References

[1] Zbigniew Leonowicz “*Reactive power Compensation”*

[2] Dixon J “*Reactive power Compensation Technologies, State of Art Reveiw*”.

[3] “*CEB Statistical Digest-2011”*, Statistical Unit, Commercial & Corporate Branch, Distribution Region-3, PO Box 540, Colombo 02, Sri Lanka.

[4] M.A.S. Masoum, M. Ladjevardi, A. Jafarian, M. Sarvi “*Application of Fuzzy Theory and Local Variations Algorithm for Optimal Placement of Capacitor Banks in Distorted Distribution Feeders”* Department of Electrical Engineering Iran University of Science & Technology Tehran, Iran, 168440

[5] W.M.S. Deepika Wijesinghe *“Study of optimal location for capacitor installation in a 220/132/33 kV Grid Substation”* Department in Electrical Engineering, University of Moratuwa, February 2009

[6] *“Power Factor Basics”* www.iea-4e.org/document/43/power-factor-basics

[7] IEC 60871-1, “*Shunt Capacitor for a.c. power systems having a rated voltage above 1000V”*

[8] IEEE Std 18 *“2002 d for shunt Power Capacitors”*

[9] ABB *“Power Capacitor Units for improved power quality”*

[10] Ceylon Electricity Board “*Specifications for CEB Grid Substations”* Section 6- Employer’s Requirement, Part B – Technical Specification

[11] Grebe, T.E., *"Application of Distribution System Capacitor Banks and their Impact on Power Quality”*

[12] Department of Electrical Engineering, University of Moratuwa, Sri Lanka *“Report on Failures in the MVar capacitor bank at Pannipitiya 220/ 132/ 33 kV Grid Substation”*

[13] Silvio Segura, Ruben Romeo and Marcos J. Rider *“Efficient heuristic algorithm used for optimal capacitor placement in distribution systems”*

[14] Durga Bhavani Mupparty *“Capacitor switching transient modeling and analysis on and electrical utility distribution system using simulink software”.*

[15] Larry M. Smith *“A practical approach in substation capacitor bank applications to calculating, limiting, and reducing the effects of transient currents”.*

[16] Siemens India *"Study Report –Pallekele GSS 20Mar BSC bay installation"*

[17] Govind Gopakumar & Kalyan K Mustapi *"Shunt Capacitor Bank Switching Transients: A tutorail and case study"*

[18] D.D. Magala, K Nareshkumar & K. Varatharaja *"Design of a VAR componsation for Pannipitiya GSS"*

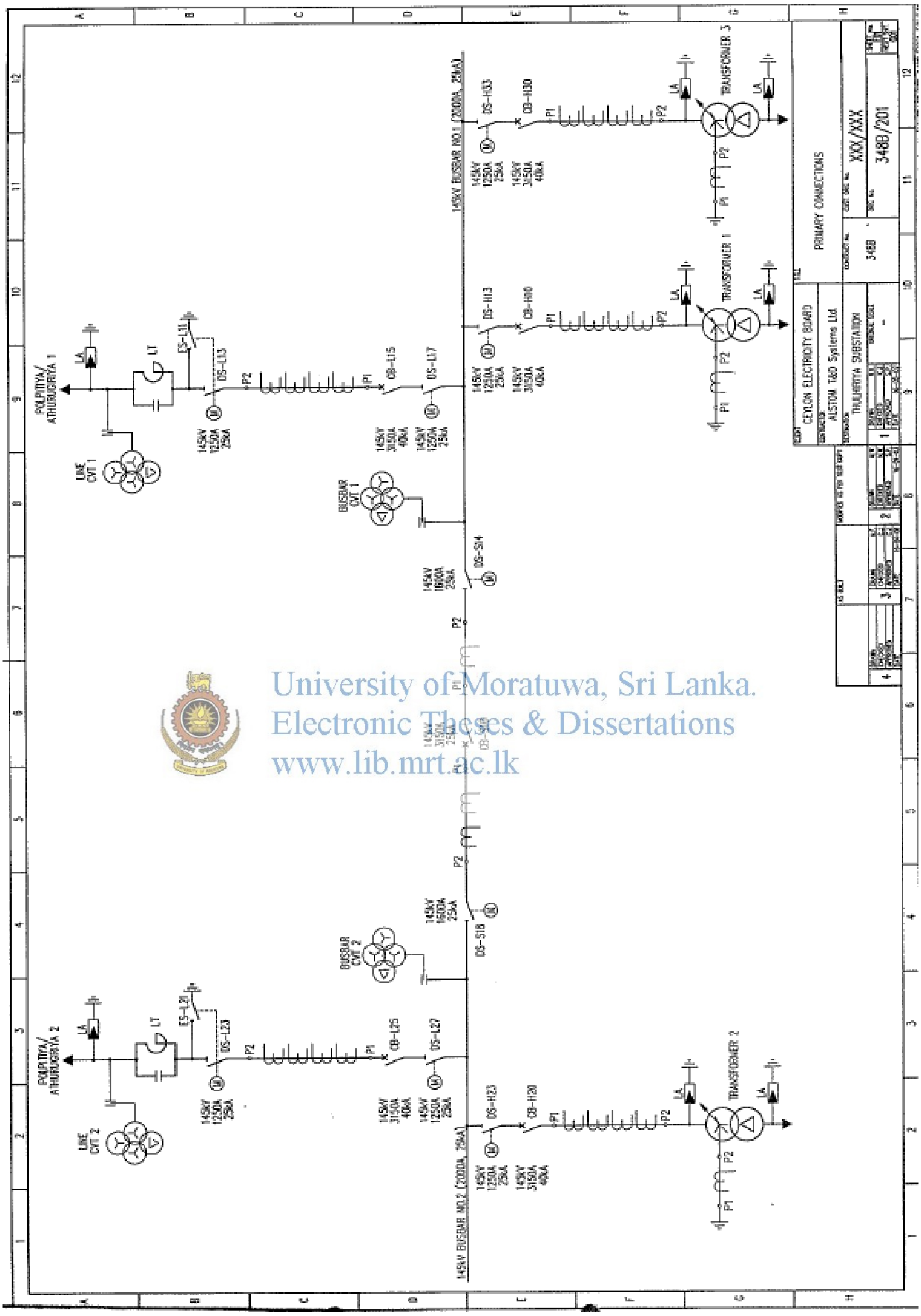
[19] J.C. Das *"Analysis and control of large shunt capacitor bank switching transients"*

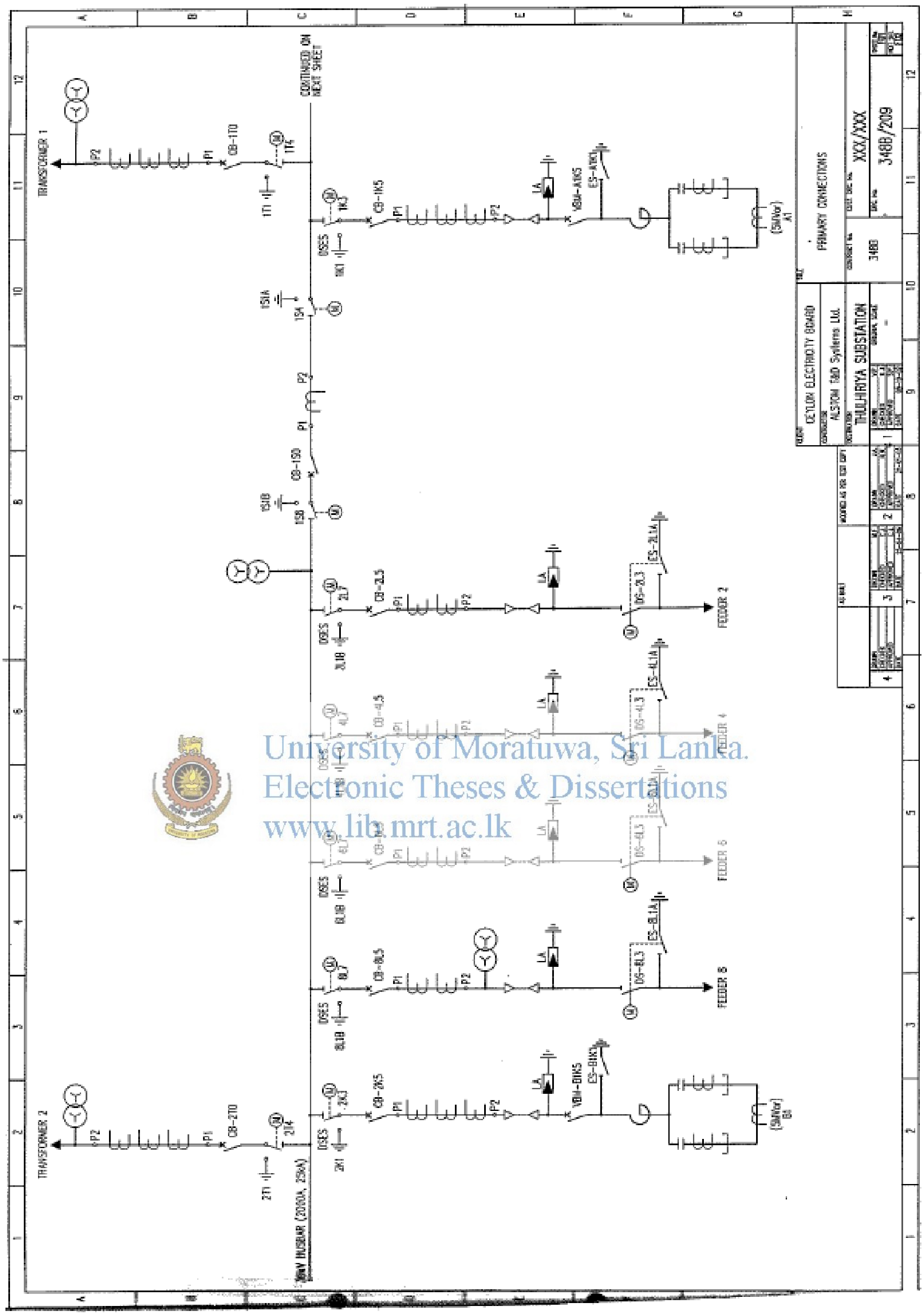
[20] ABB *"Capacitor, Detuned capacitor & filter bank products"*

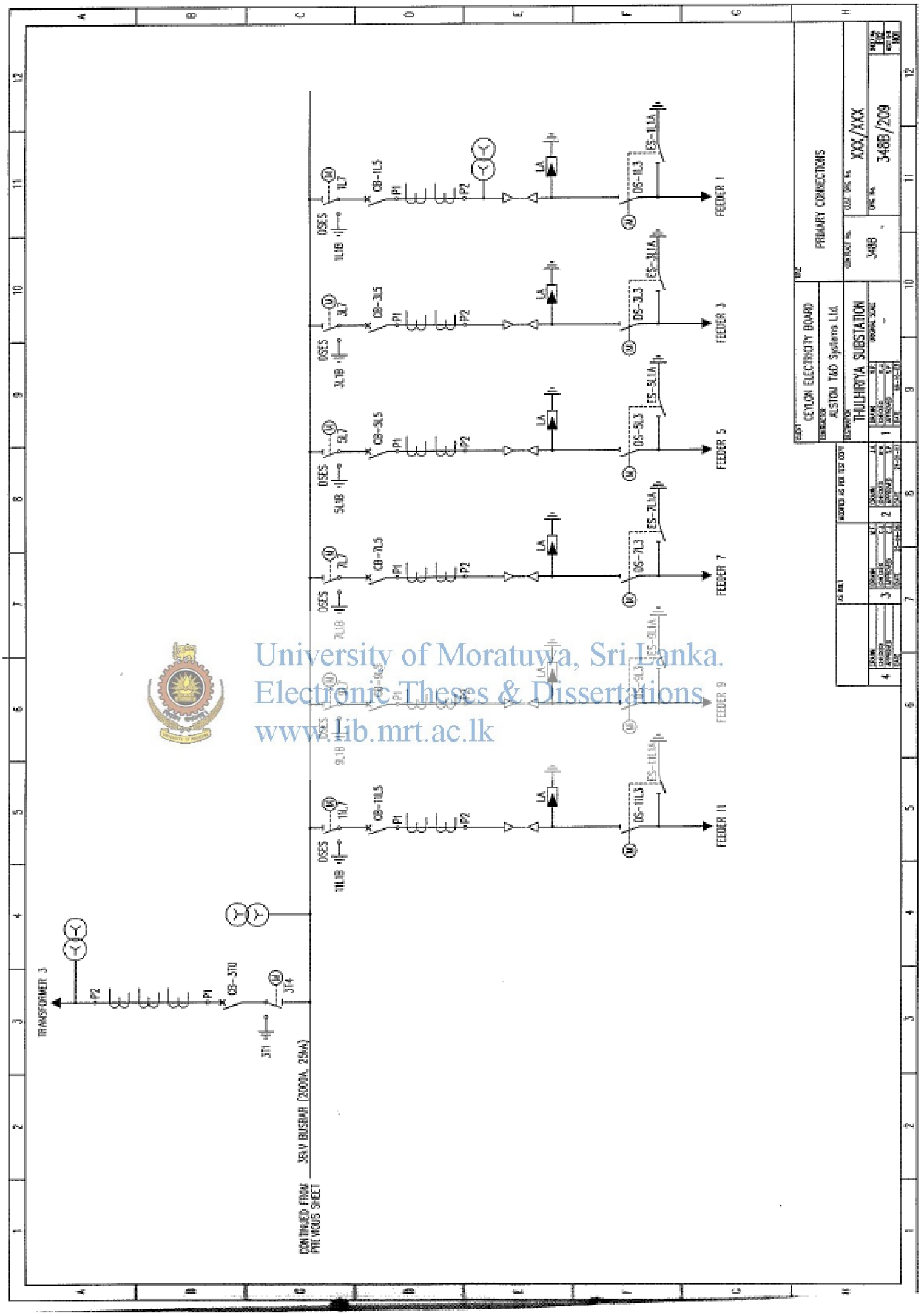
[21] Schneider Electric "*Power factor correction and harmonic filtering guide"*

[22] Switching transient task force of the IEEE modeling and analysis of system transients working group *"Modeling guidelines for switching transients"*

Appendix 01: Single line diagram of Thulhiriya substation




TRANSFORMER 1
TRANSFORMER 2
CONTINUED ON NEXT SHEET
FEEDER 2
FEEDER 8
CEYLON ELECTRICITY BOARD
ALSTOM T&D Systems Ltd.
THULHIRIYA SUBSTATION
PRIMARY CONNECTIONS
XXX/XXX
348B/209


CEYLON ELECTRICITY BOARD
ALSTOM T&D Systems Ltd.
THULHIRIYA SUBSTATION
PRIMARY CONNECTIONS
XXX/XXX
348B/209
FEEDER 1
FEEDER 3
FEEDER 5
FEEDER 7
FEEDER 9
FEEDER 11
TRANSFORMER 3
CB-3T0
CONTINUED FROM PREVIOUS SHEET
33kV BUSBAR (2000A, 25kA)

Appendix 2 : Technical Specification of 132 kV Areva Circuit Breaker

2 Technical Description

2.1 Technical Data: Circuit Breaker

Type (see nameplate)		GL311-F1/4031/VR	GL312-F1/4031/VR
Rated voltage	kV	123	145
Rated normal current	A	3150	3150
Rated frequency	Hz	50/60	50/60
Rated power-frequency withstand voltage 50 Hz, 1 min			
– To ground	kV	230	275
– Across open switching device	kV	230	275
Rated lightning impulse withstand voltage			
– To ground	kV	550	650
– Across open switching device	kV	550	650
Rated switching impulse withstand voltage (Un > 245 kV)			
– To ground	kV	Not applicable	Not applicable
– Across open switching device	kV	Not applicable	Not applicable
Rated short-circuit breaking current			
– R.m.s. value of the a.c. component of current	kA	40	40
– Percentage of d.c. component	%	36	36
Minimum opening time	ms	35	35
First-pole-to-clear factor		1.5	1.5
Rated transient recovery voltage			
– Peak value	kV	211	249
– Rate of rise	kV/µs	2.0	2.0
Short-line fault			
– Surge impedance	Ω	450	450
– Peak factor		1.6	1.6
Rated short-circuit making current	kA	104	104
Rated out-of-phase breaking current	kA	10	10
Rated duration of short circuit	s	3	3
Rated operating sequence		O-0.3s-CO-3min-CO or CO-15s-CO	
Rated line-charging breaking current	A	31.5	50
Rated cable-charging breaking current	A	140	160
SF_6 weight per breaker	kg	12	12

r

2.2 Technical Data: Spring Operating Mechanism

Type (see nameplate)		FK 3-..
Motor for charging the closing spring:		
Rated voltage (preferred values)		
– Direct voltage	V	60/110/125/220/250 *)
– Alternating voltage	V	120/230 *)
Allowable rated voltage deviation		85 to 110 % Un
Power consumption	W	<750 **)
Closing spring charging time	s	< 15
Shunt releases, closing and opening:		
Rated supply voltage (preferred values only with direct voltage)	V	60/110/125/220/250 *)
Allowable rated supply voltage deviation		
– Shunt closing release		85 to 110 % Un
– Shunt opening release		70 to 110 % Un
Power consumption of releases		
– Shunt closing release	W	340
– Shunt opening release	W	340
Minimum pulse duration	ms	10
Auxiliary circuits:		
Rated continuous load current	A	10
Auxiliary contact tripping capability		
– At 230 V alternating voltage	A	10
– At 220 V direct voltage in an inductive circuit with a time constant of L/R = 20 ms	A	2
Anti-condensation heating:		
Rated voltage (alternating voltage)	V	120 or 230 *)
Power consumption	W	80

*) Specify when ordering.
**) The exact value is shown on the motor nameplate.

Appendix 3 : Technical Specification of Alsthom power transformer

ALSTOM ELEKTRİK END.A.Ş.	2.Technical Data	Fb.Nr 316272 Sheet 1/3

2.01 Rated power :

23 / 31,5 (ONAN / ONAF)

2.02 Power definition :

Design and power definition in line with IEC 76

2.03 Voltage and currents :

Pos	HV			LV		
	Voltages (V)	Currents (A)		Voltage (V)	Currents (A)	
		ONAN	ONAF		ONAN	ONAF
1	145 200	91,5	125,3	33 000	402,4	551,1
9	127 600	104,1	142,5			
16	112 200	118,4	162,1			

2.04 Vector group symbol :

YNd1

2.05 Impedance voltage at 75°C :

Pos.	Base (kVA)	Windings	Impedance voltage (%)
7	31 500	HV / LV	10,3

2.06 No - load losses :

15 200 W. (1,00 x Un)

2.07 Load losses at 75°C :

Pos.	Base (kVA)	Windings	Load losses (W)
7	31 500	HV / LV	128 000

ALSTOM ELEKTRİK END.A.Ş.	2.Technical Data	Fb.Nr 316272 Sheet 2/3

2.08 **Insulation level :**

Windings	Max. operating voltage Um (effective value) (kV)	Rated short duration power frequency withstand voltage AC (effective value) (kV)	Rated lightning Impulse Withstand voltage LI (peak value) (kV)
HV	145	230	550
HV-N	–	95	250
LV	36	70	170

2.09 **Frequency :**

50 Hz.

2.10 **On-load tap changer :**

Make : MR
Type : M3 – III – 300 Y – 72.5/B – 10183GR
Adjustment range : +10%, -15%
Number of steps : +8 , -9
Rated through – current : 300 A

2.11 **Motor drive unit:**

ED 100 S

2.12 **Cooling method :**

ONAN / ONAF

2.13 **Temperature rise limits :**

Max ambient temperature : 40 °C
Top oil : 60 K.
Winding : 65 K.

2.14 **Setting of monitoring devices:**

For oil temperature CT 031

1.Gr Fan Stop : 50 °C
2.Gr Fan Stop I : 60 °C

ALSTOM ELEKTRİK END.A.Ş.	2.Technical Data	Fb.Nr **316272** Sheet 3/3

Alarm	: 79 °C
Tripping	: 89 °C

Winding temperature CT 033

1.Gr Fan Start	: 70 °C
2.Gr Fan Start	: 80 °C
Alarm	: 94 °C
Tripping	: 104 °C

Winding temperature CT 034

1.Gr Fan Start	: 70 °C
2.Gr Fan Start	: 80 °C
Alarm	: 95 °C
Tripping	: 105 °C

2.15 Current transformer :

T1

Burden	: 10 VA
Class	: 3
Ratio	: 200 / 2 A.

T24:

Burden	: 10 VA
Class	: 3
Ratio	: 700 / 2 A.

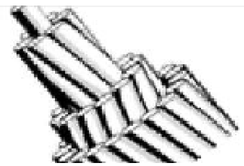
2.16 Weights (kg):

Total weight.	: 59 500 kg.
Transport weight(without oil)	: 41 000 kg.
Total weight of oil	: 14 600 kg.
Weight of active part	: 31 500 kg.

Appendix 4 : 132 kV Conductor data sheet

CONDUCTOR DATA SHEET

ALUMINUM CONDUCTORS STEEL REINFORCED (ACSR)



BRITISH SIZES

Code Name	Nominal aluminium area	Equivalent copper area	Stranding and wire diameter		Overall diameter	Total area			Weights			Calculated breaking load	Maximum dc resistance at 20 °C
			Aluminium	Steel		Aluminium	Steel	Total	Aluminium	Steel	Total		
	mm^2	mm^2	mm	mm	mm	mm^2	mm^2	mm^2	kg/km	kg/km	kg/km	kN	Ω /km
TIGER	125	80.7	30/2.36	7/2.36	16.52	131.2	30.62	161.8	362	240	602	58.0	0.2202
WOLF	150	96.8	30/2.59	7/2.59	18.13	158.1	36.88	194.9	437	289	726	69.2	0.1828
DINGO	150	97.9	18/3.35	1/3.35	16.75	158.7	8.81	167.5	437	69	506	35.7	0.1815
LYNX	175	113	30/2.79	7/2.79	19.53	183.4	42.79	226.2	507	335	842	79.8	0.1576
CARACAL	175	113.7	18/3.61	1/3.61	18.05	184.2	10.24	194.5	507	81	587	41.1	0.1563
PANTHER	200	129	30/3.00	7/3.00	21	212.1	49.48	261.6	586	388	974	92.3	0.1363
LION	225	145	30/3.18	7/3.18	22.26	238.3	55.60	293.9	659	436	1095	100.5	0.1212
BEAR	250	161	30/3.35	7/3.35	23.45	264.4	61.70	326.1	730	483	1213	111.2	0.1093
GOAT	300	194	30/3.71	7/3.71	25.97	324.3	75.67	400.0	896	593	1489	135.8	0.0891
SHEEP	350	226	30/3.99	7/3.99	27.93	375.1	87.53	462.6	1034	684	1718	156.3	0.0770
ANTELOPE	350	226	54/2.97	7/2.97	26.73	374.1	48.49	422.6	1032	379	1411	118.5	0.0773
BISON	350	226	54/3.00	7/3.00	27	381.7	49.48	431.2	1056	388	1444	120.9	0.0757
JAGUAR	200	130	18/3.86	1/3.86	19.3	210.6	11.70	222.3	580	91	671	46.6	0.1367
DEER	400	258	30/4.27	7/4.27	29.89	429.6	100.20	529.8	1186	785	1971	178.5	0.0673
ZEBRA	400	258	54/3.18	7/3.18	28.62	428.9	55.60	484.5	1186	435	1621	131.9	0.0674
ELK	450	290	30/4.50	7/4.50	31.5	477.1	111.30	588.4	I318	872	2190	198.3	0.0606
CAMEL	450	290	54/3.35	7/3.35	30.15	475.9	61.70	537.6	I314	483	1797	145.9	0.0607
MOOSE	500	323	54/3.53	7/3.53	31.77	528.5	68.51	597.0	1462	537	1999	161.0	0.0547

Appendix 5 : Manual of Joslyn Circuit Breaker

JOSLYN

Joslyn Hi-Voltage Corporation
4000 East 116th Street
Cleveland, Ohio 44105

Telephone (216) 271-6600
Fax (216) 341-3615

I. 750-310
Revised September, 1995
Supersedes May, 1992

Model VBM Fault Interrupter

Instructions

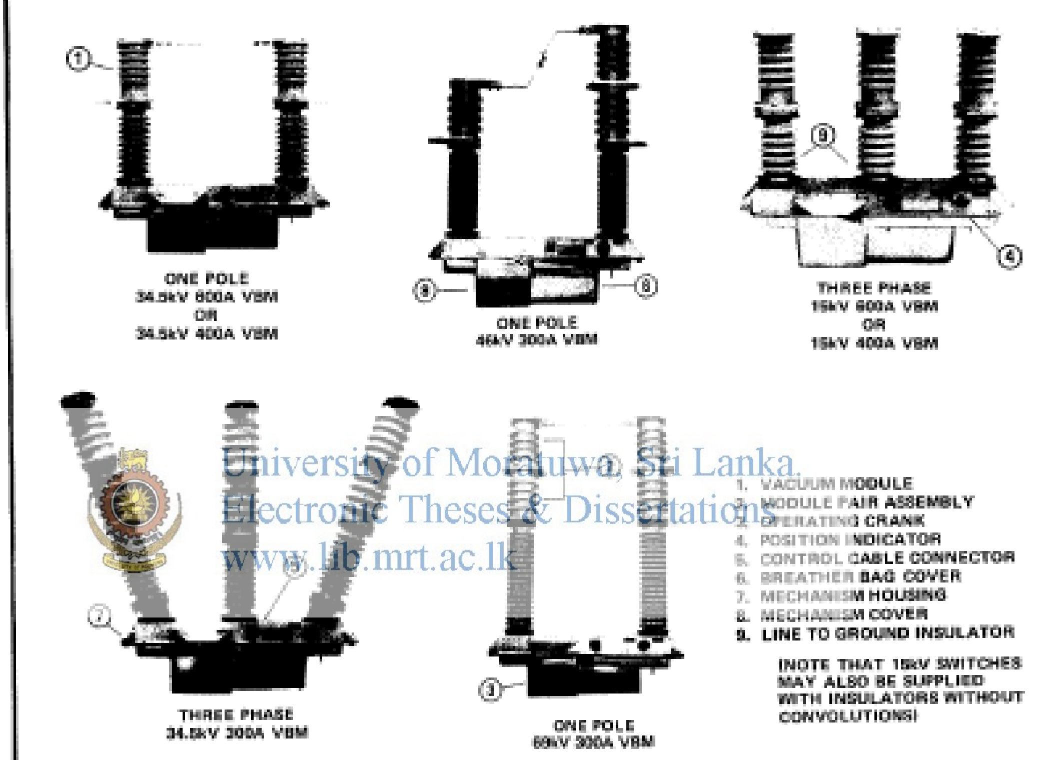


Figure 1. Model VBM Fault Interrupters

Contents

I. GENERAL

1. DESCRIPTION (Figures 1, 2, & 3)

The VBM Vacuum Interrupter is manufactured in voltage ratings from 15 to 69 kV with continuous current capabilities from 300 amperes. The mechanism may be operated manually, or electrically by solenoid or motor operators.

The assembly containing the vacuum interrupter is called a module (Figure 2). Each module has an interrupter contact (Figure 3) sealed in Joslyte, a solidified foam which provides mechanical strength, high dielectric strength and complete moisture sealing. The module housings are cycloalephetic or EPR rubber bonded to a fiberglas tube. One or two modules are mounted on each insulator and connected to the mechanism by a high strength pull rod.

The completely sealed operating mechansim housing supports line-to-ground insulators and the modules. An expansion bag in the housing prevents "breathing-in" contaminants or moisture and contains a desiccant package to maintain dry air.

All electrical control connections to the mechanism are made through a single environmental control cable connector.

An "Open-Closed" position indicator is directly coupled to the mechanism. A separate operating crank enables manual operation of the switch. The entire assembly can withstand several G's without damage. Depending upon rating there may be one or more mechanisms for a three phase switch.

2. SERVICING

Servicing of VBM switches is easily accomplished by referring to the appropriate section of these instructions. The following tools are required:

a. 0 to 1.000" dial indicator, graduated in .001".
b. Continuity lamps as required.
c. 0–150 inch-pound torque wrench.
d. Socket or wrench set.
e. C-Clamp.
f. 30kV AC High Potential Test Set.

3. REPLACEMENT PARTS

Replacement parts are stocked in Cleveland, Ohio. Furnish complete nameplate data and the Hi-Voltage Corporation G. O. Number, applying to the original purchase, along with description of the part and quantity required.

II. INSTALLATION

1. INSPECTION AND UNCRATING

Carefully inspect the equipment on arrival and report any damage to the carrier, file a claim, and contact Joslyn for replacement parts and service.

Remove crating surrounding the VBM switch. Do not unbolt the switch from the wooden base. PERFORM HIGH POTENTIAL AND CONTACT RESISTANCE TEST DESCRIBED IN SECTION III, PRIOR TO PUTTING EQUIPMENT INTO SERVICE.

2 MOUNTING

Attach an erecting sling to each mechanism as shown in Figure 4. Make certain the lift is stabilized. Remove the three nuts holding VBM to the wooden base. Hoist the switch to its mounting with the manual operating handle facing the desired direction. Fasten the VBM to its mounting with three 5/8" bolts and remove the erecting sling. THE STRUCTURE AND VBM MECHANISM HOUSING MUST BE SOLIDLY GROUNDED.

3. CONTROL WIRING

Control power must meet the requirements of the drawing supplied with the switch.

All control connections are made through either of the following, depending on the switch:

a. Environmental cable and connector. The cable may be shortened to desired length. Connection to the control en-

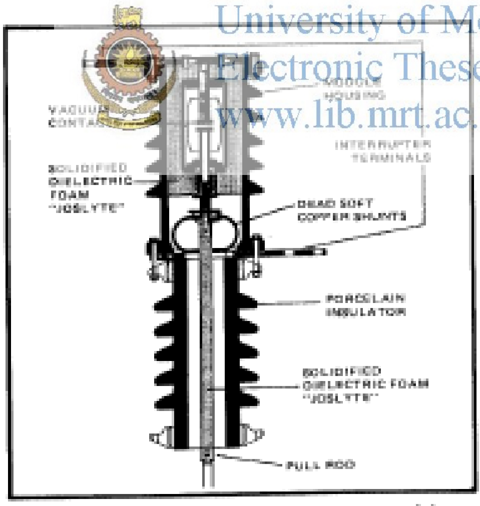


Figure 2. Cutaway drawing of single vacuum module on 15kV line to ground insulator.

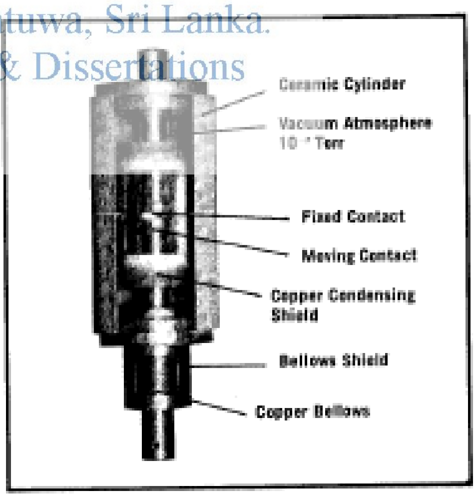
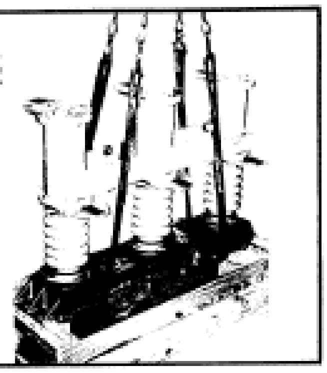


Figure 3. Cutaway photograph of vacuum contact. Moving contact separates 0.160" from fixed contact. Copper bellows preserves vacuum interrupting dielectric.



CAUTION!

Typical Erecting Sling

Figure 4

closure must be in accordance with the approved wiring diagram.

b. A NEMA 12 junction box mounted on the housing wired to the mechanism through conduit.

4. HIGH VOLTAGE CONNECTIONS

The terminal pads are aluminum alloy with standard NEMA two-hole drilling. The electrical connection at the terminal pad must be treated with Alcoa No. 2 joint compound or equivalent. Wire brushing through the compound will improve the connection.

III. TESTING AND EVALUATION OF VACUUM CONTACTS

Two tests may be performed to evaluate the vacuum contacts. They should be perfomed across each module separately. Figure 5 indicates connection point for single and double vacuum module assemblies.

1. HIGH POTENTIAL

Loss of vacuum results in complete breakdown across the open [illegible] contact at voltages below 30 kV RMS. Only AC high potential testing is recommended. DC testing cannot be used. Apply 30 kV RMS across each individual contact for 15 seconds with the switch open. To avoid possible generation of X-rays, do not apply more than 30 kV RMS.

During the high potential testing, self-extinguishing, momentary breakdowns lasting only a few microseconds may occur. These "barnacles" are not significant but can result in false indication of vacuum loss, if the test set utilizes a high speed overload relay or breaker.

During normal operation with the switch in service, loss of vacuum or a defective switch module may be indicated by excessive radio noise with the switch open or observation of different surface temperatures of modules on the same switch. See Joslyn Engineering Memo T.D. 750-918.

2. CONTACT RESISTANCE

With the switch closed, the resistance across each module should be less than 200 micro-ohms. On switches with modules connected in parallel for higher current operation, remove the connecting bus to perform this test. If higher resistance values are measured contact the Joslyn H-Voltage Corporation.

IV. SERVICING PROCEDURES

1. REMOVAL AND REPLACEMENT OF THE HOUSING COVER AND BREATHER BAG

Remove screws that hold the mechanism cover to the switch base. Care must be taken to keep the gasket and mating surfaces free of tool marks, scratches, scars, and foreign material. The valve stem protruding from the bottom of the mechanism housing should be kept sealed. It is intended only for leak testing during manufacture. The expansion chamber or breather bag is held by one bolt accessable from inside the mechanism cover. It may be removed or replaced by opening the closure plates or the separate breather bag cover added to switches supplied beginning 1982.

Before replacing the cover, clean and dry the gasket and mating surfaces. Apply silicone grease (Dow Corning DC III or equivalent) to mating surfaces and position gasket. A new or revitalized desiccant package should be placed in the operator cavity section of the cover. Secure the twelve cover screws torqued to 50 inch-pounds.

2. REMOVAL AND REPLACEMENT OF A MODULE ASSEMBLY

A. REMOVAL

One or two modules are mounted on each insulator depending on switch rating. Module pair assemblies should not be separated in the field because special tools are required for assembly and adjustment. If one module of a module pair assembly is defective, the complete module pair assembly must be replaced.

To remove a module assembly, disconnect all power from the VBM and remove the mechanism cover. Disconnect pull rod from the switch mechanism by removing two bolts and washer plates (see Figure 6, Item 7). Remove four bolts at top of insulator and lift module assembly complete with lower terminal pad and pull rod from the insulator. Insulators may be removed by taking out four cap screws holding them to switch base.

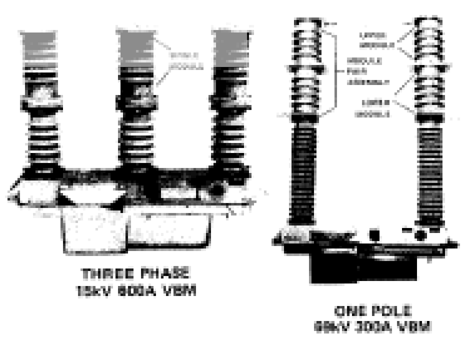


Figure 5.
Connection Points for
High Potential and Resistance Testing

3

B. REPLACEMENT

1. PREPARATION OF THE REPLACEMENT MODULE ASSEMBLY

Remove the bolts temporarily holding the lower terminal plate to single replacement modules. **WITH THE BOLTS REMOVED, EXTREME CARE MUST BE USED NOT TO PUT ANY FORCE WHATSOEVER ON THE LOOSE TERMINAL PAD SINCE THIS FORCE WOULD BE DIRECTLY TRANSMITTED TO THE DELICATE BELLOWS OF THE VACUUM MODULES. ANY TWISTING COULD RESULT IN IMMEDIATE LOSS OF VACUUM.** The double module assembly consists of two modules in series, an upper terminal plate and a lower terminal. It should not be disassembled. The single module and module pair assemblies are mounted in the same manner. An aluminum clevis link may be bolted in the mechanism end of replacement pull rods. If so, remove the aluminum clevis link and discard it. DO NOT attempt to replace the link already in the mechanism.

All single replacement modules are supplied with a separate "screw-on" pull rod. It is installed by slowly screwing onto the bolt in base of the module. Stop as thread bottoms to avoid putting any stress or strain on the vacuum contact. Back the rod off a maximum of one turn as required to mate with the clevis link on mechanism.

Earlier modules utilized either a permanently attached pull rod or a "screw-in" design. To replace a "screw-in" pull rod, slip the 1" nylon bushing supplied over the bolt end of the rod and slowly screw into the threaded module base. Stop as thread bottoms and back rod out approximately three full turns as required for proper orientation with mechanism.

Double module assemblies of the present design utilize a pull rod which is bolted to a draw bar in the lower module. All necessary hardware is supplied with replacement double module assemblies. The former design utilized a "screw-on" pull rod system.

All module assemblies are interchangeable and may be used on the same mechanism, regardless of type of pull rod, however using a present and former design double module pair assembly on the same mechanism requires special considerations. If this situation is required, contact the Joslyn Hi-Voltage Equipment Division.

BUMPING OR TWISTING ANY PULL ROD WHEN ATTACHED TO A MODULE CAN DAMAGE THE VACUUM INTERRUPTER.

2. MOUNTING THE REPLACEMENT MODULE ASSEMBLY

Apply silicone grease (Dow Corning DC III or equivalent) to all mating surfaces. Cork gaskets should be replaced. Rubber gaskets may be reused. Insert pull rod through insulator with module terminals in proper position. Fasten the replacement module to insulator with the ½" bolts, nuts, and washers from the original module. Tighten the bolts evenly.

In mounting insulators and vacuum switch modules, particular attention should be paid to torque values. If a bolt head or nut bears on porcelain it should be torqued to 25 inch-pounds, otherwise torque to 50 inch-pounds.

With switch mechanism closed, attach pull rod to the steel clevis link of the mechanism with bronze bolts, nuts, lockwashers, and stainless steel washer plates placed outside the pull rod side pieces. Do not tighten the nuts to facilitate adjustment.

3. SYNCHRONIZATION OF REPLACEMENT MODULE ASSEMBLY (Figure 6)

Operation of a replacement module assembly must be synchronized with other module assemblies on the mechanism. Module pair assemblies are synchronized using the lower contacts only. Synchronization refers to the difference in overtravel of modules (or lower contacts of module pair assemblies) on the same operating mechanism. Although the actual overtravel measurement will be dependent upon the ambient temperature, synchronization is not affected by the ambient temperature.

a. Place the continuity lamps across all modules connected to line-to-ground insulators on the mechanism. DO NOT ATTEMPT TO SYNCHRONIZE A LOWER MODULE WITH AN UPPER MODULE ON A MODULE PAIR ASSEMBLY.

b. Attach a dial indicator (1) to the mechanism to measure vertical movement of the switch actuating bar. Joslyn recommends the dial guage indicator be positioned against the bolt head as indicated by the arrows in Figure 6. It is shown out of position to enable photographing of other components.

c. CLOSED POSITION INITIAL REFERENCE

Put switch in closed position. The close stop (2) should be positioned so that toggle lines (3) are about one degree off vertical toward open position of the switch (see Figure 7 or 12 for solenoid or motor operators respectively). If adjustment is necessary, loosen the clamping bolts, reposition, and retorque to 120 inch-pounds. Adjust dial indicator to zero.

d. FULL TRAVEL

Put switch in open position. Dial indicator should read 0.205" ±0.005". If out of tolerance, adjust open stop (4). Retorque bolts to 120 inch-pounds.

e. OVERTRAVEL

With switch in closed position, slowly move the mechanism toward the open position with a ⅝" wrench on a toggle link (3). Observe the dial guage reading at which the continuity light(s) on the other module(s) goes out. This movement measured is the "OVERTRAVEL". At ambient temperatures between 50 and 80°F, the lights should go out at 0.040" ±.004" travel. Insert a spacer (5) between the close stop (2) and bumper (6) to hold the mechanism at a reading midpoint between opening readings of the two other module assemblies, or at the same reading if there are only two module assemblies on the mechanism. The spacer should be inserted on the opposite side from that shown in Figure 6. Torque the connecting bolts (7) on the replacement assembly pull rod to 75 inch-pounds.

f. SYNCHRONIZATION

Remove the spacer and close the mechanism. Slowly open the mechanism and observe the continuity lamps. Note the dial readings at which the replacement and adjacent modules open. The last lamp must go out within 0.005" mechanism travel after the first lamp. If synchronization is not achieved, loosen pull rod varying the "set" position in appropriate direction until all single or lower contacts open within 0.005" of mechanism travel.

g. After module pair assemblies have been synchronized using the lower contacts only, the synchronization between upper and lower contacts should be verified. The synchronization of upper and lower contacts is related to ambient temperature. At temperatures between 50°F. and 80°F. the dial gauge should measure a maximum of 0.010" travel of the actuating bar between the opening of each lower contact and its corresponding upper contact.

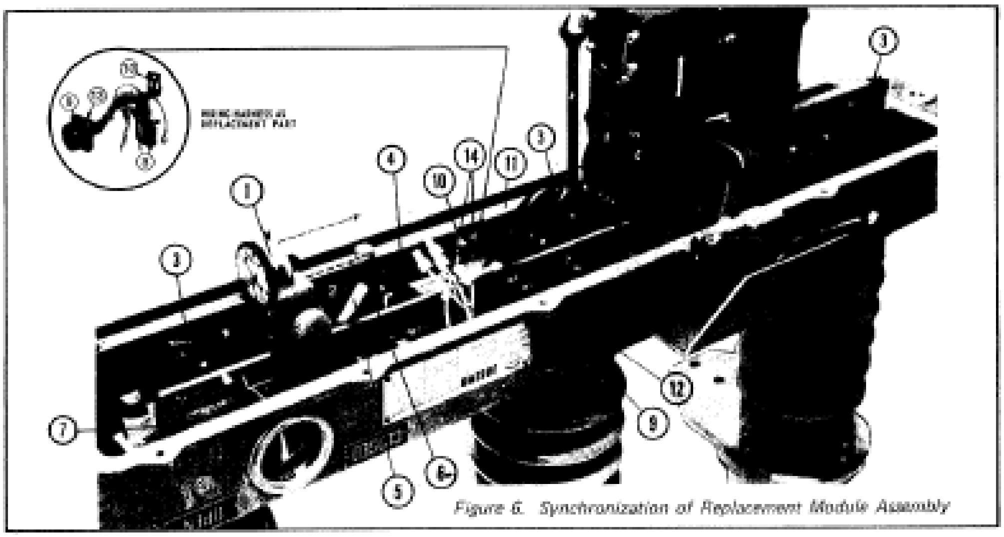


Figure 6. Synchronization of Replacement Module Assembly

4. THE SOLENOID OPERATOR

In the single solenoid operator, two solenoids, one for opening and one for closing are used to move a toggle linkage over center releasing stored spring energy to open and close the vacuum contacts. This operation is sequentially described in Figure 7.

Some solenoid operators use a double solenoid assembly which utilizes two solenoids each for close and open operation. The operation and maintenance of the double solenoid operator is similiar to that described for the single solenoid operator. The switch may be operated manually using a switch hook. An operating crank is located on the switch housing. The crank ends are notched to receive a switch hook. To close the interrupter, place [illegible] the words "[illegible] to close" and push. This moves the toggle linkage [illegible] releasing [illegible] to close the contacts at high [illegible] independent of speed at which the [illegible]. To trip or open the interrupter, place the switch hook in the notch [illegible] the words [illegible] and push.

a. SOLENOID ASSEMBLY REPLACEMENT (Fig. 7)

Open splicing connectors on the four black solenoid wires. Leave black wires as long as possible. Remove two bolts (F) and the solenoid assembly is released. As the assembly is removed, the nylon actuating pins (G) will fall out.

One or both solenoids can be replaced by removing and replacing the appropriate bolts holding the assembly together. All bolts should be torqued to 70 inch-pounds.

To remount the solenoid assembly, insert nylon actuating pins and position the assembly. Torque two mounting bolts (F) to 200 inch-pounds. Connect the four black solenoid coil leads to corresponding wires using new insulated compression splices.

To insure operating components freedom of movement necessary to achieve proper operation speed, use a feeler gauge to check that end play of each actuating pin should be between .070 and .090". Manually change switch position to check other pins. End play is adjusted by adding or removing flat washer shims (H) under nylon spacer sleeves.

b. WIRING HARNESS AND AUXILIARY SWITCH ASSEMBLY REPLACEMENT (Figure 6)

The auxiliary switch (8) and cable connector (9) are integral parts of the wiring harness assembly. The entire assembly must be removed as a unit. Open splicing connectors on the four black solenoid wires. Remove the auxiliary switch bracket (10) from the support bar (11). Remove four screws (12) which hold the environmental control cable connector and pull wiring harness assembly out of housing.

To install wiring harness, clean surfaces of casting where connector mounts. Apply a small amount of silicone grease (Dow Corning DC 111 or equivalent) to gasket (13) of new connector. [illegible] assembly, remount and adjust the auxiliary switch and rewire.

c. AUXILIARY SWITCH ADJUSTMENT (Figure 6)

With mechanism in closed position, use a C-clamp to hold the operating crank to its cover, so the crank cannot move from the closed position. Attach dial indicator (1) and set at zero. With a wrench on toggle link (3) move the mechanism toward the open position. The auxiliary switch (8) should operate at or before .175" vertical movement is indicated. Slowly return mechanism to closed position. The auxiliary switch should operate before the mechanism has returned to within .025" of the fully closed position. If adjustment is not correct, release bolts (14) and reposition bracket in appropriate direction. Retighten the bolts and recheck operation. Repeat until auxiliary switch operations occur within the allowable range. Tighten bolts to 70 inch-pounds. If proper adjustment cannot be achieved, replace wiring harness and auxiliary switch as directed per instructions.

5. SWITCHES RATED 1,000 AMPERES AND HIGHER

These switches utilize modules connected in parallel. For some ratings more than one mechanism per pole is used. They are installed per instructions in Section II and connected per Hi-Voltage Corporation drawings and control schematic for the particular switch.

All servicing and testing is performed on separate mechanisms by removing the connecting bus and referring to the appropriate section of these instructions.

6. THE MOTOR OPERATOR

A series motor drives a cam which loads a spring assembly. When the springs are fully loaded, the cam releases a linkage closing the vacuum switch using one-half the energy in the spring assembly. A low energy solenoid releases the remaining energy in the spring assembly through the same linkage to open the interrupter. Operation is sequentially described in Figures 8 through 11. The design inherently prevents closing the switch, unless sufficient energy to trip is stored in the spring assembly.

The VBM motor operator is designed to operate at 24VDC, 48VDC, 125VDC, or 120VAC depending upon application.

The switch may be operated manually using a switch hook. An operating crank is located on the switch housing. The crank ends are notched to receive the switch hook. To close The Fault Interrupter, place a switch hook in the notch above the words "Push to Close" and pump. After approximately 25 strokes, the switch will close. A unique rotary clutch allows strokes of any length to rotate the cam. A single swift push in the notch above the words "Push to Open" will trip the switch. Vacuum contact operating speed is independent of speed of manual activation.

The motor operator consists of a mechanical energy storage assembly and a control assembly. The control assembly is located in the base of the VBM switch. Connections to external circuitry are made through a control cable with environmental connectors.

1. ELECTRICAL

a. Control Assembly (Figure 15):
Remove entire controls assembly (A) by removing the mounting bolt (B) and disconnecting cable connector (C), and install new control assembly.

b. Replace by disconnecting cable connector (C) and remove leads from terminals of auxiliary switch(es) (D). Remove four screws (E) which hold the environmental connector (F) and pull wiring harness (G) out of the housing. To install wiring harness (G), clean surfaces of casting where connector mounts. Apply a small amount of silicone grease to gasket of new connector. Install new harness (G) and rewire.

c. Auxiliary Switch(es) (D) (Figure 8):
Replace by removing leads and two mounting screws.

1) Replace auxiliary switch assemblies and actuating rod. With mechanism in open position set clearance between auxiliary switch mounting bracket and actuating bar at .125" to .132". (Note location of the mounting bolts.
2) With mechanism in closed position, use a C-clamp to hold the operating crank to its cover, so the crank cannot move from the closed position, attach dial indicator (1) and set to zero. With a wrench on toggle link (3) move the mechanism toward the open position. The auxiliary switch contacts should change state at or after .040" vertical movement is indicated. Slowly return mechanism to closed position. The auxiliary switch contacts should change state before the mechanism has returned to within .040" of the fully closed position. Auxiliary switch should have a .020" min. overtravel. (Ref. Figure 6).
3) If adjustment is not correct, release bolts (14) and reposition brackets in appropriate direction. Retighten bolts and recheck operation.
4) Repeat until auxiliary switch operations occurs within the allowable range. Tighten bolts to 20 inch-pounds.
5) Reconnect leads.

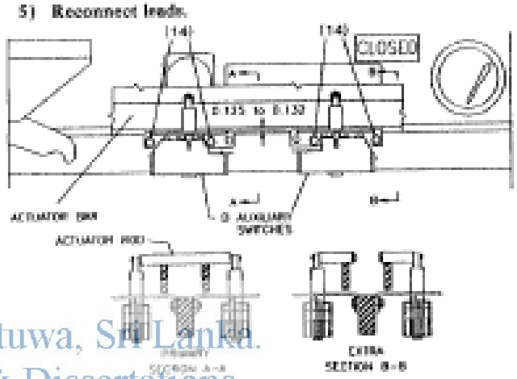


Figure 8

Note: An obsolete auxiliary switch (As noted by observing a metal pin actuator through the actuator bars to the auxiliary switch(es)) can be replaced as described above. However, the old metal pin actuator must be cut as shown in figure 8, for removal.

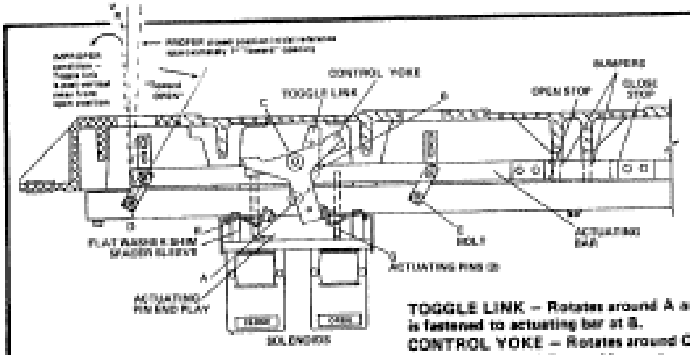


Figure 7. The Solenoid Operator

TOGGLE LINK – Rotates around A and is fastened to actuating bar at B.
CONTROL YOKE – Rotates around C.
ACTUATING BAR – Moves in arc around D and E.

DESCRIPTION OF OPERATION

1. Switch is open. Spring assembly connected between toggle link and control yoke holds open stop against bumper.
2. Control circuit energizes close solenoid. Actuating pin rotates control yoke clockwise until toggle link is over center.
3. Spring assembly pulls toggle link and actuating arm in counterclockwise arc until close stop and bumper engage. Vertical movement of actuating bar raises pull rods and closes vacuum contacts.
4. When open solenoid is energized, the control yoke is rotated counterclockwise until the toggle link is over center and pulled clockwise by the spring assembly. This returns the actuating bar to the original position, opening the vacuum contacts.

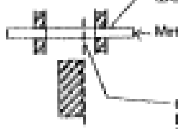


Figure 9

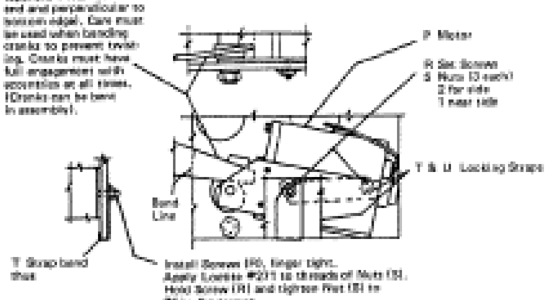


Figure 10

d. Motor

Not all motors are identical. When ordering replacement motors, the catalog number from the VBM nameplate must be supplied. New control panel may be required for obsolete motors.

1) Remove two set screws (H) (if present).
2) Disconnect push-on connectors of motor leads from relay.
3) Deform locking strap (I) and remove two bolts (J).
4) Remove motor (K).
5) Install motor (P) using set screw (R).
6) Install locking straps (T&U) and nuts (S) using Loctite #271 on threads.
7) Bend corners of locking straps (T&U).
8) Bend both cranks as shown in Figure 10 if necessary.
9) Connect push-on connectors of motor leads to relay.

2. MECHANICAL

If a malfunction of the motor operator linkage occurs, replace the entire operator assembly (Figure 16). Two spring compressor devices are needed to hold and relieve pressure from the two main spring assemblies (S1 in Figure 4). Figure 16 shows where motor operator assembly is attached at points (L), (M) and (N).

a. Detach Control Assembly as explained in Section 1.a.

b. Remove two cotter pins (not shown) holding pin (M). Remove pin (M).

c. Remove Sel-Lock pins in holds (L) and (N) by driving them with an appropriate rod.

d. Install new motor operator in reverse order. Re-use Sel-Lock pins.

e. Adjust the motor operator as required.

f. Verify position of the "close" and "open" stops of the VBM per Section 3, with special attention to the "closed position initial reference".

g. Adjust main operating lever assembly stops of motor operator assembly (Figure 15). With VBM fault interrupter in the closed position, the pin "R" (Figure 13) should turn freely. There should be no contact between the pin "R" and the stops. A separation of 0.015" ± 0.005" between the pin "R" and the bolt heads should be achieved by adjusting the bolts. The separation should be equal on both sides so that symmetrical forces are imparted to the motor operator assembly as the VBM fault interrupter is opened.

h. Adjust toggle link assembly stop (Figure 13) as follows:
1) Close VBM fault interrupter.
2) Verify proper "closed position initial reference" is achieved, see Section 3, paragraph C.
3) Screw in toggle link assembly stop Q until VBM fault interrupter trips.
4) Back the screw ¼ turn.
5) Close the VBM fault interrupter. Unit should not trip free. If it does, back screw out an additional one-fourth turn.
6) The screw Q should not be backed out more than one turn from the reference point at which the VBM fault interrupter trips, as described in step (2) above.
7) After proper operation has been achieved, apply "C" grade Locktite to fix screw setting and tighten locking nut.
8) Verify that operation of all vacuum modules are synchronized per Section 3.

V. RECLOSING OPERATOR

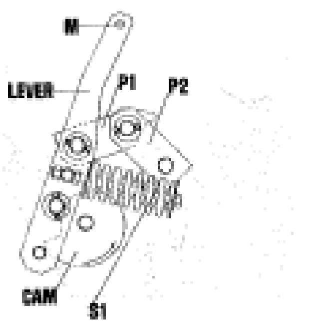
VBM Fault Interrupters furnished with the Reclosing Operator are typically applied for breaker applications where both high speed reclosing and minimum interrupting time are the most significant requirements. The Reclosing Operator does not require periodic lubrication or adjustment. Contact the Customer Service Section at the Hi-Voltage Equipment Division for assistance.

Figures 11, 12, 13 and 14

MOTOR OPERATOR

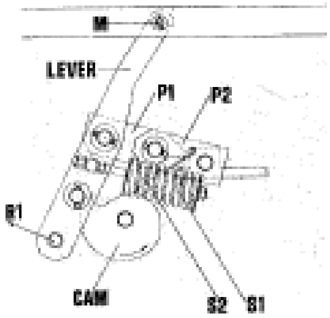
DESCRIPTION OF OPERATION

Figures 11, 12, 13 and 14 illustrate sequential operation of the assembly. The motor operator lever is connected to the switch actuating bar at point M. The actuating bar linkage is connected to the pull rods (not shown) of each module assembly.



1. Switch is open.
2. Toggle links P1 and P2 are in relaxed position.
3. Spring assembly S1 is relaxed.
4. Cam is rotated counter-clockwise by motor or manual pumping.

Figure 11



5. Lever is displaced in direction R1.
6. Spring assembly S1 is compressed storing energy in springs.
7. Lever pulls toggle links P1 and P2 over center.
8. Toggle spring S2 brings toggle linkage in extended position against stop.
9. The switch is open and the mechanism is ready to close.

Figure 12

10. As spring assembly S1 is fully loaded the cam releases lever and stops.
11. Lever pivots around fulcrum T. Pin R moves in arc R2 and comes against motor assembly chassis stop using 1/2 total energy in spring assembly S1.
12. M is moved in arc M1. M's displacement moves the switch actuating bar and closes the interrupter contacts.

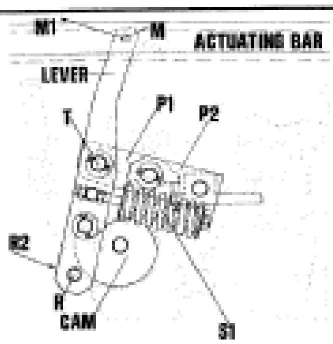
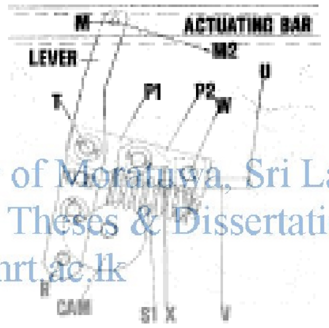


Figure 13



13. Switch is closed.
14. Solenoid exerts force U on lever V which pivots on fulcrum W exerting force X on toggle linkage P1 and P2.
15. Toggle link assembly is displaced. The remaining 1/2 total energy S1 pulls lever which pivots on fulcrum R.
16. M moves in arc M2 moving switch actuating bar and opening contacts.
17. The switch is open.

Figure 14

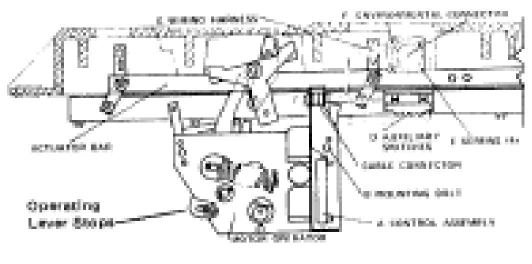


Figure 15 *Mechanism Housing with Motor Operator*

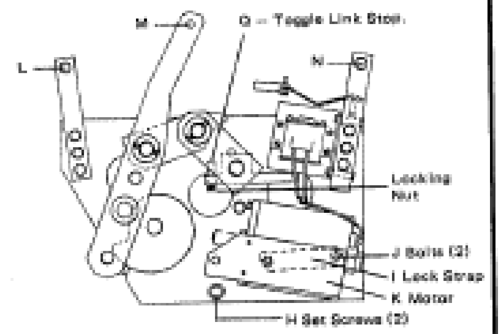
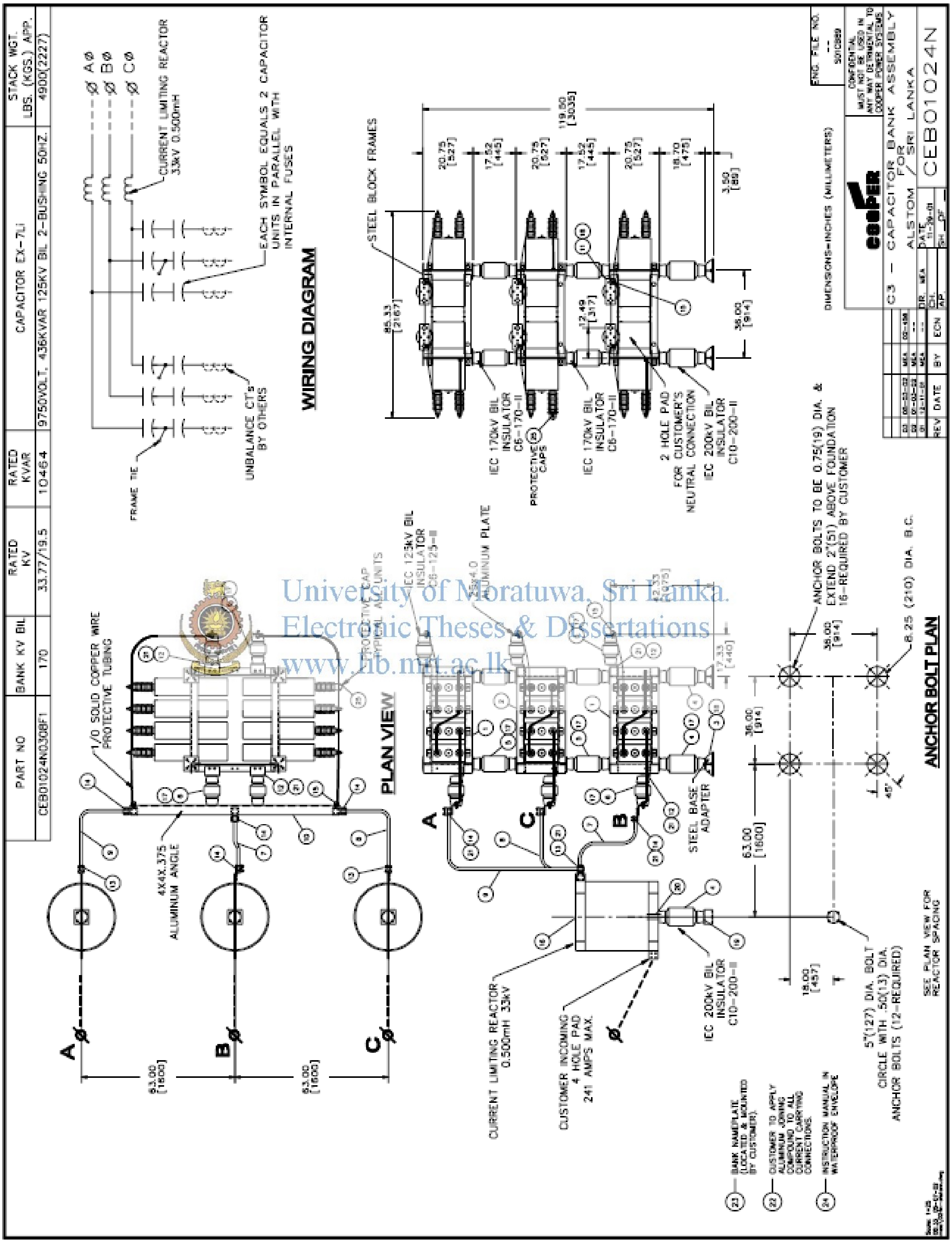


Figure 16 *Motor Operator*

Appendix 6 : Installation of capacitor bank at Thulhiriya GSS



Appendix 7 : Technical Specification of Novar 300 Controller

2. TECHNICAL SPECIFICATION

2.1 RATINGS, OPERATING RANGES & FEATURES

Voltage Rating (Vn)	110 V, 120 V, 415 V, 480 V. Others available in range 63.5 V to 500 V max.
Current Rating (In)	1 A or 5 A. Others available in the range 0.5 A to 5 A max.
Input Connections	IA, VBC, or IB, VCA or IC, VAB IR, VYB, or IY, VBR or IB, VRY, IR, VST, or IS, VTR or IT, VRS.
Line Current Transformers	Class 1, 5 VA
Operating Ranges	
Voltage	85 ... 110 % Vn
Current	0...120 % In
Frequency	50/60 Hz
Humidity	0...93 % +2 % -3 % Relative (non-condensing)
Temperature Range	Storage: -40... 80° C Operating: -10... 55° C
Settings	c/k 0.03...1.00 cos phi 0.80...1.00...0.95 leading
Overload Ratings	1.5 x Vn for 10 seconds 2 x In continuously 20 x In for 3 seconds
Isolation	The controllers will withstand: 2 kV rms, 50/60 Hz for 1 minute between: - all terminals to case - current terminals to all others - voltage terminals to all others - output contact pairs (Volt Free versions)
Impulse Voltage Test	The controller will withstand: 5 kV 1.2/50 us, 0.5J, to BS923 and IEC 255-22-1 between: - all terminals and case - current input terminals - voltage input terminals - output contacts (open) - any pair of independent circuits
Output and Alarm contact rating	Make 1250 VA, 500 V a.c. resistive Carry 5 A a.c. Break 5 A a.c. Type: one normally open

2.1 RATINGS, OPERATING RANGES & FEATURES (cont.)

No-volt release

All output contacts are disabled within 15 ms. After the supply voltage is restored, normal operation is resumed, and the outputs are energised in sequence after the appropriate safety lockout time has elapsed.

Burdens

Current circuit: 0.2 VA at In
Voltage circuit: 9 VA (6 stages energised)
15 VA (12 stages energised)

Net weight

All models: 1.5 kg

Terminals

Barrier type: M3.5
Plug-in wire size: 1...2.5 mm^2 (18...14 AWG)

Switching style

Rotational or linear (see Figure 3). Selected at time of order. Rotational switching evens the contactor wear (for the largest step size only) and generally reduces the system response time. It is implemented for all sequences on NOVAR 300, if requested.

Intelligent switching

If twice the minimum capacitor size (or more) is required, then the NOVAR will switch in a double step. This applies for all sequences. For sequence 00 (1:1:1:1), the second capacitor will be connected after an additional delay of two seconds.

Limit selection

Up to 12 plus alarm output. The maximum possible for any configuration is determined by the number of relays fitted and the selected sequence. If the selected value is too high, the unit will automatically override it to the highest allowable value.

Safety lockout

The time required to safely discharge a capacitor can be set to any of 8 different values. The NOVAR will not allow any capacitor to be re-energised until this time has elapsed.

Providing that the safety lockout time has passed, the capacitor can be called after one fifth of the programmed time. It is not possible to override this lockout time.

2.1 RATINGS, OPERATING RANGES & FEATURES (cont.)

Exit from manual

The AUTO/MAN button allows the user to switch between automatic and manual operating mode as required.

To safeguard against leaving a system indefinitely in manual mode, an automatic exit has been included. This will return the operating mode from manual to automatic five minutes plus the selected safety lockout time after the last manual mode operation. Relevant manual mode operations are pressing the lower button and operation of an output relay.

Models without the automatic exit from manual are available.

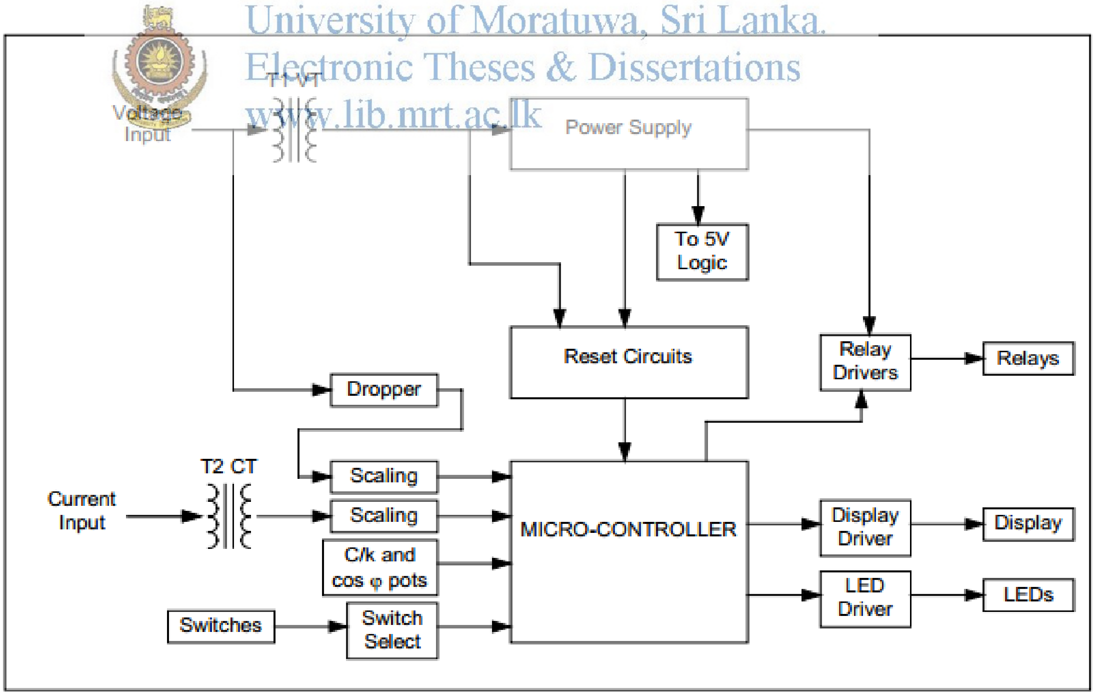
Alarm output

Signals failure to meet target cos φ
See also Self Test

Self Test

At reset and every ten minutes in operation, the NOVAR executes an internal hardware check for correct functioning. During this process, the model number will be displayed.

If the unit fails this self test, the IND and CAP LEDs are toggled and the alarm relay (if fitted) is also “flashed “ in time with this.

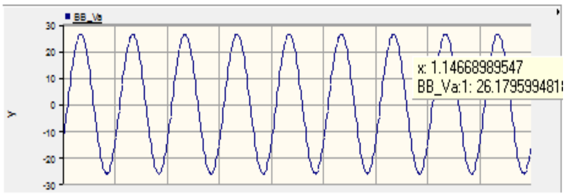


NOVAR 300 Block diagram

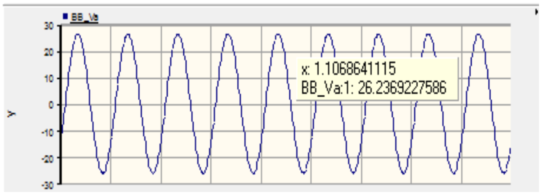
Appendix 8 : Waveforms obtained for model validation

Simulated 33 kV bus voltage waveform for two our intervals on 18th October 2013

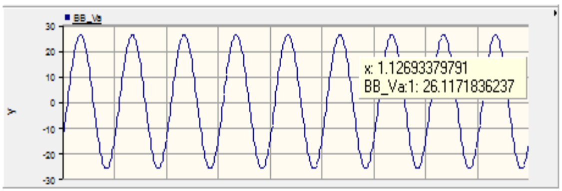
02.00 hr



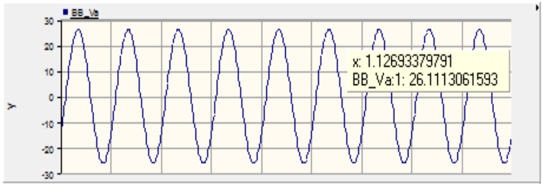
04.00 hr



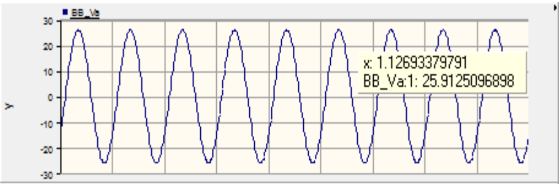
06.00 hr



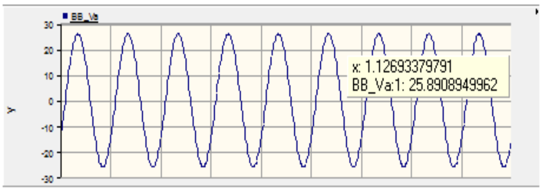
08.00 hr



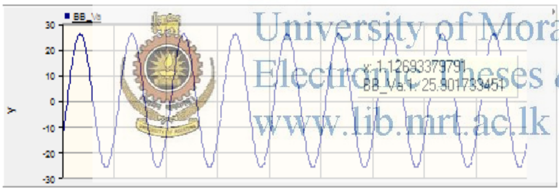
10.00 hr



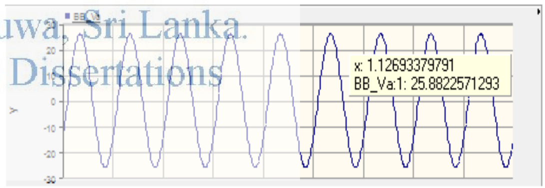
12.00 hr



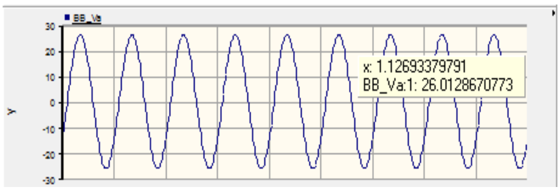
14.00 hr



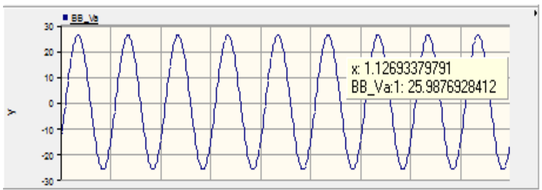
16.00 hr



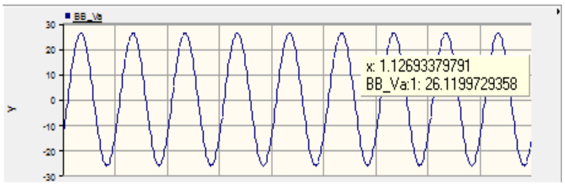
18.00 hr



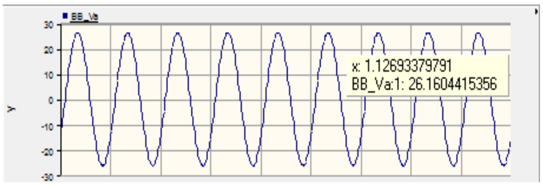
20.00 hr



22.00 hr

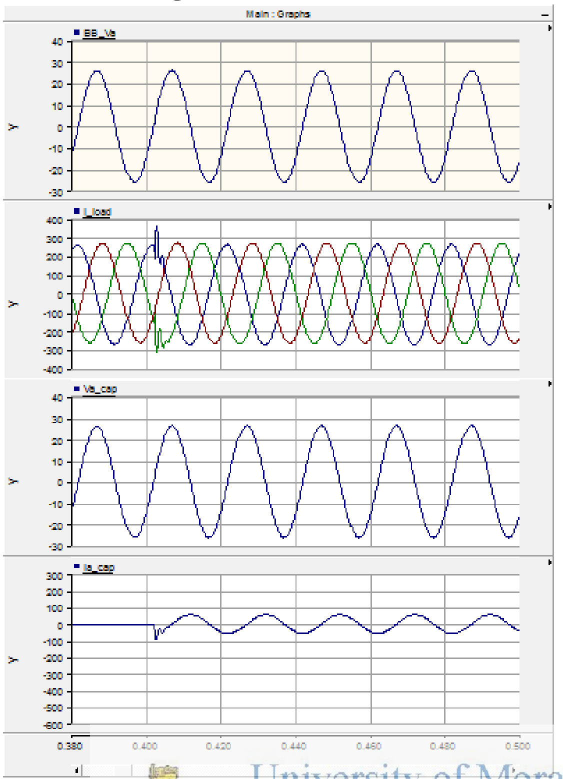


24.00 hr

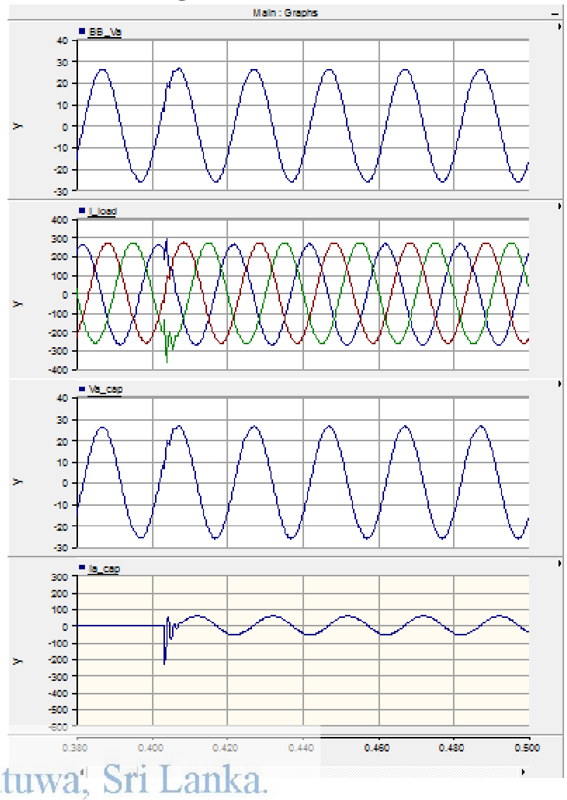


Appendix 9 : Simulated waveforms for capacitor bank one closing

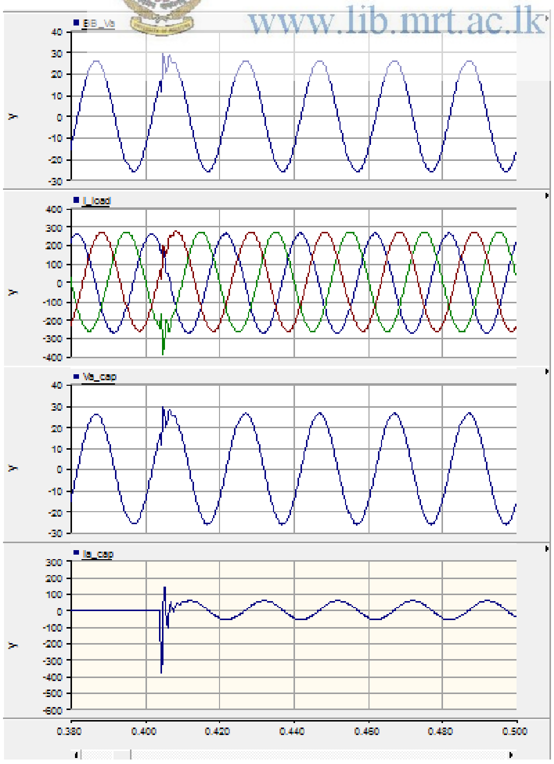
Zero Crossing



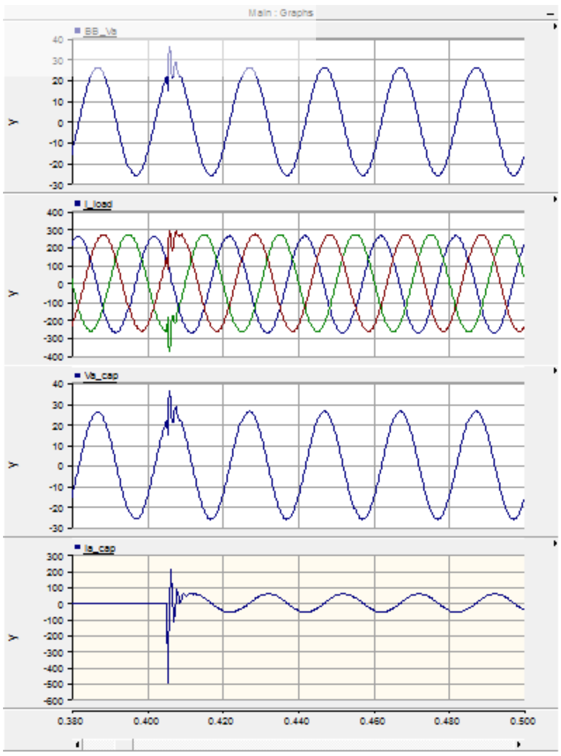
Zero Crossing+1ms



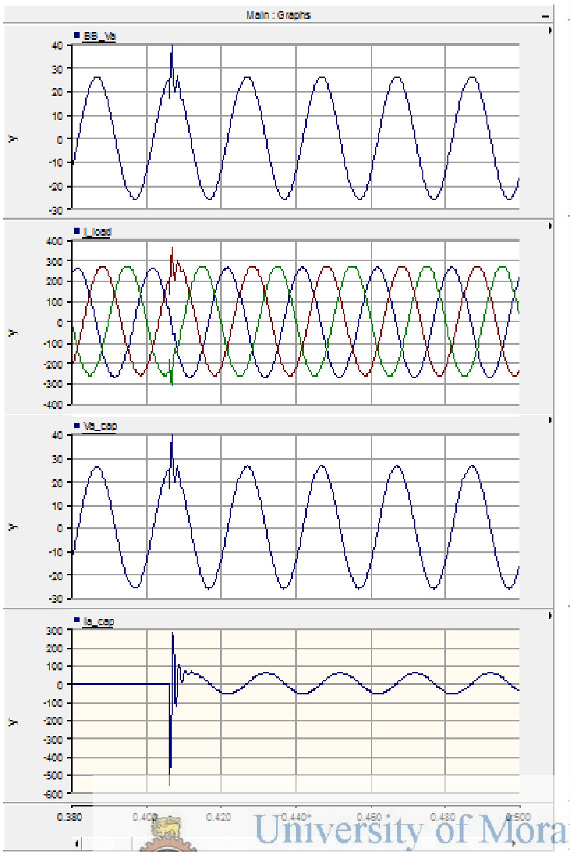
Zero Crossing+2ms



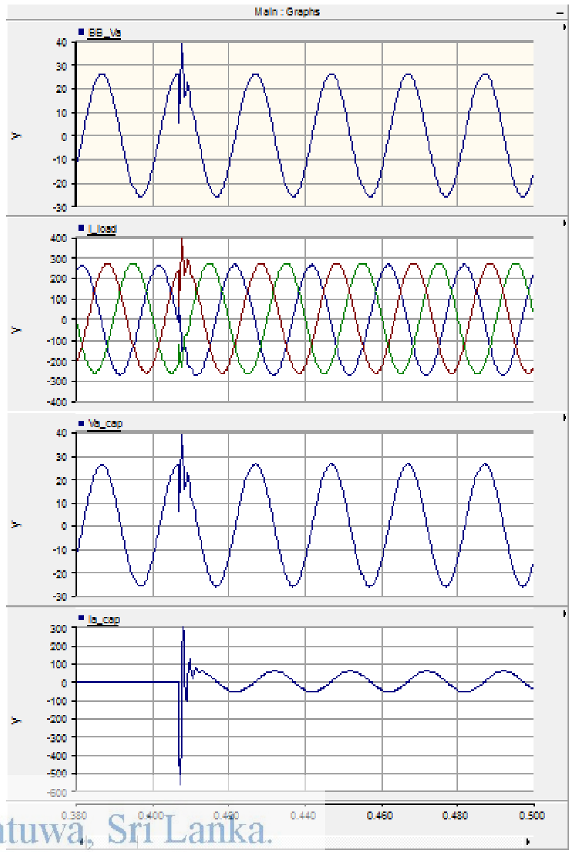
Zero Crossing+3ms



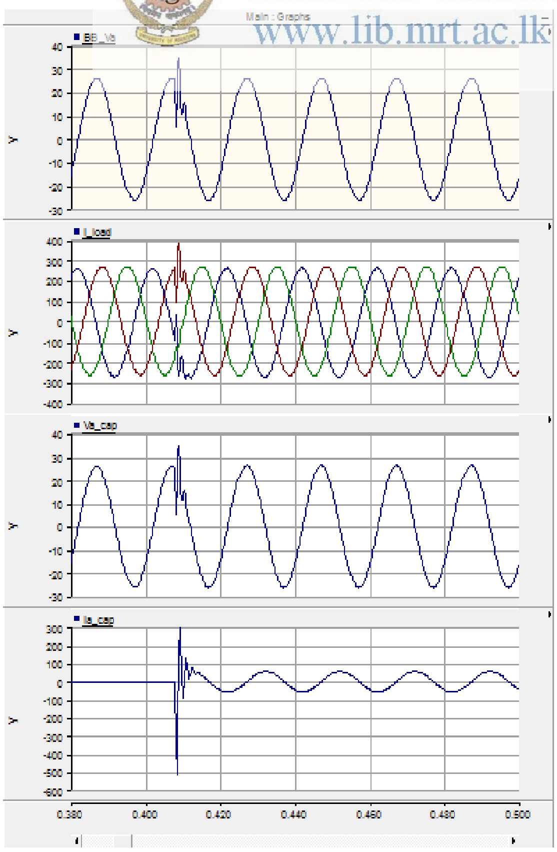
Zero Crossing+4ms



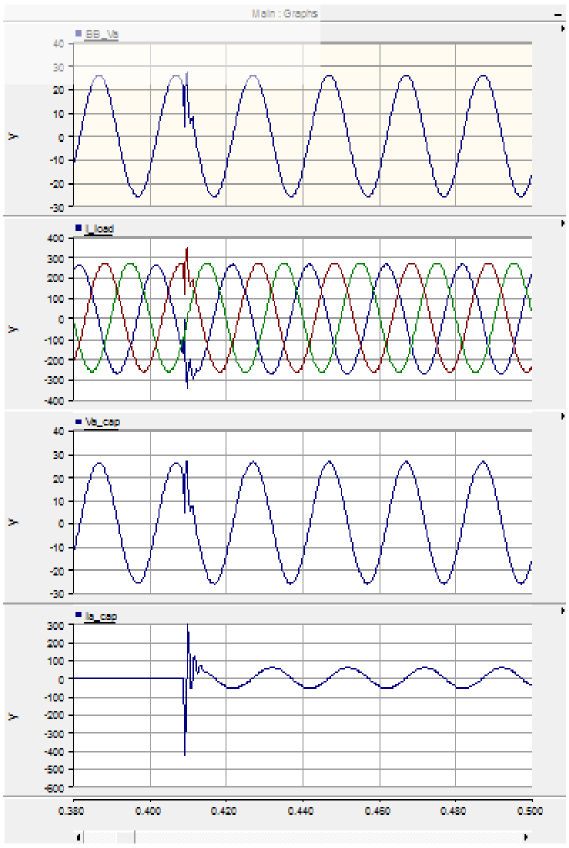
Zero Crossing+5ms



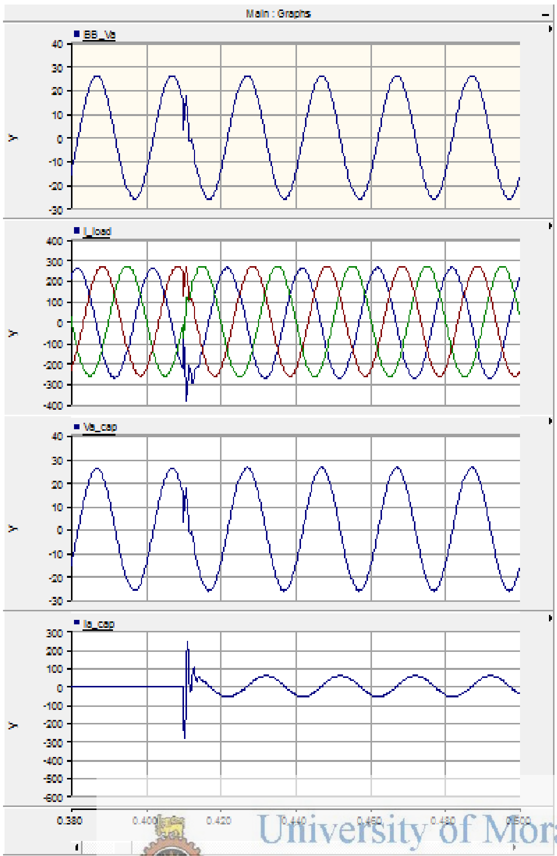
Zero Crossing+6ms



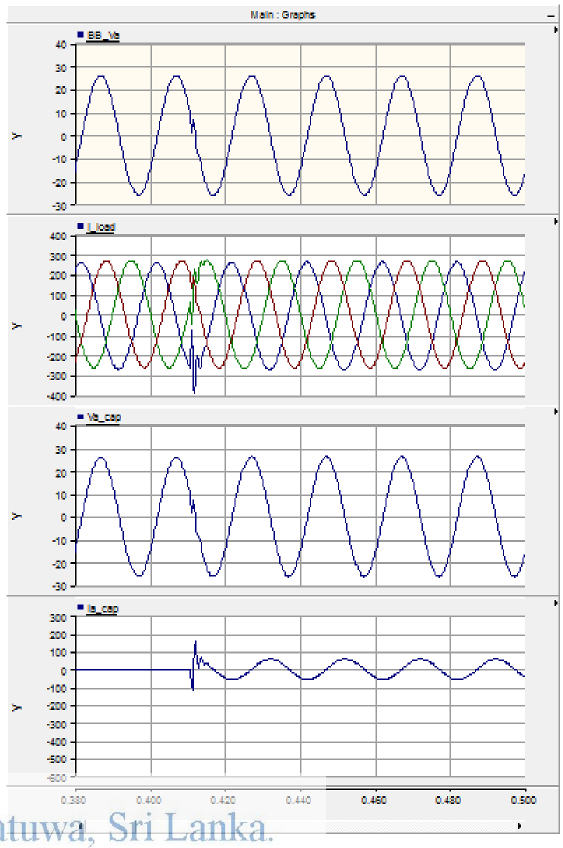
Zero Crossing+7ms



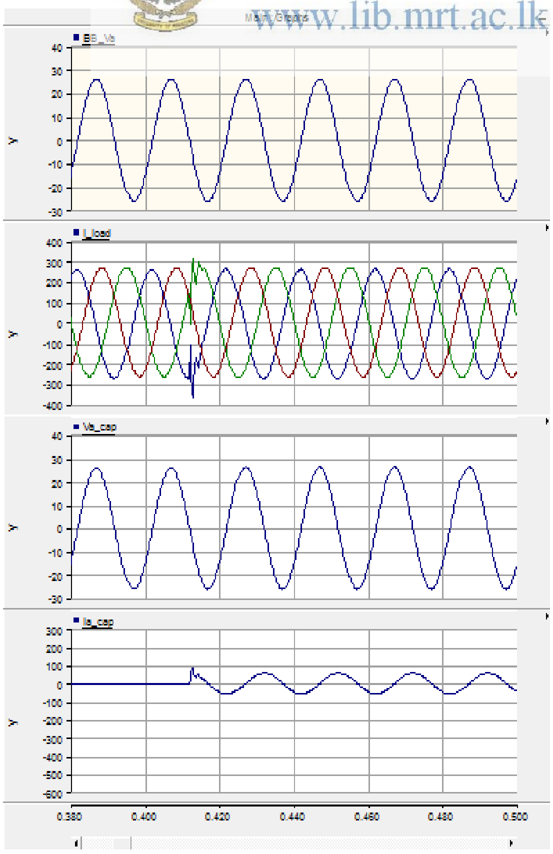
Zero Crossing+8ms



Zero Crossing+9ms

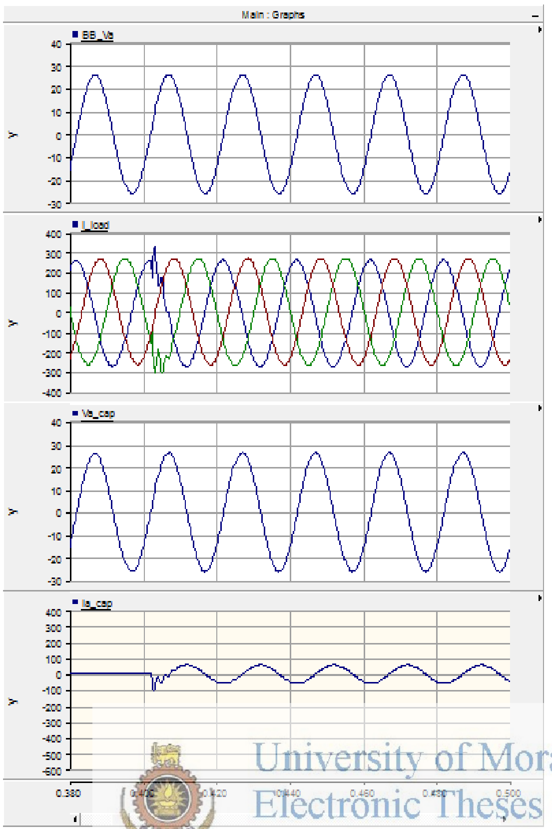


Zero Crossing+10ms

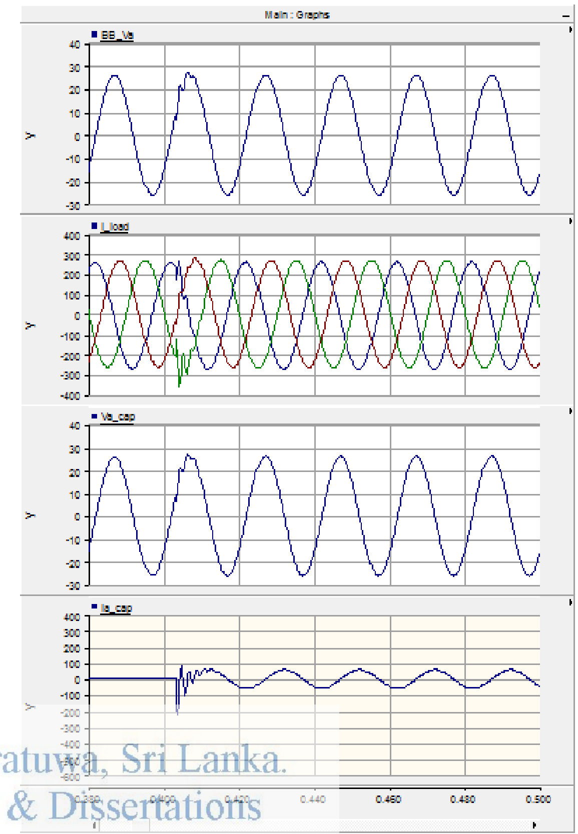


Appendix 10 :   Simulated waveforms for capacitor bank two closing

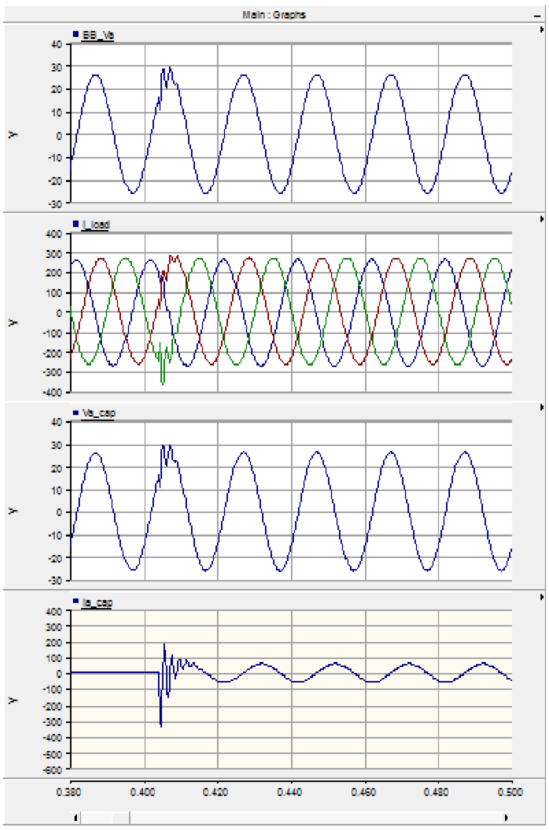
Zero Crossing



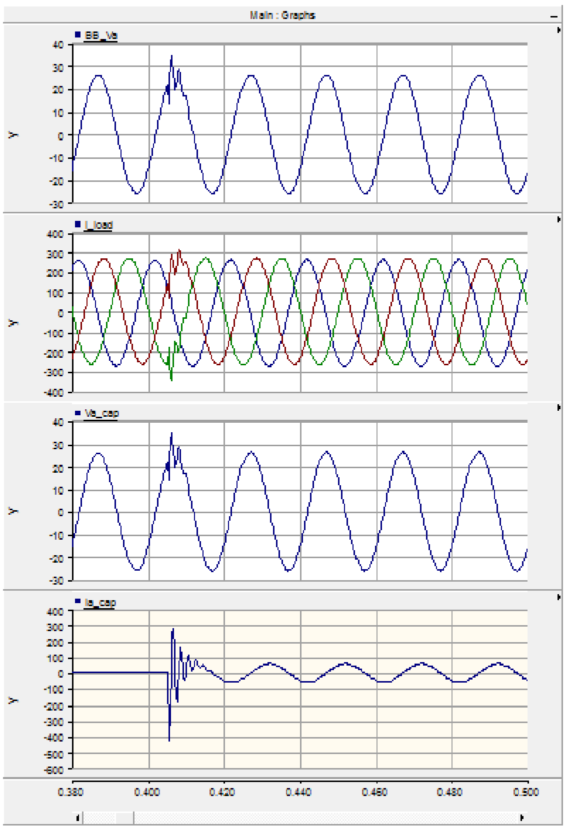
Zero Crossing+1ms



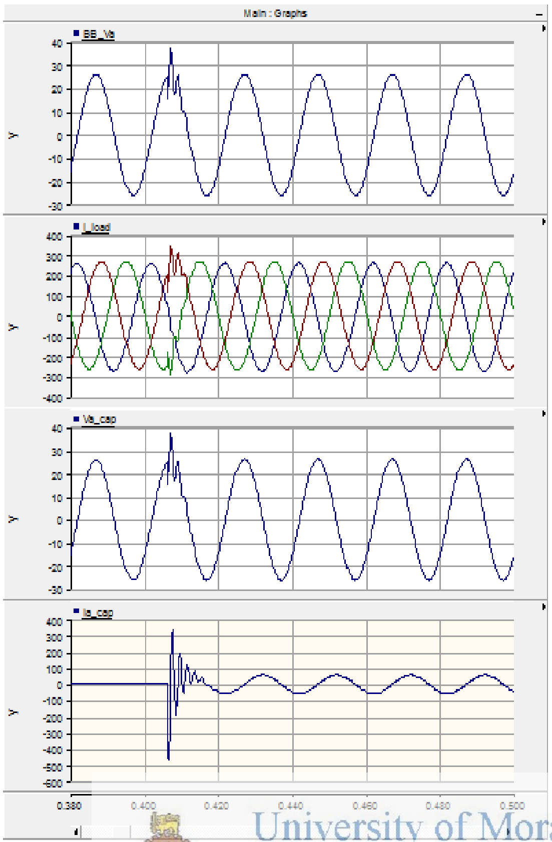
Zero Crossing+2ms



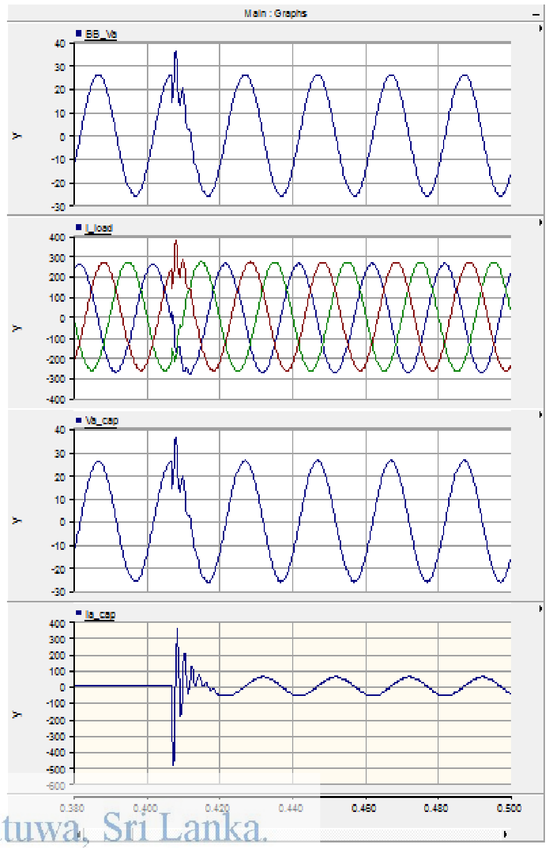
Zero Crossing+3ms



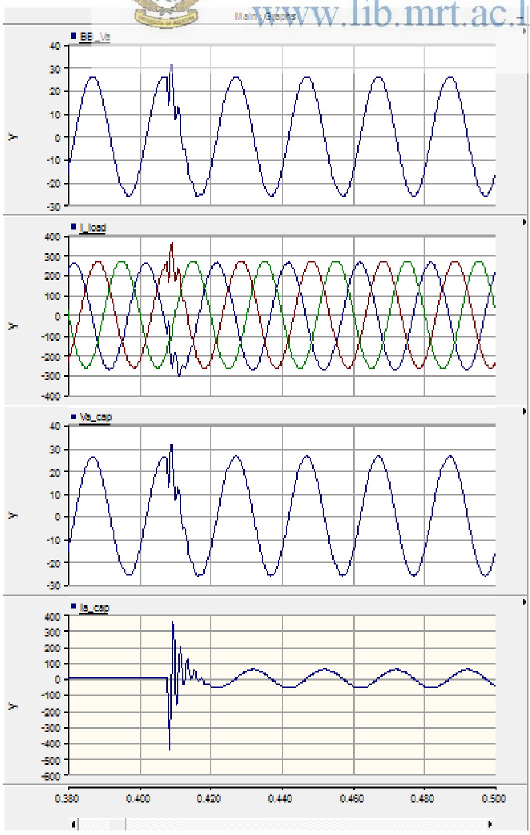
Zero Crossing+4ms



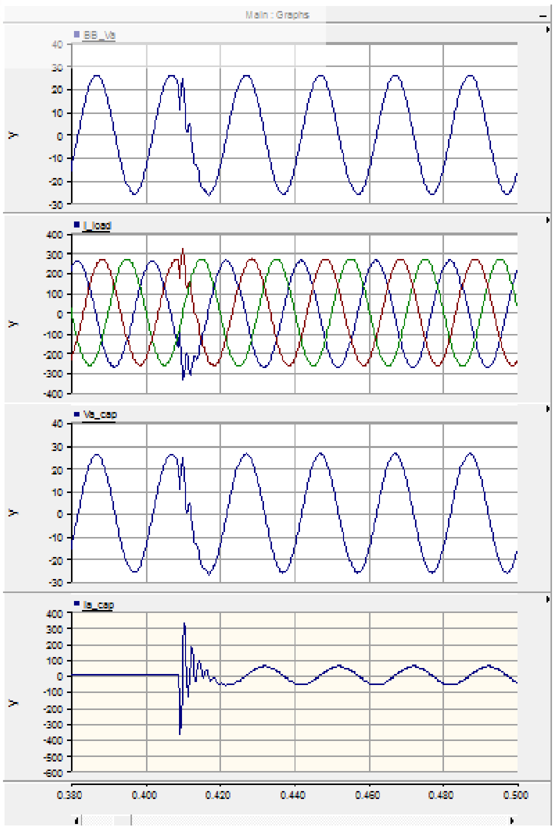
Zero Crossing+5ms



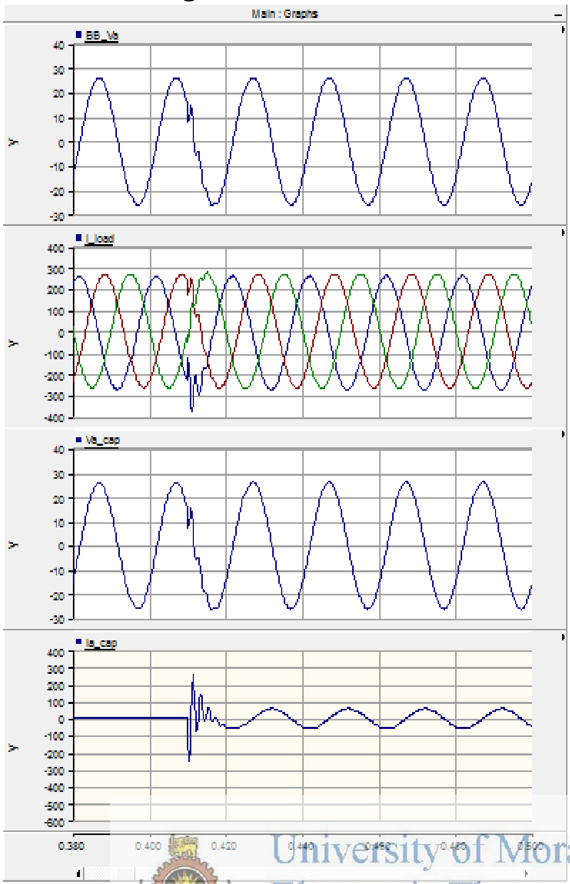
Zero Crossing+6ms



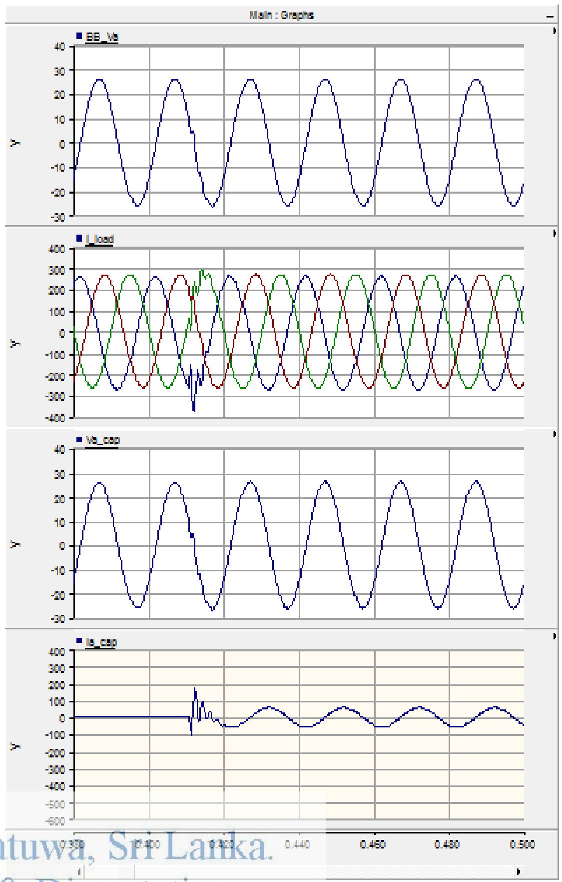
Zero Crossing+7ms



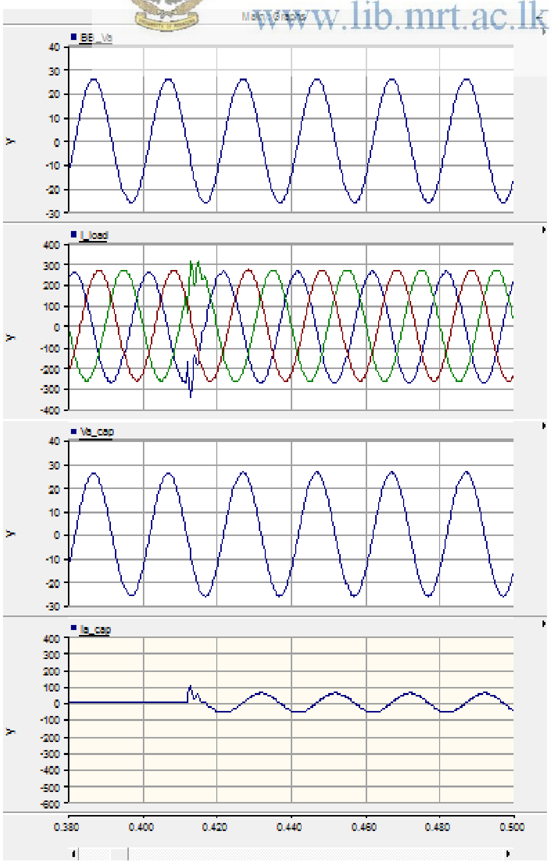
Zero Crossing+8ms



Zero Crossing+9ms

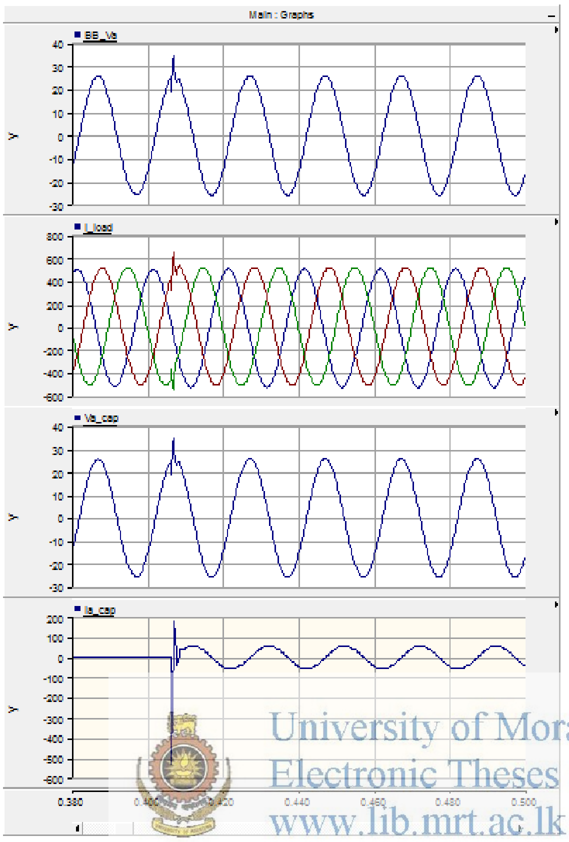


Zero Crossing+10ms

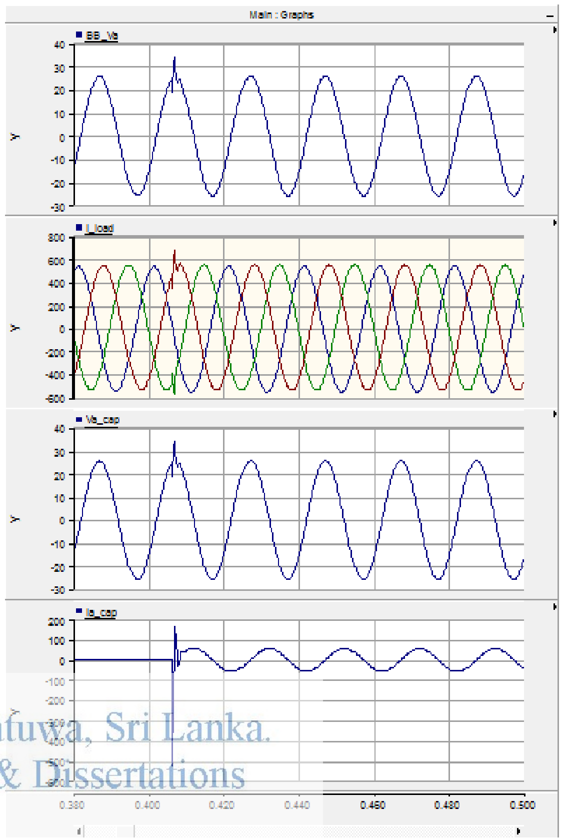


Appendix 11: Switching of capacitor bank one for randomly selected loads at voltage peak

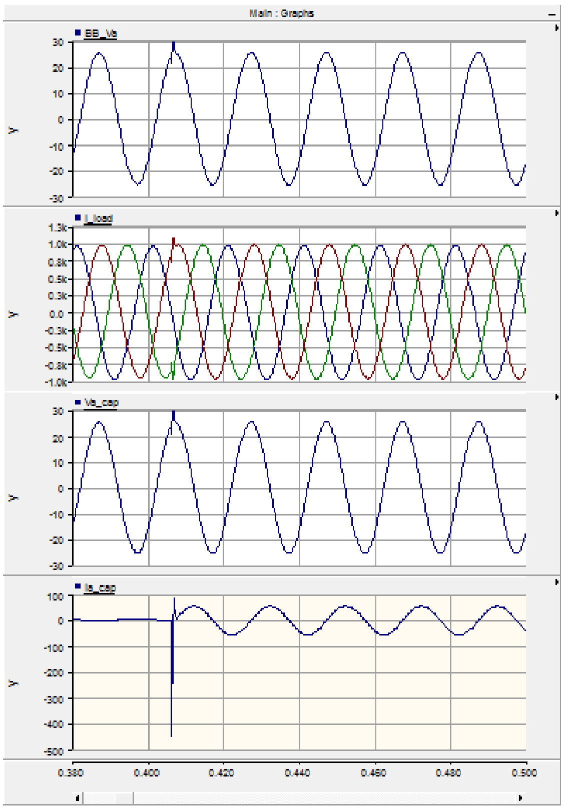
00.30 hr



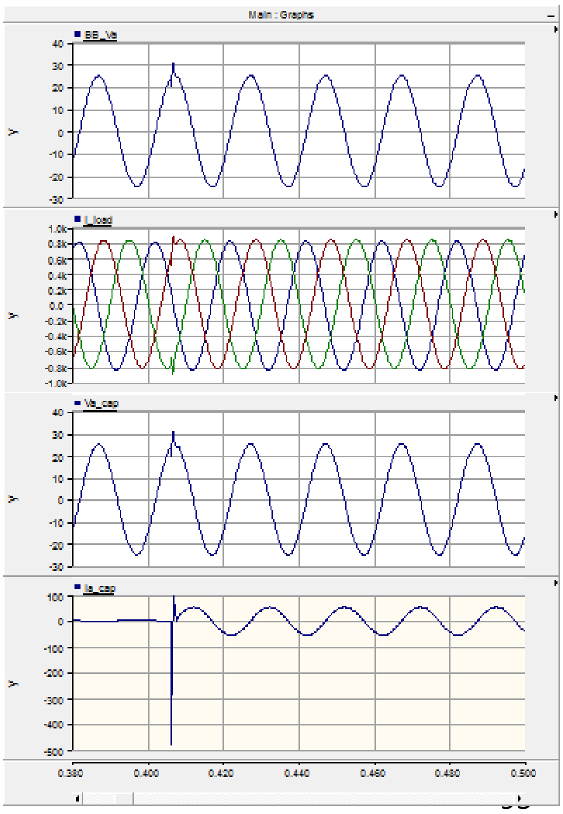
04.00 hr



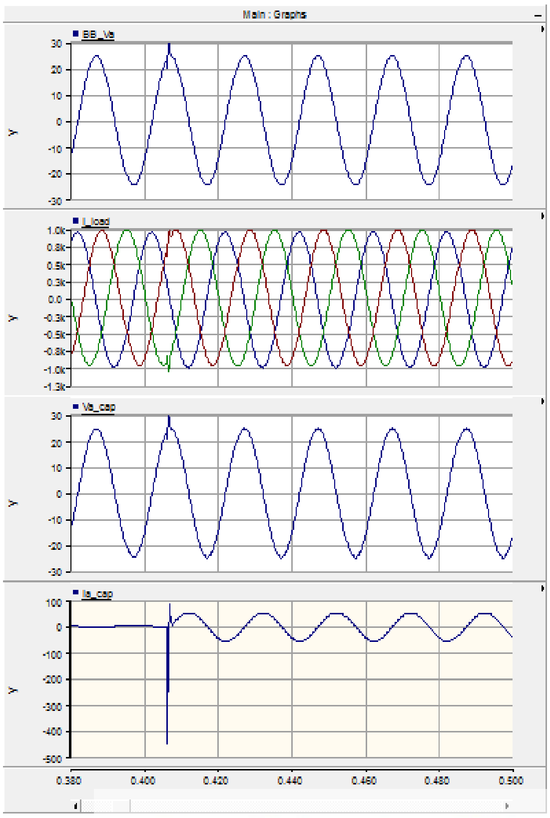
06.00 hr



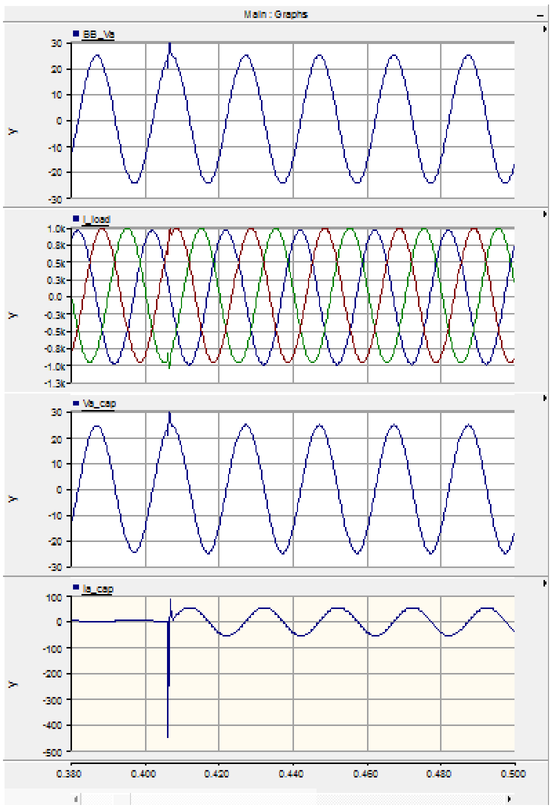
09.00 hr



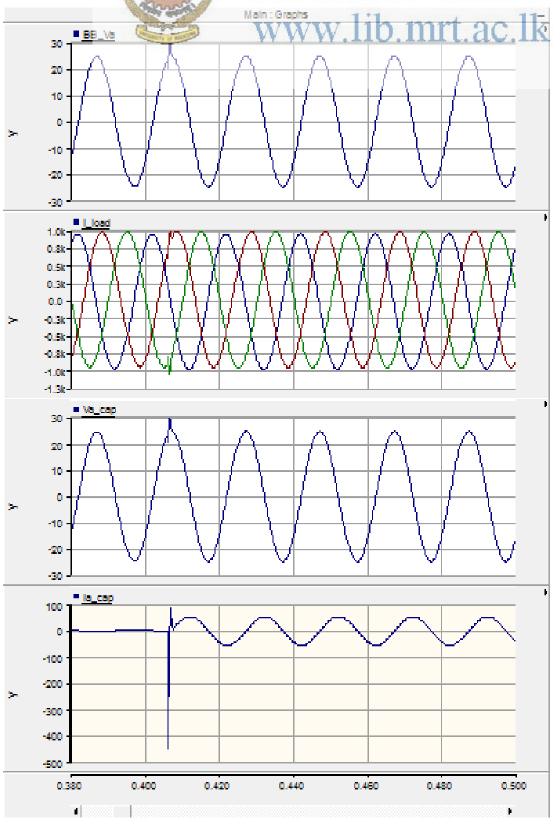
12.00 hr



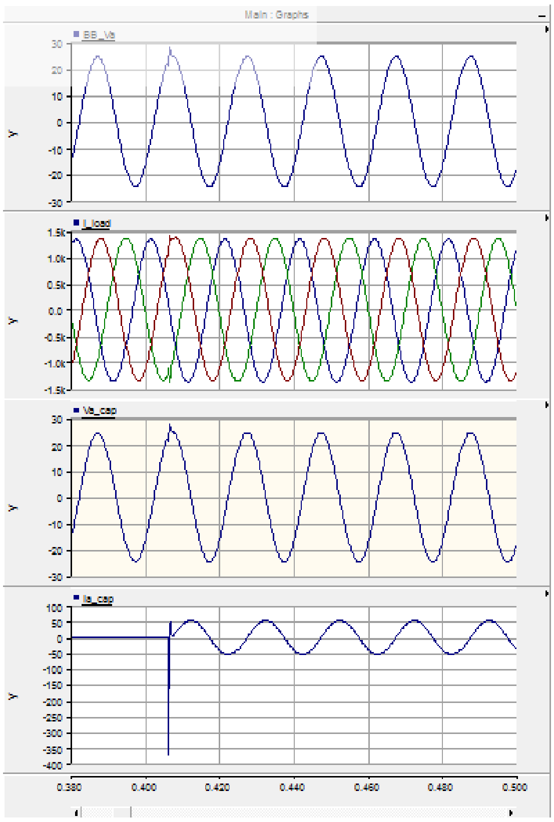
15.00 hr



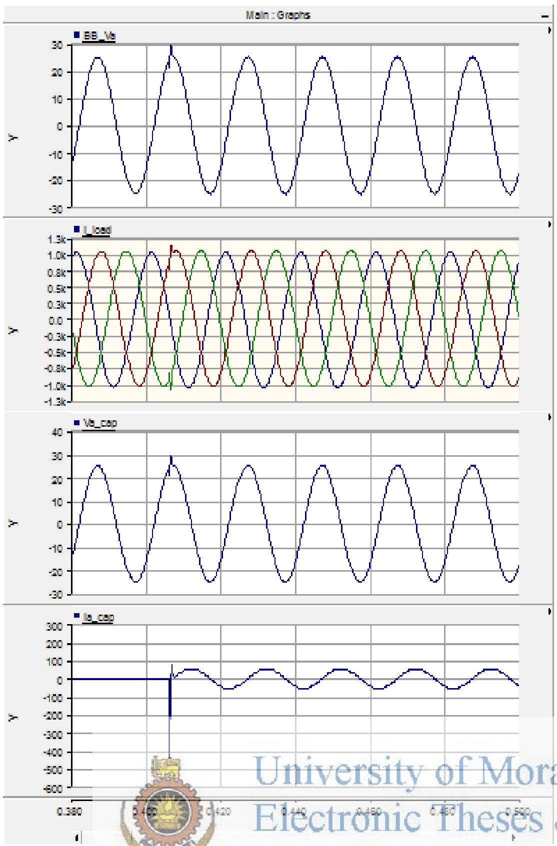
17.00 hr



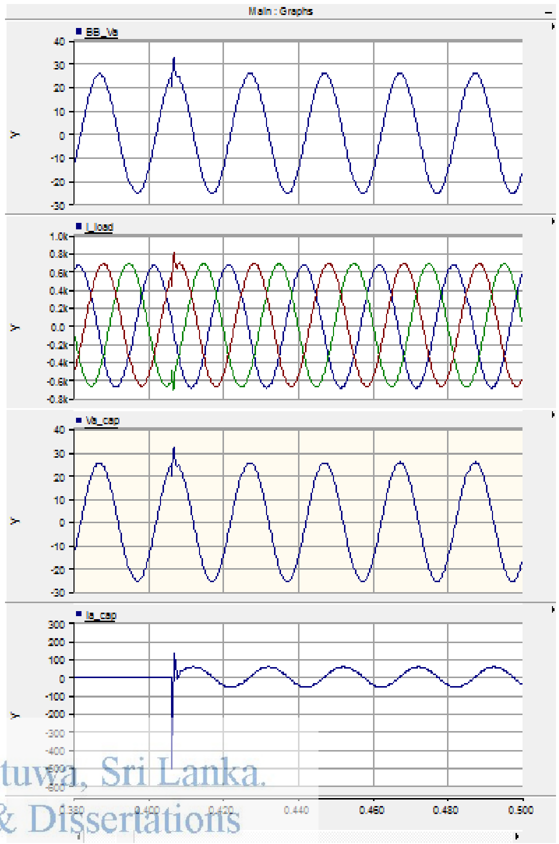
19.30 hr



21.30 hr

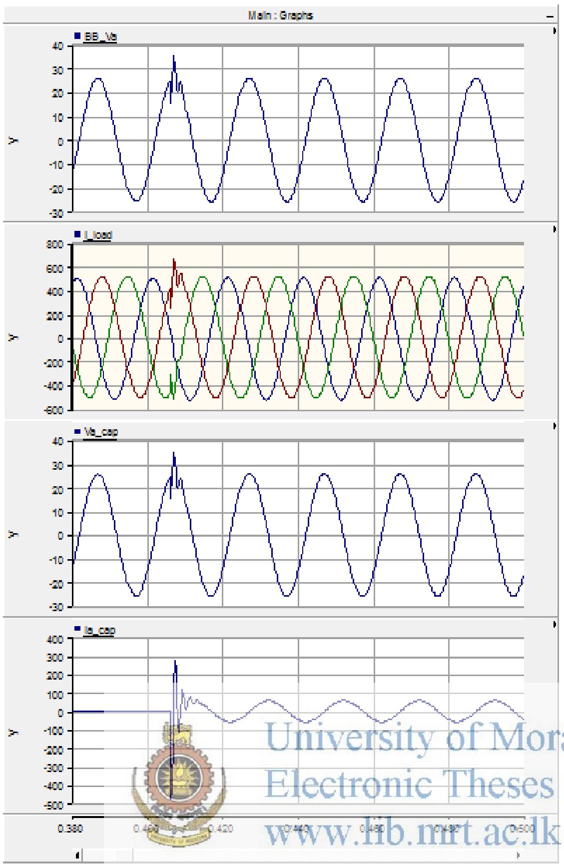


23.00 hr

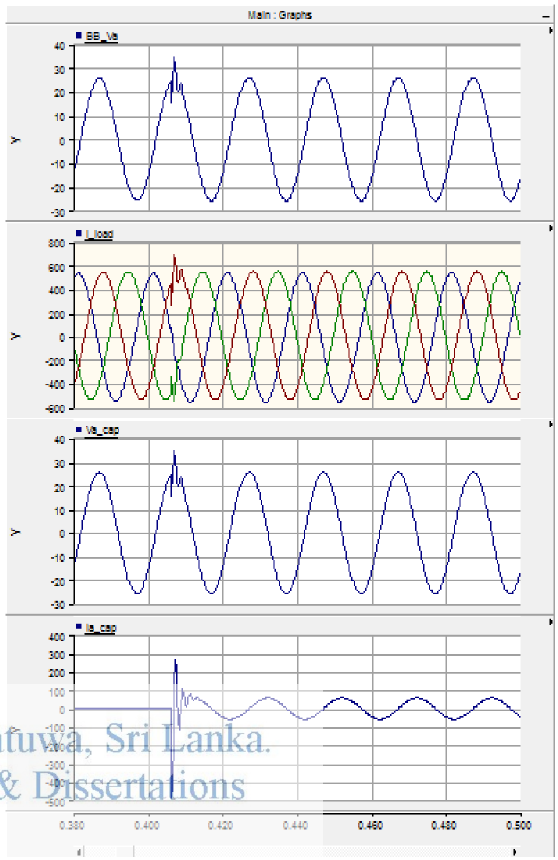


Appendix 12: Switching of capacitor bank two for randomly selected loads at voltage peak

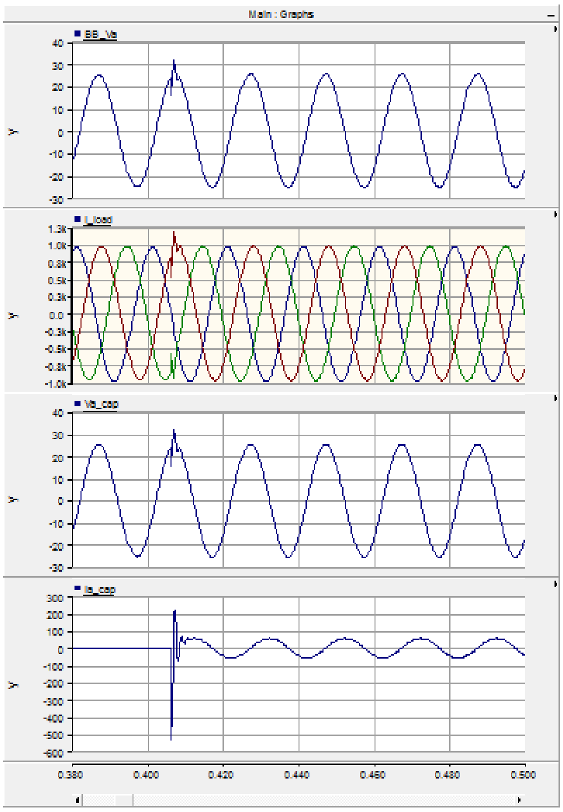
00.30 hr



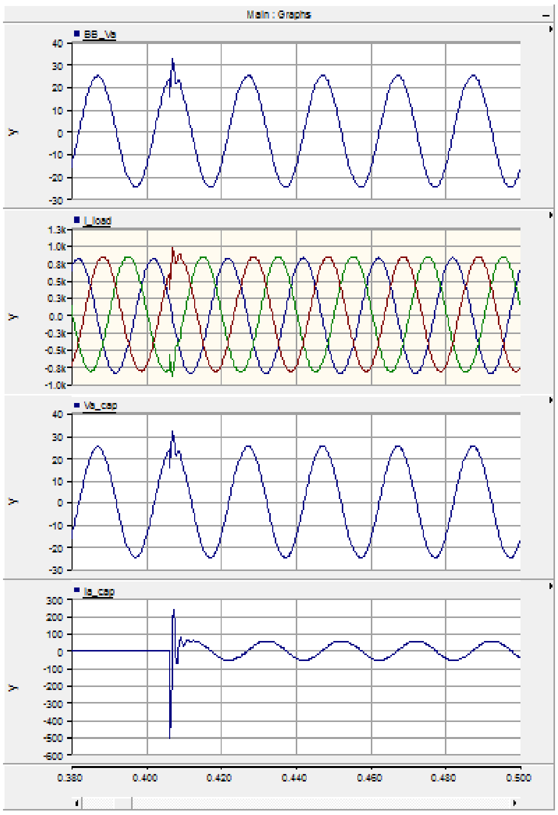
04.00 hr



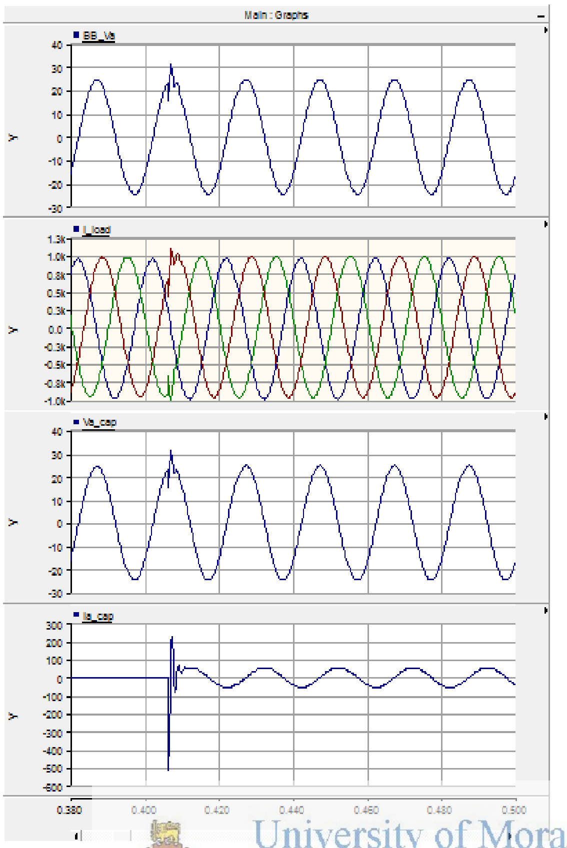
06.00 hr



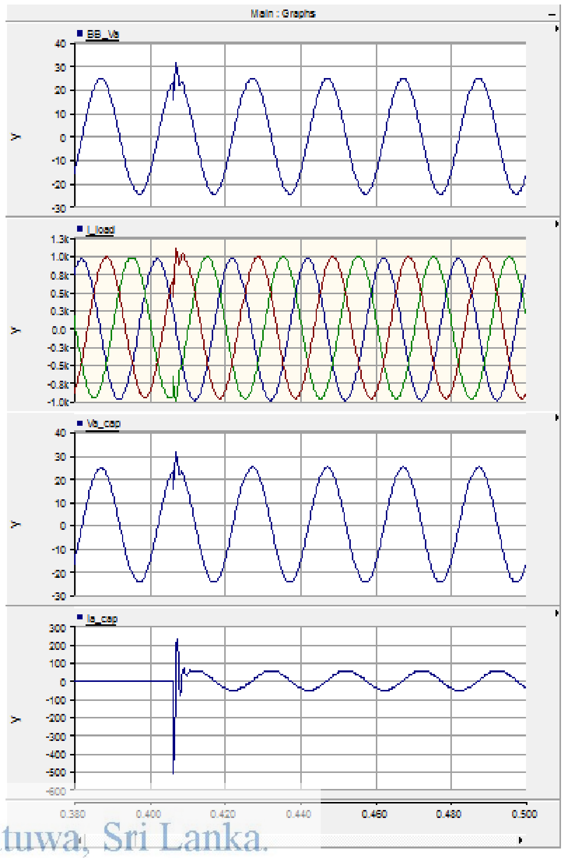
09.00 hr



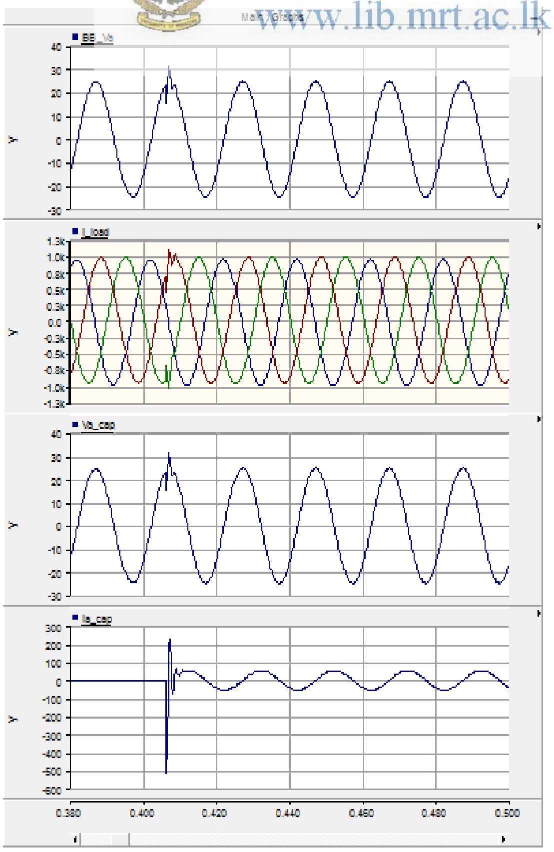
12.00 hr



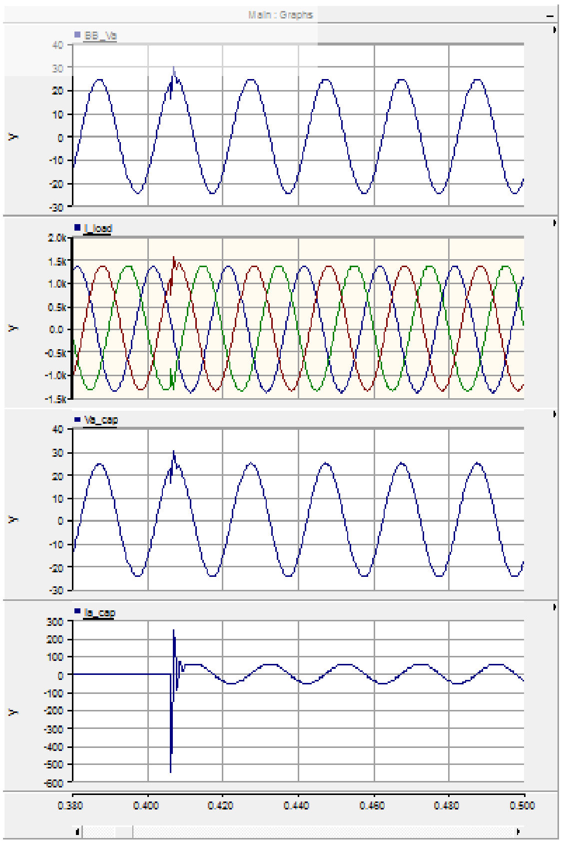
15.00 hr



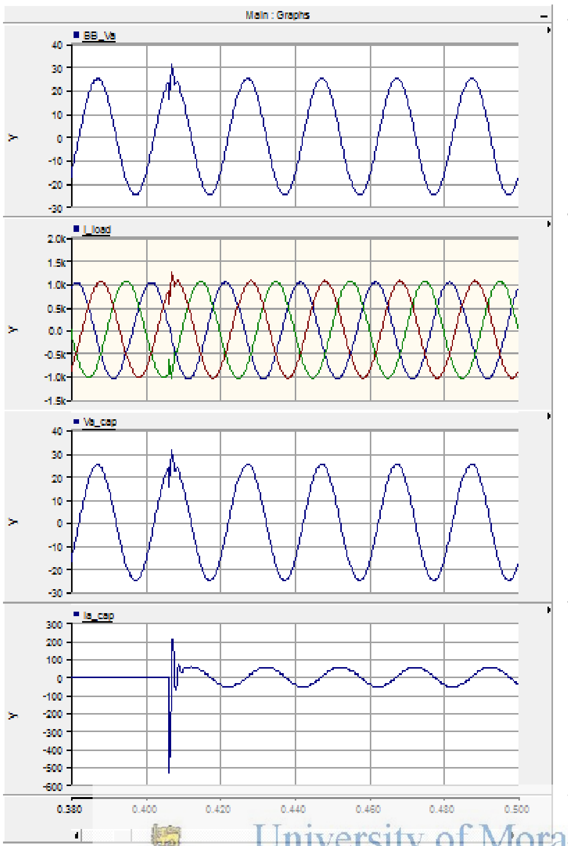
17.00 hr



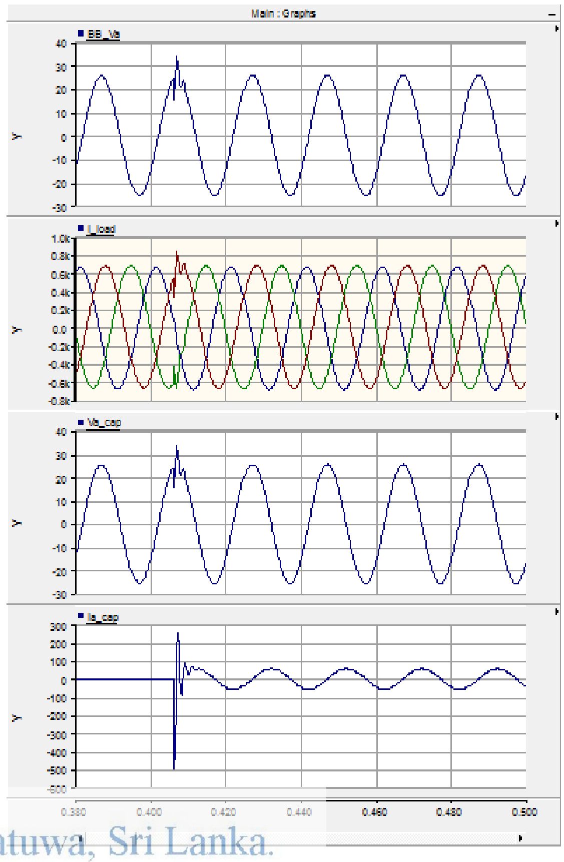
19.30 hr



21.30 hr

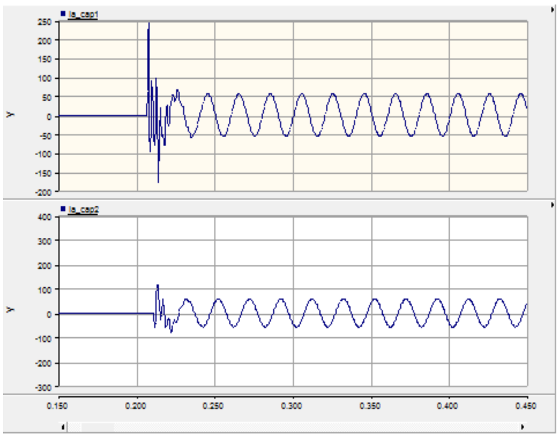


23.00 hr

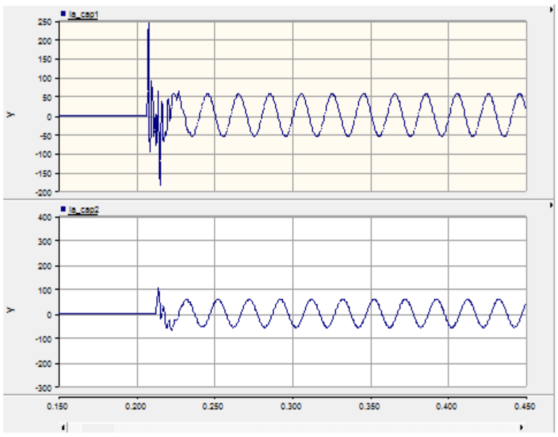


Appendix 13: Fast switching of capacitor banks sequence of bank one to two with 1 ms delay time increasing

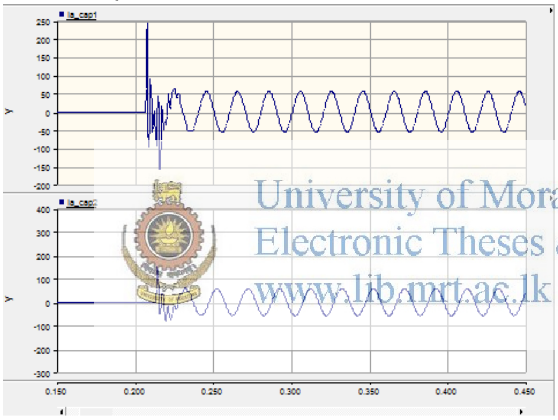
4 ms delay



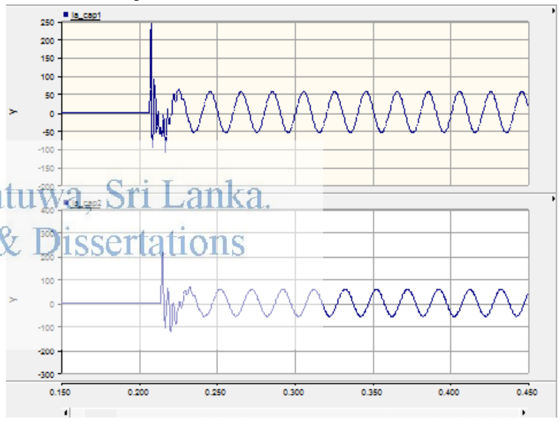
5 ms delay



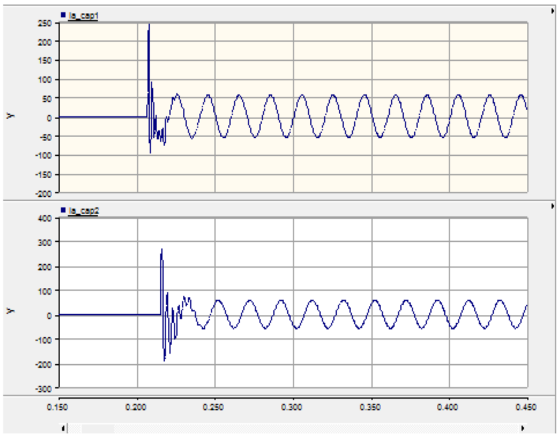
6ms delay



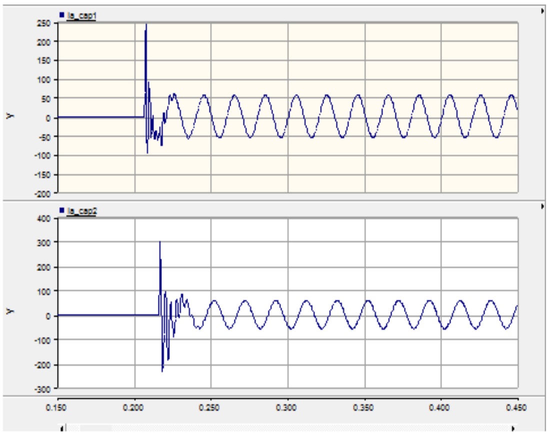
7 ms delay



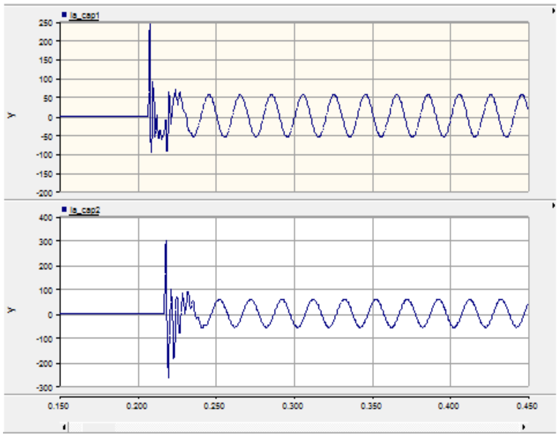
8ms delay



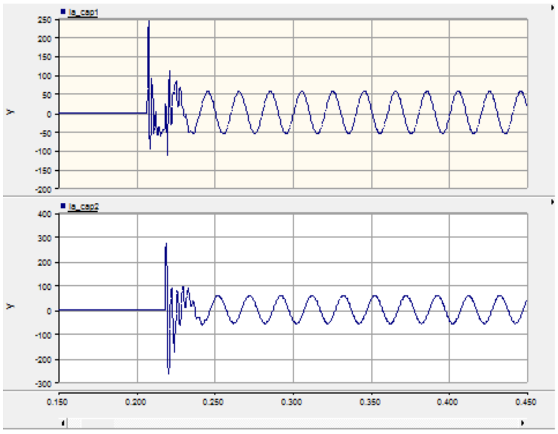
9 ms delay



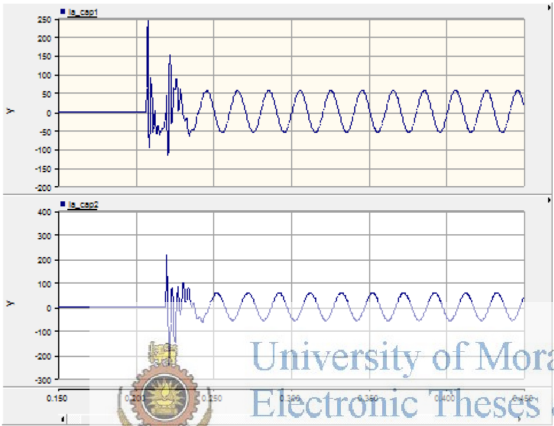
10ms delay



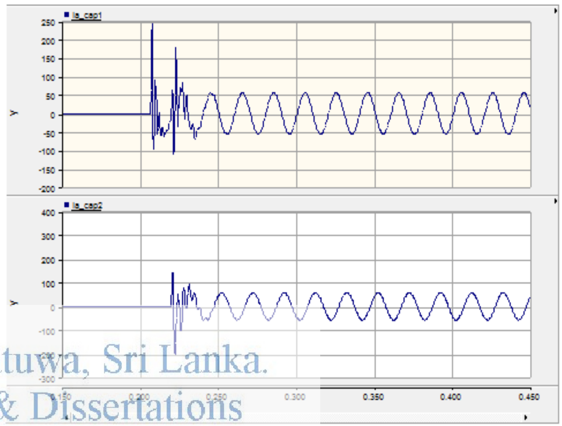
11 ms delay



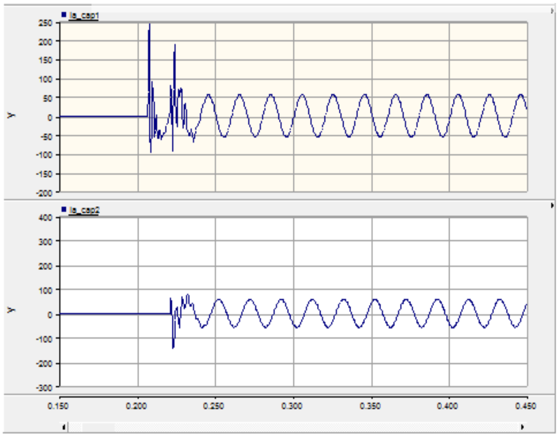
12ms delay



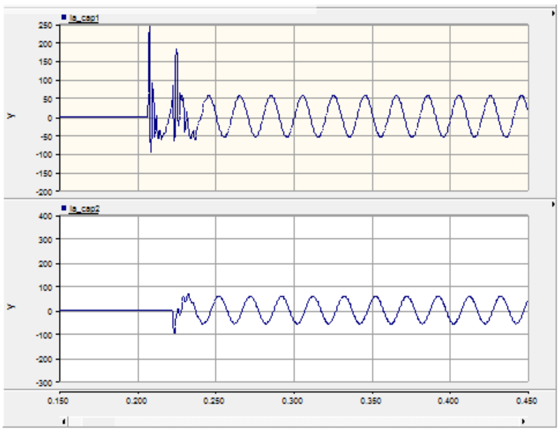
13 ms delay



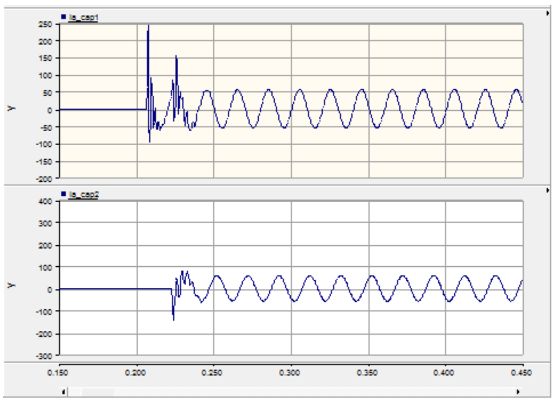
14ms delay



15 ms delay

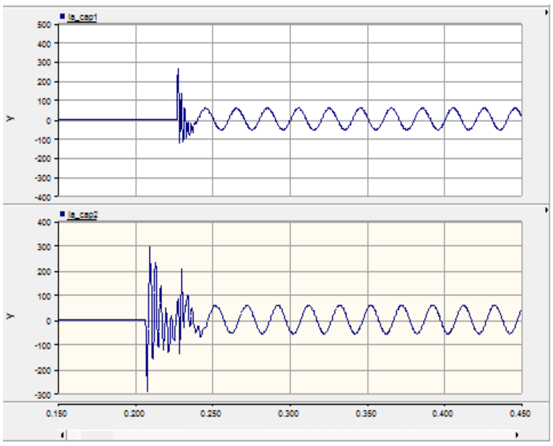


16ms delay

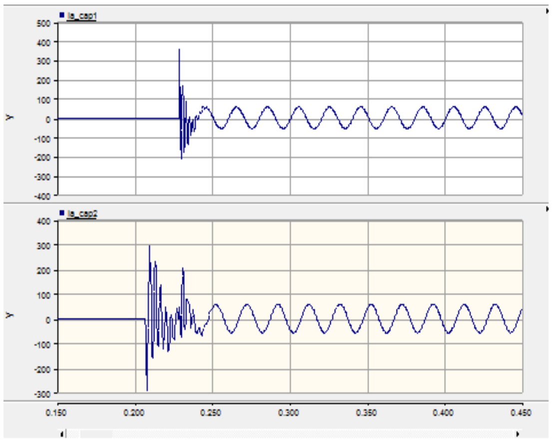


Appendix 14: Fast switching of capacitor banks sequence of bank two to one with 1 ms delay time increasing

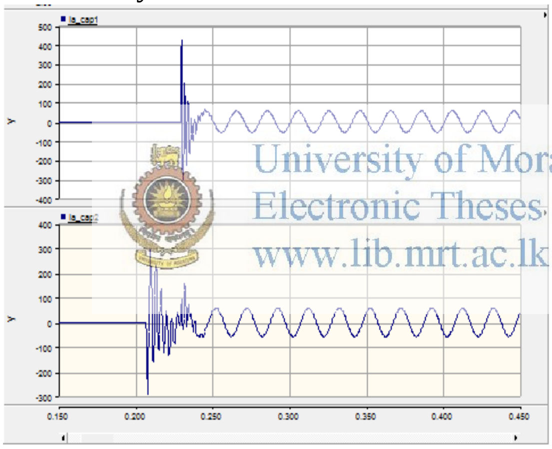
20 ms delay



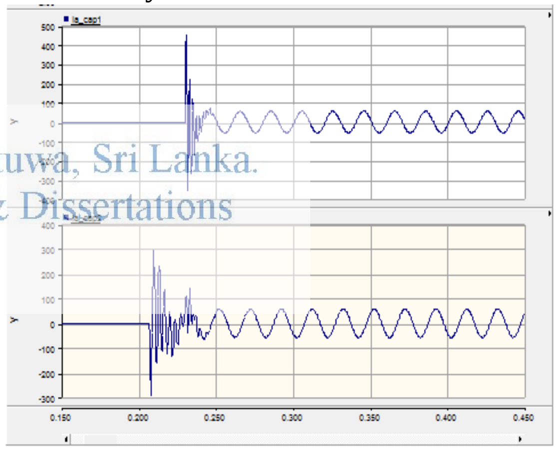
21 ms delay



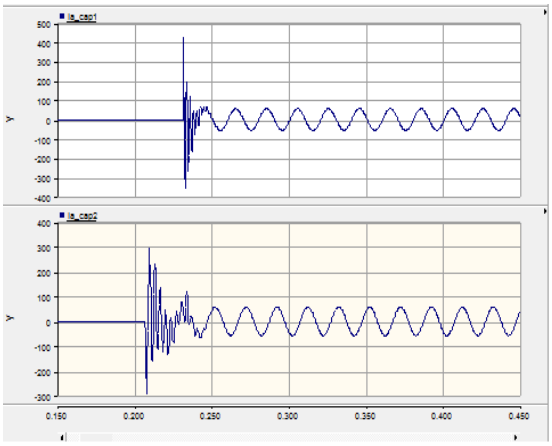
22 ms delay



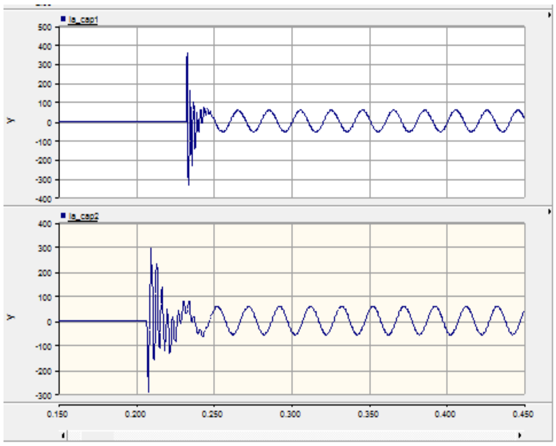
23 ms delay



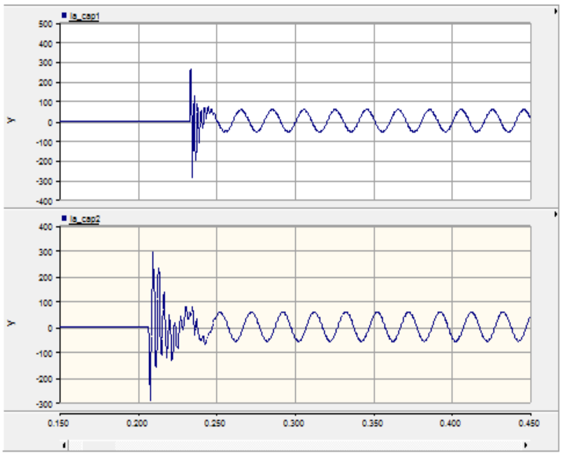
24 ms delay



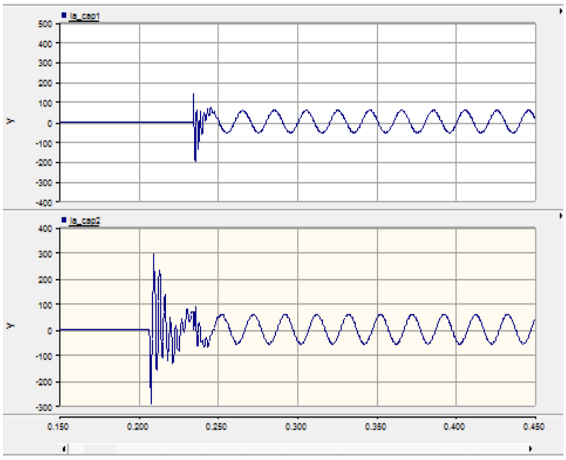
25 ms delay



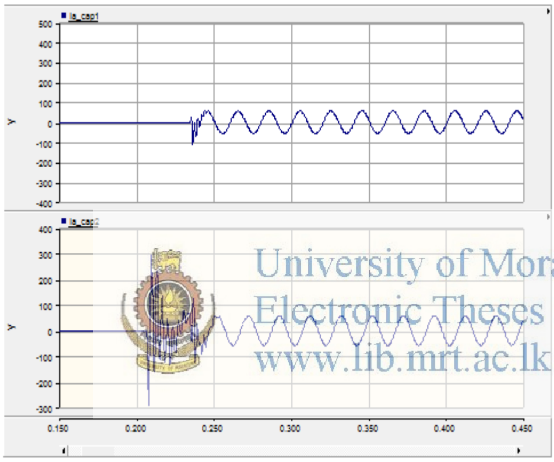
26 ms delay



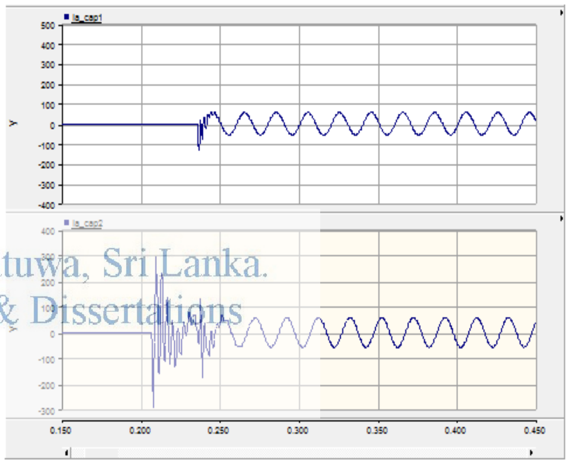
27 ms delay



28 ms delay



29 ms delay

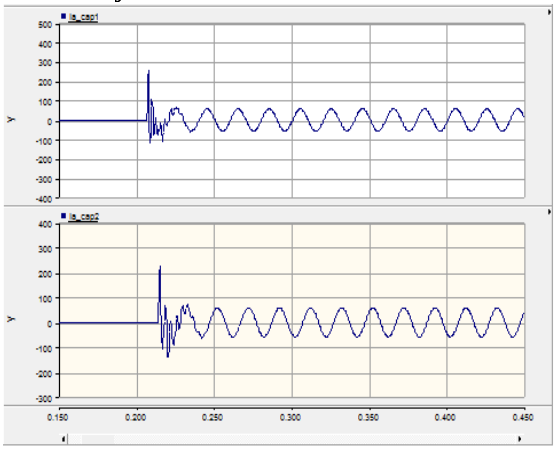


Appendix 15: Fast switching for selected loading

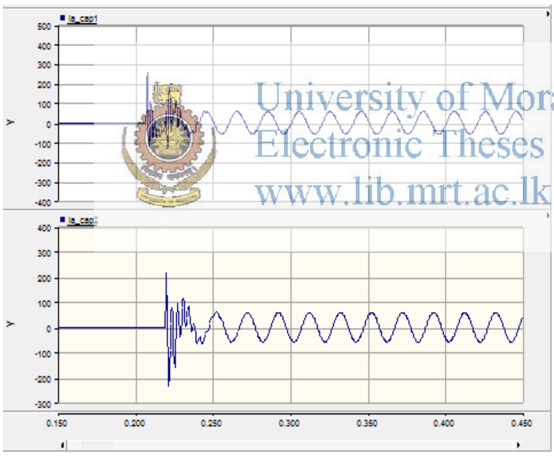
Fast switching for several 33 kV loading (00.30 hr)

Switching sequence bank one to two

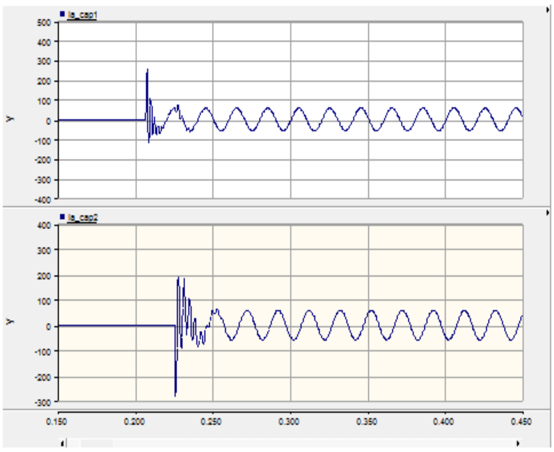
7ms delay



13 ms delay

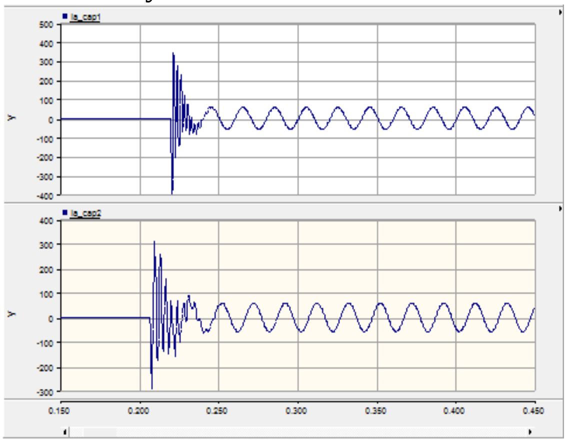


18 ms delay

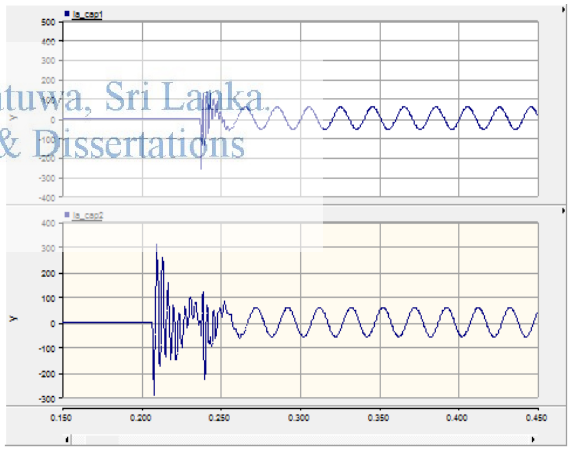


Switching sequence two to one

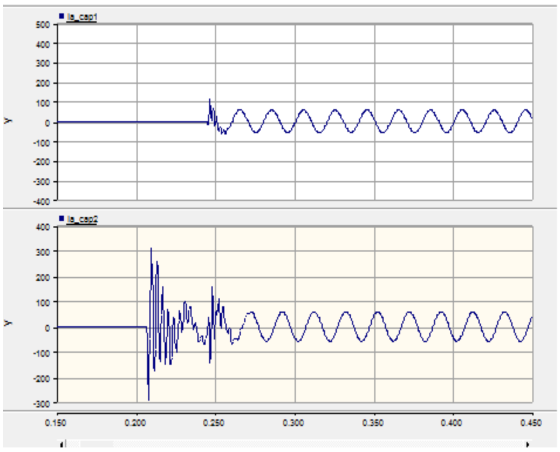
13 ms delay



30 ms delay



38 ms delay

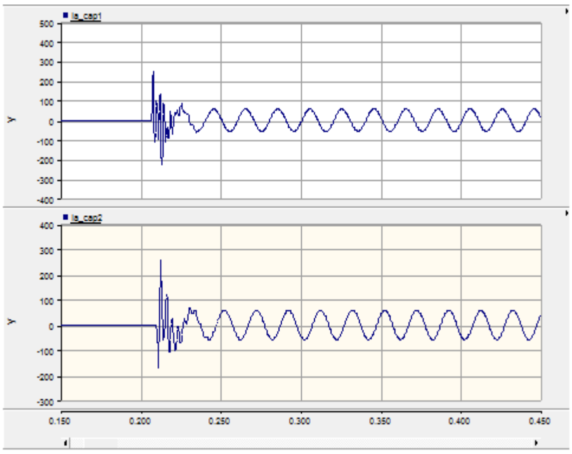


Fast switching for several 33 kV loading (04.00 hr)

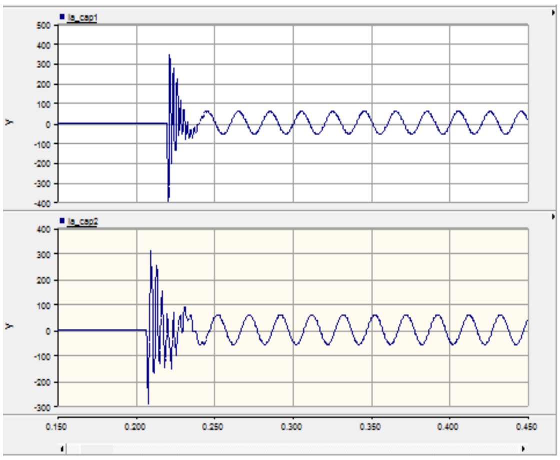
Switching sequence bank one to two

Switching sequence two to one

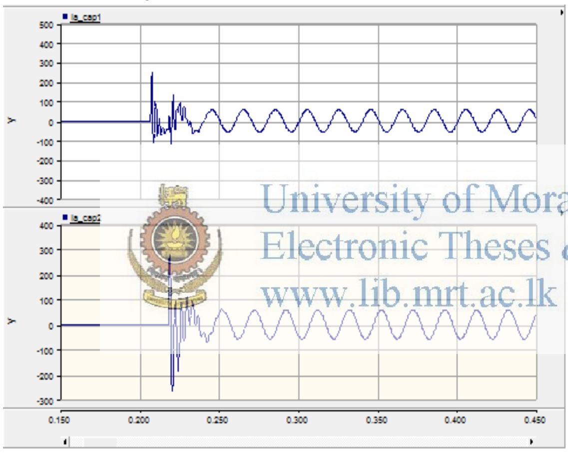
3ms delay



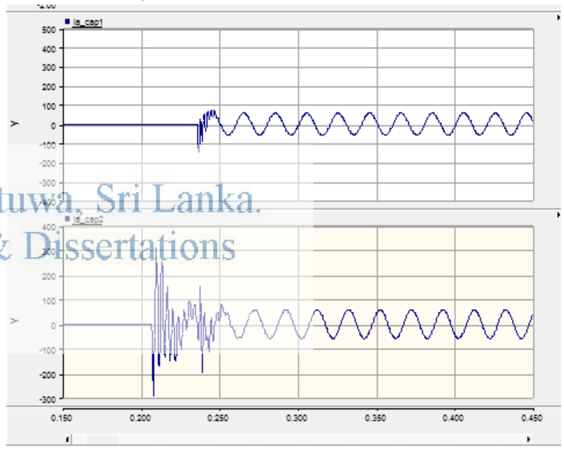
13 ms delay



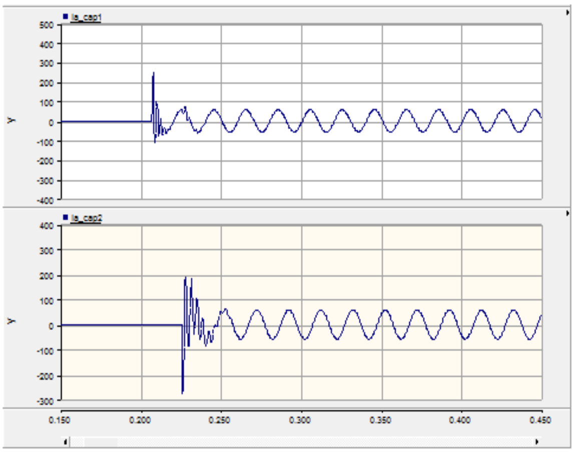
11 ms delay



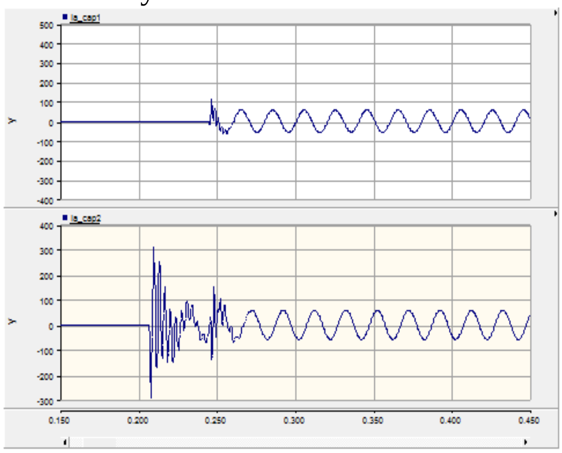
29 ms delay



18 ms delay



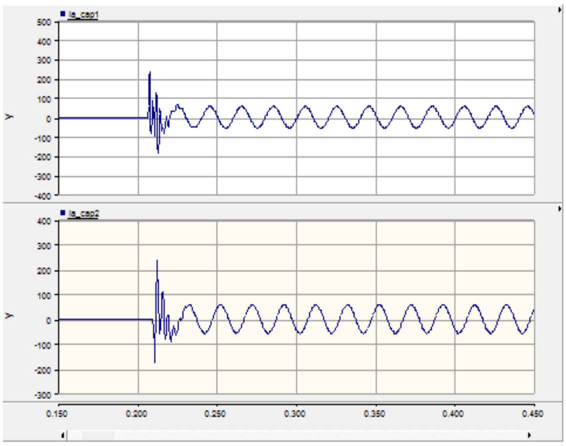
38 ms delay



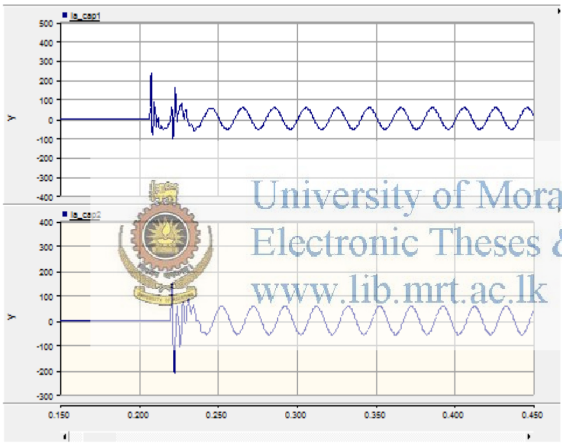
Fast switching for several 33 kV loading (06.00 hr)

Switching sequence bank one to two

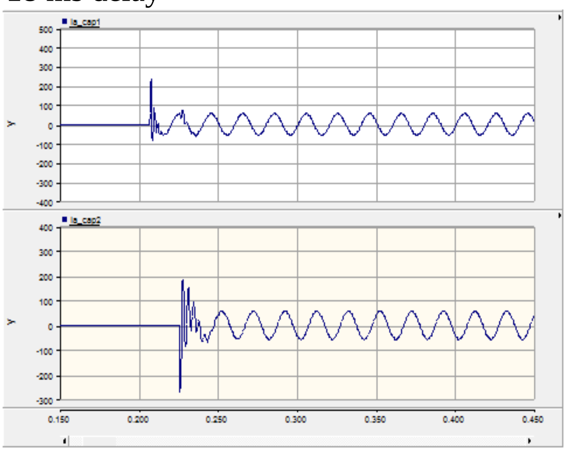
3 ms delay



13 ms delay

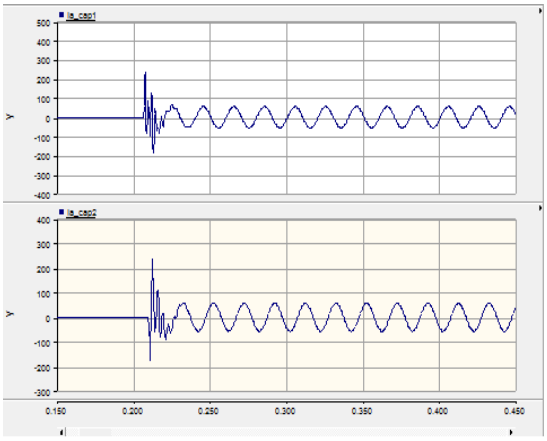


18 ms delay

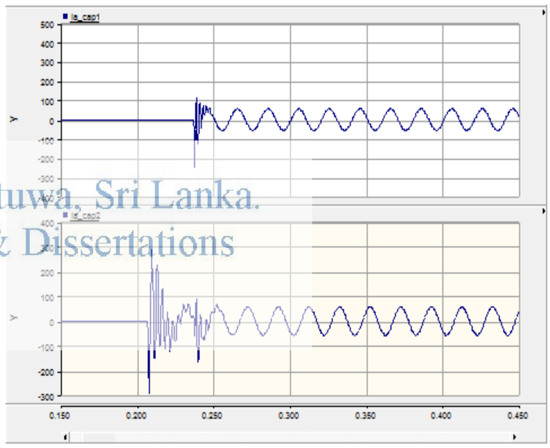


Switching sequence two to one

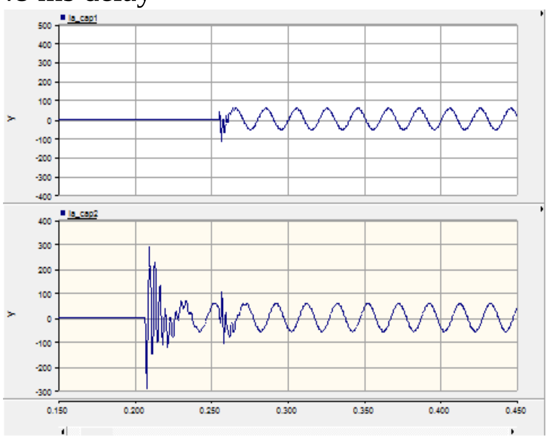
3 ms delay



30 ms delay



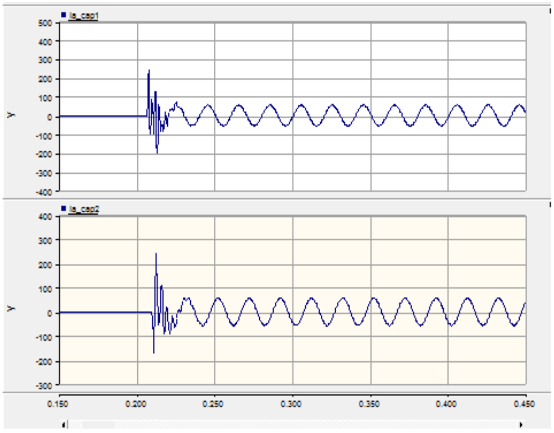
48 ms delay



Fast switching for several 33 kV loading (09.00 hr)

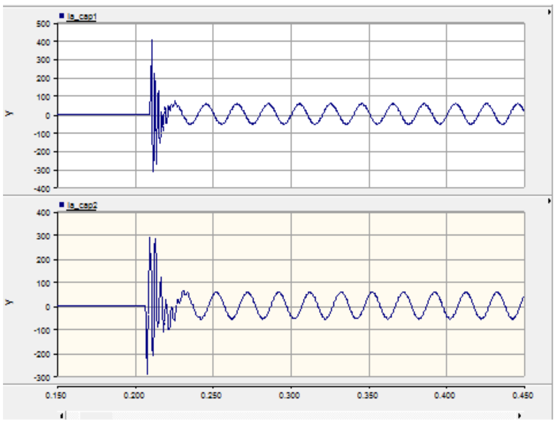
Switching sequence bank one to two

3 ms delay

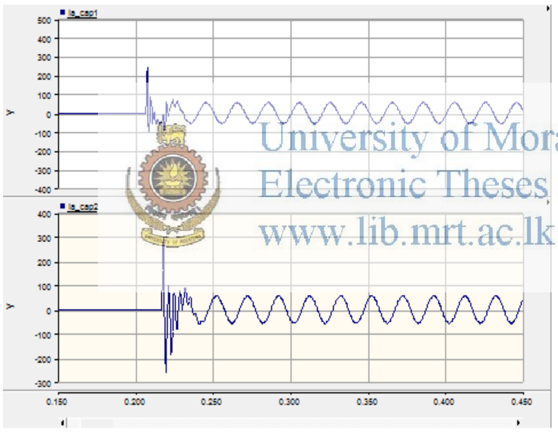


Switching sequence two to one

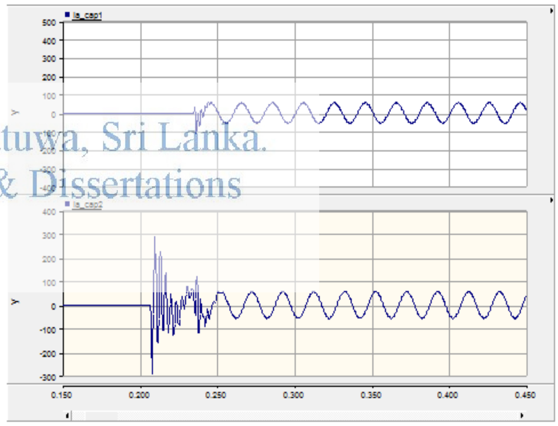
3 ms delay



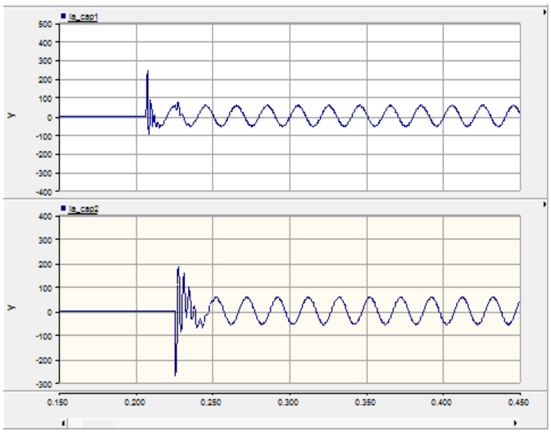
10 ms delay



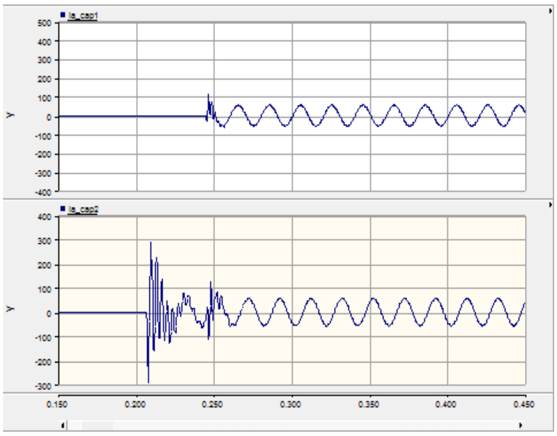
28 ms delay



18 ms delay



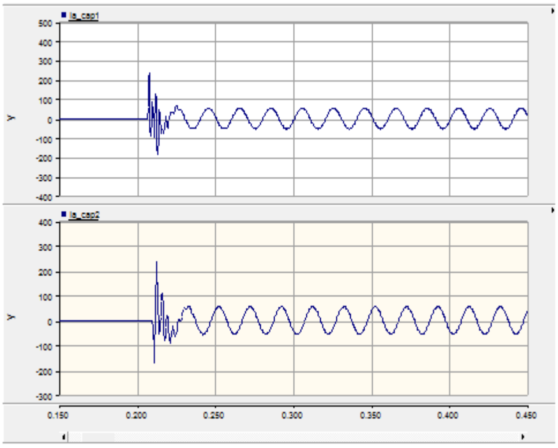
38 ms delay



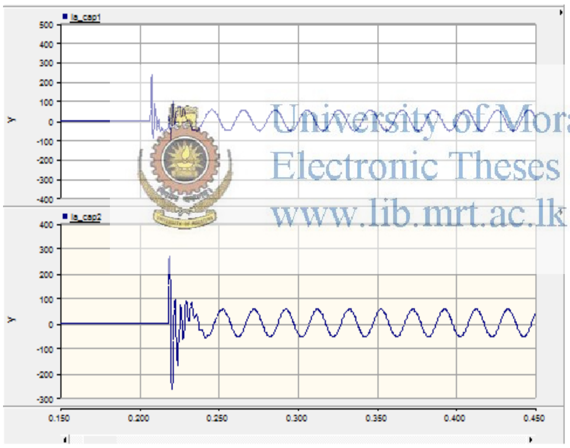
Fast switching for several 33 kV loading (12.00 hr)

Switching sequence bank one to two

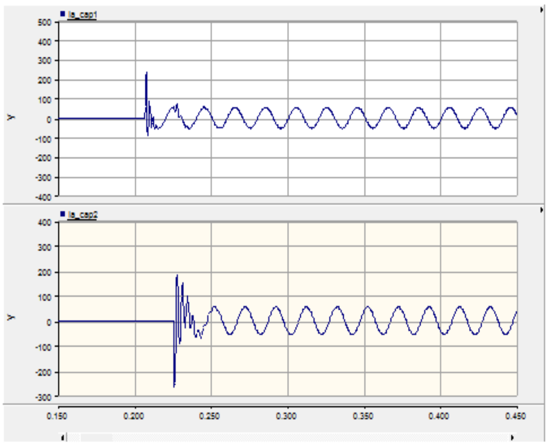
3 ms delay



11 ms delay

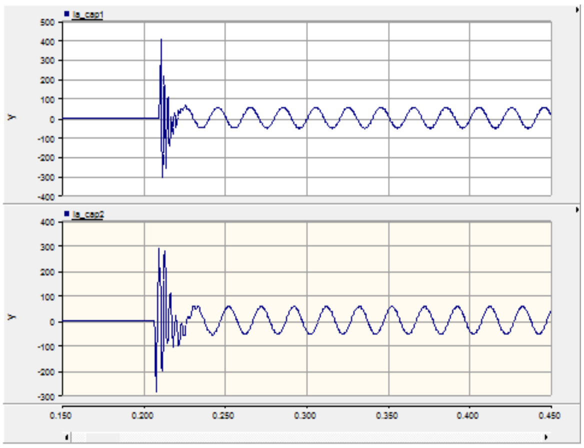


18 ms delay

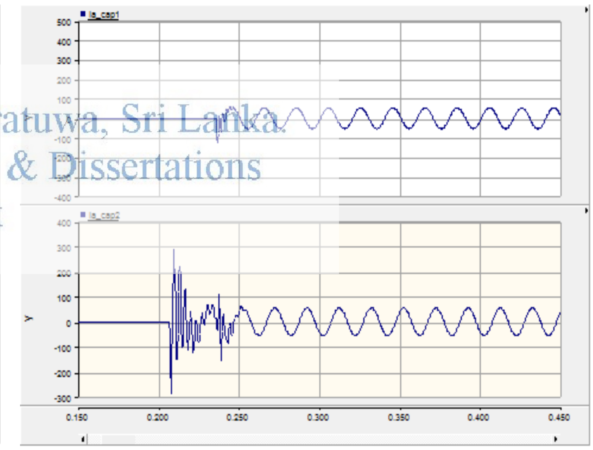


Switching sequence two to one

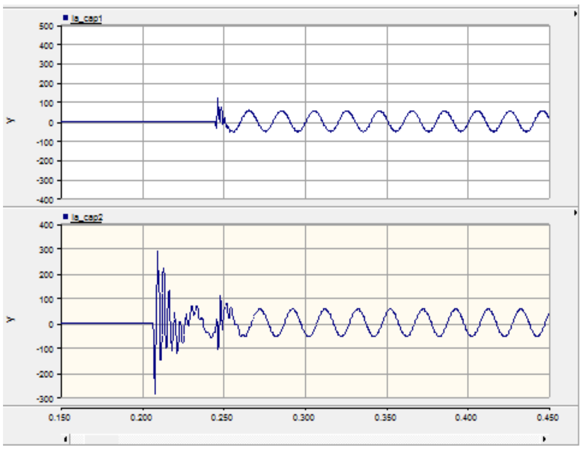
3 ms delay



29 ms delay



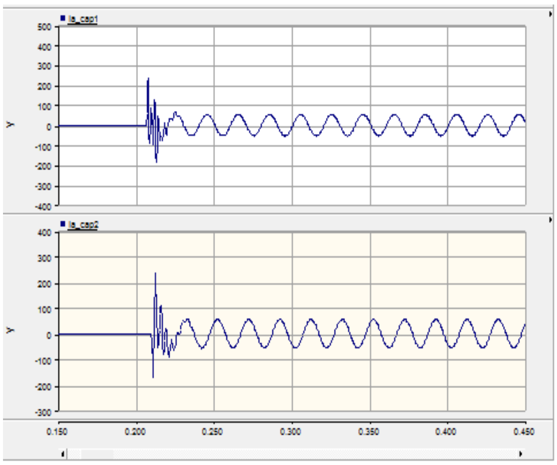
38 ms delay



Fast switching for several 33 kV loading (15.00 hr)

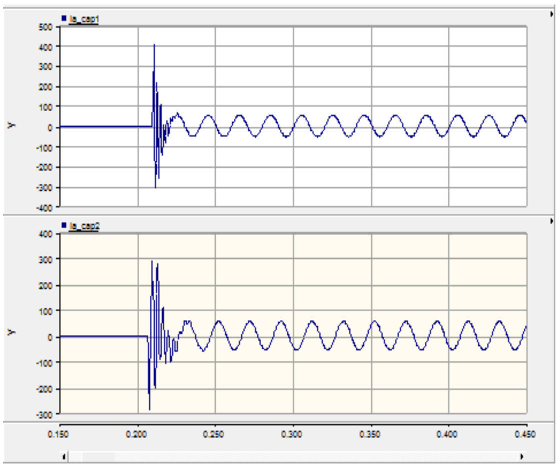
Switching sequence bank one to two

3 ms delay

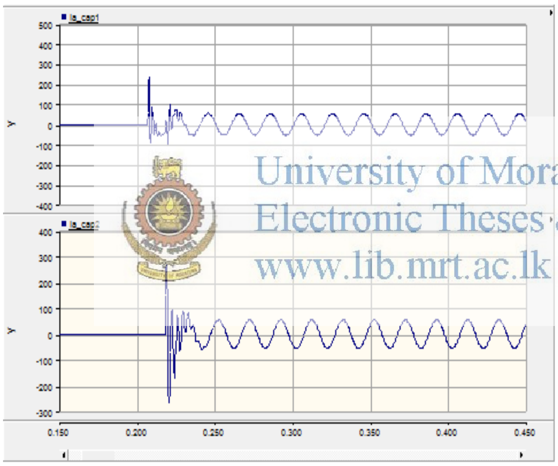


Switching sequence two to one

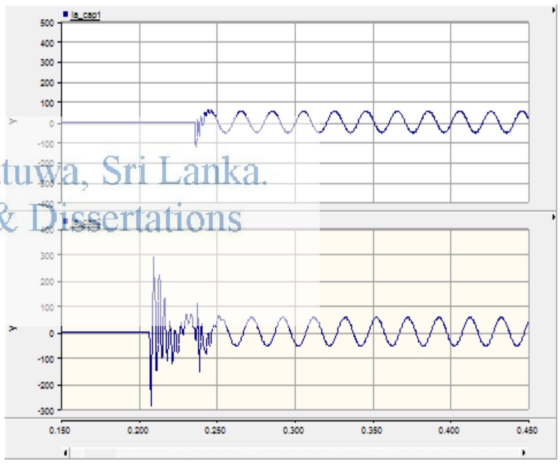
3 ms delay



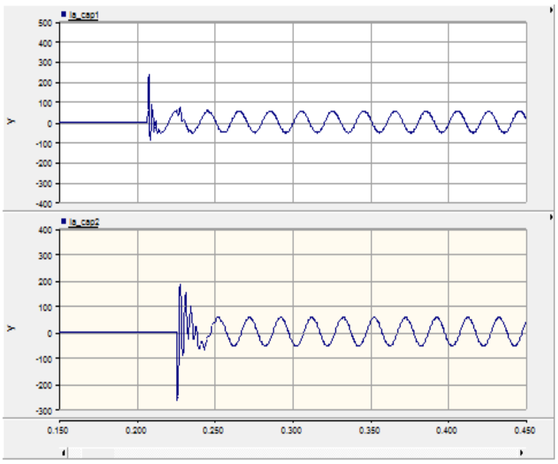
11 ms delay



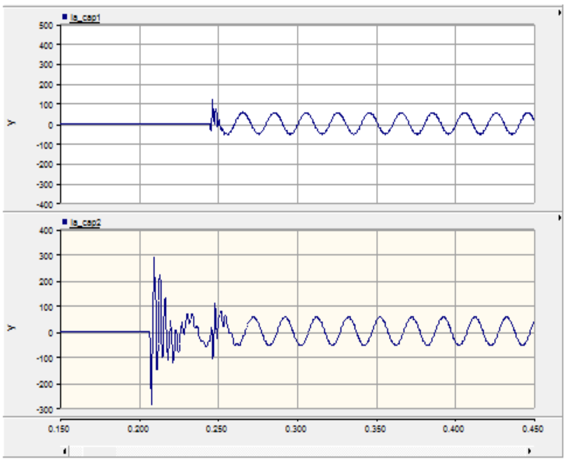
29 ms delay



18 ms delay



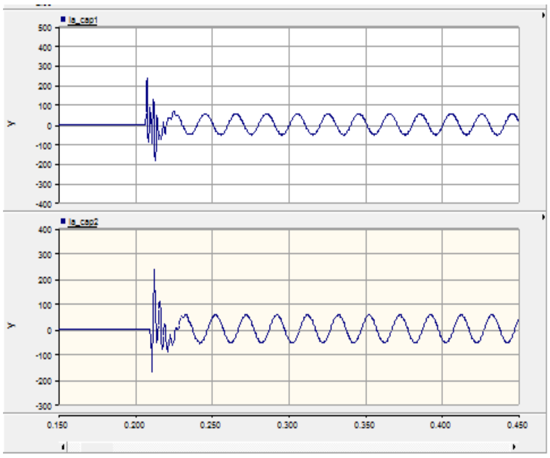
38 ms delay



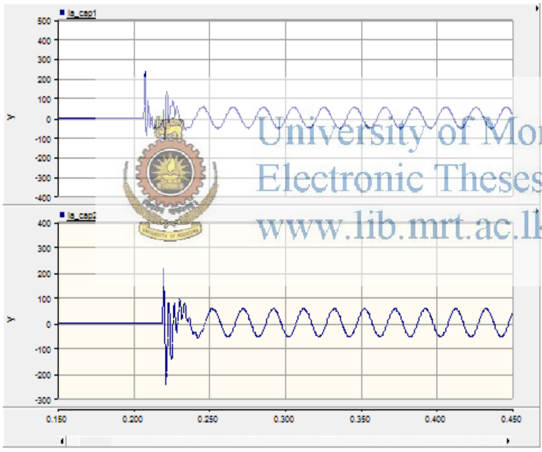
Fast switching for several 33 kV loading (17.00 hr)

Switching sequence bank one to two

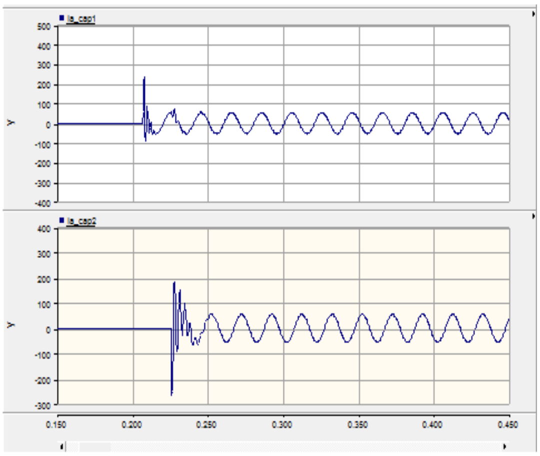
3 ms delay



12 ms delay

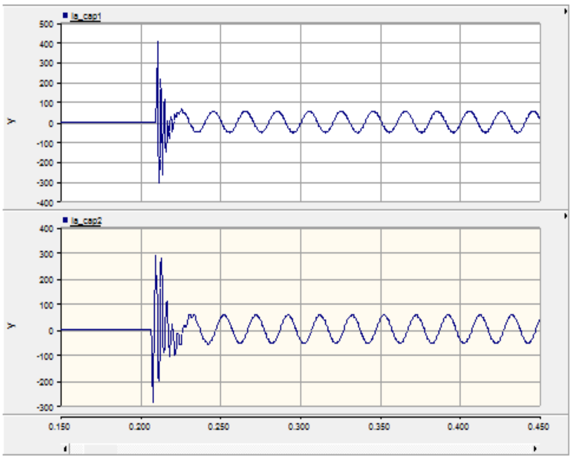


18 ms delay

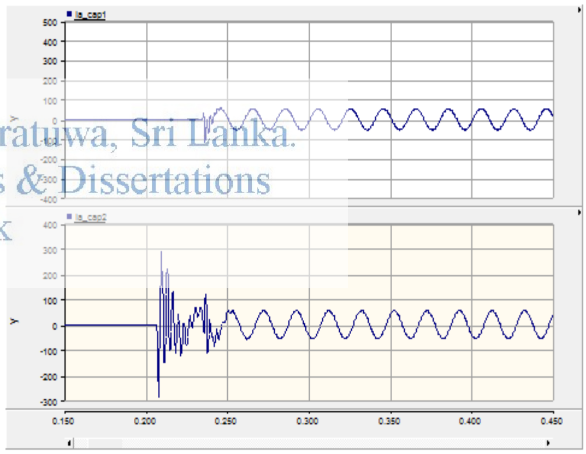


Switching sequence two to one

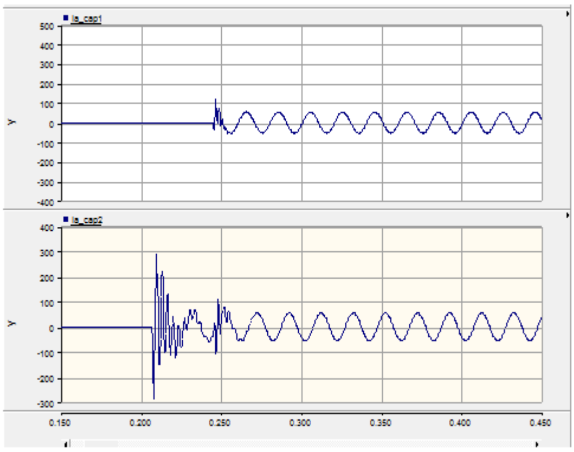
3 ms delay



28 ms delay



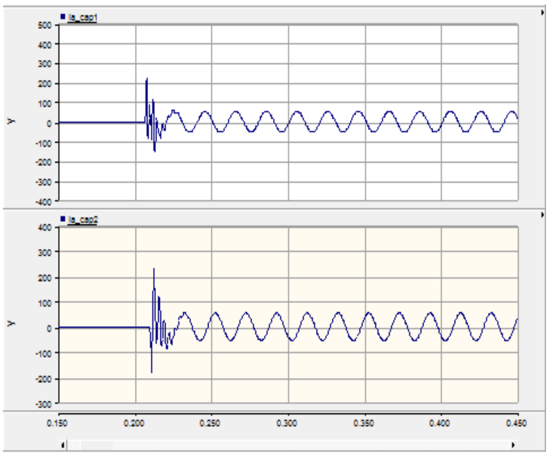
38 ms delay



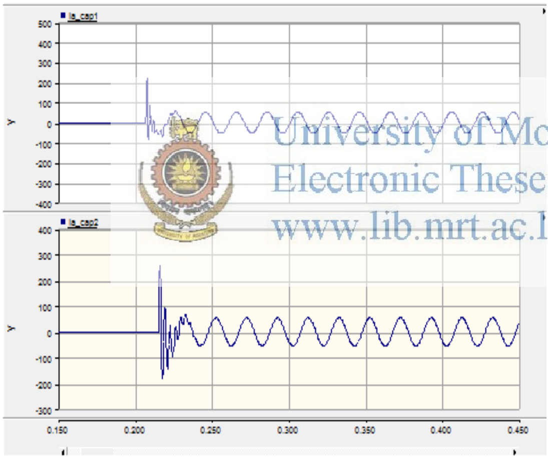
Fast switching for several 33 kV loading (19.30 hr)

Switching sequence bank one to two

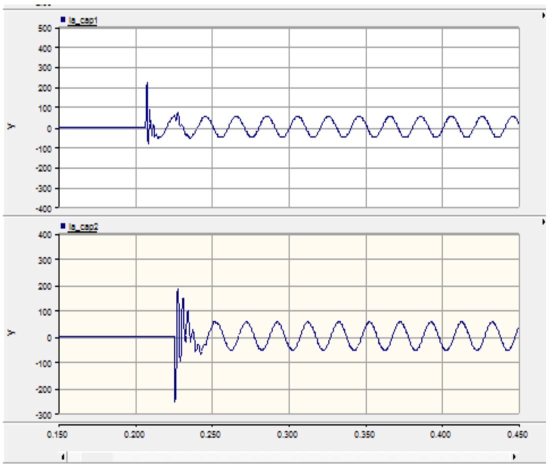
3 ms delay



8 ms delay

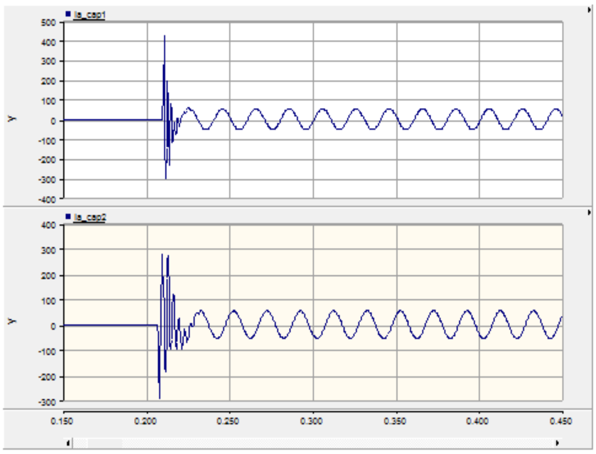


18 ms delay

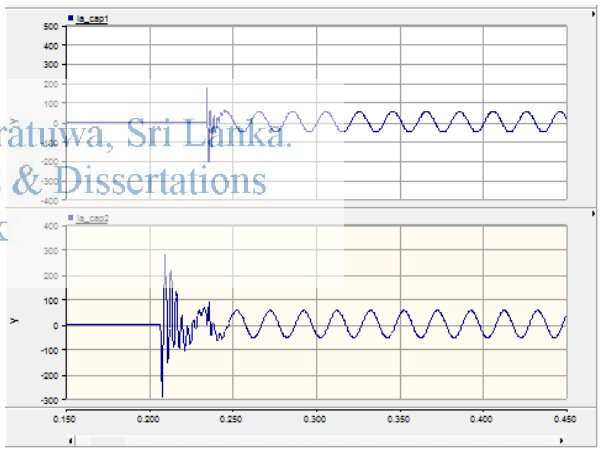


Switching sequence two to one

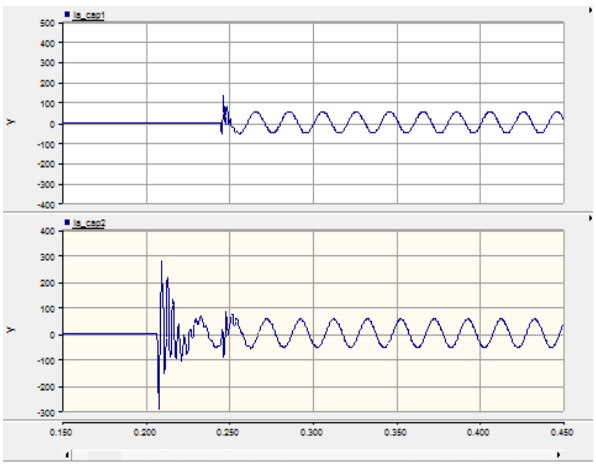
3 ms delay



27 ms delay



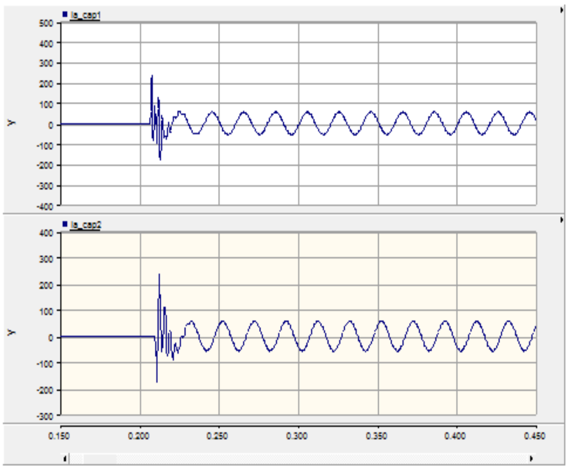
38 ms delay



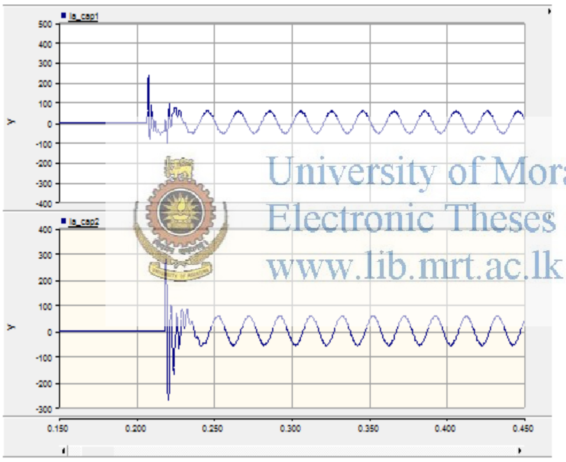
Fast switching for several 33 kV loading (21.30 hr)

Switching sequence bank one to two

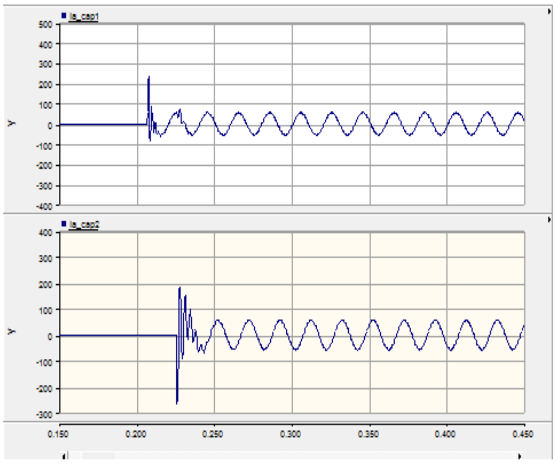
3 ms delay



11 ms delay

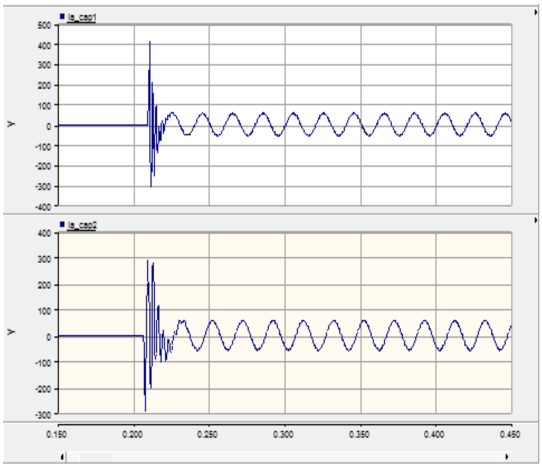


18 ms delay

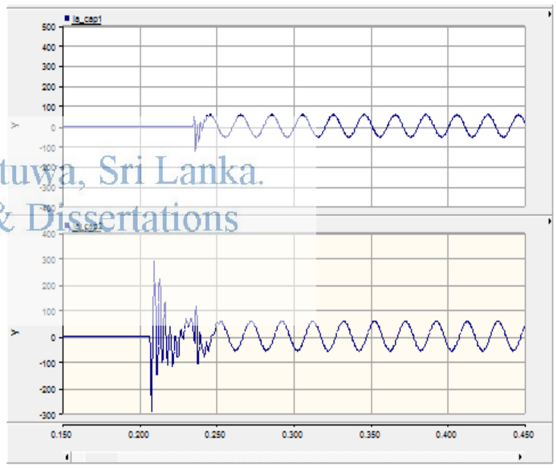


Switching sequence two to one

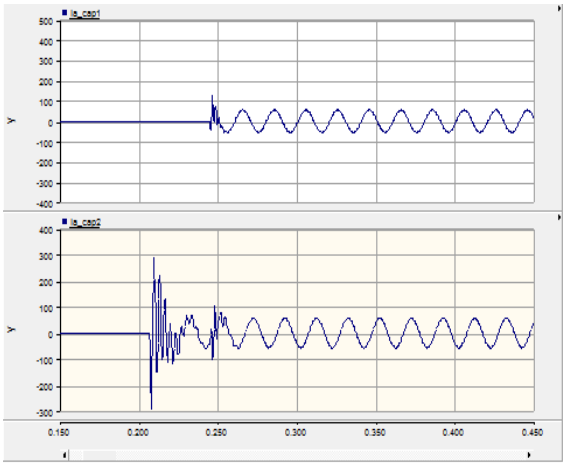
3 ms delay



28 ms delay



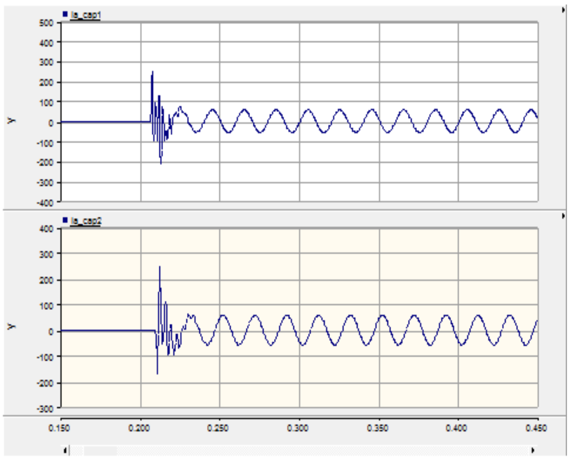
38 ms delay



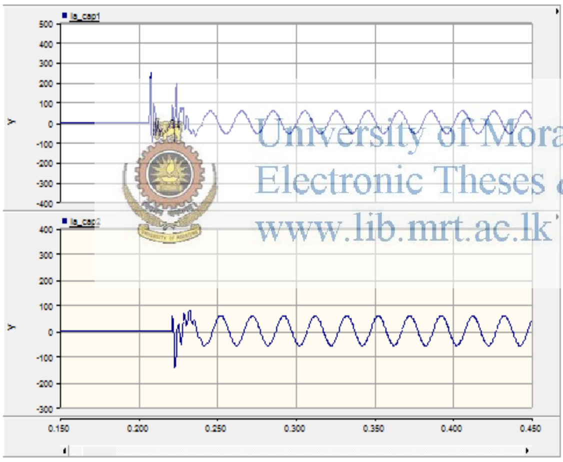
Fast switching for several 33 kV loading (23.00 hr)

Switching sequence bank one to two

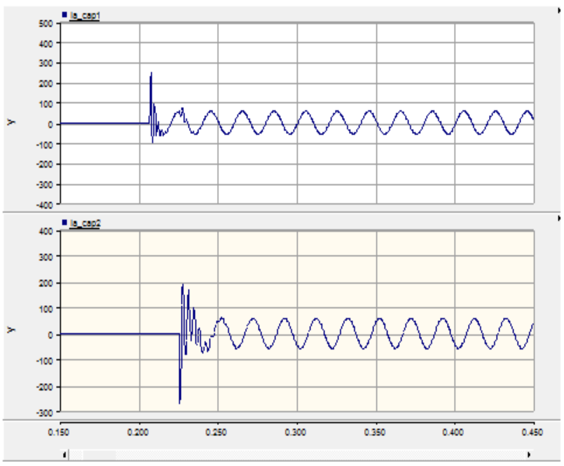
3 ms delay



14 ms delay

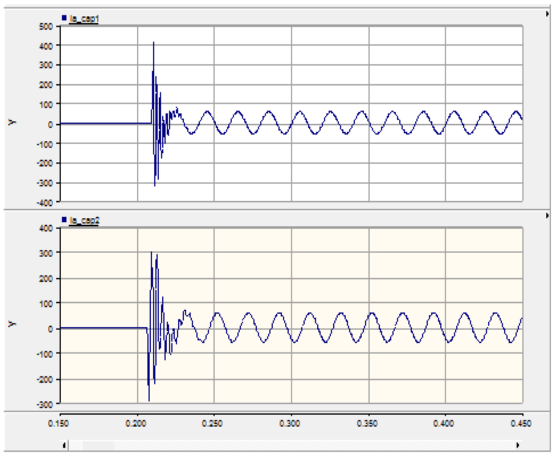


18 ms delay

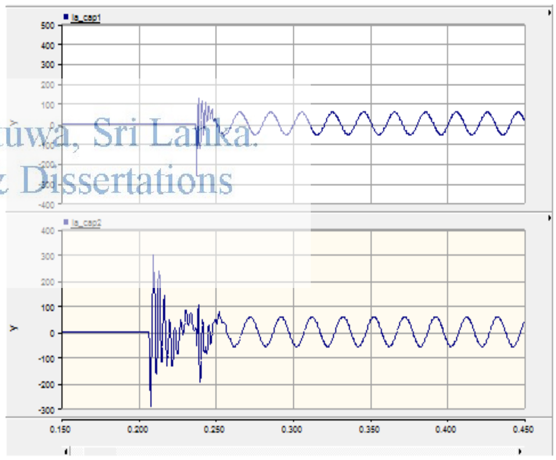


Switching sequence two to one

3 ms delay



30 ms delay



38 ms delay