

## **EXPERIENCE IN SHORT CIRCUIT TESTING OF LV SHORT CIRCUIT TESTING TRANSFORMER**

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### **Abstract:**

For an On-line Short Circuit Facility, the main component of the facility is the Short Circuit Testing Transformer. There are no regular manufacturers of such transformers. Design of such transformers needs to be done taking into account many factors. The role of the manufacturer in getting the transformer designed for a particular application is very critical. Detailed checking the design calculations for various parameters including adequate design margins for heavy electromagnetic forces during short circuit, before commencement of manufacturing is very important. Such transformers are usually low impedance transformers and short circuit testing of such transformers to verify the design poses several problems, since the full-scale short circuit test means abnormally high electromagnetic forces, and may reduce the life of test transformer. It is debatable whether full-scale short circuit testing is necessary. Recently a Low Voltage short circuit test station was set up at Bangalore for an US multinational. Brief design features of the Test transformer and short circuit testing of the LV Short Circuit Transformer, decisions taken regarding full scale applicability of Short Circuit Tests with reasons thereof are enumerated in this paper.

### **INTRODUCTION:**

The scope of the test facility that was to be set up was to have complete type test facility for six Low Voltage products as per IEC / IS and UL standards. The short circuit test capability was to be in excess of 10 kA for the Laboratory. The same short circuit transformer was to be used for over current endurance tests at least up to 2500A test current. Specifications for all other equipment/test rigs required for the Laboratory for conducting all the other tests also were to be written and procured from the right sources to make the facility complete. These included temperature rise facility up to 6000A short time, multiple overload endurance facilities to take care of varying current requirement of control circuit devices, MCB, RCCB/RCBO and Contactors, Dielectric test facilities, Mechanical test facilities, EMI facilities etc.

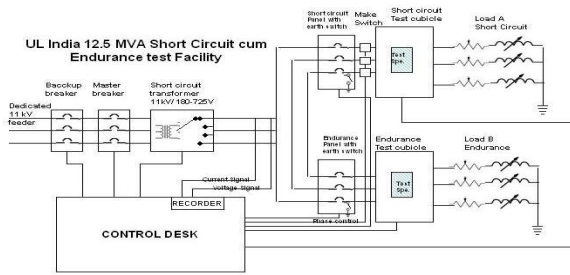
The main equipment required for the laboratory is the Short Circuit Testing

Transformer. The transformer design was to take care of both overload endurance requirement up to 2500A test current and short circuit test in excess of 10 kA.

### **SINGLE LINE DIAGRAM:**

The laboratory is spread over two floors of a three-storied building. The total power estimated for the Laboratory was 4 MVA, which included the power requirement for short circuit testing, overload endurance testing temperature rise testing and power requirement for Medical, IT and motor test Labs. A 1000 KVA transformer with on-load tap changer takes care of regulated power requirement for all the Labs except the Short Circuit Test Station and high current endurance test facility. A 1500 KVA Short Circuit Transformer meets the power requirement for these two facilities.

A single line diagram of the Short circuit test station is reproduced below.



The main equipment of the facility is the 1500 KVA Short Circuit Test transformer. Other important components are Make Switch, Master and back-up VCBs, Load Banks for Short Circuit and over-load endurance tests, Data acquisition system and the control desk. All these were designed and sourced with in India except the Make Switch, which was sourced from abroad.

### **BRIEF DETAILS OF THE 1500 KVA SC TESTING TRANSFORMER**

This main equipment was designed with following requirements in mind

- Suitable for testing all low voltage products for any Voltage from 110 V to 690V, which means all, rated Voltages any where in the world.
- The transformer shall be rated in such a way adequate factor of safety is considered. In this case this was about 4 to ensure foolproof working.
- The transformer to be rated for both Short Circuit tests up to 10 kA, 690V and overload endurance tests up a test current of 2500A at 690V.
- Since the input Power to the Laboratory is at 11 kV delta, it shall be possible for connecting the HV of the transformer in Star also and hence a change over switch was to be designed.
- A well designed Voltage selection board with link arrangement for easy changing of Test voltages suitable for bus duct connection from the transformer to the Short Circuit and Endurance Power Panels.

With the above requirements in mind , Vendor identification for manufacturing of this unique transformer was taken up and it was really a difficult task. This is mainly because no manufacturers manufacture such transformer on a regular basis.

Many vendors were approached both with in India and abroad including, Taiwan, China, Turkey and USA. It was found that many manufacturers were not interested in taking up such a One-off transformer. We were able to obtain finally four offers – two from India and one each from China and USA.

Finally after extensive discussions with all the manufacturers and on the basis of techno-economical considerations, a manufacturer in India was selected. The manufacturer selected (M/S Atlanta electricals, Anand, Gujarath) was agreeable to design the transformer as per our requirements. He showed his capability by sending the design calculations that met our requirement. He also agreed to test the transformer for all routine tests, Short Circuit, Impulse and temperature rise tests to prove his design beyond doubt. This manufacturer also offered the fastest delivery period.

The transformer has the following main features.

#### **MAIN FEATURES OF SHORT CIRCUIT TESTING TRANSFORMER**

Sr. No.	Description	Unit	Spesification
1	Service		Indoor
2	KVA Rating	HV winding	kVA 1500 kVA at LV 690 volts
		LV winding	kVA Refer Table
3	Rated No load voltage	HV winding	kV 11000
		LV winding	kV Refer Table
4	Rated Frequency	Hz	50
5	Number of Phases		3 Phase

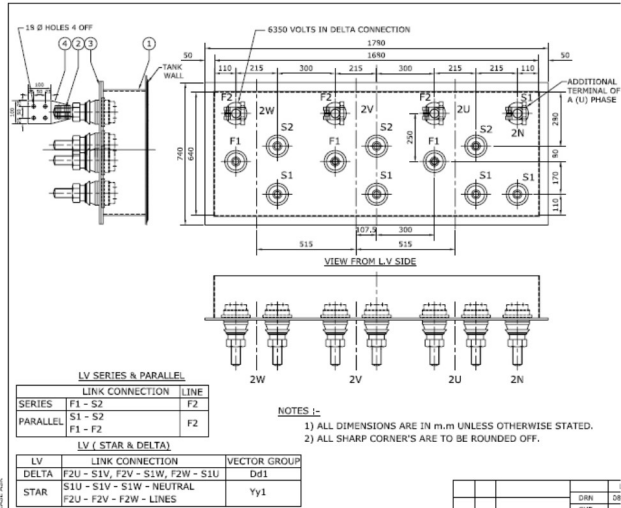
6	Connections	HV winding		Delta/Star
		LV winding		Delta/Star-Series/Parallel
	iv)	OLTC or Off circuit Tap switch	Off Load Tap Changer	
7	Type of Cooling			ONAN
8	Temperature rise above 50°C	Top Oil	°C	55
		Winding	°C	65
9	Insulation Level			
	i) Separate source power frequency voltage withstand	HV winding	kV rms	28/5 kV rms for one minute
		LV winding	kV rms	
	ii) Induced over voltage withstand	HV winding	kV rms	2x Rated voltage and frequency for one minute
LV winding		kV rms		
iii) Impulse voltage withstand	HV winding	kVp	75 kVp/nil	
10	Efficiency at 75 °C at unity power factor	At full load		98.94
		At ¾ full load		98.90
		At ½ full load		98.68
11	Approximate weight	Core and winding	Kg	10000
		Tank, fitting and Accessories	Kg	4480
		Oil	Kg	5520
		Total weight	Kg	20000
12	Approx. overall dimensions	L x B x H	Mm	4500 x 2400 x 4400
13	Insulating Material			Pre-compressed pressboard, permawood Nomex Paper for Winding wires.
14	Terminal Arrangement	HV		Cable Box
		LV		Bus Bar
15	Reference Standards			IEC 60076/IS 2026

Changes in HV Configuration, HV tap Position; Series/Parallel connection on LV side followed by Star/Delta connection would yield following Test Voltages

P – Parallel, s – Series, d – LV Delta, s – LV Series			
LV winding	LV 3 phase configuration	HV tap position	LV Volts
<b>HV DELTA</b>			
p	d	1	181.8
p	d	2	190.5
p	d	3	200.0
p	d	4	210.0
p	d	5	219.5
p	d	6	229.8
p	d	7	241.1
p	d	8	252.9
p	d	9	265.9
p	d	10	286.6
p	d	11	302.4
p	s	1	314.9
p	s	2	329.9
p	s	3	346.4
p	s	4	363.8
p	s	5	380.1
p	s	6	398.0
p	s	7	417.6
p	s	8	438.0
p	s	9	460.5
p	s	10	496.5
p	s	11	523.8
s	d	1	363.6
s	d	2	381.0
s	d	3	400.0
s	d	4	420.0
s	d	5	438.9
s	d	6	459.5
s	d	7	482.2
s	d	8	505.7
s	d	9	531.7
s	d	10	573.3
s	d	11	604.8
s	s	1	629.8
s	s	2	659.8
s	s	3	692.8
s	s	4	727.5
s	s	5	760.2
<b>HV STAR</b>			
p	d	1	105.0
p	d	2	110.0
p	d	3	115.5
p	d	4	121.3
p	d	5	126.7
p	d	6	132.7
p	d	7	139.2
p	d	8	146.0
p	d	9	153.5
p	d	10	165.5
p	d	11	174.6

The required Voltage for testing is selected using the link connection from a Link Board given at the front side of the transformer.

### LINK BOARD FOR THE TRANSFORMER



### TESTS ON THE SHORT CIRCUIT TESTING TRANSFORMER :



The Short Circuit Testing Transformer

The decision regarding extent testing of such non-standard transformers requires a many points to be considered before the actual type test takes place. All the routine tests on the transformer, as per IEC 60076, for various configurations is a must at different stages of transformer

manufacturing to ensure that the quality is kept up. In addition it is also necessary to conduct type tests like Temperature rise tests, Lightning Impulse Voltage test and Short Circuit Test. While Lightning Impulse Voltage test can be done as is done on a regular transformer, it is important to decide as to what configuration of Primary and secondary is to be used for Temperature Rise and Short Circuit Tests.

Since Short Circuit testing is very costly and time consuming, it is impossible to test at all desired configurations. Hence it is better that we decide on a configuration that is important from the point of view regular testing.

For Short Circuit testing, even though it is desirable to test at the lowest impedance tap of the transformer as it would see the highest short circuit current at this position. Testing at highest voltage highest current configuration would also be an option to be considered. This would amount to a reduced short circuit current but highest voltage the transformer is designed for. Even here the Short Circuit currents are extremely high compared to a regular transformer of the same rating.

It is also to be kept in mind that applying 9 shots of short circuit currents is also likely result in accelerated ageing of the Test Transformer and may reduce the life of the transformer which is not desirable. Reference is made to following CIGRE publication which brings out the pros and cons of short circuit testing.

Thirteen years test experience with Short-circuit withstand capability of large power Transformers

by Mr Smeets, Mr Leufkens and Mr Te Paske of KEMa and Mr. Fogelberg of ABB.

It is also to be noted that, as per IEC 60076, the maximum short circuit current, as per the impedance table, will be 25 times the full load current (Corresponding to 4 % Impedance).

Keeping all these facts in mind, it was decided that the short circuit tests would be done at the maximum Voltage LV connection (HV tap position 3 -LV windings in series and three phase connected in Star) and the 9 Short circuit shots shall be equivalent to 25 times the full load current of the transformer. Further to test other HV taps, it was decided to apply 3 shots each in tap positions 1, 3 and 5. The short circuit current was about 32 kA. This is more than 3 times the Max test current the transformer is to be used for. It was assumed that this level of testing will not stress the transformer to the extent of reducing its useful life significantly.

This would reasonably validate the design calculation from the point of withstanding the short circuit forces and at the same time we are not stressing the transformer to a point where the future life of this costly piece of equipment is jeopardized.

The short circuit testing was carried out at an accredited laboratory at Bhopal at a current of 25 times the full load current (rms) and peak being at 2.3 times rms. The transformer successfully withstood this. The variation of reactance at the end of 9<sup>th</sup> shot was within 2 % as per the requirement of the standard. Pre and post routine tests also showed that the transformer met all the requirements of the standard.

### **CONCLUSION:**

There is a need to properly analyze the functional requirement of special transformers (like the short circuit testing transformer) before deciding on the full scale applicability of all testing requirements as per the standard. Intelligent interpretation of the test requirement is necessary to avoid undue stressing of the transformer.

Blindly applying the entire standards requirement may reduce the life the special transformer.

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