Near East University

Faculty of Engineering

Department of Electrical and Electronic Engineering

ENERGY EFFICIENCY MANAGEMENT AND OPTIMIZATION

Graduation Project

EE-400

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Abstract

Standing up to the fact that one third of all known species on Earth will have been wiped out by 2050 due primarily to global warming as a result of our current practices, We have seen that we need to consider that in mind. Hence, we have got the idea to make this research on optimizing and managing the energy.

The main focus will be on the renewable energy, stating as much as we can get on them, spreading the knowledge of the renewable energy between us as individual to start it ourselves in our homes, to be completely dependent and not to mention about how useful it will be for our environment.

This project presents a framework for using simulation- based optimization approach in reducing primary energy consumption using renewable energy. However, the control parameters that influence the primary energy consumption are identified using a sensitivity analysis. Accordingly; it is found that the supply fuel price, the wind speed and solar radiation required to improve efficiency are the main parameters that should be controlled to reduce the primary energy consumption.

We have conducted in this project one optimization control approach using **ENERGY PLUS.**

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Chapter 1

Project Overview

1.1 Introduction

All of us use energy services in our daily lives. Many of these are based on grid electricity, which is essentially clean and convenient at the point of use in your home or office. However, grid electricity is only one form of energy and it has some rather significant disadvantages. One of this is that -in Egypt-, it is derived from non-renewable and environmentally problematic sources of energy such as gas and coal. And, as it turns out, gas and coal have particularly high local and global environmental impacts.

Recently, there have been growing concerns about the availability and cost of energy and about environmental impacts of fossil energy use. Those concerns have rekindled interest in energy efficiency, energy conservation and the development and commercialization of renewable energy technologies.

Many of the existing energy efficiency and renewable energy programs have authorizations tracing back to the 1970s. Many of the programs have been reauthorized and redesigned repeatedly to meet changing economic factors. The programs apply broadly to sectors ranging from industry to academia, and from state and local governments to rural communities.

Modern Renewable Energy Systems and Energy Efficient Options are technically mature, commercially established, readily accessible, and they are more or less just as expensive or cheap as the conventional option of grid. It is always difficult to start on a new path, but one of the benefits of renewable energy and energy efficiency is that; you can start small and transform your energy utilization patterns and energy service systems slowly and within the constraints of your budget. The more you implement changes, the more monthly disposable income will become available (from the savings you make) for further

1.2 Renewable energy benefits

1. Energy savings: you can save energy, and hence natural resources, which benefits everyone.
2. Financial savings: by using less energy (energy efficiency) and substitution of one form of (non-renewable and expensive) energy to another (renewable or cheaper) form.
3. Reduced consumption of our natural resources.
4. Operational security: renewable energy systems can be designed to provide better reliability than conventional grid systems, such as power for telecommunications, navigational beacons ...etc.
5. Diversity of supply: diversification of supply means there is less risk of experiencing a total loss of power due to the sole source of energy (electricity) going down for some reason.
6. Reduced or deferred infrastructure costs: including generation, transmission, distribution and maintenance.
7. Environmental benefits: renewable energy systems do not degrade the environment to the same extent as nonrenewable systems.
8. Social benefits: increased employment opportunities through manufacture, installation and operation of renewable energy systems.

1.3 Purpose and Objectives

The objective function is to minimize the overall cost of electricity and natural gas for a system operation over a time horizon while satisfying the energy balance and complicated operating constraints of individual energy supply equipment and devices. Also, the key to the most cost- effective use of renewable energy systems is the matching of the energy services that you require with the capacities and characteristics of available technologies and systems.

Assess your real energy service needs (after having reduced the consumption of your existing energy supplies to more realistic levels, through energy efficiency measures and increased use of more efficient electrical appliances as above).

Substitute or expand your range of energy supplies to utilize these more effectively, using solar radiation or wind rather than grid electricity.

Start to increase your overall use of renewable energy to reduce your use (and dependence) on non-renewable energy supplies.

Monitor (and then manage) your consumption and the costs of this consumption (including social and environmental costs if you feel up to it) on an ongoing basis.

1.4 The initial questions that you should enquire about include

1. The initial costs of supply and installation.
2. The operating and maintenance requirements (even renewable energy systems need to be maintained).
3. The levels of service which are offered.
4. The implications of upgrading (or downgrading) as your needs change.
5. The costs of ongoing maintenance.
6. The quality assurance for the equipment.

We hope you enjoy the experience of taking responsibility for your own energy service needs. The risks are small by comparison with entrusting your (and the Earth's) future to others. Stand up to the fact that one third of all known species on Earth will have been wiped out by 2050 due primarily to global warming as a result of our current practices.

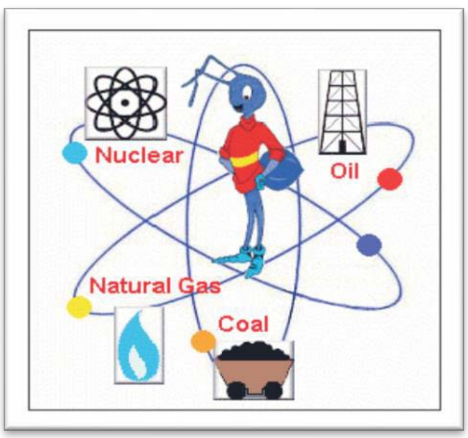
Chapter 2

Renewable Energy Recourses

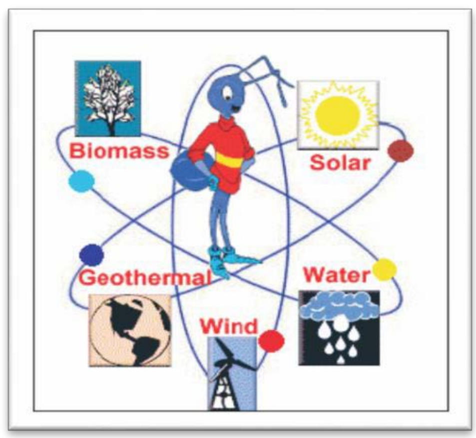
2.1 Introduction

Renewable energy is energy obtained from sources that are essentially inexhaustible. Examples of renewable resources include wind power, solar power, geothermal energy, tidal power and hydroelectric power (See Figure). The most important feature of renewable energy is that it can be harnessed without the release of harmful pollutants.

Non-renewable energy is the conventional fossil fuels such as coal, oil and gas, which are likely to deplete with time.



Non Renewable Energy



Renewable Energy

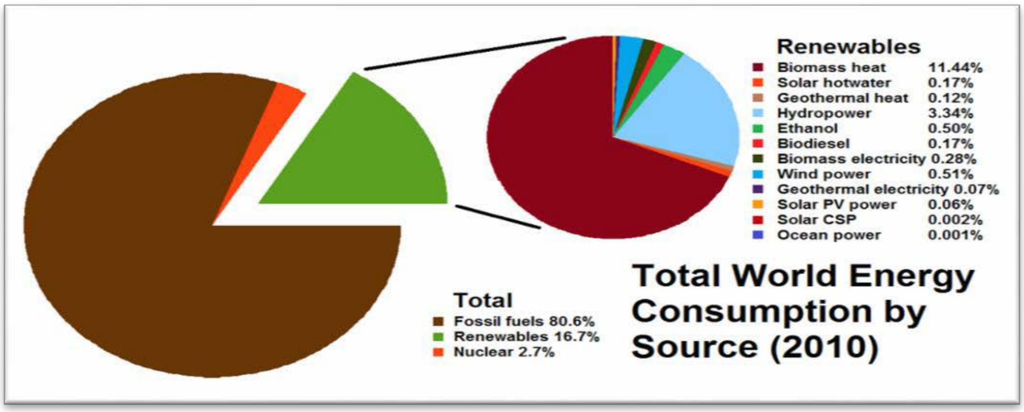
(Figure 2.1: Renewable&Non Renewable Energy)

Coal and other fossil fuels, which have taken three million years to form, are Likely to deplete soon. In the last two hundred years, we have consumed 60% of all resources. For sustainable development, we need to adopt energy efficiency measures.

Today, 85% of primary energy comes from nonrenewable and fossil sources (coal, oil... etc.). These reserves are continually diminishing with increasing consumption and will not exist for future generations. It has the additional advantage that being a naturally distributed resource; it can also provide energy to remote areas without the need for extensive energy transport systems.

Renewable energy is currently experiencing dramatic growth. The fastest growing renewable energy technology is currently grid connected PV with 40% annual year on year growth.

But the renewable energy technology that has made the largest contribution to date is wind power with over 60 GW installed in EU countries and 95 GW worldwide by the end of 2007.



(Figure 2.2: World Energy Consumption)

2.2 Integrating Renewables into Power Systems

The term ***grid*** is often used loosely to describe the totality of the network. In particular, ***grid connected*** means connected to any part of the network.

Integration specifically means the physical connection of the generator to the network with due regard to the secure and safe operation of the system.

The integration of generators powered from renewable energy sources is fundamentally similar to that of fossil fuelled powered generators and is based on the same principles.

A renewable energy generator may be described either as ***standalone*** or ***grid –connected.***

In a standalone system a renewable energy generator supplies the greater part of the demand. In a grid-connected system, the renewable energy generator feeds power to a large interconnected grid, also fed by a variety of other generators.

2.3 Wind Power System

Wind power is the conversation of wind energy into a useful form of energy, such as using wind turbines to produce power, windmills for mechanical power, wind pump for water pumping or drainage and sails or propel ships.

Large wind farms consist of hundreds of individual wind turbines which are connected to the electric power transmission network. For new constructions, ***onshore*** wind is an inexpensive source of electricity, competitive with or, in many places, cheaper than fossil fuel plants, and ***offshore*** wind is steadier and stronger than on land, and offshore farms have less visual impact.

Onshore turbine

Off shore turbine

(Figure 2.3: Onshore& Off shore turbines)

The first wind powered electricity was produced by a machine built by Charles F. Brush in Cleveland, Ohio in 1888. It had a rated power of 12 kW DC. In 1930's the first large scale AC turbine was constructed in USA. During the 1980's installed capacity costs dropped considerably and wind power has become an economically attractive option.

For commercial electricity generation, large wind farms or wind power stations have become a common sight in many western countries. In 2001, Denmark alone had 2000 Megawatts of electricity generating capacity from more than 5,700 wind turbines, representing 14% of their national electricity consumption.

2.3.1 Classification system for wind turbines:

Scale	Rotor diameter	Power rating
Micro	Less than 3 m	50 W to 2 KW
Small	3 m to 12 m	2 KW to 40 KW
Medium	12 m to 45 m	40 KW to 999 KW
Large	46 m and larger	More than 1 MW

2.3.2 Global use of wind power:

As of 2011, Denmark is generating more than a quarter of its electricity from wind and 83 countries around the world are using wind power to supply the electricity grid. In 2010; wind energy production was over 2.5% of total worldwide electricity usage and growing rapidly at more than 25% per annum.

Wind power generation in Egypt:

Unlike the trend toward large-scale grid connected wind turbines seen in the West, the more immediate demand for rural energy supply in Egypt and other developing countries is for smaller machines in the (5 - 100 kW) range. These can be connected to small, localized micro-grid systems and used in conjunction with diesel generating sets and/or solar photovoltaic systems.

Egypt enjoys excellent wind regimes, particularly in the Suez Gulf where the average wind speed reaches 10.5 m/s.

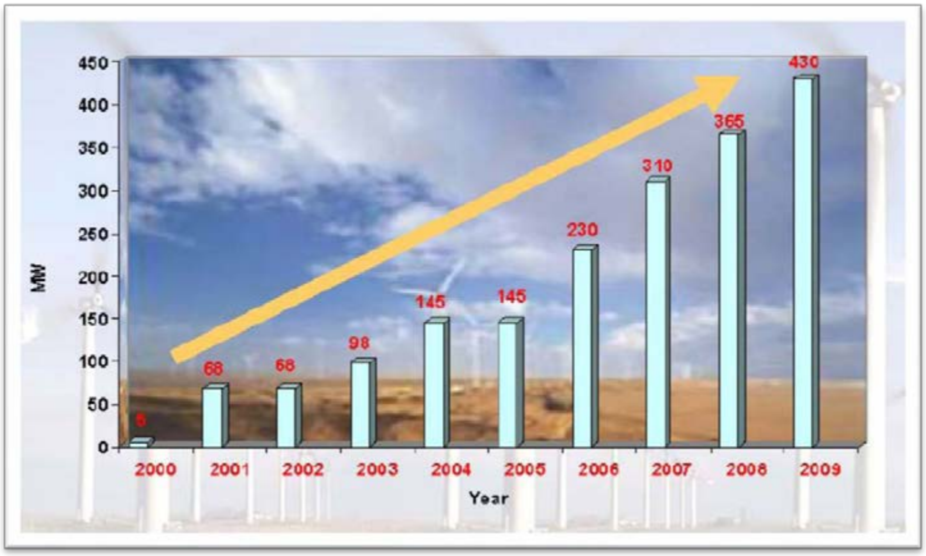
With 322 MW wind energy installed Zaafarana, Egypt has saved 190,000 T.O.E (tons of oil equivalent) and reduced emissions of about 450,000 Tco2 in 2007 and after the expected growth of 7200 MW wind energy installed, Egypt would Approximately Save 4.25 Million T.O.E and reduce emissions of about 10 Million Tco2.

The wind energy industry in Egypt could participate for the creation
of 75,000 direct jobs by 2020

The amount of wind energy available at any location depends on:

a. Climatic factors including: Time of day, Season, Geographic, and Local weather.

b. Mechanical factors including: Diameter of rotor, Type of turbin



(Figure 2.4: Wind Energy Production in Egypt)

2.3.3 Planning Constraints for wind turbines

There is a number of planning related issues that may make it difficult for you to install a turbine on your site and it would be wise to ensure that you are not going to fall foul of any of these before proceeding:

1. Military installations: Avoid these installations, especially if it is an air force base or communication centers.
2. Proximity to built-up area: When housing estates are concerned, ideally consider a distance of at least (200 - 300m) depending on the size of the turbine.
3. Designated areas or listed buildings: National Parks or Areas of Outstanding Natural Beauty are more difficult to satisfy the local planning officer to install a wind turbine on it or near it.

2.3.4 Steps to planning and building a wind farm

1. Consultation with the local authority.
2. Consultation with the Public near the site.
3. Land acquisition.
4. Wind Assessment.

5. Wind Farm Design.
6. Environmental Impact Assessment.
7. Economic and Financial evaluation.
8. Site Preparation.
9. Construction.

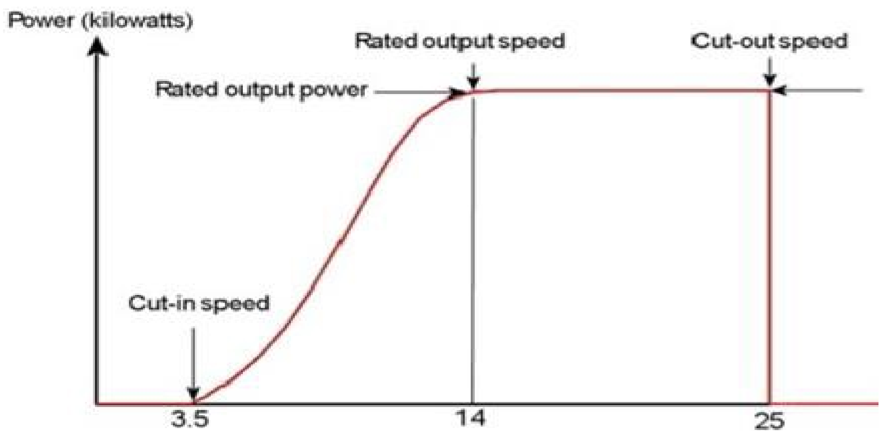
Finally, the wind turbine is tested. All components are calibrated on site and verified against the supplier's specifications, before becoming fully operational

2.3.5 Wind Turbine Speeds

Average Wind Speed m/s (km/h)	**Suitability for power generation**
Up to 4 (15)	Not good
5 (18)	Poor
6 (22)	Moderate
7 (25)	Good
8 (29)	Excellent

a. **Start-up Speed:** This is the speed at which the rotor and blade assembly begins to rotate.
b. **Cut-in Speed:** Cut-in speed is the minimum wind speed at which the wind turbine will generate usable power. This wind speed is typically between 7 and 10 m/s for most turbines.
c. **Rated Speed:** The rated speed is the minimum wind speed at which the wind turbine will generate its designated rated power.

At wind speed between cut in and rated, the power output from a wind turbine increases as the wind increases. The output of most machines levels off above the rated speed. Most manufacturers provide graphs called “Power Curves”, showing how their wind turbine output varies with wind speed.



(Figure 2.5: Steady wind speed m/s)

d. **Cut-out Speed:** At very high wind speeds, typically between 45 and 80 m⁄s, most wind turbines stop power generation and shut down. The wind speed at which shut down occurs is called the cut- out speed, or sometimes ***furling speed***. Having a cut-out speed is a safety feature which protects the wind turbine from damage.

2.3.6 Integrating wind system into the network:

Commonly, larger machines are connected to a grid distribution network. So electricity can be sold to the electricity utility (providing an agreement can be made between the producer and the grid).

When an excess is produced and purchased when the wind is low, using the national grid helps provide flexibility to the system and does away with the need for a back-up system when wind speeds are low.

Micro-grids distribute electricity to smaller areas, typically a village or town. When wind is used for supplying electricity to such a grid, a diesel generator set is often used as a backup for the periods when wind speeds are low. Alternatively, electricity storage can be used, but this is an expensive option.

Hybrid systems use a combination of two or more energy sources to provide electricity in all weather conditions. The capital cost for such a system is high but subsequent running costs will be low compared with a pure diesel system.

Advantages of using wind power:

Wind power, as an alternative to fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation and uses little land. The effect on the environment is generally less problematic than those from other power sources.

Environmental concerns:

Wind power is a clean renewable energy source. There are some environmental considerations to keep in mind when planning a wind power scheme. They include the following:

1. Electromagnetic interference - some television frequency bands are susceptible to interference from wind generators.
2. Noise-wind rotors, gearboxes and generators create acoustic noise when operating.
3. Visual impact-modern wind machines are large objects and have a significant visual.
4. Impact on their surroundings.

Cost–Economics:

The cost of producing electricity from the wind is heavily dependent on the local wind regime. The power output from the wind machine is proportional to cube of the wind speed and so, a slight increase in wind speed will mean a significant increase in power and a subsequent reduction in unit costs. Capital costs for wind power are high, but running costs are low, and so loans are an obvious advantage when considering a wind- electric system. If a hybrid system is used a careful cost-benefit analysis needs to be carried out. A careful matching of the load and energy supply options should be made to maximize the use of the power from the wind.

2.4 Photovoltaic Systems

The word “photovoltaic” combines two terms; “photo” means light and “voltaic” means voltage. A photovoltaic system uses photovoltaic cells to directly convert sunlight into electricity.

Two approaches for using PV's:

1. Stand-alone system: Requires batteries to store power for the times when the sun is not shining.
2. Grid-interface system: Uses power from the central utility when needed and supplies surplus home-generated power back to the utility.

2.4.1 Global use of solar energy:

Global capacity for solar energy production reached 39.8 Giga Watts (0.0398 terawatts) in 2010. Here are the top 9 solar energy producing countries in the world:

1. Germany (9,785 MW).
2. Spain (3,386 MW).
3. Japan (2,633 MW).
4. United States (1,650 MW).
5. Italy (1,167 MW).
6. Czech (465 M.W).
7. Belgium (363 M.W).
8. China (305 M.W).
9. France (272 M.W).

Overall, the sun emits about 7,000 times more energy than is required for human consumption. Presently; the total amount of solar energy consumed for human use is less than 1% of our entire energy requirements.

This means that an incredible amount of energy is still waiting to be captured. The annual global electricity requirement for human civilization is estimated at around 17,000 terawatt-hours. This is roughly the equivalent of an hour of bright uninterrupted sunshine striking the earth's surface.

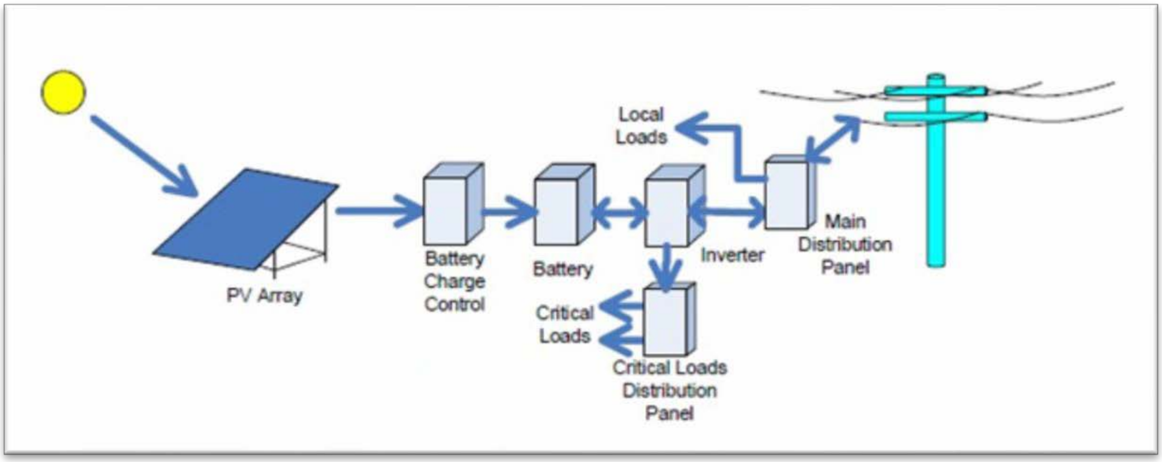
Solar Energy in Egypt:

Due to its location, topography and climate, Egypt has an average level of solar radiation of between 2,000 to 3,200kWh per m2 a year, giving it significant potential for utilizing this form of renewable energy. Until now, solar projects have been slow due to high capital costs. In 2010, Egypt’s only major solar power project was commissioned in Kuraymat. The plant is a 140MW solar thermal combined cycle power plant of which 20MW is from solar energy.

Here, the investment cost of solar power plants is currently very high in comparison with oil and gas fired power plants and it is envisaged that Egypt’s strategy for developing its renewable energy capacity will be mainly directed at the wind sector.

2.4.2 Factors affecting the output from a solar PV system:

1. Total size of the PV array: Each kWp (kilo watt peak) requires approximately 8m2 of area.
2. Type of module used:
    a. Amorphous: These are approximately 8-10% efficient. An advantage of these modules is that they are not too susceptible to shading and are suited to low light levels.
    b. Polycrystalline: These modules are made from silicon crystals. They are approximately 14% efficient.
    c. Mono-crystalline: Made form pure silicon crystals. These are approximately 16% efficient.
    d. Hybrid: Combine mono-crystalline technology along with amorphous. These are top of the range and have an efficiency of 20%.
3. The orientation from due south: The array should ideally face due south. Any deviation from due south will reduce the potential yearly output.
4. The latitude of the installation: The further south is the better.
5. The angle from horizontal: The ideal angle from horizontal is between 30-45 degrees. Other angles are also suitable, but slightly less efficient. To capture the maximum amount of solar radiation over a year, the solar array should be tilted at an angle approximately equal to a site's latitude and facing within 15° of due south.
6. Anything which shades the panels: Shading of a module can dramatically reduce the output from the whole array. Shading should therefore always be avoided, especially from any trees or buildings to the South of the array.



(Figure 2.6: Connecting PV arrays to the grid)

PV can be installed on top of a roof or integrated into the roofs and facades of houses, offices and public buildings.

The electricity (direct current) generated by the solar cells in the PV modules is transported via normal cables to an inverter. This electrical tool, which is often installed somewhere close to the house's connection point to the public grid, transforms the dc current into ac current in order to make it compatible with the electricity in the house and the public grid.

Large-scale grid-connected PV arrays have not so far become a major part of the market, mainly because of the difficulty in finding enough space in built-up areas.

2.4.3 Advantages of using Solar Power:

1. Solar energy is free although there is cost in the building of cells and other equipment required to convert solar energy into electricity.
2. Solar energy does not cause pollution.
3. Solar energy can be used in remote areas where it is too expensive to extend the electricity power grid.
4. Many everyday items such as calculators and other low power consuming device can be powered by solar energy effectively.
5. It is estimated that the world's oil reserves will last for 30 to 40 years. On the other hand, solar energy is infinite.

2.4.4 Disadvantages of using Solar Power:

1. Solar energy can only be harnessed when it is daytime and sunny.
2. Solar collectors, panels and cells are relatively expensive to manufacture although prices are falling rapidly.
3. Solar power stations can be built but they do not match the power output of similar sized conventional power stations. They are also very expensive.
4. In countries such as UK, the unreliable climate means that solar energy is also unreliable as a source of energy. Cloudy skies reduce its effectiveness.
5. Large areas of land are required to capture the suns energy. Collectors are usually arranged together especially when electricity is to be produced and used in the same location.
6. Solar power is used to charge batteries so that solar powered devices can be used at night. However, the batteries are large and heavy and need storage space. They also need replacing from time to time.

Environmental Concerns:

There is no pollution in the form of exhaust fumes or noise during operation.

2.4.5 Usage of Solar Energy:

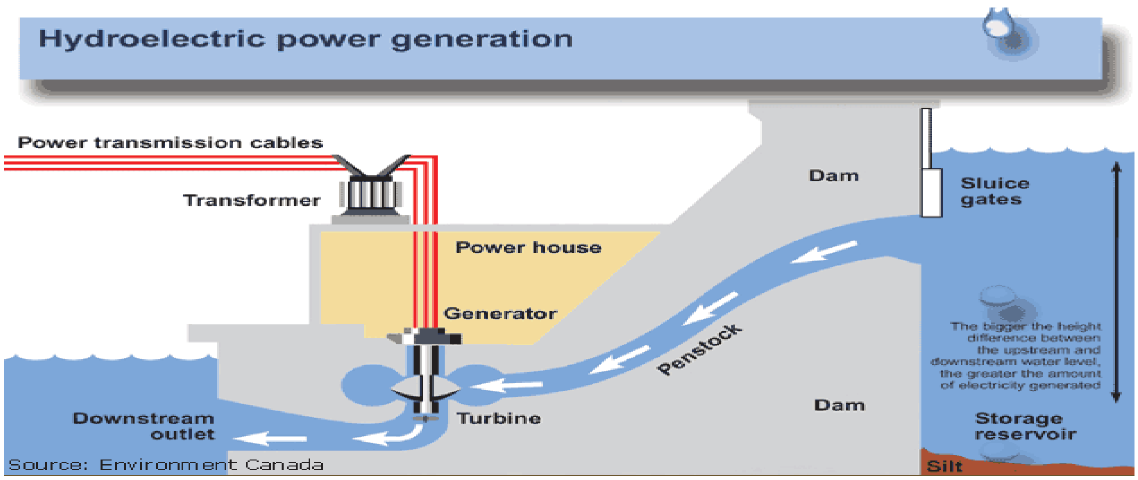
1. **Large Scale:**
    - Solar Fields that supply energy to electrical “Grids”.
    - Large Corporation Companies.
    - Large Scale Housing Units.
    - Suburbia Towns and Villages.
2. **Medium Scale:**
    - Farming.
    - Domestic Housing.
    - Small scale companies.
3. **Small Scale:**
    - Everything from Calculators to Parking meters.

Why all future energy can't need met with rooftop PV power?

Grid-connected PV or wind turbines technologies do not provide all of the characteristics necessary for a consistent electricity supply as:

1. It is unable to provide energy at all times that it is needed and cost. Perhaps; 10% to 25% could be met with roof-mounted PV arrays.
2. Without energy storage, PV generation can provide the most electricity during midday on sunny days, but none during evenings or at night.
3. PV output can increase and fall rapidly during cloudy weather.

2.5 Hydroelectric Power



(Figure 2.7: Hydroelectric Power Generation)

Hydro-power or water power is power derived from the energy of falling water and running water, which may be harnessed for useful purposes. Since ancient time, hydro-power has been used for irrigation and the operation of various mechanical devices such as, watermills, sawmills, textile mills, dock cranes, power houses and paint making. Hydro power is a renewable energy source.

2.5.1 World distribution of hydropower:

Hydropower is the most important and widely-used renewable source of energy. Hydropower represents 19% of total electricity production. China is the largest producer of hydroelectricity, followed by Canada, Brazil, and the United States.

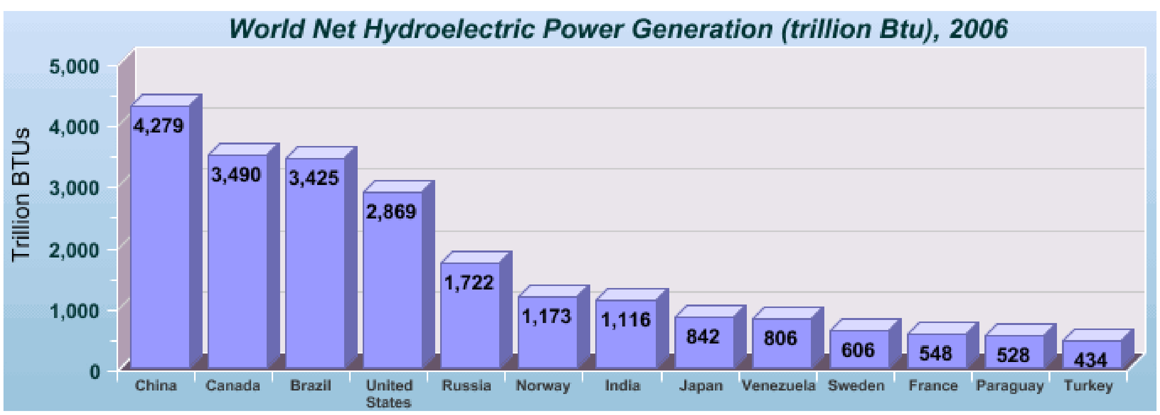
Approximately; two-thirds of the economically feasible potential remains to be developed. Untapped hydro resources are still abundant in Latin America, Central Africa, India and China.

Producing electricity using hydroelectric power has some advantages over other power-producing methods.

Hydroelectric power for Egypt:

Although, most energy in Egypt is produced by combined cycle power plants, hydroelectricity is still important to the Nation, as about 11.9% of total power is produced by hydroelectric plants (High Dam). Water flowing through the dam spin turbine blades (made out of metal) which are connected to generators. Power is produced and is sent to homes and businesses.

Hydroelectric-power production in the world:



(Figure 2.8: Hydroelectric Power production)

The chart shows hydroelectric power generation in 2006 for the leading hydroelectric-generating countries in the world. China has developed large hydroelectric facilities in the last decade and now leads the world in hydroelectricity usage. But, from north to south and from east to west, countries all over the world make use of hydroelectricity. The main ingredients are a large river and a drop in elevation.

2.5.2 Advantages of hydroelectric power:

1. Fuel is not burned so there is minimal pollution.
2. Water to run the power plant is provided free by nature.
3. Hydro power plays a major role in reducing greenhouse gas emissions.
4. Relatively low operations and maintenance costs.
5. The technology is reliable and proven over time.
6. It’s renewable- rainfall renews the water in the reservoir, so the fuel is almost always there.

2.5.3 Disadvantages of hydroelectric power:

1. High investment costs.
2. In some cases, inundation of land and wildlife habitat.
3. In some cases, loss or modification of fish habitat.
4. Fish entrainment or passage restriction.
5. In some cases, changes in reservoir and stream water quality.
6. In some cases, displacement of local populations.

2.5.4 Hydropower and the Environment:

Hydropower is nonpolluting, but does have environmental impacts:

1. Dams and reservoir would obstruct fish migration.
2. Changing of water temperature and the river's flow.
3. Reservoirs may cover people's homes, important natural areas, agricultural land and archeological sites.

Hydroelectric power sounds great, so why don't we use it to produce all of our power?

Mainly; because we need lots of water and a lot of land where we can build a dam and reservoir, which all takes a lot of money, time, and construction. The trend for the future will probably be to build small-scale hydro plants that can generate electricity for a single community.

Typical hydroelectric power plant:

Hydroelectric energy is produced by the force of falling water. The capacity to produce this energy is dependent on both the available flow and the height from which it falls. Building up behind a high dam, water accumulates potential energy. This is transformed into mechanical energy when the water rushes down the sluice and strikes the rotary blades of turbine. The turbine's rotation spins electromagnets which generate current in stationary coils of wire. Finally, the current is put through a transformer where the voltage is increased for long distance transmission over power lines.

How do we get electricity from water?

The theory is to build a dam on a large river that has a large drop in elevation. The dam stores lots of water behind it in the reservoir. Near the bottom of the dam wall there is the water intake. Gravity causes it to fall through the penstock inside the dam. At the end of the penstock, there is a turbine propeller, which is turned by the moving water. The shaft from the turbine goes up into the generator, which produces the power. Power lines are connected to the generators that carry electricity to your home.

2.5.5 Reusing water for peak electricity demand:

Demand for electricity is not flat and constant. Demand goes up and down during the day, and overnight there is less need for electricity in homes, businesses, and other facilities.

Hydroelectric plants are more efficient at providing for peak power demands during short periods than are fossil-fuel and nuclear power plants, and one way of doing that is by using **"*pumped storage*"**, which reuses the same water more than once.

Pumped storage is a method of keeping water in reserve for peak period power demands by pumping water that has already flowed through the turbines back up a storage pool above the power plant at a time when customer demand for energy is low, such as during the middle of the night. The water is then allowed to flow back through the turbine-generators at times when demand is high and a heavy load is placed on the system.

Chapter 3

Energy Management and Efficiency

3.1 Definition & Objectives of Energy Management

One definition of energy management is:

The judicious and effective use of energy to maximize profits (minimize costs) and enhance competitive positions.

(Cape Hart, Turner and Kennedy, Guide to Energy Management Fairmont press Inc. 1997)

Another comprehensive definition is:

The strategy of adjusting and optimizing energy, using systems and procedures so as to reduce energy requirements per unit of output while holding constant or reducing total costs of producing the output from these systems.

The objective of Energy Management is:

1. To minimize energy costs /waste without affecting production & quality.
2. To minimize environmental effects.

3.2 Energy Audit

Energy Audit is the key to a systematic approach for decision- making in the area of energy management. It attempts to balance the total energy inputs with its use. It quantifies energy usage according to its discrete functions.

As per the Energy Conservation Act, 2001, Energy Audit is defined as "the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption".

Need for Energy Audit

Energy Audit will help to understand more about the ways energy and fuel are used in any industry, and help in identifying the areas where waste can occur occur and where scope for improvement exists.

The primary objective of Energy Audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs.

3.2.1 Types of Energy Audit

The type of Energy Audit to be performed depends on:

- Function and type of industry.
- Depth to which final audit is needed, and
- Potential and magnitude of cost reduction desired. Thus Energy Audit can be classified into the following two types:
    1. Preliminary Audit.
    2. Detailed Audit.

Preliminary Energy Audit Methodology:

Preliminary energy audit is a relatively quick exercise to:

- Establish energy consumption in the organization.
- Estimate the scope for saving.
- Identify the most likely and the easiest areas for attention.
- Identify immediate (especially no-/low-cost) improvements/ saving.
- Set a "***reference point***".
- Identify areas for more detailed study/measurement.
- Preliminary energy audit uses existing, or easily obtained data.

Detailed Energy Audit Methodology:

A comprehensive audit provides a detailed energy project implementation plan for a facility, since it evaluates all major energy using systems.

This type of audit offers the most accurate estimate of energy savings and cost. It considers the interactive effects of all projects, accounts for the energy use of all major equipment, and Includes detailed energy cost saving calculations and project cost.

In a comprehensive audit, one of the key elements is the energy balance. This is based on an inventory of energy using systems, assumptions of current operating conditions and calculations of energy use. This estimated use is then compared to utility bill charges.

Detailed energy auditing is carried out in three phases:

- Phase I - Pre Audit Phase.
- Phase II - Audit Phase.
- Phase III - Post Audit Phase.

3.2.2 Guide for Conducting Energy Audit at a Glance:

Industry-to-industry, the methodology of Energy Audits needs to be flexible.

A comprehensive ten-step methodology for conduct of Energy Audit at field level is presented below. Energy Manager and Energy Auditor may follow these steps to start with and Add/change as per their needs and industry types.

Phase I -Pre Audit Phase Activities:

A structured methodology to carry out an energy audit is necessary for efficient working. An initial study of the site should always be carried out, as the planning of the procedures necessary for an audits most important.

Initial Site Visit and Preparation Required for Detailed Auditing:

An initial site visit may take one day and gives the Energy Auditor/Engineer an opportunity to meet the personnel concerned, to familiarize him with the site and to assess the procedures necessary to carry out the energy audit

During the initial site visit the Energy Auditor/Engineer should carry out the following actions:

- Discuss with the site's senior management the aims of the energy audit.
- Discuss economic guidelines associated with the recommend ations of the audit.
- Analyze the major energy consumption data with the relevant personnel.

- Obtain site drawings where available building layout, steam distribution, compressed air distribution, electricity distribu- tion etc.
- Tour the site accompanied by engineering/production.

The main aims of this visit are:

- To finalize Energy Audit team.
- To identify the main energy consuming areas/plant items to be surveyed during the audit.
- To identify any existing instrumentation additional metering required.
- To decide whether any meters will have to be installed prior to the audit e.g. kWh, steam, oil or gas meters.
- To identify the instrumentation required for carrying out the audit.
- To plan with time frame.
- To collect macro data on plant energy resources, major energy consuming centers.

Phase II- Detailed Energy Audit Activities:

Depending on the nature and complexity of the site, comprehensive audit can take from several weeks to several months to complete. Detailed studies to establish, and investigate, energy and material balances for specific plant departments or items of process equipment are carried out. Whenever possible, checks of plant operations are carried out over extended periods of time, at nights and at weekends as well as during normal daytime working hours, to ensure that nothing is overlooked.

The audit report will include a description of energy inputs and product outputs by major department or by major processing function, and will evaluate the efficiency of each step of the manufacturing process. Means of improving these efficiencies will be listed, and at least a pre limitary assessment of the cost of the improvements will be made to indicate the expected payback on any capital investment needed. The audit report should conclude with specific recommendations for detailed engineering studies and feasibility analyses, which must then be performed to justify the implementation of those conservation measures that require investments.

The information to be collected during the detailed audit includes:

a. Energy consumption by type of energy, by department, by major items of process equipment, by end-use.
b. Material balance data (raw materials, intermediate and final products, recycled materials, use of scrap or waste products, production of by-products for re-use in other industries, etc.)
c. Energy cost and tariff data.
d. Process and material flow diagrams.
e. Generation and distribution of site services (eg: compressed air, steam).
f. Sources of energy supply (e.g. electricity from the grid or self-generation).
g. Potential for fuel substitution, process modifications, and the use of co-generation systems (combined heat and power generation).
h. Energy Management procedures and energy awareness training programs within the establishment.

Existing baseline information and reports are useful to get consumption pattern, production cost and productivity levels in terms of product per raw material inputs.

The audit team should collect the following baseline data:

a. Technology, processes used and equipment details.
b. Capacity utilization.
c. Amount & type of input materials used.
d. Water consumption.
e. Fuel Consumption.
f. Electrical energy consumption.
g. Steam consumption.
h. Other inputs such as compressed air, cooling water etc.
i. Quantity & type of wastes generated.

j. Percentage rejection / reprocessing.
k. Efficiencies / yield.

3.2.3 Energy Audit Reporting:

After successfully carried out energy audit energy manager/energy auditor should report to the top management for effective communication and implementation. A typical energy audit reporting contents and format are given below. The following format is applicable for most of the industries. However the format can be suitably modified for specific requirement applicable for a particular type of industry.

Application for energy management in buildings:

We will discuss a small application do some analysis, load simulation, and calculate the heating and cooling loads necessary to maintain thermal control set points and energy.

We will use small description using ***Energy Plus*** program.

3.3 EnergyPlus

3.3.1 What is EnergyPlus?

EnergyPlus is energy analysis and load simulation program Based on a user's description of a building. It calculates energy consumption and the cost.

EnergyPlus will calculate the heating and cooling loads necessary to maintain thermal control set points and energy consumption. It is a simulation program designed for modeling building with **HVAC** equipment.

EnergyPlus has its roots in both the ***BLAST*** (building loads analysis and system thermodynamics) and ***DOE-2*** which were written in older version of ***FORTRAN***.

Starting Energy Plus:

Start > programs > EnergyPlus V8 > EP.Launch.

What is EP.Launch?

EP.Launch is the engine that deals with the input files and does the simulation to get the output results. It serves various types of output files (excel files, text files, graphs, etc.)

Start EP.Launch:

1. By opening EP.Launch, you can get the screen showing above.
2. Select input file by clicking on Browse and choose file saved in your computer and select weather file by clicking on Browse.
3. Run the input file by clicking on Simulate to start simulation. While simulating a black DOS window display, it will show the simulation process.
4. After run the simulation, the black DOS window closes and a status message is displayed showing in the figure. This status gives you a quick overview of the process and if there were errors or not.
5. After you press OK, you can now see the results.
6. When choosing Drawing file, it will run EP Draw. When choosing Spreadsheets, it will open any generated CSV files.
7. If you want to edit the input file, click IDF Editor. This will start a separate program called IDF Editor

IDF-Editor:

The IDF Editor is a simple "intelligent" editor that reads the EnergyPlus Input Data Dictionary (IDD) and allows creation/revision of EnergyPlus Input Data File (IDF).

IDF-Editor has two options:

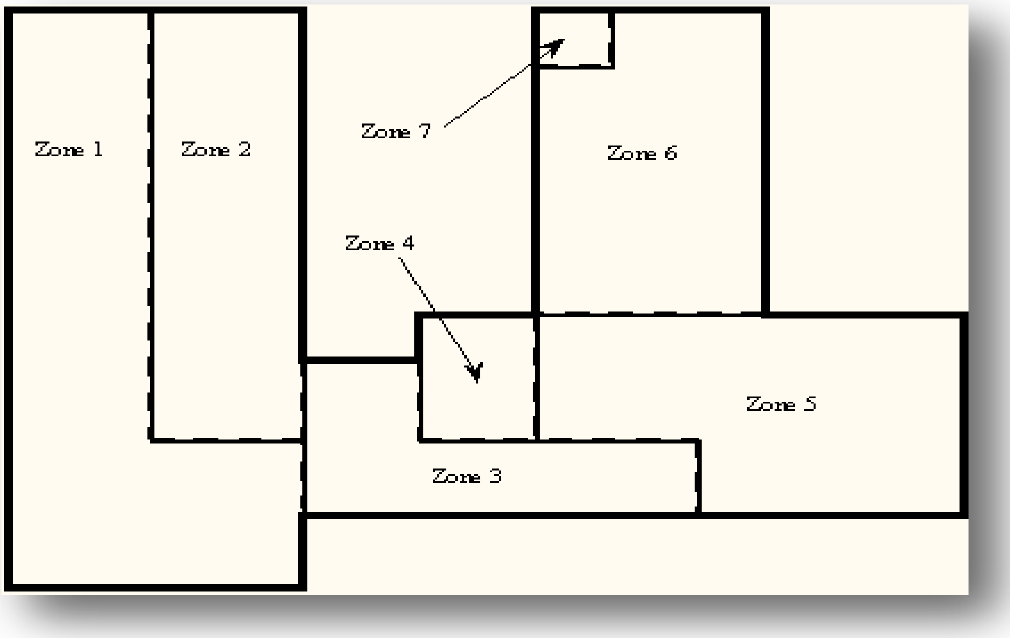
1. Selecting an existing one for editing.
2. Creating a new one.

3.3.2 What is ZONE in EnergyPlus?

A **zone** in EnergyPlus is a ***thermal*** concept not ***geometric***. It is an air volume at a uniform temperature plus all the heat transfer and heat storage surfaces bounding or inside the air volume.

EnergyPlus calculates the energy required to maintain each zone at a specified temperature.

Minimum number of zones will usually be equal to number of systems serving the building.



(Figure 3.1: EnergyPlus Zones Simulation)

3.3.3 Building Simulation

Step 1: Plan ahead:

Energy Plus requires some information about building construction and surface constructions.

Step 2: "ZONE" the building:

There are two types of surfaces inside the building:

1. **Heat transfer surface:** separate between spaces at a different temperature "outside walls, roofs and floors".
2. **Heat storage surface:** separate between spaces at a same temperature "interior surfaces".

Step 3: Prepare to construct building model after choosing zones:

1. Determine heat transfer and heat storage surfaces.
2. Define equivalent surfaces.
3. Specify surfaces construction and materials.
4. Compile surfaces information.

Step 3.1. Determine heat transfer and heat storage surfaces.

Step 3.2. Define equivalent surfaces.

- Define all roofs and floors as rectangles regardless of the shape of the zone.
- Define all heat storage surfaces of the same construction within a zone as a single surface. The size of the single surface is obtained by summing the individual surface areas exposed to the zone.

Step 3.3. Specify surfaces construction and materials.

Combine all windows on a given exterior surface into a single window. Usually each exterior surface should have only one window of each type.

By using the Window Material: Glazing construction for your glass door, they will be correctly modeled in EnergyPlus with sunlight transferring into the zone.

Step 3.4. Compile surface and subsurface information.

Surface information: Base Surface Type: Heat Transfer/Heat Storage Surfaces may be of the following types: wall, floor, roof, internal mass, or subsurface.

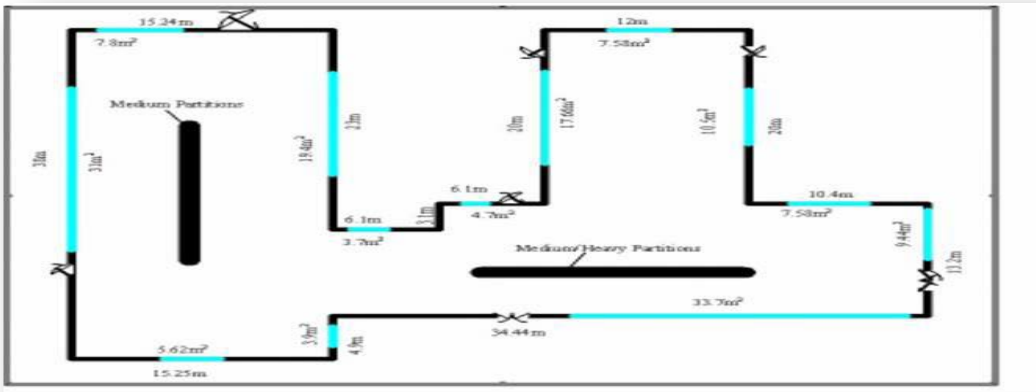
Subsurface information:

1. Subsurface are Windows, Doors or Glass Doors.
2. Area: Area of the subsurface.
3. Reveal: For windows only, the distance it is inset from the outside surface of a wall. For simplicity, put all the windows in the same physical plane as the wall they are on.

Facilitate the construction of zone information:

A few simple conventions should be followed to facilitate the construction of zone information tables:

1. Number all surfaces in order counter-clockwise around the zone.
2. Keep the subsurface with the base surface on which they are located.
3. Specify lengths for base surfaces and areas for subsurface and internal mass.
4. Specify the roof and floor as rectangles of the correct size.



(Figure 3.2: EnergyPlus One Zone Model)

Step 4: Compile Internal Space Gain Data:

People, lights, equipment, outside air infiltration and ventilation all constitute "internal gains" for the thermal zone. These gains are described to EnergyPlus as a design or peak level with a schedule that specifies a fraction of the peak for each hour. The peak level is calculated by the user.

Gain Type: The code used to differentiate between various types of internal gains.

Size: The peak load. This is the actual size of the load for every hour that the schedule specifies "100%".

Schedule: The hourly schedule that specifies the percentage of peak load for each hour of the day.

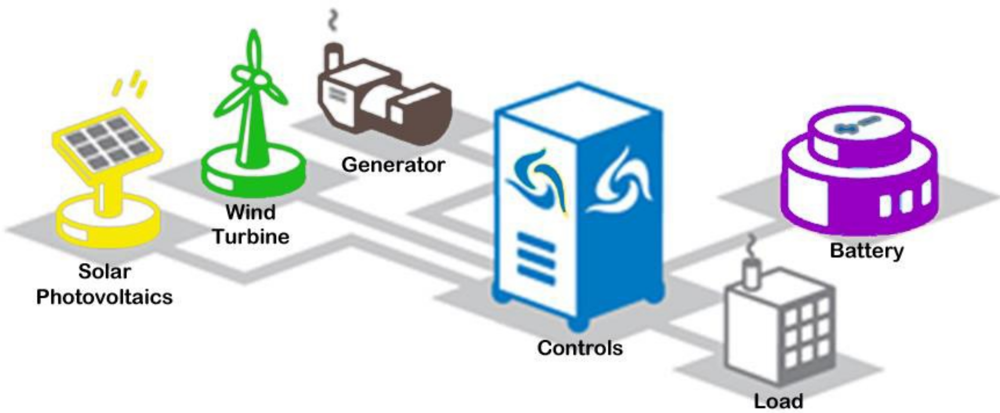
Zone	Gain Type	Size	Schedule
1	People	205	Office occupancy
	Lights	26360 W	Office lighting
	ZoneInfiltration	.75 m^3/sec	Constant

(Figure 3.3: Space gain data)

Chapter 4

Microgrid Component

4.1 What is microgrid?



(Figure 4.1: Microgrid Simulation)

Microgrid are the systems that integrate distributed generation (DG) units, energy storage systems (ESS) and controllable loads on a low voltage network which can operate in either grid-connected mode or stand-alone mode.

In the grid-connected mode, the microgrid adjusts power balance of supply and demand by purchasing power from the main grid or selling power to the main grid to maximize profits.

In the stand-alone mode, the microgrid is separated from the distribution grid, and aims to keep a reliable power supply to customers using DG.

4.1.1 Why Microgrid?

1. If connected to the grid electricity is imported when needed or exported when there's excess capacity.
2. Increased safety against outside disruptions like power cuts.
3. Better matching of supply with demand.

4. Use green power sources.
5. Electric and gas prices fluctuations.
6. Efficiency: Reduce fuel consumption - Supply close to demand minimize distribution losses.

4.1.2 Applications of microgrid:

1. Hospitals, Universities.
2. Commercial/Industrial facilities.
3. Remote “off grid” communities.
4. Military Sites
5. Oasis

4.1.3 Components of a microgrid:

Generally, a microgrid consists of: Power source (PV cells, wind turbines or distributed generators), AC or DC loads, Storage elements (batteries or Hydrogen tank) and Converters (inverter and rectifier).

4.2 Distributed Generators (DG):

We will focus our attention on Diesel Generators as they’re the most common type used in Egypt.

Diesel generator: is the combination of a diesel engine with an electric generator (often an alternator) to generate electrical energy.

Diesel generators set:

1. From 8 to 30 KW**:** used for small shops and offices.
2. From 8 kW up to 2,000 kW: used for large office complexes, factories.
3. More than 2,000 kW set: used for systems needed to be operated by a standalone power source or as a standby backup to grid power.

4.2.1 Operation principal of diesel generators:

The main function of a diesel generator is to convert mechanical energy created by the diesel combustion engine into electrical energy. In the diesel engine, air is drawn into the cylinder and is compressed to a high ratio (14:1 to 25:1). During this compression, the air is heated to a temperature of 700–900°C.

A metered quantity of diesel fuel is then injected into the cylinder, which ignites because of the high temperature and the energy (mechanical) created is transferred to the alternator which, in turn translates the power generated by the combustion engine into electrical energy. As the pistons in the engine turn, they spin a shaft which runs directly into the center of the alternator, thus providing the alternator with the needed mechanical power to generate electricity.

4.2.2 Advantages of a Diesel Engine:

1. Modern diesel engines have overcome disadvantages of earlier models of higher noise and maintenance costs.
2. They require less maintenance as compared with gas engines of similar size.
3. They are more rugged and reliable.
4. There is no sparking as the fuel auto-ignites. The absence of spark plugs or spark wires lowers maintenance costs.
5. Fuel cost per Kilo Watt produced is thirty to fifty percent lower than that of gas engines.
6. Diesel units have a significantly longer life compared with gas units.

4.2.3 The Disadvantages of Diesel Operated Generators:

1. Diesel-powered generators are louder than a gasoline or natural gas generators.
2. Like all fossil fuel powered generators, diesel generators create carbon dioxide and other gases as part of the combustion process.
3. Running diesel generators is more expensive than gas generators.
4. Cost of installation is higher than gas generators because they weight more.
5. Diesel engines are more difficult to start than gas engines, particularly in cold weather.

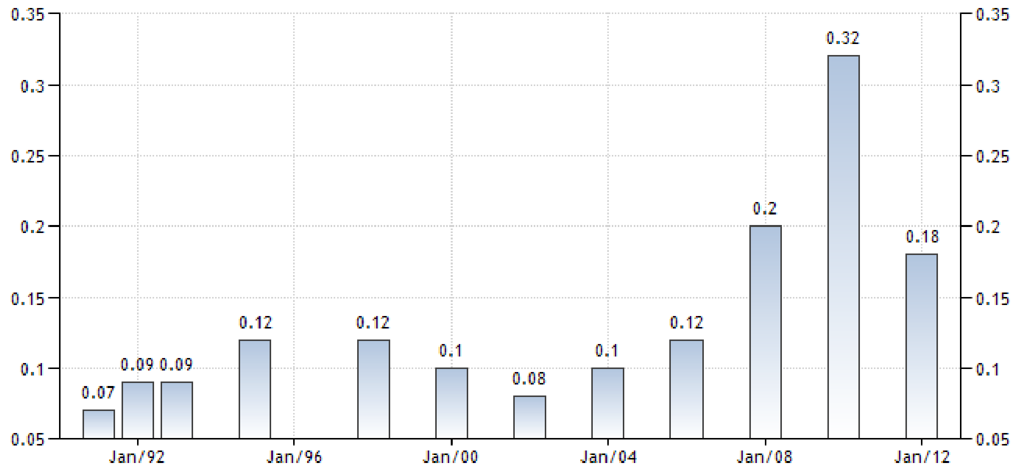
4.2.4 Diesel Generators Costs:

Fuel consumption is the major portion of diesel plant cost for power applications. Specific consumption varies, but a modern diesel plant will consume between (0.28 - 0.4 L/kWh) of fuel at the generator terminals.

This table approximates the fuel consumption of a diesel generator based on the size of the generator and the load at which the generator is operating at.

Generator Size (kW)	1/4 Load (gal/hr)	1/2 Load (gal/hr)	3/4 Load (gal/hr)	Full Load (gal/hr)
20	0.6	0.9	1.3	1.6
30	1.3	1.8	2.4	2.9
40	1.6	2.3	3.2	4.0
60	1.8	2.9	3.8	4.8
75	2.4	3.4	4.6	6.1
100	2.6	4.1	5.8	7.4
125	3.1	5.0	7.1	9.1
135	3.3	5.4	7.6	9.8
150	3.6	5.9	8.4	10.9
175	4.1	6.8	9.7	12.7
200	4.7	7.7	11.0	14.4
230	5.3	8.8	12.5	16.6
250	5.7	9.5	13.6	18.0
300	6.8	11.3	16.1	21.5
350	7.9	13.1	18.7	25.1
400	8.9	14.9	21.3	28.6
500	11.0	18.5	26.4	35.7
600	13.2	22.0	31.5	42.8
750	16.3	27.4	39.3	53.4
1000	21.6	36.4	52.1	71.1
1250	26.9	45.3	65.0	88.8
1500	32.2	54.3	77.8	106.5
1750	37.5	63.2	90.7	124.2
2000	42.8	72.2	103.5	141.9
2250	48.1	81.1	116.4	159.6

(Figure 4.2: DG Fuel Consumption)



(Figure 4.3: DG Fuel price in Egypt)

4.3 Converters (Rectifiers and Inverters)

The power we get from the renewable energy sources is mostly DC power , so to operate our load which is AC driven we need inverters.

An inverter (DC/AC converter) is used to connect this system to the utility grid.

Inverters are thus essential part to get energy from renewable energy sources.

This is especially true for renewable and solar-based power sources, which generate electricity in the form of direct current (DC). Photovoltaic (PV) solar cells and fuel cells produce only direct current.

Wind power is highly variable and needs leveling and balancing prior to use.

These and other energy sources must be converted for use by appliances, lighting, etc., by means of an inverter. Recent advances in inverter design, manufacturing, and operation are the keys to further development and acceptance of alternative energy systems.

Converters transform AC into DC and vice versa.

There are two types of converters (***rectifiers*** and ***inverters***).

4.3.1 Rectifiers

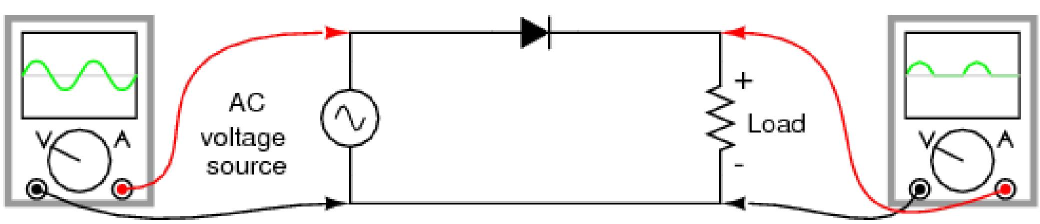
A rectifier is an electrical device composed of one or more diodes that converts alternating current (AC) to direct current (DC).

A diode is like a one-way valve that allows an electrical current to flow in one direction. This process is called rectification. Rectifiers are rated as either (***half-wave*** or ***full-wave***).

Half-wave rectifier:

It is the simplest type of rectifier, which is made with just one diode.

1. When the voltage of the alternating current is positive, the diode becomes forward-biased and current flows through it.
2. When the voltage is negative, the diode is reverse-biased.
3. The result is a cropped copy of the alternating current waveform with only positive voltage. This pulsating direct current is adequate for some components, but others require a more steady current.



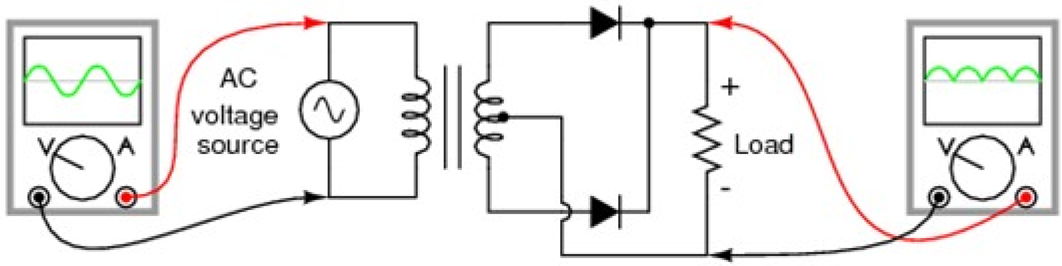
(Figure 4.4: Half-wave rectifier)

Full-wave rectifier:

This rectifier is essentially made of two half-wave rectifiers, and can be made with two diodes and an earthed center tap on the transformer. The center tap allows the circuit to be completed because current cannot flow through the other diode.

1. When the voltage of the alternating current is positive, one of the diodes become forward biased whereas the other gets reverse biased. Hence, current flows through the forward biased diode.
2. When the voltage of the alternating current is negative, the previous reverse biased diode becomes forward biased whereas the other gets reverse biased. Hence, current flows through the forward biased diode.
3. Thus, current flows at least through one of the diodes at a time.

Therefore, the result is still a pulsating direct current, but with double the frequency.



(Figure 4.5: Full-wave rectifier)

4.3.2 Inverters

(Figure 4.6: An inverter for solar mounted free standing planet alongside with Rhine)

A power inverter or inverter is an electronic device that changes direct current (DC) to alternating current (AC).

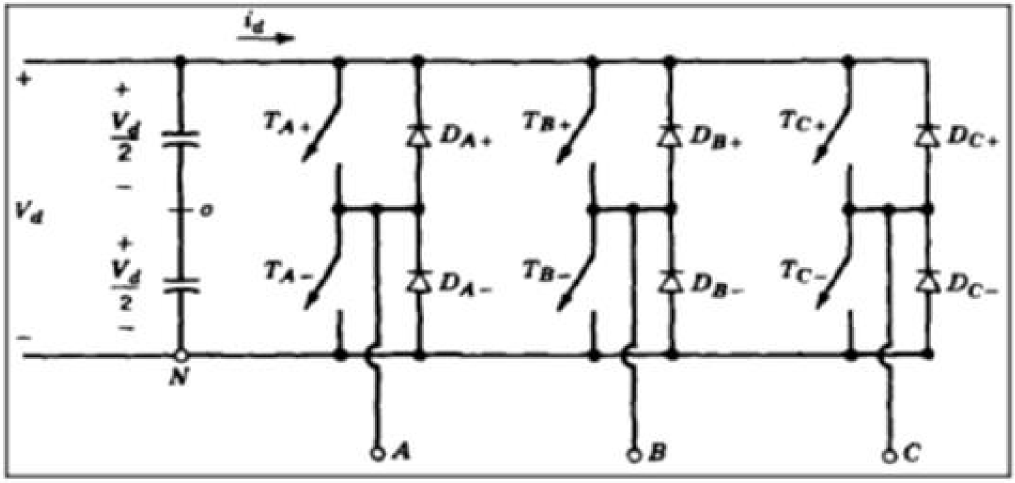
The inverter does not produce any power, and the power is provided by DC source.

The output wave form (Voltage over time) varies with the quality and cost of inverter form:

1. **Rectangular**: poorest quality and least cost.
2. **Trapezoidal**: better quality and more cost.
3. **A true sin wave identical to that directly produced by AC generator**: best quality and more expensive.

Inverter can be connected either in parallel for higher power, or in series for higher voltage.

Inverter used in microgrid:



(Figure 4.7: Three-phase inverter)

Inverters convert DC power into AC power. Conversation of energy is done with a ***three phase full bridge inverter***, and for every single switch, we need anti parallel diode.

The main idea behind an inverter is to get a pure sinusoidal voltage and current for the DC driven load.

Basic installation steps of an inverter:

1. **Battery Capacity Determination:** The performance of the inverter system is greatly affected by the battery type and the size. So make sure that the chosen one is apt for the needs to be served. It depends upon the electrical load to be met with and the extent of backup power to be provided in terms of time.
2. **Determining the Charging System:** An appropriate charging system is essential to ensure adequate power availability when in need. It also makes sure that the battery of the inverter system is maintained in its best working condition. It has to be in accordance to the specifications of the particular inverter system.
3. **Choice of an Apt Location:** To avoid any electrical or fire hazards, make sure that the inverter system is not installed in close vicinity of flammable materials

or in compartments containing batteries. Do not place it in areas where it is exposed to excess moisture as well.

4. **Mounting the Inverter:** The inverter system can be mounted horizontally on a vertical surface**.** It can also be done on or under a horizontal surface.
5. **Battery Cable Connectivity:** Due to the low-voltage high current input, low resistance wiring is essential between the battery and the inverter system. This is needed to deliver the maximum amount of usable energy to your load of electrical appliances that have been connected.

Adequate precautions are necessary during the installation process of the inverter system to avoid any hazards associated with the use.

4.4 Batteries

(Figure 4.8: Battery)

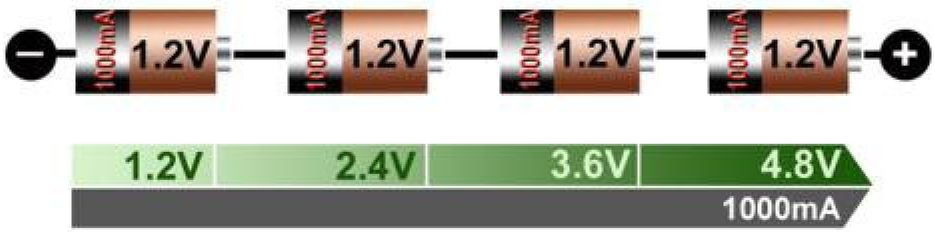
The runtime of an inverter is dependent on the battery power and the number of plugs utilizing the inverter at a given time. As the amount of equipment utilizing the inverter increases, the runtime will decrease. In order to prolong the runtime of an inverter, additional batteries can be added to the inverter.

When attempting to add more batteries to an inverter, there are two basic options for installation: (***Series Configuration*** and ***Parallel Configuration***).

4.4.1 Series Configuration

If the goal is to increase the overall voltage of the inverter, one cans daisy chain batteries in a Series Configuration.

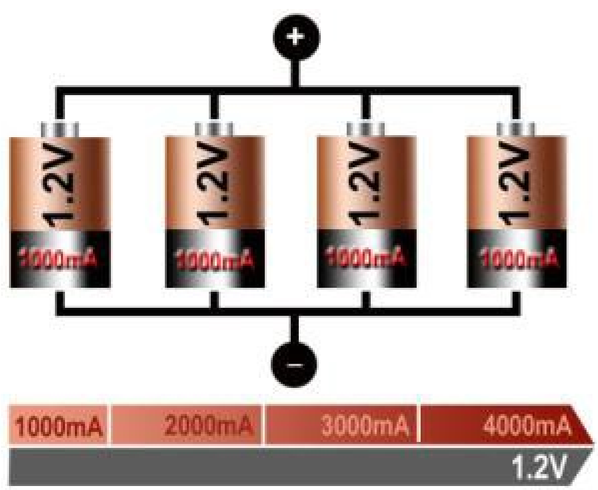
In a Series Configuration, if a single battery dies, the other batteries will not be able to power the load.



(Figure 4.9: Series Battery)

4.4.2 Parallel Configuration

On the other hand, if the goal is to increase capacity and prolong the runtime of the inverter, one can connect batteries in a Parallel Configuration. In a Parallel Configuration, if a single battery dies, the other batteries will be able to power the load.

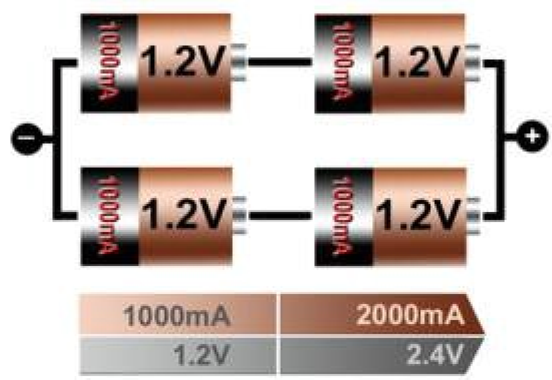


(Figure 4.10: Parallel Battery)

4.4.3 Serial/Parallel Connection

The serial/parallel Configuration “shown in Figure” allows superior design flexibility and achieves the wanted voltage and current ratings with a standard cell size.

The total power is the product of voltage times current, and the four 1.2V/1000mAh cells produce 4.8Wh.



(Figure 4.11: Serial/Parallel Battery)

Capacity and discharge:

A battery's capacity is the amount of electric charge it can deliver at the rated voltage. The more electrode material contained in the cell the greater its capacity. Capacity is measured in units such as ampere per hour (A.h).

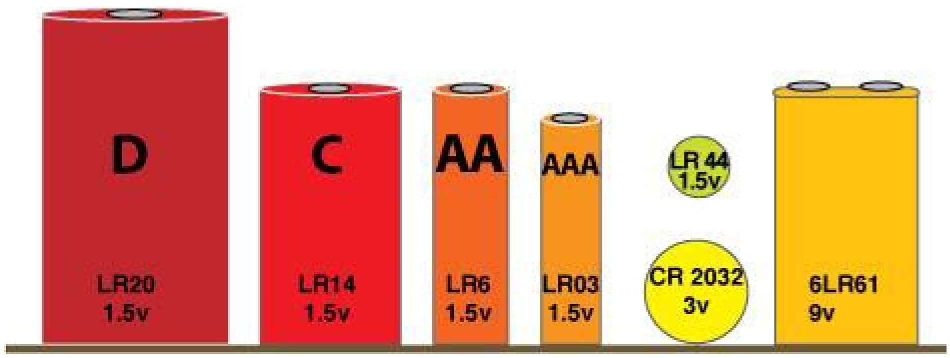
The rated capacity of a battery is usually expressed as the product of 20 hours multiplied by the current that a new battery can consistently supply for 20 hours at 68 °F (20 °C), while remaining above a specified terminal voltage per cell. For example, a battery rated at 100A·h can deliver 5A over a 20-hour period at room temperature. The higher the discharge rate, the lower the capacity.

Overcharging:

If a charger cannot detect when the battery is fully charged then overcharging is likely, damaging it.

Battery sizes:

Primary batteries readily available to consumers range from tiny button cells used for electric watches, to the No. 6 cell used for signal circuits or other long duration applications.



(Figure Random Battery Sizes)

Conclusions

The electric grid is a complex network that is an integral part of our society. Running the grid in the presence of increasing fuel costs and growing environmental concerns will require new technologies and ways to use them. While renewable power technologies will be an essential part of our energy future, no one technology can provide all of the energy and services we need. Careful integration of distributed generation and careful deployment of utility-scale generation will be needed to provide the mix of power and reliability that we require for a healthy electric supply as renewables contribute an increasingly larger share of our energy needs.

In this project a framework for implementing of simulation based optimization method has been introduced to reduce the primary energy consumption from a generation system in a remote site in Egypt. This reduction was achieved by penetrate renewable energy system that influence the energy consumption from generation system. Within this framework, simulation based optimization, method and developed to find the best configuration by using EnergyPlus. These optimization approaches have high potentials to guarantee the best net present cost configurations.

This framework could be implemented to solve operational problems now in Egypt represented in off grid operation; moreover, it could also be adopted for reducing the fuel usage, while taking into consideration the parameters that could affect the consumption. Also Renewable power technologies like PV and wind power generation fluctuate depending on the weather conditions. Therefore, the implantation of renewable power generation requires a good knowledge on the meteorological circumstances and spatial-temporal characteristics of each renewable power generation. A model for quantifying the optimal mix between different power generations in Egypt is adopted in this project in order to find the optimal mix between renewable power generations and the non-renewable generation.

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