ELECTRICAL OVERCURRENT PROTECTION GRADING IN V4D

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CERTIFICATION OF APPROVAL

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December 2015.

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Miguel Angel Engonga Ela Akaba

ABSTRACT

Selective Coordination contributes to the localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the choice of overcurrent protective devices and their ratings and settings. Selective Coordination is critical for the reliability of electrical distribution system and must be analyzed and test regularly. A properly engineered and installed system will allow only the nearest upstream overcurrent protective device to open for both overload and all types of short-circuits, leaving the remainder of the systems undisturbed and preserving continuity of service. The aim of this study is to perform a Coordination and Overload study for the electrical installation in Village-4D T1, in order to know the root causes of the continuous tripping of its main Circuit Breaker which results in frequent power outage in the area. The revision of past researches was the first step taken toward understanding the concept involving protections; followed by a series of site inspections which helped gather the relevant data needed for the study such as the types of protective devices and their arrangement as well as the ratings. The methodology required a sensitivity analysis of the CBs in the area of study and Overload study in which fault levels were simulated using Simulink/MATLAB. The preliminary results of the study based on CBs level of sensitivity showed that V4D protective devices level of sensitivity is medium, therefore less prone to nuisance tripping outside the nominal tripping current. Thus sensitivity is not the factor causing the breaker to trip. However the results from the overload study show that the increasing number of overheating appliances used by students causes the circuit to overload, thus tripping the main breaker.

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LIST OF ABBREVIATIONS

NEC	National Electric Code
CB	Circuit Breaker
V4D	Village-4
UTP	Universiti Teknologi PETRONAS
ABB	ASEAN Brown Boveri
ELCB	Earth Leakage Circuit Breaker
RCCD	Residual Current Circuit Breaker
In	Nominal Current
OSHA	Occupational Safety and Health Act
BS 7671	British Standard 7671
RCB	Residual Current Breaker
RCD	Residual Current Device
AC	Alternating Current
ROC	Residual Operating Current

Chapter 1

INTRODUCTION

1.1 Background of Study

Reducing the risk of equipment damage in the event of an electrical fault, is the primary objective and the most important part of an electrical distribution systems. A major power outage will not only paralyze any ongoing activity, but will also have a considerable economic impact and in some cases, it can cause the loss of a valuable information which might have not been saved at the moment of the failure. Thus, it is an essential requirement that the design of electrical systems takes into account its Electrical Overcurrent Protection Grading or Selective Coordination.

1.1.1 Selective Coordination

Article 100 of the National Electric Code (NEC) defines Selective Coordination as the localization of an overcurrent condition to restrict outages to the circuit or equipment affected, accomplished by the choice of overcurrent protective devices and their ratings or settings [1]. It refers to the selection and setting of protective devices in an electric power system in such a manner as to cause the smallest possible portion of the system to be de-energized due to an abnormal condition. Being overcurrent condition the most commonly encountered abnormality.

It is important to wisely select overcurrent protective devices while designing electrical distribution systems. Major power failures are sometimes the consequences of inconsistent devices and ratings (or settings) selection. However a good device and ratings selection will determine if a system is selectively coordinated.

Electric Protective devices include:

- Lightning arresters
- Surge protectors
- Fuses and Relays
- Circuit Breakers and
- Reclosers

A power distribution system properly coordinated will open the downstream protective device nearest to the fault, leaving the rest of the system unaffected.

1.1.2 Selective Coordination Avoids Blackout

Figure 1 shows conditions to illustrate selective coordination operation. The diagrams represent two electrical distribution systems with their corresponding Bus-bar, protective devices and loads. The systems to the right is selectively coordinated what means that if an electrical fault occurs at one of its downstream circuit, only the nearest upstream Circuit Breaker (CB) protecting the affected area will open thus isolating it from the rest of the systems as can be seen in the line-diagram. The remaining parts of the system will not be affected.

The systems to the left is not selectively coordinated thus a fault on one of the circuits, will open unnecessarily all the upstream circuit breakers, resulting on unwanted power loss on loads that should have not been affected. In addition, if the overcurrent occur on a feeder circuit, a selectively coordinated system will open the immediate upstream overcurrent protective devices to isolate the feeder.

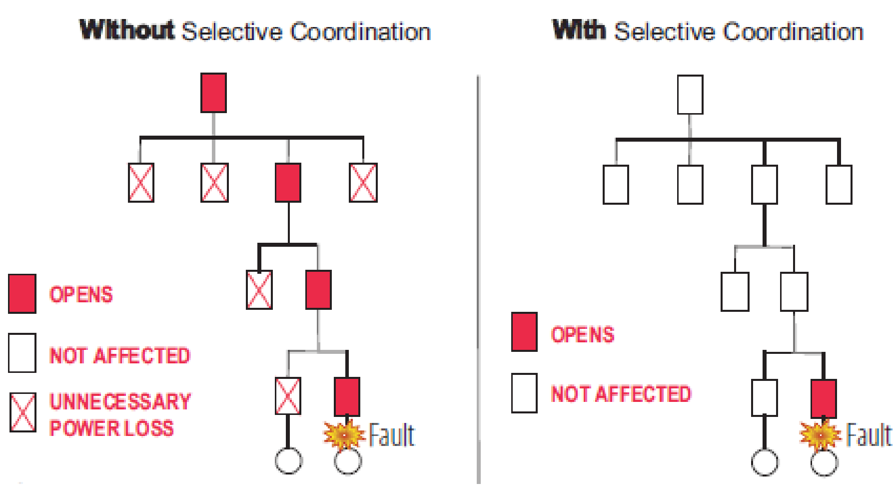

Figure 1: ***Line-Diagram illustrating selective coordination***

1.2 Problem Statement

The Village-4 D (V4D) is located within Universiti Teknologi PETRONAS (UTP) campus. It is one of the newest student hostels built in response to the increasing number of student in the campus. The V4 is divided into blocks being V4D one of the blocks.

V4D T1 regularly experience power outages caused by the tripping of the main CB located at the pantry. This power failure disturbingly leaves without electricity all the rooms in V4D T1 compartment. In consequence, student sometimes lose unsaved valuable information since it gives them no time to properly save their files and shutdown the computers. Thus the purpose of this project is to provide UTP with a coordination study for all existing installation in V4D T1 for it will help us to quickly detect the root causes of the power loss and come up with their possible solutions.

The basic hypothesis here is that due to poor maintenance and/or testing of the protection system, the risk for protective device miscoordination in the event of an overcurrent condition is high. What would unnecessary trip the man CB at V4D T1 pantry resulting in electrical power loss in the affected area.

1.3 Project Objectives

The primary objective of this project is to carry on a protection system study for the electrical installation in V4D T1, in order to know the causes of the continuous power loss in that area. The study aims to provide UTP with a time current curves for all the affected protective devices.

The specific objectives of the project are:

a. To survey the protective device settings for V4D T1
b. To evaluate coordination against protection principles
c. To propose a new device settings or alternative arrangement for protective devices in V4D T1 for proper overcurrent protection grading thus achieving devices coordination and maximizing protection system's selectivity, reliability and speed.

1.4 Scope of the Study

This study focuses mainly on V4D T1 protective devices. These devices are principally ASEA Brown Boveri (ABB) and Earth Leakage CBs (ELCB). The ABB CBs are of type Residual Current Circuit Breaker (RCCB) –F362, having a nominal current (In) of 63Amps. The Earth Leakage CBs are of type DZ47-60 with a rated current of 20 Amps each. . Most of the data gathering was done through site inspections with the help of the system One-Line-Diagram. Through site inspection, it was possible to check the protective devices in the area of study and their ratings.

Chapter 2

LITERATURE REVIEW

Basically all electrical installations experiences overcurrent. Unless removed in time, even moderate overcurrents quickly overheat system components, damaging insulations, conductors and equipment. Large overcurrent may melt conductors and vaporize insulation. Very high current produce magnetic forces that bend and twist bus bars. They can pull cables from their terminal and crack insulators and spacers. Very often fire explosions, poisonous fume and panic accompany uncontrolled overcurrent. They do not only damage electrical systems and equipment, but may cause injury or death to people around.

To reduce these hazards the (NEC), Occupational Safety and Health Act (OSHA) regulations and other applicable design and installation standards require overcurrent protection that will disconnect overload or faulted equipment [2]

Electrical systems must all meet applicable code requirement including those for overcurrent protection before electric utilities can provide electric power to a facility. Thus Littlefuse [3] defines a system with quality overcurrent protection as the one meeting the following characteristics:

- Meets all legal requirement such as NEC, OSHA, local codes etc.
- Provides maximum safety for personnel, exceeding minimum code requirements as necessary.
- Minimizes overcurrent damage to property, equipment, and electrical systems.
- Provides coordinated protection. Only protective devices immediately on the line side of an overcurrent opens to protect the systems.
- Is cost effective. Provides reserve interrupting capacity for future growth. Not subject to obsolescence. Requires minimum maintenance that can be done by regular maintenance personnel using readily available tools and equipment.

A basic rule to consider in electrical protection systems is that the downstream protective device should trip faster than the corresponding upstream device for any current equal or lower than the short circuit level of the area.

It should be noted that protections should be slow enough to allow the flow of normal current and overcurrent. However it should be faster to protect equipment.

2.1 Objectives of System Protection

Lewis B and Thomas J [4] clearly define the fundamental objective of a protection system as to isolate a faulty area of a power system as quickly as possible, minimizing in that way its impact to the rest of the system. Protections lack of the ability to prevent a fault or equipment failure from occurring. It will only act after the unwanted condition has occurred, limiting the problems that it may cause. The fundamental aspects of a protection system are:

- **Reliability**

  Reliability has two factors, dependability and security. Dependability is defines as the degree of certainty that a protection system will operate correctly [5]. Security relates to the degree of certainty that a protection system will not operate correctly [5]. Therefore dependability indicates the ability of a protection system to perform correctly when required, whereas security is its ability to avoid unnecessary operating during normal day-after-day operation and faults and problems outsides the designated zone of protection. Thus the protection must be secure, yet dependable.

- **Speed**

  A fault should be clear as quickly as possible in order to maximize safety, minimize equipment damage and minimize system instability. Thus it is desirable that a protection isolates a trouble zone as quickly as possible. Zero-time or very high speed protection may results in an increased number of undesired tripping. Generally, the faster the operation is the higher the probability on incorrect operation. A high-speed relay is one that operates in less than 50msec (three cycles on a 60Hz basis) [6]. Because speed is essential in clearing a damage element, to minimize the cost and delay in making repairs, protection should neither be too slow which may result in damage to equipment, nor should it be too fast which may result in undesired operations.

- **Simplicity**

  Protection systems should be as simple as possible to accomplish its goals

- **Sensitivity**

Sensitivity is the ability of the protection system to operate reliably under the real condition that produces the least operating tendency. The protection device must be sufficiently sensitive so that it will operate under the minimum condition expected. Protection system will operate reliably when level of fault condition just crosses the predefined limit.

- **Selectivity**

It is the ability to correctly locate and classify the fault. A relay should be able to discriminate whether the fault is in its jurisdiction or not. Thus jurisdiction of a relay is called zone of protection. Protection is arranged in zones are to make sure no part is left unprotected. When a fault occurs, the protection is required to select and trip the nearest CB only. It is also known as time discrimination.

2.1.1 Zones of Protection

A protective device zone of protection is a region which defines its jurisdiction. Protection are implemented in zones or areas of protection to limit or isolate the portion of the power system which is disconnected when a fault occurs, as shown in Figure 2. Ideally protection areas should overlap so that no area of the systems remain unprotected. However Rezon T. [7], on his analysis on power systems, realized that for practical, physical and economic reasons, this ideal is not always achieved. In the majority of the cases, current transformers are located only in one side of the switch. In that case there will be an area between the switch and the current transformer that is not fully protected in the event of a failure.

Protections are classified into primary and backup protection.

- **Primary protection**

  In primary protection, CBs are located in the connections to each power element making it possible to disconnect only the faulty element. A separate zone of protection is established around each system element. Any failure occurring within a given zone will cause the tripping of all CBs within that zone.

  Adjacent zones overlap around a CB. Relaying equipment of the zone trip not only the breakers within its zone but also one or more breakers of the adjacent zone.

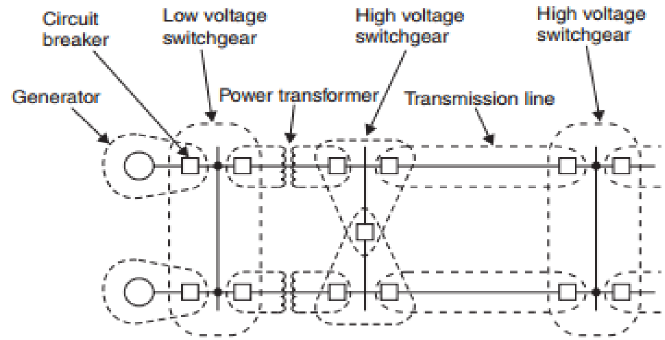

Figure 2: ***Zones of protection***

- **Backup protection**

Backup protection functions only if primary protection fails. It is arranged in a way that it does not control anything in common with the primary protection it backs-up. Back-up protection provides primary protection when the primary protection equipment is out of service for maintenance or repair.

Figure 3 illustrates the concept of backup protection, where we have three zones of protection. Zones of protection 1 and 2 are protected by the CB located in panel board C, which in this case act as a backup to the main CB in panel B in zone-2.

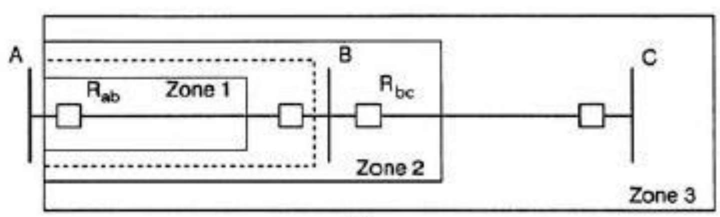

Figure 3: ***Backup Protection***

2.2 The Discrimination Principle

Protection functions form a consistent system depending on the overall structure of the power distribution system and the neutral grounding arrangement. They are based on the "Principle of Discrimination which consists of isolating the faulty part of the power system and only that part as quickly as possible, leaving all the fault-free parts of the power system energized" [8].

Discrimination is implemented through:

- Time based discrimination
- Current-based discrimination
- Data exchange discrimination
- Directional discrimination
- Differential discrimination and
- Combined discrimination

2.3 Protective Devices: Residual Current Circuit Breakers

British Standard 7671 (BS 7671) defines Residual Current Breaker (RCB) as a switching protective device which will isolate the protecting circuit, by impeding the flow of residual current after it has reached certain value within the predefined conditions [9].

Residual Current Devices (RCD) serve as disconnectors of flow of electrical current during unwanted situations caused by overcurrent, lightning or cable insulator melting. For single phase circuits, the device checks the continuous reading of current between both line and neutral conductors [10].

For circuit with high degree of stability, the sum of the current in both line and neutral conductors is zero during normal operations. When a line-to-ground fault occurs, part of line current will not return through the neutral conductor. When fault current reaches a predefined value, the RCD will detect the difference in current therefore tripping to isolate the circuit.

RCD primary objective is to protect the installation from the abnormal situations that will damage the protecting equipment. It provides protection against fault, fire. However it does not properly protect the installation against overcurrent. Circuit Breakers and Fuses are the most appropriate protective devices for overcurrent.

2.4 Protection against Overcurrent

An overcurrent is a current exceeding the levels of rated Amperes of a conductor, an equipment or a device. The term overcurrent includes overload and short circuit, and the latter flows out of the normal pathways.

2.4.1 Overloads

An overload of the components of the installation occurs when a service nominal current intensities exceed the values assigned by the manufacturer for prolonged periods, and when the electrical equipment such as switches, motors, cables produce heat and reduce the useful life of the insulation. Intense overload quickly reach the temperature limits [12]. Overload protection should trip before it exceeds the permissible time and causes damage or short circuit in the system

2.4.2 Sustained Overload

Sustained Overloads are commonly caused by an over-installation of equipment such as public lighting, electromechanical equipment [12]. If the overload is not disconnected within the time limit, it will overheat the system components, causing thermal damage to the insulation and other parts of the electrical system. Sustained Overload protective devices will disconnect electrical circuits and equipment that are experiencing continuous overload before they are overheated.

2.4.3 Temporary Overload

The most frequently occurring overload faults are temporary overload, which are the results of the starting of inductive loads such as motors. Ideally Overload protection are not designed to trip during the starting of a motor [13]. Protective devices should have enough time delay to support sudden burst of engines and temporary overloads. However if a continuous fault occur, protective devices should instantly open the circuit before system equipment are damaged.

A short circuit in the other hand is a current outside the normal levels and cause by the rupture of the insulation or connection failure. During a normal operation of a circuit, total current draw is determined by the total connected load. While during a short circuit, current is bridged by a conductor

2.5 The lifespan of Electrical Conductor

The quality and correct use of electrical wires play a key role in the lifespan of the conductors as well as the building electrical installation. When the operating temperature of the conductor is not exceeded due to a correct selection of wires and there is a minimum rate of overload faults in the system, the lifespan of an installation is 20 years or more [14]. However, small overloads that may not be detected by protective devices, can shorten the lifespan of a conductor.

The continuous use of electrical appliances such as electric cooker, kettles and microwave must be accompanied by an analysis of the load capacity of the electrical system; to determine whether it can withstand the increasing power consumption due to the addition of more electrical appliances in the system. Otherwise the risk of electrical faults and power shortages affecting the system design will be very high [14]. The typical accidents that repeatedly occur in an electrical installation can be prevented if the safety and security on an electrical installations is considered during the system design.

A safe and reliable electrical installation is one in which its components guarantee that the probability of occurrence of electrical accidents that will endanger the consumers life, as well as the possibility of electrical faults in the electrical equipment will be minimized. Due to that, all electrical installations where poor quality devices have been used or where the designers did not consider the safety of the installation, a prone to repeatedly experience electrical faults and in consequence, power shortages.

2.5.1 Old Electrical Installations: Imminent danger

Old electrical installations should be the main focus of attention to the problem mention previously since they are not prepared to withstand the growing electrical demand [14]. Wires that have exceed their lifespan are the main cause of electrical accidents due to the following factors:

- The section of the conductors cannot withstand the increasing power consumption of the system

- Wires overheating produced by the excess of power consumption, result in an accelerated aging of the insulation
- Wire used are if power quality with differences in the actual section of the copper despite being of the same nominal section
- Mechanical damage to the cable produced during the installation when the cables are not channeled properly

In addition, it is highly recommend to consider that:

- The poor conditions of the insulation material due predominantly to the aging of the installation, can cause leakage current and short-circuit. The presence of moisture in the installation also increase this danger
- The uncontrolled growth of the installations through the use of extensions and without the assistance of qualified electricians can cause installation overload
- The acquisition of inappropriate materials, without certification, which generally do not meet standard requirements and product safety can put at risk the electrical installation as well as the consumers.
- The absence of preventive maintenance of the facility, increases the risk through aging of the installation.

The useful life of electrical wire of an installation is considered when it has been in service for a minimum of 20 years. After 20 years, the conductor and protective devices should be replaced or go through a more technical maintenance. In the same way, it is important to use installation remodeling for inspection and to determine if it is in conditions to withstand the load of appliances being used and that of those that will be used during the system expansion.

It should be considered that the use of old electrical wires can result in increased power consumption in the system, so that its renewal is the best alternative to have a safe and reliable installation. In this aspect, the designer plays an important role and must be aware of the risk associated with having an installation in poor condition.

2.5.2 Typical loads in low voltage installations

Electrical loads can be of three types resistive, capacitive and inductive. An incandescent lamp is a resistive load, a motor is an inductive load and a capacitor bank is a capacitive load. Most loads of electrical appliances are combined with a large number of circuits that contain resistance and capacitance.

Different electrical appliances such as lamps, heaters, water pumps and electronic devices are frequently connected to the system. All of these are predominantly inductive and affect the system power factor. A great number of industries use capacitive loads to correct the power factor being 0.95 the preferable value for the system power factor [15]. A high value of power factor will help prevent the heating of distribution line due to an excess of reactive power transmission predominantly inductive. Analyzing the system electrical circuit help represent each of the system loads as impedance which is a combination of resistance and reactance. Their combination is represented as follows:

$$Z = R \pm jX \tag{2.1}$$

Where:

R is the resistance and

X is the reactance which can be capacitive or inductive

2.5.2.1 Resistive Loads

Resistive loads are the cause of major consumption of active power in the system. Resistive loads can be found in incandescent lamps, kettles, rice cookers and iron, where the energy required for its operation is transformed into light, heat with a unity power factor. In a purely resistive load, the current is in phase with the voltage thus an immediate function of the voltage is obtained. Therefore if the current and the voltage are in phase, their relationship can be expressed in the following equation:

$$R = \frac{V}{I} \tag{2.2}$$

2.5.3 Installed Power Demand and Utilization Factor

In AC circuits, the average of electric power developed by a two terminal device is a function of the effective values or quadratic mean values, of the potential difference between the terminal and the current flowing though the device. If a voltage *v(t)* with a peak value Vo is applied to an inductive receptor

$$v(t) = Vo.\sin(wt) \tag{2.3}$$

That will create a current *i(t)* lagging at angle θ behind the voltage

$$i(t) = Io.\sin(wt - \theta) \tag{2.4}$$

And the instantaneous power will be expressed as the product of the above equations

$$p(t) = Vo.Io.\sin(wt).\sin(wt - \theta) \tag{2.5}$$

Which, trigonometrically can be expressed as:

$$p(t) = Vo.Io.\frac{\cos(\alpha) - \cos(2wt - \theta)}{2} \tag{2.6}$$

And substituting the peak values with the effective values we obtain:

$$p(t) = VIcos(\theta) - \mathrm{VIcos}(2\mathrm{wt} - \theta) \tag{2.7}$$

In that way, the power is expressed through a constant value

$$P1 = VIcos(\theta) \tag{2.8}$$

And a variable value

$$P2 = VIcos(2wt - \theta) \tag{2.9}$$

The first expression is the active power and the second expression is the fluctuating power. Because of the sinusoidal characteristic of the fluctuating power, its mean value takes the value zero. If:

$$\theta = 90°$$

$$then\ \ cos(90) = 0$$

A case that describes the characteristic of a purely inductive o capacitive circuit

2.5.3.1 Apparent (S), Active (P) and Reactive (Q) Power

Apparent, active and reactive power can be express through the following set of equations:

$$S = IV \tag{2.10}$$

$$P = IVcos(\theta) \tag{2.11}$$

$$Q = IVsin(\theta) \tag{2.12}$$

Respectively. In an electric circuit, apparent power is not the actual power consumed except in the case where the power factor is unity $\cos(\varphi) = 1$. What is an indication that the supply network not only meets the power consumed by resistive loads.

Active power is the actual power consumed by circuit elements to meet the demand. Active power is used to determine the load demand in an electrical system. From Ohm law, $P = I^2R$, active power is due to resistive elements.

The reactive elements of the system are the major cause of the system reactive power which, based on Ohm, can be obtain from the equation:

$$Q = IVSin(\theta) = IZIsin(\theta) = I^2Zsin(\theta) = I^2X \tag{2.13}$$

2.6 Summary of the Literature Review

Table 1 shows a summary of the past researches revised:

Table 1: ***Summary of the Literature Review***

Author/ Date	**Paper Title**	**Topic/ Focus/ Question**	**Conclusion/ Advantage/ Disadvantage**
NEC-70, 2005 ed.	----	This standard focuses on defining Electrical parameters and the conditions they should be used.	Information about the practical safety of person and property from electrical hazards
NEC-700, 2005 ed.	Emergency Systems	Installation, operation and maintenance of ES	Defines all installation standards required for protections
Littlefuse, 2005	Circuit Protection solutions	Electrical devices protection	It does not include a coordination study
J. L. Blackburn and T. J. Domin, 2007ed	Protective relaying principles and applications	Info in new development and topics in protective relaying	It covers all aspects of protection and the factors affecting Protections
IEEE Std C37-2, 2008	Electrical power systems device function numbers	It applies to the definition of device function numbers	Not intended to assure safety and security in all circumstances
IEEE Std C37-100, 2001	Definitions for Power Switchgears	Electrical terms definitions	Establishes meaning of terms used in switchgear standards
R. T. Amador, 2007	Protecciones Electricas	Low-Voltage protection systems and Protection reliability	It focuses on all types of discrimination principles: Time, Current and T-C

E. Csanyi, July-2012	Isolating the fault with Time-Based Discrimination	Principle of TB discrimination and its operating mode	Detailed explanation on how to calculating the discrimination interval

Chapter 3

METHODOLOGY

3.1 Sensitivity and Data Analysis

In this stage, the data obtained from the site surveys is analyzed as to have a clearer picture of the problem. Data analysis is performed using two approaches:

- Sensitivity analysis of the main CB and
- Overload study which include the simulation of the fault based on the load.

3.1.1 UTP Single Line Diagram

The single line diagram in Figure 4 is a simplified notation representing UTP's Power System from Sub-Station DS2 connected to a Low Voltage (LV) Main Switchboard to the distribution of power through the respective Villages and Buildings. The solid yellow line marks the connection to V4D which is protected by 200 Amps MCC. The Line-Diagram for power distribution in V4D is not available the reason why it is not displayed here. However, to estimate the distribution of power throughout the building, it was necessary to manually trip the CBs and check its range of protection by observing the power lost in the area when the CB is OFF.

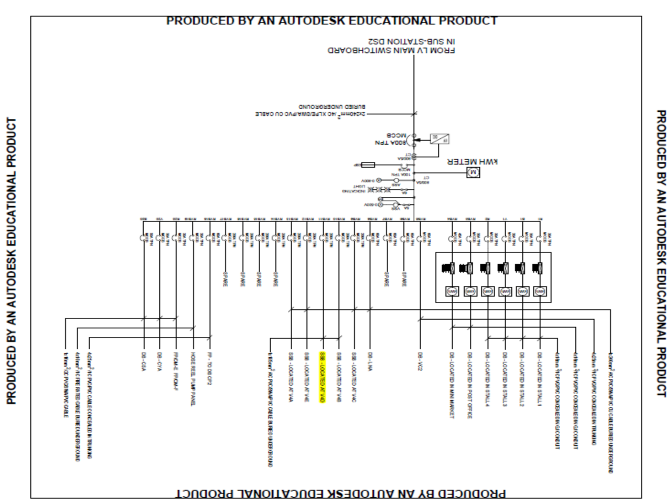

Figure 4: ***UTP power system's Single Line Diagram***

3.1.2 CBs Sensitivity Analysis

IEC 60755 standard defines three types of RCD based on the device frequency and the current for which the device will trip. They are classified as:

- AC-Type: which trips for sinusoidal residual AC current
- A-Type: which trips for pulsating DC current and
- B-Type: which is the same as type AC and 1kHz-current

For an RCCB protecting a circuit, load diversification is the most preferable and secure technique. RCCD degree of sensitivity is an indication of device operating current, noted $I\Delta n$. Thus based on the degree of sensitivity and the value of CBs residual current, RCCD can be categorize into the following groups:

- Highly sensitive: 6 – 10 – 30 mA Residual current
- Mediumly sensitive: 100 – 300 – 500 – 1,000 mA
- Low sensitivity: 3 – 10 – 30 A

The device operating current for the main CB in the area of study is 100mA which falls under the group of devices with a medium degree of sensitivity

3.2 Overload Study

The main problem that need to be addressed is to performance of an overload study on V4D T1 due to a several sudden power loss in that area.

The very first step taken to successfully carry on with the project is the revision of past researches on Load and Coordination studies. That is followed by a series of site inspections or site surveys in order to gather more data of the electrical equipment involved in the load study for that specific area. From the site surveys it was possible to know the types of protective devices affected, their ratings and their manufacturer. Thus basically, the required information needed to perform the study is:

- An accurate One-Line Diagram of the area of study
- Equipment ratings
- Protective devices

3.2.1 V4D-T1 Breaker Box Connection

Single line diagram is crucial when performing a fault analysis or coordination study since it helps us evaluate upstream and downstream CBs connections and it also provide us with more information on the protective device and equipment located in the area of study. Due to the lack of a Single-Line diagram of the area of study, a different approach had to be implemented in order to know the internal wiring of the area of study. And that required a continuous manual switching of the CBs in the Breaker Box located in the Pantry as can be observed Figure 5.

The Panel Box is equipped with 18 ELCB numbered from 1 to 9 and divided into two sets of CBs:

- **Lamps Protection:** ELCBs 1 to 6 are connected to the Fluorescent Lamps in the rooms of the area of study while ELCB-8 is connected to the Fluorescent Lamps in the pantry. ELCB-9 is the protection for the Exit Lights while ELCB-7 remain spear.
- **Socket Protection:** The sockets in the rooms are protected by ELCBs 1 to 6 while ELCB-7 provide protection for sockets in the pantry. Both ELCBs-8 and 9 remain spares.

Beside the ELCBs protecting the Sockets and Fluorescent Lamps, there is the Main Switch which is a RCCB with a Nominal Current In of 63 Amps and rated Residual Operating Current (ROP) of 100 mA.

Figure 5: ***V4-D T1 Panel Box***

3.2.2 Electrical Load Classification

V4-D T1 power consumption or electrical load has been classified based on its continuity or discontinuity for a defined period of time. Based on the above classification the following load categories were obtained:

3.2.2.1 Continuous Loads

Continuous load is any load which is ON for 3 hours or more [11]. This includes all the electrical equipment running for a long period of time without power interruption. Their power consumption can be considered as constant within the defined parameters. Ceiling fans, Fluorescent Lamps and the Fridge in the pantry fall under that classification as their activity is barely interrupted, making their power consumption oscillated within the rated peak values.

The table 2 provides information on the type of appliance and the power consumption per appliance as well as the amperage the device draw on the circuit.

Table 2: ***Continuous Load devices***

Appliances	Watts	Volt Circuit
Fluorescent Lamps	28	240
Ceiling Fans	75	240
Fridge	168	240

- **Fluorescent Lamps**

The total number of Fluorescent Lamps in every student apartment in V4-D is 22 Lamps per apartment. What make them a fundamental device to consider in term of power consumption. In that aspect is essential to analyze their internal wiring, which help understanding how a Fluorescent Lamps work.

The most important component of a Fluorescent Lamps is the Electronic Ballast Figure 6 which control the flow of current through the circuit and the terminal voltage. Due to a high current draw in a Filament Tube, a ballast circuit is used to limit the flow of current throughout the lamps thus preventing it from its self-destruction.

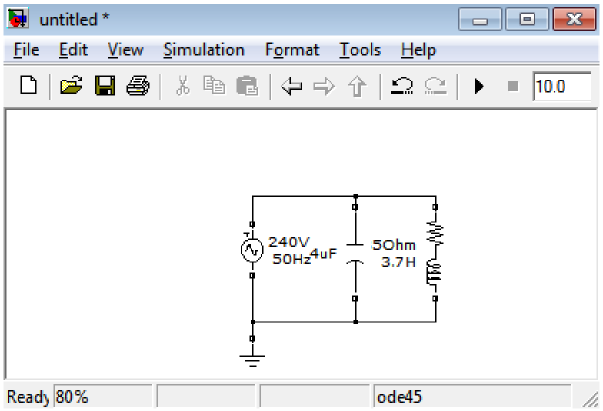

Figure 6: ***Fluorescent Lamp Ballast circuit diagram***

- **Ceiling Fans and Fridges**

Fans and Fridges which are continuously running are also considered as continuous loads. There is a total of 6 ceiling fans in the V4-D-T1 apartment. When fans are running at maximum speed their power consumption reaches the peak value therefore, their load neglected. The operation of a single fan is linked to a capacitor start motor which is composed of starting and running winding as can be observed in the circuit diagram in Figure 7 a capacitor is connected to the winding mainly to determine the direction of rotation.

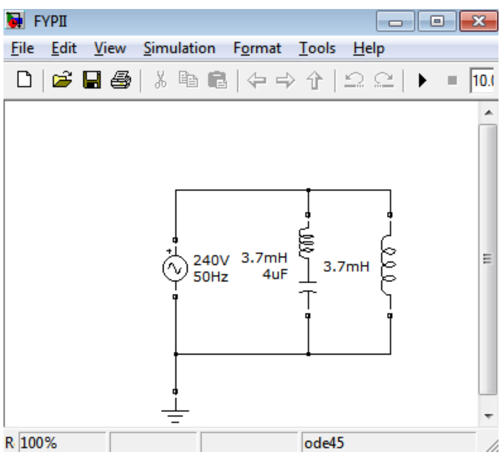

Figure 7: ***Ceiling Fan circuit diagram***

3.2.2.2 Non-Continuous Loads

Non continuous loads refers to those appliances that are not running for the most part of the day or those running for less than 3 hours daily. The list of appliance which load is not considered as continuous includes rice cookers, water heaters, mist-fans, PCs, personal air-conditioners, printers. The types of appliances considered as non-continuous loads in this study as well as their watt and amp-ratings are provided in Table 3. The study considers only those appliances that can be found in the majority of student rooms in the campus and particularly in V4.

Table 3: ***Intermittent load devices***

Appliances	**Watts**	**Volt-circuit**
PC	65	240
Printers	1.23h	240
Rice cookers	700	240
Air-Conditioner	1119	240
Fans	65	240
Mist-Fans	90	240
Jug Kettle	1500	240
Speakers	156	240
PlayStation	250	240
Electric Iron	1000	240
Induction Cooker	2400h	240

3.2 Flow Chart

The methodology of the project up to this stage can be summarize in the following flow chart diagram. As observed in Figure 8, it was fundamental to start working on the project after a thorough revision of past researches on protection system and load analysis. The revision of past researches was followed by a series of field surveys in the area of study. Field surveys helps gathering and collecting all the relevant information on protective devices used in the installation, such as the device type, rating and manufacturer. After obtaining the relevant information needed for the project, the next step was to perform a qualitative and quantitative analysis of the data obtained, which involved calculations and simulations that led to an accurate interpretation of the results.

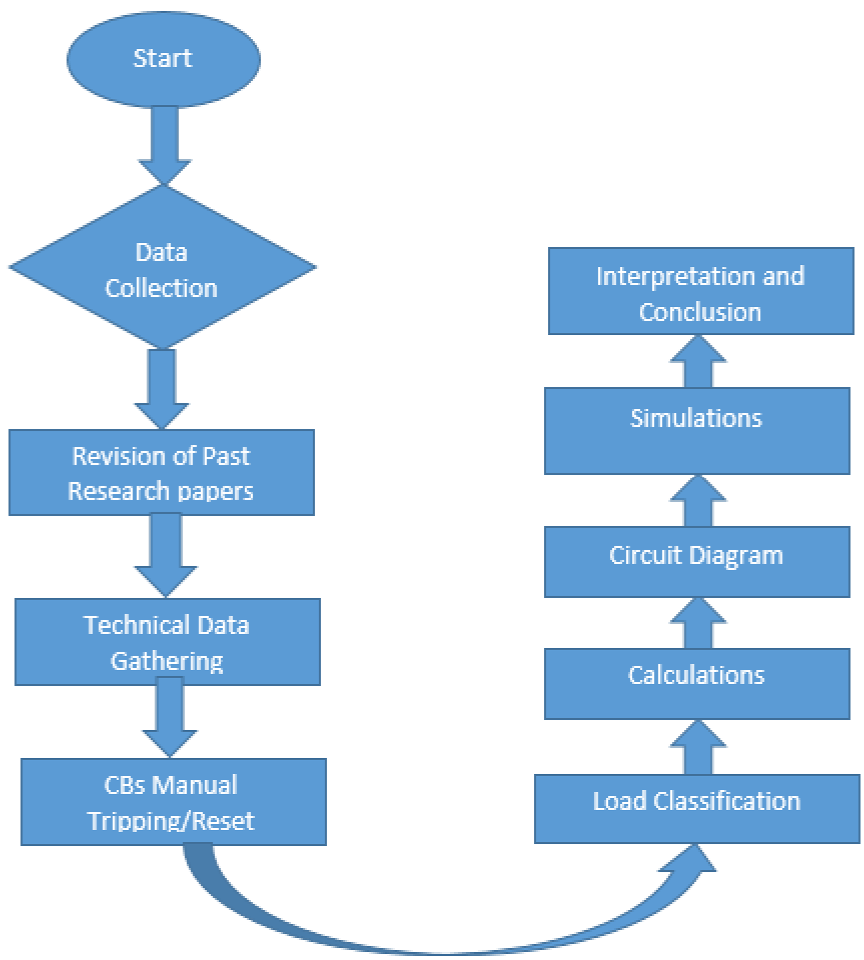

Figure 8: ***Methodology flow chart***

Chapter 4

RESULTS AND DISCUSSION

This chapter consist of three sections. Continuous and non-continuous load calculations are presented in the first section, followed by the Simulink Circuit Diagram of the area of study and the simulation results

4.1 Calculation

Simulink simulation of the data gathered from the site survey required the use of some mathematical calculations to approximate the value of the system continuous and intermittent loads. Using the maximum power rating labelled on each device and system voltage, it was possible to calculate the amperage draw of each system device based on the equation:

$$P = VI \tag{4.1}$$

Thus the main CB, with a nominal current (In) of 63Amps and 240V, will have a Voltage-Current relationship of:

$$P = VI = 63x2400 = 15120\,W$$

and the amperage draw in both continuous and intermittent loads will be calculated as follows:

4.1.1 Total Power draw in Continuous loads

Table 4 shows the total current draw or the total power consumption in continuous loads which is minimum as compared to the CB capacity.

Table 4: ***Calculation of current draw in Continuous Loads***

Appliances	Watts/Unit	Num. Units	Total (W)	Voltage (V)	Current (A)
Fluorescent L.	28	22	616	240	2.57
Ceiling Fans	75	6	450	240	1.875
Fridge	168	3	504	240	2.1
Total			**1570**	**240**	**6.546**

4.1.2 Total Power draw in Non-Continuous loads

The total current draw or power consumption in intermittent loads is shown in Table 5. As can be observed, the power consumption in intermittent loads is very high when compared to the value obtained for continuous loads. Device such as Electric Iron, Jug kettle and Induction Cooker can easily overload the system due to their high power consumption.

Table 5: ***Calculation of current draw in Intermittent Loads***

Appliances	Watts/Unit	Num. Units	Total Power (W)	Voltage (V)	Current (A)
PC	65	12	780	240	3.25
Printers	1.23h	4	4.92	240	0.021
Rice cookers	700	3	2100	240	8.75
Air-Conditioner	1119	1	1119	240	4.663
Fans	65	2	130	240	0.542
Mist-Fans	90	2	180	240	0.75
Jug Kettle	1500	2	3000	240	12.5
Speakers	156	3	468	240	1.95
PlayStation	250	2	500	240	2.083
Electric Iron	1000	3	3000	240	12.5
Induction Cooker	2400h	1	2400h	240	10
Total			**13681.92**	**240**	**57.009**

4.2 Circuit Diagram

The fundamental objective of the performance of load analysis was to be able to come up with a circuit that simulates the power flow in the area of study. After detailed examination of the electrical installation in the area, the circuit in Figure 9 was obtained; with the advantage that it shows the parallel arrangement of the devices to maintain the 240 V system voltage across their terminals.

Fluorescent Lamps and Ceiling fans are represented with reference to their configurations and the values of their internal components which are basically resistors, inductors and capacitors combined in an RC and LC circuits. The current and voltage characteristic in this arrangement approximate the current flow in the actual circuit.

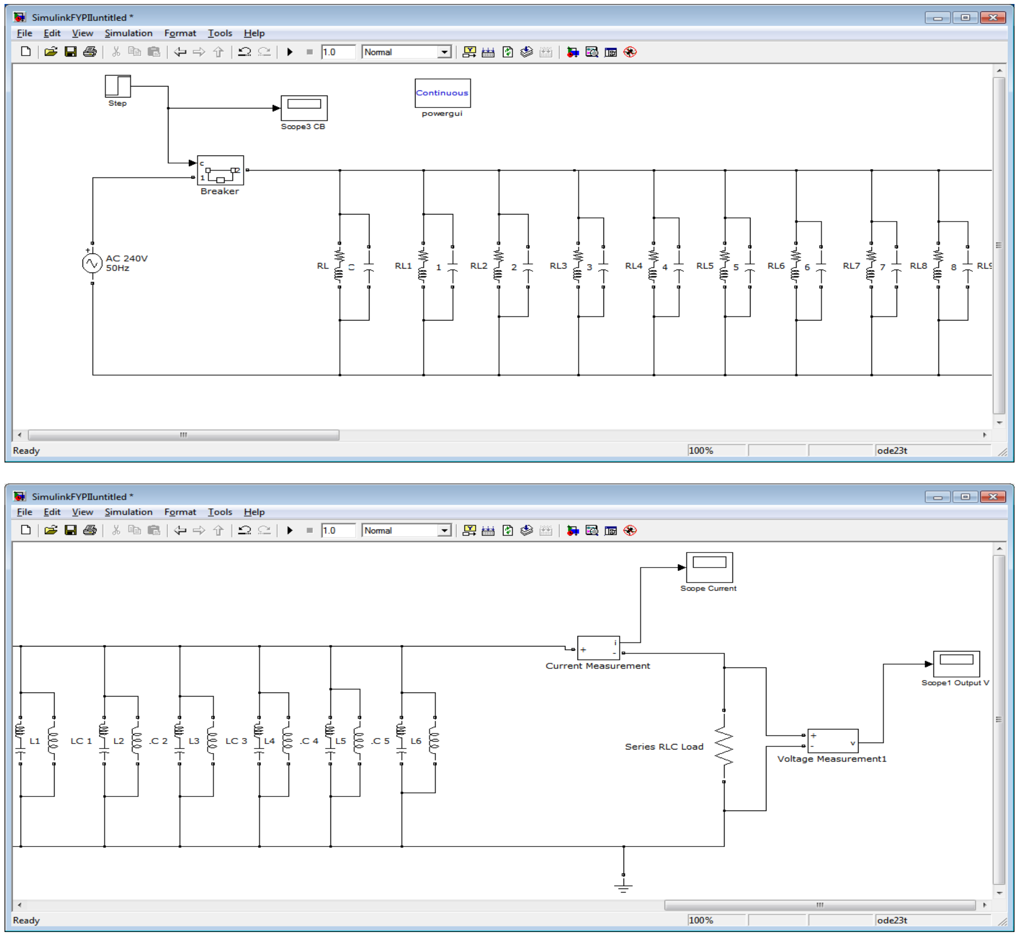

Figure 9: ***Preliminary circuit diagram of the area of study***

However due to the complexity of the internal design of some continuous loads such as the fridge in the pantry, it was necessary to design a circuit that only relate to both the continuous and non-continuous. As can be observed in Figure 10, the continuous loads is constant while the non-continuous load is variable as it depends on student usage of the electric appliances.

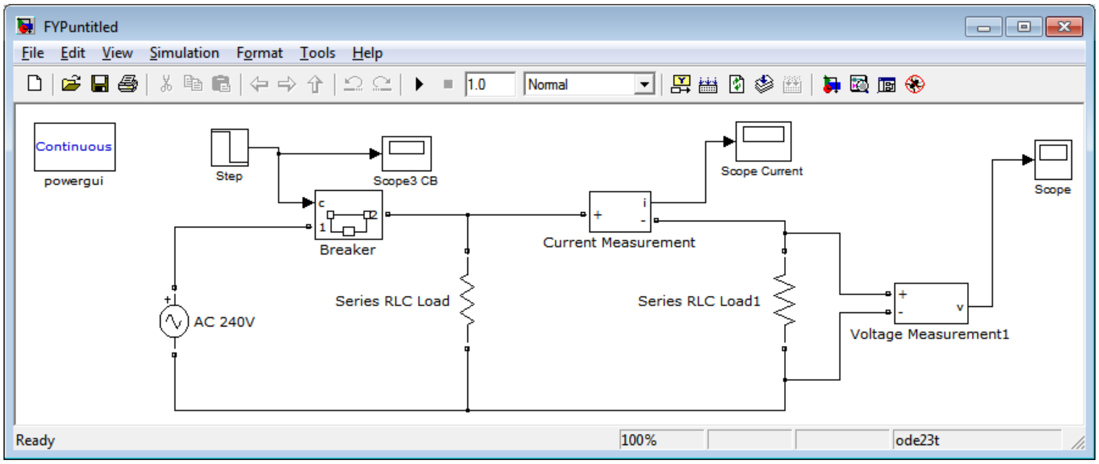

Figure 10: ***Actual Circuit Diagram of the area of study***

4.3 Simulation Results

Results from overload study, for the cases where the intermittent loads were subjected to a set of different values can be observed in Figure 14 to Figure 18. The waveform describes the current characteristic when intermittent loads increase due to an increase in the number of electrical appliances connected to the circuit diagram.

The first waveform represent the ideal case in which the number of electrical devices connected to the system is minimum and abide by UTP's rules and regulations. Figures 14-18 reflect the behavior of the current when the number of devices connected to the system increases.

4.3.1 Ideal Case:
Each student in the apartment has a PC and at least each student has a printer.

The total power consumption in this case is 792.3 W as can be observed in Table 6 which is the power consumed in the intermittent loads, while the power consumption in the continuous loads remains constant at 1570 W

Table 6: *Power consumption in the ideal case*

Appliances	Watts	Num. U.	Total W	Volt-circuit	Amps
PC	65	12	780	240	3.25
Printers	1.23h	12	12.3	240	0.021
Total			**792.3**	**240**	**3.271**

The continuous and non-continuous load values obtained from the above calculations for the ideal case were inserted in the system circuit for simulations as can be observed in Figure 11 and Figure 12 respectively. The Block Parameters in Figure 11 shows the power consumption in continuous load as calculated previously while the power consumed in intermittent load is observed in Figure 12 with a system nominal frequency of 50 Hz.

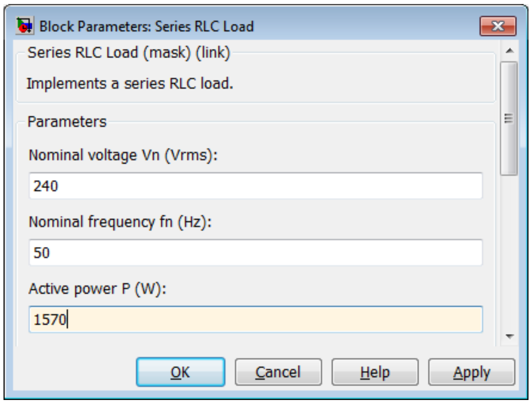

Figure 11: ***Continuous load***

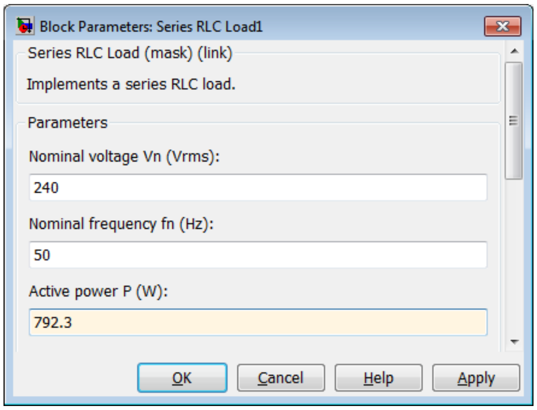

Figure 12: ***Intermittent loads***

Figure 13 (a) and (b) show current and voltage characteristics for the values obtained in the ideal case where each student has only one PC and one printer. In that case, the current consumed in the intermittent load is minimum. The value obtained from the graph as can be observed, is 3.3 Amps which is approximately the same as the calculated value. While the voltage remain constant as observed in Figure 13 (b)

- **Current Waveform**

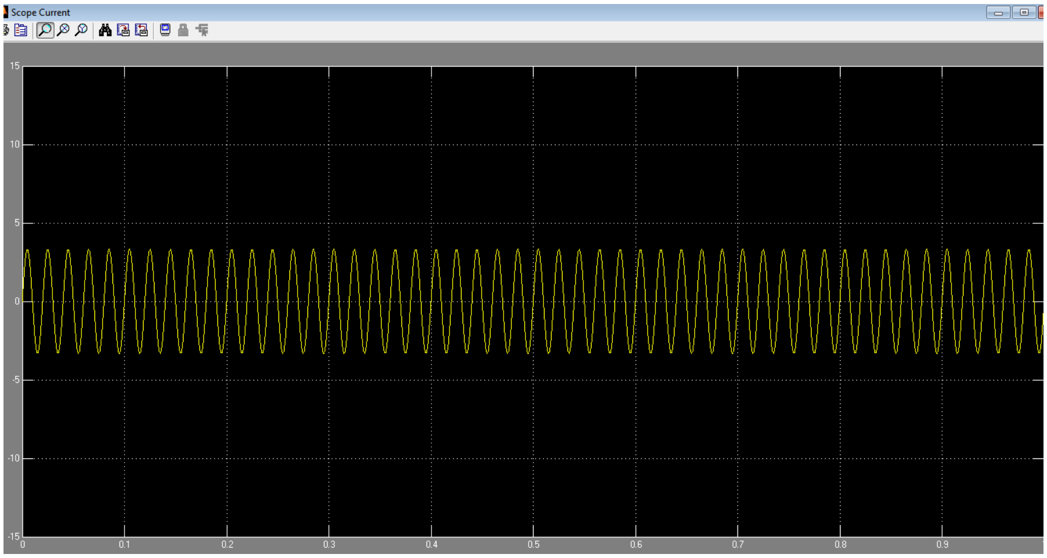

Figure 13 (a): ***Current waveform for ideal case***

- **Voltage Waveform**

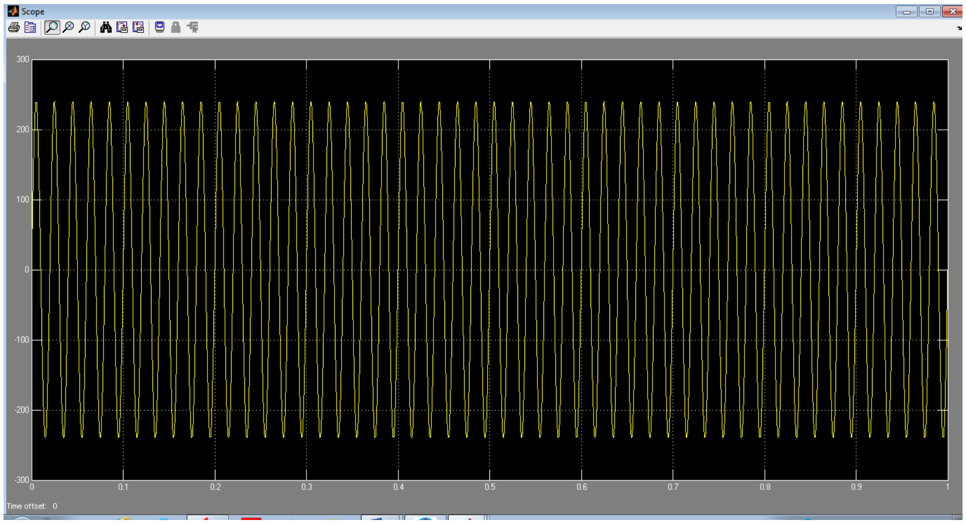

Figure 13 (b): ***Voltage waveform for ideal case***

4.3.2 4000 W Intermittent Load

Figure 14 (a) and (b) show voltage and current characteristic as the intermittent load is increased to 4000 W, based on the number of appliances connected to the system. The current draw in the intermittent load in that case increase to approximately 17 Amps which is still within the secure range of current that the CB can withstand base on its capacity. The voltage is maintained constant at 240 V as observed in Figure 14 (b).

- **Current Waveform**

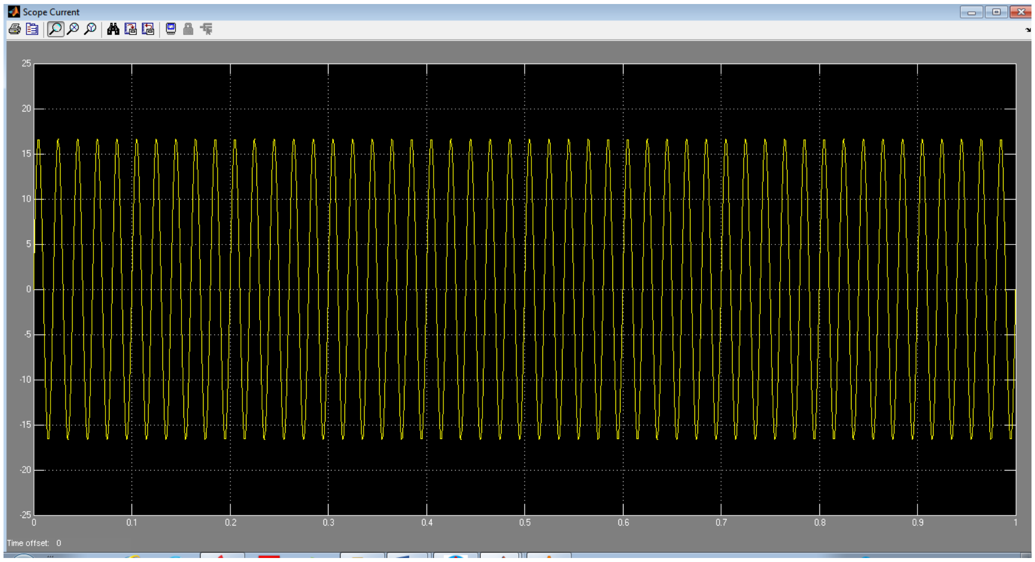

Figure 14 (a): ***Current waveform for 4000W***

- **Voltage Waveform**

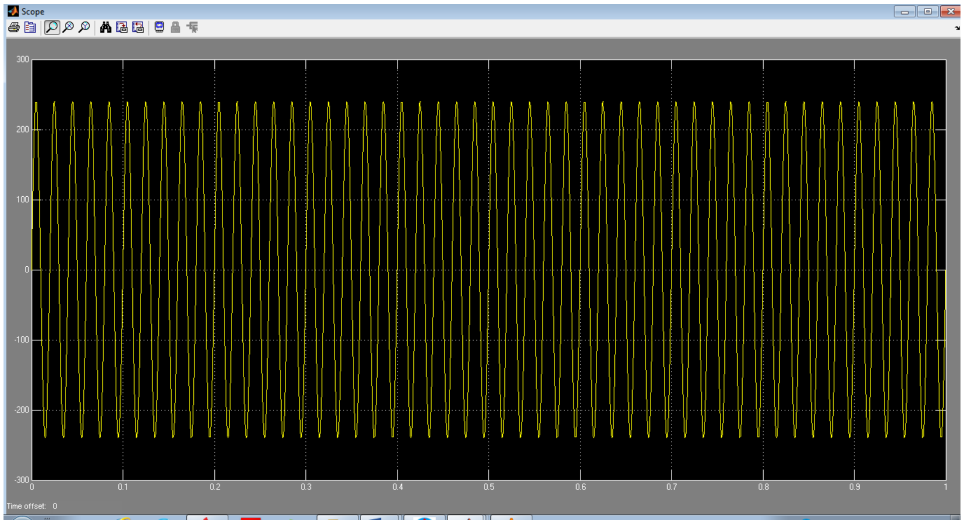

Figure 14 (b): ***Voltage waveform for 4000W***

4.3.3 8000 W Intermittent Load

As the power consumption increases to 8000 W, the current draw in intermittent loads is approximately 33 Amps as can be observed in Figure 15 (a), which is approximately twice the value obtained in Figure 14 (a). The current value obtained in Figure 15 (a) is 52.4 % of the main CB capacity, therefore the main CB can withstand that power consumption without any unwanted tripping.

- **Current Waveform**

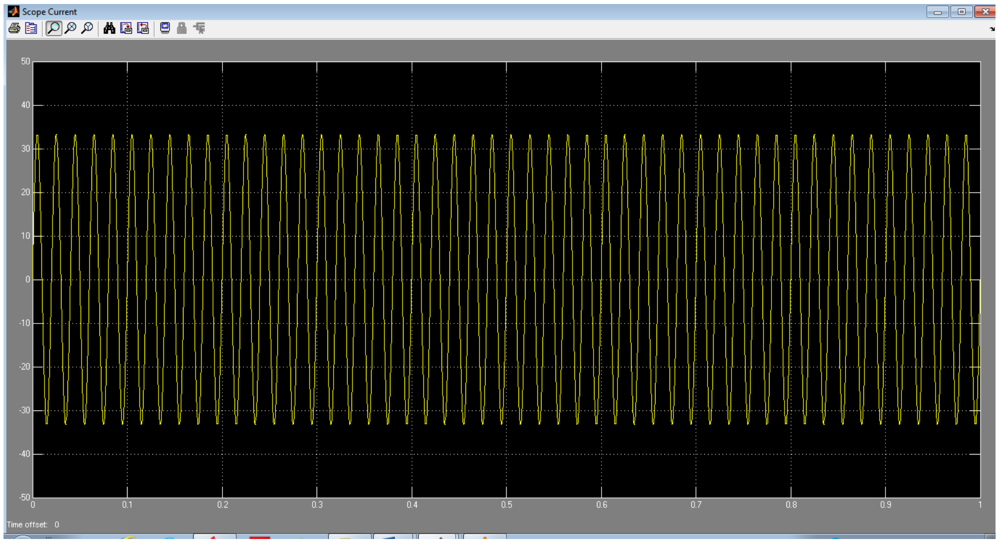

Figure 15 (a): ***Current waveform for 8000W***

- **Voltage Waveform**

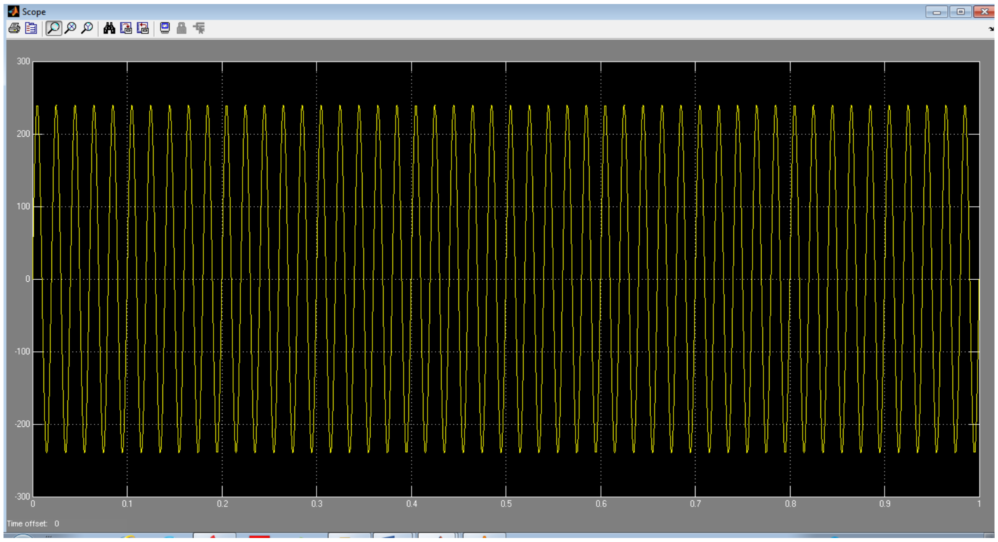

Figure 15 (b): ***Voltage waveform form 8000W***

4.3.4 12000 W Intermittent Load

Increasing the power consumption in intermittent to 12000 W increases the current draw in the same load to 50 Amps with a constant voltage of 240V shown in Figure 16 (a) and 16 (b) respectively. 50 Amps of current draw represent a 79.4 % of the main CB capacity therefore at this level, the risk for CB tripping due to overload is high as compared to previous cases. That is because 79.4 % is close to maximum safety level of the main CB which is 80 %.

- **Current Waveform**

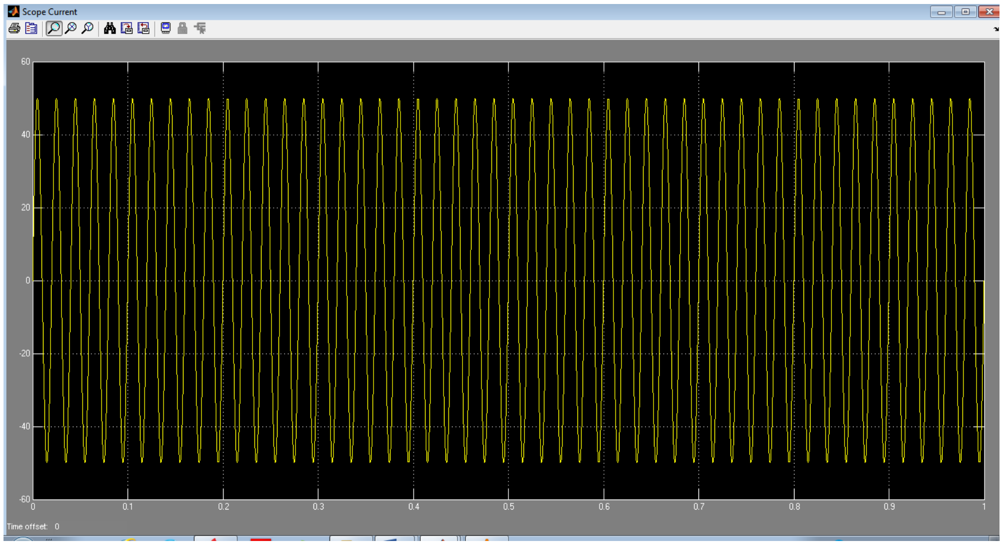

Figure 16 (a): ***Current waveform for 12000W***

- **Voltage Waveform**

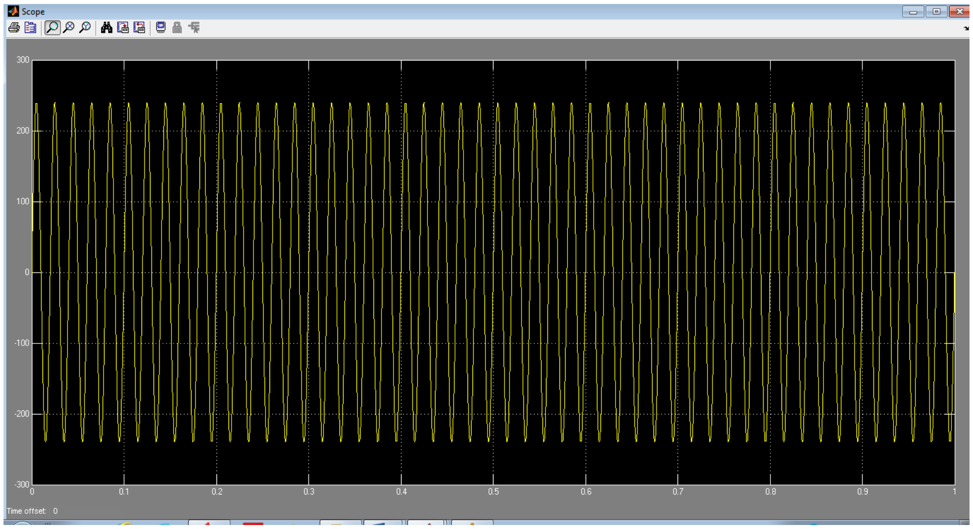

Figure 16 (b): ***Voltage waveform for 12000W***

4.3.5 13681.92W Intermittent Load

As the intermittent power consumption reaches its maximum value, the current draw in the loads increases to 57 Amps as can be observed in Figure 17 (a), which is approximately 90 % of the main CB capacity. As the safety level of the CB is reached and considering the current draw in continuous loads, the possibility of CB tripping at this level is high due to system overload.

- **Current Waveform**

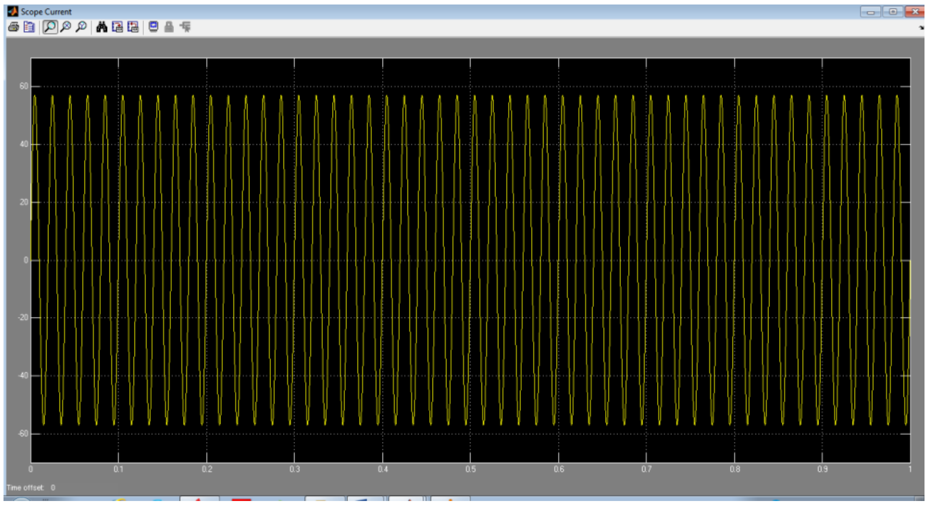

Figure 17 (a): ***Current waveform for 13681.92W***

- **Voltage Waveform**

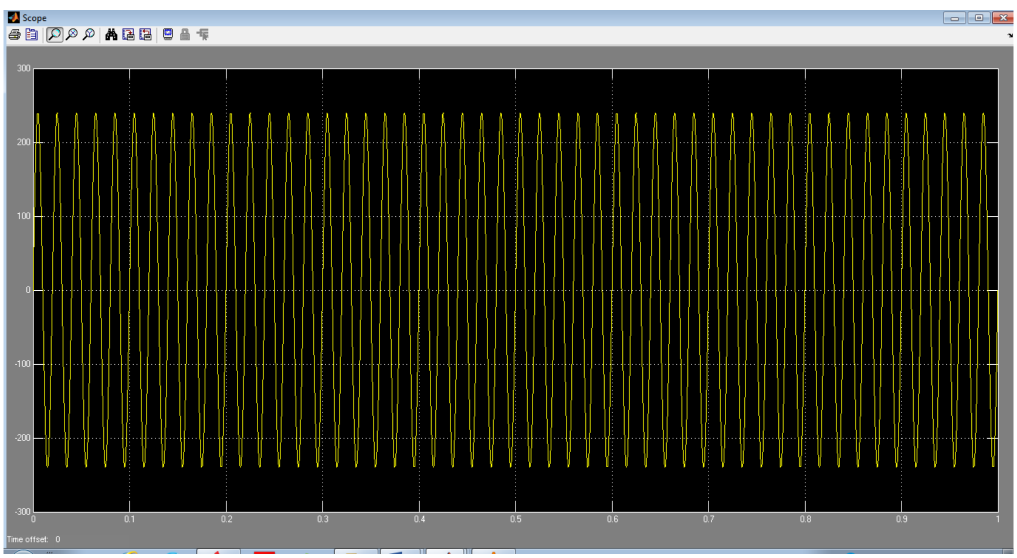

Figure 17 (b): ***Voltage waveform for 13681.92W***

4.3.6 Short Circuit Current

An important aspect of the research is to study the current characteristic when a fault occur in the systems. As can be observed in Figure 18(a), the current waveform prior to the fault follows the pattern described in previous sections, increasing with an increase in the load added in the system, while the voltage is maintained constant at 240 V. However when the fault occurs at 0.1sec, the current in the circuit increase abruptly causing the Circuit Breaker to trip thus, interrupting the flow of power in the system as can be observed in Figure 18(a).

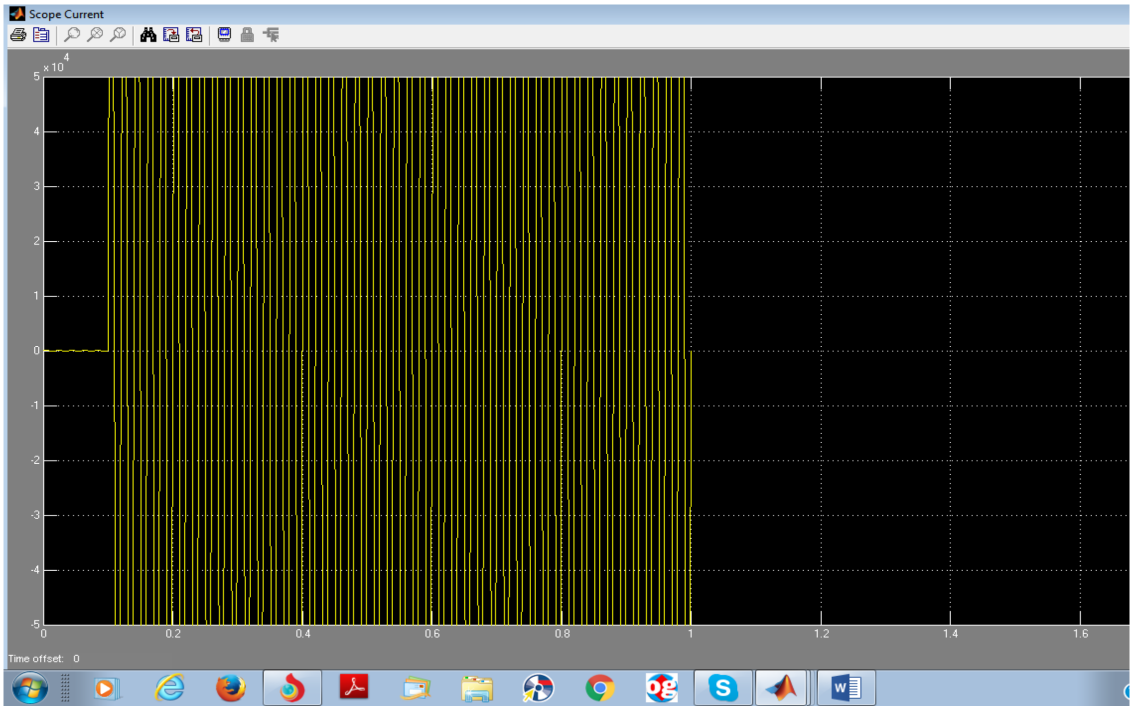

Figure 18 (a): ***Current waveform at fault level***

The voltage however turns to zero instantly after the fault has occur as can be observed in Figure 18 (b).

Figure 18 (b): ***Voltage waveform at fault level***

4.4 Discussion

The values of intermittent loads that have been used to study the current characteristic of the circuit are 792.3 W, 4000 W, 8000 W, 12000 W and 13681.92 W respectively. The first value represent the ideal case in which students only use those devices registered in UTP's rules and regulations. The subsequent values represent the power consumption as more electrical appliances are in use. The relationship between simulated power consumption and current draw in the circuit can be observed in Table 7.

Table 7: ***Amperage draw per Load***

Simulation	Watts	Current (Amps)
1	792.3	3.3
2	4000	17
3	8000	33
4	12000	50
5	13681.92	57
5	15000	63

From the graph above it has been observed that as the value of the power consumption increases, the current draw in the circuit also increases correspondingly. In the ideal case where the number of appliances in the system is minimum, there is as low as 3.3 Amps needed to keep the devices running. However in the case where the number of appliances connected to the system is maximum the current draw in the circuit increases up to 57 Amps which is near the rated current of the main CB which is 63 Amps.

4.5 Project Gantt chart

The overall work done on the project along with the time taken for the tasks to be completed, are summarized in a Gantt chart in Figure 20.

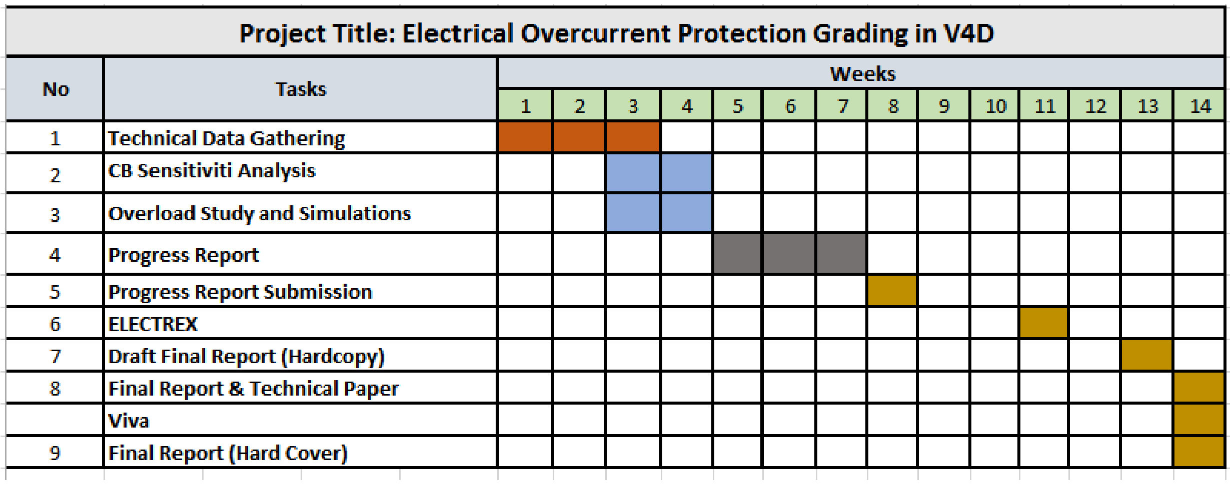

Figure 19: ***Project Gantt chart***

Chapter 5

CONCLUSION

The continuous tripping of V4D CB has been analyzed using two different approaches: CBs sensitivity analysis and circuit overload. The preliminary results showed that sensitivity is not the factor causing the breaker to trip. The sensitivity level for protective devices in V4D is medium what makes it less prone to nuisance tripping outside the nominal tripping current. From the manual inspection it was observed that the increasing use of overheating appliances causes the circuit to overload, since overheating appliances pull in more amps than normal. Therefore, it was necessary to perform an overload analysis of the area of study which required a technical data gathering process. The data obtained helped classify the Electrical Appliances in the area of study into two categories: Continuous and Intermittent loads.

The power calculated from both Continuous and Intermittent Loads was simulated in different sequences using SIMULINK/MATLAB. The results obtained showed that as load increases, the current draw in the circuit also increase proportionally and the maximum value obtained was 57Amps. Which is close to the 63Amps rating of the main CB. Therefore, if more appliances are connected to the system, that will increase the current draw and in consequence trip the main CB protecting the area of study.

Chapter 6

RECOMMENDATIONS

Further analysis could be done in the area of study to minimize the rate of occurrence of the problem. The installation and protective devices in the Student Villages should be tested regularly to increase installation safety and devices reliability. Testing the electrical installation will help detect and prevent defects that would cause electrical faults and damage in the system.

Extensive analysis could be done on Buildings wiring. Electrical conductors play an important role in the installation safety due to its impact on the presence of electrical faults. Thus proper selection of the cables and their periodic inspection will contribute to the overall safety of the electrical installation.

In Student Villages, activities such as cooking and heating water take place in the apartment pantries. Knowing that the increasing use of overheating appliances causes the circuit to overload thus tripping the protective device, the incoming line could be split off on two separated lines with one of them taking the power to the rooms and the other to the pantry and both having two separate Circuit Breakers. This arrangement will help tripping the CB in the faulted line and leaving the rest of the system undisturbed.

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