ABSTRACT

In electrical system, grounding is the most important component to provide low impedance path to ground for personal and equipment protection. Currently, the connection of grounding system in High Voltage Laboratory, Faculty of Electrical Engineering in UTeM is connected between building electrical grounding and transformer. Thus, the testing of the high voltage can be done only if all apparatus grounding system are terminated. This is not the good solution since it is difficult to monitor the grounding system. Optimal size of the grid and highest resistivity material can improve the ground system in order to get low ground resistance below than 1Ω as stated in Standard IEEE 80-2000. This project is focus to analyze the difference size of grid and material to be used as the High Voltage Laboratory grounding system.

(Keywords: grounding, ground resistance, size of grid)

Key Researches:
Anis Niza binti Ramani
Aine Izzati binti Tarmizi
Aziah binti Khamis
Farhan bin Hanaffi

Email : anisniza@utem.edu.my
Tel. No. : 06 555 2311
Vote No. : PJP/2011/FKE (9B) S00827

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LIST OF SYMBOLS AND ABBREVIATIONS

Z	-	Impedance
R	-	Steady State
A	-	Ampere
V	-	Voltage, volts
I	-	Current
Ω	-	symbol of resistance
kA	-	kiloampere
s	-	Second
t	-	Time

CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter will cover more on introducing and understanding about the transient behaviour of the grounding grids. Before this discussion goes farther to the detail the basic idea and the focus should be understand so that the analysis can be more oriented. The experiment of this project is carried out in laboratory using scale model since have difficulties in cost and it is more practical.

This project will focus on the efficacy of the grids in channeling the currents injected to it by using different designs of grids. By completing this, analysis and comparison can be done. In this chapter will discuss about the objectives and the scopes briefly that are important in getting know more about the flow of the project. Likewise, the grounding system will be explained further so that the basic idea can be obtained. Since this project is circulating on grounding system the basic idea of protection will be included because it is all about safety of the system that is leads to this project.

1.2 Introduction

In electrical system, protection of the system and the elements and equipment are very crucial. It is because one system can contain huge number equipment and cost from thousand and more. Thus, if the system cannot be protected it can face damaged when fault occur and the cost of fixing is quite high.

In this project, for the grounding system, the grounding grids are investigated. There are some other factors that are important in grounding system. However grounding grids have a huge role for better result. So, by studying the grids a better solution for earthing fault can be used.

Malaysia is in the second in place of the country that's have the highest number of lightning strike in the world [12]. According to Malaysian Metrological Department, the highest mean annual number with lightning in Malaysia is recorded as many as 309 numbers of days of lightning per year at KLIA, Sepang. In Malaysia, the effect due to lightning strike is very tremendous in damaging the equipment that had been struck by the lightning. Some of the incident involving lightning strike including the runway of the Sultan Abdul Aziz Shah airport in Subang that had been damaged seriously that caused three Firefly flights to be disrupted [13].

So, it is undeniable that grounding system is very important because it not just to protect the electrical system or equipment but also human lives. Lightning occurrence or earth fault is same in the way that it is involve huge amount of currents which is very dangerous to both human and buildings.

1.3 Grounding System

Grounding system or so-called earthing system is compulsory in any building all over the world. However, the grounding system can be different to one another. A high tower and building is a skyscraper which is more vulnerable to lightning strike because it is stand out from lower building. Also, the building huge so current fault probability is higher. For factories, since there are many operations, machines and production, earth can fault can happen when the electrical equipment facing error or malfunctioned.

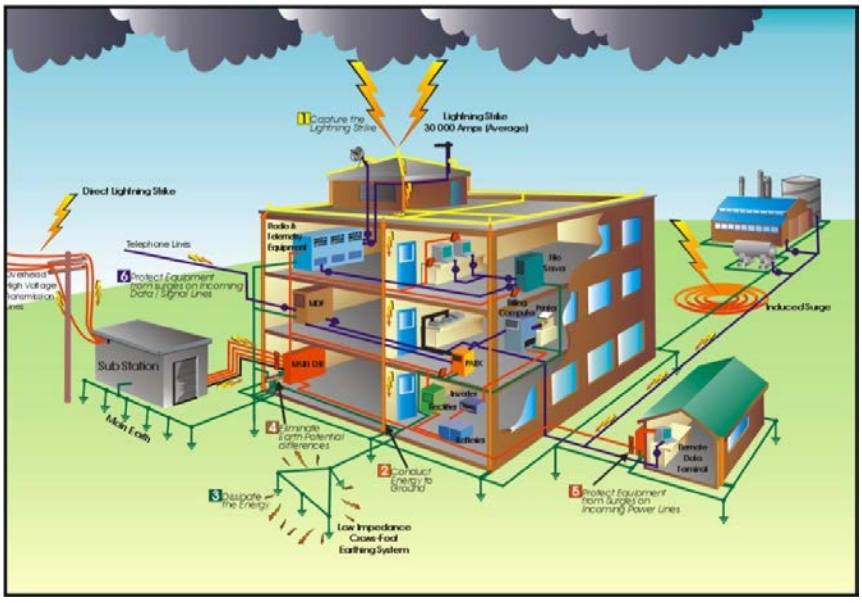

Figure 1.1: The basic grounding system for building and substation [4]

From Figure 1.1, the basic constructions of the grounding system is shown in a way that ease people to understand the basic idea of grounding system. From the above figure, it can be observed that the high building has antenna to capture the lightning strike which then channeled the captured surge to ground. All the electrical equipment in the building also grounded to a separate grounding system as a protection.

Also, the substation and the transmission line are also grounded as seen in the figure. For substation, since it is used in delivering power to rural area or building it contains a high voltage. Earth fault or lightning that are not well conducted can cause explosion to that particular system. Figure 1.2 below shows the system for houses.

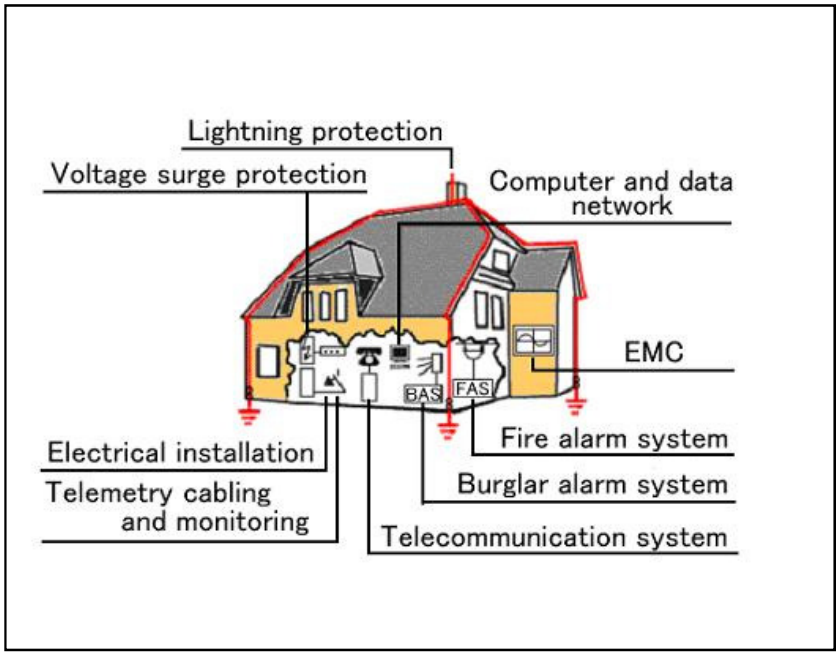

Figure 1.2: The basic grounding system for houses [4]

However, for this project the focus is given to grounding grids which are used in the grounding system. These grids are the factors that determine the efficiency and efficacy of the grounding system. In real grounding system, the grids will be buried in the ground so deep enough for it to work properly and do not damage anything on the surface.

1.4 Problem Statement

The purpose of the scale model experiments is the investigation of the variation of the transient resistance of the grounding grids, when the impulse current is injected each time at a different point of the grounding grid. Typically, when a lightning strike, a huge current is transmitted to the system. The same is happen when current fault occur in electrical system of a building. This current have to be channeled to ground to protect that system. However, channeling a huge current require a meticulous and reliable grounding system. That is the reason to why the grounding grid is important. Different configuration of the grid could produce different result. The meshes that tested can give a different results which the best can be design can be determined. Thus, better protection can be chosen and can keep our protected system safely.

1.5 Objectives

Objective studies of this experimental study are:

- Set up appropriate experiment or method to analyze transient performance.
- Analyze the effectiveness and necessity of grounding grid in grounding system.
- Find the best meshes of the grids to provide the best protection.

1.6 Scope of the Project

Scopes of this project are:

1. There are many ways of protecting our system. Soil, material and grid are some of them. Nevertheless, this project is focusing only on the grid. This is because grounding grid could result in huge effect on the system itself.

2. The scale model for this project requires the grids. Soil is also used in this project but as a medium of earth. The grids designed will be buried in the soil. Hence, the reading will only be taken at the grid.

3. Different configurations of meshes of the grids are taken into consideration. Of all the meshes, current injections are at different point and giving diverse reading. The one that can handle the current in term of transient impedance versus time the best is measured.

1.7 Research Aim

The project research aims are:

a) To obtain better understanding about grounding grids.
b) To obtain the characteristic of transient of the grids.
c) To analyze the effects of the grids to existing grounding system.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In this chapter will cover a lot on the analyzing the characteristics of transient of the grounding grids. The behaviour of the grids during steady is needs not to be studied and is sufficient to know that it is lower than it is in transient state. Also, there are a lot to study about the grids before really understand the properties of the grids before and during testing.

There are many past studies from the past journals in IEEE describing their studies for the transient analysis studies. However their studies are basically the properties of the soil for the grounding system. Past research is very important when to do a research or experiment. It is due to the basic concept developed by the researcher itself. If the basic principle cannot be grasped, the experiment or study might be astray.

The information varied where the basic importance of grounding system is studied first. After understanding the basic grounding system then focus on grounding grids which is the element that is investigated, specified in its transient behavior that is resistance. So, all the information needed for this experiment will be inserted and arranged so that the flow of information is effective.

2.2 Basic Principle of Grounding System

The main purpose of this project is to study the transient property of the impedance by using grounding grids. There are some factors affect the transient performance of grounding system. Some of them are [1]:

1. The point where the current is injected
2. The resistivity of the soil used that are surrounding the ground areas.
3. The grounding's dimensions and also the shape of the grounding.
4. Ionization of the soil. Whether it is developed or it is not.
5. The injected current's wave shape can also affect.

As a matter of fact, the impedance of grounding system in steady state is clearly lower than in transient state. The reason this is happen is because [2]:

- It is because the soil might be dry due to highly injected current's value which can enhance the resistivity of the soil.
- The decrease of effective length of ground conductor which is happens as the result from front time decrement of impulse current injection.
- The short period of time whereby it affect the conductors' reactance and connection's reactance. The reactance of both parameters is become higher which then leads the impedance of the earth also higher.
- The skin effect which causes the increment of earth conductor's impedance. This is due to the frequency that is high.

Comprehending the performance of grounding systems to transient state of current is crucial to develop the efficacy of the system of protection from lightning that offered by electrical installation of protective devices [4].

The ratio of the potential difference to injection current is the elements that represent transient impedance's impulse. The equation of obtaining impedance is [1-2]:

$$\boldsymbol{z(t)} = \frac{\boldsymbol{u(t)}}{\boldsymbol{i(t)}} \tag{2.1}$$

Figure 2.1 below will show the parameters that are considered in this experiment as in the equation.

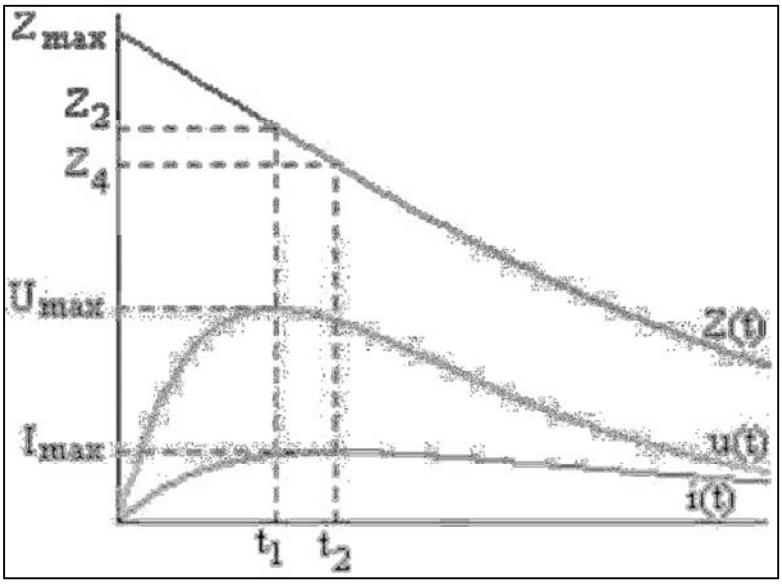

Figure 2.1: Definition of parameter used [2]

The best design of the grounding grids need students to study about the impact of parameters that typically measured or considered. Some of the elements are the grounding grids' length, the square of meshes in one grids, the length of diameter of the conductor grounding, the depth grid inside ground or liquid and the impacts of utilizing ground rods [6]. However, it is not possible and not practical to study this parameter on full-size model because there is some lacking in controlling the condition the variation of the soil in term of its resistivity at the area. Hence, for experimental study, scale model can is chosen for its practicality and average costing as an alternative method. Basically, the test of scale model is utilized in order to determine the resistance of the grounding and the distribution of potential during fault of the ground if the arrangement of the grounding is complex where the possible calculation analytically is rarely precise [6].

Based on Ramamoorty et al [4] there are several important factors in determining the transient response in diverse arrangement of grounding. The first factor is the grounding resistance which is about the resistance caused by each element in grounding systems. The second one is inductance which is circulated about extensive grounds like grids and the counterpoises of the transient behaviour. The other one is the ohmic resistance of the electrode and fourth one is the capacitance of the grounds.

Another research, Gupta and Thapar [5] have developed a quite distinct approach whereby they using equivalent parameters to measure the impulse impedance of the grounding grids. Thapar's work is very unique and distinctively helping in the research of the grids implanted in grounding systems in term of discharging and the impulse of the lightning. Nevertheless, the modeling which he was established has some weaknesses. For instances:

- For the process of dissipation of the current impulse, the impact of rods which is buried in the ground is not being considered.
- The analysis is only based on the square type of grids whereby in actual, the configuration of the grids can be different and complex.
- The starting current distributed in the grids is assumed obtain from the equally distributed currents in the grids itself.
- The computation of the resistance of the ground is carried out by considering the grids as a plate that equivalently circular and the principle of balancing energy is used to calculate effective inductance.

2.3 Experimental Layout

For the experimental layout, an alternating current is used to avoid polarisation. The applied voltage to the model is obtained from a 220 VAC source through a variac. The magnitude of this voltage is kept constant during the different tests. By measuring the voltage applied to the model and the current flowing through the electrolyte between the model grid and the return electrode, the effective grid resistance can be obtained. The potential of the test probe with respect to the return electrode is monitored by a voltmeter of a very high internal resistance [6].

2.4 Scale Factor Selection

There are several points in choosing the proper scale factor for the model grids. One of these is the maximum size grid which could be accommodated in a given size tank. Another is the original specifications for this grid.

A scale factor of 100:1 is a convenient choice for the size of grid used. Typical grid conductors are made for 4/0 copper, with a diameter of 1.35 cm. The conductor diameter of the model is 0.135 mm, but this size of wire is not available and it is difficult to construct a model with this small diameter. A few tests showed that it is not necessary to the wire diameter by the same scale factor as the other grid dimensions. This will be discussed later in Chapter 3. As the wire diameter is always small compared with the mesh spacing, a change in wire diameter has no effect on the potential profiles. Thus all model grids are made of 1 mm conductor diameter, which is available, and it is also easy to build models with this diameter.

A few tests were carried out to determine the maximum size of a model grid which can be used in the tank avoiding the distortion of the electric field due to the tank walls. It is concluded that the maximum size of the model grid used must be 25cm×25cm to minimise boundary effects due to the tank walls.

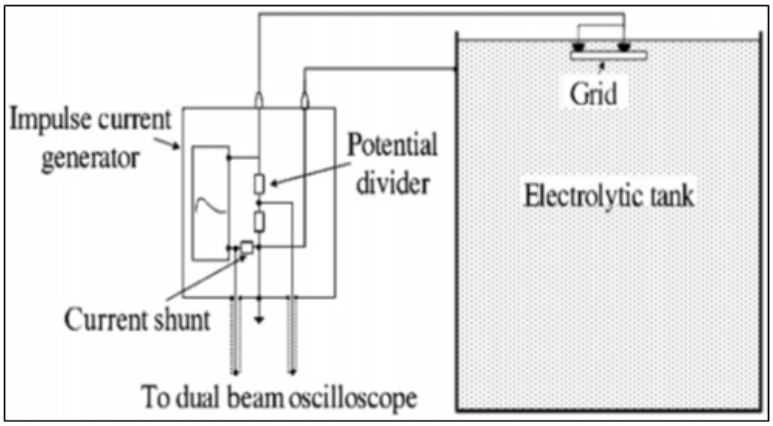

Figure 2.2: Typical configuration of the experiment [2]

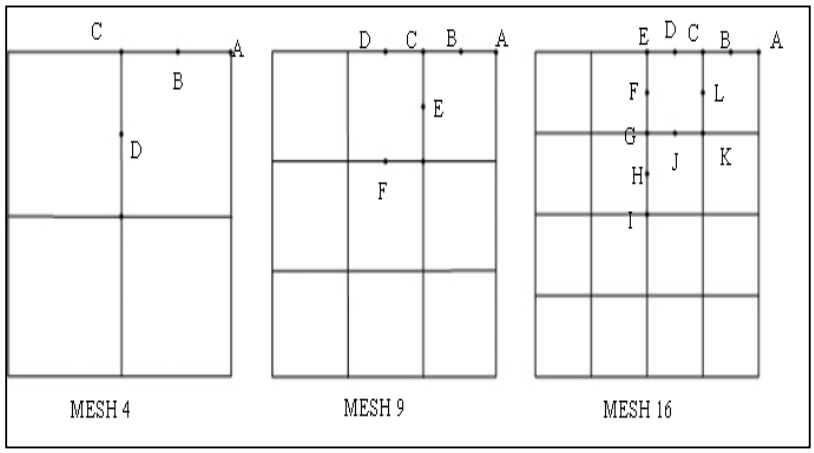

Figure 2.3: Basic design of grounding grids [2]

Figure 2.3 shows the grids that will be used in the experiment though the injection will be changed for a bit.

2.5 Test procedure

The grid was first installed and adjusted to the proper depth. The grid was then energised and the voltages and currents were monitored and the grid resistance could be obtained. The probe carriage was aligned over the centre line of the grid. The potential values were recorded at intervals of 2cm starting from the grid centre and ending at approximately 10cm outside the grid. The positions considered cover the area of one quarter of a grid, due to symmetry.

2.6 Test result

To determine the effect of length of ground rods and number of meshes on grid resistance and maximum values of touch and step potentials, a series of tests were performed on a 20cm × 20cm grid, at a depth of 2cm, with either 4 or 16 meshes. The lengths of the tested ground rods varied from 0cm to 7cm. The ground rods werelocated at each conductor junction.

A comparison between experimental and theoretical results of the grid resistance and mesh potential was carried out to obtain the nearly accurate theoretical method which can be used. Some analytical methods using simplified equations are used [6-8] to obtain the resistances of 25 cm × 25 cm square grids with different numbers of meshes, at a depth of 1m. The resistivity considered was that of water. Scalemodel tests on these grids were performed, and the values are obtained for different numbers of meshes. By dividing these values by the scale factor, the full scale resistance values are obtained.

CHAPTER 3

METHODOLOGY

3.1 Overview

For this chapter, it is mainly focused about the implementation of the project. Implementation of the project is circulating around researching about the idea or facts or any related information of the project. After gaining the basic requirement, the other steps are then can be carried out to resume the project.

3.2 Obtaining basic ideas

3.2.1 Gathering information

When a focus or project's title of study is determined, the first thing to do is understand about the chosen project. Misunderstanding about the subject could lead to failure and stray from the main focus. Hence, reading related journal or article is hugely helpful for student to acquire the main idea of the subject.

Therefore, information about the transient performance of grounding grids is searched in library and surfing of internet. Most information obtained from IEEE. From the journal of past researchers, grid is one of factors that are useful for protection. In situation where lightning strikes, the current will be transmitted to the where the lightning touch. So, configuration of grid is important so that the current can be handled evenly to protect the systems.

3.2.2 Understanding subject

This part is very crucial throughout the project. After gaining some knowledge, the student should notice that past research have some shortcoming or weaknesses. Then, the problems surfaced from past researches must be identified. Also, the problem found then is subjected to be corrected or reduced.

The purpose of this research is mainly to study the transient behaviour of the grounding grid. The transient behaviour of the grounding system is influenced by several factors. In other word, if we are about to study about the transient, those factor can be controlled to carry out the project or to enhance our understanding about that parameter.

The transient impedance is identified in symbol as '*z(t)*' as for it is correspond to time when reading is taken. The impedance includes resistance, inductance and capacitance. The impulse transient impedance is referred to the ratio of potential difference of point to the injected current. This is the parameter that we are going to study.

3.2 Transient behaviour on grounding grids

For this experimental study, the grids are buried in the ground instead of water. The current is injected in the grid. The current is generated by impulse current generator. The output of this generator is connected to the grid so that the current can be injected. The injection of current is done in different part of the grids. This is to analyze the impedance of the circuit in the grid during transient state whether it is affect the result or not. The distribution of current is different for diverse area of currents injection. Research shows that that outer place of the grid produces higher impedance during transient state.

3.3 Scale model design

Scale model design for this project include the tank, grid and some other electronic devices connected together to take a reading. In actual the best tank is in shape of hemispherical. Due to practical problem orthogonal tank is typically used for an experiment. The dimension of the tank can be designed in length of $30 \times 30 \times 20$ m^3. The maximum dimension of the grids should be lower for two times at least for a minimum

dimension of the tank. The dimension of grid is calculated diagonally. Hence, the outer dimensions for the grids are set to 16 × 16 m^2. The figures of the goods are shown below.

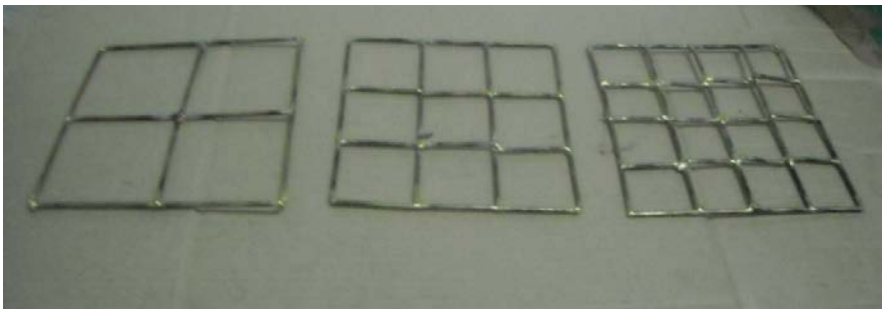

Figure 3.1: The tank that used to sustain the soil

For above configuration, soil is used in electrolytic tank. For the grounding grid, there are several grids used to investigate the transient. In this project three type of grids that are being used. The grids are meshes of 4, 9 and 16 respectively. The figures of grids are shown below.

Figure 3.2: The grids that buried in the soil

Above figures are the types of grids. The points with alphabet are the points where the current is injected. The points will be shown in Chapter 4.

3.4 Methodology Flow Chart

The main purpose of this flow chart is to follow the procedure or step by step instructions in order to ensure that the project is done according to plan. The reason of having this flow chart is to avoid making false observations or research during the implementation of the project. The flow chart can be divided into three parts, which is the study of the project, simulation analysis and analysis result. The flow chart of this project is shown in Figure 3.3. The scale model is first visualized on paper to get a better view. Then, after the model already built, the reliability and leakage will be checked by using water to know whether it is leak and can contain soil or not. After confirming the reliability of the equipment, the experiment is set using the tank, the grids, some wiring, AC power supply and oscilloscope. The data is then tabulated and analyzed. If the result is not sufficient or not reliable, some modification can be done to the set up to get better and clear results.

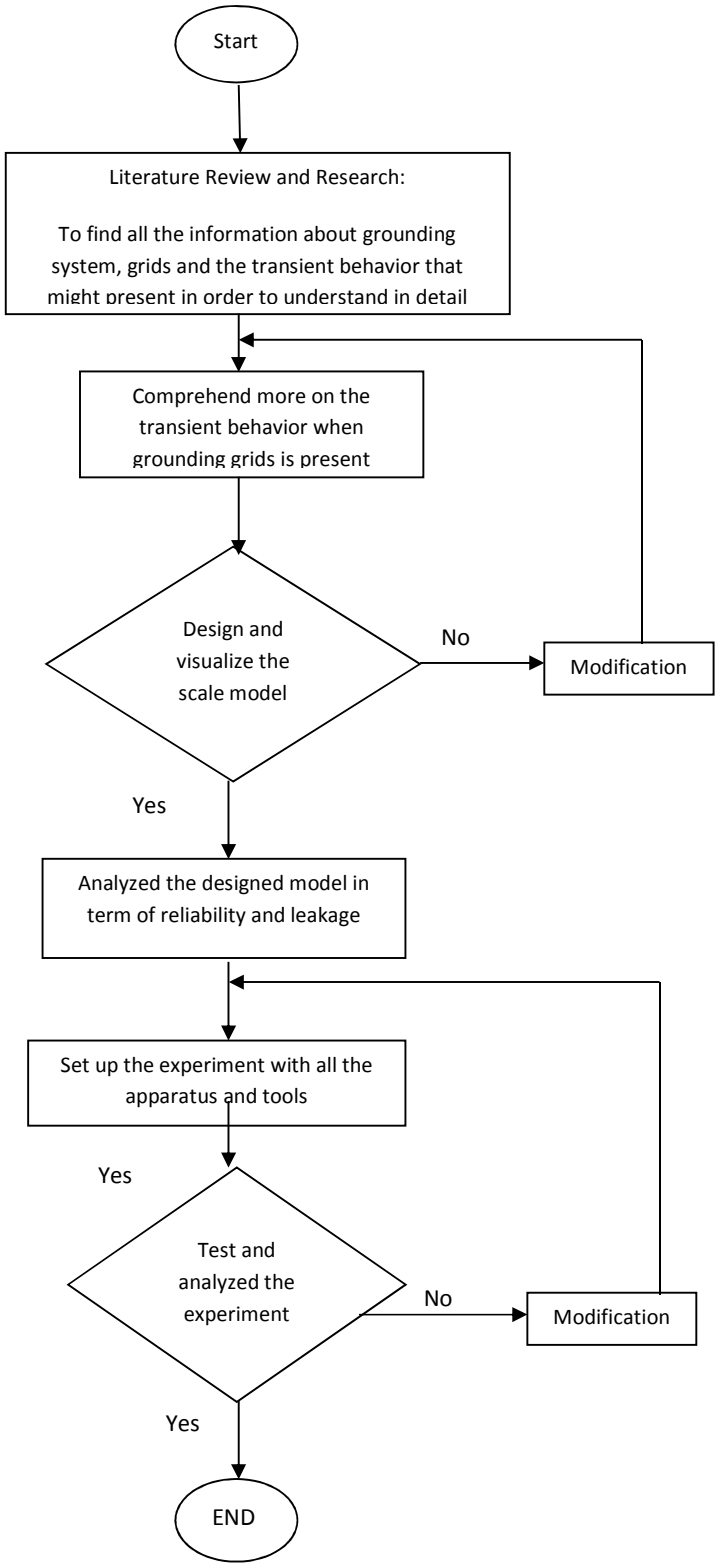

Figure 3.3: Flow chart of the project