KACO new energy.

Application Note

UTE C 15-712-1

Medium Voltage Transformers for 3 * XP350 PV Inverter

Scope of Application

This document describes the requirements of medium-voltage transformers that are connected to

3 * XP350 PV inverters for one Mw Station.

KACO new energy only accepts the warranty for medium-voltage transformers that have been installed following the guideline provided in this application note.

1 Technical Properties

The transformer used in Fig.1, is a multi-winding transformer. Its low-voltage side is connected to each XP350 of which rated output voltage is 290V and its high voltage side is for connection to the medium-voltage grid in Europe is mostly 20kV. However, other high voltages are also possible: 10 kV, 15 kV, 22 kV, 25 kV, 27 kV, 30 kV or 35 kV.

This transformer must comply with the following technical specifications:

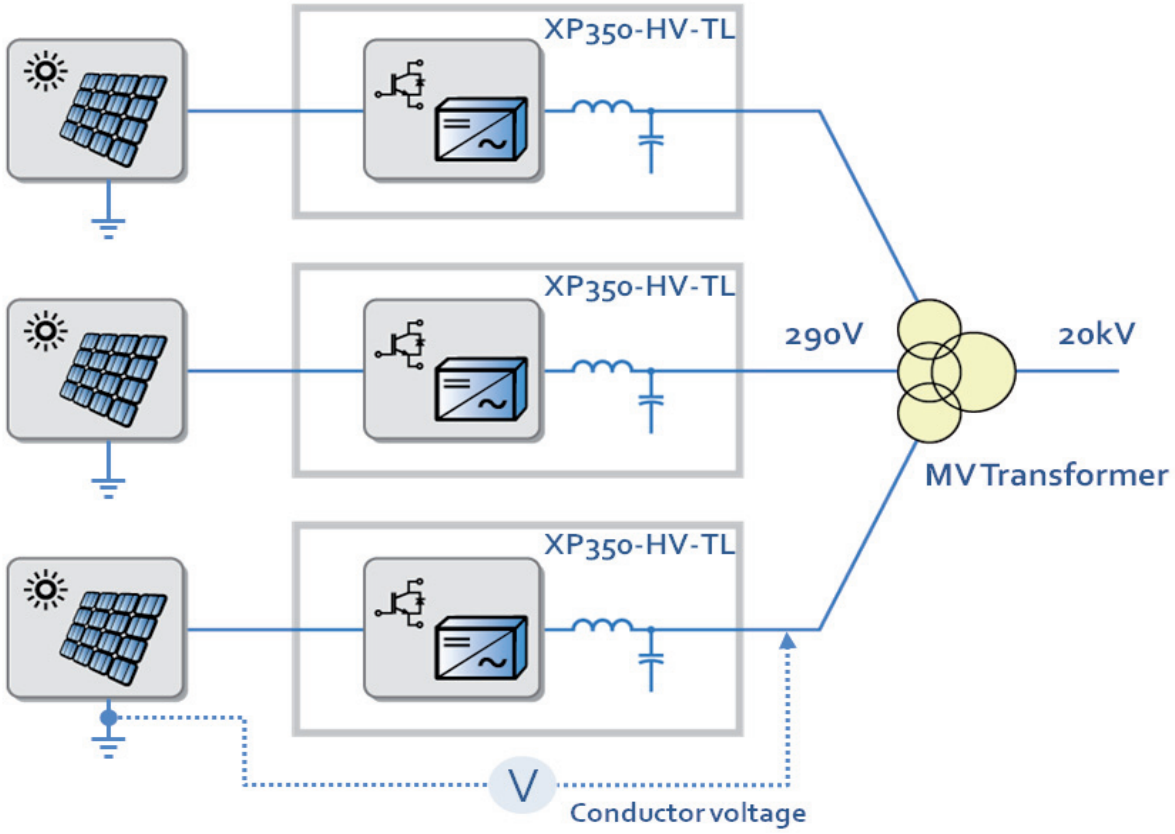

Figure 1: 1350-HV-TL with Multi-winding Transformer

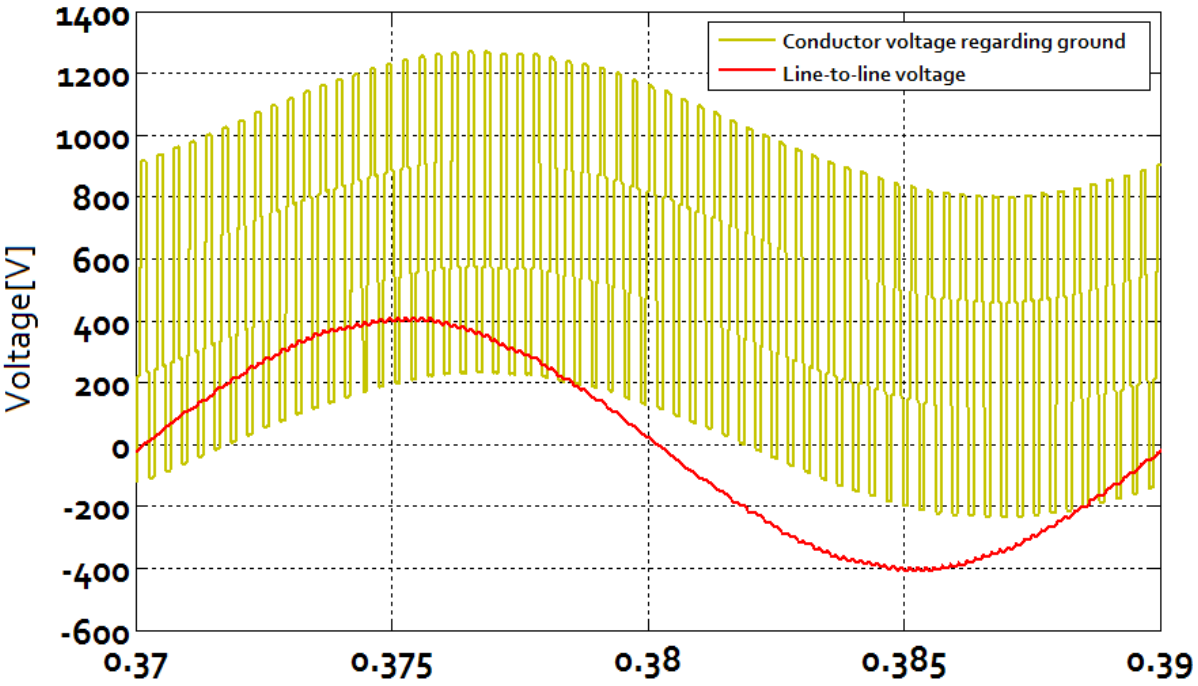

Figure 2: Conductor volatage regarding ground and line-to-line voltage

1. The transformer must be suitable for PWM (Pulse Width Modulation) Inverter. The transformer should be designed such that its magnetic flux is not saturated even if 1% of DC current flow on its low voltage winding. Also the transformer should be designed and tested in accordance with IEC-60076.
2. The transformer must be designed for the voltages that arise during pulsed operation of the inverter. The voltages can reach a magnitude of maximum ±1300 V reference to the ground. The rms-value of the voltages reference to the ground is maximum 700V. (See Fig.2)
3. The transformer must be designed for voltages on its low-voltage windings that can exhibit a voltage gradient dU/dt of up to 500V/µs reference to the ground. The line-to-line voltages are sinusoidal.
4. A shield winding that is grounded to the tank is necessary between the low-voltage windings and the high voltage windings. This shield plate must be designed to protect against the heat due to eddy current by the flux of both the low voltage winding and the high voltage winding. This serves as an additional dV/dt filter.
5. The transformer is provided with separate galvanically isolated low-voltage windings for XP350-HV-TL.
6. Equivalent series impedance between low voltage and high voltage winding:
   The equivalent series impedance Z(%) of the transformer must, in relation to every inverter, be 6 % in each case(See Fig.4). Impedance voltage tolerance limits of between 5.4 % and 6.6 % must be maintained. This value can be determined when the high-voltage windings is short-circuited and the voltage on the other low-voltage winding is increased until the nominal current flows. At the same time another low voltage windings are idle (see Fig.3).

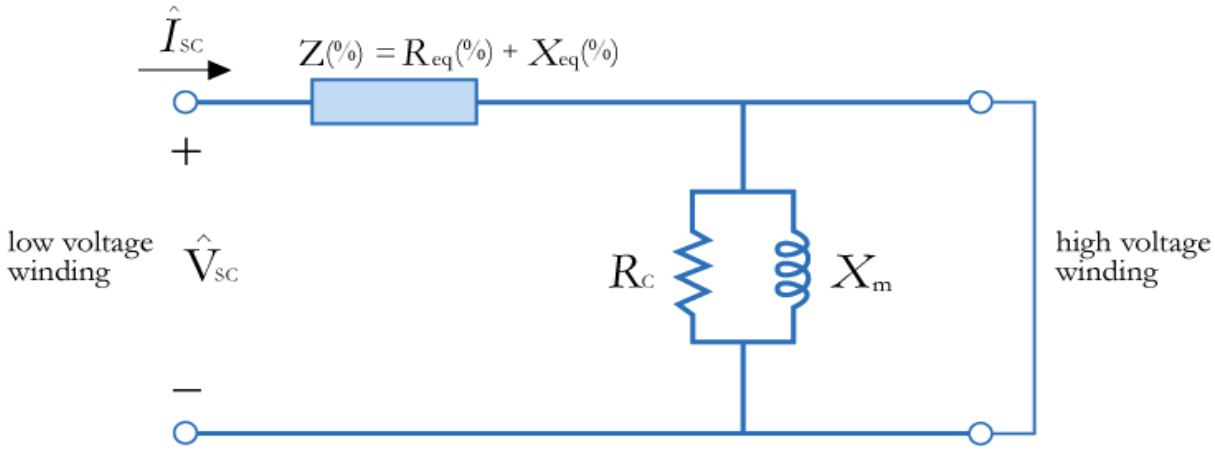

Figure 3: Equivalent circuit with short circuited high voltage winding

7. Equivalent series impedance between both low voltage winding:
   The equivalent series impedance Z(%) between both low-voltage windings must be 10 %(See Fig.4). The tolerance limits of this impedance voltage of between 9 % and 11 % must be maintained. This value can be determined when one of the low-voltage windings is short-circuited and the voltage on the other low-voltage winding is increased until the nominal current flows. At the same time the high-voltage windings and the other low voltage windings are idle (see Fig.4).

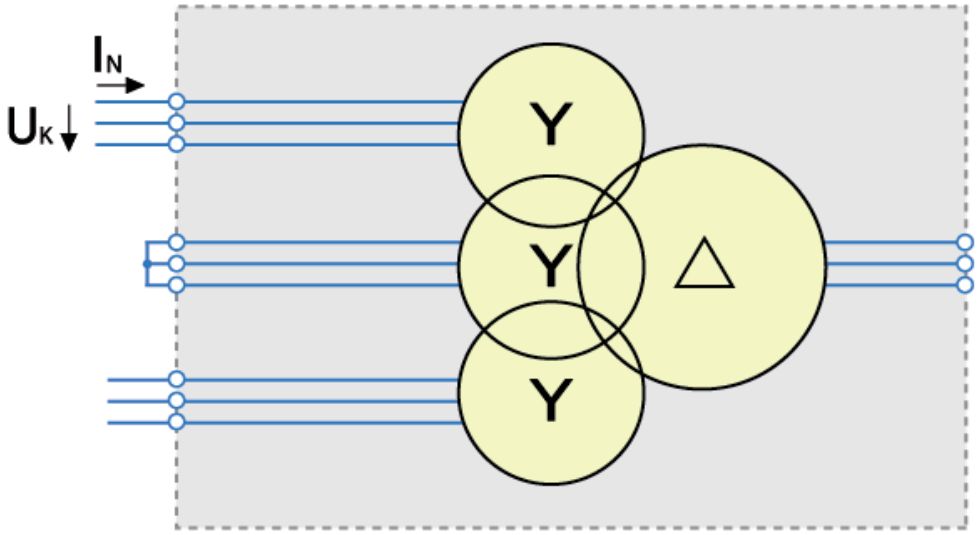

Figure 4: Equivalent circuit with short circuited high voltage winding

8. Equivalent series impedance Z(%) of the multi-winding transformer:
   To summary of the contents in Article 6 and Article 7, the equivalent series impedance Z(%) of the multi-winding transformer can be shown as followed.
   ZL is the equivalent series impedance of low voltage winding, and ZH is the equivalent series impedance of high voltage winding.

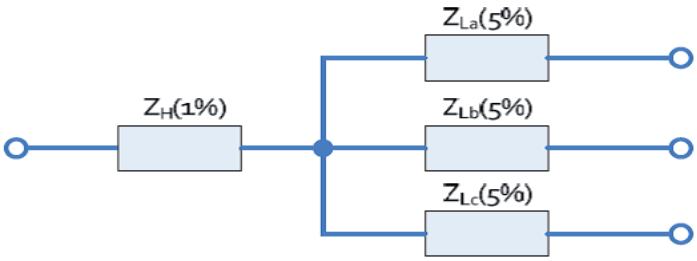

Figure 5: Equivalent series impedance Z(%) of multi-winding transformer

9. In ambient temperatures off up to 50 °C the transformer must have a current load capability of 110 %. In ambient temperatures of above 50°C, a linear de-rating to nominal power occurs assuming that the temperature of the heat-sink in IGBT stack is 76°C. Further information can be found in the following documentation:
   - XP Inverter data sheet
   - Power derating of XP series.
10. During thermal rating, the load curve and the ambient conditions at the respective installation site should be taken into account.
11. No neutral point is required on the low voltage side. If a neutral point is nevertheless present on thelow-voltage side, this neutral point must not be either connected or grounded.
12. Four-winding transformers (double-storey transformer) with varying windings each on the high-volage side and the low-voltage side can be used. For example YNd11d11d11, YNd5d5d5, YNd1d1d1 or Dy11y11y11, Dy5y5y5, Dy1y1y1 with an ungrounded neutral point on the low-voltage side (see Fig.6).

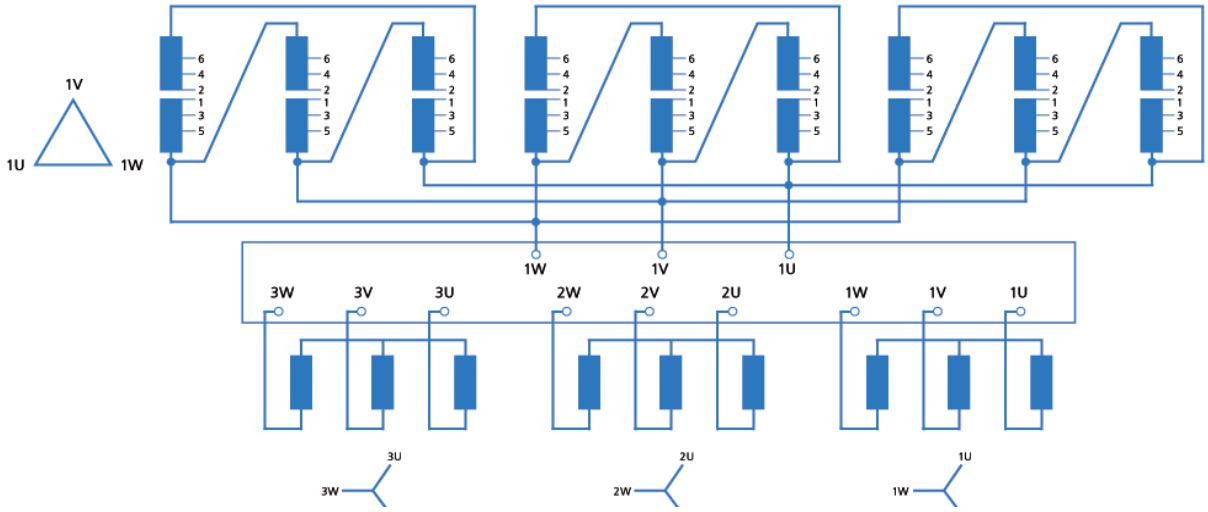

Figure 6: Diagram of multi-winding transformer

13. KACO new energy recommends the use of a transformer with a tap changer on the high-voltage side that enables an alignment to the voltage level of the medium-voltage grid. Our recommendation is 5 tap with 2.5% resolution.
14. The country-specific grid frequency is to be taken into consideration.
15. The country specific standards valid are to be taken into consideration.

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Current harmonics according to EN 61000-3-12

Test Conditions

Power (per phase) P = 83.33kW

Item	Value	Result	Item	Value	Result	Item	Value	Result
THD	1,68%	PASS	THD	1,90%	PASS	THD	1,90%	PASS
PWHD	3,90%	PASS	PWHD	3,66%	PASS	PWHD	3,08%	PASS
THDv		OK	THDv		OK	THDv		OK

Harmonic Order	Limit	Phase 1			Phase 2			Phase 3		
		av. Current [A]	Limit	Margin to Limit	av. Current [A]	Limit	Margin to Limit	av. Current [A]	Limit	Margin to Limit
	61000-3-12 Tabelle 3	61000-3-12 Frame: 2.5min	61000-3-12 Bal. 3ph [A]		61000-3-12 Frame: 2.5min	61000-3-12 Bal. 3ph [A]		61000-3-12 Frame: 2.5min	61000-3-12 Bal. 3ph [A]	
1		405,33	-	-	400,38	-	-	380,32	-	-
2	8,00%	1,66	32,43	94,9%	1,57	32,03	95,1%	1,64	30,43	94,6%
3	–	2,17	-	-	3,67	-	-	2,76	-	-
4	4,00%	0,61	16,21	96,2%	0,70	16,02	95,6%	0,55	15,21	96,4%
5	10,70%	3,33	43,37	92,3%	4,42	42,84	89,7%	4,68	40,69	88,5%
6	2,67%	0,26	10,82	97,6%	0,26	10,69	97,6%	0,25	10,15	97,6%
7	7,20%	2,83	29,18	90,3%	2,46	28,83	91,5%	2,39	27,38	91,3%
8	2,00%	0,19	8,11	97,7%	0,20	8,01	97,5%	0,21	7,61	97,3%
9	–	0,25	-	-	0,36	-	-	0,18	-	-
10	1,60%	0,16	6,49	97,5%	0,16	6,41	97,5%	0,15	6,09	97,5%
11	3,10%	0,37	12,57	97,1%	0,23	12,41	98,1%	0,41	11,79	96,5%
12	1,33%	0,14	5,39	97,4%	0,15	5,33	97,2%	0,15	5,06	97,0%
13	2,00%	1,98	8,11	75,6%	1,66	8,01	79,2%	2,37	7,61	68,8%
14	1,14%	0,32	4,62	93,0%	0,25	4,56	94,6%	0,24	4,34	94,5%
15	–	2,85	-	-	1,78	-	-	1,37	-	-
16	1,00%	0,21	4,05	94,8%	0,57	4,00	85,7%	0,60	3,80	84,2%
17	–	2,45	-	-	2,66	-	-	1,88	-	-
18	0,89%	0,09	3,61	97,6%	0,15	3,56	95,9%	0,12	3,38	96,4%
19	–	0,73	-	-	1,24	-	-	1,33	-	-
20	0,80%	0,09	3,24	97,1%	0,10	3,20	96,8%	0,08	3,04	97,4%
21	–	0,25	-	-	0,11	-	-	0,23	-	-
22	0,73%	0,13	2,96	95,6%	0,27	2,92	90,7%	0,25	2,78	91,0%
23	–	0,58	-	-	0,42	-	-	0,26	-	-
24	0,67%	0,11	2,72	95,9%	0,13	2,68	95,2%	0,10	2,55	96,0%
25	–	0,16	-	-	0,18	-	-	0,23	-	-
26	0,62%	0,11	2,51	95,8%	0,11	2,48	95,4%	0,08	2,36	96,4%
27	–	0,12	-	-	0,15	-	-	0,14	-	-
28	0,57%	0,09	2,31	96,1%	0,13	2,28	94,2%	0,10	2,17	95,6%
29	–	0,18	-	-	0,18	-	-	0,05	-	-
30	0,53%	0,03	2,15	98,7%	0,04	2,12	98,3%	0,03	2,02	98,6%
31	–	0,04	-	-	0,17	-	-	0,18	-	-
32	0,50%	0,04	2,03	97,8%	0,05	2,00	97,7%	0,02	1,90	98,8%
33	–	0,04	-	-	0,04	-	-	0,03	-	-
34	0,47%	0,03	1,91	98,4%	0,06	1,88	97,0%	0,03	1,79	98,3%
35	–	0,05	-	-	0,07	-	-	0,05	-	-
36	0,44%	0,02	1,78	99,1%	0,01	1,76	99,2%	0,02	1,67	98,6%
37	–	0,04	-	-	0,04	-	-	0,08	-	-
38	0,42%	0,03	1,70	98,3%	0,03	1,68	98,3%	0,01	1,60	99,3%
39	–	0,05	-	-	0,05	-	-	0,02	-	-
40	0,40%	0,02	1,62	98,7%	0,04	1,60	97,6%	0,02	1,52	98,7%
41	N/A	0,05	-	-	0,07	-	-	0,03	-	-
42	N/A	0,01	-	-	0,01	-	-	0,01	-	-
43	N/A	0,03	-	-	0,02	-	-	0,03	-	-
44	N/A	0,03	-	-	0,03	-	-	0,01	-	-
45	N/A	0,04	-	-	0,03	-	-	0,02	-	-
46	N/A	0,01	-	-	0,02	-	-	0,01	-	-
47	N/A	0,06	-	-	0,04	-	-	0,02	-	-
48	N/A	0,02	-	-	0,01	-	-	0,01	-	-
49	N/A	0,03	-	-	0,03	-	-	0,01	-	-
50	N/A	0,01	-	-	0,01	-	-	0,01	-	-