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COORDINATION AND SELECTION OF MV AND LV FUSES FOR DISTRIBUTION TRANSFORMER PROTECTION

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Department of Electrical Engineering

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DECLARATION

The work submitted in this dissertation is the result of my owninvestigation, except where otherwise stated.

It has not already been accepted for any degree, and is also not beingconcurrently submitted for any other degree.

D.D.K.G. Sandasiri

Date: 15th March 2013

I endorse the declaration by the candidate.

Prof. J.R Lucas

Senior Professor

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ABSTRACT

The Ceylon Electricity Board (CEB) has the responsibility of distributing electricity to the consumers in Sri Lanka except few areas which belong to the Lanka Electric Company (LECO). When considering about the distribution network, distribution transformers play the major role. Protection of transformers is therefore very much important. Transformer failure rate and the distribution network reliability are major concerns of the CEB. Distribution transformer failure rate is high in theCEB network and also the fuse usage is unacceptably high.

Present CEB fuse selection practice and practical situation at the field have been analyzed to find out better solution for above problems. Theory behind distribution transformer fuse selection has been discussed in detail. K type expulsion fuses are the recommended primary side fuses by the CEB. The study has proposed several changes to the existing fuse selection practice recommended by the CEB.

The present distribution transformer protection scheme do not provide over load protection. It has been identified that nearly 13% transformers had failed annually due to over load within the Southern Province. The study revealed that lower capacity of transformers such as 100kVA and 160kVA have the higher probability of getting overloaded. Furthermore, 15% of distribution transformers installed in the Southern Province have at least one phase overloaded.

A Primary side K type fuse does not provide overload protection to the distribution transformer. Hence, secondary side fuse should provide the over load protection but above findings tell that the expected task cannot be achieved by the present system. The study has proposed three options to solve this problem. Introduction of a primary fuse which is having special Time Current Characteristic (TCC) curve is the first option. The fuse type is called “SloFast” and it has a duel TCC curve.The SloFast fuse TCC curve behaves very much parallel to the transformer damage curve at some low level of current unlike K type fuse TCC curve, which intersects transformer damage curve at some low level of current.

The second option is adding a main secondary fuse in between the transformer secondary terminal and the feeder fusses. So that the feeder fuse does the overload

protection of the feeder conductor and the main secondary fuse does the overload protection of distribution transformer.

The third option is limitation of the number of outgoing feeders from a transformer. This is very important for the distribution transformers having low capacities such as 100kVA and 160kVA, because the probability of getting overloaded is high with the present feeder arrangement. It is recommended the maximum number of feeders for each distribution transformer capacity.

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LIST OF ABBREVIATIONS

Abbreviation	Description
CEB	Ceylon Electricity Board
IEEE	Institute of Electrical and Electronic Engineers
MV	Medium Voltage
LV	Low Voltage
DDLO	Drop Down Lift Off
HRC	High Rupturing Capacity
MCCB	Molded Case Circuit Breaker
TCC	Time Current Characteristic

CHAPTER 1

INTRODUCTION

1.1 Background

In recent years, demand for the electricity has been increased significantly. To meet the requirement new power lines and distribution substations are added to the distribution system. While enlarging the distribution system, the electricity utilities have to improve the reliability and the quality of supply to the consumer.

In Sri Lanka, the distribution system consists of 33kV and 11kV Medium Voltage (MV) network with 400V Low Voltage (LV) network. At present, more than 20,000 distribution transformers have been installed in the entire country to meet the demand. To provide continuous supply to the consumers, reliable MV and LV network as well as distribution transformers should be there.

Protective devices of distribution transformers should be properly selected and those should coordinate with upstream and downstream protective devices to have a reliable supply from distribution transformers. The protection of distribution transformers involve in the careful balancing of many protection and operating concerns. Mainly the distribution transformers are protected from damaging over current due to overloading or short circuiting and lightning surges.

There are many varieties of protective devices available to protect transformers from over current. Out of those, fuses are the most common selection due to its simplicity and cost effectiveness. Though it is simple, proper study must be done to select the best fuse rating for each and every distribution transformer capacity.

A properly selected fuse should not be operated during the transformer energizing or temporary overloading periods. But it should protect the transformer from damage due to long time overloads and secondary faults. The fuses must be able to remove a faulty transformer from the distribution system, with minimum effect to the rest of the system by maintaining and enhancing proper coordination with upstream protection devices. More importantly, a fuse must prevent the transformer from disruptive failure due to high current internal faults. Also, a secondary side fuse shall prevent the transformer damage due to secondary side faults or excessive overloading.

1.2 Motivation

There are several ratings of fuses with different types purchased by the CEB to protect distribution transformers which also have several kVA ratings. Therefore, proper selection criteria should be established in each unit in the CEB to provide maximum protection for all distribution transformers to achieve the objective of reliable supply to consumers. But due to lack of information and instructions to the field staff, improper fuse ratings are used to protect distribution transformers. Hence, proper selection and coordination of fuse ratings for each transformer capacity has to be done and that should be applied to all distribution units in the CEB as a guide line.

1.3 Scope of work

- To find out proper fuse ratings for each distribution transformer capacities used by the CEB and compare it with preset fuse ratings used by the field staff.
- Selection of fuse ratings for secondary side protection for each distribution transformer capacity used by the CEB.
- Coordination study for selected primary and secondary side fuse ratings.
- Study and propose new fuse types for better performance.
- Reduce distribution transformer failures due to overload.
- Finally, advance the system reliability and improve the life time of the distribution transformer.

CHAPTER 2

PROBLEM STATEMENT

When considering about distribution network, the distribution transformer is the most important and costliest item. To achieve the 100% electrification target in year 2012, more and more distribution transformers were added to the network. Table 2.1 tabulates the number of transformers installed in the southern province under CEB distribution network at the end of year 2010 [01].

Table 2.1: Number of transformers installed in the Southern province at the end of year 2010

	Distribution Area	Number of transformers installed
1	Ambalangoda	468
2	Galle	465
3	Weligama	389
4	Matara	436
5	Tangalle	451
6	Hambantota	440
	Total	2649

The number of MV fuse links used to protect above transformers from January to August in the year 2010 is tabulated in table 2.2 [02].

Table 2.2: MV fuse usage from January to August in year 2010

Distributaion Area	Month							
	Jan.	Feb.	Mar.	App.	May	Jun.	Jul.	Aug.
Ambalangoda	190	200	270	480	60	10	270	200
Galle	40	90	490	75	110	290	320	110
Weligama	160	20	300	310	385	230	210	85
Matara	210	185	670	120	220	295	280	160
Tangalle	505	515	990	1385	555	740	660	215
Hambantota	310	50	665	480	690	590	430	495
Total	1415	1060	3385	2850	2020	2155	2170	1265

The number of fuse links used during the period considered was unacceptably high and the average monthly cost for the above fuse usage was Rs. 300,000.00. The situation was same as for the previous years. One of the main reasons behind this was improper fuse selection. For example, MV fuse ratings used to protect the 33kV 100kVA transformer was checked in different areas and was found that it differs from area to area. Most of the areas have used 2A or 3A fuse while some areas have used 5A fuses and it was found that even 10A fuses were used.

Compared to other provinces, transformer failure rate is slightly high in Southern province. Table 2.3 tabulates the number of transformers failed during the year 2008 to 2010 [03].

Table 2.3: Transformer failures in the Southern province form 2008 to 2010

Distribution Area	Number of transformer failures		
	2008	2009	2010
Ambalangoda	16	19	13
Galle	8	12	20
Weligama	7	9	13
Matara	13	13	7
Tangalle	6	12	7
Hambantota	13	6	1
Total	63	71	61

Failure reasons for each and every transformer have not been analyzed in detail though most of those are categorized as “failed due to lightning”. But there are a large number of failed transformers of which the exact reasons for their failure are not found.

As the demand for electricity increases, the number of transformers getting overloaded is increasing. Also number of outgoing LV feeders from a transformer is also increased to meet the demand.

Most of the studies done so far have been focused on short circuit protection. When transformers are overloading beyond the limits described in IEEE std. C57.109-1993, IEEE Guide for Liquid Immersed Transformer Through Fault Current Duration, it is noted that the life time of the transformer is getting reduced.

Annex-3 and Annex-4 tabulates the peak time load reading data for 100kVA and 160kVA transformers respectively in the Ambalangoda Area of CEB [04]. As per the data available, it is clear that most of the transformers have an unbalanced load hence one or more phases are loaded beyond its rated value.

Having considered the above facts, it is very important to study and find out proper fuse ratings for distribution transformer protection.

THEORETICAL DEVELOPMENT

3.1 Distribution Transformer

Distribution network in Sri Lanka comprises of 11kV and 33kV networks. Distribution transformers are used to step down the above voltage to the level of Low Voltage (LV) network, which is 400V. Power ratings of distribution transformers used by the CEB are 100, 160, 250, 400, 630, 800, 1000 & 2000kVA. Of this series, up to 400kVA distribution transformers are mounted on concrete poles and the rating of 630kVA and above are mounted on a plinth.

Figure 3.1: Pole mounted distribution transformer

Figure 3.2 shows a single line diagram for a typical distribution substation. In the CEB, Expulsion fuses and Current Limiting Fuses are used to protect distribution transformers by over current. Expulsion fuses are at the primary side and the current limiting fuses are used for each outgoing LV feeder from the distribution transformer. Surge Arrestors are mounted on a transformer tank at the primary side to protect it from lightning and other surges.

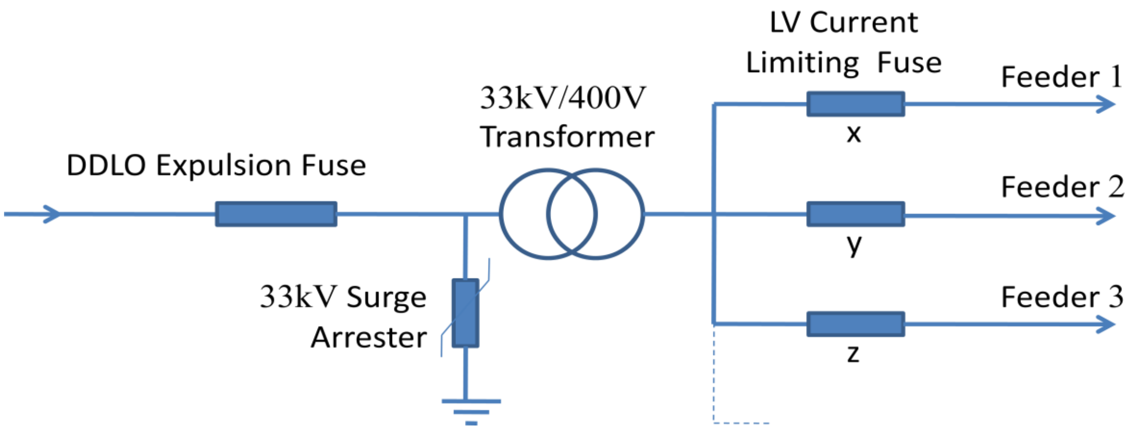

Figure 3.2: Typical arrangement of distribution substation

3.2 Fuse Protection

For over hundred years, fuses have formed an important and cost effective part in power system protection field. Several types of fuses are used to protect distribution transformers all over the world.

The main transformer protective device of the CEB owned overhead distribution transformers is Drop Down Lift Off (DDLO) type expulsion fuse. DDLO fuses are the common choice in many countries to protect distribution transformers as it's a simple and cost effective method.

High Rupturing Capacity (HRC) type current limiting fuses are used for secondary side feeders in normal outdoor distribution transformers and MCCBs are used in special cases. This research is mainly focused on fuse protection of distribution transformers hence, MCCB applications will not be discussed.

The fuse link may be considered as an electrically weak element in the distribution system. This so-called weak element is purposely introduced into the system to prevent any damages to the transformers, lines and other equipments which is used in the distribution network. Whenever a fault current passes through a fuse link, it must melt in time to open the circuit and prevent damage to the line or equipment.

The most important thing to take in to consideration when selecting a fuse to protect a transformer or line is the Time Current Characteristic (TCC) Curve. Each fuse is usually defined by two characteristic curves as shown in figure 3.3.

- Minimum Melting Curve: The relationship of the magnitude current passing through a fuse to the time required for the fuse element to melt is referred to as the minimum melting time current characteristic of the fuse.
- Total Clearing Curve: The relationship of the magnitude of the current passing through the fuse to the time required for the fuse element to melt and the arc to be extinguished is referred to as the total clearing time current characteristic of the fuse link.

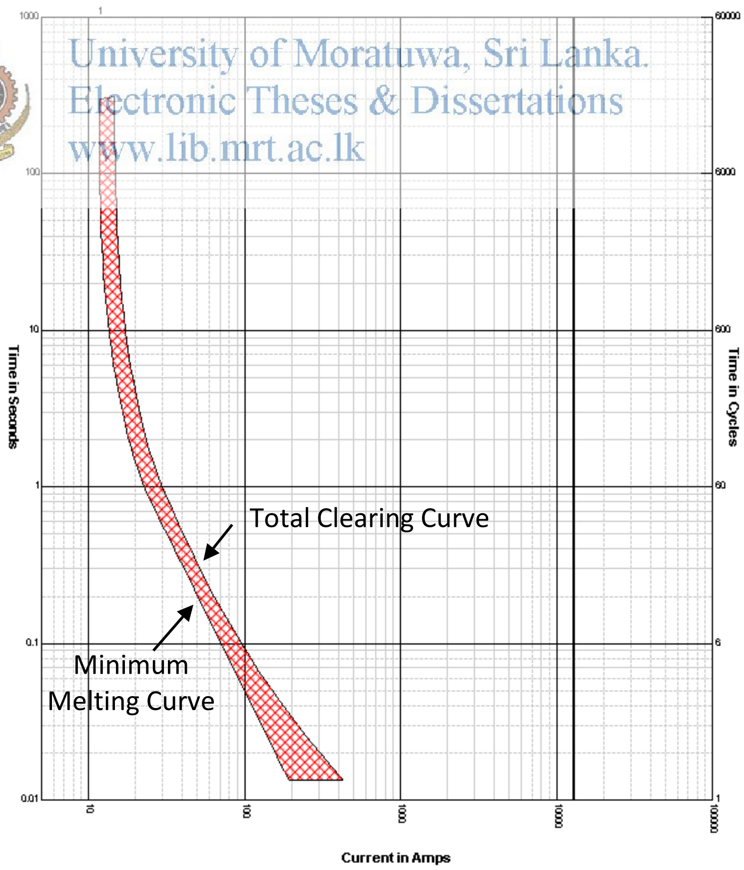

Figure 3.3: Time Current Characteristic Curves

3.2.1 DDLO type Expulsion fuse

The expulsion fuse link consists of a Conductor (Tail), Current Responsive element (Fuse) and a Head. The fuse link is used with a medium voltage expulsion fuse switch normally called a DDLO switch. Therefore the fuse link must have sufficient mechanical strength against shock loading of closing and effectively resist deterioration under normal climate condition.

Figure 3.4: DDLO Switch

The conductor (Tail) is made of tinned stranded copper cable. The diameter of the conductor should be sufficient to prevent corona discharge and eventual breakdown due to ageing. The current responsive element is made of Silver, Silver Copper Alloy or Nickel Chromium Alloy and enclosed with an insulating sleeve having arc extinguishing properties.

Figure 3.5 shows how an expulsion fuse interrupts a high fault current by showing the current through and the voltage across the fuse link with respect to time [05]. For normal operating conditions, the fuse link act as a part of line, however it reacts when there is a fault in the circuit. Due to high fault current the element of the fuse heats up until it reaches its melting point and breaks up. Then an arc is initiated due to molten ionized particles from the fuse element. The arc burns the remaining particles inside the fuse tube and heats up the fiber wall of the tube. The heated fiber release de-ionizing gases, which create pressure within the tube that causes compression and supersonic flow of the hot gases, which act to cool and stretch the arc. The current, which is cyclical in nature, continues to flow in the form of an arc until it reaches zero current. All the current available from the first half cycle of the fault current is let through to the system during the expulsion fuse operation, and the expulsion fuse cannot extinguish the arc until the current naturally crosses zero. As the current wave reaches zero current, the arc is momentarily extinguished. After passing through zero, the arc may re-establish itself at lower fault level through the same ionized particles due to the voltage established between the severed ends of the link. This process continues until the arc no longer re-strikes because the dielectric strength is built up faster than the voltage stress. Once the dielectric is built up sufficiently, the arc cannot re-strike, resulting in final extinction and removal of the fault form the system.

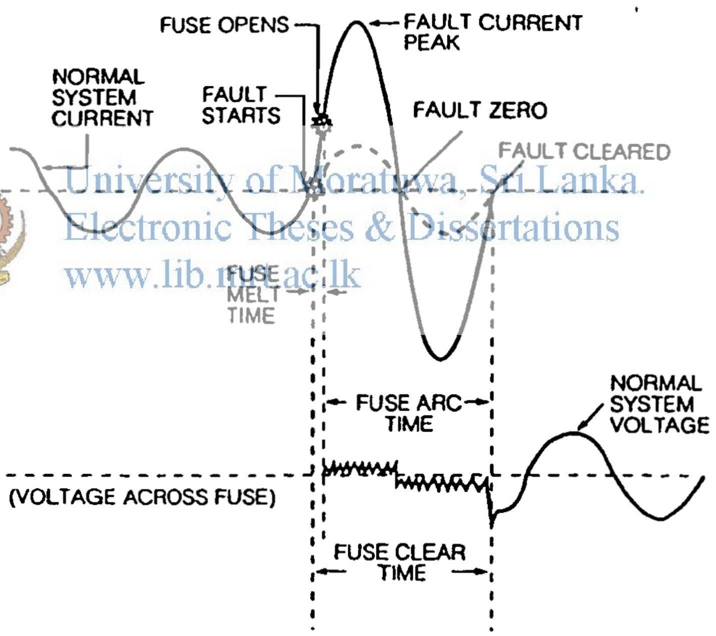

Figure 3.5: Current and Voltage Waveforms for an Expulsion Fuse Operation [05]

3.2.2 Current Limiting Fuses

HRC type current limiting fuses with blade contacts (Knife edge type) and of Size 1 & 2 as per IEC 60269 are used by the CEB to protect low voltage distribution systems. Figure 3.6 shows a typical HRC fuse used by the CEB.

Figure 3.6: HRC fuses

The following ampere ratings of HRC fuses recommended by the CEB as per CEB standard 052-1:2000 and maximum permissible power dissipation is tabulated in table 3.1.

Table 3.1: Current limiting fuses used by CEB [06]

Fuse Rating (A)	Maximum Permissible Power Dissipation (W)
100	7.5
160	16.0
200	18.0
250	23.0
400	34.0

Fuse elements of current limiting fuses are made of silver and it is usually wire or ribbon in form and is suspended between two end caps. The suspended element is surrounded by fine granular silica sand and housed in a strong fiberglass fuse tube. The sand inside the fuse tube plays a very important role in the operation, because it introduces a relatively high resistance to the circuit when the element melts. Operation characteristic of a current limiting fuse can be described using figure 3.7 [05].

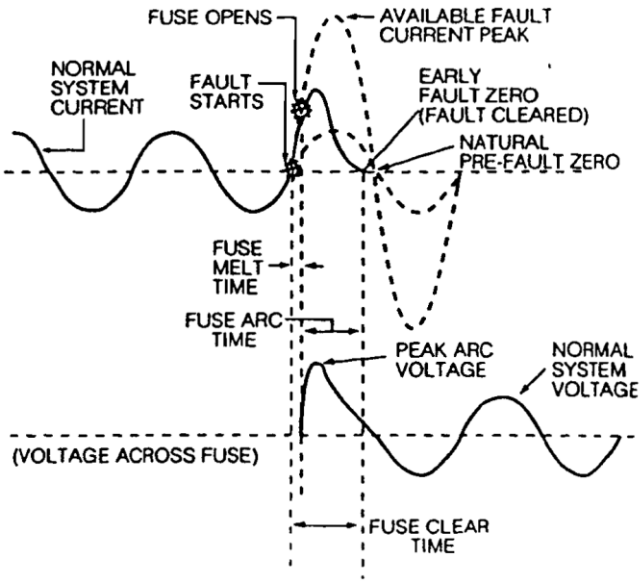

Figure 3.7: Current and Voltage Waveforms for a Current Limiting Fuse [05]

When a fault occurs, the fuse's silver element heats up until it reaches its melting point, it vaporizes along its entire length, and blows the molten element into the surrounding sand. Arcing occurs while the current continues to flow and the heat generated by the arc melts the sand around the arc, forming a glass-like structure called a "fulgurite". The fulgurite compresses the arc, which forces the resistance of the fuse to increase dramatically. The increased resistance limits the current let through to the system to a value much less than what is available from the fault and forces it down to zero quickly, not waiting for the fault current to naturally cross zero. Hence the greatest benefit of using current limiting fuses is they limit peak current magnitude and available fault energy, as well as reducing fault time duration for better equipment protection.

3.3 Distribution Transformer Protection

3.3.1 Factors to be considered when selecting the primary fuse

There are several important factors to be considered when selecting primary fuses for a distribution transformer.

➢ System Voltage

The maximum design voltage rating of the fuse should equal or exceed the maximum phase to phase operating voltage of the system. The voltage rating of a fuse is a function of its capability to open a circuit under an over current condition. Mainly the voltage rating determines the ability of the fuse to suppress the internal arcing that occurs after a fuse link melts and an arc is produced. If a fuse is used with a voltage rating lower than the circuit voltage, arc suppression will be impaired and under some fault current conditions, the fuse may not clear the over current safely.

➢ Ampere Rating

Each and every fuse has a specific ampere rating. Proper selection of an ampere rating for a fuse link is very important in several ways. Mainly, to protect the transformer against damaging over current and then to accommodate the normal transformer loading level, including daily or repetitive peak loads, and emergency peak loads. The next important factor is to withstand the magnetizing inrush current associated with the energizing of an unloaded transformer, as well as the combine magnetizing and load inrush current associated with the re-energizaiton of a loaded transformer following a momentary or extended outage. Knowing the ampere rating of a fuse link is also important to coordinate with other over current protective devices and protect the load side conductors against damaging over current.

➢ Short Circuit Interrupting Rating

The symmetric short-circuit interrupting rating of the transformer primary fuse should equal or exceed the maximum available fault current at the transformer location. In addition, the interrupting rating of the fuse should be chosen with sufficient margin to accommodate anticipated increases in the interrupting duty due to system growth.

➢ Transformer Inrush Current

A fuse should not be operated by the transformer’s magnetizing inrush current, hot load inrush current and cold load inrush current. The minimum melting curve of the fuse should be greater than these inrush values to ensure that the fuse will withstand transformer energizing current or re-energizing current after an outage.

➢ Transformer Damage Curve

Transformer damage curve is composed of time current points that combine both the thermal and mechanical withstand capabilities of distribution transformer. Therefore the selected fuse should clear the current before the transformer damage curve is reached.

➢ Fusing Ratio

Fusing ratio is another common factor to be considered when selecting fuses. The fusing ratio defines how much current a fuse will carry continuously without melting the fuse element [05].

$$Fuse\,Ratio = \frac{Fuse\,current\,carrying\,capacity}{Transformer\;\,full\,load\,current}$$

There are trade-offs in using a high fusing ratio versus a low fusing ratio.

When the fusing ratio is high;

- Transformer failure rate is high.
- Increased overload allowance for the transformer.
- Reliability of supply increases.
- Fuse damages due to transformer energization is low.

When the fusing ratio is low,

- Fewer transformers damage as a result of overloads.
- Reliability of supply decreases.
- More fuses damage due to inrush current

3.3.2 Transformer Inrush current

➢ Magnatizing Inrush Current

When an unloaded distribution or power transformer is energized, there occurs a short-duration inrush of magnetizing current of which the transformer primary fuse must be capable of withstanding without operating (or, in the case of certain types of fuses, without sustaining damage to their fusible elements). A conservative estimate of the integrated heating effect on the primary fuse as a result of this inrush current is roughly equivalent to a current having a magnitude of;

- 12 times the primary full-load current of the transformer for a duration of 0.1 second and,
- 25 times the primary full-load current of the transformer for a duration of 0.01 second.

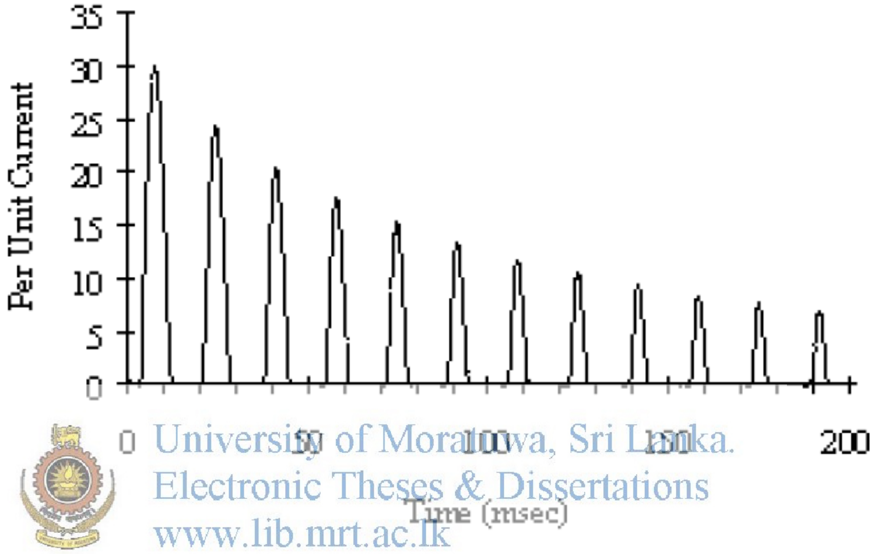

Figure 3.8: Magnatizing inrush current [07]

An example of the magnetizing-inrush current for a small overhead distribution transformer is shown in Figure 3.8 [07]. The inrush that occurs on any particular energization will depend, among other things, on the residual magnetism of the transformer core as well as the instantaneous voltage when the transformer is energized. Since these two parameters are unknown and uncontrollable, the fuse must be sized to withstand the maximum inrush that can occur under worst-case energization. The minimum- melting curve of the primary fuse should be such that the fuse will not operate as a result of this magnetizing-inrush current.

➢ Hot Load Inrush Current

The transformer-primary fuse must also be capable of withstanding the inrush current that occurs when a transformer that is carrying load experiences a momentary loss of source voltage, followed by re-energization (such as occurs when a source-side circuit breaker operates to clear a temporary fault, and then automatically recloses). In this case, the inrush current is made up of two components: the magnetizing-inrush current of the transformer and the inrush current associated with the connected loads. The ability of the primary fuse to withstand this combined magnetizing and load inrush current is referred to as 'hot-load pickup' capability.

The integrated heating effect on the transformer-primary fuse as a result of the hot-load pickup current is equivalent to a current having a magnitude of between 12 and 15 times the primary full-load current of the transformer for a duration of 0.1 second. Here again, the minimum-melting curve of the fuse should exceed the magnitude and duration of the combined inrush current.

- Cold Load Inrush

The final type of inrush current to which the transformer-primary fuse will be exposed is long-duration overcurrent that occurs due to the loss of load diversity following an extended outage (30 minutes or more). This long-duration overcurrent is referred to as 'cold-load pickup.' The cold-load pickup phenomenon is typically associated with utility distribution transformer loading practices, where the transformers are often sized for the average peak load rather than the maximum expected peak load, thereby exposing the transformers to the overcurrent up to 30 minutes duration following re-energization. This phenomenon occurs since large electrical loads such as air conditioners, refrigerators, and electric heaters are thermostatically controlled and the cycle on and off at random relative to one another so that only a fraction of a total possible load is connected to the system at a time. After an extended loss of power, many more of the thermostatically controlled devices will be out of their respective set-point limits. As a result, soon as power is restored, the thermostats will demand power for their controlled equipment.

To avoid a nuisance operation of the transformer-primary fuse, it must be capable of withstanding the magnetizing inrush current of the transformer superimposed on the transient overcurrent associated with picking up cold, the expected overload current associated with the total kVA connected. The time integrated heating effect of the cold-load current profile on thermally responsive devices, such as fuses, are usually represented by the following equivalent multiples of transformer nominal rated load current:

- 6 times primary full load current for one second;
- 3 times primary full load current for up to 10 seconds; and
- 2 times primary full load current for up to 900 seconds.

The ability of the transformer primary fuse to withstand the combined magnetizing- and load-inrush current associated with an extended outage is referred to as its cold-load pickup capability.

3.3.3 Inrush points for a 33kV 160kVA transformer

For an example, let's consider 33kV 160kVA transformer:

$$Transforme\ primary\ Full\ Load\ Current\ (A) = \frac{160kVA}{\sqrt{3} \times 33kV}$$

$$= 2.80A$$

Magnetizing Inrush / Hot-load pick up points:

-12 times full load current at 0.1s : [33.6, 0.10]

-25 times full load current at 0.01s : [70, 0.01]

Cold-load pick up points:

-6 times full load current at 1s : [16.8, 1.0]

-3 times full load current at 10s : [8.4, 10]

-2 times full load current at 900s : [5.6, 900]

Using above inrush points, inrush curve for 33kV 160kVA transformer is plotted as shown in figure 3.9.

3.4 Transformer Damage Curve

The most important application principle to be considered when selecting a primary fuse for a three-phase power transformer is that, it must protect the transformer against damage from mechanical and thermal stresses resulting from secondary-side faults that are not promptly interrupted. A properly selected primary fuse will operate to clear such faults before the magnitude and duration of the over current exceed the through fault current duration limits recommended by the transformer manufacturer or published in the standards. Curves representing these limits can be found in ANSI/IEEE Standard C37.91-1985, "Guide for Protective Relay Applications to Power Transformers", and ANSI/IEEE C57.109-1993, "Guide for transformer Through-Fault Current Duration". The standards state, "If fault current penetrates the limits of the thermal damage curve, insulation may be damaged. The validity of these damage limit curves cannot be demonstrated by test, since the effects are progressive over the life time of the transformer. They are based principally on informed engineering judgment and favorable, historical field experience" [08].

In ANSI/IEEE C57.109-1993, there are four categories of through fault protection curves, depending on the transformer rated power, as it is shown in table 3.2 [08].

Table 3.2: Categories of through fault protection curves

Category	Three Phase Transformer (kVA)	Single Phase Transformer (kVA)
I	15 - 500	5 - 500
II	501 - 5000	501 - 1667
III	5001 - 30000	1668 - 10000
IV	Above 30000	Above 10000

As per the table 3.2 above, distribution transformers installed by the CEB are categorized as Category I and Category II. Damage curve for those two categories defined by the IEEE std. C57.109-1993 are shown in Table 3.3 [08].

Table 3.3: Damage curve for Category I & Category II liquid immersed transformer

Time (s)	× Rated Current (A p.u.)
1800	2
300	3
60	4.75
30	6.3
10	11.3
2	25

The degree of transformer protection provided by the primary fuse should be checked for the level of fault current and type of fault (i.e., three-phase, phase-to-phase, or phase-to-ground) producing the most demanding conditions possible for each particular application, viz., those for which the ratio of the primary-side line current to the transformer winding current is the lowest. For these situations, one or more of the primary fuses will "see" a proportionately lower level of current than the windings and, as a consequence, the primary fuses must be carefully selected to operate fast enough to avoid damage to the transformer windings. Table 3.4 lists the ratio of per-unit primary-side line current to per-unit transformer winding current for four common transformer connections under a variety of secondary-fault conditions.

Table 3.4: Relationship between Per-Unit Primary Side Line Current and Per-Unit Transformer Winding Current [07]

Transformer Connection		Ratio of per-unit primary side line current to per-unit transformer winding current		
Primary side	Secondary side	Three Phase Fault	Phase to Phase Fault	Phase to Ground Fault
Delta	Wye-G	1.0	$2/\sqrt{3}$	$1/\sqrt{3}$
Wye-G	Delta	1.0	$\sqrt{3}$	-
Delta	Wye	1.0	$\sqrt{3}$	$1/\sqrt{3}$
Delta	Delta	1.0	1.0	-

From Table 3.4, it is clear that a phase to- phase secondary fault on a delta/delta connected transformer and a phase-to ground secondary fault on a delta/grounded-wye connected transformer produce the most demanding conditions possible for those particular transformer connections, since the per-unit primary-side line current is less than the per-unit transformer winding current. Accordingly, to ensure proper transformer protection for these two situations, it is necessary to "shift" the appropriate through - fault protection curve to the left (i.e., in terms of current) by the ratio of the per-unit primary side line current to the per-unit transformer winding current listed in Table 3.4. The shifted through-fault protection curve will then be in terms of the primary side line current and, as such, will be directly comparable with the total-clearing curve of the primary fuse. Damage curve for a 33kV 160kVA transformer is shown in figure 3.6 [08][09].

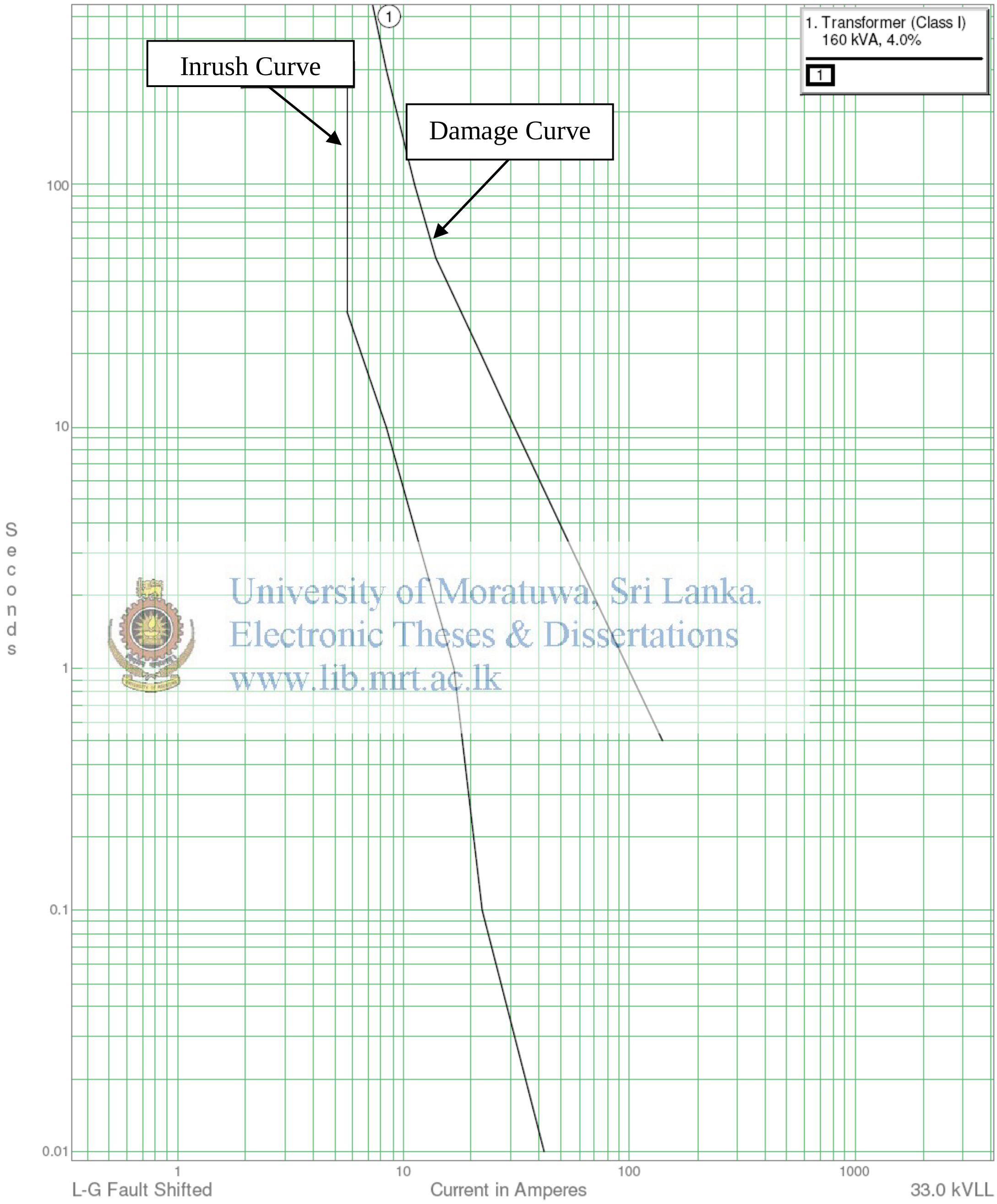

Figure 3.9: Damage and Inrush Curves for 33kV 160kVA transformer

CHAPTER 4

FUSE SELECTION AND COORDINATION

4.1 Distribution transformer over current protection

Except in Colombo and Kandy city areas, almost all distribution transformers owned by the CEB are outdoor type transformers mounted on a single pole or a double pole structure or a plinth. Fuses are used on the primary side as well as the secondary side of the transformer to protect it from damaging over current due to short circuit or overloading. DDLO switches with Expulsion type fuse links are used on primary side of the distribution substation to protect the transformer and/or isolate the faulty section due to transformer internal fault or secondary side fault. Overload protection is not expected from expulsion fuse links and current limiting fuses are used on secondary side of the distribution substation for that purpose.

4.2 Distribution transformer primary side protection

Expulsion fuse links with DDLO switches on primary sides of the distribution substations are the most common and cost effective methods selected by protection Engineers all over the world for decades.

Proper selection of a primary side fuse rating for each transformer capacity is very important. Each transformer should be studied separately to obtain the proper primary side fuse rating

160kVA 33kV/400V transformer has been taken as an example to discuss the primary fuse selection criteria. The transformer impedance was taken as 4% as per the nameplate. The transformer damage curve was developed using “category I” through fault duration curve (damage curve) in IEEE Std. C57.109-1993. The transformer inrush curve was developed as discussed in previous sections. Transformer damage curve and inrush curve are shown in figure 4.1, along with expulsion fuse TCC curves. Out of the standard fuse ratings of K-type, 3A, 6A and 8A fuse characteristic curves are plotted on figure 4.1.

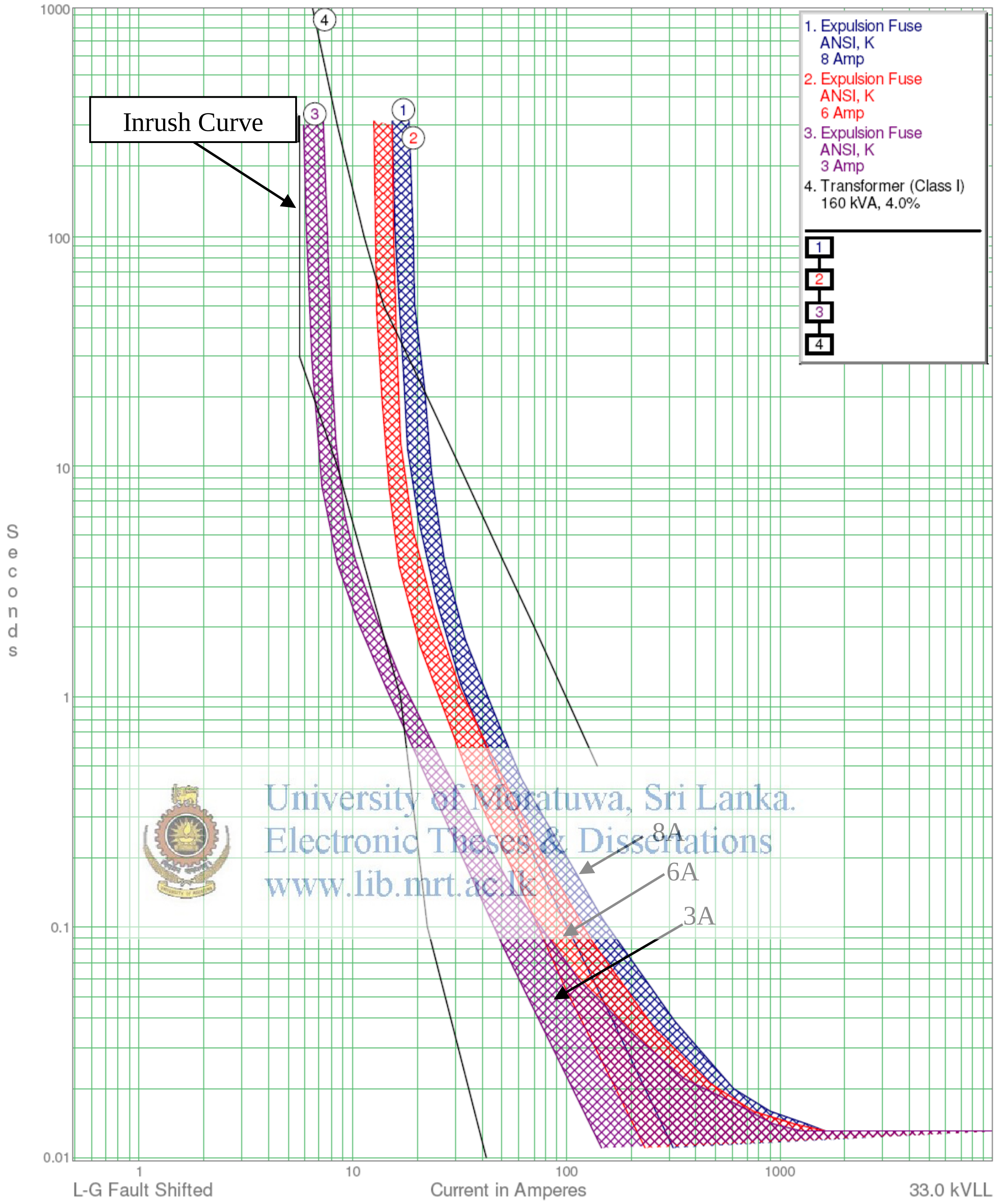

Figure 4.1: Fuse characteristic curves with 160kVA 33/0.4kV transformer damage curve and inrush curve

It is clear that the 3A fuse is not the best option as it cuts the transformer inrush curve. The next available fuse rating is 6A. The minimum melt curve of 6A fuse cuts the transformer damage curve for current level below 12A. But this situation is considered as a minor deviation and can be explained as follows.

The transformer damage curves obtained as per IEEE Sts. C57.109-1993 are taken as a guide and they are recommended as a criterion against which to measure the degree of transformer protection provided by the primary fuse. To meet this criterion for high-magnitude secondary side faults, the total clearing curve of the primary fuse should pass below the damage curve of the transformer. Also as discussed in previous sections, the primary fuses are not intended to provide overload protection. Therefore, the total clearing curve of the primary fuse will cross the damage curve at some low level current. Because the primary fuse does not provide overload protection for the transformer, this should not be concerned; however, effort should be made to keep the current values at which the fuse characteristic curve and transformer damage curve intersect as low as possible to maximize protection for the transformer against secondary side faults.

As shown in figure 4.1, the minimum melting curve of 8A fuse cuts the damage curve further right to the 6A fuse and it will not blow for some secondary side faults having low current. Therefore out of the fuse range, 6A fuse will be the best selection for 160kVA 33/0.4kV transformer primary side fuse.

Using the above method, suitable fuse ratings for all CEB outdoor distribution transformer capacities that have been obtained and relevant TCC figures are in Annex-1. Selected fuse ratings for each transformer capacity along with current practice of CEB are tabulated in Table 4.1 and 4.2.

4.3 Comparison of selected MV fuses ratings with the CEB specified fuse ratings.

Table 4.1: Comparison of selected fuse ratings with CEB specified values for 33kV

Transformer kVA rating (33kV)	Selected fuse link rating (A)	CEB Specified Value (A)
100	3	3
160	6	6
250	8	8
400	12	10
630	20	12
800	25	15

Table 4.2: Comparison of selected fuse ratings with the CEB specified values for 11kV

Transformer kVA rating (11kV)	Selected fuse link rating (A)	CEB Specified Value (A)
100	8	6
160	12	10
250	20	12
400	30	20
630	50	30
800	65	40

Table 4.1 and 4.2 shows the comparison of selected MV fuse ratings with the CEB specified fuse ratings for 33kV and 11kV transformer capacities respectively. For the 33kV application, the selected ratings and the CEB values are the same for 100, 160 & 250kVA rated transformers and differs for the rest of the ratings. It can be observed that the selected values are higher than the CEB values and the difference between the CEB and the research findings are further increased when the transformer kVA increases. This variation can be analyzed using the TCC curves and to explain it in detail, 33kV 630kVA transformer is selected. The TCC curve of 20A & 12A fuse with 630kVA transformer damage curve and inrush curve are plotted as shown in figure 4.2.

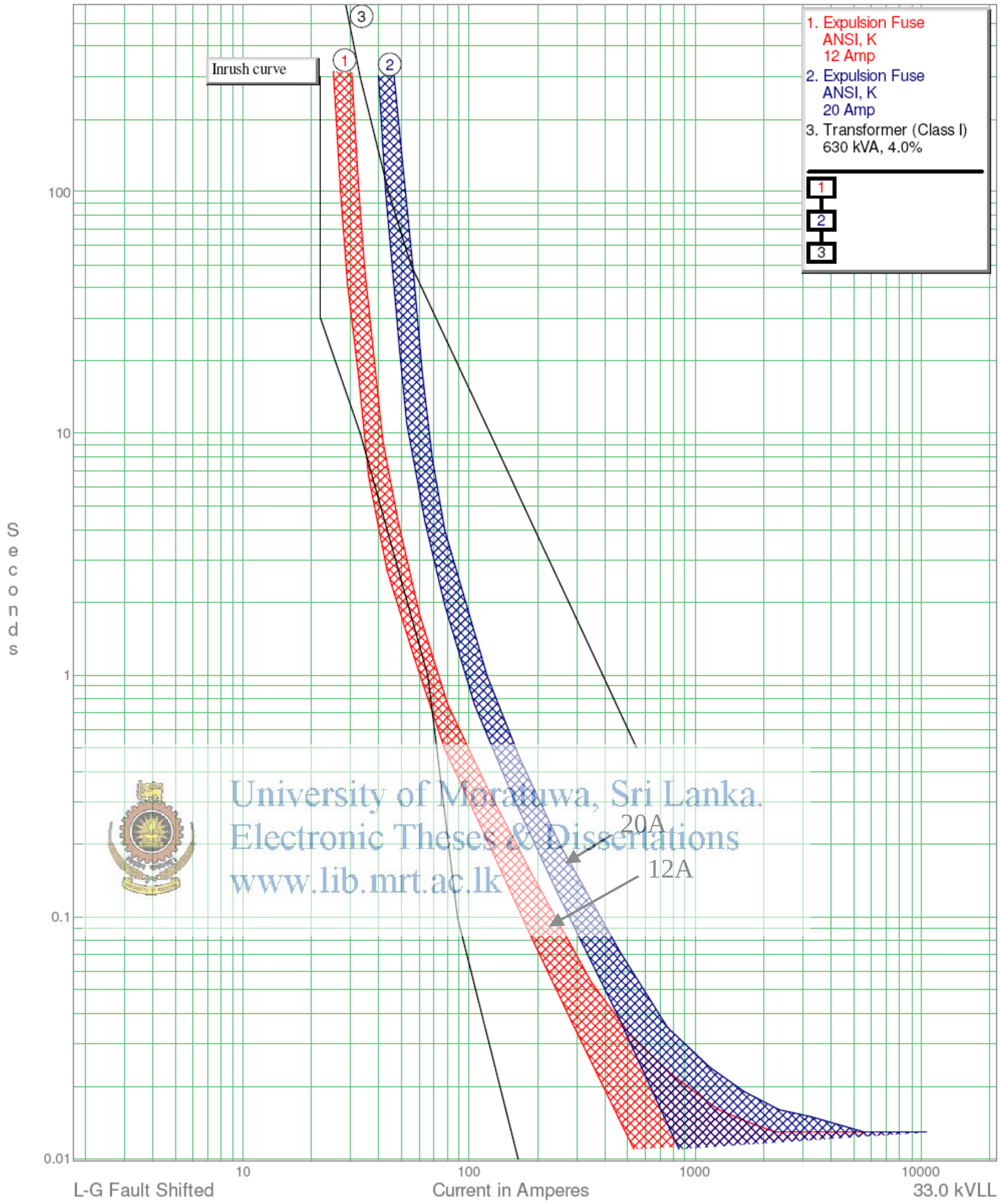

Figure 4.2: 33kV 630kVA transformer damage curve and inrush curve with 12A and 20A fuse TCC.

As shown in figure 4.2, the minimum melting time current curve of 12A fuse cuts the inrush curve at cold load inrush stage of the transformer. Therefore if the MV fuse is 12A, it will blow unnecessarily due to inrush current which flows when re-energizing a transformer after an outage. But in the CEB distribution system, 12A fuses are used for the 630kVA transformer as most of the transformers are not fully loaded hence cold load inrush current lies further left to the TCC of the fuse. Unnecessary fuse blowings are reported when the transformer load increases with time.

The situation is the same as above for the rest of the mismatches between research findings and the CEB practice.

Fusing ratios for the selected fuse values are tabulated below.

Table 4.3: Fusing ratios for 33kV transformer fuse selection

Transformer ratingkVA	Rated Current (Primary side)-(A)	Fuse Selected (A)	Fusing Ratio
100	1.75	3	1.71
160	2.80	6	2.14
250	4.37	8	1.83
400	7.00	12	1.71
630	11.02	20	1.81
800	14.00	30	1.79

Table 4.4: Fusing ratios for 11kV transformer fuse selection

Transformer ratingkVA	Rated Current (Primary side)-(A)	Fuse Selected (A)	Fusing Ratio
100	5.25	8	1.52
160	8.40	12	1.43
250	13.12	20	1.52
400	20.99	30	1.43
630	33.07	50	1.51
800	41.99	65	1.55

Fusing rations for selected fuse rating are within the generally accepted fusing ratio of 1.5 to 2.5. The above result proves that the research findings are more accurate than the current CEB practice.

4.4 Secondary side fuse selection and coordination

There are two options used by the CEB as secondary side protective devices and those are HRC fuses and MCCBs. Normally, HRC fuses are used for outdoor type distribution substations. MCCBs are used for bulk supply consumer substations and very rarely used for distribution substation. HRC fuses are less expensive than MCCBs and installation & operation too are easy.

HRC fuses are mounted on fuse switch disconnecter sets as shown in figure 4.3. To disconnect the LV feeder, the fuse switch disconnecter should be pulled down using an operating rod. Principle of HRC fuse operation is discussed in chapter 3.

Figure 4.3: Fuse switch disconnecter

4.4.1 Current CEB practice

A fuse switch disconnecter set consists of three HRC fuses for each phase and a copper bar for neutral conductor. Fuse switch disconnecter sets are used for each outgoing feeder form a distribution substation and those are mounted on substation poles.

Present day LV fuse selection criteria used by the CEB is very simple as only 160A rated HRC fuses are used for all transformer ratings and the basis for this selection is the current carrying capacity of the LV conductor. There are two types of conductors used in the LV distribution system.

- All Aluminum Conductor 7/3.40mm.
- Arial Bundle Conductor of 3 nos. 70mm^2 phase conductors and 54.6mm^2 neutral conductor.

The current carrying capacities of above conductors are around 155A. Hence, to protect the LV conductor from over current, 160A HRC fuses are used.

4.4.2 Coordination with 160A fuse

100kVA 33/0.4kV distribution transformer is selected first for fuse coordination study. 3A expulsion fuse is the selected rating for MV side and the CEB current practice is also the same.

It is assumed that the transformer has only one LV outgoing feeder with 160A HRC fuse per phase.

TCC curves for 3A fuse and transformer curves along with 160A current limiting fuse TCC curve referred to MV side is plotted on the same graph as shown in figure 4.4.

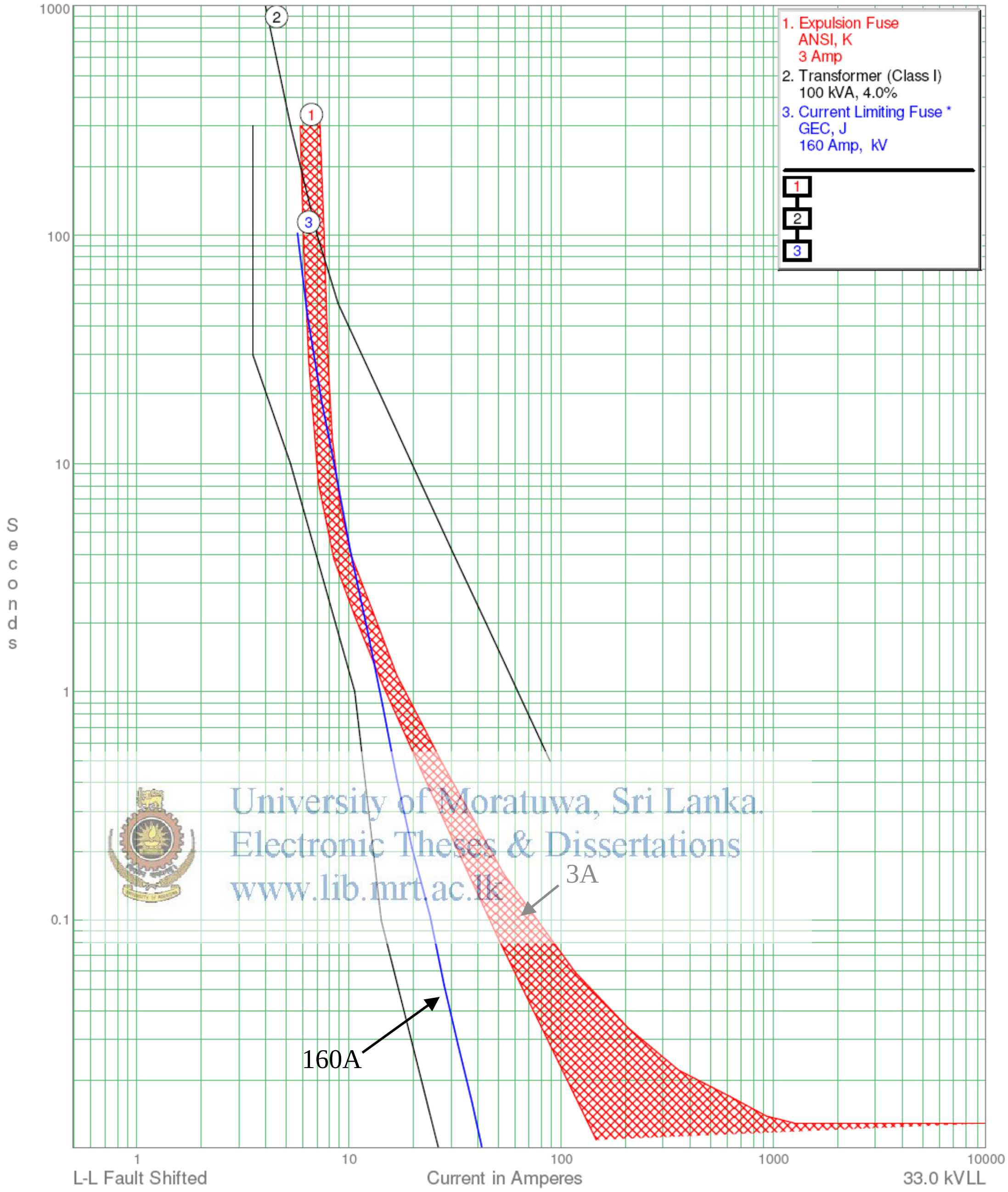

Figure 4.4: TCC curves for 3A MV fuse and 160A LV fuse with 100kVA 33/0.4kV transformer curves

It can be observed that the interesting phenomena, the 160A LV fuse TCC curve referred to MV side lays above the MV side 3A fuse TCC curve for some low current values and therefore the LV fuse does not coordinate with the MV fuse. As discussed in the previous chapter, the over load protection is not expected from MV side fuses, hence the LV fuse should operate when there is an overload condition.

Also, as per the figure 4.4, the TCC curve of 160A LV fuse crosses the transformer damage curve at low current values. Therefore, it is clear that the selected fuse does not coordinate with the 3A expulsion fuse at MV side.

As per IEC 60269-1 standard, the next available fuse ratings which can be considered for coordination study of 100kVA 33/0.4kV are 80A, 100A or 125A. Figure 4.5 shows the TCC curves of 80A, 100A & 125A LV fuse with MV fuse TCC curve and transformer curves.

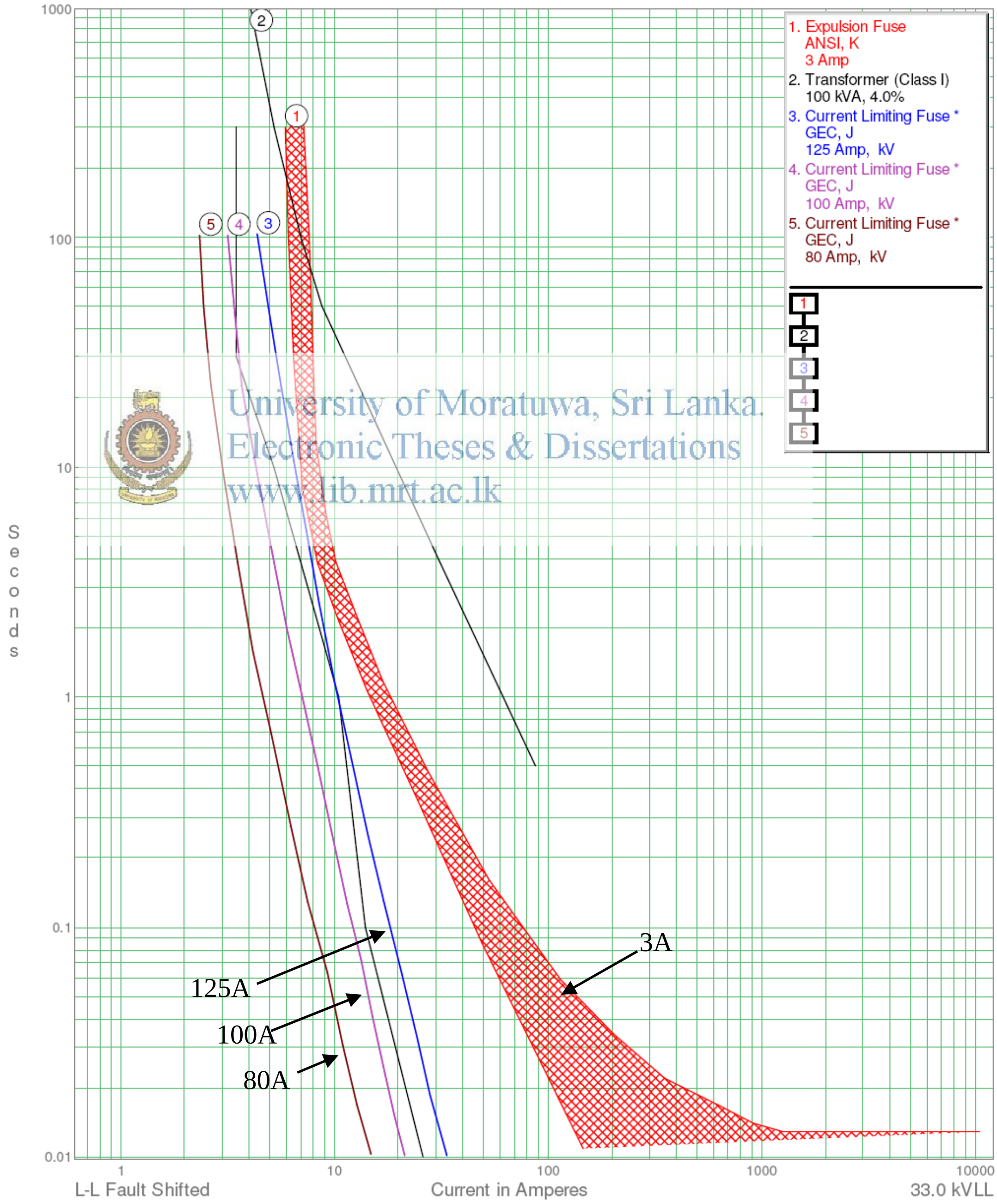

Figure 4.5: LV fuse options for 100kVA 33kV transformer

As per the figure 4.5 above, 100A LV fuse is the best option for selected transformer rating as it properly coordinates with the MV fuse and also with the transformer damage curve.

160kVA 33/0.4kV transformer is considered next. Primary side 6A fuse with 160A secondary side fuse TCC curves are plotted as shown in figure 4.6.

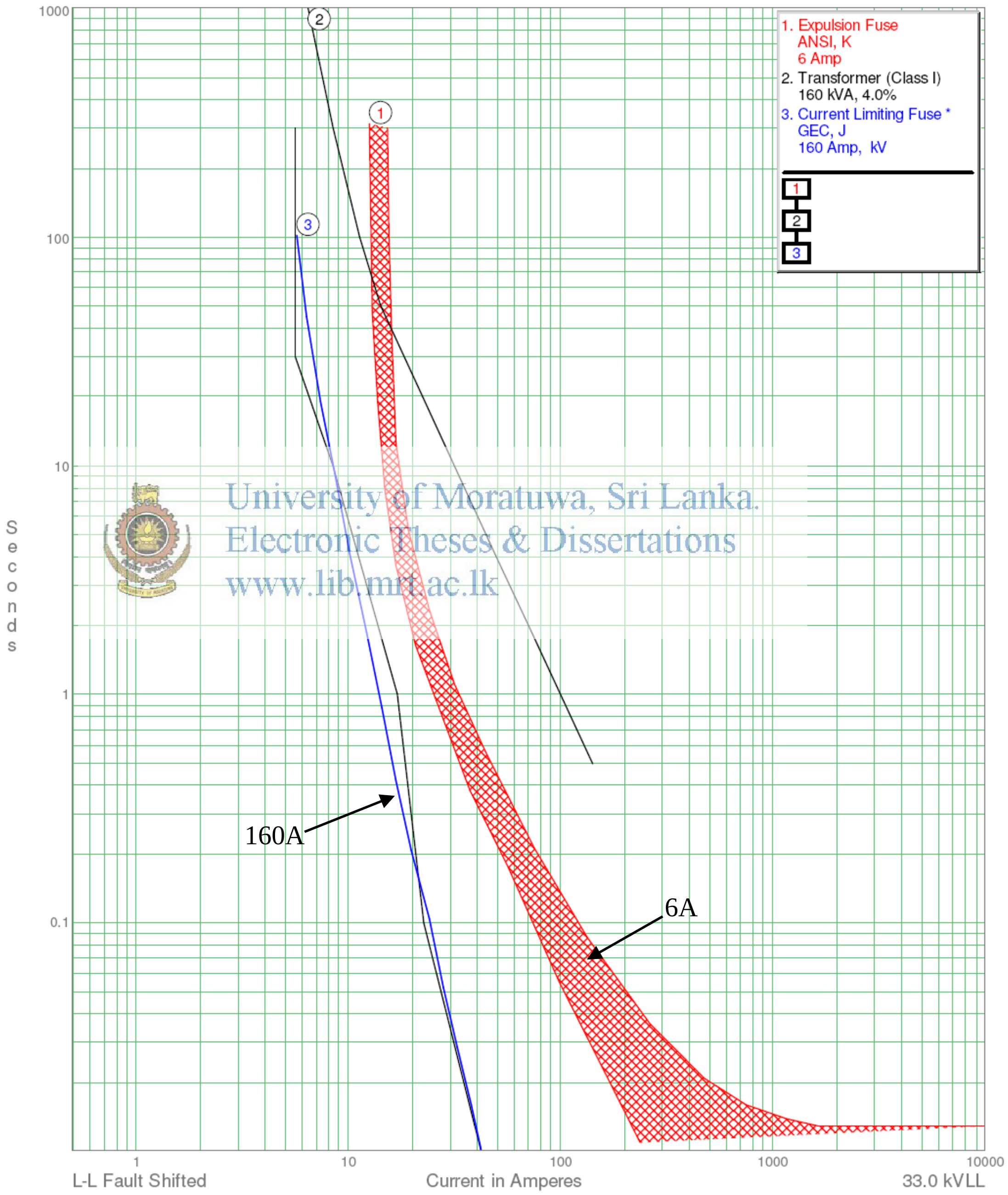

Figure 4.6: 160kVA 33/0.4kV transformer curves with selected MV and LV fuse TCC curves

As shown in figure 4.6, 160A secondary side fuse characteristic curve lays further left to the primary side 6A fuse and does not cross the transformer damage curve. Hence, it can be considered that the 160A fuse coordinates with the MV side fuse.

Accordingly, fuse curves for transformers' rated from 250kVA and above a have better coordination margin. Therefore, detailed coordination study for those transformer ratings are not required and the 160A LV fuse option is recommended for transformers' rated form 160kVA and above.

When considering about 11kV transformers, the LV side fuse selection is the same as the 33kV transformer ratings described above, as the LV side voltage is 400V in both cases.

Summary of the LV side fuse selection is tabulated in Table 4.5.

Table 4.5: LV fuse selection

Transformer Capacity (kVA)	LV fuse rating for 33kV transformer (A)	LV fuse rating for 11kV transformer (A)
100	100	100
160	160	160
250	160	160
400	160	160
630	160	160
800	160	160

4.4.3 Drawbacks of LV fuse selection practice

The above selection is valid if there is only one LV outgoing feeder. But, practically this is not the case as there are at least 3 outgoing feeders per transformer. The condition is worst if someone recommends 160A fuses for all distribution transformer ratings.

To explain above, let's take load reading data for 100kVA and 160kVA distribution transformers installed at Ambalangoda Area. LV feeder wise peak load reading data for 100kVA and 160kVA transformer rating are tabulated in Annex 3 & 4 respectively.

By analyzing the data in Annex 3 and 4, it is fund that there are some transformers which are having at least one phase overloaded though the transformer is loaded less than 100%. Several worst case transformers are extracted and shown in Table 4.6.

Table 4.6: Examples for transformers having one phase overloaded [04]

Transformer Name	Rating (kVA)	% load	Feeder	Current (A)			Remarks
				Phase 1	Phase 2	Phase 3	
Dhammakusala MW	100	75%	F1	39	43	28	Phase 3 over loaded
			F2	12	28	75	
			F3	26	23	54	
			Total	77	94	**157**	
Belgiyanu gama	100	70%	F1	12	54	40	Phase 2 over loaded
			F2	37	70	10	
			F3	25	23	32	
			Total	74	**147**	82	
Habakkala	100	91%	F1	46	55	80	Phase 3 over loaded
			F2	5	13	38	
			F3	28	30	80	
			F4	9	5	5	
			Total	88	103	**203**	
Sahana J	160	88%	F1	110	90	110	Phase 3 over loaded
			F2	12	26	100	
			F3	15	25	30	
			F4	22	45	38	
			Total	159	186	**278**	
Gonalagoda	160	76%	F1	14	38	80	Phase 3 over loaded
			F2	38	32	125	
			F3	60	100	42	
			Total	112	170	**247**	

Percentage of transformer load is taken into consideration for system augmentation and planning activities but, above phenomenon is not addressed.

4.5 Transformer failures due to over load

Number of transformer failures in the Southern Province during years 2008, 2009 & 2010 are 61, 71 & 63 respectively. When analyzing the failures, it is noted that reasonable amount of transformers have failed due to over loading.

Table 4.7: Transformer failures due to overload [03]

Year	Total number of transformer failures	Number of transformers failed due to overload	Overload failures as a percentage of total
2008	61	08	13.1%
2009	71	12	16.9%
2010	63	09	14.3%

Table 4.7 shows the number of transformer failures due to overloading during the years 2008, 2009 and 2010 in the southern province [03]. As an average, 15% transformer failures are due to overloading.

It is highly important to take necessary changes in the existing system and do modifications to reduce the transformer failure rate. As transformers are more expensive and important items in the distribution system, reducing one transformer failure saves minimum of one Million Rupees to the CEB.

When considering about the transformer overloading protection, following modifications or changes can be proposed.

- Option 1: Over load protection using MV fuse
- Option 2: Main LV side fuse per phase
- Option 3: Limitation of number of outgoing feeders

4.6 Option 1: Over load protection using MV fuse

As described in the previous chapter, MV expulsion fuse is used to protect the transformer or the isolate the faulty transformer from the system due to over current as a result of transformer internal faults or secondary side short circuiting. According to IEEE Std. C57.109-1993, overcurrents up to 3.5 times transformer rated current can be considered as overloading. Hence, MV fuses are selected based on that and therefore there is an unprotected region as shown in figure 4.7 of which the protection in that region depends on secondary side protective device.

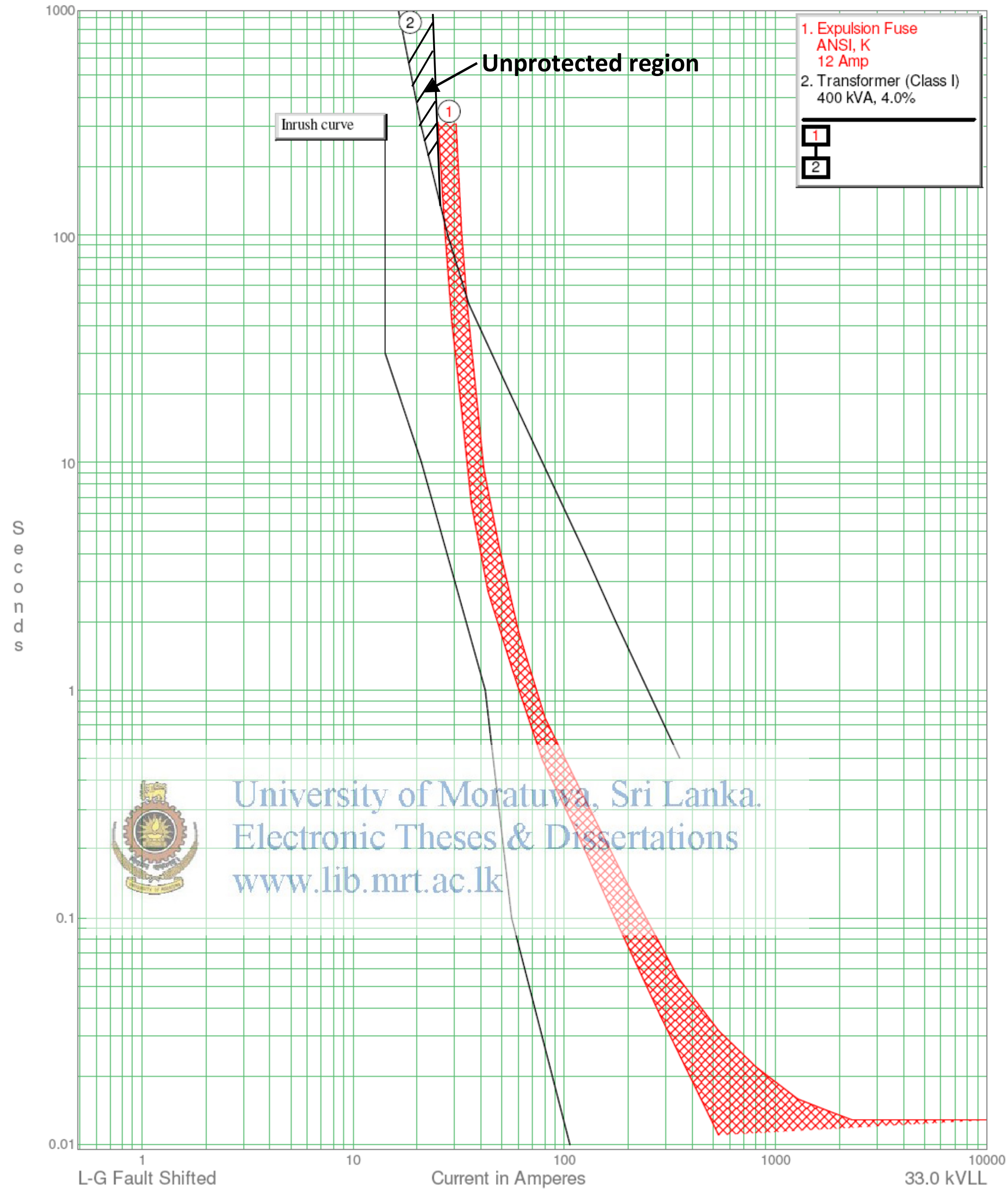

Figure 4.7: Unprotected region of transformer by MV fuse

To address the above matter, selection of lower rating MV fuse will not be the solution. There is a special type of expulsion fuse called “SloFast” developed by A.B.CHANCE Company, USA which is having a duel characteristic curve and it would be the solution for the above matter.

4.6.1 SloFast fuse link

The special feature of the SloFast fuse link is the dual Time Current Characteristic Curve as shown in figure 4.8.

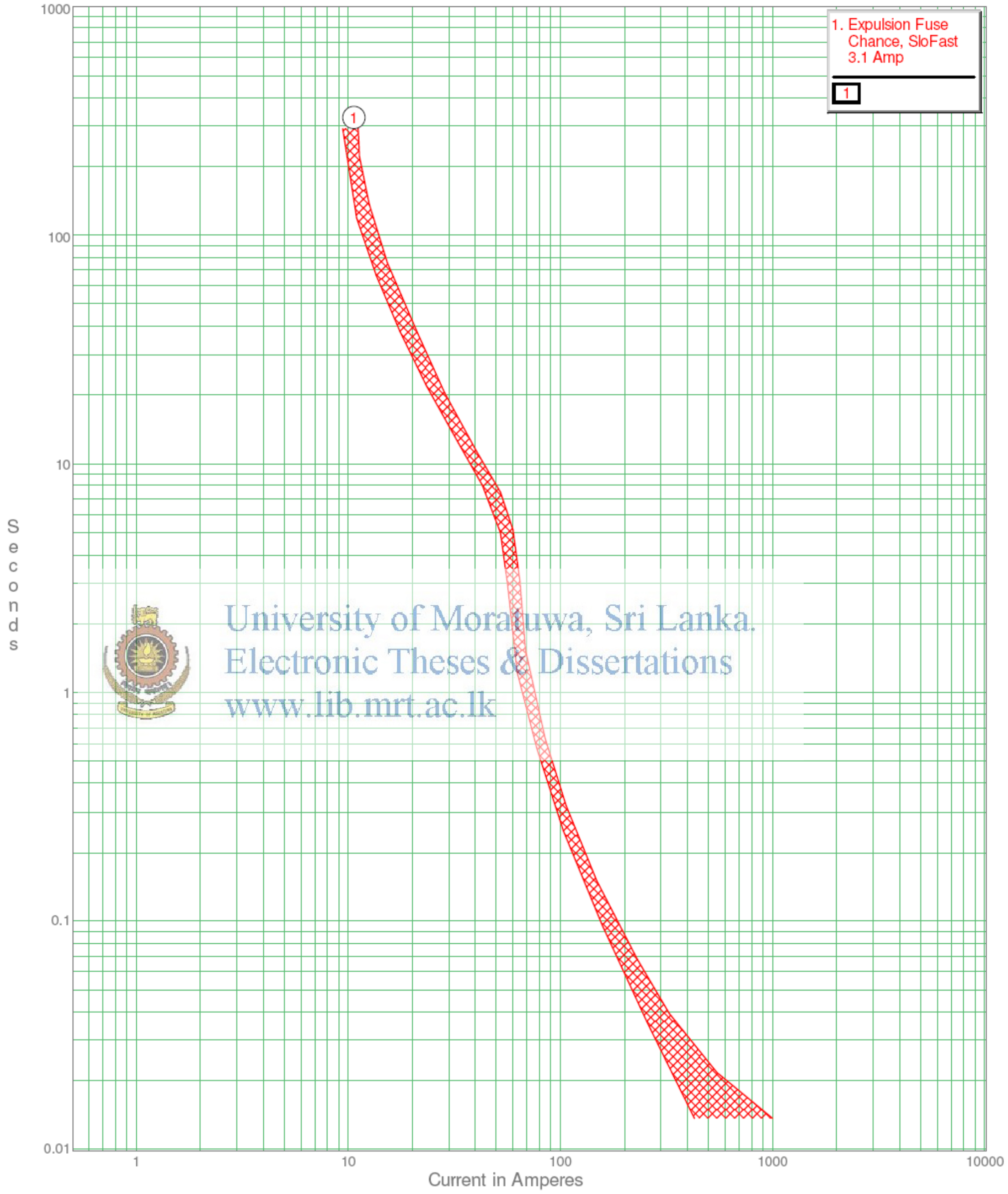

Figure 4.8: Time Current Characteristic Curve for a SloFast fuse

Inner construction of a SloFast fuse link is shown in figure 4.9 below. Unlike K type fuse link, the SloFast fuse link consists of two current responsive elements called slow element and fast element.

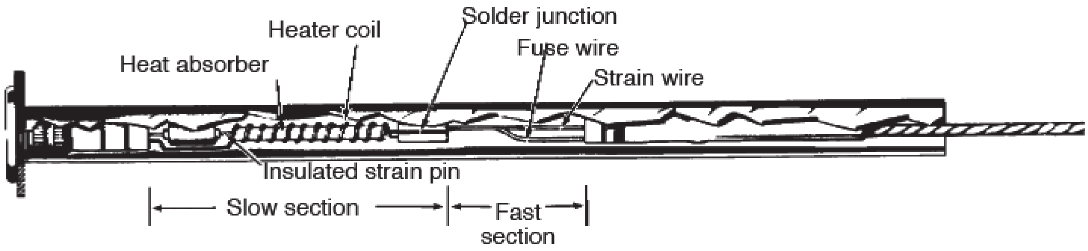

Figure 4.9: Inner construction of a SloFast fuse

The slow current responsive element consists of several components. Out of that, the main components are the heater coil and the soldering junction. The insulated strain pin carries the tension exerted when the fuse link is installed in fuse cutout and as a heat conductor to the soldered junction. There is a ceramic tube, which act as the heat absorber [10].

The function of the slow current responsive element can be described in the following manner. The heater coil generates heat at a rate which is proportional to the square of the current. This heat is absorbed by the ceramic material and transmitted to the soldered junction via the metallic strain pin. When a certain value of current flows for a specific length of time, sufficient heat is generated and transmitted to the soldered junction to cause melting of the solder, and the separation of the fuse link for the interruption of the circuit. TCC curve portion corresponding to the slow element is the portion above the "knee" (above 4 second in time axis) as in the figure 4.8.

The construction of fast current responsive element is the same as the conventional fuse link. The fast element represents the TCC curve portion below the knee in the TCC curve.

4.6.2 SloFast fuse selection

Selection procedure of SloFast fuse is not similar to the method described in the previous sections. The fuse rating series is completely different form ANSI/NEMA standard series and available ratings are 0.4, 0.6, 0.7, 1.0, 1.3, 1.4, 1.6, 2.1, 3.1, 3.5, 4.2, 5.2, 6.3, 7.0, 7.8, 10.4, 14.0, 21, 32 and 46. These are an unusual current rating values and the original meaning of these rating as described in CHANCE fuse link product catalogue is that this ratings represent the primary rated current of the transformer that is intended to protect.

250kVA 33/0.4kV transformer is selected as an example to study the above fact. Primary rated current for this transformer is calculated as 4.37A. Hence, the SloFast fuse rating selected as 4.2A form the available series. Figure 4.10 shows the TCC curve of 4.2A SloFast fuse with selected transformer damage and inrush curves.

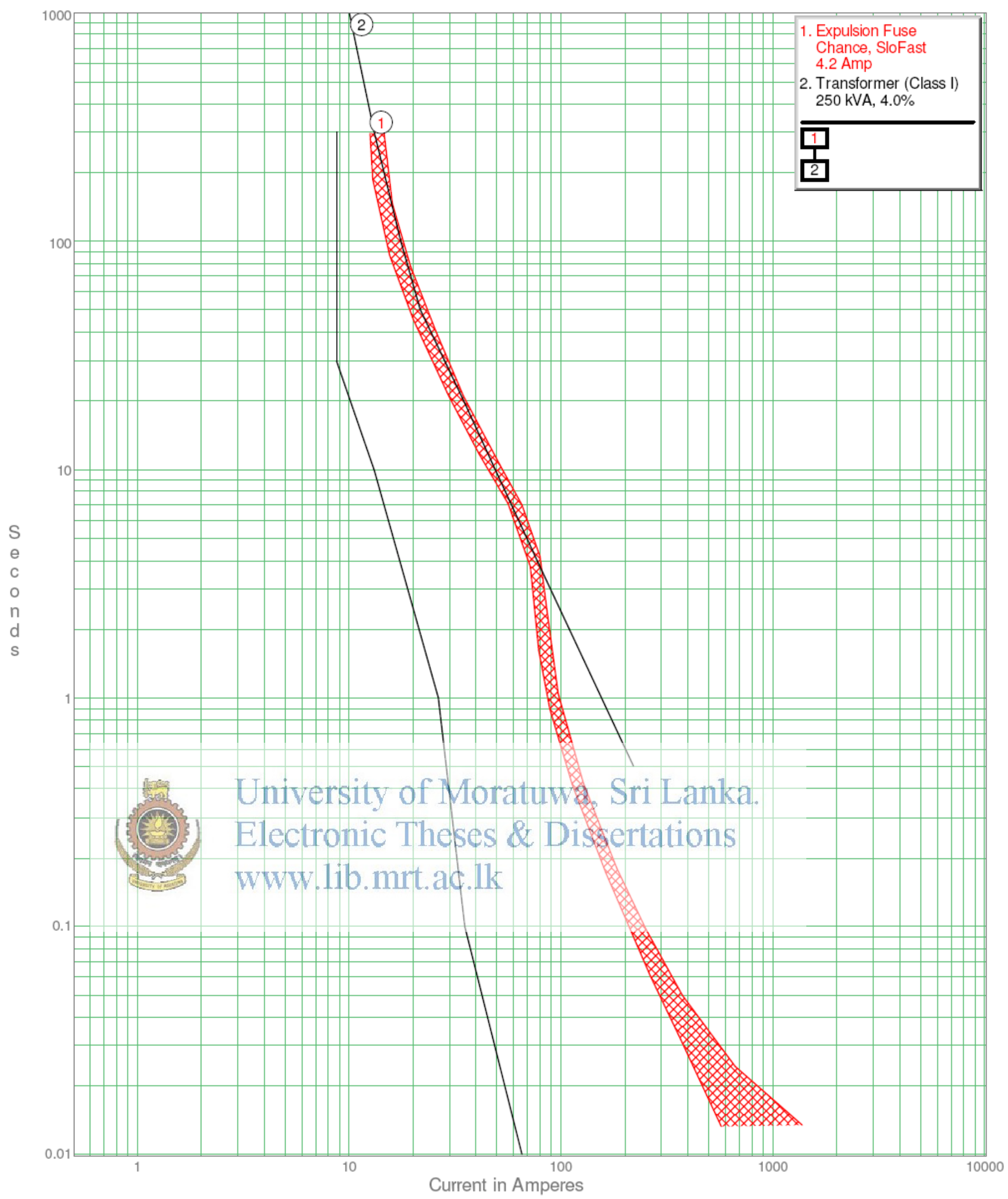

Figure 4.10: 250kVA 33/0.4kV transformer curves with 4.2A SloFast fuse TCC curve

As shown in figure 4.10, the TCC of SloFast fuse behaves very much in parallel with the transformer damage curve. This is because the original transformer damage curve is shifted further left by considering load side single phase to earth faults as described in section 3.5. Therefore, 4.2A SloFast fuse will not provide maximum protection expected. The fuse TCC curve should be shifted further left to achieve the target. Therefore, a fuse should be selected with fuse rating less than 4.2A. The next available fuse ratings such as 3.5A, 3.1A and 2.1A are plotted in figure 4.11 below.

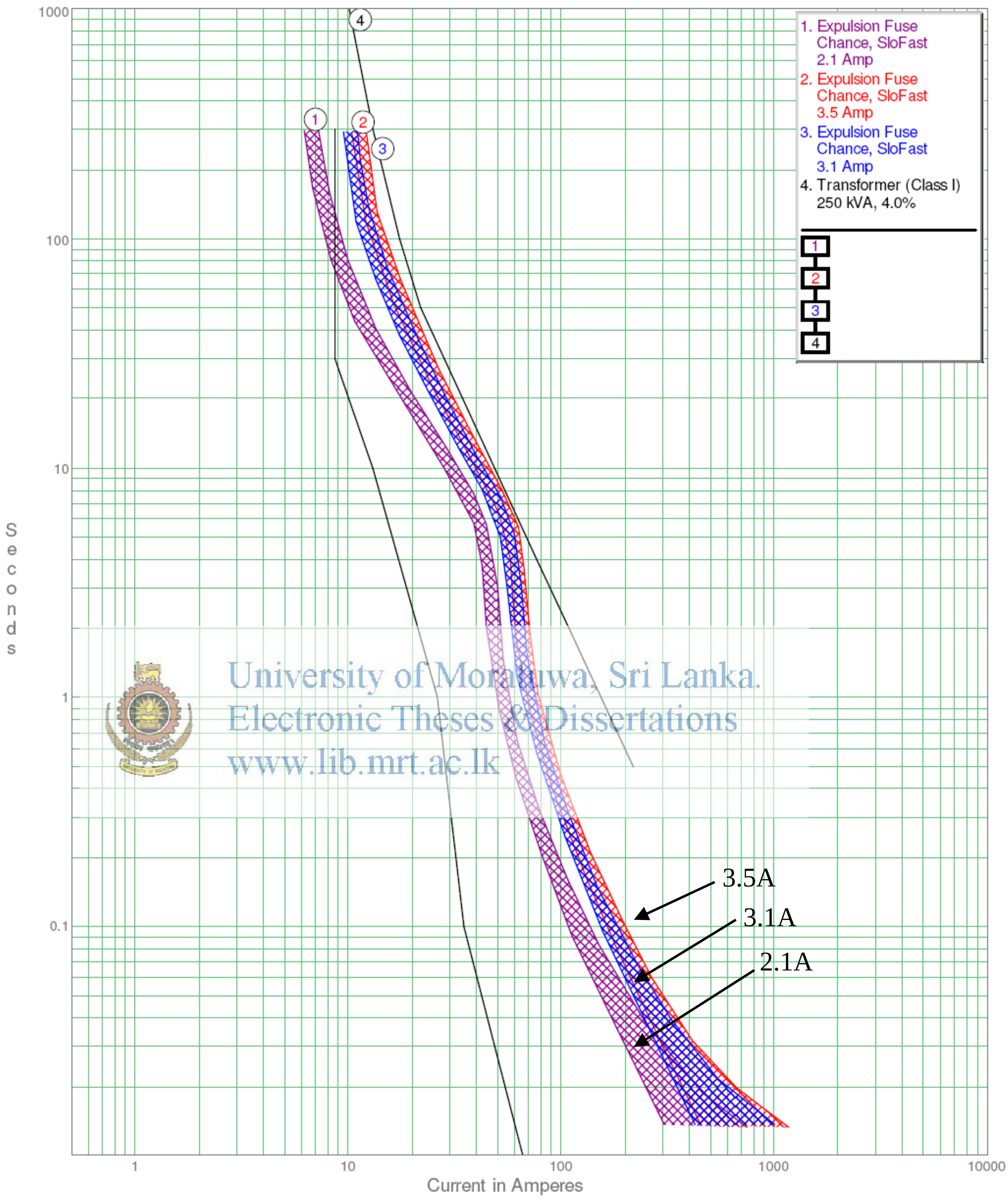

Figure 4.11: 250kVA 33/0.4kV transformer with SloFast fuse TCC curves of 2.1A, 3.1A & 3.5A

The most suitable fuse rating for the 250kVA 33/0.4kV transformer is 3.1A as it behaves very closely parallel to the shifted damage curve. Therefore it gives the maximum protection for the transformer from faults and overloads which could either damage or shorten its life expectancy.

Using above method, SloFast fuse rating for all distribution transformer ratings could be obtained. The TCC curve for 100kVA 33/0.4kV transformer is shown in figure 4.12 and rest of the transformer rating with selected fuse TCC curve are shown in Annex-2.

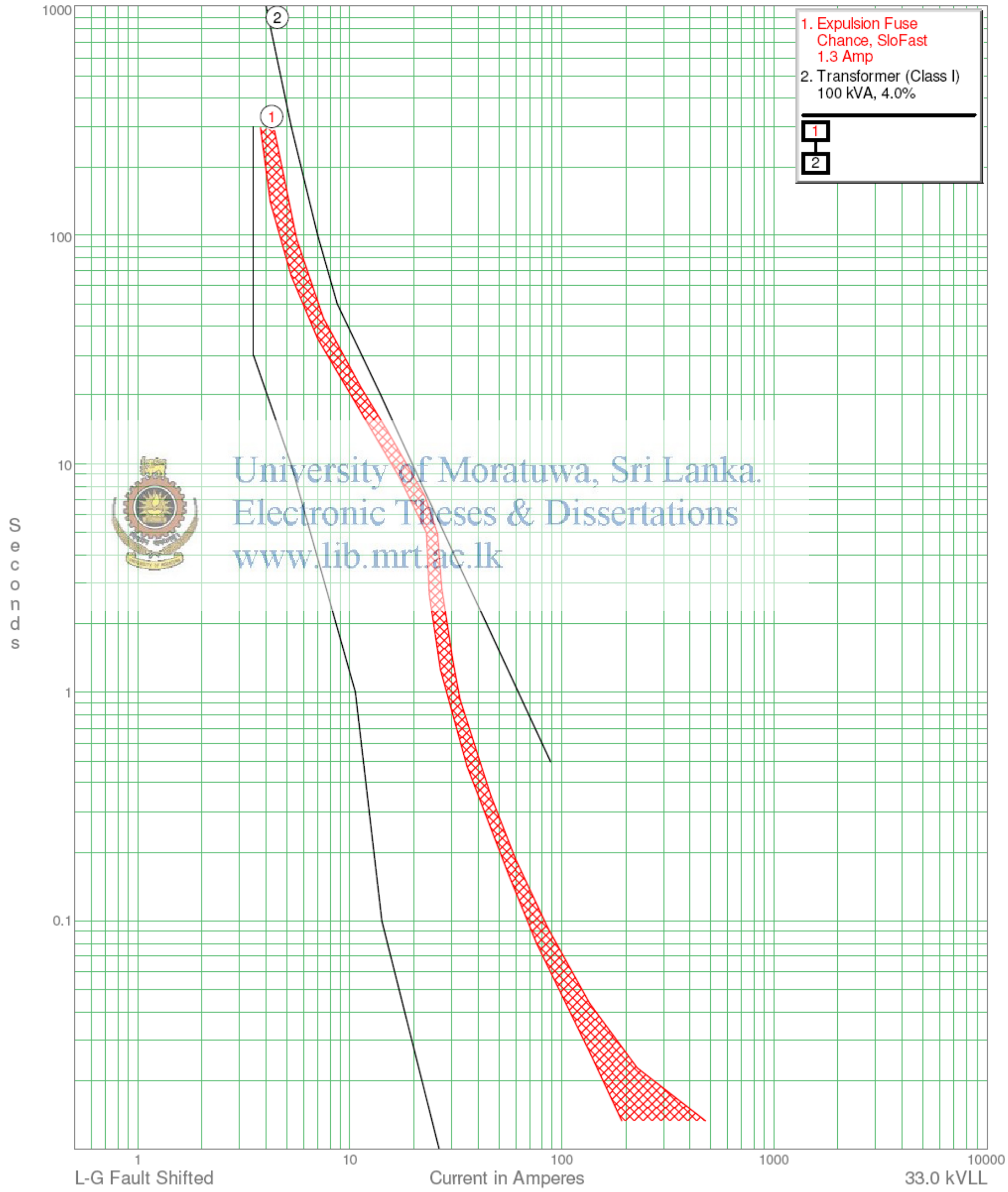

Figure 4.12: TCC curve for 100kVA 33/0.4kV transformer with 1.3A rated SloFast Fuse

A summary of selected fuse ratings for each transformer rating is tabulated in table 4.8.

Table 4.8 SloFast fuse ratings for each transformer rating

Transformer Rating (kVA)	SloFast fuse rating for 33kV System (A)	SloFast fuse rating for 11kV System (A)
100	1.3	3.5
160	1.6	6.3
250	3.1	10.4
400	5.2	14.0
630	7.8	21.0
800	10.4	32.0

4.7 Option 2:Main LV side fuse per phase

The LV fuse ratings that have been obtained by assuming a transformer has only one LV feeder. When the number of LV feeders increase, over load protection cannot be achieved from the LV side HRC fuse. For example, if a 33kV 100kVA has four LV feeders with 100A fuses, then the minimum possible current per phase is 400A and its 2.77 times secondary side rated current.

Restricting one LV feeder per transformer is practically not possible. Hence, secondary side can have the following option.

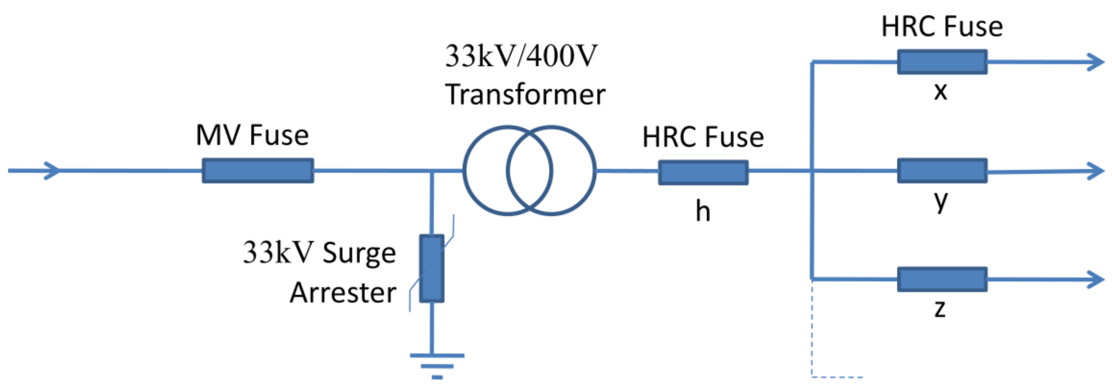

Figure 4.13: Distribution substation arrangement for option 2.

In this modification, HRC fuse ‘h’ has been placed in between the transformer secondary and feeder fuses. The new fuse can be called as the main secondary fuse and x, y, z are feeder fuses.

For the protection of the conductor, fuse rating for x, y and z should be 160A, except the 100kVA transformer. The main secondary fuse rating for 100kVA transformer should be larger than the x,y & z fuse rating of 100A.

As per the IEC 60269-1, available HRC fuse ratings to be selected as the main secondary fuse for distribution transformers are 160, 200, 250, 315, 400, 500, 630, 800, 1000 and 1250. The size-2 HRC fuses are available up to 400A only. The 500A & 630A HRC fuses are size-3 and 800A, 1000A and 1250A are available with size-4.

The TCC curves of above fuses have been plotted with transformer curves & MV fuse TCC curves to obtain the suitable ratings for the main secondary fuse. For an example, figure 4.14 shows the selected fuse curves with 33kV 160kVA transformer curves. Table 4.9 summarizes the selected fuse ratings for each transformer capacity.

As per the available HRC fuse ratings, there is no option for 800kVA transformers. Therefore, main LV fuse option is not suitable for 800kVA transformers.

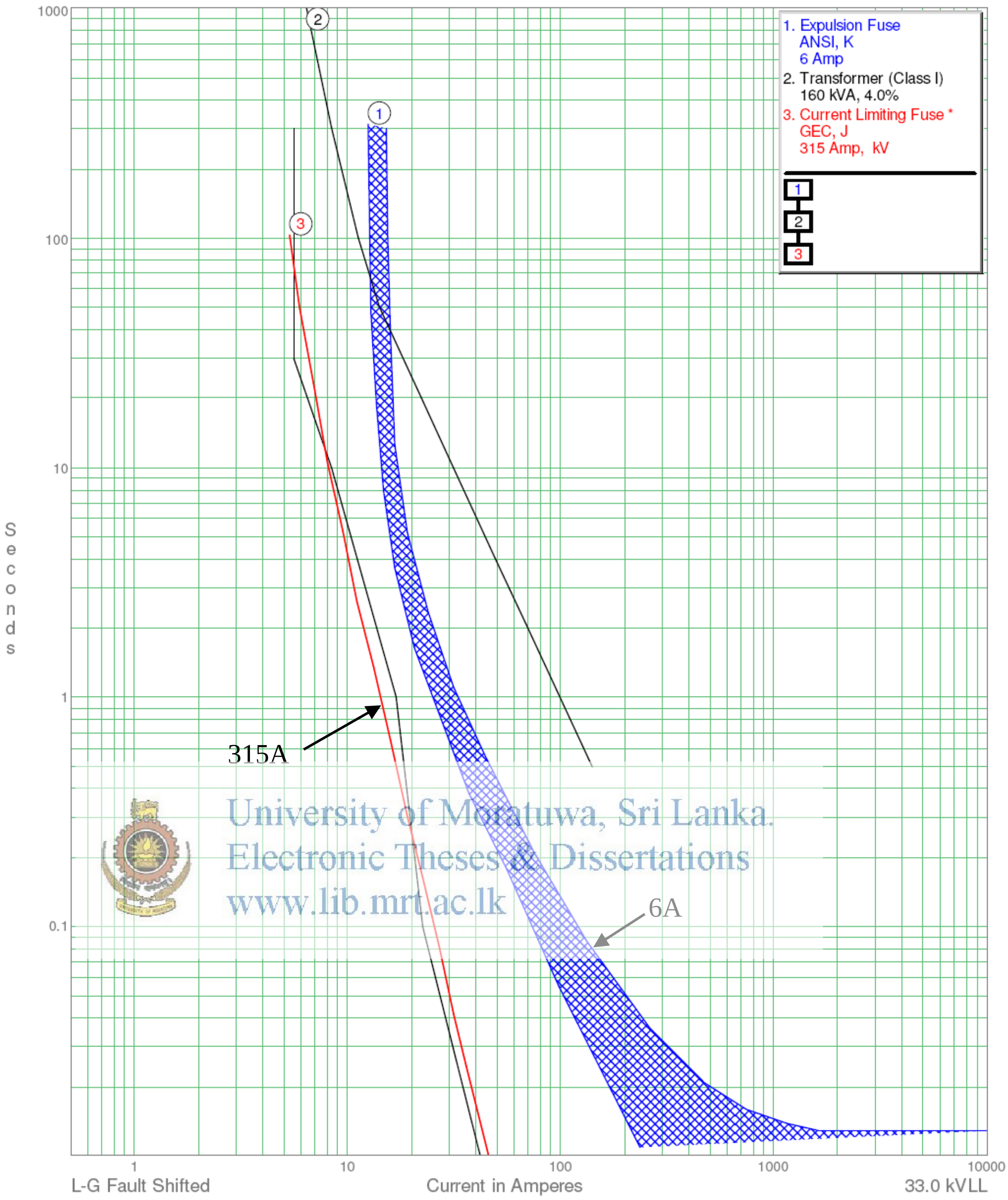

Figure 4.14: 315A Main secondary fuse TCC for 33kV 160kVA transformer

Table 4.9: Fuse ratings for main secondary fuses.

Transformer Rating (kVA)	Main Secondary fuse (A)	Fuse size
100	125	Size-2
160	315	Size-2
250	500	Size-3
400	800	Size-4
630	1250	Size-4

4.8 Option 3: Limitation of number of outgoing feeders

Limitation of LV feeders from a transformer is another option to protect it from over loading. The present CEB system has an average of 3 LV feeders per transformer for 100kVA and 160kVA ratings. For the rest of the ratings, the number of LV feeders increases with the transformer kVA.

Selected fuse ratings and number of LV feeders for each transformer capacity is tabulated in table 4.10. By considering practical requirement and 100% use of transformer capacity, total allowable secondary current per phase is limited from 1.5 to 2.0 times its rated value. Properly balancing of LV feeders is very important to implement the above method, otherwise unnecessary fuse blowing may take place frequently.

Table 4.10: LV feeder limitation

Transformer Rating (kVA)	LV fuse (A)	Maximum Number of feeders	Ratio of allowable secondary current to rated current
100	80	3	1.66
160	125	3	1.63
250	160	4	1.77
400	160	6	1.66
630	160	9	1.58
800	160	12	1.66

4.9 Advantages of proposed MV and LV fuse selections

i. Reliability of the supply will be improved by reducing unnecessary outages. Only the faulty transformer or LV feeder can removed from the system without affecting the consumers at upstream or other LV feeders.

ii. Travelling time to find the fault is reduced because the only faulty transformer or LV feeder is isolated. Average repair time to clear a fault in present system is 2 hours.

iii. Transformer failures due to over load will be minimized. Average transformer failures per year due to over loading in the Southern Province and expected cost saving by new fuse selection are given in table 4.11.

Table 4.11: Annual cost of transformers failed due to over loading

Transformer rating (kVA)	Average no. of failures due to over load per year	Unit Cost (Rs.)	Cost (Rs.)
100	06	701,360.00	4,208,106.00
160	02	863,600.00	1,727,200.00
250	01	1,092,200.00	1,092,200.00
Total	09	-	7,027,560.00

Above cost is calculated considering only the cost of transformer replacement while the actual figure should include the cost of transportation and installation.

iv. Annual fuse usage can be reduced by implementing the new fuse selection scheme.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 Conclusion

The objective of this study is to improve distribution system reliability and reduce transformer failures due to overloading. Under this study, an effort has been taken to introduce a proper selection scheme of MV and LV fuses for distribution transformers used by the CEB.

Proper selection of fuses will reduce unnecessary fuse blowing, transformer failures, repair time and finally a saving to the organization.

Distribution transformer failure rate is high in the Southern Province. Out of the failed transformers, nearly 15% are failed due to over loading. Field staffs are not yet properly educated about importance of protection of distribution transformers. It has been noticed that 10A MV fuse is used instead of 3A fuse and the field staff do not know the severity of the error.

It has been identified that there is a higher probability of overloading distribution transformers with the present system. The main function of the primary side fuse is isolating the transformer due to its internal faults or short circuit conditions and an overload protection is not expected. Therefore, a secondary side fuse should be properly selected to protect the transformer from damaging by over current. The possibility of over loading 100kVA and 160kVA transformers are high and it found that over 15% of transformers have at least one phase loaded beyond its rated value.

5.2 Recommendation

In this study, a proper methodology has been proposed to select primary side expulsion fuses and secondary side current limiting fuses for outdoor type distribution transformers.

5.2.1 Improvements to the present fuse selection practice

K type fuses are the recommended MV fuse for distribution transformers by the CEB. In this study, a new fuse scheme has been proposed as shown in table 4.3 and

4.4 as the result of the present fuse scheme has several drawbacks. The new fuse scheme will provide maximum utilization of transformer without nuisance fuse blown.

With the present fuse selection practice used by the CEB, 100kVA transformer secondary fuse will not coordinate with its primary fuse. Therefore, the secondary fuse rating should be revised as recommended by this study.

5.2.2 Overload protection

This study has proposed three options to overcome the overload protection issue.

Option 1: A fuse with special time characteristic curve called SloFast will be the best option as it can provide maximum protection for distribution transformers. The selected fuse ratings are given in table 4.8.

Option 2: A main secondary fuse has been introduced in addition to the conventional feeder fuse and selected ratings are tabulated in table 4.9.

Option 3: It has been identified that the increase of the number of outgoing feeders will increase the probability of overloading distribution transformers, special lower rated transformers such as 100kVA and 160kVA. This study proposed maximum number of outgoing feeders for each distribution transformer capacity. Lower ratings of LV fuses are recommended for 100kVA and 160kVA transformer outgoing feeders to give maximum protection.

Physical size of the distribution transformer is the main factor considered by the field staff to recognize its rating and fuses are selected accordingly. But, this is completely a wrong practice and make several mistakes. It is recommended to implement a colour scheme for each transformer capacity and the same for the relevant fuse packing. This will minimize erroneous fuse selection by the field staff.

Lack of proper training to the field staff about correct fuse selection is one of the main drawback identified by the study. It is highly recommended to train all field staff who involves in re-fusing.

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[01] Ceylon Electricity Board, “Monthly Progress Reports – Southern Province, January 2010 to December 2010” CEB, December 2010.

[02] Annual Procurement Report, CEB, 2010.

[03] Ceylon Electricity Board, “Southern Province – Transformer Failure Reports from January 2007 to December 2010” CEB, 2010.

[04] Ceylon Electricity Board, “Southern Province – Transformer load readings”, CEB, December 2010.

[05] John C. Gravunder, “Transformer Fusing Protection and Coordination” Cooper Power Systems, September 1996.

[06] Ceylon Electricity Board, “CEB Standard 052:2000 – Specification for HRC Fuse Links” CEB, 2000.

[07] “Overcurrent Protection of Transformers – Traditional and New Fusing Philosophies for Small and Large Transformers”, S&C Electric Company, 2002-2003 News Archive.

[08] IEEE Std C57.109-1993, “IEEE Guide for Liquid-Immersed Transformer Through-Fault-Current Duration.

[09] Lanka Transformers Limited, “Specification for Transformer Overcurrent Protection”, July 2004.

[10] Catalogues, Brochures and Technical Documentation from several Manufactures: ABB, Cooper Power Systems, GE, A.B. Chance Company & Hubbel Power Systems.

[11] Ceylon Electricity Board, “Investigation of Distribution Transformer Failures-Region 01” CEB, October 2004.

[12] Ceylon Electricity Board – Distribution Planning and Development Branch – Region 4, “Selection of MV Fuses”, CEB, July 2006

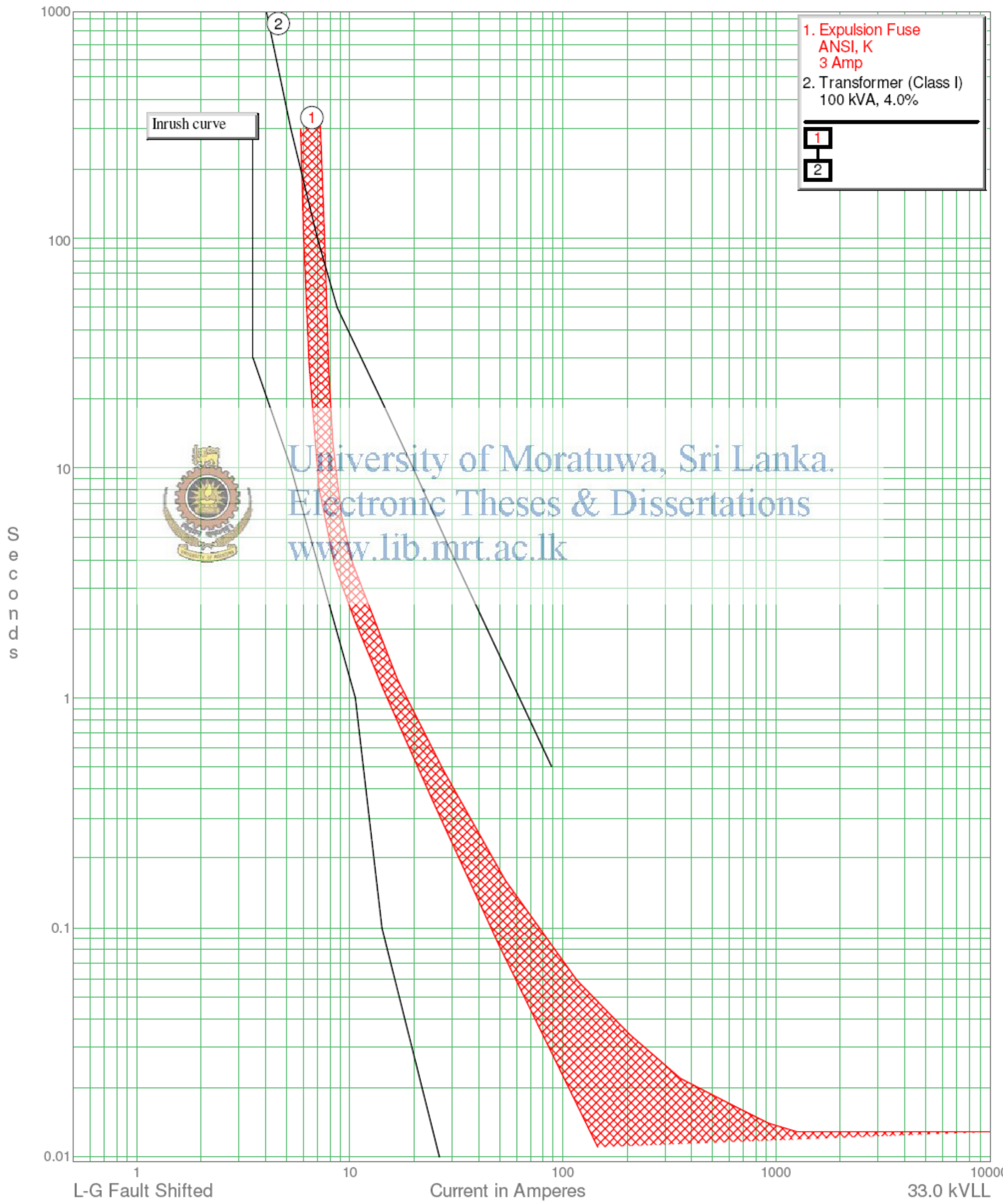
[13] Ceylon Electricity Board, “CEB Standard 059:1997 - Specification for High Voltage Expulsion Fuse Links” CEB, 1997.

[14] Break down reports-Southern Province, CEB, 2010.

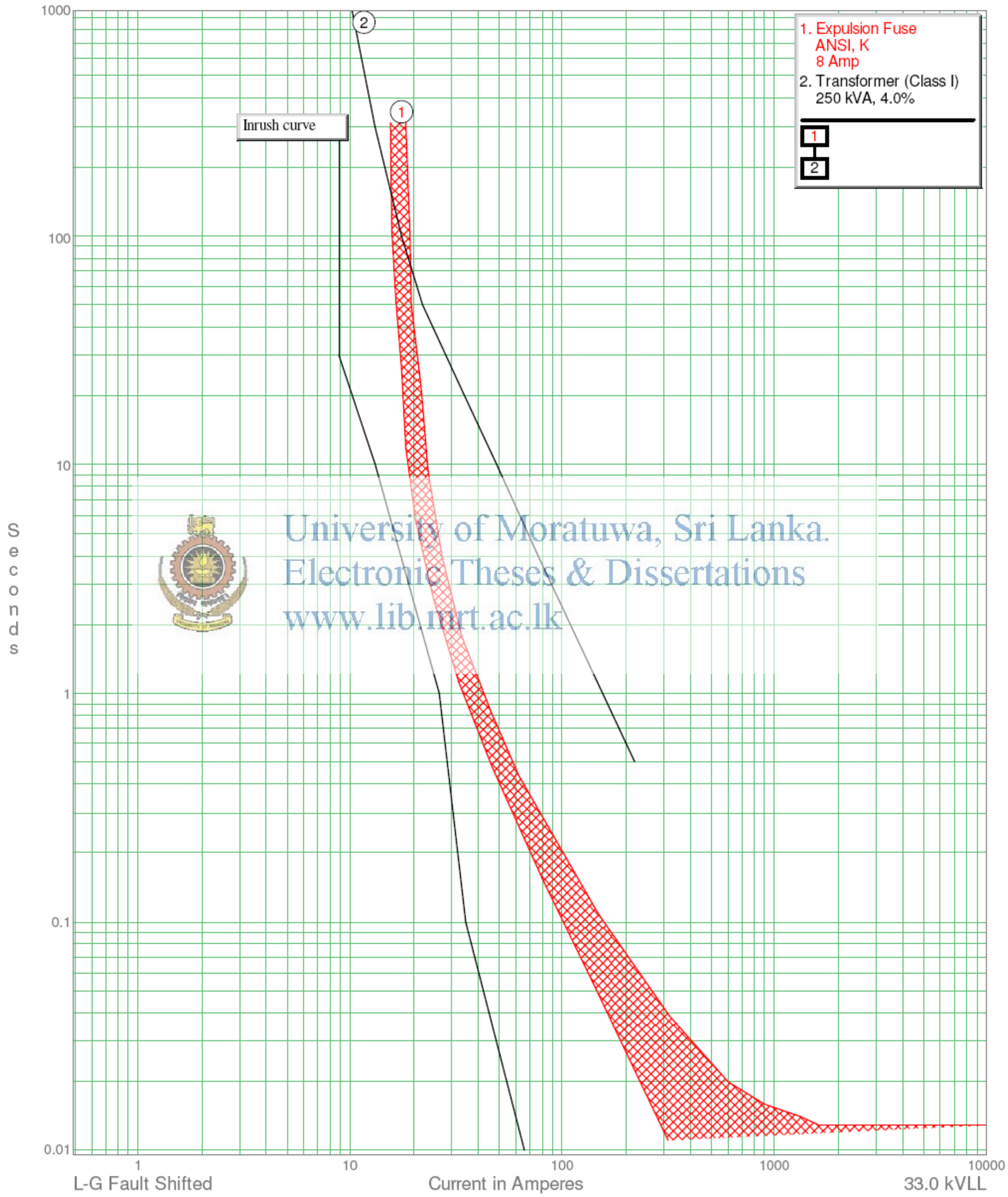
Annex-1

K type Fuse Selection

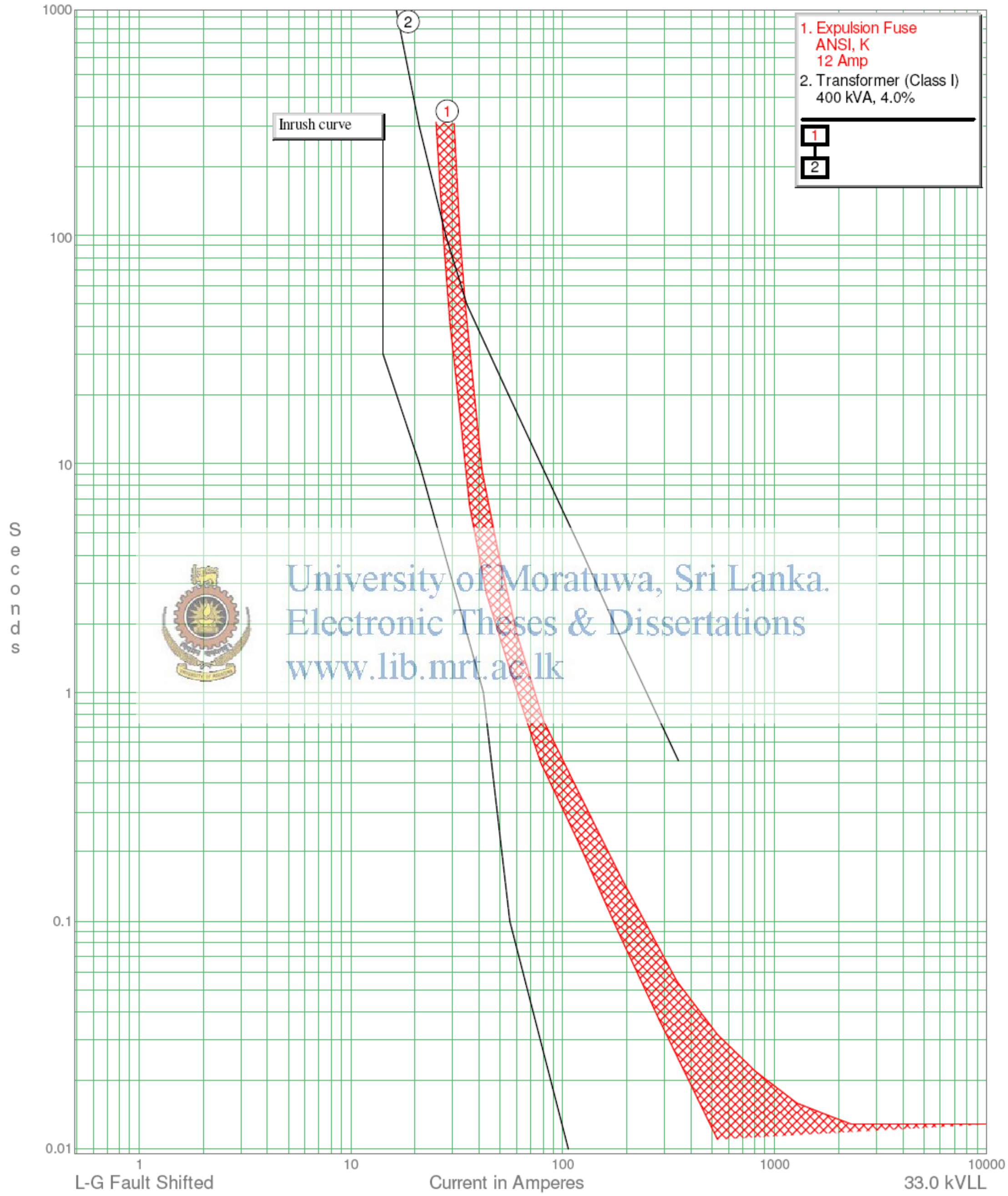
1. TCC for 100kVA 33/0.4kV transformer with 3A fuse



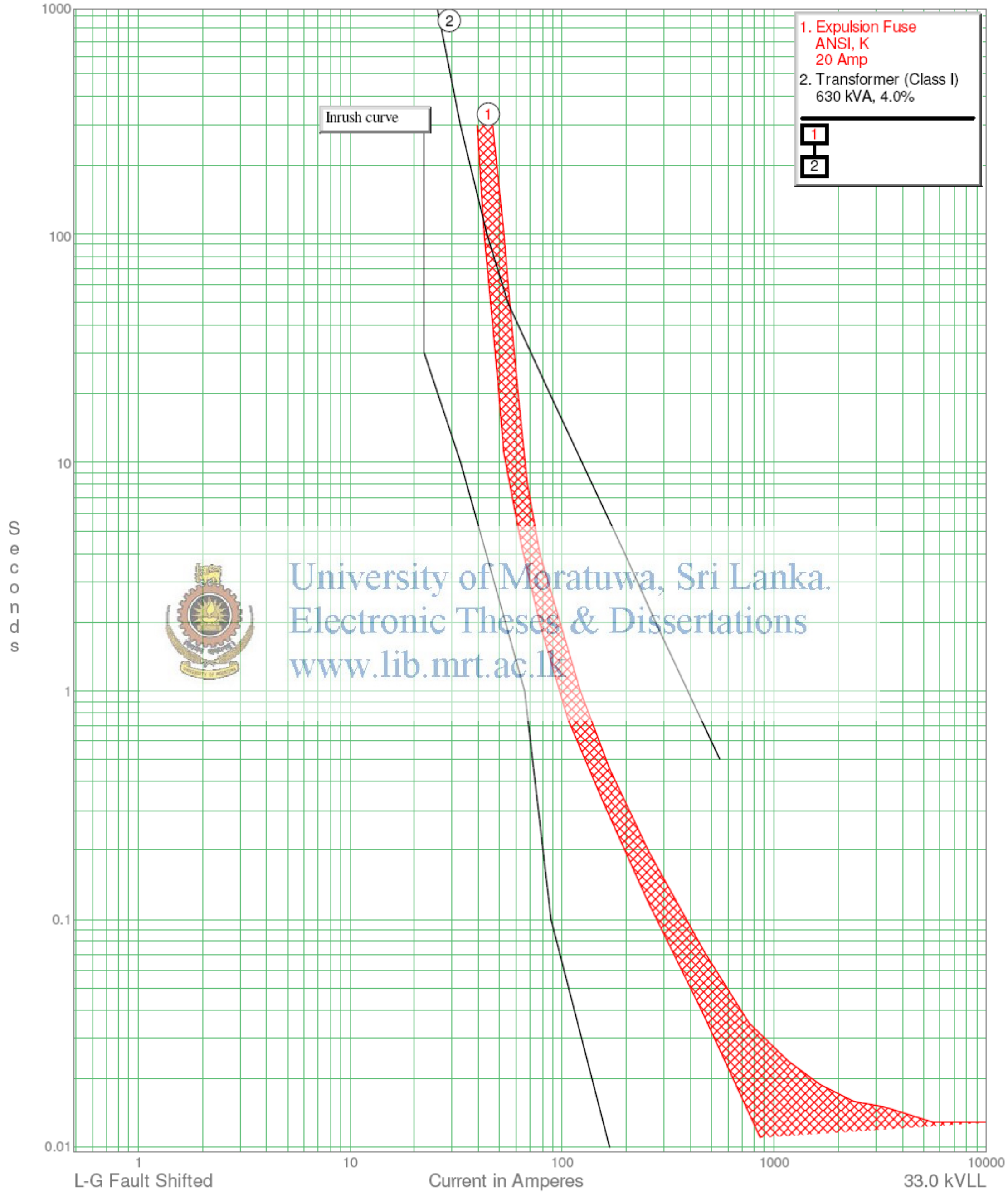
2. TCC for 250kVA 33/0.4kV transformer with 8A fuse



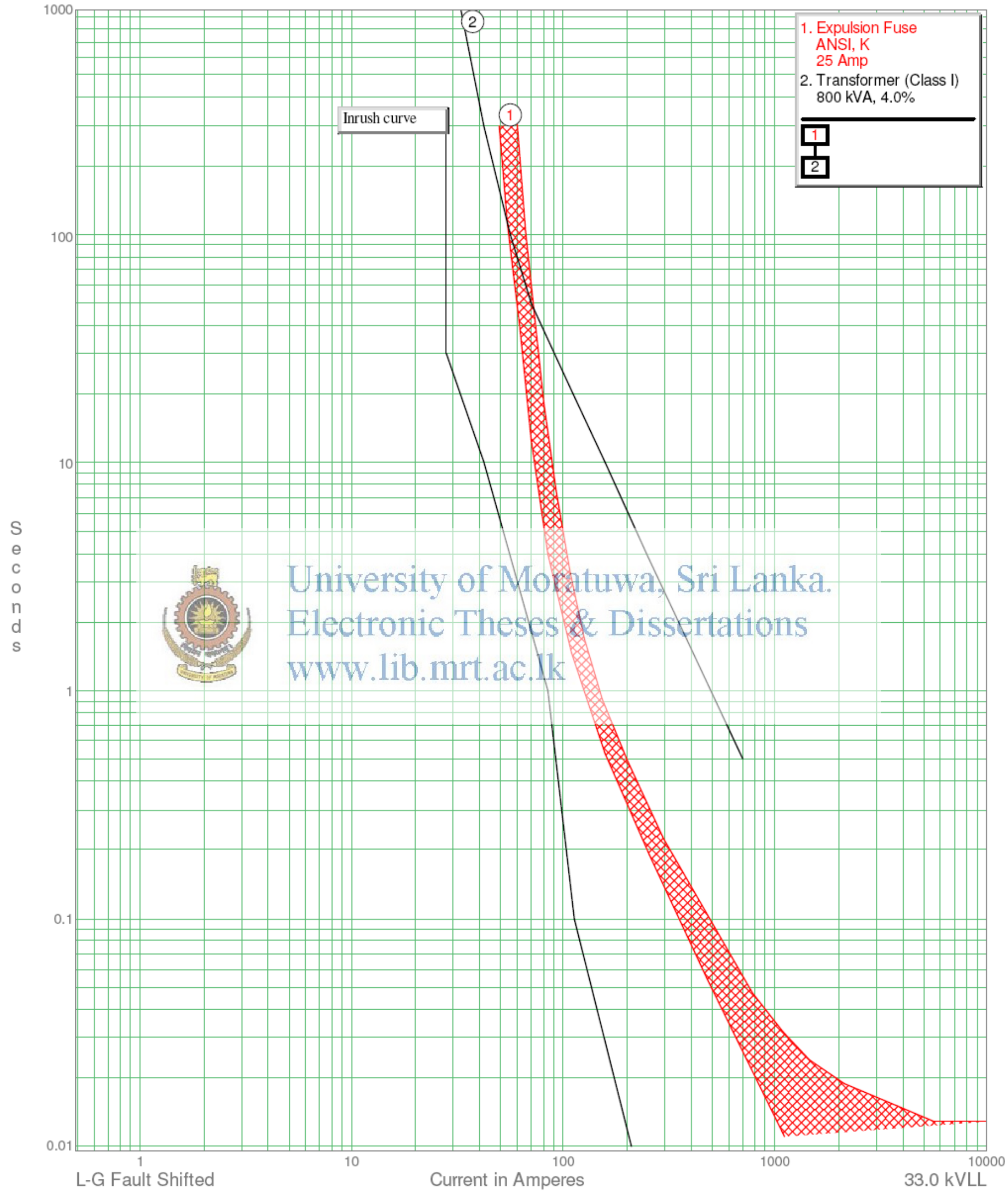
3. TCC for 400kVA 33/0.4kV transformer with 12A fuse



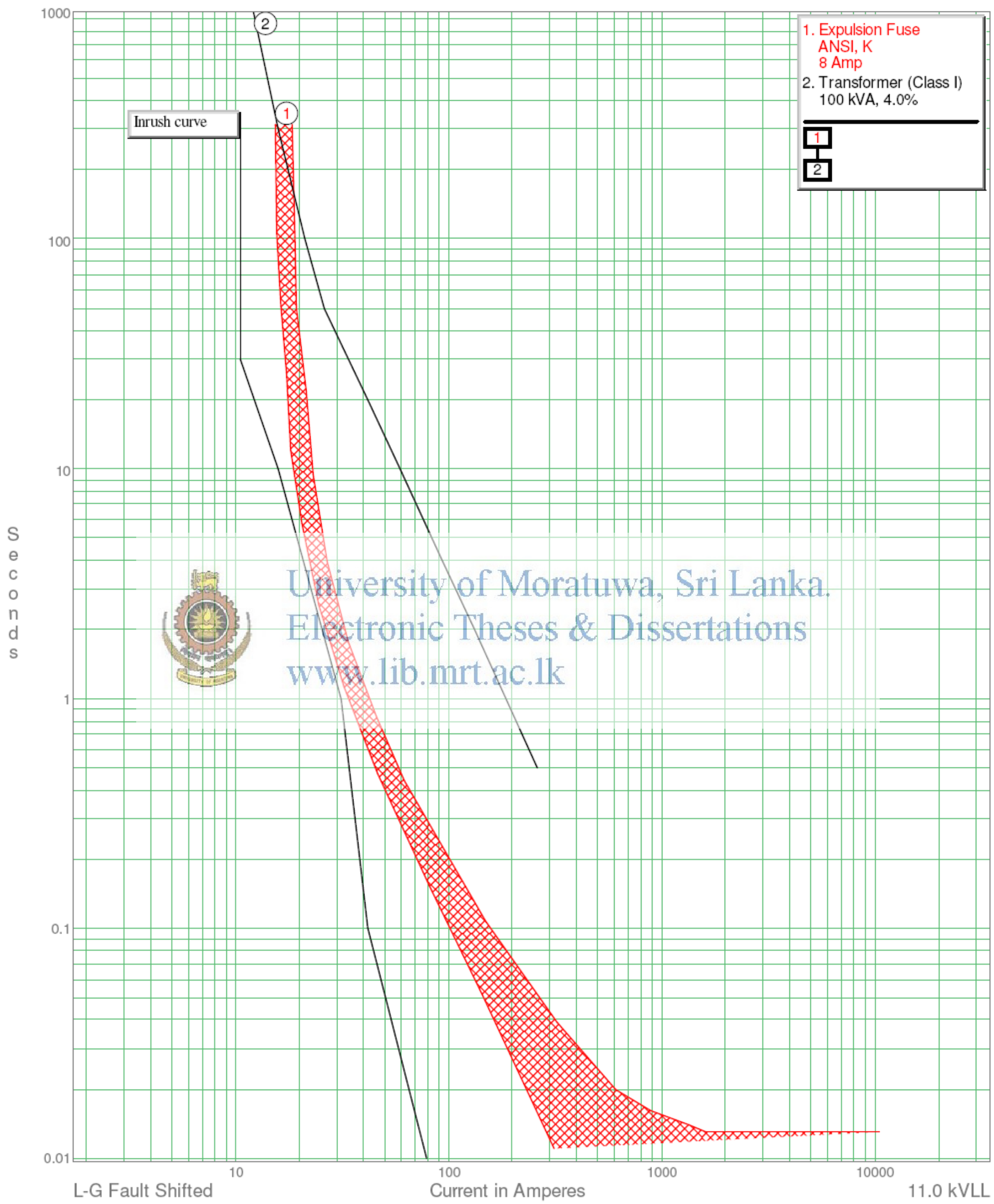
4. TCC for 630kVA 33/0.4kV transformer with 20A fuse



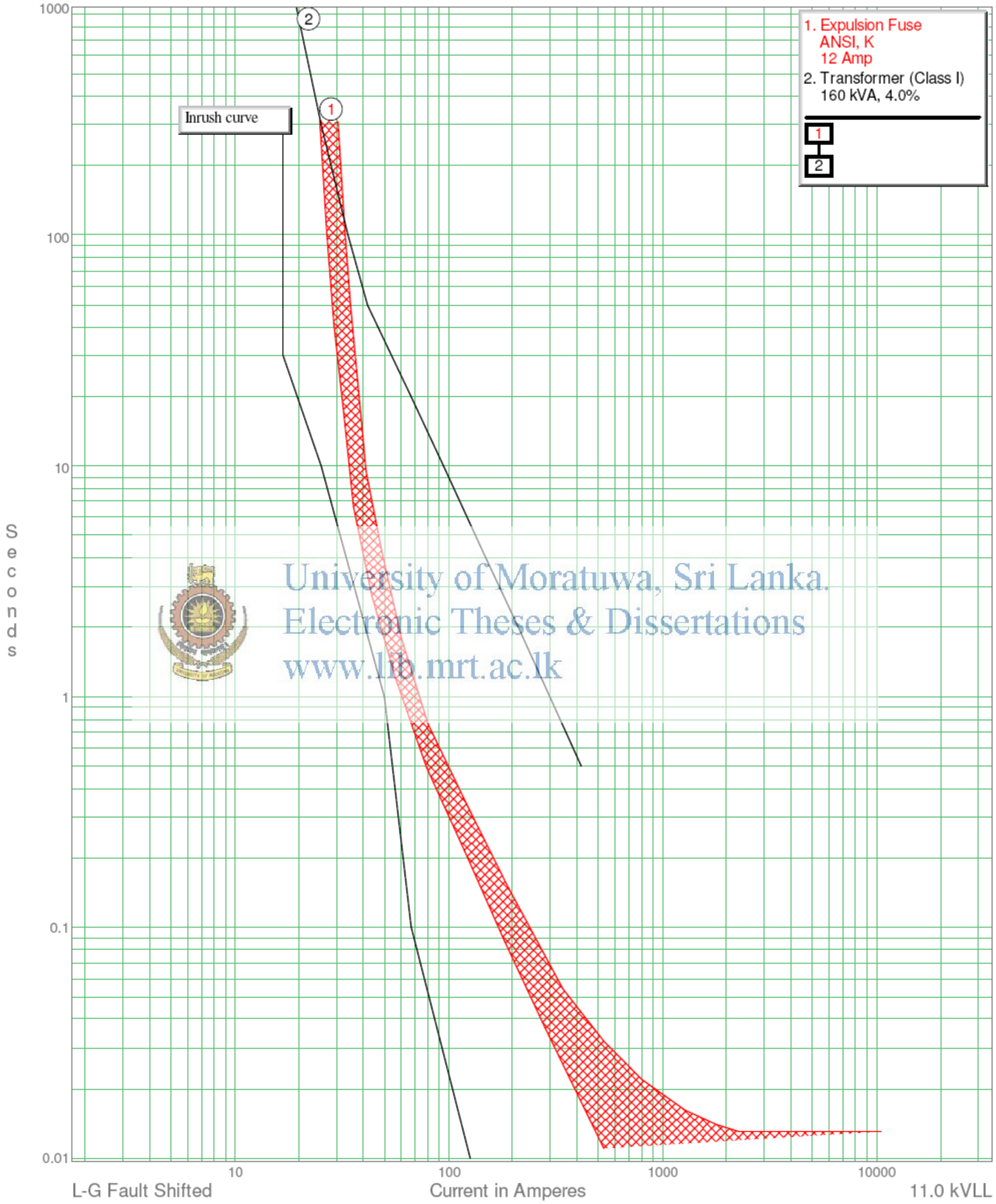
5. TCC for 800kVA 33/0.4kV transformer with 25A fuse



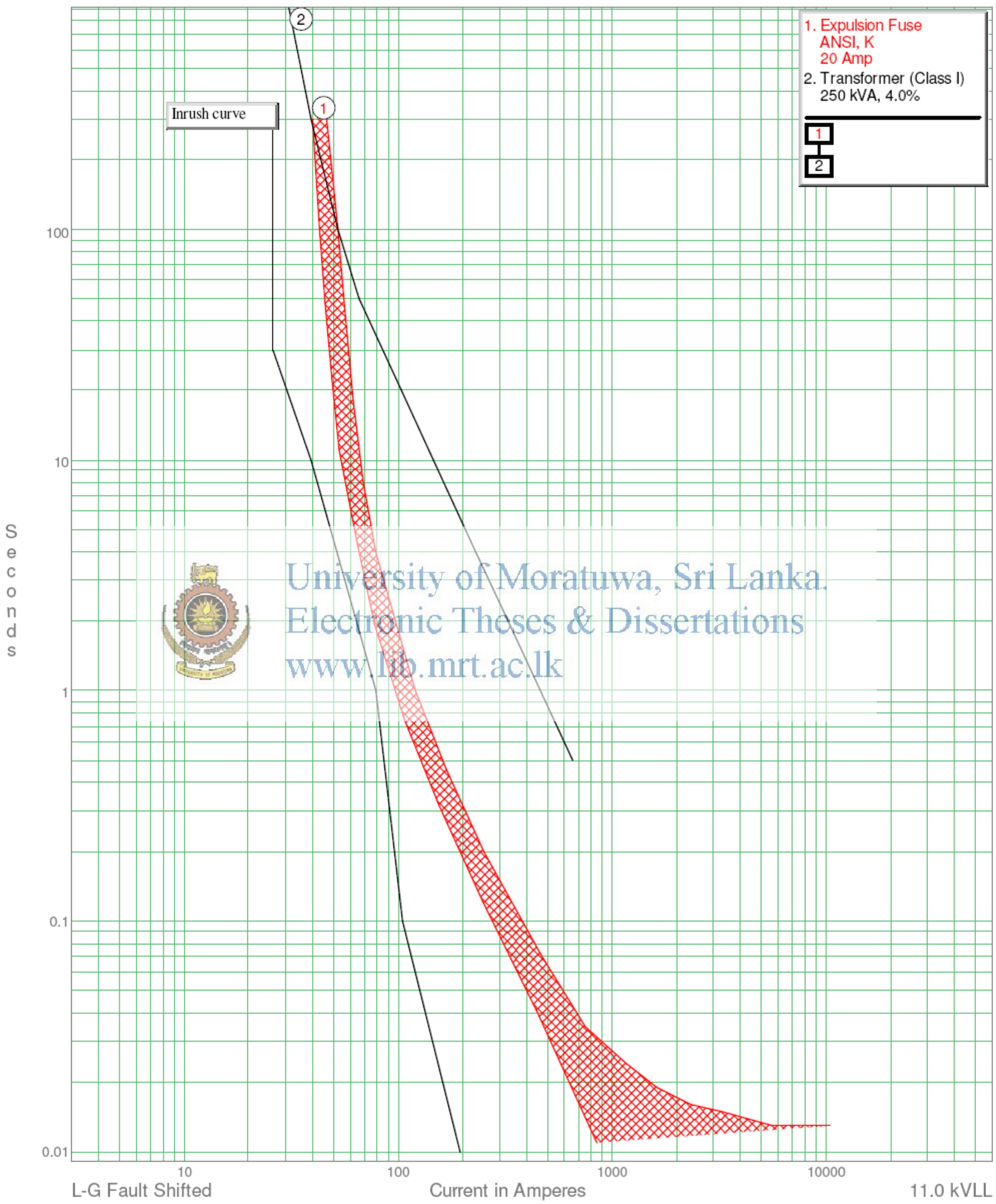
6. TCC for 100kVA 11/0.4kV transformer with 8A fuse



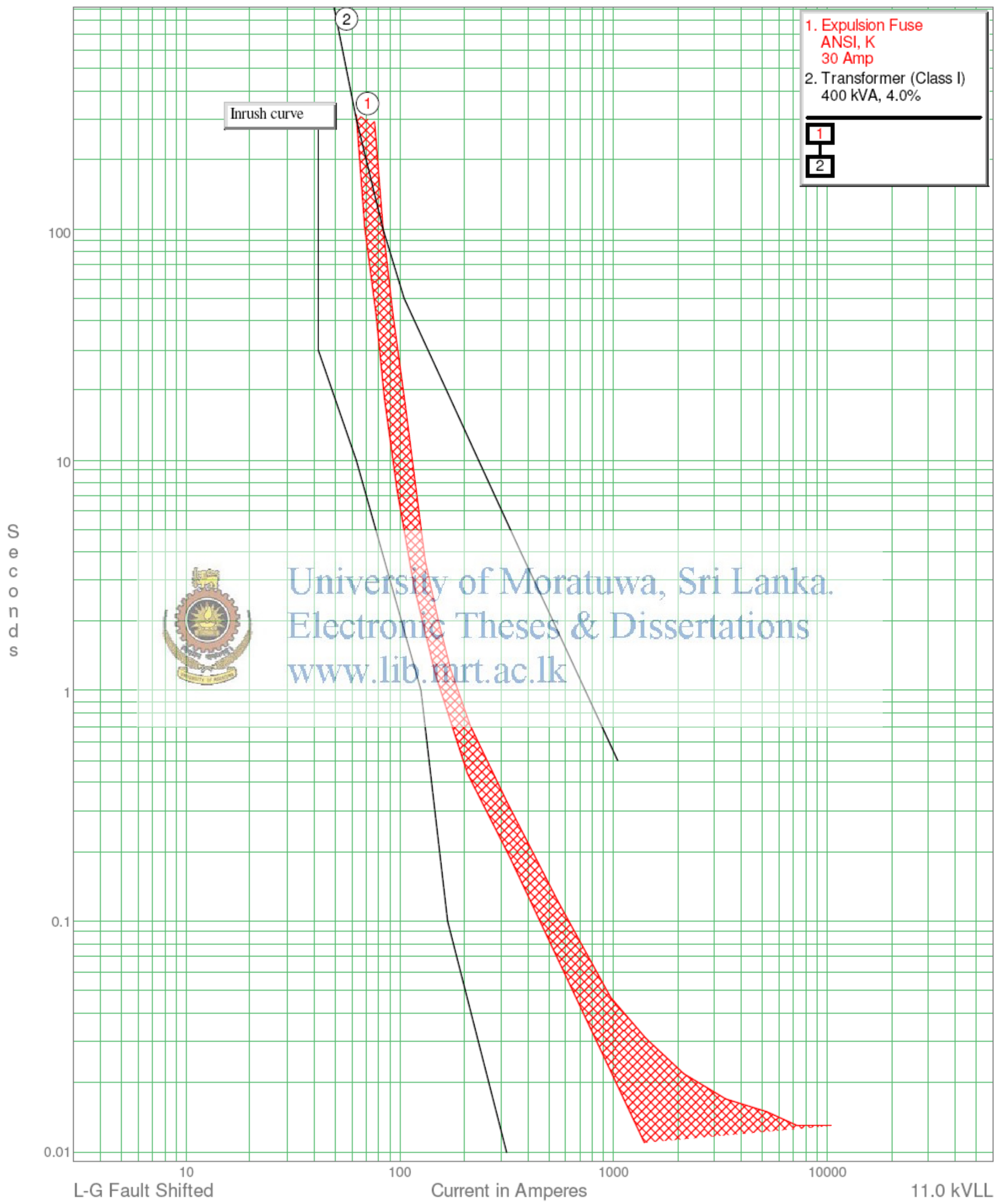
7. TCC for 160kVA 11/0.4kV transformer with 12A fuse



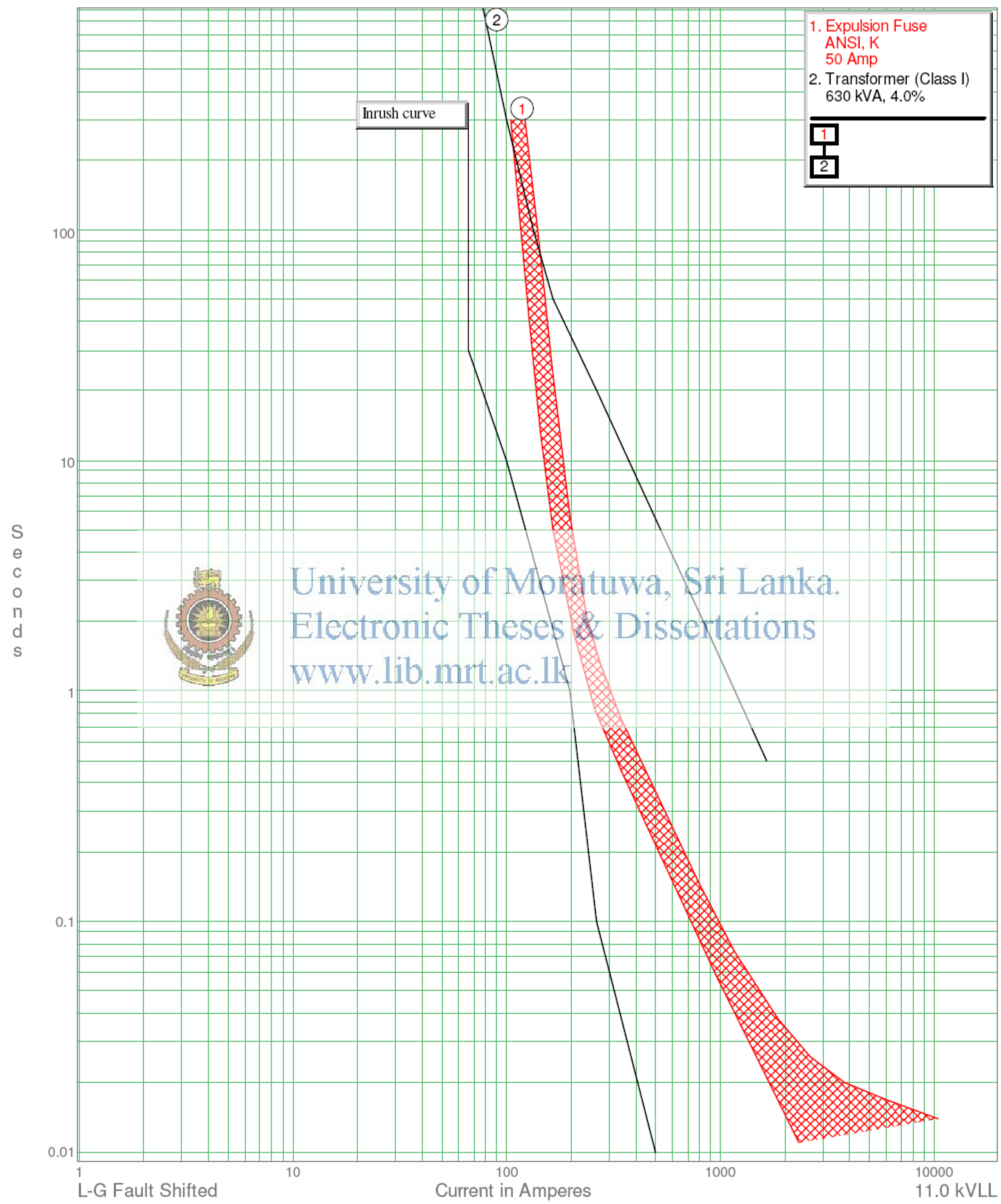
8. TCC for 250kVA 11/0.4kV transformer with 20A fuse



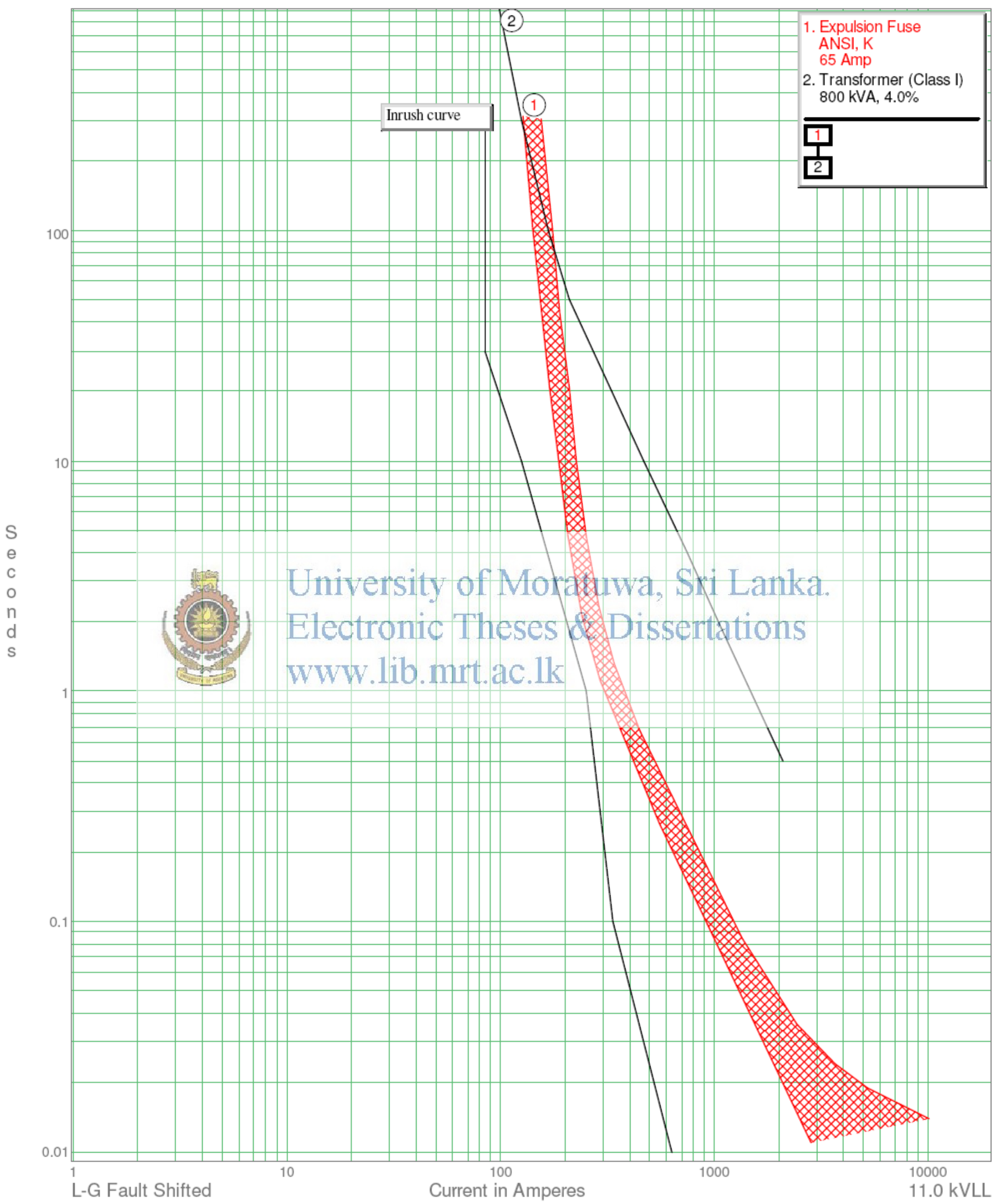
9. TCC for 400kVA 11/0.4kV transformer with 30A fuse



10. TCC for 630kVA 11/0.4kV transformer with 50A fuse



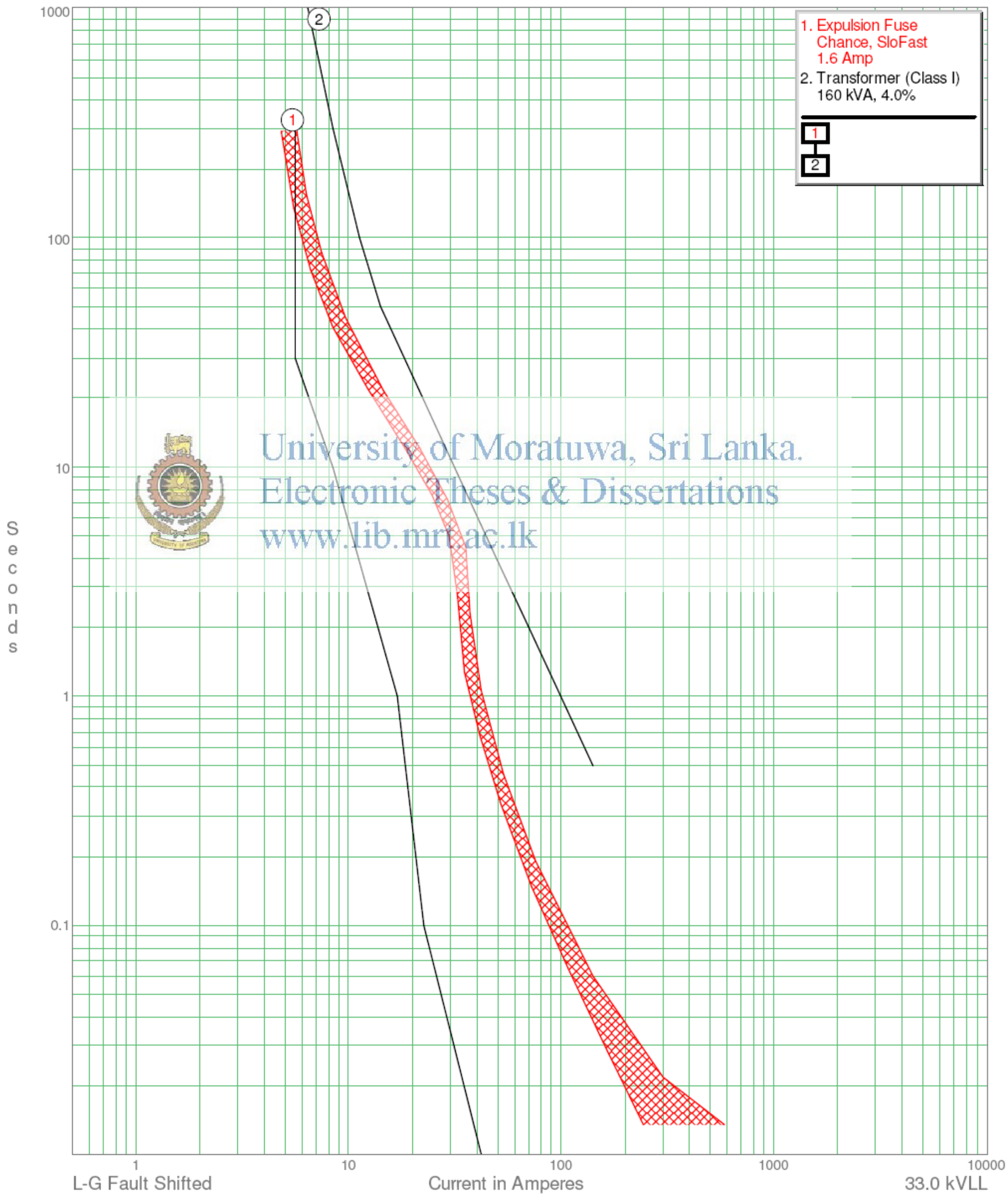
11. TCC for 800kVA 11/0.4kV transformer with 65A fuse



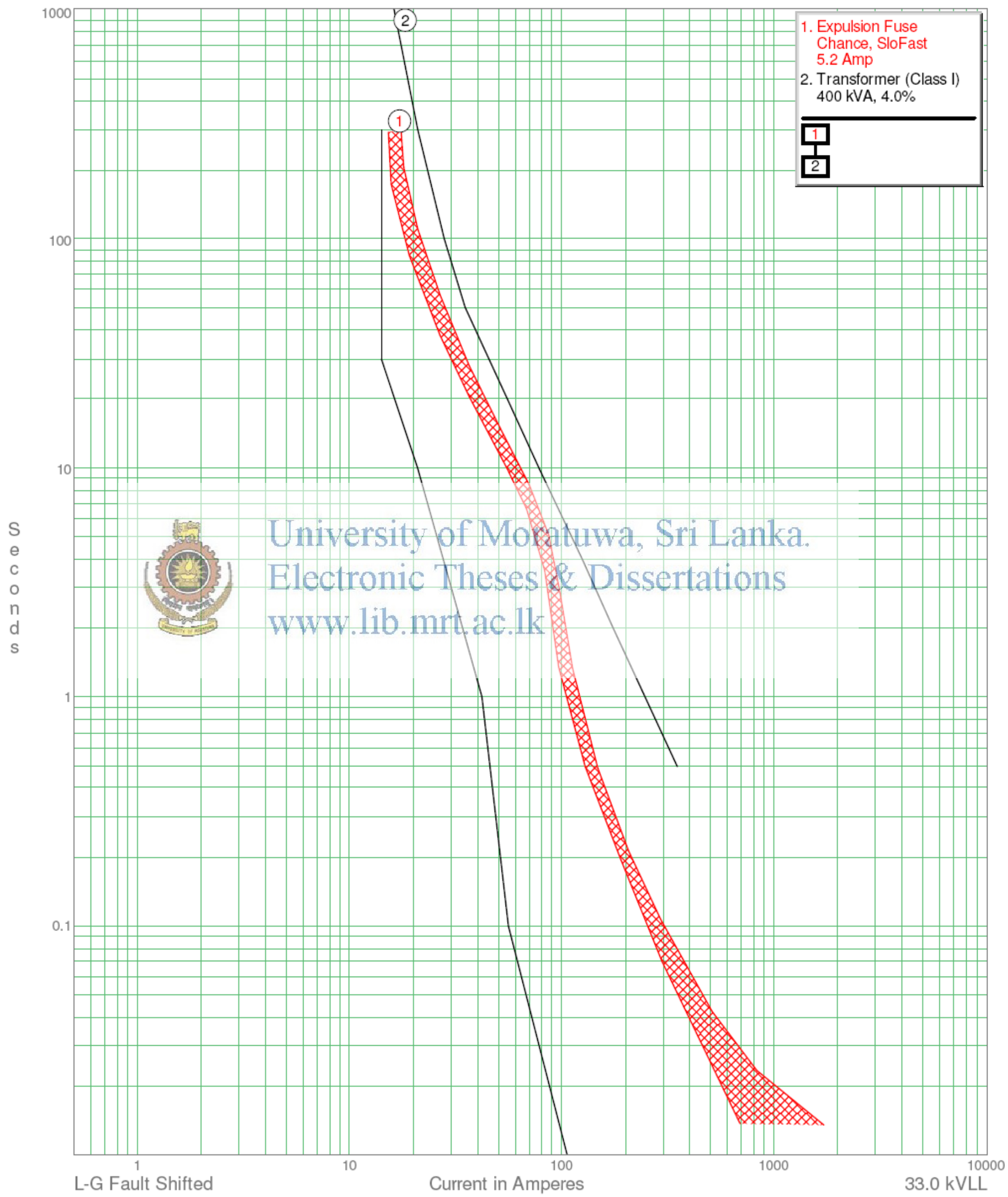
Annex-2

SloFast Fuse Selection

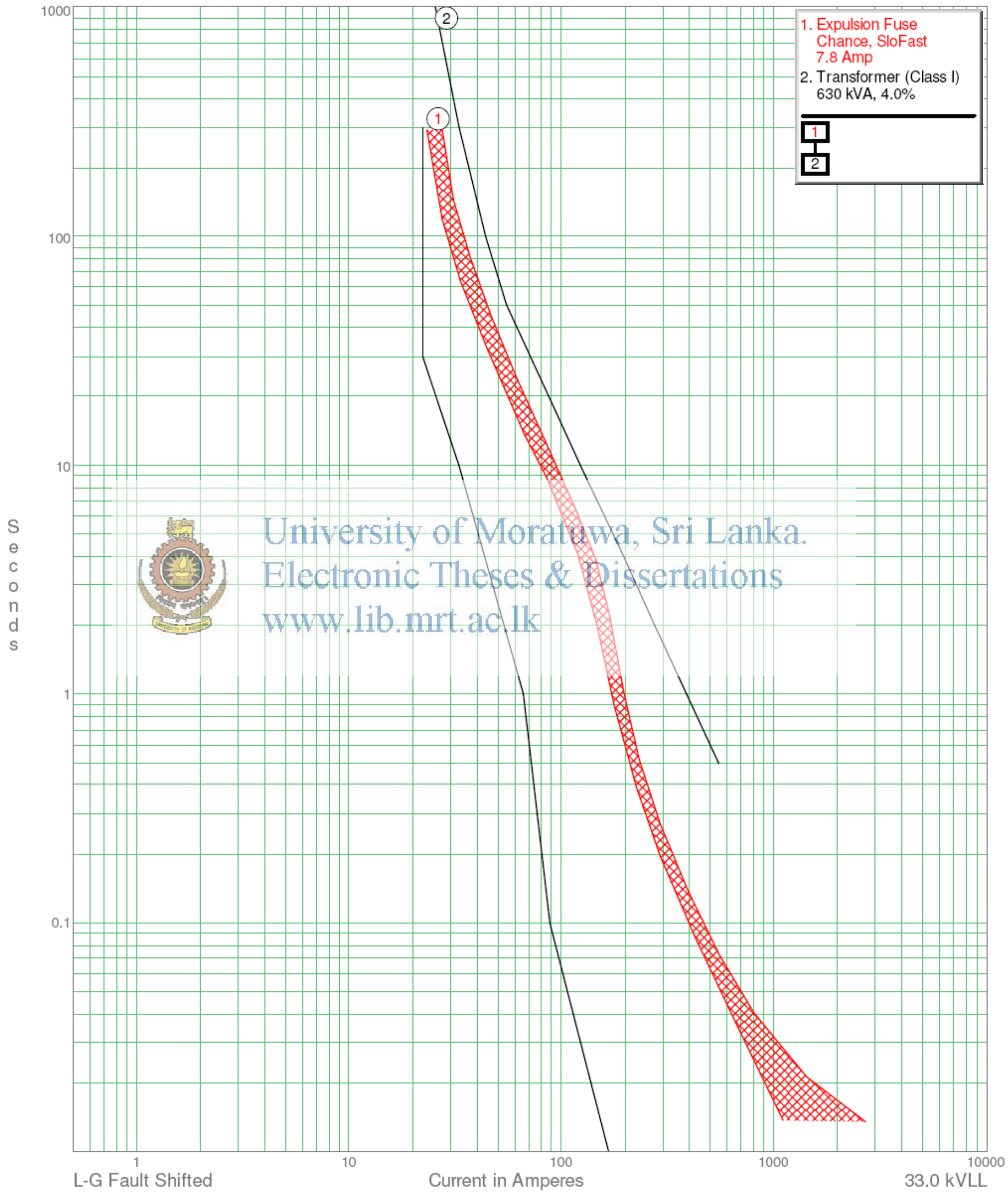
1. TCC curve for 160kVA 33/0.4kV transformer with 1.6A rated SloFast Fuse



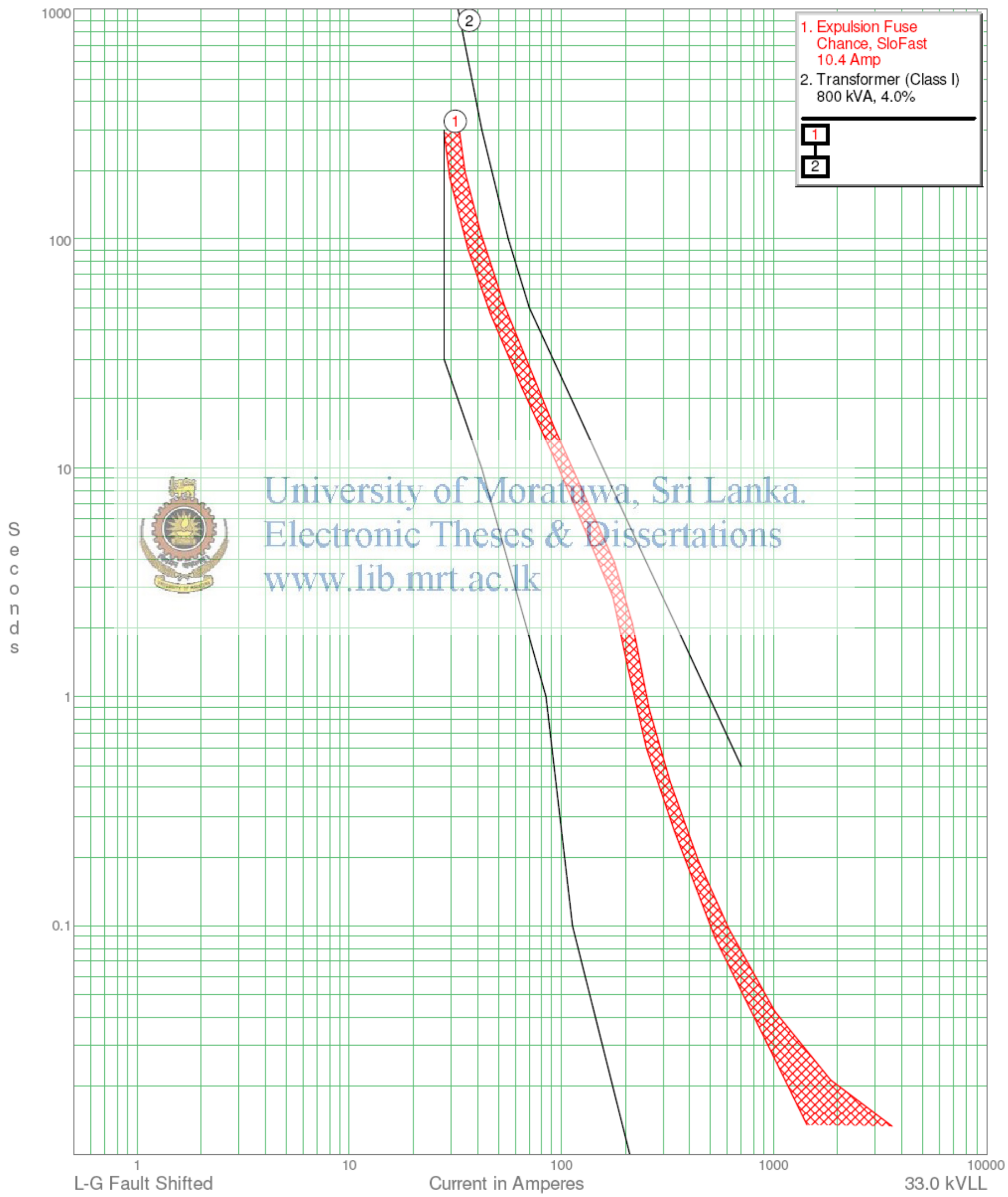
2. TCC curve for 400kVA 33/0.4kV transformer with 5.2A rated SloFast Fuse



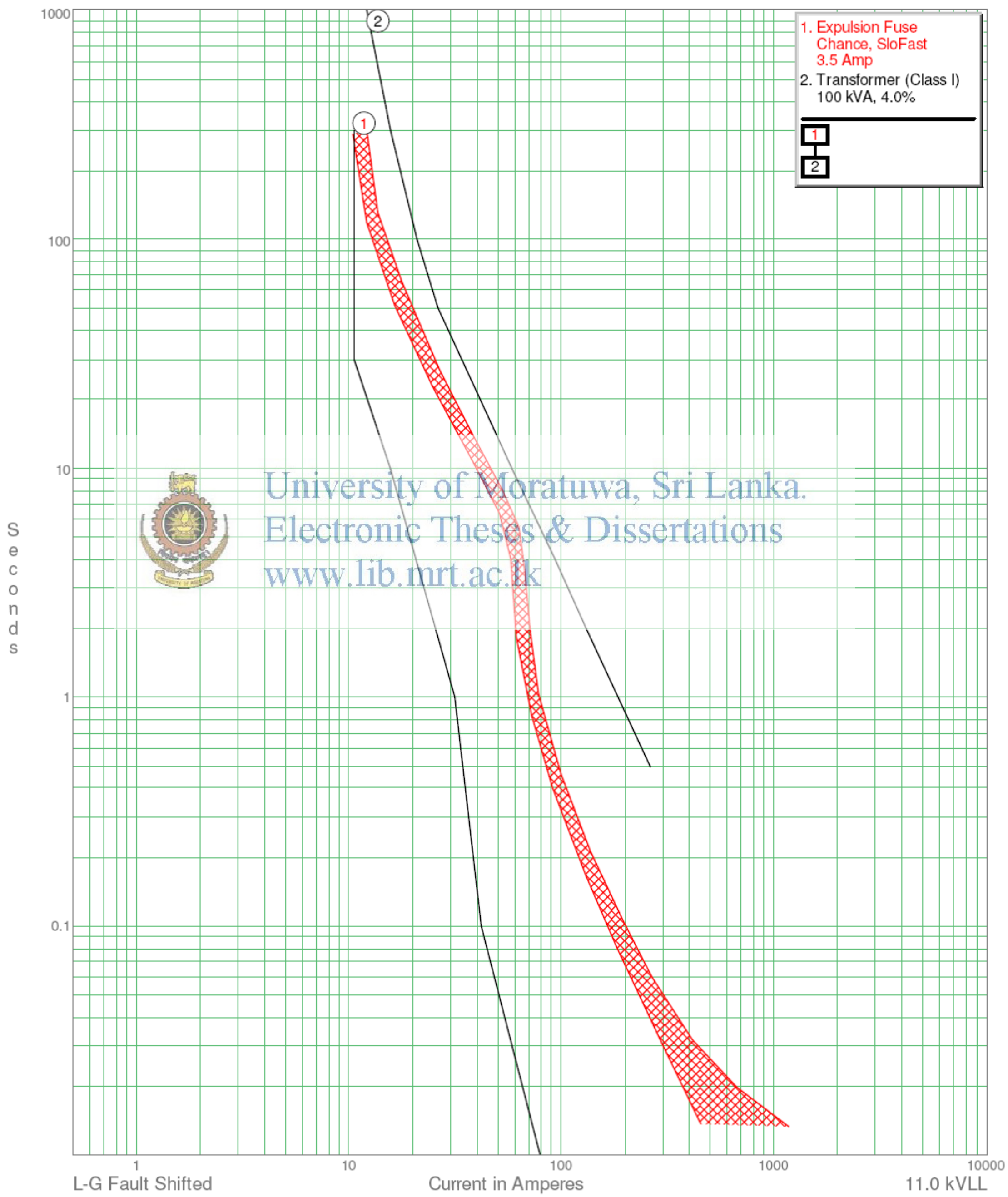
3. TCC curve for 630kVA 33/0.4kV transformer with 7.8A rated SloFast Fuse



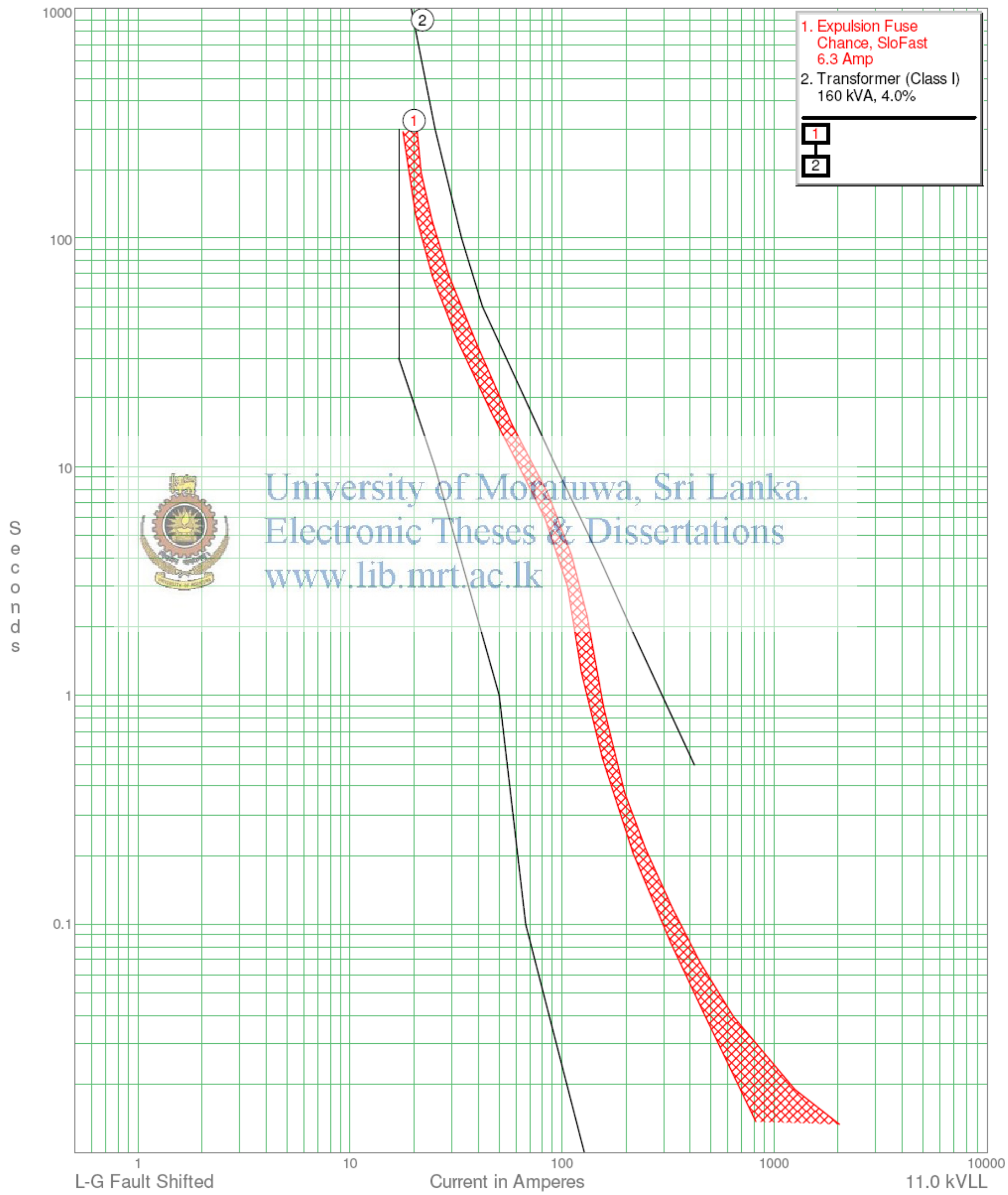
4. TCC curve for 800kVA 33/0.4kV transformer with 10.4A rated SloFast Fuse



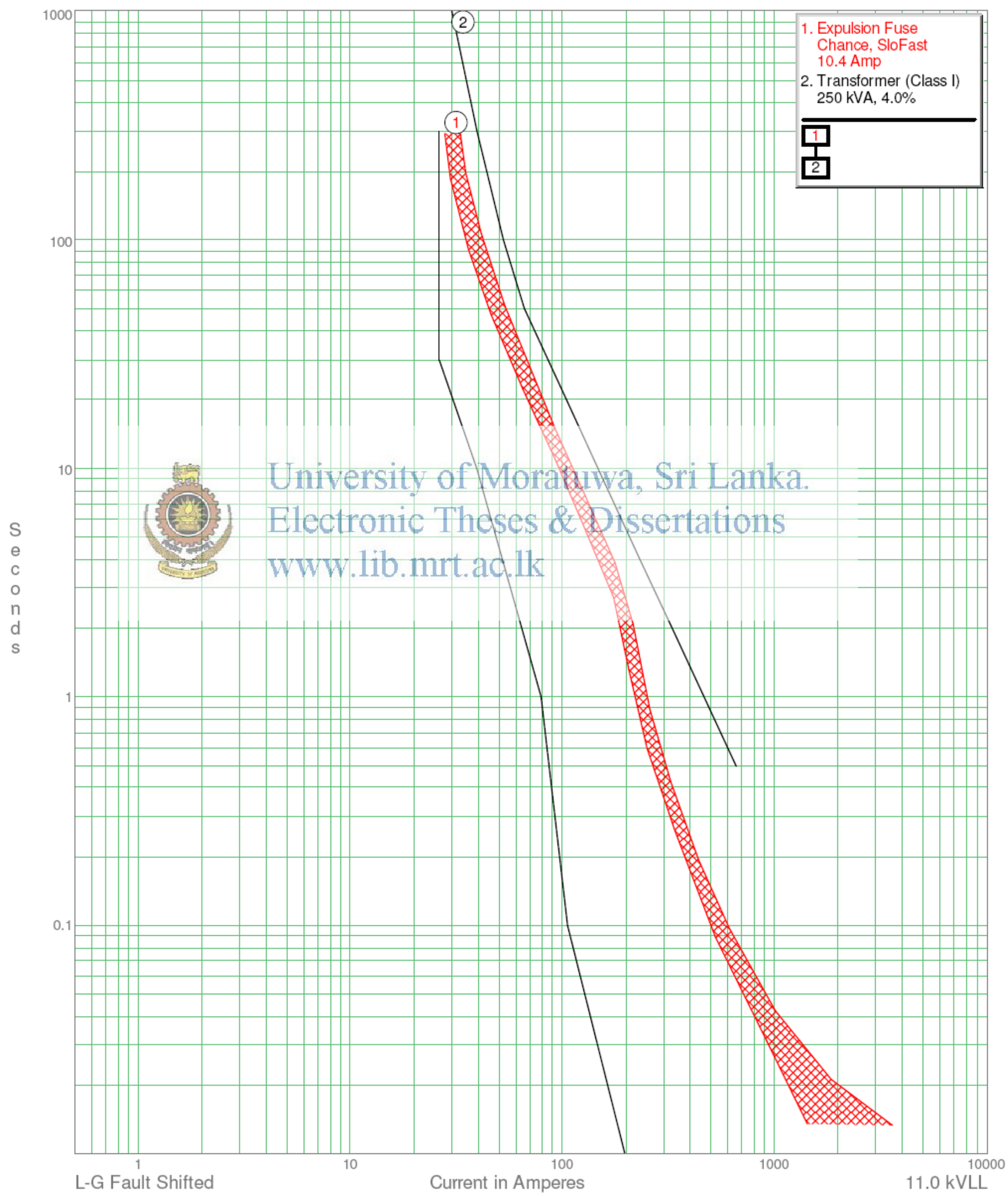
5. TCC curve for 100kVA 11/0.4kV transformer with 3.5A rated SloFast Fuse



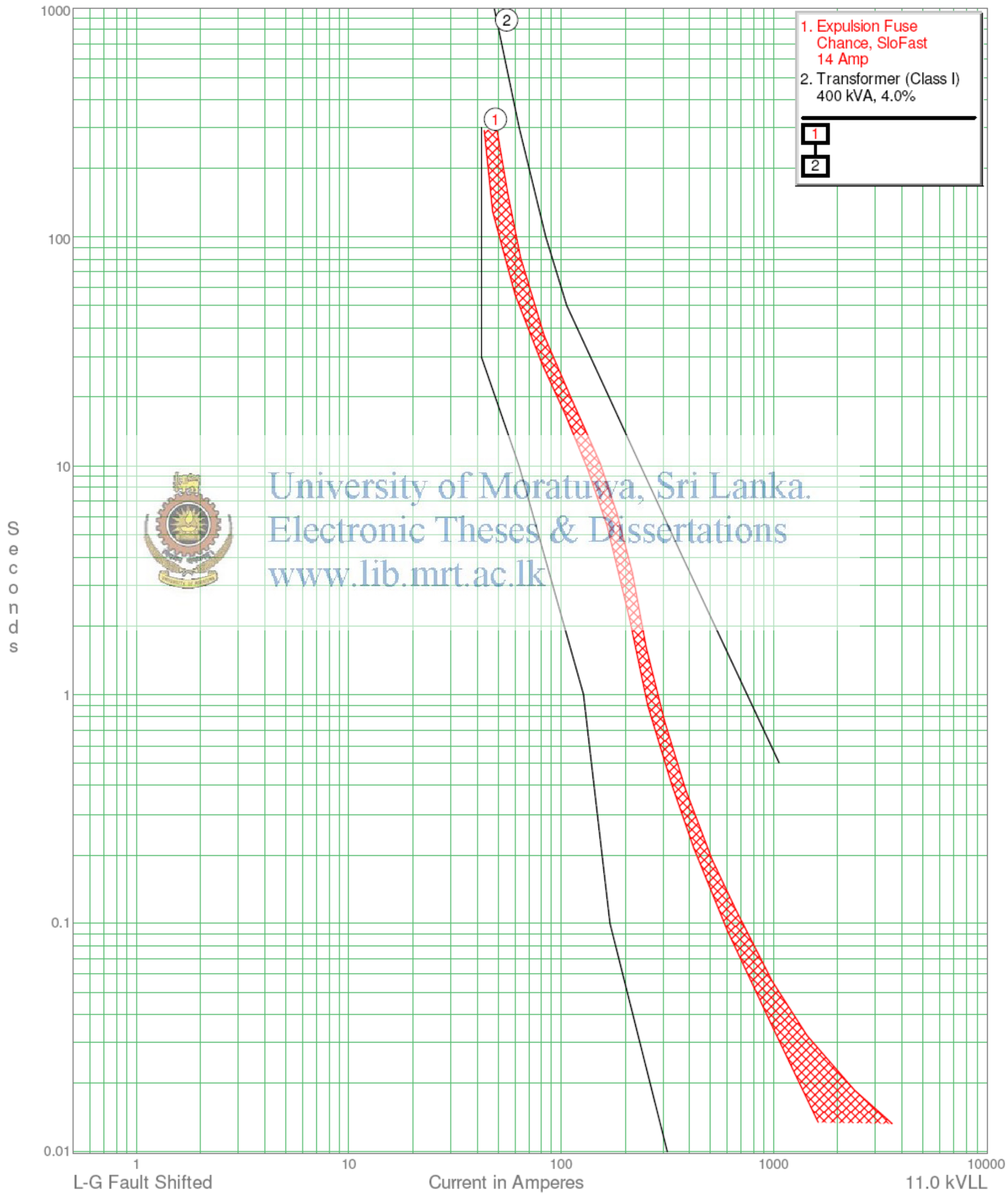
6. TCC curve for 160kVA 11/0.4kV transformer with 6.3A rated SloFast Fuse



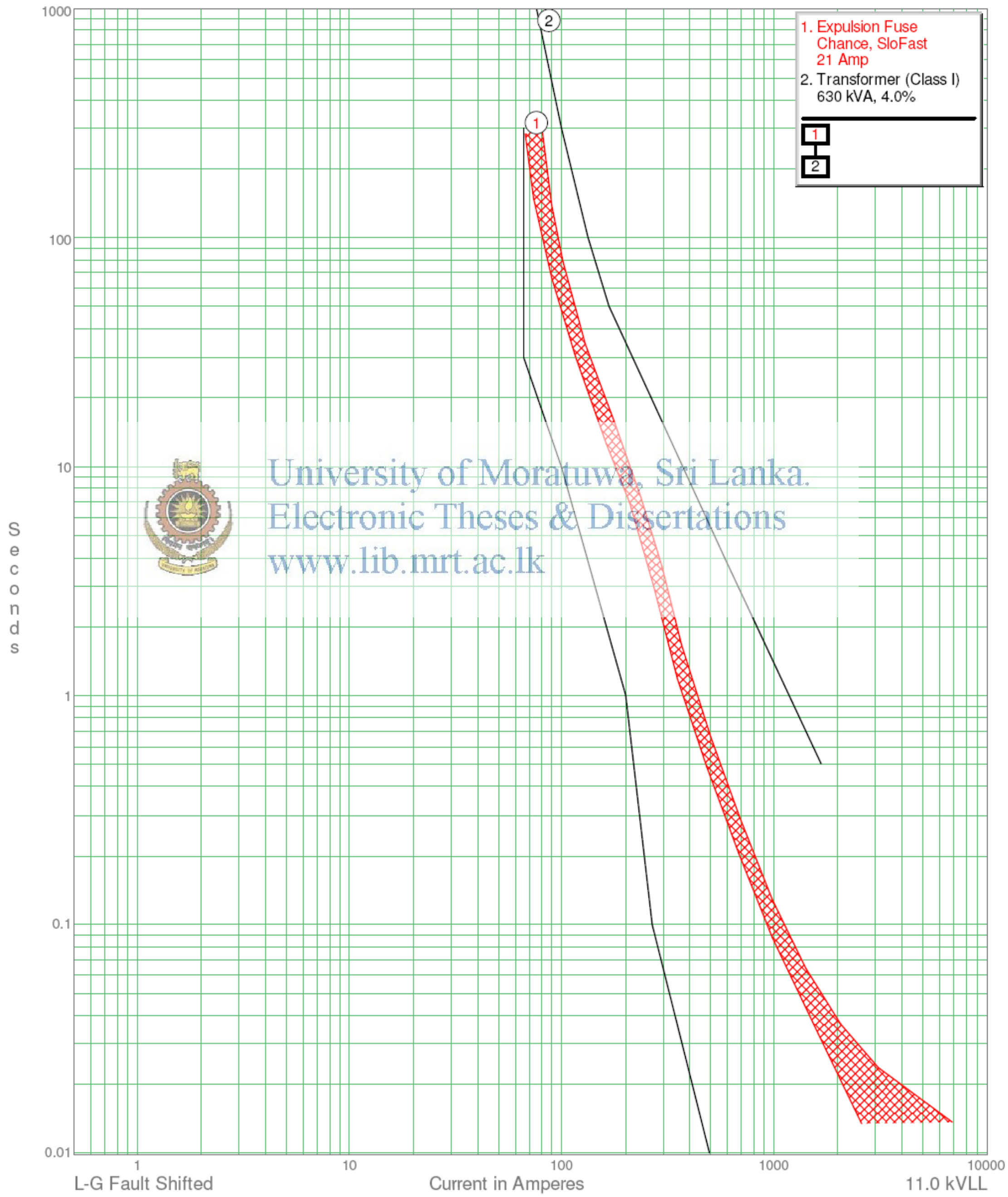
7. TCC curve for 250kVA 11/0.4kV transformer with 10.4A rated SloFast Fuse



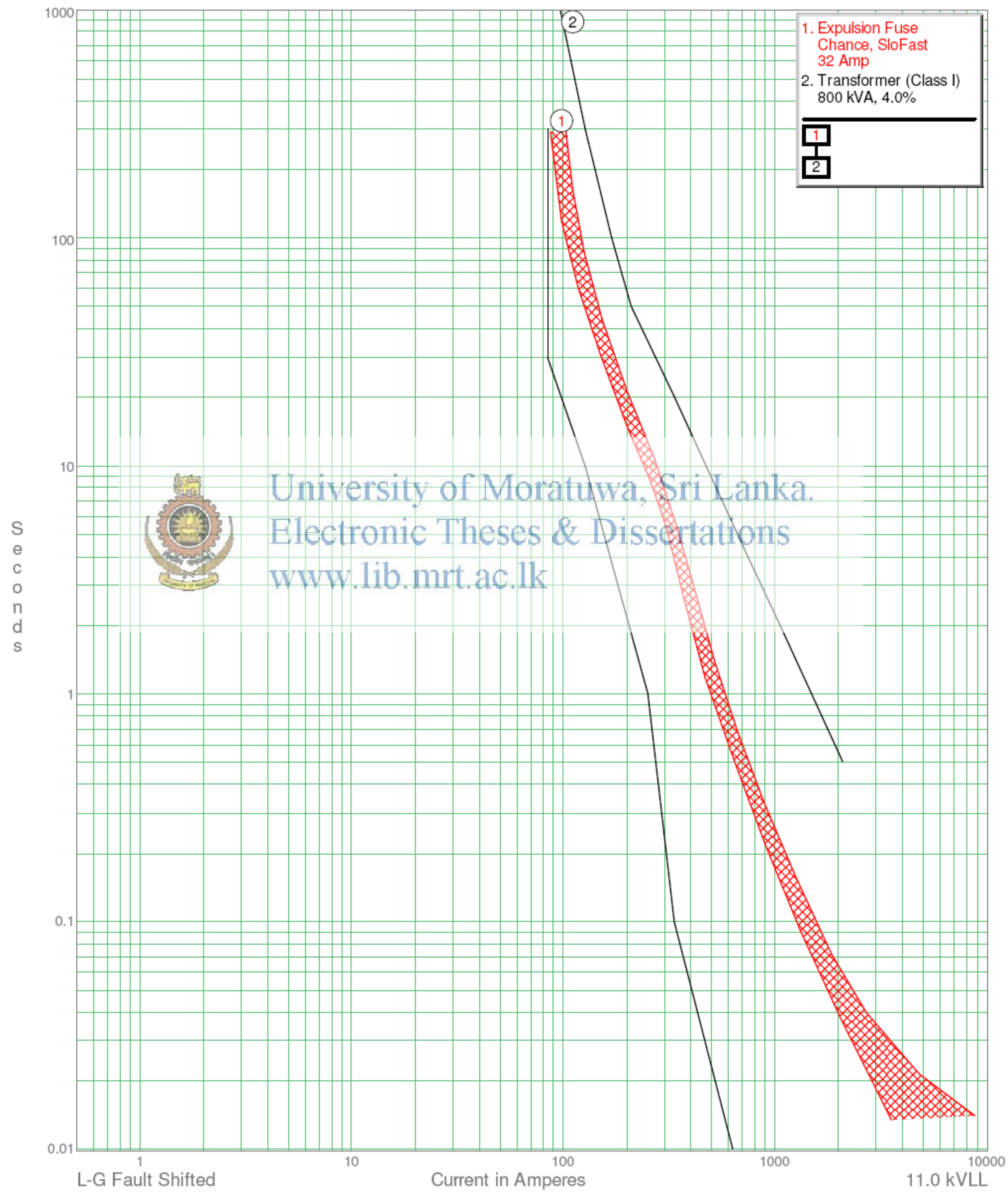
8. TCC curve for 400kVA 11/0.4kV transformer with 14.0A rated SloFast Fuse



9. TCC curve for 630kVA 11/0.4kV transformer with 21.0A rated SloFast Fuse



10. TCC curve for 800kVA 11/0.4kV transformer with 32.0A rated SloFast Fuse



160kVA Substration Peak Load Reading in Ambalangoda Area **Annex 4**

	Substation Name	Sin No	Capacity	KVA Load	Load %	Feeder 1				Feeder 2				Feeder 3				Feeder 4				Total				% of per phase loading
						R	Y	B	N	R	Y	B	N	R	Y	B	N	R	Y	B	N	R	Y	B	N	
1	Thilakapura New	AS012	160	**92.23**	**58%**	98	68	70	40	10	50	32	36	34	15	24	22					142	133	126	98	<80%
2	Dalukanda Tsunami	AS025	160	**33.81**	**21%**	10	22	20	10	25	20	15	10	10	10	15	10					45	52	50	30	<80%
3	Vocational Tra	AS027	160	**48.3**	**30%**	25	20	15	5	15	25	45	8	25	20	20	5					65	65	80	18	<80%
4	Thalgasgoda CTB	AS030	160	**193.2**	**121%**	90	110	100	50	110	100	100	10	20	20	20	40	100	30	40	40	320	260	260	140	>100%
5	Unagaswela	AS080	160	**116.15**	**73%**	30	60	60	40	30	50	60	40	60	65	90	20					120	175	210	100	80% -100%
6	Madakumbura	AS090	160	**144.9**	**91%**	47	85	85	37	90	100	105	25	75	8	35	52					212	193	225	114	80% -100%
7	Magala North	AS112	160	**143.29**	**90%**	120	110	98	35	75	80	60	20	50		30	50					245	190	188	105	>100%
8	LenagalaPalatha	AS114	160	**86.48**	**54%**	160	75	80	90	5	38	18	32									165	113	98	122	<80%
9	Borakanda	AS150	160	**170.43**	**107%**	45	50	50	15	45	50	95	60	140	100	140	40	9	12	5	12	239	212	290	127	>100%
10	MahaEdanda	AS160	160	**112.7**	**70%**	50	70	70	40	70	90	140	45									120	160	210	85	80% -100%
11	Amarakeerthigama	AS167	160	**46.92**	**29%**	10	10	15	5	25	22	20	5	30	32	40	10					65	64	75	20	<80%
12	Patteraketiya	AS180	160	**120.75**	**75%**	65	65	55	25	50	60	55	25	60	65	50	22					175	190	160	72	80% -100%
13	Kirimetiya	AS190	160	**108.56**	**68%**	60	65	120	50	95	25	65	35	42	0	0	38					197	90	185	123	80% -100%
14	Dorala	AS200	160	**181.01**	**113%**	75	80	50	20	50	63	55	22	78	60	62	29	48	55	46	17	260	306	221	121	>100%
15	Kahatapitiya TF	AS210	160	**183.31**	**115%**	66	39	54	27	72	129	61	52	72	120	60	48	40	47	37	7	250	335	212	134	>100%
16	Sunil Garment	AS220	160	**25.3**	**16%**	40	35	35	5													40	35	35	5	<80%
17	Illukpitiya	AS260	160	**249.55**	**156%**	150	145	150	30	100	100	150	30	100	80	110	30					350	325	410	90	>100%
18	Meetiyagoda Town	AS290	160	**174.8**	**109%**	100	200	100	75	110	100	150	75									210	300	250	150	>100%
19	Galduwa	AS300	160	**88.78**	**55%**	63	97	68	31	8	15	22	11	31	30	52	25					102	142	142	67	<80%
20	Galagoda Tsunami-1	AS302	160	**40.25**	**25%**	10	10	8	5	22	25	20	15	20	30	30	10					52	65	58	30	<80%
21	Galagoda Tsunami-11	AS305	160	**34.04**	**21%**	20	25	25	5	10	12	8	4	15	18	15	4					45	55	48	13	<80%
22	Galagoda Tsunami-111	AS313	160	**20.7**	**13%**	20	18	20	5	12	10	10										32	28	30	5	<80%
23	Galduwa New Colony	AS315	160	**20.7**	**13%**	20	20	15	6	10	10	15	5									30	30	30	11	<80%
24	Pathegama	AS340	160	**181.7**	**114%**	100	125	100	40	70	25	70	30	130	50	120	50					300	200	290	120	>100%
25	Ambana-Sinha Kawaya	AE 020	160	**143.98**	**90%**	66	80	81	28	74	90	66	18	58	53	58	6					198	223	205	52	80% -100%
26	Kahaduwa	AE30	160	**126.04**	**79%**	48	41	35	13	19	28	35	17	52	75	58	18	45	72	40	25	164	216	168	73	80% -100%
27	Andurathwila	AE40	160	**64.86**	**41%**	54	26	16	35	26	64	96	57									80	90	112	92	<80%
28	Miriswatta T/F	AE50	160	**68.31**	**43%**	5	0	8	7	90	87	107	30									95	87	115	37	<80%
29	Eramulla T/F	AE60	160	**100.74**	**63%**	44	17	44	29	96	44	43	54	40	60	50	17					180	121	137	100	<80%
30	Gonathippala	AE65	160	**27.6**	**17%**	49	34	37	16													49	34	37	16	<80%
31	Polgahawila Nugetota	AE90	160	**54.51**	**34%**	9	14	19	5	16	18	2	1	29	51	39	0	6	7	27	21	60	90	87	27	<80%
32	Agaliya Mulkada	AE100	160	**76.36**	**48%**	40	16	3	36	70	45	41	29	17	50	50	40					127	111	94	105	<80%
33	Ella Ihalagoda	AE120	160	**68.77**	**43%**	59	53	91	34	7	43	13	30	15	6	12	14					81	102	116	78	<80%
34	Ellawatta T/F	AE140	160	**104.88**	**66%**	27	39	46	13	11	1	28	16	76	68	34	39	56	36	34	54	188	162	168	123	80% -100%
35	Kurundugaha Gantry Sub	AE180	160	**28.75**	**18%**	10	9	3	7	16	41	46	25									26	50	49	32	<80%
36	Igalkanda	AE190	160	**38.64**	**24%**	0	3	18	18	0	0	0	0	91	37	11	59	1	4	3	4	92	44	32	81	<80%
37	Kurundugahahethekma	AE200	160	**70.38**	**44%**	50	74	83	34	56	18	25	52									106	92	108	86	<80%
38	Saranankara	AE240	160	**115.92**	**72%**	52	89	91	20	53	25	34	16	41	21	5	26	40	49	4	22	186	184	134	84	80% -100%
39	Thilaka T/F Pituwala	AE260	160	**80.362**	**50%**	92	46	48	40	30	40	21	23	16	33	23	15	0.3	0	0.1	0.3	138	119	92	78	<80%
40	Pituwala	AE270	160	**126.73**	**79%**	95	92	85	15	18	43	11	28	74	73	60	15					187	208	156	58	80% -100%

41	Elpitiya T'Com	AE280	160	**101.43**	**63%**	16	30	54	4	63	46	40	23	45	60	32	23	20	18	17	5	144	154	143	55	<80%
42	Vocational Training	AE310	160	**34.96**	**22%**	78	29	40	35	3	1	1	1									81	30	41	36	<80%
43	Rajamaha Vihara Mawatha	AE320	160	**43.93**	**27%**	54	34	17	21	40	17	29	19									94	51	46	40	<80%
44	Ketapola RE	AE330	160	**54.97**	**34%**	53	73	28	31	3	5	1	3	59	13	4	54					115	91	33	88	<80%
45	Police Training	AE340	160	**46**	**29%**	43	2	28	35	21	18	45	23	16	12	15	6					80	32	88	64	<80%
46	Omaththa	AE380	160	**53.36**	**33%**	27	29	20	17	14	26	32	18	21	12	10	14	5	36		32	67	103	62	81	<80%
47	Opatha	AE400	160	**30.13**	**19%**	21	22	12	5	30	14	29	16	1	1	1	0					52	37	42	21	<80%
48	Maitheegama	AE420	160	**225.4**	**141%**	95	112	131	7	89	96	119	12	112	119	107	8					296	327	357	27	>100%
49	Mukalanhena	AE426	160	**35.19**	**22%**	2	58	5	50	41	13	34	30									43	71	39	80	<80%
50	Batuwanhena(Kumarasingh	AE428	160	**81.19**	**51%**	63	50	97	40	2	1	1	2	20	61	58	53					85	112	156	95	<80%
51	Nawadagala Jambugahahe	AE430	160	**83.03**	**52%**	39	20	31	20	5	88	46	68	46	40	46	23					90	148	123	111	<80%
52	Thilini Metal Crusher	AE432	160	**1.15**	**1%**	2	1	2	1													2	1	2	1	<80%
53	Atakohota	AE440	160	**77.74**	**49%**	6	24	31	24	3	62	56	37	67	59	30	37					76	145	117	98	<80%
54	Hipanwatta	AE447	160	**48.3**	**30%**	4	3	9	6	27	19	29	12	19	28	27	12	8	21	16	9	70	94	96	52	<80%
55	6th Mill post	AE 449	160	**68.54**	**43%**	10	43	35	30	9	12	25	10	25	71	68	40					44	126	128	80	<80%
56	11 Mill post	AE450	160	**89.01**	**56%**	19	35	2	28	45	23	70	37	35	44	19	13	17	24	54	32	116	126	145	110	<80%
57	Talagaspe	AE490	160	**72.68**	**45%**	49	37	19	18	27	27	22	5	21	18	27	35	24	26	19	9	121	108	87	67	<80%
58	Kellapatha T/F	AE510	160	**41.86**	**26%**	38	43	31	13	31	21	18	21									69	64	49	34	<80%
59	Amaragama	AE520	160	**109.71**	**69%**	45	45	45	1	10	11	11	4	140	100	70	60					195	156	126	65	80% -100%
60	Amugoda	AE530	160	**109.25**	**68%**	37	49	65	34	26	34	52	52	78	93	29	56	1	9	2	9	142	185	148	151	80% -100%
61	Pitigala P/ St.Totupolr Ro	AE560	160	**31.05**	**19%**	15	21	39	17	12	12	18	5	3			4	5	3	7	8	35	36	64	34	<80%
62	Hattaka	AE610	160	**111.32**	**70%**	26	26	29	10	46	48	90	32	60	81	43	37	14	13	8	7	146	168	170	86	<80%
63	Uhanovita	AE620	160	**38.64**	**24%**	60	26	42	19	1	23	16	22									61	49	58	41	<80%
64	Pitigala North	AE630	160	**75.44**	**47%**	24	55	58	29	79	63	44	26	1	1	3	1					104	119	105	56	<80%
65	Sohana J.	AI 090	160	**140.798**	**88%**	110	90	110	25	12	26	100	28	15	25	30	20	22	45	38	20	159	186	278	93	>100%
66	Kirimetiyawa	AI 170	160	**87.688**	**55%**	18	45	30		30	35	40		30	20	60		25	25	30		103	125	160	0	<80%
67	Polathupalatha	AI 190	160	**132.075**	**83%**	28	11	0	10	2	6	12	8	105	120	110		38	70	85		173	207	207	18	80% -100%
68	Pathirajagama	AI 200	160	**151.42**	**95%**	70	30	70		80	100	130		70	20	100						220	150	300	0	>100%
69	Bridge Bentota	AI 225	160	**27.6**	**17%**	10	28	20	16	10	30	22	18									20	58	42	34	<80%
70	Galwehera	AI 290	160	**157.776**	**99%**	10	12	41	22	59	95	98	38	125	135	117	12					194	242	256	72	>100%
71	Piyagama	AI 320	160	**105.564**	**66%**	98	81	47	39	27	28	43	18	43	45	51	8					168	154	141	65	<80%
72	Wellangoda	AI 353	160	**81.42**	**51%**	75	63	53	26	53	50	60	8									128	113	113	34	<80%
73	Cinesco Village	AI 368	160	**28.06**	**18%**	28	31	19	12	11	18	5	5	5	3	2	0					44	52	26	17	<80%
74	Arora Village	AI 369	160	**28.75**	**18%**	15	36	21	18	12	36	5	19									27	72	26	37	<80%
75	Kosgoda Telecom	AI 400	160	**58.824**	**37%**	45	60	40	26	26	35	26	9	15	8	3	7					86	103	69	42	<80%
76	AIDA	AI 430	160	**90.06**	**56%**	130	125	140	15													130	125	140	15	<80%
77	Obadawatta	AI 440	160	**147.288**	**92%**	16	90	70	70	90	30	120	80	50	110	70	50					156	230	260	200	>100%
78	Sumanagiri	AI 555	160	**65.09**	**41%**	41	29	28	11	25	28	32	8	45	39	16	23					111	96	76	42	<80%
79	Etawalawatta	AI 560	160	**71.051**	**44%**	42	40	38	2	40	2	7	38	35	52	48	28	0	0	9		117	94	102	68	<80%
80	Gonagalapura	AI 590	160	**111.264**	**70%**	10	5	12	8	10	15	36	27	125	70	105	60	20	35	45	22	165	125	198	117	80% -100%
81	Swasthi mill	AI 610	160	**24.97**	**16%**	25	40	45	20													25	40	45	20	<80%
82	Galapatha	AI 650	160	**80.585**	**50%**	50	60	50	10	55	70	70	30									105	130	120	40	<80%
83	Adagantota	AI670	160	**103.512**	**65%**	85	132	73		10	16	40		15	26	57						110	174	170	0	<80%

84	Dedduwa Junction	AI675	160	**74.75**	**47%**	60	30	50	40		35	40	40	20		5	30	35	30							100	100	125	90	<80%
85	Haburugala	AI 680	160	**136.427**	**85%**	60	70	70	15		120	100	90	28		30	28	28	0		2	1	2	0		212	199	190	43	80% -100%
86	Thuduwa	AI 700	160	**142.783**	**89%**	46	100	100	40		65	130	140	75		25	13	10	12							136	243	250	127	>100%
87	Horawala J.	AI 710	160	**120.31**	**75%**	35	15	40	30		95	100	110	20		5	25	30	18		15	20	40	20		150	160	220	88	80% -100%
88	Green Garden	AI 725	160	**36.57**	**23%**	8	10	6	4		39	26	35	12		12	15	8	10							59	51	49	26	<80%
89	Pilekumbura	AI 730	160	**106.917**	**67%**	20	35	52	18		35	55	65	26		40	65	55	20		3	20	26	18		98	175	198	82	80% -100%
90	Gallindawatta	AT010	160	**41.4**	**26%**	50	50	80	30		0	0	0	0		0					0					50	50	80	30	<80%
91	Gurugodella	AT030	160	**59.11**	**37%**	110	105	41	68		0	0	1	1												110	105	42	69	<80%
92	Horangalla	AT060	160	**61.64**	**39%**	56	50	42	17		39	41	40	13												95	91	82	30	<80%
93	Dodangahawatte Wattehe	AT080	160	**80.73**	**50%**	83	56	77	20		31	59	45	30												114	115	122	50	<80%
94	Porawagama	AT100	160	**136.39**	**85%**	76	88	82	23		67	57	106	22		43	16	58	6							186	161	246	51	>100%
95	Marakanda	AT140	160	**80.73**	**50%**	78	81	76	26		38	38	40	3												116	119	116	29	<80%
96	Weihena	AT175	160	**91.54**	**57%**	56	27	35	24		80	88	112	33												136	115	147	57	<80%
97	Bambarawana	AT180	160	**73.37**	**46%**	18	50	49	31		60	60	82	85												78	110	131	116	<80%
98	Susantha T/F	AT190	160	**67.85**	**42%**	13	27	13	14		82	80	80	2												95	107	93	16	<80%
99	Godamuna T/F	AT220	160	**54.05**	**34%**	62	80	93	22																	62	80	93	22	<80%
100	Perusingha T/F	AT260	160	**65.09**	**41%**	80	26	49	40		30	98		76												110	124	49	116	<80%
101	Hillway T/F	AT290	160	**61.64**	**39%**	20	23	41	25		32	52	81	43		6	6	7	3							58	81	129	71	<80%
102	Mapalagama Central	AT330	160	**37.95**	**24%**	57	58	28				7	15													57	65	43	0	<80%
103	Silvery T/F	AT410	160	**106.03**	**66%**	58	38	40	18		125	100	100	26												183	138	140	44	<80%
104	Nagoda walauwatta	AT420	160	**117.3**	**73%**	56	69	83	27		13	36	47	37		56	45	57	14		38	7	3	36		163	157	190	114	80% -100%
105	Gonalagoda	AT430	160	**121.67**	**76%**	14	38	80	20		38	32	125	90		60	100	42	50							112	170	247	160	>100%
106	Ranavirugama	AT440	160	**99.36**	**62%**	109	102	86	17		63	30	42	23												172	132	128	40	<80%
107	Keppitiyagoda	AT450	160	**73.14**	**46%**	80	14	24	70		30	80	90	21												110	94	114	91	<80%
108	Udalamatta	AT480	160	**139.38**	**87%**	90	90	70	26		75	100	115	12		10	16	40								175	206	225	38	80% -100%
109	Rukmalgoda	AT500	160	**105.34**	**66%**	102	36	45	57		8	32	14	24		69	80	72	20							179	148	131	101	<80%
110	Rathnaudagama	AG020	160	**125.81**	**79%**	42	32	54	22		129	94	69	30		27	32	68	31							198	158	191	83	80% -100%
111	Rejjipura	AG040	160	**99.36**	**62%**	55	48	61	18		95	75	98	15												150	123	159	33	<80%
112	Imbulgoda	AG050	160	**117.99**	**74%**	60	55	55	5		73	65	70	5		40	35	60	10							173	155	185	20	80% -100%
113	Panwila	AG060	160	**82.34**	**51%**	45	52	66	20		61	59	75	19												106	111	141	39	<80%
114	Mawadawila	AG070	160	**91.77**	**57%**	76	56	29	44		2	3	1	2		57	61	114	56							135	120	144	102	<80%
115	Dewapathiraja School	AG086	160	**6.44**	**4%**	8	10	10	5																	8	10	10	5	<80%
116	Thelwatta	AG120	160	**71.76**	**45%**	49	55	30	20		68	70	40	25												117	125	70	45	<80%
117	Kiralagahawila	AG140	160	**82.8**	**52%**	50	45	45	6		75	85	60	25												125	130	105	31	<80%
118	Jo Lanka	AG195	160	**127.65**	**80%**	190	180	185	6																	190	180	185	6	80% -100%
119	Veihena	AG250	160	**31.05**	**19%**	44	49	42																		44	49	42	0	<80%
120	Indurupathwila	AG260	160	**111.09**	**69%**	65	18	4			63	81	88	32		71	41	52	21		0	0	0	0		199	140	144	53	80% -100%
121	Nayapamula	AG280	160	**72.91**	**46%**	34	29	38	5		52	48	62	12		15	18	21	5							101	95	121	22	<80%
122	Halpathota Gin Ganga Wo	AG290	160	**96.14**	**60%**	54	68	75	20		76	61	84	26												130	129	159	46	<80%
123	Halpatota New city	AG295	160	**57.96**	**36%**	42	34	39	6		45	51	41	10												87	85	80	16	<80%

124	Arachchikanda	AG330	160	**72.059**	**45%**	44	49	20	30		18	13	1	17		75	42	24	43		12	1	14	13		149	105	59	103	<80%
125	Dodankahawila	AG340	160	**131.79**	**82%**	71	80	65	25		40	36	25	15		98	83	75	20							209	199	165	60	80% -100%
126	Ginimellagaha West	AG350	160	**86.25**	**54%**	52	96	32	59		45	31	27	29		34	40	18	28							131	167	77	116	<80%
127	Sirikandura watta	AG355	160	**68.54**	**43%**	64	52	59	6		36	39	48	17												100	91	107	23	<80%
128	Keradewela Majuwana	AG360	160	**112.47**	**70%**	10	12	8	5		80	90	72	19		17	35	34	20		30	48	53	25		137	185	167	69	80% -100%
129	Horagampita	AG400	160	**104.88**	**66%**	20	18	15	3		56	44	55	5	#	38	44	29	18		37	52	48	8		151	158	147	34	<80%
130	Baddegama new Bridge	AG420	160	**119.6**	**75%**	44	50	103	45		15	15	30	20		70	86	64	13		20	21	2	0		149	172	199	78	80% -100%
131	Baddegama WaterSupp. 1	AG430	160	**52.9**	**33%**	75	78	77	3																	75	78	77	3	<80%
132	Ruksarasewana	AG475	160	**22.31**	**14%**	20	22	34	17		0	0	9	9		8	4	0	6							28	26	43	32	<80%
133	Henegoda	AG515	160	**95.68**	**60%**	44	39	51	12		42	34	28	14		66	54	58	8							152	127	137	34	<80%
134	Ganegama South	AG580	160	**82.8**	**52%**	81	48	92	28		51	48	40	12												132	96	132	40	<80%