CHAPTER 1
INTRODUCTION

1.1. Background

The geoelectric method is one of the geophysical methods that studies the nature of the flow of electricity in the earth, by injecting current into the earth through two current electrodes and measuring the potential difference through two potential electrodes on the earth's surface. The measurement results of the current and potential difference on the surface are then derived into variations in the resistivity value of each layer below the measuring point. The resistivity value in rocks is influenced by several factors such as rock homogeneity, water content, porosity, permeability and mineral content contained in it [1].

There are several instruments used in this geoelectrical resistivity method, namely Naniura for measuring rock resistivity in 1D or known as Vertical Electric Sounding (VES), Supersting Multichannel connected using a cable for measuring rock resistivity in 2D or known as Electrical Resistivity Tomography (ERT), and full-waver system which is an autonomous system in its measurement as well as a wireless connection for measuring rock resistivity in 3D. 3D measurement technology is developing rapidly with the aim of speeding up the measurement process with a large enough measuring area.

Several previous studies related to geoelectric measurement instruments; Geoelectric measuring instruments use the working principle of an inverter to increase the voltage and function to convert DC current into AC current and vice versa [2], design of a thin film resistance measuring instrument using the four-probe method (two outer probes for input current and two inner probes for measuring output voltage), the output voltage values are amplified with an instrumentation amplifier and processed with the ATMega8535 microcontroller using the Bascom programming language to obtain resistance values [3], design of a subsurface resistivity instrument using the 1D sounding method using the Arduino-Promini microcontroller which is divided into two blocks, Block A for measuring current and Block B for measuring potential difference [4], design of geoelectric devices with a voltage amplifier system using IC CD4047 up to 350 Volts, automatic current injection features, data storage systems using SD Card modules and control systems using Arduino Mega2560 [5], geoelectrical tool prototype using Arduino Uno R3 with the ACS712 sensor as a detector of injected current and a INA219 sensor as a voltage meter at the potential electrode which is then sent via the nRF24L01+ transceiver [6], design of a soil resistivity measuring device with four electrodes (four-point probe) [7], multiprobe electrical resistivity tomography (ERT) prototype with current and probe interval settings using a touchscreen interface [8], construction and design of electrical resistivity meters for characterization of archeological targets [9], User-programmable multichannel geo-resistivity meter [10].

The studies [3], [4], [5], [6], dan [7] show that the instrument is designed using four electrodes connected using a cable to the main unit which is then processed by a microcontroller. In one setting of the electrodes, one point measurement data is obtained. So, to get subsurface information in 2D it takes several different electrode arrangements, so it takes a long time and is less efficient in the acquisition process. Then there is the design of a multiprobe resistivity meter which can carry out measurements automatically and interconnect between probes using a cable [8], [9], [10]. There are some limitations of those researches; the voltage for injecting current is not sufficient to be carried out in geophysical exploration in the field and the measurement coverage; even some do not include the option of current injection (If there is a choice of current injection, the selection is based on the maximum distance of the measurement line. Meanwhile, the type of rock beneath the surface affects the need for the appropriate current injection.); during the field-testing process, the maximum measurement range is limited to no more than 20 meters. Meanwhile, in geophysical exploration, measurement lines often reach hundreds of meters or even up to 1 km in a rural area without internet connection, depending on the exploration target. If the research is implemented in geophysical exploration, then several improvements are necessary, starting from expanding the measurement range which will require a larger power source to inject current into the ground. In addition, with the expanded range, the length of the cables used to connect all electrodes during measurements will also increase.

Exploration of geophysics in the field using commercial instruments, such as the “Supersting”, often involves a significant number of human resources. This is caused by the large number of equipment that must be carried and installed, including the cables used to connect all electrodes during measurement. The measurement requires 4 pieces of cable. Where each cable has a length of 250 meters and weighs about 32 kg. So that the total length of the cable that must be stretched to connect all the probes is about 1 km and the total mass of the cable is around 128 kg. Therefore, the use of cables in geoelectrical resistivity measurements in the field is considered to take a lot of time due to the preparation set up and high costs due to requires a lot of human resources in preparation for the measurements.

Wireless communication is something that is currently booming in the field of communication today [11]. Most of the technologies used in everyday life already use a lot of wireless communication. Where several devices can communicate with each other wirelessly. Then, LoRa communication technology is one example of wireless communication. LoRa communication technology has been widely used in several studies to monitor a measurement or to conduct remote measurements, such as; remote instrumentation in bearing housing [12], monitoring system of groundwater resources [13], landslide monitoring [14], soil moisture sensing [15], and oil mist concentrate monitoring [16].

Therefore, this research will design a Geo-electric Resistivity Meter (GERM) multinode using a Wireless Sensor Network in the resistivity data acquisition process. Resistivity measurements are conducted in a distributed manner/ multinode and each node can communicate wirelessly using the LoRa wireless network. So that the results will provide a reduction in the mass of the cable carried out in the measurement, because the cable used is no longer connecting between probes on the measurement line. Furthermore, this research enhances the effectiveness of the resistivity meter on measurement process.

1.2. Problem Identification

Figure 1.1 shows a mind map of problems and solutions in this thesis. Geo-electrical single channel performing multiple electrode reconfigurations to obtain 2-D resistivity profile. This is because for a specific electrode configuration, one resistivity datum is obtained with a single current injection. Conventional geoelectrical resistivity meter, even on commercial or previous research, uses cable to connect all electrodes. The device needs to inject current and measure the surface potential across the line through the cable automatically. It makes the mass of the cable heavier, and this led to some limitations in land field measurement with long coverage, even up to 1 km or more even for land field measurement. Therefore, we need an improvement of the GERM device by reducing the cable and replacing it with WSN. Furthermore, in several previous studies, there were limitations, including insufficient voltage source at the current injection, no ways used to achieve effective current injection selection and the maximum coverage in field testing is considered too short, less than 20 m. While conducting geophysical exploration, measurement lines are often in the range of hundreds of meters to 1 kilometer. Furthermore, we need a system that can estimate the rock and mineral conditions between a pair of electrodes, which can be considered when selecting injection currents for greater effectiveness in the field. Therefore, in order to be implemented in geophysical exploration, it is necessary to enhance the system's capabilities.

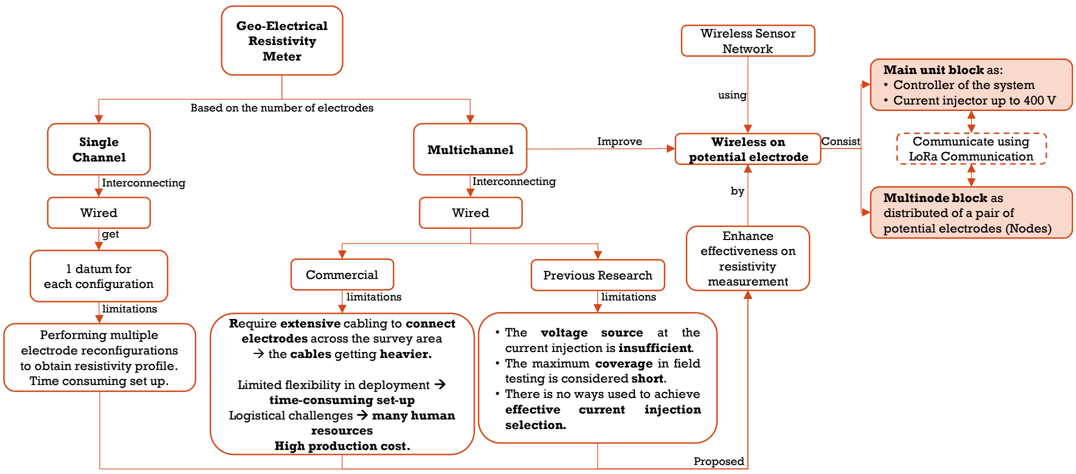

Figure 1. 1: The mind map used in this thesis.

The problem is how to enhance the Geo-electrical Resistivity Meter capability by implementing WSN in GERM. We need to reduce the cable on the system which was used to inject the current and measure the potential difference simultaneously along the measuring line. The system is divided into two blocks, Main unit block as current injector and controller of the entire system and Multinode block to measure potential difference on the surface due to current injection on main unit block. WSN implemented in multinode as a pair of potential electrodes and main unit which control the device and injecting current. There are many configurations of electrode in GERM such as Wenner, Schlumberger and Dipole-dipole. WSN can be done in GERM with dipole-dipole configuration. The dipole-dipole configuration makes in one injection we could get many datum point/ measurements result because the potential electrodes are placed outside the current electrode. We expect that this can overcome the limitations present in the GERM single channel. In one current injection, we obtain several resistivity data points. Improvement of capabilities in the main unit and multinode, such as increasing the maximum voltage in current injectors, there are options for injection power, and the system can estimate subsurface conditions between electrode pairs. All these improvements have been made by utilizing LoRa communication technology in their implementation. Therefore, we can reduce the need for cable usage in resistivity measurements. Furthermore, reducing the use of cables in the system and replace it with WSN can overcome limitations in conventional GERM multichannel.

The problem identification consist of; how to design a Geoelectrical Resistivity Meter (GERM) Multinode for the Geo-electrical measurement wirelessly, how to design current injector and controller in main unit block, how to design multinode block, how to choose network topology to communicate between MU and multinode block on Geoelectrical Resistivity Meter Multinode so data measurement transmitting effectively, how is the storage technique dan data transmission with minimum power consumption and zero loss data, how to measure reliability of data transmission on wireless sensor network.

1.3. Objectives

This thesis considers following assumptions:

1. This thesis designs and develops a Wireless Geo-electrical Resistivity Meter system that utilizes wireless communication technology, between main unit and multinode block, to enhance measurement effectivity and reduce physical setup constraints.

2. ~~This thesis seeks to validate sensor accuracy and calibration by assessing the accuracy of sensor in Wireless Geo-electrical Resistivity Meter system.~~
3. ~~This thesis focuses on synchronizing measurement timing through the implementation to ensure timing of current injections and potential difference measurements across multiple nodes, crucial for accurate subsurface resistivity prediction.~~
4. ~~This thesis aims to enhance communication reliability by evaluating the wireless communication using LoRa technology between the main unit block and the multinode block, by considering Packet Delivery Rate (PDR) and latency.~~
5. ~~This thesis develops a data handling strategy that complies with the zero data loss principle during storage.~~
6. This thesis conducts system validation to confirm the system's performance in real-world geological settings.

1.4. Scope of Work

The scope of work of this thesis are:

1. Measurement configuration in this thesis uses dipole-dipole configuration.
2. The network topology used is a star topology
3. This thesis determines the value of apparent resistivity
4. The measured data apparent resistivity (ρ_{app}) is adjusted to the inversion software format.

1.5. Expected Results

In the previous work [8], [10] and [9] design low cost, automatically and programable multichannel Geoelectrical Resistivity meter. However the electrodes are connected by a cable, so the mass of cable is getting heavier. It means the device requires a lot of workers, more time in the data acquisition preparation process on land field measurement. Meanwhile the device is tested in short maximum coverage on the field, 7,5 meters [9], 22 meters [8] and 30 meters [10]. This thesis proposes a new geoelectrical resistivity method by reducing the use of cables connecting the potential electrodes and replacing it with wireless sensor network technology. In previous research, it was successful in designing a current injector using TTGO LoRa ESP32, but the maximum voltage is 12 volts [17]. It means the current injector has a limitation in coverage and is not integrated yet with potential difference measurement. We expect a better device with land field measurement more effective and the maximum coverage reach longer range using LoRa communication.

1.6. Research Methodology

In this thesis, we use fundamental study and experiment based on work-Packets (WP). These are the following WP for this thesis:

WP1: Design current injector.

WP2: Design multinode sensor.

WP3: Design full system of multinode wireless sensor on GERM prototype.

WP4: Evaluate the sensor measurement both current and potential.

WP5: Evaluate the communication performance.

WP6: Tests the device in land field and compare the result of inversion to the given model.

WP7: Analize the whole system.