UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION
INSTITUE OF SCIENCE AND TECHNOLOGY

AUTOMATED METER READING TO MONITOR POWER CONSUMPTION IN ELECTRICAL DISTRIBUTION NETWORKS

MASTER THESIS

Salman Aziz Dakhil Dakhil

THE DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

THE PROGRAM OF ELECTRICAL & ELECTRONICS ENGINEERING

JUNE 2017

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Salman Aziz Dakhil Dakhil, having student number 1406030023 and enrolled in the Master Program at the Institute of Science and Technology at the University of Turkish Aeronautical Association, after meeting all of the required conditions contained in the related regulations, has successfully accomplished, in front of the jury, the presentation of the thesis prepared with the title of: "AUTOMATED METER READING TO MONITOR POWER CONSUMPTION IN ELECTRICAL DISTRIBUTION NETWORKS".

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THE UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION
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I hereby declare that all the information in this study I presented as my Master's Thesis, called: AUTOMATED METER READING TO MONITOR POWER CONSUMPTION IN ELECTRICAL DISTRIBUTION NETWORKS, has been presented in accordance with the academic rules and ethical conduct. I also declare and certify with my honor that I have fully cited and referenced all the sources I made use of in this present study.

12.06.2017

Salman Aziz Dakhil Dakhil

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Thanks to the most compassionate, gracious and merciful. May Allah’s blessings and peace be upon our prophet Mohammed who protects us from the depths of darkness and leads us forth into light, and his house hold.

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Finally I dedicate this success to the spirit of my mother, who was not good at reading and writing but she struggled to complete my studies.

JUNE 2017 Salman Aziz Dakhil Dakhil

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LIST OF ABBRIVIATION

CT	**:**	Communication Technology
GSM	**:**	Global System for Mobile Communications
SG	**:**	Smart Grid
AMR	**:**	Automated Meter Reading
EU	**:**	electricity utility
GW	**:**	Giga Watt
SGP	**:**	Smart Grid Power
ICTs	**:**	information and communication technologies
DSM	**:**	demand side management
ADSL	**:**	Asymmetric Digital Subscriber Line
WAOMS	**:**	Wide Area Operational Measurement System

ABSTRACT

AUTOMATED METER READING TO MONITOR POWER CONSUMPTION IN ELECTRICAL DISTRIBUTION NETWORKS

Salman Aziz Dakhil Dakhil

Master, Department of Electrical & Electronics Engineering

Thesis Supervisor: Assist. Prof. Dr. Javad RAHEBI

JUNE 2017, 40 pages

In this thesis we provided an efficient method for Automated meter reading to monitor power consumption in electrical distribution networks. In last decade there is no a lot of control for electric ministry in Iraq. For this reason there is a big problem in energy side. Since our aim is to optimize the energy consumption of the electric in the Iraq. Most of people down the electric from the towers and this makes uncounted and unspecified losses in the power networks. We designed a new model for detection of override the electrical grid. The microcontroller Mega and Uno Arduino are used for practical part and the MATLAB 2016a is used for simulation and testing of the proposed method. The distribution network mostly are in the air also the proposed method is installed in the air condition.

Keywords: Automated Meter Reading, Control, Distribution Network, Smart Grid Power System.

ÖZET

ELEKTRİK DAĞITIM ŞEBEKELERİNDE GÜÇ TÜKETİMİNİ İZLEMEK İÇİN OTOMATİK SAYAÇ OKUMA

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Tez Danışmanı: Yrd. Doç. Dr. Javad RAHEBI
HAZIRAN 2017, 40 sayfa

Bu tezde, "Otomatik Sayaç Okuma" ile dağıtım şebekesinde "Akıllı Şebeke Güç Kontrol Sistemi" için etkili bir yöntem sağladık. Son on yıldır Irak Elektrik Bakanlığı tarafindan yaygın bir denetim çalışması yapılamıyor. Bu nedenle enerji dağıtım alanında büyük bir sorun var. Amacımız Irak'taki elektrik enerjisinin tüketimini optimize etmektir. Çoğu kişi elektrik trafolarından kaçak elektrik kablosu çeker ve bu güç şebekelerinde kayıplar yaratır. Elektrik şebekesi için bu duruma karşı koyan yeni bir model tasarladık. Pratik için Mikrodenetleyici tabanlı "Arduino Mega" ve "Arduino Uno" geliştirme kartları, önerilen yöntemin simülasyon ve test yazılımları için de "MATLAB 2016a" kullanılmaktadır. Dağıtım ağı çoğunlukla havada olup önerilen yöntem de havada kurulmuştur.

Anahtar Kelimeler: Uzaktan Sayaç Okuma, Kontrol, Dağıtım Şebekesi, Akıllı Şebeke Güç Sistemi.

CHAPTER 1

INTRODUCTION

1.1 Background

The Smart Grid can be defined as the dynamic integration of developments in electrical engineering. Energy storage and advances in information and communication technology (CT) within the electric power business including generation, transmission, distribution, storage and marketing, alternative energies allowing the coordination areas of protection, control, instrumentation, measurement, quality and energy management, etc., to be concatenated in a single management system with the primary objective of an efficient and rational use of energy.

The previous concept could also be the integration of other actors in the area of measurement and control, such as gas sources and water service. Thus, intelligent electricity grids are part of a macro concept of territorial domain, such as smart cities.

The term intelligent network is often associated with the concept of smart meters capable of offering detailed billing by time slots, which would allow consumers not only to choose the best rates from different electric companies, but also to discern between the hours of consumption, which in turn would allow better use of the network. This system would also make it possible to more accurately map consumption and better anticipate future needs at a more local level.

1.2 Problem Definition

There are different types of Smart Grid Power System Control algorithms in the Distribution Network and these algorithms usually differ with the aim of the algorithm. Many of the algorithms are improved depending on the requirements of the related application.

1.3 Proposal Work

In this thesis we will use current sensor, Arduino. For communication we will use RF and GSM. We will test our device in the laboratory of THK University. Totally we will use 3 sensors, one of them for main source and others will be used in the two test place.

1.4 Aims

The aim of this thesis is to provide an efficient method for Smart Grid Power (SGP) System Control in Distribution Network with Automated Meter Reading. In last decade there is no a lot of control for electric ministry in Iraq. For this reason there is a big problem in energy side. Since our aim is to optimize the energy consumption of the electric in the Iraq. Most of people down the electric from the towers by illegal way. The distribution network mostly are in the air. The proposed method will be install in the air.

1.5 Organization of The Thesis

Chapter2 includes the literature review, in this chapter we will discuss about the literature which authors worked in Smart Grid Power System Control. In chapter 3 the methodology will be present. In chapter 4 the simulation result will be discuss and the result will be compare with other classical methods. Finally, in chapter 5 we will finish our thesis with the conclusion.

CHAPTER 2

INTELLIGENT POWER SUPPLY

The term "smart grid" covers the communicative networking and control of electricity generators, storage units, electrical consumers and network equipment in power transmission and distribution networks of electricity supply [1]. This makes it possible to optimize and monitor the interconnected components. The aim is to ensure energy supply on the basis of an efficient and reliable system operation [2].

From a global perspective, the Smart Grid (SG) can be defined as the dynamic integration of developments in electrical engineering energy storage and advances in information and communication technologies (CTs). Within the electric power business (generation, transmission, distribution, storage and marketing, including alternative energies); Allowing the coordination areas of protection, control, instrumentation, measurement, quality and energy management, etc., to be concatenated in a single management system with the primary objective of an efficient and rational use of energy.

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The emergence of renewable energy in the energy landscape has significantly changed energy flows in the grid: now users not only consume but also produce electricity through the same network. Therefore, the energy flow is now bidirectional.

2.1 Background and Motivation

While electricity generation has dominated so far, the trend is towards decentralized generation plants, both from the production of fossil primary energy from small cogeneration plants and from renewable sources such as photovoltaic plants, solar thermal power plants, wind power plants and biogas plants. This leads to a much more complex structure, primarily in the area of load regulation, voltage maintenance in the distribution network and maintenance of grid stability. In contrast to medium to larger power stations, smaller, decentralized generator systems also feed directly into the lower voltage levels, such as the low-voltage network or the medium-voltage network.

In general, networks, including electrical power networks, are designed for the possible maximum load. The reduction of the maximum load and the time shift of the energy to be transferred during periods of low utilization allow the necessary network infrastructure to be designed smaller and thus lead to cost advantages on the operator side. In this case, the overall transmission energy remains approximately the same, only the utilization of the networks is optimized. For example, electricity consumption in Switzerland in 2009 was only 30 to 40% on average. Cost advantages and security of supply are therefore incentives for the network operators to avoid expensive load spikes and, in the ideal theoretical case, to have only a load constant which is as constant as possible over time, which is above the so-called basic load fraction. This leveling of the load can be carried out by means of smart networks by means of automatic controls and control of consumption systems in the context of a load control.

A feature of these networks is the possibility to retrieve and process status information and load flow data from the individual network elements, such as eg generation plants, consumers (households or industrial plants) or also transformer stations in real time. In addition to the production facilities, a smart electricity network also includes larger consumers such as heat pumps, hot water storage tanks, freezers, car batteries, etc., in network management.

In addition, a smart power grid offers the advantage that consumers' forecasts of consumption and potential savings are identified through the support of demand side management (DSM). With this information, users can align their consumption with the current generation situation by orienting themselves to dynamic tariffs [3].

Power plants were strategically located to be close to fossil fuel reserves (whether mine or own wells, or near rail, highway or port power lines). The location of hydroelectric dams in mountain areas also strongly influenced the structure of the emerging network. The nuclear power plants were located availability of cooling water. Finally, central fossil fuels were initially very polluting and are located to the extent of the most economical way of population centers once the electricity distribution networks allow. In the late 1960s, the electricity network reached the overwhelming majority of the population of developed countries, with only peripheral regional areas remaining 'out-of-network'.

Towards the end of the 20th century, electricity demand patterns were established: domestic heating and air conditioning led to daily peaks in demand that were met by a series of 'peak hours' that can only be activated for periods The relatively low level of utilization of these generators at peak times (commonly, gas turbines are used because of their relatively lower capital cost and faster start times), together with the necessary redundancy in the network In the 21st century, some developing countries such as China, India and Brazil were seen as pioneers in the implementation of smart grids.

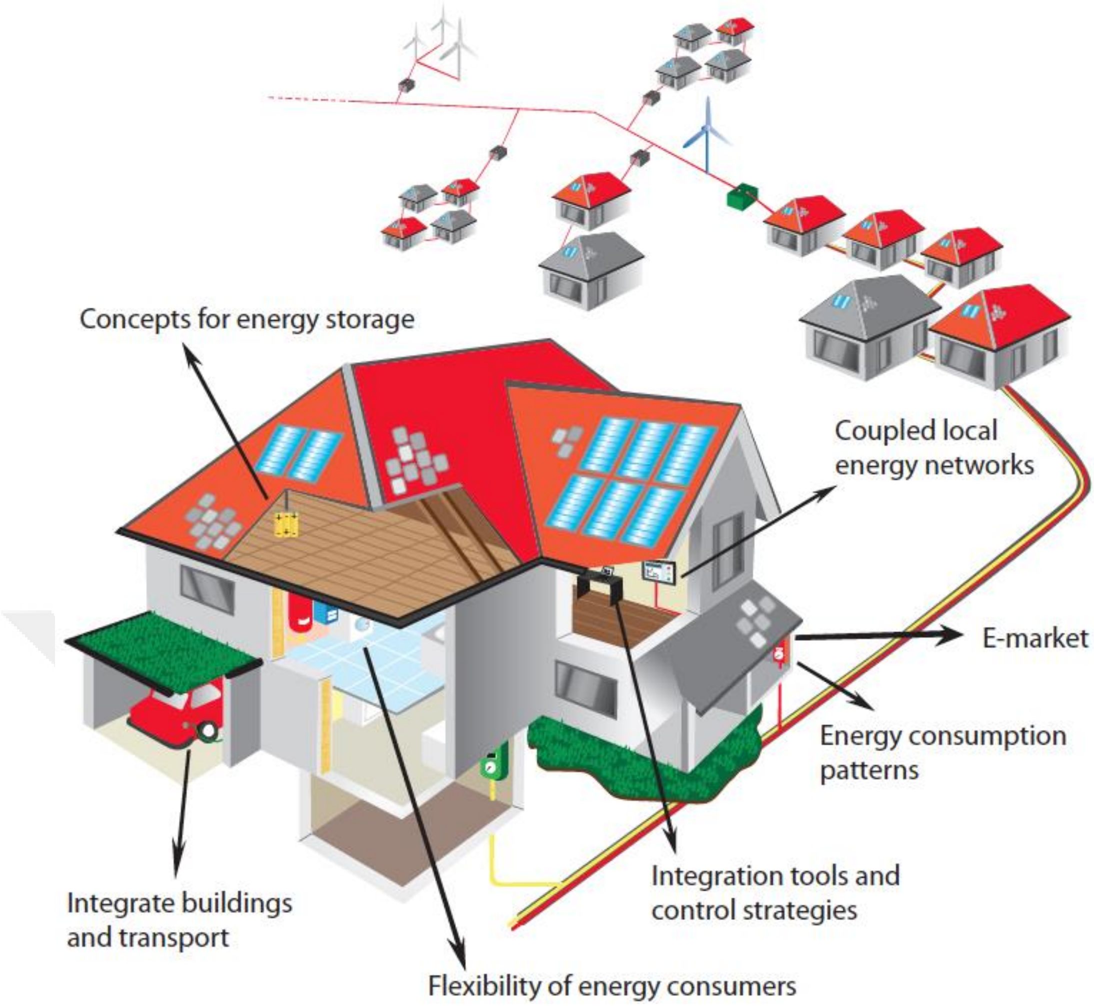

Figure 2.1: Distribution grid [3].

2.2 Construction of an Intelligent Electricity Network

An intelligent electricity network integrates all the actors in the electricity market through the interplay of production, storage, network management and consumption into an overall system. Power and storage systems are already controlled in such a way that only as much electricity is produced as is required. Intelligent power grids include consumers as well as decentralized small energy suppliers and storage locations, so that on the one hand a more uniform time and space is generated (also intelligent energy consumption) and, on the other hand, inhomogeneous generators (eg wind power) and consumers (eg Lighting) can be better integrated.

Electricity storage, which is gaining in importance due to the fluctuating production of renewable energies, has long been realized with the aid of storage power stations. Added to this are, for example, decentralized storage devices such as vehicle accumulators, which, however, is still far from cost coverage.

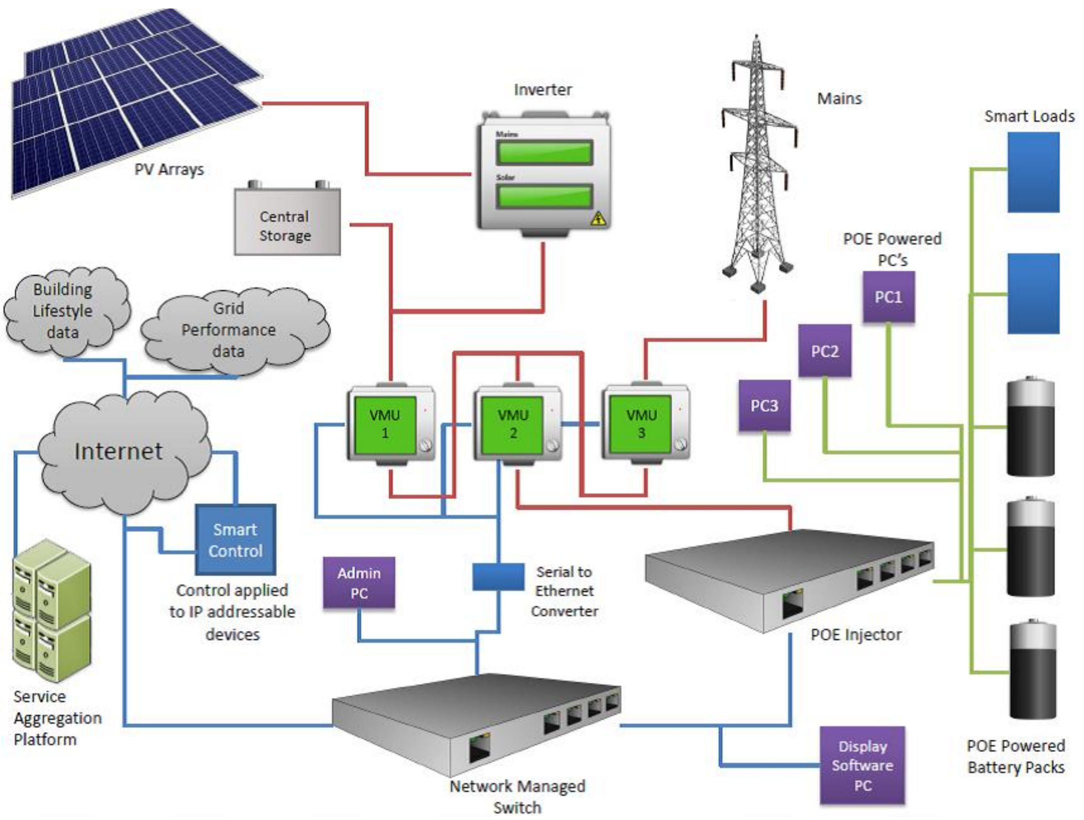

Figure 2.2: Developing system intelligence for optimizing building electricity networks.

For consumers is a significant change in the installation of smart meters (even smart meters). Their core tasks are remote reading and the possibility to realize fluctuating prices in the short term within a day. All current meters must therefore be replaced with those with data transmission. The data transmission between the individual components runs in pilot projects mostly via telephone modem, pioneer project - like smart power in Switzerland - already work with ADSL connections.

The consumer can, however, only realize price advantages without compromising comfort, if he also has devices that automatically work preferably during low tariffs. These are time-critical processes such as heat pumps with latent heat storage, freezing, heating (electro boilers), washing or dishwashing. With night-time furnaces and fixed overnight tariffs, this has already been realized decades ago, but modern systems can work more flexibly and intelligently, which is particularly important for the integration of renewable energies. A technology for this is the rotary control technology. This has already matured as a power supply-side remote control of time-uncritical systems for large-scale consumers in the industry, and is gradually being extended to small-scale consumers as well as to small-scale producers such as solar systems.

2.3 Supply and Demand Page

Since electric power networks cannot store energy and the demand for electrical power must always be equal to the supply of electrical power to maintain stability in the electricity grid, either the supply side has to be adapted to the consumption demand, as is largely the case in classic electricity networks by changing the power plant's output, or by an adjustment by means of load shifts of the consumers to the current supply of the generator devices, similar to those realized in the case of so-called load discharge customers in the case of supply bottlenecks since the beginning of the electric power networks.

Even if the time-dependent load shifts of selected consumers in the form of load control are only possible in the range of hours to a few days, they can be used as a convenient way of adapting these to the demand-oriented supply in renewable energy systems by means of an artificial change in the current demand. The advantage of the demand adjustment lies in its great energy efficiency, since, unlike storage plants, they can be used very little or without loss [4]. Heat and cold machines, such as refrigerators, refrigerators, heat pump heaters, etc., are particularly suitable. However, energy-intensive industrial processes such as aluminum production by electrolysis, electric steel production and the operation of cement mills and ventilation systems for load shifts are also limited.

For example, the specific switch-on time of a correspondingly designed intelligent refrigerator can be shifted at a certain time interval in such a way that it more closely matches the supply of electrical power without the cooled food being heated to an unacceptably high degree. The control can be either indirectly via the price or directly via power supply or network operators; larger companies can also act directly on the regulatory energy market. Other loads, in particular consumers where the power required is directly required, such as, for example, in the case of illumination, cannot be shifted in principle.

In the effects, the shift in load results in the same effects as the use of storage plants for the supply adjustment: the increase in load (switching on the load with current surges) corresponds to the charge of a store, the later load reduction of the storage discharge; Therefore, load shifting acts as "virtual memory" [5].

2.4 Current Activities in Europe

The need for the EU 's objectives in terms of smart grids is growing.

1. A reduction in carbon dioxide emissions
2. An increased energy independence (see energy autarky)
3. The increase in energy efficiency
4. A planned increase in the share of renewable energy, which must be integrated into the European energy networks on the other.

For the first time ever, the Italian energy supplier Enel has installed an automated reading system for current meters since the end of the 1990s as a step towards intelligent power grids. This was done in particular to prevent the large losses caused by electricity theft, which was stopped by the modern meters.

For a completely different reason, the Federal Republic of Germany initiated an analysis in six so-called "model regions" within the framework of the E-Energy funding program, funded by the German Federal Ministry of Economics and Technology and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, which examined the effects of intelligent electricity networks and their practical Implementation in real power supply networks [6]. According to the results of this project, intelligent energy networks are in a position to significantly reduce grid expansion in the future. A first step in the implementation of smart grids in the Federal Republic of Germany is the comprehensive introduction of smart metering. However, this module is actually a component of the Smart Market and enables demand- oriented load reduction.

There are also initiatives from the private sector to promote electromobility in model communities. In Garmisch-Partenkirchen, for example, the intelligent power grid is being tested in addition to electro mobility [7, 8].

Within the project Web2Energy, which is sponsored by the Seventh Framework Program (FP7) of the European Commission, a non-discriminatory communication system is established and tested for all involved market partners within an intelligent electricity network in South Hesse, using the internationally recognized IEC standards.

In the E2SG project "Energy to Smart Grid", 31 partners from 9 European countries have been working on key issues of intelligent supply networks since April 2012: methods for secure communication in the supply network, optimized technologies for efficient current / voltage conversion and improved methods for demand determination and grid control Should help to integrate renewable sources of energy and improve energy efficiency. E2SG is funded by ENIAC Joint undertaking and the national states of the project partners [9].

In Austria there is also an initiative on intelligent electricity networks [10]. The Austrian Federal Ministry of Transport, Innovation and Technology is funding research and demonstration projects on the topic as part of the Energy Systems Program of the Future and the Energy Research Program of the Climate and Energy Fund [11]. A number of pioneer regions are emerging together with power grid operators and technology companies. For instance, Salzburg AG has launched two projects. On the one hand the project "ElectroDrive" and the project "Smart Grids". These two projects were awarded and sponsored by the Austrian Climate and Energy Fund with 1.9 million and 1.7 million euros. They are almost inseparable, since the electric vehicles serve as energy storage. There are currently 300 electric vehicles in Salzburg [12].

According to the German Association of Electrical Engineering, Electronics and Information Technology, the potential for shifting the load is half for energy-intensive companies and half for private households, business and trade as well as services. Load management can offset demand and significantly reduce the costs of energy generation [13].

2.5 Problems and Challenges in Intelligent Power Lines

In Switzerland, the electricity measurement is the responsibility of the local electricity utility (EU) in the context of the non-discriminatory grid connection. Non-discriminatory means that all electricity customers receive the same conditions (i.e. individual customers are not allowed to purchase special discounts or special services).

The measurement information is available to the energy supplier, which means that they cannot be made freely accessible, in particular not to a competitor. Furthermore, the data obtained must be taken into account when data are collected (for example, the power consumption of the coffee machine indicates when someone is standing up in the morning).

It is also problematic that there are no universally accepted standards as to what is being measured and how the data are transferred to a target. Therefore, proprietary measuring systems are currently used in test systems, which cannot be easily combined or interchanged. After the introduction of standards, a complex change of systems may be necessary. The smart power project is based on protocols common in ICT. This allows any non-proprietary systems to be combined.

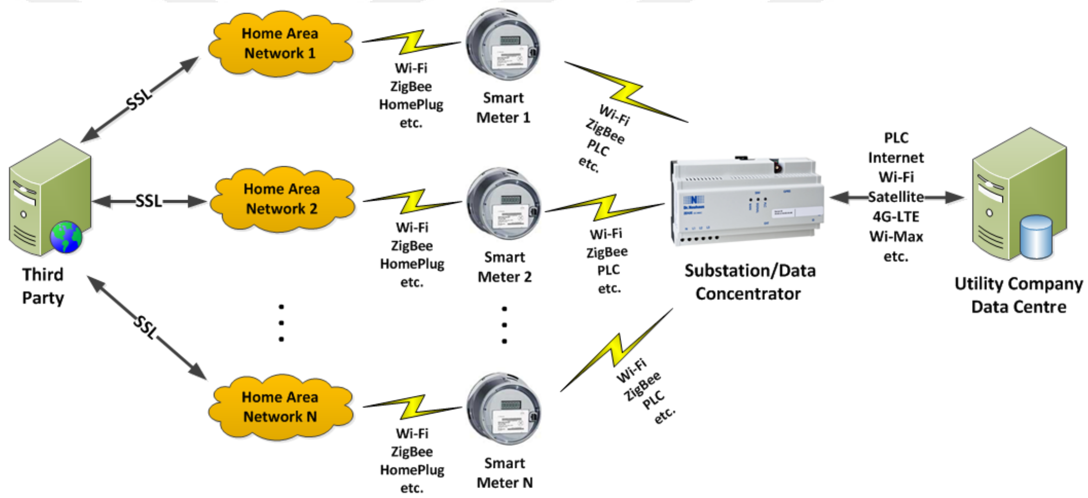

Figure 2.3: Security challenges in smart-grid metering and control systems [14].

A popular approach to avoiding different standards due to the use of different gateways is the harmonization by means of an open gateway platform.

Although the development and standardization is still running, you can already install a simple "Smart Grid" in your home. A good example of this is the consumption indicators and the "Stand By Killer" of a canton in Switzerland. The customer can use these devices, which work wirelessly through a wireless connection

1. The electricity consumption
2. The current performance

3. And he can disconnect his consumers (television, video, etc.) from the electricity network in the evening (saving between 20 and 30 euros per year).

2.6 Standards

On an international level, data models and communication protocols of IEC 61850 are further developed. Originally designed for automation in substations, the application field of this standard also extends to decentralized power generation in distribution networks.

In addition to ICT-related standardization, system-stabilizing electro technical properties, i.e. the reaction to voltage and frequency changes, are important for the intelligent behavior of many smaller systems on the grid. These are defined, for example, in the medium voltage directive in Germany.

At European level, DIN EN 50438 (requirements for the connection of small generators to the public low-voltage grid) [8], as well as DIN CLC / TS 50549 for larger feeders from 11 kVA (requirements for the connection of electricity generating plants 16 A per phase to the low-voltage distribution network or to the medium-voltage distribution network) [14].

In the US, IEEE 1547 (Standard for Interconnecting Distributed Resources with Electric Power Systems) [15] is of relevance.

CHAPTER 3

SMART METER

3.1 Background

A smart meter is, in the narrow sense, a current meter which receives and transmits digital data and is integrated into a communications network. Received data are e.g. Tariff changes, sent data e.g. the electricity consumption.

Such smart meters have been in operation since the 1990s, mainly for large customers, but they have also been offered for private households since about 2010.

Depending on the model, smart meter data can also be transmitted to the energy supply company at a fast pace, which should enable it to improve network and resource control. The system is then rather a communicating measuring device. The customer may also read and view current and logged values.

Smart meters, together with automatic load and resource management, are part of smart grid systems.

In addition, meters for remote metering are also known as smart meters for gas, water and district heating. Such measuring devices are also called English smart meters.

A Smart electricity meter is shown in figure 3.1.

Figure 3.1: Smart electricity meter.

3.2 Terminology

Currently available digital counters with or without communication module are referred to as "modern counters" or "EDL21 / EDL40 counters" [16]. They are to be replaced by smart meters in the future according to an architecture specially developed by the Federal Office for Security in Information Technology. These are referred to as "intelligent measuring systems" [17]. An intelligent measuring system consists of a "modern measuring device", which counts the physical current flow digitally, and a “smart meter gateway", which can store counter values, process data and communicate with a network. Both units can be in one device. If only a modern measuring device is installed in the house, it must not be integrated into a communication network, such as the Internet. It can, however, be equipped with a separate Smart Meter gateway to an intelligent measuring system.

The point between the network and the customer system, where the electricity consumption is measured, is called "measuring point". The person who installs and operates the Intelligent Measuring Systems is therefore called "measuring point operator". This is regularly the local power distribution network operator. There are, however, also competitive measuring point operators who, at the request of the customer, provide the measuring devices independently of the network operator.

3.3 Application Areas

For providers, the use of smart meters is interesting to adapt the provision to consumption. Remote-readable counters also make the annual read-out on the spot superfluous, as the meter data can be electronically read out by the supplier. In addition, the readings and also the settlements of several supply networks can be combined. The installation of communicative counters is primarily of interest when an appropriate infrastructure has to be created for electricity or gas meters, where a legal obligation exists, as well as the routine exchange of old meters.

Variable tariffs, for example hourly or last-variable billing are possible as an optional customer service and thus also better tariff systems. It is also interesting for the consumer that the devices provide current data via an interface, for example via a TV or computer. This means that the consumption can be optimized, both by changing the usage behavior, as well as by finding devices with particularly high consumption.

Overall, smart meters can not only be economically interesting, they also serve to make the use of resources more sustainable.

3.3.1 Electrical Power

The most prominent examples are the intelligent current meters, which display the current power in the minimum version, in addition the consumption of the last 24 hours, week, month, year and / or are equipped with a communication module [18, 19]. This module allows the supplier to transmit the meter reading in different time frames and to visualize the customer via a web portal.

3.3.2 Natural Gas

Similar variants are possible for the natural gas range as for the current meters. This means that the current gas consumption can be read out by suppliers such as customers [20].

The introduction of meters which directly indicate the consumption in kilowatt hours instead of the usual cubic meters is also conceived. However, bidirectional communication is necessary for this, since the gas composition (condensing value) can change and this value should be fed in real time in the counter (or the conversion electronics).

3.3.3 District Heating

District heating is another area of application for smart meters.

3.3.4 Water

There are also smart meters for utility and drinking water. These show the current consumption, which in the case of water, in contrast to other networks, serves primarily to make it possible to quickly detect water pipe breaks or non-twisted water cocks, ie the malfunction monitoring [21].

3.4 Technical Realization

Current meters are per se electrical measuring devices. Gas, district heating or water meters can be remotely readable using different methods. Mechanical bellows-type gas meters [22] or impeller meters for water can be easily equipped with an electronic interface and an integrated remote transmission device just like Electromechanical Ferraris counters. Pure mechanical measuring instruments or older counting devices can be retrofitted with a digital read-out device which determines the counter reading with an optical text recognition.

For data transmission, the following options are available:

1. PSTN (Public Switched Telephone Network)
2. GSM
3. GPRS (General Packet Radio Service / Mobile)

4. LAN (Local Area Network / Local Area Network)
5. PLC (Powerline Communication / Data transmission via the power supply network).
6. Sigfox

3.5 Electricity Distribution Network

The Electric Power Distribution Network or Electric Power Distribution System is the part of the power supply system whose function is to supply power from the distribution substation to the end users (customer meter). It is carried out by the Distribution System Operators (DSO). The one example about Electrical Power Distribution is illustrated in figure 3.2.

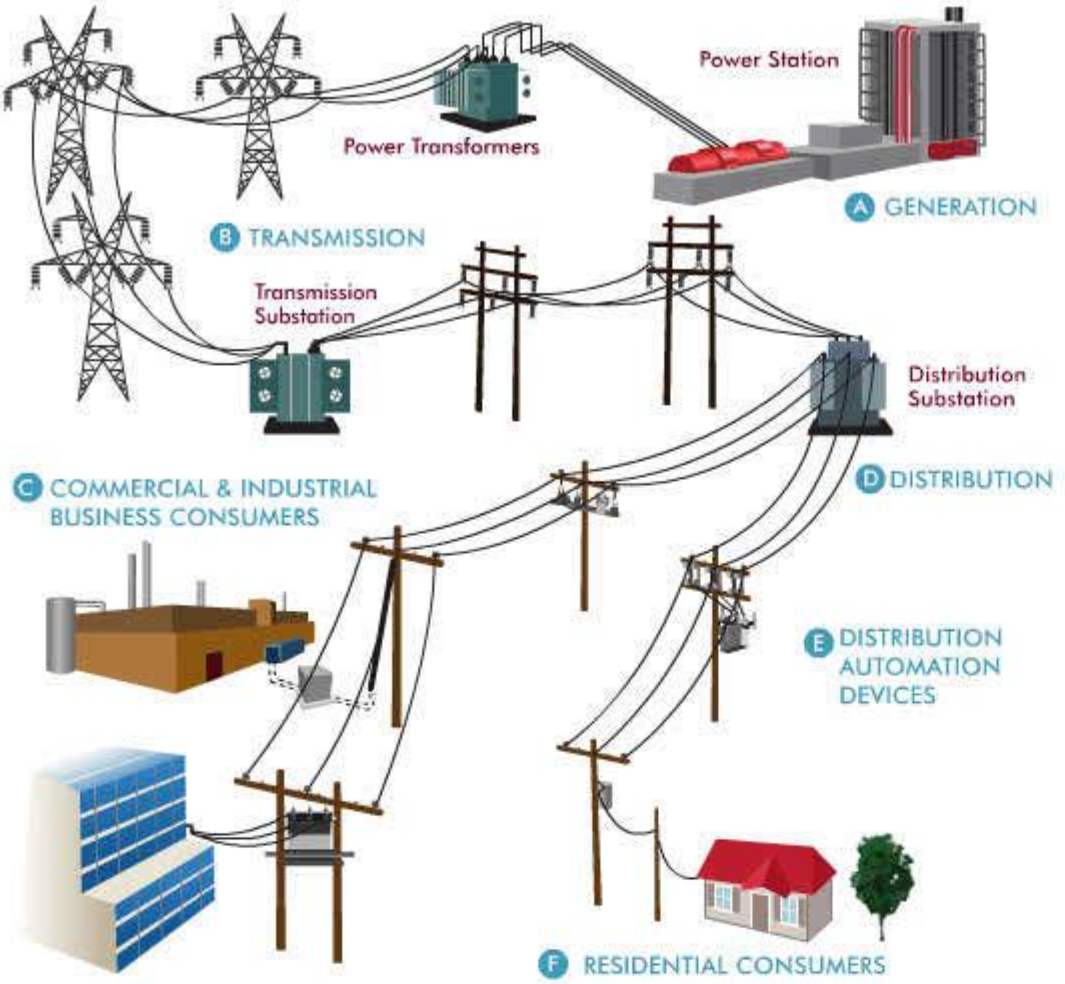

Figure 3.2: Electrical power distribution.

The elements that make up the network or distribution system are the following:

Distribution Substation: a set of elements (transformers, switches, disconnectors, etc.) whose function is to reduce the high voltage levels of transmission lines (or sub transmission) to medium voltage levels for branching in multiple outputs.

1. Primary Circuit.
2. Secondary Circuit.

The distribution of the electric energy from the substations of transformation of the transport network is realized in two stages.

The first consists of the distribution network, which, starting from the transformation substations, distributes the energy, usually through rings that surround the large consumption centers, until reaching the transforming stations of distribution. The voltages used are between 25 and 132 kV. Intercalated in these rings are the distribution transforming stations, in charge of reducing the voltage from the distribution level to the medium voltage distribution.

The second stage is the distribution network itself, with operating voltages of 3 to 30 kV and a very radial characteristic. This network covers the area of large consumption centers (population, large industry, etc.), linking transforming distribution stations with transformation centers, which are the last stage of medium voltage supply, since Output of these centers is low voltage (125/220 or 220/380 V 1).

The lines that form the distribution network are operated radially, without forming meshes, unlike the transport and distribution networks. When there is a fault, a protection device at the beginning of each network detects it and opens the switch that feeds this network.

The troubleshooting is done by the "trial and error" method, dividing the network that has the fault into two halves and energizing one of them; As the zone is broken down, the supply is returned to the rest of the network. This causes that in the course of location several interruptions can occur to the same user of the network. The 250 kVA distribution transformer mounted on pole is shown in figure 3.3.

Figure 3.3: 250 kVA distribution transformer mounted on pole

The Power supply system is shown in figure 3.4.

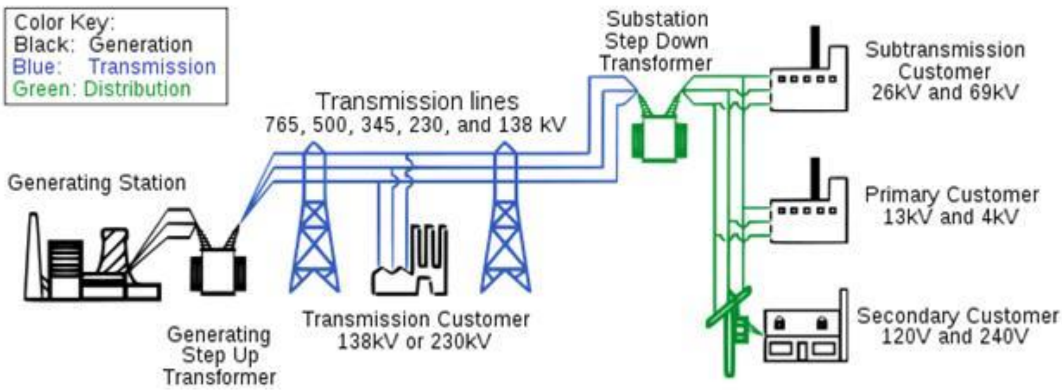

Figure 3.4: Power supply system.

3.6 Typical Topologies of Distribution Networks

The topology of a distribution network is referred to the scheme or arrangement of the distribution that is the way in which the energy is distributed through the arrangement of the segments of the distribution circuits. In this sense it focuses on the way the energy is distributed from the source of supply.

3.6.1 Radial Network or Network in Antenna

It is characterized by the feeding of only one of its ends transmitting the energy in a radial form to the receivers and the emitter. It also has a wiring in the parts.

3.6.2 Advantages

They emphasize its simplicity and the facility that they present to be equipped with selective protections. Virtually without electricity we cannot do anything in today's life, everything works with it, television, internet, radio, blenders, refrigerators, washing machines, vacuum cleaners, pumps to send you water for your house, etc.

3.6.3 Disadvantages

Their lack of service guarantee. These disadvantages can now be compensated for by the modern automatic disconnection devices in the fault zone called "Network Cutting Bodies" or the use of devices called "recloses" which disconnect and close the fault zone, Way to clear the failed zone and return the service on the complete line.

3.6.4 Open-loop networks

This means that any point of consumption, in this structure, can be fed by two possible electric roads, since only one of these two paths is effective, the emergency is done by this possibility of looping.

3.6.5 Advantages

All the advantages of the distribution in radial networks and also the possibility of feeding alternatively from one source or another, so that in case of fault situations and using OCRs and Recloses, the smallest possible fault area would always be out of service and the Rest of the line in service.

3.6.6 Disadvantages

If the structure is far from the lightning rod the electricity would be directed to the ends of the earth which would affect the nearest structures.

3.6.7 Network in Ring Or Closed Loop

Is characterized by having two of its ends fed, these points being inserted in the ring or loop.

3.6.8 Advantages

As a fundamental advantage we can cite its service safety and ease of maintenance.

Criteria for designing distribution networks regulation.

The regulation is related to the voltage drop in the conductors of a given network, in generators and electric transformers. It is not desirable that there is an excessive voltage drop in the conductor because the end-user or transformer from MT to BT voltage would be powered by a very low voltage value much different from the assigned value.

There are basically two definitions of regulation, depending on the country where the installation is done:

US regulations: regulation is defined as follows:

$$\Delta V\% = \frac{V_{1n} - V_{2n}}{V_{1n}} \tag{3.1}$$

V_{2n} Is the voltage at the terminals of the load or transformer

European regulation: regulation is defined as:

$$\Delta V\% = \frac{V_{1n} - V_{2n}}{V_{2n}} \tag{3.2}$$

where:

V_{1n} Is the upstream voltage (the closest part to the production plant) of the load or transformer, ie in the feeder

The regulation given by IEC is greater than the American standard.

3.6.9 Short Circuit Currents

The short-circuit currents for phase-to-phase faults will be limited only by the impedances of the source, the line, and the fault itself, so that as long as the source has more short-circuit power, it will flow through the larger current line.

The phase-to-ground short-circuit currents are limited by all the above reasons but also by the neutral ground system of the Network. There are several ways of doing this. Isolated. That produce the minimum currents and maximum surges, perhaps recommended for distributions not very extensive and that the need to continue with the missing line in service is imperative. Detection of the lack of a selective form has some complication. However, it is recommended that you transfer to a healthy line in the shortest possible time. Directly grounded. They produce the maximum currents and minimum surges, perhaps recommended for extensive distributions and that can be sectioned by means of semiautomatic or automatic devices. The selective detection of the fault is easy, which together with the use of automatic devices "Reclosers", would leave the missing area out of service.

It must be taken into account that the correct choice is very important since after a few years it will be very difficult to restructure the Network to change the earthling system.

3.7 Balance Between Production and Consumption

Electricity is one of the few energies that cannot be stored on a large scale (except hydraulic dams, which can be considered as electromechanical reserves of low inertia energy). This is why network operators must ensure a balance between supply and demand at all times. If there is an imbalance between supply and demand, two negative phenomena can occur:

In the case where the consumption exceeds the production, there is a risk of "blackout" due to the rapid loss of synchronism of the alternators, whereas in the case of production exceeding consumption, a "blackout" By the acceleration of the generators that produce the electricity.

This situation is typical of insular power grids where wind over-production sometimes leads to the emergence of "high" frequencies in networks.

Interconnections between countries can better share the risk of blackouts in the interconnected territories, since they are mutually supportive in managing the balance between supply and demand.

The massive emergence of Distributed Generation networks also leads to taking into account this global balance of networks, especially in issues in tension. The emergence of smart grids or Smart Grid should contribute to the overall balance of the transport network (frequency, voltage), with the balance of local distribution networks. In order to do this, European operators are thinking about the relevant technical solutions, taking into account the evolution of the generation modes, which are now very centralized (hydroelectric, thermal, nuclear...), but could become much more decentralized in the future (Wind energy, photovoltaic solar energy, etc.)

Equipment used in distribution networks like:

1. Transformation equipment
2. Conductors
3. Electric towers

Protection Equipment, including all protective equipment, grounding of different equipment and insulator systems between towers and conductors.

CHAPTER 4

METHODOLOGY AND EXPERIMENTAL RESULT

4.1 Proposed Method

In The low voltage network distributing in Iraq the electrical wiring is usually bare and not insulated and suspended in the air using electricity poles as you can see in the pictures so it's very easy to connect with this wires by illegal way in addition some people connect the high load devices like air conditions and heaters without pass it through the electrical meter for this reasons the ministry of Iraqi electricity doesn't have full control on the consumption power so since 2003's the MOIE has been working to increase the products but the load increases double. Figure 4.1 shows the Baghdad city which the cable is used in the air.

Figure 4.1: Baghdad City which the wires is naked and used in the air.

Also the figure 4.2 shows the illegal connection of some people which they use the electricity.

Figure 4.2: The illegal connection.

So the MOIE tried to find solutions to this problem in several ways One of these way, It was connected limited circuit breaker (10 amperes) for each residence and suspended it in the air.

The figure 4.3 shows haw Connect limited circuit breaker (10 amperes) for each residence.

Figure 4.3: Connect limited circuit breaker (10 amperes) for each residence.

In my opinion this way was stupid solution because also the people can connecting by illegal way.

Other solution was changing the naked wires by other one insulated, but also this way was useless.

The figure 4.4 shows the changing the naked wires by other one insulated.

Figure 4.4: Changing the naked wires by other one insulated.

Figure 4.5. shows the comparison between the power production and the power sold to people for the years between 2007 to 2011.

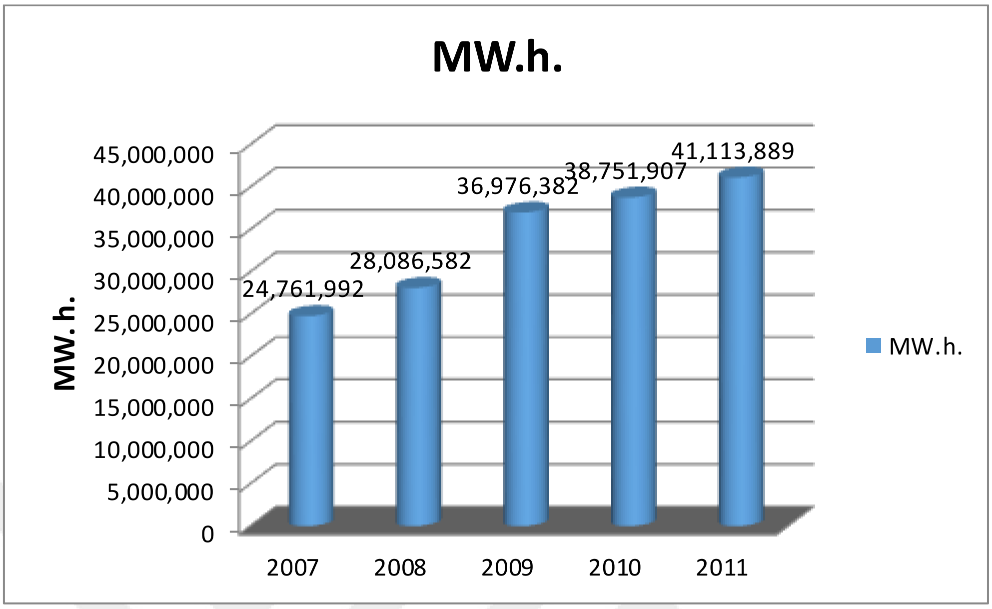

Figure 4.5: The Electrical Power (MW. h.) received from Transfer power sector to Distribution power.

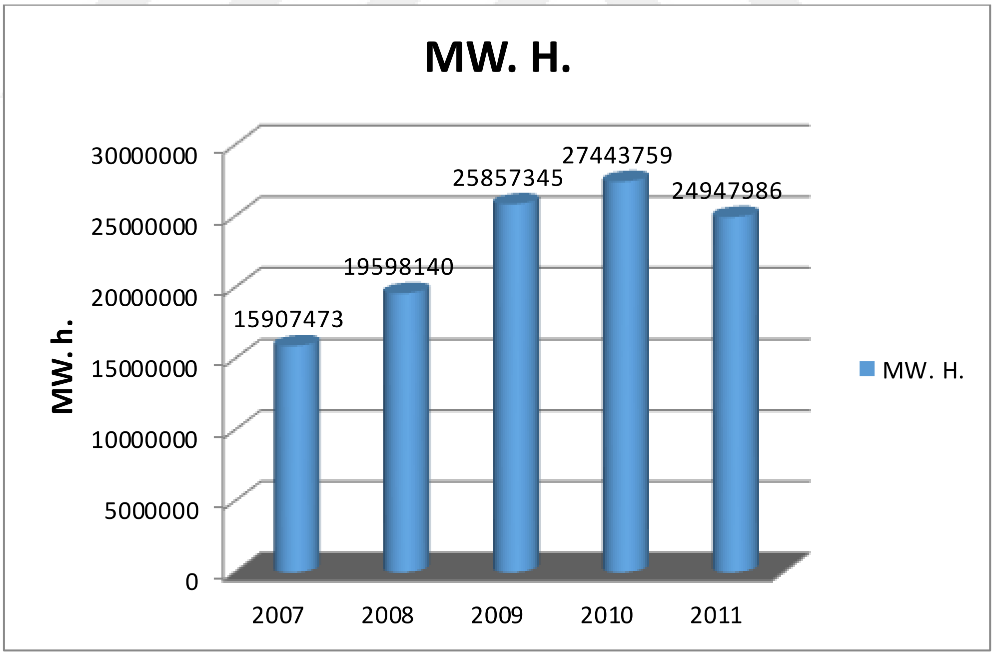

Figure 4.6: The Electrical Power (MW. h.) sold to the people.

The power lost near to 50%, so we thought to solve this problem in this thesis we used the smart meter for each residence, this meter will read the power consumption and send the data to the main smart meter.

Figure 4.7: Location of the smart meters.

The smart meter for each residence is the slave box

The Slave box which used in this thesis is shown in figure 4.8.

In this box there is Arduino, NRF24L1 and digital power meter. As seen in this figure the Arduino read the data from the TTL connection of digital power meter and send this information to the main box by using the RF block.

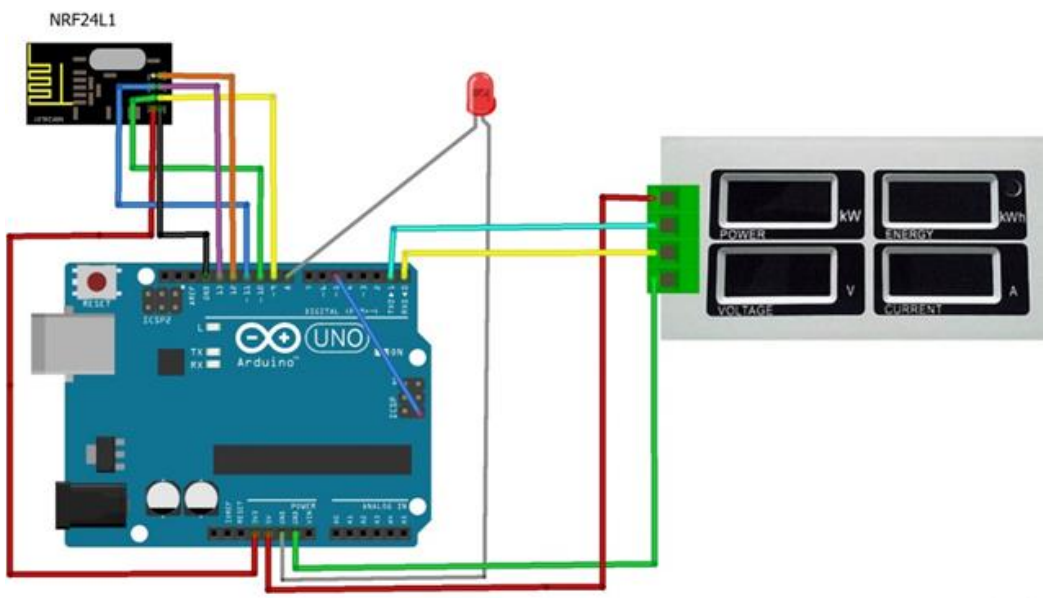

Figure 4.8: Slave box.

The parameter of the secondary box is shown in Table 4.1.

Table 4.1: Parameter of the secondary box.

Secondary Box	
A	**B**
Arduino Uno D0	Power Meter Rx
Arduino Uno D1	Power Meter Tx
Arduino Uno 5v	Power Meter GND
Arduino Uno GND	Power Meter VDD
Arduino Uno GND	NRF24L GND
Arduino Uno 3.3v	NRF24L VCC
Arduino Uno D9	NRF24L CE
Arduino Uno D10	NRF24L SCN
Arduino Uno D13	NRF24L SCK
Arduino Uno D11	NRF24L MOSI
Arduino Uno D12	NRF24L MISO
Arduino Uno D8	LED
Arduino Uno GND	LED GND
Arduino Uno D5 OR D4	Arduino UNo ICSP GND

Main smart meter which is connected with the main source in the distribution transformer.

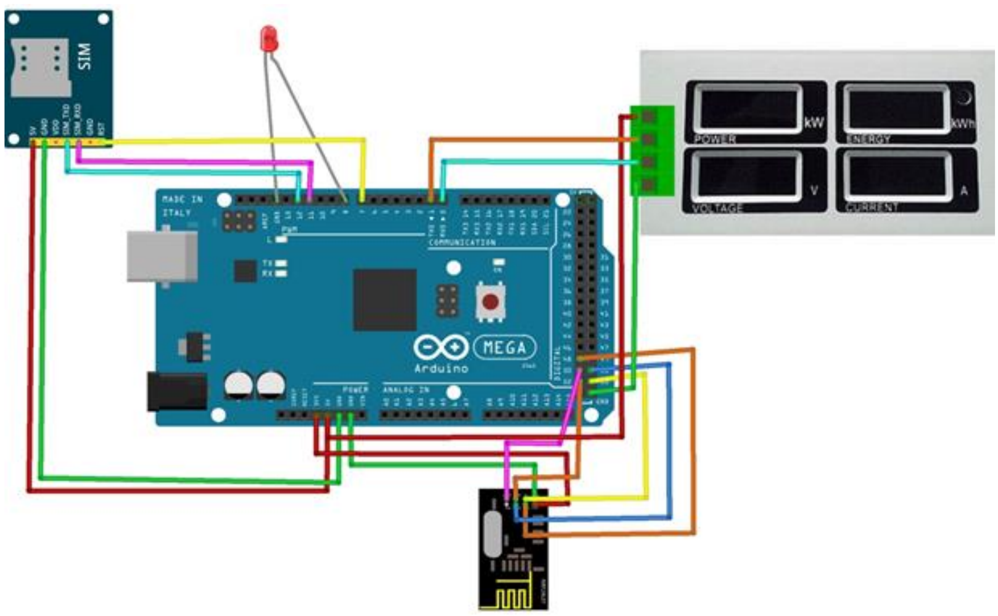

Figure 4.9: Master box.

The main smart meter has four functions, Read the total power consumption receive the data from all residence, collect it, Compare between the total power consumption and the data power received from residences. If the total power consumption greater than the data power received from residences that mean somebody still electricity or connect by illegal way Send a warning message content the ID of transformer to the central control unit for necessary action In this thesis we used the Arduino for controlling of the electricity usage in the transmission line. The Mega 2560 Arduino is used for the controlling. For transferring data we used the RF radio frequency with 1 GSM cart. The flow chart of the proposed method is shown in figure 4.10.

The parameter of the primary box is shown in Table 4.2.

Table 4.2: Parameter of the secondary box.

Primary Box	
A	**B**
Arduino Mega D1	Power Meter Rx
Arduino Mega D2	Power Meter Tx
Arduino Mega GND	Power Meter GND
Arduino Mega 5v	Power Meter VDD
Arduino Mega GND	NRF24L GND
Arduino Mega 3.3v	NRF24L VCC
Arduino Mega 53	NRF24L CE
Arduino Mega 48	NRF24L SCN
Arduino Mega 52	NRF24L SCK
Arduino Mega 51	NRF24L MOSI
Arduino Mega 50	NRF24L MISO
Arduino Mega D11	GSM SIM808 RX
Arduino Mega D12	GSM SIM808 TX
Arduino Mega D7	GSM SIM808 7
Arduino Mega D8	LED
Arduino Mega GND	LED GND
Arduino Mega D6	Arduino Mega ICSP GND

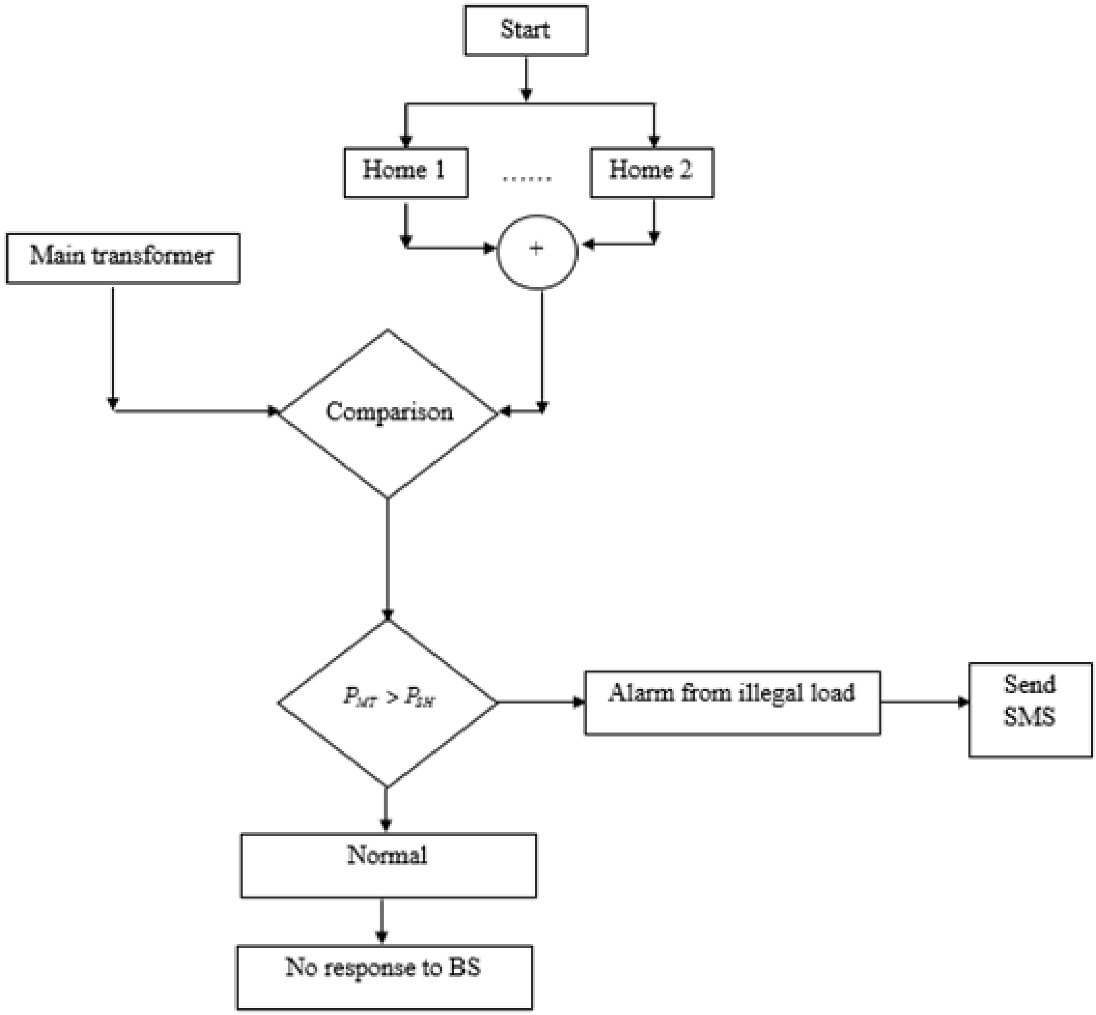

Figure 4.10: Flowchart of the proposed method.

As shown in this figure in the first step the houses electricity power will collect and will compare with the main transformer meter. After comparison if the power Main transformer greater than the power of all houses that's mean some body use the illegal electricity from the station. At this time the sensor will send the alarm to control station. This alarm contain the ID and the position of the usages person. If this power is equal the power of the house that time there will not send any alarm to base station. We simulated this scenario in MATLAB-SIMULINK and this situation is shown in figure 4.11.

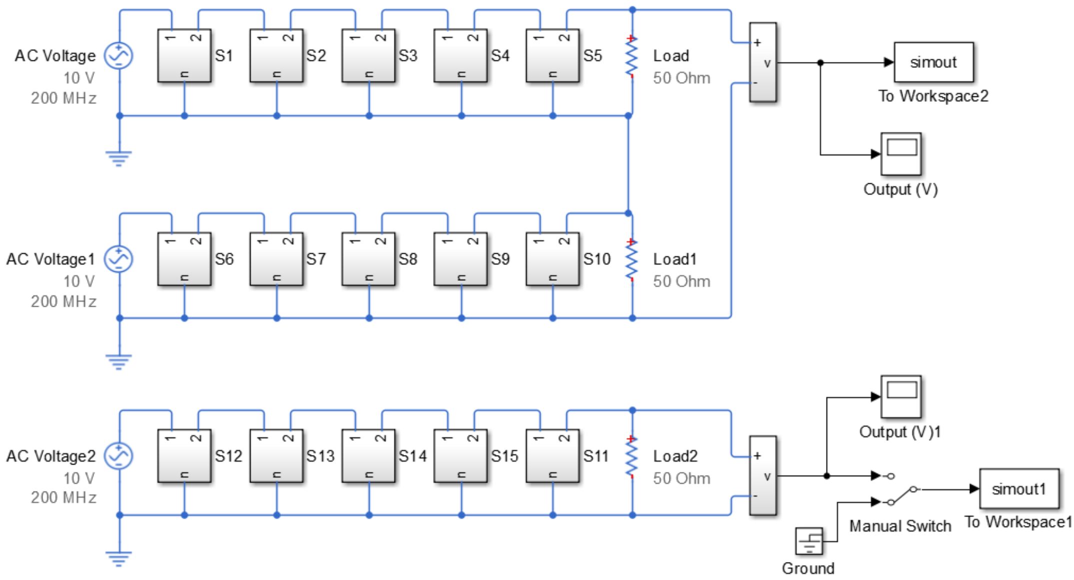

Figure 4.11: Simulink model of the power electricity which the two person are use.

For the parameter which we used in this thesis is shown in table 4.3.

Table 4.3: Parameter which used in this model.

Parameter	Value
length	5 km
Number of Segments	50
Resistance per unit length	0.0067
Capacitance per unit length	100e-12
Nominal impedance	50
Conductance per unit length	5e-6

For transmission line we used 5km.

The Amplitude of the output voltage vs. time is shown in figure 4.12.

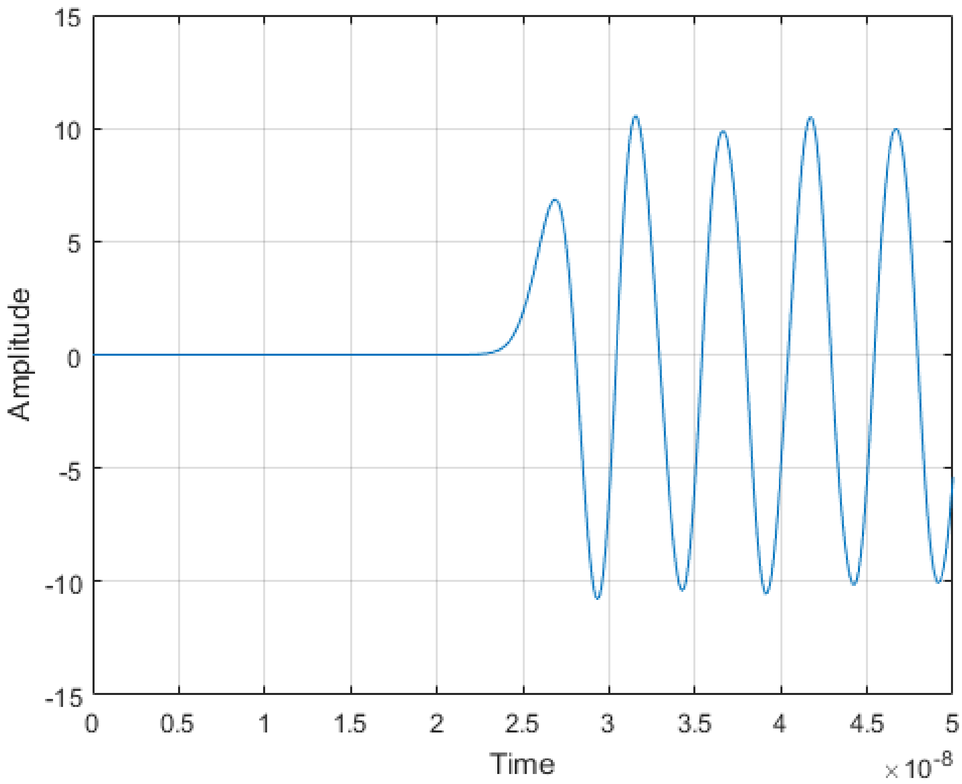

Figure 4.12: Amplitude of the output voltage vs. time.

The Simulink model of the proposed method is shown in figure 4.13.

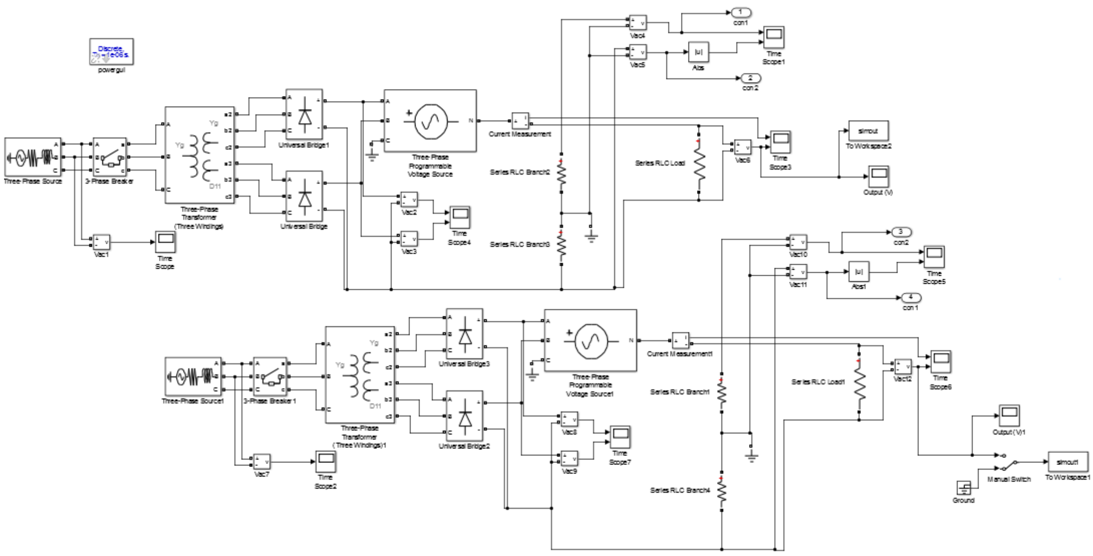

Figure 4.13: Simulink model of the proposed method.

The devices which we used in this thesis is shown in table 4.4.

Table 4.4: The specification of the proposed model for SGSC.

Device name	Model	Number
RF	N24	6
Arduino	Uno	4
Arduino	Mega	2
GSM	SIM808	2
Socket	16A, 250V	6
USB cable	mini	6
Power	Invertor AC to DC	6
Step Down	Lm2596	2
GSM antenna	Sim808	2
Current transformer	0~100A	6
Main cable	2x0.75mm^2	6
Cover box	10 x 20 cm	6

4.2 Dataset

In this thesis, we used two transformer smart meter each transformer connected with 2 houses smart meters. This scenario is illustrated in figure 4.14 but for n users.

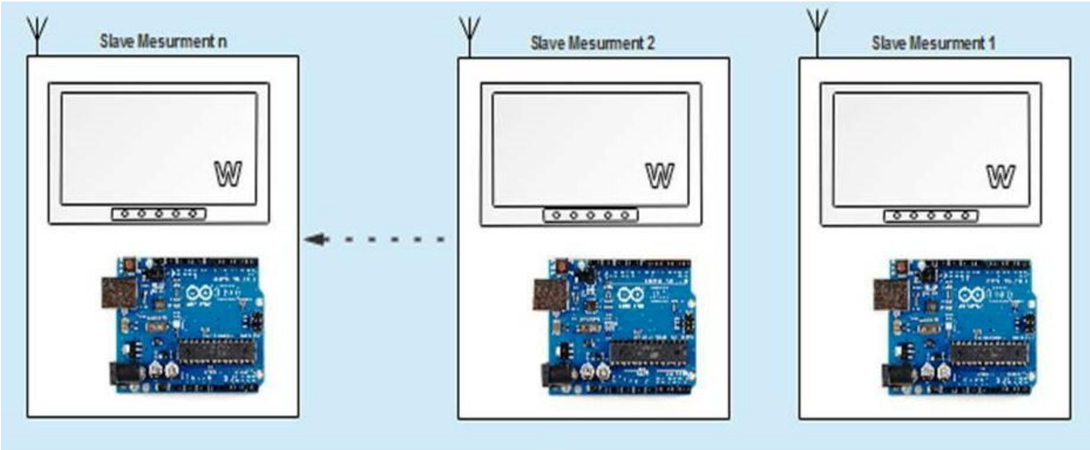

Figure 4.14: Smart meter connection.

The figure 4.15 shows the location of the users and the main box.

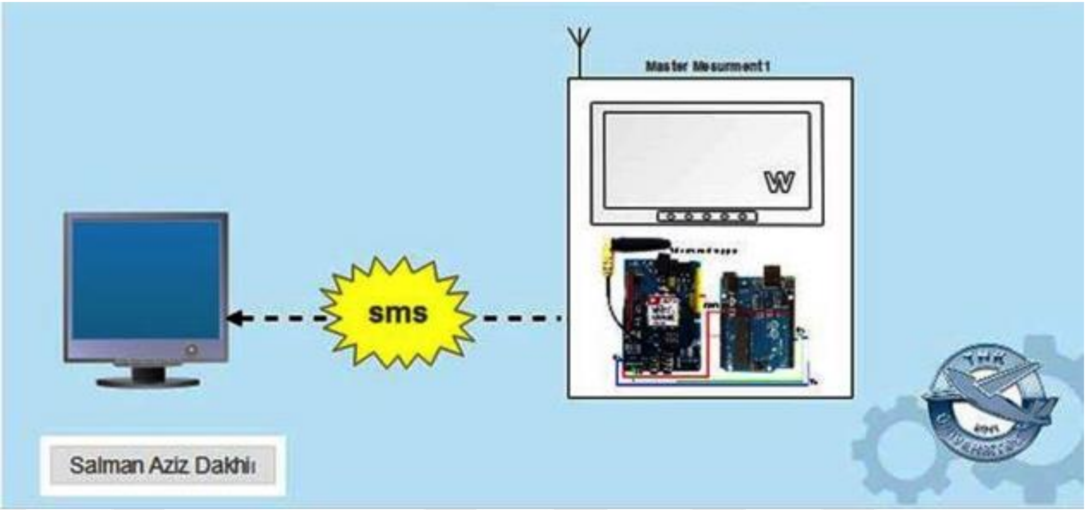

Figure 4.15: Sending message from GSM to center.

As seen in this figure there is main box which receive data from the secondary box which is located in the houses. We designed by *Edraw max* software. In this thesis we used two users as legal users and we added the other user as illegal user.

The overall of the work is shown in figure 4.16.

Figure 4.16: Overall of the work.

CHAPTER 5

CONCLUSION

From a global context, the smart grid can be defined as the dynamic integration of developments in electrical engineering, energy storage and advances in information and communication technologies (ICTs), Within the electric power business (generation, transmission, distribution, storage and marketing, including alternative energies); Allowing the coordination areas of protection, control, instrumentation, measurement, quality and energy management, etc., to be concatenated in a single management system with the primary objective of efficient and rational use of energy. The previous concept could also be the integration of other actors in the area of measurement and control, such as gas sources and water service. Thus, intelligent electricity grids are part of a macro concept of territorial domain, such as smart cities. The term intelligent network is often associated with the concept of smart meters capable of offering detailed billing by time slots, which would allow consumers not only to choose the best rates from different electric companies, but also to discern between hours of consumption, which in turn would allow better use of the network. This system would also make it possible to more accurately map consumption and better anticipate future needs at a more local level. The emergence of renewable energy in the energy landscape has significantly changed energy flows in the grid: now users not only consume, but also produce electricity through the same network. Therefore, the energy flow is now bidirectional. There are different types of Smart Grid Power System Control algorithms in the Distribution Network and these algorithms usually differ with the aim of the algorithm. Many of the algorithms are improved depending on the requirements of the related application. In this thesis we will discuss on general aspects of smart grids and focuses on some smart grid features at distribution level like interconnection of distributed generation. The aim of this thesis is to provide an efficient method for Automated meter reading to monitor power consumption in electrical distribution networks. In last decade there is no a lot of control for electric ministry in Iraq. For this reason there is a big problem in energy side. Since our aim is to optimize the energy consumption of the electric in the Iraq. Most of people down the electric from the towers. The distribution network mostly are in the air. The proposed method will be install in the air. In this thesis we used the current sensor, Arduino. For communication we used RF and GSM. We tested our device in the laboratory of THK University. Totally we used 3 sensors, one of them for main source and others used in the two test place.

Future work

In future we can use this device in the transmission line for best controlling of the electricity and power which use in the big houses. Also we can use the full for distribution line.

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APPENDIX

Appendix A: Arduino Software For The Master Box.

```
#include <SPI.h>
#include "RF24.h"
#include <avr/interrupt.h>
#include <avr/io.h>
#include <nRF24L01.h>
#include "Adafruit_FONA.h"
#include <SoftwareSerial.h>
#define FONA_RX 11
#define FONA_TX 10
#define FONA_RST 7
//HardwareSerial *fonaSerial = &Serial;
SoftwareSerial fonaSS = SoftwareSerial(FONA_TX, FONA_RX);
SoftwareSerial *fonaSerial = &fonaSS;
// this is a large buffer for replies
char replybuffer[255];
// We default to using software serial. If you want to use hardware serial
// (because softserial isnt supported) comment out the following three lines
// and uncomment the HardwareSerial line
// Hardware serial is also possible!
// HardwareSerial *fonaSerial = &Serial1;
```

```
// Use this for FONA 800 and 808s
Adafruit_FONA fona = Adafruit_FONA(FONA_RST);
bool radioNumber = 1;
RF24 radio(53, 48);
unsigned int primaryUnit = 1;
unsigned int secondaryUnit = 2;
unsigned int tertiaryUnit = 3;
unsigned int whoAmI = 0;
unsigned int powerUnits[10] = {0, 0, 0, 0, 0, 0, 0, 0, 0, 0};
unsigned int powerUnitTimeout[10] = {0, 0, 0, 0, 0, 0, 0, 0, 0, 0};
unsigned int powerUnitTimeoutMax = 10000;
unsigned int powerRemoteTotal;
unsigned int powerUnitOrder;
unsigned int powerPercent, powerRemoteTotalUpLimit,
powerRemoteTotalDownLimit;
unsigned int totalMembers;
// SETUP 1 FREQUENCIES
const uint64_t addresses[2] = {0xE8E8F0F0E1LL, 0xE8E8F0F0E2LL};
#define timeoutLimit 200
unsigned long startTime;
int ttlMessage[8];
unsigned int powerLow, powerHigh;
unsigned int power, powerRemote;
unsigned int hysteresis = 15; //15 WATTS DIFFERENCE WILL ALERT ME
WITH SMS
boolean suspectedActivity = false;
int totalCRC;
bool ttlCommunicationError = true;
bool rfCommunicationError;
bool blinky;
byte sendMe[4];
```

```
byte receiveMe[10];
unsigned int tcnt2;
int count;
byte sendIt = 1;
//SoftwareSerial Serial(2, 3);
unsigned long smsTime = 10000;
boolean sendSmsFlag = false;
void setup() {
 Serial1.begin(9600);
 Serial.begin(38400);
 Serial.write("hello");
 fonaSerial->begin(4800);
 while (!fona.begin(*fonaSerial)) {
  //Serial.write("Fona Serial Begin Line \n");
  delay(1000);
 }
 uint8_t n = 0;
 while (n != 1) {
  n = fona.getNetworkStatus();
  Serial.write(n);
  delay(1000);
 }
 pinMode(8, OUTPUT);
 pinMode(7, OUTPUT);
 flick(100);
 flick(100);
 flick(100);
 flick(100);
 //Setup Timer2 to fire every 1ms
 noInterrupts();
```

```
  TCCR2B = 0x00;        //Disbale  Timer2  while  we set it up
  TCNT2  = 130;         //Reset  Timer  Count  to 130 out of 255
  TIFR2  = 0x00;        //Timer2  INT Flag Reg:  Clear Timer  Overflow  Flag
  TIMSK2 = 0x01;        //Timer2  INT Reg:  Timer2  Overflow  Interrupt  Enable
  TCCR2A = 0x00;        //Timer2  Control  Reg  A: Wave Gen Mode normal
  TCCR2B = 0x05;        //Timer2  Control  Reg  B: Timer  Prescaler  set to 128
  interrupts();
  radio.begin();
  radio.setPALevel(RF24_PA_LOW);
  radio.openReadingPipe(1,  addresses[0]);
  radio.openReadingPipe(2,  addresses[1]);
  radio.startListening();
  Serial.write("TESTING  POWER METER  \n");
  ttlSetAddress();
  Serial.write("POWER  METER  TEST  OK \n");
}
ISR(TIMER2_OVF_vect)  {
  for (int  i = 0; i < 10; i++) {
    if (powerUnitTimeout[i]  > 0) {
      powerUnitTimeout[i]--;
    }
  }
  if (smsTime  > 0) {
    smsTime--;
  }
  /* Reload  the timer  */
  TCNT2 = 130;
  TIFR2  = 0x00;
}
```

```
void loop() {
  ttlReadPower();
  Serial.write("LOOPING \n");
  if (!ttlCommunicationError) {
    startTime = millis();
    rfCommunicationError = false;
    while (! radio.available()) {
      if (millis() - startTime > timeoutLimit) {
        rfCommunicationError = true;
        break;
      }
    }
    delay(100);
    if (!rfCommunicationError) {
      radio.read(&receiveMe, 3);
      //Serial.write(receiveMe, 3);
      //Serial.write(powerHigh);
      //Serial.write(powerLow);
      powerRemote = receiveMe[0];
      powerRemote = (powerRemote << 8);
      powerRemote += receiveMe[1];
      powerUnitOrder = receiveMe[2];
      powerUnitTimeout[powerUnitOrder] = powerUnitTimeoutMax;
      powerUnits[powerUnitOrder] = powerRemote & 0x3FFF;
      powerRemoteTotal = 0;
      totalMembers = 0;
      for (int i = 0; i < 10; i++) {
        if (powerUnitTimeout[i] == 0) {
          powerUnits[i] = 0;
        } else {
```

```
    totalMembers++;
  }
  powerRemoteTotal  += powerUnits[i];
}
String reportingString = "SYSTEM ID: 1\n";
String totalMembersString = "Total Members: ";
totalMembersString.concat(totalMembers);
totalMembersString.concat("\n");
String powerRemoteTotalString = "Remote Total Power: ";
powerRemoteTotalString.concat(powerRemoteTotal);
powerRemoteTotalString.concat(" W\n");
String powerLocalTotalString = "Local Total Power: ";
powerLocalTotalString.concat(power);
powerLocalTotalString.concat(" W\n");
String smsTimeString = "Time To SMS: ";
smsTimeString.concat(smsTime);
smsTimeString.concat(" ms\n");
Serial.print(reportingString);
delay(100);
Serial.print(totalMembersString);
delay(100);
Serial.print(powerRemoteTotalString);
delay(100);
Serial.print(powerLocalTotalString);
delay(100);
Serial.print(smsTimeString);
delay(100);
if (power > hysteresis) {
  powerRemoteTotalUpLimit = power + hysteresis; // 15 WATTS DIFFERENCE
  powerRemoteTotalDownLimit = power - hysteresis;
```

```
    if ((powerRemoteTotal < powerRemoteTotalDownLimit) || (powerRemoteTotal
> powerRemoteTotalUpLimit)) {
      if (smsTime == 0) {
        fonaSerial->begin(4800);
        while (!fona.begin(*fonaSerial)) {
          //Serial.write("Fona Serial Begin Line \n");
          delay(1000);
        }
        int n = 0;
        while (n != 1) {
          n = fona.getNetworkStatus();
          Serial.write("Trying to connect to network \n");
          delay(1000);
        }
        fona.sendSMS("00905393009429", "TEST SETUP 1 HAS ILLEGAL
ACTIVITY");
        delay(100);
        Serial.write("STEALING \n");
        delay(6000);
        // RF DOESN'T WORK AFTER SMS, WE NEED TO RESTART THE
RADIO
        radio.begin();
        radio.setPALevel(RF24_PA_LOW);
        radio.openReadingPipe(1, addresses[0]);
        radio.openReadingPipe(2, addresses[1]);
        radio.startListening();
        smsTime = 10000;
      }
      flick(100);
    } else {
      smsTime = 10000;
```

```
        }
      } else {
        smsTime = 10000;
      }
    } else {
      Serial.write("RF ERROR... \n");
      flick(3000);
      // RF DOESN'T WORK AFTER SMS, WE NEED TO RESTART THE RADIO
      radio.begin();
      radio.setPALevel(RF24_PA_LOW);
      radio.openReadingPipe(1, addresses[0]);
      radio.openReadingPipe(2, addresses[1]);
      radio.startListening();
      smsTime = 10000;

      flick(3000);
    }

  } else {
    flick(1000);
    flick(1000);
  }
}
void ttlReadPower() {
  byte ttlReadPower[] = {0xB2, 0xC0, 0xA8, 0x01, 0x01, 0x00, 0x1C};
  Serial1.write(ttlReadPower, sizeof(ttlReadPower));
  startTime = millis();
  while ((Serial1.available() < 3) && ((millis() - startTime) < timeoutLimit));
  for (int i = 0; i < 10; i++) {
    ttlMessage[i] = 0xFF;
```

```
  }
  delay(400);
  if (Serial1.available() < 3) {
   ttlCommunicationError = true;
   Serial1.flush();
  }
  else {
   totalCRC = 0;
   int n = 0;
   while (Serial1.available() > 0) {
    ttlMessage[n] = Serial1.read(); // Then: Get them.
    totalCRC += ttlMessage[n];
    n++;
   }
   if (((totalCRC - ttlMessage[n - 1]) & 0xFF) == ttlMessage[n - 1]) {
    powerLow = ttlMessage[2];
    powerHigh = ttlMessage[1];
    power = (powerHigh << 8) + powerLow;
    ttlCommunicationError = false;
    Serial1.flush();
   }
   else {
    ttlCommunicationError = true;
    Serial1.flush();
   }
  }
}
void ttlSetAddress() {
  byte ttlSetAddress[] = {0xB4, 0xC0, 0xA8, 0x01, 0x01, 0x00, 0x1E};
  while (ttlCommunicationError == true) {
```

```
Serial1.write(ttlSetAddress, sizeof(ttlSetAddress));
startTime = millis();
while ((Serial1.available() < 3) && ((millis() - startTime) < timeoutLimit));
for (int i = 0; i < 10; i++) {
 ttlMessage[i] = 0xFF;
}
delay(400);
if (Serial1.available() < 3) {
 if (Serial1.available() > 0) {
  while (Serial1.available() > 0) {
   Serial.write(Serial1.read()); // Then: Get them.
  }
 } else {
  Serial.write("No answer");
 }
 ttlCommunicationError = true;
 Serial1.flush();
}
else {
 totalCRC = 0;
 int n = 0;
 while (Serial1.available() > 0) {
  ttlMessage[n] = Serial1.read(); // Then: Get them.
  totalCRC += ttlMessage[n];
  n++;
 }
 if (((totalCRC - ttlMessage[n - 1]) & 0xFF) == ttlMessage[n - 1]) {
  ttlCommunicationError = false;
  Serial1.flush();
 }
```

```
      else {
        ttlCommunicationError = true;
        Serial1.flush();
      }
    }
  }

}

void flick(int delays) {
  digitalWrite(8, HIGH);
  delay(delays);
  digitalWrite(8, LOW);
  delay(delays);
}
```

Appendex B: Arduino software for the slave box.

```
#include <SPI.h>
#include "RF24.h"
#include <avr/interrupt.h>
#include <avr/io.h>
bool radioNumber = 1;
RF24 radio(9, 10);
unsigned int secondaryUnit = 2;
unsigned int tertiaryUnit = 3;
unsigned int whoAmI = 0;
unsigned int powerUnits[10] = {0, 0, 0, 0, 0, 0, 0, 0, 0, 0};
unsigned int powerUnitTimeout[10]= {0, 0, 0, 0, 0, 0, 0, 0, 0, 0};
unsigned int powerUnitTimeoutMax = 10000;
unsigned int powerRemoteTotal;
unsigned int powerUnitOrder;
unsigned int powerPercent, powerRemoteTotalUpLimit,
powerRemoteTotalDownLimit;
// SETUP 1 FREQUENCIES
 const uint64_t addresses[2] = {0xE8E8F0F0E1LL, 0xE8E8F0F0E2LL};
#define timeoutLimit 200
unsigned long startTime;
int ttlMessage[8];
unsigned int powerLow, powerHigh;
unsigned int power, powerRemote;
unsigned int hysteresis = 10;
```

```
boolean suspectedActivity = false;
int totalCRC;
bool ttlCommunicationError = true;
bool rfCommunicationError;
bool blinky;
byte sendMe[4];
byte receiveMe[10];
unsigned int tcnt2;
int count;
byte sendIt = 1;
//SoftwareSerial Serial(2, 3);
unsigned long smsTime = 100000;
boolean sendSmsFlag = false;
void setup() {
  Serial.begin(9600);

  pinMode(8, OUTPUT);
  pinMode(5, INPUT_PULLUP);
  pinMode(4, INPUT_PULLUP);
  if (digitalRead(5) == LOW) {
    whoAmI = secondaryUnit;
    for(int i=0;i<4;i++){
      blinky ^= 1;
      digitalWrite(8, blinky);
      delay(300);
    }
  }
  else if (digitalRead(4) == LOW) {
    whoAmI = tertiaryUnit;
    for(int i=0;i<2;i++){
```

```
    blinky ^= 1;
    digitalWrite(8, blinky);
    delay(300);
   }
  }
  //Setup Timer2 to fire every 1ms
  noInterrupts();
  TCCR2B = 0x00;       //Disbale Timer2 while we set it up
  TCNT2  = 130;        //Reset Timer Count to 130 out of 255
  TIFR2  = 0x00;       //Timer2 INT Flag Reg: Clear Timer Overflow Flag
  TIMSK2 = 0x01;       //Timer2 INT Reg: Timer2 Overflow Interrupt Enable
  TCCR2A = 0x00;       //Timer2 Control Reg A: Wave Gen Mode normal
  TCCR2B = 0x05;       //Timer2 Control Reg B: Timer Prescaler set to 128
  interrupts();
  //Serial.begin(9600);
  radio.begin();
  radio.setPALevel(RF24_PA_LOW);
  if (whoAmI == secondaryUnit) {
   radio.openWritingPipe(addresses[0]);
  }
  else if (whoAmI == tertiaryUnit) {
   radio.openWritingPipe(addresses[1]);
  }
  ttlSetAddress();
  for(int i=0;i<8;i++){
   blinky ^= 1;
   digitalWrite(8, blinky);
   delay(100);
  }
}
```

```
/*
 * Install the Interrupt Service Routine (ISR) for Timer2 overflow.
 * This is normally done by writing the address of the ISR in the
 * interrupt vector table but conveniently done by using ISR() */
ISR(TIMER2_OVF_vect) {
  for(int i=0; i<10; i++) {
    if(powerUnitTimeout[i] > 0) {
      powerUnitTimeout[i]--;
    }
  }
  if(smsTime > 0){
    smsTime--;
  }
  /* Reload the timer */
  TCNT2 = 130;
  TIFR2 = 0x00;
}
void loop() {
  ttlReadPower();
  if (!ttlCommunicationError) {
      sendMe[0] = powerHigh;
      sendMe[1] = powerLow;
      sendMe[2] = whoAmI;
      radio.write(&sendMe, 3);
      blinky ^= 1;
      digitalWrite(8, blinky);
      delay(100);
      blinky ^= 1;
      digitalWrite(8, blinky);
  }
```

```
}

void ttlReadPower() {
 byte ttlReadPower[] = {0xB2, 0xC0, 0xA8, 0x01, 0x01, 0x00, 0x1C};
 Serial.write(ttlReadPower, sizeof(ttlReadPower));
 startTime = millis();
 while ((Serial.available() < 3) && ((millis() - startTime) < timeoutLimit));
 for (int i = 0; i < 10; i++) {
  ttlMessage[i] = 0xFF;
 }
 delay(400);
 if (Serial.available() < 3) {
  ttlCommunicationError = true;
  Serial.flush();
 }
 else {
  totalCRC = 0;
  int n = 0;
  while (Serial.available() > 0) {
   ttlMessage[n] = Serial.read(); // Then: Get them.
   totalCRC += ttlMessage[n];
   n++;
  }
  if (((totalCRC - ttlMessage[n - 1]) & 0xFF) == ttlMessage[n - 1]) {
   powerLow = ttlMessage[2];
   powerHigh = ttlMessage[1];
   power = (powerHigh << 8) + powerLow;
   ttlCommunicationError = false;
   Serial.flush();
  }
```

```
    else {
      ttlCommunicationError = true;
      Serial.flush();
    }
  }
}
void ttlSetAddress() {
  byte ttlSetAddress[] = {0xB4, 0xC0, 0xA8, 0x01, 0x01, 0x00, 0x1E};
  while(ttlCommunicationError == true) {
    Serial.write(ttlSetAddress, sizeof(ttlSetAddress));
    startTime = millis();
    while ((Serial.available() < 3) && ((millis() - startTime) < timeoutLimit));
    for (int i = 0; i < 10; i++) {
      ttlMessage[i] = 0xFF;
    }
    delay(400);
    if (Serial.available() < 3) {
      ttlCommunicationError = true;
      Serial.flush();
    }
    else {
      totalCRC = 0;
      int n = 0;
      while (Serial.available() > 0) {
        ttlMessage[n] = Serial.read(); // Then: Get them.
        totalCRC += ttlMessage[n];
        n++;
      }
      if (((totalCRC - ttlMessage[n - 1]) & 0xFF) == ttlMessage[n - 1]) {
        ttlCommunicationError = false;
```

```
    Serial.flush();
   }
   else {
    ttlCommunicationError = true;
    Serial.flush();
   }
  }
 }
}
```

CURRICULUM VITAE

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