

**T.C.
ISTANBUL GEDİK UNIVERSITY
INSTITUTE OF GRADUATE STUDIES**



**DESIGN, PLANNING AND MANAGEMENT OF A SMART ELECTRIC
DISTRIBUTION NETWORK WITH RENEWABLE ENERGY SYSTEMS**

MASTER'S THESIS

Saadoon Awad Sultan SULTAN

Engineering Management Department

Engineering Management Master in English Program

JANUARY 2022

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LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ MÜDÜRLÜĞÜ

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DECLARATION

I, Saadoon Awad Sultan SULTAN, do hereby declare that this thesis titled as “Design, Planning and Management of A Smart Electric Distribution Network With Renewable Energy Systems” is original work done by me for the award of the masters degree in the faculty of Mechatronics Engineering. I also declare that this thesis or any part of it has not been submitted and presented for any other degree or research paper in any other university or institution. (05/01/2022)

Saadoon Awad Sultan SULTAN



DEDICATION

I would like to present this dissertation and my humble efforts for accomplishing this work to my kindly family, classmate and all my sincere friends for the great support, advising and encouragement along the period of my trip for education, search and life. Special dedication goes to my supervisor Prof. Dr. Gözde ULUTAGAY my father, my mother and my family for their support and prayers during my research work, and thanks so much to my university "Istanbul Gedik University".



PREFACE

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January 2022

Saadoon Awad Sultan SULTAN

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ABBREVIATIONS

CO₂	: Carbon Dioxide.
CHP	: Combined Heat and Energy.
DER	: Distributed Energy Resources.
DGs	: Distributed Generators.
DNO	: Distribution Network Operator.
DNOs	: Distribution network operators.
DR	: Demand Response.
DRC	: Democratic Republic of the Congo.
ENS	: Energy Not Served.
GHG	: Greenhouse Gas.
IoT	: Internet of Things.
IRENA	: International Renewable Energy Agency.
MATLAB	: Matrix Laboratory.
PDF	: Probability Density Function.
R&D	: Research and Development.
RE	: Renewable Energy.
RESs	: Renewable Energy Sources.
SAIDI	: System Average Interruption Duration Index.
SAIFI	: System Average Interruption Frequency Index.
SCADA	: Supervisory Control and Data Acquisition.
SDN	: Software Defined Networking.
SG	: Smart Grid.
TEP	: Transmission Expansion Planning.

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DESIGN, PLANNING AND MANAGEMENT OF A SMART ELECTRIC DISTRIBUTION NETWORK WITH RENEWABLE ENERGY SYSTEMS

ABSTRACT

Climate change is a trend right now. Because a considerable proportion of power is still generated using fossil fuels, much effort is being put into decarbonizing the electric industry.

To achieve this goal, a number of measures have been made in distribution networks, including widespread use of distributed generation (DGs) and the implementation of energy price schemes. However, because the generation of common DGs, like the generation in wind turbines (WTs) and photovoltaic (PV), is mostly dependent on availability of the natural resources, a high penetration of DGs may result in a potential mismatch between generation and demand profile.

The work presented in this thesis has focused on the design of smart distribution network planning frameworks, dynamic pricing models, and variable power generation pricing mechanisms. In particular, a RES resource management mechanism has been developed to achieve revenue leveling and network performance improvement. The proposed model was represented using MATLAB program and in two ways: The first is the traditional numerical analysis method in load flow analysis. The second method was depending on the optimization. The outcomes of the representation demonstrated that the performance of the system dependent on the second process is better and most stable.

The results of the representation showed that the execution of the smart distribution network is better in the case of the availability of solar energy production, especially when using the optimization method, as the peak voltage peaks were very small, unlike the traditional method of analyzing the load flow and the lack of renewable energy, and the execution of the energy storage systems was better, and a participation of these systems at the peak time was better.

Keywords: *Climate, distribution network, load flow, optimization*

YENİLENEBİLİR ENERJİ SİSTEMLERİYLE AKILLI ELEKTRİK DAĞITIM ŞEBEKESİ TASARIMI, PLANLAMASI VE YÖNETİMİ

ÖZET

İklim değışikliđi řu zamanda bir akım. Enerjinin çok bir oranı řu zaman'a kadar fosil yakıtlar kullanılarak üretildiđinden, elektrik endüstrisinin sektöründen karbonu arındırmak "karbonsuzlařtırmak" için çok çaba sarf ediliyor. O amaca ulařmak için, elektrik dađıtım ađlarında, dađıtık üretimin (DG'ler) yaygın kullanımı ve enerji fiyat planlarının uygulanması dahil olmak üzere bir dizi önlem alınmıřtır. Bununla birlikte, rüzgar türbinleri (WT'ler) ve fotovoltaik (PV) gibi DG'lerin ortak üretiminin üretimi, çođunlukla dođal kaynakların mevcudiyetine bađlı olduđunu yüzünden, DG'lerin yüksek penetrasyonu, üretim ve talep profili arasında potansiyel bir uyumsuzluđa yol açaabilir. Bu bilimsel tezde sunulan çalıřma, akıllı dađıtım ađı planlama çerçevelerinin, dinamik fiyatlandırma modellerinin ve enerji üretimin'a deđiřken fiyatlandırma mekanizmalarının tasarımına odaklanmıřtır. Özellikle, gelir seviyelendirme ulařmak ve ađ performansının iyileřtirilmesini geliřtirmek için bir RES kaynak yönetimi mekanizması geliřtirilmiřtir. Önerilen model MATLAB programı kullanılarak ve iki řekilde temsil edilmiřtir: Birincisi, yük akıřı analizinde geleneksel sayısal analiz yöntemidir. İkinci yöntem optimizasyona dayanıyordu. Temsil sonuçları, ikinci yönteme dayalı sistemin performansının en iyi ve en kararlı olduđunu göstermiřtir. Temsil sonuçları, güneř enerjisi üretiminin mevcudiyeti durumunda akıllı dađıtım řebekesinin performansının, özellikle optimizasyon yöntemini kullanırken, geleneksel analiz yönteminin aksine tepe voltaj tepe noktaları çok küçük olduđu için daha iyi olduđunu göstermiřtir. yük akıřı ve yenilenebilir enerji eksikliđi ve Enerji depolama sisteminin performansı daha iyiydi ve enerji depolama sisteminin yođun zamanda katılımı daha iyiydi.

Anahtar Kelimeler: *İklim, dađıtım ađı, yük akıřı, optimizasyon*

1. INTRODUCTION

1.1 Background

The electric industry became the cornerstone of contemporary society, and practically all of modern society's manufacturing and daily necessities rely on stable and secure electrical supplies. The primary goal of today's electrical power systems is the same as it was for the first power system. The evolution of the electric power supply business is heavily influenced by changes in the economic and social environment. Global climate change is currently causing public worry, with traditional fossil fuel generators accounting for the majority of carbon dioxide emissions (Toke, 2011). As a result, worries about global environmental issues are assisting the power industry's decarbonization. Distribution network operators (DNOs) in the United Kingdom, for example, are undergoing considerable changes as a result of the UK's 2050 energy ambitions. By 2020, renewable energy sources (RESs) are expected to present around 15% of total energy consumption in the UK, resulting in a 20% reduction in a dangerous emission of the greenhouse gas (GHG). Furthermore, by 2050, an 80 percent decrease in GHG emissions should be accomplished. In addition to initiatives in the UK, renewable energy sources like the wind and solar are predicted for meeting around half of the EU's electricity needs by the year 2050, (Pye, 2015).

To meet the following goals, a number of initiatives have been made in distribution systems. These include widespread use of distributed generators (DGs), the implementation of demand-side participation mechanisms, and the implementation of novel electricity tariff structures. All of these activities have a substantial impact on the existing electrical power sectors. Finally, the following is a summary of the thesis's overall backdrop (Thomas, Sharma and Nazarathy, 2019).

- Renewable energy resources penetration

Current electric industries are encouraged to become more environment-friendly and sustainable because of concerns over global climate change. Thereby, the aim of

electricity generation from renewables is one of the electricity systems and therefore reduces emissions of GHGs. Thus, the penetration of DERs, driven mainly by expanding consumer commitments to eco-friendly production, government incentives, rising energy costs and reductions in DER technology, has risen considerably. electronic power systems in particular, are distribution system systems.

- Renewable generation cost Declined

The information that was presented by a New Report from the International Renewable Energy Agency (IRENA), which explained the so quickly and currently decreasing in the cost of renewable energy that the electricity is projected to be consistently more suitable in price than the old fossil fuels during a next years. The reduction in renewable energy costs and the positive policies to promote an increase in renewable energy production makes renewable energy viable on the electricity market. During the wind blow or the sunny hours, a renewable generator owner can charge its generating output comparatively low, (Obi *et al.*, 2017).

- Demand side sharing

The demand side offers consumers the chance, by offering numerous alternatives to regulate their energy use, to actively engage in the competitive electricity market. Smaller customers may be engaged in activities such as enhancing energy efficiency through a reduction in the standby power system, moving peak demand, lowering consumption and producing own electricity through roof panels or tiny turbines, (Wu, Tazvinga and Xia, 2015).

In general, the activities of the above-mentioned demand-side participation allow DNOs and power suppliers to influence the energy consumption behavior of power users, thus increasing their average renewable capacity factor and efficiently alleviating congestion problems in both the highest demand and the highest renewable generation periods. It is envisaged that the existing financial incentive framework and essential instruments for demand involvement will be replaced in the near future by the hourly dynamic electrical retail pricing and day-to-day pricing framework. DNOs and power providers thus require a novel optimization framework for optimum pricing signals and optimized distribution systems design and operation with consideration of new demand-side involvement mechanisms.

1.2 Implementation And Planning of The Distribution Network

The design and planning of the distribution network may be seen as the major phases in the creation and management of a distribution system. In order for distribution network design systems to meet demand growth as sensitive, cheap, dependable and safe as feasible, the goal is, on the one hand. Distribution network design. Typically, more than 10 years before construction, a distribution network has to be built. In the design of a distribution system, two important concepts are: the prediction of the demand growth of electrical users and upgrades to the planning system and expansions in advance, and the choice of optimum facilities and equipment in order to replace the assets with a maximum lifetime. In traditional one-way systems, the energy delivery path from high voltage transmission to low-voltage distribution feeders is generally used as the conventional network design framework (Boloukat and Foroud, 2018).

Conventional distribution planning can, nevertheless, be viewed as a network operating strategy in order to provide a dependable, affordable and minimal cost of energy delivery. DNOs in particular forecast high needs in the projected plan horizon and study effective network design strategies to meet the expected high demands.

Traditional distribution systems are intended mainly for the uniform transport of energy from substations to customers in a radial system and have little regard for electricity user engagement. The growing penetration of DER into distribution networks, the decrease in renewable generating prices and the use of novel technologies to participate on the demand side have brought about major changes in the conventional function of distribution systems. Distribution systems are generally steadily transitioning from existing passive systems to future active ones. This distribution systems review guarantees that future networks may minimize the impact of connecting big DGs and integrating DERs, enabling a high degree of integration of DERs and high penetration of RES-based DGs.

Generally, at the times of normal operation, the distribution networks reconfiguration can help in loads equilibrium, minimize the energy losses and upgrade the indexes of quality. In the power systems, the increased using for the electrical equipment that can be controlled it remotely leads the development of much functional methods for the networks automatic reconfiguration techniques, which be more important and

effectiveness at the Smart Grid (SG) applications. Therefore, the need for quality improvement and increased power system reliability, has led to high levels in the fields of SG and has become more and more popular because of the increasing use of resources related to automation systems and information technology. Smart Grid has a great effect on different power utility automation or widely used information systems, such as supervisory, data acquisition and remotely controlled tools or in normal operation works and other important services such as, planning, management, etc.

One of the important characteristics of these networks is that it should be reconfigurable with quicker and more flexible at changing times of various service conditions.

During last years, new and more appropriate methodologies of distribution network reconfiguration have been proposed and used, discover more perfect features of computer systems such as, the greater capacity and speed, growing the information availability and the development of automation systems, like, the supervisory control and data acquisition (SCADA), which will help to reconfigure the distribution networks to become more able equipment of control and plan at the real time.

In normal operation, the main objective of the distribution networks reconfiguration applications is the reduction of energy losses usually, and reconfiguration includes some important aspects, such as, it is necessary to determine the effectiveness and importance of the reconfiguration, therefore from its important things, establish a relationship between the cost with the benefit, the network must be in the high level of flexibility to help the designer in the reconfiguration works; and the switching technical feasibility must be studied at the real time, especially, according to the existing measurements availability (Pfischer *et al.*, 2013).

With the last development in the technical fields and the advanced levels has been achieved by technologies of the electric Internet of Things (IoT), the intelligent terminal products are used exceedingly in systems of power of these Internet of Things networks. Under the available and used architecture of distribution Internet of Things networks, the free oncoming of expected huge number of intelligent terminals will cause big and complicated problems such as the complications of data security

with over-centralization hurdles. The distribution Internet of Things (IoT) network architecture can be illustrating in the figure 1.1, (Zhen *et al.*, 2020).

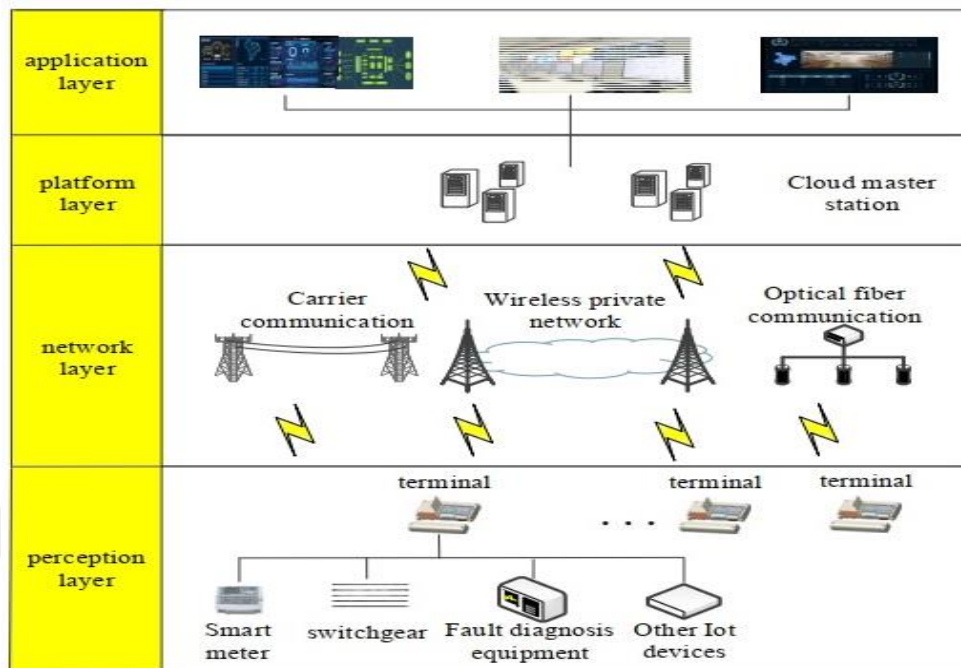


Figure 1.1: The General Architecture of Distribution Internet of Things (IoT) Network

The tremendous development of Intelligent substation and communication technology during the last century, made the degree of substation centralization becomes higher and more reliability, which led to improve and assortment the broad range of possible data and this led to provide a higher plane for functions of the control and protect the centralization sensitive foundations.

So, depending on the features of information sharing for these digital substations, by the its characteristic of collection and measurement of the real time operating status and electrical data of equipment, it was be necessary to propose a centralized protection for station. The used two layers configuration include modules of bay protection with network protection, while centralized backup protection had been proposed for substation in order to implement the centralized protection important hardware equipment wide-area and to access difficulties to utilize in engineering applications, (Bo *et al.*, 2015).

.1.3 Objectives and Aims of the Research

Due to concerns about environmental implications and limited fossil fuel resources, distributed renewable energy will play a significant role in future power systems. As a result, the possibility of using novel optimization methodologies to boost the penetration and average capacity factor of DERs in distribution networks has sparked a lot of interest. Much of the previous work has focused on influencing electricity consumers' consumption behavior through applicable economic incentives, such as varied pricing schemes, in order to maximize the economic advantages to both utilities and customers.

Furthermore, the prevalent employing of distributed energy resources (DERs) and the rapid growth of demand as a result of urbanization and industrialization have created new issues for the appropriate and optimal design of new distribution networks and the upgrade of standing and current networks. One of the most essential major challenges during network planning is the reduction of power losses. The conductor size selection challenge, in particular, can be considered a significant procedure in distribution network design.

There are no specialized optimization frameworks, dynamic pricing mechanisms, or day-ahead pricing mechanisms in the literature that comprehensively address the impact of a high penetration of DERs and network congestion problems. Furthermore, no unique optimization framework has been presented in the literature to deal with the optimal renewable energy variation problem in the distribution network design process by systematically evaluating the impact of high DER penetration and network congestion concerns. As a result, the thesis's goals and objectives can be characterized as two key features in response to these research gaps.

First, design smart management system for learning and managing distribution network contains renewable energy sources, propose dynamic pricing mechanisms and proposed to help distribution networks host more RESs and increase the average capacity factor of DERs. Second, propose an optimization method for managing the energy in the grid in such way to mitigate the voltage disturbance that caused by loading and power generating variation.

1.4 Thesis Outlines

This thesis contains five chapters, chapter one is an introduction. The literature review is in chapter two, while the methodology of the work and the proposed system design are in chapter three. The results to be obtained through simulation and the discussion are in chapter four, and the conclusions and future works are in chapter five.



2. LITERATURE REVIEW

The main aim of the electricity system is to meet customers' energy needs. The main parts of a typical electricity system are power production, transmission systems and distribution systems. Generators produce the needed energy from various resources, such as fossil fuels, nuclear energy and renewable resources. The transmission lines are designed to supply huge volumes of energy from the concentrates to major energy consumption sites. The distribution systems are then responsible for transporting energy with the correct voltage level and power frequency to each and every electricity consumer. Different voltage levels are used for the transmission systems and distribution systems, necessitating the required transformer to adapt the voltage to the correct levels. The fundamental structure of the typical power system comprising the main subsystems is shown in figure 2.1. The conventional power system is designed using concentrated fossil-fuel, big hydropower or nuclear power facilities to generate the bulk of electricity.

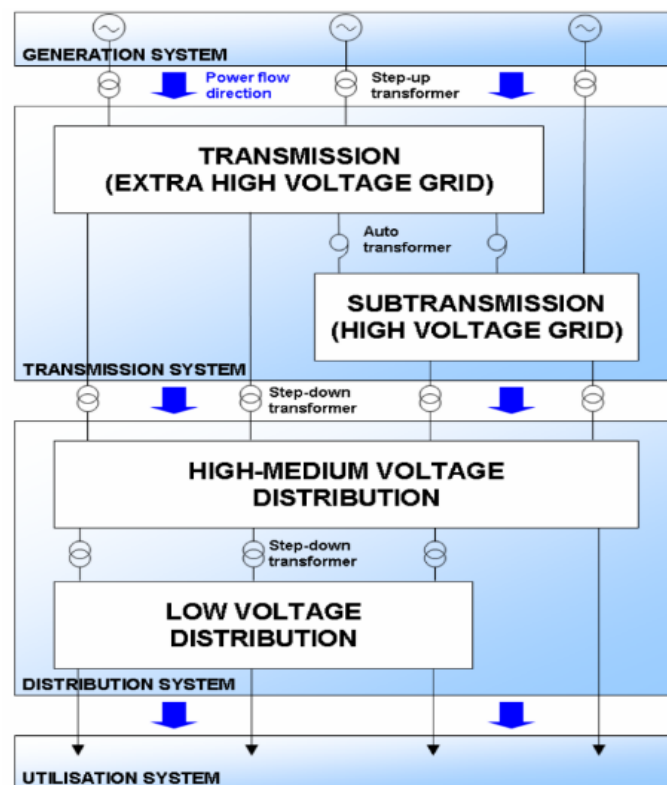


Figure 2.1: Typical Power System Structure

The availability and efficiency of the present power system is projected to increase with social and economic growth owing to consumers' demand. Furthermore, the extensive use of renewable resources and energy market liberalization are driving electrical systems to undergo major and useful system-level operational and planning changes in the near future. In particular, electricity competition and continued assistance from the Government encourage participants in the electrical market to pay more attention to system operating economies and the cost of energy acquisition. Concerns about growing environmental concerns due to CO₂ emissions also encourage a clean and efficient energy supply for the power industry. The steady growth of electricity consumption in Europe indicates the capacity to solve problems with congestion and to optimize electricity delivery. The usual way to overcome these difficulties is to install new big generating units using fossil fuels and to improve the transmission system. Vertically integrated power corporations were responsible for developing new bulk generators and new transmission networks before the electricity linearization process and the growth of renewable energies(Wang *et al.*, 2019).

The growing use of RESs is mainly due to dispersed generators such as solar power plants and wind turbines or small wind farms. Distributed generating systems are often directly linked via static conversion systems to distribution networks. In the near future the percentage of power generation from thermoelectric steam turbine generators will diminish, and these types of generators will generally be linked directly to transmission networks via the required transformers. The reduction in conventional synchronous generators influences the capacity to provide important auxiliary services, such as real-time power balance, from the point of view of the complete power system. The construction and strengthening of transmission lines may be prolonged since DGs can meet the increased demand for electricity and therefore postpone expenditures in power supply infrastructure (Zhang *et al.*, 2018).

However, the energy system has still another alternative to cope with issues of growing energy demand and energy congestion in efficient and more environmentally friendly power production technologies as combined heat & energy (CHP) and renewable energy resources (RESs) (Anand, Narang and Dhillon, 2019).

2.1 Power Generation Stations Aims and Challenges

Many of developed and developing countries had proposed and tried to apply three important main energy aims that can help to guide the huge developments of the future energy fields. These three objectives can be summarized as:

- The aims of supply: for guarantee the saving of enough and cost-effective supplies of the energy by making to develop the both indigenous power resources (renewable or non-renewable energy resources) depending on using diverse supply sources and the fewer cost choices.
- The aim of utilization: in order to promote the energy effective appropriate utilizations and to determine the huge and different wasteful shapes of energy or consumer shapes of energy.
- The aim of environmental: for reducing the dangerous negative effects that can be produce during the energy production, utilization, transportation, consumption or conversion in the around the environments.

The constantly generating electricity and achieve the increasing demands represent for the electric important two challenges and exerting huge and continuous pressure on available infrastructures of the energy in the developing and developed countries around the world.

In many developed countries, there are five types of sources have been used in the sectors of electricity generation; oil, natural gas, coal, hydro and others (solar, biogas and biomass), while work is being done to replace a coal instead of employed natural gas in the fields of electricity generation, in order to decrease the elevated dependence on natural gas depending on the growing of coal using. Regarding to fossil-fuel, depending on it for generation of electric represent the difficult trouble challenge the power generation sectors in some of these developed countries, while throughout the significant reliance on the natural gas or coal grow as master resource in the other countries as Malaysia, as for depending on the oil as a source in the electric generation sectors started to decrease through the few last years, the various cost and the dependence on the different types of generation fuels can illustrate in figure 2.2.

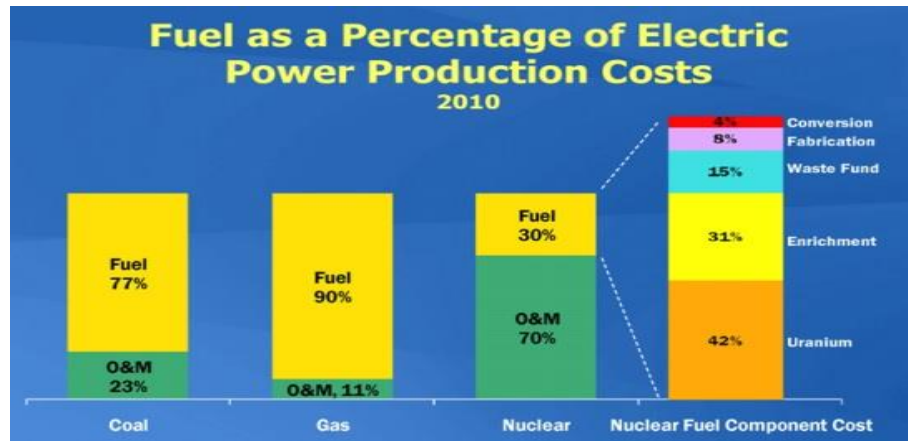


Figure 2.2: Production Costs Between the Different Types of Generation Fuels

The challenges that could impede the renewable energy (RE) growth and good implementation can be summarized by financial, technical and information impediments that must be processed for optimal and useful upgradation.

Because of the many new products and technologies are still new, the market prices of the RE systems will be higher for recovering the grants or R&D costs (Ali, Daut and Taib, 2012).

2.2 Distributed Energy Resources

Power companies all across the world were faced with considerable increases in electricity demand in the early 1990s, which were partly ascribed to population development and industrialization (Chen *et al.*, 2016). As a result of this circumstance, massive investments in electrical transmission lines and related supplementary or protection facilities have been made. As a result, during that time period, high-voltage and high-capacity transmission infrastructure were widely designed and built (Carlini *et al.*, 2019). Environmentalists have noted the potential for contamination as the number of fossil fuel generators grows (Proops *et al.*, 1996). Different fossil fuel sources, such as coal and gas, are used to power conventional generation systems. The average operation efficiency of traditional coal plants is around 35%, and it varies greatly depending on the operating conditions (Meng *et al.*, 2016). These conventional resources are steady and concentrated, and they have borne the brunt of the power supply burden until now. Traditional generation technologies, on the other hand, all have the problem of producing carbon dioxide during the combustion process. Growing concerns about our planet's climate and

environment have been expressed in light of the substantial issues posed by carbon dioxide pollution.

However, carbon dioxide is not the only pollutant created by fossil fuel production systems; traditional generation processes also produce many other more severe types of pollution, including as nitrogen and sulphur oxides, which can cause acid rain and have a substantial impact on human health. As a result, environmental concerns became a major worry for humanity, with fossil fuels accounting for more than 70% of all electrical energy produced. Governments and the energy sector have been disturbed by climate change and the greenhouse effect generated by non-sustainable electricity generation, forcing them to investigate alternate ways of supplying electricity using reduced generation strategies (Allam *et al.*, 2013).

A traditional power system distributes electricity via a vast network of interconnected transmission systems operating at various voltage levels. Electrical energy losses occur from production centers to points of consumption from an electrical standpoint. Long-distance power transmission can be made more efficient by using high-voltage and innovative materials. However, due to economic considerations in network design and planning, lowering power losses to a low level in the majority of distribution networks is difficult. As a result, transmission networks lose about 4 percent to 5 percent of the energy produced in power plants, whereas distribution systems lose 10-15 percent of the energy produced in power plants. Furthermore, rising electricity use puts a financial strain on the construction of new transmission lines. For example, a new transmission line with a capacity of 100 MW is anticipated to be used to serve a maximum load demand of 50 MW. Transmission network operators are required to upgrade the transmission line after just 10 years if the demand grows at a rate of 5 MW per year. As a result, new electricity generation technologies are projected to not only address environmental problems but also postpone expenditures in power transmission systems. Renewable energy is regarded as one of the finest alternatives for addressing environmental issues, and it has the potential to postpone transmission line construction projects (Ameli *et al.*, 2014; Majd, Farjah and Rastegar, 2020). Because renewable resources like wind and solar energy are typically spread in remote regions, it is thought that consuming renewable energy through linking these sources to local load-consuming areas via distribution systems is the best option (Wang and Nehrir, 2004; Kayal and

Chanda, 2013) As a result, distribution networks are a part of this challenge and must address the possible problems associated with the integration of non-dispatchable renewable resources. Wind generating and photovoltaics are the most important generation ways among the numerous sustainable resources, and they have been extensively employed in different countries. Due to their enormous capacity, large-scale wind farms or PV panel stations are frequently connected to transmission systems (Liserre, Teodorescu and Blaabjerg, 2006; Weicheng *et al.*, 2018) Small-scale solar PV panels, on the other hand, can be put on the roofs of commercial or residential structures, or ground-mounted near load needs in the vicinity of commercial and industrial regions, while small wind generators are prevalent in rural areas (Thomson and Infield, 2007).

Based on their technical characteristics, small-scale solar PV panels, such as roof-mounted units and tiny wind turbines, are determined to be sources of distributed generation or decentralized production. The use of these terms has evolved over time, indicating that DG has gradually phased out the phrase "decentralized production" from nearly all relevant scientific literature. Embedded generation, in addition to these phrases, is commonly used in some books (El-Khattam and Salama, 2004). The phrase distributed resource is also sometimes used to refer to the idea of DG. Distributed generators (DGs) are small-scale power plants that are connected to the main grid and positioned near demand. DGs are either meant to run independently to meet local demands or to connect to the main grid to supply energy to the rest of the power system. The main sources of distributed generating are renewable energy sources like wind and solar. DG units typically range in size from less than 1 kW to 10 MW in installed capacity. Apart from the characteristics listed above, DGs are classified into four groups based on their production capacity: micro (1 W to 50 kW), small (5 kW to 5 MW), medium (5 to 50 MW), and big (5 to 50 MW) (more than 50 MW).

2.3 Electric Transmission Networks Intelligence Techniques and Expansion Planning

Transmission system is a one of the main and axial divisions of the electrical power networks. It provides a reliability and enough energy for customers and represent a perfect connection between the first stage (generation stations) and last stage

(distribution network). The main objective of a power transmission networks is carrying the energy to load centers (cities, factories and so on) from the power generation plants securely, efficiently and reliably. Since energy transmission systems is expanding continuously, therefore transmission expansion planning (TEP) needs to determine appropriate place in order to replace the old circuits by other may be more modern to fill the needing to the growing request that representing by transferring the energy to new network from the old. In general, for getting and applying the effective plan, appropriate place, capacity, timing and types of new and upgrade equipment of transmission should be determined accuracy for meeting the indigence continuous, raise the level of requested power flow and generation addition. But the cost-effective is one of the major issues that can be challenge the transmission expansion plan of the power system.

Depending on horizon of the planning, TEP can be categorized to two types, single-stage (namely static) and multi-stage (dynamic) planning. In single-stage, only on a single time period is be depended on considered as a one planning horizon, while in the dynamic planning it depending on the planning horizon during the period separating of study to determined multiple phases (Dewani, Daigavane and Zadgaonkar, 2012).

The negative and big effects of (CO₂) emission on the appropriate capacity planning of the systems of transmitted energy. In the depended planning of developed countries, there has been a transference from structure depending on vertically integrated and regulated power system to an unbundled and free industry of electricity. The objective of the new structure is promoted for creating an electrical energy supply system with high and desired efficient. Generally, a perfect proposed transmission planning result two important and useful aims:

- A working to reduce the cost in out-of-merit generators.
- A working on design the strong transmission network that don't allow frequent interruptions under illogical causes (Kazerooni and Mutale, 2010).

After the intelligent electricity networks applications, demand response (DR) achieved a significant amount of interest because of its great and desired impacts that causing the reduction peak demands and achieve the balance for power supply and requesting of it. With other side, when demand response arrives to undesired levels

in the marketing, the market behavior of demand response (DR) becomes an unsuitable for these networks too.

Therefore, power transmission expansion planning TEP becomes a complex mission of decision-making, which needing to more and more risk analysis. For instance, in the DRC increased from 5.62 to 8.19 M\$ for plan 1 while for plan 2, increased from 3.24 to 4.08 M\$) where it is expected for using more DR resources, as explain in figure 2.2.

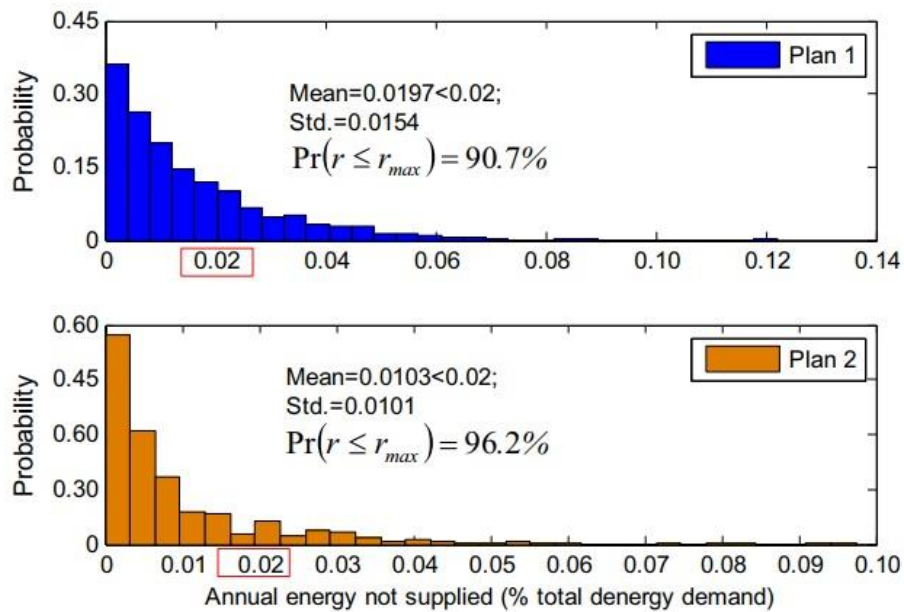


Figure 2.3: Probability Distribution of Annual Energy Not Supplied (Percentage of Total Energy Demand) for Plans 1 and 2

While the comparison between the probability density function (PDF) with different (a) in the risk constraint, where ENS is more suitable to be distributed near the number of (zero), and the PDF tail may be shorter, that can be explain in figure 2.3, (Qiu, 2018).

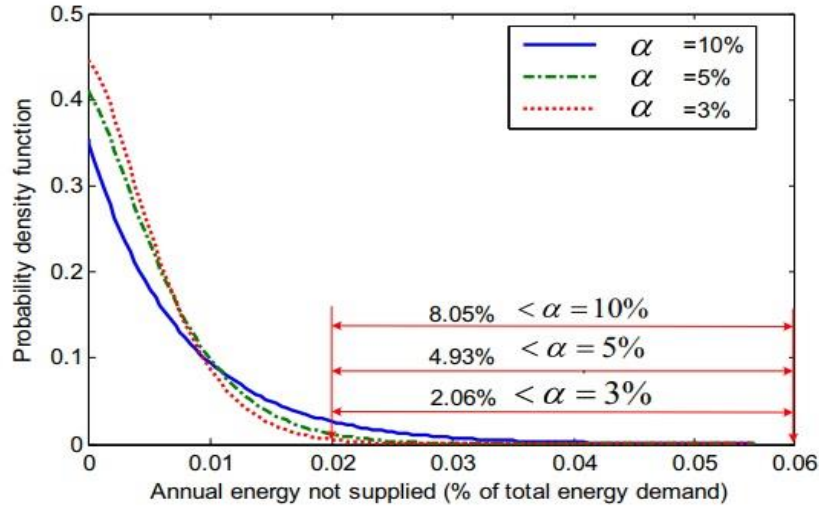


Figure 2.4: Probability Density Functions Of Annual Energy Not Supplied With Different Risk Levels

2.4 Electric Distribution Networks

Today, the distributed networks of the energy have important characteristics such as the reliability in an efficient, adaptive and distributed electricity. However, the external impacts that connected with the flow of the power and practical boundaries of network operation, represent a great impediment for form like these markets. The pricing policies in the electrical distribution networks especially, play a basic function in the foundry of consumers behavior. depending on Kirchhoff's law, any local various in the power network such as power injection, will affect state of the global power network, that is mean this will affect on the either voltage or the power flow or both. Depending on an outcome of this change, the regional measures always cause un suitable external costs related with line losses, voltages, flows of power, and so on. which represent a nagging barrier challenges the shaping efficient markets of the electricity networks.

For a radial distribution network, many of studies proposed using the branch flow model, which focusing on the power flows and the currents through the individual branches. This model is used mainly in order to model distribution networks which resort to be radial (Li, 2015).

According to distribution operations of the functional state guess techniques for primarily-radial 3-phase distribution networks, estimation represents all analysis of various information and data which help a dispatcher of the distribution to be more

acquaint with state topology of the real-time and 3-phase electrical of the specific distribution network with comparatively few telemetries of SCADA.

The state estimation was actually utilized on the transmission networks for calculating the better estimation for desired voltages, actual generation, power flows and various loads in determined real time depending on available measurements of the real-time SCADA.

There are an important of considerable variations in the properties of the representative networks of the distribution comparison to exemplary transmission networks, which can be abstracted in the table 2.1 (Hoffman, 2006).

Table 2.1: Comparing Typical Transmission and Distribution Networks

Sector	Transmission	Distribution
Topology	Generally extensively meshed & must be analyzed as a whole	Generally many independent substations each supplying several radial feeders. Can be analyzed as multiple independent islands
Phase unbalance	The degree of unbalance is generally sufficiently small that it can be ignored and only positive sequence terms analyzed	The degree of unbalance, at least in North American style networks, may be quite large and each phase must be considered independently.
SCADA Measurements	A high percentage of devices have measurements. Much of the network has measurement redundancy and is mathematically observable.	Generally has many more load points than measurements. Practically speaking there is usually no measurement redundancy and, considering SCADA measurements only, is highly unobservable.
Network Size	A typical network size ranges from a few hundred busses to one or two thousand.	A typical network size ranges from 10,000 to 100,000 electrical nodes

At present, the needing of using the local central-stations is reducing because of the traditional significant wasting of the resources, increasing costs of the transmission and distribution, doubled the concerns of environment, and technological development.

In the figure 2.5 illustrate a 3D shape for the typical power loss according to the size of DG (Distributed Generations (DGs), can be defined as a term significantly used for small-scale generations and present a suitable solution to much novel challenges) for every bus in a criterion 69-bus distribution experiment system. From the figure, for a particular bus it is appearing that as the magnitude of DG is grewed, the wastages will reach the lowest level of amount and increased beyond a size of the Distributed Generation for this constructing place, while in the status of increasing the size of DG, the losses start to be higher and it may start to transcend the basic case losses.

Also, that Distributed Generation (DG) location plays vary great role to minimize the energy losses (Kansal *et al.*, 2011).

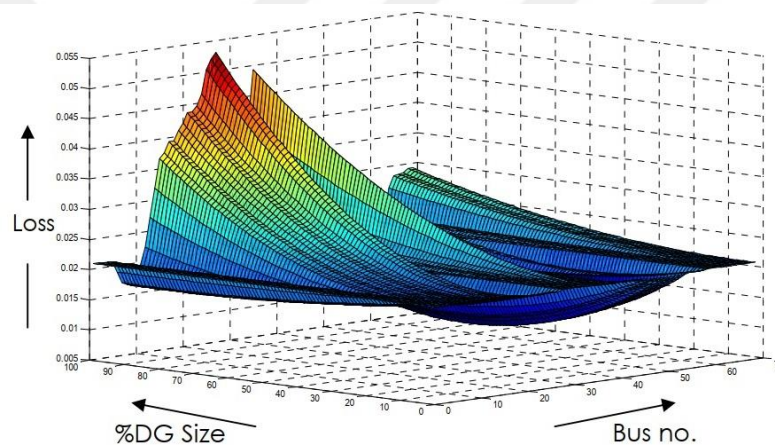


Figure 2.5: Effect of Size and Location of DG on System Loss

2.4.1 Design and planning of electric distribution networks

Generally, there is necessarily to time not less than 10 years for planning and design of a distribution network before starting with construction (Lakervi and Holmes, 1995). Typically, it is so important the significant principles are considered in the works of the design and planning of a distribution system, which can be summarize into two objectives:

- In order to upgrades and extensions in advance of the distribution system, it is should be expected the growth of predicting the demands of electricity users and planning system in future.
- choosing the appropriate optimal facilities and best equipment in order to replace this old equipment that will reach their maximum lifespan as soon (Ziari *et al.*, 2012; Georgilakis and Hatziargyriou, 2015).

The design and planning of the distribution system are difficult and complicated missions with several main and accurate procedures (Ziari *et al.*, 2012).

Practically, there are many factors and calculations that should depend on it during the planning and design process, which can be listed as following:

- supply the reliable and efficient of demanded energy during the life cycle of designed station, taking into consideration of the evolution of the predictable load during future
- Appropriate components of the network should be specifying and provide them.
- The suitable and more economical solution of distribution network planning have to be chosen.
- Reduce the electricity prices to the harmless amount of pricing.
- Increase the profits of distribution network power supplier, operators or both, to the harmless amount of pricing for the users.

Thus, the important and main aims and targets for processes of the distribution network design and planning, can be abstract them as below:

- Load forecasting.
- Power quality.
- Compliance with standards.
- Investments.
- Power losses. (saboori *et al.*, 2017; wang *et al.*, 2018; ehsan and yang, 2019).

It is known that distribution systems are designed depending on the load that should supply it, including industry customers, commercial customers and common household customers and so on, and there are many definitions of the load properties that are generally used in expected loads. These definitions are: demand, load factor, coincident factor and diversity factor (Grbić, Salamon and Mikulović, 2019; Hassan *et al.*, 2019).

2.4.2 Conditions and constrains of the distribution network operation

The main objective of distribution network planning is supplying electricity with the perfect level of reliable and uninterrupted energy. Power quality can be practically

definition depending on the following factors: voltage, supply frequency, power factor and the harmonic content of the network (Huang and Jiang, 2017).

the reliability supply of electrical distribution has been much studied during the last century and until this day because of the complications and significant issues of these networks due to the various types and modules of new technologies that connected with the “Smart Grid” term and due to the many equipment of the distribution networks are be ageing therefore they became less reliable clearly, so the continuous using without any renewal or maintenance will lead to more and more in failure rates across all asset classes.

For the better predict performance of the network, it is necessarily to consider the combine of the multiple changes, over the network operations to shape a desired and suitable system. Some of studies had search in the effect of continuous maintenance on the desired reliability of network, so optimizing maintenance is very significant factor in order to minimize the outages and increase performance network. These studies have concluded that the failure of technicians to perform maintenance will lead to poor performance, where lower maintenance leads to more failures (Clements and Mancarella, 2018).

2.4.3 Distribution network reconfiguration technologies

practically, power losses over distribution networks reach to 70% of the aggregate wastages in network of the power system, where the amount of power loss significantly effects on the operational cost of a power system because the system has to reach the desired amount of energy that should supply it. For investigating the aim of reduce the losses in power over the specific distribution systems, different and many approaches should be considered and applied by network operators and designers, distribution network reconfiguration, especially, network voltage raising, re-conducting and capacitor bank installation (Badran *et al.*, 2017; Pegado *et al.*, 2019).

The distribution network reconfiguration is considered as one of these important approaches that requires low level of investment cost for the operators of these networks, because it's easy to use this technology by available infrastructures in distribution networks. generally, the wide application of DGs and the distribution network reconfiguration are always studied separately. Therefore, the work for

integrating both sub-problems can help to achieve more advantages and optimization for system of the distribution (Eason, Noble and Sneddon, 1955).

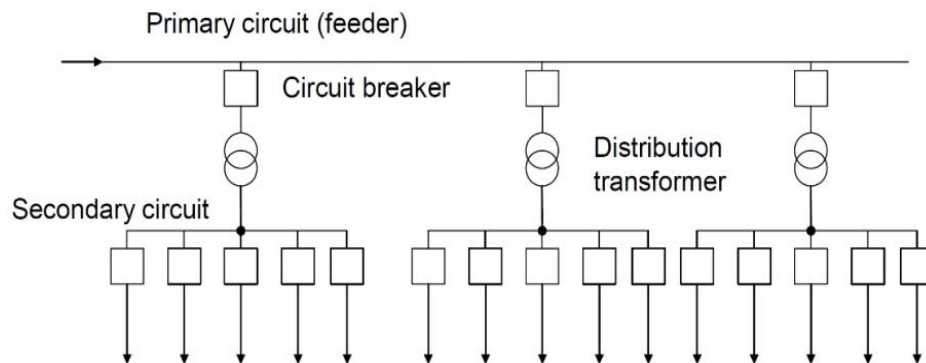


Figure 2.6: Type of Simple Structure Of Distribution Network

Plurality of the distribution networks operate with a radial topology and loop structure design, therefore this topological of this network is convertible easily and at low cost (Enacheanu *et al.*, 2008), so the reconfiguration of distribution networks aims to progress the efficiency and the accuracy of the network operate with reduce the high-power wastages based on the requirement and the conditions of operation. The network reconfiguration approach can be applying through change the two statuses of the sectionalizing (on/off) and the tie line switches available on the network (Sahoo and Prasad, 2006). Practically, the term of reconfiguration of the distribution networks can be known as a procedure to find the best network configuration during the handles, the status of the open/close for switches of the sectionalizing or/and tie-switches for improving various criteria through achieve the operational constraints (Baran and Wu, 1989). Some studies searched about the importance of discover new methodologies and ways in order to achieve the desired balance between network multiple aims and constraints during considering the distributed generation penetration and applying the various technologies of network reconfiguration(Liu *et al.*, 2008). The figure 2.6 illustrate the simple structure of distribution network (Abdmouleh *et al.*, 2017).

2.5 Investments in the Distribution Systems

The assess of the investment costs for the desired system infrastructures and the practical predict for the management costs and the pertinent operations during the expected lifespan of the network, is consider as one of the most important procedure in distribution network planning and design, especially, when designers and planners

are required not only to achieve the standards which have been agreed upon for power system operation, for instance the frequency constraints or the voltage constraints but also to produce a logical and practical financial analysis and should have includes the lifecycle costs during the distribution network design and planning process. Therefore, the important factors such as, power quality, the efficient reliability and investment costs all significantly sure affect the network planning process, and these procedures will help to achieve the desired operation and distribution by apply the optimization models depending on the required principles and the aims of the reconfiguration (Liu *et al.*, 2019).

The investment strategy of a power system can be classified into two categories:

- New investments: are used in purpose of expand the old or dilapidated network or to configure the desired and new distribution network in the district that have been agreed upon.
- Replacement investments: are applied for replacing or upgrade the old major components which available in the network. Normally, this procedure is use for the purposes of the normal maintenance due to malfunction problems that is may happening because of the component ageing.

In particular, three important major factors are considered in the cases of investment of the distribution network:

- Capital costs: this factor intends the costs of infrastructure different material procurement, labor and other necessary costs during the building of network and other related construction.
- Operational costs: include the cost of all inspection, power loss, reconditioning, maintenance, and other necessary costs.
- Interruption costs: include the costs of both failure and discard. The equation 2.1 calculate the total costs of investment of the existing distribution network:

$$C_{total} = CC + \sum_{t=1}^T (OC_t + IC_t) \quad (2.1)$$

Where:

C_{total} = the total costs of network investment.

CC = represents the cost of capital.

OCt = represents the operation costs in operation year (t).

ICt = the interruption costs in operation year (t).

T = the expected life span (Dunnan *et al.*, 2019; Liu *et al.*, 2019).

2.5.1 Electricity market reform

In line with the growth of electricity market and deep and comprehensive encouraging for the related repairing programs with the distributed network system, there will be much multiple and important subjects, which will make the planning, design and operation of distribution network more complex in order to reach the optimum distribution. It actually reflects in the below three points:

(1) The orderly implementation of the distribution network planning is difficult manner, so, whenever the planning of the distribution network is implemented, there will be a huge rivalry among the various investment organizations. And the interacting issue as a trouble between the different investors and may appear ongoing or more frequently, and this will bring number of difficulties which will lead to a delay the distribution network planning organized execution.

(2) Practically, the accurate estimation of the power demand is so difficult. With power sales side market liberalization, the prices of the electric fluctuate depending on the important two factors, they are the supply and demand of the power. The cause of the changes of the prices of electric from the region to other, the power users will be affected according to the time and the region of using energy. This will create a state of regression for the developments of local power load, and will form a significant difficulty may prevent the exact energy demand prediction.

(3) The illustration of the variation among the profit and cost of distribution networks is very hard. In order to avert the undesired low investment efficiency and the snatching the market for number of investors, the invested organizations and companies hope to invest in developed regions which have excellent savings and return high rate, remarkably. Moreover, nation company of the country has to be responsible for the following up the construction work of the distribution network of rural and poor areas without planning to get high benefit (Fan *et al.*, 2018).

Figure 2.5 the figure shows the electricity market structure under the competition of retailers (MacDonald and Eyre, 2018).

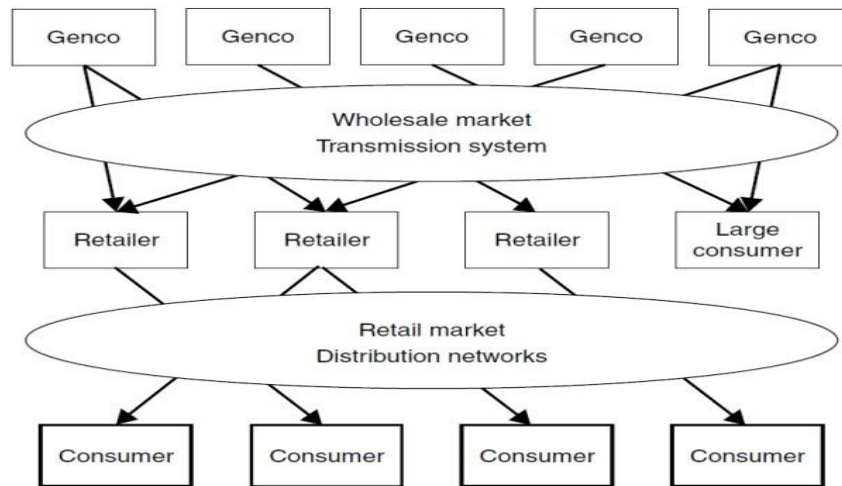


Figure 2.7: The Electricity Market Structure Under the Competition of Retailers

2.5.2 Increment commercial business for distribution network works

The theories of new electric power system reform suggest to putting a large investment space in works of increment of distribution, through putting the suitable space for the social capital to participate in the projects of the distribution increment and operation. In this case. It is axiomatic that the competition between the invest companies will grow and this lead to increase the difficulties of general planning of the distribution networks.

Practically, these difficulties can be summarized in two aspects:

(1) The increasing in the errors of power loads estimations:

The power loads for the network will estimated by National Electricity Company for reaching the appropriate distribution in the future plan during the work of actual power grid planning, by considering many of objectives and factors. The invest companies actually will able to supply the desired power load, so long as the estimation of the loads gets to specific scale, while if the network of the increment distribution is liberated, then portion of the added load is taken through the rivalry, and this will lead to decrease the ability of the desired and suitable power load prediction capacity which was determined by the National Electricity Company. It will prevent the chance of get the profitable investments because of the significant error of power load estimations.

(2) The increment of the difficulties in total design of the desired distribution network:

With the liberation of business of the distribution increment in order to repair the new electric power system, latter power market existences involving social capital can start in the investment with the National Electricity Company. Practically, this will result new and more modern power grid construction (Qiannan, 2017).

In the present, many projects of the investment from different sources or variegated ownerships are appropriated for the applications of construction of the distribution networks. The accomplishment of added distribution network design will help to overcome the problems of bad fineness from the power supplies, sure security risks and so on.

Compared with the investment of the conventional distribution networks, the reliability and safety of the grid should not only be insuring by the business of distribution increment, but also must guarantee the economic feasibility and the operation quality of the distribution network because of the involvement of the available social capital, and more indicators and factors of the evaluation necessary for evaluating the projects of incremental distribution network construction, , such as economic factors (cost of both, unit and life cycle) and technical factors (economical operation, safe reliability, solving the current heavy overload problems, solving the old, maximum power supply capability, the quality of the power, meeting the new power load and problems of the hidden safety).

In order to general appreciation the investment precedence of all projects of distribution network infrastructure. Figure 2.7 show the evaluation indicator system in depended on the multi-grade indicators (Chen *et al.*, 2020).

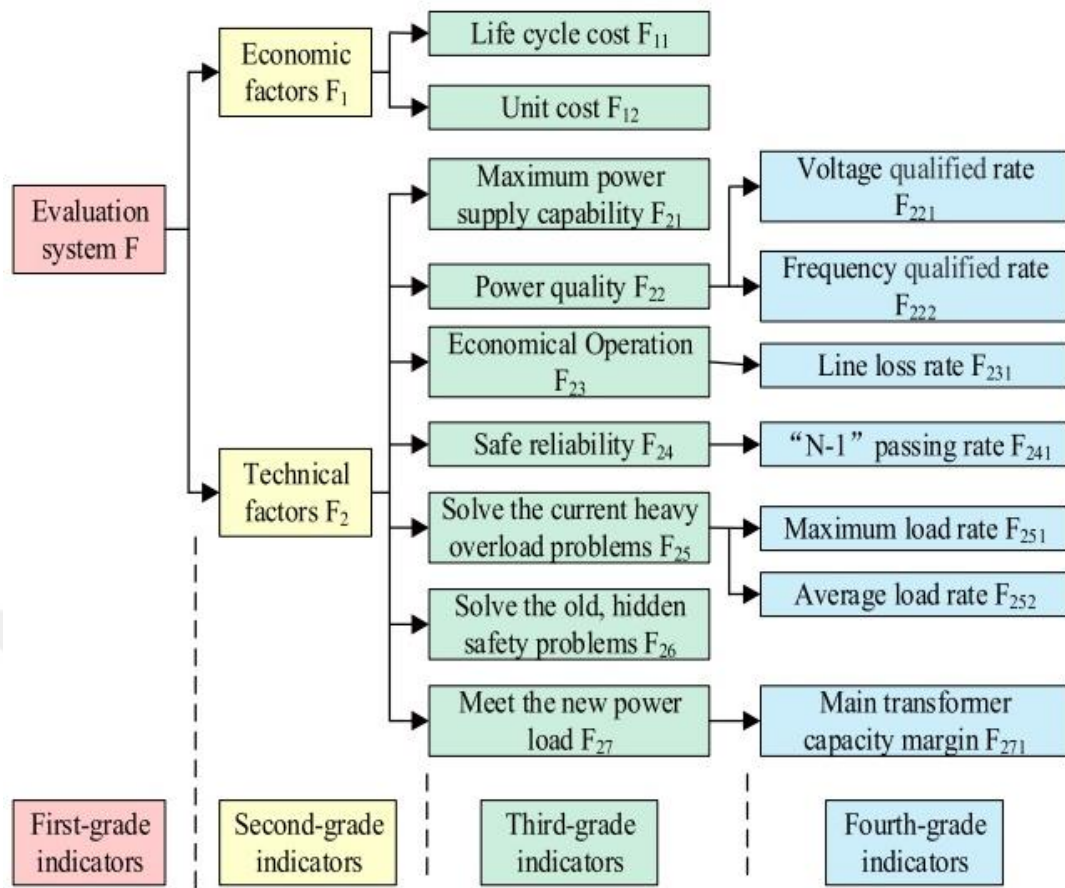


Figure 2.8: The Evaluation Indicator System in Depended on the Multi-Grade Indicators

2.6 Intelligent (Smart) Distribution Networks (SDN)

It is very important for the future planning of the develop and developed countries which working on promote the operation level of distribution network, should be planning for construct intelligent distribution network for supporting the scientific development sectors and evaluate the management of the distribution network, therefore, it should be working on the evaluation of the investment effectiveness at starting of the construction or renovation implementation (Liang *et al.*, 2015).

In near future, the desired evolution of the various systems of the energy will be depended on the design, management and planning procedures of construction of the distribution systems depending on the meaning of the Smart Grid term, where, these approaches theoretically will include the significant employ of developed technologies associated with the communication and data and modern different systems of control to reaches of desired and optimum smart distribution systems.

One of the important challenges that face the present studies is the reliability of the functioning of the whole desired infrastructures of communication, information and future power according to the significant demand and the complicating of the Means that require reliable and efficient power supplies to accomplish their tasks. In order to overcome the classical deterministic contingency analysis with apply exceedingly correct stochastic approach, so a modern tool was be developed for evaluating the efficient and the precision of the future network of distribution based on a developed simulation programs, which have the ability to simulation of the whole intelligent various and used distribution system and the guess of the unexpected impacts on its execution in the times of the outages of the employed wireless communication systems that control the available network (Guo, Levi and Buhari, 2015).

The robust management of the different distribution networks can have two effects on the accuracy of the developed distribution systems in the future:

- It can improve the indexes of defined reliability (SAIDI and SAIFI) for unfavorable (negative) loads and prop the link for freelance producers (investors) depending on the known operation methods, for instance, reconfiguration by internet for alleviating the restrictions of load transfer (da Silva *et al.*, 2012).
- There are some concerns about the probability exposing the high level of reliability for dangerous after using new SDN technologies. Indeed, the intelligent control will be employed to repair much of emergencies in the implementation stages directly whenever they appear (Guo, Levi and Buhari, 2015).

The development in the technology sectors contribute to shape systems of the power, in present, including of the distribution network, where these modern technologies led to generate the local renewable and reduce the investment costs which concerning with distribution-network, and optimum national prop plans that result a large market permeation of distributed generation (DG) on numerous develop and developed countries (Pérez-Arriaga *et al.*, 2013).

3. METODOLOGY AND PROPOSED SYSTEM DESIGN

Environmental friendliness, renewable energy resources (RES) have been viewed as a viable option for addressing global warming and harmful emissions of carbon dioxide from conventional fossil-fuel power generation stations. The widespread use of renewable DG units, in particular, is seen as a viable alternative to traditional power plants. Globally, total installed renewable energy capacity climbed by 8.3% in one year, from about 2000 GW in 2016 to 2167 GW in 2017 (Petinrin and Shaabanb, 2016). However, the properties of distributed generation various sources, like bad prediction and output unpredictability, have an impact on the distribution system's stability and efficiency. Power wastages on certain lines of the transmission or sub-transmission, on the other hand, accounted for 30% of overall power losses, while undesired wastages in a various distribution network system reaches to 70% out of the final grand the power wastages. A power system's operational cost is directly affected by power loss. Various measures are considered and utilized by network operators and designers for decreasing the losses of the power in the various system s of the distribution. Increasing voltage of the network, installation of capacitor bank, re-conducting and reconfiguration of the distribution network are examples of these approaches (Petinrin and Shaabanb, 2016; Pegado *et al.*, 2019). Among the aforementioned techniques, reconfiguration of the distribution network is considered that the way or procedure that requires the least amount of investment from distribution network operators, as this technology may be implemented using existing network equipment. However, the reconfiguration of distribution networks and the widespread use of DGs are usually researched separately.

Because the majority of distribution networks have a radial topology and are designed with a loop structure, their topologies are convertible(Enacheanu *et al.*, 2008). As a result, the topological structure of the distribution network is redesigned to improve network efficiency or reduce active power losses, depending on the necessity. The sectionalizing and tie line switches' on/off statuses are changed to reconfigure the network (Sahoo and Prasad, 2006). The execution of the distribution

network reconfiguration, in particular, could be characterized as a procedure that deals with the status of the open/close of the sectionalizing switches and tie-switches for discovering the optimal configuration of the network which meets operational restrictions while optimizing multiple criteria (Baran and Wu, 1989).

As previously stated, the growing use of distributed generations puts the common algorithm of the distribution network reconfiguration approach (Baran and Wu, 1989; Nguyen, Truong and Phung, 2016) to the test. When using network reconfiguration technologies and considering the high penetration of distributed generation, it is critical to investigate new methodologies for achieving a equilibrium among the specific objectives of the network multiple and the necessarily constraints (involving the load balance, system losses and voltage performance).

3.1 Smart Grid Energy Management System

The proposed system based on optimized energy management algorithm, the system managing flowchart is shown in figure 3.1 which includes five working cases.

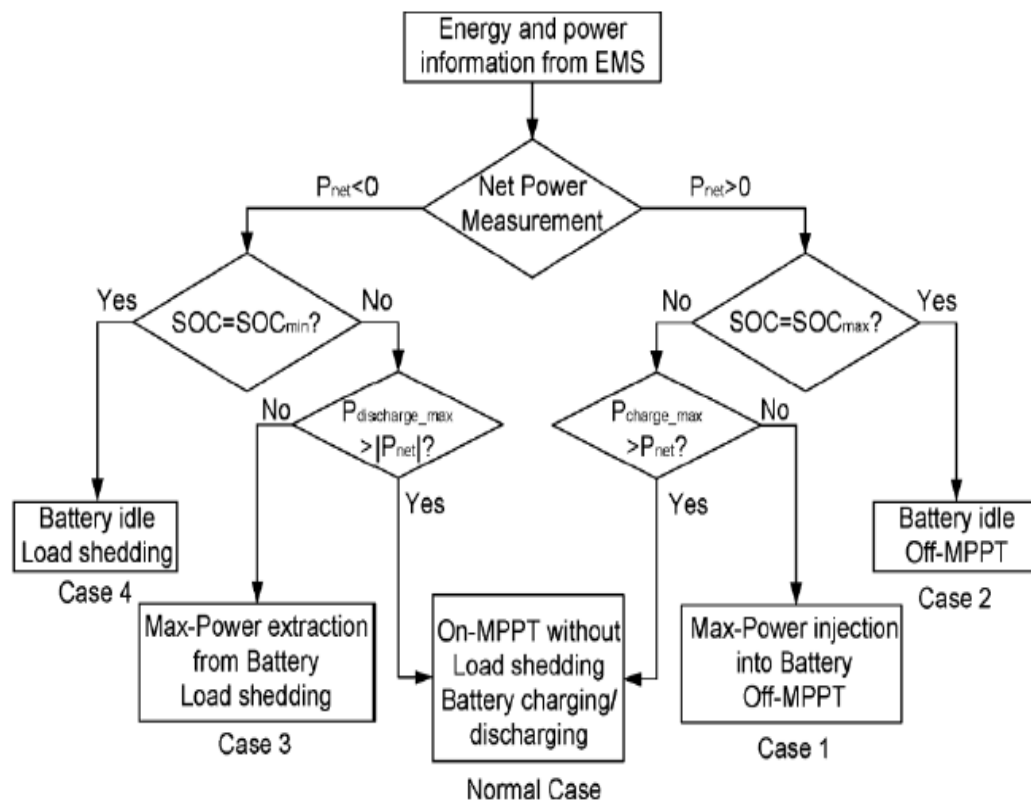


Figure 3.1: Proposed System Management Flowchart

The smart distribution electric power grid contains utility grid point of connection to connect the smart grid to the utility grid, variable load (home load), constant load, renewable energy system (PV array) and energy storage system (Battery) as in figure 3.2, all those components are used in the simulation of the proposed system, the smart grid simulated using MATLAB platform. A linear optimization algorithm is used for energy management and the system is simulated with and without using the optimization algorithm.

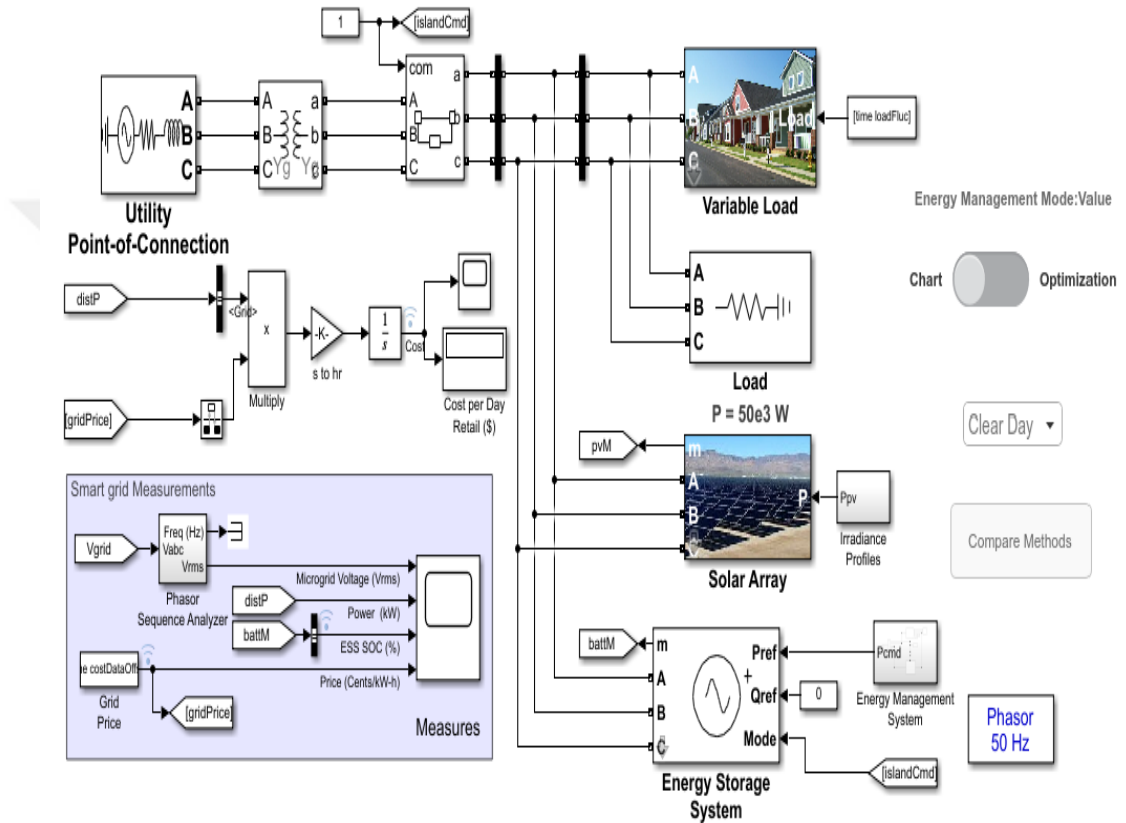


Figure 0.1: Proposed System Simulink Model

3.2 Peak Demand Shift Optimization

The main objective is to minimize the total cost of variable priced electricity, the cost is expressed in equation 3.1:

$$C_{total} = \sum_{k=0}^N C_{grid}(k) \cdot E_{grid} \quad (3.1)$$

While the storage system energy is given in equation 3.2:

$$E_{battery}(k) = E_{battery}(k - 1) + P_{battery}(k)\Delta T \quad (3.2)$$

For system balance case source power must be equal to loads power as in equation 3.3:

$$P_{pv}(k) + P_{grid}(k) + P_{battery}(k) = P_{loads}(k) \quad (3.3)$$

Linear optimization method is used to minimize the cost, the optimization algorithm is expressed in equation 3.4:

$$\min_x f^T x \text{ such that } \begin{cases} A \cdot x \leq b \\ A_{eq} \cdot x = b_{eq} \end{cases} \quad (3.4)$$

Here the state variable x must be defined for LP optimization:

- $P_{grid}(1:N)$: power grid used from time steps from 1:N.
- $P_{battery}$: power from battery for the period 1 to N.
- $E_{battery}$: energy stored in battery for the period 1 to N.

The state variable is expressed as in equation 3.5:

$$x = [P_{grid}(1:N) \quad P_{battery}(1:N) \quad E_{battery}(1:N)]^T \quad (3.5)$$

Equation 3.4 contains equivalent constrains and inequality constrains:

$$A_{equ} = \begin{bmatrix} I_{N \times N} & I_{N \times N} & 0_{N \times N} \\ 0_{N \times N} & \gamma_{N \times N} & \emptyset_{N \times N} \end{bmatrix} \quad (3.6)$$

$$B_{equ} = \begin{bmatrix} P_{load}(1:N) - P_{pv}(1:N) \\ P_{battery}(1) \\ 0_{N-1} \end{bmatrix} \quad (3.7)$$

Where:

$$\gamma_{3 \times 3} = \begin{bmatrix} 0 & 0 & 0 \\ \Delta T & 0 & 0 \\ 0 & \Delta T & 0 \end{bmatrix} \quad (3.8)$$

$$\emptyset_{3 \times 3} = \begin{bmatrix} 1 & 0 & 0 \\ -1 & 1 & 0 \\ 0 & -1 & 1 \end{bmatrix} \quad (3.9)$$

While the inequality constraints are:

$$a = \begin{bmatrix} 0_{N \times N} & I_{N \times N} & 0_{N \times N} \\ 0_{N \times N} & -I_{N \times N} & 0_{N \times N} \\ 0_{N \times N} & 0_{N \times N} & -I_{N \times N} \\ 0_{N \times N} & 0_{N \times N} & I_{N \times N} \end{bmatrix} \quad (3.10)$$

$$b = \begin{bmatrix} P_{max} \\ -P_{max} \\ E_{max} \\ -E_{max} \end{bmatrix} \quad (3.11)$$

To simulate the proposed system, it needed to initialize all components, an m-file used to make initialization for all variables.



4. RESULTS AND DISCUSSION

The system simulated for many operating cases such as variable load capacity and power factor, constant load capacity, renewable energy generation, and with or without optimization.

4.1 System Operating Without Renewable Energy Generation

4.1.1 Case 1

The system components rating are listed in table 4.1 for this case.

Table 4.1: Case 1 System Ratings

Item	Irradiance level w/m^2	Constant load		Variable load (kw)		Operation mode
		kva	pf	KVA	pf	
Value	0	53.851	0.928	125	0.8	Normal

The system simulation results are shown in figure 4.1, and 4.2 respectively:

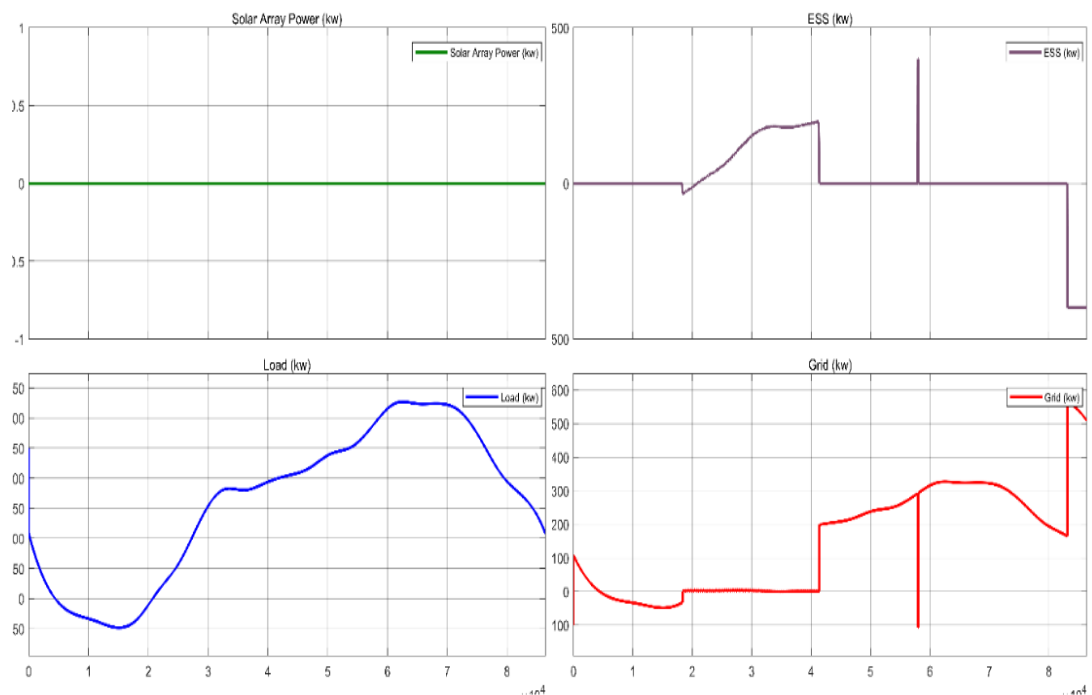


Figure 4.1: System Power Curves in Case Irradiance = 0 W/m^2

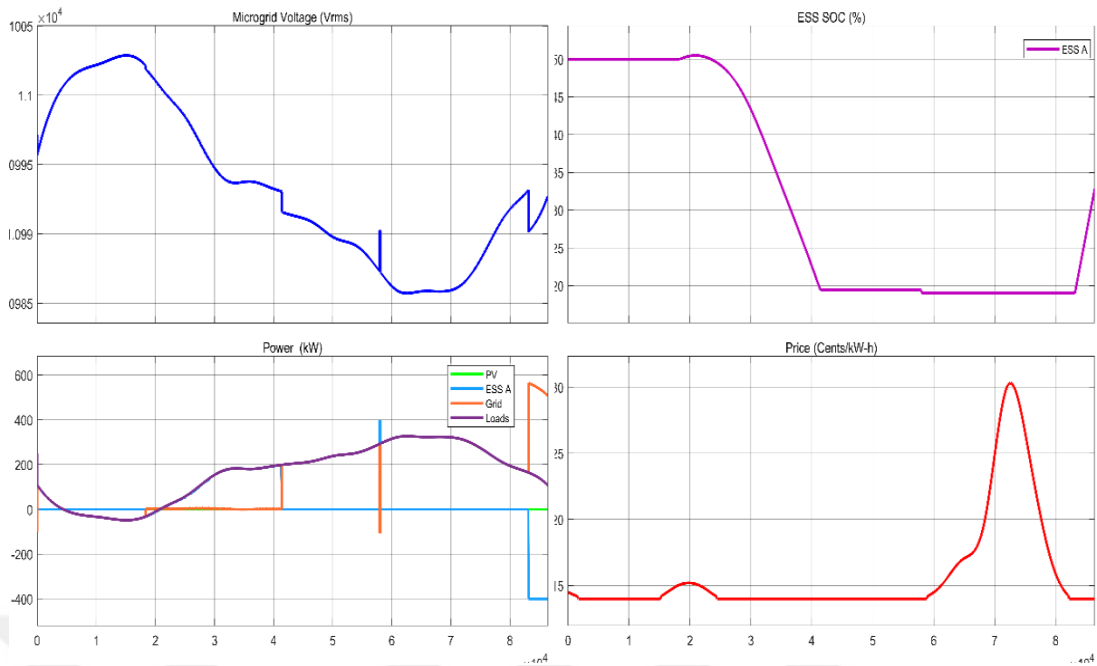


Figure 4.2: System Vole, Ptagowers, ESS SOC and Price Curves for Case (Irradiance = 0 W/m²)

Operating the system under these conditions shows that the grid voltage affected by loading, in maximum loading interval the grid voltage is in its minimum level, energy storage system state of charge is divided into two intervals also it reaches its minimum level when loading peak arrived. The pricing curve shows that the highest price occurs during the peak load interval.

4.1.2 Case 2

In this case the system operating in optimized mode, system ratings are listed in table 4.2, while simulation results are shown in figures 4.3 and 4.4 respectively.

Table 4.2: Case 2 System Ratings

Item	Irradiance level w/m ²	Constant load		Variable load (kw)		Operation mode
		KVA	pf	KVA	pf	
Value	0	53.851	0.928	125	0.8	Optimization

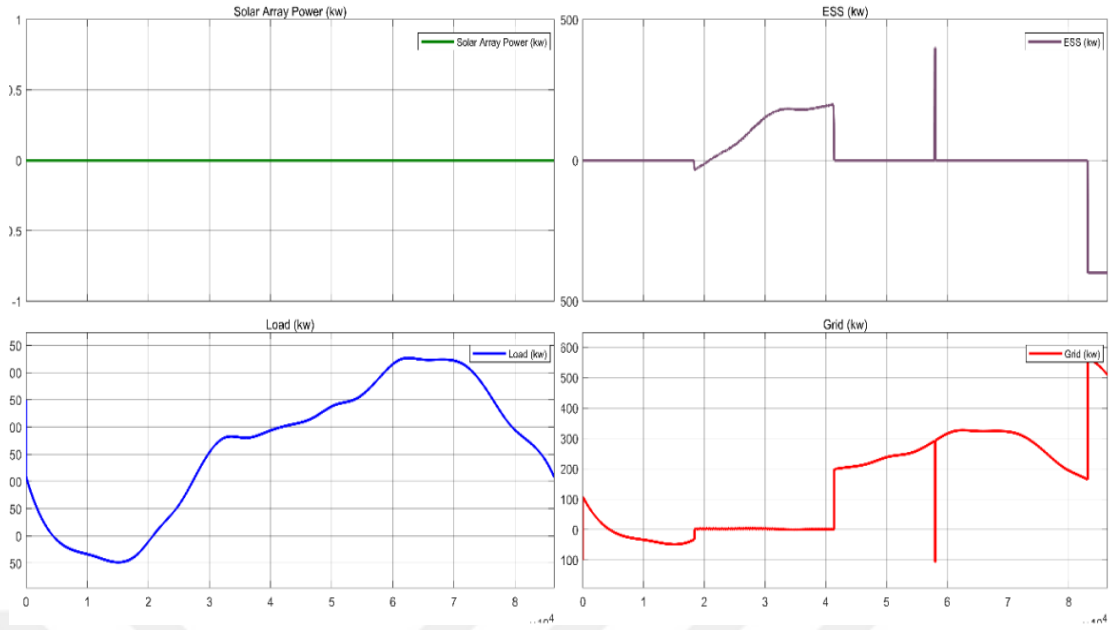


Figure 4.3: System Power Curves In Case Irradiance = 0 W/m²

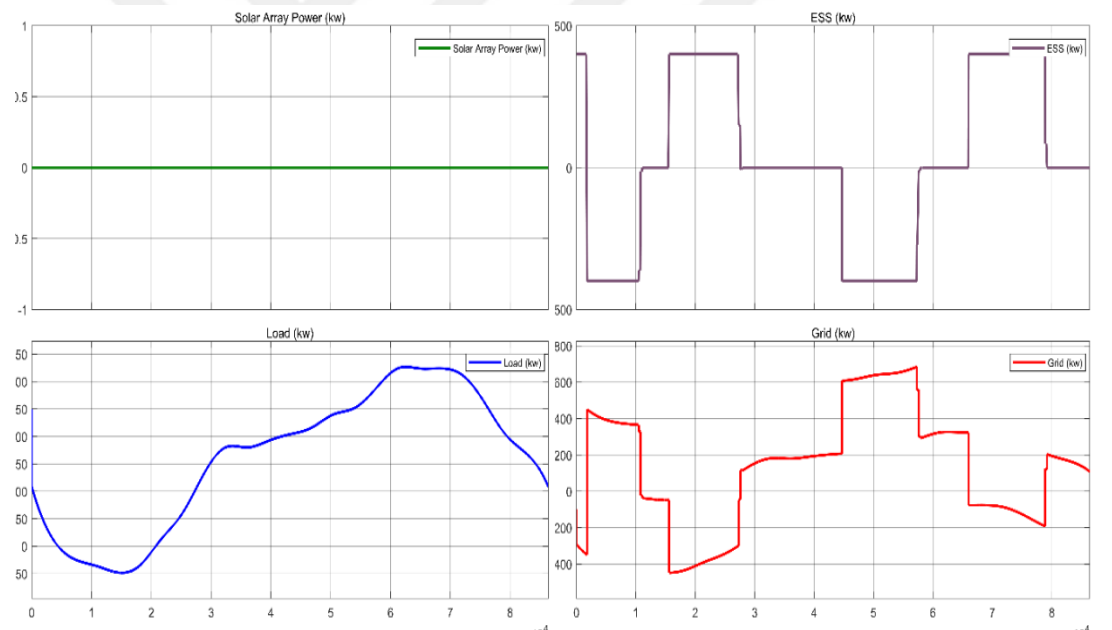


Figure 4.4: System voltage, powers, ESS SOC and price curves for case (Irradiance = 0 W/m²)

In this case the effect of using optimized operation mode is appeared on the ESS SOC and the grid voltage level, while energy pricing is not affected because there is no renewable energy source used in this case.

4.2 System Operating with Limited Renewable Energy Generation

4.2.1 Case 1

In this case the system operating in normal mode, system ratings are listed in table 4.3, while simulation results are shown in figures 4.5 and 4.6 respectively.

Table 4.3: Case 2 System Ratings

Item	Irradiance level w/m ²	Constant load		Variable load (kw)		Operation mode
		KVA	pf	KVA	pf	
Value	500	53.851	0.928	125	0.8	Normal

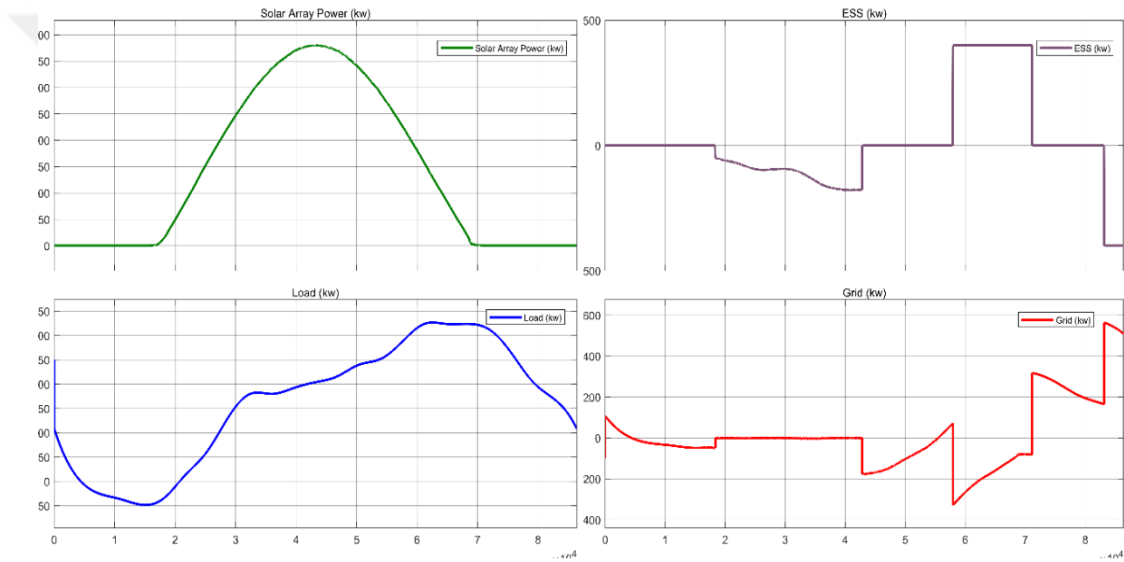


Figure 4.5: System Power Curves in Case Irradiance = 500 W/m²

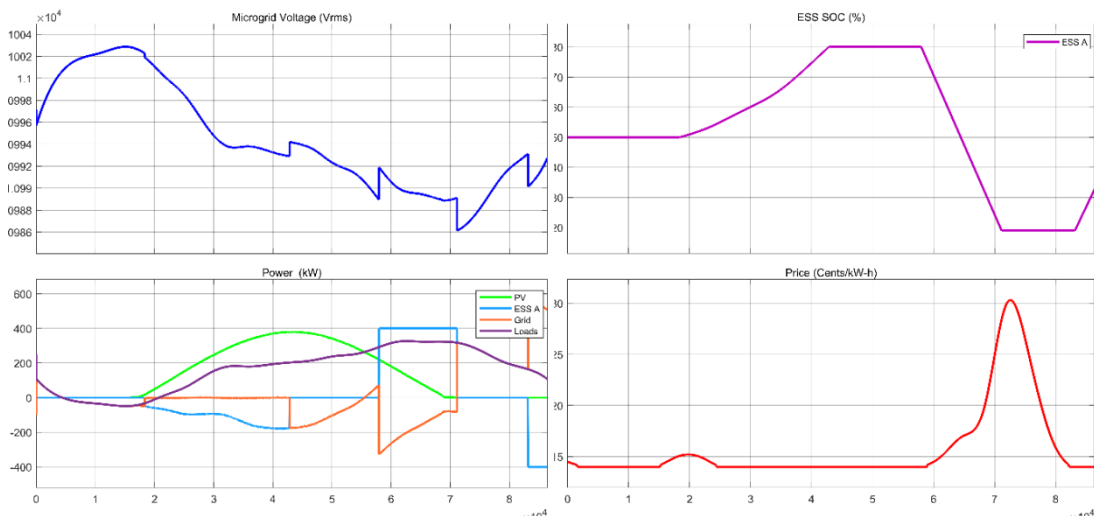


Figure 4.6: System Voltage, Powers, ESS SOC and Price Curves for Case (Irradiance = 0 W/m²)

4.2.2 Case 2

In this case the system operating in optimized mode, system ratings are listed in table 4.4, while simulation results are shown in figures 4.7 and 4.8 respectively.

Table 4.4: System Ratings

Item	Irradiance level w/m ²	Constant load		Variable load (kw)		Operation mode
		KVA	pf	KVA	pf	
Value	500	53.851	0.928	125	0.8	Optimized

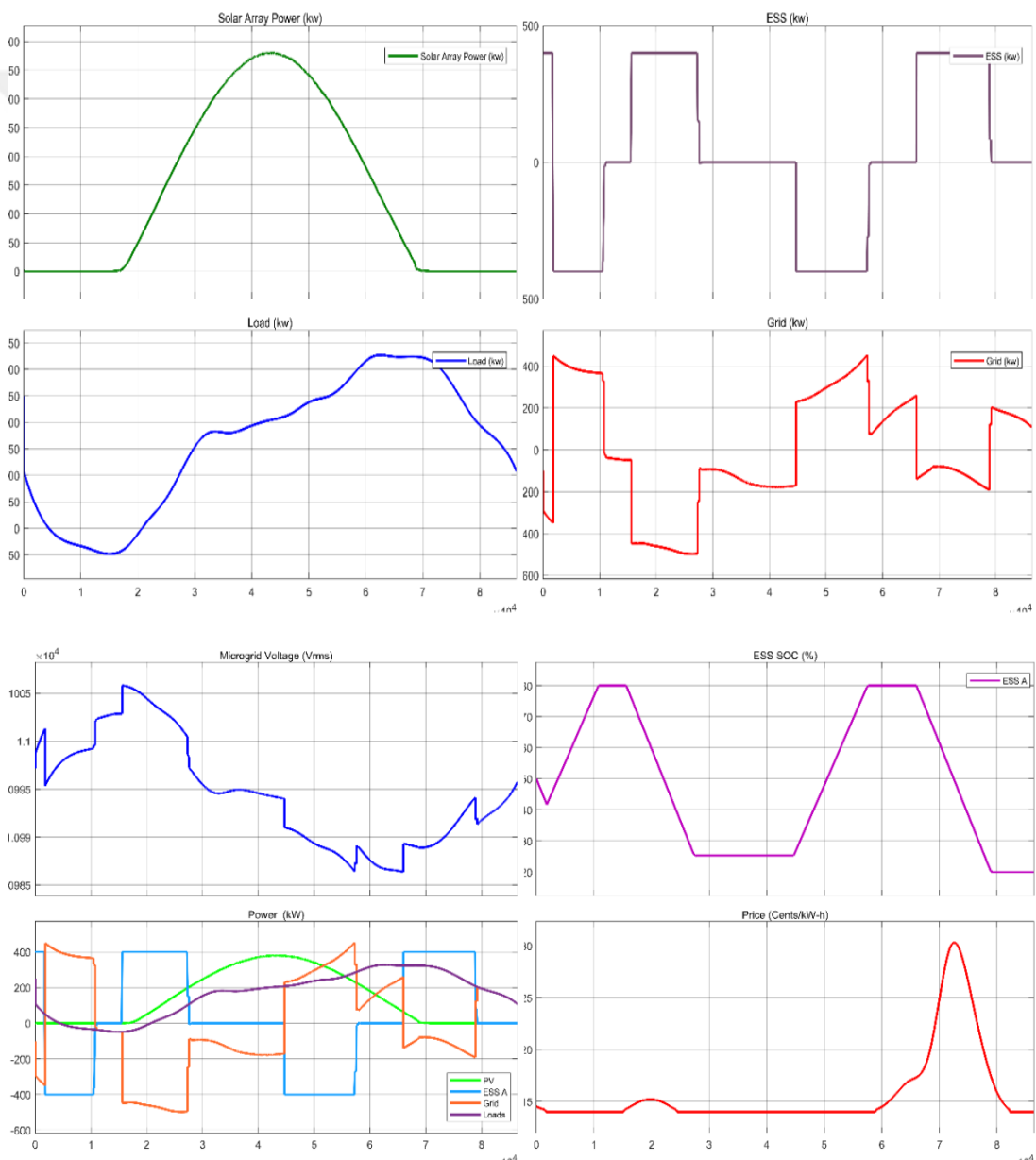


Figure 4.7: System Voltage, Powers, ESS SOC and Price Curves for case (Irradiance = 500 W/m²)

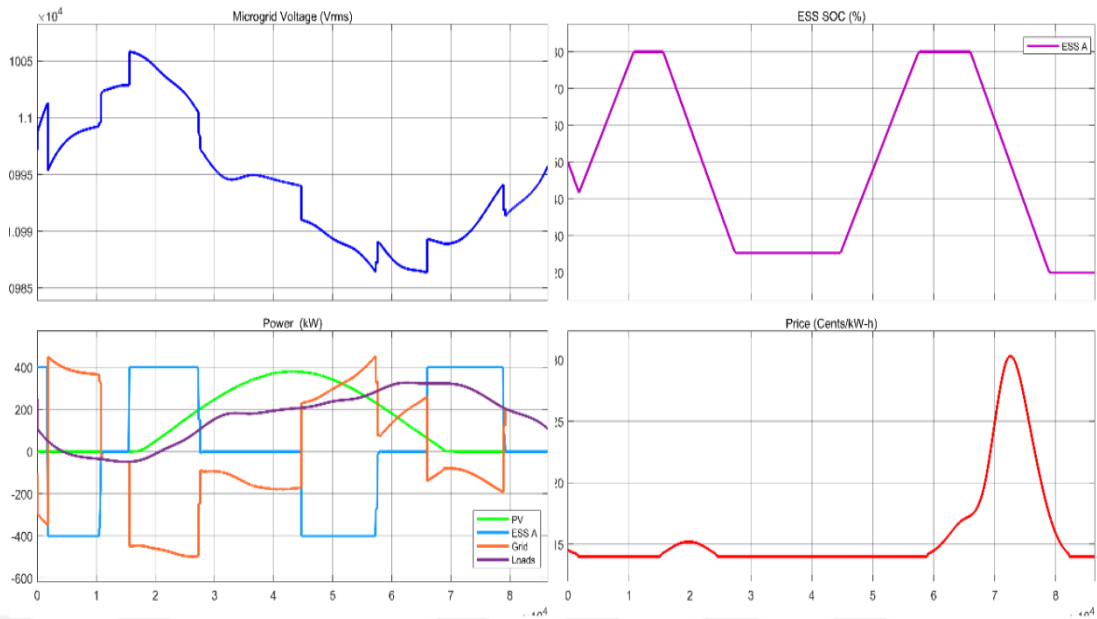


Figure 4.7: (Cont). System Voltage, Powers, ESS SOC and Price Curves for Case (Irradiance = 500 W/m²)

When the renewable energy is utilized, the effect is appeared clearly on the system performance (grid voltage level and ESS SOS), also the system performance in case 2 when operating in optimized mode is higher than that in normal operation).

4.3 System Operating with Full Capacity Renewable Energy Generation

4.3.1 Case 1

In this case the system operating in normal mode, system ratings are listed in table 4.5, while simulation results are shown in figures 4.9 and 4.10 respectively.

Table 4.5: System Ratings

Item	Irradiance level w/m ²	Constant load		Variable load (kw)		Operation mode
		KVA	pf	KVA	pf	
Value	1000	53.851	0.928	125	0.8	Normal

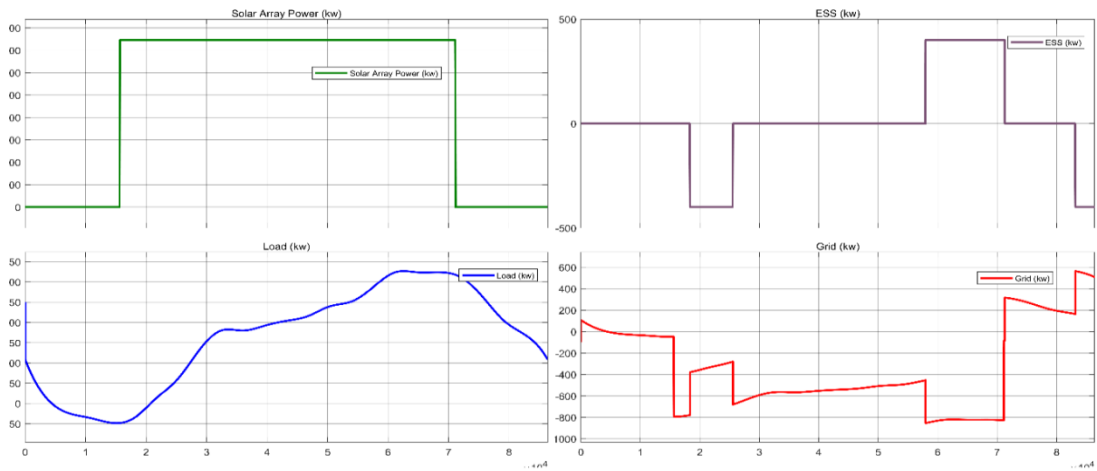


Figure 4.8: System Power Curves in Case Irradiance = 1000 W/m²

System performance in this case is best that that in case when the solar radiation level in range of 500 w/m², grid voltage magnitude affected by loading but in accepted range.

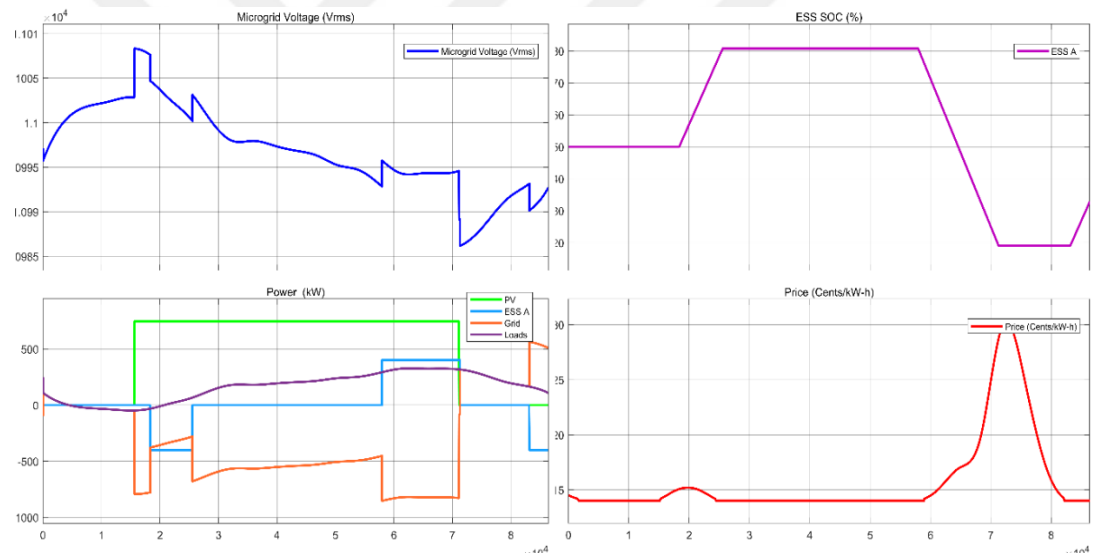


Figure 4.9: System Voltage, Powers, ESS SOC and Price Curves for case (Irradiance = 1000 W/m²)

4.3.2 Case 2

In this case the system operating in optimized mode, system ratings are listed in table 4.6, while simulation results are shown in figures 4.11 and 4.12 respectively.

Table 4.6: System Ratings

Item	Irradiance level w/m ²	Constant load		Variable load (kw)		Operation mode
		KVA	pf	KVA	pf	
Value	1000	53.851	0.928	125	0.8	Optimized

When system working in optimized mode the performance is the best among all simulated cases, since the grid voltage magnitude in all simulation period is about 1 p.u also the ESS is utilized for energy management in such way to give the grid voltage its stability. The simulated case may be a virtual case because the solar radiation can't be stable along daytime because of clouds during winter, spring or outman seasons, and dust during summer, so that cases of cloudy weather (section 4.4) may be the closest case to practical case.

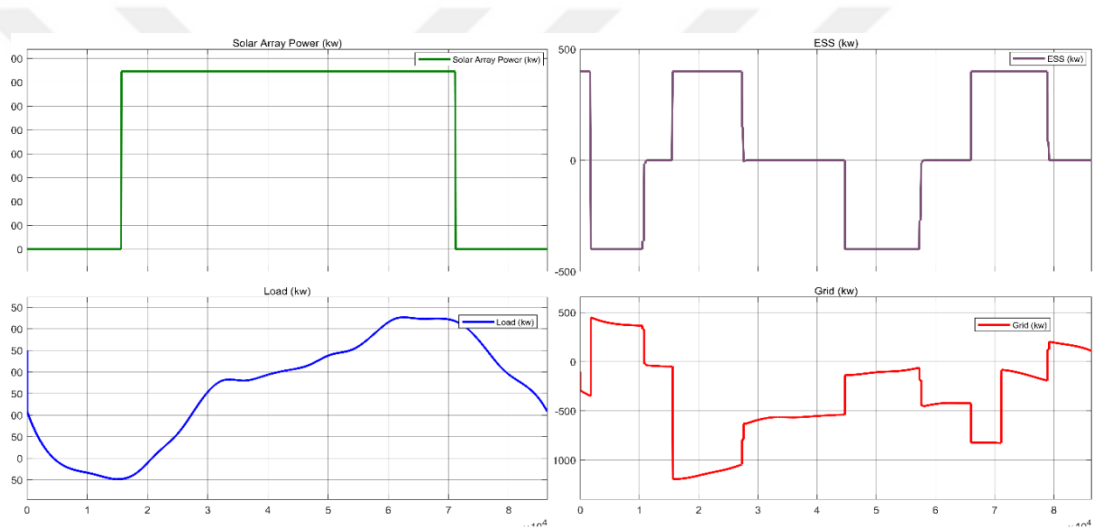


Figure 4.10: System Power Curves in Case Irradiance = 1000 W/m2

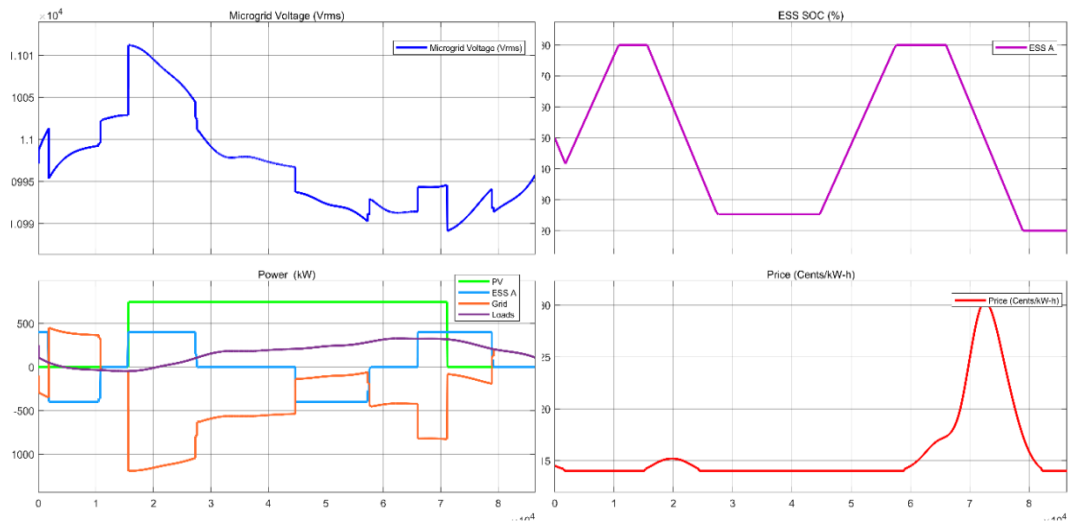


Figure 4.11: System Voltage, Powers, ESS SOC and Price Curves for Case (Irradiance = 500 W/m2)

4.4 System Operating with Limited Capacity Renewable Energy Generation (Cloudy Weather)

The effect of clouds is taken in care in system simulation. The solar radiation in cloudy weather swings between maximum and minimum levels. The real power generated in each case is depending on the solar radiation and effects the overall system performance. This case simulated for two simulation situations (normal operation and optimized operation).

4.4.1 Case 1

In this case the system operating in optimized mode, system ratings are listed in table 4.7, while simulation results are shown in figures 4.13 and 4.14 respectively.

Table 4.7: System Ratings

Item	Irradiance level w/m ²	Constant load		Variable load (kw)		Operation mode
		KVA	pf	KVA	pf	
Value	Cloudy weather	53.851	0.928	125	0.8	Normal

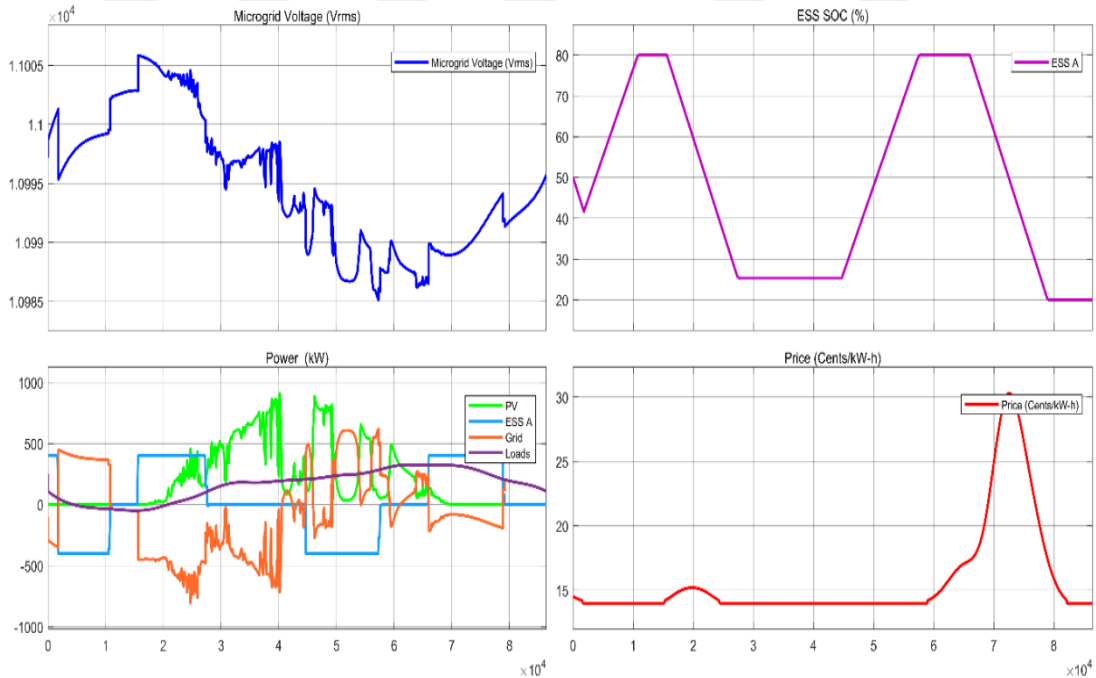


Figure 4.12: System Voltage, Powers, ESS SOC and Price Curves for Cloudy Weather Case

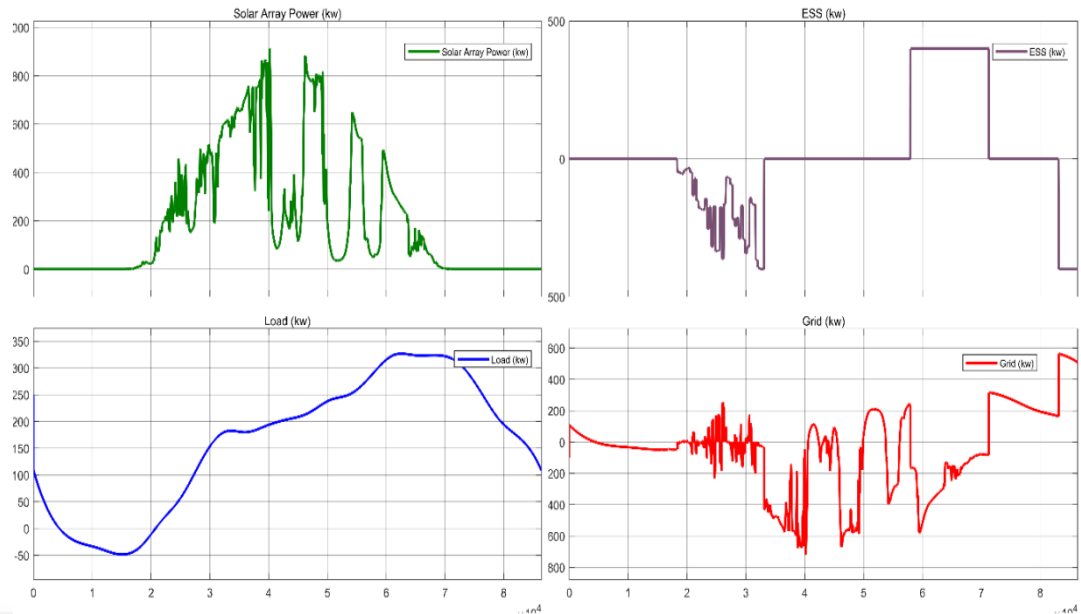


Figure 4.13: System power curves in case of cloudy weather

4.4.2 Case 2

In this case the system operating in optimized mode, system ratings are listed in table 4.8, while simulation results are shown in figures 4.15 and 4.16 respectively.

Table 4.8: System Ratings

Item	Irradiance level w/m ²	Constant load		Variable load (kw)		Operation mode
		KVA	pf	KVA	pf	
Value	Cloudy weather	53.851	0.928	125	0.8	Optimized

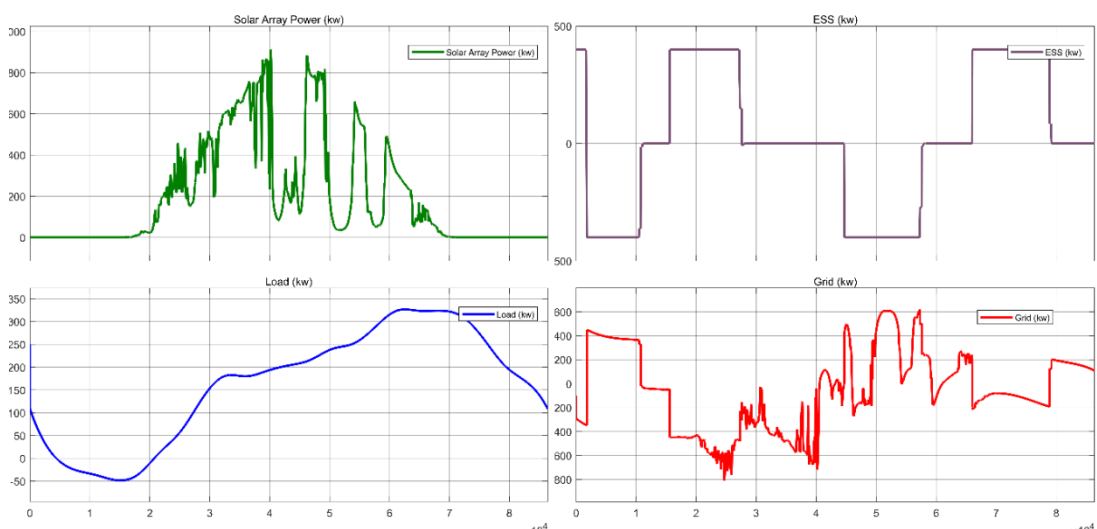


Figure 4.14: System power curves in case of cloudy weather

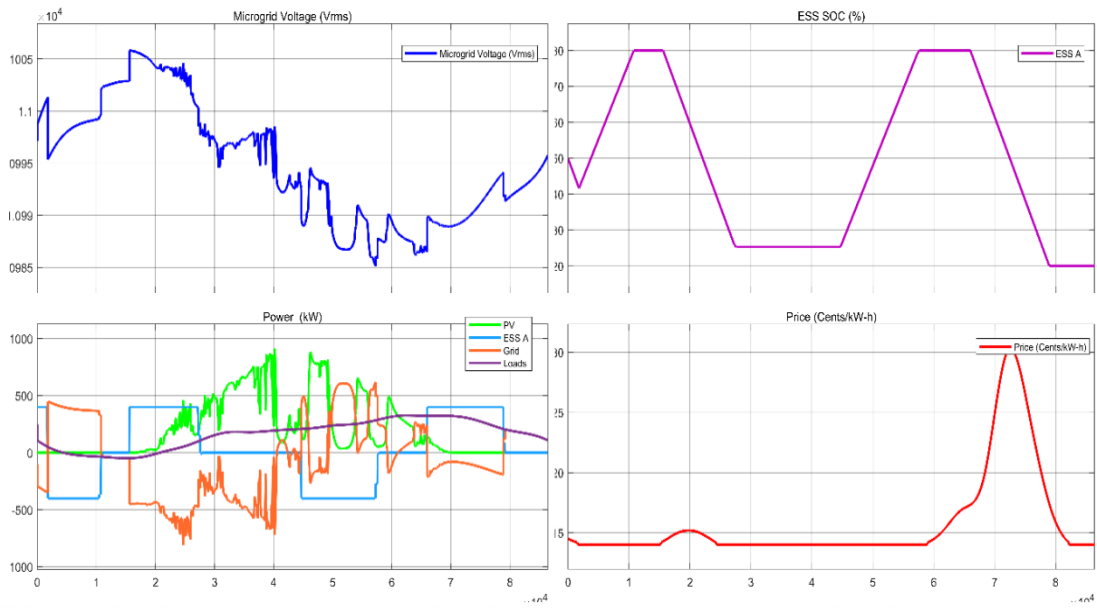


Figure 0.1 : System voltage, powers, ESS SOC and price curves for cloudy weather case

5. CONCLUSIONS AND FUTURE WORKS

5.1 Conclusions

A smart micro grid is designed and simulated using MATLAB for energy management process and utilization of both renewable energy source (solar array) and energy storage system to mitigate the grid voltage disturbance caused by loading. Two types of loads are used in this work, home application load and constant power load. The proposed system simulated for many cases trying to cover all possible practical conditions. The simulation is done using normal operation and optimized operation cases. For all expected operating cases the simulation has been done and the results are discussed. The simulation results showed that the system performance in optimized operating mode is the better than that the operation under normal mode. The best simulation results occurred under highest solar radiation and optimized operating mode. While the worst case occurs in case of absence of solar radiation and stored energy.

The proposed distribution grid management system has the ability to manage energy in smart distribution grid even it contains more than one type of renewable energy sources.

5.2 Future works

There are many operating conditions can assume to be future works:

- Load variation effects can be studied especially when the solar radiation in its minimum level.
- Flexible AC transmission systems FACTs can be used to control power flow in the smart grid, or may be used for load shading to mitigate voltage disturbance in the grid.
- Use another optimization method and study the system performance.
- Simulating the same system using another platform such as "PowerWorld program"

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RESUME

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