

**Online Monitoring System for Domestic Distribution Box  
(Final Report)**

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## **ABSTRACT**

A new method for domestic distribution box control and monitoring is proposed and developed using an interconnection of microcontroller system, android device and server with internet connection. Data acquisition from the supply voltages inside the distribution box and control of the circuit breakers, are performed to analyze the cause of power disruption and to cut off the faulty line which is usually time consuming to perform manually. The system works by automatically testing each of the plugs connected to determine the cause of the failure and isolate it. With the faulty line or lines being found, the appropriate data will be sent to a server through a wireless connection which will then notify the user the modification made. The advantage of this system is to quickly notify the user the disruption occurred, the possible fault location while allowing the user the flexibility to take any further action by switching the circuit breakers to affirm the cause of failure. Parallel processing via multi-threading in server are used to increment the upper limit of TCP transmission's throughput. Multiple SQLite-database will be used by multiple threads for parallel storage of data to increase performance.

# **CHAPTER 1**

## **INTRODUCTION**

### **1.1 BACKGROUND**

The safety of any human being has always been the highest priority in any location, be it in our home or at work but we are usually not aware of it until an unexpected event have occurred, either caused by lightning strike, overload or faulty appliances.

Electrical power supply interruption due to temporary and/or permanent faults has been a common problem in domestic areas and the conventional method of restoring the power supply is usually time consuming. Manual power supply restoration are usually performed in such conditions.

Till today, we relied extensively on the protection system which are based only on circuit breakers. In order to overcome the hassle of manual fault isolation and power restoration, a novel automated system has been proposed. This project serves to enhance the existing protection systems in a domestic area.

### **1.2 PROBLEM STATEMENT**

The typical power protection system used in a domestic area is manually controlled thus requires time and effort to restore the power supply depending on the type of fault.

Such events, is undesirable as power discontinuity can cause large amount of loss in asset. Server room, refrigerator room, security systems, aquarium shops and fire alarm systems are a few of the sectors which will be affected.

Several possible problems are as follows:

1. Circuit breakers in trip condition, until it is manually switch ON but will not be, if the house tenant is away and unable to return for a period of time.
2. Current auto reset Residue Current Circuit Breaker (RCCB) system is unable to operate if the faulty MCB is still in ON position.
3. Prolonged power discontinuity will contribute to property loss such as food damage, malfunction of alarm system, and dying of exotic fish.

### **1.3 OBJECTIVES AND SCOPE OF STUDY**

It is therefore important to devise a better way to restore power continuity in a more efficient method by integrating a smart and semi-automated systems for finding the cause while allowing the flexibility to control the circuit breaker remotely and securely from anywhere with internet access.

A low cost Supervisory Control and Data Acquisition(SCADA) system is proposed to be integrated into a typical protection system by means of employing functionalities for fault detection, isolation and power recovery.

The system will be embedded with Wi-Fi connectivity for internet access. In addition, a Graphical User Interface (GUI) will be made on multiple client devices for visualization and control of circuit breakers conditions.

The objective of the project is to design a domestic electrical protection system with the ability :

1. Auto-reset RCCB if there is no permanent fault.
2. Auto-detection the fault location if any permanent fault occurred.
3. Isolate the fault by switching OFF the affected MCB in order to ensure the power continuity in the building via wireless technology.

## **CHAPTER 2**

### **LITERATURE REVIEW**

The conventional protection system used in domestic area are usually made of circuit breakers which trips when the specific requirements are meet, such as when current conduction and/or earth leakage current (with reference to the voltage level) reaches a certain limit. The user will usually not know that there may be an irregularities in the power system until one of the circuit breaker trips[1].

Even though the conventional system usually perform its required functionality by tripping the circuit breaker after the failure condition has been meet, but it is not yet able to provide a complete protection to the electrical system and/or person, nor does it provides any indication on when the hazard that is about to happen [1]. According to [2], it is possible that even with a healthy RCCB, the hazard of a faulty device to harm a person cannot be prevented by highlighting the number of accidents in Italy between 1960-1987.

One of the drawbacks in the use of a typical circuit breakers is the lacking of a smart system or automated system to detect the type of fault, pinpoint the source of fault and disconnect the nearest faulty connection and/or reconfigure the amount of load [3]. In the event of a permanent or temporary fault in a household, the tripping of a regular circuit breaker, will usually remain open circuit regardless of the type of fault until it is manually reset after the inspected of a qualified electrician[1]. If the fault were to occur in a distribution network with vast amount of switches, it will be unfavourable and risky for the technician to travel to the field and perform manual maintenance [4].

According to [5], systems in power distribution network has implemented intelligent systems where if a power interruption occurs, fault analysis will be perform with the help of a computer having access to remote-controlled circuit breaker.

Due to the complex topology in a power distribution system, methods such as Fuzzy Logics by Bellman-Zadeh [5] algorithm are used to solve multiple criteria conditionings for finding the best topology to perform load transfer to effectively restore power to the customer with the least amount of time. Not long later, another method of performing multi-criteria selection which is Analytic Hierarchical Process(AHP) [4] are adapted for its ability to handle multiple-level criteria checking effectively. Both [4] and [5] implemented their algorithm to perform the load transfer in software simulation using real data from power utility to prove the efficiency of their work which can be implemented in a complete power system.

Similarly, a software named, Electrical Transient Analyzer Program (ETAP) is used by [3] for performing multiple type of power analysis for monitoring and process to determine the solution to different types of fault possibly happen in a substation. The software runs on collected data from substations and emphasizes on protective device coordination analysis, harmonic analysis, motor starting analysis, short-circuit analysis, load flow analysis, and capacitor calculation analysis, for analyzing the condition of a power system and suggesting appropriate solution.

Power grids implementing such intelligent systems are known as 'Smart Grid' where it is capable of implementing new functionalities such as automatic fault detection and power restoration without requiring human intervention [6].

Work from [7] on the other hand uses a different approach to locate the faulty line where by 15 lines are being monitored continuously up to 16 bit resolution with sampling rate of 10 kHz. During an interruption, the monitored signal will be time-stamped using a GPS clock which will synchronize the time between different circuit breakers before sending all the information to a central personal computer(PC) for data storage and analysis. This is to ensure accuracy of the acquired data for better signal analysis. The data transmission are sent wirelessly using Frequency Hopping Spread Spectrum (FHSS) technology for one to all and all to one communication



similar to a star connection. The advantages offered by FHSS is the protection where the frequency hops from one to another frequency in a pseudorandom sequence preventing eavesdropping and jamming.

Similar to [7], the work by [8] utilizes the same method for bus bar monitoring in substation. Current transformers are being monitored continuously via a node which samples at 3840hz at 16bit resolution. The collected data then sent to a centralized server via fibre optic to be stored and to simulate the fault condition.

In smaller scale power systems such as the power connection in a household, a different approach was proposed by [1] which monitors individual plugs known as Smart Plug. The device works by measuring the temperature, voltage and current of a plug to determine the power consumption. A threshold value is then set by the user to allow the system to notify the user for early indication of faulty devices or irregularities in the system. Wireless connection utilizing wireless local area network (Wi-Fi) are used for data transfer between the sensor nodes residing in the Smart Plugs and the Server. To increase the coverage area of the Wi-Fi, master nodes with broader coverage are positioned in every room of the building for redirecting data sent from the sensor nodes to the server. By using an android device, the user will also be able to monitor the signals, which are the rating of power consumption, by logging into the web server and take required precaution for any detected irregularities.

Similar to [1], a cost effective Power Outlet Overload Protection Monitoring (POOPM) system proposed by [9] has an added advantage, by offering the possibility of plug control using Solid State Relay (SSR) residing in the smart outlet for switching on or off the device connected. The smart outlet relies on Power Line Communication (PLC) for communication with the server running on an Acorn RISC Machine (ARM) processor powered embedded system with Wi-Fi connectivity. Each smart outlet with their own microcontroller will acquire data and send the information, which is the power consumption rating value to the server for monitoring purposes. The server running on UNIX operating system with Web Server will allow user to browse through the monitored values and control accordingly.

In the communication sector, work by [10] mentioned the overheads residing in typical TCP communication in normal networking adapter causing slow down in data transfer. With the introduction of Remote Direct Memory Access (RDMA) capability to reduce CPU overheads allowing for higher through-put and low-latency networking, the effort require is immense and the protocol is not common. InfiniBand is a host bus adapter used in parallel data transfer between vast amount of super computers. The findings of [10] found that the upper limit of TCP transmission has been greatly improved to an extent, where it is better than RDMA due to multi-threading capability in the server to handle TCP transmissions in parallel..

In comparison with the work of [10] which utilizes metadata server (MDS) and Object-based Storage Device (OSD) which allows high transfer rating, the work by [11] suggested the use of SQLite database for embedded systems for its balance of functionality and storage capability which are the main concern in embedded systems.

In addition, the work by [12], mentioned SQLite as a platform independent, lightweight in size, compact and fast database. The use of Advance Maryland Automated Network Disk Archiver (AMANDA) was suggested in the use alongside SQLite for its standard format which are useful when making backup from multiple clients to a single server.

SCADA system are widely used in various sectors where one of such is the energy management sector. In many case, such system are used along with Geographic Information System (GIS) for more diverse collection of data including the geographical information. Such systems are mentioned in the work of [13] where a software adapter are presented by the author to enable data exchange between the used protocol in SCADA and GIS system. With the bridging of geographical and other data, the functionality of locating failed components geographically will be possible.

A comparison between the work of [1] and [9] are tabulated in Table 2.1. The work of [7] is summarized as in Table 2.2 while [3] and [4] are summarized in Table 2.3 and Table 2.4 respectively.

Table 2.1 : Summary of Power Outlet Monitoring System

Ref. No.	Summary
<b>A. Power Outlet Monitoring System</b>	
[1]	<ul style="list-style-type: none"> <li>• <b>Background</b> : Discuss the presence of electrical hazard in a house due to faulty appliances and electrical power distribution.</li> <li>• <b>Problem</b> : Insufficient protection by existing housing protection system.</li> <li>• <b>Solution</b> : Presented a monitoring socket outlet with wireless sensors to monitor power consumption. Will trigger a warning and alert the user if power consumption reaches a threshold value.</li> <li>• <b>Concept</b> : Upon requesting data from a user smart phone, the power sockets in each room will respond by transferring its acquired data to a master node, to a server for data storage and finally back to the user smart phone to display.</li> <li>• <b>Result</b> : A system allowing the user to monitor Temperature, Voltage, Current, Device Id, Time and Date.</li> </ul>
[9]	<ul style="list-style-type: none"> <li>• <b>Background</b> : Discusses the widespread of smart house systems for better convenience, comfort, energy efficiency and security.</li> <li>• <b>Problem</b> : The cost of a smaller scale system may be costly for installation and other maintenance.</li> <li>• <b>Solution</b> : Proposed a cost effective system for monitoring power consumption at power outlets. The system will issue a warning for possible overload events.</li> <li>• <b>Concept</b> : Power outlets throughout the house embedded with Hall effect sensor and Solid State Relay will communicate with a server consisted of an ARM micro server using Power Line Communication (PLC). The server will have Wi-Fi connectivity allowing for internet connection.</li> <li>• <b>Result</b>: A paper presenting the above concept and will be implement it in the future.</li> </ul>

Table 2.2 : Summary of Substation Monitoring System

Ref. No.	Summary
<b>B. Substation Monitoring System</b>	
[7]	<ul style="list-style-type: none"> <li>• <b>Background</b> : The reliability of a circuit breaker is critical for its purpose to reconfigure the power system in a substation.</li> <li>• <b>Problem</b> : Circuit breaker has no intelligent and if does not function according to its command, the incomplete operation will shutdown the power system.</li> <li>• <b>Solution</b> : Proposed a system to monitor all circuit breakers in real time.</li> <li>• <b>Concept</b> : Intelligent Electronic Device with GPS clock receiver located on each circuit breakers will send time stamped analogue signals, during a trip, wirelessly (FHSS) to a PC in a Control House for storage and processing.</li> <li>• <b>Result</b> : A system that monitors the change in circuit breaker condition for evaluating the cause of its' event and isolate any faulty line if necessary.</li> </ul>

Table 2.3 : Summary of Substation Fault Analysis Software

Ref. No.	Summary
<b>C. Substation Fault Analysis Software</b>	
[3]	<ul style="list-style-type: none"> <li>• <b>Background</b> : Lack of power analysis in electrical power network.</li> <li>• <b>Problem</b> : If fault occurs, it is time consuming to find and isolate it. There is also hazard when performing manual switching on circuit breakers.</li> <li>• <b>Solution</b> : A Electrical Transient Analyzer Program(ETAP) is used to analyse the network to find the fault type and location.</li> <li>• <b>Concept</b> : Using practical data, the software analyzes it for calculating harmonic analysis, short-circuit analysis and other.</li> <li>• <b>Result</b>: The use of a power analysis software simulation to tell the type of fault occurred in the power network.</li> </ul>

Table 2.4 : Summary of Smart Grid System

Ref. No.	Summary
<b>D. Smart Grid System</b>	
[4]	<ul style="list-style-type: none"> <li>• <b>Background</b> : Power discontinuity is undesired and should be minimized.</li> <li>• <b>Problem</b> : Typically during a fault tripping a circuit breaker, a maintenance crew has to travel far distance to the site to check and restore the power.</li> <li>• <b>Solution</b> : Presented a Smart Grid system to automatically find and isolates the fault line before restoring power to the grid.</li> <li>• <b>Concept</b> : In conjunction with an already operating Supervisory Control and Data Acquisition (SCADA) system, the proposed methodology performs load transfer by considering multiple criteria through Analytic Hierarchical Process (AHP).</li> <li>• <b>Result</b> : A power grid switching methodology for working with a SCADA system for choosing the best topology during contingencies to minimize affected areas.</li> </ul>

## CHAPTER 3

### METHODOLOGY

The system's main purpose is to monitor the continuity of the incoming electricity and control the circuit breakers by means of wireless remote control via smart devices. The project consisted of several sections which are required to setup the monitoring system which in total consisted of a Server , several Client ,and several Supervisory Control Node (SCN).

In overall the system consisted of the following blocks.

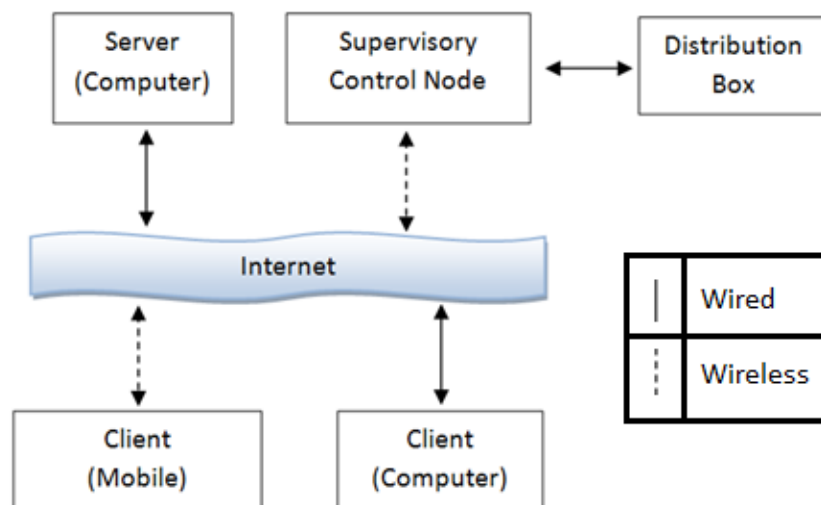


Figure 3.1 : Overall System

In comparison with other designs, the proposed system are designed in a way to allow for faster implementation with the least setup or hardware requirement while allowing the flexibility to integrate additional features. The system works by transferring data both ways via a custom transmission protocol which replaces the common Hypertext Transfer Protocol (HTTP) formatting for a more direct

transmission with the possibility to integrate custom encryption engine. The communication protocol will be described in detail in section 3.1.

The sequence of the system originates from the Client and the SCN while the Server will only listen and only accept any valid incoming connections. Both the Client and the SCN establishes connection by sending packets of data via Transmission Control Protocol (TCP) to the public Internet Protocol (IP) and to a dedicated public Port for this Monitoring purpose. A more detailed configuration will be discussed in section 3.2.1 Server.

For the completion of this project which requires design of circuitry and creation of application for both computer and mobile Operating System (OS), the following software tools are required :

1. QT Creator, a open-source Integrated Development Environment (IDE) for developing the Server Software with C++ language.
2. Android SDK, a open-source IDE for developing client applications used in Android OS. Developed with Java language.
3. Altium Designer, a tool for designing circuits. Will be used to construct the Monitoring Node circuits and to produce a Gerber file for Printed Circuit Board (PCB) manufacturing.
4. MPLAB, a open source IDE for developing firmware for Microchip microcontrollers. Microcontrollers are needed to be used in the SCN.

### **3.1 TRANSMISSION PROTOCOL**

A communication takes place from both the Client and the MCN to the Server upon connection and terminates after a transaction to make space for the remaining traffics to enter. Data are exchanged at an interval of 1 second for both the Client and the MCN where each transaction averaging at an estimated time of 2mili seconds (duration of accessing, modifying and extracting data from the database). The amount of traffics allowed varies with the interval therefore higher intervals of data exchange will result in higher traffics.

Since a custom transmission protocol is used for the data transmission, the data structure is also designed in a way to accommodate the variation of data types. A detailed view of the data structure is shown in Fig. 2 where ID is the identification

number to distinguish different sets of client and MCN to prevent cross communication, while the TYPE is to differentiate between the data type being transmitted and the SIZE is to allowed a known number of VALUE being sent.

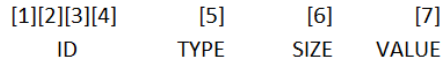


Figure 3.2 Data Structure

With this data structure which occupies at least 7 characters (more, if the SIZE is more than 1), the transmission protocol consisted of several types and can be varied up to 255 types (8 bits). The data length is variable where the server accepts a line of data and terminates at the end of a line or at a specific data length. The typical data type used in the transmission are such as 'heartbeat', 'login authentication' and 'data update'.

The data transmission flow are shown in Fig. 3 indicating how the data transaction is done. Upon successfully authentication of username & password or id from the client or MCN, heartbeat will be sent at an interval of 1 second to acquire new data from the other side of the server. Both client and MCN are allowed to perform 'data update' if conditions are met, to send data to MCN and client through the server.

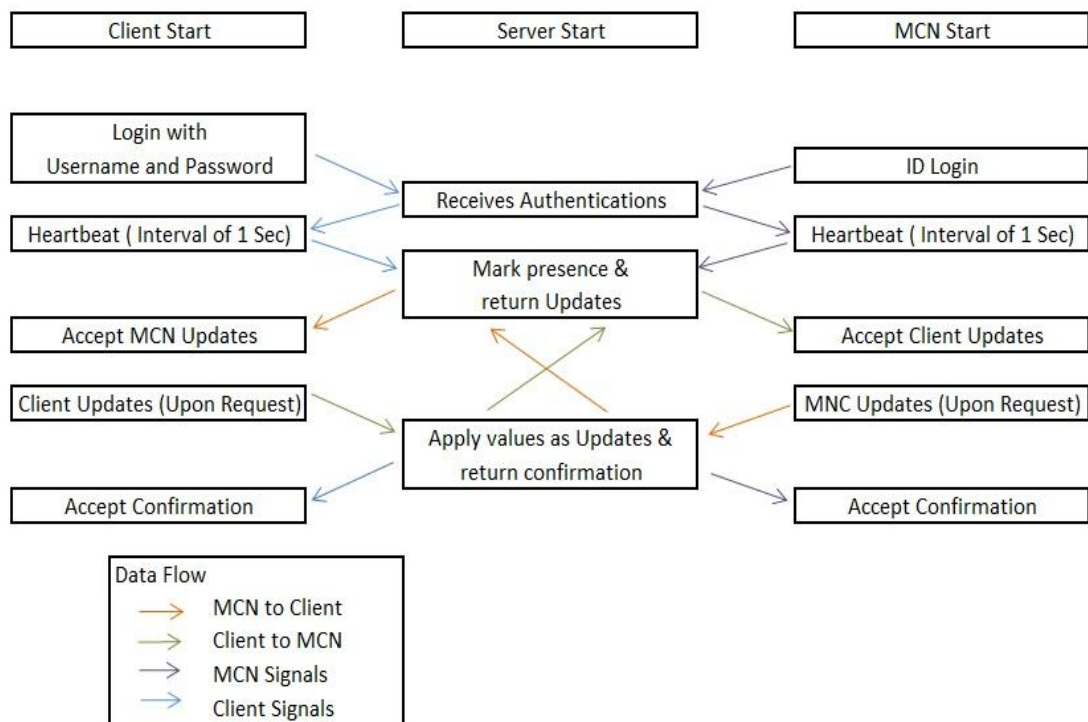


Figure 3.3 Communication Protocol



Since the server program are meant to handle multiple input connections, the transaction of data depicted in figure 3.3 will be multiplied for every incoming connection. The updating and returning of values are performed by writing and reading of an SQLite database which will be described in detail in the Software Design section. Different from other database, the SQLite database does not allow two or more connection to connect at one time, thus when two transaction are in progress, one of the transaction shall occupy the database while the other will wait until the previous transaction has finished. This is visualized by the 'MCN to Client' and 'Client to MCN' arrows in figure 3.3 where one of the process shall be held pending until the other has finished.

The same process applies for other sets of Client and SCN, but one set of Client and SCN does not affect another set of Client and SCN thus allowing for vast amount of sets to communicate without affecting each other.

## **3.2 CONFIGURATION**

### **3.2.1 SERVER**

Prior to starting the server, there are two choices of configuration. If were needed to be put into large scale usage that host multiple users' monitoring on multiple nodes, the server program needs to be installed in a server computer in location accessible to the internet and is connected via TCP/IP connectivity to a router which allows IP and Port re-routing capability.

Since the server is needed to provide connections to multiple users and monitoring nodes, the server computer is preferred to have the following requirements :

1. Multi-threading with 4 or more cores.
2. Random Access Memory of 8GB or more.
3. Windows Operating System with 64-bits.
4. Local Area Network Adapter with speed of at least 100mbps.

It is also important to select a compatible router for this purpose as well as an internet connection with fixed IP from the service provider to allow accessibility for client and monitoring nodes from any location. The router then create a new connection by forwarding two items which are the IP and Port value. The router

needs to forward the public IP to the subnet IP assigned to the Server Computer as well as the public port to an internal port (can be any value not used by other programs, for example, 1234) used by the server.

After meeting all the requirements, the Server program can be setup easily by copying all the necessary files. Having the setup on the router done, the server program can then be started by configuring it to listen to the IP address assigned to the Server computer and the Port value such as 1234 as specified previously.

In comparison with the first configuration, the second configuration will be slightly easier to setup as it is meant for a closed network monitoring system. Having the Client and the Monitoring node connected to the same network, in a campus an internet connection is not required.

The client and monitoring node only needs to configure to transmit data to the IP assigned and Port used by the Server computer. It is advised not to use other programs along with Server Computer which utilized the network adapter.

### **3.2.2 CLIENT**

The Client device used in this system is smart phone device running on Android Operating system. Since the "Client" is an Android Application, after installing the program into the smart phone device, the only configuration needed are listed as the following:

1. Server's IP address.
2. Server's Port value.
3. Username.
4. Password.

The IP address to be inserted are the Server Computer's IP address while the Port value is the Port value listening by the Server Program. Different set of Username and Password will be used to access different Monitoring Nodes. This will allow for multiple users' monitoring of multiple Monitoring Nodes.

### 3.2.3 SUPERVISORY CONTROL NODE (SCN)

The Supervisory Control Node is an embedded system residing in the Monitoring Device which is driven by a PIC18F458 Microchip microcontroller. The device have two main communicates modules which are the Controlled Area Network(CAN) and the UART (Universal Asynchronous Receiver and Transmitter). The CAN communication are mostly used for debugging and can be used to extend the capability of the Monitoring Node.

In order to communicate with the Server, the Monitoring Node need to send data via the UART communication to a Xbee-S6B device which translates UART data into TCP communication and sends it wirelessly via the WiFi communication to a nearby wireless router. In order for this to work, the XBee-S6B must be configured for the following purposes :

1. To log into a nearby wireless adapter which are directly or indirectly connected to the server.
2. To send data to a specified IP and Port address which should be the Server's IP and Port value.

In order to configure the following items, the adapter must be connected to a computer installed with X-CTU, a program developed by "Digi" for configuring the Xbee-S6B. After plugging in the device and opened the program the device should configure according to the following steps :

1. Select the device from the "Select Com Port" list and Press Test/Query. If returned with ID and OK, continue, else exit the program, re-plug in the device and open the same program.
2. Go to "Modem Configuration" tab and press "read" to obtain the current settings.  
To enter a wireless network router.
3. Press "Active Scan", and look for the desired wireless network, key in the password if necessary, and press OK. It shall takes a few moments to connect.

To configure the Server's IP Address and Port.

4. Press "Addressing" to expand the drop-down list, select "Destination IP Address", press "Set" and key in the IP address of the server.
5. Repeat step 4 but instead, select "Destination Port" and key in the Port value in Hexadecimal. The Port address selection in the Server is in decimal therefore it must be converted into Hexadecimal value for this item.

### **3.3 SOFTWARE DESIGN**

#### **3.3.1 SERVER**

The server program is made by creating a computer application which will run on Microsoft Operating System (OS). The designed program will listen to specific Internet Protocol (IP) address and specific port for command and data transmission.

In total, there are 4 tabs which are known as :

1. Main - To start or stop the server program.
2. User Manager - To add, remove or modify user data.
3. Monitoring - To monitor the availability of devices and any changes in behaviour.
4. About - About the Author.

In the Main tab, a list of IP addresses will be prompted for the user to select from and a text bracket to insert the Port value. The server application will also be programmed along with the functionality to create new user, remove existing user and modify existing user. This is known as the User Manager tab. For every created user, a new SQLite database file is created with regards to a specific Identification Number. Each of the database will contain the following items :

1. SCN Identification number.
2. Client Username.
3. Client Password.
4. Node Username.
5. Node Password.
6. Digital Values read by the Node.
7. Digital Values to be output by the Node.

For every incoming connection, a thread will be generated, and will locate the created database according to its' SCN Identification number. The thread will then open the database, apply the required modification, look for any updates and return any necessary data which are already depicted in the Figure 3.3.

Two main items communicating with the server are the Client and Supervisory Control Node. The main task to be performed by the server is to :

1. Listen to incoming connection and decode the message.
2. Compare the decoded incoming ID and check if it is in the allowed list.
3. If allowed, check the message type.
4. If the type is username, userpass, nodename or nodepass, it will look into the database and compare its' string value. If correct a true will be returned and false if otherwise.
5. If the type is to modify digital values the message data will be used to overwrite the data inside the database and it will be marked as updated..
6. If the type is a heartbeat type, the server will read the database looking for any updated values, return the data and unmark the updated value. This will occur when a client device is looking for updates in the monitoring device or vice versa.

When any incoming connection successfully performed a task, the client or node will be marked online in the Monitoring section. The monitoring section will be used to tell the operator which device is online, and what are the modified and monitored values.

A simple design of the server design is depicted in figure 3.4 to show the flow of data incoming from an outside router to the program and how multiple threads are spawned to handle multiple connection residing in multiple sockets. Each of the threads will also handle a specific SQLite database for parallel access of database to increase throughput of user connectivity.

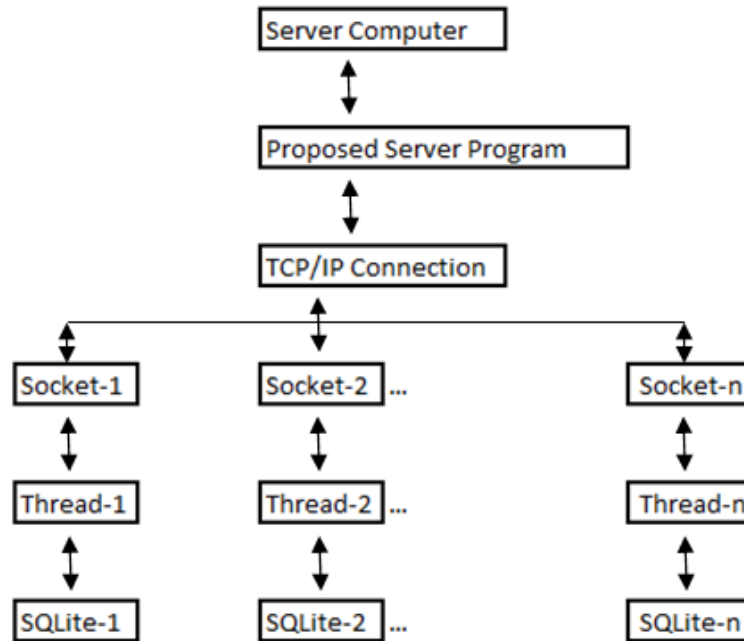


Figure 3.4 : Server Design

In the User Manager tab, users will be allowed to add more database for new sets of Client and SCN. This will allow the administrator to control only limited amount of Client and SCN to access the server.

The functionalities possible to be done in the User Manager tab are:

1. Create database for new sets of Client and SCN. Different 'User ID' determines different sets of Client and SCN.
2. Check for existing sets of Client and SCN.
3. Modify Client and SCN settings for 'Username', 'Userpass', 'Nodename' and 'Nodepass'.
4. Remove any existing sets of Client and SCN.

In the Monitoring tab, the administrator will be allowed to monitor the connections that is taking place with the server. The following items will be available for monitoring :

1. Total number of connections.
2. Client-x Online
3. SCN-x Online
4. Client-x Data.

## 5. SCN-x Data.

The '-x' value signifies the total number of connection allowed, and in this case, it is from 1 - 2000 users. therefore there are 2000 times the item 2. to 5 which are arranged in a table.

There is a timer at the back of the system that will set any connection as offline if they did not receive any messages for a specified timeout value. Even in the case of a disconnection of either the Client or the SCN, any updated value shall be stored in the database and will be sent to the other end, repeatedly until the other end has confirmed the acceptance, to prevent lost of data.

### 3.3.2 CLIENT

The clients main objective is to allow the user to observe the conditions of the circuit breakers, whether they are ON or OFF while at the same time allow the user the flexibility to manually turn ON or OFF any controllable circuit breakers.

The client is a smart-phone device running on Android OS therefore the software needs to be designed to perform the following functionalities in Java code :

1. TCP library for opening and closing connections.
2. Timer for periodical triggering of data transmission.
3. Notification manager to notify user via Vibration and Sound.
4. Page updater to display changes in values.
5. Custom Transmission Protocol for this application to handle functions such as Login, UpdateValue and RetrieveValue.
6. Auto server reconnection to prevent disconnection during data lagging.

In total 4 pages with GUI are created for the following purposes :

1. Login Page for entering of Internet Protocol Address, Port, Username, User password.
2. Monitoring Page for displaying of the circuit-breaker's condition, sockets' condition, the connectivity of the Monitoring Node, and the setting of Auto-Recovery feature.
3. Setting Page for allowing control on the reset of the circuit breaker, switching of the sockets and to enable or disable the Auto-Recovery feature.

4. About Page for more information of the author.

During an unexpected event, where any of the input changes, the server will send notification which contains information of the event to the Client upon connection to the server. The case of a recovery from power disruption, the modified outputs will also be sent to the user in the Monitoring page to notify the user the faulty sockets.

The main Client application will be created only for usage in Smart Phone with Android OS to this extend due to time constrain.

### **3.3.3 SUPERVISORY CONTROL NODE (SCN)**

The main board is a custom made circuit board which is made specifically to send and obtain, measurement and control data, to and from the extension board which contains circuit breakers.

The circuit will perform two task periodically every 3-5 seconds. This is also known as the heartbeat of the monitoring node. If the node successfully perform the heartbeat, the node ID in the Server's Monitoring page will be showed as Online.

The two tasks to be performed are :

1. Perform updates by updating the server for any changes in the readings .
2. Obtain any updated output values from the server and apply it.

In order to perform such functionality, the microcontroller needs to be programmed to utilize the following functionalities :

1. CAN Library for data transmission to additional extension boards if necessary or for debugging purposes.
2. UART Library for data transmission to the server via the X-Bee S6B.
3. Digital Input reading.
4. Digital Output.



### **3.4 HARDWARE DESIGN**

#### **3.4.1 SERVER**

The server is a computer with the following specification running the designed Server Program on Windows OS :

1. Intel Core i3-4350, 3.6Ghz.
2. Asus Motherboard.
3. Kingston 2500Mhz Random Access Memory (RAM).
4. 120GB Solid State Drive.

This specification was chosen with the limited amount of funding to perform the operations with the least amount of performance. The limitation with this spec is the amount of transmission it will be able to handle as the Server program spawns a new thread for every new incoming connection. The recommended specs are stated in the "Configuration -> Server" section which will be able to handle multiple threads easily without lagging.

#### **3.4.2 CLIENT**

The Client hardware device is a Smart Phone device running on Android OS. The hardware client are not designed by the Author nor is it part of the project's scope therefore a Samsung S4 Smartphone is used for the designed Android application. It is recommended to select any Android device with Android version 4.4.2 and above with WiFi capability for the designed Android Application.

#### **3.4.3 SUPERVISORY CONTROL NODE (SCN)**

A detailed diagram showing the interconnection between the Supervisory Control Node and the Distribution Box represented by the Solid State Relay (SSR) can be seen in figure 3.3. The SCN node consisted of two section which are; first, a Main board (also known as Microchip in the diagram) connected to; second a Peripheral Board containing the following items :

1. Electric Leakage Circuit Breaker (ELCB)
2. MCB (Main Relays)
3. SW1, SW2, SW3 (Secondary Relays)

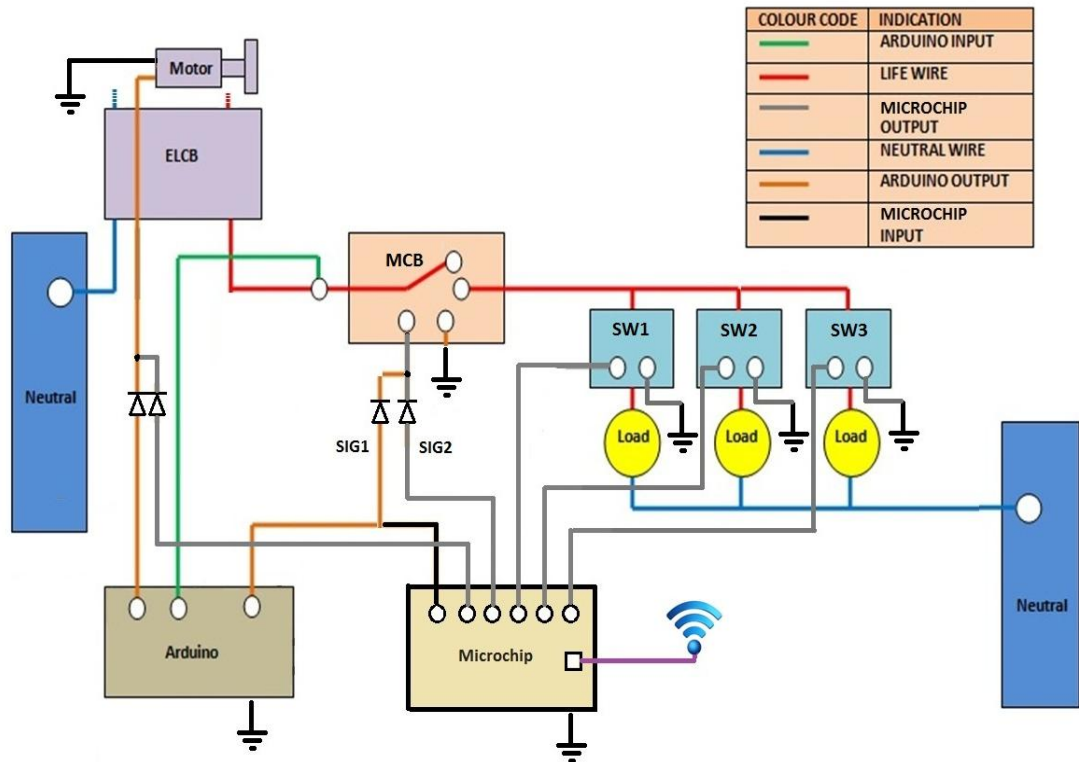


Figure 3.5 : Supervisory Control Node Design

The third item which are the Arduino are used to control the ELCB in the case of tripping due to lightning strikes for three times. If it occurred more than three times, the SSR\_M will be disconnected and the ELCB will be reset to closed condition allowing the Microchip to continue its task. The functionality and design of Arduino will not be discussed in this report as it is done by the previous student.

### 3.4.3.1 MAIN BOARD

The main board is a custom made circuit board which is made specifically to send and obtain measurement and control data, to and from extension boards which are attached to the circuit breakers. The obtained data then passes to the server through a Wi-Fi module with internet connectivity.

The following are the components inside the main module:

1. Microchip PIC18F458.
2. XBee Starter Kit without module.
3. Digi XBee S6B, Wi-Fi module
4. MCP2562, CAN Transceiver.

5. 5V Voltage Regulator.
6. Switches.
7. Zener diodes.
8. Resistors
9. Ports.
10. Light Emitting Diodes (LED).

### **3.4.3.2 PERIPHERAL BOARD**

The peripheral board are switches which enable the main board to perform a variety of tasks. The current peripheral board connected to it allows the control of 230V electricity to different plugs. The plugs are represented as "Load" according to figure 3.3.

The current board utilizes the use of 4 Solid State Relays to control electricity flow to different power outlets allowing for the functionality to disconnect plugs connected to faulty appliances and recover electricity to the remaining plugs connected to operational appliances.

The design of the board allows for dual control of the SSR\_M by both the Arduino and the Microchip with the use of Diodes. This is not necessary for the remaining three relays as they only accept signals from the Microchip.

The actual main board and peripheral board is shown in Figure 3.4. The Xbee S6B WiFi module can be seen attached to the main board.

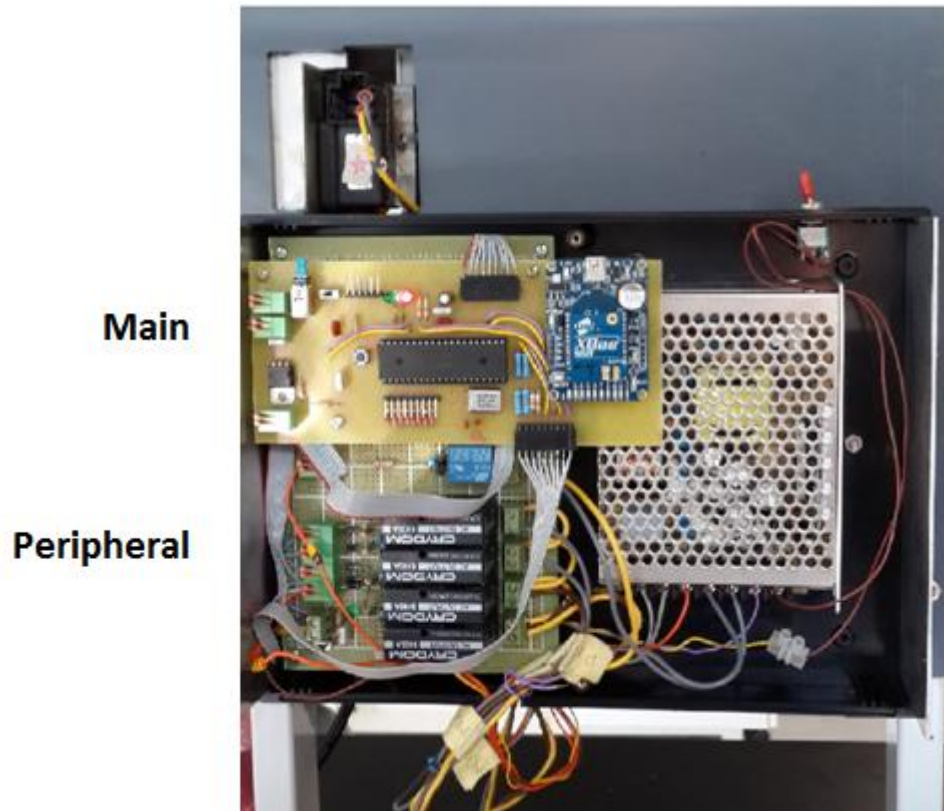


Figure 3.6 : Supervisory Control Node Hardware

### 3.4.3.2 EXTENSION BOARD (OPTIONAL)

The extension boards can also be any other boards or a replication of the main system as to extend the amount of outputs and inputs for larger scale usage allowing for scalability and flexibility in functionalities. This is possible to extend the connection of the boards up to 112 units from the features of the MCP2562 CAN transceiver IC.

## 3.5 APPLICATION

The monitoring and control of the system can be performed in the Android Application which the Monitoring page and Setting page are shown in figure 3.5 and figure 3.6 respectively.

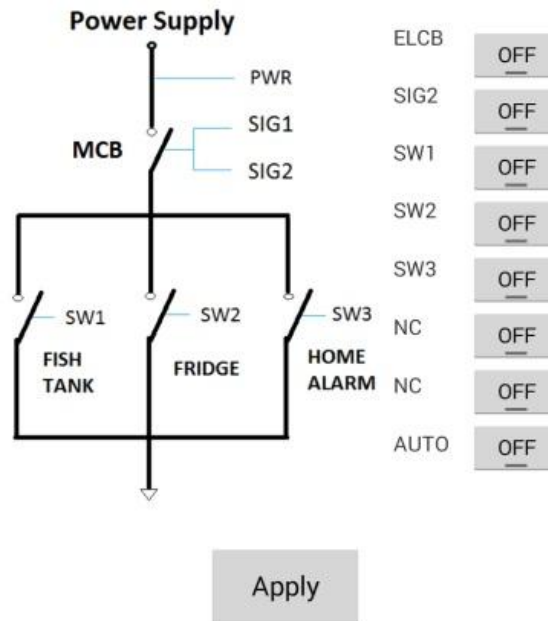


Figure 3.7 : Setting Page.

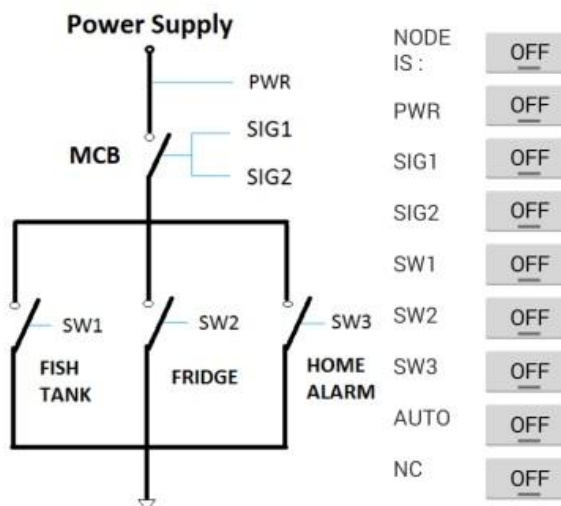


Figure 3.8 : Monitoring Page.

In the case of faulty appliances in SW2 which are connected to a "Fridge", the following sequence will be used to locate the fault section :

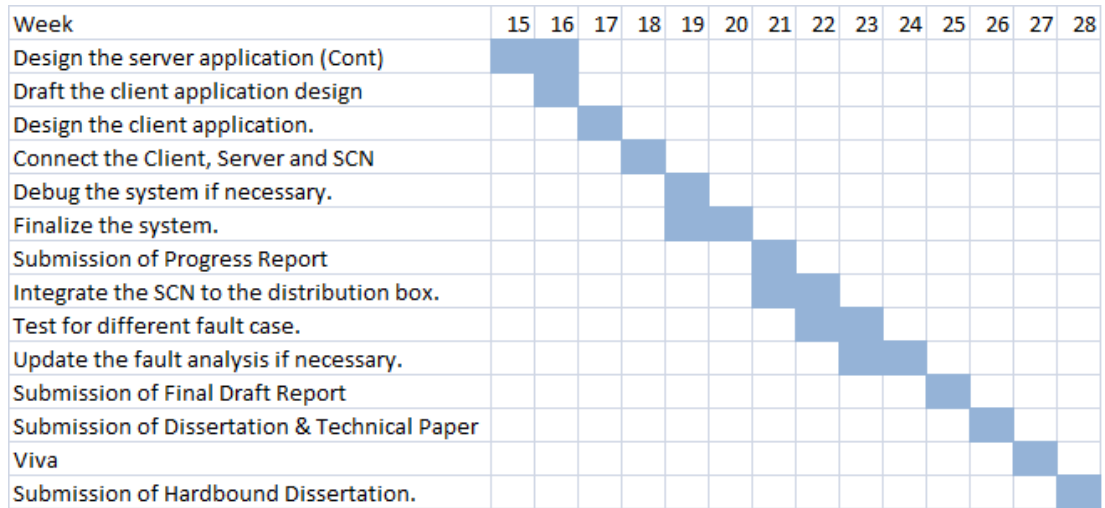
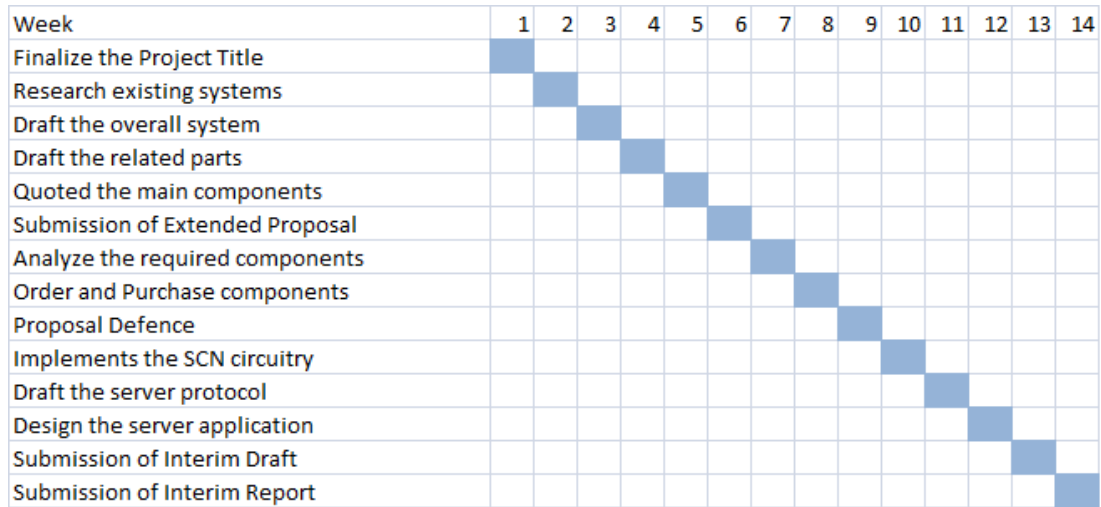
1. Live wire in Fridge is connected to Earth.
2. ELCB Trips Once, PWR drops to 0.
3. Arduino will reset ELCB via Motor increment count to 1.
4. ELCB Trips Second time, PWR drops to 0.
5. Arduino will reset ELCB via Motor increment count to 2.

6. ELCB Trips Third time, PWR drops to 0.
7. Arduino will reset ELCB via Motor increment count to 3.
8. ELCB Trips Forth time, PWR drops to 0.
9. Arduino will set SIG1 to 0, opening MCB connection.
10. Arduino will reset ELCB via Motor.
11. User receives Notification in Android App (also applicable at step 2,4 & 6).
12. User opens Monitoring Page and SIG1 is OFF, and PWR is ON indicating Arduino has disconnected the main connection via MCB.
13. User uses Android Device to Set SW1, SW2, SW3 to OFF and APPLY.
14. User Set ELCB to ON and APPLY, to reset ELCB via Motor.
15. User Set SIG2 to ON and APPLY, to close MCB connection.
16. User Set SIG2 to ON & SW1 and APPLY, to try Fish Tank.
17. User Set SIG2 to ON & SW2 and APPLY, to try Fridge Tank.
18. User receives Notification for PWR is OFF, which indicates Fridge is faulty
19. User again Set ELCB to ON and APPLY, to reset ELCB via Motor
20. User Set SIG2, SW1 & SW3 to ON and APPLY, to disconnect Fridge while connecting Fish Tank and Home Alarm.
21. Power is recovered.

### 3.6 KEY MILESTONE

Month	1	2	3	4	5	6	7	8
Drafted the overall system.								
Acquired main components.								
Implemented the SCN Nodes								
Implemented the Server Software								
Implemented the Client Applications.								
Configured the whole system.								
Test and Debug the system.								
Submit related papers								

### 3.7 GANTT CHART



## **CHAPTER 4**

### **RESULT AND DISCUSSION**

#### **4.1 SERVER**

The server section consisted of a computer server running on the custom made Server application residing in a Microsoft OS. The Server will be required to perform the following functionalities :

1. Accept TCP connections from Client and/or SCN Node.
2. Check the Id Number from the Client and/or SCN and check for availability.
3. Check the Username and Password from Client as well as SCN and check for validity in the allowable list.
4. Save acquired data during any events from the SCN and/or any modification sent from the Client.
5. Return data to the Client or SCN for any Updates.

At the time of the report, the Server application has been tested for its functionality in performing the following :

1. Able to accept TCP Connections from both Client and SCN for receiving and transmitting of data.
2. Able to write and read data to and from a SQLite database.
3. Able to perform multi-threading for every incoming TCP Connection.
4. Proper storage system for User Login Details, Password, Client Id and other Permanent Settings.
5. Displaying no of TCP Connections.



In the previous discussion, several additional features such as the followings were planned to be added but were not fulfilled due to several disadvantages explained in the followings :

1. To perform Fault signal analysis in the server computer
  - a. Is time consuming and might not be able to run in the case of disconnection of server in the case of small scale application which will delay the power recovery. Factors such as internet accessibility, latency and speed.
  - b. Too reliant on other Server computers' performance which may vary the result. The server might not be able to process the amount of information given.
2. Drawing of analogue signals from array.
  - a. Is not important in the power recovery process and will consume most of the communication bandwidth required for other data transfer.

To compensate for the above removal of functionalities, the following functions will has been implemented instead with the following reasoning :

1. To perform Fault testing in the SCN by testing all the individual sockets for faultiness.
  - a. Is less time consuming and processing will be done solely in the SCN unit itself, distributing the processing required therefore a decrease in processing speed requirement in the Server computer, in the internet speed, as well as the space required to store the information.
  - b. Does not need to rely on the Server, allowing for auto recovery without internet connection as an selectable option.

## **4.2 CLIENT**

The client section which previously planned to be designed for both Android based device and Microsoft OS based computer is now scaled down to only Android based device as it is easily accessible by the users, can be connected to the internet with the least effort and is mobile compared a computer.

With this, the Android program which will need to be programmed in Java language will need to perform functionalities to obtain and display the important information

collected from SCN on the screen of the device as well as displaying buttons allowing for remote control of the SCN.

#### **4.2.1 ANDROID APPLICATION**

The Android application will require several library to be implemented in the system. Such libraries are the Transmission Control Protocol (TCP) library for establishing internet connection with the server located elsewhere. Several other libraries are used for drawing buttons as well as writing the analyzed fault type obtained from the server. Users will also need to enter login details and password prior to getting connected to the server for data transmission.

At the time of the report, the Client application has been tested for its functionality in performing the following :

1. Able to open TCP connection to the server.
2. Able to accept input on IP addresses and Port Value which determines the location of the Server.
3. Able to accept input on Username and Password which determines which SCN to connect with.
4. Able to accept data containing modifications in the state of the SCN via the pressing of Buttons, encode it and transfer the encoded data.
5. Able to perform auto-reconnection with the server in the case of internet instability to prevent hassles therefore increases the stability.
6. Able to monitor the changes and produces a notification in the mobile phone via Sound and Vibration.
7. Will recollect data every time after a successful login to prevent incorrect data shown in the Monitoring section after re-logging in.

Since the analogue fault analysis was removed in the system due to reasoning stated in the previous section, the following additional functions will be added :

1. A button to toggle the Auto-Recovery mode in the SCN.
2. A additional monitoring item to indicate the activation of the Auto-Recovery function.



After programming the related sections required to perform the above settings, it was found that the dsPIC33 Microchip is unstable, which occasionally reboots and resets its saved data.

The following are the possible factors contributing to the auto reset:

1. Usage of too many functions which leads to overflow of Stack Pointers due to the requirement of handling Timer, CAN transmission, and UART transmission all simultaneously.
2. Miss-configuration in the microcontroller clock configuration which did not properly lock the core clock.

The following factors have been tested NOT to contribute to the unstable behaviour of the microcontroller :

1. Usage of internal clock which is unstable at high frequencies.
2. Circuit design.

The benefits of switching to PIC18F458 are as follows :

1. Lesser design of board is required as the PIC18F458 which was previously planned to be used solely for acquisition of data and output settings is now also used for signal transmission with the use of only two wires. The dsPIC33 board is replaced at the price of two pins in the PIC18F458 which is acceptable.
2. Lesser debugging required in the whole system as one system is removed reducing the percentage of error in the whole system.

Thus far, the Main board circuit has been designed and programmed to perform the following :

1. Connection via UART with a 5v-to-3.3v translator attached to the Wi-Fi module to communicate with the Server in a local area network.
2. Connection via CAN with other boards for debugging purposes.
3. Able to login to the server via UserID to retrieve required information for modifying the output at the Extension Board as well as sending data containing the input conditions to the Server's database.

### **4.3.2 PERIPHERAL BOARD**

Since the design of the whole system was brought up with the modification of the previous system, which runs only on Arduino, the peripheral board used in the previous project is removed and is recreated to allow for dual input signal for the use of both the previous Arduino and the current Microchip. The circuit has been redesigned utilizing diodes to prevent from reverse current flow in the switching operation.

Currently the peripheral circuit has been designed for the following specification:

1. Dual input for the MCB switching operation utilizing SSR.
2. Dual input for the ELCB switching operation utilizing normal Relay.
3. Possible to be modified to dual input for the additional 3 SSR controlling the 3 power plugs.

### **4.3.3 EXTENSION BOARDS (OPTIONAL)**

After the modifications applied where the dsPIC33 was replaced by the PIC18F in the Main Board, the extension board is now not necessary to be used in the system given the amount of GPIO is sufficient to control all the required peripherals in the Peripheral Board. But if required, they can be in anytime added due to the CAN connection which allows it to connect to the Main board as well as any other boards in a "Mesh" connection.

The possible type of Extension board to be added are as follows:

1. Pure GPIO Extension board - to extend the Digital Input Output (DIO) pins by 33 for each board.
2. Control Panel Extension board - to add control and visualization in the SCN.

## **4.4 OPERATION PRINCIPLES**

The system's main purpose is to monitor the continuity of the incoming electricity and control the circuit breakers remotely via a smart devices. In the event of a permanent fault (current leakage to earth) in any of the socket (SW), tripping the ELCB three times consecutively, the secondary system shall open the MCB and reset

the ELCB via the motor, cutting off power to the SW1, 2 and 3 to prevent further damages.

In this event, the Auto Recovery feature can be enabled to automatically test each and every sockets. The recovery process flow is shown in Figure 4.1. Every time after the Auto-Recovery has successfully taken place, the modified outputs will then be notified to the Client device. In the obtained data, the monitoring page shall be modified where sockets which are 'OFF' are isolated and detected as the faulty. Even after the recovery, if the user still desires to test the faulty socket, the user will still be able to switch it on remotely via the client application.

If the Auto Recovery is disabled, client is allowed to manually test each and every sockets for the tripping event which is indicated by the 'PWR' indicator in Figure 3.8. The 'ELCB' button shown in Figure 3.7, gives the client the functionality to reset the ELCB remotely. Relays controlling the MCB, SW1, SW2 and SW3 can be also be controlled via buttons indicating SIG2, SW1, SW2 and SW3 in the same page by toggling them and pressing the apply button.

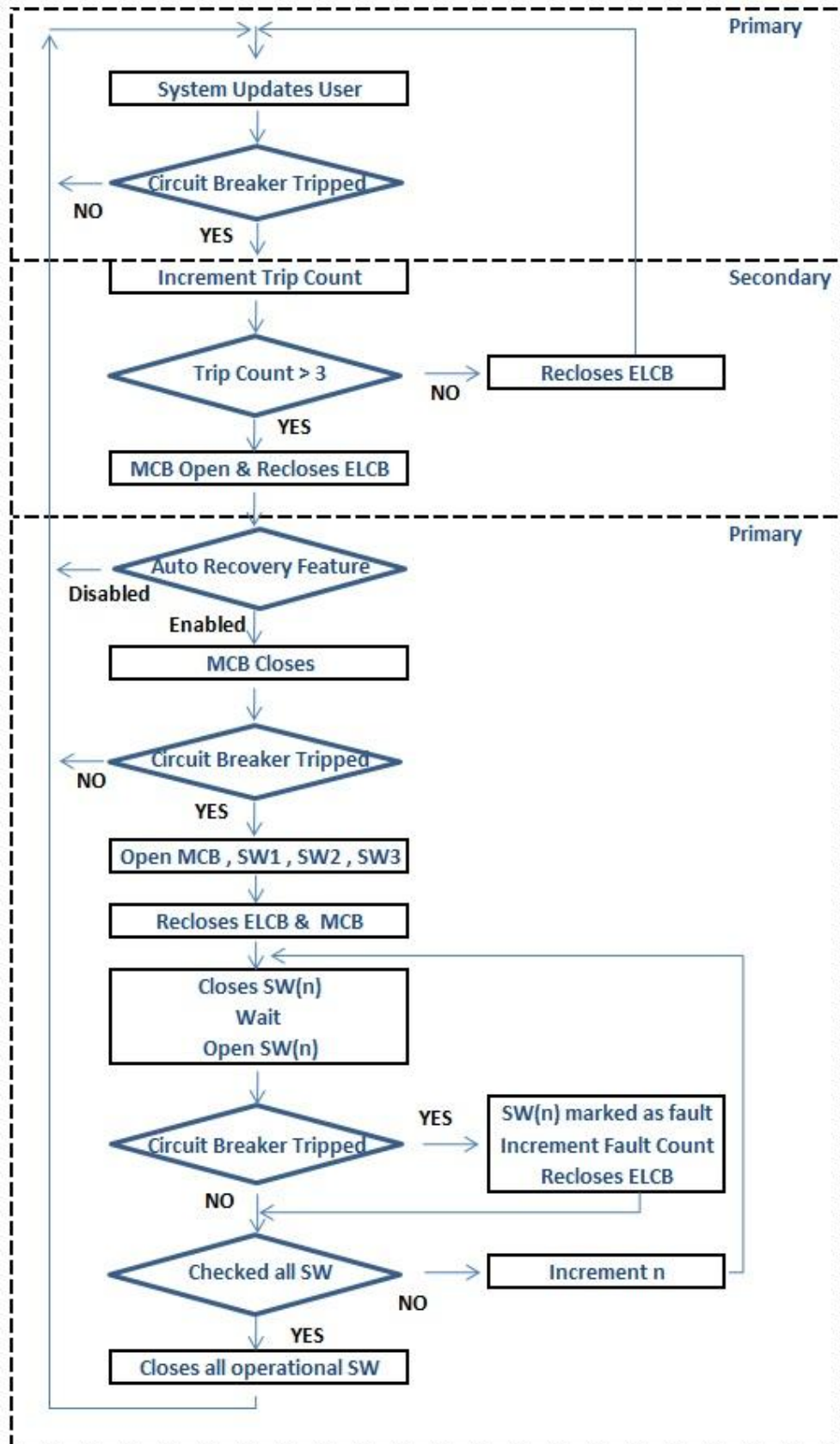


Figure 4.1 : Recovery Operation

## **CHAPTER 5**

### **CONCLUSION AND RECOMMENDATION**

#### **5.1 CONCLUSION**

The presented work serve to enhance the existing electrical protection system by filling the gap between Smart Grid systems and the Internet of Things concept. These concepts have thus far implemented separately in different sectors but were never combined. By combining the concepts, and implementing it in the public and/or private sectors residing in the domestic area, users will be able to monitor and control their systems from anywhere with internet access, remotely.

The developed prototype was tested to successfully perform the power recovery in a closed network connection. Even in the case of internet disconnection, the Auto Recovery feature is able to automatically detect the source of the fault and isolate them accordingly. The designed smart system will therefore reduces power discontinuity by means of isolating the faulty section if present, automatically and restore the power connection which is important to sectors where power continuity is critical. Users will no longer required to be present in front of the distribution box, to analyze the fault and to manually switch the circuit breakers.

Future work includes software upgrades to implement power analysis calculation in the SCN which may take into consideration the power quality for higher accuracy and faster fault detection. The communication module based on Digi Wi-Fi S6B can be replaced by modules with functionalities to open and close sockets which will increase the connection stability of TCP communication.



## **5.2 RECOMMENDATIONS**

Future work for the proposed system includes designing low cost circuitry for control of plug connection to extend the range of fault detection. Other than that, GSM connection is also possible to be added to the system in the case of internet disconnection. The currently used X-Bee S6B WiFi module is unstable where connections may be dropped causing lost of data packets and is recommended to be swapped with a more reliable WiFi module which allows for control in opening and closing of TCP sockets.

In terms of software upgrades, the possible features to be added are such as power analysis calculation in the SCN which may take into consideration the power quality therefore allowing for faster and higher accuracy of fault detection. The pre-requisite to this upgrade is an additional peripheral board with Current and Voltage sensors connected to the Analogue input of the Main board.

Additional system can be added to the server such as an Artificial Intelligent system to allow for logging of faults occurred in different household and advice the user the necessary steps to be taken. Other features such as detection for faultiness in the switching system can also be taken into consideration in the future work as circuit breakers' lifetime (switching operation) may deplete over time and is usually unnoticeable until tested.

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# APPENDICES

## APPENDIX A

### THE ONLINE MONITORING SYSTEM FOR DOMESTIC DISTRIBUTION BOX



THE PREVIOUS FYP PROJECT

