INVESTIGATION ON THE POSSIBLE IMPACTS OF SMART GRIDS IN THE MODERN SOCIETY

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A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering (Hons.) Electrical and Electronic Engineering

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September 2016

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **"INVESTIGATION ON THE POSSIBLE IMPACTS OF SMART GRIDS IN THE MODERN SOCIETY"** was prepared by **ANG KEAT HONG** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Engineering (Hons.) Electrical and Electronic Engineering at Universiti Tunku Abdul Rahman.

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ACKNOWLEDGEMENTS

I would like to thank everyone who had contributed to the successful completion of this project. I would like to express my gratitude to my research supervisor, Dr. Stella Morris for her invaluable advice, guidance and her enormous patience throughout the development of the research.

In addition, I would also like to express my gratitude to my loving parents and friends who had helped and given me encouragement along the way until the completion of this project. Furthermore, my parents voluntarily brought me to and from the location of the smart meters installed which is located in Melaka numerous times. All cost is absorbed by them willingly. Moreover, both RF meter and the Geiger Muller counter are also purchased by them. I am glad that my total expenditure for this project is on the low end.

Besides that, I like to say thank you to Encik Haris from TNB Sdn. Bhd. for replying my emails and confirming certain technical aspects of the smart grid system. Also, I got the opportunity to visit the actual pilot project of the smart grid in Melaka. Among others, I am exposed to handling public relations as I officially wrote and speak face to face with certain staffs and personals from UNITEN and TNB. Thus, these experiences can be proved useful when I start off my working career in future.

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ABSTRACT

Smart grid is based on two directions of delivering of energy from one end to another. It promotes more efficient way of transmission and distribution of energy plus it gives the freedom to the end users to decide on their energy consumption patterns. Moreover, it includes advanced technologies in order to supply real time information and to maintain the stability of both the demand and supply side of the grid. Thus, the aim of this project is to investigate both negative and positive impacts of smart grid on society. Impacts can be categorized into environmental, consumer, security, economic and reliability. However, three out of five impacts will be selected to be critically analysed. Specific factors and areas of each impact will be stated to be further scrutinized. Then, data collection and analysis will be carried out of each of those stated. After that, relationship between related impacts will be established. Furthermore, negative impacts are given higher weightage in this project due to the popularity of positive impacts stated in most studies or researches. Hence, measurements of RF radiation from smart meters are recorded in order to evaluate the intensity of the radiation. The level of intensity will be then analysed in order to determine whether it is close or far from the threshold limits imposed by FCC. Thus, the impact of RF emission from smart meters can be related to the customers' general health. Furthermore, ionizing radiation and EMF radiation will be obtained in order to obtain more comparison to deduce the severity of the levels of different types of radiation on human's health. Also, by comparing the RF radiation emitted by daily household devices, a clearer picture can be obtained in order to evaluate the impact of RF radiation from smart meters on our general health. On the other hand, a survey will be conducted in order to evaluate the customers' satisfaction and also

awareness whereby all of these are in terms of customer impact of the smart grid. However, in terms of environmental impact, official request for specific data sharing from various institutions or companies are sent out using email or by telephone calls. TNB Sdn. Bhd. already successfully roll out the first phase of pilot program for smart grid in Bandar Ayer Keroh, Melaka. Thus, with the relevant data and by obtaining their customers web portal, real time information of energy consumption and cost plus environmental impact are all displayed on the website. Hence, those metadata on the web portal can be used to support some of the statements listed in this project. So, ultimately for different impact, the weightage for both negative and positive impact can be deduced accordingly and an overall conclusion could be made regarding the overall impact of smart grid on the modern society as a whole. In summary, it can be concluded that RF radiation from smart meters does cause biological effects on end users' health but is insufficient to trigger health effects as there is a significant buffer zone between the maximum RF radiation emitted and the globally recognized MPE limits of RF radiation. Thus, it cannot be categorized as health hazard as only health effects can cause detrimental side effects on end users' health. Moreover, by implementing smart grid, it is proven that there are significant savings in terms of total amount of carbon dioxide emitted due to much less energy generated compared to the traditional grid based on real data obtained from trusted and reliable sources of government bodies.

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LIST OF SYMBOLS / ABBREVIATIONS

RFI	Radio Frequency Interference
FCC	Federal Communications Commission
AC	Alternating Current
AMI	Advanced Metering Infrastructure
RF	Radio Frequency
GE	General Electric
DOE	Department of Energy
BPL	Broadband-over-power-lines
EMF	Electromotive Force
UHF	Ultra High Frequency
AAP	American Academy of Paediatrics
PG&E	Pacific Gas and Electric Company
CCST	California Council on Science and Technology
UL	Underwriters Laboratory
EEA	European Economic Area
DR	Demand Response
DSM	Demand Side Management
FERC	Federal Energy Regulatory Commission
EPRI	Electric Power Research Institute
PNNL	Pacific Northwest National Laboratory
EPA	United States Environmental Protection Agency
FWS	US Fish and Wildlife Service
NIST	National Institute of Standards and Technology
SCADA	Supervisory Control and Data Acquisition
LAN	Local Area Network
IEC	International Electro-Technical Council
NERC	North American Electric Reliability Corporation
TNB	Tenaga Nasional Berhad

WHO	World Health Organization
MPE	Maximum Permissible Exposure
IARC	International Agency for Research on Cancer
CPM	Counts per Minute
EIA	US Energy Information Administration
AMR	Automatic Meter Reading

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CHAPTER 1

INTRODUCTION

1.1 Background

The traditional grid has been around for many years. While constant upgrading of the traditional grid has been ongoing for all these years in order to meet the current demand, the traditional grid still has been operating the same way it did when it was first founded. The overall process of the traditional grid can be simplified as the energy will flow from centralized power plants to the end users or consumers. There is also an issue of reliability where it should be resolved by preserving surplus capacity. (Frye W, 2008).

However, the traditional grid has its flaws. Basically, it is not environmental friendly due to its emission of greenhouse gases plus it does require fossil fuels to run. Also, it is not designed for distributed or renewable energy sources to be integrated into the grid itself. Thus, this grid will not have the ability to meet the ever increasing energy demand of the world. As the global economy strengthens and the cost of living rises, society in general will require a reliable and affordable electricity source. Nevertheless, there were major changes along the way from the initial years of this grid started regarding how electricity were generated, transmitted and distributed.

Fossil fuels still is the primary source of energy in most major countries. Now, this traditional grid is poised with various types of obstacles ranging from increase of digital loads which contributes to frequent power outages and also high levels of demand from end users. Thus, power consumption from generation until distribution is now being scrutinized in order to devise a strategy to reduce or eliminate the above obstacles and making the traditional grid to become a more efficient and reliable system in a whole. (Hossain MR, Ali S, 2010). With the new concept of smart grid comes along a myriad of solutions which consist of empowering customers, enhancing transmission lines and distribution systems, providing real time information between utility and end users plus integration of renewable energy sources into the smart grid.

Technological revolution in communications does help to improve monitoring and control and indirectly make it more flexible and effective while maintaining the operational cost to be average. Smart grid is the potential of utilizing information and communication technologies in order to revolutionize existing power systems. (Liyanage K, Wu J, 2012). Investments are made in a large global scale which will cause any modifications to be highly expensive and thus need concrete justifications. An example includes greenhouse gases which is currently increasing in terms of quantity and thus deteriorates our global climate. So, electricity generation without emission of carbon dioxide is the ultimate solution.

Moreover, efficient management of reduction of losses and energy wastage will require detailed information while the utilization of renewable energies will require integration of loads to contribute to the balance between the supply and demand sides. Smart meters can provide real time information regarding the loads and the power flow in the whole system. Monitoring every section of the system will enable greater chances of control to be implemented. Looking into the future of smart grid, a feasible solution which is known as decarbonized electrical power system could be implemented where it will be based on generation of mixture of renewables, nuclear energy and fossil-fuelled plants plus the ability to carbon capture and storage.

Thus, in this project, some of the above obstacles will be addressed plus additional ones which will be stated below in order to investigate the possible impacts of the smart grid in our modern society. This impact study can be divided into four major categories which are environmental, economic, customer and reliability impacts. Moreover, another two possible impacts have been included into this project which are security and natural disasters impacts bringing it to a total of six major possible impacts. However, only some of those categories will be analysed in terms of positive and negative sides plus summary of data collection and analysis will be included too. Also, examples will be used whenever applicable and relationship between different impacts could be established too.

1.2 Aims and Objectives

The purpose of this project is to investigate the possible impacts of smart grid on the modern society. Those possible impacts consist of environmental, customers, reliability, economic, security and natural disasters. In terms of customer impact, there are three areas which are financial savings, customer satisfaction and customer awareness. In terms of environmental impact, there are two areas which are demand response and demand side management and in terms of security impact, three aspects are security requirements, types of attacks and preventive measures. Each impact will yield both or either positive or negative outcomes. Also, not every impact will have equal weightage of positive or negative outcomes. Thus, this project actually highlights the negative impacts more instead of the positive ones as few research or studies actually consider negative impacts as their main focus or subject.

There are limitations of this project whereby in terms of data collection from various institutions or companies, terms and conditions are imposed duly before the permission to utilize those data in this project will be permitted by the relevant parties. Hence, due to these constraints and the privacy of customers' energy usage, thus there are alternatives available like seeking publicly available information from other countries and also engage with customers in order for them to willingly share their energy consumption data to be used in this project with credits given. By providing a different point of view, a different perspective can be achieved and more detailed and in depth analysis executed by experts in this relevant field where more advanced software and more technical knowledge could be applied in order to support or reject any criteria of the impacts stated in this project.

Hence, the objectives of this project are:

- To highlight all possible impacts whether they are positive or negative in nature and categorize them into separate categories.
- For each impact, either factors or areas of investigation need to be stated in order to enable more specific data collection, description, elaboration, sampling and analysis to be performed.

- To take measurements of RF radiation from smart meters and other various locations and also varying distances in order to compare the RF power intensity to other devices plus establish whether the radiation emitted is close or far from the maximum limits imposed by various regulatory bodies like FCC and also from Bio Initiative 2012.
- To obtain similar ionizing radiation readings plus EMF readings in order to further analyse the levels of radiation readings and to infer whether those other limits have been exceeded according to those maximum permissible limits set.
- Based on those readings obtained, a conclusion or overall statement will be drawn in order to justify the impact of RF radiation from smart meters towards human health in general.
- To evaluate whether smart grid yields positive environmental impact based on total amount of carbon dioxide emitted to atmosphere and also the total energy generation savings compared to the traditional grid by selecting the same time period and same city or location.
- To conduct survey in order to evaluate the customer impact of smart grid and to officially request for specific data from various institutions or companies to facilitate the data analysis and comparison needed for this project.

1.3 Project Milestones

Table 1.1: Project Milestones for Part 1

No.	Description	Total duration (weeks)
1	Literature Review	5
2	Data Collection and Research	3
3	Determine various methodologies	2
4	Determine materials and equipment for obtaining data samples	1
	Total	11

Table 1.2: Project Milestones for Part 2

No.	Description	Total duration (weeks)
1	RF data collection and sampling	2
2	Simulation software modelling	2
3	Simulation data analysis	4
4	RF data analysis	4
5	Conclusion	1
6	Necessary modifications	1
	Total	14

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Smart Grid

Smart grid is "an electricity network that can intelligently integrate the behaviour and actions of all users connected to it whether they are generators, consumers and those that do both in order to efficiently ensure sustainable, economic and secure electricity supply". (EC Task Force for Smart Grids, 2010a). In general, the smart grid is intelligent, efficient, opportunistic, quality-focused and green. The grid is deemed intelligent because it could detect overloads and thus redirect power flow away from the point of overload in order to mitigate the occurrence of power outages. Also, it can work autonomously if a decision is needed immediately because it can execute them faster than any human. Moreover, it could also meet the demand of sudden increase in terms of usage without adding additional infrastructure at all.

2.2 Overview on smart grid

There are many various different types of components of smart grid. They include intelligent appliances, smart power meters, smart substations, smart distribution, smart generation and universal access to low carbon power generation. Firstly, intelligent appliances could start to draw power by following the customers' pre-set instructions. Thus, this ability can reduce peak loads in a long term basis which in turn can significantly decrease the cost of generation of electric. Furthermore, less land need to be cleared and also less trees need to be chopped. Initial findings states that customers did save up to 25% on their energy consumption just by giving information on usage and the tools in order for management purposes.

Next component is the smart power meters whereby a two-way communication is used to automatically collect data about billing and also to detect power outages. This will then shorten the amount of time taken for the repair crew to detect and rectify the problem in order to restore power supply to its original state. The smart grid also consists of smart substations which includes monitoring and control of data like power factor performance, transformer, security and breaker. Smart distribution is the particular component where it is self-healing in terms of long distance transmission plus monitoring and analysis tools which are able to predict or detect any kinds of failures based on real time information.

Furthermore, smart generation is able to sort of learn the behaviour of generation of power in order to enhance production of energy and to make sure the voltage, frequency and power factor are maintained automatically based on feedback at any points on the grid itself. Lastly, the access to the renewable energy power generation and storage systems are universal in nature. (Bichlien Hoang, 2006). Moreover, there are five key technology enabled areas where smart grid operates on. They include advanced components, advanced control methods, sensing and measurement, improved interfaces and decision support plus integrated communications.

Advanced components can be applied in both standalone or interconnected to one another to form a more complex system like microgrid. These components can determine the electrical behaviour of the grid. Among some examples of these components are flexible AC transmission system, smart meters and solid state transfer switch. The next key technology is called advanced control methods which are in the form of devices or algorithms that are able to analyse and diagnose conditions in the grid plus able to execute suitable response in order to reduce or prevent power outages. This method will enable control of the real and reactive power across states. Examples of these methods include substation, distribution and feeder automation.

Sensing and measurement technologies will convert data into information and improves various aspects of the power system. This technology will review the health status of equipment and also the grid's integrity. Furthermore, it will also provide instantaneous total energy consumption, reduce energy theft and support multiple meter readings. This will reduce congestion and also greenhouse gas emission just by empowering customers and utilizing demand response plus supporting various control methods. Some examples include advanced metering infrastructure (AMI), power quality monitoring system, wireless condition monitoring, power outage monitoring system and many more.

The next technology is called improved interfaces and decision support. This technology will transform complex power system data into data which are understandable by the operators. This can assist the operators in order to analyse and identify issues at any given time based on data display techniques which includes virtual reality, animation and many more. Examples of this technology includes phasor measurement analysis, distributed energy resources interface and many more. The final technology is known as integrated communications where an interactive and dynamic infrastructure is formed for power exchange and real time information. Examples include ZigBee, WiFi and broadband power cables. (Enabling Technology, 2013).

2.3 Customer Impact of Smart Grid

2.3.1 Benefits

There are various types of benefits which smart grid could deliver. Among them includes the capability of being more energy self-sufficient due to the integration of renewable energy sources and different kinds of energy storage systems. Besides that, the frequency of power outages and the time frame of the power outages will decrease due to the communication system of the smart grid compared to the traditional grid. Moreover, there should be certain amount of reduction of energy costing due to the savings from distribution and retail amounts which are contributed by the system efficiency of the smart grid. Also, other services like home automation plus electric vehicles could benefit directly from the smart grid too.

2.3.2 Areas of Customer Impact

Three different types of areas will be examined under customer impact. Based on the total number of smart grid projects worldwide, statistical data has been gathered in order to determine the severity of each impact for each different category. Hence, it is found that financial and energy savings yields the most overall impact. The second area of customer impact is customer satisfaction. This area contributes to the second highest overall impact while the third area which is known as customer awareness yields the lowest overall impact according to Figure 2.1.

Average customer impact ratings are quite low meaning that about a quarter of the total number of projects obtained scored a high or very high rating of impacts on the customer. On the other hand, there was an indication of positive environmental impact which arises from the changes of customer energy consumption. Hence, there could be a link or relationship between energy consumption which is directly related to environmental impact and customer impact of smart grid in order to reduce greenhouse gas emissions.

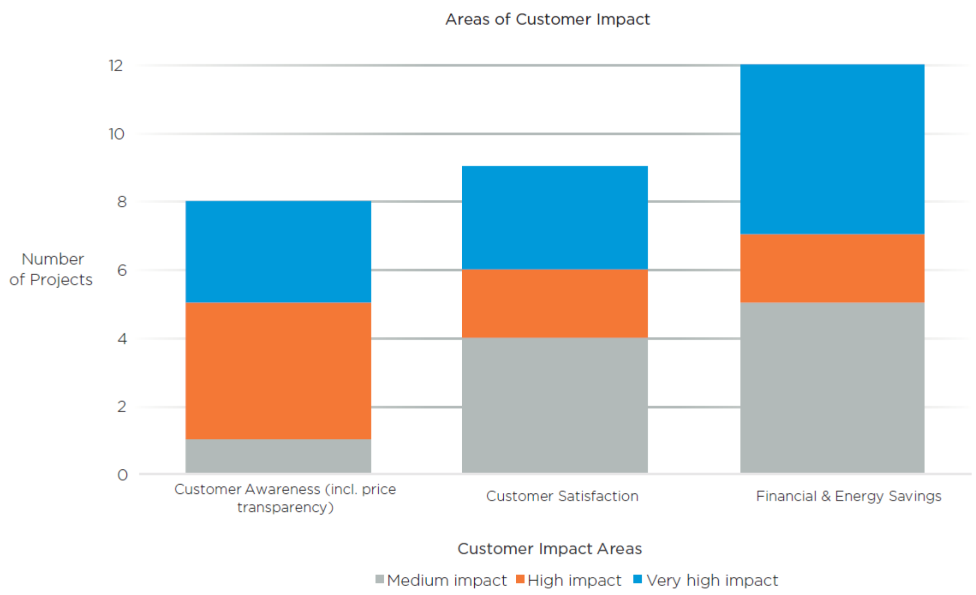

Figure 2.1: Areas of Customer Impact of Smart Grid

2.3.3 Customer Impact Regional Trends

In this impact study, there are four major regions worldwide which are Asia, Oceania, Europe and North America. Among the four regions, Oceania had the highest impact among all three areas of customer impact by referring to Figure 2.2. The major reasons that pushed Oceania to be highly customer oriented includes customers have the final say, ideology of spreading awareness to the public plus providing positive experience. These factors contribute to the success of implementing a full scale smart grid although certain parts of Oceania did not allow the smart grid concept. North America scored the second best in terms of overall impact in all three areas. There is a significant contrast between Europe and Asia especially in the financial and energy savings area due to the nature of Asia region which prioritize infrastructure typed projects compared to Europe region which prioritize environment friendly typed projects.

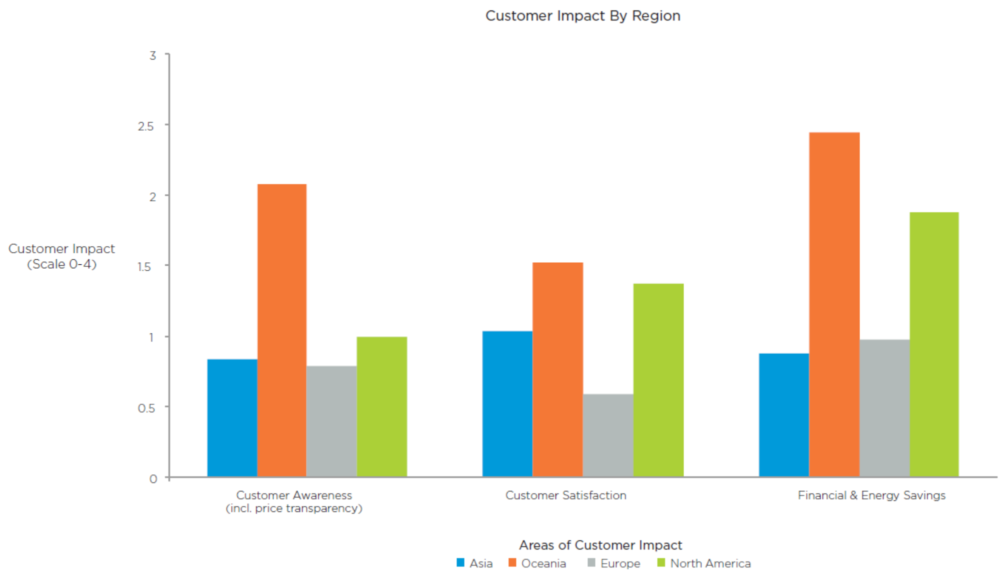

Figure 2.2: Areas of Customer Impact by Regions

2.3.4 Customer engagement

Almost all benefits of smart grid will need to be accepted by the customers. Also, the customers' engagement and their interest in smart grid are highly determined by a strategic guide where knowledge and awareness of the customers are cultivated and instilled by various means. Globally, smart grid projects are using many various types of media in order to cultivate customer engagement. Among them include press release, media event, video conferencing, emails, newsletters, reports, websites, phone, television, advertisement, social media, helpline and awards. However, a combination of these media yields the most effective approach.

Just by relying on media alone is not sufficient as a wider approach with a combination of education, social media and feedback system are required in order to promote customer engagement and promote the benefits of smart grid. Furthermore, smart meter data are used in order to enable customers to conserve energy consumption by understanding the information derived from the meter data. Moreover, mobile phone applications, electronic reports and web portals are publicly available to customers to utilize them and thus forming the foundation of the relationship between customers and the utility provider. Besides that, utility providers also could educate their customers and promote in terms of energy efficiency, automated control of different systems, smart billing and various pricing tariff plus the availability of solar generation on the roof of houses.

There are also downsides to customer engagement due to certain negative customers' response and certain negative media influences regarding the smart metering system worldwide. Hence, there are some utility providers which offset customer engagement by deploying grid-side technology. Nevertheless, in the near future, smart meter system will be eventually accepted by majority of customers worldwide due to the advantages which will outweigh the disadvantages in terms of behaviour response. Some examples include customers will want the frequency of power outages to be as low as possible which they could occur due to natural disasters, customers will purchase electric vehicles instead of petrol or diesel variants and customers will utilize many smart appliances in their household.

Thus, utility providers should promote and convince their customers that by utilizing grid-side technologies and by proving scientifically with concrete evidence or studies that show that there are few negative outcomes of impact on their customers, then only the implementation of these technologies will start to gain momentum and could be deployed worldwide with ease and public acceptance. Ultimately, the success of smart grid implementation worldwide depends heavily on customer impact as the customers are the end users and if there are significant negative impacts on them, then the customers will surely oppose this concept in their personal capacity and capability. (Global Smart Grid Impact Report, 2013).

As mentioned above, when utility providers educate their customers in order to reduce energy consumption, thus there will be much less greenhouse gas emissions. By real time monitoring of smart meter data, customers can decide when to switch off unwanted appliances which consume high power rating. Thus, less power needs to be generated. Hence, there will be less emissions which arises from less power generations due to less burning of coal in the power generation sector. So, based on the above scientific evidence and relationship, there is a direct relationship between reduction of energy consumption and reduction of greenhouse gas emissions. Thus, it can be deduced that there is a strong direct relationship between environmental impact and the customer impact.

2.3.5 RF radiation from smart meters

On the other hand, smart metering is somewhat equivalent to converting an appliance into a radiofrequency radiation (RF) transmitter. Furthermore, many existing household appliances are already an RF transmitter. For examples, microwave ovens, clothes dryer, refrigerator, air conditioner, television, printer and computer do emit RF waves. General Electric (GE) and other manufacturers are integrating transmitters into their product designs and the DOE are issuing tax credits. Customers are not able to disable those transmitters as that could lead to the void of warranties. On a different note, customers which installs smart meters in their houses will be technically exposed to RF radiations every day.

Furthermore, all appliances with RF transmitter does transmit peak power bursts way above the existing safety standard limits whereby those peaks fall in the ultra-high frequency band in the electromagnetic spectrum few times a minute. Also, all transmitters indoor must communicate with the smart meter located outdoor of each building or home. Then, that outdoor meter will send a higher frequency signal to a centralized hub in that specific neighbourhood. These signals could be reflected from each outdoor meter to another meter of the neighbours before arriving at the final point which is the centralized hub. Thus, this implies that RF exposure also originates from the surrounding smart meters in that specific neighbourhood. In future, gas and water utility companies too can implement smart metering system.

Many numerous studies have shown the side effects of frequencies emitted at low power intensity. Those side effects have detrimental effects on health. If the distance of the major transmitter is less than 1500 feet from the residential home, health implications like sleeplessness, dizziness, headache, fatigue and other harmful effects have been recorded. Those similar side effects have been reported by customers who has smart meters already installed. Based on facts, every system in the human body are somewhat sensitive to low amount of electromagnetic fields due to the body cells are actually electromagnetic systems on its own. “Dirty electricity” is directly associated with diabetes, breast cancer, thyroid cancer and lung cancer when a research is conducted by Magda Havas and Samuel Milham.

Multiple frequencies exposure where RF combines with low frequencies can be called dirty electricity. Broadband-over-power-lines (BPL) is totally deemed as dirty electricity as RF radiation from the socket can be confirmed using an RF meter. Furthermore, certain medical equipment and pacemakers can either malfunction or behave unexpectedly due to radiofrequency interference (RFI) which is fundamental to smart grids. Also, RFI originated from surroundings did cause the automatic ignition switches in automobiles to not start up unless the automobile is situated in a location of very low RF signals. Thus, the cumulative effects of RF and the effects of RFI can be worrying to the customers’ health in general. Hence, a threshold limit need to be fixed and deduce whether that limit has been exceeded or not.

FCC standards takes into account the entire human body exposure in terms of radiation limits instead of each different types of organs of the body. Human brain cells absorb energy in a different rate and concentration compared to other organs. Besides that, the FCC standards specified that the exposure threshold is an average value in a time span of about 30 minutes. However, smart meters emit peak pulses for about less than a second which does not match the FCC regulatory standards as the duration of exposure is totally different and thus yields different effects. Radiation emitted from antennas of appliances has a power density value of 0.18W at 4.5 seconds per hour but outdoor smart meters emit 1W at less than two minutes per hour. (Richard Tell, 2008).

According to Richard Tell, those values seems insignificant but taking into consideration of other various appliances in the neighbourhood at that particular moment, the peak pulses total energy can be about 20 times or higher. Nevertheless, he stated that radiation emitted from smart meters is 15,000 times less than FCC standards threshold limit. On the other hand, engineers like Stephen Scott of EMF Services of California obtained measurements of peak pulses every few seconds. Utility companies will not reveal the exact number of peak pulses but an estimation done by Southern California Edison obtained a reading of 229,000 mW/cm^2 at eight inches from transmitter. That translates into high intensity UHF signals which are in the form of peak pulses few times a minute.

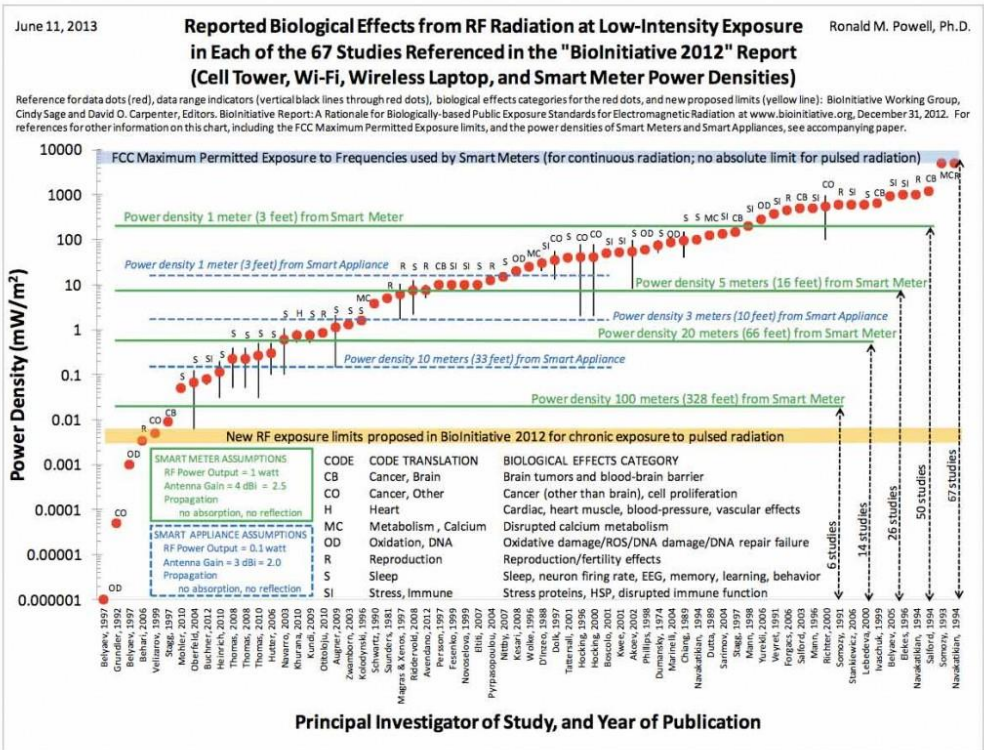

Figure 2.3: Effects from RF Radiation at low intensity exposure

Based on Figure 2.3, it shows different RF exposure levels from a total of 67 studies whereby biological effects on human beings were significant. Furthermore, various information can be derived from the figure above. Among them is that the FCC maximum exposure limit is set at a high level so much so it offers no protection towards human from the biological effects found in all 67 studies conducted. Hence, a new maximum limit has been proposed which stands at 1 million times lower than the FCC maximum limit which will reduce nearly all of the biological effects obtained. Moreover, it is found that one household smart meter could emit RF radiation which directly cause those biological effects in nearly all of the studies conducted though it depends on the distance of the human from the smart meter.

Also, up to eight neighbours equipped with smart meters installed can cause the total amount of exposure to be multiplied when measured in one of the residential homes. Interestingly, those biological effects which includes DNA damage and infertility cannot be detected by humans. Luckily, there are some effects which can be detected which includes sleep, learning, behaviour and memory related issues. Furthermore, young children and those unborn foetuses are more prone towards the side effects of RF radiation compared to adults. The American Academy of Paediatrics (AAP) issued a statement which states that young children can absorb huge amounts of RF waves into their brains compared to adults. (Ronald M. Powell, 2013).

On 1st June 2010, there were 1500 non health related complaints and also 2000 health related complaints reported to the California Public Utilities Commission. Customers residing in California does not fully agree with the concept of smart grid. They used various techniques like signing petitions, organize forums and so on to show their disapproval. They also demanded that PG&E will approve the usage of existing meters or those meters must be physically connected to phone cables in order to prevent RF transmission. So far, many resolutions have been approved in order to ban smart meters to be implemented in households. Other countries should emulate the persistence and the approach executed by the residents of California.

Also in the same year 2010, a state assemblyman convinced the California Council on Science and Technology (CCST) in order to perform a review of the impact of smart grid towards human health side effects. The next year, CCST concluded that there were no harmful side effects found affecting human health. However, the people residing in California were dissatisfied with the findings. Other experts on this field stated that CCST's findings are not backed by evidence shown and that the experts' suggestions or recommendations were brushed one side. State hearings were held and the outcome was to halt the implementation of smart meters until health and safety issues were reviewed and analysed in further details. The latest finding was that smart meters are not Underwriters Laboratory (UL) certified.

In Germany, their Environment Ministry warned their citizens not to adopt wireless technology and instead utilize wired technology for communication purposes. Wireless routers installed in the French main national library were removed after staffs fell ill. Also the EEA is actively seeking ways in order to decrease radiation exposure due to wireless routers, mobile phones and other types of antennas. The European Parliament even displayed maps of RF-contaminated zones in the country so that the citizens could avoid these places. This step is not necessary if RF radiation has little significant impact on our general health. Moreover, Sweden categorized certain areas and beaches to be RF-free zones so that certain people could take a break in those zones as they are more sensitive to RF radiation.

2.4 Environmental Impact of Smart Grid

2.4.1 Areas of investigation

Among the areas of investigation under environmental impact includes demand response, demand side management (DSM), the increase of electric vehicle and renewable energy integration plus infrastructure efficiency and energy delivery.

2.4.2 Demand Response

Federal Energy Regulatory Commission (FERC) states that demand response can be defined as variations of electrical usage by the end users from the usual energy consumption trends in response to variations of electricity pricing. (FERC, 2010). In simpler terms, demand response is the initiative of the utility company to control load trends. They could achieve this by offering monetary compensation to end users and encourage the electricity consumption during off-peak hours. Utility company has the capability of sending request which could trigger the control systems in order to decrease energy consumption by means of either switching off air conditioning systems, water heater or other equipment.

Furthermore, demand response can regulate certain equipment's power demand in order to reduce the frequency of congestion or over usage condition. On the other hand, the charging of electric vehicles when connected to the smart grid will determine the impact on the grid. Thus, demand response can be used in that situation to regulate the demand load of electric vehicles too. Another point of view is that demand response could be used as a contingency method when deemed necessary by the utility company at their own jurisdiction. End users have been accustomed to reduce energy consumption during peak hours which normally are about few hours during the afternoon. This has been shown in many trails and studies of demand response. (FERC, 2009).

Smart grid technologies especially smart charging electric vehicle device does display electricity pricing and could even alter the end users' energy consumption trends accordingly. Until present years, demand response has been used on water heaters and air conditioners. If demand response is used as a contingency method as stated above, it does mean that the process of demand response actually shifts the energy consumption period. For example, the dimming of lights could yield significant energy savings due to the decrease in total kWh. As intensity of lighting decreases, the energy consumption decreases proportionally. Hence, energy generation decreases and there will be less greenhouse gas emissions as stated above.

Demand response when applied to load regulation will yield less emissions due to the energy generation and load is more accurately matched in terms of minutes. (ORNL, 2000). Hence, demand response does provide positive environmental impact. The norm is that demand response is used by utility providers to reduce peak load demand when necessary. However, this also causes end users to be aware of their energy consumption total usage indirectly. (PNNL, 2010). Thus, indirect relationships could be derived by linking energy consumption reductions, energy consumption shifting plus environmental and energy consumption awareness.

2.4.3 Demand Response in terms of smart grid

However, the potential of smart grid is not utilized to its fullest yet. Two way communications and autonomous decision software should be used in order to fully utilize the concept of the smart grid. Advanced metering infrastructure (AMI) can regulate both the generation and the load sides which contributes to a more complex system of dispatch curves. Moreover, AMI technology allows renewable energy sources to be connected to the grid and thus reducing the usage of carbon related energy generation sources in order to generate power to fuel electric vehicles for example. This concept can be used for other types of devices that when regulated can reduce emissions while at the same time generates energy to the grid too.

By conducting more demand response programs, peak demand growth rate will significantly decrease to 0.83% per year. Furthermore, if the programs are conducted in an ideal environment or conditions, the peak demand rate will further decrease to about 0.53% per year. The Brattle Group had already listed four possible conditions which may arise in a dynamic pricing environment. (Hledik, 2009). Two of them are partial participation and full participation. The best and the ideal condition among the four is full participation due to dynamic pricing is quite high. Also, the effectiveness of the pricing will determine whether supply and demand are equally balanced. However, there are challenges to the pricing which are in terms of technological, economic and regulatory.

In terms of regulatory, those regulators can impose electricity surcharges in order to decrease overall peak demand. However, in this current era, utility companies and their relationship with regulators will cause the actual monetary values in dynamic pricing to be not publicly known to the end users. EPRI does highlight plausible monetary savings from demand response and energy efficiency which ranges from economic potential to technical potential. Based on Table 2.1, the capability to reduce peak demand in the USA is shown below which also highlights the combination of demand response and energy efficiency. These predicted savings values are possible when customers voluntarily participate in demand response activities. Furthermore, more new standards created will cause higher amounts of savings and lesser overall peak demand.

Table 2.1: Peak Demand Savings in terms of Gigawatts originating from Demand Response and Energy Efficiency Activities

	2010	2020	2030
Technical Potential			
Energy Efficiency	67	222	304
Demand Response	170	163	175
Total	237	385	479
Maximum Achievable Potential			
Energy Efficiency	11	82	117
Demand Response	30	66	101
Total	41	148	218
Realistic Achievable Potential			
Energy Efficiency	2	35	78
Demand Response	17	44	78
Total	18	79	157

According to The Brattle Group's article, its primary priority is regarding public policies instead of technical aspects. Besides that, it emphasizes the relationship between smart grid and the environmental benefits. Much later, there is another study conducted in order to justify reduction of peak demand from demand response programs due to its classification under reduction methods and not dynamic pricing. (Pratt et al., 2010). Also, customers are conserving energy consumption due to awareness of usage via AMI devices. Thus, due to that a 3% decrease in terms of electrical usage has been recorded as shown in Table 2.2. Moreover, this study conducted by PNNL considers demand response as load shifting where about 10% of load is shifted away from peak periods. Thus, smart grid does facilitate load shifting via AMI and hence overall grid efficiency increases.

Table 2.2: Direct and indirect reduction of energy consumption due to smart grid

Mechanism	Reductions in Electricity Sector Energy and CO2 Emissions*	
	Direct (%)	Indirect (%)
Conservation Effect of Consumer Information and Feedback Systems	3	-
Joint Marketing of Energy Efficiency and Demand-Response Programs	-	0
Key Enabling Technology: Disaggregation of Total Loads into End Uses	-	-
Deployment of Diagnostics in Residential and Small/Medium Commercial Buildings	3	-
Measurement & Verification (M&V) for Energy Efficiency Programs	1	0.5
Shifting Load to More Efficient Generation	<0.1	-
Support Additional Electric Vehicles and Plug-In Hybrid Electric Vehicles	3	-
Conservation Voltage Reduction and Advanced Voltage Control	2	-
Support Penetration of Renewable Wind and Solar Generation (25 percent renewable portfolio standard [RPS])	<0.1	5
Total Reductions	**12**	**6**
*Assumes 100 percent penetration of the smart grid technologies.		

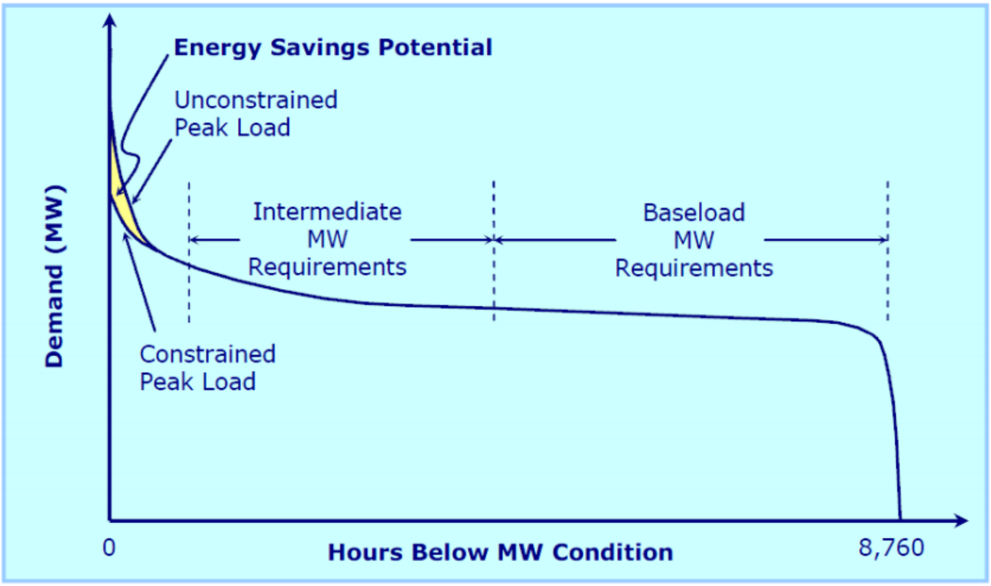

Figure 2.4: Potential energy savings from demand response activity

Based on Figure 2.4, EPRI's estimated energy savings originating from a demand response activity is illustrated. A rough calculation of about 0.08% of electricity retail sales of every industry originates from the reduction due to demand response. Findings from different sources above varies with one another due to different methods used for calculation in order to obtain an estimate in terms of how much can the load demand decrease.

2.4.4 Demand Side Management

DSM is executed in order to guide end users to change their trends in terms of energy consumption by programs or activities conducted by the utility company. DSM which includes load management and energy conservation methods is actually a superset of demand response whereby it incorporates energy efficiency techniques which are not authorized by the government. (FERC, 2010). Also, DSM is different compared to demand response in the context of the utility company regulates load demand by regulating generation of energy. Moreover, DSM is targeted on the behaviour of end users where they can decrease consumption based on real time information or applying automation based on usage patterns like programing smart appliances to switch on based on user defined settings.

DSM now incorporates automated response and dynamic pricing with the creation of smart grid technologies. When smart grid technologies are combined with smart appliances, the energy demand will be determined by both utility company and the end user's intention. For example, a particular appliance can be pre-set to switch on at low power output when energy cost during that period is high and vice versa. Thus, DSM which based mainly on the end user's intention share certain similarities with the demand response which based mainly on the utility company intention. Hence, when overall energy consumption decreases during peak periods, the emissions released decreases. This alone contributes to 3% energy reduction in terms of consumption due to AMI. (PNNL, 2010).

DSM promotes energy efficiency but not on energy conservation. (FERC, 2009). Another report classifies DSM as load shaping by utilizing energy efficiency and load management. (World Bank Report, 2005). Also, DSM can be simplified into a term where it is a combination of demand response with energy efficiency. There are challenges in terms of economic, technological and regulatory associated with cultivating the concept of DSM on the consumers' side. (National Assessment of Demand Response Potential, 2009). By utilizing AMI, the technological challenge is resolved. Also, in terms of economic challenge, end users do not receive much incentives in order to fully cultivate the concept of DSM.

However, utility companies operate by making profit from selling generated electricity to end users. Thus, in terms of their point of view, they will support demand response as this will enable them to reduce fuel cost at the generation side due to the reduction of peak demand of the loads. They are unlikely to support DSM as the term of energy efficiency translates into reduction of electricity consumption which will jeopardise the utility company's profit. On the other hand, end users are encouraged to follow the dynamic pricing but in certain situations, the pricing itself increased some of the end users' bill to a high figure causing negative perception which in turn will trigger regulators to protest or stop the concept of dynamic pricing eventually. (Bakersfield Effect, 2010).

2.4.5 DSM and Demand Response in terms of Smart Grid

According to a study conducted, the control mechanism and communication technology of smart grid are able to reduce transmission and distribution losses in power lines, channel feedback information to end users, provide reliable and efficient demand response with load management, improve measurements and verification ability plus the ability to constantly commission buildings. Those mentioned will be able to yield better energy savings and thus reduce emission levels. (EPRI, 2008). On the other hand, the implementation of smart grid can decrease energy consumption from 56 to 203 billion kWh in the year 2030 based on EPRI findings. EPRI takes into consideration the potential of having more renewable generation sources plus electric vehicles compared to PNNL findings.

Nevertheless, both PNNL and EPRI agree that the presence of renewable sources and electric vehicles will reduce emissions from the combustion engines of conventional vehicles. Furthermore, EPRI predicted that after taking into consideration of all the seven smart grid mechanisms, about 60 to 211 million metric tons of carbon dioxide can be avoided in the year 2030.

2.4.6 Negative environmental impacts of Smart Grid

Both EPA and US Fish and Wildlife Service (FWS) has insufficient grant or funds and officials in order to evaluate the impact of RF radiation towards the environment including wildlife. Furthermore, there are some environmentalist which are supporting smart grid implementation. They are unaware of the significant relationship between smart grid and the environmental impact it produces. Also, there are certain terms which excludes smart grids from National Environmental Policy Act. Ultimately, majority of smart meters nowadays are not backwards compatible meaning additional high end equipment must be bought to allow the energy generated by renewable energy to be sold back to the grid.

2.5 Security Impact of Smart Grid

2.5.1 Aspects of Security Impact

Among the aspects include security requirements, usual types of security attacks and preventive measures plus management. The first factor is security requirements where US National Institute of Standards and Technology (NIST) suggested three major security requirements which includes integrity, confidentiality and availability. (Guidelines for Smart Grid Cyber Security, 2010). Availability of this aspect will guarantee access towards information relating to cyber systems like SCADA, distribution management system, control centres and communication networks to only validated users. Also, a denial of service attack (DoS) will yield losses in terms of economic and also cause security issues where the capability of monitoring and control of the systems are taken away from them by unscrupulous parties. Hence, this security requirement proves to be the most important aspect of security impact.

Integrity is upheld by preventing modification of vital information such as values of sensors or commands used for control purposes by unauthorized personnel or software. This is crucial in order to avoid false positive responses which leads to safety problems due to the misleading outcomes caused by unintended modification of information. An example is an operator executes an unnecessary response due to the unauthorized modification of data. Confidentiality is regarding the prevention of private information from landing into the hands of unauthorized people. Those confidential information includes customer's information, electrical data and utility company's information. Nowadays, customer's information is accessible over the internet thus making confidentiality of vital importance.

Second aspect is the usual security attacks. DoS targets the nodes of the smart grid and this type of attack will either corrupt or block the exchange or generation of information signals. This attack method can cause the availability to decrease. Smart grids run on IP protocols where TCP/IP could be subjected to DoS attacks. Hence, preventive measures must be created as soon as possible in order to prevent unwanted incidents. Besides that, malicious software like malware also can cause the three major security requirements to be compromised. Moreover, certain malwares can be embedded into existing programs and remain dormant until when needed to create a security attack in the near future.

Other usual security attacks include identity spoofing. This is accomplished without the knowledge of the actual user's password by disguising as the rightful owner and thus logging into the system with the rightful owner's credentials. Moreover, password pilfering is regarding the attempt to match the exact passwords used. This attack can be executed by pure guessing, dictionary brute force attack, password sniffing and many more. A more sophisticated type is known as eavesdropping. This type of attack is done by sniffing the IP packets on the local area network (LAN) of the smart grid. (D. Dzung et al., 2005). Intrusion is another well-known method whereby an unauthorized user successfully accessed a system and could gain control of the system to compromise integrity and confidentiality. There are some tools in order to execute intrusion attacks and they include port scans or IP scans. (Jie Wang, 2009).

Lastly, there is an exploitive type of attack known as side-channel attacks. This method exploits certain types of information from the cryptosystem in order to deduce the cryptographic key. (S. Ravi et al., 2007). Examples of this particular type of attack are power analysis attacks (E. A. Dabbish et al., 2002), timing attacks (P. Kocher, 1996) and electromagnetic analysis attacks (K. Gandolfi et al., 2001). Equipment of the smart grid entire system which are like the smart meters and substations are easy targets which could be compromised in terms of end users' privacy, account information and passwords plus even the administrative access of the entire system. (Guidelines for Smart Grid Cyber Security, 2010).

Therefore, preventive measures and management are needed urgently as smart grid implementation are more widespread and acceptable by many countries worldwide. The International Electro-Technical Council (IEC) had proposed a number of suitable measures. In terms of technical solutions, there are encryptions, virtual private network, firewall, access control, antivirus, detection systems and certain standards like IEC 62351 plus many more. On the other hand, in terms of management, there are solutions which include risk assessment, key management, post recovery, security policies, vulnerability reports and many more. (F. Cleveland, 2005).

2.5.2 Assessments of important areas of cyber security

Risk assessment normally is initiated by a vulnerability test for a period of the next three years. For example, Chen-Ching Liu et al. have used attack trees and Petri nets to evaluate the aspect of vulnerability in terms of SCADA systems. They then created software like PENET in order to counter the vulnerabilities. (Srdjan Pudar et al., 2009). Nevertheless, this poses a tough challenge due to the interrelationship between power system and security networks plus experimental data are lacking. Also, there are models and simulations techniques available in order to test interaction and dependencies of vital infrastructures. (B. Rozel et al., 2008). The preferred method is bottom-up modelling technique.

A technique to obtain experimental data is to create a simulation which could simulate real life conditions like the US Idaho National Lab SCADA test bed. (W.Dong et al., 2010). Also, European 6th Framework Program (FP6) project called Critical Utility Infrastructure Resilience (CRUTIAL) created a micro grid test bed in order to obtain data statistics and simulate cyber attacks. (G. Dondossola et al., 2009). Moreover, the University of Arizona has a test bed in order to evaluate the security of SCADA control systems. (M. Mallouhi et al., 2011). Other parties thought of exploiting the power grid network simulator based on software or API methods using simulation software like MATLAB and OpenDSS. (T. Godfrey et al., 2010).

Lately, various bodies placed cyber security as an important factor in smart grid related issues like the NERC-CIP and IEEE. Thus, many types of standards, requirements and guidelines have been formalized. Examples include IEC 62357 and IEC 62351 plus many more. The NERC-CIP standards touches on security protection of the most important electrical transmission and generation parts or areas. (NERC CIP Cyber Security Standards, 2011). NERC is combining efforts with DOE and NIST in order to create a cyber security risk management guideline for the whole grid. (2012 NERC Business Plan and Budget, 2012).

2.5.3 Initial studies on the effects of cyber attack

Initial predictions and findings states that cyber-attacks will yield many negative impacts of the smart grid. Based on a graph-based modelling system, impact study can be executed. (D. Kundur et al., 18). Thus, a simulated model was created using MATLAB which highlights the violation of data integrity on load management as shown in Figure 2.5. Based on the model, breaker B3 and B2 can disconnect the load at any given point in time as long as a single or combination of load demand triumphs over the generation capacity as this will prevent system instability. Furthermore, every sensor signals are directed at the control centre. Thus, cyber-attack will compromise those sensor signals and therefore, the whole system is left open to cyber-attacks.

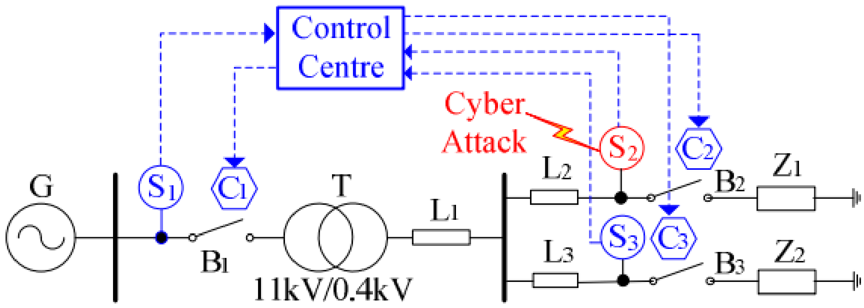

Figure 2.5: Diagram of a power system when cyber attack occurs

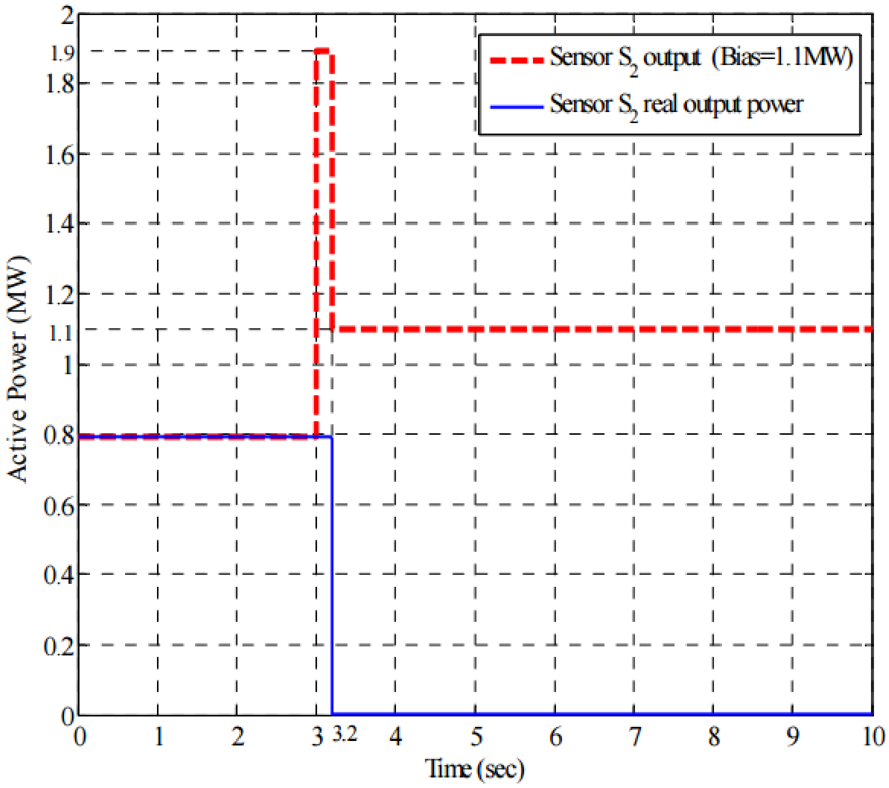

Figure 2.6: Sensor S2 output power

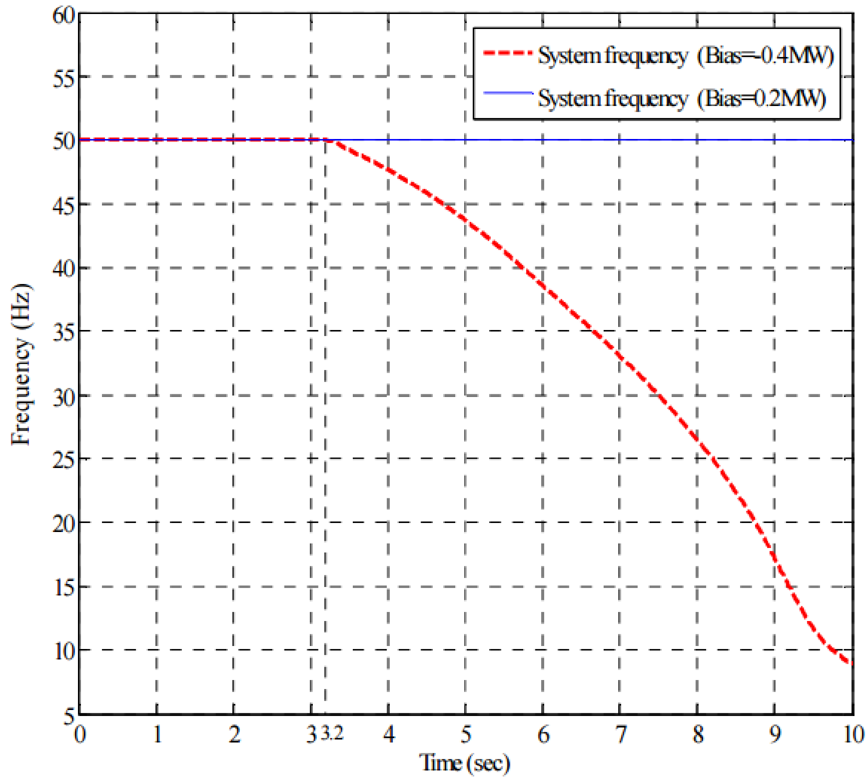

Figure 2.7: Frequencies of the system

Based on the graphs above, an equation can be formed which is shown below. At 3 seconds, a cyber-attack is launched on the S2 sensor and a bias is added onto the total active power. Hence, the load in the control centre has been slowed down by 0.2 seconds. Figure 2.6 shows the active power output of S2. The initial 3 seconds, a load is being supplied. $\S_2$ = 1.1MW in terms of bias represents a cyber-attack which causes the S_2 value to increase way above the generator capacity. The control centre transmits signals to C1 and C3 to disconnect so that B3 remains connected but B2 is disconnected. Hence, it is obvious that a bias will cause load shedding to be inaccurate.

$$S_2(t) = P_2(t) + \S_2(t) \tag{2.1}$$

where

S_2 = Sensor information under cyber-attack

P_2 = Actual power of S2

$\S_2$ = Representation of a cyber-attack in terms of bias

By referring to Figure 2.6, a bias of 0.4MW is applied to the same sensor at 3 seconds. Thus, when the modified output of S_2 is sent to the control centre, the system will decide incorrectly by commanding the C_3 to be connected so that both load outputs Z_1 and Z_2 can be transmitted. In that particular situation, the generator will be overloaded. Also, based on Figure 2.7, the frequency of the system decreases steadily after the 0.2 seconds delay. On a side note, the generator will trip in a matter of time if the frequency drops lower than a threshold value which when it occurs eventually, it will affect the reliability of the power generated. Nevertheless, there is a situation where cyber-attack yields a positive impact on power transmission. If the bias of 0.2MW at the same sensor is generated, the system frequency remains constant throughout and thus the control centre does not decide incorrectly unlike those situations above.

2.5.4 Negative sides of security impact

During the month of August of 2009, about 179,000 Toronto Hydro customers' private information were hacked. Moreover, a security consultant demonstrated the ease of installing malicious software in the form of worms which can gain control access of the smart grid. Those worms could be created in order to tamper with billing, collect information on energy consumption and trigger power outages to residential homes. Besides that, according to Ross Anderson and Shailendra Fuloria at Cambridge University, certain unscrupulous parties or terrorists can cripple the entire country just by disrupting power generation. On the other hand, by using simplified jamming devices, the entire smart grid can be disrupted.

Once confidentiality has been compromised, then that unauthorized person can infer that if there are no or very low energy consumption, there is no one in the house. Furthermore, utility companies can remotely switch on and off appliances in the house. On a different note, some end users' electricity bills who are residing in California rose three folds from USD 200 to USD 600 in one month. Those affected customers filed a lawsuit against Pacific Gas & Electric (PG&E). Finally, that utility company partially agreed that about 23,000 of their smart meters could be defective. Also, there are some smart meters which explode and cause fire. There are 422 related cases of fires in the year 2010 in New Zealand.

It is clear that PG&E lack technical knowledge as shown in a public forum. Besides that, other questions regarding exposure levels and smart meters' specifications are not given to the audience where majority are home owners. Hence, if this company were to implement smart meters in their region in a large scale, that will prove to be worrying to the general public and end users especially. On a side note, lawyers vote against a bill which wanted smart meters to be compulsory for all residential owners in the Netherlands in the year 2006. United Kingdom government is revaluating issues regarding smart meters and also whether to implement smart metering system or not.

CHAPTER 3

METHODOLOGY

3.1 Data collection from web sources

Initially, various different sources from the internet are gathered and scrutinized. Then, only those relevant and plausible impacts or effects of smart grid are selected and then summarized. About six major impacts are identified. Finally, three major impacts which have some sort of relationship between one another were selected for data analysis and comparison in this project. Also, both positive and negative impacts are highlighted where data analysis will prove whether which side of the impacts are more significant than the other. Then, a relationship will be established in order to see the outcome whether any of the two impacts can be correlated with one another.

3.1.1 Publicly available data on websites

Actual data are publicly available to anyone who wants to use them for educational or research purposes. Among the types of available data includes electricity consumption intervals, customer household and peak events and its customers' response plus rebates received for those peaks. Thus, after further scrutinizing, only relevant information from those above will be selected in order to obtain comparison or relationship between those data. The selection of data will be listed in the results and discussion section. This section applies more for the environmental impact whereby the data obtained must be fairly compared and modified in order to obtain a justified basis of comparison. Thus, similar time period and the total amount of energy generated need to be divided or scaled down with consideration for the unit of measurement used for the same city at the given time frame.

3.2 TNB pilot project in Bandar Ayer Keroh, Melaka

3.2.1 RF waves data collection

In order to further investigate the impact of RF radiation on human's general health due to smart meters, a RF meter will be used in order to collect readings from actual smart meters installed in the pilot project located at Bandar Ayer Keroh, Melaka. Besides that, another application in the form of Android application will be used as a comparison with the RF meter readings when recording all the values. The Android application is a freeware and is called Ultimate EMF detector. It uses the mobile phone's magnetic sensor to obtain measurement of the magnetic field on three axis. These values are then combined in order to create the magnetic field final value. In order to standardize the values obtained, the magnetic field will be measured in terms of micro Telsa (uT). Usually, normal readings of magnetic field will range from 30 until 60 uT which is also the range of our Earth's magnetic field.

However, any metal or magnets and certain types of wires will affect the magnetic field readings. Thus, this precautionary step will be always checked first before obtaining readings from both the application and meter. Furthermore, various locations will be used in order to obtain a fair comparison of the strength of RF waves present in various locations and devices. Among the locations include a residential house, cell phone substation and the location where smart meters are installed at. Besides that, readings will also be taken when the application and meter reader is placed next or as near as possible to various devices or equipment like wireless router, microwave oven, air conditioning, refrigerator, computer, monitors, DECT phones and others if possible.

In terms of RF meter, a multi field electromagnetic field (EMF) meter bearing the model number TM-195 will be used in this project. This meter is manufactured by Tenmars Electronics Co. Ltd. Located in Taipei, Taiwan. It can also be used to measure RF waves because RF waves falls in the range from 100 kHz until 300 GHz. Furthermore, this meter has a resolution of 0.001 $\mu W / m^2$ and its frequency ranges from 50 MHz to 3.5 GHz. Smart meters from PG&E operate in the range of about 900 MHz range which it falls in the frequency resolution of this multi field EMF tester.

Moreover, this meter has the capability to indicate the intensity of RF waves where the indicator represents either ‘Good’, ‘Normal’ or ‘Warning’. Also, this meter has high accuracy where it translates into +_ 2db accuracy.

3.2.2 RF waves data analysis

The data collected from both meter and application are tabulated in terms of various devices and appliances from different locations. These values will be arranged in ascending order in terms of $\mu W / cm^2$ and then they will be converted into W / m^2. Then, they will be compared against various standards of RF maximum permissible exposure limits from different bodies especially FCC and Bio Initiative 2012. Also, a summary will be obtained together with the data analysis as how close the values are to the limits or whether they exceed those limits. Furthermore, the difference between time-averaging RF values and pulsed RF values will be compared too as smart meters emit pulsed RF waves. Also, there are many other external factors when taking into consideration the strength of pulsed RF waves.

Distance from smart meters, different meter models, the surrounding environment, position in terms of altitude and the type of data transmitted can ultimately determine the actual intensity of RF waves and whether it is close to the maximum limits imposed by FCC. Moreover, smart meters are unpredictable as the frequency of RF transmission for each meter varies and does not follow any patterns. PG&E in their internal document only states the median value of about 10,000 pulses a day and lack of transparency on the actual method of operation of smart meters leads end users being sceptic. Nevertheless, with many uncertainties and lack of disclosure of information, the possibility of pulsed RF waves by smart meters which triggers a significant biological effect on humans compared to constant RF radiation by other devices remains highly plausible as concluded too in some researches.

Table 3.1: FCC maximum permissible exposure limits in terms of controlled and uncontrolled exposure.

Controlled Exposure (6-Minute Average)				*Uncontrolled Exposure (30-Minute Average)*		
Frequency Range (MHz)	*Electric Field Strength (V/m)*	*Magnetic Field Strength (A/m)*	*Power Density (mW/cm^2)*	*Electric Field Strength (V/m)*	*Magnetic Field Strength (A/m)*	*Power Density (mW/cm^2)*
0.3-3.0	614	1.63	(100)*			
3.0-30	1842/f	4.89/f	$(900/f^2)$*			
0.3-1.34				614	1.63	(100)*
1.34-30				824/f	2.19/f	$(180/f^2)$*
30-300	61.4	0.163	1.0	27.5	0.073	0.2
300-1500	--	--	f/300	--	--	f/1500
1,500-100,000	--	--	5	--	--	1.0
f = frequency, in MHz.						
* = Plane-wave equivalent power. (This means the equivalent far-field strength that would have the E- or H-field component calculated or measured. It does not apply well in the near field of an antenna.)						
-- = Not specified.						

3.3 Ionizing radiation data collection and analysis

In terms of ionizing radiation, a Geiger Muller (GM) Counter is used for this project. The model purchased is named GMC-320 Plus. This device is manufactured by GQ Electronics LLC. This portable GM counter has audible sound when certain level of radiations is detected. Furthermore, if more precise data logging is required, each second intervals could be derived from its internal memory. Also, these data logging can be connected to a computer and together with its software, the data can be plotted in terms of graphical shape and that is useful for data analysis. This device can detect beta, gamma and X-rays radiation. These rays are only detectable if they are within 0.1 to 3.0 MeV. Another plus point of this device is that it can be powered using car cigarette charger, USB charger, wall adapter or its own inbuilt battery.

A basic guide was issued by the manufacturer of this device whereby within a certain range of counts per minute (CPM), thus it can be declared safe or otherwise. Moreover, a reading of between 20 to 40 CPM indicates background radiation while 50 to 83 CPM indicates radiation similar to a granite table top. Its GM tube used is named M4011 and its tube can be interchanged with another model provided it can fit inside the GM counter. This is an advantage whereby if the user wants a more sensitive GM tube, the user can purchase another tube which could measure alpha radiation too. Besides that, the units used by this device is either uSv/h, mR/h or CPM. However, since the guide provided by the manufacturer is stated in terms of CPM, thus CPM will be used for this project in order to standardize the unit of comparison.

Hence, similar to the procedures above for RF radiation, the CPM recorded will be averaged out and then compared to the radiation safety guide provided by the manufacturer in order to determine if smart meters emit radiation exceeding the 'normal' category or not. Also, the levels of radiation detected will be then analysed further and justified. Furthermore, this can be used to determine the magnitude of background radiation at the location of recording. Trends and pattern of data obtained will be scrutinized and compared with the trends of data from the RF radiation too in order to observe any similarities between two different types of radiation. It is a fact that smart meters do not emit ionizing radiation but this could be used to determine the background radiation and it should fall within the normal category of ionizing radiation.

3.4 Official Data Request via email for data sharing purposes

3.4.1 Official Request for Data Sampling and collection

An official request of information in terms of data sampling and data collection has been directed in the form of email to relevant personnel in TNB Sdn. Bhd. Approval is needed by the principal researcher of smart grid department, Dr. Mohd. Fadzil Mohd. Siam. Once approval is accepted, then their engineer in charge of smart grid named Mr. Shashiteran will release those specified data listed in the email and they could be used in this research project for further comparison and analysis. As approval by the principle researcher is pending, six specific data have been highlighted in the email which will display or proof the following aspects which includes energy savings in terms of financial and energy generation, web portal regarding the real time energy information plus savings obtained by end users, demand response, AMI, dynamic pricing, load shifting, DSM and security aspect.

If approval is obtained for either partial or full data sharing based on the six aspects mentioned above, they will be included in this report and cited accordingly in the reference section. Those data also can be compared to international countries in order to observe any similarities or differences between them. Then, data analysis will be executed and relationship will be deduced for each six aspects above. On the other hand, similar approach is applied to other companies or bodies which include Masers Energy Inc., Universiti Tenaga Nasional (UNITEN) and Cyient Ltd. However, Masers Energy and Cyient Ltd. did not reply in the form of email or telephone call up till the time of writing.

A lecturer from UNITEN named Prof. Dr. Ong Hang See which is in charge of a smart grid test bed in that university did reply to my email. However, there are terms and conditions which will be imposed before data sharing is allowed. Among them is a collaboration between both universities and a non-disclosure agreement need to be signed by both deans of both parties. Furthermore, the lecturer also stated that in order to obtain data from TNB Sdn. Bhd., it will be a challenge to do so. Thus, indirectly he meant that the chances of approval from the principal researcher is quite slim. Nevertheless, I will follow up with the principal researcher in order to obtain at least one or some of the six aspects mentioned in my email. However, due to many various terms and conditions imposed, therefore little useful data was obtained from one of their engineers of our major utility company.

3.5 Data Request from smart grid TNB customers

3.5.1 Door to door request for smart meter data sharing

A trip to Bandar Ayer Keroh, Melaka where door to door request will be performed in order to obtain customer consent for citing their energy consumption and cost in the form of graphical plot or statistical data. Their identity and location will be kept anonymous for this research purposes. Also, according to TNB Melaka branch general manager, Datuk Baderul Sham Saad, he mentioned that by referring to the customers' web portal online, they could also monitor the environmental impact too. (TNB Consumers in Melaka to Get Smart Meters by the end of 2016, 2016). That proves to be useful information where customer impact and environmental impact can be interrelated just by viewing real time data on TNB smart meter web portal.

Moreover, the second and third areas of customer impact can be further analysed. This is achieved by creating a questionnaire or conducting a survey in order to evaluate customer satisfaction and customer awareness. Basic and general questions will be created and standardized in order to obtain answers from both residential customers or either commercial customers. After that, the outcomes from both survey and questionnaire will be summarized and compared in order to evaluate those two areas of customer impact in terms of locally. A scale from zero to four will be awarded for both levels of degree of satisfaction and awareness where zero represents the lowest impact and four represents the highest impact. Then, they can be compared with the outcomes of the four major continents worldwide as displayed in the literature review section where the findings will be analysed further.

However, initial take off was not as smooth as I expected. End users or residential customers of the smart grid city in Melaka were sceptical and asked me many questions as to the actual intention of this survey conducted. As majority of them will not disclose their energy consumption data due to security reasons and I do not have a valid official clearance letter from TNB Sdn. Bhd., thus majority of end users are reluctant to comply. I also understand their concerns and scepticism; thus this section has to be omitted from execution. Nonetheless, door to door data request is one of the feasible methods of obtaining data for comparison and analysis which could highlight customer impact in terms of customer satisfaction and awareness.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 RF data collection

In terms of smart meters used, there are four types of different models all from different manufacturers. After initial data recordings are collected, it is observed that three of the models can be categorized into a single category due to its almost similar RF radiation readings magnitude. However, the fourth model which is SGM 3031 made by General Electric's Sdn. Bhd. shows higher RF radiation waves compared to the other category. Hence, two categories are created under the smart meter category and will be analysed further. In terms of traditional meters, there is only one standardized type made by TNB Sdn. Bhd. throughout the entire country. Next, all RF readings obtained will be standardized according to distances.

Three different distances are selected which are 1 meter, 3 meter and 5 meter respectively. From the values obtained for each type, trends and patterns of the data can be deduced in order to obtain a reasoning behind those values obtained. A fixed time period of six minutes is applied to every single reading recorded. This is to ensure better accuracy of data obtained and for the RF magnitudes to reach the maximum average values. The final magnitude chosen for each data recording is actually the maximum averaging value during the entire six minutes. Also, this maximum averaging values only occur for a short moment during the time span but is useful to be noted in order to obtain the approximate maximum degree of side effects of RF radiation can produce to our health.

Since the values on the RF meter keeps fluctuating due to its averaging mode activated, the values during six minutes will decrease and increase without any patterns. Thus, for every increase in terms of the readings will be recorded and at the end of six minutes, the maximum value among all the peaks will be put into the table as shown above. That represents the maximum possible value of RF radiation for the entire six minutes at that distance specified. Moreover, all meters are standardized whereby they are placed on a camera tripod and the height of the tripod is set to the maximum in order for the RF meter to be as close as possible to the smart meter. When the distance shifts to three meters, the tripod is also moved to the next distance specified and so on.

The location of the site where these readings are recorded are from a row of shop lots located in Jalan TU 2, Taman Tasik Utama, 75450 Melaka. By selecting this exact row of shop lots, this experiment can be justified properly. In that same row of shop lots, there are many shops which uses different models of smart meters. Hence, two sets of readings for each model are taken in order to obtain average values to improve accuracy of data. Moreover, two sets of data are also taken during a weekend and a weekday in order to find out whether higher energy consumption leads to a more frequent RF communication between smart meters and substations. On the other hand, for traditional meter, the RF readings are obtained at my residential home which can represent any other homes in our country.

Moreover, those RF readings will also be confirmed and compared with the android application of a smart phone. The application actually measures EMF waves where RF is a part of the EMF spectrum. Hence, similar trends and patterns should be observed when comparing the readings with EMF readings. Other equipment like household items will also be used to compare with the RF readings of smart meter in order to justify the strength of RF emission from smart meters and to find out whether smart meters do really emit higher RF than other household items. Smart meters are installed on the end of distribution side. Hence, transmission side will also need to be taken into consideration.

High powered overhead lines which are 132 kV is located in Melaka. Thus, RF readings will be collected at about 5 metres distance from the base of the tower of one part of the overhead lines. There is a restricted zone along each base tower due to the nature of high voltages. Hence, due to personal safety reasons, the RF radiation will be only taken at 5 metres distance from the base tower of the overhead line. On the other hand, there is a smart substation which is part of the distribution side whereby a RF communication tower was built in the vicinity of the substation. That was confirmed by one of the TNB engineers. This RF tower sends and receives RF signal from the neighbouring smart meters. When RF readings were taken at 1 metre distance from the substation, RF readings which were recorded does match the levels of RF from the SGM 3031 smart meter thus indicating presence of RF signals.

4.2 RF readings at 1 metre distance from various sources

Table 4.1: First batch of RF radiation readings from various sources

RF radiation readings (W/m2)				
Smart Meters		Traditional Meters	Others	
SGM 3031	Sprint/MK29 /Metronix	TNB meter	Sub Station	Overhead line
1 meter	1 meter	1 meter	1 meter	1 meter
0.0025	0.00096	0.00015	0.0019	0.0001

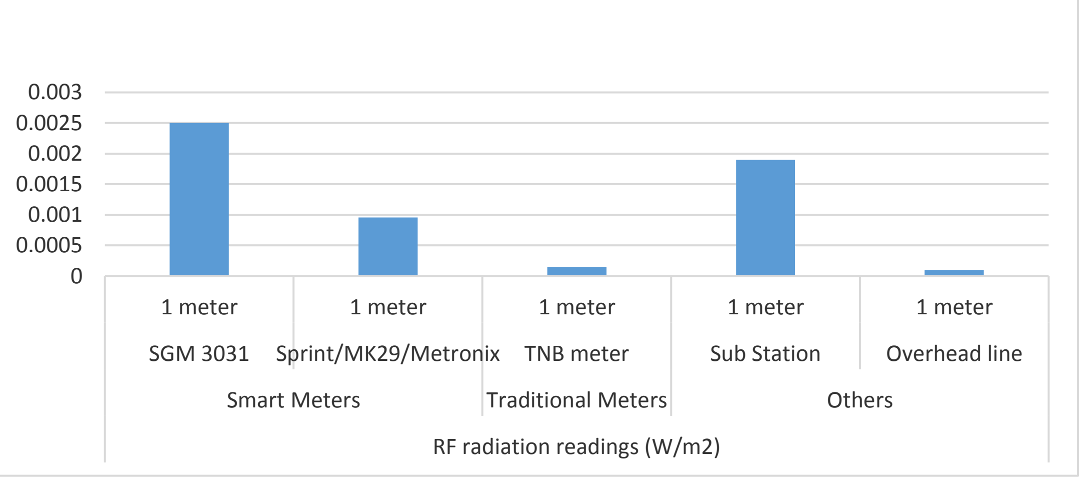

Figure 4.1: Bar chart of RF radiation readings versus types of energy meters and other various sources

Based on the table above, it is observed that SGM 3031 smart meter yields the highest averaging RF value among all other energy meters. Its peak was at 0.0025 W/m^2. Comparing that with the other three smart meters, the percentage difference is 89.02%.

Besides that, for the traditional energy meter, the RF value recorded was about 145.95% difference between the other three smart meters' value and yields 177.36% difference compared to the SGM 3031. Furthermore, for the smart substation, the RF measured was about the same magnitude as the SGM 3031 whereby the percentage difference equals to 27.27% difference only. As for the overhead line, the RF measured was close to the magnitude of the traditional meter whereby the percentage difference is exactly 40%.

Based on the RF measured, certain trends and hypothesis can be deduced. The traditional meter and the overhead line are quite close in terms of magnitude. Those two readings are relatively small compared to the RF emitting smart substation and smart meters. Thus it can be concluded that traditional meter and the overhead line either do not or emit negligible RF radiation. However, based on facts, traditional meter does not emit RF radiation as at certain intervals, meter readers will visit residential homes in order to record the power consumption and print out the energy bill on the spot for each house. Hence, there is no RF communication between traditional meters and substations. The magnitude of RF radiation from the traditional meter suggest it actually originates from background RF waves.

Hence, the background RF waves at the site can be calculated by using the average values between those two readings which yields 0.000125 W/m^2. Now, the difference between the SGM 3031's RF reading is about twice higher than other smart meters. Many possible factors could contribute to the two-fold increase of intensity of RF waves. Among possible factors are reflection of other smart meters along the vicinity, constructive interference with other RF emitting devices like wireless routers, smart phones or any others which creates a particular 'hot spot' to have elevated levels of RF compared to any other surrounding areas and also certain types of structural material of buildings can distort radiation patterns.

These RF readings were recorded on a weekend in the afternoon which is about 4pm. However, smart meters do not emit RF at fixed frequencies or intervals rather, they emit RF more at certain times and less at other times. Thus, multiple RF measurements will be recorded in order to ensure more accurate results. Exact steps and procedures are executed as above and the second batch of results are recorded on another weekday but on the same time period which is in the afternoon at about 3.30pm as shown below. The average between both batch of results will be calculated to be analysed and the differences between both batch will be compared. If the percentage differences are quite equivalent, thus the RF measurements are accurate and both batch follows the same trends and pattern of RF emission.

Table 4.2: Second batch of RF radiation readings from various sources

RF radiation readings (W/m2)				
Smart Meters		Traditional Meters	Others	
SGM 3031	Sprint/MK29 /Metronix	TNB meter	Sub Station	Overhead line
1 meter	1 meter	1 meter	1 meter	1 meter
0.071	0.0014	0.00015	0.0026	0.000079

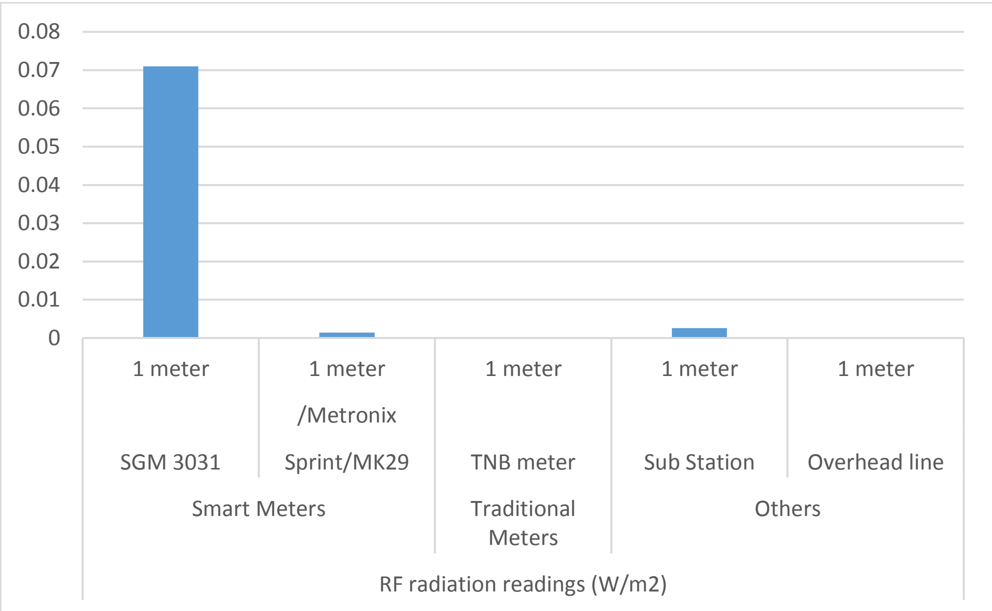

Figure 4.2: Bar chart of RF radiation readings versus types of energy meters and other various sources

After the second batch of results were recorded using the same exact steps and procedure as the first batch, the RF readings were tabulated. The maximum average RF values were once more from the SGM 3031 smart meter. However, the magnitude of RF emission recorded was much higher than the one recorded on the weekend. The percentage difference was found to be equals to 186.39%. Next, for other smart meters, the RF reading recorded was 37.29% higher than the first batch. The smart substation yields a percentage difference of 31.11% higher than the first batch. Both traditional meter and overhead line produced an average reading or known as mean of 0.000115 W/m^2 which is very close to the first batch average reading of 0.000125 W/m^2. Hence, it can be concluded that the background RF radiation at the site equals to the mean value of 0.000120 W/m^2.

Thus, a variation of results in terms of percentage difference from 31% to 37% is acceptable. However, the only outlier is the RF reading where the percentage difference is 186%. If smart meters emit more frequent RF waves based on higher energy consumption like on weekdays, then the other readings should be higher than 66.67% in terms of percentage difference but it is proven otherwise. Thus, based on the results recorded, it can be deduced that smart meters do not communicate more frequently if it is a weekday rather it emits more RF at certain times and less at other times not following any sorts of pattern or intervals. The number and frequency of RF emissions can be categorized as random and only known by the utility company or the manufacturer of the smart meter.

Based on trends, the second batch of results are similar to the first batch whereby both smart substation and the other three smart meters produce RF emission of exactly 60.00% in terms of difference. Besides that, the readings of both traditional meter and overhead line differs by 62.01%. As expected, SGM 3031 produced RF waves of 192.27% higher compared to the three smart meters and yields 199.16% more compared to background RF measured by traditional meter. Since this outlier is not based on higher energy consumption, the high surge of RF level is due to ‘hot-spot’ reason as during weekdays, there are many working adults which uses wireless devices which adds into the interference of RF waves causing a huge spike at that particular 1 metre distance from the source.

Furthermore, the RF recorded for traditional meter is 161.29% lower than the readings of the other three smart meters. As discussed earlier, RF for traditional meter will be categorized as background ambient RF value which is almost the same as the first batch that yields a mean of 0.000114 W/m^2. Therefore, it can be concluded that background RF for both batches at 1 metre distance from various sources is about 0.0001 W/m^2 while RF emitted from the RF communication tower in the smart substation is nearly double in terms of magnitude as some of the smart meter models where the percentage difference is 60%. If there is an opportunity to obtain third batch of readings, it will be included later on to further increase accuracy and to further justify the abnormally shown above.

4.3 RF readings at 3 metre distance from various sources

Table 4.3: First batch of RF radiation readings from various sources

RF radiation readings (W/m2)				
Smart Meters		Traditional Meters	Others	
SGM 3031	Sprint/MK29 /Metronix	TNB meter	Sub Station	Overhead line
3 meter	3 meter	3 meter	3 meter	3 meter
0.0014	0.00085	0.00052	Not applicable	Not applicable

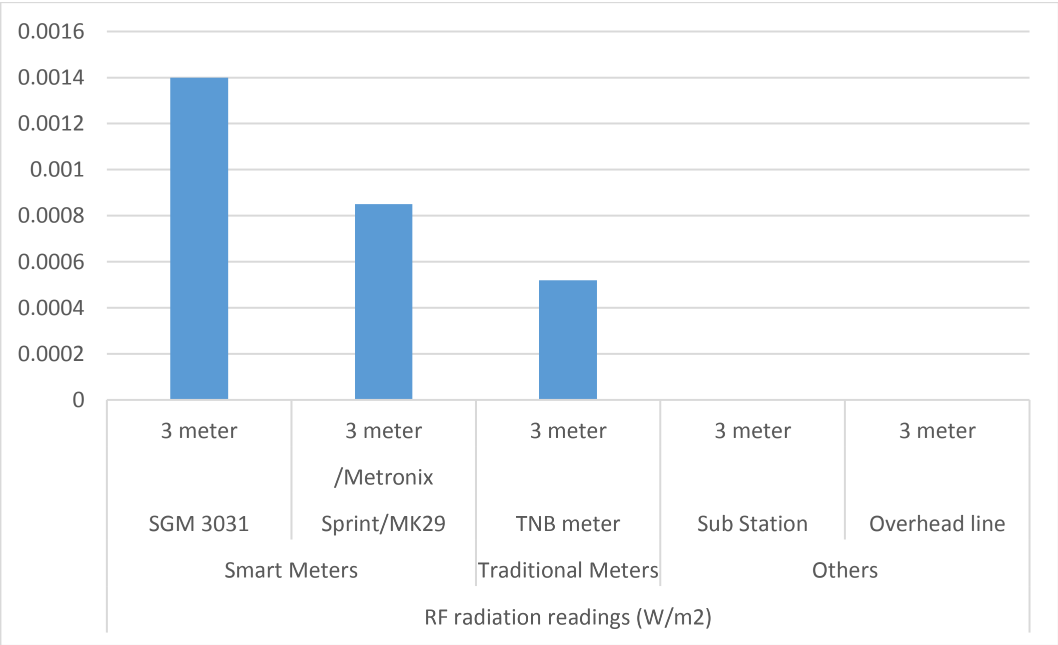

Figure 4.3: Bar chart of RF radiation readings versus types of energy meters and other various sources

At 3 meters' distance from the sources, there should be differences in terms of power density of RF waves. RF measurements were not taken for the smart substation due to the location of data sampling falls exactly in the centre of a two lane city major road. Besides that, RF readings were also not taken for the 132 kV overhead line due to danger warnings all around the base tower because of potentially lethal high voltages. Thus, although these two readings were omitted, it still can be inferred based on the results obtained for 1 metre readings from various sources. Hence, the reading of overhead line can be derived from the traditional meter reading which is 0.0005 W/m^2 averaged out and that will be used as the background RF value for this batch of readings.

The ratio between the reading of RF emitted by SGM 3031 and the other three smart meters is 48.89% difference. However, the ratio of maximum average values for SGM 3031 and the background RF magnitude is 91.67% difference while the ratio of other smart meters differs by 48.18% from the background RF magnitude. Hence, the ratio between both values during comparison are still less than 49% thus accuracy is still maintained and trends are similar. No outliers were observed. Next, these values will be compared with the readings obtained for 1-meter distance from sources in order to observe the outcome of increasing distance on the magnitude of power intensity of RF waves.

For SGM 3031, there is a decrease of 56.41% in terms of percentage difference when the distance increases by 2 metres. As for the group of three smart meters, there is only a slight decrease of 12.15% less in terms of RF waves detected at 3 metres distance. However, there is an outlier where the RF radiation recorded for traditional meter was higher at 3 metres distance from source. Based on theoretical facts, traditional meter does not have RF transmitter in the meter itself thus the spike of RF detected is not originated from the traditional meter but rather from the background or 'hot-spots' at the site. The other two readings are less than 57% in terms of percentage difference, thus trends and pattern of data matches with the readings for 1 metre distance from source and accuracy of data is still somewhat maintained.

A second batch of readings were taken for 3 metres distance from source. SGM 3031 produced 0.001680 W/m^2 while the group of smart meters yields 0.0012 W/m^2.

Thus, the average between both batch will be calculated which translates into 0.00159 W/m^2 for SGM 3031 while for the group of smart meters, an average value of 0.00103 W/m^2 is obtained. The percentage difference between those two values for SGM 3031 is 18.18% while for the group of smart meters, a percentage of 34.15% is obtained. Hence, the variation between both magnitudes are less than 35% which shows good degree of accuracy. Also, the ratio of SGM 3031 power intensity versus other smart meters produced a percentage of 33.33% which is also less than 35%.

4.4 RF readings at 5 metre distance from various sources

Table 4.4: First batch of RF radiation readings from various sources

RF radiation readings (W/m2)				
Smart Meters		Traditional Meters	Others	
SGM 3031	Sprint/MK29 /Metronix	TNB meter	Sub Station	Overhead line
5 meter	5 meter	5 meter	5 meter	5 meter
0.0015	0.00083	0.000057	0.000145	0.000083

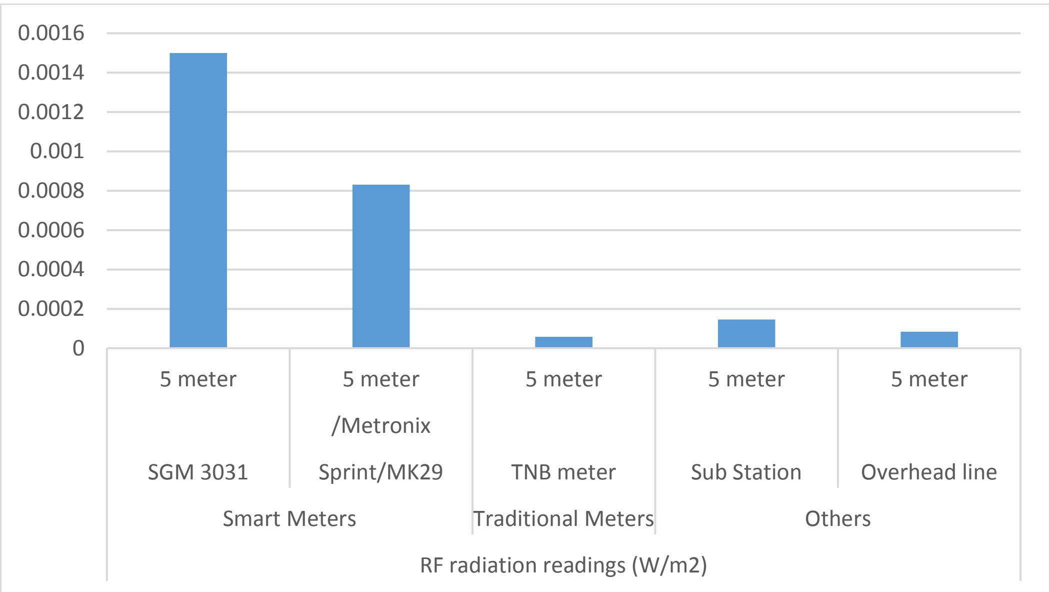

Figure 4.4: Bar chart of RF radiation readings versus types of energy meters and other various sources

As the distance between sources increases to 5 metres away, it is predicted that the RF power intensity will further reduce. Once again, the background RF for this set of data will be the average between the traditional meter and the overhead line which equals to 0.00007 W/m^2. Both readings only differ by 37.14% difference which is less than 38%. However, the smart substation yields 140.51% times less than the group of smart meters and 164.74% times less than SGM 3031. As observed from the distance of 1 metre, the percentage difference obtained was at most 38% off than either of the smart meter RF readings. Hence, in this situation the percentage difference increased to exactly 6 times less compared to the initial 1-meter distance reading. This means that the RF reading at 3 metres should be approximately three times less in terms of magnitude compared to the 1-meter distance magnitude.

In certain ways, it brings more pro than cons. RF fields decrease drastically at certain distances and based on the readings obtained, 5 metres radius from the smart substation to the nearest residential house will be the best option as RF fields drops to about ten times less than the RF from smart meters. Other unforeseen factors are the presence of underground cables originating from substations to the residential houses (How to measure EMFs from powerlines…, 2005). Directly perpendicular upwards from this cable will yield high magnitudes of EMF readings. This could constructively add up to the RF field at 1-meter distance from substation thus providing the magnitude of 0.0025 W/m^2. On the other hand, an engineer from TNB did replied me to confirm that there is a RF communication tower in the smart substation itself, hence that reading is acceptable and justified.

Both RF measured for SGM 3031 and the group of three smart meters differ in terms of percentage of 57.51%. That is once more less than 58%, thus the magnitude is somewhat accurate. Now, a second batch of readings are obtained. Similar like the other two distances earlier, similar method is used. SGM 3031 yields 0.00154 W/m^2 while the group of smart meters yield 0.00114 W/m^2. Both readings differ by a small percentage of 2.63% which is very accurate for SGM 3031 and the other readings differ by 31.47% which is also less than 32% difference. The average value between both batches can be calculated to be 0.00152 W/m^2 and 0.000985 W/m^2. Therefore, the percentage difference between both SGM 3031 and the group of three smart meters now measures at 42.71% difference which is again less than 43%.

Next, for SGM 3031 smart meter, a reduction of about 60% is observed for the decrease of RF intensity when the distance increased to 3 metres and just a mere 1% drop when the distance increases to 5 metres. As for the group of three smart meters, a decrease of 18% is observed at 3 metres distance away and just a mere additional 1% drop recorded at 5 meters away. However, there is an outlier where the RF strength for traditional meter was higher by 110% at 3 metres away but less by 160% at 5 meters away from the source. This clearly indicates that traditional meter does not produce RF radiation at all as these readings originates from the background and surrounding RF radiation.

In terms of the smart substation, since the RF measurements cannot be executed at 3 meters' distance from source, thus a comparison will be done between the readings of 1 meter away and at 5 meter away. The average reading for 1 meter away from source is 0.0022 W/m^2 and the reading for 5 meter away is 0.000145 W/m^2. Hence, from both readings, it is found that the power intensity decreases about 15.17 times less when the RF reaches the 5-meter mark. According to the inverse square law, the power intensity of radiation will decrease one fourth the magnitude when the distance is doubled from the point of radiation. Thus, this rule can be applied to RF propagation. As 5-meter mark lies just after four times the distance, thus the power intensity of RF should decrease slightly more than one eight of the magnitude.

By using the formula of inverse square law as shown below, more precise value can be obtained in order to calculate the exact magnitude of intensity at 5 metre distance.

$$\frac{I_1}{I_2} = \frac{{X_2}^2}{{X_1}^2} \tag{4.1}$$

where

I_1= RF power intensity (W/m^2) at initial distance of 1 meter

I_2 = RF power intensity (W/m^2) at final distance intended of 5 meter

${X_1}^2$ = Distance in meter of initial intensity

${X_2}^2$ = Distance in meter of final intensity

Hence, by substituting the appropriate values, the theoretical value for the supposed power intensity at 5 meters is calculated to be equals to 0.000088 W/m^2.

$$\frac{0.0022}{I_2} = \frac{5^2}{1^2}, I_2 = 0.000088$$

Then, the ratio between the theoretical value and the measured value is calculated in order to obtain the percentage difference which equals to 48.93%. This is still below the acceptable range because there are other external factors taken into consideration like cumulative RF interference from background RF waves. Besides that, the point source of RF radiation located at the peak of the tower at the substation is high up from ground level. Hence, the surface area of RF waves when reaches the RF meter will be very large thus the intensity of RF will decrease significantly.

4.5 Adjusted RF readings at all three distances from various sources

Table 4.5: Finalized RF radiation readings from various sources

RF radiation readings (W/m2)								
Smart Meters						Traditional Meters		
SGM 3031			Sprint/MK29/Metronix			TNB meter		
1 meter	3 meter	5 meter	1 meter	3 meter	5 meter	1 meter	3 meter	5 meter
0.0028	0.0015	0.0015	0.0012	0.001	0.00099	0.00015	0.00052	0.000057

RF radiation readings (W/m2)					
Others					
Sub Station			Overhead line		
1 meter	3 meter	5 meter	1 meter	3 meter	5 meter
0.0023	0	0.00015	0.00009	0	0.000083

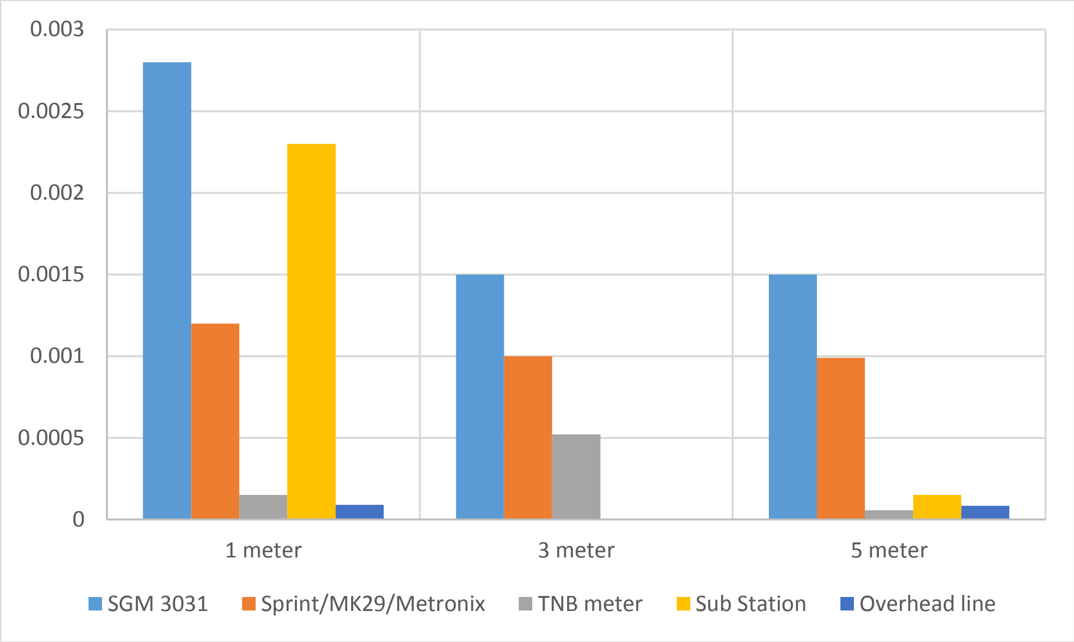

Figure 4.5: Bar chart of adjusted RF radiation readings versus types of energy meters and other various sources

As stated above, the RF radiation readings are averaged out based on both batches for each distances in order to increase accuracy of data obtained. Then, all five different sources are grouped together based on three distances which are one, three and five meters respectively. Thus, an overview of entire data obtained can be compared easily. SGM 3031, a specific smart meter emits the highest RF intensity for all distances. However, for three and five meters, the RF readings obtained are quite equal. Similar pattern is observed for the group of three smart meters where their RF measured at three and five meters respectively are quite equal in terms of magnitude while the reading obtained at one meter is 18% higher. On the other hand, SGM 3031 drops by 60% when RF is measured at 3 meters away from source.

If both categories of smart meters are averaged out, the mean drop in terms of percentage can be calculated and an average percentage of 39% is obtained. Hence, it can be stated that after one meter away from the smart meter, an average of 40% decrease in RF intensity is recorded. After that, the RF intensity is about the same when measured at three and five meters away from the source. Thus, another reading will be taken at seven meters just to confirm the trends and pattern of data. The value of RF obtained is therefore 0.00114 W/m^2. Once more, by obtaining the percentage difference, 27.27% is obtained by calculation and can be rounded to 30%. In short, a total decrease of 66% can be obtained by placing smart meters at least seven meters away from residential houses or commercial buildings.

In real life application, the distance from the main door to the outside gate is approximately 9 meters in total as measured in a double storey terrace residential house. Thus, by installing smart meters in an enclosure located at the walls of the outside gate area of the house, hence a total reduction of about 66% in terms of RF intensity originating from smart meters can be achieved based on real world measurements. This reduction contributes to significant decrease in intensity but based on Bioinitiative 2012's precautionary limits of 0.000003 W/m^2, the limit unfortunately has been exceeded. Since the unit has six significant figures, comparison of data will be done using miliwatts instead of watts which equals to 0.003 mW/m^2.

Based on one-meter distance, the maximum averaging RF recorded is from the SGM 3031 which carries the value of 2.8 mW/m^2. That magnitude is 933 times higher than the revised precautionary limit. However, the international approved limit is known as the FCC MPE limit of 10,000 mW/m^2 where the recorded RF magnitude is 3571 times less than the FCC limit. Hence, the dilemma remains as to which report should the general public rely on. If both limits are compared equally, thus FCC limit is set about 3 million times higher than the Bio Initiative 2012 limits. Nevertheless, the Bioinitiave Report is conducted by a group of scientist, professionals and researches unlike the FCC which is an independent agency of the US government body which regulate communication matters in the US.

FCC has therefore more credibility and their research and findings should be used as a basis of comparison rather than a group of researchers who are not part of any government bodies and do not possess any international recognition. On the other hand, IARC has classified RF fields as possibly carcinogenic to humans under Group 2B for mobile phone RF radiation only. Hence, if the RF levels from a mobile phone is higher than the smart meters, thus it is possible that smart meters do not pose a health effect yet. Biological effect as reported by Bio Initiative Report is different compared to health effect in terms of severity. These will be further analysed based on thermal and non-thermal effects. Besides that, household appliances which emit RF waves will be compared with the maximum averaging RF emitted by the SGM 3031.

In terms of biological effects, heating of living tissues is the main concern to human health. Especially long term exposure to RF fields may cause heating of tissues which could lead to health effects. Luckily, up till now, there is no dated health effects due to the long term exposure to RF waves but leading scientists globally strive to keep researching this issue due to growing concerns about RF radiation on human health. (WHO, 2016) stated that biological effects do not mean they are detrimental to human's health. As a comparison, playing basketball will cause certain types of biological effects too. Furthermore, our body are sophisticated enough to adapt to certain kinds of external factors in the surrounding environment. The conditions that will yield health effects are certain kinds of irreversible or long term stress changes.

According to WHO also, it is agreeable that certain threshold of RF radiation will trigger biological effects thus the statements by Bio Initiative Report 2012 may be plausible to cause biological effects. Supporting statements from WHO further strengthens the suggestions made by Bio Initiative Report 2012 but the threshold limits are not specifically stated by WHO. Besides that, WHO has reviewed many published articles regarding potential biological effects that RF radiation might cause and have reached a conclusion. It is found that the existing scientific evidence do not show the presence of any health hazards that is due to exposure to low levels of RF radiation but it is further agreed that more in depth research should be conducted to further investigate this matter.

Moreover, WHO further state that symptoms like headaches, anxiety, depression, low libido and fatigue as reported by the Bio Initiative Report 2012 are not directly caused by exposure to RF radiation as there is still no scientific evidence to support a causal link between those symptoms and RF radiation. Any links attempt to link those two factors together must be supported by scientific evidence and endorsed by the scientific community or international regulators or bodies. There are many controversial cause and effects to these matter. Furthermore, there is very little scientific evidence to back the term electromagnetic hypersensitivity as discussed much earlier. If RF radiation can show a causal link between exposure and cancer inducing agents, then that research might be a breakthrough.

4.6 RF readings of other appliances or equipment for comparison

Table 4.6: RF radiation readings for other equipment or appliances

RF radiation readings (W/m2)		
Wireless Router	Mobile Phone	SGM 3031
0.434	0.86	0.0028

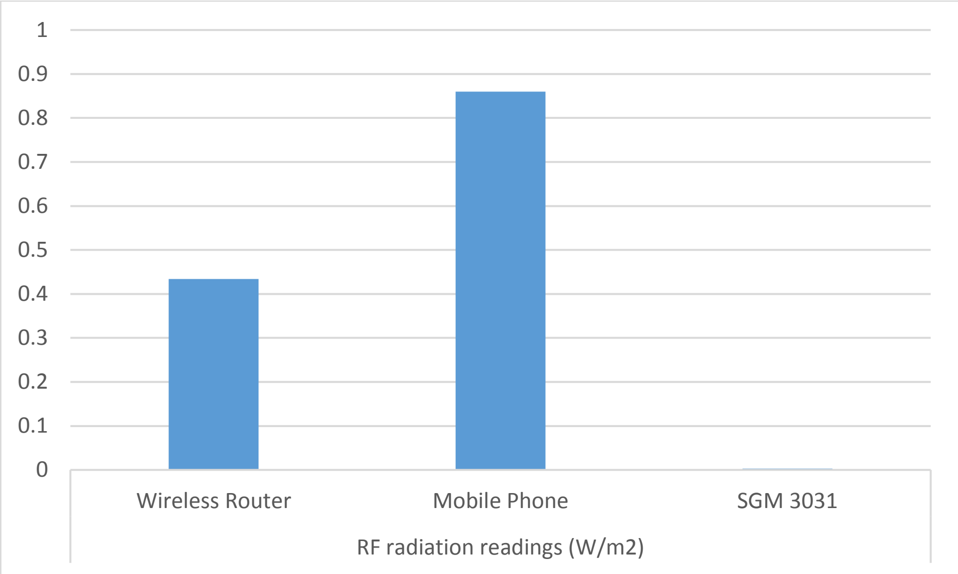

Figure 4.6: Bar chart of RF radiation readings versus other equipment

For mobile phone, the device used for this experiment is a Samsung Galaxy Note 3. RF radiation readings are measured on the phone and the recording is repeated at three different locations in order to obtain an average RF emission by mobile phone. Besides that, all readings are done by placing the RF meter on the surface of the phone in order to obtain RF power intensity of other devices versus smart meters. Hence, surprising magnitudes are observed. The wireless router used for this experiment is named TP-Link and its model is TL-WR841HP. This router is a 300Mbps High Power Wireless N Router. The SGM 3031 is a smart meter derived from the section above. Furthermore, other devices or equipment are not recorded in this project due to its RF readings which are less than the SGM 3031 smart meter.

By using percentage difference, a fair comparison in terms of RF intensity can be analysed. The mobile phone does produce the highest maximum RF intensity recorded in this project. This device is suitable to be compared with smart meter because both devices are found everywhere from residential homes to commercial shop lots. Thus, the highest levels of RF recorded is 307 times higher compared to smart meter. However, that RF reading for mobile phone is recorded when an active phone call was made. This is done because during active phone call, RF levels are elevated in order to be able to send and receive RF signals to and from the phone to base station. The magnitude of RF is almost exactly 300 times larger than the highest level of RF from smart meter.

Another commonly known high power RF transmitting device is the wireless N router. Almost every home in this century has a wireless router or wired ones in order to have internet access. The maximum RF radiation recorded for this router is 155 times higher than the maximum radiation of the smart meter. Thus, IARC which categorize mobile phone as Class 2B for RF radiation shows that if RF emitted is about 300 times higher than the measured RF for smart meters, that could yield possible detrimental effects on our health. The magnitude of 300 is a large significant figure. A buffer zone of that magnitude could mean that smart meters does not pose any significant carcinogen agents to our health. Thus, based on all the facts and statements above, there is still no scientific bodies or studies which can create a causal link between maximum RF emission of smart meter and any of the health hazards known.

4.7 Android application to measure EMF levels of various sources

Another device which is a smart phone application uses the phone sensors to obtain the magnetic field surrounding the mobile phone. This could be used to measure RF radiation emitted from smart meter by placing the mobile phone on the smart meter itself. Hence, the data obtained can be used as a comparison in order to further justify the trends and patterns of the data obtained in earlier sections. Furthermore, it is known that any reading less than 60 µT is merely the Earth's magnetic field. Similar procedures and steps are used as the earlier batches of RF and ionizing radiation readings. The readings are obtained twice and the values are tabulated below.

Table 4.7: Magnetic field readings for different smart meters

Magnetic Field Readings (μT)	
SGM 3031	Sprint/MK29/Metronix
72	41

The MPE limits of magnetic field on humans is 1.13 mT. Hence, the SGM 3031 produced 15.69 times lower than the MPE limit while the group of smart meters produced 27.56 times less than the MPE limit. Hence, even magnetic field readings indicate that SGM 3031 does emit higher amounts of magnetic field compared to the group of smart meters. Thus, SGM 3031 has a higher RF intensity in general compared to the other three smart meters. It is preferred if one of the other three smart meters be implemented instead of SGM 3031. As seen from the results obtained, the MPE for magnetic field also has not been reached for smart meters. Thus, smart meters still do not cause significant health effects even after taking both fields into consideration.

4.8 Ionizing radiation readings at various distances from various sources

Table 4.8: Ionizing radiation readings for various sources

Ionizing radiation readings (CPM)								
Smart Meters						Traditional Meters		
SGM 3031			Sprint/MK29/Metronix			TNB meter		
1 meter	3 meter	5 meter	1 meter	3 meter	5 meter	1 meter	3 meter	5 meter
30	33	34	24	23	22	24	27	22

Ionizing radiation readings (CPM)					
Others					
Sub Station			Overhead line		
1 meter	3 meter	5 meter	1 meter	3 meter	5 meter
25	0	23	24	0	25

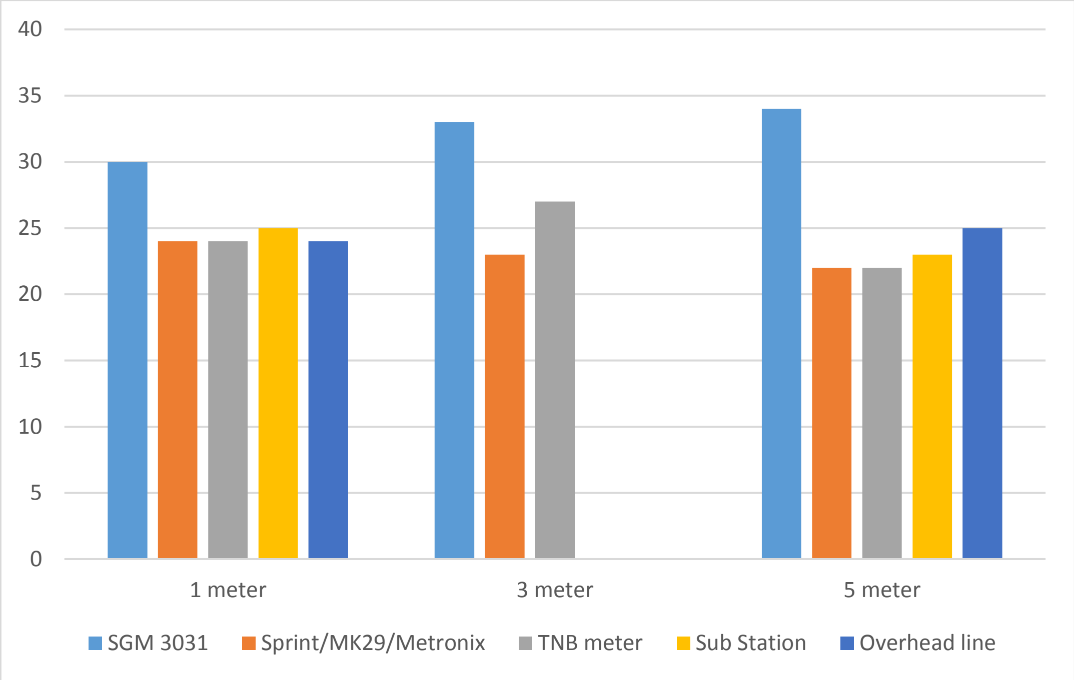

Figure 4.7: Bar chart of ionizing radiation readings versus various sources at various distances

Ionizing radiation readings are recorded in one batch only unlike the non-ionizing radiation readings of RF radiation. This is because based on theoretical facts, smart meters do not emit ionizing radiation. Nevertheless, ionizing radiation readings will be recorded in this project for comparison and data analysis. Actual sources of ionizing radiation are derived from either cosmic rays or isotopes. These are known as background radiation. The unit used is counts per minute (CPM). Similar steps and procedures are observed by following the ones listed in RF radiation recordings. Also, this section is included much later, thus there is no time for a second batch of readings. The device used is a portable Geiger Muller Counter made by GQ Electronics.

In terms of SGM 3031, the recorded CPM is 30 and it increases by 3 when the GM counter is moved to three meters away. At five meters away, the CPM increased by 1 which yield a total of 34 CPM. Any types of radiation when radiating from a source will decrease with increasing distance. However, based on the GM counter values, the results obtained clearly proves that the CPM recorded does not originate from the smart meter but rather from the background of cosmic rays and natural isotopes. They make up the value of the background ionizing radiation. Moreover, smart meters do not emit x-rays, gamma rays, alpha rays and beta rays as there are no atomic particles being released from the smart meter. If there were such rays, this could be dangerous and can cause cancer in humans.

Same facts are applied to traditional meters and overhead lines. These structure and devices merely display energy consumption and transmit power through vast distances in order to reach the distribution network respectively. In no circumstances, they emit ionizing radiation at all. However, interestingly the highest background CPM recorded originates from SGM 3031. In all three distances, highest CPM were recorded for this smart meter. This is exactly the same trends and patterns for RF radiation for this particular smart meter. Nonetheless, both analysis cannot be used to compare the trends and patterns of data because RF radiation lies in the left end of the non-ionizing section in the EMF spectrum while ionizing radiation constitutes the further right end of the EMF spectrum. Both types of radiation do not intersect at all.

Based on the graph above, it can be derived that the background CPM at one-meter distance from various sources is 24.5 CPM. Next, at three meters' distance from those sources, the average background reading is 27.67 CPM while at five meters away, the average background CPM is calculated to be 23 CPM. The percentage difference at one meter away compared to three meters away from various sources is calculated to be 6.32% while from three meters to five meters away, the percentage difference is 18.43%. Those values are below 66% and thus they are within the acceptable accuracy range. Since all three average readings are due to natural background radiation in terms of CPM, therefore the mean value of background radiation equals to the average value which is calculated to be 25.06 CPM.

Thus, after averaging the background radiation of various sources at each distance, then the mean value of all three CPM at each distances is calculated to be 25 CPM. This is the only indicator which can be useful to obtain in terms of ionizing radiation readings. Based on the nuclear radiation safety limits imposed, 25 CPM falls in the category of normal ionizing radiation levels. Hence, it is completely safe and no actions are required totally. Thus, the final mean value is acceptable and proven to be valid plus they do not originate from the smart meters completely as they do not obey the inverse square law of radio waves propagation.

4.9 Assessment of Environmental Impact

4.9.1 Sources from website collected and data analysis executed

After various and numerous data searching, there is one case which can be used for data comparison and analysis due to the controlled factors which can be justified. The location for this analysis is a school named Mesa Elementary School situated in Boulder, Colorado, USA. A device known as EGauge is used in order to monitor energy patterns when renewable energy integration like solar panels are connected to the grid. The EGauge meter can measure and then record energy consumption in order to be monitored and analysed using the internet. Any load or power generated variations will be recorded and can be scrutinized easily. The owner of this device has set the device to public access, thus enabling data analysis to be performed as this proves useful in order to further investigate the environmental impact.

On the other hand, in order to obtain a fair comparison, traditional power grid's data need to be obtained from verified sources for the same city or area. Hence, in the city of Colorado, total energy generation is measured by the USA Energy Information Administration (EIA). This is a USA government body which deals with official energy statistics and therefore the data originating from this body is reliable and accurate. The energy data is publicly available to anyone who needs them for data analysis and comparison. Hence, the latest time period of April 2016 is chosen as both sources are able to produce the required data for that time period. Two vital factors will be analysed in this section which is the total energy generation and also total amount of carbon dioxide saved due to renewable energy integration.

Table 4.9: Environmental savings comparison

	Smart grid	Traditional Grid
Total Energy Generation (MWh)	1.35	4487282
Total Carbon Dioxide Emissions (metric tons)	0.906	3206000

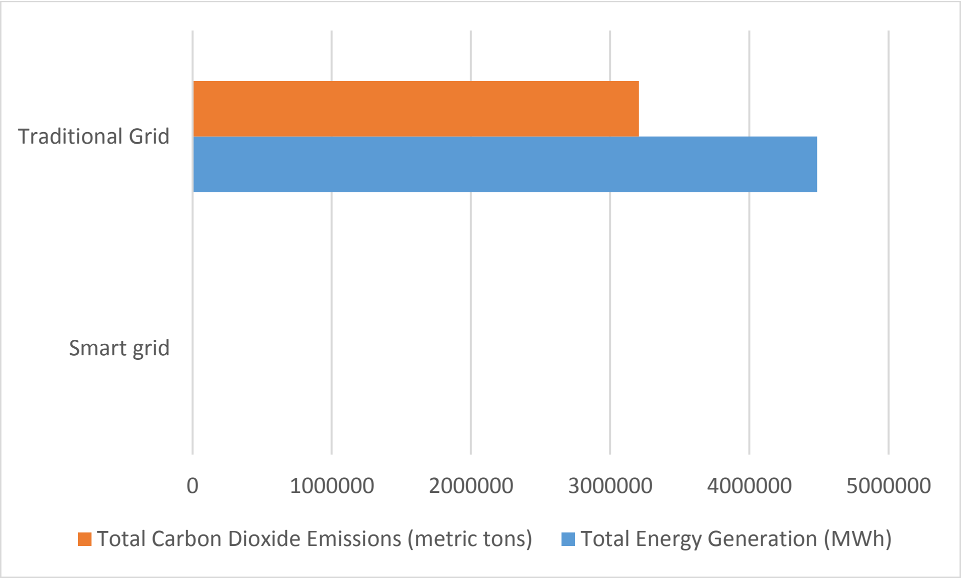

Figure 4.8: Bar chart of data comparison between smart grid and traditional grid

Based on the figure above, a small scale smart grid in Boulder city generates very little power due to small scale photovoltaic solar panel integrated into the smart grid. As expected, the power generated will be surely much smaller compared to the traditional grid. The solar panels in the smart grid city produces energy which is 3.3 million times less compared to the traditional grid for that city and for the same time period of April 2016. Moreover, in terms of carbon dioxide emission, smart grid emits 3.5 million times less metric tons of carbon dioxide compared to the traditional grid. Hence, since both magnitudes are about 3 million times less, it translates into almost equal size in proportion of energy generation and emission. It can be assumed that smart grid is like 3 million times smaller compared to traditional grid.

Based on the data collected, smart grid does emit much less metric tons of carbon dioxide due to renewable energy integration like solar and wind energy.

Therefore, less power needs to be generated by coal in order to supply energy to end users. Since the energy proportion is quite equal, thus efficiency of power generation is somewhat same. In future, if smart grid gains higher rate of implementation, therefore less metric tons of carbon dioxide will be emitted into the atmosphere while maintaining almost similar power output based on efficiency. These results supports that smart grid should replace traditional power grid in future at the same time releasing much less carbon dioxide into the atmosphere. Therefore, it is proven to yield positive environmental impact as much less carbon dioxide is emitted.

Although total energy generation is somewhat equal but in order to break even with the capability of traditional grid, full scale implementation of smart grid across nearly all major cities must be executed in order to match the energy generation of traditional grid. When end users have the ability to monitor their own real time energy consumption together with monetary savings plus total amount of carbon dioxide emission saved, thus this combination can facilitate the customers' acceptance towards full scale implementation of smart grid across all major cities in order to serve as a substitute of the traditional grid in the near future.

On contrary, more hardware need to be implemented in order to achieve the full potentials of smart grid which translates into possible clearing of forestry or lands but the effects of carbon dioxide exceed the effects of space needed for additional hardware to support the internet of things. Clearing of lands can be mitigated by installing additional hardware in high rise buildings or landed properties in order to reduce the total amount of land which need to be cleared but the effects of high levels of carbon dioxide will cause global warming. The severe effects of global warming will cause the thinning of ozone layer which is irreversible. That is a known theoretical fact hence, it is a better option to solve the additional hardware issue following the steps above instead of allowing global warming effects to be more severe due to elevated amount of carbon dioxide emitted into the atmosphere if smart grid concept is rejected by end users.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 RF radiation analysis

In summary, WHO is an international government body where its research and findings are globally accepted and recognized by the scientific community. WHO did state that certain amount of RF radiation will trigger certain types of biological effects in humans' health but biological effects are not the same as health effects. Health effects does prove to be detrimental and have certain degree of severity on our health. However, it is found that the highest averaging RF emitted from smart meters equals to 2.8 mW/m^2 which is 3500 times lower than the accepted FCC limits of RF exposure. That proves that there is a huge safety margin in terms of power intensity reduction is obtained and will not cause any significant health effects. Nonetheless, it will cause some biological effects like fatigue, dizziness and so on.

Furthermore, there is no causal link proven scientifically that certain limits of RF radiation will cause cancer or other reported side effects of RF waves. On the other hand, RF emitted from mobile phone is measured to be 300 times higher than the maximum RF from smart meters. That proves another huge safety of margin as IARC declares mobile phone RF radiation as Class 2B which means possibly carcinogen to humans. Thus, based on both globally recognised MPE limits, therefore it can be concluded that RF radiation from smart meters are relatively much lower than the MPE limits. Hence, although biological effects are somewhat apparent but it does not pose any danger to humans' health in general. Nonetheless, there are ways to reduce the biological effects from RF radiation.

Magnetic field can be used as another alternative in order to measure the intensity of EMF radiation. Based on the results, similar trends of data are obtained whereby SGM 3031 emits the highest magnetic field among all devices. Moreover, the MPE limits for magnetic field is still 15 times higher than the magnetic field recorded. Furthermore, no ionizing radiation is observed as the CPM recorded is from naturally occurring background radiation of 25 CPM which proves to be normal. Hence, it can be deduced that RF radiation from smart meters do not pose any significant health hazards towards humans' health as they are so much lower than globally recognized MPE RF limits and also no causal link can be established between RF radiation and those symptoms recorded by using scientific approach until now.

5.2 Environmental impact analysis

By obtaining data from reliable sources and scale them down to a fair basis of comparison using the same time period and same location or city, hence a side by side comparison and analysis can be executed. In our case study of Boulder, Colorado, the smart grid city concerned yield about 3 million times less for both the magnitude of energy generation plus the total amount of carbon dioxide emission to the atmosphere averaged out. Hence, it is quite proportional in terms of that scale given that smart grid is about 3 million times smaller in perspective compared to the traditional grid. However, that comparison is relative.

Besides that, by utilizing demand response and demand side management, hence less energy need to be generated in order to meet end users' energy demand especially during peak hours. Also, by incorporating load shifting, customer awareness, cost savings, dynamic pricing and others, thus the near perfect balance between supply and demand of energy generation can be achieved in order to minimize energy wastage and maximize energy efficiency plus reducing overall amount of carbon dioxide generated due to the reduction of energy generation. Also, both utility company and end users will benefit directly from positive environmental impact by just reducing peak demand and turning off unwanted devices or appliances for the end users side and by reducing overall peak load demands can be achieved using dynamic pricing and load shifting for the utility company's side.

5.3 Further recommendations

There are actually many other variables and factors which must be taken into consideration when obtaining RF radiation values in order to obtain nearly perfect experimental results. Among those factors omitted for this project are RF antenna gain located in the smart meter, actual RF power output of smart meter, absorption and reflection factor. If these values are known accurately either by the smart meter manufacturer or by the utility company, then precise RF power density can be calculated and tabulated for more accurate analysis. Furthermore, the duty cycle of RF pulse from smart meter will not be publicly available to consumers as only the utility company knows the actual percentage of duty cycle. Nonetheless, the RF meter used to measure RF radiation is reasonably accurate and sensitive to a wide range of RF frequency hence making those RF values to be acceptable to a certain degree.

Furthermore, higher end instruments can be used like high frequency analyser HF 35C which can produce an audible sound in order to distinguish the real source of RF radiation. Different sources will produce different intensity or types of audible sound from the meter itself. This ensures that the RF recorded is actually emitted by smart meters for example and not from any other background sources or other equipment. Additionally, it is recommended that the same methodology is applied and the entire project to be redone later in future as the current smart meters are in pilot testing stage and not in the final nationwide implementation phase. Hence, if RF readings are taken when nationwide implementation starts, the RF recorded may be different in terms of magnitude and intensity.

In terms of effort to reduce biological effects of RF from smart meters, many feasible and plausible solutions will be listed. Based on the trends of data, just by placing smart meters at the main gate in an enclosure of a residential house, the power intensity of smart meters dropped to almost 67%. Hence, that proves to be a simple solution in order to drastically reduce power intensity of RF from smart meters. Another solution is to replace RF transmitter in smart meters with either BPL or use AMR ‘bubble up’ drive-by-meter. BPL totally eliminates the need of RF transmitter in smart meter, thus no more RF radiation issues. BPL has been generally accepted by the public and Boulder City implemented BPL instead of RF transmitter in all of their smart meters.

The other option is to keep RF module in smart meter but use the ‘drive-by’ concept whereby once a month, a utility vehicle will drive pass the residential homes and then collects RF signals from smart meters using a wireless receiver. This drastically reduce the frequencies of RF signals emitted from smart meter as they only emit RF signals once a month. Furthermore, the power intensity of those smart meters are much less because they only need to reach the road outside their house in order to be collected by the utility vehicle. On the other hand, there are certain specialized enclosures in the market today which can drastically decrease RF power intensity emitted from smart meter which functions similarly like a mobile phone casing.

Smart grid is a broad term whereby the generation, distribution and transmission makes up the whole grid. However, due to time constraint, future projects can be targeted to the generation or transmission sides instead of just distribution side. In another four years, our country will have full scale implementation of smart grid nationwide. Then, more detailed and precise data recording and analysis can be executed. As of the time of data collection, there is only one pilot project situated in Melaka. Thus, when taking multiple RF data, many trips has to be made in order to get average values and to improve accuracy of data recorded.

Lastly, the major utility company in our country, TNB Sdn. Bhd. requires official request with certain conditions before providing any general data like a screenshot of the web portal whereby customers of the pilot project can view real time data and obtain real time amount of carbon dioxide emissions savings due to reduction of peak demand. Furthermore, even trivial types of data need to be approved by their director in charge and that will require long periods of waiting time as this project is categorized as not top priority compared to their major ongoing projects. Hence, if they are more willing to share generalized publicly available data to be used in this project, then more data can be obtained in order to investigate possible impacts of environmental and security impacts of smart grid too.

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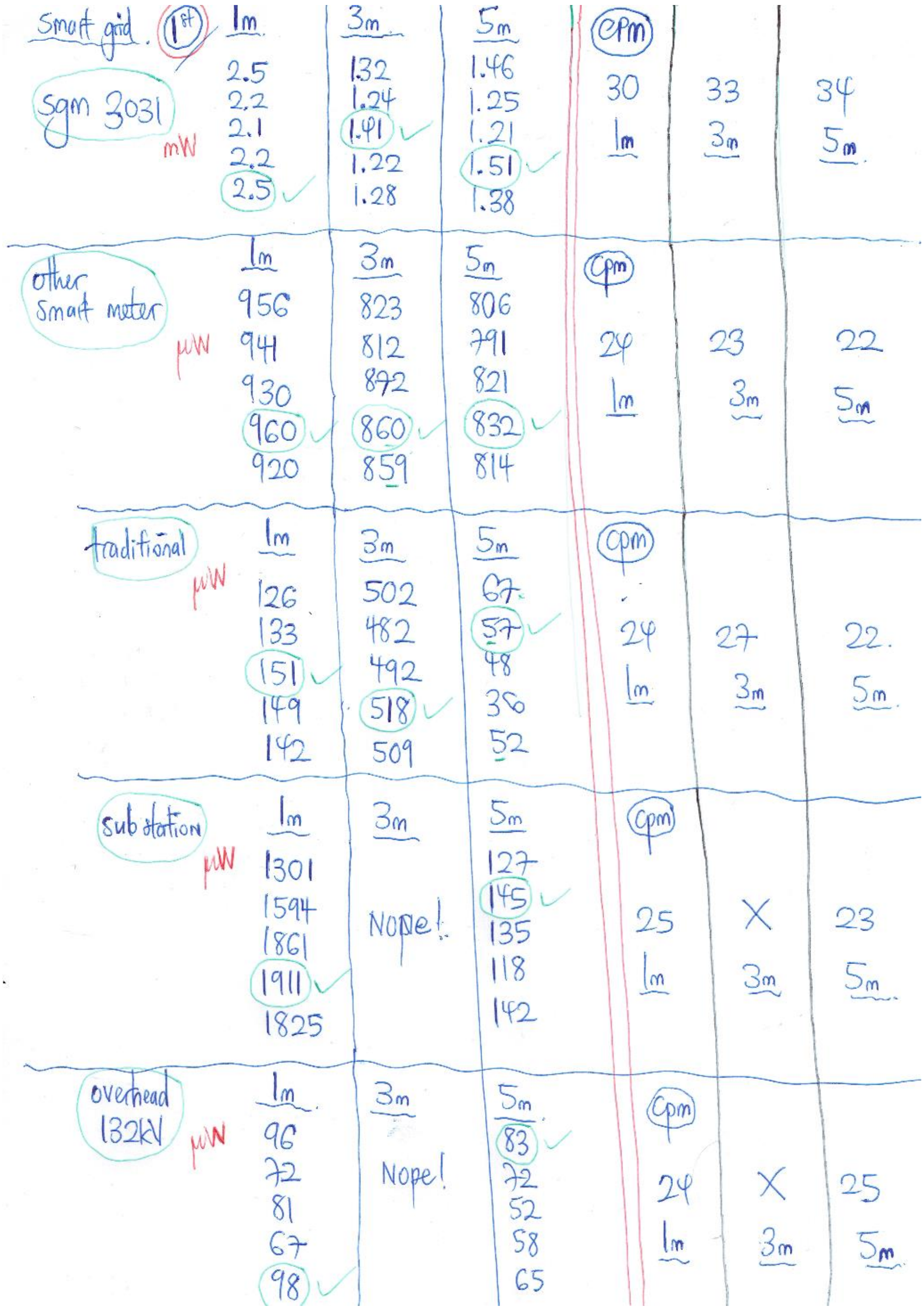
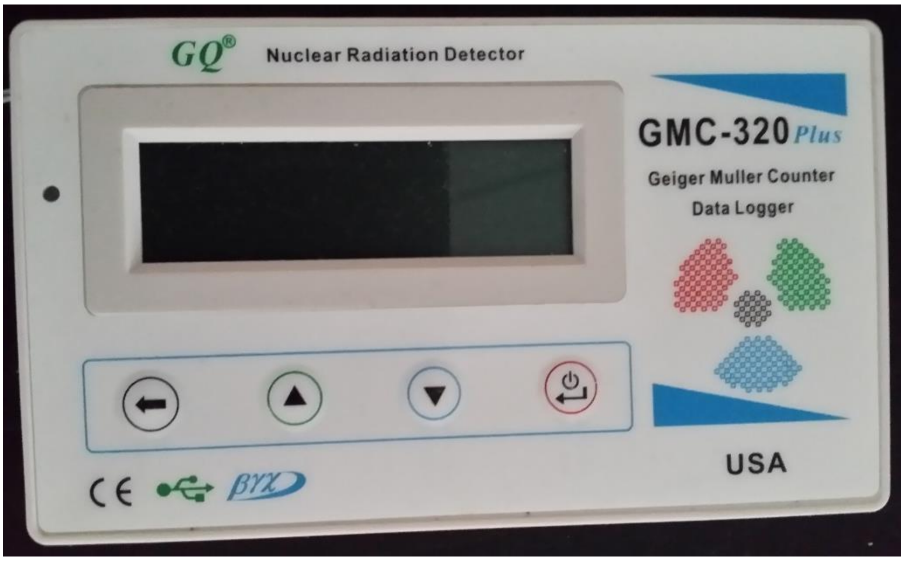
APPENDICES

APPENDIX A: Pictures



Source	Unit	1m	3m	5m	cpm 1m	cpm 3m	cpm 5m
Smart grid (1st) SGM 3031	mW	2.5, 2.2, 2.1, 2.2, **2.5**	1.32, 1.24, **1.41**, 1.22, 1.28	1.46, 1.25, 1.21, **1.51**, 1.38	30	33	34
other Smart meter	µW	956, 941, 930, **960**, 920	823, 812, 872, **860**, 859	806, 791, 821, **832**, 814	24	23	22
traditional	µW	126, 133, **151**, 149, 142	502, 482, 492, **518**, 509	67, **57**, 48, 36, 52	24	27	22
sub station	µW	1301, 1594, 1861, **1911**, 1825	Nope!	127, **145**, 135, 118, 142	25	X	23
overhead 132kV	µW	96, 72, 81, 67, **98**	Nope!	**83**, 72, 52, 58, 65	24	X	25

RF and ionizing radiation raw data recordings of various sources



GMC-320 Plus Geiger Muller Counter for measuring ionizing radiation.

TENMARS TM-195 for measuring RF radiation from various sources.

Group of the three brands of smart meters which are from left to right ;- Metronix, Sprint, and Mk29.

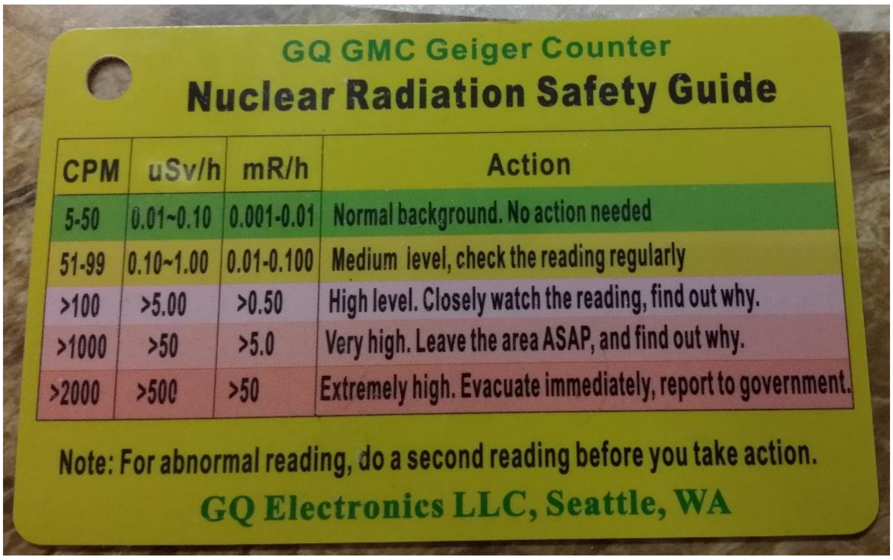
SGM 3031 smart meter made by General Electric.

Melaka’s 132 kV overhead line

Smart Substation with RF communication tower in the background.

Method of measuring magnetic and RF radiation from other devices and smart meters by placing the smartphone and GM counter touching the various sources.

Method of measuring RF radiation from smart meters and traditional meters by placing TM-195 on a tripod at maximum height at various distances from the source.



GQ GMC Geiger Counter

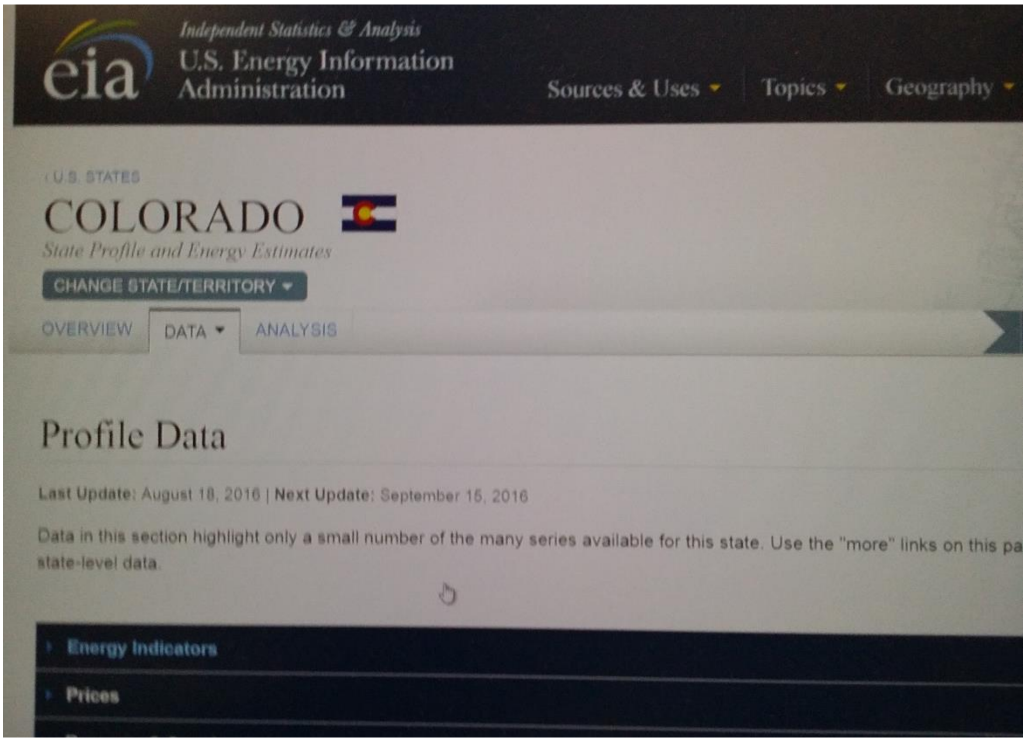
Nuclear Radiation Safety Guide

CPM	uSv/h	mR/h	Action
5-50	0.01~0.10	0.001-0.01	Normal background. No action needed
51-99	0.10~1.00	0.01-0.100	Medium level, check the reading regularly
>100	>5.00	>0.50	High level. Closely watch the reading, find out why.
>1000	>50	>5.0	Very high. Leave the area ASAP, and find out why.
>2000	>500	>50	Extremely high. Evacuate immediately, report to government.

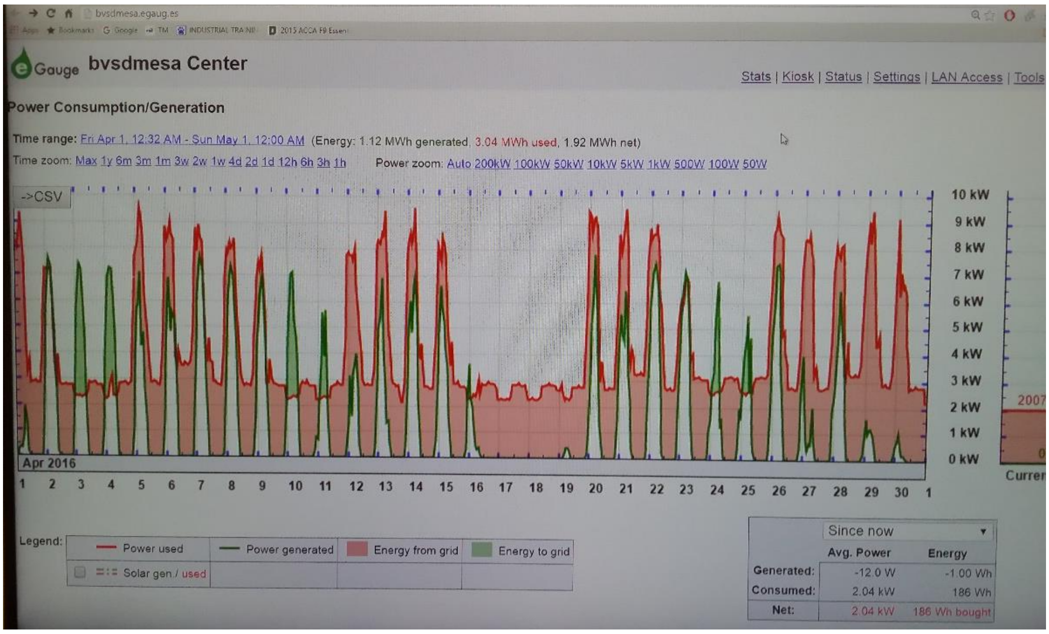
Note: For abnormal reading, do a second reading before you take action.

GQ Electronics LLC, Seattle, WA

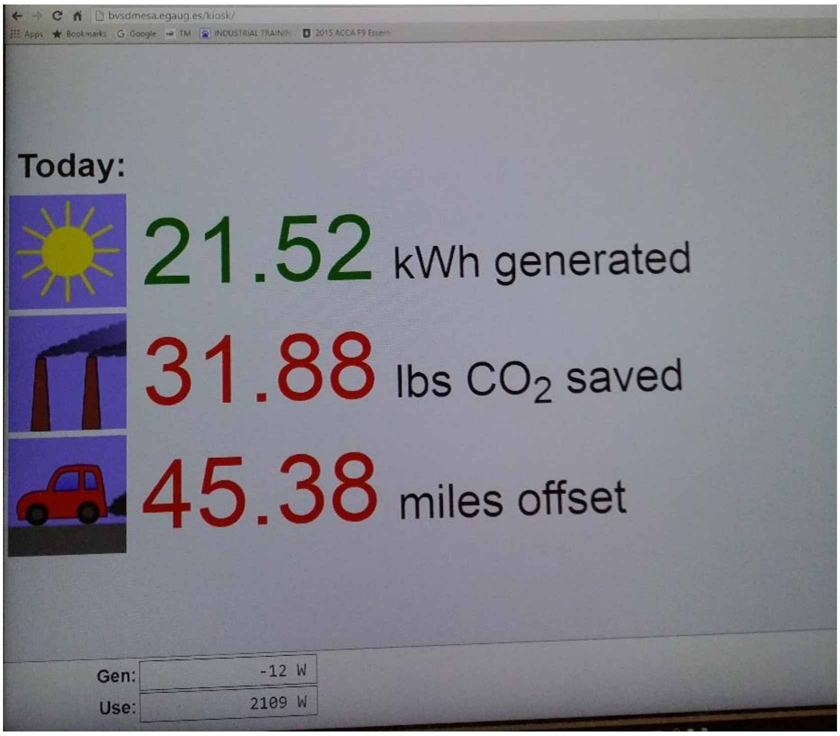
Ionizing radiation readings categories which determines the severity of ionizing radiation towards humans' health.



EIA website where data collection is obtained for environmental impact analysis specifically for traditional grid.



Publicly available data of renewable energy integration of solar panels connected to smart grid in Boulder City in a user defined time interval.



Automated kiosk by solar panel integration of the smart grid which calculates the total amount of carbon dioxide saved in the user defined time period.

Application | Specification

- Display type: Liquid-crystal (LCD), 4-1/2 digits maximum reading 19999.
- Measurement method: Digital, triaxial measurement.
- Directional characteristic: Isotropic, triaxial.
- Measurement range selection: one continuous range.
- Display resolution:0. 1mV/m, 0.1μA/m, 0.001μW/m2, 0.001μW/cm2
- Setting time: typically 1.5s (0 to 90% measurement value.)
- Sample rate: 1.5 times per second.
- Audible alarm: Buzzer.
- Units: mV/m, V/m, μA/m, mA/m, μW/m2, mW/m2, μW/cm2
- Display value: Instantaneous measured value, maximum value, average value, or maximum average value.
- Alarm function: adjustable threshold with ON / OFF
- Calibration factor CAL: adjustable
- Manual data memory and read storage:200 data sets.
- Batteries: 9V NEDA 1604, IEC 6F22 or JIS 006P
- Battery life: Approximate 15 hours.
- Auto power off: Default time 15 minutes. Adjustable threshold 0~99 minutes.
- Operating temperature range: 0°C to + 50°C
- Operating humidity range: 25% to 75 % RH
- Storage temperatures range: -10°C to +60°C
- Storage humidity range: 0% to 80% RH
- Dimensions: 60(L)*60(W)*195(H) mm.
- Weight (including battery): Approx.200g.
- Accessories: User's manual, 9V battery, Carrying case.

Full specifications of TENMARS TM-195 RF radiation meter

Specification:

- Radiation detection: Beta, Gamma and X-Ray .
- Detectable Energy Range: 0.1~3.0 MeV
- Own Background: 0,2 Pulses/s
- Working Voltage: 3.2-4.0V
- LCD Display: Dot matrix with back light
- Working power: 0.045W - 0.2W
- Power: 3.6V/3.7V battery / USB power

Click here to see 'GQ Geiger Cou

The following CPM data is measured by GMC-320:

Source	CPM reading
Background	20~40
Public park granite table	50~83
Uranium glass bead 238U	320
Uranium ore 238U	2905
Standard 5uCi radioactive source	26500

Full specifications of GMC-320 Plus Geiger Muller counter

UNIVERSITI TUNKU ABDUL RAHMAN

Wholly Owned by UTAR Education Foundation (Company No. 578227-M)

29th February, 2016

Dr. Stella Morris,
Final Year Project Coordinator,
Lee Kong Chian Faculty of Engineering and Science,
University Tunku Abdul Rahman.
Tel: +603-9086 0288
Email: stellam@utar.edu.my

Dear Sir/Madam,

To whom it may concern

Re: Data request for final year project

The bearer of this letter Mr. Ang Keat Hong (student ID: 11UEB00916) is a final year student of our university. As part of his Bachelor of Engineering studies, he is required to do a Final Year Project. In this regard, he has planned to conduct an investigation on smart grids which requires some data, on smart grids, from your organization for the analysis and/or simulation and/or investigation purposes.

I request you to kindly provide him with the required data from your organization and I shall be very thankful for this kind favor. The information gathered from your organization will be used only for educational purpose.

I shall be highly grateful for your support and cooperation. Should you have any queries or require any further information, please do not hesitate to contact me.

With thanks and regards,

UNIVERSITI TUNKU ABDUL RAHMAN
LEE KONG CHIAN FACULTY OF ENGINEERING AND SCIENCE

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Associate Professor,
LKC Faculty of Engineering and Science,
Universiti Tunku Abdul Rahman,
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Tel: (603) 9086 0288 **Fax:** (603) 9019 8868 **Homepage:** http://www.utar.edu.my

Official letter to inform the relevant parties regarding data collection intended for FYP purposes.