DESIGN OF DC POWER DISTRIBUTION SYSTEM USING HYBRID POWER (WIND AND SOLAR) FOR ETHIOPIA MINISTRY OF SCIENCE AND TECHNOLOGY DATA CENTER

A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCE

OF

NEAR EAST UNIVERSITY

By

MEDHIN GIRMA DEBELE

In Partial Fulfillment of the Requirements for

the Degree of Master of Science

in

Electrical and Electronic Engineering

NICOSIA 2019

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Applied Science

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

Energy is the highest vital necessity for human existence on earth. In today's era of knowledge and development, in nearly each part of the world the demand for energy is ever increasing whereas the source is not adequate to encounter this. The fast increasing server energy expenditure and the threat of climate variation have forced the IT business to look at datacenters powered by renewable energy. Hence it has become essential to find out alternative sources of energy such as wind and solar those are straightforwardly accessible. This thesis describes the design of DC power distribution system using hybrid power (wind and solar) for Ethiopia Ministry of Science and Technology (MoST) data center situated in Ethiopia capital of Addis Ababa. The city is located at latitude 9.005401 and longitude 38.76361 with height 2356 meters and found to have annual solar radiation of 6.55KWH/m^2 per day and 4.2 m/s annual average wind speed at height 25m. Those wind speed and solar radiation of the particular site is collected from National Metrological Agency of Ethiopia (NMA). For analysis and understanding of DC distribution systems secondary source of data is also implemented for the thesis. By means of HOMER software the hybrid system design and different analysis is completed. Load estimation is mainly concerned with calculating total electrical power capacity needed to sustain the data center, together with IT and chilling apparatus, power backup and lighting. The simulation outcome displays that the PV, wind and diesel generator with battery setup is ranked first since it has the least net present cost as compared with the other possible optimal results. The optimized result ranked first, with the cost of operation and renewable fraction being $0.328kWh and 74%, respectively, with a capacity shortage of 0%. Another finding of the thesis is that the DC distribution system in the datacenter minimizes the number of converters in the distribution system, which then decreases the prices on the entire datacenter and increases the overall efficiency of the system by reducing the losses.

Key words: Hybrid PV-wind; wind energy potential; solar energy potential; net present cost (NPC); renewable energy; off-grid PV systems; DC distribution and homer software.

ÖZET

Enerji, yeryüzündeki insan varlığının en büyük hayati gerekliliğidir. Günümüzün bilgi ve gelişim çağında, neredeyse her yerde enerji talebi artarken, enerji kaynakları ihtiyaca cevap vermek için uygun değildir. Hızla artan sunucu enerji harcaması ve iklim değişikliği tehdidi, bilgi Teknoloji merkezleri, işini yenilenebilir enerji ile desteklenen veri merkezlerine bakmaya zorladı. Bu nedenle rüzgar ve güneş gibi kolay erişilebilir alternative enerji kaynaklarının bulunması zorunlu hale gelmiştir. Bu yazıda Etiyopya Etiyopya Bilim ve Teknoloji Bakanlığı (MoST) veri merkezi için, hibrid (rüzgar ve güneş) kullanan DC güç dağıtım sisteminin tasarımı anlatılmaktadır. Şehrin enlemi 9.005401, boylami 38.76361 ve yüksekliği 2356 metre olup, yıllık 6.55KWH/m2/gün güneş radyasyonu ile 25m yüksekliğinde 4.2m/s yıllık ortalama rüzgar hızının olduğu hesaplanmıştır. Bu değerler, belirli sitelerin rüzgar hızı ve güneş radyasyonu olup, Etiyopya ulusal metroloji servis ajansından alınmiştir (NMSA). DC dağıtım sistemlerinin analizi ve anlaşılması için ikincil veri kaynağı da tez için simule edilmiştir. HOMER yazılımı ile hibrid sistem tasarımı ve farklı analizler tamamlandı. Yük tahmini, esas olarak, güç yedekleme, aydınlatma, bilgi Teknolojisi ve soğutma aparatları için gereken güç ile veri merkezini beslemek için gereken toplam elektrik gücü kapasitesini hesaplamakla ilgilidir. Simülasyon sonucu, batarya, PV, rüzgar ve dizel jeneratörün olduğu kurulum diğer olası en iyi sonuçlarla karşılaştırıldığında en az NPC'ye sahip olduğu için ilk sırada yer aldığını gösterdi. Optimize edilmiş birinci sonuçun, işletme maliyeti ve yenilenebilir fraksiyonu $ 0.328kWh ve % 74 olarak hesaplanmış olup, kapasite darlığının 0% olduğu görülmüştür. Bu tezin bir başka bir bulgusu ise veri merkezindeki DC dağıtım sistemi dönüştürücü sayısını en aza indirir, bu da tüm veri merkezi sistemindeki fiyatları düşürür ve kayıpları azaltarak sistemin genel verimliliğini artırır.

***Anahtar kelimeler*:** Hibrit PV-rüzgar; rüzgar enerjisi potansiyeli; güneş enerjisi potansiyeli; net simdiki maliyet (NPC); yenilenebilir enerji; sebeke dışı PV sistemleri; DC dağıtım ve homer yazılımı.

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LIST OF ABBREVIATIONS

IT:	Information Technology
DC:	Direct current
NMSA:	National Metrological Service Agency of Ethiopia
NPC:	Net present cost
COE:	Costs of energy
EEPCo:	Ethiopian Electric Power Corporation
GIS:	Geographical information systems
HOMER:	Hybrid optimization model for electric renewable
kWh:	Kilo watt hour
NREL:	National Renewable Energy Laboratory
NMA:	National Metrological Agency
NASA:	National Aeronautics and Space Administration
O&M:	Operation and maintenances
HVDC:	High voltage direct current
PDF:	Probability density function
SMSE:	Surface Meteorology and Solar Energy database
PV:	Photovoltaic
IECI:	International Electro Technical Commission
UPS:	Uninterruptible power supply
SAN:	Storage area network

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Over the past centuries, the identical ideas of renewable energy and sustainability have appeared by way of a significant central of civilization that is placed at the connection of culture, policy, science, innovation, technology, economics and the surroundings. These matching philosophies remain together enclosed as a resources to alleviate the damaging effects of natural reserve reduction, water consumption, energy consumption, and greenhouse gas releases interrelated with anthropogenic happenings. Owing to the energy predicament, ecological, political, and economic and business, and community issues, investigators and academies ought to remain concerned to cultivate bases of bearable and renewable energies toward safeguarding the atmosphere, to secure and energy consumption, and to endorse regional growth (Abbas et al., 2015).

Present days there are numerous methods of renewable energy. Greatest of these renewable energies hang on in one way or another on sunshine. By accumulating sunshine and changing it into electrical energy solar power will be created. This is through solar panels, which are big horizontal boards prepared through numerous separate solar cells (Gilbert, 2004). The other is wind power which is created by using wind generators to harness the kinetic energy of wind. It is ahead worldwide acceptance as a great weighbridge energy foundation.

Energy distribution and studying of efficient distribution system becomes the most issue of the researchers. AC design power distribution became the dominant power distribution in the nineteenth century, since transformers inexpensively resolved the difficult of receiving power more than a kilometer from a central power location (Kristof et al., 2001). DC power is basically the solicitation of a fixed or constant voltage through a circuit consequential in a constant current. Nevertheless, this electrification scheme was low voltage, due to the incapability to step up DC voltage at the period, and therefore it was not accomplished of transferring power over extended distances.

The distribution voltage equal remained the similar as the transmission one. It was constructed for only a 100 km distance of conduction line using 100 KV voltages (Kenzelman, 2012).

So far, today; the world faces the paralleled issues of distribution systems. The fast development of power electronic devices has led to have innovative distribution systems and solve the earlier challenge of voltage conversion. Specially, high voltage direct current system of transmission was developed back quickly and now days this transmission system is increasing its amount in the generation side due to the promotion of renewable/alternative energy sources (Cetin, 2010).

DC distribution system can include from 230 KV to 500 KV voltages for transmitting power over long distance (Sudeep and Mohammad, 2013). These power electronic devices enable also to develop DC distribution systems at medium and low voltage level from the existed AC power generation system. Medium voltage DC distribution (MVDC) system can be developed from AC/DC converter (Mule, 2017). Solar energy may also be noted as producing DC output as well. A wind farm is one technology which uses AC/DC/AC conversion for connecting with the grid. Not only generation, is DC once more displaying its being there in consumer load side through up-to-date equipment such as mobiles, IT equipment's, LED lighting etc.

Ethiopian Ministry of Science and Technology (MoST) is a public organization that established in December 1975 by proclamation No.62/1975 as a commission. Some of power and duties of the Ministries are organizing science, technology and innovation database, compiling information, setting national standards for information management, preparing and ensuring the solicitation of science and technology innovation indicators. For the overhead stated duties the ministry build data center with a capacity of 1.5 petabytes. The Ministry smart cloud data center is a modular data center because it can be expendable up to 500 server's homes. The cloud has two main cloud data center infrastructure management Systems such as Netco server which can manage remotely with an interface facilities air conditioner, UPS, security camera, access control, sensors, humidity, fire alarm, water detection and etc. (MoST, 2016).

An estimate of Ethiopia’s future electricity generation capacity includes more than 45000MW, 10000MW and 5000MW from hydropower, wind and geothermal resources, respectively. In spite of the copiousness of prospective wealth appropriate and intended for the energy district expansion, the level of electrical energy making has been poor. The electrically powered supply scheme all over the state is interrelated structure. This possibly will be accredited to a regular of difficulties, like a high cost of encompassing MV dissemination route, deficient generation capability, lack of good planning and etc. (Mule, 2017).

1.2 Statement of the Problem

The literature has distinguished abundant indication of the necessary importance of access to a reliable supply of electricity for economic progression. However, a suitable and stable source of electricity is distant from a reality in developing states, and this is particularly a difficult in Sub-Saharan Africa states like Ethiopia. Even though Ethiopia has substantial electricity generation potential (650TWh per year) she is still characterized by being one of the least electrified in the world and has low per capital electricity consumption (Abdisa, 2018).

The common power outage happening all over Ethiopia has come to be a recurrent problem. The regularly diverse and recurrent power-driven inside the country is creating a lot of glitches on residents: reaching from domestic side by side to commercial organizations. People and both public organizations and the isolated division have been continually grouchy that the everyday power outage is troublesome their daily accomplishments (Herald, 2015).

To mitigate the negative impacts of power outages, users have to invest in backup means of producing electricity from renewable energy bases such as wind and PV. To minimize loss and cost throughout energy generation and distribution system for standalone renewable hybrid energy systems (RHESs) DC distribution system is acceptable in this 21 century (Abdisa, 2018). Hence on this thesis we design standalone hybrid energy system for datacenter with DC distribution arrangement.

Loss of energy during the transmission of the electrical energy from production place to running down place is problem in power system. The transmission of the energy formed by renewable hybrid energy systems by the minimum conceivable forfeiture is tremendously imperative subsequently these systems are costly and the making remains intermittent. In the AC energy schemes, the power factor becomes complicated; hereafter this unfavorably touches the active power conveyed. Thus, it is important to investigate the way forward to minimize such a difficulty of damage of energy by using direct current systems.

Global development of data centers consequently takes straight significances intended at worldwide power consumption. According to Makris (2017) power usage in data centers specifically for global data center demand reaches approximately 30 GWs (about 3% of the total electricity) causing an enormous amount of CO_2 productions annually (Census, 2011). Consequently, the energy effectiveness of data centers is inordinate monetary significance for the operatives (Simens, 2009). In this 21 century a datacenters are predictable to be ran by combined renewable energy arrangements that hybrid various power generation systems (Burch, 2001).

For computer load and cooling load in data centers, power necessity is delivered toward totally pertinent electrical apparatuses nearby the regulator with the greatest consistency. Different system faults or even a power outage and the consequential statistics damage and breaks of processes involve countless monetary impairment for data center operatives. The scenario for data center running in Ethiopia is characterized by poor energy generation, transmission and distribution system. Therefore supplying energy from hybrid grid off standalone system will help the above mentioned problems.

1.3 Objective of the Study

1.3.1 *General objective*

The main objective of this thesis work is to design DC power distribution system using hybrid power (wind and solar) for Ethiopia Ministry of Science and Technology data center.

1.3.2 *Specific objectives*

- To analyze the overall power and energy demand of the data center by considering the basic needs of the loads.
- To select appropriate solar modules, wind turbines and batteries depending on the energy demand for the sites.
- Literature review about AC and DC distribution systems
- Identify the various DC distribution components and DC powered loads.
- Identify efficiency of the dedicated DC distribution system scenarios.

1.4 Significance of the Study

The unavailability of protected and consistent electrical power is a restriction to undertaking commerce in unindustrialized countries. Industrial firms and governmental organization in developing countries adopt different strategies to cope with deficiencies in electricity supply. This thesis will show the option to have standalone hybrid grid off system for a data center in Ethiopia. This will be useful for Minister of Science and Technology for decreasing power outage triggered by old electric power distribution lines. This will help to control fault occurring during power blackout, system failure, subsequent damage and disruptions of processes involve countless financial destruction for data center workers. The other issues undertaken by this thesis will propose the way forward to minimize the loss happening during power transmission from the production place to consumption place. In addition it will show the importance of direct current power delivery methods.

1.5 Methodology

1.5.1 *Source of data*

In this thesis primary and secondary source of data were implemented for analysis and for understanding the subjects matter. Primary data is collected from Ethiopian Minister of Science and Technology (MoST) and National Metrological Agency (NMA). The power demand for each IT load (physical server racks, computers networking equipment and routers), chilling apparatus, power reserve and light, security such as firewall or biometric security system, has been estimated and calculated based on information from MoST. In addition to primary data secondary data has been implemented for total load calculation. The wind speed and sunshine duration for Addis Ababa are collated from different sources such as: National Aeronautics and Space Administration and Ethiopia metrological service agency. By using sunshine duration of Addis Ababa and using an empirical equation solar radiation for Addis Ababa is calculated. NMA documented wind data by means of data logger attached to an anemometer, which is fixed at 2 m height. The measurement made at 2 m is extrapolated to hub height (25 m) by the logarithmic law. For analysis and understanding of the AC and DC distribution systems and for identifying ways of incorporating the DC distribution system in existing distribution system, secondary source of data from published books, journal articles and official documents is also implemented.

1.5.2 *Data analysis*

The hybrid system is modeled and simulated with Hybrid Optimization Model for Electrical Renewable (HOMER) software grounded on the primary and secondary analyzed data to get the greatest optimized solution for total load approximations. HOMER program makes it easier to the task of assessing the design of energy system by means of optimization algorithms. Moreover, the software applied for designing, modeling and inquiry to govern the best structural design, and size of the combined power scheme. In addition for calculating annual average solar radiation for the site, Microsoft excel spread sheet and MATLAB were used based sunshine duration data from NMA for 5 consecutive years (2013-2017).

1.6 Ethical Consideration

Considering the preparation of design requirements and standards ethical features of design procedures is implemented during the thesis work. Furthermore use of commonly recognized standards or customs, such as protection or confidentiality, are at pale; of trade-offs between different designs principles. The other ethical consideration is using the ideas or words of another person with giving appropriate credit.

CHAPTER 2

LITERATURE REVIEW AND BASIC THEORY OF SYSTEM COMPONENTS

Access to energy offers countless profits to growth through the delivery of consistent and effective heating, lighting, cooking, and mechanical power, transport and telecommunication services. Moreover, access to power has supported financial well-being, as production increases with companies, replacing labor-intensive work by automatic processes and finally leading to a positive virtuous growth cycle (Feron, 2016) Energy demands are growing globally with economic growth and the people are concerned with efficiency first for saving some money. Now a day’s energy distribution and studying of efficient Distribution system becomes the most issue of the researchers (Birhan, 2017).

2.1 Renewable Energy Technologies

Rapid growth of population creates human movement overloading this causes our atmosphere through carbon dioxide and other worldwide warming emissions. The consequence is a web of trivial and damaging influences, more frequent storms, sea level rise, from stronger, to drought, and extinction. In dissimilarity, most renewable energy foundations produce slight to no global warming emissions. Uniform when including “life cycle” releases of clean energy (i.e., the emissions from each stage of a technology’s life manufacturing, operation, installation, decommissioning), the global warming emissions related through renewable energy are negligible (Union of concerned scientists, 2017).

2.1.1 Wind energy

From renewable energy source wind energy source is one of them. In this dates wind energy has arisen as one of the utmost striking source of unpolluted power in arrears to its frequent profits such as mature and easily plant connection nature (Tariq et al., 2016). Global wind is instigated by pressure variances crossways the earth’s outward owing to the irregular space warming of the earth by solar radiation. The irregular solar heating of the earth resulted in circulation of the atmosphere which is greatly prejudiced by the properties of the revolution of the earth. In addition, variations in the movement can be caused due to periodical differences in the delivery of solar power (Nag, 2008).

The three core constituents of wind turbine are the barbican of which conveys the nacelle, the 2nd is the rotor and its blades one is which imprisonment the wind energy and transmit its power to the rotor center before electrical generator, 3rd is the nacelle which comprises the important constituents of the wind turbine, containing the electrical generator and the gearbox (Sons, 2004). Consequently, for wind turbine mechanism there are three foremost energetic drive establishments used: pitch control toward changing the aerodynamic loading on the blades, yaw drive to bring into line the nacelle through wind direction (Hussien et al., 2017). Depending on the axis round which the turbine blades rotate wind turbine is classified in to two. Those are vertical axis wind turbine and horizontal axis wind turbines see Figure 2.1.

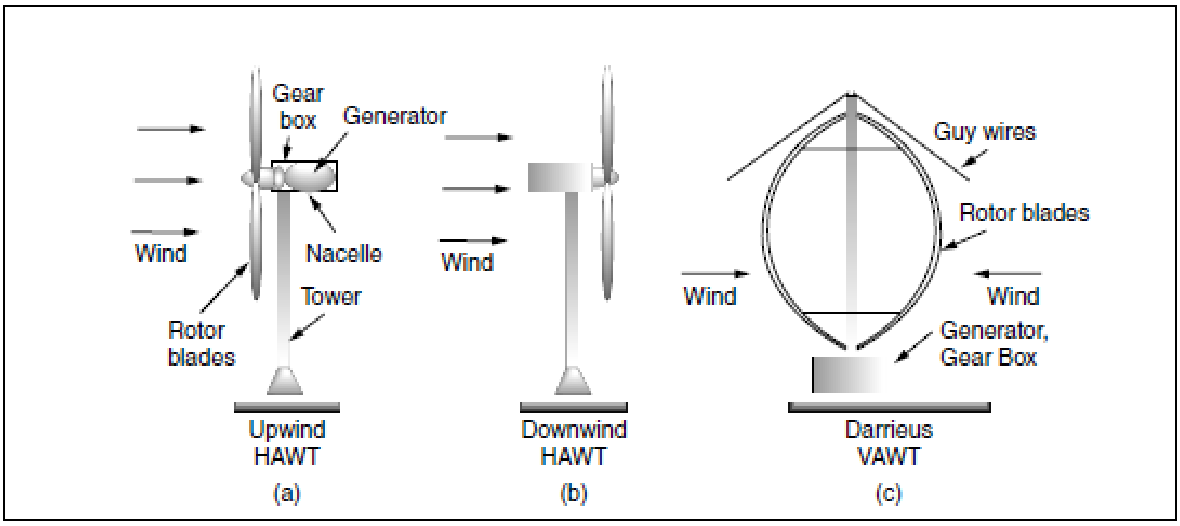

Figure 2.1: Horizontal and vertical axis wind turbine (Grid, 2017)

Floating off shore wind turbine (FOWT) is a kind of offshore wind turbines, which is placed on a floating raised area. FOWTs entice consideration for the reason that they obligate specific benefits: abundant wind wealth on the oceanic are accessible, generation price discount is conceivable since of a cheap of gauge, and around motionless continue massive appropriate setting up places. However this wind turbine has some disadvantage, the floating idea of the FOWTs and joint result of wind and waves stance numerous difficulties such as vacillations of raised area and generator power, and upsurge in exhaustion loads of the wind turbine apparatuses (Johnson, 2009).

2.1.1.1 *Wind data analysis and resource estimation*

Wind resource or power making possible of a particular site can be evaluated by direct and statistical techniques. Wind is produced due to temperature variation which results in pressure variation, and it blows from great pressure to low pressure area. The power from wind can be premeditated using the formula

$$P = \frac{1}{2}\rho A U^3 \tag{2.1}$$

where p is wind power

A= rotor area

U= wind speed

ρ= is air density

And this can be labeled by its power curve (or characteristics curve) which is shown in Figure 2.2. The features curve illustrates the following terms:

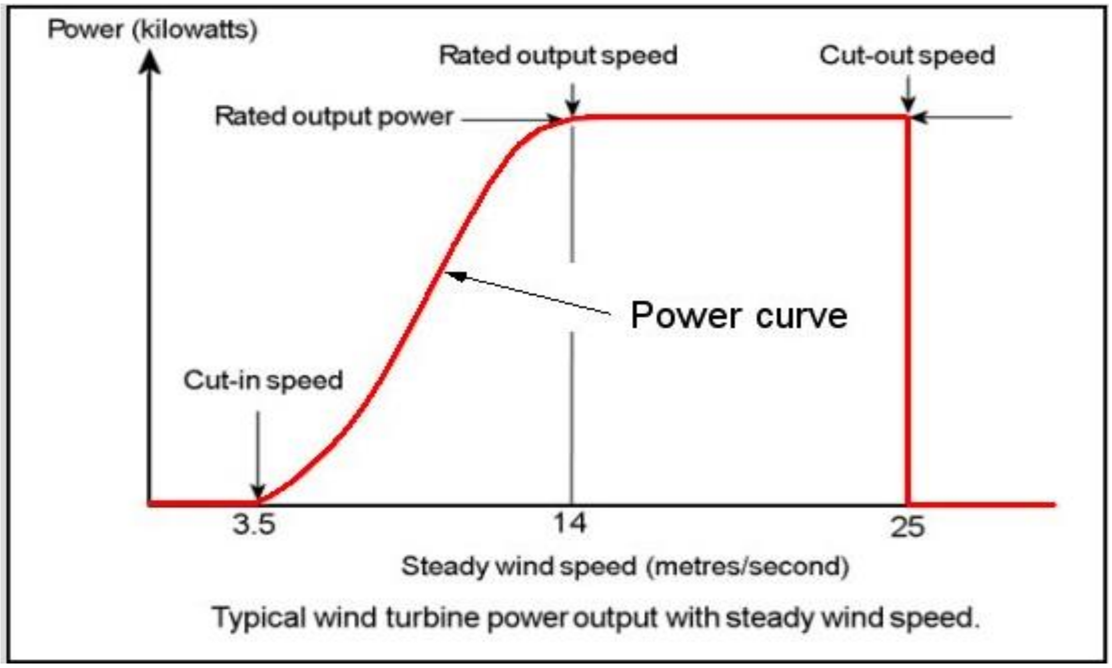

Figure 2.2: Power curve for wind turbine (Mohan, 1995)

2.1.1.2 Assessment of wind potential

Wind resources are determined using different ways from those methods the NASA database is one of them, and it seeing the wind direction at 50 m beyond sea level. The database arrange for the once-a-month wind speed averaged for specific month in between 10 years. Every monthly an average of value is assessed as the mathematical average of 3 hourly standards for the specified month. All sites are not suitable for the setting up of effective wind turbines. The yearly wind speed average might be a good pointer of the appropriateness of the setting up of a wind turbine in a specified place and normally values above 5 m/s and for few months less than 4 m/s are measured adequate for satisfactory results (Kassam, 2011). Different scholar's they conclude wind energy strong and reliable source of energy for Ethiopia and can generate a considerable quantity of electricity at an equitable cost which can even be disseminated to neighboring nations. The regions which can deliver the utmost potential for wind energy are the central, eastern, northern, and southwestern portion of the Ethiopia. Addis Ababa is also one of the districts in the central part of Ethiopia where there is good potential of solar and wind energy (Bekele, 2009).

Afterward the wind speed statistics has remained chronicled for more than five years, the dissemination chance can be used to forecast a forthcoming wind speed obtainability and clarify: first the retro when the wind is weak or short of wind, start up the wind turbines; second when the range of most likely wind speeds; and third the insignificant power output and the chances related through numerous productions (Bekele, 2009). The wind data can then be analyzed using two different analysis methods. These are the Rayleigh which uses the mean wind speed as a parameter, and Weibull which uses two parameters for statistical analysis (Gilbert, 2004).

2.2 Solar Energy

2.2.1 Basic theory of solar energy

The sun by nuclear fusion of hydrogen nuclei to helium it can produces energy (Kiros, 2014). The radiation constantly dropped on earth by the sun signifies the most basic and inexhaustible source of energy which is the mother of all forms of energy- conventional, renewable or non-renewable the only exception being nuclear energy (Nag, 2008).

Solar energy very large and infinite; the power from the sun captured by the earth is about $1.8 * 10^{11}$ MW, which is various thousands of times greater than the current depletion rate of all viable energy sources. Therefore solar energy, in principle, could bounce all the current and upcoming energy need of the world. Solar energy has altered benefit one is an ecologically uncontaminated foundation of energy which is obtainable in satisfactory amounts most of the world. However there are certain problems associated with it is use such as it is dilute source of energy, hardly exceeding 1kwm^2. Thus large collecting areas are required in many applications resulting in excessive costs.

2.2.1.1 Methods of solar energy utilization

Various techniques of solar energy exploitation are given in Figure 2.3. It is seen that the energy from the sun can be used directly and indirectly. The direct means contain photovoltaic conversation and thermal whereas the indirect means comprise the usage of the winds, water power and biomass.

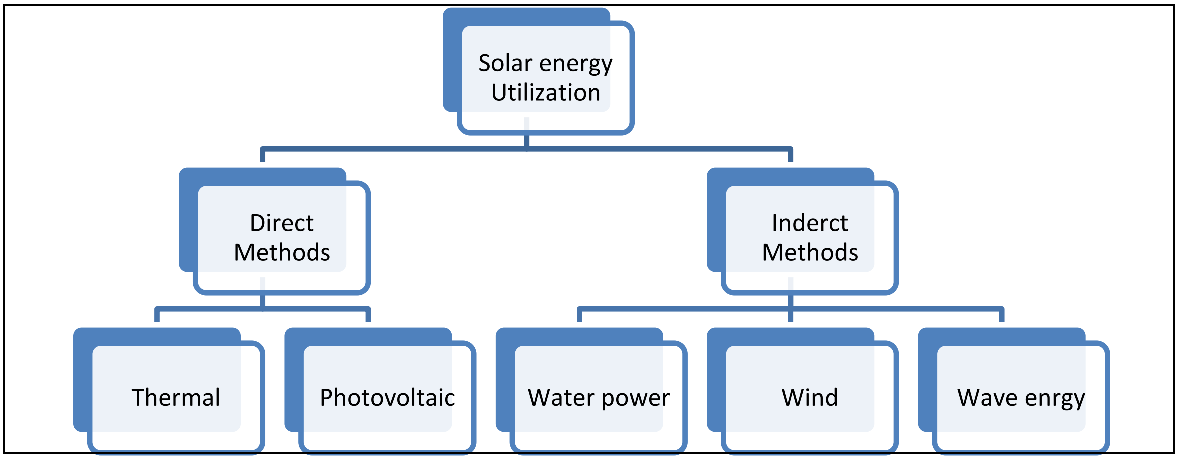

Figure 2.3: Methods of solar energy utilization

2.2.1.2 *Photovoltaic conversion*

For changing the energy confined of photons sunlit to an electrical voltage and current photovoltaic is a material or device is central. The historical time of photovoltaic originated by old French physicist, Edmund Becquere was in 1839 when he was 19 year old (Gilbert, 2004). In photovoltaic translation, solar radiation falls on semiconductor devices termed as solar cell which converts the sunlight straight into electricity (Nag, 2008). Let Consider in the purlieu of a *p–n* junction at the minute it is bare to sunshine. As electromagnetic radiations are engrossed, hole-electron couples might remain shaped (Mohan, 1995). If these movable charge haulers spread the neighborhood of the link, the electrically powered arena cutting-edge the exhaustion region drive the hovels hooked on the *p*-side and shove the electrons addicted to the *n*-side, as revealed in Figure 2.4. The *p*-side accumulates fleabags then the *n*-side collects an electron that generates a power which will be used to supply current.

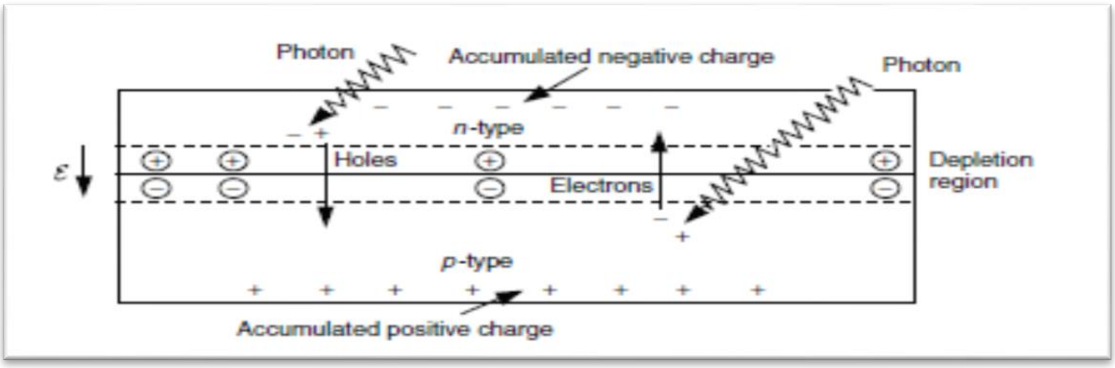

Figure 2.4: p - n junction for solar cell (Kiros, 2014)

From Arrays, Modules and Cells

Ever since a single cell creates simply nearly 0.5 V, it is an infrequent solicitation intended for which impartial a solitary cell is of whichever usage. As an alternative, the simple construction chunk for PV requests is a module which is prepared up of a quantity of pre-wired cells in sequence, all covered in threatening, and meteorological conditions-unaffected packages. A standard module has 36 series cells and is often marked as a “12-V module.” In turn, numerous modules can be wired in series to increase the voltage and in parallel to increase the current, producing power (Gilbert, 2004).

A significant component in PV structure scheme is determining in what way sundry modules must be linked in series and by what means several in parallel to bring whatsoever energy is required. Such amalgamations of units are bringing active to such equally an array.

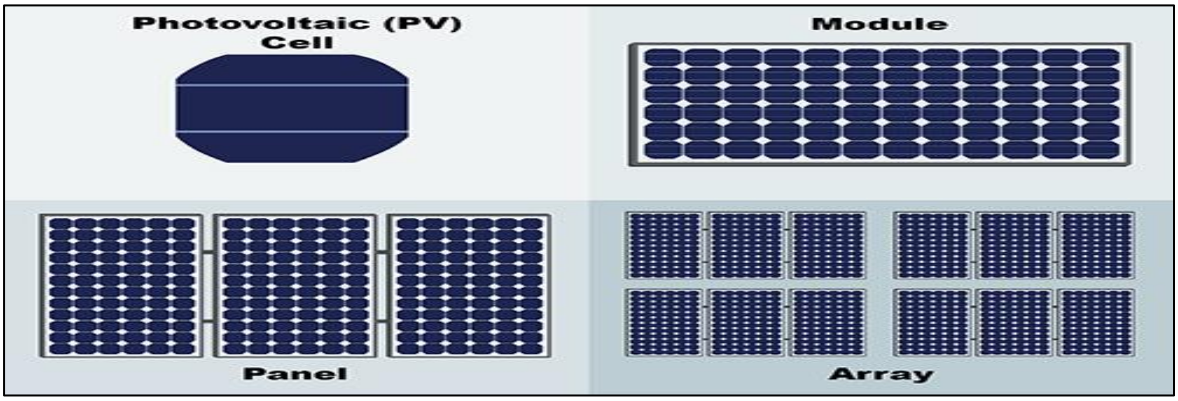

Figure 2.5: Photovoltaic Cells, Modules and Arrays

2.2.1.3 Major Photovoltaic system

Photovoltaic power systems are usually categorized rendering to their operational requirements, functional and, how the apparatus is coupled to other power sources and electrical loads and their component configurations (FSEC, 2014). The most frequently encountered PV Systems arrangement are schemes that fodder power directly into the utility grid, separate battery charging systems, possibly with generator reserve, and solicitations in which the load is straight coupled in the direction of the PVs, as is the situation utmost the highest water driving methods (Nag, 2008).

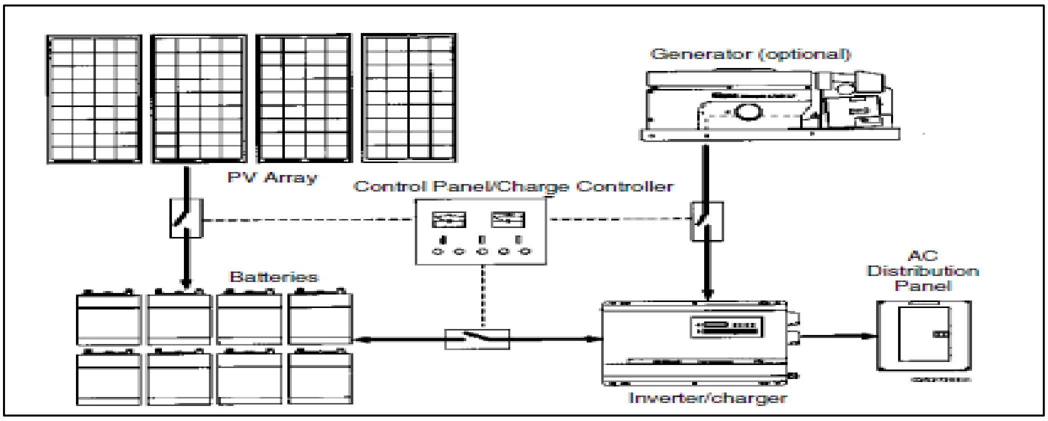

Figure 2.6: Stand-alone PV system (Nag, 2008)

Stand-alone PV systems are thoughtful to work autonomous of the electric utility grid, and are frequently envisioned and sized to amount convinced DC and/or AC electrical loads (FSEC, 2014). These structures can be much price in effect in unreachable location the lone substitutes might remain high-maintenance generators piping hot comparatively costly petroleum noisy, or spreading the current utility grid toward the place, which can price thousands of moneys each mile (Kiros, 2014). This scheme hurt after numerous disorganizations, nevertheless, as well as battery-operated losses besides the detail that the PVs typically function healthy off of their greatest well-organized working point (Gilbert, 2004). Figure 2.6 shows an off-grid, stand-alone battery storage scheme and a reserve power generator. In this specific method, based on the load an inverter and converter is applied where as if the load DC without any inverter the load will be run.

2.3 Hybrid System for Data Center

Succeeding the approach aimed at reducing hazardous gas and obeying with maintainable operative replicas, contemporary data centers consumption green energy bases like solar, hydro and wind energy. To maintain a consistent power distribution even during possible power failures for internal IT facilities through Uninterrupted Power Supplies (UPS) is basic thing in data center power distribution system (Makris, 2017). Based on research (Hosman, 2013) they are several recent technologies breakthrough for data center energy system design that is, energy-aware cloud computing, low-power computing platforms and

DC power distribution. This ultra-efficient method changes storage and computing nearer toward the consumer, upturns safety for confined information, decreases ecological footmark and energy prices.

2.4 DC Power Distribution System through Hybrid System

Power distribution system development initially was conceived in the method of DC distribution system. But, due to different weakness of this system and the invention of transformer, it was shifted to AC distribution system. As a result, the manufacturer created AC powered loads to the customers to meet AC generation systems. AC system dominated the market for a long time. Lately, the developments achieved in power electronics area led to further studies in direct current power systems (Birhan, 2017). The condition today is not the same due to expansions in solid-state power electronics (Cemal and Murat, 2014). Electric grid out- ages are shared, and datacenters be contingent on generators. Now days prices for diesel fuel dramatically increasing and unfettered effluence intensities from such generators, an innovative method are immediately wanted (Baikie, 2013).

A DC micro grid and the related distribution organization stay collected of power electronic converters which are present an overall auxiliary of electromagnetic transformers of the alternative current distribution scheme. In addition in this system, there are different types of power electronic converters associated to a DC Distributed Power System (Dastgeer, 2011).

2.4.1 Advantage of DC distribution system

Due to increasing request and setting anxiety, the addition of renewable energy source (RES) to power scheme is cumulative daytime. The RES such as wind turbine, solar, fuel cells are essentially DC power bases. This requires the outline of DC-AC converter at generation end, thus adding conversion fatalities and difficulty (Cetin, 2010). Then, in last two decays, the unceasingly increments in the growth of DC applications is lessening the structure load but maintains to introduce AC-DC converter and increase the conversion loss and difficulty of the scheme (Cemal and Gulb, 2015).

The DC incorporation of renewable energy bases for current straight AC distribution schemes compromises important assistances, for instance easy switch, developed voltage stability, and organization chances (Cemal and Murat, 2014). Furthermore, in DC distribution system harmonics and reactive power difficulties is not acquainted. Henceforth, the feature of power in DC distribution organizations is also additional healthy related with AC distribution system (Cemal and Gulb, 2015).

2.4.2 DC/DC converter for MVDC distribution

Stephan Kenzelman with the paper entitled “DC to DC converter for DC distribution and collection of networks” in his work the DC/DC converter used as a bridge in DC distribution system among different generation farms like wind, solar and other generation sources connected to the DC grid to supply AC loads by converting the distribution line into AC system with the help of inverter. The most important thing from this research work is DC to Dc converter used for high voltage distribution system. Krismer and Kolar with the paper entitled “Medium-Voltage High-Frequency DC-DC Converter” describe the efficiency of DC system converter for the application of DC medium voltage. This DC/DC converter transfers power between medium voltage input up to 28 KV and low voltage output from 650 V to 700 V. The level of DC voltages can able to transform over a long distance like transformer.

2.5.1. Fundamental component in data center

Uninterruptible Power Supply

For supplying very critical loads such as computer used for controlling important process, some medical equipment, and like it may be necessary to use UPS. These deliver voltage regulation during power streak above voltage and below voltage condition and give defense in contradiction of power outage. They are also excellent in terms of overpowering inward streak fleeting and sung turbulences. UPS in their block diagram form are shown in Figure 2.7 a rectifier is used for altering single phase or three phase ac contribution in to dc, which supplies power to the inverter as well as to the battery bank to keep charged (Mohan, 1995).

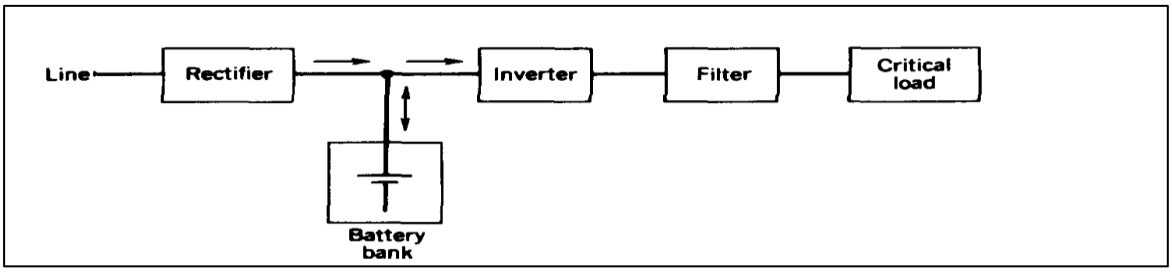

Figure 2.7: A UPS block diagram (Mohan, 1995)

UPS schemes remain in edict toward evade conceivable, undesirable significances of diminutive power letdowns. They sieve interventions, specifically voltage hollows and bond breaks popular the network. This benefit to stop computer cracks, transmission errors, and program faults and information damage. The other main pillars of data center are computers, Servers, networking equipment, specifically as routers, security system, storage, SAN or holdup/duct tape loading, management software/uses. In addition it includes Power and chilling apparatuses, like air physical server racks/chassis, conditioners or generators, cables and Internet backbone.

CHAPTER 3

RESOURCE ASSESSMENT AND LOAD ESTIMATION

3.1. Assessment of Solar Radiation

Ethiopia exist amid longitudes 33°E to 47.5°E, latitudes 3°N to 17.5°N and is a region having great solar irradiance all over the day and time (Abebayehu and Tesfaye, 1989). Ethiopian Minister of Science and Technology is located in the capital city of Addis Ababa. The city is located at latitude 9.005401, and longitude 38.763611 with the GPS coordinates of 38° 45' 48.9996" E and 9° 0' 19.4436" N through 2356 meters height above sea level (latlong, 2012).

From different scholars the maximum radioactivity glassy happening in Ethiopia is expected through south eastern regions, and north western in addition the lowermost via the western region. In the country entirely in all month’s solar radiation present in gradients from the north to center region which include the countries capital city Addis Ababa at which the thesis will be implemented. In the country the lowermost radiation level is in august and July and the highest is in the middle of the months June-April; analogous to the raining and arid season, correspondingly (Getachew and Gelma, 2012). All over the day and time a boundless percentage of the country including Addis Ababa obtains of 5500 wh/m^2 per day an average heat. This indicates the country consumed boundless radiation level which designates potential of solar power production (Kiros, 2014) (Abebayehu and Tesfaye, 1989).

The assessment of the potential of Addis Ababa in solar radiation is completed mainly by captivating statistics from and NMA of Ethiopia. There are two popularly used measuring instruments to distinguish the quantity of energy and radiation incident on horizontal surface of a particular Addis Ababa area. Among these the one which measures the sun shine duration is used by the national metrological service agency of Ethiopia. Hence, some mechanism has to be used to convert the values of the measured data (sunshine duration of Addis Ababa) to the required solar radiation to know the possibility of using solar system as source of electricity. Hence, in this work theoretically proofed formulas on equation 3.1 through 3.5 are used to figure out the solar radiation of the Addis Ababa site.

$$G_{on} = G_{sc}\left[1 + 0.033\cos\left(\frac{360n}{365}\right)\right] \tag{3.1}$$

where: G_{on} is the interplanetary heat dignified on the flat normal to the heat on the n^{th} day of the year (W/m^2) and G_{sc} is determined value (1366.1 W/m^2).

Based on the result of G_{on} obtained using equation 3.1, the total radiation incidence can be figure out using equation 3.2

$$\boldsymbol{H_o} = \left[\cos(\emptyset)\cos(\delta)\sin(\omega_s) + \left(\frac{\pi\omega_s}{180}\right)\sin(\emptyset)\sin(\delta)\right]\frac{24\times3600G_{sc}}{\pi}\left[1 + 0.033\cos\left(\frac{360N}{365}\right)\right] \tag{3.2}$$

Where $\emptyset$ = latitude of the selected area;

δ = declination angle

ω_s = sunset hours in degree

The daily solar radiation is measured J/m^2, however, G_{sc} is in W/m^2.

The declination angle illustrates the angular location for sun at planetary to the flat of the equator can be found from the equation 3.3.

$$\delta = 23.45\sin\left(360\,\frac{284+n}{365}\right) \tag{3.3}$$

The sunset hour in degrees is calculated by

$$\omega_s = \cos^{-1}(-\tan(\emptyset)\tan(\delta)) \tag{3.4}$$

n= day in continuous function of time of the year.

$$N_s(N) = \frac{2}{15}\times\omega_s\left(\frac{hours}{day}\right) \tag{3.5}$$

The sunshine duration data from NMA of Ethiopia is given in Table 3.1. The measurements are taken for five successive years from 2013- 2017. Hence, only the five year data is taken to convert in to MJ/m^2 using equation 3.1.

Table 3.1: Sunshine Duration of Addis Ababa

Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
2013	8.8	9.8	7.1	6.8	5.7	4.5	2.3	2.2	5.2	6.9	8.8	9.7
2014	8.7	7.7	8	8	6.2	5.1	2.3	3	3.2	6.6	8.5	9.2
2015	9.4	9.5	8.5	7.9	5.6	4	3.9	3.8	5.2	8.4	8	7.5
2016	7.4	9.1	7.6		5.7	4.1		2.6	4.4	7.5	7.8	9.4
2017	10	7.9	8.2	8.4		5.4	2.4	2.8	3.7		8.9	9.8
Mon. average	8.8	8.8	7.8	7.7	5.8	4.6	2.7	2.8	4.3	7.3	8.4	9.1
Annual average											6.54	

3.1.1 Estimation of solar radiation for Addis Ababa

Solar resource is one of the greatest significant inputs to PV power plant harvest and enactment evaluations. In order to guarantee well-founded choices in designing cost-effective solar power plants, the solar irradiance should be measures in the assessment phase (Parimita et al., 2016). Two different instruments are commonly used for measuring hours of bright sunshine in countries which have no instrument for measuring the solar irradiance directly. From that method Campbell-14 Stokes sunshine recorder are one of them and which usages a hard cut-glass compass at about 10cm by way of a lens that harvests spitting image of the sun on the contradictory superficial of the sphere, and the other is photoelectric sunshine recorder (Kiros, 2014). In areas where the radiation data's are not available in such Addis Ababa case empirical formulas can be cast-off to approximate the solar particle emission which is average from the hours of sunshine duration. The monthly average solar radiation then can be calculated using equation 3.6.

$$\frac{H}{H_o} = a + b\,\frac{h}{N} \quad , H = H_o\left(a + b\,\frac{h}{\mathrm{Ns}}\right) \qquad (3.6)$$

where H_o extraterrestrial radiation for the location which can be calculated using equation 3.2 and N_s indicates the calculated values for day length which are obtained using equations 3.5 The value for the coefficients α and b which are used to calculate average solar radiation (H) varies with location, and hence the approximate values for the selected site Addis Ababa are taken to be 0.30 and 0.50 for α and b respectively (Drake and Mulugetta, 1996).

The monthly average solar radiation for the hours of bright sunshine measured in 2013, 2014, 2015, 2016 and 2017 is converted in to MJ/m^2. Then result of the analysis shown in table 3.2 is the regular solar particle emission for each monthly in MJ/m^2 for the sunshine duration is determined using Matlab R2016a. Finally the monthly average solar radiation of the selected site based on the five year fully measured data is summarized and obtained to be as revealed in Table 3.2**.**

Table 3.2: Annual average and monthly solar radiation in MJ/m^2 of Addis Ababa

Year	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
2013	31.6	35.29	25.57	24.49	20.53	16.20	8.28	7.92	18.73	24.85	31.69	34.93
2014	31.3	27.73	28.81	28.81	22.3	18.37	8.28	10.80	11.52	23.77	30.61	33.13
2015	33.85	34.21	30.61	28.45	20.17	14.40	14	13.68	18.73	30.25	28.81	27.01
2016	26.65	32.77	27.37		20.53	14.76		9.36	15.84	27.01	28.09	33.85
2017	36.01	28.45	29.53	30.25		19.45	8.64	10.08	13.32		32.05	35.29
Mon. average	31.9	31.6	28.3	27.99	20.8	16.6	9.8	10.37	15.6	26.46	17.57	32.84
Annual Average											22.4 MJ/m^2	

From principal input parameter used by HOMER software monthly average solar radiation is there. But the values specified in Table 3.3 are not enough to use as an input to the software and to determine the potential of the area for implementing photovoltaic system.

Consequently, these are then converted in to KWh/m^2 using the conversion relation 1 MJ is equal to 277.78 Wh (Ivanova, 2012). Finally, the monthly and annual average solar irradiance in KWh/m^2 is obtained as shown in Table 3.3. As it can be understood in Table 3.3 the monthly average solar irradiance of Addis Ababa has maximum value on February with a value of 9.5 KWh/m^2 and minimum on July and August with a Monthly average value of 2.723 KWh/m^2 and 2.88 KWh/m^2 respectively. Since July and August are the months of the rainy season of Addis Ababa, the intensity of solar has reduced as compare with the other months of the year. The annual average solar radiation of the area is found to be 6.5454 KWh/m^2, and this value indicates that the area has good potential for the implementation of photovoltaic (PV) system to provide electrical energy toward the public.

Table 3.3: Monthly average solar radiation of Addis Ababa in KWh/m^2

Year	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
2013	8.8	9.8	7.1	6.8	5.7	4.5	2.3	2.2	5.2	6.9	8.8	9.7
2014	8.7	7.7	8	8	6.2	5.1	2.3	3	3.2	6.6	8.5	9.2
2015	9.4	9.5	8.5	7.9	5.6	4	3.9	3.8	5.2	8.4	8	
2016	7.4	9.1	7.6		5.7	4.1		2.6	4.4	7.5	7.8	9.4
2017	10	7.9	8.2	8.4		5.4	2.4	2.8	3.7		8.9	9.8
Mon. average	8.86	8.8	7.88	7.775	5.8	4.62	2.72	2.88	4.34	7.35	8.4	9.12
Annual Average										6.54 KWh/m^2		

3.2 Wind Resource Assessment

The areas which can provide the greatest potential for wind energy are the northern, central, eastern and southwestern part of the Ethiopia. Addis Ababa is also one of the regions in the central part of Ethiopia where there is potential of wind energy. Wind speed (The rate of the motion of the air on a unit of time) data of Addis Ababa station was composed from NMA. NMA documented wind statistics by means of facts logger devoted to anemometer which is stable next to 2 m above the ground. The wind speed which is annual average dignified at 2 m is 3.28 m/s. As specified in Table 3.4 the monthly wind speed of Addis Ababa varies between 2.75 m/s and 6 m/s at a height of 2 m with annual average of 3.28 m/s. These numbers indicate that the area has a potential for implementing wind system to give electric power supply to the Ministry of Science and Technology data center which is found in Addis Ababa.

Wind Speed of Addis Ababa

Region: - Addis Ababa Obs

Elevation: - 2386 m

Table 3.4: Average annual wind speed in m/s

Year	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
2013	5	1	2	2	0	2	2	3	0	1	4	4
2014	6	4	4	4	4	6	4	4	2	6	4	2
2015	4	4	3	6	4	4	3	2	4			
2016	2	2	2	4		4	2		2		2	7
2017	4	4	4	2	2	2	2	2		2	4	3
Mon. average	4.2	3	3	3.6	3.3	3.6	2.75	2.88	2.6	3	3.5	4
Annual Average											3.28 m/s	

The measurement made at 2 m is inferred to hub tallness at 25 m using the logarithmic rule, which undertakes that the wind speed is related to the logarithm of the elevation beyond the ground equally agreed by equality or equation 3.7 (Bekele, 2009).

$$\boldsymbol{V = V_{ref}} * \left(\frac{\ln\frac{Z}{Z_o}}{\ln\frac{Z_{ref}}{Z_o}}\right) \qquad (3.7)$$

where:

$\boldsymbol{Z_{ref}}$ =height at reference in m

$\boldsymbol{Z}$ = the assumed height (m) to determine the wind speed

$\boldsymbol{Z_o}$= unevenness surface measurement (0.1 to 0.25 from smooth hard ground, calm water to large city with tall building crop). For Addis Abba case it will be 0.4.

V= Hub height wind speed in m/s,

$\boldsymbol{V_{ref}}$= Reference height wind speed in m/s

Equation 3.7 is then used to determine the values in Table 3.5.

Table 3.5: Average annual wind speed (m/s) at 25 m height

Year	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
2013	5.7	1.1	2.3	2.3	0.0	2.3	2.3	3.4	0.0	1.1	4.5	4.5
2014	6.8	4.5	4.5	4.5	4.5	6.8	4.5	4.5	2.3	6.0	4.5	2.3
2015	4.5	4.5	3.4	6.8	4.5	4.5	3.4	2.3	4.5	0.0	0.0	0.0
2016	2.3	2.3	2.3	4.5	0.0	4.5	2.3	0.0	2.3	0.0	2.3	4.0
2017	4.5	4.5	4.5	2.3	2.3	2.3	2.3	2.3	0.0	2.3	4.5	3.4
Mon. average	4.8	3.4	3.4	4.1	3.8	4.1	2.8	3.3	3.0	3.4	4.0	4.5
Annual Average											4.3 m/s	

As a result, the annual average wind speed of Addis Ababa which is located at latitude 9.005401, and longitude is 38.763611 is 3.28 m/s at an elevation of 2 m. And the monthly regular wind speed of the city is between 2.8 m/s and 4.8 m/s at a height of 25 m. This value is used as input to the wind res source in simulating the hybrid setup. The wind speed data shown in table 3.5 is at a blade height of the selected wind turbine which is converted using equation 3.7. The other option is taking data from NASA which will be described in chapter 4, based on NASA data the annual average wind speed is 4.25 m/s which is almost similar to the data calculated based on the value of Ethiopia National Metrological Agency.

3.3. Load Estimation

Now a day's hyper scale data center owner company like Google, Facebook, Microsoft, apple, have erected at the front in green power inventiveness, as pioneer's discovering their intrinsic commercial, ecological and communal worth. Microsoft aimed at built 100% hydropower in quincy, Washington, and is testing with operating a 200 kW data center in wyoming with biogas commencing a local cheyenne wastewater conduct ability. In the same manner Apple, which partakes erected hooked on its earliest, 20 mw solar power that empowers entire confidence on renewables, or Verizon infrastructures, which publicized 2 adapting renewable energy to the data center. This shows that renewable energy like wind and solar are being used in wide rage data center applications (Maddox, 2013).

Load estimation mainly concerned with calculating whole electricity volume wanted on the way to sustenance the loads, together with IT load and chilling apparatus, power reserve and light. The total IT load contains servers, computers networking equipment, such as routers or switches, security, such as firewall or biometric security system, power and cooling devices, physical server racks/chassis. Estimating the size of the electrical service, these fundamentals can remain rummage-sale toward approximation the power production volume of a reserve generator scheme, if individual is obligatory for the data center loads. The Ministry data centers are part of a ministry edifice. Therefore the load estimation will twitch by resembling the competence obligatory for that share of the office block devoted to the data room.

3.3.1 General information about the data center

As per the data taken from Ministry of Science and Technology (MoST) the data center have total floor area of 187 m^2 and with power house 45 sq. m, telecom 12 sq. m, and staging area 20 sq. m. The storage capacity 2 PB in two disk arrays with 72 racks, 2 modular enclosures, and the enclosure contain cold aisle, 1 modular has 36 racks with a combination of 2 PDU for power redundancy, 7 air conditioners. The Ministry data center power distribution described as follows. The total power comes from Ethiopian electric power through national grid with capacity 1000 KW which goes to PDF room lies on 1600 AMP MCCB then it goes to 1000 AMP MCCP then from 1000 AMP there will be four 250 AMP breakers two of them is energies to PDU in power house, and a third line to data center PDU for direct power connection to AC. There are two PDU on each module at the beginning of their rows.

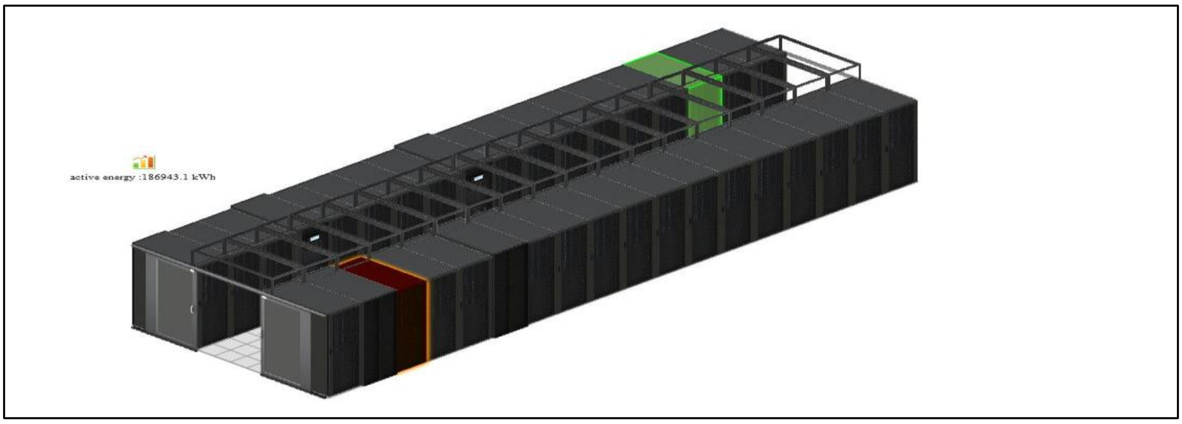

Figure 3.1: MoST Data center 3D-rack layout

The Data Center operation hour is 24/7, but some services are required only in working hours. But others like web hosting run 24/7 which means the DC is running 24/7. The average amount of power consumed in the building during peak usage (workday) periods is 163 – 256 KW which is for data center AC, for 2 racks, for UPS and others is 10-25 KW. And for the total building power consumption with 150 Employee Laptop and Computers, Printers, Lights and Socket Use and etc. is around 35-40 KW. Regarding Power change in a day/year/month, at this instant there is no power change on consumption, but on load variation mostly day time or working days use which is described in the above sentence. For the night time and weekend the power consumption is 45-60 KW**.**

Table 3.6: Different loads in a Ministry Science and Technology building

Description	Electric power demand (KW)	Share of electric energy use (%)
Overall Building Load	1000KW	
Standby Generator	1000KW	
Building - (other non-Data Center load	140KW	14
Total Data Center Load	780KW	86

As we can see from the Table 3.7 Electric powers was supplied to the Ministry of Science and Technology building from the utility passes through 1666.6 KVA transformers which is equivalent to 1000 KW. This power directly goes to the breaker under low voltage breaker with capacity 1600 A/3P and passes through different breaker each having 400 A/3P. The data center computer power is provided directly from 400 A/3P via single throw safety switch; by using Uninterruptible Power Supplies (UPS's) with capacity 480 KVA. In addition, there is standby generator with the capacity 1000 KW serving the facility. In the data center there are different types of load, based on data center management from Ministry of Science and Technology they classify the load mainly in three, and those are critical IT load, cooling system load and UPS. The load are using AC power from national grid often a backup generator to provide reliable power in case of power outage.

A. Critical loads

A load that makes the IT system purposeful is the critical IT load which comprises of IT hardware components. Those are computers, storage devices, telecommunications equipment servers, routers, in addition to the safety systems that defend the overall system (Sawyer, 2011). To know the total required critical load, about the voltage requirements, power rating, and the type of phase the equipment nameplate information will be one option. But this method as some scholar mentioned on their research papers, the nameplate grade of utmost IT equipment is well in extra of the real working capacity by a dynamic of at minimum 33 percent (Code, 2017).

For this thesis the overall load of the data center is in used from Ministry of Science and Technology. As we see from Table 3.7 the total power for data center estimated to be 780 KW and from this 285 KW power which is 36.5% is operational by critical load. From the total critical load the overall data center rack component (servers, networking device) electric consumption takes more than 94%. A data center rack is predominantly intended to stock servers in diverse method issues such as blade servers. Granting they exist mostly intended to grip servers, various are intended to grip additional mechanisms, such as telecommunication and networking equipment (techopidia, 2012).

Table 3.7: Total of Electricity loads for Critical load

Load Type	Description	Electric power demand (KW)	Share of electric energy use (%)
Critical loads	Data Center Rack Load	270	94
	Fire and monitoring systems like CCTV, Fire alarm	15	5.3
Total		285 KW	

B. UPS loads

UPS effectiveness differs among merchandise replicas and differs melodramatically contingent on the filling of the system of UPS. UPS are infrequently worked at the working facts wherever their promoted effectiveness is delivered. A truthful and adequately exact rate intended for UPS effectiveness in a characteristic system is 88 percent. For the Ministry data center they are two UPS with product specification HUAWEI UPS5000-E Series (40 kVA–480 kVA). As described on Table 3.9 both of the UPS from the input side they have 250 A/3P power electric capacities and from the output side they have the capacity to deliver 200 kW power. Then the out power is delivered to server rack of the datacenter. The UPS5000-E is recommended for poor power grids because it supports a wide range of input voltages and frequencies. The UPS5000-E works at full load when the line voltage is 305–485 V AC and is linearly rerated when the line voltage is 305–138 V AC. The input PF is 0.99, and the total distortion of the input current waveform is below 3% for these specific UPS and delivers an efficiency of more than 99%-96% in energy control operation (ECO) mode.

Table 3.8: UPS Electrical Measurements

Description	Unit	Electric power demand (KW)
UPS input	KW	250AMP
UPS output	KW	200KW
Losses	KW	5%
Efficiency	%	99-96%

C. Cooling system

1. *Chiller*

The green grid consortium approximate that even in a well-organized datacenter, 42% of the whole electricity is castoff through the chilling methods. Cooling for the data center facility was helped by the structure’s main cooler plant and the makeup air method. The building chilled water system included two air-cooled chillers with chilled water pumps. The cooling system inside the data center included two Computer Room Air Handling (CRAH) units that received chilled water from the chiller plant serving complete building. The data center, along with the remainder of the building is used uses water and humidifier for chillers. There are two chillers in data center each chiller had a design power consumption of 35 kW per ton of produced refrigeration. Based on this the total power needed for chiller is 70 KW. Throughout the monitoring period the chillers operated at approximately 49% to 54% of total motor capacity Chiller #1 carrying 46% of the cooling load, chiller #2 carrying 64%.

2. Air handler for computer room (CRAH)

CRAH is a scheme rummage-sale regularly in data centers to treat through the warmth manufactured via utensils. It uses motorized cooling to calm the air presented to a data center, a CRAH usages cooling coils, fans and a water to eliminate warmness. Three out of five package Computer Room Air Handling (CRAH) units were in operation in MoST data center, supplying the data center with cold air from the one-foot raised floor.

The CRAH’s were Pomona Air Model # PW 3000 units. No reheat coils or humidifiers were included in the CRAH units.

Using software that handles the requirement of AC to cool down IT equipment, when cooling was not required the software lets the AC to rest for reducing the load. Consequently at night time since there is no IT load and also night time is colder, there Power load will show a considerable 60% load variation to be down. On weekends, there is almost same amount of power load variation on the night time. The end-use breakdown for the data center’s electric power demand for cooling system is revealed in Table 3.10.

Table 3.9: Power load for cooling system and lighting

Load Type	Description	Electric power demand (KW)
Cooling system load	Data Center CRAH Units	70
	Chillers (DC portion)	70
Lighting	Data Center Lighting	3
Losses	Data Center UPS Losses	5-10
Total	At Full Capacity	UPS Loss+ Light+ others
Total		490 KW

D. Lighting loads

Light loads story for all the illumination in the data center share of the structure then remain a purpose of the data center ground part. Considering energy efficient lamps based on Table 3.11 the total power used for data center lighting purpose is 3 kw.

Table 3.10: Equivalent energy efficient lamps for different conventional lamps, (Kiros, 2014)

Electrical power equivalents for differing lamps			
Minimum light output	Electrical power consumption		
Light output Lumens (lm)	LEDS(watts)	CFLs (Watts)	Incandescent (Watts)
450	4-5	8-12	40
300-900	6-8	13-18	60
1100-1300	9-13	18-22	75-100
1600-1800	16-20	23-30	100
2600-2800	25-28	30-35	150

E. Future loads

In Ministry data center there are different future plan like upgrading the UPS capacity for additional 40 KVA Module on both UPS, 5 IT RACK will added with 25 KW capacity. And after two years National data center servers and services are coming to MoST data center which have three AC with chiller and CRAH with consumption of 105 KW to additional to the existing system. Accordingly during the implementation the power consumption will be modified and also load variation will also change since they are adding service on the data center.

Table 3.11: Total load summary

Description		Electric power demand (KW)	Share of electric energy use (%)	Daily energy consumption(KWH)
Critical loads	Data Center Rack Load	270 (but at a time the use only 40% of the total power)	34.4	2592
	Fire and monitoring systems like CCTV, Fire alarm	15	1.9	165
Cooling system load	Data Center CRAH,AC Units	490	62.3	1190
Lighting	Lighting	3	0.4	72
Losses	Data Center UPS Losses	7.5	0.94	30
Total at full capacity		785.5	100	6569

CHAPTER 4

MODELING OF THE HYBRID STRUCTURE AND INPUT DATA TO THE SOFTWARE

4.1 Modeling of the Hybrid

The annual average solar radiation for Addis Ababa is 6.555 KWh/m2, and this value designates that the area has suitable prospective for the implementation of photovoltaic (PV) structure to give electric access to the data center. In addition the annual average wind speed measured at 2 m is found to be 3.28 m/s. These figures direct that the area has a probable for implementing PV-wind hybrid system to give electric access to community, commercials and residential purpose. But for these thesis the electricity generated we will be implemented for Ethiopia Ministry Science and Technology data center.

Due to recurrent power outage occurring in Ethiopia specifically in the capital Addis Ababa customer they are complying every time. From those customers Ethiopian Ministry of Science and Technology is one of them which responsible for the data center management. For this problem developing countries like Ethiopia which have good resources in both systems (PV and wind) to use stand-alone hybrid system for supplying electricity for decreasing damage happing because of power outage and for increasing profit.

Data centers generally run 24/7 all day and time round, and they are actual energy demanding by characteristic power densities of 538–2153 W/m^2 that occasionally container spread up to 10 KW/m^2 (Bergqvist, 2011). In height energy ingesting cylinder is credited principally to the IT stresses and refrigeration gear, as well as lighting, power distribution and other necessities. The chilling scheme consume up to 40 percent in normal of the Energies stresses of a data center, by the utmost well-organized schemes by means of 24 percent of the whole energy and the least well-organized 61 percent (Jiacheng and Xuelian, 2017). The Ethiopia Ministry Science and technology data center from the total data center loads cooling system accounts 55-60%, and which it indicates the efficiency of the data center is in a question.

The PV-wind hybrid system may not be satisfactory to supply energy on 24 hours for the whole years, and therefore has to be supported by generator and batteries which can be used as a gridlock for supplying sustainable electricity using hybrid setup.

The core impartial of this thesis effort remains toward design DC control distribution method using hybrid power (wind and solar) for Ethiopia Ministry of Science and Technology data center. The generated power will be distributed through DC distribution system for the total data center power load. Also it assess resource potential and to model wind/PV combine method by generator and sequence as a backup toward fulfills the whole data center load, and the model is also simulated for the load at the end of the life span of the project which is obtained using simple load forecasting. The schematic diagram for the total system is described in Figure 4.1.

As shown in Figure 4.1 for the hybrid model there different component which makes the system active and give power for data center with a good efficiency. The power generated from diesel generator, PV (Photovoltaic) and wind turbine directly fed to the DC bus and fed to the loads. Excess power goes to the battery bank and utilized by the system in case of absence of power wind, and PV sources.

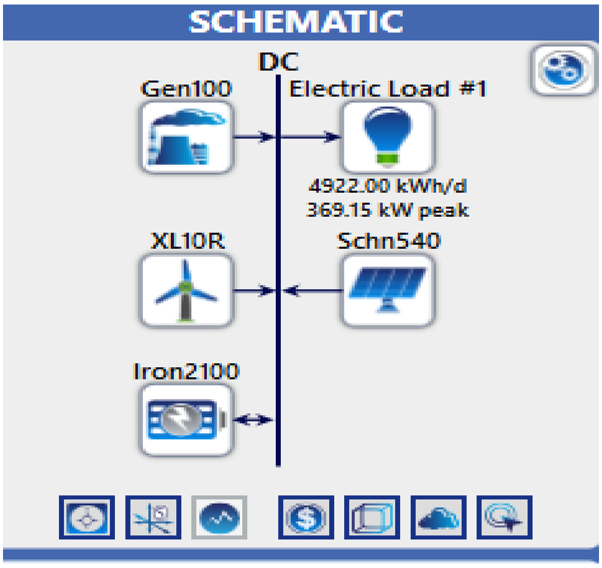

Figure 4.1: Model of the hybrid setup

As we see from Figure 4.2 in Dc distribution system architecture there are different component those are DC delivery section, dc bus and etc. the DC distribution panel are designed to provide over current safeguard or departure of single source in to multiple feeds on the output DC. Hence proper construction and testing is required. The DC distribution panel require two pioneer coupled with battery charger one and two to be connected two set battery one and two respectively. The charger and battery will be connected to the load of DC switch board through separate 2-pole of MCCP (Molded case circuit breakers) of suitable rating.

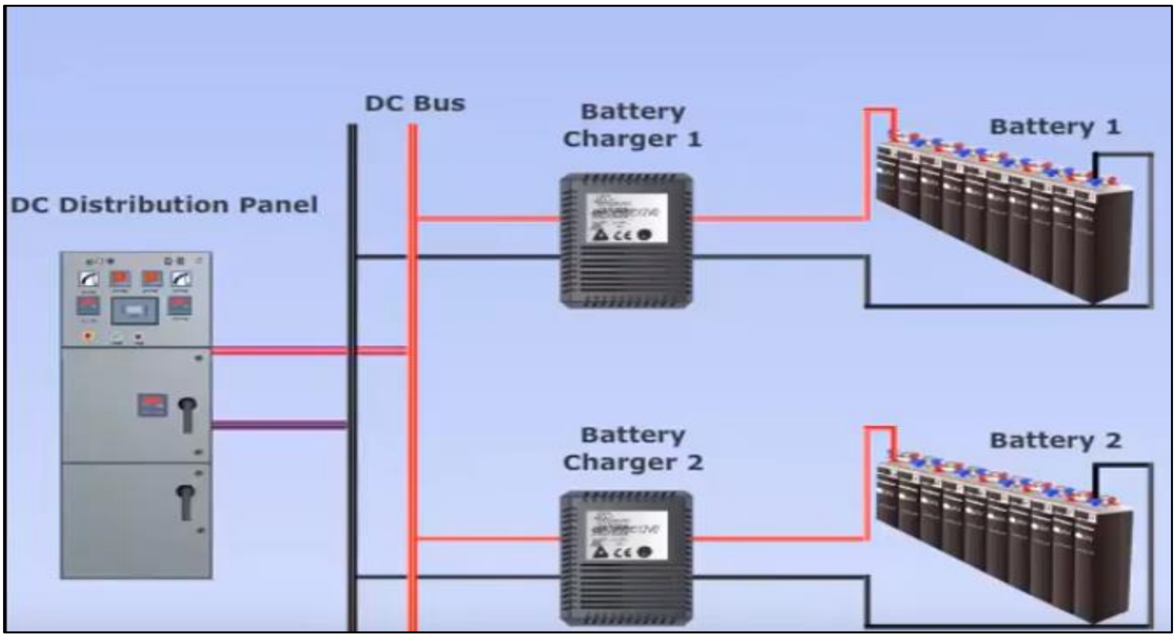

Figure 4.2: DC distribution system architecture

4.2 Power Distribution Unit

Using AC or DC power delivery to data center load can be accomplished. Alternative current power remains stereotypically dispersed at the native mains voltage of difference value like 120 or 230 V. Direct current power is characteristically disseminated at the communications ordinary at a 48 V voltage. Lately, new theoretical proposals have been situated founded on direct current delivery at 48 voltages and overhead DC, in order to overwhelm certain of the previous difficulties by direct current energy distribution system (Neil, 2011).

The Ministry of Science and Technology data center uses an AC distribution system which is cause for different losses those are UPS fatalities, the power distribution losses, the division circuit distribution wiring, the leading distribution wiring, and the IT power delivery losses are taking the major. DC power could lower the energy requirements and decrease complication by removing a coating of mechanisms that can be unsuccessful (Neil, 2011). Existing data center power distribution strategies practice AC power, distributed from the utility to the ability at 480V - 600V AC contingent on the magnitude of the capability. This alternative current is formerly treaded depressed from 208 V to 120 V AC via converters aimed at delivery to attendant racks aimed at usage by the waiters and additional acute data center gear.

Alternative current is too castoff in driving the auxiliary provision gear, such data center CRAH units and chillers (DC portion) and lighting. This set up commonly includes transforming inward alternative current to direct for energy storing. The direct current control at that time transformed spinal to alternative current for the ability delivery network then directed toward power distribution units PDUs for dissemination to apparatus in server and for the overall rack.

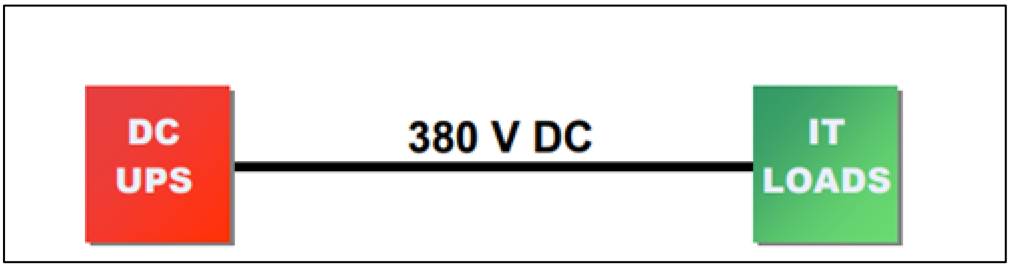

Figure 4.3: High efficiency DC distribution

For this thesis a theoretical method distributing 380 V DC distribution systems will be implemented. Figure 4.3 represents this approach. IT maneuvers deliberate to function after 380V DC would need to occur in imperative for this method to effort. The 380 V DC systems provide the maximum productivity (87.64%) of the schemes demonstrated. Regarding efficiency of the DC UPS, marketable merchandises by normal stipulations remain not extensively obtainable but on different researchers provided DC UPS efficiency value varies from 95.1%, - 97.7% which is best value for efficiency (Birhan, 2017).

Regarding of efficiency of the dissemination wiring, the cabling loss is the similar for an AC or DC connection.

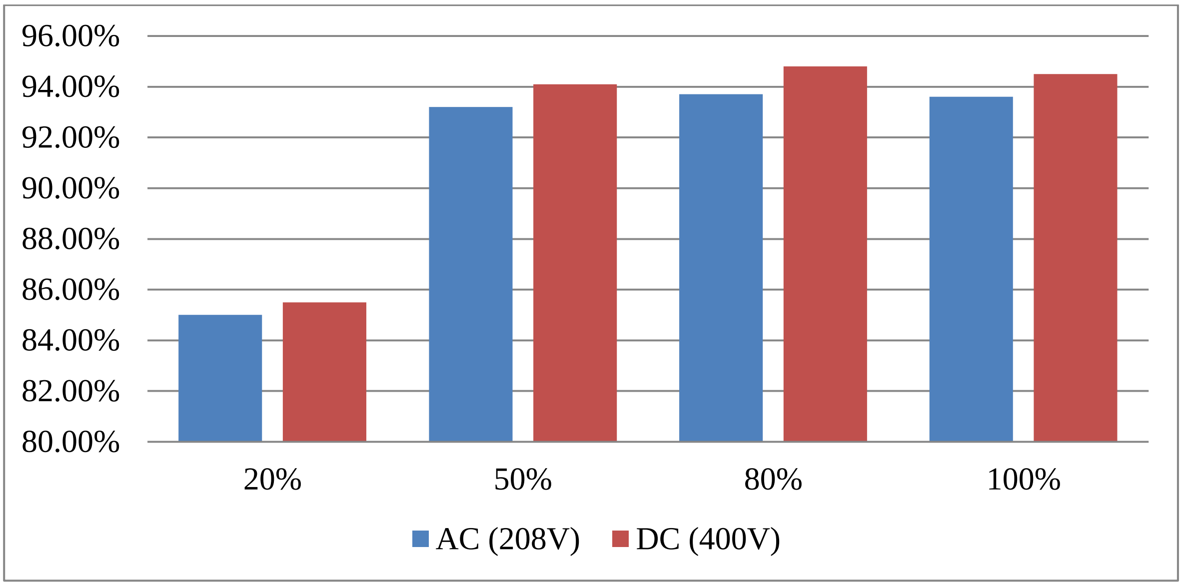

Figure 4.4: UPS efficiency

The other point is concerning effectiveness of the IT power supply, the little competence of these from the past power deliveries put forward that big improvements strength is likely if high direct current input process remained established. Nevertheless, the utmost current AC schemes are currently regularly 92% effective or better ended a comprehensive variety of working loads, rendering to printed power source productivity information commencing numerous companies. From Figure 4.4 the average efficiency standards for power supply at full load DC is 94.5% which is advanced than the value for AC power supply (93.6%).

Table 4.1: Power distribution efficiency

Power Supply	UPS	Dissemination cabling	IT power source	Complete effectiveness
DC	96.5%	99.5%	94.1%	90.35%
AC	96.3%	99.5%	93.2%	89.30%

4.2 Inputs to the Software

The main drives of this thesis is on the way to design the PV and wind combined system using generator in addition to battery storage as an alternative to develop a greatest improved system and giving electrically powered through DC distribution system to the Ministry of Science and Technology data center. The greatest optimization result will be nominated by making an allowance for the complete net existent price energy cost, and impact of renewable energy technologies. The simulation of the hybrid model is done using Hybrid Optimization Model for Energy Renewable (HOMER) software, and this needs different input parameters for different energy sources and components of the model. Based on this there different input values which will be used by the homer software for simulation, optimization, sensitivity analysis. Those input values will be discussed below.

4.3.1 Total load input

Library, design and results, are three project outlooks for HOMER software. On Design view the software need to have input for total system load, component and finally there Resources tabs to construct the method though in the Project outlook (Homer, 2015). From those inputs consideration adding the electrical load data which is dignified load statistics is infrequently obtainable, and frequently manufacture load statistics by stipulating characteristic daily load outlines then addition in certain haphazardness. This procedure yields lone year of hourly load statistics which will be useful for homer software. From Figure 4.5 below, it can be discerned that the daily profile of the load given to HOMER software and the values varies between 256 KW and 163 KW of power per in different hours of the day. This data is in use from Maximum load per day for IT load which is 90 KW, Maximum for cooling is 140 KW, for lighting which is 3.5 KW and for the UPS loss is 7.5 KW of power.

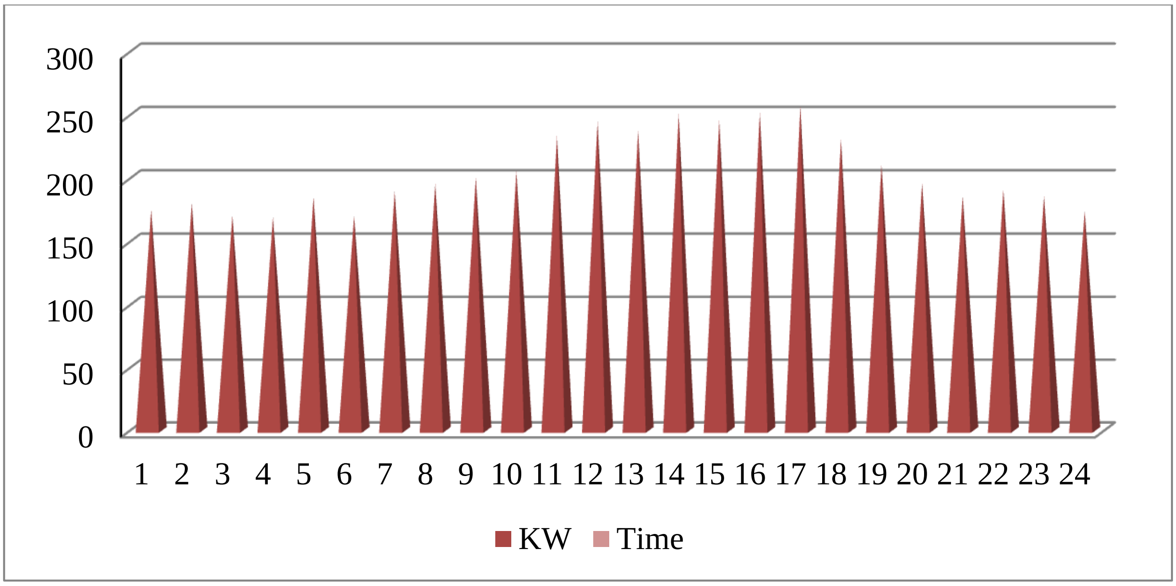

Figure 4.5: Daily profile for the total load

This measured tell that the load was in dissimilar hours of the daytime toward get the regular everyday load outline and the periodic outline for a data center. As a result, Homer instrument computes the yearly regular load, the top load and the load factor established on the worth go in for each hour of the day with DC load kind. The values are shown in Figure 4.6.

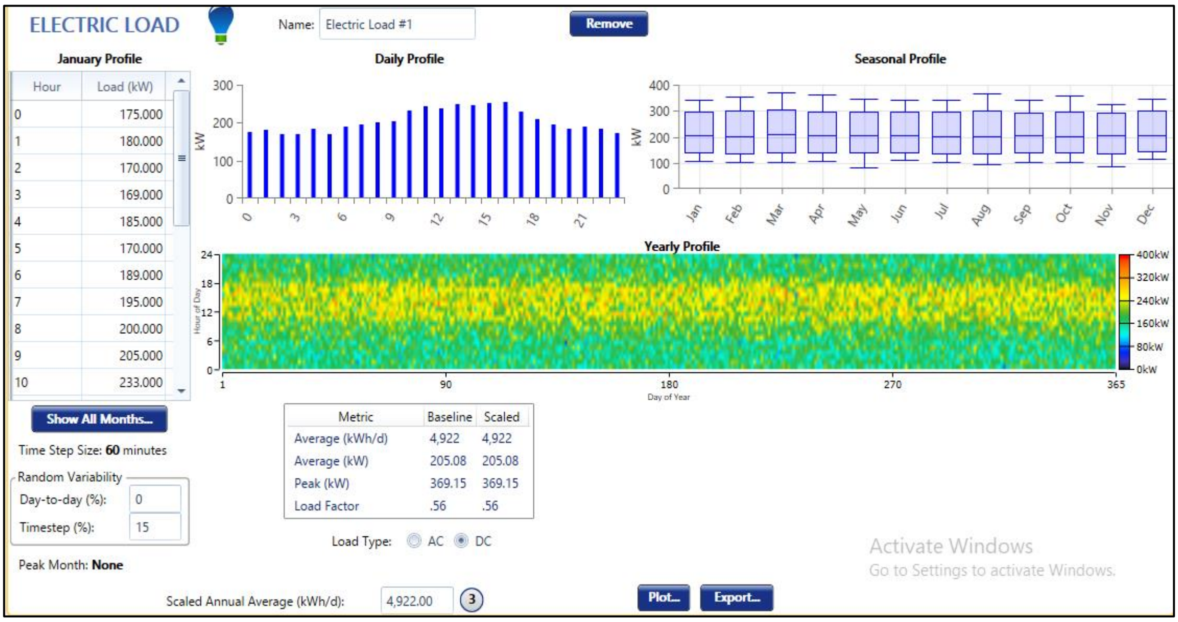

Figure 4.6: Input window for the total load in homer

4.3.2. Component settings (Generators, PV, Wind Turbine and battery)

Components input setting which will give detail information on what machineries ensures to create and to comprise in the scheme project and by what means and which extent of apiece constituent must you practice for the total system. A component is a slice of apparatus that is chunk of a power scheme. Therefore, for this thesis is generator, PV, wind, and battery for energy storage will be used as the main component for the system. From the component except battery all of them require resource information.

1. Generator

For providing designed inputs such as the size characteristics and cost, of a generator the generator inputs window will be used. It also access to the fuel curve, fuel resources, maintenance, emissions and schedule which is put the generator to be on, off, or augmented agreeing to the Homer dispatcher (Homer, 2015). For this thesis from the two homer dispatch strategy cycle charging (CC) is used. Based on the total load for data center the size characteristics, amount and cost for the generator is given on inputs to the software as described on table 4.2. The require resource for generator component is fuel resource which will describe name for the fuel, its properties and limits for the price. For this design the price for diesel taken is 0.58 - 1 $/L which is current diesel price value for Ethiopia. On The input values are shown in Figure 4.7.

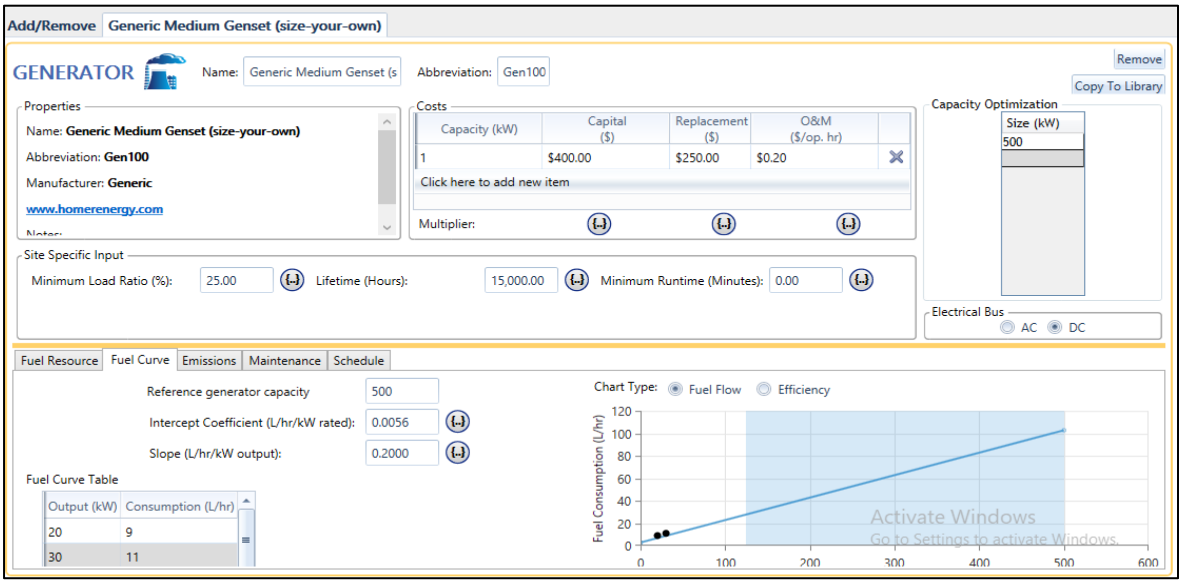

Figure 4.7: Homer input window for generator system

2. *PV (Photovoltaic)*

For designing Photovoltaic system it should be needed to model the lifetime, the total cost (capital, maintenance, replacement and operating cost) per year as an input. Moreover, different PV sizes can then be added on the size to consider button to get different possible options for optimization. In addition to this they need to provide MPPT, advanced input and temperature for the system. For this data center total power load design the capital cost for PV module is taken to be 3000 $/KW peak and a typical cost for onshore wind farms has reached around 1000 $/KW of installed rated capacity, and for off shore wind farms about 1600 $/KW (Ragheb, 2017). Derating factor of 80% and ground reflectance of 20% deprived of tracing is deliberated. Additionally, the PV modules are sloped at 9.0 degrees which is the latitude of the selected site (Addis Ababa).

For this system flat panel PV array will be implemented. For this PV array Global Horizontal Irradiation (GHI) Source is needed to compute the flat PV array production. Monthly average solar radiation of Addis Ababa in KWh/m^2 is calculated and described on Table 3.4 of chapter three. Established on the designed worth the annual regular solar radiation of Addis Ababa is 6.55 KWH/m^2 which is shown in Figure 4.8.

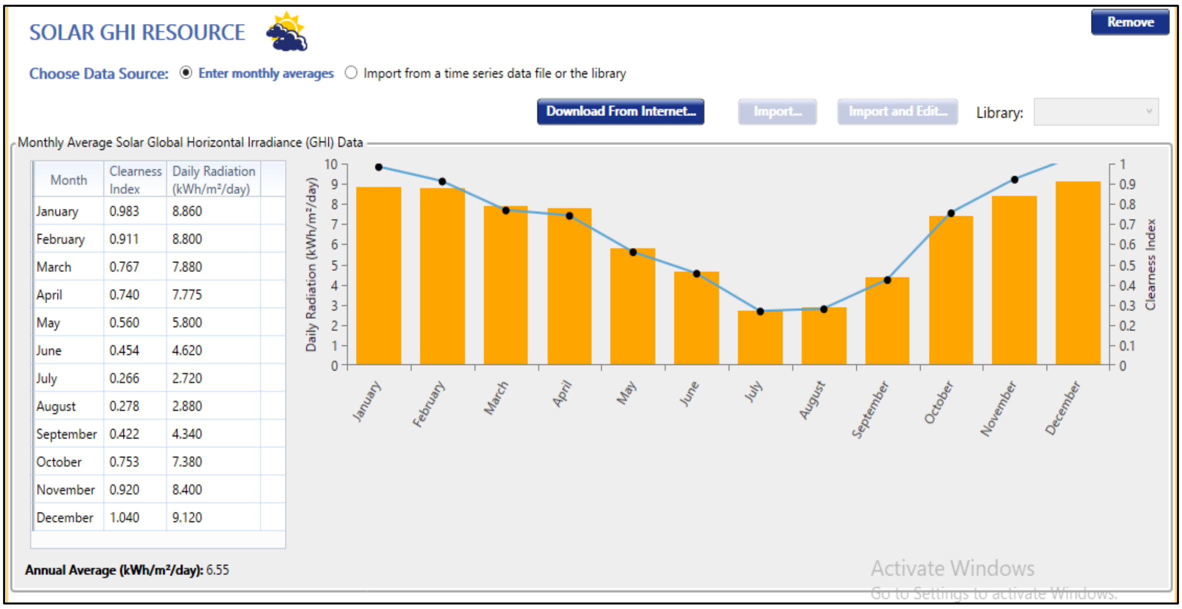

Figure 4.8: Monthly solar radiations in KW/m^2 of Addis Ababa

3. Wind turbine

Another component is wind turbine, in HOMER software for designing wind power system the software provide different type wind turbine model with the total cost. Moreover it will also provide turbine losses and power curve. Based on this the total cost per kW of connected wind power capacity wind turbine is taken to be 1.1 $/W. A usual 10 kW Bergey GridTek home wind energy wind turbine with typical production of 35-75 KWH per day DC energy. And 4.2 m/s (see Figure 4.8 cut in speed of is used for simulation from the turbine types available in the software since it has the lowest cut in speed. The cut in speed of this turbine is below the lowest monthly normal wind speed of Addis Ababa.

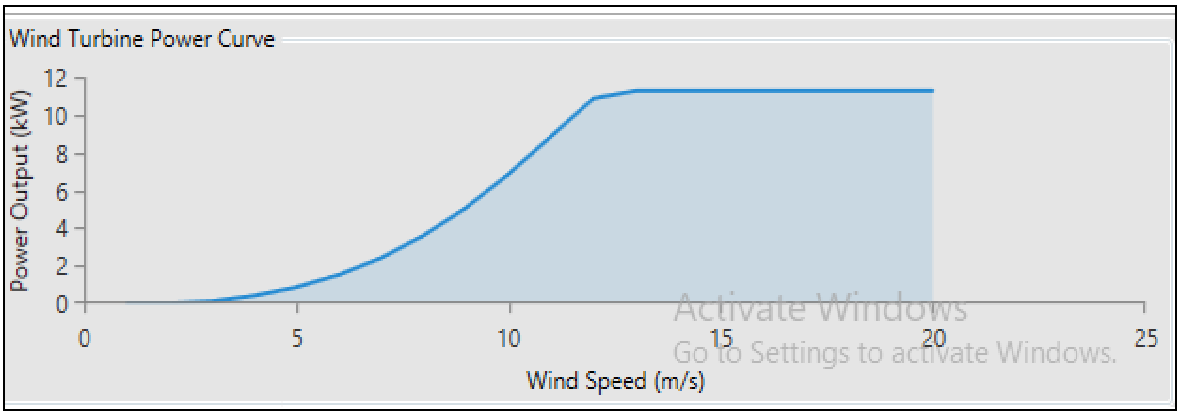

Figure 4.9: Wind speed vs. wind turbine power curve

For wind turbine system design wind resources must feed to the homer software to describe the available wind resources. By using wind resource input window we can describe wind speed, variables related to altitude and variation with height. As given in chapter three Table 3.5 and Figure 4.10 annual average wind speeds for Addis Ababa is 4.3m/s and 4.2m/s respectively.

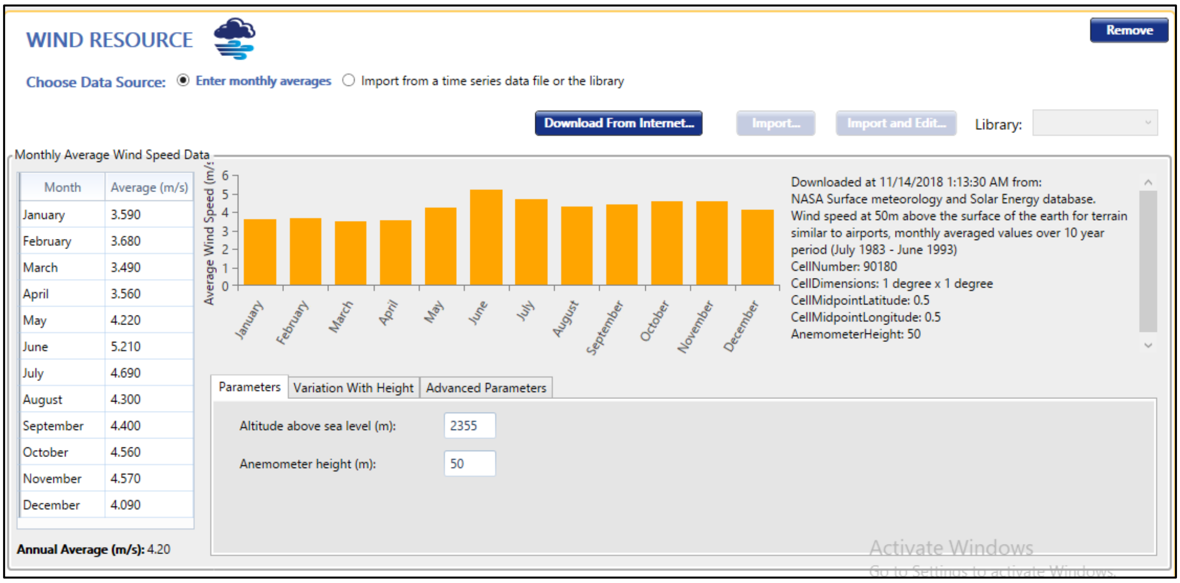

Figure 4.10: Resource window with data for wind resource for Addis Ababa

In the same way, the capital cost for the battery, is fed to the software. For description of greenhouse effect, a \$20/t of disadvantage for CO_2 release is considered in design. Extreme yearly energy shortage and least renewable portion are fixed to 10% and 0% correspondingly. Interest rate of 14% and 25 years project life time is castoff for existent price examination.

Table 4.2: Total inputs to the software

Parameter	Wind turbine	Diesel generator	PV	Battery
Model	10 kW Bergey GridTek	Generic Medium Genset	Schneider ConextcoreXC 540kw	Tesla power pack
Size	10KW	500KW	1Kw	2100Ah
Capital cost ($)	10,000-20,000	$4,000-$10,000	2,160	1250
O&M($/op.hr)	300-500	0.2	10	25
Replacement	3000-500	250.00	2,160	1,100.00
Life time years	20	15.00	20.00	20
Sizes considered (kW)	270kw	500KW		130
Quantity considered	27	1	0-100	0-70

CHAPTER 5

SIMULATION STUDIES AND DISCUSSIONS

5.1. Simulation Studies

The simulation outcome window of HOMER software displays about Electrical output which shows details about the production and ingesting of power by the method. In addition it gives details for each output for PV, wind turbine, generator, battery, and emissions. In the same fashion it describes about the cost summary which refer to the whole currencies pour, classified whichever by part or by price type, and the cash flow tab that shows the year by year money flows in a customizable graphical arrangement. The list of the optimization results which are proficient of meeting the system load and constraints are then displayed in overall form and categorized form. In the overall form the top ranked system configuration (i.e. a permutation of a specific statistics and magnitude of equipment or component) according to the NPC are displayed see Table 5.1. The cost is categorized form smallest-cost systems for each system configuration are displayed.

To get an answer for the effect of input variables having dynamic nature a sensitivity analysis is similarly completed. It takes the greatest price of effective system configuration for each amalgamation of sensitive variable values. The results of this analysis can be displayed either in a graphic or tabular form. In this work PV replacement cost multiplier, linked with PV capital cost multiplier, wind speed and diesel price are used as sensitivity parameters for sensitivity analysis, even though, nearby a lot of parameters to be well-thought-out. As a result, HOMER is castoff for simulating the hybrid system containing PV, wind, generator and storage battery to get optimal arrangement of the hybrid components which might stay applied as a hybrid method for providing power to Ethiopia Minister Science and Technology data center.

Table 5.1: Sensitivity results

Diesel Fuel Price ($/L)	Electric Load #1 Scaled Average (kWh/d)	Schn540 (kW)	Schn540-MPPT (kW)	VergMP-C	Gen100 (kW)	Iron2100	Dispatch	Cost/Initial capital ($)	System/Ren Frac (%)
0.59	4554.321	540.1	540.1	2	500	34	CC	Cost/NPC ($)	74.0802
0.59	4621.99	540.1	540.1	2	500	34	CC	4346894	73.06705
0.59	4921.999	540.1	540.1	2	500	34	CC	4346894	67.52473
0.8	4554.321	540.1	540.1	2	500	34	CC	4346894	74.0802
0.8	4621.99	540.1	540.1	2	500	34	CC	4346894	73.06705
0.8	4921.999	540.1	540.1	2	500	34	CC	4346894	67.52473
0.9	4554.321	540.1	540.1	2	500	34	CC	4346894	74.0802
0.9	4621.99	540.1	540.1	2	500	34	CC	4346894	73.06705
0.9	4921.999	540.1	540.1	2	500	34	CC	4346894	67.52473
1.2	4554.321	540.1	540.1	2	500	34	CC	4346894	74.07268
1.2	4621.99	540.1	540.1	2	500	34	CC	4346894	73.06705
1.2	4921.999	540.1	540.1	2	500	34	CC	4346894	67.52007

Note: $= US dollar, kWh/d= Kilowatt hour per day, Kw=Kilowatt

5.1.1 Electric Production Designed for Total Load

The simulation is done for two loads which are critical IT load and cooling load which are already estimated in chapter 3. The first case is done by considering Critical loads (270 KW) for data center which contains rack with consist of Servers, storage media, network equipment and etc. In addition to this load there are also15 KW of power usage for fire monitoring systems like CCTV and fire alarm refer to Table 3.5. Table 5.2 shows results of the first case in categorized form.

Table 5.2: Results of the first case in categorized form

Schn540 (kW)	Schn540-MPPT (kW)	VergMP-C	Gen100 (kW)	Iron2100	Dispatch	Cost/COE ($)	Cost/NPC ($)	Cost/Operating cost ($/yr)	Cost/Initial capital ($)	System/Ren Frac (%)	System/Total Fuel (L/yr)	Gen100/Hours	Gen100/Production (kWh)	Gen100/Fuel (L)	Gen100/O&M Cost ($/yr)
540.1	540.1	2	500	34	CC	0.328656	7167669	219819.3	4346894	73.06705	933398.18	909	454365.9	933398.18	90900
		2	500	34	CC	0.467938	1.02E+07	579190.3	2717800	14.19814	297541.7	2895	1447500	297541.7	289500
		2	500		CC	0.687263	1.50E+07	1137771	2800000	10.81393	325224.1	8750	1504593	325224.1	875000
540.1	540.1	2	500		CC	0.747441	1.63E+07	1113276	1909094	24.87856	277677.6	8717	1267319	277677.6	871700
540.1	540.1	2		4012	CC	10.16257	2.22E+08	-5239474	2.89E+08	100	0				

As an outcome, the outputs from the software are acquired as revealed in Table 5.1 and Table 5.2 for the sensitivity and categorized form respectively. Also the data tabulated in Table 5.1 and 5.2 for the load estimation indicates the optimization results which are candidate for implementation. The overall result is described in appendix C which describes the overall output with different types of cost. As it can be comprehended in Table 5.2, the optimum results displayed in the overall form have different possible arrangements of wind, PV, generator, and battery. But as the list for the overall result is extended, fragment of it takes be there condensed custody lone those of utmost attention. On Table 5.2, the optimum results displayed in the overall form have different possible arrangements of PV, generator, wind, and battery. The greatest price operative arrangement through the lowermost NPC is the PV-wind-diesel generator and battery setup for the first case, where the battery runs by means of a cycle charging (CC) approach, and this approach one of dispatching strategy which proposed by HOMER software. Here the battery functions at complete output power to function the data center critical IT load, cooling load and any extra electrical production energies to the lower precedence objectives.

Table 5.3: Production Summary

Component	**Production (kWh/yr)**	**Percent**
Schneider ConextCoreXC 540kW with Generic PV	1,118,450	60.8
Generic Medium Genset (size-your-own)	430,872	23.4
Vergnet GEV MP-C [275kW]	288,856	15.7
Total	1,838,178	100

Note: kWh/yr= Kilowatt hour per year, Kw=Kilowatt

The whole result of the overall form is then shown in appendices C and D. They are ranked in their ascending order according to increasing total life-cycle price or net present cost (NPC). The PV/wind/battery setup is ranked first in both cases since it has the least NPC as compared with the other possible optimal results. The total NPC of the optimized result ranked first is $7,038,355.00 and its COE and renewable fraction are 0.328 $/kWh and 74% respectively with a capacity shortage of 0%. Therefore most optimized hybrid system's result is with 74% renewable fraction of Wind and PV set. The feasible system is mentioned on the Table 5.3 and Figure 5.1 for the total energy production for the data center energy consumption. the contribution from solar PV system is 1,118,450 kWh/yr, which takes 60.8% of total production, from the diesel generator (generic medium genset) 430,872 kWh/yr with 23% from total production and from the wind turbine 288,856 kWh/yr with 15% share from total production of energy production. Hence, the generator and wind are smallest contributors for the hybrid system when we compare with PV system.

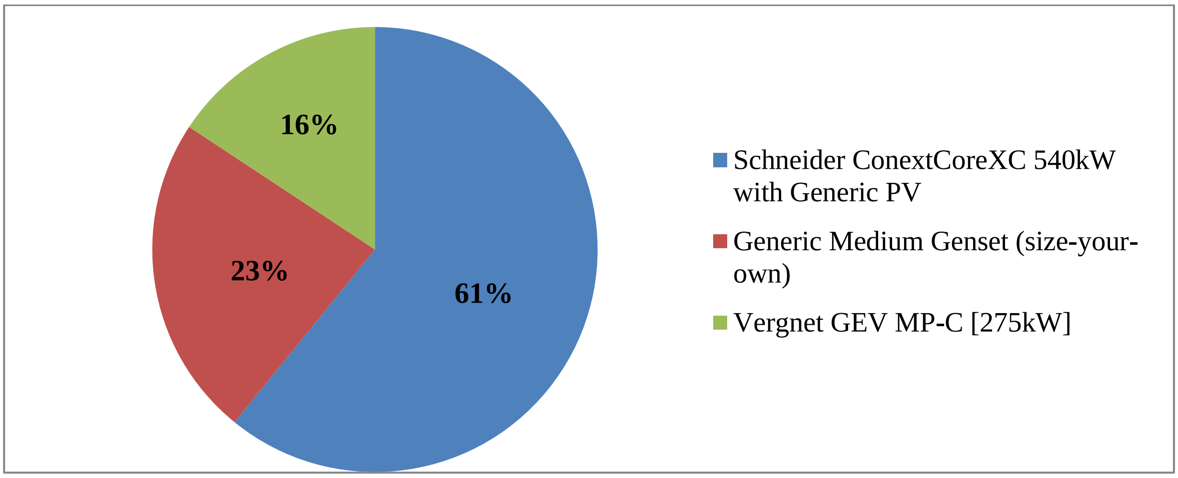

Figure 5.1: Contribution of power units for utilization of renewable resources

As shown in the monthly electric production result (Figure 5.1), for the most optimum feasible system, the main energy contributor is PV with highest percent share, and the highest energy production is in June.

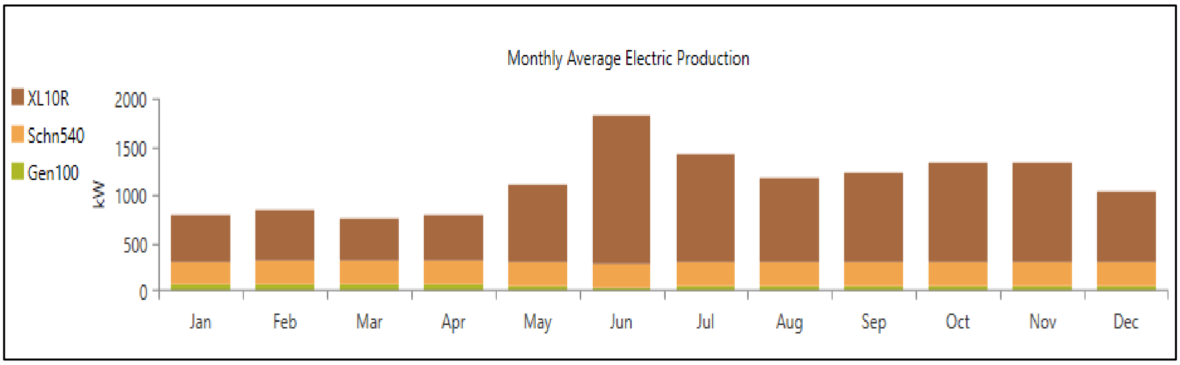

Figure 5.2: Monthly average electric production

The system is also replicated in order to estimate its working appearances, such as yearly electrically powered energy consumption, yearly electric energy production, unmet electric load, extra electricity, renewable energy fraction, and capacity shortage.

Table 5.2 shows the overall system report with input data of: Global solar radiation 6.55 KWH/m^2 /day, and wind speed of 4.2 m/sec. Diesel fuel price is supposed to be \$1/litter, and wind turbine capital multiplier of 0.6.

1. *Diesel Generator Electric Production*

Table 5.4 below indicates about diesel generator total electric production summary which describe about electric production per year, mean electric output, Minimum and Maximum Electrical Output. In addition to this homer energy software also gives analysis about Fuel Summary and under this for the total one year power generation 88,569 L of diesel fuel will be required for the system. Moreover with regarding of exact fuel consumption 0.206 L/kWh is required. Regarding of operation life for generator is 15 year, for generating 1kw of power it will take 110 \$ and it is marginal generation cost is 0.118 \$/kWh. When we compare the cost for 1 KW with wind the cost of generator is expensive.

Table 5.4: Generic Medium Genset (size-your-own) Electrical Summary

Quantity	Value	Units
Production of electric	430,872	kWh/yr
Mean Electrical Output	500	kW
Min Electrical Output	429	kW
Max Electrical Output	500	kW
Consumption Fuel	88,569	L
Specific Fuel Consumption	0.206	L/kWh
Input Fuel Energy	857,395	kWh/yr
Mean Electrical Efficiency	50.3	%
Hours of Operation	862	hrs/yr
Operational Life	17.4	yr
Fixed Generation Cost	110	\$/hr
Marginal Generation Cost	0.118	\$/kWh

2. *PV Electric Production*

Table 5.5 describes about total electric generation for the photovoltaic system. The minimum and maximum electric production of the photovoltaic system is 0KW and 540KW respectively. The total hour of operation and levelized cost for PV system for the specific area is 4,469 hrs/yr and 0.119 $/kWh respectively. The mean output of specified generic PV ConextCoreXC 540kW is 3,064kWh/d and the total Electric production amount is 1,118,450 kWh/yr with rated capacity value of 540 kW.

Table 5.5: Schneider ConextCoreXC 540kW with Generic photovoltaic Electrical Summary

Quantity	Value	Units
Min Output	0	kW
Max Output	540	kW
Penetration for PV	67.3	%
Operation of hours	4,469	hrs/yr
Levelized Cost	0.119	$/kWh
Rated Capacity	540	kW
Mean Output	128	kW
Mean Output	3,064	kWh/d
Total Production	1,118,450	kWh/yr

3. *Wind Electric Production*

On the same manner with PV and diesel generator the wind energy minimum output, penetration, total rated capacity, mean output, total production, and hours of operation is presented on the Table 5.6 with respect to each unit.

Table 5.6: Vergnet GEV MP-C [275kW] electrical summary

Quantity	Value	Units
Min Output	0	kW
Max Output	401	kW
Wind penetration	17.4	%
Hours of operation	5,238	hrs/yr
Leavlized cost	0.0275	$/kWh
Total rated capacity	550	kW
Mean out put	33.0	kW
Capacity factor	6.00	%
Total production	288,856	kWh/yr

Storage: Iron Edison LFP 2100Ah

Input of Homer contains all the types battery that are present within the homer component library, for this specific power system design Iron Edison LFP 2100Ah battery is selected and for the input window we provides many various information regarding coast and storage capacity with different properties. Based on the input provided for the software Table 5.7 provide an average energy cost, energy in and out, storage depletion, nominal capacity, and lifetime throughput values with respect to each units.

Table 5.7: Iron Edison LFP 2100Ah Result Data and Statistics

Quantity	Value	Units
Average Energy Cost	0.0437	$/KWh
Energy In	762,136	KWh/yr
Energy Out	725,085	KWh/yr
Storage Depletion	1,083	KWh/yr
Losses	38,134	KWh/yr
Annual Throughput	743,921	KWh/yr
Autonomy	14.4	Hr
Storage wear cost	0.214	$/KWh
Nominal Capacity	3,427	KWh
Usable Normal Capacity	2,742	KWh
Lifetime Throughput	11,669,616	KWh

5.1.2 Cash Flow

The cash flow summary from the result of the software, for most optimum system according to the total net present cost (NPC) is revealed in the Figure 5.3. In addition the cost breakdown for hybrid setup containing PV/wind/generator and battery is illustrated. From the graph the net present cost of PV has the maximum among the constituents of the setup. Total net present cost (or life-cycle price) of a constituent is the current price of all the costs of installing and operative the constituent over the project era, minus the present value of all the profits that it receives over the project lifetime. HOMER computes NPC of each component in the system, and for the system as an entire, including costs for replacement, O&M costs, capital costs, fuel costs, emissions consequences, and the costs of purchasing power from the grid (Homer, 2015). The total NPC is HOMER's main economic output, the value by which it ranks all system configurations in the optimization results, and the basis from which it calculates the total annualized cost and the levelized cost of energy.

For this system the components are wind turbine, PV, battery, and diesel generator. Even though there are other optimum outcomes which can be candidate for implementation only the system report of the designated simulation results are described.

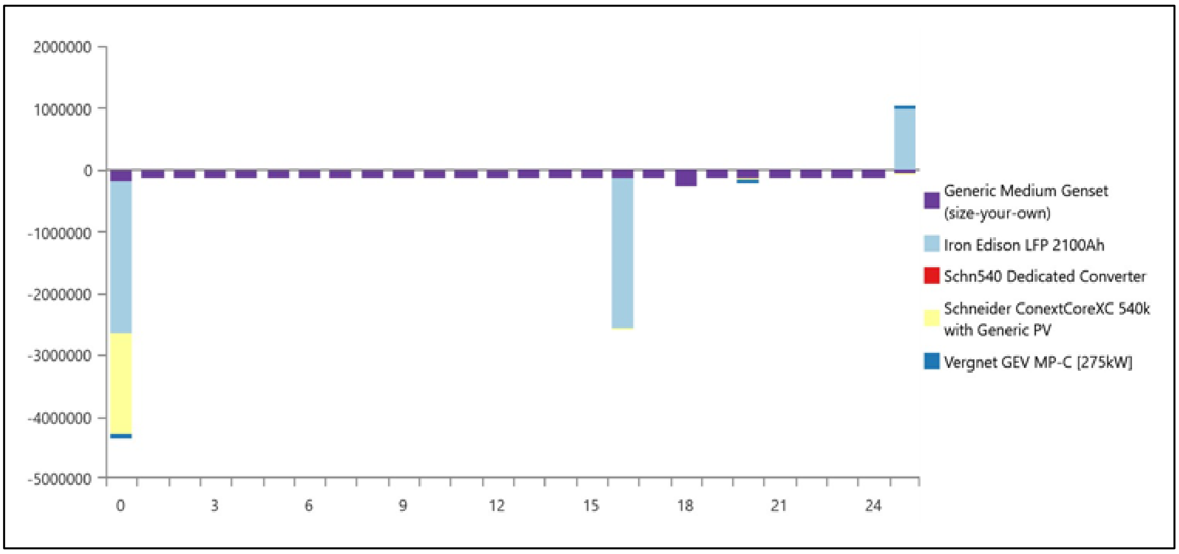

Figure 5.3: Cash flow summary of the feasible optimum system

Figure 5.4 indicates that about the amount of the capital, functioning, fuel, replacement and salvage value for each constituent. From the result the price for capital is taking the highest share from the total cost.

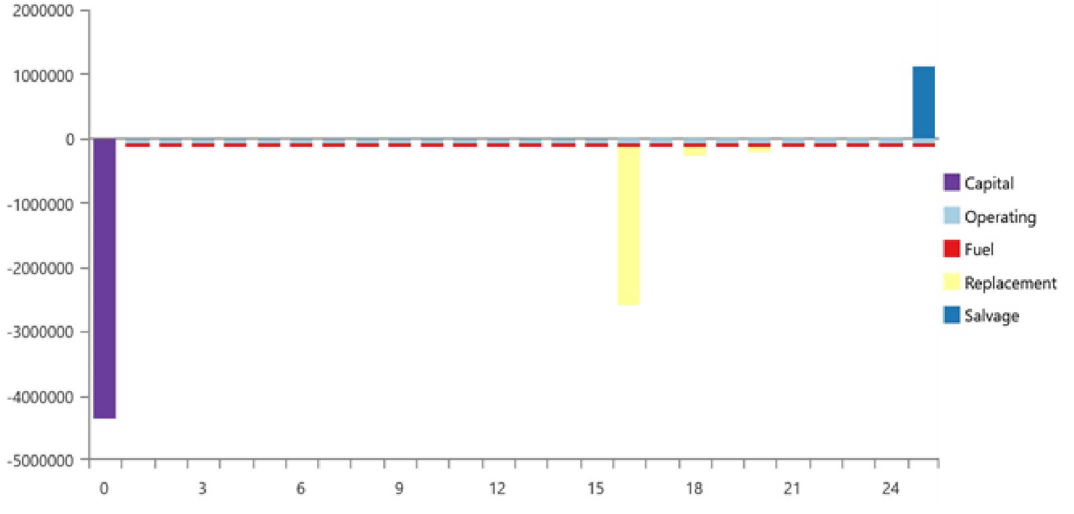

Figure 5.4: Cost break down

In general there are several alternate practical hybrid arrangements, through altered ranks of input by the renewable resources stood achieved. In spite of the many options, the select is limited by the changing NPC of energy and influence of renewable energy means of every arrangement. The price of energy of the arrangement hybrid is associated with the present total electricity price in Ethiopia, and it is found that the costs of the feasible setups obtained for PV which is 0.119 $/kWh and is greater than the present tariff (0.09 $/kWh) in Ethiopia. In other side for wind energy price (0.0275 $/kWh) is less than that off the current price in the country which is 0.09 $/kWh. Nevertheless, the current leading foundation of energy in Ethiopia is hydropower, the hybrid standalone system it will have a contribution in assuaging pollution, inhibition of soil deprivation and it has a substantial outcome in reducing the unavailability of power inside the country as well as in the discount of hazardous gas in to the environment.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATION

6.1 Conclusions

The general objective of the thesis work is to design DC power distribution system using hybrid power (wind and solar) in the case of Ethiopia Ministry of Science and Technology data center. By measuring wind and solar energy capabilities of Addis Ababa, a feasibility study for a stand-alone hybrid setup for electric power supply for the data center is done. The solar energy potential of the Addis Ababa is resolute based on the data taken from National Metrological Agency (NMA). Meanwhile only sunshine hour data are available; hypothetically verified typical procedures are used to change in to solar radiation to figure out the potential of the site. The outcome is similarly crossed tested paralleled to the satellite data acquired from NASA. From the results annual solar radiation of Addis Ababa is 6.55 KWH/m^2 /day. In the same fashion, for the wind energy potential wind speed data of Addis Ababa was collected from NMA. NMA recorded wind data using data logger involved to anemometer which is fixed at 2 m height is 3.28 m/s and using the logarithmic law this is generalized to hub height (25 m), which give as the annual average wind speed 4.2 m/s. From both wind and solar radiation resources it indicates the handiness of widespread functional solar and wind energy at the designated site.

The hybrid arrangement is at that juncture simulated by means of HOMER software in order to choice the greatest augmented outcome. For improving the viability of the supply and to decrease power variability problems the sources are combined with supplementary energy adaptation systems i.e. diesel generator and battery with UPS system. Regarding the power distribution system DC only power distribution is implemented for the purpose of increasing power system efficiency by decreasing loss. The feasibility study for the hybrid arrangement is constructed on the discoveries of the wind and solar energy possibilities at the particular site Addis Ababa. With the promises resolute, the approaches followed in the hybrid system design is based on the total critical IT load and load for cooling the data center. High energy consumption can be credited primarily to the IT demands and cooling equipment, as well as lighting, power distribution and other necessities. The total load for data center which is estimated based on the current consumption and by making forecasting based on the total demand for data center future plan.

In the results, several different practicable hybrid arrangements, with different levels of impact by the renewable resources were acquired. Regardless of the many alternatives, the excellent is delimited by the changing cost of energy and involvement of renewable energy properties of each setup, based on the net present cost (NPC) with respect to the total production of electrical power generation system which is suitable for the total load. The PV/wind/diesel generator /battery setup is ranked first in both cases since it has the least NPC as compared with the other possible optimal results.

On the other hand, considering the shortage of electricity in the country frequent power outage caused by old electric power distribution lines, this thesis finding will help to control Fault occurring during short-term or a long-term loss and the consequential data forfeiture and disruptions of maneuvers involve innumerable pecuniary damage for data center operators. Another finding of the thesis is direct current distribution system in the datacenter stream will can eradicate the requirement for converter in distribution system, which decreases the prices on the entire datacenter system and it will increase the overall efficiency of the system by reducing losses.

6.2 Recommendation

From the outcome of the inquiries, it is understood that this area (Addis Ababa) is rich in renewable resources. It subsidizes to assure maintainable and viable electrical power sources other similar areas with same climate. On the other hand, considering the shortage of electricity in the country frequent power outage caused by old electric power distribution lines, This thesis finding will help to control fault occurring during short-term or a long-term loss and the consequential data forfeiture and disruptions of maneuvers involve innumerable pecuniary damage for data center operators. Hence, implanting the finding of the thesis it will improve the overall system. Regarding the distribution system increasing awareness of DC distribution is useful at this time for implementing the system. In addition to the above points this thesis can be used as reference material for supplementary studies for scholars in the part. It can initiate policy makers, government or NGOs implementing standalone wind/PV hybrid electrification platforms either in this region or in other similar meteorological segments of the country.

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APPENDICES

APPENDIX 1

QUESTIONER

Part one [General Information about data center]

1. The data center total floor area of ---------- square feet (ft2) or ------------m^2
2. storage capacity -----------------------------
3. Number of racks-----------------------------
4. Is there any backup power for the occurrence of a power outage?

Yes	No

5. If the answer for question 4 is yes what types of power are using?
6. The Data Center operation hour on a 24 hour per day is ____________________
7. the average amount of power consumed in the building during peak usage (workday) periods in KW

KW

8. load variation between day and night or between weekdays and weekends

Part Two [End-Use of Electricity of the Data Center Building]

Description	**Electric power demand (KW)**	**Share of electric energy use (%)**
Overall Building Load		
Building - (other non-DC load		
Data Center Computer Load		
Data Center computer room air handler (CRAH) Units		
Chillers		
Data Center UPS Losses		
Data Center Lighting		
Total Data Center Load		

Part three [End-Use of Electricity of the Data Center]

Description	**Electric power demand (KW)**	**Share of electric energy use (%)**
Data Center Rack Load		
Data Center CRAH Units		
Chillers (DC portion)		
Standby Generator		
Data Center UPS Losses		
Data Center Lighting		
Total Data Center only		

APPENDIX 2

THE FINAL RESULT OF MATLAB OUT PUT FOR ADDIS ABABA SOLAR RADIATION

```
n=[17 47 75 105 135 162;198 228 258 288 318 344]

n =
    17    47    75   105   135   162
   198   228   258   288   318   344

format shortG
s=23.45*sind(360*(284+n)/365)

s =
      -20.917      -12.955      -2.4177       9.4149       18.792       23.086
       21.184       13.455       2.2169      -9.5994      -18.912       -23.05

g=1366.1

g =
       1366.1

format shortG
G=g*(1+0.033*cosd((360*n)/365))

G =
       1409.3       1397.2       1378.5       1355.5       1335.3       1323.8
       1322.6       1334.2         1354         1377       1397.2       1408.3

p=9.005401,

p =
       9.0054

format shortG
w=acosd(-tand(9.01)*tand(s))
```

```
format shortG
y=cosd(p).*cosd(s).*sind(w)+((pi.*w)/180).*sind(p).*sind(s)

y =
     0.8365     0.90806     0.97644      1.0149      1.0156      1.0071
     1.0115      1.0185     0.99646     0.93319     0.85604     0.81462

format shortG
Ho=x.*y

Ho =
  3.2444e+07  3.5219e+07  3.7871e+07  3.9362e+07  3.9387e+07  3.9055e+07
  3.9229e+07  3.9499e+07  3.8647e+07  3.6194e+07  3.3202e+07  3.1596e+07

a=0.3,b=0.5,

a =
         0.3

b =
         0.5

h13=[8.8 9.8 7.1 6.8 5.7 4.5;2.3 2.2 5.2 6.9 8.8 9.7]
h13 =
          8.8          9.8          7.1          6.8          5.7          4.5
          2.3          2.2          5.2          6.9          8.8          9.7

H13=Ho.*((a+b.*(h13./N)))

H13 =
  2.2107e+07  2.5289e+07  2.2612e+07  2.2777e+07   2.086e+07  1.8737e+07
  1.5386e+07  1.5385e+07  1.9935e+07  2.1445e+07  2.2571e+07  2.2823e+07

h14=[8.7 7.7 8 8 6.2 5.1;2.3 3 3.2 6.6 8.5 9.2]

h14 =
          8.7          7.7            8            8          6.2          5.1
          2.3            3          3.2          6.6          8.5          9.2
```

APPENDIX 3

SENSITIVITY RESULTS

Sensitivity/ Arctic Diesel Fuel Price ($/L)	Sensitivity/Electric Load #1 Scaled Average (kWh/d)	Architecture/Schn 540 (kW)	Architecture/Schn540-MPPT (kW)	Architecture/VergMP-C	Architecture/ Gen100 (kW)	Architecture/Iron2100
0.59	4554.321	540.1	540.1	2	500	34
0.59	4554.321			2	500	34
0.59	4554.321			2	500	
0.59	4554.321	540.1	540.1	2	500	
0.59	4554.321	540.1	540.1	2		3740
0.59	4621.99	540.1	540.1	2	500	34
0.59	4621.99			2	500	34
0.59	4621.99			2	500	
0.59	4621.99	540.1	540.1	2	500	
0.59	4621.99	540.1	540.1	2		4012
0.59	4921.999	540.1	540.1	2	500	34
0.59	4921.999			2	500	34
0.59	4921.999			2	500	
0.59	4921.999	540.1	540.1	2	500	
0.59	4921.999	540.1	540.1	2		6324
0.8	4554.321	540.1	540.1	2	500	34
0.8	4554.321			2	500	34
0.8	4554.321			2	500	
0.8	4554.321	540.1	540.1	2	500	
0.8	4554.321	540.1	540.1	2		3740
0.8	4621.99	540.1	540.1	2	500	34
0.8	4621.99			2	500	34

0.8	4621.99			2	500	
0.8	4621.99	540.1	540.1	2	500	
0.8	4621.99	540.1	540.1	2		4012
0.8	4921.999	540.1	540.1	2	500	34
0.8	4921.999			2	500	34
0.8	4921.999			2	500	
0.8	4921.999	540.1	540.1	2	500	
0.8	4921.999	540.1	540.1	2		6324
0.9	4554.321	540.1	540.1	2	500	34
0.9	4554.321			2	500	34
0.9	4554.321			2	500	
0.9	4554.321	540.1	540.1	2	500	
0.9	4554.321	540.1	540.1	2		3740
0.9	4621.99	540.1	540.1	2	500	34
0.9	4621.99			2	500	34
0.9	4621.99			2	500	
0.9	4621.99	540.1	540.1	2	500	
0.9	4621.99	540.1	540.1	2		4012
0.9	4921.999	540.1	540.1	2	500	34
0.9	4921.999			2	500	34
0.9	4921.999			2	500	
0.9	4921.999	540.1	540.1	2	500	
0.9	4921.999	540.1	540.1	2		6324

APPENDIX 4

OPTIMIZATION RESULTS

Diesel Fu	Electric Lo	Schn540 (	Schn540-N	VergMP-C	Gen100 (k	Iron2100	Dispatch	Cost/COE	Cost/NPC	Cost/Ope	Cost/Initia	System/R	System/To	Gen100/H	Gen100/P
0.59	4554.321	540.1	540.1	2	500	34	CC	0.327521	7038355	208196.3	4346894	74.0802	88568.83	862	430871.9
0.59	4621.99	540.1	540.1	2	500	34	CC	0.328656	7167669	218199.3	4346894	73.06705	93398.18	909	454365.9
0.59	4921.999	540.1	540.1	2	500	34	CC	0.336247	7809219	267826	4346894	67.52473	119927.2	1167	583427.9
0.8	4554.321	540.1	540.1	2	500	34	CC	0.33871	7278800	226795.8	4346894	74.0802	88568.83	862	430871.9
0.8	4621.99	540.1	540.1	2	500	34	CC	0.340282	7421224	237812.9	4346894	73.06705	93398.18	909	454365.9
0.8	4921.999	540.1	540.1	2	500	34	CC	0.350265	8134795	293010.8	4346894	67.52473	119927.2	1167	583427.9
0.9	4554.321	540.1	540.1	2	500	34	CC	0.344038	7393297	235652.6	4346894	74.0802	88568.83	862	430871.9
0.9	4621.99	540.1	540.1	2	500	34	CC	0.345818	7541965	247152.7	4346894	73.06705	93398.18	909	454365.9
0.9	4921.999	540.1	540.1	2	500	34	CC	0.356941	8289831	305003.5	4346894	67.52473	119927.2	1167	583427.9
1.2	4554.321	540.1	540.1	2	500	34	CC	0.360115	7738775	262376.9	4346894	74.07268	88596.61	863	430996.9
1.2	4621.99	540.1	540.1	2	500	34	CC	0.362427	7904187	275172.2	4346894	73.06705	93398.18	909	454365.9
1.2	4921.999	540.1	540.1	2	500	34	CC	0.377043	8756694	341117.4	4346894	67.52007	119946.8	1168	583511.7

APPENDIX 5:

EMISSIONS

Pollutant	Quantity	Unit
Carbon Dioxide	231,659	kg/yr
Carbon Monoxide	1,576	kg/yr
Unburned Hydrocarbons	63.8	kg/yr
Particulate Matter	6.31	kg/yr
Sulfur Dioxide	468	kg/yr
Nitrogen Oxides	126	kg/yr

PLAGIARISM REPORT

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