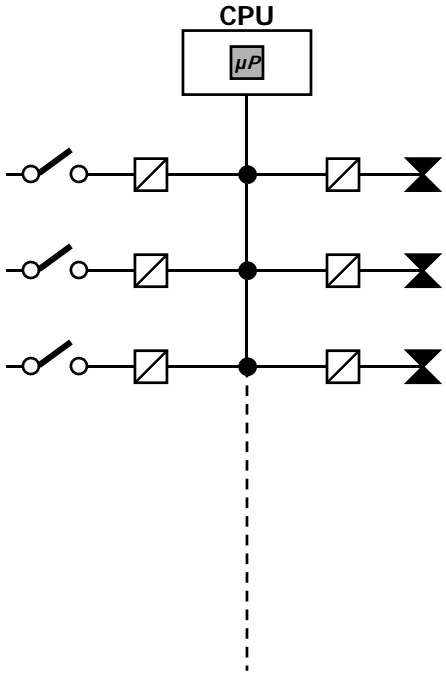


**TMR vs. QMR**

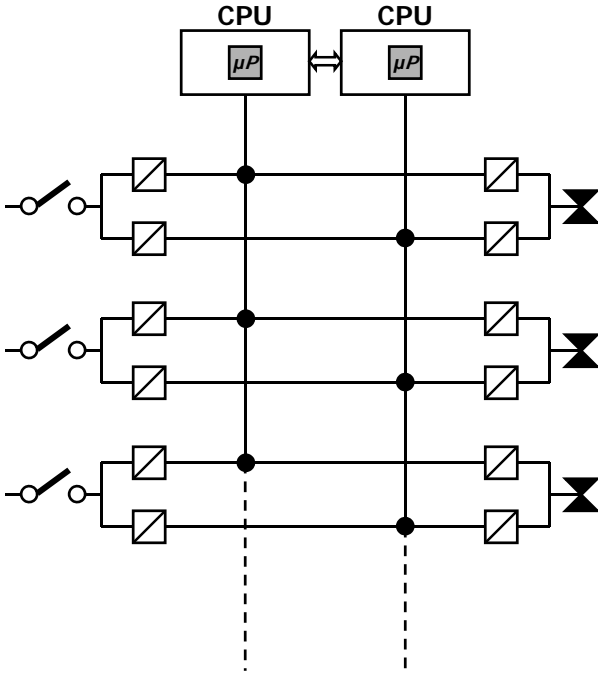
---

# SYSTEM STRUCTURE

**SIMPLEX**  
(1-out-of-1)

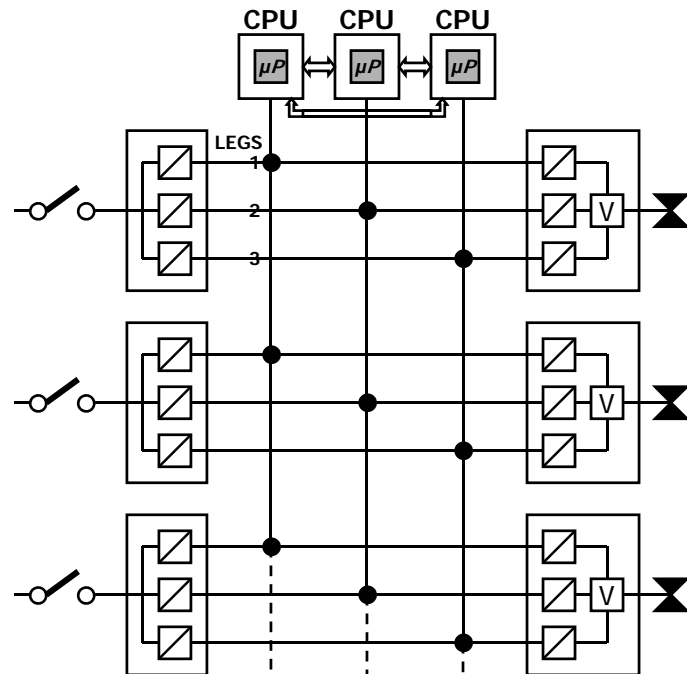


**DUPLEX**  
(2-out-of-2 or 1-out-of-2D)

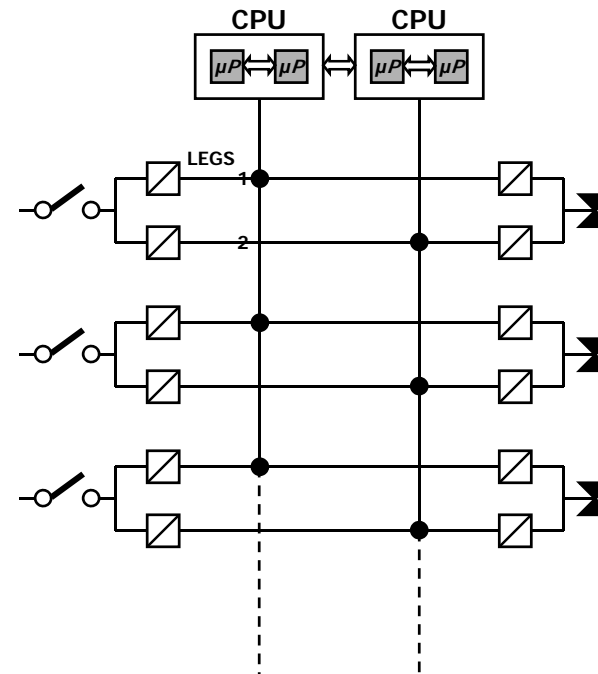


# SYSTEM STRUCTURE

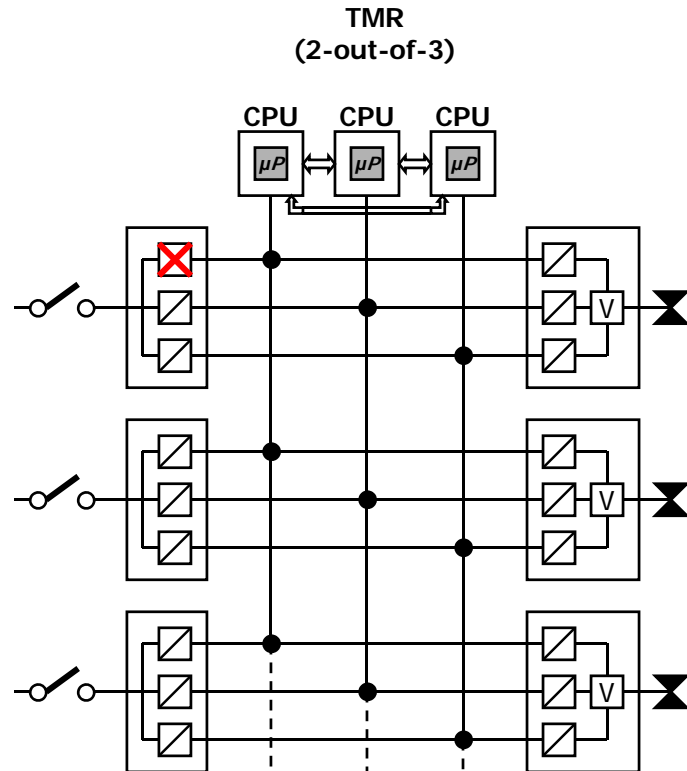
TMR  
(2-out-of-3)



QMR  
(2-out-of-4D)



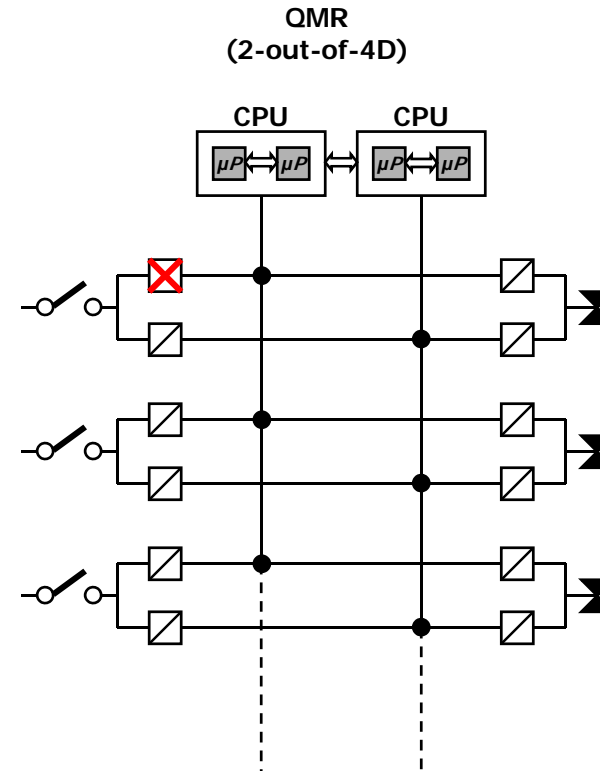
# FAILURE OF ONE INPUT LEG



No voting on the card = basic principle killed

Diagnostic downgrade

Time limit

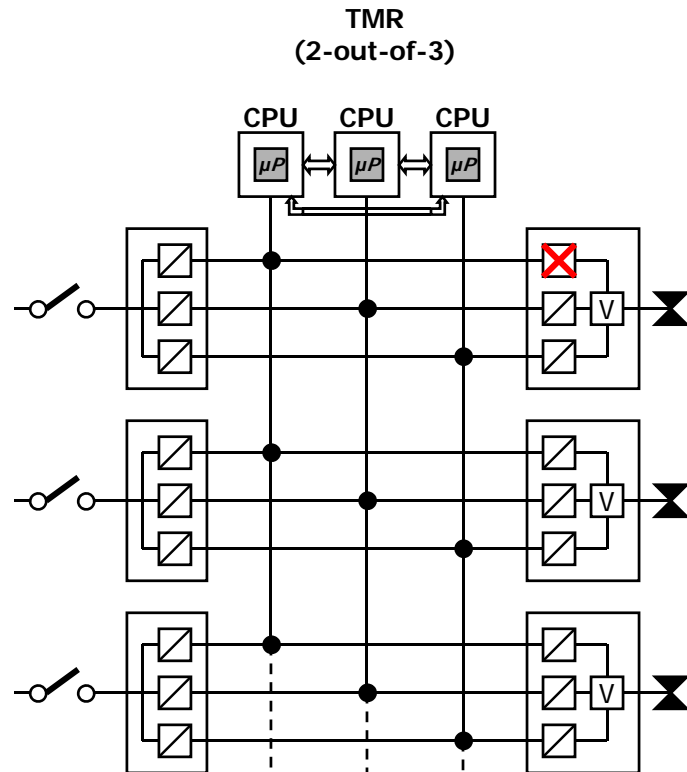


100% diagnostic on healthy card

No downgrade

No time limit

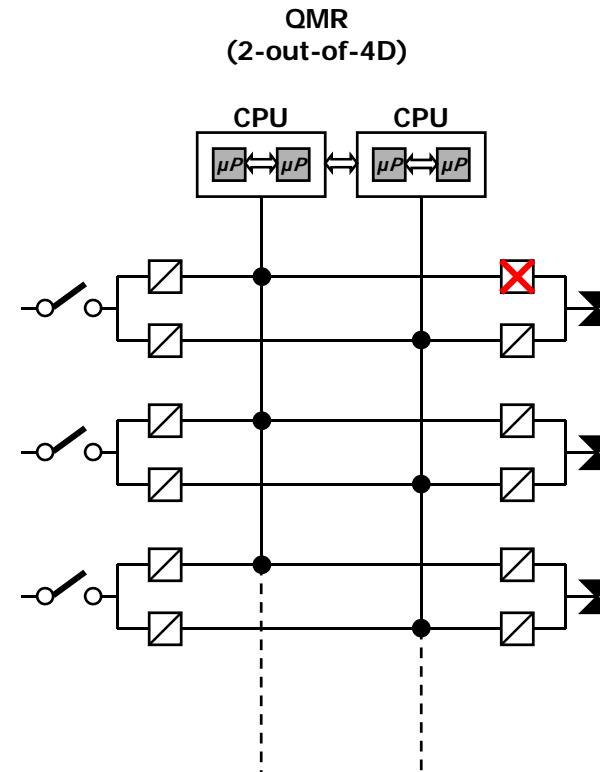
# FAILURE OF ONE OUTPUT LEG



No voting on the card = basic principle killed

Diagnostic downgrade

Time limit

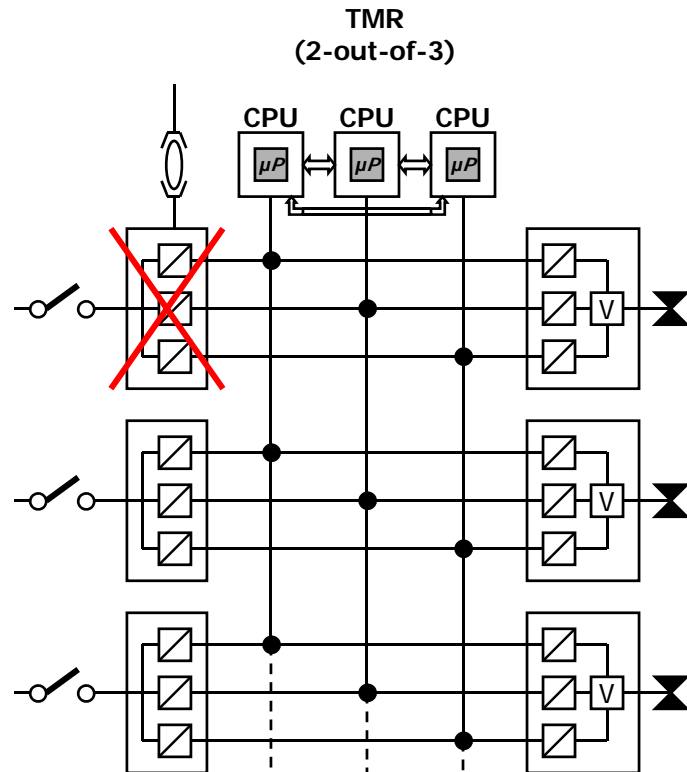


100% diagnostic on healthy card

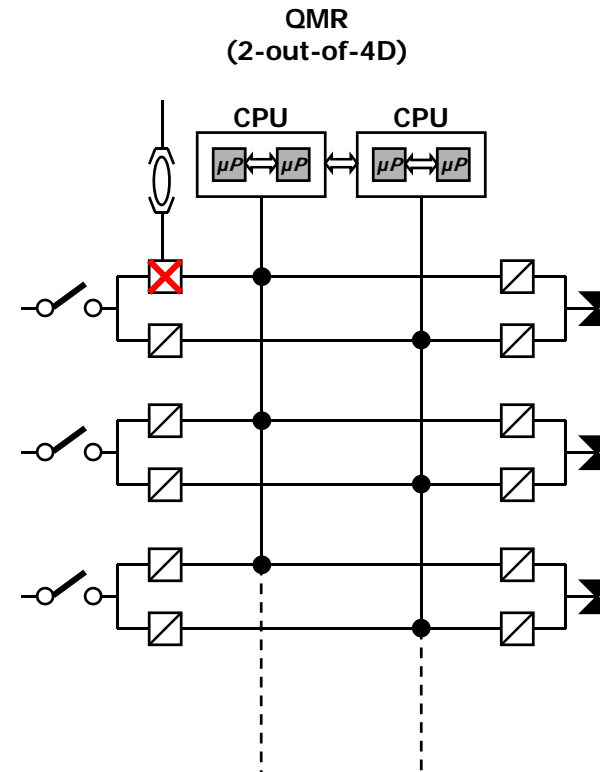
No downgrade

No time limit

# FAILURE ON INDIVIDUAL POWER SUPPLY



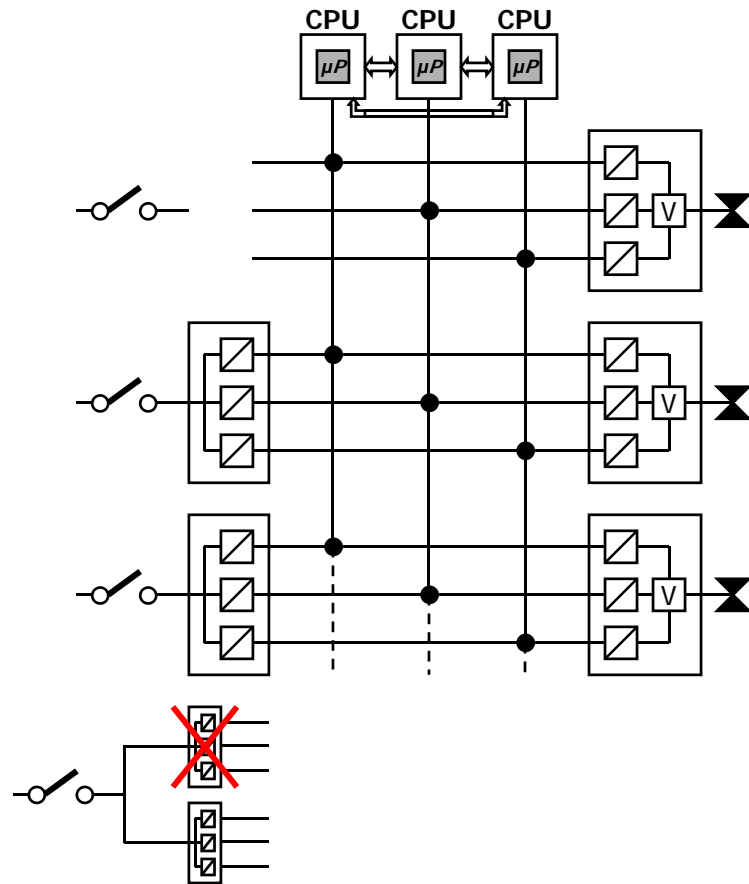
No signal available for control  
Redundancy on input/output killed  
Common Cause Failure



No effect  
No Common Cause Failure

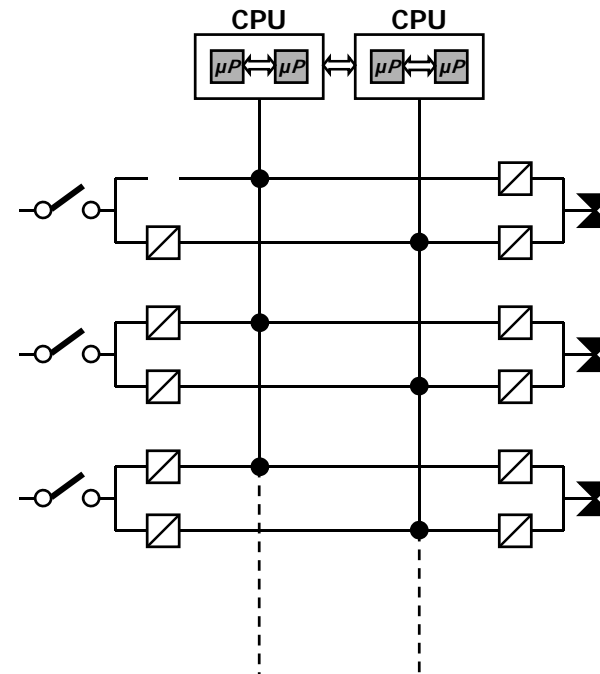
# REPLACEMENT OF FAILED MODULE

TMR  
(2-out-of-3)



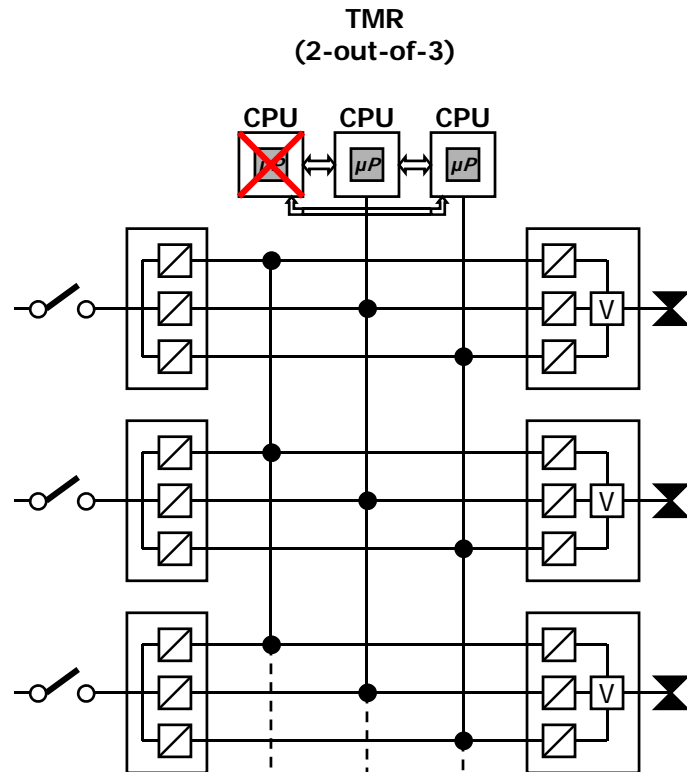
When replacing, a stand-by card must be inserted, unless installed redundant cards

QMR  
(2-out-of-4D)



No problems for continuation

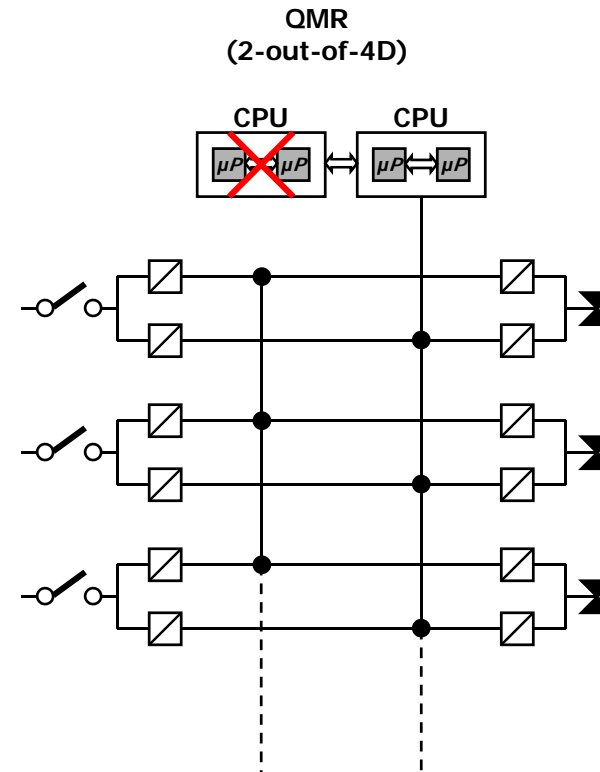
# FAILURE OF ONE CENTRAL MODULE



The basic diagnostic principle "voting" is killed on all input and output cards

Diagnostic downgrade

Time limit



No impairment

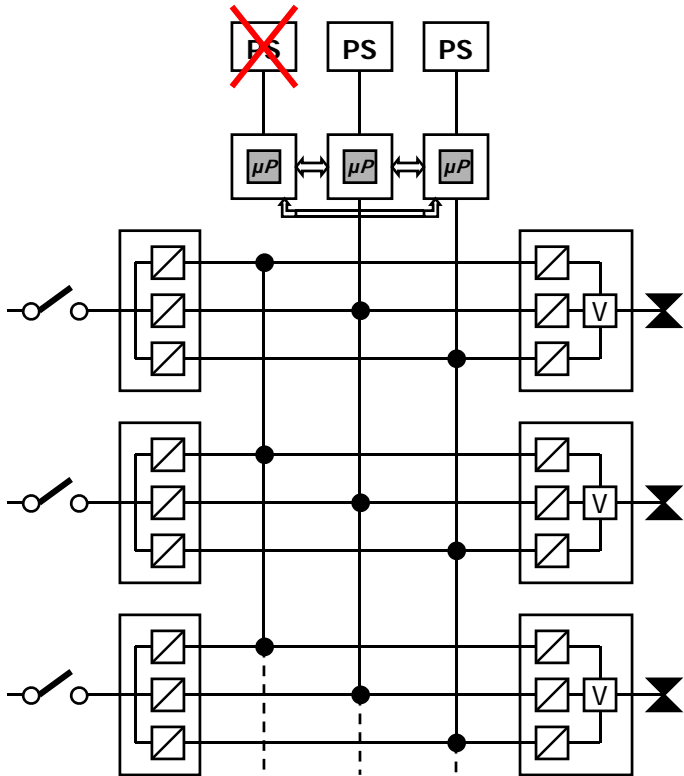
No downgrade

No time limit



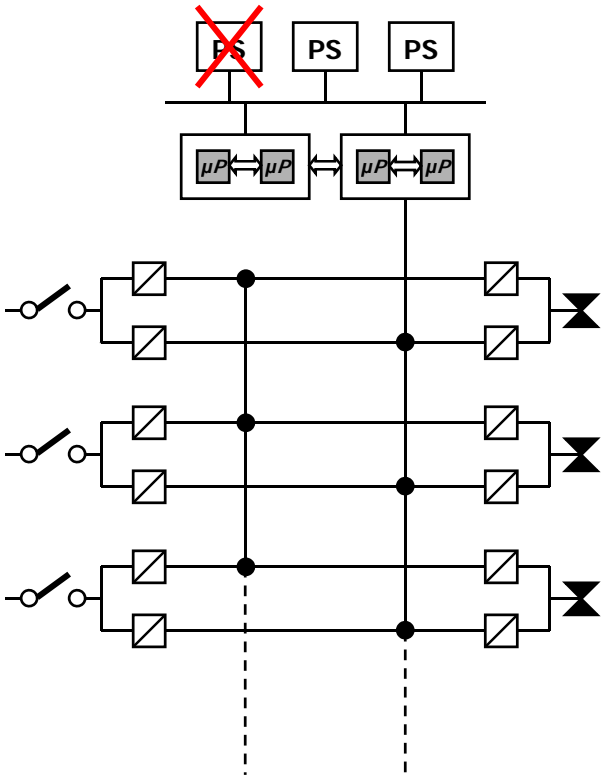
# THE LOSS OF POEER UNIT

TMR  
(2-out-of-3)



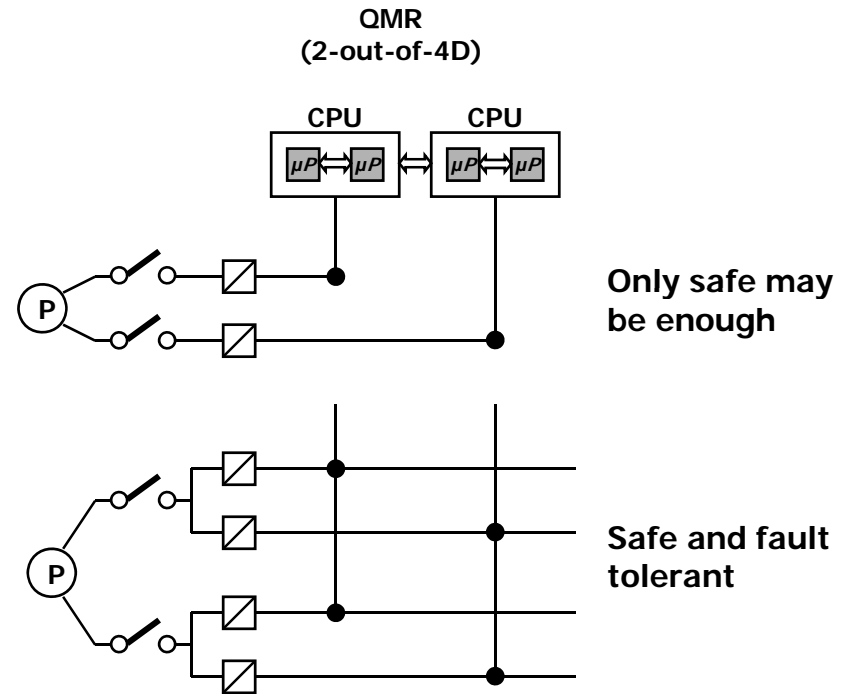
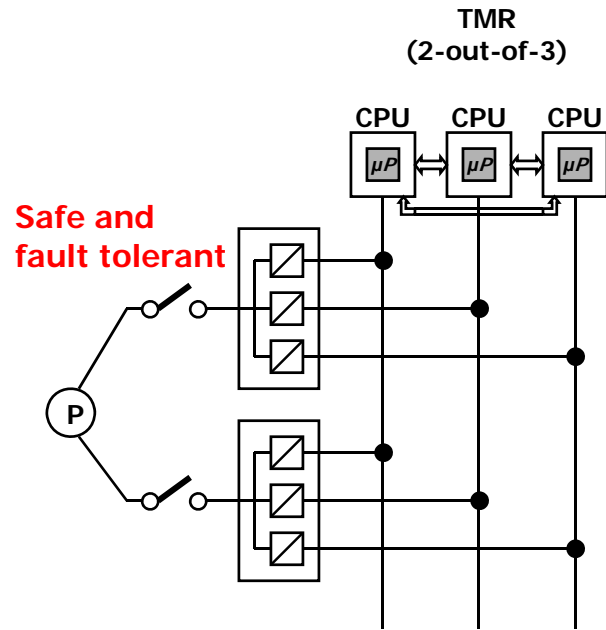
(In some TMR systems), it causes failure of the relevant central unit, bus, legs, and etc.

QMR  
(2-out-of-4D)



No problems for continuation

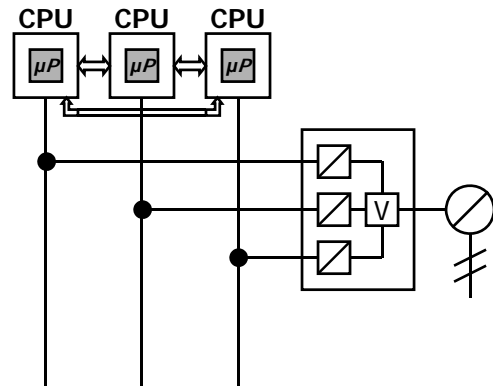
# SIL 3: NON SAFETY RELATED SENSORS MUST BE DUPLICATED



HENCE, TWO POINTS OF CONNECTION NEEDED

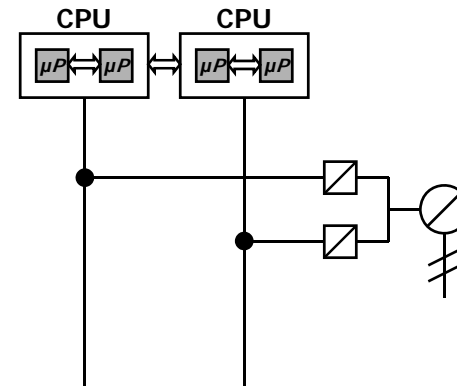
# ANALOG OUTPUT FAULT TOLERANT

TMR  
(2-out-of-3)



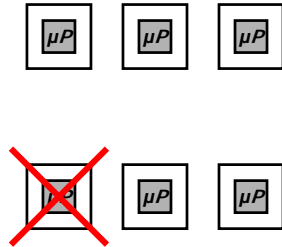
**Not available**

QMR  
(2-out-of-4D)

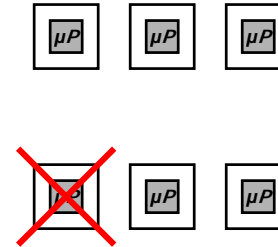


**Available**

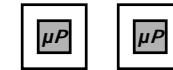
## TMR CENTRAL SYSTEM DOWNGRADING STEPS



**STOP**



**TIME LIMIT**



**REASON BEING:** The diagnostic coverage factor provided by the healthy COUPLE of CU's is...

**NOT  
SUFFICIENT**

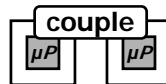
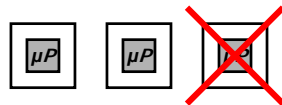
**Pilz**

**SUFFICIENT BUT...  
NOT ENOUGH**

**Triconex**

# HIMA IS MORE FAULT TOLERANT THAN TMR

TMR  
(2-out-of-3)

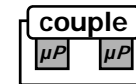
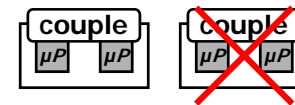
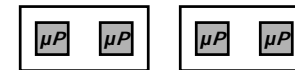


Limited diagnostic coverage

Time limit

IMPERFECT COUPLE

QMR  
(2-out-of-4D)



Full diagnostic coverage

No time limit

PERFECT COUPLE

## CONCLUSION

**TMR: What customer believe...**

**One triplicated system combines the benefits of three safety systems**

**Downgrade is  $3 \rightarrow 2 \rightarrow 1 \rightarrow 0$**

**Fault tolerant is maximum**

**The superiority of triplicated system is confirmed by Markov modeling**

**It is more expensive because it is worth more**

**MTBF is higher**

## CONCLUSION

**Indeed...**

**As far as safety is concerned TMR needs three systems to do what HIMA can do with one!**

**Downgrading steps are as many as HIMA (3 → 2 → 0 vs. 4 → 2 → 0)!**

**HIMA is more fault tolerant than TMR!**

**HIMA's MTBF is about 10 times higher than TMR!**

**TMR has more Common Mode Failures (voting itself, power, disturbance to external influences, and etc.)!**

**TMR requires a lot of cycles to perform the complete memory test (for an average application, a time from 20 to 30 seconds can be expected – what about the safety time then?)!**

**What is the meaning of faster cycle time?!**

**Ask customers about false trips by TMR, high maintenance costs, alarming due to flickering of contacts!**