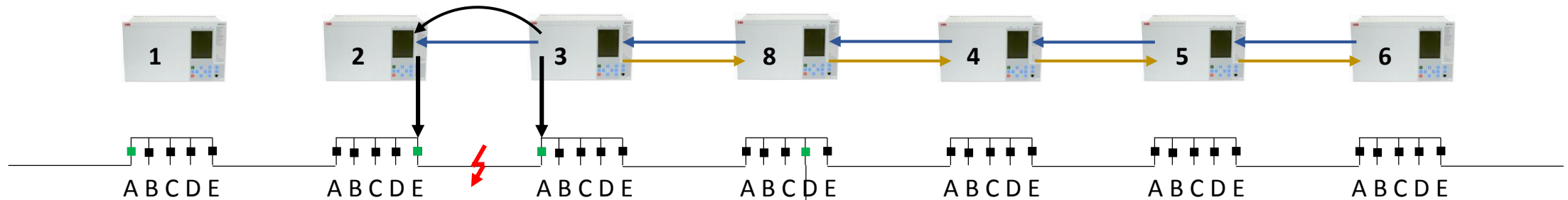 - 3-source vault behaves as 2-source vault as "Transfer to Alternate Source" is NOT active

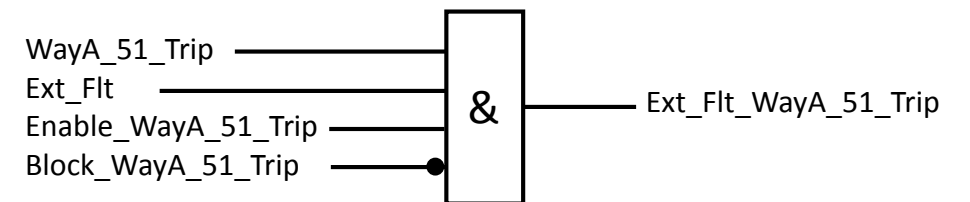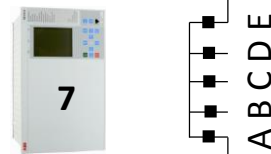GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup
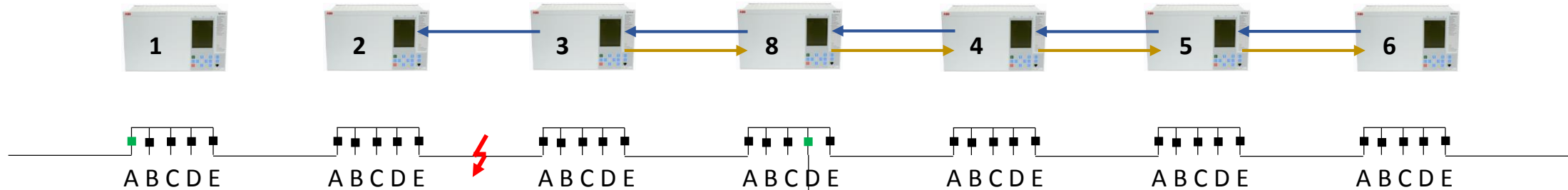
- Vault 8

  - WayA 51 pickup and WayE 51 pickup = 'line' (external) fault detected

  - WayA

    - GBR_Vlt4_WayA_51_Pickup = enable

    - GBR_Vlt3_WayE_51_Pickup = block

    - No Ext Flt WayA trip

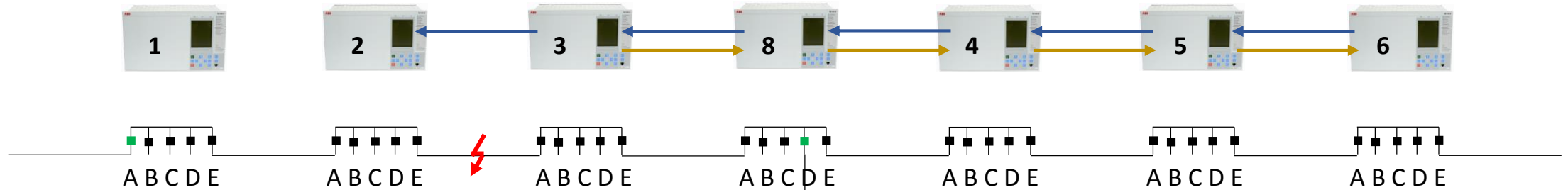WayA_51_Trip
Ext_Flt
Enable_WayA_51_Trip
Block_WayA_51_Trip

&

Ext_Flt_WayA_51_Trip

ABB

51 / 51N – "Line" Protection

- 51 'line' (external) fault – source MB EVE

  - 3-source vault behaves as 2-source vault as "Transfer to Alternate Source" is NOT active

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup

A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E
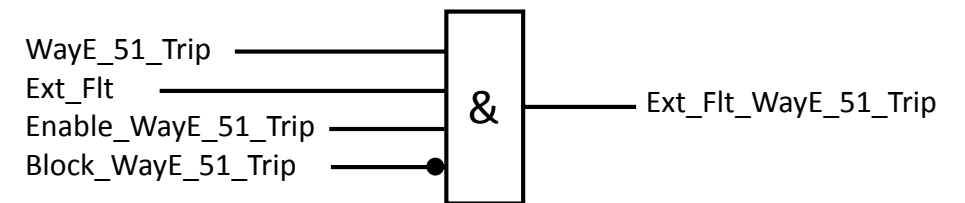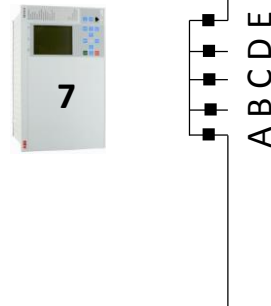
- Vault 8

  - WayA 51 pickup and WayE 51 pickup = 'line' (external) fault detected

  - WayE

    - GBR_Vlt3_WayE_51_Pickup = enable

    - GBR_Vlt4_WayA_51_Pickup = block
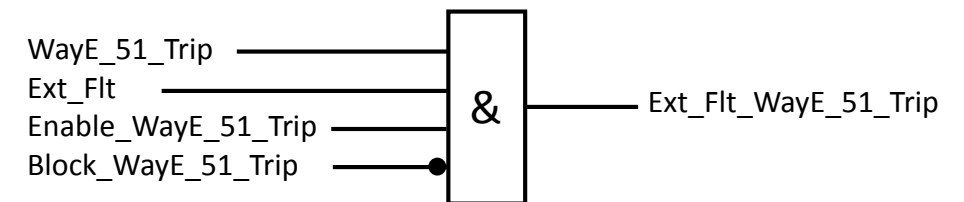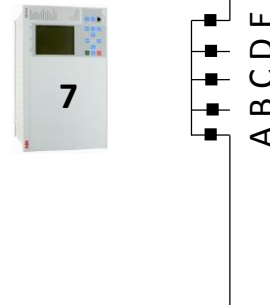
    - No Ext Flt WayE trip
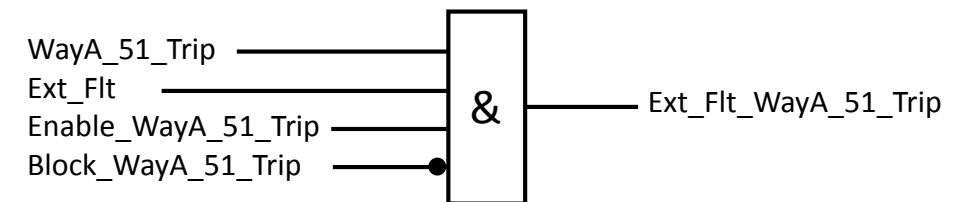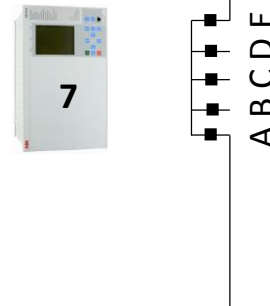
WayE_51_Trip

Ext_Flt

Enable_WayE_51_Trip

Block_WayE_51_Trip

&

Ext_Flt_WayE_51_Trip

51 / 51N – "Line" Protection

- 51 'line' (external) fault – source AB EVA ("Transfer to Alternate Source" active)

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup

GBS_AltVltn-1_WayD_51_Pickup
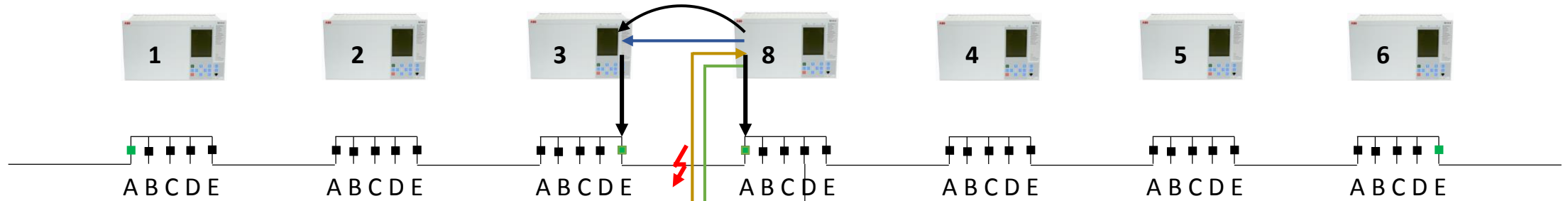
- Vault 8

  - WayA 51 pickup and WayD 51 pickup = 'line' (external) fault detected (A-dir)

  - WayA

    - GBR_AltVlt7_WayE_51_Pickup = enable

    - No GBR_Vlt3_WayE_51_Pickup = no block
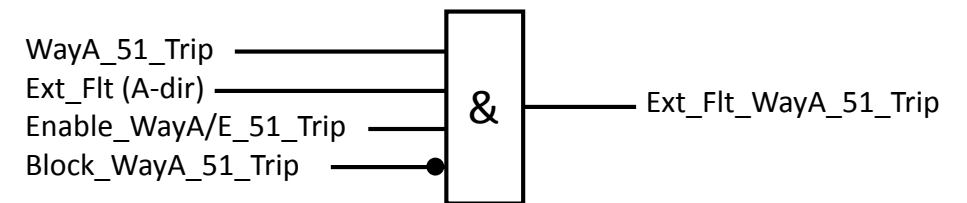
    - Ext Flt WayA trip after DT delay

WayA_51_Trip
Ext_Flt (A-dir)
Enable_WayA/E_51_Trip
Block_WayA_51_Trip

& ——— Ext_Flt_WayA_51_Trip

51 / 51N – "Line" Protection

- 51 'line' (external) fault – source AB EVA ("Transfer to Alternate Source" active)

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup

GBS_AltVltn-1_WayD_51_Pickup

- Vault 7

  - WayA 51 pickup and WayE 51 pickup = 'line' (external) fault detected

  - WayE

    - EVA = enable

    - GBR_3-SVlt8_WayD_51_Pickup = block

    - No Ext Flt WayE trip
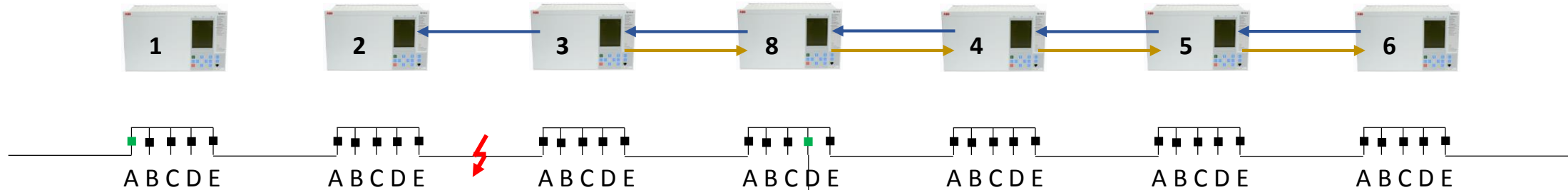
WayE_51_Trip
Ext_Flt
Enable_WayE_51_Trip
Block_WayE_51_Trip

&

Ext_Flt_WayE_51_Trip

ABB

51 / 51N – "Line" Protection

- 51 'line' (external) fault – source AB EVA ("Transfer to Alternate Source" active)

GBS_Vltn+1_WayE_51_Pickup


```
 [1]      [2]      [3]      [8]      [4]      [5]      [6]

A B C D E  A B C D E  A B C D E  A B C D E  A B C D E  A B C D E  A B C D E
```
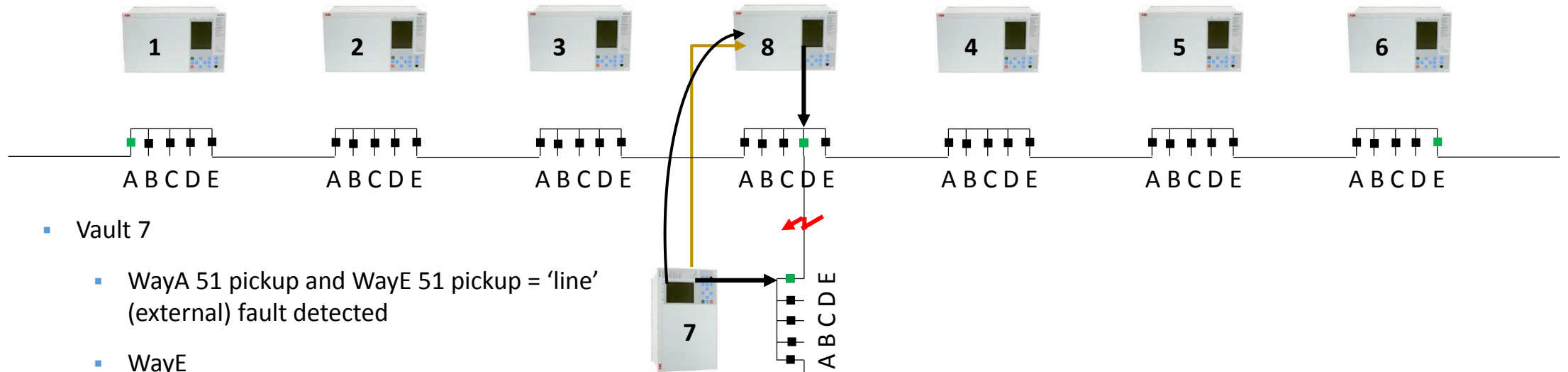
- Vault 7

  - WayA 51 pickup and WayE 51 pickup = 'line' (external) fault detected

  - WayE

    - EVA = enable

    - No GBR_3-SVlt8_WayD_51_Pickup = no block

    - Ext Flt WayE trip after DT delay

```
WayE_51_Trip ——————|
Ext_Flt ——————————|  &  |—— Ext_Flt_WayE_51_Trip
Enable_WayE_51_Trip ——|
Block_WayE_51_Trip ——●|
```

ABB
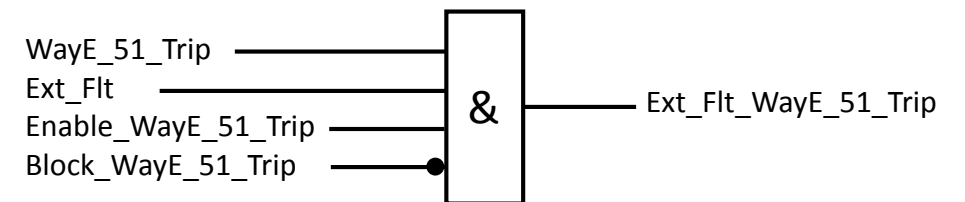
51 / 51N – "Line" Protection

- 51 'line' (external) fault

  - Comm Fail

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup
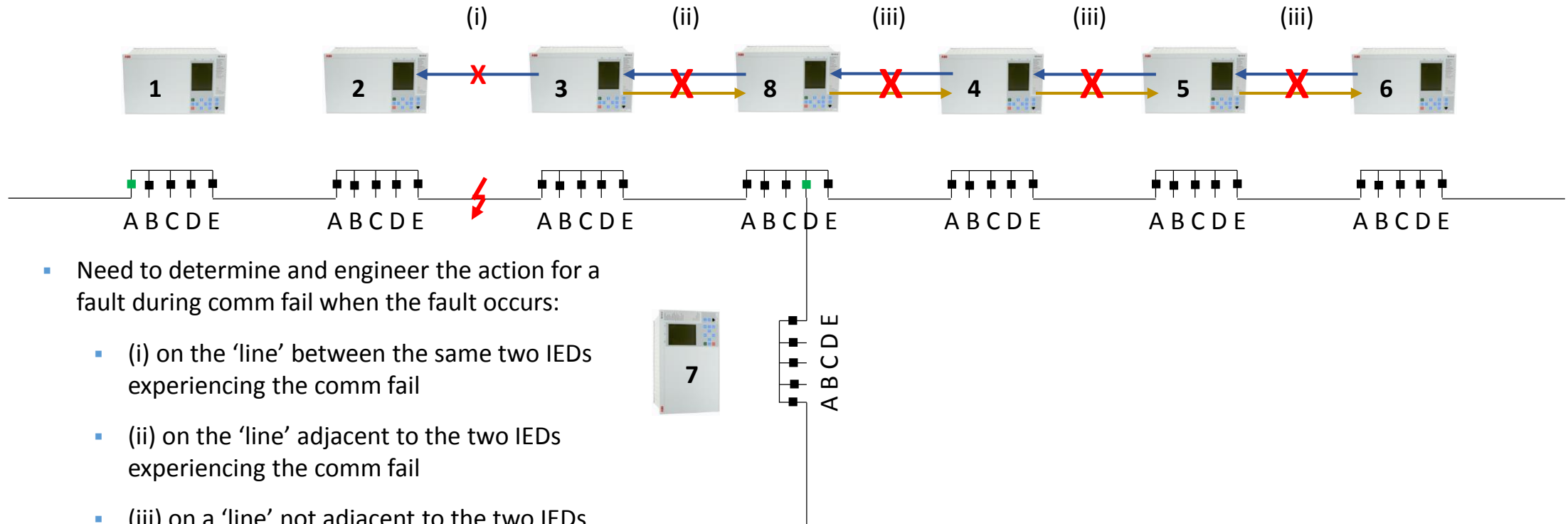
- Need to determine and engineer the action for a fault during comm fail when the fault occurs:

  - (i) on the 'line' between the same two IEDs experiencing the comm fail

  - (ii) on the 'line' adjacent to the two IEDs experiencing the comm fail

  - (iii) on a 'line' not adjacent to the two IEDs experiencing the comm fail

50 / 50N – Load Protection

- WayB load pickup coordination


```
                    OFF → logic 0
                    ON → logic 1          OFF-DELAY
                                        ┌──────────┐
  → ON/OFF_Selection ─────────────┐ ┌───┤    t     ├──── Block_WayB_50&50N
                                  └─┤&│  │  ┌────┐  │
   GBR_LoadSGWayB_50+50N_Pickup ──┤ │ │  └──┘    └──┘
   │                              └─┘
   │
   │                                    ON-DELAY
   │                                  ┌──────────┐
   │    WayB_50_Trip ──────────┐ ┌────┤    t     ├──── WayB_50+50N_Trip
   │                           └─┤OR│  │  ┌────┐  │
   │    WayB_50N_Trip ─────────┤ │  │  └──┘    └──┘
   │                           └─┘           ↖
```
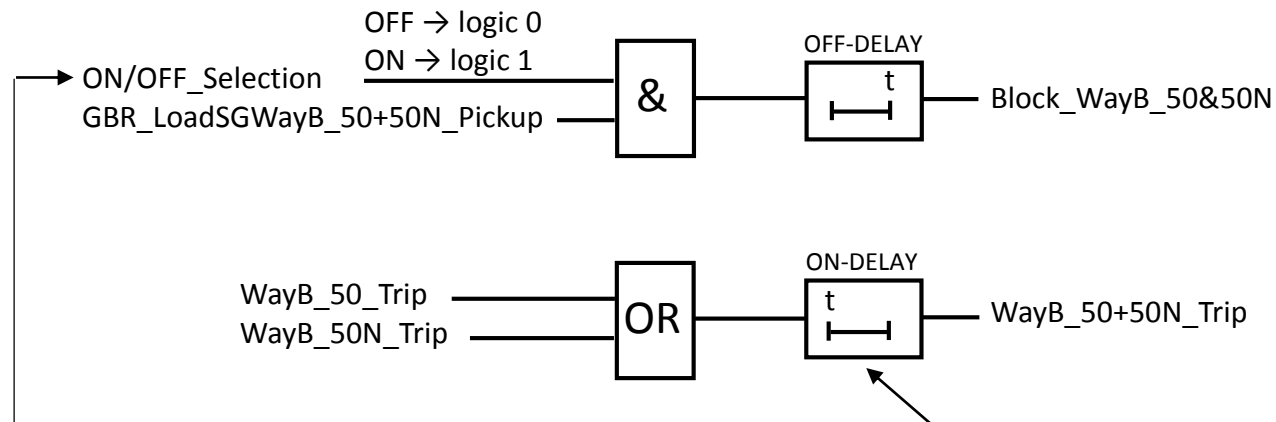
- Not required: select OFF

- Required: select ON

- On-delay timer provides the required 'wait for blocking signal' coordination time

    - If this functionality is not required, i.e. OFF selected, set the on-delay to zero

    - If this functionality is required, i.e. ON selected, set the on-delay to the appropriate wait time

- WayC identical

50 / 50N – Load Protection

- WayD load pickup coordination

  - Essentially identical to WayB and WayC, with one added part to the "Block" signal

ON/OFF_Selection
GBR_LoadSGWayD_50/N_Pickup

OFF-DELAY
t

3-source

OR → Block_WayD_50/50N
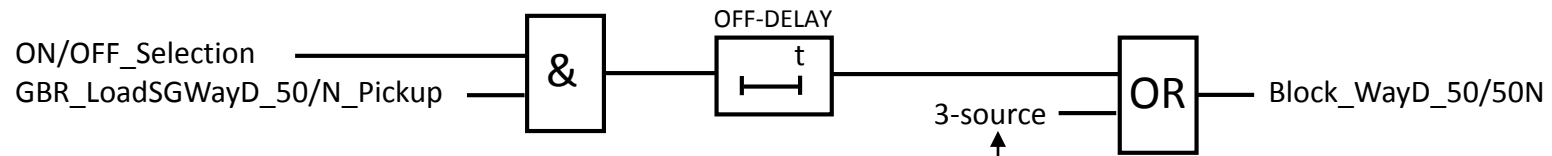
- Blocks (disables) 50/50N load protection on 3-source vault

50 / 50N – Load Protection

- Load fault, WayC – source MB EVE

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup

- Vault 2

  - WayE 51 pickup, but no WayA 51 pickup = no 'line' fault detected

  - WayC 50 (or 50N) pickup = WayC trip
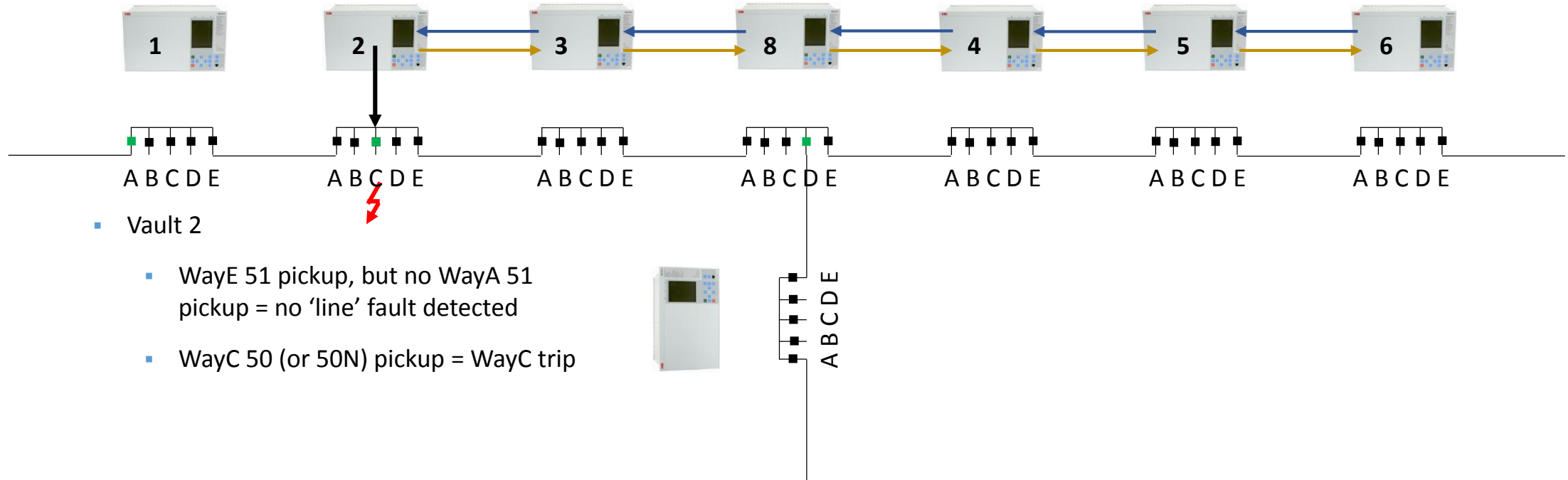
94 Trip Signals
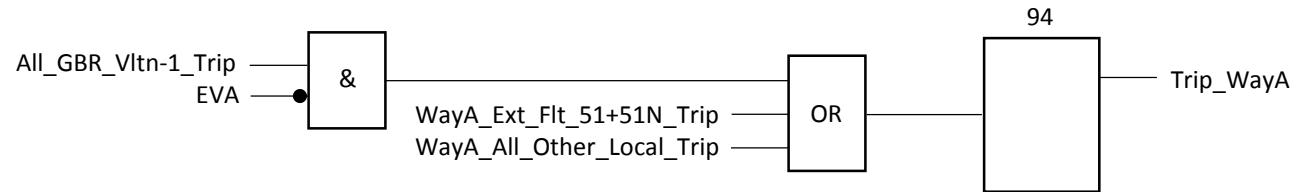
- ## WayA

- ## WayE

94 Trip Signals

- WayB (= WayC)

```
                                94
                              ┌──────┐
                              │      │
  WayB_50+50N_Trip ───────────┤      ├───── Trip_WayB
                              │      │
                              └──────┘
```

- WayD

```
  All_GBR_AltVltn-1_Trip ──────┐ &  ┐
  3_SVlt_Trfer_AltS     ──────┘    │
                                    │
                                    ├──┐ OR ┐      94
  WayD_All_Other_Local_Trip ───┐ &  ┐ │    ├──┐  ┌──────┐
  3-SVlt_Trfer_AltS      ──────┘    ┘─┘    │  │  │      │
                                           ┘──┤  ├──────┤──── Trip_WayD
  WayD_50+50N_Trip ────────────┐ &  ┐         └──┘  └──────┘
  3-SVlt          ──●──────────┘    ┘
```
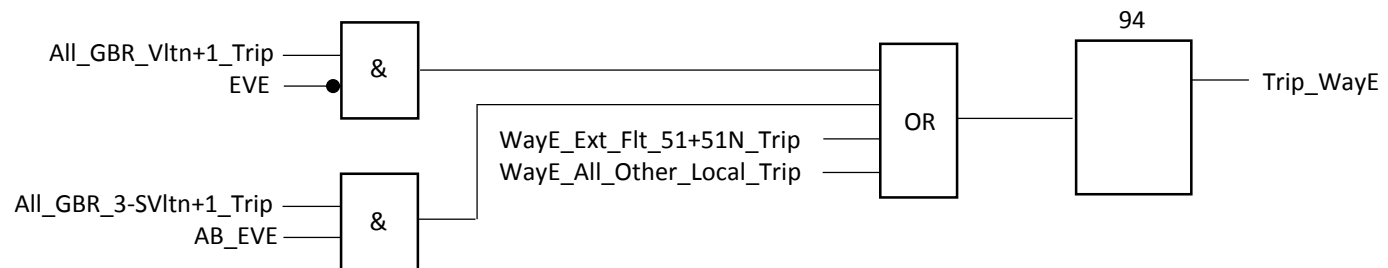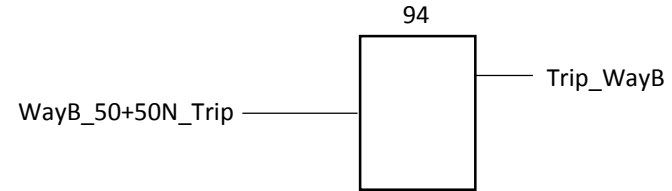
50BF Protection

- WayA, WayE and 3-source WayD

  - Not always possible to use detection of current dropping from fault current to zero to determine successful tripping of the fault interrupter

  - Examples

WayD GBR Trip (3-S Vault, Trfer to AltS active)
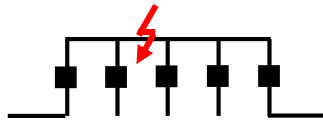
87 fault – fault infeed is from one side only, therefore the away from source end interrupter cannot detect successful tripping by detecting current crossing from above to below some threshold

WayE GBR Trip

Source EVE

Source EVA AB
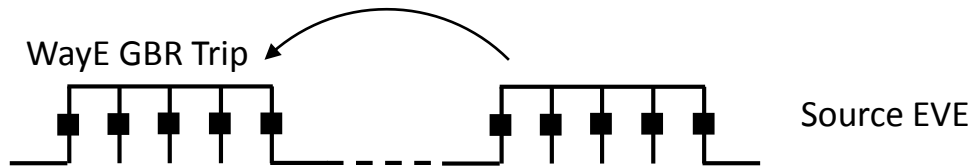
GBR trip – with the source at EVE, cannot detect successful tripping of the WayE interrupter by detecting current crossing from above to below some threshold
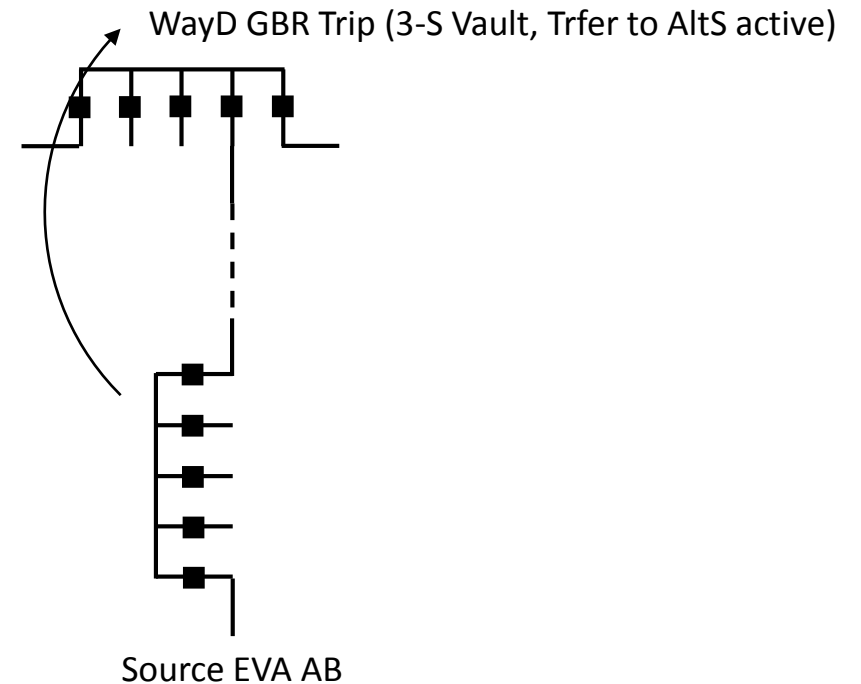
GBR trip – with the source at AB EVA, cannot detect successful tripping of the WayD interrupter by detecting current crossing from above to below some threshold

50BF Protection

- 'Line' (external) fault – source MB EVE – CB Fail Vlt2 WayA

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup
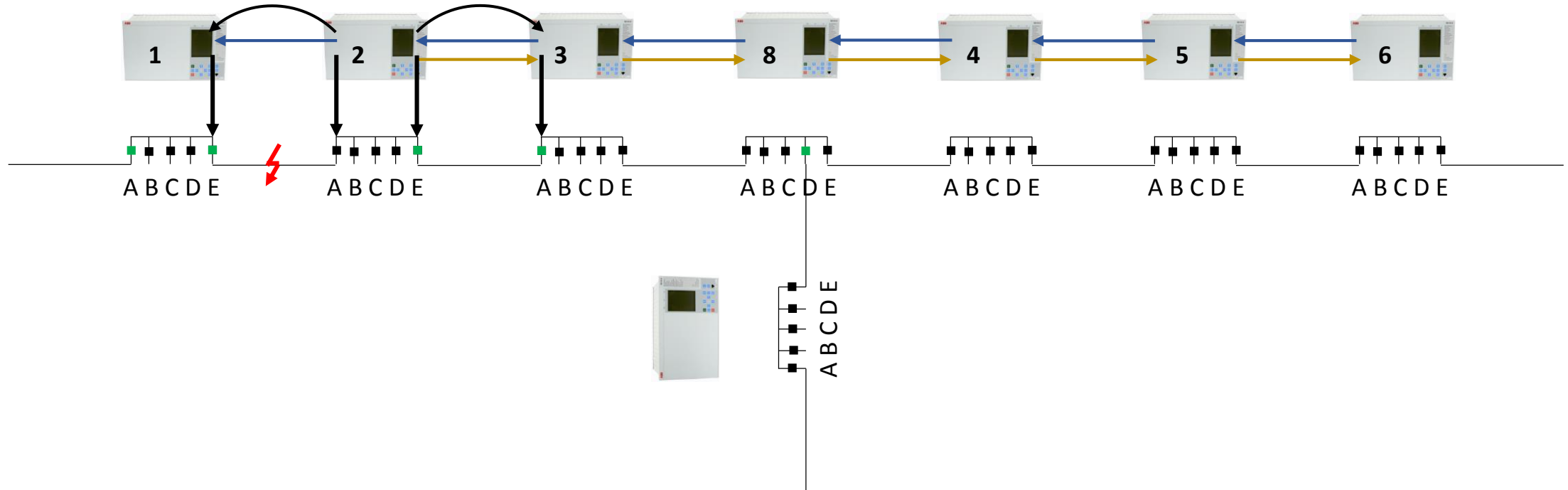
50BF Protection

- 'Line' (external) fault – source MB EVE – CB Fail Vlt2 WayE

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup
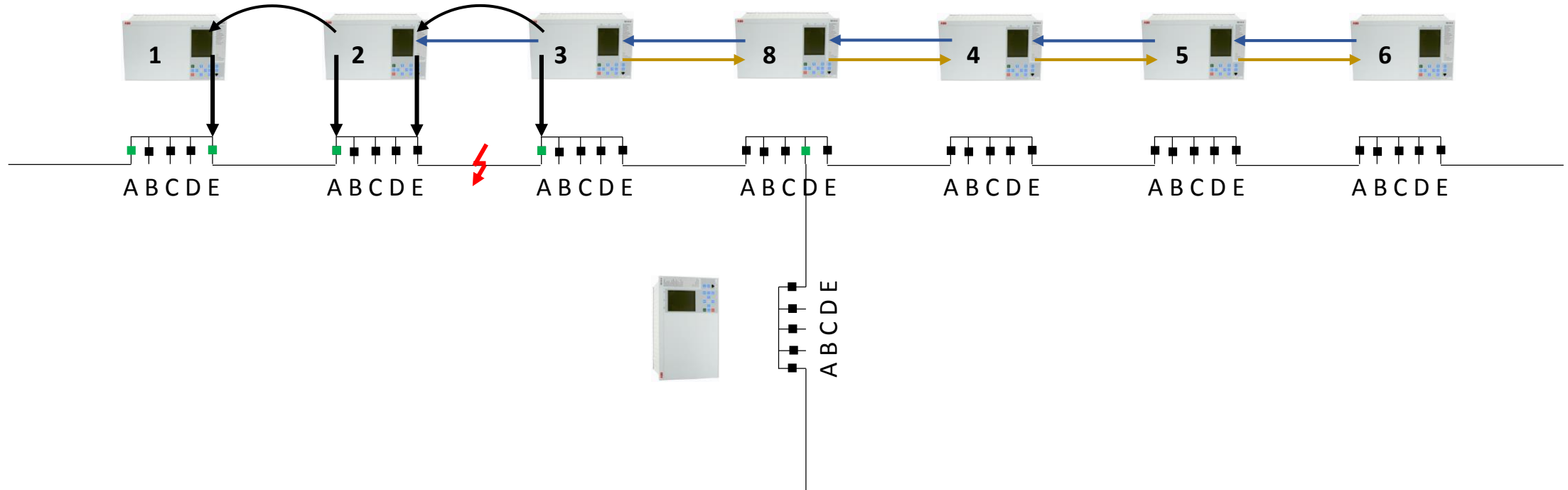
50BF Protection

- Load fault WayC – source MB EVE – CB Fail Vlt2 WayC
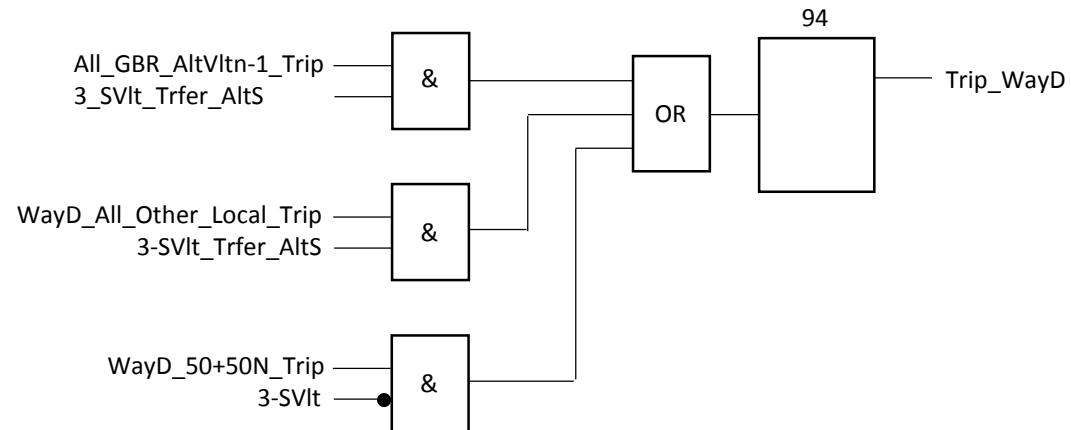
GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup
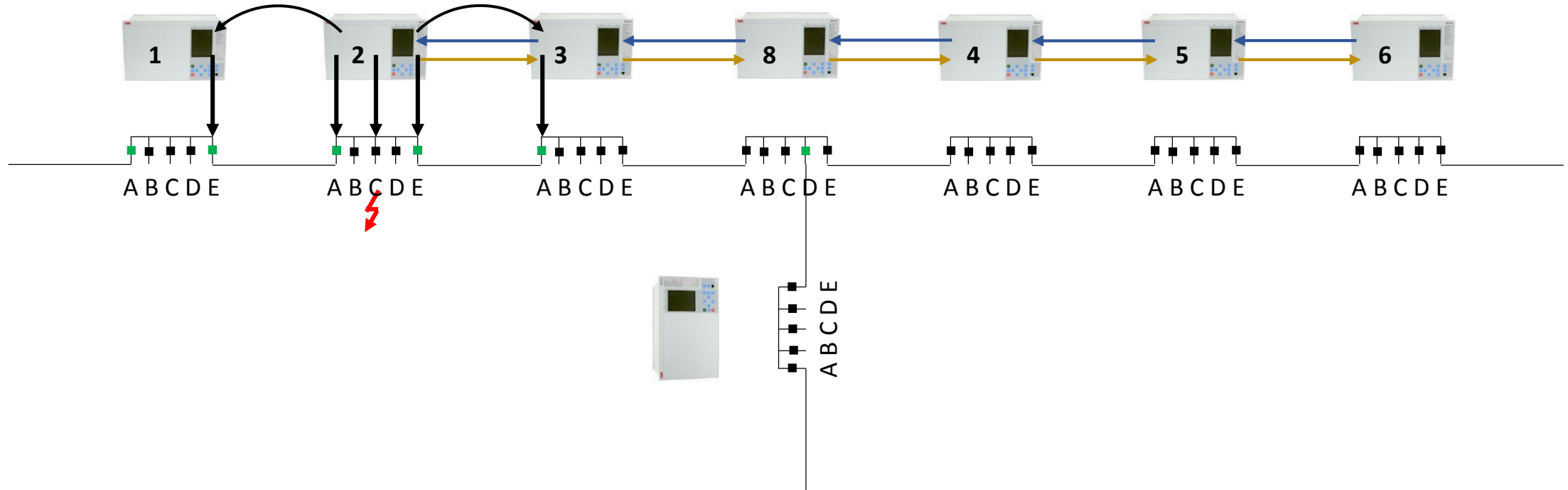
50BF Protection

- 'Line' (external) fault – source MB EVE – CB Fail Vlt8 WayA

  - "Transfer to Alternate Source" NOT active

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup
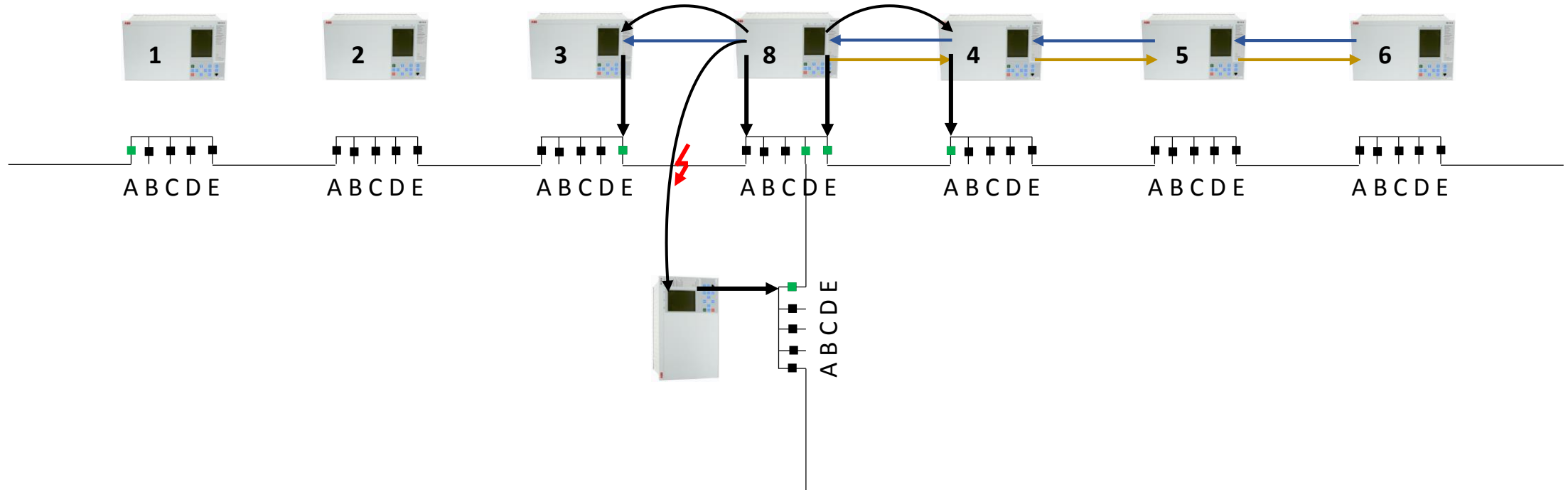
50BF Protection

- 'Line' (external) fault – source AB EVA – CB Fail Vlt8 WayA
  - "Transfer to Alternate Source" active

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup

GBS_AltVltn-1_WayD_51_Pickup
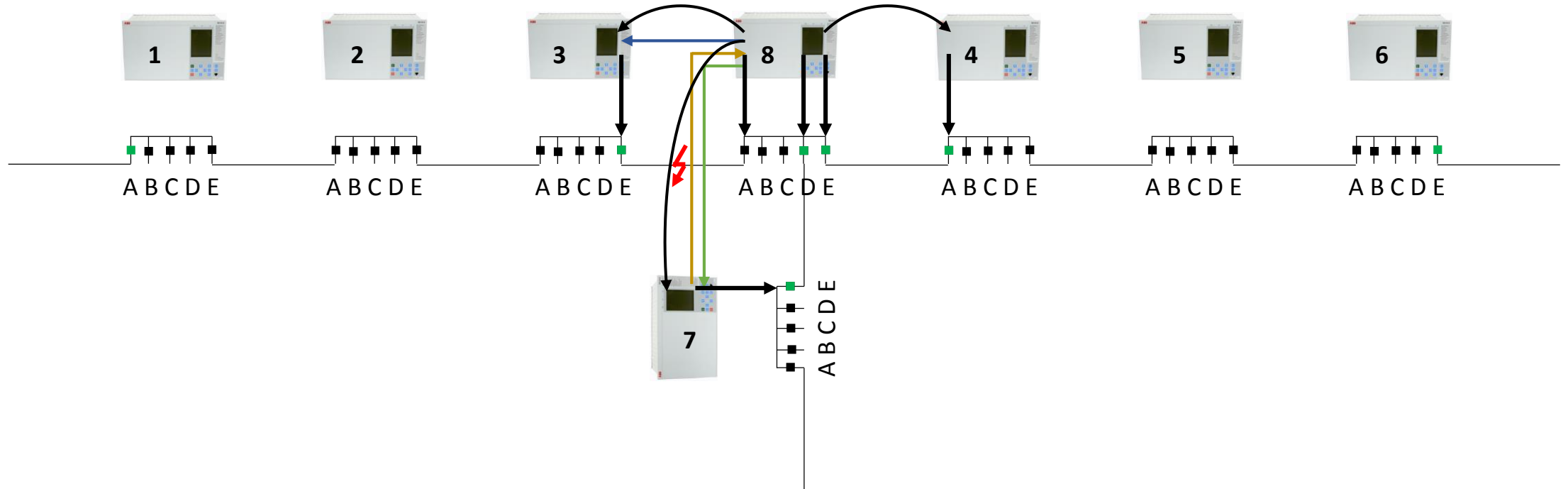
50BF Protection

- Load fault – source MB EVE – CB Fail Vlt8 WayC

  - "Transfer to Alternate Source" NOT active

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup
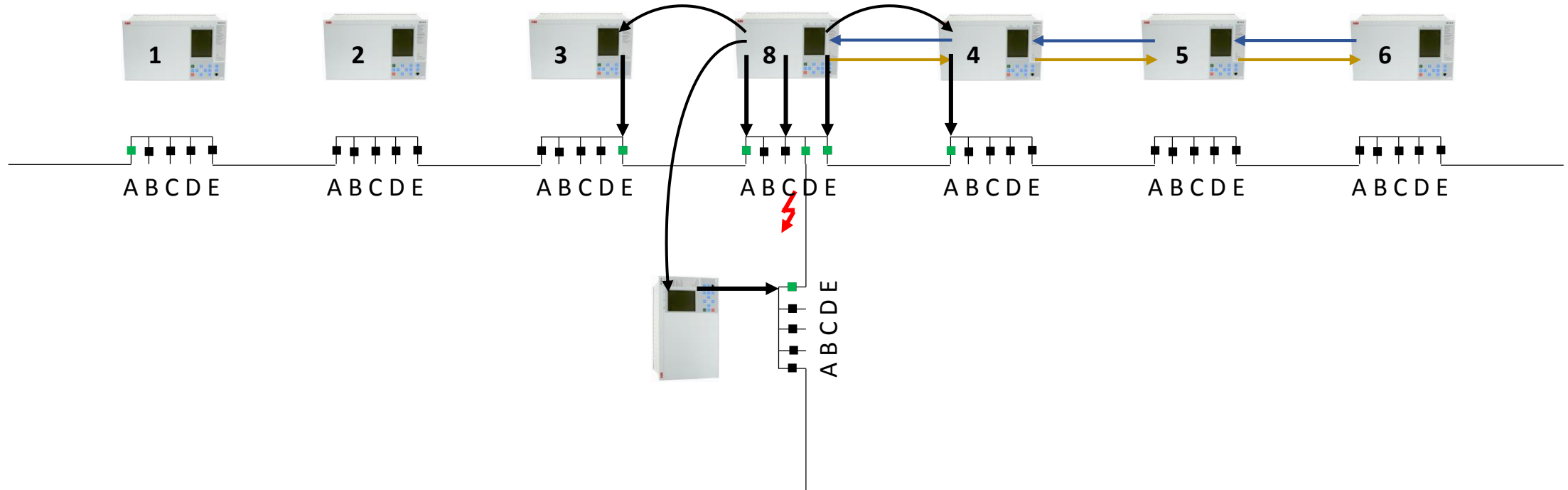
50BF Protection

- Load fault – source AB EVA – CB Fail Vlt8 WayC

  - "Transfer to Alternate Source" active

GBS_Vltn+1_WayE_51_Pickup

GBS_AltVltn-1_WayD_51_Pickup
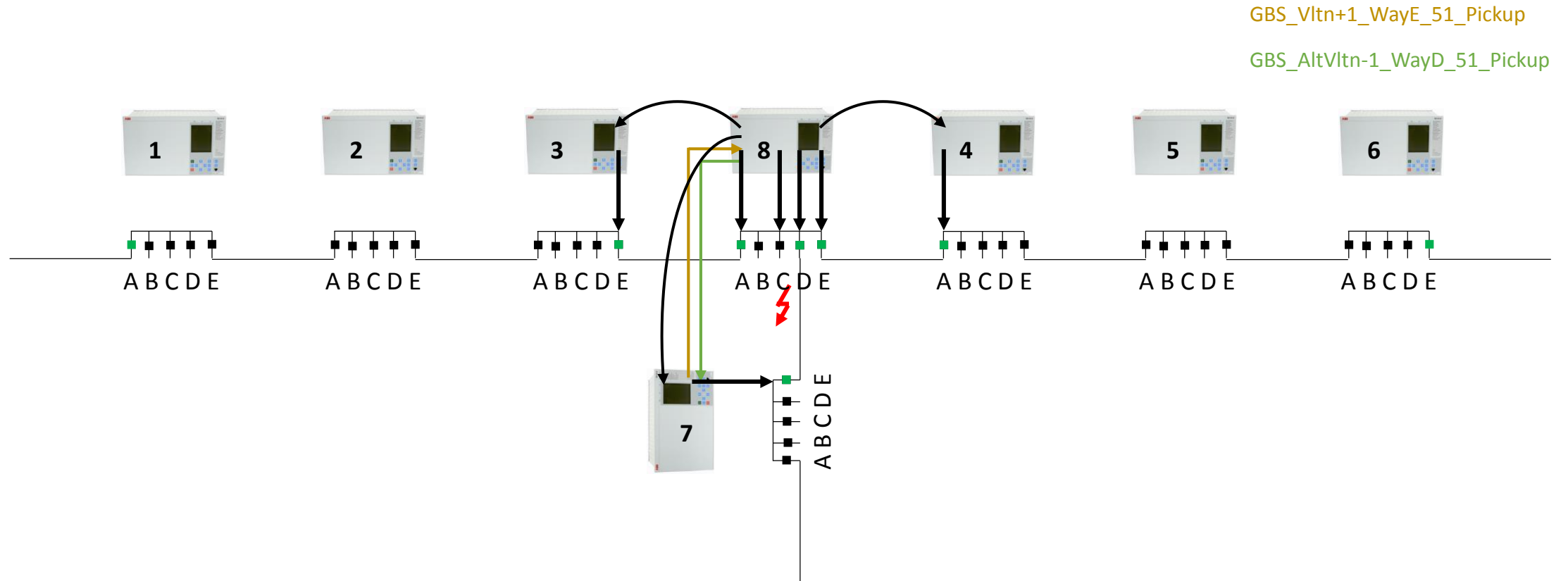
50BF Protection

- 'Line' (external) fault – source AB EVA – CB Fail Vlt7 WayE

  - "Transfer to Alternate Source" active

GBS_Vltn+1_WayE_51_Pickup
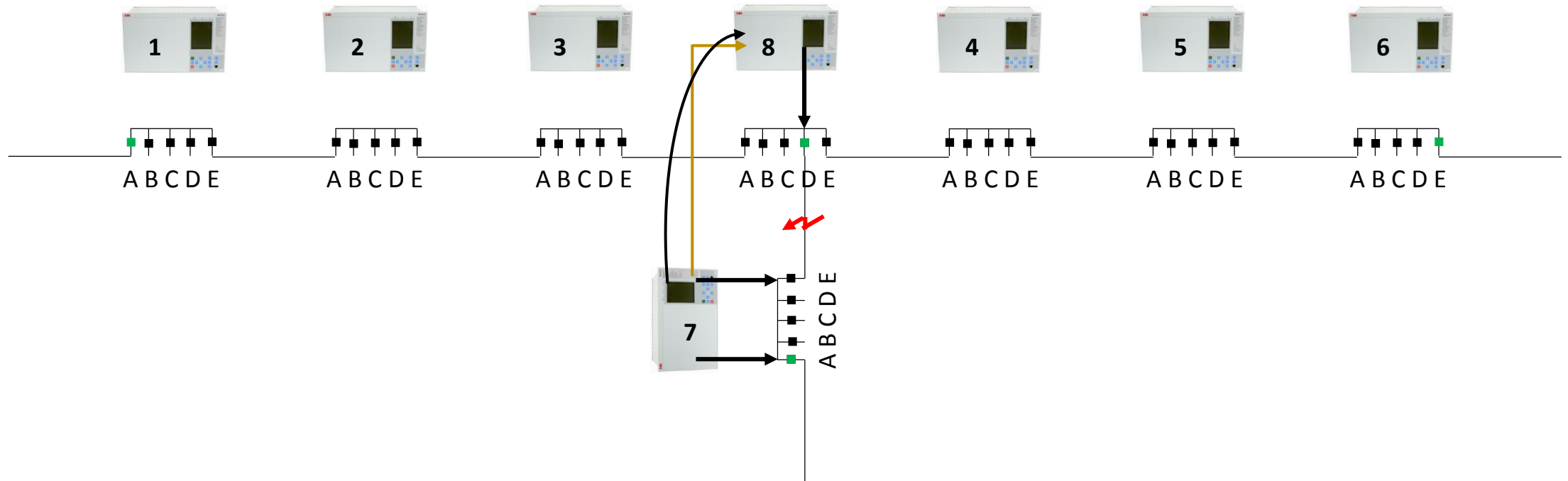
50BF Protection

- 'Line' (external) fault – source AB EVA – CB Fail Vlt8 WayD

  - "Transfer to Alternate Source" active

GBS_Vltn+1_WayE_51_Pickup
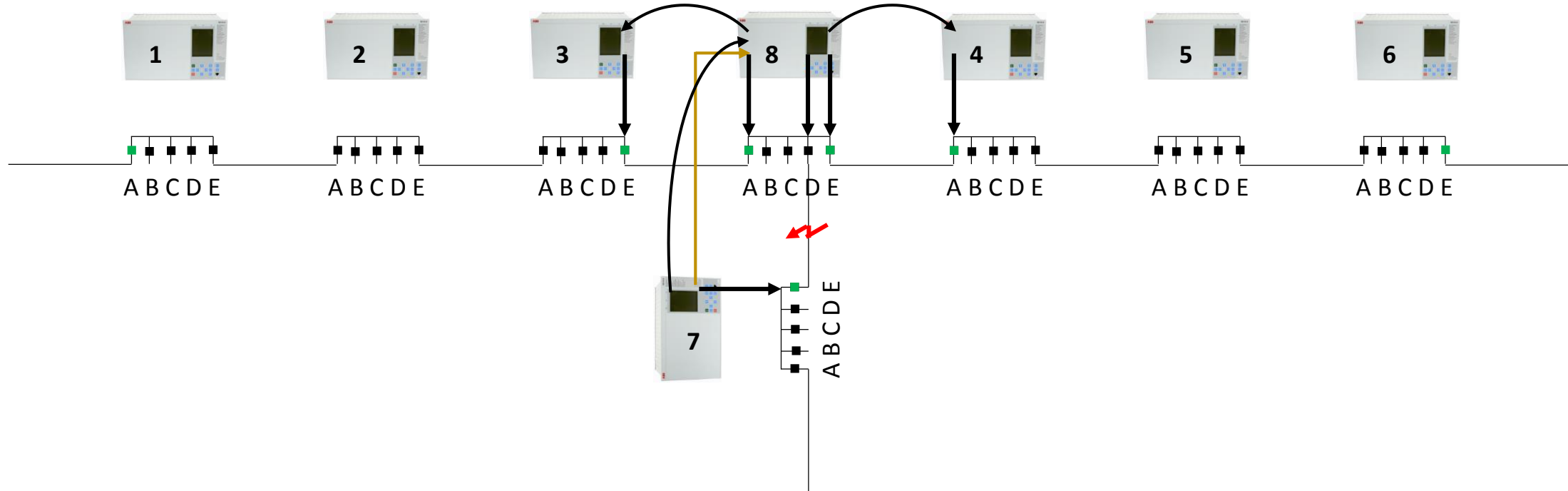
Signal Transfer Along the Vault Line – MB only

- Source of signal "X" Vlt1 (MB EVA) – transmit to all MB vaults

  - After transfer, all vaults from Vlt1 (MB EVA) in the n+1 direction to Vlt6 (MB EVE) will have signal "X" status
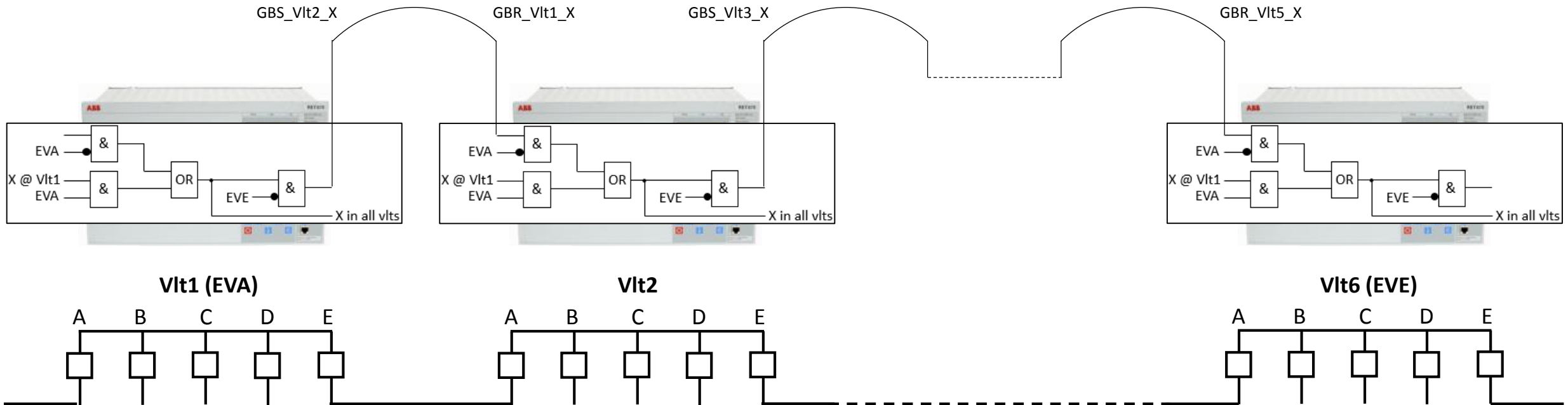
  - Similarly for a signal "Z" requiring transmission from Vlt6 to Vlt1 (MB EVE to MB EVA) – after transfer, all vaults from Vlt6 (MB EVE) in the n-1 direction to Vlt1 (MB EVA) will have signal "Z" status

Signal Transfer Along the Vault Line – MB only

- Source of signal "Y" Vlt3 (MB) – transmit to all MB vaults

  - After transfer, all vaults in both the n+1 direction to Vlt6 (MB EVE) and n-1 direction to Vlt1 (MB EVA) will have signal "Y" status
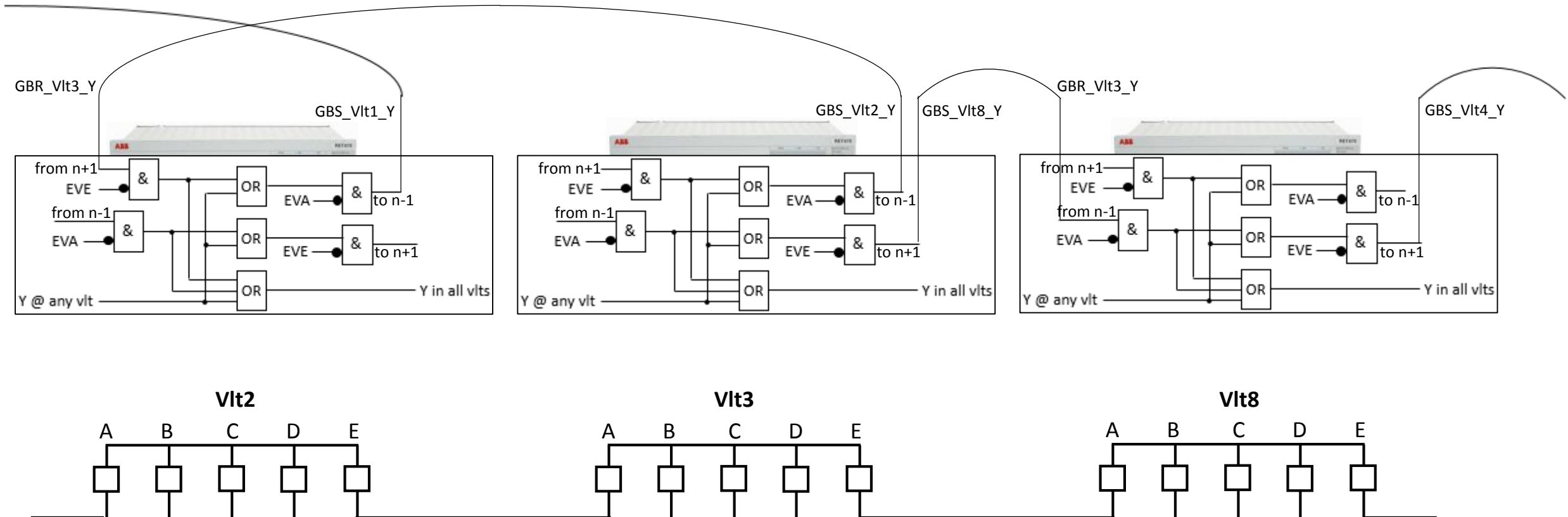
Transfer to Other EV

- Principle of operation

  - MB single-end source, e.g. MB EVE

  - No LO

  - Fault, fault isolation, close open end
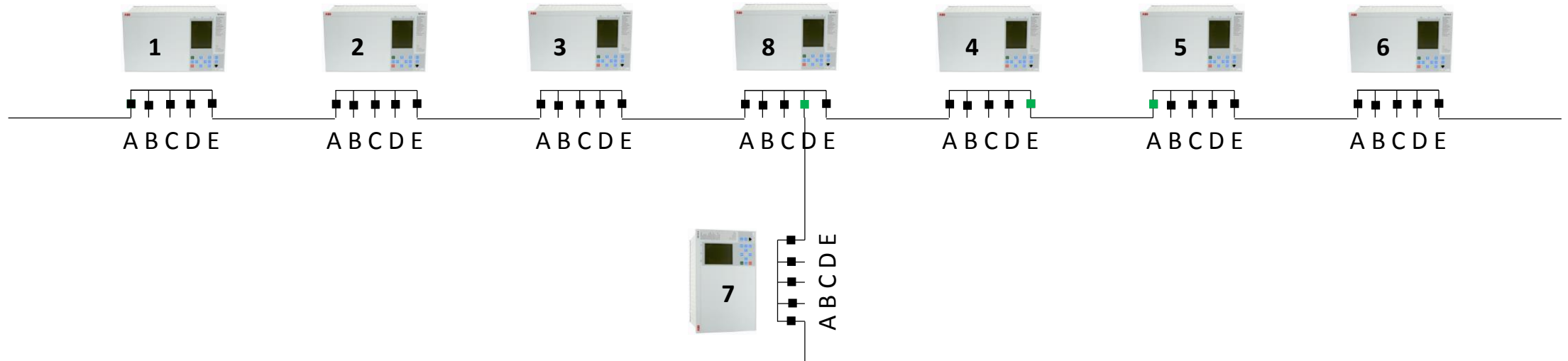
Transfer to Other EV

- Set/Reset LO

  - LO set/reset can be issued at any MB vault; transferred along the MB vault line to all vaults; all MB vaults have the same selection

  - When LO is set, "Transfer to Other EV" is not permitted

  - A distinction is made between the reasons causing LO to be set, which can be allocated to one of two categories

    - Type(i) LO set that requires the reset LO command to reset

      - E.G. Set command; "Transfer to Other EV" occurred, successful or unsuccessful; fault was not isolated at the non-source side; etc

    - Type(ii) LO set that can be automatically reset when the condition causing the set goes away

      - E.G. open point anywhere along the MB vault line, except EVA WayA or EVE WayE; voltage is low at the opposite end to the source; comms fail anywhere along the MB vault line; etc
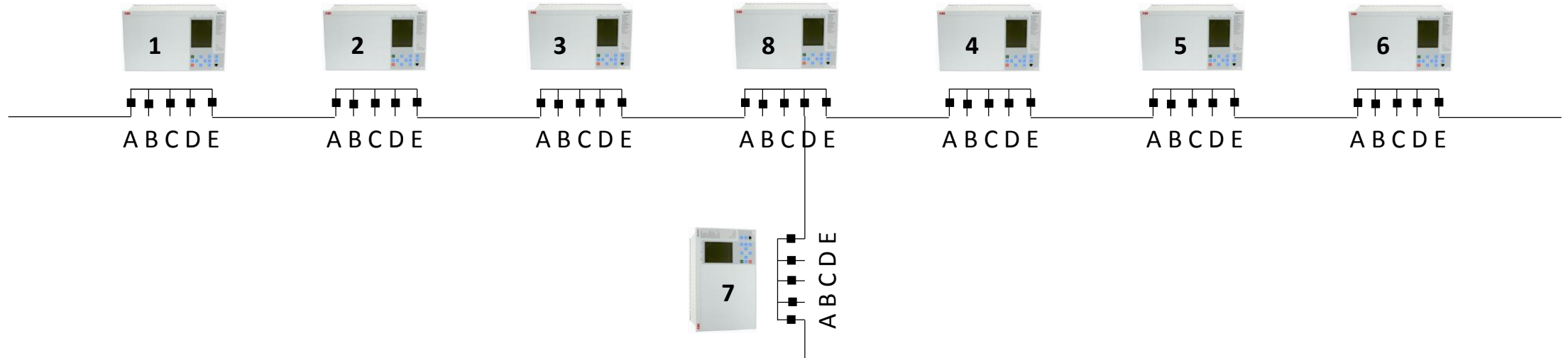
Transfer to Other EV

- Set/Reset LO

    - E.G. Type(i) LO set – OR-function of all 'set LO' type(i) signals

        - Set 'type(i)' LO "Transfer to Other EV" at the vault where this OR-signal originates

        - Send this signal to the n+1 adjacent vault (so long as the vault where the signal originated is not MB EVE) and to the n-1 adjacent vault (so long as the vault where the signal originated is not MB EVA)

        - When the n+1 vault receives the signal from the n-1 vault, send it in the n+1 direction (until MB EVE is reached)

        - Likewise, when the n-1 vault receives the signal from the n+1 vault, send it in the n-1 direction (until MB EVA is reached)

        - Set 'type(i)' LO "Transfer to Other EV" at each vault on receipt of the transmitted signal – in this way, all vaults on the MB vault line will get "Transfer to Other EV" 'type(i)' LO set
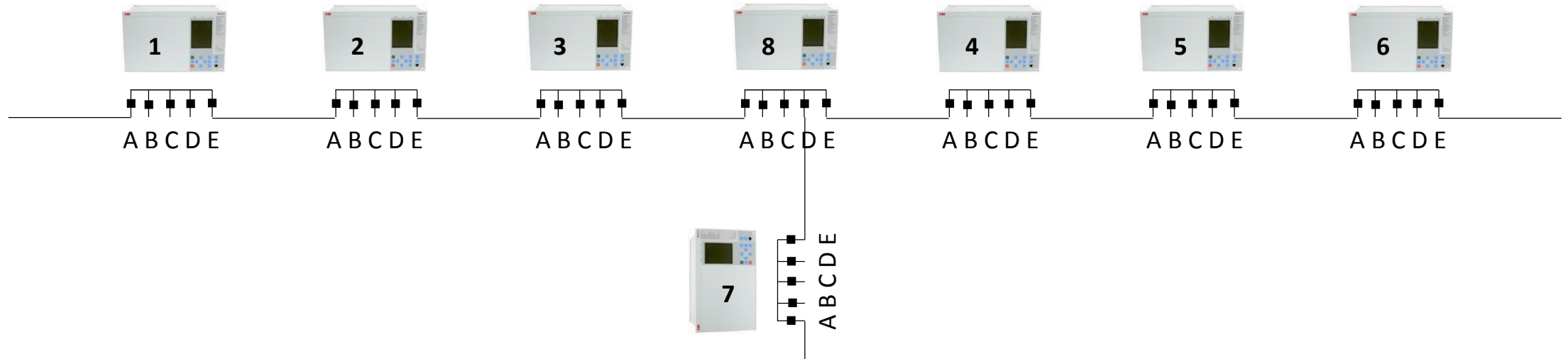
Transfer to Other EV

- Set/Reset LO

  - All vaults will have "Transfer to Other EV" LO set

  - All vaults will 'know' the 'type' of LO that has been set

  - All vaults will have the same 'type' of LO set
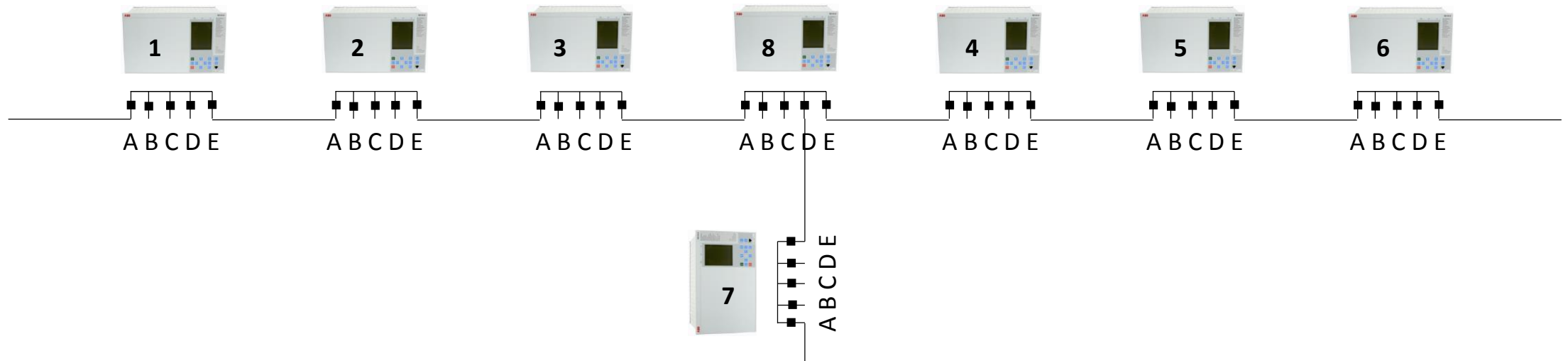
Transfer to Other EV

- Direction of MB source
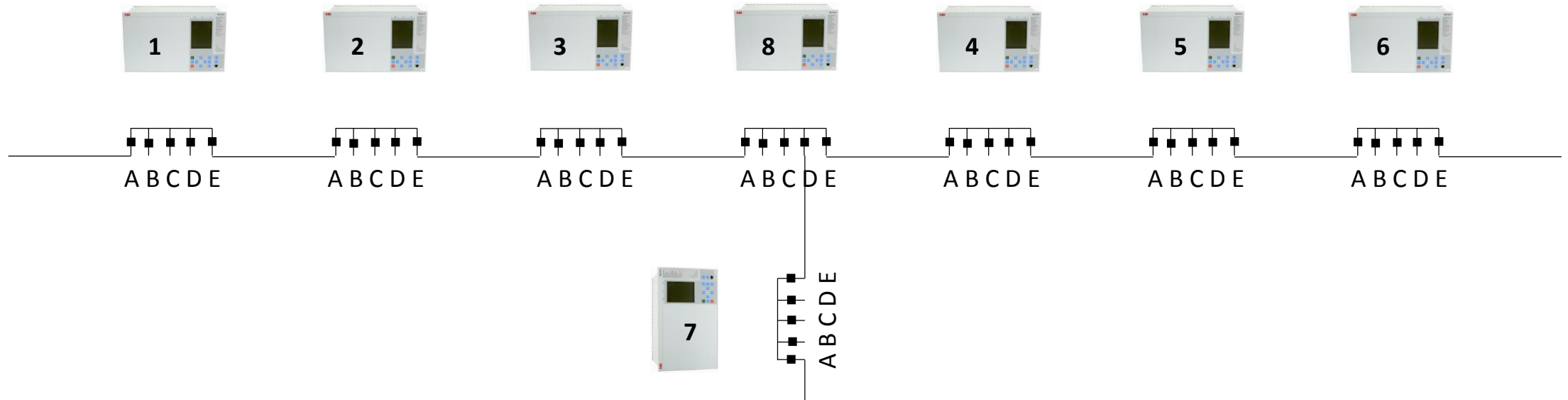
- Ext_Flt_WayA_51/N_Trip
  - EVE source-end
- Ext_Flt_WayE_51/N_Trip
  - EVA source-end

Transfer to Other EV

- Direction of MB source
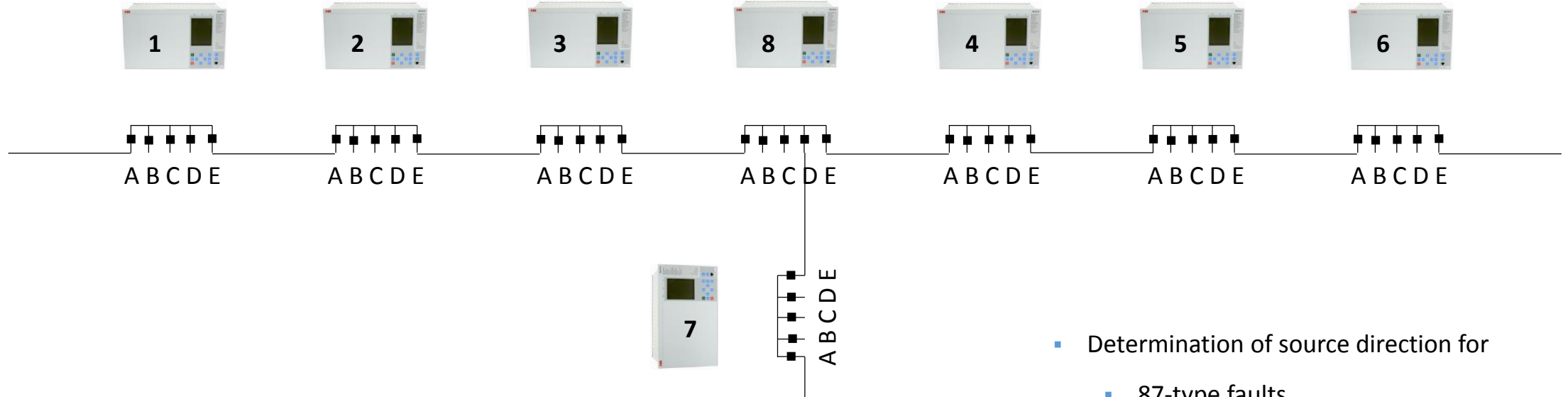
- Internal 87/N-type fault, 50/N load-side fault (with CB fail of load interrupter)

  - MB interrupters WayA and WayE are tripped, so want "Transfer to Other EV"

  - What is the direction of the source?

  - In what direction must the "Transfer to Other EV" close signal be sent?

- Determination of source direction for

  - 87-type faults

  - WayB+C+2-SD_50BF
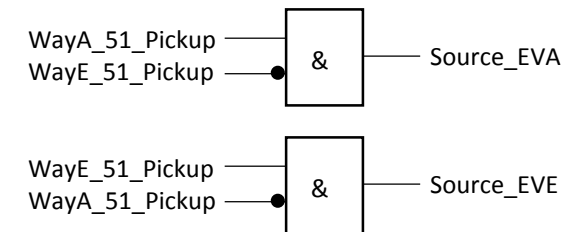
- Similar logic based on 51N pickups for 87N-type faults

Transfer to Other EV

- 51 'line' (external) fault – source at MB EVE

GBS_Vltn-1_Cmd_Set_LO_Trfer_Oth_EV

GBS_Vltn+1_Cmd_Set_LO_Trfer_Oth_EV

GBS_Vltn+1_EVA_WayA_Closed

GBS_Vlt1_Trfer_OEV_Close_EVA_WayA

GBS_Vlt2_Trfer_OEV_Close_EVA_WayA

GBS_Vlt3_Trfer_OEV_Close_EVA_WayA

GBS_Vlt8_Trfer_OEV_Close_EVA_WayA

GBS_Vlt4_Trfer_OEV_Close_EVA_WayA

GBS_Vlt5_WayE_Op+WayE_BF_WayA_Op

GBS_Vlt4_WayA_51+51N_Trip

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup

Transfer to Other EV

- 51 'line' (external) fault – source at MB EVE – Vlt4 WayE "fails to open" (CB fail)

GBS_Vltn-1_Cmd_Set_LO_Trfer_Oth_EV

GBS_Vltn+1_Cmd_Set_LO_Trfer_Oth_EV

GBS_Vltn+1_EVA_WayA_Closed

GBS_Vltn-1_Trfer_OEV_Close_EVA_WayA

GBS_Vlt5_WayE_Op+WayE_BF_WayA_Op

GBS_Vlt8_WayE+3-SD_50BF_BUTrip

GBS_Vlt4_WayA_51+51N_Trip

1   **2**   **3**   **8**   **4**   **5**   **6**

A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E

A B C D E

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup
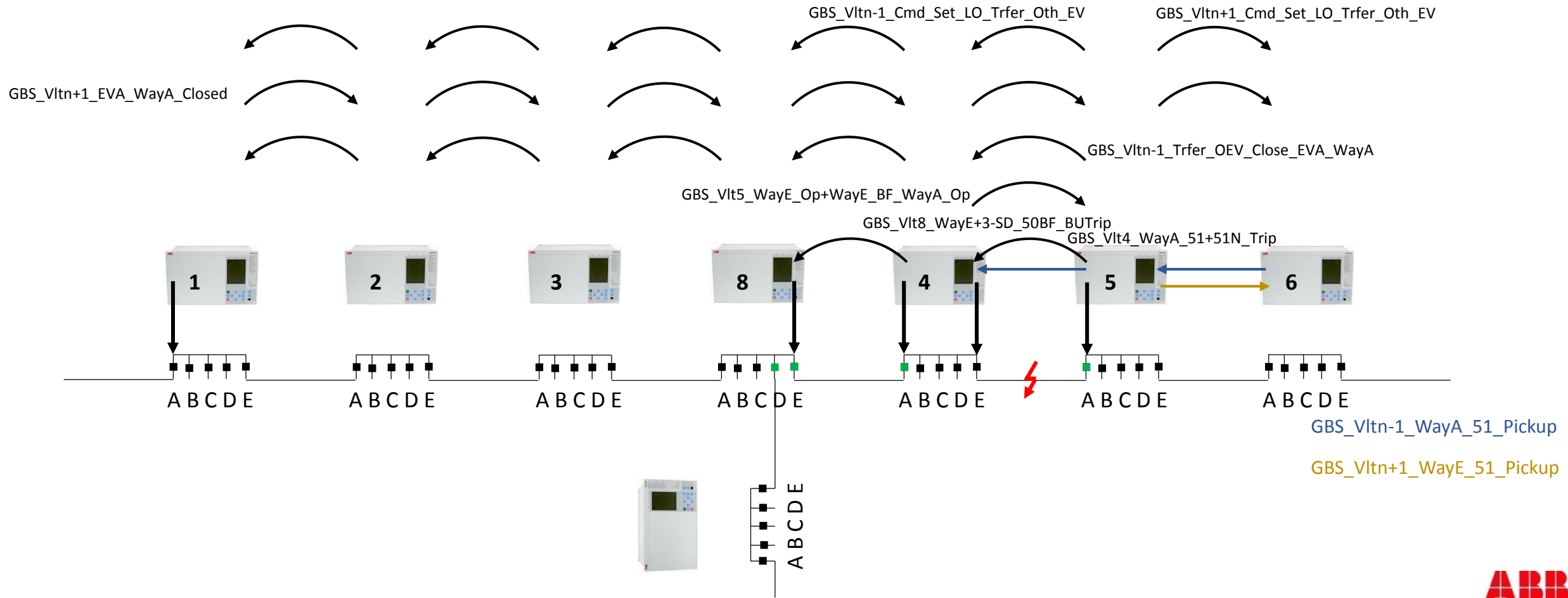
Transfer to Other EV

- Internal 87-type fault in Vlt5 – source at MB EVE

GBS_Vltn-1_Cmd_Set_LO_Trfer_Oth_EV

GBS_Vltn+1_Cmd_Set_LO_Trfer_Oth_EV

GBS_Vltn+1_EVA_WayA_Closed

GBS_Vltn-1_Trfer_OEV_Close_EVA_WayA

GBS_Vlt5_WayE_Op+WayE_BF_WayA_Op

GBS_Vlt4_87+87N_Trip

GBS_Vlt6_87+87N_Trip

1   2   3   8   4   5   6

A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup

A B C D E

WayE_51_Pickup
WayA_51_Pickup

&

Source_EVE

Transfer to Other EV

- Load-side fault Vlt5 WayC – source at MB EVE – WayC "fails to open" (CB fail)

Transfer to Other EV

- 51 'line' (external) fault – source at MB EVE – Vlt1 WayA "fails to close"

GBS_Vltn-1_Cmd_Set_LO_Trfer_Oth_EV

GBS_Vltn+1_Cmd_Set_LO_Trfer_Oth_EV

GBS_Vltn-1_Trfer_OEV_Close_EVA_WayA

GBS_Vlt5_WayE_Op+WayE_BF_WayA_Op

GBS_Vlt4_WayA_51+51N_Trip

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup

Transfer to Other EV

- 51 'line' (external) fault – source at MB EVE – failure to isolate at vault (Vlt4) on non source-side of fault

GBS_Vltn-1_Cmd_Set_LO_Trfer_Oth_EV

GBS_Vltn+1_Cmd_Set_LO_Trfer_Oth_EV

GBS_Vlt4_WayA_51+51N_Trip

1   2   3   8   4   5   6

A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E   A B C D E

A B C D E

GBS_Vltn-1_WayA_51_Pickup

GBS_Vltn+1_WayE_51_Pickup

Pri-Source Selection

- Set/Reset commands

  - Can select either MB EVA or MB EVE to be pri-source

    - MB EVA pri-source set/reset

      - Set to select MB EVA pri-source

      - Reset to deselect MB EVA pri-source

    - Similarly, MB EVE pri-source set/reset

  - Not possible to select both MB EVA and MB EVE pri-source

  - Possible to have neither of MB EVA or MB EVE selected pri-source

  - MB EVA set pri-source is transmitted along the MB vault line from EVA to EVE – EVA set, or not set (reset), is known at both MB EVA and MB EVE

  - Likewise, MB EVE set pri-source

1	2	3	8	4	5	6
EVA (MB)						EVE (MB)
A B C D E	A B C D E	A B C D E	A B C D E	A B C D E	A B C D E	A B C D E
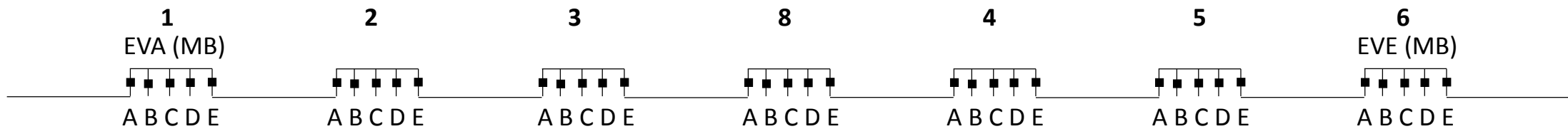
Pri-Source Selection

- Set MB EVA pri-source

  - AND-function of:

    - Set command

    - No block

  - Block set MB EVA pri-source, OR-function of:

    - MB EVE set pri-source

    - Comms not OK [between any two vaults] anywhere on the MB vault line

    - Path is open at any MB vault, excluding EVA WayA and EVE WayE

    - No path is open, EVA WayA is open and EVE WayE closed [can't close EVA WayA as then there'd be no open point anywhere in the MB vault line, so can't make MB EVA pri-source]

- Similarly, set MB EVE pri-source
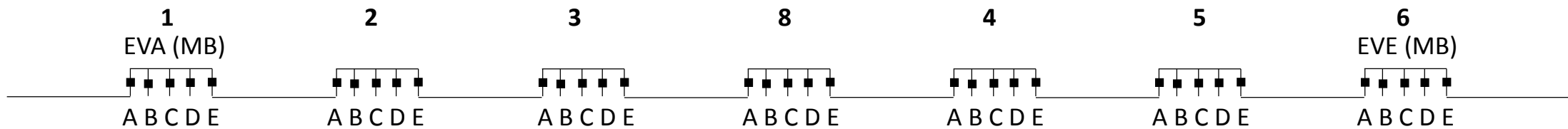
1	2	3	8	4	5	6
EVA (MB)						EVE (MB)
A B C D E	A B C D E	A B C D E	A B C D E	A B C D E	A B C D E	A B C D E

Transfer to Secondary Source

- Principle of operation

    - MB single-end source, e.g. MB EVE

    - No LO

    - The voltage at the source-end goes low, the voltage at the non source-end is high, transfer

    - If the original source-end is selected as the pri-source, and that end's voltage returns to high, retransfer
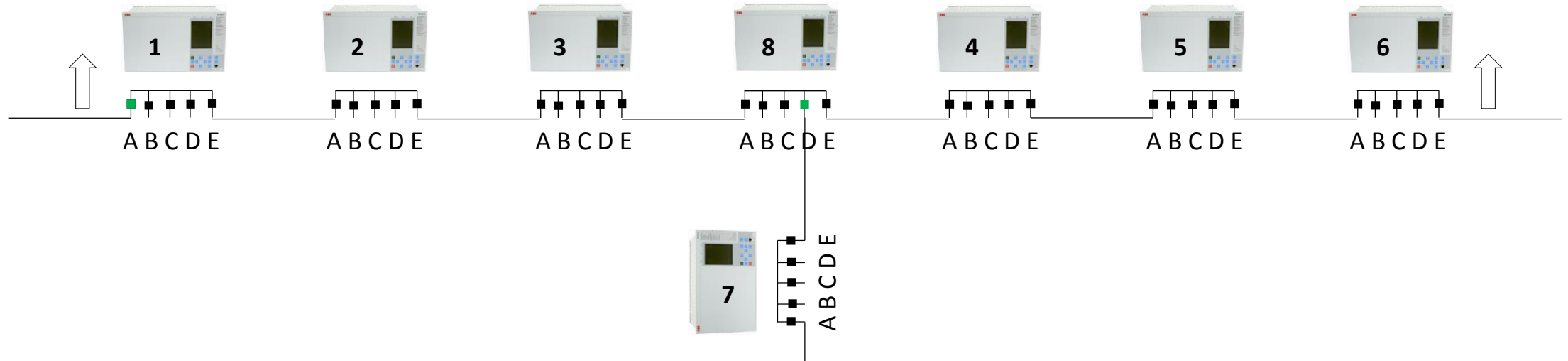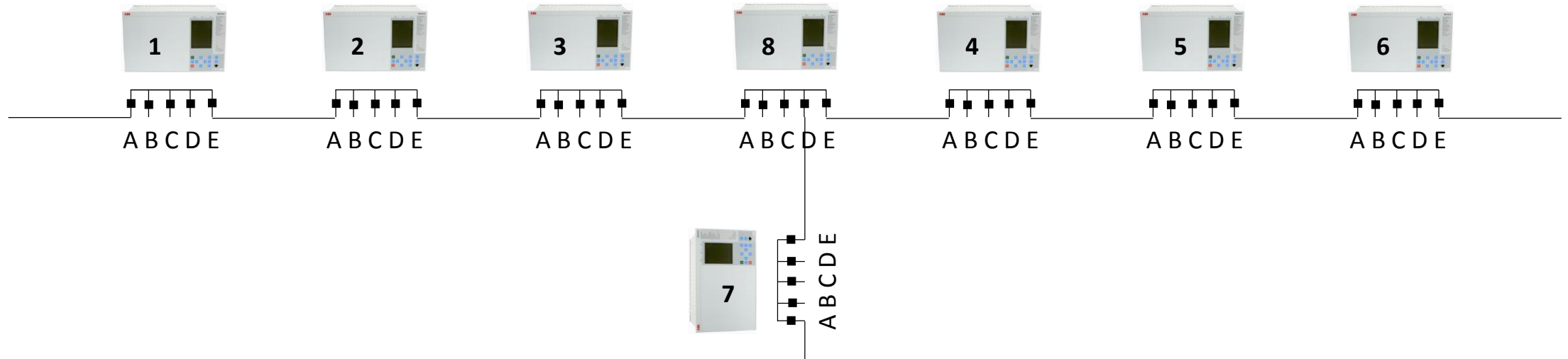
Transfer to Secondary Source

- Set/Reset LO

  - LO set/reset can be issued at either MB EVA or MB EVA; transferred along the MB vault line to the other EV; both MB EVs have the same selection

  - When LO is set, "Transfer to Secondary Source" is not permitted

  - A distinction is made between the reasons causing LO to be set, which can be allocated to one of two categories

    - Type(i) LO set that requires the reset LO command to reset

      - E.G. Set command; "Transfer to Secondary Source" or ReTransfer from Secondary Source" not successful

    - Type(ii) LO set that can be automatically reset when the condition causing the set goes away

      - E.G. open point anywhere along the MB vault line, except EVA WayA or EVE WayE; comms fail anywhere along the MB vault line
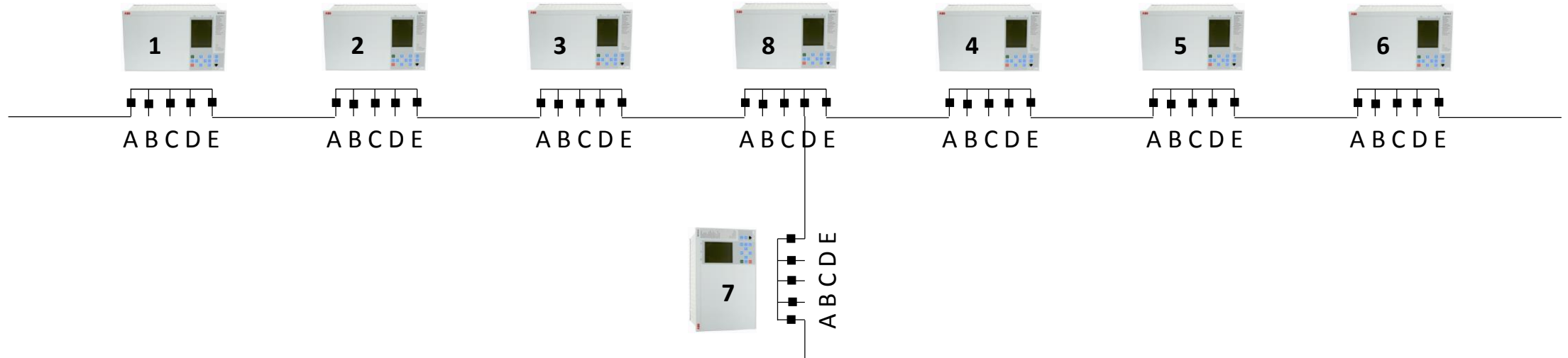
Transfer to Secondary Source

- Set/Reset LO

  - Both MB EVs (EVA & EVE) will have "Transfer to Secondary Source" LO set

  - Both MB EVs will 'know' the 'type' of LO that has been set

  - Both MB EVs will have the same 'type' of LO set

Transfer to Secondary Source

- ## Principle of operation – "Transfer to Secondary Source"

@ MB EVA (vault line source)
WayA voltage goes low (not due to fault)
EVE WayE voltage is high → Set_Trfer_to_SecS_@_EVA
WayA is closed and EVE WayE is open → GOOSE sent down the MB vault line from EVA to EVE
No LO

Trfer_to_SecS_Set_@_EVA → Open WayA
Trfer_to_SecS_Set_@_EVA & WayA open → Close EVE WayE (GOOSE sent down the MB vault line from EVA to EVE)
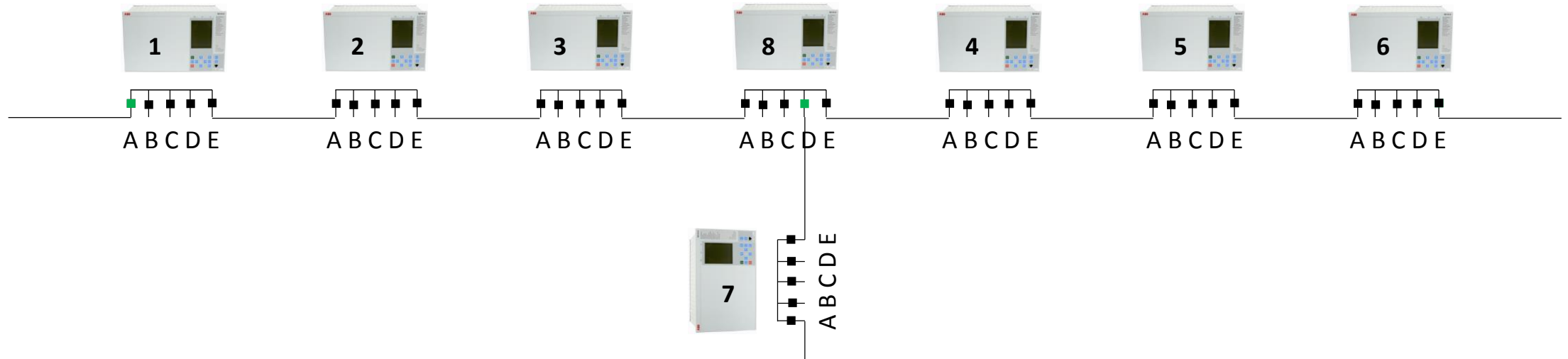

@ MB EVE
On receipt of GOOSE → Close WayE

@ MB EVA
End state correct (WayA open, EVE WayE closed) → "Transfer to Secondary Source" successful
End state not correct (after time delay) → "Transfer to Secondary Source" not successful

Transfer to Secondary Source

- ## Principle of operation – "ReTransfer from Secondary Source"

@ MB EVA (vault line source)
WayA voltage returns high
Trfer_to_SecS_Set
EVA_Pri_Set
WayA is open and EVE WayE is closed

→ Set_ReTrfer_from_SecS_@_EVA

If no pri-source selected, can select Y/N to transfer
To retransfer, originating end must be selected pri-source

ReTrfer_from_SecS_Set_@_EVA → Close WayA
ReTrfer_from_SecS_Set_@_EVA & WayA closed → Open EVE WayE (GOOSE sent down the MB vault line from EVA to EVE)

@ MB EVE
On receipt of GOOSE → Open WayE

@ MB EVA
End state correct (WayA closed, EVE WayE open) → "ReTransfer from Secondary Source" successful
End state not correct (after time delay) → "ReTransfer from Secondary Source" not successful
Not successful with WayA closed and EVE WayE closed → Open WayA
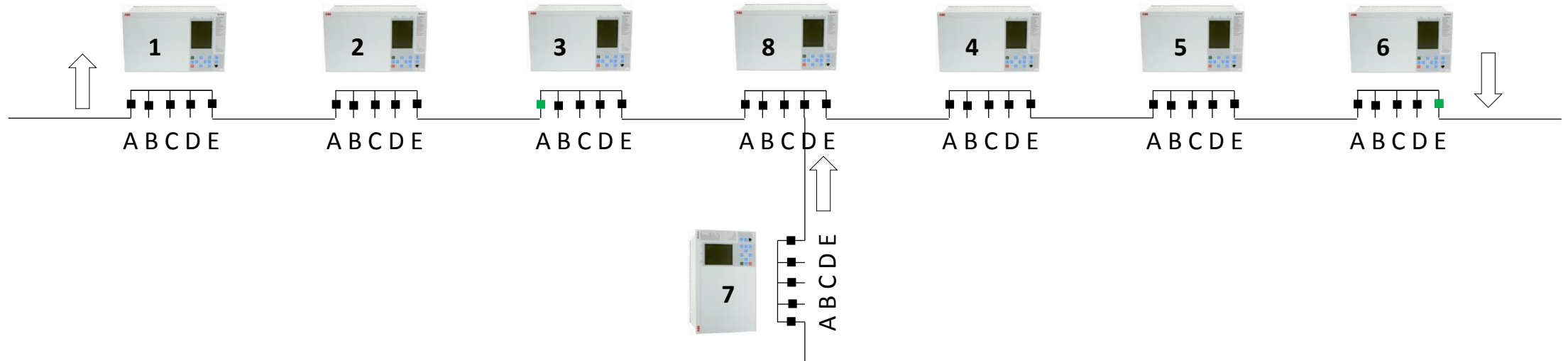
Transfer to Alternate Source

- Principle of operation

    - MB single-end source, e.g. MB EVE

    - No LO

    - The voltage at both MB EVs goes low, the voltage at the 3-source vault WayD is high, transfer
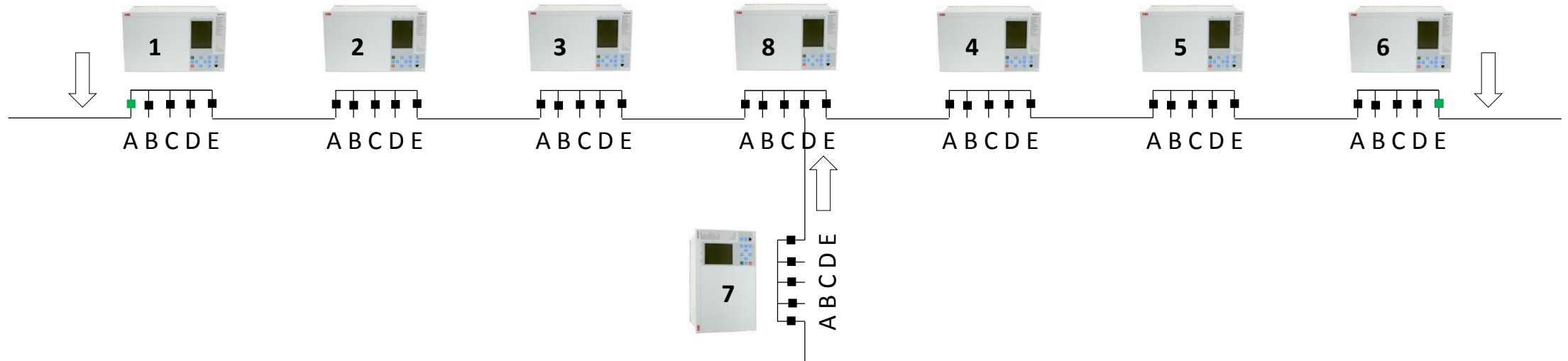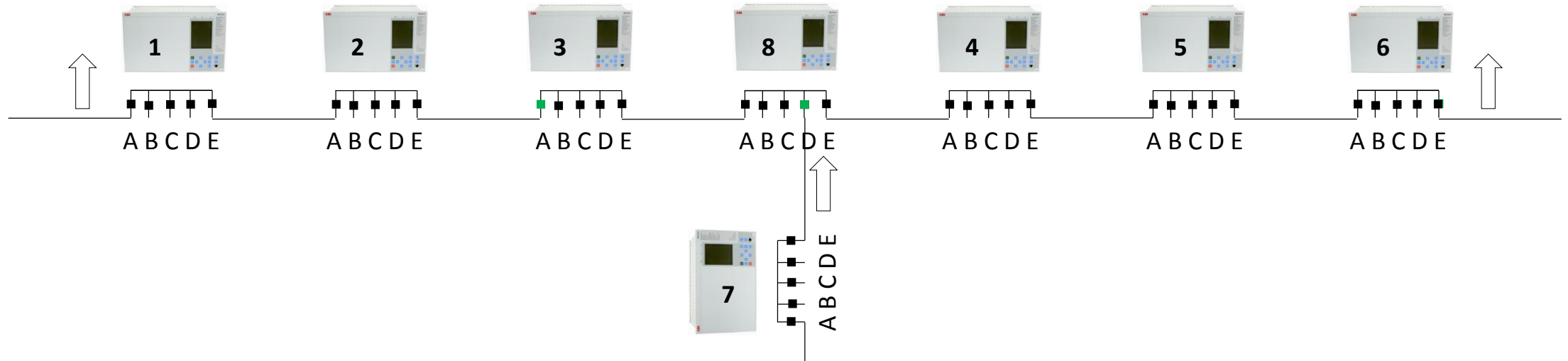
Transfer to Alternate Source

- Principle of operation

  - MB EVE is the source to the open point from the EVE-side, MB EVA is the source to the open point from the EVA-side

  - The 3-source vault is supplied from the MB EVE source

  - No LO

  - The voltage at the MB EVE source goes low, the voltage at the 3-source vault WayD is high, transfer
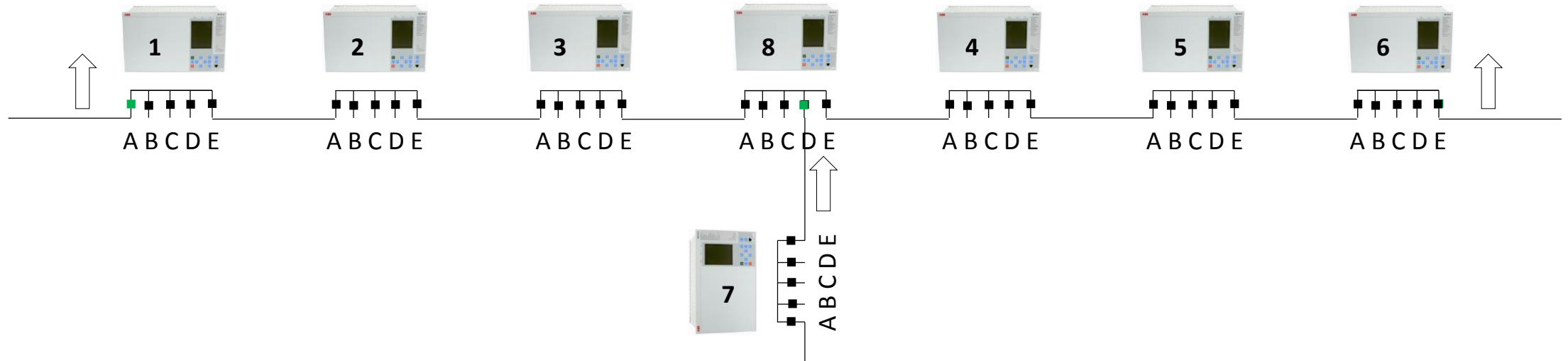
Transfer to Alternate Source

- Principle of operation

  - "Transfer to Alternate Source" is active

  - There is an open point on the EVA-side of the 3-source vault

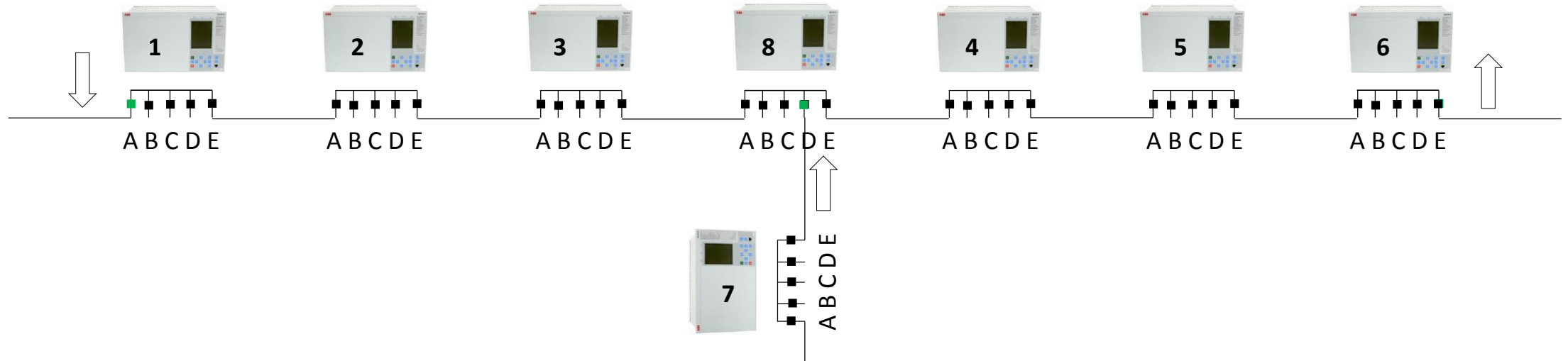 - The voltage at the MB EVE source returns to high, retransfer

Transfer to Alternate Source

- Principle of operation

  - "Transfer to Alternate Source" is active

  - There is NO open point on the MB vault line (except EVA WayA, EVE WayE)

  - The voltage at both MB EVs simultaneously returns to high, retransfer to…

    - the MB EV selected as the pri-source

    - if no pri-source is selected, the EV that was the in-service source before transfer

Transfer to Alternate Source

- Principle of operation

  - "Transfer to Alternate Source" is active

  - There is NO open point on the MB vault line (except EVA WayA, EVE WayE)

  - The voltage at only MB EVE returns to high, retransfer to MB EVE

    - If MB EVE is selected as the pri-source, no further action

    - If no pri-source is selected, no further action
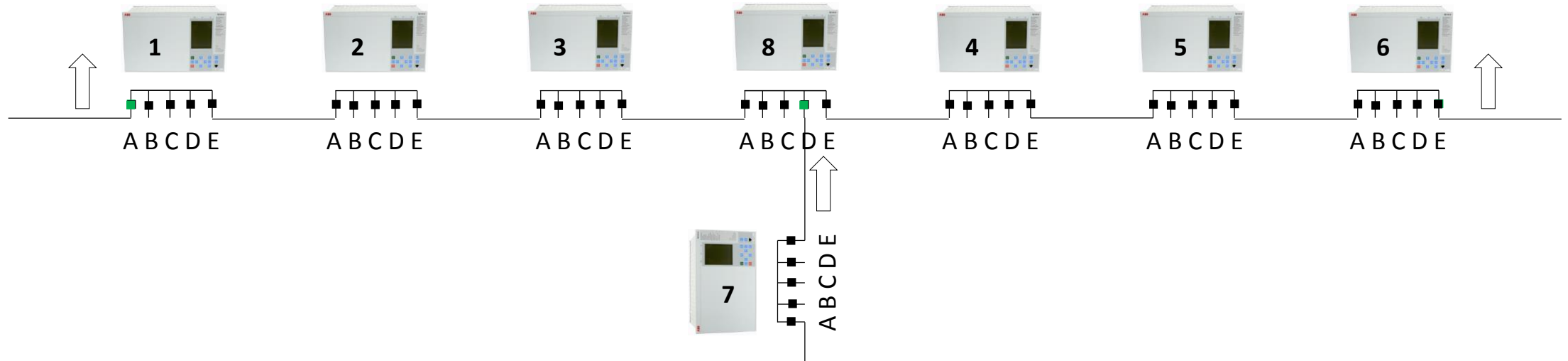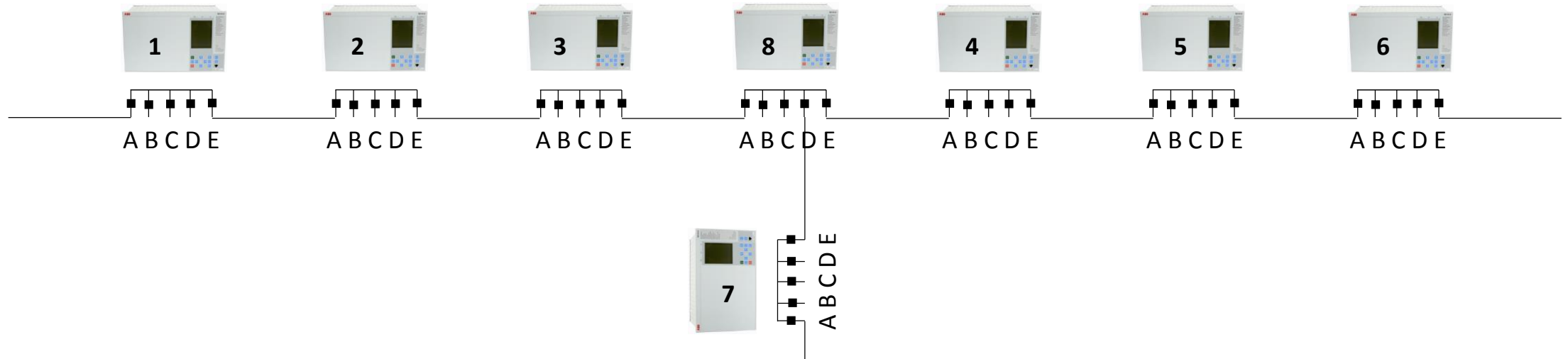
Transfer to Alternate Source

- Principle of operation

  - "Transfer to Alternate Source" is active

  - There is NO open point on the MB vault line (except EVA WayA, EVE WayE)

  - The voltage at only MB EVA returns to high, retransfer to MB EVA

    - If MB EVA is selected as the pri-source, or if no pri-source is selected, no further action

    - If MB EVE is selected as the pri-source, when the voltage at MB EVE returns to high, retransfer to MB EVE
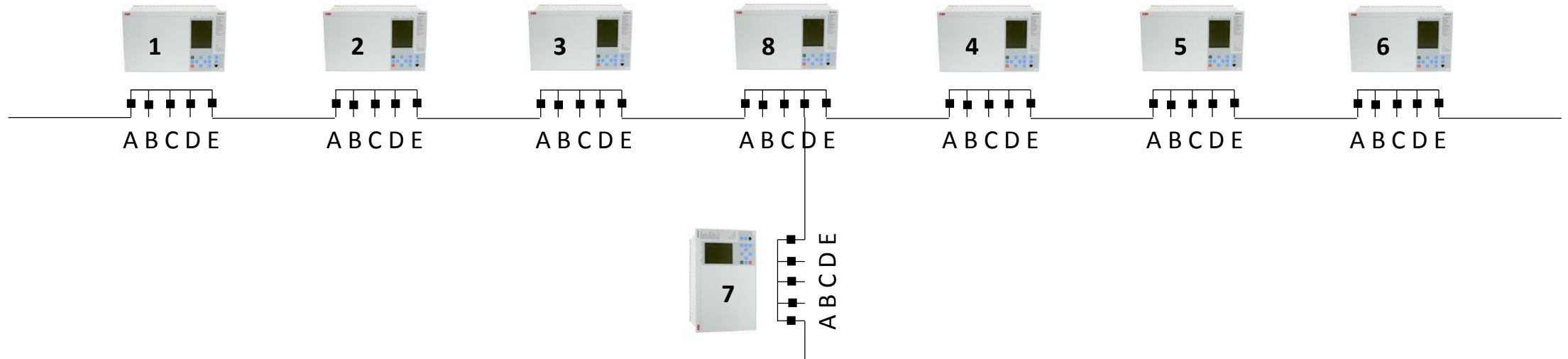
Transfer to Alternate Source

- Set/Reset LO

  - LO set/reset issued at the 3-source vault

  - When LO is set, "Transfer to Alternate Source" is not permitted

  - A distinction is made between the reasons causing LO to be set, which can be allocated to one of two categories

    - Type(i) LO set that requires the reset LO command to reset

      - E.G. Set command; "Transfer to Alternate Source" or "ReTransfer from Alternate Source" not successful

    - Type(ii) LO set that can be automatically reset when the condition causing the set goes away

      - E.G. there is an open point along the MB vault line in the EVA-direction from the 3-source vault as well as in the EVE-direction from the 3-source vault; comms fail anywhere along the MB vault line

Transfer to Alternate Source

- Set LO

  - The 3-source vault will have "Transfer to Alternate Source" LO set

  - It will 'know' the 'type' of LO that is set

Transfer to Alternate Source

- ## Principle of operation – "Transfer to Alternate Source"

  @ 3-S
  Trfer_to_AltS_Set → Send GOOSE command to EVA to open WayA if no path is open in the EVA-dir and EVA WayA is closed
  → Send GOOSE command to EVE to open WayE if no path is open in the EVE-dir and EVE WayE is closed

  @ MB EVA
  On receipt of GOOSE → Open WayA
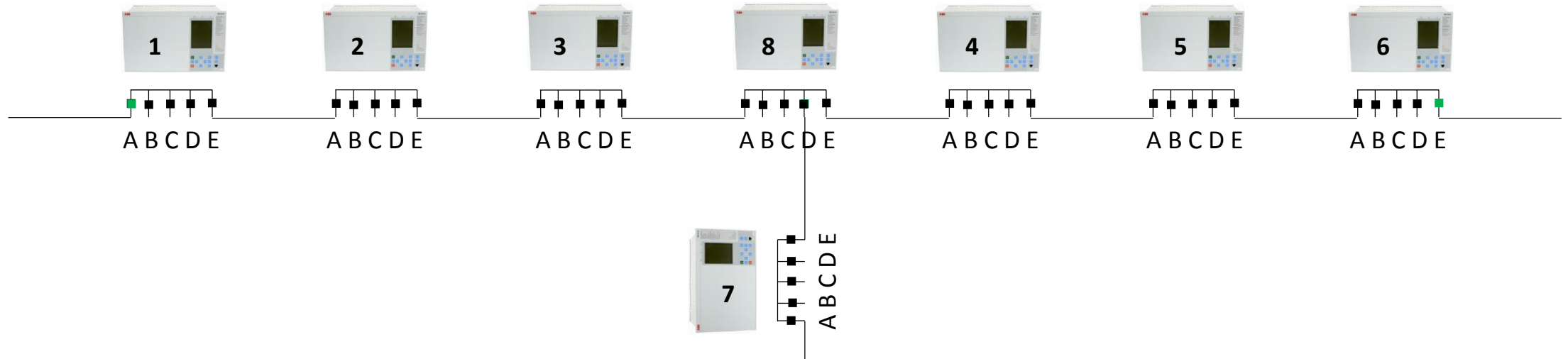
  @ MB EVE
  On receipt of GOOSE → Open WayE

  @ 3-S
  (EVA WayA open + path open EVA-dir) & (EVE WayE open + path open EVE-dir) & WayD voltage high → close WayD
  End state correct (WayD closed) → "Transfer to Alternate Source" successful
  End state not correct (after time delay) → "Transfer to Alternate Source" not successful

Transfer to Alternate Source

- ## Principle of operation – "ReTransfer from Alternate Source"

@ 3-S

ReTrfer_from_AltS_Set → Send GOOSE command to EVA to close WayA if it is MB EVA WayA to be closed

→ Send GOOSE command to EVE to close WayE if it is MB EVE WayE to be closed

@ MB EVA
On receipt of GOOSE → close WayA

@ MB EVE
On receipt of GOOSE → Close WayE

@ 3-S
(EVA WayA closed & path not open EVA-dir) + (EVE WayE closed & path not open EVE-dir) → open WayD
End state correct (WayD open) → "ReTransfer from Alternate Source" successful
End state not correct (after time delay → "ReTransfer from Alternate Source" not successful
Not successful with EVA WayA (+EVE WayE) closed and WayD closed → Open EVA WayA (+ EVE WayE)
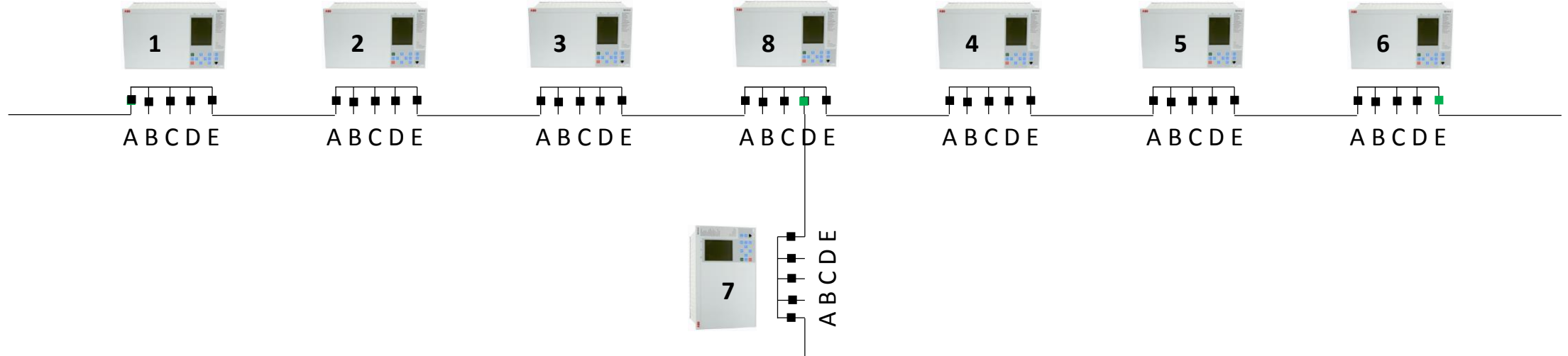
Other Functionality

- Apparatus control (local/remote)
  - WayA, WayE, 3-source WayD
- Pole discrepancy, current based, separately for all Ways
- Battery test

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