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Memory of the end of study, with the aim of the getting of the certificate of Master in computer science

Option: Computer Systems

Topic:

Realization of a Control and optimization software of energy consumptions in smart grids.

Prepared by:

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Presented on October 5, 2020, in front of the jury composed of:

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Thanks

First, we thank Allah the almighty, for giving us courage and will to accomplish this modest job.

Our thankfulness and gratitude Goes to the jurors who honored us by judging this work, and with their availability and all Observations allowed us to enrich our job.

We also thank from all our heart all teachers who contributed to our study since first year until this day.

We thank all persons who participated of direct or indirect way in the concrete expression of this job.

Lyes and Mohammed Elamine

Dedication

I dedicate this work to my parents for all mental and financial help and also to my brother and all my family also not to forget the hard working friend that helped me realize this honest and modest work

I also dedicate it to my friends and classmates, and to all Master students comrades.

Lyes

``

Dedication

If I arrived here, it is thanks to Allah.

I want firstly to thank my Parents for their great support and encouragement.

I also thank my roommate for his entire patient and help him provided.

In addition, I insist to thank my partner for his hard work on this project.

I also dedicate it to all my friends and classmates,

Mohammed Elamine

Abstract:

This work will abroad the subject of Realization of a Control and optimization software of energy consumptions in smart grids system. As the title mentioned the system is a combination of two major fields. Renewable energy concerns especially with solar energy, wind turbines, bio thermal and geothermal energy. Smart grid is the injection of different technologies in the traditional power grid in precise network technologies and communication requirements. This system evolves the traditional power grid to be smart. It installs on every node in the grid with its specifications. The system ensures the power flow in the grid and the process of exchanging energy through buying or selling according to parameters like length and cable type.

Key *Word*: –

Smart grids, Renewable energy, solar energy, wind turbines, bio thermal, geothermal energy, power grid, exchanging energy.

ملخص:

هذا العمل سيبرز موضوع أنجاز برنامج يقوم بالتحكم والتحسين في استهلاك الطاقة في نظام شبكة الطاقة الذكية. كما يذكر العنوان فان هذا النظام عبارة عن مزيج من مجالين رئيسيين. الطاقات المتجددة على وجه الخصوص الطاقة الشمسية، الطاقة الناتجة عن توربيدات الرياح، الطاقة الحيوية والطاقة الحرارية الأرضية. شبكة الطاقة الذكية هي محاولة دمج مختلف التكنولوجيات الحديثة وأنظمة التواصل المتطورة في شبكة الطاقة التقليدية بهدف تحسين خدماتها وتقليل حجم الأعطال المتوقعة بها. يتم تثبيت هذا البرنامج في جل النقط المختلفة في الشبكة مهما كانت مواصفاتها عميل او إدارة. يضمن النظام عملية تدفق الطاقة في الشبكة كذا عملية تبادل الطاقة من خلال بيع او شراء وتتم وفقا لمعايير مثل بعد النقطتين عن بعضهما ونوع الكابل الرابط بينهما.

الكلمات المفتاحية:

شبكة الطاقة الذكية، الطاقات المتجددة، الطاقة الشمسية، توربيدات الرياح، الطاقة الحيوية، الطاقة الحرارية الأرضية، تبادل الطاقة.

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General introduction

Renewable energy become an essential element in the 21 century. The growth of population and economic development made an urgent need of energy. However, climate change, global warming and air pollution consist of staying away of traditional fossil fuels.

Therefore, the world started to invest in solar, wind, biomass and geothermal energies because it generates a lot of power, it is affordable and the most important it is environment friendly.

It is hard not to notice in national news and professional conferences of the last few years all the talks and activities in the electric power industry about smart grids. Smart grid, intelligent grid, modern grid, future grid have all been used to describe a digitized and intelligent version of the present-day power grid

With the great development of these two large fields, is it possible to inject renewable energies in smart grids? In addition, if so how to handle this power? Moreover, how to perform sustainable power flow in this grid?

These questions made clear the need of certain technologies and systems to ensure the best power flow and a stable grid. There is some solutions, that works with the present of an operator but the need for a solution more intelligent is required.

This paper is going to have four chapters. The first chapter will aboard renewable energies solar, wind, bio thermal and geothermal energy and discuss every energy with some advantages and disadvantages. Second chapter will introduce information's about smart grid field, which talked about smart grid technologies, and communication technologies used with it. Third chapter is going to talk about the theoretical approach of the system with communication layer, development environment, grid architecture and user parameters. Finally, in the last chapter we will talk about the behavior of the solution and how it solve some problems.

Chapter I

Renewable Energy

1.1 Introduction

With the increase of population and technologic and economic development, human beings need more energy to create a better life environment. However, burning traditional fossil fuels is causing a series of environmental problems, such as climate change, global warming, air pollution and acid rain.

Therefore, there is an urgent need for the development of renewable energy Technologies, in order to deal with the political, economic and environmental challenges that are involved in generate electricity that is affordable and the most important green.

1.2 Progress in renewable energy technologies

The oil price shocks in the 1970s made it painfully clear how much the development and the welfare of countries depend on a steady and affordable energy supply. Therefore, it is not surprising that governments, especially in industrialized countries, initiated research programs that looked for alternative energy sources in order to improve the security of energy supply. The increasing concerns about climate change and global warming renewed and reinforced the interest in non-fossil energy sources as they promise to lastingly reduce greenhouse gases [1].

The term “renewable energy” is energy derived from a broad spectrum of resources, all of which are based on self-renewing energy sources such as sunlight, wind, flowing water, the earth’s internal heat, and biomass such as energy crops, agricultural and industrial waste, and municipal waste. These resources can be used to produce electricity for all economic sectors, fuels for transportation, and heat for buildings and industrial processes.

Figure 1.1 Wind turbines and a large solar panel in Palm Springs, California

Renewable energy contributes as much today to U.S. energy production as nuclear power (10%) [1]. each renewable energy technology is in a different stage of development and commercialization. Some technologies are already commercial, at least for some situations and applications [2].

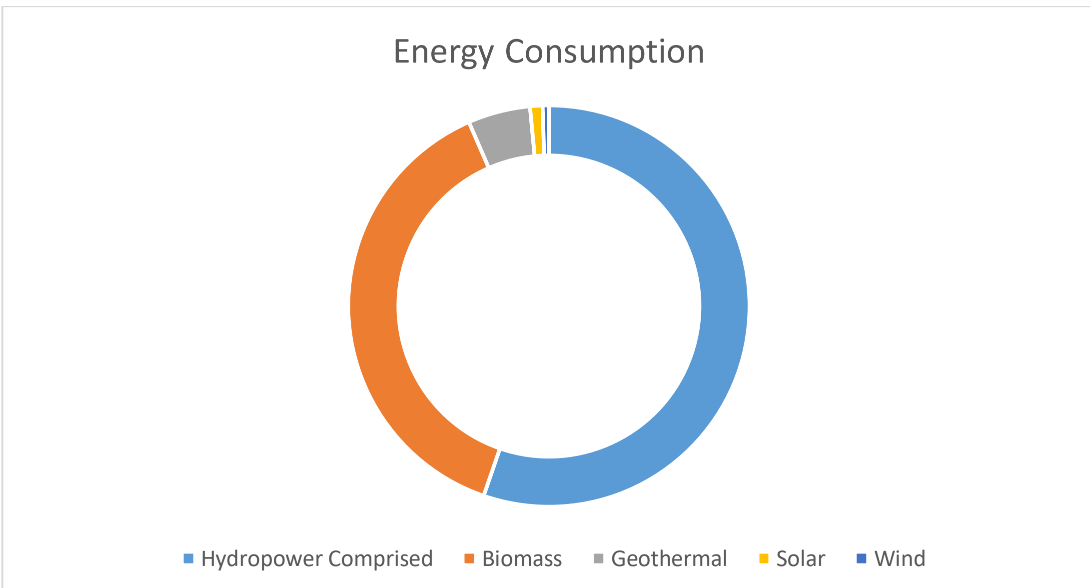

Figure 1.2 renewable energy consumed in the United States in 1998

Detailed information on over 7000 facilities that generate U.S. grid-connected electricity from renewable resources is available electronically [4]. Renewable energy technologies offer important benefits compared to those of conventional energy sources [5].

Renewable energy resources are abundant; worldwide, 1000 times more energy reaches the surface of the earth from the sun than is released today by all fossil fuels consumed.

Resource	Annual Delivered Energy (KWH/m2)
Wind Energy (intermittent)	11 (average wind speed) 18 (high wind speed)
Biomass (baseload)	15 (low efficiency) 45 (high efficiency)
Photovoltaics (intermittent)	50-100
Geothermal (The Geysers) (baseload)	160-200

Table 1.1 the energy delivered per square meter of land for four renewable resources [6].

Similar to fossil fuels, renewable energy resources are not uniformly distributed throughout the world. However, every region has some renewable energy resource. And, because different renewable energy resources complement each other, taken together they can contribute appreciably to energy security and regional development in every nation of the world, without dependence on foreign energy sources that are subject to political instability or manipulation [10].

Most renewable energy systems are modular, allowing flexibility in matching load growth. Today's markets for renewable energy technologies range from specialized niche markets to centralized energy production. For centralized energy production, renewable energy systems are relatively capital intensive compared to competing conventional technologies such as natural gas combined cycle power plants.

However, after the initial investments have been made, the economics of renewable energy technologies improve in comparison with conventional technologies because operating and maintenance costs are low compared with those incurred using conventional fuels. This is especially true in the regions of the world where world fuel prices are relatively high, and will be especially true in the future as fuel prices increase. For both solar and wind systems, the fuel cost is not only constant, it is zero, for the life of the system. Renewable energy systems generate little if any waste or pollutants that contribute to acid rain, urban smog, and health problems, and do not require environmental cleanup costs or waste disposal fees.

Potential global climate change, caused by excess carbon dioxide and other gases in the atmosphere, is the latest environmental concern; systems using solar, wind, and geothermal sources do not contribute any carbon dioxide to the atmosphere [7]. In fact, today renewable sources of electricity help the United States avoid about 70 million metric tons of carbon emissions per year that would have been produced had that electricity been generated by fossil fuels [8].

Biomass does release carbon dioxide when it is converted to energy, but because biomass absorbs carbon dioxide as it grows, the entire process of growing and using biomass results in very low to zero carbon dioxide emissions. Although the energy of the sun and wind has been used by mankind for millennia, modern applications of renewable energy technologies have been under serious development for only about 20 years. In that period of research and development investment by industry and government [primarily the U.S. Department of Energy (DOE)], dramatic improvements have occurred in the cost, performance, and reliability of renewable energy systems (see Fig. 1). A summary of these improvements is given below; many excellent reviews of the past two decades of progress in renewable energy technologies are available [9].

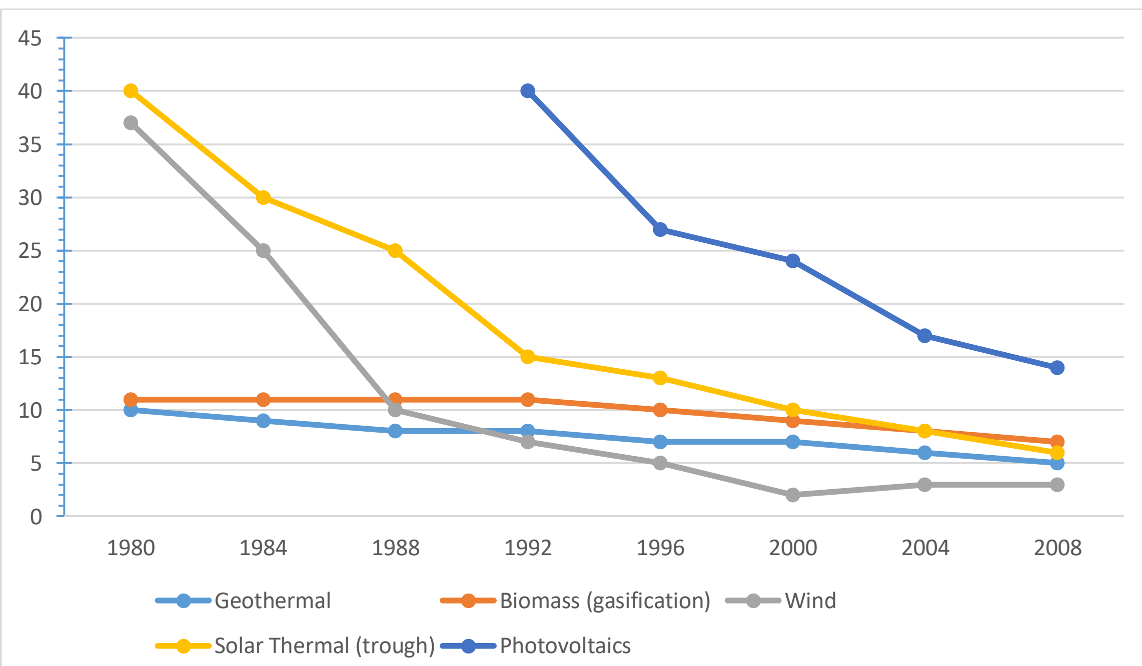

Figure 1.3 Renewable electricity cost trends and projections

1.2.1 Photovoltaic solar energy

The photovoltaic solar energy (PV) is one of the most growing industries all over the world, and in order to keep that pace, new developments has been rising when it comes to material use, energy consumption to manufacture these materials, device design, production technologies, as well as new concepts to enhance the global efficiency of the cells [11].

Figure 1.4 Photovoltaic Solar energy panels.

The conversion of solar radiation into electricity occurs due to the photovoltaic effect, which was observed by the first time by Becquerel in 1839 [11, 14]. This effect occurs in materials known as semiconductors, which present two energy bands, in one of them the presence of electrons is allowed (valence bad) and in the other there is no presence of them, i.e., the band in completely “empty” (conduction band), see Fig. 2.

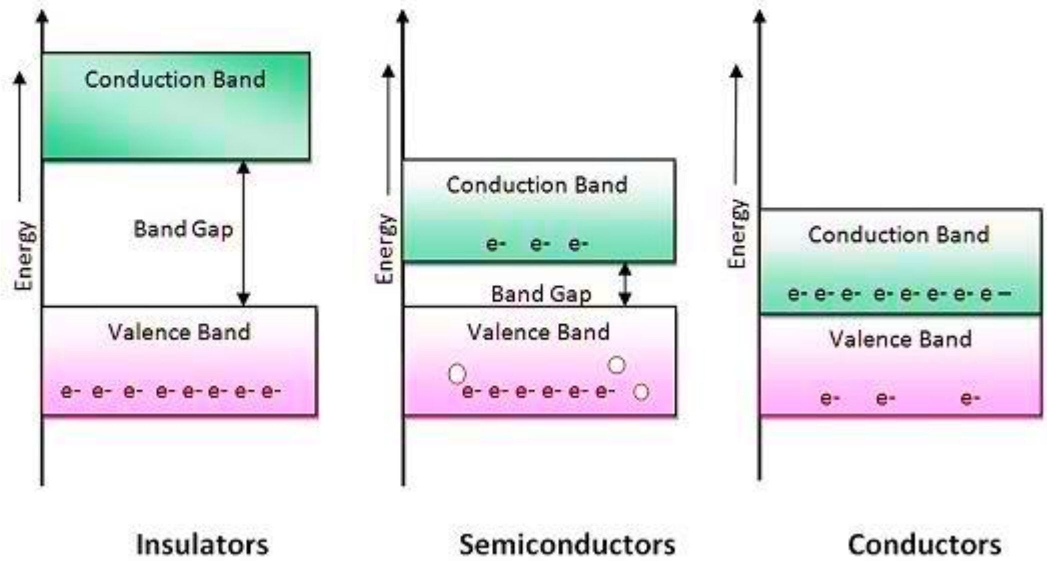

Figure 1.5 the components of a photovoltaic cell.

The semiconductor material more commonly used is the silicon, second most abundant element on Earth. Its atoms are characterized by having four electrons that connect to its neighbors, creating a crystal network. The function of sunlight on the photovoltaic effect is to supply an amount of energy to the outermost electron to make it possible for him to move from the valence band to the conduction band in the material, thereby generating electricity.

As [12] in the case of silicon, specifically, it is needed 1.12 eV (electro volts) for electrons to exceed the GAP. Further, according to [15], the semiconductor material must be able to absorb a large part of the solar spectrum. Virtually all photovoltaic devices incorporate a PN junction in a semiconductor, which through a photo voltage is developed. These devices are also known as solar cells or photovoltaic cells [15].

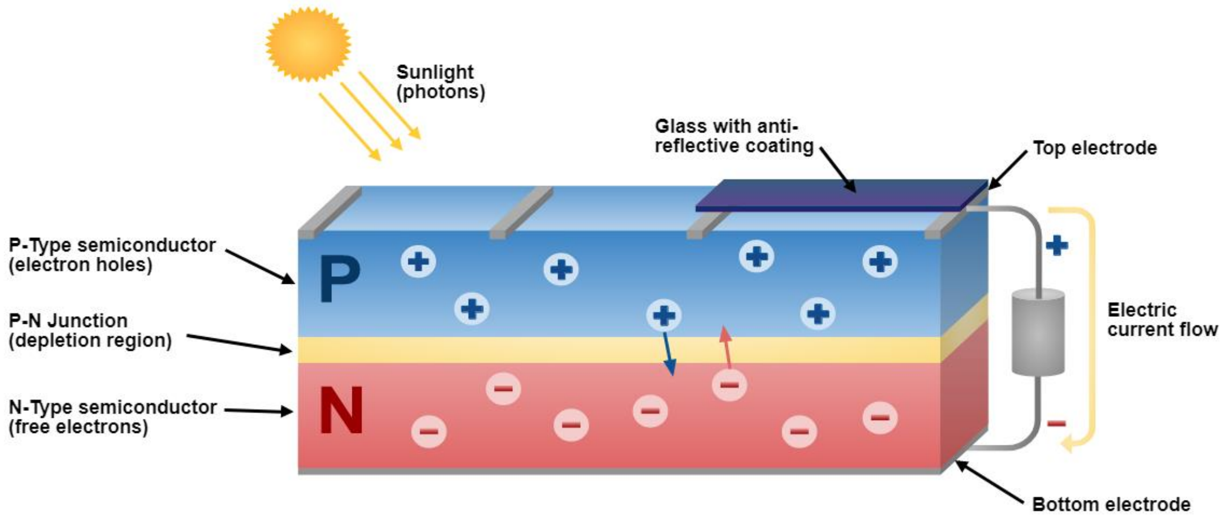

Figure 1.6 typical solar cell

The PN junction is the main part of the cell where the light receiving portion is the N-type material in the part below this the material is P-type. The main advantages and disadvantages of photovoltaic solar energy are described as follows:

Compared to conventional power generation sources, such as those using fossil fuels, photovoltaic technology does not bring the serious environmental problems that these sources cause during generation, such as climate change, global warming, air pollution, acid rain and so on. Another advantage in relation to fossil fuels is that solar energy does not need to be extracted, refined or transported to the generation site, which is close to the load.

However, during its life cycle, it consumes a large amount of energy and emits some greenhouse gases in some stages (manufacturing process of solar cells, assembly of photovoltaic modules and transport of material, among others) [11, 14]. Photovoltaic technologies, consume per unit of electricity produced, 64 times more material resources, 7 times more human resources and 10 times more capital than nuclear technology. Although this data is biased, this is a clear indication of the extreme inefficiency of PV technologies in regions of moderate sunshine to help achieve the goal of providing a resource-efficient, efficient electricity supply system.

Despite its limitations, the photovoltaic power generation systems allow the installation of a short-term power plant, with the possibility to generate several MW in less than a year. As the environmental impacts, they are minimal, photovoltaic systems remove the need for preliminary studies that require long-term assessment, unlike the highly polluting systems [13]. Using photovoltaic solar energy is used in both spatial and Earth applications.

The installation of photovoltaic plants in the desert may be one of the most suitable places for the use of photovoltaic solar energy due to the high levels of solar radiation. In the Atacama desert in Chile, for example, it is a viable option capable of contributing to the continued supply of sustainable electricity in the north of the country, contributing to the stabilization of electricity prices, thus benefiting the Chilean mining industry [16].

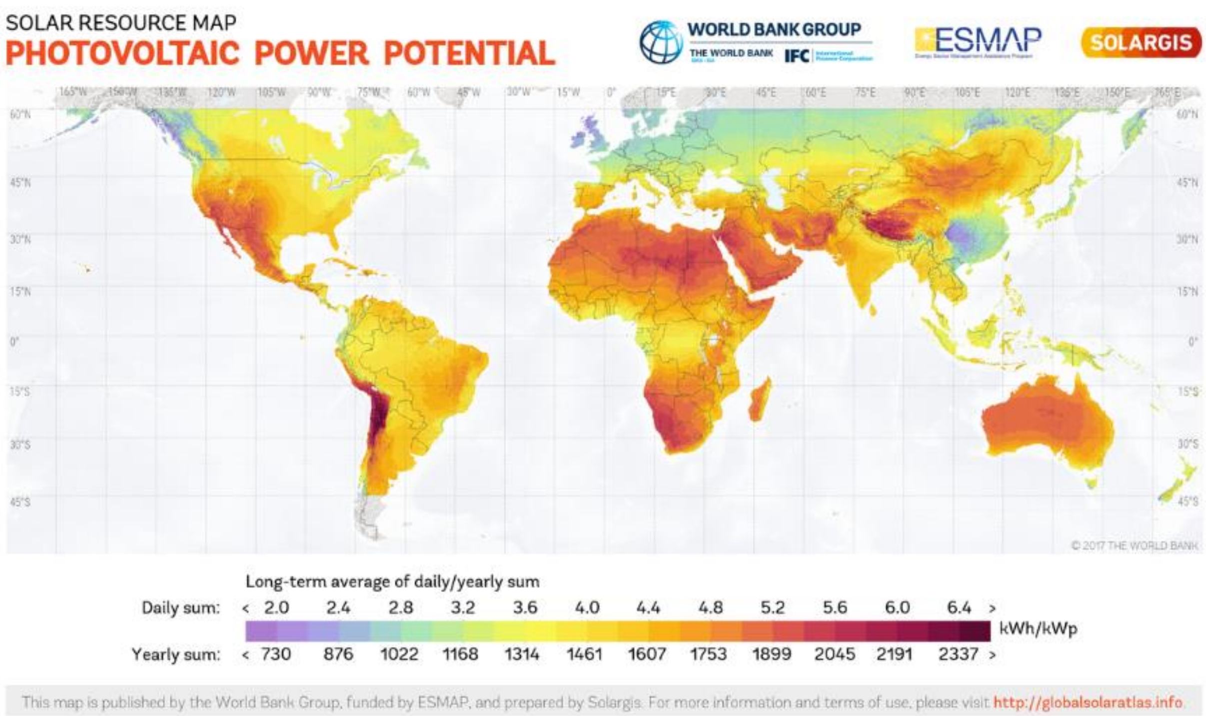

Figure 1.7 Energy produced by photovoltaic cells in the world

1.2.1.1 Elements of the photovoltaic solar energy system

A typical photovoltaic solar system consists of four basic elements: Photovoltaic module, charge controller, the inverter and battery when necessary (Fig. 4). The photovoltaic module consists of photovoltaic cells, i.e., the surfaces that generate electricity, which convert directly solar energy into electricity.

These surfaces have no moving parts to wear out or suffer breakdowns and works without the use of fuel without vibrations without noise and without harming the environment [14]. As for the charge controller, it has the function to preserve the batteries from being overcharged or discharged completely, increasing its useful life.

The inverter, in turn, is responsible for converting the power generated by photovoltaic panels (electricity generating DC – DC) to alternating current – AC voltage levels and network frequency. Batteries are used in photovoltaic systems to store the surplus produced by the modules to be utilized at night or on days with low sunshine or overcast [14].

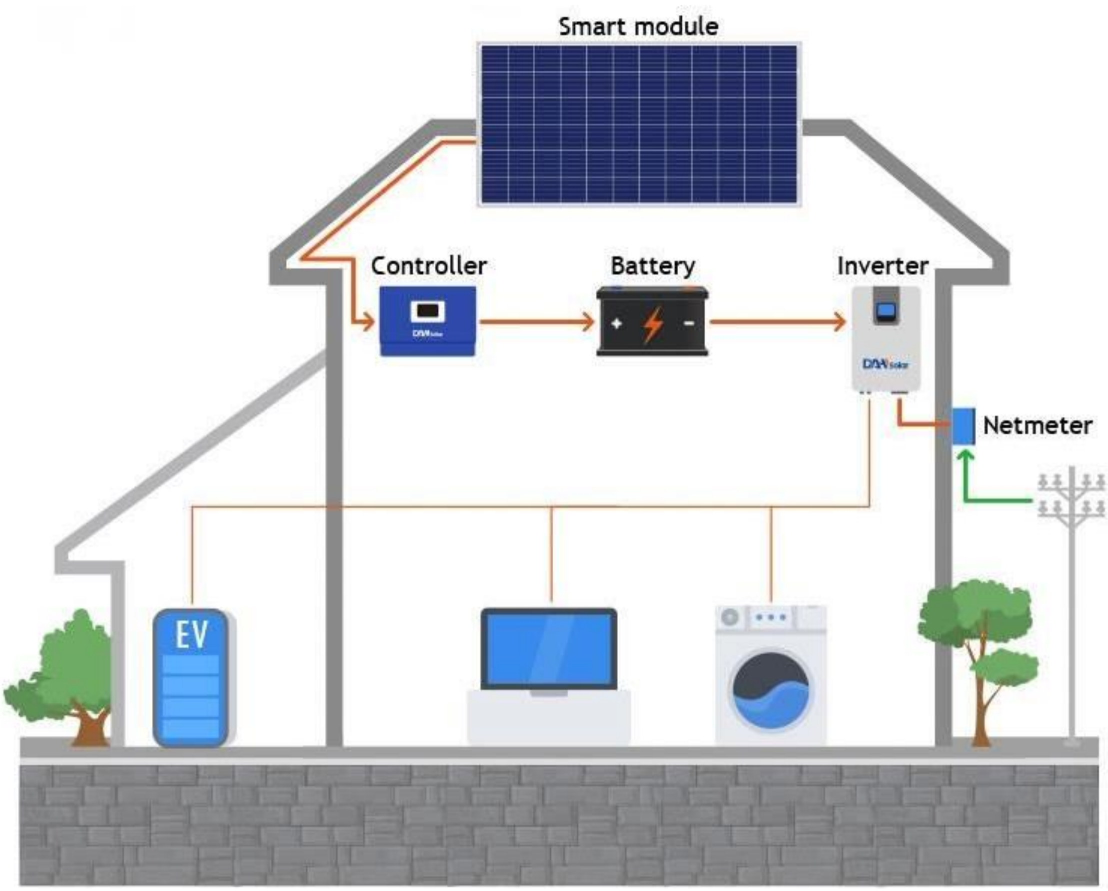

Figure 1.8 Solar energy to electricity system.

1.2.1.2 Advantages

1.2.1.2.1 Renewable Energy Source

Among all the benefits of solar panels, the most important thing is that solar energy is a truly renewable energy source. It can be harnessed in all areas of the world and is available every day. We cannot run out of solar energy, unlike some of the other sources of energy. Solar energy will be accessible as long as we have the sun, therefore sunlight will be available to us for at least 5 billion years when according to scientists the sun is going to die.

1.2.1.2.2 Reduces Electricity Bills

Since you will be meeting some of your energy needs with the electricity your solar system has generated, your energy bills will drop. How much you save on your bill will be dependent on the size of the solar system and your electricity or heat usage. Moreover, not only will you be saving on the electricity bill, there is also a possibility to receive payments for the surplus energy that you export back to the grid. If you generate more electricity than you use (considering that your solar panel system is connected to the grid).

1.2.1.2.3 Diverse Applications

Solar energy can be used for diverse purposes. You can generate electricity (photovoltaics) or heat (solar thermal). Solar energy can be used to produce electricity in areas without access to the energy grid, to distill water in regions with limited clean water supplies and to power satellites in space. Solar energy can also be integrated into the materials used for buildings. Not long ago Sharp introduced transparent solar energy windows.

1.2.1.2.4 Low Maintenance Costs

Solar energy systems generally don’t require a lot of maintenance. You only need to keep them relatively clean, so cleaning them a couple of times per year will do the job. If in doubt, you can always rely on specialized cleaning companies, which offer this service from around £25-£35. Most reliable solar panel manufacturers offer 20-25 years warranty. Also, as there are no moving parts, there is no wear and tear. The inverter is usually the only part that needs to be changed after 5-10 years because it is continuously working to convert solar energy into electricity and heat (solar PV vs. solar thermal). Apart from the inverter, the cables also need maintenance to ensure your solar power system runs at maximum efficiency. So, after covering the initial cost of the solar system, you can expect very little spending on maintenance and repair work.

1.2.1.2.5 Technology Development

Technology in the solar power industry is constantly advancing and improvements will intensify in the future. Innovations in quantum physics and nanotechnology can potentially increase the effectiveness of solar panels and double, or even triple, the electrical input of the solar power systems.

1.2.1.3 Disadvantages

1.2.1.3.1 Cost

The initial cost of purchasing a solar system is fairly high. This includes paying for solar panels, inverter, batteries, wiring, and for the installation. Nevertheless, solar technologies are constantly developing, so it is safe to assume that prices will go down in the future.

1.2.1.3.2 Weather Dependent

Although solar energy can still be collected during cloudy and rainy days, the efficiency of the solar system drops. Solar panels are dependent on sunlight to effectively gather solar energy. Therefore, a few cloudy, rainy days can have a noticeable effect on the energy system. You should also take into account that solar energy cannot be collected during the night. On the other hand, if you also require your water heating solution to work at night or during wintertime, thermodynamic panels are an alternative to consider.

1.2.1.3.3 Solar Energy Storage Is Expensive

Solar energy has to be used right away, or it can be stored in large batteries. These batteries, used in off-the-grid solar systems, can be charged during the day so that the energy is used at night. This is a good solution for using solar energy all day long but it is also quite expensive. In most cases, it is smarter to just use solar energy during the day and take energy from the grid during the night (you can only do this if your system is connected to the grid). Luckily your energy demand is usually higher during the day so you can meet most of it with solar energy.

1.2.1.3.4 Uses a Lot of Space

The more electricity you want to produce, the more solar panels you will need, as you want to collect as much sunlight as possible. Solar PV panels require a lot of space and some roofs are not big enough to fit the number of solar panels that you would like to have. An alternative is to install some of the panels in your yard but they need to have access to sunlight. If you don't have the space for all the panels that you wanted, you can opt for installing fewer to still satisfy some of your energy needs.

1.2.1.3.5 Associated with Pollution

Although pollution related to solar energy systems is far less compared to other sources of energy, solar energy can be associated with pollution. Transportation and installation of solar systems have been associated with the emission of greenhouse gases. There are also some toxic materials and hazardous products used during the manufacturing process of solar photovoltaic systems, which can indirectly affect the environment. Nevertheless, solar energy pollutes far less than other alternative energy sources.

1.2.2 Wind turbines energy

The power of the wind has been utilized for at least three thousand years. Until the early twentieth century, wind power was used to provide mechanical power to pump water or to grind grain. At the beginning of modern industrialization, the use of the fluctuating wind energy resource was substituted by fossil fuel fired engines or the electrical grid, which provided a more consistent power source [17].

In the early 1970s, with the first oil price shock, the interest in the power of the wind re-emerged. This time, however, the main focus was on wind power providing electrical energy instead of mechanical energy. This way, it became possible to provide a reliable and consistent power source by using other energy technologies as a backup [17].

Figure 1.9 Wind turbines

Wind power systems convert the kinetic energy of the wind into other forms of energy such as electricity. Although wind energy conversion is relatively simple in concept, turbine design can be quite complex. Most commercially available wind turbines use a horizontal-axis configuration with two or three blades, a drivetrain including a gearbox and generator, and a tower to support the rotor [4].

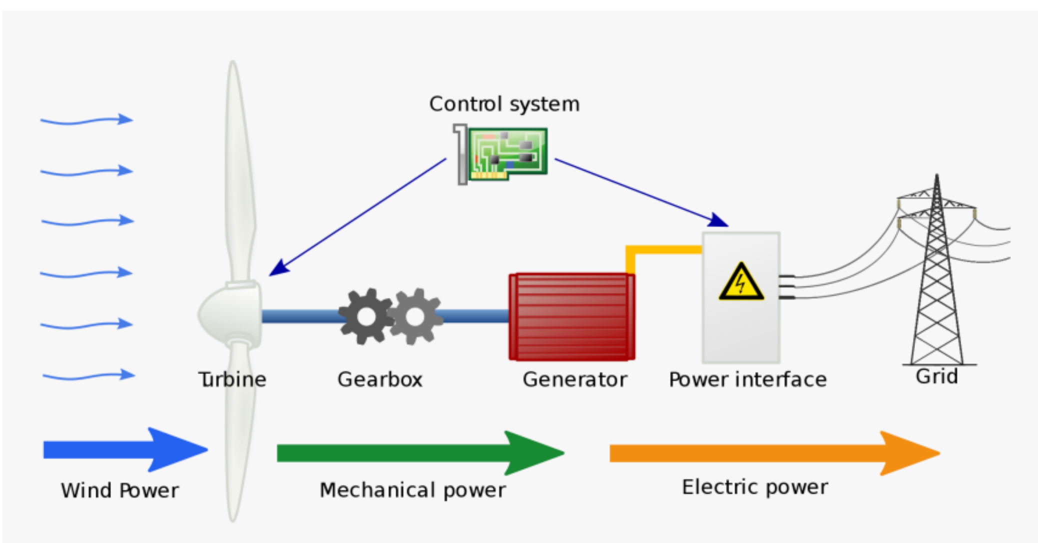

Figure 1.10 Wind energy to electricity system

Wind-turbine capacity has increased over time. In 1985, typical turbines had a rated capacity of 0.05 megawatts (MW) and a rotor diameter of 15 metres. Today's new wind power projects have turbine capacities of about 2 MW onshore and 3–5 MW offshore.

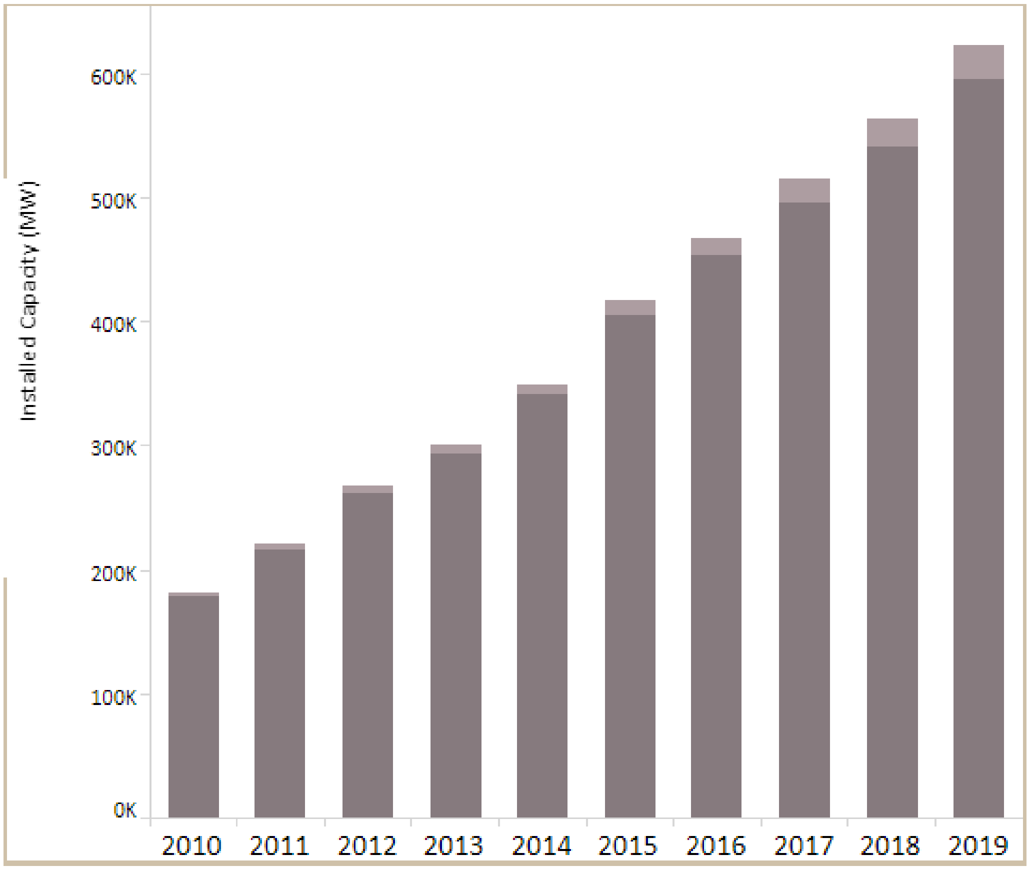

Figure 1.11 Wind energy generation around the word [18]

According to IRENA's latest data, the production of wind electricity in 2016 accounted for a 6% of the electricity generated by renewables. Many parts of the world have strong wind speeds, but the best locations for generating wind power are sometimes remote ones. Offshore wind power offers tremendous potential [18].

1.2.2.1 Advantages

The advantages of wind energy are more apparent than the disadvantages. The main advantages include an unlimited, free, renewable resource (the wind itself), economic value, maintenance cost, and placement of wind harvesting facilities. First and foremost, wind is an unlimited, free, renewable resource. Wind is a natural occurrence and harvesting the kinetic energy of wind doesn't affect currents or wind cycles in any way [19].

Next, harvesting wind power is a clean, non-polluting way to generate electricity. Unlike other types of power plants, it emits no air pollutants or greenhouse gases. The wind turbines harmlessly generate electricity from wind passing by. Wind energy is far more ecofriendly than the burning of fossil fuels for electricity. Currently, the United States, along with other countries, remains dependent on fossil fuels imported from unstable and unreliable nations [19].

Strains on supply (of fossil fuels) are likely to increase the prices of fossil fuel resources and leave the worlds economy exposed to international market volatility. Wind power has the ability to free the world from the figurative economic bondage of fossil fuels. Once turbines and energy centers have been installed, the cost of maintaining turbines and generating wind power is next to nothing [19].

Another advantage of wind power is the ability to place turbines wherever necessary. After performing research and finding areas that have adequate wind, experts may place the turbines in desired areas. These areas are usually unpopulated (offshore wind turbines, for example). In fact, offshore winds tend to blow harder and more uniformly than on land, providing the potential for increased electricity generation and smoother, steadier operation than land-based wind power systems [19].

1.2.2.2 Disadvantages

The two major disadvantages of wind power include initial cost and technology immaturity. Firstly, constructing turbines and wind facilities is extremely expensive. The second disadvantage is technology immaturity. High cost of energy can, in part, be addressed directly with technology innovations that increase reliability and energy output and lower system capital expenses [19].

Offshore wind energy produces more energy than onshore wind energy, but costs much more to establish. The primary costs of wind turbines include construction and maintenance. New technology is needed to lower costs, increase reliability and energy production, solve regional deployment issues, expand the resource area, develop infrastructure and manufacturing facilities, and mitigate known environmental impacts [19].

Therefore, one may argue that implementation of wind energy must be delayed until technological advancements are made. Other disadvantages include: Aesthetic impact: Many people are concerned with the visual effects that wind turbines have on the beautiful scenery of nature. They believe that giant wind turbines distract viewers from the beautiful surroundings. Fig. 2 shows just how big wind turbines can be [19].

Figure 1.12 Turbine blade convoy passing through Edenfield, England (Source: Wikimedia Commons)

Wildlife: Wind turbines may be dangerous to flying animals. Many birds and bats have been killed by flying into the rotors. Experts are now conducting research to learn more about the effects that wind turbines have on marine habitats. Remoteness of location: Although this may be an advantage (placing wind turbines in desolate areas, far away from people), it may also be a disadvantage. The cost of travel and maintenance on the turbines increases and is time consuming. Offshore wind turbines require boats and can be dangerous to manage. Noise: Some wind turbines tend to generate a lot of noise which can be unpleasant Safety at Sea: In the darkness/at night it may be difficult for incoming boats to see wind turbines thus leading to collisions [19].

1.2.3 Bio power

Biomass power plants generate electricity from biomass resources ranging from agricultural and forest product residues to crops grown specifically for energy production. Direct-combustion systems burn biomass in a boiler to produce steam that is expanded through a turbine/generator to produce power; cofiring substitutes biomass for coal in existing coal-fired boilers; gasification converts biomass to a fuel gas that can be substituted for natural gas in combustion turbines.

1.2.4 Biofuels

Ethanol is frequently used as a gasoline additive or converted to another additive called ethyl-tertiary-butyl ether to raise the octane level of gasoline and promote cleaner combustion. According to the U.S. Environmental Protection Agency, the use of ethanol blended with gasoline can reduce motor vehicle emissions of carbon monoxide by 25% to 30% and also reduce ozone levels that contribute to urban smog.

In addition, the combustion of ethanol produces 90% less carbon dioxide than gasoline. A blend of 10% ethanol and 90% gasoline has been widely used throughout the nation for many years. Higher level blends of 85% and 95% ethanol are being tested in government fleet vehicles, flexible-fuel passenger vehicles, and urban transit buses. Although there are nearly 50000 such vehicles in operation, their use is expected to grow as federal, state, municipal, and private fleet operators seek to comply with the alternative fuel requirements of the Energy Policy Act of 1992 and the Clean Air Act Amendments of 1990.

Ethanol sold today is produced from corn kernels using traditional fermentation technology to meet a market demand of more than a billion gallons of fuel a year. Because corn requires high amounts of energy (as fertilizer and farm equipment fuel) to grow, renewable energy research has focused on producing ethanol (termed bioethanol) from corn waste, waste newspaper, rice straw, forest thinning to prevent wildfires, and grasses and trees cultivated as energy crops [20]. Biological production of ethanol involves hydrolysis of fibrous biomass, using enzymes or acid catalysts, to form soluble sugars, followed by microbial conversion of sugars to ethanol.

Ultimately, the goal is for bioethanol to become competitive with gasoline in price [21]. Research focuses on low-cost production of enzymes to break down cellulose, improve microorganism performance and produce suitable energy crops [22].

1.2.5 Geothermal Energy

Geothermal resources include dry steam, hot water, hot dry rock, magma, and ambient ground heat. Steam and water resources have been developed commercially for power generation and ambient ground heat is used commercially in geothermal heat pumps; methods of tapping the other resources are being studied. Research centers on lowering costs, improving methods for finding and characterizing reservoirs, and tapping broader resources [23], [24].

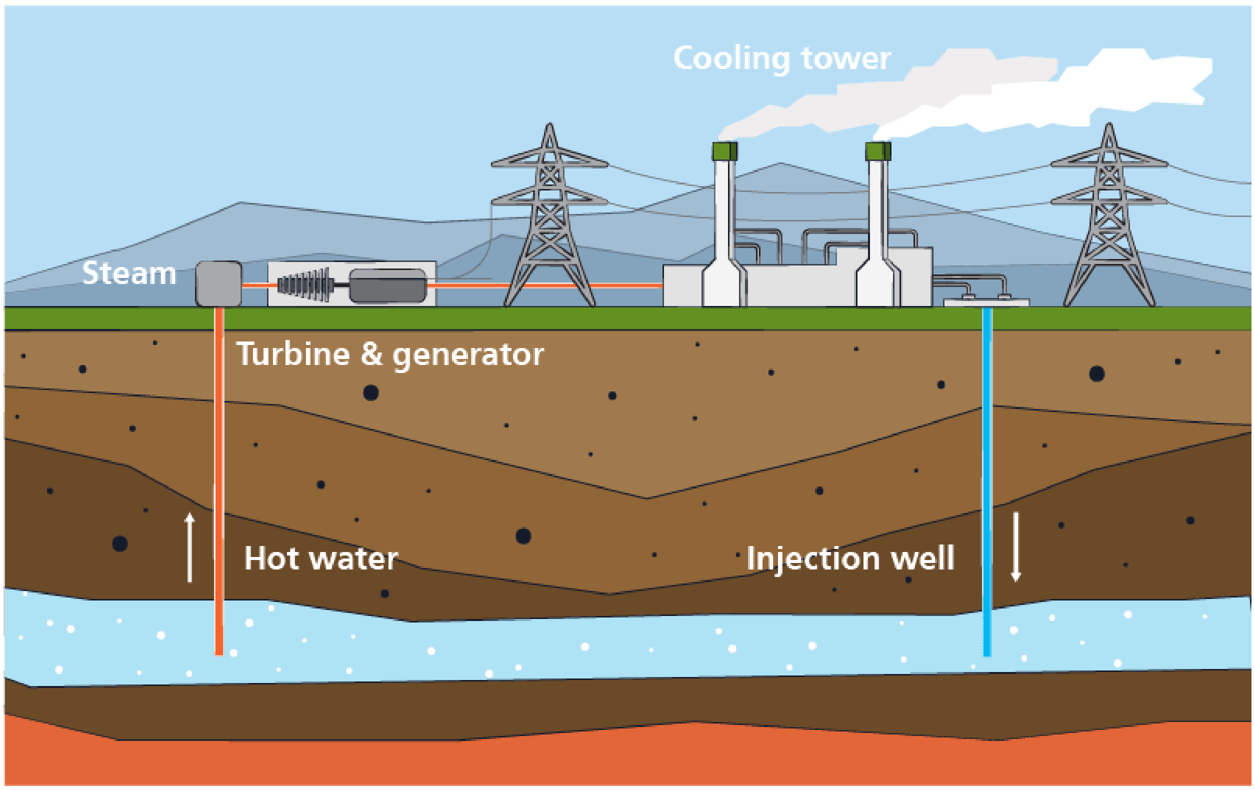

Figure 1.13 Geothermal energy to electricity system

The Geysers steam power plant in California is the oldest and largest geothermal power plant in the world, with a capacity of 2000 MW. Hot-water plants have been developed more recently and are now the major source of geothermal power in the world [25].

Geothermal heat pumps do not generate electricity, but they reduce the consumption of electricity by using heat exchangers and the constant temperature of the earth several feet under the ground to heat or cool indoor air. The market for geothermal heat pumps has been growing rapidly and expectations are that they will soon reach the level of installation on more than 400000 homes and commercial buildings per year [26].

1.3 Conclusion

Within the broad variety of technologies that constitute renewable energy, some are already making large inroads in the marketplace. Other technologies, perhaps those most beneficial to a sustainable future, are further from commercialization. Most, however, are progressing more quickly than ever; there are no technical obstacles for renewable energy. Renewable energy is a force today and will be a major force in the worlds future—the only question is when. The answer will depend only on the will of the people for clean energy—or the next major political disruption in the Middle East.

Chapter II

GNERAL INFORMATION ON SMART GRID

2.1 Introduction

Smart grid is the integration of advanced information, communication and networking technologies in traditional electric grid to make it smarter and faster in making decisions. This integration will bring more automation, reliability of electrical services, safety of electrical equipment and hence increases in consumer comfort level. Smart grid has applications in generation, transmission, distribution, and consumption of electrical energy. Smart grid technology enables distributed power generation, where power can be generated locally, use the required energy and save the power by implementing smart energy management system.

2.2 Defining Smart Grid Concept

It would be quite difficult to draw a clear distinction between a "smart grid" and a regular grid. Therefore, it is much more practical to consider "smart grid" as a term that enables the opportunities for improving power system operation.

Figure 2.1 Basic structure of smart grid.

The term Smart Grid was coined by Andres E Carvallo on April 24, 2007 at an IDC (International Data Corporation) energy conference in Chicago, where he presented the Smart Grid as the combination of energy, communications, software and hardware. His definition of a Smart Grid is that it is the integration of an electric grid, a communications network, software, and hardware to monitor, control and manage the creation, distribution, storage and consumption of energy. The 21st century Smart Grid reaches every electric element, it is self-healing, it is interactive, and it is distributed [3].

In general, the 'Smart Grid' can be defined as 'a system of systems'. It is a platform that enables functioning of different technologies and systems. It can be viewed as a better electricity delivery infrastructure. A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it - generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies [27].

Here are some other definitions of the Smart Grid:

- A power system that contains multiple automated transmission and distribution (T&D) systems, all operating in a coordinated, efficient, and reliable manner.
- A power system that serves millions of customers and has an intelligent communications infrastructure, enabling the timely, secure, and adaptable information flow, needed to provide power to the evolving digital economy.

The smart grid is a broad collection of technologies that delivers an electricity network that is flexible, accessible, reliable and economic. Smart grid facilitates the desired actions of its users and these may include distributed generation, the deployment of demand management and energy storage systems or the optimal expansion and management of grid assets [28].

The Smart Grid will be characterized by a two-way flow of electricity and information to create an automated, widely distributed energy delivery network. It incorporates into the grid the benefits of distributed computing and communications to deliver real-time information and enable the near instantaneous balance of supply and demand at the device level [30].

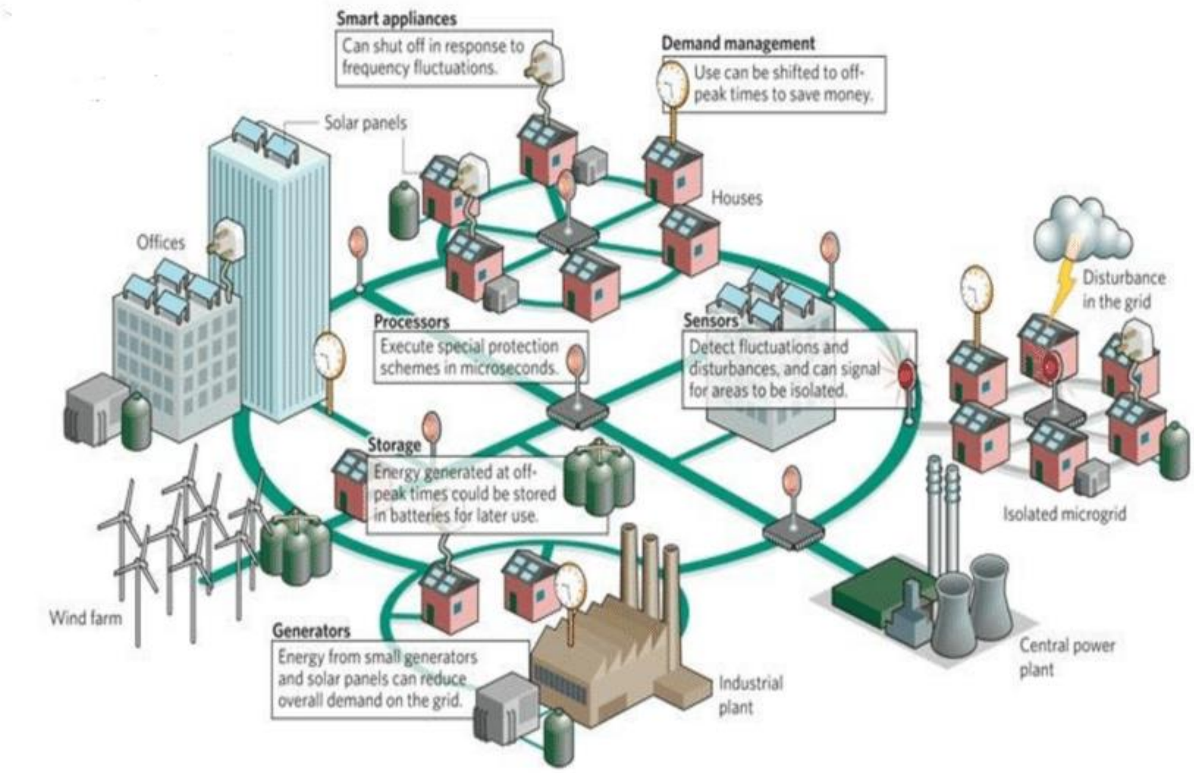

Figure 2.2 Detailed Smart Grid structure.

After analyzing the definitions stated above, the following characteristics of the Smart Grids can be distinguished [28]:

• Optimized for best resource and equipment utilization

• Distributed by its structure (assets and information)

• Interactive (customers, retailers, markets)

• Adaptive and scalable (for changing situations)

• Proactive rather than reactive (to prevent emergencies)

• Self-healing (can predict/distinguish/bypass abnormal)

• Reliable and secure (from threats and external)

• Efficient and reliable

• Open for all types and sized of generation

• Environmental friendly (using renewable energy)

• Integrated (monitoring, control, protection, maintenance, DMS, AMI)

2.3 Smart Grid Technologies (SGT)

The US Department of Energy defines the following five fundamental technologies that derive the Smart Grid systems:

• Integrated communications – connecting components to open architecture for real-time information and control, allowing every part of the grid to both talk‘ and listen‘

• Sensing and measurement technologies – to support faster and more accurate response such as remote monitoring, time-of-use pricing and demand-side management

• Advanced components – to apply the latest research in superconductivity, storage, power electronics and diagnostics

• Advanced control methods – to monitor essential components, enabling rapid diagnosis and precise solutions appropriate to any event

• Improved interfaces and decision support – to amplify human decision-making, transforming grid operators and managers quite literally into visionaries when it comes to seeing into their systems [31].

The above written five technologies sum up to make the smart grid more efficient and reliable

than the present grid. Table 1.2 summarizes the difference between the present grid and the smart

grid [32].

Characteristic	Today's Grid	Smart Grid
Enables active participation by consumers	Consumers are uninformed and non participative with power system	Informed, involved and active consumers – demand response and distributed energy resources
Accommodates all generation and storage options	Dominated by central generation – many obstacles for distributed energy resources interconnection	Many distributed energy resources with plug and play convenience focus on renewable
Enables new products, services, and markets	Limited wholesale markets, not well integrated – limited opportunities for consumers	Mature wholesale markets, growth of new electricity markets for consumers
Provides power quality for the digital economy	Focus on outages – slow response to power quality issues	Power quality is a priority with a variety of quality/price options – rapid resolution of issues
Optimizes asset utilization and operate efficiently	Little integration of operational data with asset management – business process	Greatly expanded data acquisition of grid parameters – focus on prevention minimizing impact to consumers
Anticipates & responds to system disturbances (self-heals	Responds to prevent further damage – focus is on protecting assets following faults	Automatically detects and responds to problems – focus on prevention, minimizing impact to consumer
Operates resiliently against attack and natural disaster	Vulnerable to malicious acts of terror and natural disasters	Resilient to attack and natural disasters with rapid restoration capabilities

Table 2.1 Today's grid and Smart grid [32]

Smart grid technologies allow us to manage energy usage and save money by giving the liberty to choose when and how to use our electricity, when and who that I buy from or sell to electricity. It is the feature of the technology that allows us to optimize the integrated demand-supply chain use of electricity. A yearlong study by the U.S. Department of Energy showed that real-time pricing information provided by the smart meter help consumers reduce their electricity costs 10% on average and 15% on peak consumption [31].

2.4 COMMUNICATIONS TECHNOLOGIES AVAILABLE FOR SMART GRIDS

The grid as it exists today was originally designed more than fifty years ago, long before the creation of computer and telecommunication systems that we rely on today. The pressure that our increased power-needs exercise on the grid is shown through interruption of service and occasional blackouts, which pose significant economic and safety threats to our society. Smart grids have the potential to offer a number of advances, including some that automatically monitor and evaluate grid conditions, and report these conditions back to the utility‘s control room when they occur. Devices on the network can communicate with each other to automate rerouting and switching to avoid power lines with faults, and detect and even repair faults in wires before they lead to outages.

The smart grid also introduces a new level of communication between the consumer and the power suppliers. The current interface between the suppliers and the customer is the meter, which has remained basically the same, technologically-speaking, for the past century, and cannot communicate information to or from the consumer. Smart grids, however, allow power companies and consumers to gather precise information about the quantity and timing of household consumption, and enable consumers to receive information, such as real-time pricing and emergency grid requests to lower energy consumption [33].

Different communications technologies supported by two main communications media, i.e., wired and wireless, can be used for data transmission between smart meters and electric utilities. In some instances, wireless communications have some advantages over wired technologies, such as low cost infrastructure and ease of connection to difficult or unreachable areas. However, the nature of the transmission path may cause the signal to attenuate. On the other hand, wired solutions do not have interference problems and their functions are not dependent on batteries, as wireless solutions do.

Basically, two types of information infrastructure are needed for information flow in a smart grid system. The first flow is from sensor and electrical appliances to smart meters, the second is between smart meters and the utility's data centers. As suggested in [35], the first data flow can be accomplished through power line communication or wireless communications, such as ZigBee, 6LowPAN, Z-wave and others. For the second information flow, cellular technologies or the Internet can be used. Nevertheless, there are key limiting factors that should be taken into account in the smart metering deployment process, such as time of deployment, operational costs, the availability of the technology and rural/urban or indoor/outdoor environment, etc. The technology choice that fits one environment may not be suitable for the other. In the following, some of the smart grid communications technologies along with their advantages and disadvantages are briefly explained. An overview of smart grid communication technologies can be found in Table I.

2.4.1 ZigBee

ZigBee is a wireless communications technology that is relatively low in power usage, data rate, complexity and cost of deployment. It is an ideal technology for smart lightning, energy monitoring, home automation, and automatic meter reading, etc. ZigBee and ZigBee Smart Energy Profile (SEP) have been realized as the most suitable communication standards for smart grid residential network domain by the U.S National Institute for Standards and Technology (NIST) [36].

2.4.2 Wireless Mesh

A mesh network is a flexible network consisting of a group of nodes, where new nodes can join the group and each node can act as an independent router. The self-healing characteristic of the network enables the communication signals to find another route via the active nodes, if any node should drop out of the network. Especially, in North America, RF mesh based systems are very popular. In PG&E's Smart Meter system, every smart device is equipped with a radio module and each of them routes the metering data through nearby meters. Each meter acts as a signal repeater until the collected data reaches the electric network access point. Then, collected data is transferred to the utility via a communication network [37].

2.4.3 Cellular Network Communication

Existing cellular networks can be a good option for communicating between smart meters and the utility and between far nodes. The existing communications infrastructure avoids utilities from spending operational costs and additional time for building a dedicated communications infrastructure. Cellular network solutions also enable smart metering deployments spreading to a wide area environment. 2G, 2.5G, 3G, WiMAX and LTE are the cellular communication technologies 4 available to utilities for smart metering deployments. When a data transfer interval between the meter and the utility of typically 15 minutes is used, a huge amount of data will be generated and a high data rate connection would be required to transfer the data to the utility [39].

2.4.4 Power Line Communication

Power line communication (PLC) is a technique that uses the existing power lines to transmit high speed (2 - 3 Mbps) data signals from one device to the other. PLC has been the first choice for communication with the electricity meter due to the direct connection with the meter [37] and successful implementations of AMI in urban areas where other solutions struggle to meet the needs of utilities. PLC systems based on the LV distribution network have been one of the research topics for smart grid applications in China [38]. In a typical PLC network, smart meters are connected to the data concentrator through power lines and data is transferred to the data center via cellular network technologies. For example, any electrical device, such as a power line smart transceiver-based meter, can be connected to the power line and used to transmit the metering data to a central location [39].

2.4.5 Digital Subscriber Lines

Digital Subscriber Lines (DSL) is a high speed digital data transmission technology that uses the wires of the voice telephone network. It is common to see frequencies greater than 1 MHz through an ADSL enabled telephone line [34]. The already existing infrastructure of DSL lines reduces installation cost. Hence, many companies chose DSL technology for their smart grid projects [34].

2.5 SMART GRID COMMUNICATIONS REQUIREMENTS

The communication infrastructure between energy generation, transmission, and distribution and consumption requires two-way communications, inter-operability between advanced applications and end-to-end reliable and secure communications with low-latencies and sufficient bandwidth [49]; Moreover, the system security should be robust enough to prevent cyber-attacks and provide system stability and reliability with advanced controls. In the following, major smart grid communication requirements are presented.

2.5.1 Security

Secure information storage and transportation are extremely vital for power utilities, especially for billing purposes and grid control [47]. To avoid cyber-attacks, efficient security mechanisms should be developed and standardization efforts regarding the security of the power grid should be made.

2.5.2 System Reliability, Robustness and Availability

Providing the system reliability has become one of the most prioritized requirements for power utilities. Aging power infrastructure and increasing energy consumption and peak demand are some of the reasons that create unreliability issues for the power grid [50]. Harnessing the modern and secure communication protocols, the communication and information technologies, faster and more robust control devices, embedded intelligent devices (IEDs) for the entire grid from substation and feeder to customer resources, will significantly strengthen the system reliability and robustness [50].

The availability of the communication structure is based on preferred communication technology. Wireless technologies with constrained bandwidth and security and reduced installation costs can be a good choice for large-scale smart grid deployments [48]. On the other hand, wired technologies with increased capacity, reliability and security can be costly [48]. To provide system reliability, robustness and availability at the same time with appropriate installation costs, a hybrid communication technology mixed with wired and wireless solutions can be used.

2.5.3 Scalability

A smart grid should be scalable enough to facilitate the operation of the power grid [40]. Many smart meters, smart sensor nodes, smart data collectors, and renewable energy resources are joining the communications network. Hence, smart grid should handle the scalability with the integration of advanced web services, reliable protocols with advanced functionalities, such as self-configuration, security aspects.

2.5.4 Quality of Service (QoS)

The communication between the power supplier and power customers is a key issue of the smart grid. Performance degradation like delay or outage may compromise stability, therefore, a QoS mechanism must be provided to satisfy the communications requirements (for example high speed routing) and a QoS routing protocol must be applied in the communications network. This incurs two important questions unique to smart grid:

• How to define the QoS requirement in the context of smart grid.

• How to ensure the QoS requirement from the home appliance in the communications network. To answer the first question, the detailed mechanism of power price, based on the dynamics of the load must be investigated.

Then, a reward system is built for the home appliance based on the power price and the utility function of the appliance, thus obtaining the impact of delay and outage on the reward of the home appliance. Finally, the QoS requirement is derived by optimizing the reward [51]. To answer the second question, routing methodologies meeting the derived QoS requirement are focused on. Due to the requirements of high computing and storage capabilities imposed by the heterogeneity of the smart grid, multiple QoS-aware routing within multiple (more than 2) constraints must be considered (for example a greedy algorithm with K-approximation, where K is the number of constraints) [51].

A QoS requirement usually includes specifications, like average delay, jitter and connection outage probability. To derive the QoS requirement, it is important to describe the probabilistic dynamics of the power system, to evaluate the impact of different QoS specifications on the smart grid system and to derive the QoS requirement from the corresponding impact. The power price is typically determined by locational margin price (LMP) [52] driven by the load that varies with time.

A constrained optimization problem can be used to derive the LMP from the load and other parameters, where the Lagrange factors of the constraints are considered as prices. To efficiently link together the large number of smart grid components, a powerful data communications infrastructure will be provided. It is expected that part of this infrastructure will make use of the power distribution lines themselves as communications carriers using PLC technology [53]. It is also expected to have a combination of wireless technologies to establish a reliable communications infrastructure. Also, recent standardization efforts under the umbrella of IEEE (P1901.2), ITU (ITU-G.hnem), and others are dedicated to PLC technology for Smart Grid applications.

One of the challenges of employing PLC in power distribution grids is multi-hop transmission message routing. The basic idea is that network nodes, i.e., PLC enabled devices, act as repeaters of messages in order to achieve sufficient coverage [54], [55]. The focus in these two previous studies is on reliable delivery of messages taking into account unpredictable and possible sudden changes of communications links and network topology. In this regard, for flooding of messages, the concept of single-frequency network (SFN) transmission is presented in [54], [55]. In [56],

The problem of routing in PLC networks is revised taking into account that network nodes are static and thus, their location is known a priori. In other words, the nodes know in which direction a message is intended to flow. More specifically, if a node receives a packet it can decide whether to forward it or not. Such routing algorithms are known as geographic routing in the wireless communications literature [57], where they have been applied mainly in the context of wireless sensor networks. These algorithms present high performance for the application at hand: they close the gap between flooding on the one hand and improved shortest path routing on the other.

In [58], the implementation of a smart monitoring system over a wireless sensor network is presented, with particular emphasis on the creation of a solid routing infrastructure through the routing protocol for low-power and lossy networks (RPL), whose definition is currently being discussed within the IETF ROLL working group. RPL was designed in order to match the requirements of networks characterized by low power supplies and by deployment in lossy environments.

This involves both wired and wireless networks deployed in difficult environments, where the presence of high interference requires adaptive and reconfigurable network operations. In [59] a hybrid routing protocol that combines local agility with centralized control is presented. It meets the requirements of robust collection, point-to-point communication, and low footprint. It uses a distributed algorithm to form a Directed Acyclic Graph (DAG) for routing data from in-network nodes to border routers, allowing nodes to maintain multiple options that are ranked through data-driven link estimation.

2.6 Conclusion

The smart grid has been conceived as an evolution of electric power systems due to the increasing diffusion of distributed generation by renewable sources, but with the additional aim to enhance efficiency, reliability and safety of the existing power grid. To this end, remote and timely information gathering about equipment failures, capacity limitations, and natural accidents is extremely critical for ensuring proactive and real-time and reliable diagnosis of possible failures in the smart grid. This makes cost-effective remote sensing technologies vital for safe, seamless and efficient power delivery in the smart grid.

Chapter III

Routing Techniques and System Design

3.1 Introduction

In this chapter we are going to discuss the infrastructure of our basic project system that's contains two important layers: Communication, that concerns the interaction for cooperate work and the second layer is Smart system, evaluate the changes for choosing the most affordable decision. Our software called "Control and optimization software of energy consumptions in smart grids" or "COSECinSGs" for short or smart distributor if that name is available, this software will be able to manage a client's data, buy /sell power to other clients in a reliable and robust manner.

3.2 Communication Layer

The communication is very essential for a multi agent system that is appear in cooperate work it means nodes in this system evolve together. To achieve this valuable characteristic a communication between nodes is obliged.

This system simulate the notion of Internet of Things, which envisions hundreds or thousands of end-devices with sensing, actuating, processing, and communication capabilities able to be connected to the Internet [60].

These devices can be directly connected using cellular technologies such as 2G/3G/Long Term Evolution and beyond (5G) or they can be connected through a gateway, forming a local area network, to get connection to the Internet. The latter is the case where the end-devices usually form Machine to Machine (M2M) networks using various radio technologies, such as ZigBee (based on the IEEE 802.15.4 Standard), Wi-Fi (based on the IEEE 802.11 Standard), 6LowPAN over ZigBee (IPv6 over Low Power Personal Area 1 ISSN: 2331-4753 (Print) ISSN: 2331-4761 (Online) Networks), or Bluetooth (based on the IEEE 802.15.1). Regardless the specific wireless technology used to deploy the M2M network, all the end-devices should make their data available to the Internet [61].

This can be achieved either by sending the information to a proprietary web server accessible from the Internet or by employing the cloud. Online platforms such as ThingSpeak.com or Open.Sen.se, among any other alternatives, are virtual clouds able to receive, store, and process data. Besides acting as remote databases, M2M clouds also offer the following key services:

1. They offer Application Programming Interfaces (API) with built-in functions for end-users, thus providing the option to monitor and control end-devices remotely from a client device.
2. They act as asynchronous intermediate nodes between the end-devices and final applications running on devices such as smart phones, tablets or desktops. Our paper focuses on the protocols that handle the communication between the gateways, the public Internet, and the final applications (Figure 1).

They are application layer protocols that used to update online servers with the latest end-device values but also to carry commands from applications to the end-device actuators.

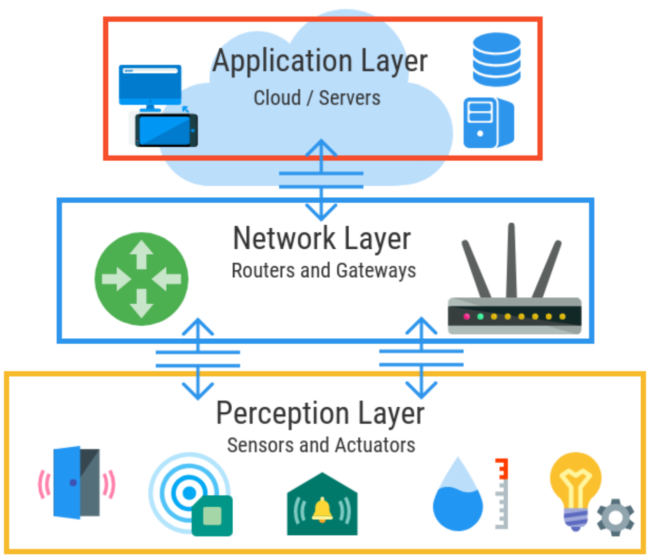

Figure 3.1 Internet of Things architecture.

3.2.1 Introduction to Photon API

Photon is an application programming interface API that is specialized in managing the network side of applications, Photon is considered to be the world's first independent cross-platform network engine, Photon is used by small software development teams to global giants [62].

Depending on the engine, framework or platform used in the software development Photon provides multiple software development kits SDKs to suit the developers needs [62].

The supported engines, frameworks or platforms are:

.NET , Android , Cocos2d-x , Construct 2 , Corona , Emscripten, HTML5,IOS,Linux,MacOS X, Magic Leap , Nintendo Switch , Playstation 4, PS Vita , tvOS , Unity , Unreal Engine , V-Play / Qt , WebGL , Windows , Windows Store , Xamarin , Xbox One [63]

Each one of these can profit from the use of one or many of the available Photon SDKs such as:

REALTIME, PUN, BOLT, Quantum, Photon CHAT, Photon VOICE, Photon SERVER [63].

3.2.2 Photon PUN 2

The Photon PUN 2 is the second and most recent version (2019/2020) of the Photon PUN SDK, which is an SDK compatible with the development environment of the “COSECinSGs” software, which is the Unity3D game engine. This SDK is free for testing and educational purposes as it supports only 20 concurrent users across the network.

The Photon PUN2 SDK links the Unity 3D environment to the Photon networking services.

Like any software development kit, the PUN2 SDK comes with many libraries that serves to ease the networking process [62].

3.2.3 Photon used Classes

3.2.3.1 Photon View

The Photon View component is a component added to the client object, it manages the client's parameters updates through what is called Remote Procedural Calls (RPCs) which means the program in a certain computer can call the execution of a procedure in another computer [64].

A Photon View component identifies an object across the network (view ID) and configures how the controlling client updates remote instances [62].

3.2.3.2 Photon Network

Photon Network is the central class of the PUN package, it is used to access the main features of the Photon PUN services, it is used to create rooms, organize clients joining the room and leaving the room and other host related procedures.

A room is the virtual environment where the software’s connection is established, clients in the same room can share data, call RPCs and access other connection features.

3.3 Development Environment

3.3.1 Brief introduction to the Unity 3d Game Engine

Unity 3d is a game engine, which means that it is a game developing software. The unity game engine launched in 2005. The aim of this game engine is to make game development accessible to independent developers and smaller studios. It launched at first for the Mac OS then later extends to other platforms such as Windows and Linux applications and web browsers. The support for making multi-player games was added in 2007, which added the support of using RPCs and other network related protocols [66].

3.3.2 Networking in unity

The reason of using Game engine to make an energy optimization in smart grids system is that a game in general can be very complex and so is this software and also a multiplayer game is very similar to a smart grid system in terms of networking. So by using one of the most popular free game engines we can access the help of the vast community hence rendering the development process very convenient and spare time to add as much features as possible.

Unity introduces developers to its networking solution, which is called Unet. however Unet lacks the support of Host migration as of 2019/2020 but it can be a solid option if running the system on a local area network.

In real life applications cloud servers would be used to control a decent sized network of clients connected to buy and sell power therefor the Photon API was used [67].

3.4 Grid Architecture

3.4.1 Grid Diagram

In order to explain how the optimization and control software of the smart grid is connected we present the following example:

In this example there are 6 clients from client 1 . . . client 6, client 5 is the host, All clients are linked to the Photon servers by running the Photon API, clients can send and receive information form the Photon servers as displayed below:

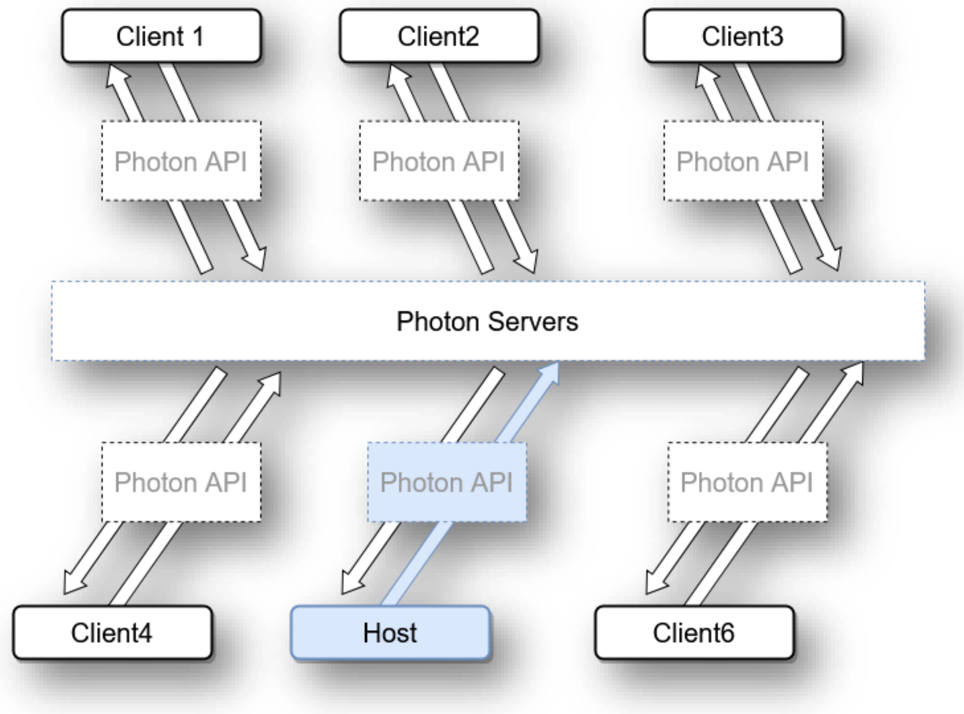

Figure 3.2 Photon API client 5 is the host

3.4.2 Client communication

In this example client 1 wants to send an information to client 6, in order to send the information client 1 sends an RPC using the Photon API to each and every client connected in the grid, alongside the information the target client id is also sent as a parameter for the RPC call.

The Photon API rem using the Photon servers, for each client in the grid the procedure is called but only the client with the same ClientID as the ClientID sent with the RPC call will execute the call , in our case client 6 will execute the procedure with the parameters sent from client 1.

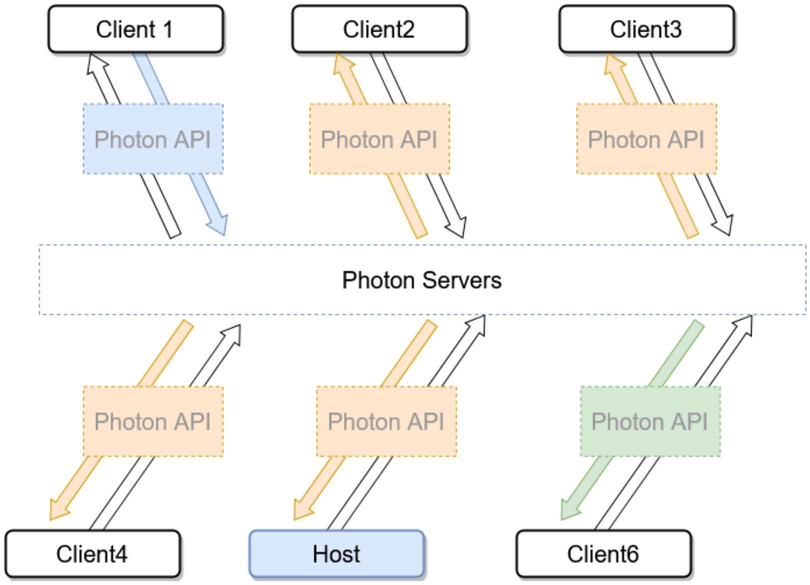

Figure 3.3 client 6 will execute order sent from client 1.

If any feedback is needed client 1 would have to send his Client ID so that when the RPC is called on Client 6, Client 6 will also receive the sender's Client ID and can now send a response in a form of an RPC call with the Client ID of client1 as receiver.

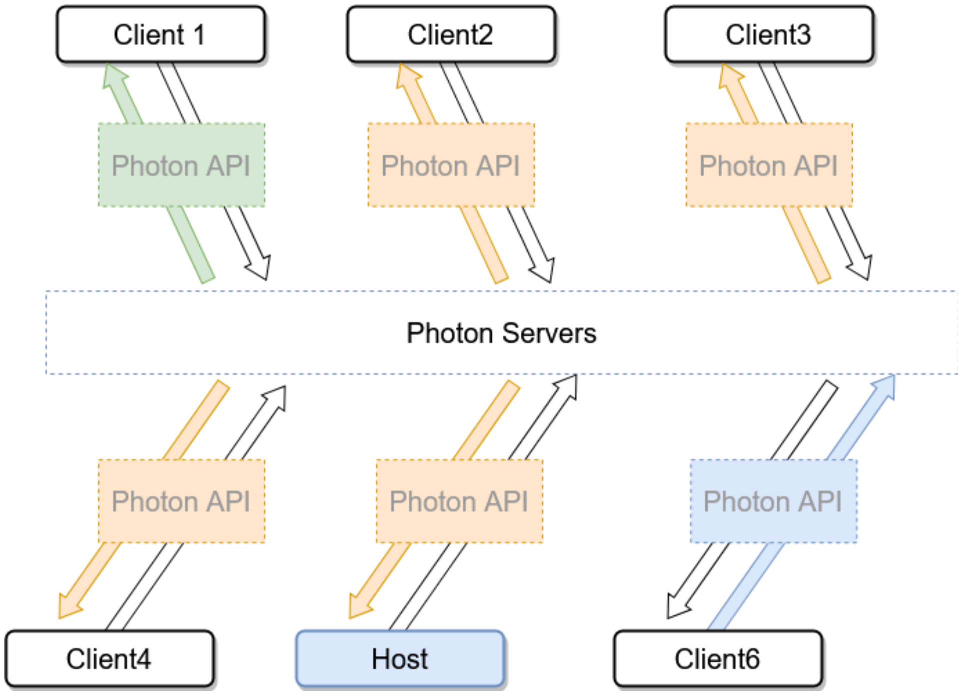

Figure 3.4 Client 1 receives feedback from host.

3.4.3 Host migration

In the Photon API, the Host is a regular Client called the Master Client and will remain a normal client unless given advantages by the developers to have more control on the software over regular clients. But in the case of the optimization and control of energy software there is no difference between the host and the client. Therefore, no advantages given to the host.

The host is chosen at first to be the first client to join the network, as there is no room open and no other client connected yet.

When a host is willingly or unwillingly disconnected from the network the Photon servers detects the absence of the master client and automatically assigns the client with the lowest View ID as master client [65]. lets' say in our case Client 6.

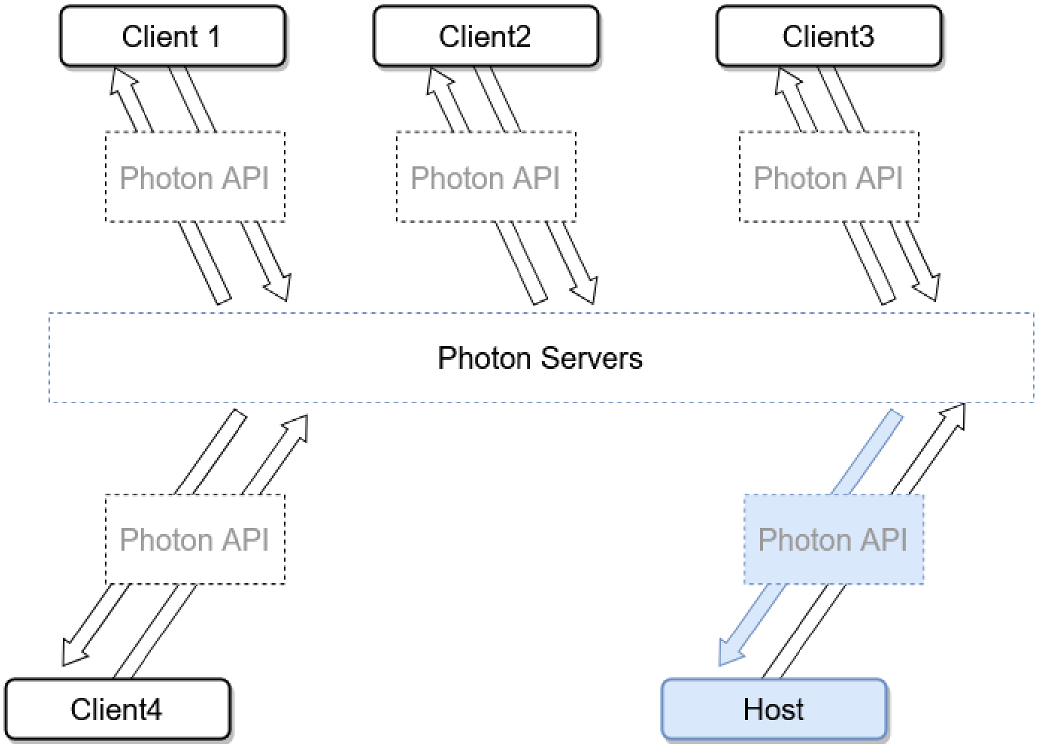

Figure 3.5 The host will change automatically in case of disconnection.

3.4.4 Connection Procedure

Every client in the network must follow certain steps to join the smart grid's network here is a diagram explaining how the procedure will occur:

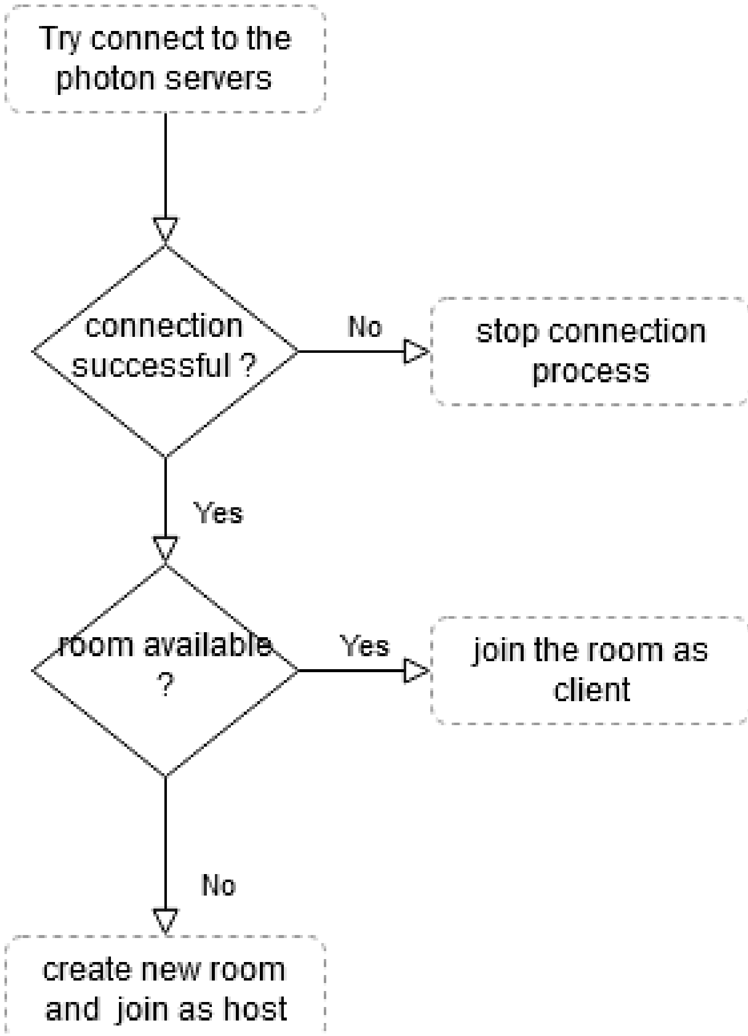

Figure 3.6 the procedure of connecting new client.

3.5 User parameters

3.5.1 User ID

Each user is granted an identification on connection to the network, the user id is composed from the View ID given by the Photon View component, and the User ID is represented as a string.

3.5.2 Available power

The available power parameter represents the amount of power that client has, the available power can be lower than what the client needs, in this case, the client has insufficient power, and a float represents the available power parameter.

3.5.3 Wanted power

The wanted power parameter represents the amount of power the client needs to power its electrical devices, the goal of the system is to keep the wanted power lower than the available power as often as possible, and a float represents the wanted power parameter.

3.5.4 Price

The design of the power optimization system allows users to enter the price wanted to sell a unit of power; a float represents the price parameter.

3.5.5 World position

The world position variable is a representation of the geographic location of the client, this variable used to calculate the power draw over distance, and a 2D vector represents this parameter.

3.5.6 Cable type

The cable type parameter refers to the material of the cable which the client is connected with to other clients is made of, this variable determines the resistivity of the cable, the cable type parameter is represented by a string.

3.6 Power request procedure

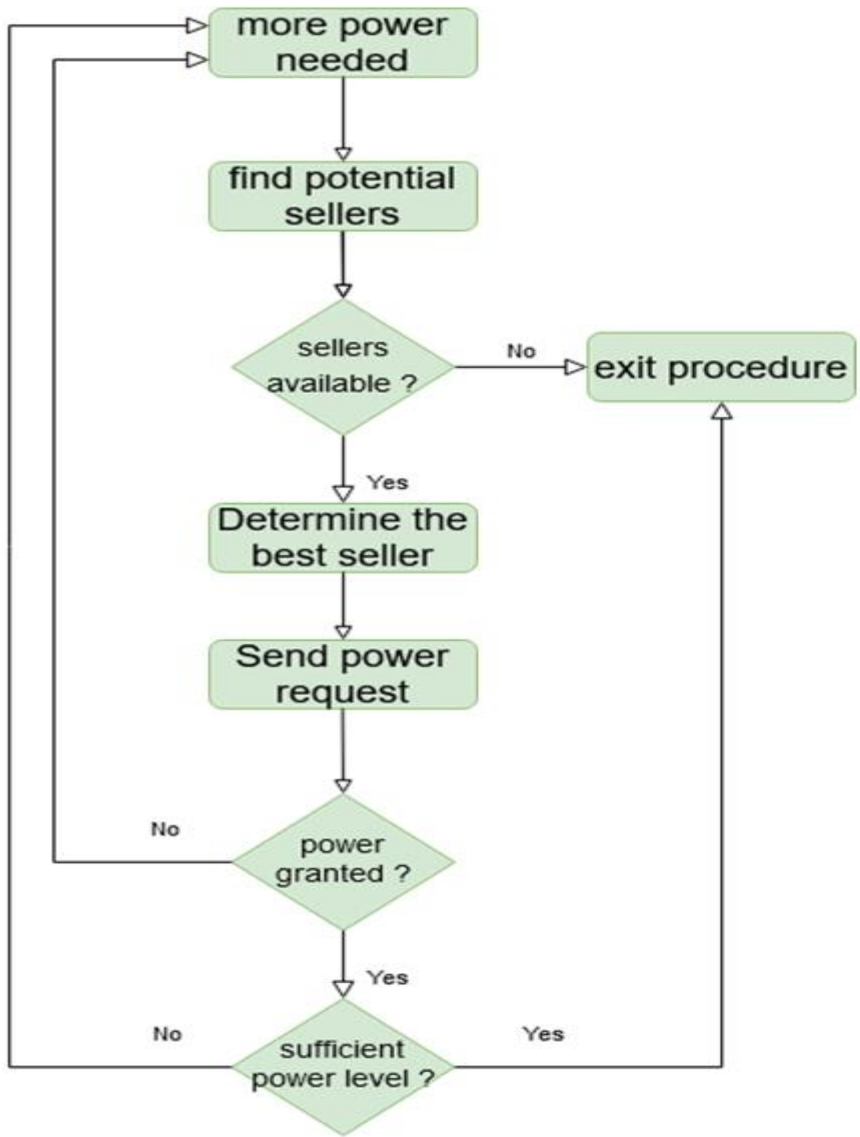

Figure 3.7 Power Distribution Diagram

3.6.1 Finding potential sellers

In this step as the name suggests the client tries to find all the potential sellers available, in order to do that the client counts on his latest update of the other clients data, to be specific their available power and needed power , the clients with a surplus of power will be selected as potential sellers.

3.6.2 Determine the best seller

In order to determine the best seller. The client must take in consideration the sellers prices and distances. As for the price the one with the lowest price is the best however when combined with the distance constraint it becomes that the lowest price isn't necessarily the best option as a client can be paying a small price but for much greater distance

So, for each seller the client will locally calculate the best seller according to their physical distance from the client's location that will help find how much power loss occurs for each seller therefore knowing how much to buy in order to receive the right amount of power that is necessary.

3.6.2.1 Cable resistance over length and material type

In order to determine the resistance of a cable according to it's length and material type we use Claude Pouillet's law [68].

$$R = \frac{rho \times L}{S} \quad \text{......................................} (1)$$

Where:

R: the resistance of the cable (ohm).

rho: the resistivity of the cable's material.

L: length of the cable (meter).

S: cable's section (mm^2).

3.6.2.2 Determining power draw

In order to calculate the power draw over distance we will use Claude Pouillet's formula alongside the electrical energy formula

$$W = R \times I^2 \times t \quad \text{.................................} (2)$$

Where:

W: Energy (joules).

R: Resistance (ohm).

I: intensity (amp).

T: time (seconds).

By applying the following steps:

- calculate the buyer's cable resistance at start using Claude Pouillet's law
- Having the buyer's needed power and cable resistance we calculate the needed intensity using the electric energy formula
- calculate the buyer's cable resistance at the potential seller's distance from the buyer
- Calculate the new energy using the calculated intensity and the newly calculated resistance
- By multiplying the new energy by the seller's price, we can find the best seller
- Send power request and receive power:
- The calculated energy will then be sent as request to the best seller found alongside the buyer's Client ID
- If the seller still has the amount of power needed, the seller then will grant the buyer access to the amount of power and the amount will be subtracted from the seller's available power and added to the buyer's needed power

3.7 Conclusion

We introduced in this chapter a theoretical description of our system of Control and optimization software of energy consumptions in smart grids by the presentation the main infrastructure. This infrastructure consist of Network API represented by Photon API, and we discussed about development environment of Unity, which make simulation quite easy, then we showcased grid architecture and finalized with some user parameters.

Chapter IV

Software Implementation “COSECinSGs”

4.1 Introduction:

We introduce in this chapter a detailed description of our application of Control and optimization software of energy consumptions in smart grids, with the valuation of performance of every stage. We will see how our system handle and respond to different changes in the network.

4.2.1 Hardware and software resources

4.2.1.1 Hardware resources

We used three computers for developing our system with this specs:

Computer	Specs
Dell Vostro 1540	Intel i5 M480 RAM 4G DDR3
Dell Inspiron 15	Intel i5 4210U Ram 8G DDR3
MSI Z170	Intel i5 6600K Ram 8G DDR4 NVidia GTX970

Table 3.1 Hardware Resources

4.2.1.2 Software resources

- Operating system: windows 10 64Bit.
- C sharp is the programming language that we used for developing this software in the unity environment due to this criteria:

Unity is a cross-platform game engine developed by Unity technologies. The engine can be used to create three-dimensional, two-dimensional, virtual reality and **simulations** and other experiences [69].

4.3 Purpose of the system

The current power grid have some problems including that the grid will stop working if the head station had stopped which make all the clients that follows receive no power and the issues that occurs in installing renewable energy solution in the grid which needs to be connected directly to the head station and the cost of this process. In order to solve these problems and much more other we proposed this system.

The idea is to insert the communication to the power grid which make easy to adjust any node through the grid and although the installation of renewable solutions in any position to the grid. This process make any node in the grid independent, which can sell or buy power, let us see how:

4.4 How Software interact

In order to highlight the buying process, we included only two clients to a grid. These two clients one of them is seller and the other is the buyer, every node have an ID, Current Power, Wanted Power and a Price.

The communication starts between the two nodes as shown in the figure bellow:

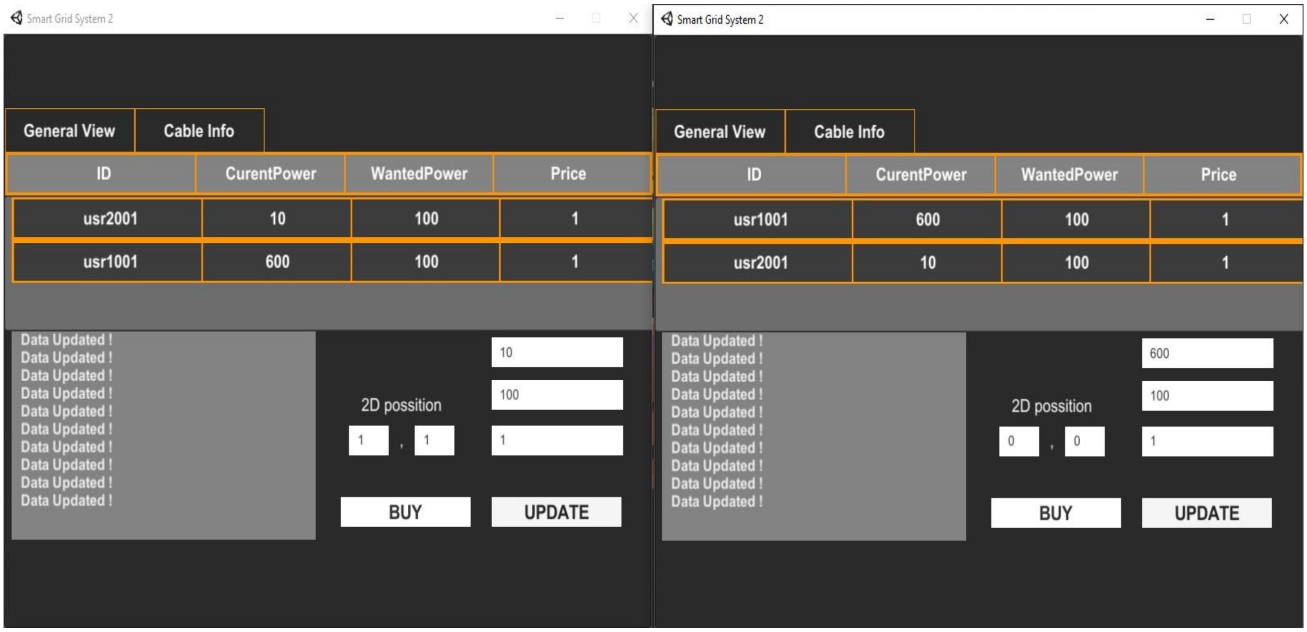

Figure 4.1 the software with two clients connected

Since there is only one seller in the network, it will be chosen as the best seller automatically. After clicking on the “BUY” button power will be requested from the seller and then will be received by the client as is clearly shown in the logs section of each client, we can notice that the power drops when it is delivered to buyer, this is caused by the distance between clients and the cable resistance.

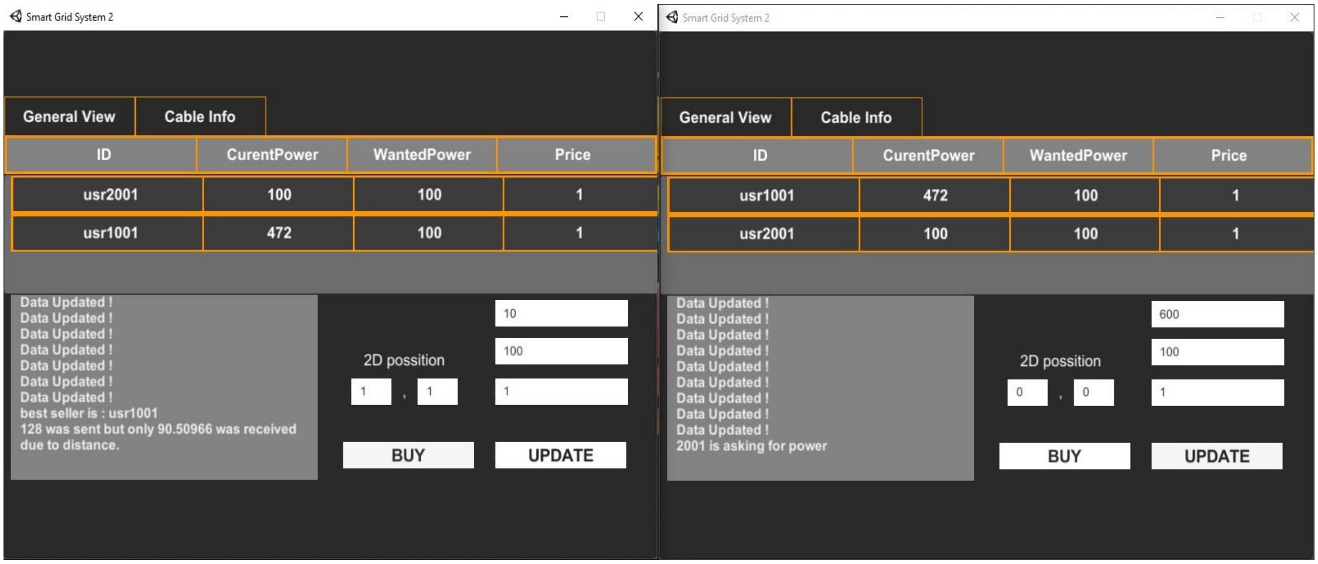

Figure 4.2 the software with two clients connected

In the case where the seller do not have enough power to provide, the buyer takes what is available and stays in a lack of power until the next seller connects.

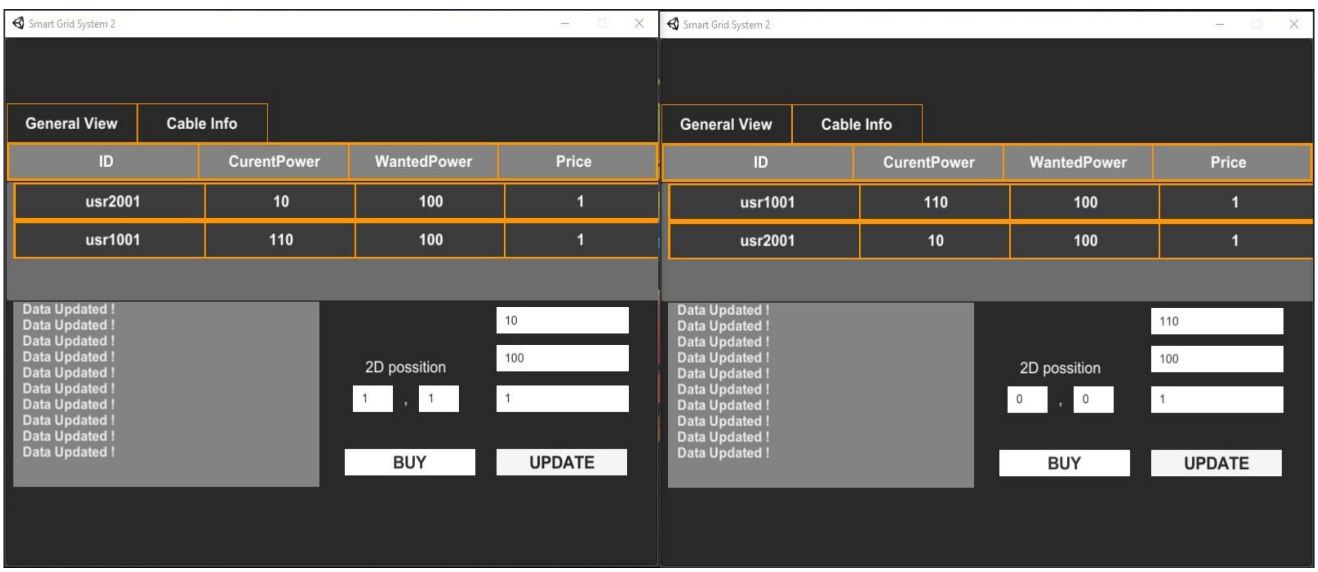

Figure 4.3 the software with two clients connected

After the clicking on the buy button, the following messages will be displayed.

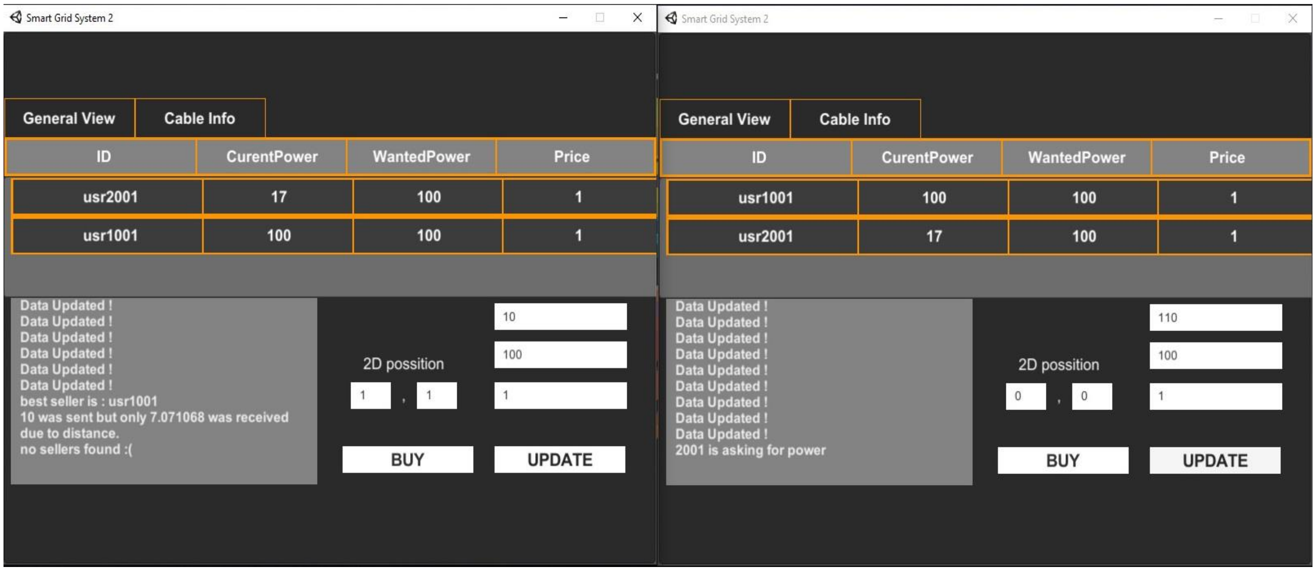

Figure 4.4 the software with two clients connected

In order to demonstrate the influence of pricing on the choice of the best seller, we logged in three clients in the network, two are sellers with different prices and one is the buyer.

Figure 4.5 the software with three clients connected

We can notice in the buyer's messages logs that the first seller is chosen according to the price the it was providing. In the same time the buyer have lack of power which will buy the rest from another client that have power to give and the cheapest price provided.

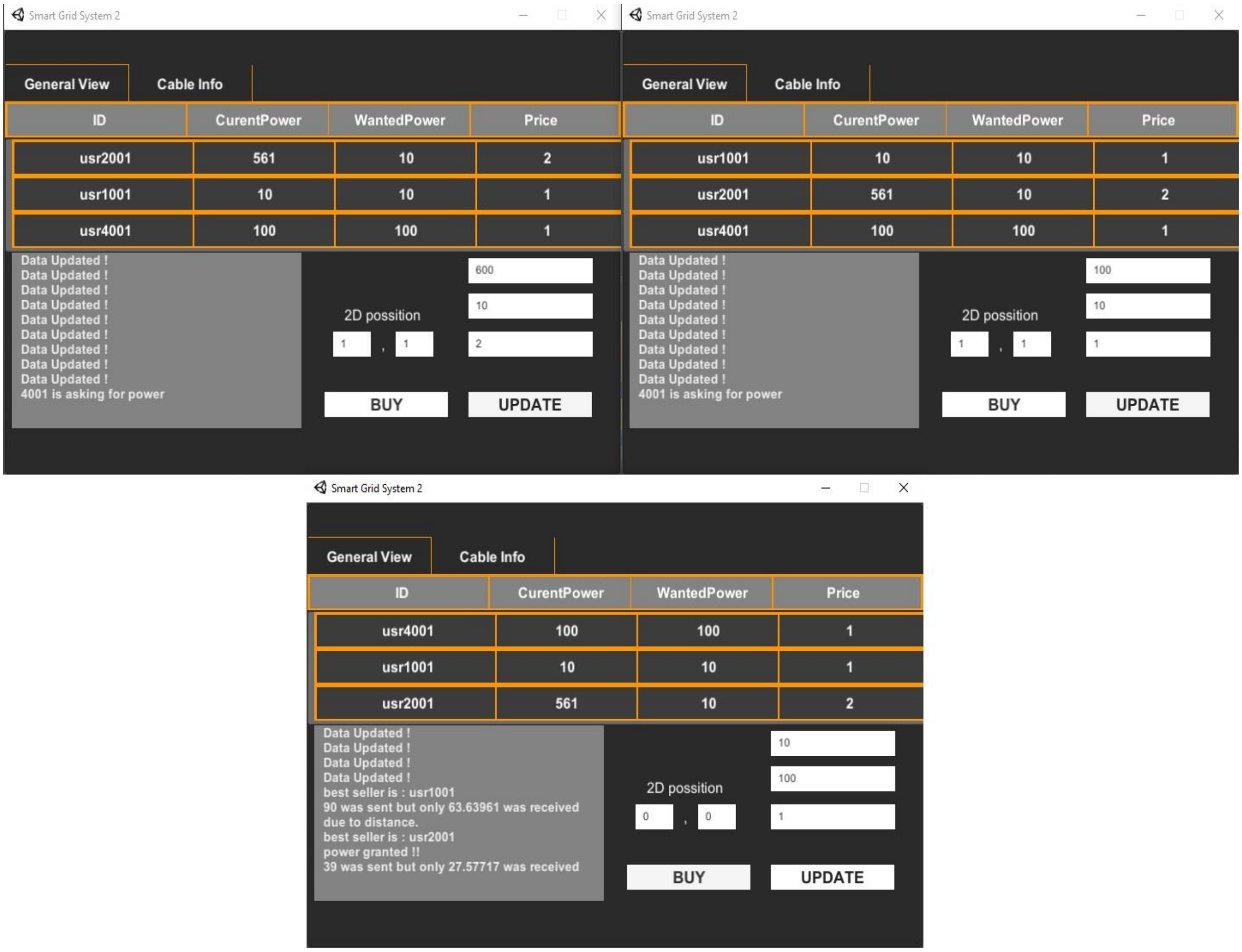

Figure 4.6 the software with three clients connected

In a real-world scenario, power draws over cables, which make cable specifications an important thing to consider. In order to demonstrate 3 clients will be logged in as usual the pricing will be the same, however the 2D position of the sellers will vary from one to another.

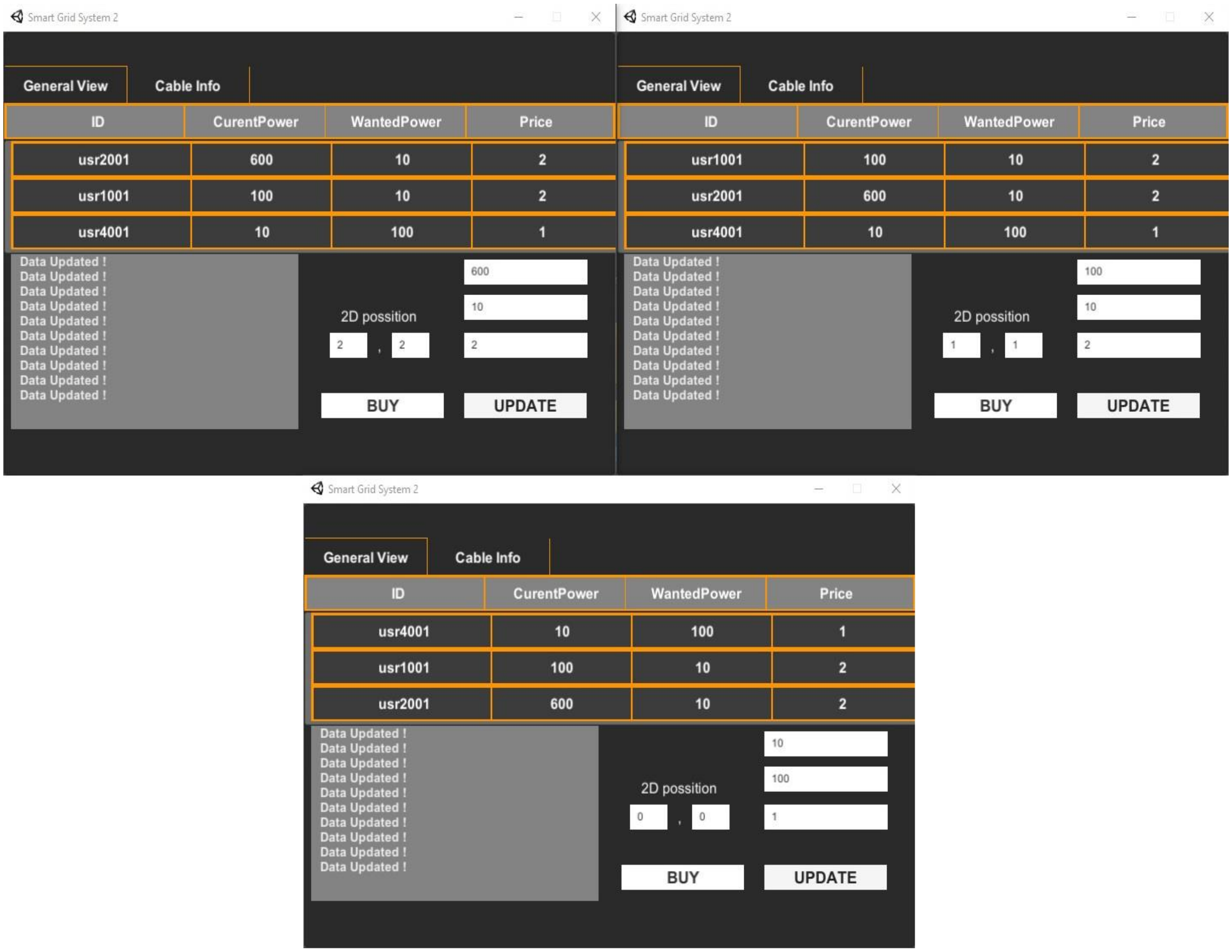

Figure 4.7 the software with three clients connected

After the buying process, we notice in the buyer's logs that the seller with the nearest 2D position was chosen at first and the remaining seller complemented the power lack.

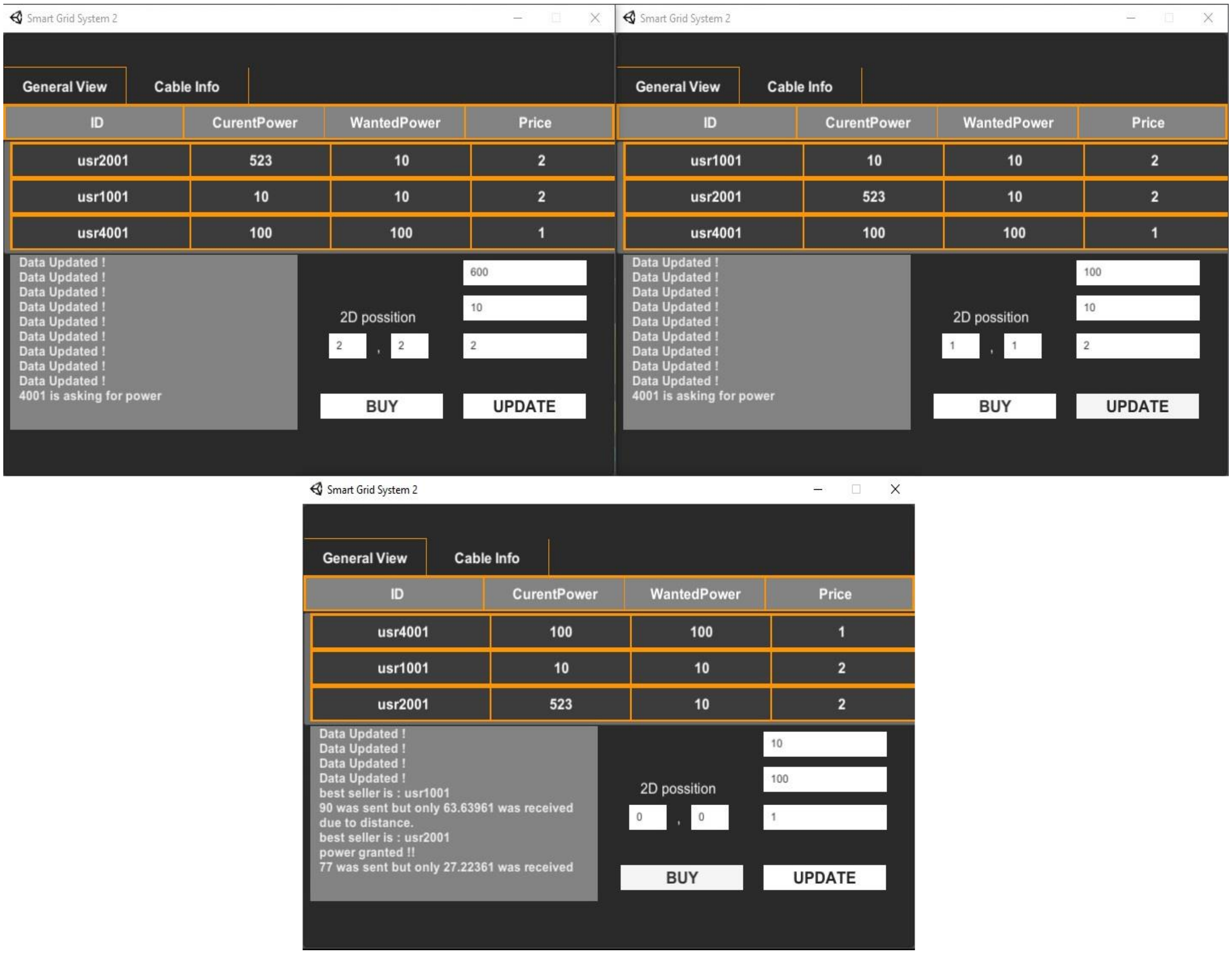

Figure 4.8 the software with three clients connected

Cable type also plays a role in determining the cable's resistance, in this example a seller have copper connections the other have gold connections , both sellers have 1 mm diameter cables:

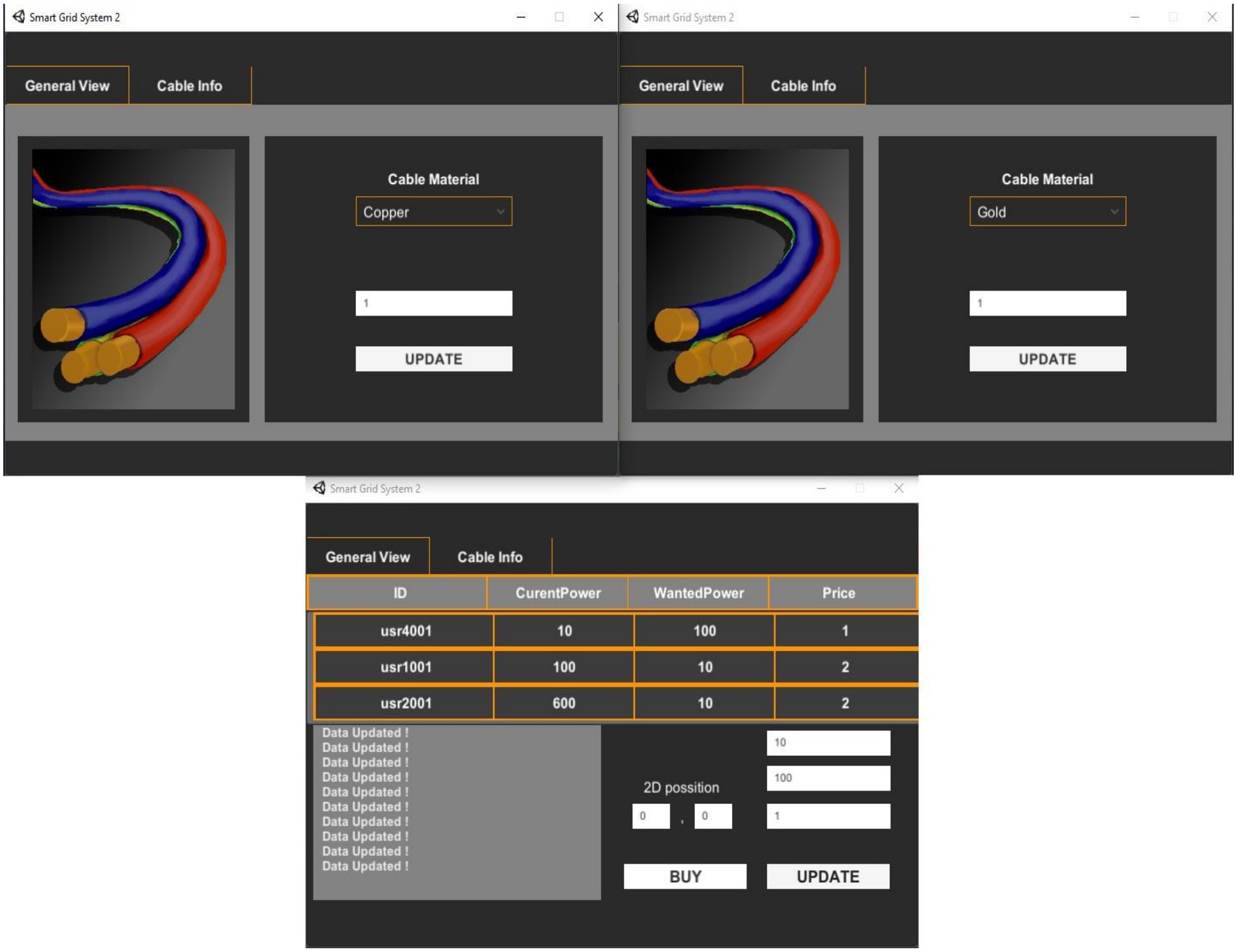

Figure 4.9 the software with three clients connected

After updating the cables data and starting the buying process, we can notice that the first best seller was the one with copper connections because copper is less resistive than gold.

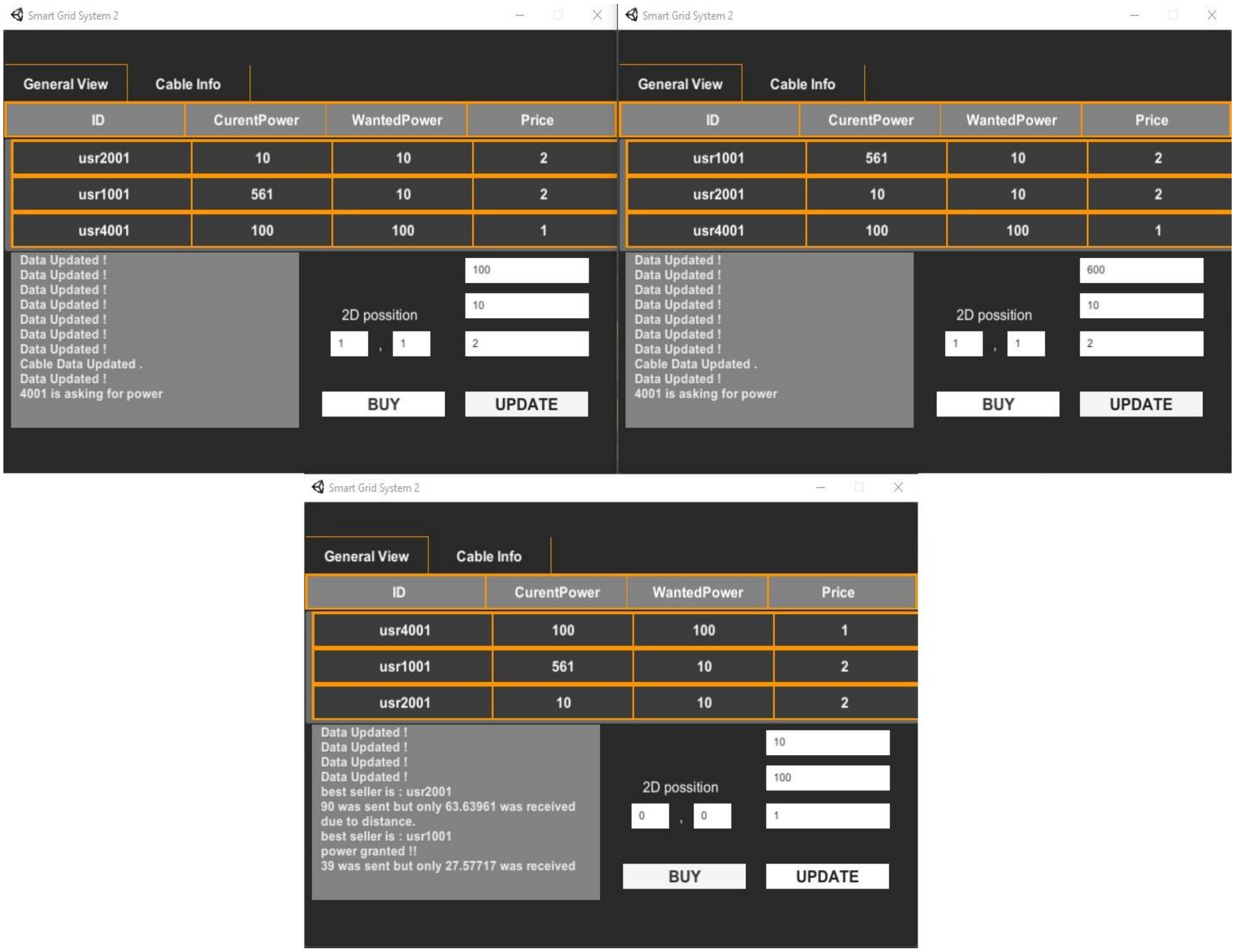

Figure 4.10 the software with three clients connected

3.8 Conclusion

We introduced in this chapter a detailed description of our system of Control and optimization software of energy consumptions in smart grids by the presentation of every case that will make smart grid much smarter. As the experiments chows that the system adapts to all changes that may occur to the grid.

General Conclusion

The goal of this work was to accomplish a smart system that control and optimize the energy usage in a smart grid. As mentioned in the first chapter any renewable energy can be used in this system whether it is solar, wind, bio power or geothermal. Then we highlighted the smart grid design and the importance of moving to a smart grid. After that, we talked about the main features needed in a smart grid ranging from security, availability, scalability and quality of service and mentioned some available communication technologies.

We managed to implement good solutions for making the system available and reliable using the Photon services. Which is a well-known service for networking, it can also scale in user count if a paying networking plan was used as the free Photon PUN plan granted us 20 concurrent users over the network. The quality of service was have took into consideration especially when handling power request delays, power availability and deferent scenarios that can occur during the software's execution as shown in the last chapter.

However, the security side of the project was basic and is in need of some improvements as that in order to accomplish an acceptable security level. A professional service would have been needed as the further development of this project would consist of, connecting between the "OCSECinSGs" and the software that control the electrical side of the smart grid in order to substantiate the variable in our system and try the system in a real world scenario.

Bibliography

Bibliography

[1] “Annual energy outlook 2000,” U.S. Dept. of Energy, DOE/EIA0383(2000), 1999.

[2] World Directory of Renewable Energy Suppliers and Services. London, U.K.: James and James, 1997.

[3] (2000) Annual Energy Review 1999. U.S. Dept of Energy. [Online]. Avalable : http://www.eia.doe.gov/

[4] ‘Renewable Energy Today and Tomorrow’ STANLEY R. BULL, PROCEEDINGS OF THE IEEE, VOL. 89, NO. 8, AUGUST 2001

[5] “Dollars from sense—the economic benefits of renewable energy,” U.S. Dept. of Energy, DOE/GO-10097-261, DE96000543, 1997.

[6] H. Chum, “Two decades of progress in research, development, and commercialization of renewable energy,” in The Enduring Nuclear Fuel Cycle, C. E. Walter, Ed: Amer. Nuclear Soc. Winter Meeting, 1997.

[7] “Climate change 1995: impacts, adaptations, and mitigation of climate change,” in Intergovernmental Panel on Climate Change. Cambridge, U.K.: Cambridge Univ. Press, 1996.

[8] “Technology opportunities to reduce U.S. greenhouse gas emissions,” National Laboratory Directors, [Online]. Available: http://www.ornl.gov/climate_change/climate.htm, 1997.

[9] “Renewing our energy future,” U.S. Congr. Office of Technology Assessment, OTA-ETI-614, 1995.

[10] Weiss, D. R. (2011). Environmental Regulations, Market Structure and Technological Progress in Renewable Energy Technology — A Panel Data Study on Wind Turbines. Spain: Nota Di Lavoro.

[11] Razykov TM, Ferekides CS, Morel D, Stefanakos E, Ullal HS, Upadhyaya HM. Solar photovoltaic electricity: current status and future prospects. Sol Energy 2011;85:1580–608.

[12] Kui-Qing P, Shuit-Tong L. Silicon nanowires for photovoltaic solar energy conversion. Adv Mater 2011;23, [198-21].

[13] Silveira JL, Tuna CE, Lamas WQ. The need of subsidy for the implementation of photovoltaic solar energy as supporting of decentralized electrical power generation in Brazil. Renew Sustain Energy Rev 2013;20:133–41.

[14] Hosenuzzaman M, et al. Global prospects, progress, policies, and environmental impact of solar photovoltaic power generation. Renew Sustain Energy Rev 2015;41:284–97.

[15] Goetzberger A, Hebling C, Schock HW. Photovoltaic materials, history, status and outlook. Mater Sci Eng: R: Rep 2003;40(1):1–46.

[16] Fuentealba E, et al. Photovoltaic performance and LCoE comparison at the coastal zone of the Atacama Desert, Chile. Energy Convers Manag 2015;95:181–6.

[17] Thomas Ackermann , Lennart Soder. An overview of wind energy-status 2002. Royal Institute of Technology, Department of Electric Power Engineering Electric Power Systems, Teknikringen 33, S-10044 Stockholm, Sweden.

[18] [Online]. Wind Energy. https://www.irena.org/wind. accessed: 11 June 2020.

[19] Dallas Lloyd. Wind Energy: Advantages and Disadvantages. December 11, 2014

Submitted as coursework for PH240, Stanford University, Fall 2014.

[20] M.M.Hamilton, “Pumping up the ethanol option, “Washington Post, p. C-1, May 1998.

[21] M. Zhang, C. Eddy, K. Deanda, M. Finkelstein, and S. Picataggio, “Metabolic engineering of a pentose metabolism pathway in ethanologenic zymomonas mobilis,” Science, vol. 267, pp. 240–243, Jan. 1995.

[22] “Office of Transportation Technologies strategic plan,” U.S. Dept. of Energy, 1996.

[23] J. D. McMillan, “Bioethanol production: Status and prospects,” Renew. Energy. vol. 10, no. 2/3, pp. 295–302, 1997.

[24] “Strategic plan for the geothermal energy program,” U.S. Dept. of Energy, DOE/GO-10098-572, 1998.

[25] [Online]. Available : http://www.eren.doe.gov/geothermal. accessed: 10.06.2020.

[26] L. Lamarre, “Heating and cooling,” EPRI J., pp. 24–31, May/June 1998

[27] [Online]. Available: European Technology Platform Smart Grids, http://smartgrids.eu/?q=node/163, accessed: 25.03.2020.

[28] Divya Asija Amity University and Pallavi Choudekar Department Of Electronics And Information Technology India ,OVERVIEW OF SMART GRID SYSTEM, March 2013.

[29] Brown, Howard J. Decentralizing Electricity Production. [ed.] Howard J Brown and Tom Richard Strumolo. s.l. : Yale University Press, 1983. 0300025696, 9780300025699.

[30] Blume, Steven W. Electric Power System Basics. s.l. : Wiley - IEEE, 2007. Vol. 32. 0470129875, 9780470129876.

[31] [Online]. Available: www.doe.gov. US Department of Energy. accessed: 20.05.2020.

[32] [Online]. Available: www.nist.org. National Institute of Standards Technology. accessed: 14.06.2020.

[33] [Online]. Available: www.smartgridnews.com. accessed: 12.04.2020.

[34] D. M. Laverty, D. J. Morrow, R. Best, P. A. Crossley, "Telecommunications for Smart Grid: Backhaul solutions for the distribution network," IEEE Power and Energy Society General Meeting, pp. 1-6, 25-29 July 2010. II, II-E

[35] L. Wenpeng, D. Sharp, S. Lancashire, "Smart grid communication network capacity planning for power utilities," IEEE PES, Transmission and Distribution Conference and Exposition, pp. 1-4, 19-22 April 2010. II

[36] Y. Peizhong, A. Iwayemi, C. Zhou, "Developing ZigBee Deployment Guideline Under WiFi Interference for Smart GridApplications," IEEE Trans. on Smart Grid, vol.2, no.1, pp. 110- 120, March 2011. II-A, II-A1, II-A2

[37] R. P. Lewis, P. Igic and Z. Zhongfu, "Assessment of communication methods for smart electricity metering in the U.K.," in Proc. of IEEE PES/IAS Conference on Sustainable Alternative

[38] M.Y. Zhai, "Transmission Characteristics of Low-Voltage Distribution Networks in China Under the Smart Grids Environment," IEEE Trans. on Power Delivery, vol.26, no.1, pp. 173- 180, Jan. 2011. II-D

[39] V.C. Gungor, D. Sahin, T. Kocak, and S. Ergüt, ‘Smart Grid Communications and Networking,‘ Türk Telekom Technical Report-11316-01, April, 2011.

[40] V.C. Gungor, G. Hancke, "Industrial Wireless Sensor Networks: Challenges, Design Principles, and Technical Approaches," IEEE Trans. on Industrial Electronics, vol. 56, no. 10, pp. 4258- 4265, October 2009. III-C

[41] D. Lu, H. Kanchev, F. Colas, V. Lazarov, B. Francois, "Energy management and operational planning of a microgrid with a PV-based active generator for Smart Grid Applications," IEEE Trans. on Industrial Electronics, Digital Object Identifier: 10.1109/TIE.2011.2119451. I

[42] P. Palensky, D. Dietrich, "Demand Side Management: Demand Response, Intelligent Energy Systems, and Smart Loads," IEEE Trans. on Industrial Informatics, Inf., vol. PP, No. 99, Digital Object Identifier: 10.1109/TII.2011.2158841 I

[43] V. Calderaro, C. Hadjicostis, A. Piccolo, P. Siano, "Failure Identification in Smart Grids based on Petri Net Modeling," IEEE Trans. on Industrial Electronics, Digital Object Identifier: 10.1109/TIE.2011.2109335. I

[44] C. Cecati, C. Citro, P. Siano, “Combined Operations of Renewable Energy Systems and Responsive Demand in a Smart Grid,” IEEE Trans. on Sustainable Energy, in press. Digital Object Identifier: 10.1109/TSTE.2011.2161624. I

[45] P. Siano, C. Cecati, C. Citro, P. Siano, “Smart Operation of Wind Turbines and Diesel Generators According to Economic Criteria,” IEEE Trans. on Industrial Electronics, vol. 58, no. 10, pp.—— (in press) Digital Object Identifier: 10.1109/TIE.2011.2106100. I

[46] A. Vaccaro, G. Velotto, A. Zobaa, "A Decentralized and Cooperative Architecture for Optimal Voltage Regulation in Smart Grids," IEEE Trans. on Industrial Electronics,, Digital Object Identifier: 10.1109/TIE.2011.2143374. I

[47] D. Dietrich, D. Bruckner, G. Zucker, P. Palensky, , "Communication and Computation in Buildings: A Short Introduction and Overview," IEEE Trans. on Industrial Electronics,, vol.57, no.11, pp.3577-3584, Nov. 2010 IV-C

[48] Q. Yang, J. A. Barria, T.C. Green, "Communication Infrastructures for Distributed Control of Power Distribution Networks," IEEE Trans. on Industrial Informatics, vol.7, no.2, pp. 316-327, May 2011. III-A, III-B

[49] T. Sauter, M. Lobashov, "End-to-End Communication Architecture for Smart Grids," IEEE Trans. on Industrial Electronics, vol.58, no.4, pp. 1218-1228, April 2011. III, IV-C

[50] K. Moslehi, R. Kumar, "Smart Grid - a reliability perspective," Innovative Smart Grid Technologies (ISGT), pp.1-8, 19-21 Jan. 2010. III-B

[51] Southern Company Services, Inc., Comments Request for Information on Smart Grid Communications Requirements, July 2010. Available: http://www.alvarion.com/index.php/. III-D

[52] R. Bo, F. Li, ”Probabilistic LMP forecasting considering load uncertainty,” IEEE Trans. on Power Systems, vol. 24, pp. 1279–1289, Aug. 2009. III-D

[53] H. Ferreira, L. Lampe, J. Newbury, T. Swart (Editors), Power Line Communications, John Wiley & Sons, 2010. III-D

[54] G. Bumiller, “Single Frequency Network Technology for Fast ad hoc Communication Networks over Power Lines,” WiKuWissenschaftsverlag Dr. Stein, 2010. III-D

[55] G. Bumiller, L. Lampe, H. Hrasnica, “Power Line Communications for Large-Scale Control and Automation Systems,” IEEE Communications Magazine, vol. 48, no. 4, pp. 106–113, Apr. 2010. III-D

[56] M. Biagi, L. Lampe, “Location Assisted Routing Techniques for Power Line Communication in Smart Grids,” in Proc. of IEEE Int. Conf. on Smart Grid Communications, pp. 274 - 278, 2010. III-D

[57] J. Sanchez, P. Ruiz, R. Marin-Perez, “Beacon-less geographic routing made partical: Challenges, design guidelines and protocols,” IEEE Communications Magazine, vol. 47, no. 8, pp. 85–91, Aug. 2009. III-D

[58] N. Bressan, L. Bazzaco, N. Bui, P. Casari, L. Vangelista, M. Zorzi, “The Deployment of a Smart Monitoring System using Wireless Sensors and Actuators Networks,” in Proc. of IEEE Int. Conf. on Smart Grid Communications (SmartGridComm), pp. 49 - 54, 2010. III-D

[59] S. Dawson-Haggerty, A. Tavakoli and D. Culler, “Hydro: A Hybrid Routing Protocol for Low-Power and Lossy Networks,” in Proc. of IEEE International Conference on Smart Grid Communications (SmartGridComm), pp. 268 - 273, 2010. III-D

[60] Tasos Kaukalias and Periklis Chatzimisios, Internet of Things (IoT) C Enabling technologies, applications and open issues, Encyclopedia of Information Science and Technology (3rd Ed.), IGI Global Press, 2014.

[61] Periklis Chatzimisios, Industry Forum & Exhibition Panel on Internet of Humans and Machines, IEEE Global Communications Conference (Globecom 2013), Atlanta, USA, December 2013.

[62] [Online]. Available: Photon documentation https://doc.photonengine.com/en-us accessed: 15.04.2020.

[63] [Online]. Available Photon documentation https://www.photonengine.com/en-US/sdks# accessed: 16.04.2020.

[64] A tutorial on ONC RPC by Dr. Dave Marshall of Cardiff University

[65] [Online].Available: Photon documentation – Master Client and Host migration https://doc.photonengine.com/en-us/pun/current/gameplay/hostmigration accessed: 27.05.2020.

[66] [Online]. Available: Unity User manual https://docs.unity3d.com/Manual/index.html accessed: 05.05.2020.

[67] [Online]. Available: Unity networking manual https://docs.unity3d.com/Manual/UNet.html accessed: 10.06.2010.

[68] Lowrie, William (2007). Fundamentals of Geophysics. Cambridge University Press. accessed: 19.06.2020.

[69] [Online]. Available: https://en.m.wikipedia.org/wiki/Unity (game engine) accessed: 20.06.2020.