Power System Protection Coordination Calculation

Report

Ph.d. Vytautas Šiožinys

Mantas Kaminickas

Contents

1. OBJECT DESCRIPTION

This study covers protection relays settings calculation for standby power system generators in company's data center. Standby power system will have 8 synchronous generators: MarelliMotori MJH630 LB4, connected to 15 kV internal power supply system. Each generator is 3,2 MVA. Generators will be started in case power supply is lost from MVA/MVB or both feeders. In island operation, network is grounding through grounding transformer. Grounding transformer feeder closes as soon as first generator circuit breaker is closed. Main feeders cannot work in parallel. Possible operation modes:

- island operation, single generator is running,
- island operation, all generators are running.

Generator relay will have these functions:

- dI>(87), generator differential,
- Idir>(67), directional overcurrent,
- T> (49), thermal overload,
- Q< (40), generator under excitation,
- Ih> (50H/51H), harmonic overcurrent,
- P(32), power protection,
- I2> (46), negative sequence,
- U> (59), overvoltage,
- U< (27), undervoltage,
- f> (81H), over frequency,
- f<(81L), under frequency.

Selected relay AQ-G257.

Network single line diagram is depicted at Annex No. 1. Calculations are performed with a power system modeling software EA-PSM.

2. LOAD FLOWS CALCULATION RESULTS

Single bypass generator apparent power is 3,2 MVA. Prime mover mechanical power is 2,6 MW. Reactive power that generator can supply at rated conditions is 1,92 MVar lagging or 1,12 MVar leading, based on generator capability curve, depicted in Figure 1

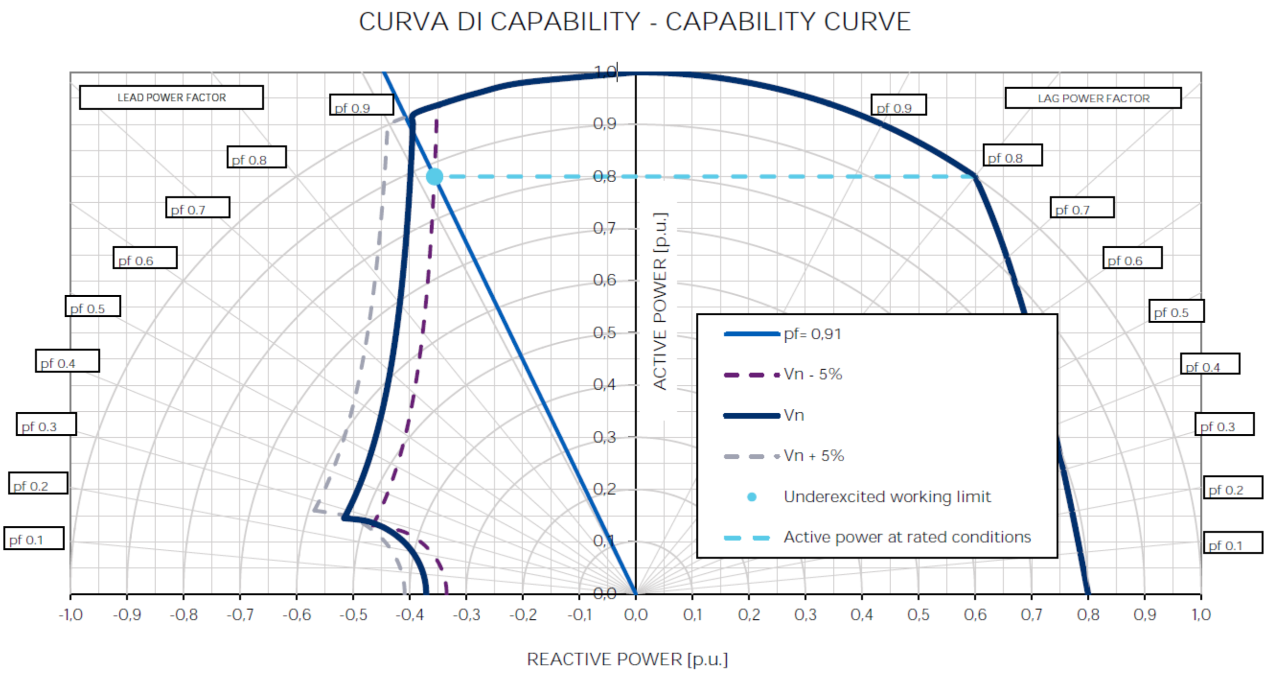


Figure 1 Generator capability curve

According to this data, maximum current from the generator at nominal voltage is 124 A. Cumulative current from all generators working in parallel is 958 A.

3. SHORT CIRCUIT CALCULATION RESULTS

Short circuit acronyms explanation:

- K3 – three phases short circuit,
- K2 – two phases short circuit,
- K1 – one phase short circuit,
- K11 – two phases with ground short circuit.

Short circuit currents when all generators are connected to bus MVG1A and fault is located at one of the generators incomer, are depicted in Figure 2.

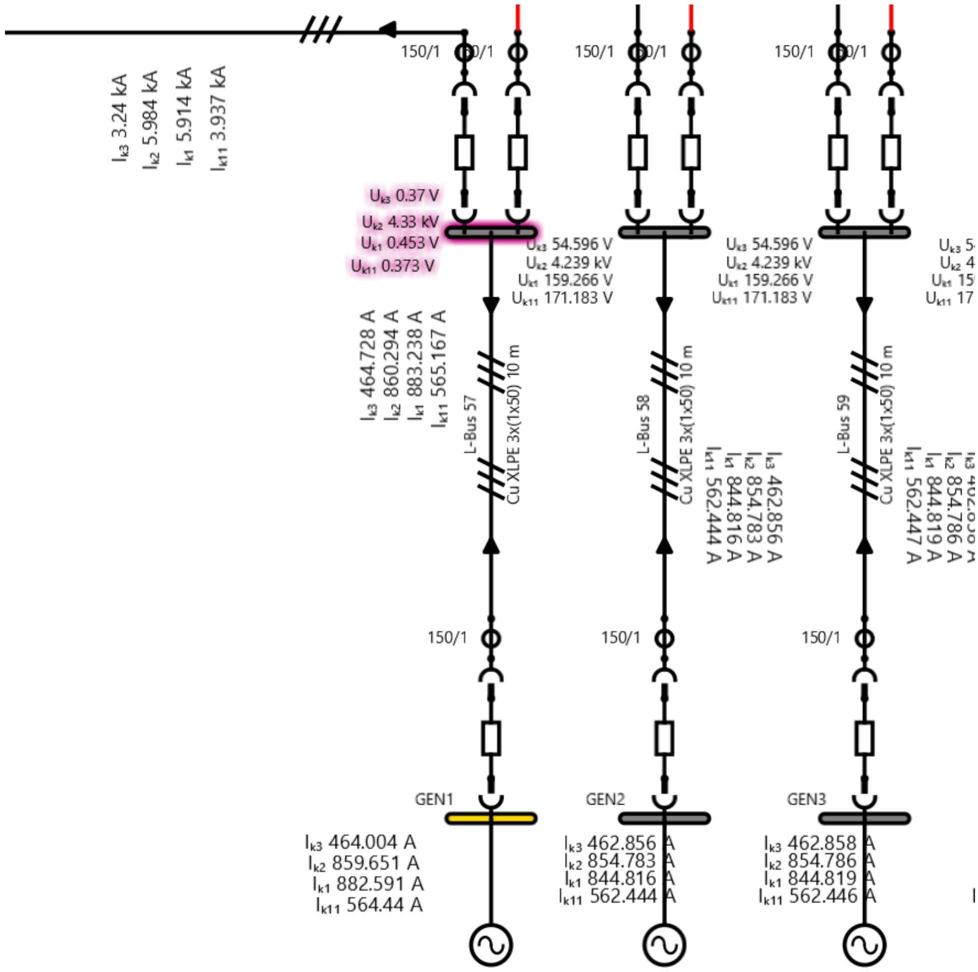


Figure 2 Short circuit currents: case A

Short circuit current when single generator is connected to bus MVG1A are depicted in Figure 3.

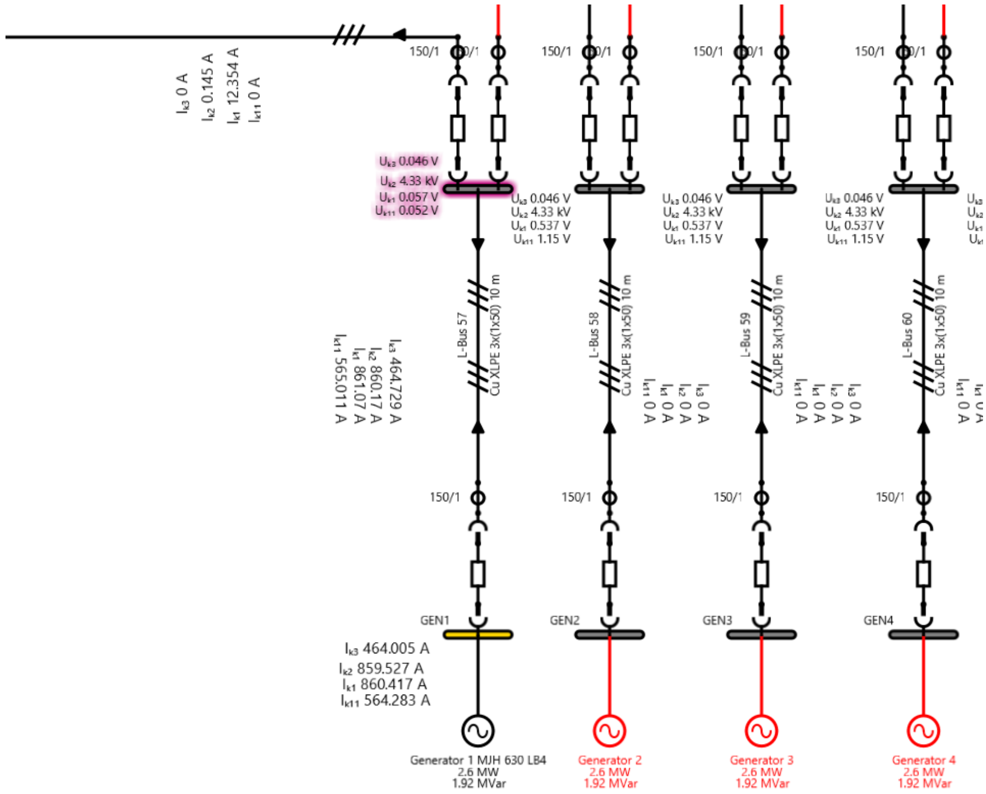


Figure 3 Short circuit currents: case B

Short circuit current when generators are connected to MVG1B are assumed the same as depicted above. Short circuit currents when fault is located at other places are not depicted in the report, but due to small impedances, currents are almost the same.

4. CURRENT TRANSFORMERS SIZING

Current transformers should not saturate during short circuit event to provide accurate readings. Assumptions for current transformers sizing are depicted in Figure 4. Transformation coefficient for all transformers is assumed 150/1.

Wire loop length	10 m
Wire cross section	2.5 mm²
PN	5 VA
Internal resistance	3 Ω
IED load	100 mΩ
Wire material	Copper

Figure 4 Assumptions for current transformers sizing

According to calculations, saturation can be avoided if accuracy limiting factor of the current transformers is at least 15. Therefore, recommended current transformer type is 5P15 or 5P20. For generator 150/1 10P10 transformer is selected, according to generator datasheet.

5. GENERATOR RELAY COORDINATION

5.1.Generator differential

Estimated current transformer is 150/1 10P10. Differential relay characteristic is depicted in Figure 5.

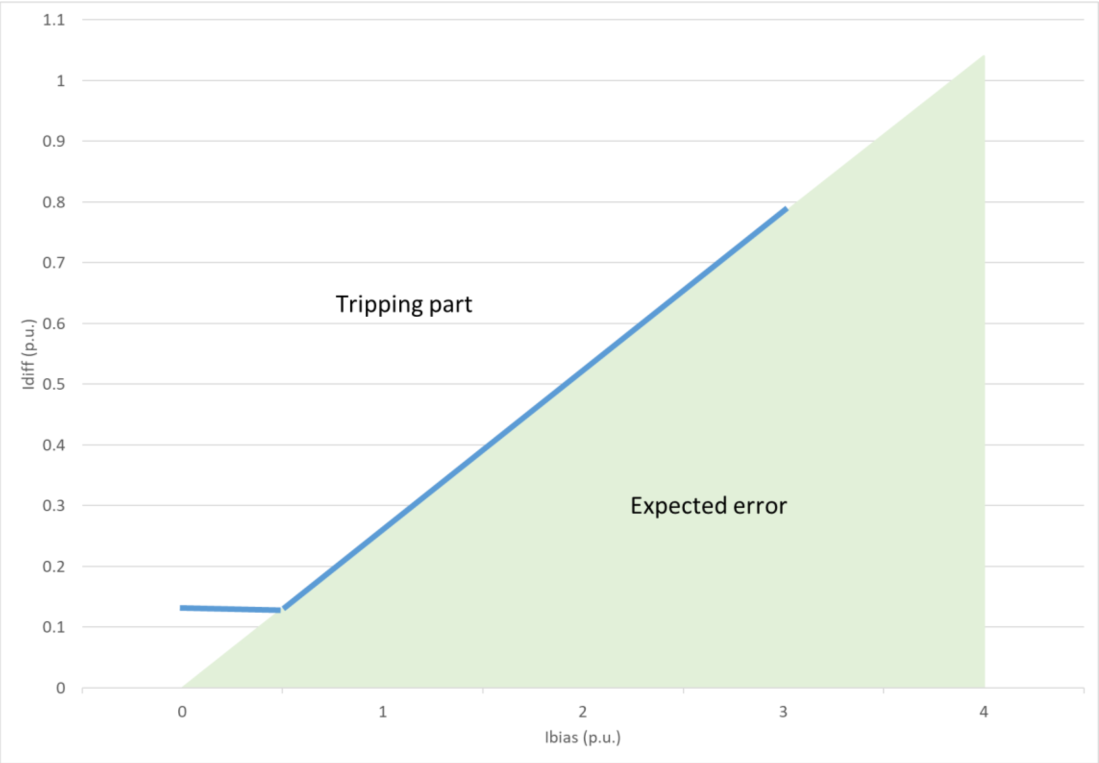


Figure 5 Differential relay characteristic

Current transformer error CTE = 10%, relay measurement error REM = 0,5%, safety margin SM = 5%. 1st slope calculation:

$$\propto_{1st\_slope} = CTE1 + CTE2 + REM1 + REM2 + SM = 10\% + 10\% + 0{,}5\% + 0{,}5\% + 5\% = 26\%$$

Base sensitivity calculation:

$$I_{diff>} = 0{,}5 \propto_{1st\_slope} = 13\% \ (130\ mA)$$

1st slope pick up calculation:

$$I_{bias\_1stslope} = 50\% \ (0{,}5 \ A)$$

2nd slope pick up calculation:

$$I_{bias\_2ndslope} = 300\% \ (3A)$$

2nd slope:

$$\alpha_{2nd\_slope} = 100\%$$

2nd differential current:

$$I_{diff\gg} = I_{diff>} + \propto_{1st_{slope}} \left(I_{bias_{2ndslope}} - I_{bias_{1stslope}}\right) = 13\% + 26\% * (300\% - 50\%) = 78\% \ (0{,}78A)$$

Settings are summarized in Table 1.

Table 1 Generator differential protection settings

Name	Value
Base sensitivity	13% (130 mA)
1st slope	26%
1st slope pick up	50% (0,5 A)
2nd slope pick up	300% (3A)
2nd slope	100%
2nd differential current	78% (0,78A)
Time	Instantaneous

Use for TRIP.

5.2. Thermal overload

Thermal overload protection monitors generator temperature and trips in case permissible temperature limit is exceeded. Generator overload curve according to manufacturer is provided in Figure 6.

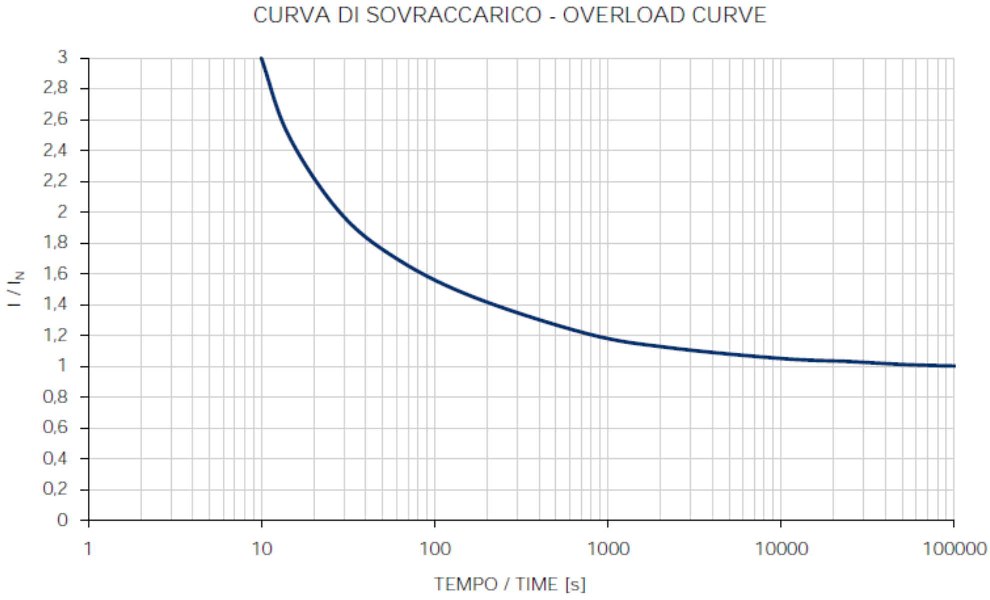


Figure 6 Generator overload curve

Estimated reference points for the overload curve are provided in Table 2.

Table 2 Overload curve reference points

I/In	t, [s]
3	10
2,6	14
2,4	17
2,2	21
2	30
1,8	45
1,6	80
1,4	200
1,2	950
1,0	9999

Recommended settings for this protection function are provided in Table 3.

Table 3 Thermal overload protection settings

Name	Value
Service factor	1 x In
Pick up current	1,05 x In
NPS	0:No NPS
Time constants	0:Single
Estimate short TC and timing	0:Manually
Long heat T const	1,25 min
Long cool T const	3,75 min
Dev. temp	2:F
Ambient temp. sel	0:Manual
Ambient line or curve	Linear est.
Man. amb. temp. set.	40

Name	Value
Temp. reference	40
k at max amb. temp	0,8xIn
k at min amb. temp	1,05xIn

Use for TRIP.

Generator overload and relay thermal curves are depicted in Figure 7.

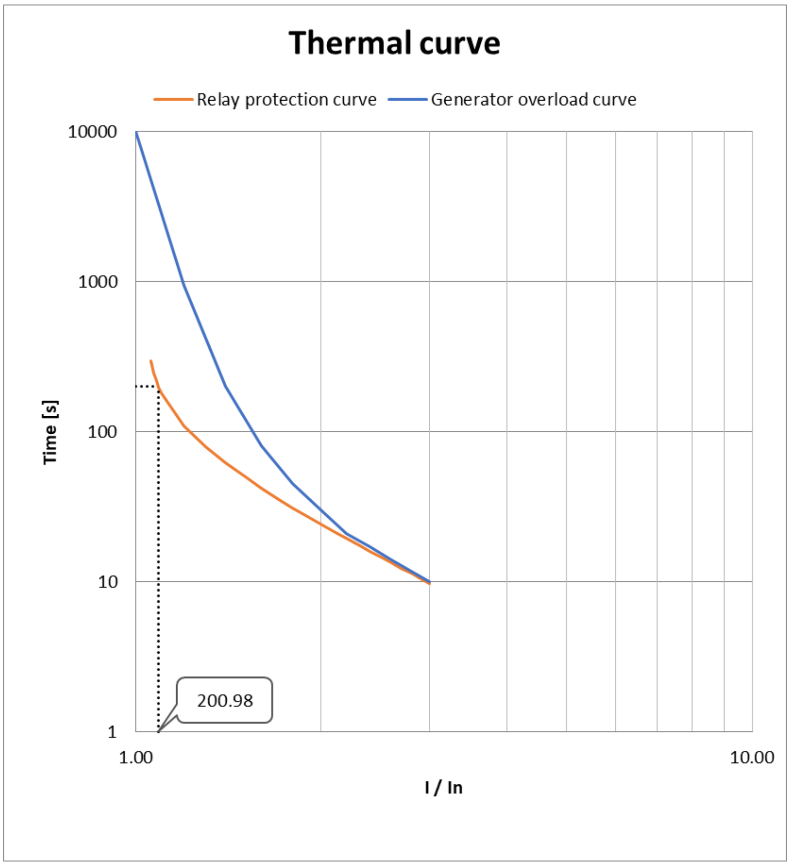


Figure 7 Generator overload and relay thermal curves

Thermal overload relay curve is lower than generator overload curve, that ensures generator protection from thermal overload.

5.3. Directional overcurrent

Directional overcurrent protection is used as backup protection. Settings of this protection function are provided in Table 4.

Table 4 Directional overcurrent protection settings

Name	Value
Characteristic direction	Directional
Operating sector center	180

Operating sector size (+/-)	88
Pickup current setting	1,2
Time	170 ms

Use for TRIP.

5.4. Generator under excitation

Generator under excitation is calculated according to generator capability curve depicted at Figure 1. Settings of this protection function are provided in Table 5.

Table 5 Generator under excitation protection settings

Name	Value
Qset mode	1:P-dependent
Qset1<	1040
Pick-up P1	0
Qset2< 1	1120
Pick-up P2	2560
Time	2 s

Use for TRIP.

5.5. Harmonic overcurrent

In island operation, all harmonics will flow through the generators, causing them to overheat. Therefore, harmonic overcurrent protection is recommended. Settings of this protection are depicted in Table 6.

Table 6 Generator harmonic overcurrent protection settings

Stage	Stage 1
Harmonic	5th
Per unit or relative	xIn
Measurement input	IL1
Ihset pu	0,04
Time	Instantaneous

Use for ALARM.

5.6. Power protection

Power protection is used to avoid reverse active power direction. Settings for this protection are provided in Table 7. Setting is calculated:

$$P_{set} = -5\% \frac{P_{prime_{mover}}}{S_{gen}} = -5\% * \frac{2590kW}{3200kVa} = -4\%$$

Table 7 Power protection settings

Name	Value
Mode	1:<Under
Pick-up	-4%
Time	2 s

Use for TRIP.

5.7. Negative sequence

Negative sequence of current unbalance function is used to protect generator from overheating, that can be caused by unbalanced operation. Settings for this protection are provided in Table 8.

Table 8 Negative sequence protection settings

Name	Value
Measured magnitude	1:I2pu
I2/I1set	8%
Time	15 s

Use for TRIP.

5.8. Overvoltage

Overvoltage protection settings are provided in Table 9.

Table 9 Overvoltage protection settings

Name	Value
Measured magnitude	0:P-P voltages
Uset	110%
Time	10 s

Use for TRIP.

5.9. Undervoltage

Undervoltage protection settings are provided in Table 10.

Table 10 Undervoltage protection settings

Name	Value
Measured magnitude	0:P-P voltages
Uset	90%
ULV_block	10%
Time	10 s

Use for ALARM.

5.10. Over frequency

Over frequency settings are provided in Table 11.

Table 11 Over frequency protection settings

Name	Stage 1	Stage 2
fpickup	51 Hz	53 Hz
Time	15 s	5 s

Use for TRIP.

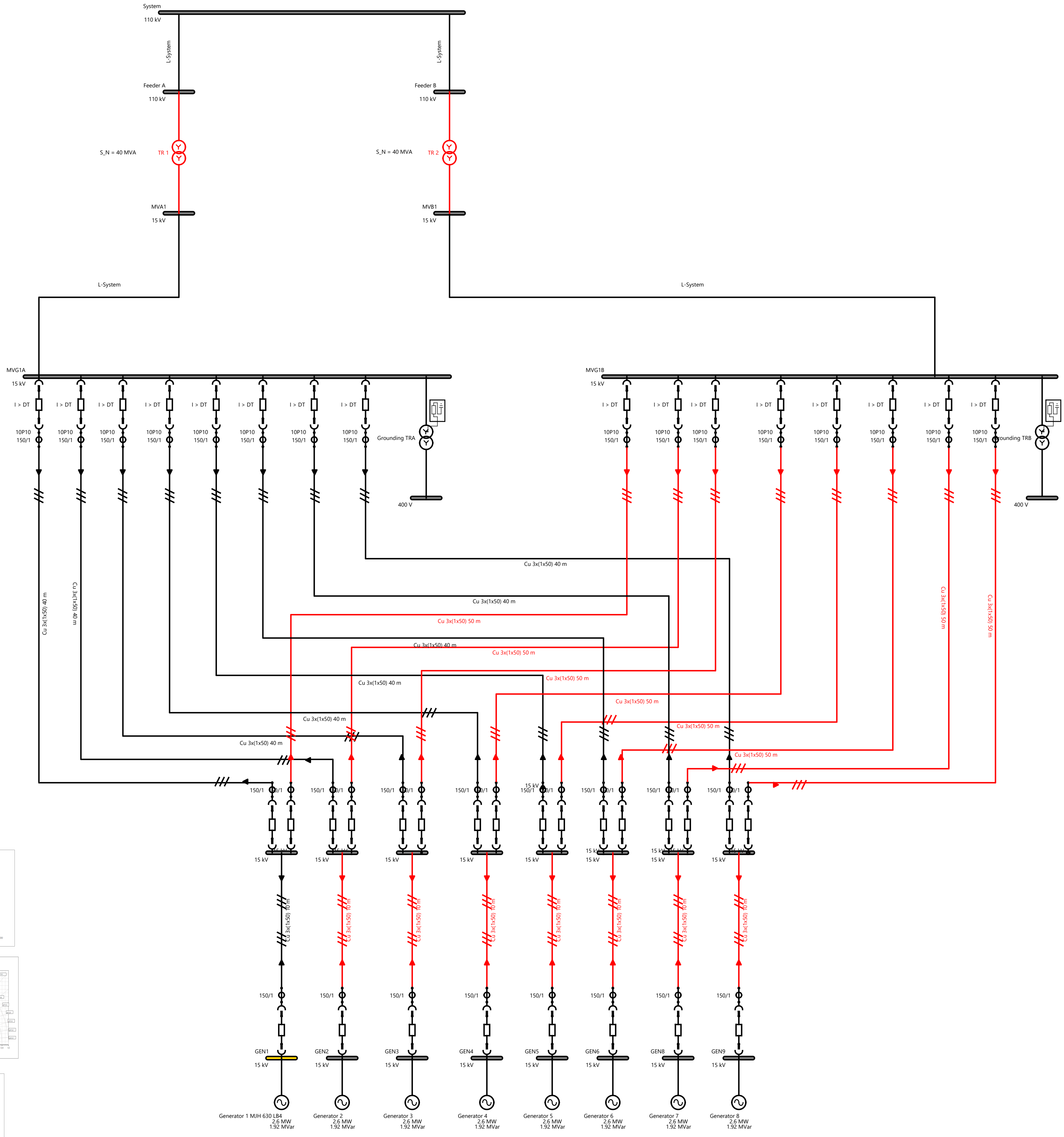
5.11. Under frequency

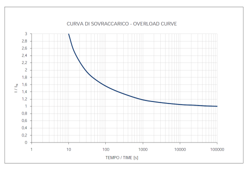
Under frequency protection settings are provided in Table 12.

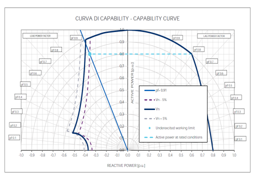
Table 12 Under frequency protection settings

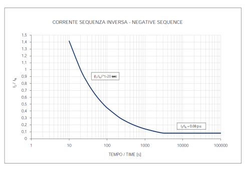
Name	Stage 1	Stage 2
fpickup	49 Hz	48,5 Hz
Time	15 s	5 s

Use for TRIP.









Rev.	Date of issue	Reason of change

Certificate No.

EA-PSM

K.Baršausko g. 59
LT-51423, Kaunas
+37065237826
info@energyadvice.lt

Annex No.1 data center standby power system

M. Kaminickas

Electrical single line diagram

Rev.

Stage

Sheet	Pages
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