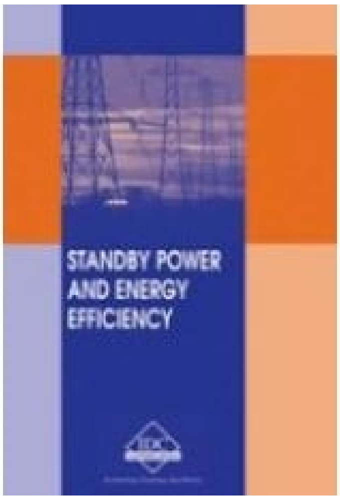
BY-E - Standby Power and Energy Efficiency



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Short Description

The initial objective of this manual is to go through the key steps in ensuring a reliable power supply to critical systems using various available options. This manual also briefly looks at the design issues involved in planning the distribution of critical power by deploying state-of-the art control devices such as static transfer equipment. Finally, strategies you can implement to optimise energy efficiencies at your facility will be examined. If you are responsible for maintaining power availability in your facility, this manual is something which you simply cannot afford to miss.

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Main Forms of Energy

1.1 Energy forms

Energy is defined as the capacity to do work. It is the potential hidden within a physical system to perform some work or action. All work involves converting one form of energy into another. There are two basic types of energy:

- Potential Energy
- Kinetic Energy

1.1.1 Potential energy

Potential energy is a stored type of energy and its natural forms are as follows:

- *Gravitational*: The physical location and mass decides the gravitational energy. Height of the water stored in a vessel or a reservoir provides a measurement of the energy stored within it. A stone perched on top of a hill has stored energy within it.
- *Mechanical Energy*: Examples of storing mechanical energy include a compressed spring or a stretched rubber band.
- *Chemical Energy*: All materials store energy in the bonds formed by their atoms and molecules. This energy gets released in chemical processes like combustion and reactions with other chemicals. Wood, coal, natural gas, and petroleum are the most commonly used sources of chemical energy.
- *Nuclear Energy*: This is the energy stored in the subatomic particles of all material and is released by fission or fusion of the atoms. Radioactive substances like uranium, plutonium, and thorium are well known sources of nuclear energy.

1.1.2 Kinetic energy

Kinetic energy involves some form of movement. It appears as any of the following:

- *Motion*: An object which is moving carries a certain amount of energy within it. When it collides or brushes with another object it transfers its energy either wholly or partially to it in the form of motion, heat or sound. Wind power and hydropower are examples of energy in motion.
- *Thermal Energy*: Thermal energy is essentially the energy in the molecular vibration within various substances. An example of a useful form of thermal energy is geothermal energy (from the Earth's underground and/or inner core).
- *Radiant Energy*: Electromagnetic waves such as light, Ultra Violet rays, and Infrared rays carry energy over huge distances.
- *Sound*: This form of energy moves through substances as compression/refraction waves.
- *Electricity*: The movement of electrons in conductors under a potential difference forms electrical energy, termed 'electricity' for short.

1.2 Energy conversion

Energy conversion is literally any process of converting energy in one form into energy of another form. In hydroelectric dams, the potential energy stored in the height of the water reservoir first gets converted into kinetic energy of falling water. The kinetic energy of water turns the water turbines and produces mechanical power which gets converted into electric energy by the electric generator. Similarly, the chemical energy stored in petroleum, natural gas, coal or nuclear energy stored in radioactive fuels are converted into thermal energy and finally into electrical energy in thermal and nuclear power plants.

Energy conversions are required to produce energies in forms in which they can be useful. The useful forms of energy are generally electricity, heating, cooling and propulsion.

Machines are required for converting energies into useful forms. Generally, several stages

of energy conversions take place before any useful work is actually performed.

Let us take an example. The chemical energy in coal is converted to heat by combustion. The heat is used to produce high pressure steam for running a turbine. The turbine runs a generator which produces electricity. Electricity is transported via transmission and distribution networks into a factory where a motor then converts the electricity into rotational mechanical energy. The motor is coupled to a compressor which converts the bulk of mechanical energy into the energy of compressed air.

The compressed air is finally used in mechanical tools. The schematic diagram in Figure 1.1 shows that six stages of energy conversion take place before any useful work can be physically extracted out of the energy stored in coal.

Figure 1.1

Energy Conversion in stages

The first law of thermodynamics states that energy can never be lost or gained. The total amount of energy in any closed system would always remain constant.

The second law of thermodynamics states that every time energy is converted from one form into another form a small amount of energy gets converted into heat and lost to the surrounding environment. This energy remains in the environment but can never be retrieved and is lost for all practical purposes.

Multiple conversion of energy reduces the overall efficiency of energy usage. Most of the energy that we use in our day to day life as well as in industry is in the form of electricity and heat.

1.3 Energy converted to electricity for direct use

The pioneering experimental work of Michael Faraday on electromagnetism and the dynamo (electrical generator), which he invented, paved the way for today's electrical power systems. The invention of the electric lamp by Thomas Edison was a major breakthrough in promoting the use of this new energy form for residential and commercial applications. The development of electric motors, which could be used as the drive for machinery, gave a further boost to its widespread use in all types of industrial applications. All these led to the establishment of centralized power generation facilities to produce electricity in an efficient way and carry it to human settlements for enhancing the standards of living and quality of life.

Electricity is produced in many different ways in today's world. The generation of electric power primarily involves conversion of some naturally available form of energy (such as chemical energy in a fuel) into electrical energy. It was in the year 1903, just over hundred years ago, that the first steam turbine generator, pioneered by Charles Curtis was put into operation at the Newport Electric Corporation in Newport, Rhode Island. Steam still remains the main energy transfer medium in many power plants where it is produced by heating water in Steam Generating Units (commonly called 'Boilers') using a variety of fuels. Coal is still one of the major raw materials used for generating the super heated steam required for power plants.

Steam generating units and turbines powered initially by coal, later by oil, natural gas, and now by nuclear fission energy, took a major leap forward in the early decades of the 20th century. Simultaneously, key improvements were made in the design of generators to obtain higher energy efficiencies. By the year 1920, high-pressure steam generators were the state of the art. Initially, the common rate of power generation by steam pressure was 1 kilowatt hour (kWh) per 15 to 20 kg of coal. Within a short time period, this was reduced to around 2 kg of coal needed for producing 1 kWh with high steam pressure turbines.

The energy sources used for producing electrical power are broadly classified as:

- Conventional energy sources
- Non conventional/Renewable energy sources

Although electricity has been discovered for just over a century, dividing power generation sources as conventional and non conventional is due to the fact that there are quite a few sources having different characteristics used for generating electrical power, Power generation using conventional fuels involves combustion of naturally occurring fuels but the latter (renewable energy sources) may or may not require a combustion stage in the conversion process. Conventional energy production processes deplete naturally available resources such as petroleum, coal, etc., in addition to being major pollution contributors.

Electric power produced by various sources is based on the internal energy content per unit weight of the source and is termed in kilocalories per kg in metric units. This is called the calorific energy of the fuel and Table 1.1 lists the calorific values for some of the major sources used today.

Table 1.1

Typical Calorific values

Fuel	Calorific Value (kCal/kg)
Paraffin	10,400
Diesel Petroleum	9,800
Charcoal	7,100
Dried Wood	4,700
Lignite	4,000
Wood (25-30% Moisture)	3,500

The term non conventional energy generally refers to power generation methods that directly use the energy from natural resources like wind, Sun, etc., without depleting these resources and with minimum or almost zero pollution. These are also termed as renewable energy sources, since these sources do not deplete at the rates of conventional sources. Hydro-electric (hydel) generation is an example of renewable energy and forms one of the most important components of power generation in many countries around the world. Other more exotic methods such as power generation from tidal and wave energy as well as from ocean thermal energy (deploying the temperature gradient of the sea water at different depths) are also under experimentation.

1.4 Use of fuels for motive powers

The choice of fuel is an important consideration where energy is to be produced directly from the fuel. The major criteria for choosing a particular fuel for a certain process are:

- Calorific value: calorific value is a measure of the heat produced by the fuel and is indicated in terms of Kcal/kg or Gross calorific value (GCV) or Net calorific value (NCV). Gross calorific value is the total heat produced by the fuel. Some of this heat gets used up in evaporating the water present in the fuel itself. The net colorific value is the difference between the gross calorific value and the latent heat required to vaporize the water content in the fuel. Comparison of fuels should be done on the basis of their net colorific values.
- Quality of combustion: Combustion takes place in the presence of atmospheric oxygen when the fuel temperature is raised to a certain level. Presence of certain elements such as Carbon, Sulfur, Hydrogen, Oxygen, Nitrogen and moisture content, either facilitate or retard the combustion process. Fuel selection would require an analysis based on the ignition

temperature, amount of oxygen required for complete combustion and the presence or absence of combustion facilitating/ retarding elements in the fuel.

- Handling and storage: Fuel has to be stored in silos, tanks or cylinders, depending on whether it is in the form of solid, liquid or gas. Fuels have to be transferred from the point of storage to the point of consumption. The period of storage would depend on the rate of consumption, frequency of consumption, availability, reliability of supply, costs of storage and inventory. During storage, fuels evaporate, absorb moisture, deteriorate chemically and physically and/or get contaminated. During transportation, there may be loss of fuel due to leakages, falling off conveyer belts etc. Highly viscous fluids like fuel oils are difficult to pump and may require a certain amount of heating before pumping and ignition. Fuel selection would need to take into account all these storage and handling issues.
- Effluents: Effluents are the residue of fuel after combustion and are mainly in the form of gases and to a lesser extent in the form of solid like ash or liquid like tar. Gaseous effluents are the main contributors to the green house gases in the atmosphere. The proper treatment and disposal of effluents for protecting the environment is almost a mandatory requisite today. The choice of fuel would decide as to what kind of waste disposal and treatment systems are needed to meet the regulations
- Availability: Fuel should also be easily available at the location of the plant or facility with assured supplies at all times and seasons at reasonably stable prices. The plant or facility design could also have the flexibility to accept two or more alternative fuels to meet occasional supply disruption of any one fuel

1.5 The global energy concerns

The production and consumption of energy at such huge scales has raised a number of environmental issues. In 1896, Swedish scientist Svante Arrhenius predicted that human activities would interfere with the way Sun interacts with the earth, resulting in global warming and climate change. Arrhenius's prediction has come true. Climate change and global warming are a reality now.

Major environmental issues of global concern are:

- Ozone Layer Depletion

- Global Warming
- Loss of Biodiversity

1.5.1 Ozone Layer Depletion

Ozone gas (O_3) forms a layer in the Earth's stratosphere which extends up to 10–50 km from the Earth's surface. This ozone layer absorbs the ultra violet – B (UV-B) rays from the Sun, and protects the human, animal and plant life from harmful effects of UV+B rays. The content of ozone in the stratosphere remains constant by a natural process. However, man-made chlorine and bromine can react with ozone and deplete its content in the atmosphere. It has been found that over the years that a release of the chemicals (FCs, HCFCs, carbon tetrachloride, and methyl bromide) generally used as refrigerants in refrigerators and air conditioners, release chlorine and bromine gases. Under the influence of UV rays each of the Cl and Br atoms react with ozone a multiple number of times (estimated up to 100,000) and destroy it.

The ozone layer thickness is measured by using a Dobson ozone spectrophotometer (measured in Dobson units) by sensing the amount of UV rays reaching the Earth's surface. These refrigerant gases have been depleting the ozone layer for the last 30 to 40 years, and have upset the natural equilibrium that existed for thousand of years.

The effects of ozone layer depletion can be seen in various ways:

- Human and Animal: increases in the UV radiation reaching the Earth's surface causes eye diseases, skin cancer and infectious diseases
- Terrestrial plants: increased radiation is destroying certain species and causing a loss of biodiversity
- Aquatic Eco-system: UV radiation can affect the distribution of phytoplankton, which form the foundation of aquatic food webs and can also impair all kinds of marine life
- Effects on biogeochemical cycles: increased solar UV radiation affects terrestrial and aquatic biogeochemical cycles and alters both sources and sinks of greenhouse and important trace gases, e.g. carbon dioxide (CO_2), carbon mono-oxide (CO), carbonyle sulphide (COS), etc. These changes contribute to a biosphere feedback responsible for the atmospheric buildup of greenhouse gases

The role of the ozone layer in filtering out the dangerous UV+B radiation from the Sun's radiation is extremely critical for human, animal, and plant life. The depletion of the ozone layer can result in harmful radiation reaching the Earth's surface with dangerous consequences.

Ozone Depletion countermeasures that have been put in place are:

- International cooperation (Montreal protocol) to phase out ozone depleting chemicals in 1974
- Taxes imposed on ozone depleting substances
- Ozone friendly substances - HCFC (less ozone depleting potential and shorter half-life)
- Recycling of CFCs and Halons

1.5.2 Global Warming

Since the industrial revolution, human activities like fossil fuel burning, deforestation and altered agricultural practices have been affecting the composition of gases in the atmosphere causing significant climatic and environmental changes.

Studies have revealed the Earth's climate to be increasingly warmer in the last 100 years compared to the previous 8000 years, when the temperatures were relatively constant. The present average global temperatures are 0.3–0.6°C warmer than a century ago.

The main greenhouse gas (GHG) causing the global warming is carbon-dioxide (CO_2). CFCs, even though they exist in very small quantities, are also significant contributors to global warming.

Sources of Greenhouse gases

Gases in some sources like water vapor, carbon dioxide, methane, nitrous oxide and ozone occur naturally. Human activities (anthropogenic activities) are adding to the levels of most of these naturally occurring gases.

Combustion of fossil fuels, decomposition of solid organic wastes, industrial and agricultural activities are the main contributors to the rise in the level of greenhouse gases. Powerful greenhouse gases that do not occur naturally include Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulfur hexafluoride (SF_6) are generated in a variety of industrial processes.

Estimates of greenhouse gases are presented in units of millions of metric tons of carbon equivalent (MMTCE) which weigh each gas by its Global Warming Potential. Global Warming Potential (GWP) is an important measure of the strength of different greenhouse gases in the atmosphere.

Each greenhouse gas differs in its ability to absorb heat in the atmosphere. HFCs and PFCs are the most heat absorbent. Methane traps over 21 times more heat per molecule than carbon dioxide and nitrous oxide absorbs 270 times more heat per molecule than carbon dioxide. Conventionally the GWP of carbon dioxide is 1. The GWPs of all other GHGs are measured relative to the GWP of carbon dioxide.

Carbon dioxide, however, is still the most important greenhouse gas contributing to about 60% of the enhancement to the greenhouse effect, since the concentration of other greenhouse gases is much lower.

Effects of Global warming

Some of the effects of global warming are:

- Rise in global temperature: There is strong evidence that most of the rises in global temperature in the last 50 years are caused by human activities. Climate models predict that the global temperatures will rise by about 6°C by the year 2100.
- Rise in sea level: The mean sea levels are expected to rise 9-88cm by the year 2100, causing flooding of low lying areas and other damages.
- Food shortages: Water resources are likely to be affected as precipitation and evaporation patterns change around the world. This may also affect agricultural output.

1.5.3 Loss of Biodiversity

Biodiversity refers to the variety of life on Earth and its biologically diverse range. The number of species of plants, animals, micro-organisms, the enormous diversity of genes in these species, the different eco-systems on the planet such as deserts, rain forests and coral reefs are all a part of a biologically diverse Earth. Biodiversity actually boosts ecosystem productivity and enables the ecosystem to sustain itself against a variety of natural disasters.

There is a World Resource Institute report, which shows a strong link between biodiversity and climate change. Global warming is known to affect the ecosystem’s adaptability to nature. Deforestation is significantly contributing to the build up of carbon dioxide in the atmosphere.