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LV Short Circuit Testing Facility

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Abstract:

Short circuit testing of products is a highly time consuming task as there are very few Short Circuit Facilities which can be used by general public for testing. The problem is more so for LV switchgear and control gear manufacturers since their requirements are for Lower voltages and smaller currents. There are a very few dedicated smaller LV test facilities available for public usage in many countries. In Contrast China has many small LV Short Circuit facilities, both in the public domain and captive Labs, which have helped the LV Switchgear and Control gear manufacturers to undertake quick development testing and come out with new and improved designs. There is a need for more and smaller LV Short circuit facilities, catering to public requirement, in other countries also. This will reduce the dependency on established Short Circuit Facilities either within the country or abroad and also allow for quicker testing dates at least for smaller test requirements. These facilities can be established at a very reasonable cost in a very short duration.
Recently an LV Short Circuit Test Facility was set up at Bangalore, India for an US MNC. The paper gives brief details about the design and implementation of such a facility..

INTRODUCTION:

The LV Switchgear forms an important part of distribution network. These cover a wide variety of devices which are intended to control and protect LT electrical networks like MCBs, Contactors, Starters, Switches, Rewirable and HRC fuses, fuse Switch Units, Distribution boxes, Motor Control Centers, Bus Ducts. For uninterrupted power supply and reliability of the distribution system, Safety, Quality and Reliability of these LV Switchgear equipment is very vital. All tests as per relevant National or International standards are to be mandatorily carried out before installing them in the system.

Short Circuit Testing is one of the most important type tests to be conducted on all high power handling equipment. This is basically a test to test the equipment for not only withstand capability of enormous electromagnetic forces but also test the capability of equipment to the dangerous temperature build up. The test also checks the safe opening of breakers under short circuit conditions.

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Keeping in view of the reliability of the equipment in the field and safety, almost all the users of high power equipment undertake Short Circuit Tests in an accredited mandatory. The government also has made full testing of LV switchgear and control gear used by household and LV industrial users mandatory. Hence the requirement of short circuit tests on equipment like transformers, Panels, Distribution boxes, Control Centers, LV Circuit breakers, Contactors, LV fuses etc have increased over the years.

But unfortunately, in many countries in Asia and Africa, there are a very few accredited Short Circuit Laboratories in Asia and Europe which cater to the public requirement.

Hence the pressure on the existing Labs have increased manifold over the last few years. This has resulted in long queues and getting a reasonably quick test dates have become impossible.

There is a need to set up smaller Short Circuit Test facilities to cater to the needs of the local industry. This reduces the dependence on bigger high voltage high power test Labs and makes developmental and type testing more economical. The cost of building such short circuit labs is not very high.

Recently a small LV Short Circuit lab was set up at Bangalore for an US MNC and the author was the main consultant for this Laboratory.

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.

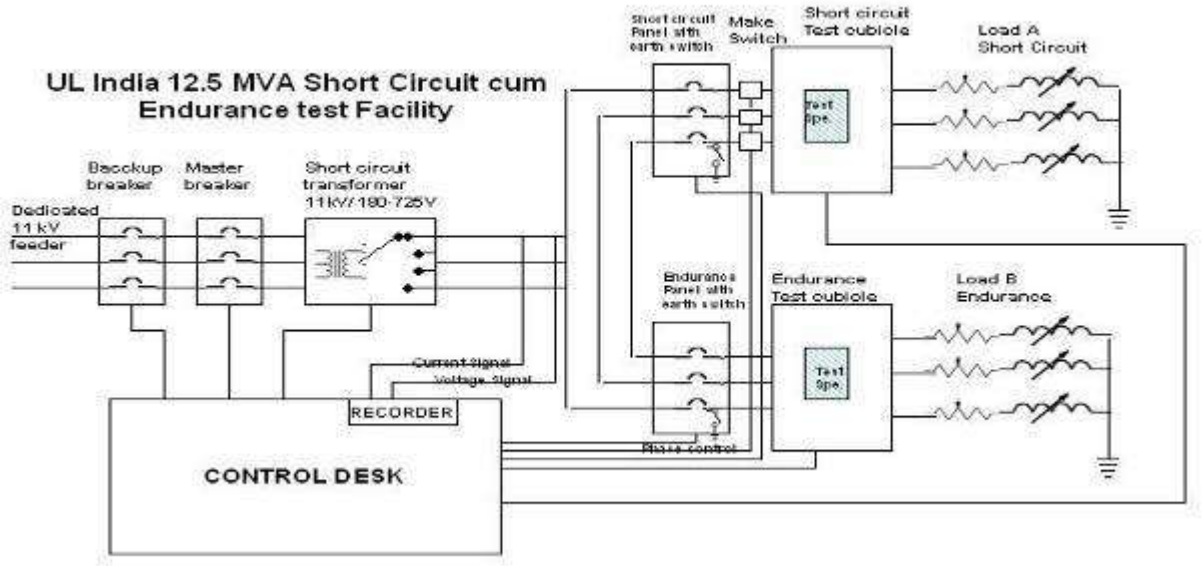
The other components of the SC facility were LT Control Panel, the Make Switch, LV Test Cubicle, Bus bar Run for connecting Transformer output to the LV Test Cubicle, HT and LT Earth Switches for safety, LT fuse protection, Variable Resistor and Inductor Load Banks, Test sequencer and Data acquisition and analysis system and Safety and Signaling system.

The present paper deals with brief details of this 12.5 MVA LV short circuit facility.

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 MAIN EQUIPMENT:

***1500 KVA Short Circuit 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 that 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 and 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 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.

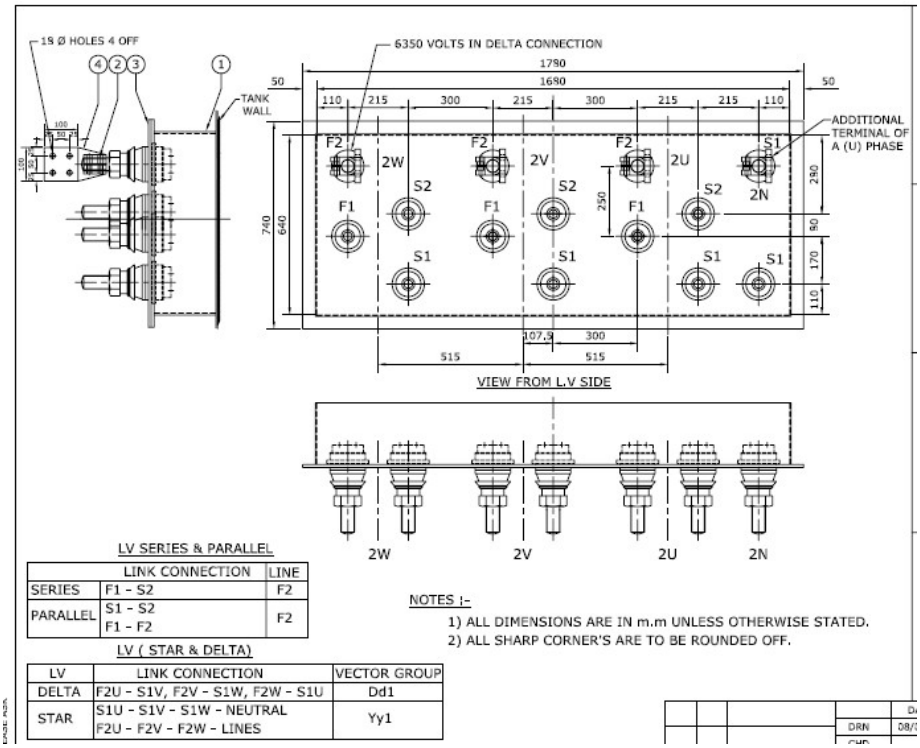
Sr. No.	Description		Unit	Offer
1	Service			Indoor
2	KVA Rating	HV winding	kVA	1500 kVA at LV 690 volts
		LV winding	kVA	Varies as per the Selected Voltage tap
3	Rated No load voltage	HV winding	kV	11000
		LV winding	kV	Varies as per the Selected Voltage tap
4	Rated Frequency		Hz	50
5	Number of Phases			3 Phase

6	Connections	HV winding		Delta/Star
		LV winding		Delta/Star - Series/Parallel
		OLTC or Off circuit Tap switch	Off Load Tap Changer	
7	Type of Cooling			ONAN
8	Temperature rise above 50ºC	Top Oil	ºC	55
		Winding	ºC	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 ºC 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 Test Voltages right from 105V to 760V. This

enables short circuit testing to be taken up at any LT voltage presently available in the world.

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



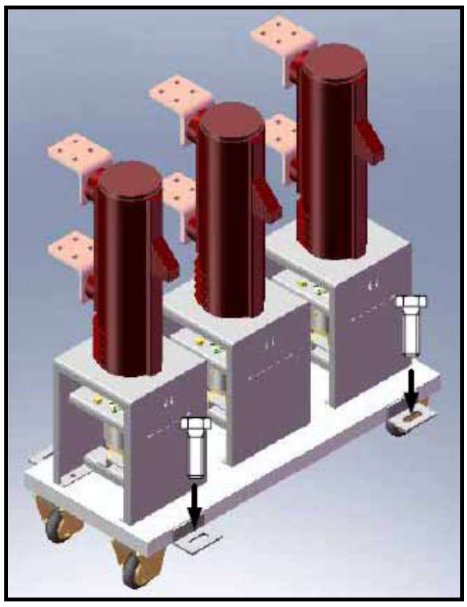
LINK BOARD FOR THE TRANSFORMER

***Short circuit making switch*:**

Make Switch is one of the important component of a short circuit test facility.
This switch is required for connecting the Transformer to the test circuit at a precise point on the voltage wave. High-speed operation is essential to enable the precision in closing instant. Prearcing during closure of the switch must be minimal, as this would affect the consistency of point-on-wave control.
Make switches used in Short Circuit Labs are very costly devices and to economise on the cost properly rated imported LV Contactor has been used and this suits the requirement of smaller Laboratories.
The Make Switch which has been used in the system is a solenoid operated Switch capable of high speed closing at the correct instant of the sinusoidal wave form. Precise angle on the voltage wave can be remotely set and operated through radio control.

Following are the main features of the Make Switch.

Sl No	Name	Unit	Data
1	Rated operating Voltage	V	1260 AC
2	Rated Insulation Level	kV	28
3	Thermal Current rating	A	1600
4	Dynamic withstand current rating	kA	25 rms, 63 peak
5	PoW angle adjustment range	Elec degree	360
6	Accuracy of angle adjustment	Elec degree	3.6
7	Operating life	Operations	30000
8	Simultaneity of three-phase contacts	ms	< 0.2
9	Operating Voltage	V	220 AC/DC
10	Average closing speed	m/s	0.4 to 0.8



Make Switch used in the facility

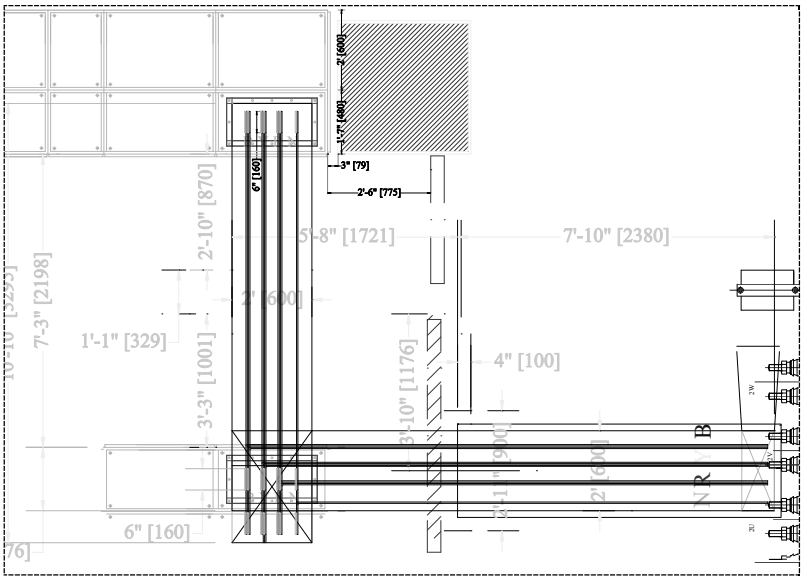
***LT Control Panel*:**

The bus bar from the Short Circuit Transformer is connected to an LT Control panel, one each in the short circuit test room and endurance test room. These LT panels house an LT ACB used for controlling and protection and an earth switch for safety purposes. The two ACBs and Earth switches are interlocked in such a way that either the control ACB or the earth switch is ON at any given time. The two Control ACBs at the Endurance room and the Short Circuit rooms are also interlocked so that at any given time only one of them is ON.
The output of these LT panels are further connected to the Make Switch or load banks in the short circuit test room and to the Test Cubicle through further controls in the endurance test room.

Figure showing Bus bar entry to LT Control Panel and connection to the Make switch and the Load Banks

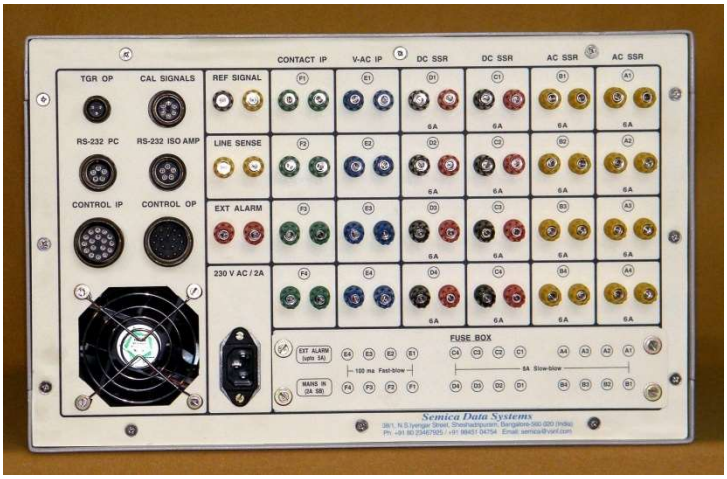
***Bus bar run*:**

The connection method from the short circuit transformer to the LT Panel and then to the Test Cubicle is of utmost importance in short circuit laboratories. The type and size of connecting links determine the source impedance and has to be as small as possible to get the maximum current from the transformer. These connections also should continuously withstand the short circuit forces produced during the testing.
The connection between the transformer and the LT panel is done by solid aluminum bus ducts using 2 runs of 160x 10 mm aluminum bus bars for phase and 1 run of the same for neutral. As per DIN 43670 this can carry a continuous current of about 3000 A for a temperature rise of 30˚C. The short time current capacity is 50 kA. This size of the bus bar is quite sufficient for undertaking short circuit tests in excess of 10 kA and endurance tests in excess of 2500 A.



***Test sequencer and data acquisition system*:**

During the short circuit testing, many operations are performed in a sequence and total time is very less to perform the operation (manually). A sequence Switch or a test sequencer performs the sequential operations. The test sequencer also is used for ON / OFF operations during endurance tests.
The test sequence controller is designed for timing and sequence control of switchgear and other tests. It replaces traditional electromechanical systems with microprocessor precision. With extensive interlocking and safety features, the Software provides control in milliseconds, cycles or degrees of phase.
This high speed controller provides precise timing for the operation of devices used for testing in low/high voltage and high power laboratories.



Sequence Controller used in the facility

The sequence controller used has 16 Solid State Relays (SSR) rated at 600 V AC/DC @ 6A. Each SSR is factory configured for AC or DC operation. Snubber / MOV / Fuse protected. 2KV Isolated. The AC SSR is instantaneous turn ON/OFF type & can turn ON/OFF at any angle of the sine wave.

Eight feedback inputs are provided to monitor the "Device under Endurance Test" & can terminate a test on fault occurrences. User programmable Voltage & Contact feedback inputs are provided, 8 Control Input & 8 Control Output lines are provided for interface to Control Desk. Each line is software configurable to take on any signal. A PLC on a Control Desk can interact with Sequence & Phase Controller for harmonious operation. Various types of signaling is supported (current loop, DC Voltage, Relay contacts etc) thus even a simple control desk with just switches & lamps could be directly connected to & controlled by Sequence & Phase Controller without the need for another controller.

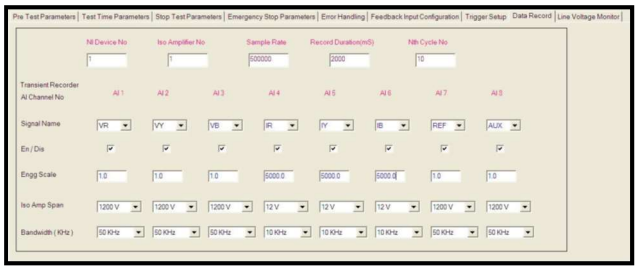
Built-in battery backup for 5 minutes operation of the system is provided. In power failure to Sequence & Phase Controller alone situations, the 'Line' is sensed & user programmed Test Termination procedure is followed.

An independent battery powered & isolated 'Watch-Dog Timer' is provided. It is user programmable to activate a relay after a preset delay from the beginning of a test. In situations where the Sequence & Phase Controller fails to turn-OFF the device after initiating a test (for whatsoever reasons) the watch dog timer takes care of protecting the DUT by switching OFF any one Circuit Breaker. The relay contacts (NO/NC) may be used to trip the CB. The watch-dog timer could be programmed with a delay slightly longer than the expected test time

Data acquisition is an important part of the instrumentation in a short circuit Lab. This should enable us to faithfully capture the data and analyze the same as per the test requirement.

The transient recorder is built using an NI transient recorder card PCI-6123. This is a 8 channel, 16 bit 500 Mega samples per channel per second system.

Transient Recorder Configuration, Arming & Data Record Software is provided.



The Isolation Amplifier is used to isolate & monitor signals from high voltage side of test equipments. Electrical isolation ensures total protection to measuring instruments & computers that have earth referenced power supplies. All signals are scaled to +/- 10 V range for easy recording & monitoring.

The unit is supplied in a 19 inch rack mountable cabinet. The unit comprises of 8 channels of Isolation Amplifiers, Isolated & floating power supplies, Micro-controller based supervisory & configuration module, EMI filters, High voltage input connectors, BNC & Transient Recorder card compatible connector outputs.

Wide range of signals covering 5 decades is supported. The amplifiers have built-in

programmable gain / attenuation that accommodate signals starting from +/- 120 mV DC to +/- 1200 VDC (75 mV RMS to 750 V RMS with 10% over drive margin).
The unit is completely programmable from an external host PC. An application program configures & monitors the status of the isolation amplifiers.
The inputs are fully protected against incorrect gain setting up to +/- 1200 VDC.
Electrical Isolation between (1) Input - Output (2) Input - Chassis (Earth) is 1500 VRMS.
Four current wave sensors Rogowski coils from Power Electronics Measurement Ltd, UK (CWT 150 B /4/500) are used. No Voltage transducers are used since the isolation amplifiers used can directly take 750 V rms.

Te s t Control

All testing is controlled and can be observed in the safety of a separate, isolated control room. The test cells and operators are segregated for safety, and operators control all test functions via state-of-the-art Control Desk. The function of the control desk together with the sequence controller is to undertake short circuit and endurance tests in a safe manner. The Control desk has remote switching provision where all the LT and the HT breakers can be controlled. It also has the Computer Mimic feature to visualize the status of various switching operations. Other features of the control desk are measuring and indication of LT and HT Voltages and Currents, settable over current protection, Transformer tap changing provision, Transformer oil temperature indication and above all interlocking of various circuit breakers. Interlocking is done for safety of the operating personnel as well as the equipment. Interlock ensure the following.

- **Only one type of test is conducted at a time using the Short Circuit Transformer**
- **When one type of test is being conducted the other test bay is safely earthed for safety of the operating personnel.**
- **Any accidental opening of the Test control room door will switch off test power.**
- **Any accidental opening of the Short Circuit Transformer room will switch off the HT power to the transformer.**

Control Desk under Installation

The control desk has emergency switch which when operated will cut off power to the transformer. The control desk also has an over-current protection relay which operated for any abnormal current in the test circuit.
Further protection in case of any unintended shorting at the bus bar run is provided by two 800A Low Voltage HBC fuse links in parallel, for each phase. In the event of a damaging short circuit, the fault energy is severely restricted by rapid fuse link operation. The fuse links limit the amount of electromagnetic stress that would otherwise cause severe and costly mechanical damage to current carrying components. All fuse links comply with the requirements of IS 13703-1993/ IEC 269-1986 and have breaking capacity of 80kA.

The control desk and the sequence controller are smoothly integrated such that once the test sequence is started though the control desk , the sequence controller takes over further switching sequence.

Both the control desk and the sequence controller are equipped with Watch Dog timers to ensure safety.

All these safety features ensure foolproof operation of the short circuit Laboratory.

Short circuit and Endurance test data are conveniently collected via the control room acquired through 8 Channel DAQ along with isolation amplifier separately for Short Circuit and Endurance Tests.

High currents are conveniently stepped down linearly using Rogowski coils or high currents Shunts. Voltages up to 750 V rms can be directly connected to the isolation amplifier.

***Variable Inductive and Resistive Load Banks*:**

Variable Load Banks are required for adjusting the exact Current and Power factor required for each test as per the requirements of IEC, UL or any other standard.

Two sets of Variable Resistive and Inductive Load Banks are used in the Short Circuit Lab which are built as per IEC requirement. Brief Specifications are

- **500 A – 7.5 kA, Duty cycle 0.5 sec. ON – 180 sec. OFF, Range of test voltage 110V 3 phase to 725V 3 phase, Power Factor 0.3 to Unity**
- **6kA – 15kA, Duty cycle 0.5 sec. ON – 180 sec. OFF, Range of test voltage 110V 3 phase to 725V 3 phase, Power Factor 0.3 to Unity**

One separate set of three phase Load Bank is used for Endurance Facility.

- **9A – 2500A, Duty cycle 0.5 sec. ON – 0.5 sec. OFF up to 1200A & 1 sec. ON – 9 sec. OFF beyond 1200A, Range of test voltage 110V 3 phase to 725V 3 phase, Power Factor 0.3 to Unity**

Figure showing One set of Short Circuit Lab Load bank

CONCLUSION:

Smaller Short circuit and Switchgear testing laboratories, in the public domain, are need of the hour for ensuring local product development on a much larger scale and also for providing easily accessible test facilities for LV switchgear and control gear manufacturers. Such a dedicated facility has now been set up at Bangalore for an US Multinational ready to take up testing assignments.