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Power Converter with a Galvanic Isolation and an Increased Efficiency

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TRANSCONVERTER

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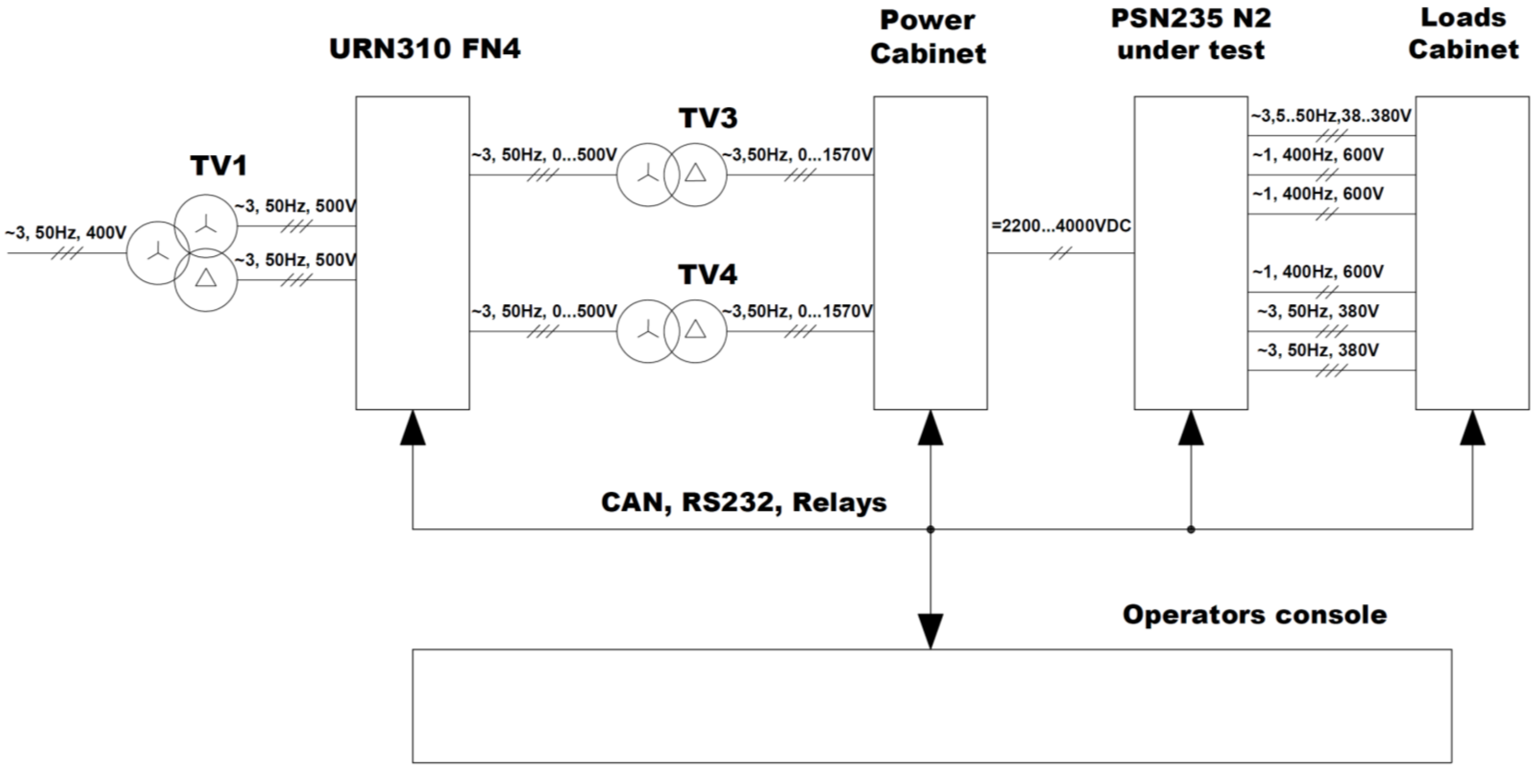
This work is focused on development of URN310 FN4 converter which is a part of the test-bench SI310 FN4, which is in its turn meant to test auxiliary power converters PSN235 N2 of electric freight locomotives of 2(3)ES4K type



Block diagram of SI310 FN4 test-bench

2ES4K Locomotive

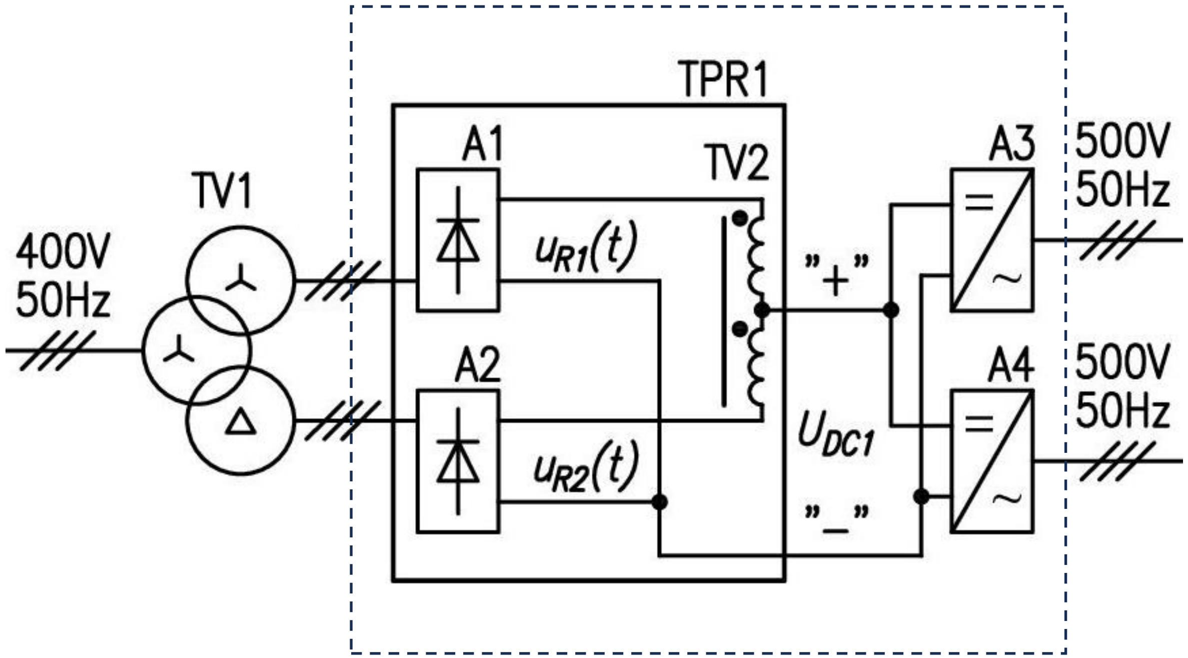
URN310 FN4

PSN235 N2 auxiliary power converter

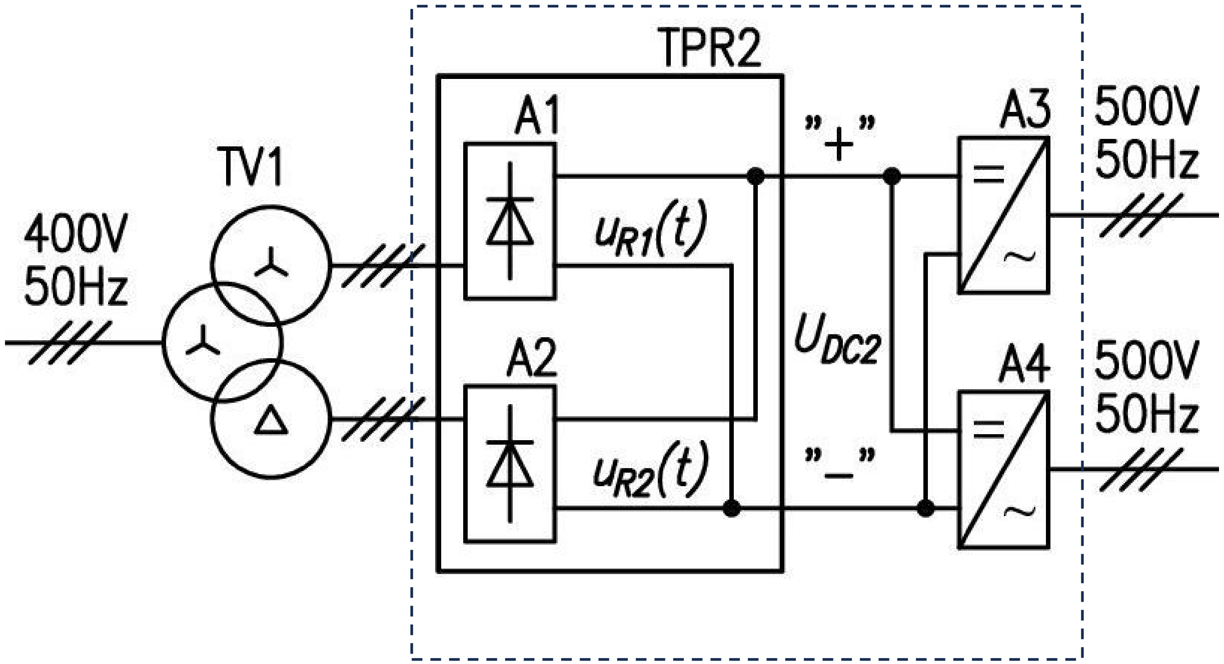
The principal technical requirements of URN310 FN4 converter

	Parameters	Value
1	Input voltage	3 ~ 50Hz, 400V
2	Output voltage (regulated)	2 channels x 3 ~ 50Hz, 0…500V
3	Summary output power, kVA	310
4	Coupling between input and output voltages	Yes
5	Type of cooling	Forced air cooling

Operational schemes to design URN310 FN4 in subject



Parallel Twelfth-Pulse Rectifier
WITH interphase transformer TV2



Parallel Twelfth-Pulse Rectifier
WITHOUT interphase transformer

Analysis of Parameters of URN310 FN4 Parallel Twelfth-Pulse Rectifiers

$$P_{VD.V} = \frac{1}{T}\int_0^T i_{VD}(t)V_{(T0)}dt;$$

$$P_{VD.r} = \frac{1}{T}\int_0^T i_{VD}(t)^2 r_T dt,$$

TPR type	The parameter of TPR				
	t^*_{on}	K^*_{TV21}	U^*_{MR}	I^*_{AV}	I^*_{RMS}
Parallel TPR with an interphase transformer	1	1	1	1	1
Parallel TPR without an interphase transformer	0.5	0.966	0.966	1	1.41

t_{on} - duration of the on-state of the power diode;
K_{TV21} - the transformation coefficient, which provides the specified U_{DC};
U_{MR} - maximum repetitive instantaneous value of the power diode’s reverse voltage;
I_{AV} and I_{RMS} - the average and effective value of the currents of power diodes.

Analysis of Parameters of URN310 FN4 Parallel Twelfth-Pulse Rectifiers

$$T_j = T_e + (P_{VD.TO} + P_{VD.r})R_{\Sigma th},$$

where $R_{\Sigma th} = R_{j-c} + R_{c-s} + R_s$.

$$T_{j1} = T_e + \left(\frac{I_{TPR}V_{(T0)}}{6} + \frac{I_{TPR}^2 r_T}{12}\right)R_{\Sigma th};$$

$$T_{j2} = T_e + \left(\frac{I_{TPR}V_{(T0)}}{6} + \frac{I_{TPR}^2 r_T}{6}\right)R_{\Sigma th}.$$

$$I_{TPR1} = -\frac{V_{(T0)}}{2r_T} + \sqrt{\left(\frac{V_{(T0)}}{2r_T}\right)^2 + 6\frac{T_{jg}-T_e}{R_{\Sigma th}r_T}};$$

$$I_{TPR2} = -\frac{V_{(T0)}}{r_T} + \sqrt{\left(\frac{V_{(T0)}}{r_T}\right)^2 + 12\frac{T_{jg}-T_e}{R_{\Sigma th}r_T}}.$$

$$I_{VD.AV1} = -\frac{V_{(T0)}}{12r_T} + \sqrt{\left(\frac{V_{(T0)}}{12r_T}\right)^2 + \frac{T_{jg}-T_e}{6R_{\Sigma th}r_T}};$$

$$I_{VD.AV2} = -\frac{V_{(T0)}}{6r_T} + \sqrt{\left(\frac{V_{(T0)}}{6r_T}\right)^2 + \frac{T_{jg}-T_e}{3R_{\Sigma th}r_T}}.$$

$$K_{ov.i} = \frac{I_{mAV.i}}{I_{AV.n}},$$

Diode type	The parameter						
	$V_{(T0)}$, V	r_T, mOhm	$R_{\Sigma th}$, K/W	$T_{j.max}$, °C	$K_{ov.1}$	$K_{ov.2}$	$\frac{K_{ov.2}}{K_{ov.1}}$
SKKD81	0.85	1.8	1.03	125	0.85	1.03	1.22
SKKD100	0.85	1.3	0.98	125	0.97	1.16	1.20
SKKD162	0.85	1.2	0.51	135	1.32	1.61	1.22

Comparison of the obtained values of the coefficients $K_{ov.1}$ and $K_{ov.2}$ allows to conclude that TPR1 can have about 20% more output average current, at which the junction temperatures of power diodes reach $T_{j.max}$, compared with TPR2.

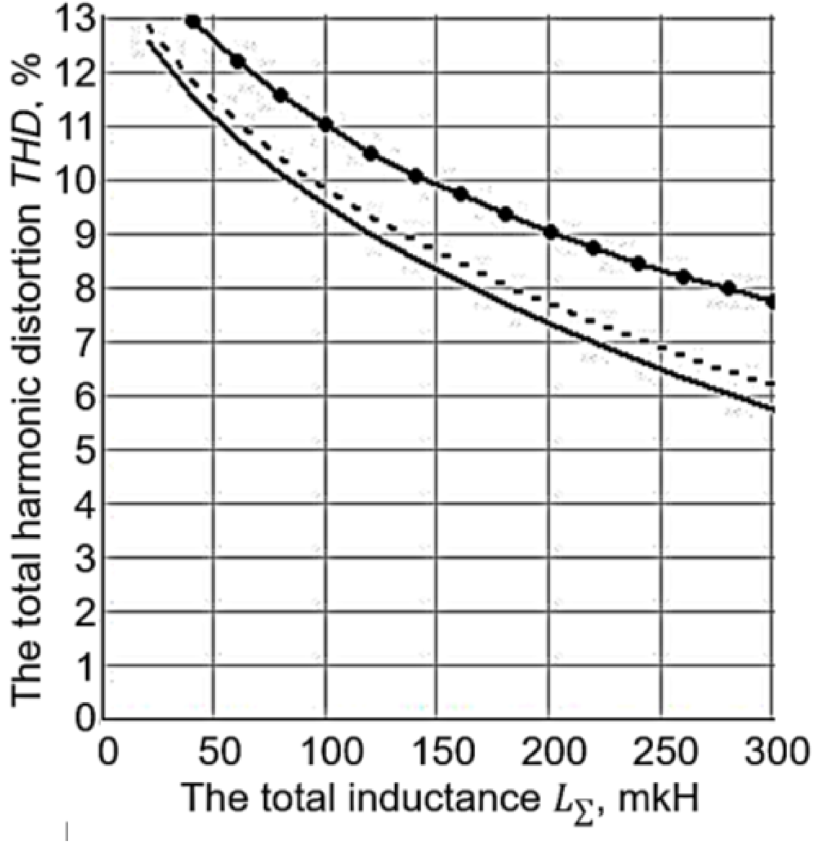
Evaluation of Total Harmonic Distortion of URN310 FN4 Input Current

We assumed that $P_{A1} \leq P_{A2}$, and introduced the symmetry coefficient:

$$\chi = \frac{P_{A1}}{P_{A2}}$$

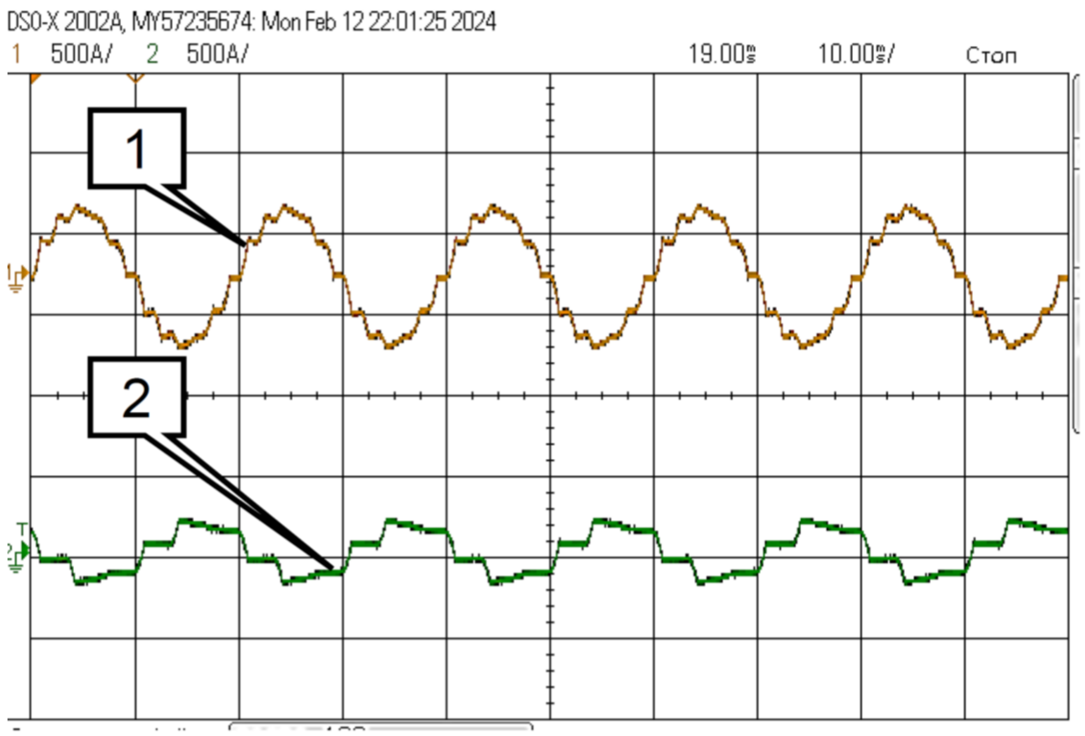
Computer simulation showed that even when changing χ from 1 to 0, the additional inductance L_f and the leakage inductance L_{s2} of the TV2 have almost no affect to *THD*. Also, we studied how *THD* depends on the total inductance $L_\Sigma = L_{in} + L_{s1}$ and the coefficient χ.

The dependence of total harmonic distortion



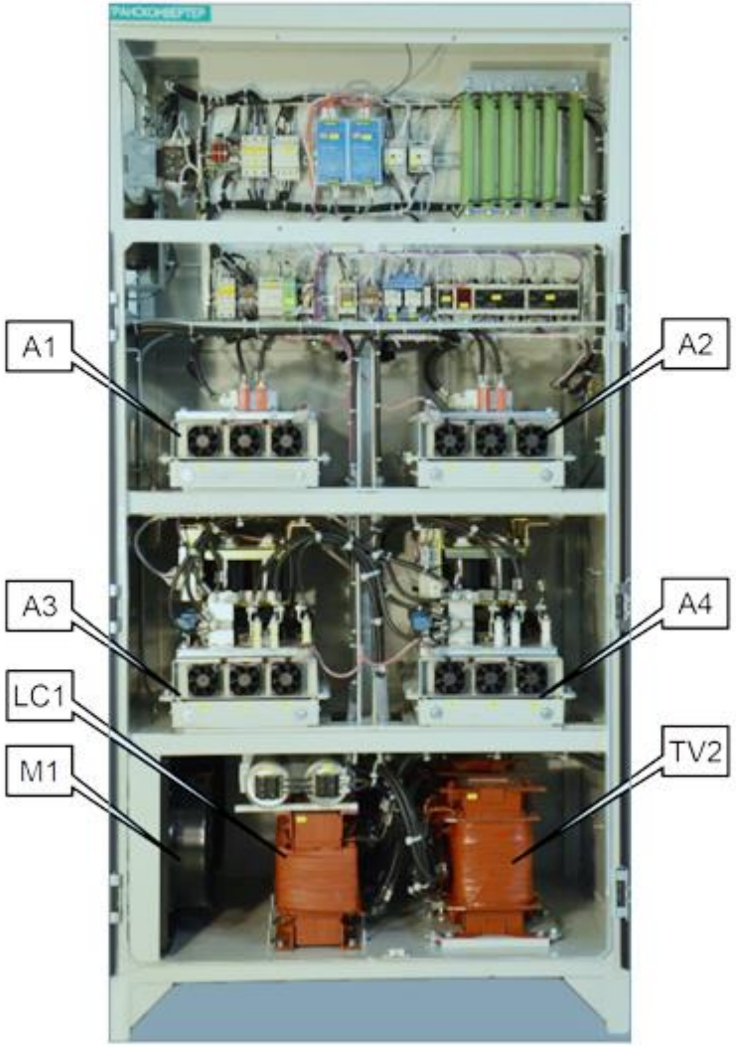
Solid line corresponds to $\chi=1$;
the dashed line corresponds to $\chi=0.8$;
the line with asterisks corresponds to $\chi=0.6$.

Test results



Oscillograms of the currents

(1) Input phase current of the developed URN310 FN4
(2) Input phase current of the A1 unit



The general view of URN310 FN4 developed

Conclusion

1 As an advantage of using the interphase transformer, the effective current value of the TPR1 power diode is 41% less compared to TPR2. This factor causes lower power losses in the power diodes in TPR1 compared to TPR2.

2 A parallel twelfth-pulse rectifier with an interphase transformer can have about 20% greater output average current, at which the junction temperatures of the diodes reach a maximum value compared to TPR2.

3 MATLAB Simulink Computer simulation confirmed the correctness of the results obtained.

4 The leakage inductance of the interphase transformer has almost no effect on THD.

5 THD increases with a decrease in the total input inductance and an increase in the difference between the parameters of the power diodes and the active resistances of the windings of the input transformer and of the interphase transformer.

6 An algorithm for calculating the additional input phase inductance, at which the considered URN has the required THD is proposed.

7 The obtained results allow electrical engineers to select both the type of twelfth-pulse rectifiers and the type of power diode for the selected rectifier and the parameters of the additional input inductance.

Thank you very much for your Attention!

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