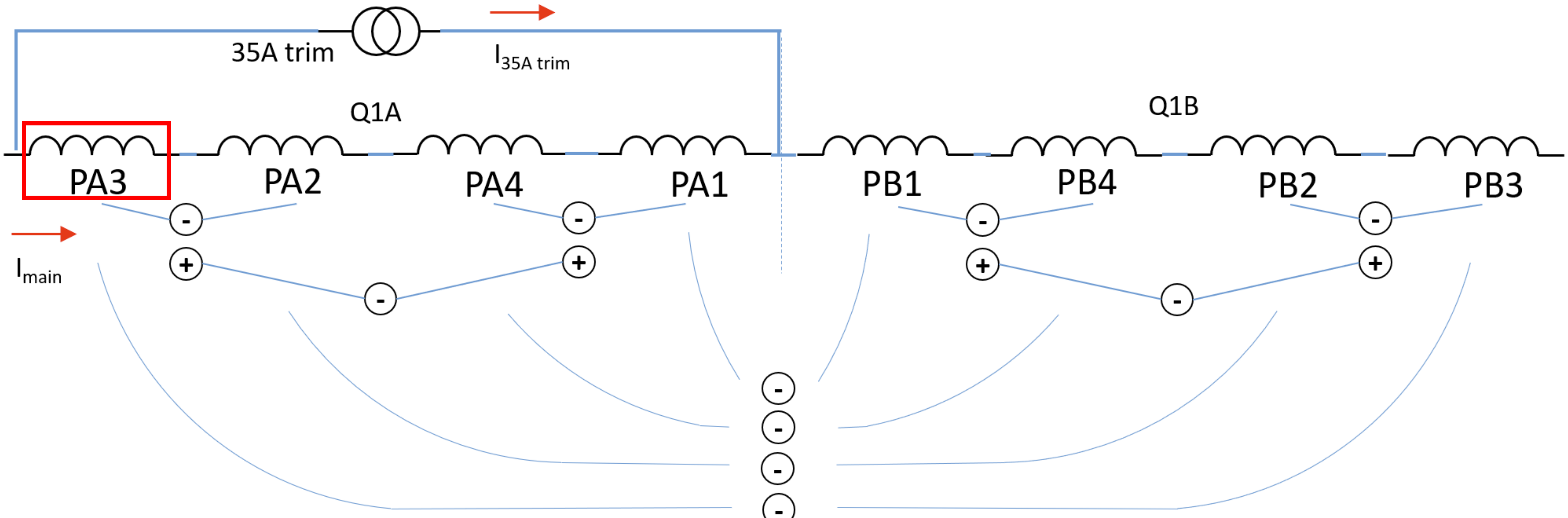
UQDS - IT– Reliability Analysis – Quench protection function

11/06/2024

Quench scenario

Is a single quench the most likely quench scenario? Yes

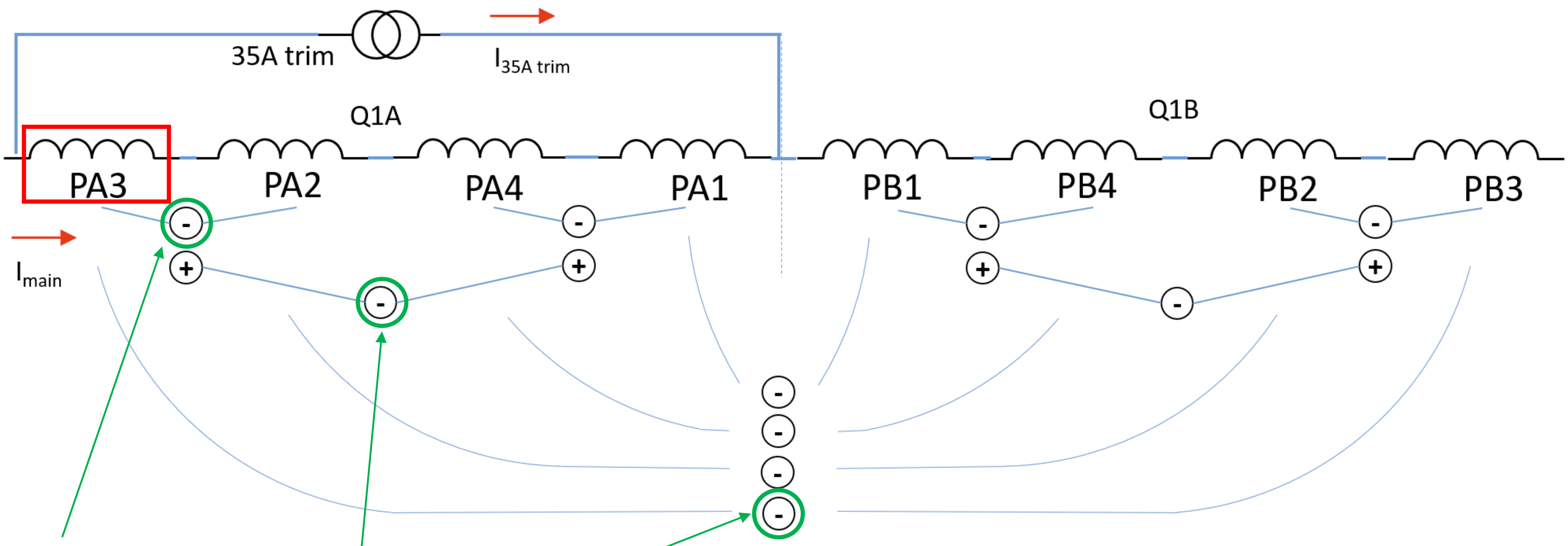


Asymmetric detection: Coil-coil comparison of neighboring coils (PA3 - PA2, PA4 – PA1, PB1 – PB4, PB2 – PB3)

Magnet symmetric detection: Comparison of magnet halves: (PA3 + PA4) – (PA4 + PA1), (PB1 + PB4) – (PB2 + PB3)

Full symmetric detection: Comparison of Coil voltages between Q1A and Q1B

Quench scenario



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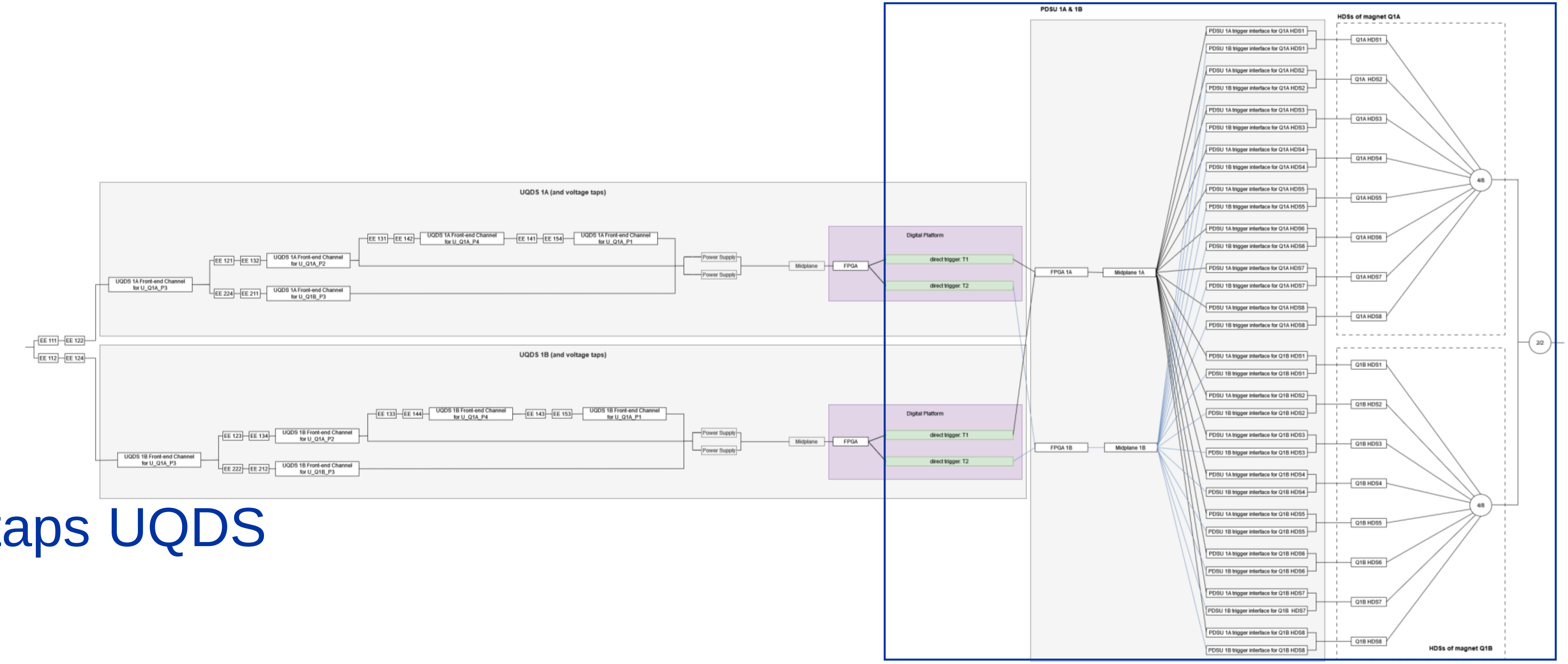
Reliability Block Diagram for a single quench in a magnet (e.g. Quench in Coil PA3) for current < 3 kA



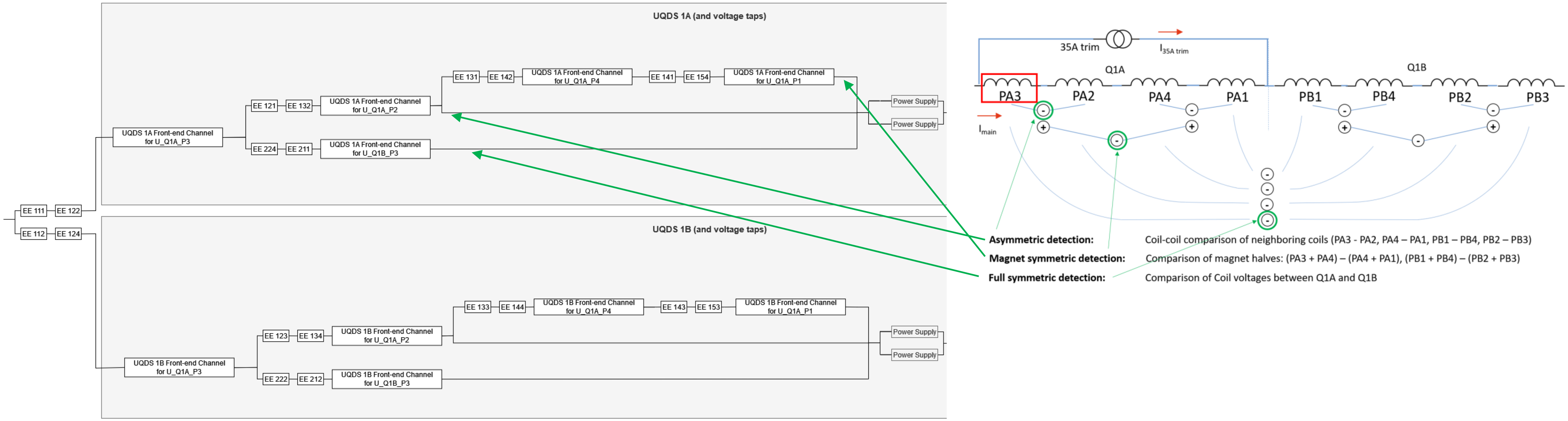
x3

V-taps UQDS

PDSU

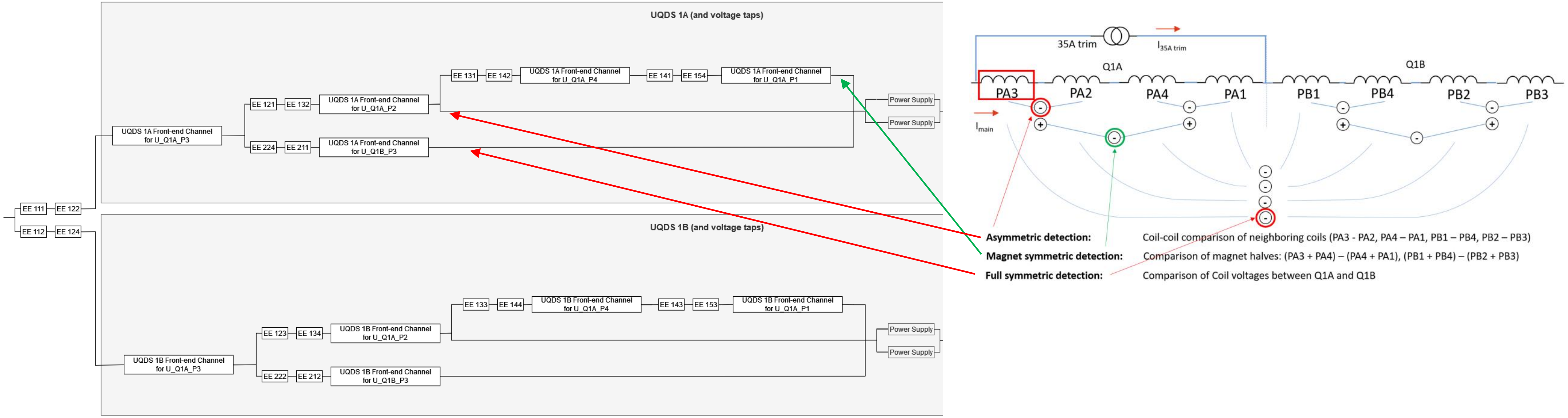
DQHDS

Reliability Block Diagram for a single quench in a magnet (e.g. Quench in Coil PA3)



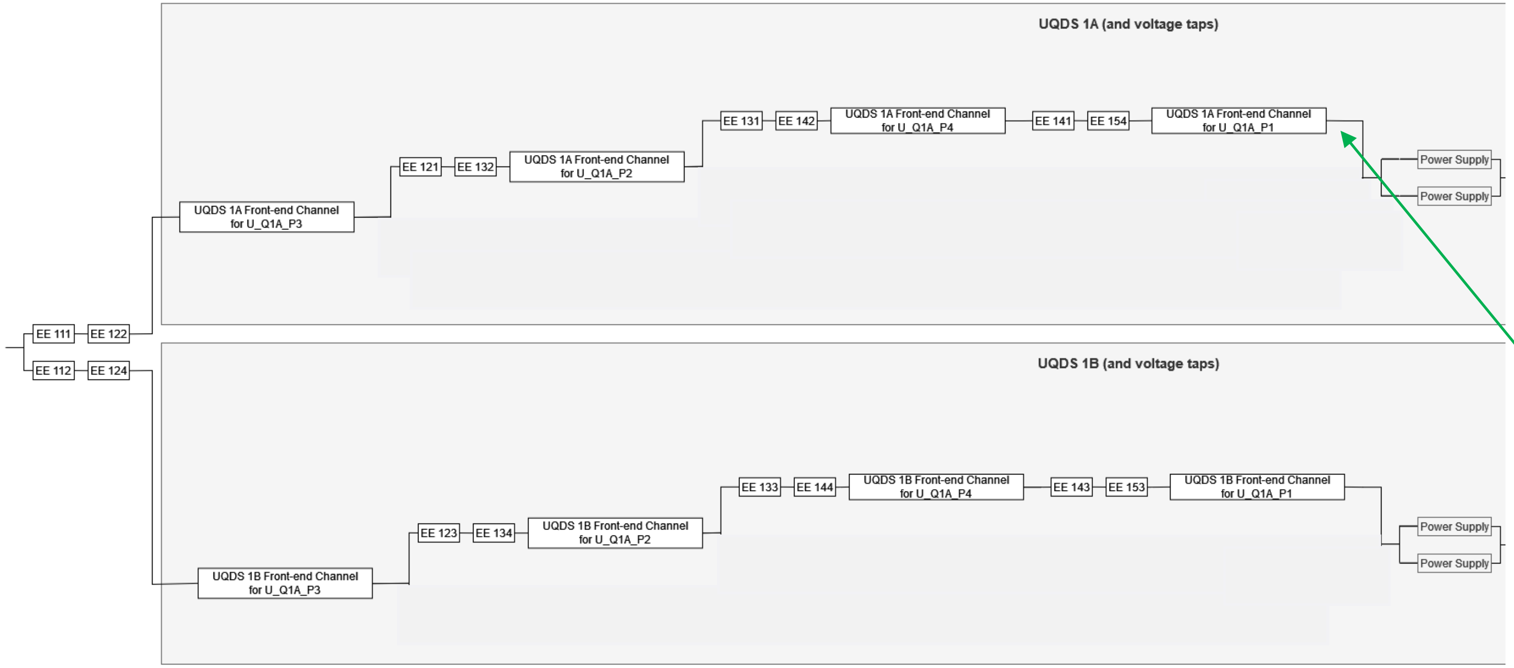
Reliability Block Diagram for a single quench in a magnet (e.g. Quench in Coil PA3)

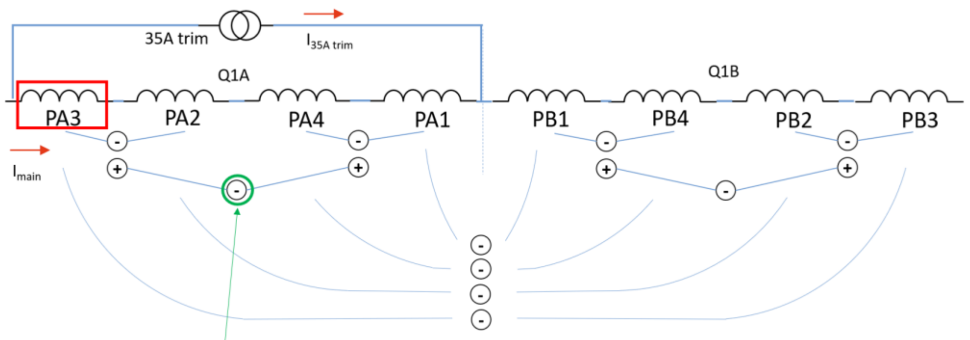
Pessimistic scenario



Reliability Block Diagram for a single quench in a magnet (e.g. Quench in Coil PA3)

Pessimistic scenario





Asymmetric detection: Coil-coil comparison of neighboring coils (PA3 - PA2, PA4 – PA1, PB1 – PB4, PB2 – PB3)

Magnet symmetric detection: Comparison of magnet halves: (PA3 + PA4) – (PA4 + PA1), (PB1 + PB4) – (PB2 + PB3)

Full symmetric detection: Comparison of Coil voltages between Q1A and Q1B

Why so pessimistic?

Quench in 2 coils

Scenario 1

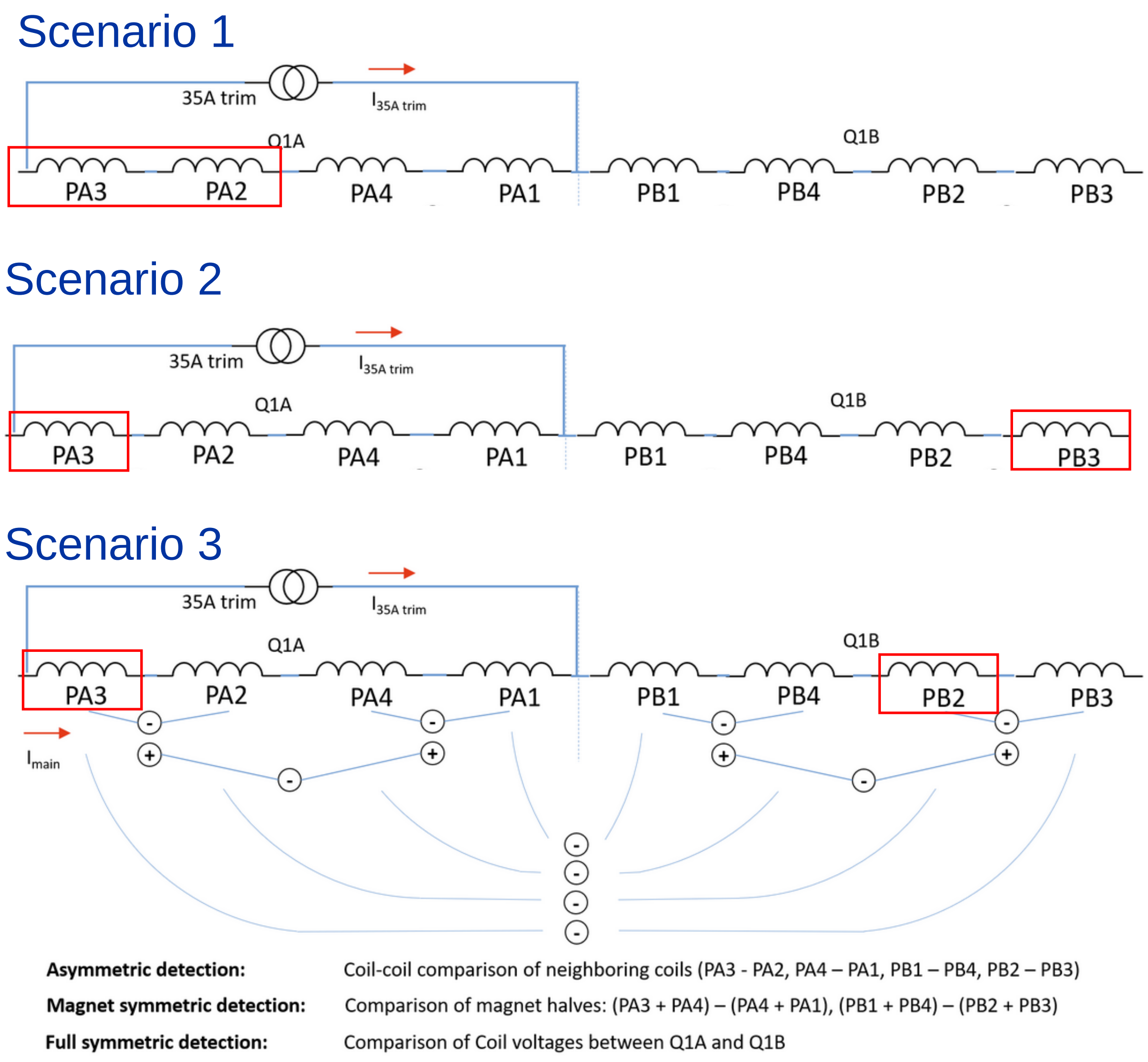
- Asymmetric
- Magnet symmetric ((PA1+PA4) – (PA2-PA3))
- Full Symmetric (PA3-PB3) & (PA2-PB2)

Scenario 2

- Asymmetric
- Magnet symmetric ((PA1+PA4) – (PA2-PA3)) and …
- Full Symmetric

Scenario 3

- Asymmetric
- Magnet symmetric ((PA1+PA4) – (PA2-PA3)) and …
- Full Symmetric (PA3-PB3) & (PA2-PB2)



→ Depending on the quench scenario certain redundancies could be bypassed.

Reliability Targets – Top Level FMECA (uQDS + PDSU)

situation	functions	description	failure modes	effects/consequence	recovery time	reliability target
quench	magnet protection + beam dump request	For this the *UQDSs* must detect a quench in a magnet (or SC links and the BBs)	fail to detect	no magnet protection no dump via PDSU/PIC	months ? (beam dump via BLMS fast enough?)	1/1000 years
		The *UQDSs* must send a signal to the PDSUs when a quench is detected.	fail to transmit to PDSU	no magnet protection no dump via PDSU	months	1/1000 years
	triggering of the CLIQs/HDSs	The *PDSUs* must trigger the CLIQs and/or HDSs.	fail to trigger the protection devices	no magnet protection	months	1/1000 years
			insufficient re-/triggering (not enough CLIQs and/or HDS are triggered)	insufficient magnet protection	months	1/1000 years
	dedicated beam dump request transmission - direct to BIS	The *PDSUs* have to trigger the beam dump request on time	fail to transmit beam dump request	no dump via PDSU-BIS connection	months	1/1000 years

Reliability Targets

- For a downtime of months, a frequency of 1/100 years or lower is acceptable.

➢ Frequency **1/1000 years** was chosen because of other system types (BIS, LBDS, BLMs, SMP, …) that can cause the same downtime.

Recovery time

months

Frequency	[1m - 20m)	[20m - 1h)	[1h - 3h)	[3h - 6h)	[6h - 12h)	[12h - 24h)	[24h - 2d)	[2d - 1w)	[1w - 1M)	[1M - 1Y)	[1Y - 10Y)
1/H	U	U	U	U	U	U	U	U	U	U	U
1/Shift	U	U	U	U	U	U	U	U	U	U	U
1/Day	A	U	U	U	U	U	U	U	U	U	U
1/Week	A	A	A	A	U	U	U	U	U	U	U
1/Month	A	A	A	A	A	A	U	U	U	U	U
1/Year	A	A	A	A	A	A	A	A	U	U	U
1/10Years	A	A	A	A	A	A	A	A	A	U	U
1/100Years	A	A	A	A	A	A	A	A	A	A	U
1/1000Years	A	A	A	A	A	A	A	A	A	A	A

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- **How many critical systems have a quench protection system with a UQDS?**

Recovery time   months

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1/H	U	U	U	U	U	U	U	U	U	U	U
1/Shift	U	U	U	U	U	U	U	U	U	U	U
1/Day	A	U	U	U	U	U	U	U	U	U	U
1/Week	A	A	A	A	U	U	U	U	U	U	U
1/Month	A	A	A	A	A	A	U	U	U	U	U
1/Year	A	A	A	A	A	A	A	A	U	U	U
1/10Years	A	A	A	A	A	A	A	A	A	U	U
1/100Years	A	A	A	A	A	A	A	A	A	A	U
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Reliability Targets

- For a downtime of months, a frequency of 1/100 years or lower is acceptable.

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- **How many critical systems have a quench protection system with a UQDS?**
  - **4 Inner Triplets**
  - **533 circuits with a quench loop**
  - **72 circuits with a UQDS and 126 UQDS units in total**
  - **9436 Quench Detection Systems**

Components and their failure rate/reliability

- Based on PCB design files, a first worst-case component based reliability estimate has been done:

		Inspection after 1 operational year		Inspection after 3 operational years	
components	**Inspection interval**	**FITs**	**R**	**FITs**	**R**
Tap + UQDS (without trigger out)		4221.39	0.9701	12664.17	0.9129
Tap		13.83	0.9999	41.49	0.9997
Channel		70.29	0.9995	210.87	0.9985
PSU		874.70	0.9937	2624.10	0.9813
FPGA (Digital Platform)		1675.00	0.9880	5025.00	0.9645
Midplane		38.42	0.9997	115.26	0.9992
trigger out (UQDS)		7.00	0.9999	21.00	0.9998
FPGA/Digital Platform + Midplane (PDSU)		3296.16	0.9765	9888.48	0.9313
Trigger Interface (PDSU)		7.00	0.9999	21.00	0.9998
HDS		435.22	0.9969	1305.65	0.9906
PS24V		54.36	0.9996	163.08	0.9988
trigger		27.18	0.9998	81.54	0.9994
thyristor		13.59	0.9999	40.77	0.9997
charger		27.18	0.9998	81.54	0.9994
capacitor		4.53	1.0000	13.59	0.9999
Strip		326.16	0.9977	978.47	0.9930
current breaker		163.08	0.9988	489.24	0.9965
Sum		**201.69**	**0.9985**	**1800.69**	**0.9957**
Failures in 1000 years		**1.45**		**12.96**	

What are the Inspection intervals for the different components?

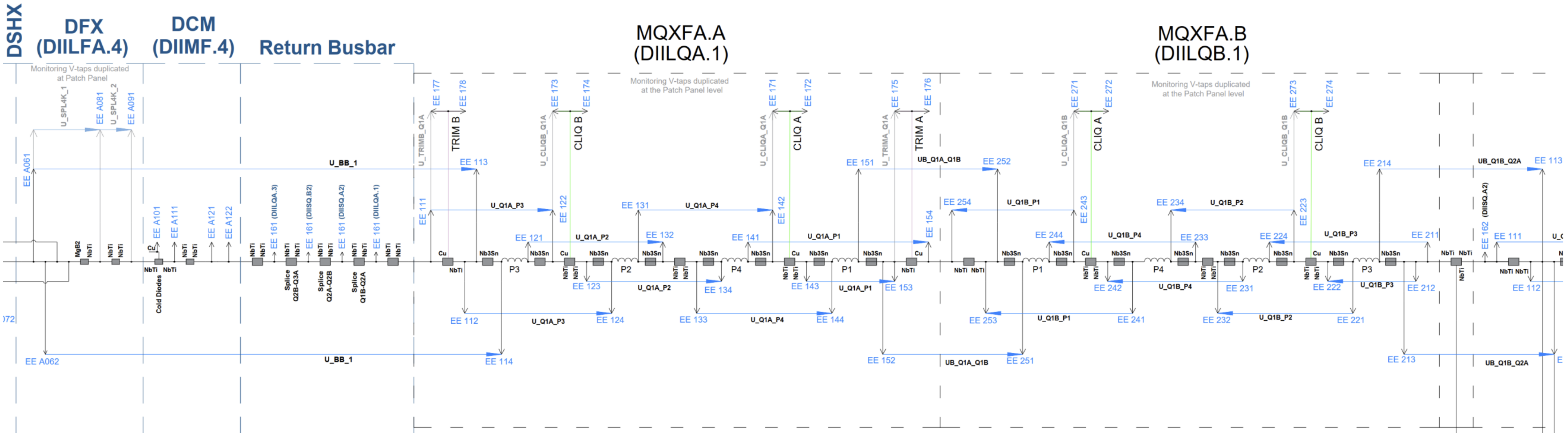
Are there faults in the instrumentation that can only be detected with Electrical Quality Assurance (ELQA)?

When considering a continuous demand (if there is a failure of the system, there is always a quench).

1 operational year = 300 days
3 operational years = 1095 days

UQDS – Busbars

- Can the two UQDSs BB of one IT detect a quench in the Busbars in between the magnets and the return busbars? Yes
- Are there in total 4 voltage taps for each type of Busbar? Yes, but they are sometimes shared with the taps used for the magnet coils.



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