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EVALUATION OF ELECTRICAL ENERGY GENERATION

by

CHARANJIT SINGH

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TO MY BABLI

ABSTRACT

This report presents a concise evaluation of different electrical power generation methods. Among the various sources discussed are conventional and some of the more exotic kinds. Five different criteria were chosen, covering a wide range of effects on engineering, economics, and environment. Tabulated comparisons are also presented. Conclusions have been drawn upon the end of this study.

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CHAPTER 1

INTRODUCTION

1.1 General

Mankind's continuing progress and his desire to improve the standard of living depends on a continuously growing demand and availability and economic use of energy. With the high and always increasing cost of non-renewable resources the importance of electrical energy will grow.

Ever-increasing amounts of electrical energy are used in industry, in farming, in mining, in transportation, in supplying warmth or coolness, in powering a multitude of household appliances, in hospital and medical research, in food production and maintenance.

Furthermore, the demand for electrical power per capita has been growing rapidly and this growth is causing concern because the generation of electricity has adverse effects on air, water, and land, which are vital for the survival of mankind.

Because of the importance of clean air, clean water, and food for the survival of human beings, the generation of electrical power plays an important role and for that purpose various methods have been developed.

It is desirable that the generation of electrical power should be controllable, maintain a constant frequency, and have as little as possible fluctuation of voltage.

1.2 Historical Background of Development of Electrical System

In 1882 Thomas Edison started operation of a 220 volt direct-current generating plant on Pearl Street in New York. This plant could only supply a limited area and small load because of small conductor size, high generation and distriubtion cost, and excessive voltage drops at this level. Thus, demand had to be met by providing independent local small plants.

The invention of the transformer spurred the development of alternating current system as the voltage levels could then be optimized independently for generation, transmission and distribution. The first North American alternating current system was placed in service in 1886 at Great Barrington, Mass. This system transmitted power at 500 volts and stepped down to 100 volts for consumers. In the same year a 2000 volts transmission line was built.

During the following years there was continual skirmishing between advocates of alternating current and direct current. Edison showed the dangers of alternating current by electrocuting dogs and Nicolai Tesla countered with stage shows in which he subjected himself to high voltages so that he sparked and glowed quite convincingly to show how safe alternating current was. His invention of the polyphase system and induction motor finally tipped the scales solidly in favor of alternating current.

Early alternating current systems were not standardized and frequencies from 16 to 133 Hz were used. Finally 60 Hz (50 Hz in Europe and Asia) became a standard. As load grew, transmission voltages and distances increased. In 1965 Quebec Hydro energized a 735 Kv system and in 1969 American Electric Power introduced a 765 Kv system. Both of these utilities, in conjunction with manufacturers, are examining the problems of 1200 - 1500 Kv transmission. Direct current, long dormant, has been revived by use of the high-voltages mercury arc rectifiers and, more recently, silicon-controlled rectifiers (now commonly known as thyristors), for high-voltage long-distance transmission. The generating plants have also grown where 300 to 600 MW units are quite common, and thermal units in excess of 1000 MW are in service. The major energy sources were and still are fossil-fuels and hydroelectric. Hydroelectric, as one of the energy sources, is not expanding in developed countries, because in most cases the source is already tapped and some which is untapped is remote and uneconomical for the time being. The use of nuclear energy is increasing, however, there is a strong anti-nuclear movement pioneered and led by environmentalists in most of the countries and recently strongly reinforced by fact of Three Mile Island's reactor failure in the United States. Alternative sources of power are under active consideration. These include solar, wind, geothermal, tidal, biomass, and ocean power. These sources will not likely have much impact until 2000 A.D. and beyond because of the development time requirements.

Because of the importance of electric power generation the object of this report is to describe various generation methods and highlight the pros and cons.

This study provides a comparison of different generation methods using common criteria which are set in Chapter 2. This comparison is done for all the conventional and exotic types of generation.

Evaluation and comparison is done in a descriptive manner based on the available information. For clarity the various tables are presented for ease of comparison.

These results are expected to be useful for providing better understanding of electrical energy generation methods. Further they provide the reader all the pros and cons and draw his attention to the possible undesirable effects which could be considered in system design and applications.

CHAPTER 2

EVAULATION OF GENERATION METHODS

This Chapter includes the different generation methods. These methods are compared and evaluated on a common criteria.

2.1 Generation Methods

a) Fossil-Fuel-Fired:

1) Coal-fired;

2) Crude Oil-Fired;

3) Natural Gas-fired;

b) Hydroelectric Power:

c) Nuclear Power:

1) Fission;

2) Fusion;

d) Solar Power:

e) Wind Power:

f) Geothermal Power:

g) Biomass Power:

h) Tidal Power:

i) Ocean Thermal Gradients:

2.2 Common Criteria

a) Availability of energy resources;

b) Status of know-how in generation technology;

c) Efficiency of energy resources utilization by various generation methods;

d) Environmental impact of various generation methods;

e) Economic consideration of various generation methods.

2.3 Fossil-Fuel-Fired Generation

The backbone of the electric utility industry, almost worldwide, is fossil-fuel-fired generation plants powered by coal, or crude oil, or natural gas. A fossil fuel plant converts the chemical energy stored in coal, crude oil or natural gas into electrical energy.

2.3.1 Coal-Fired Generation

2.3.1.1 Availability of energy resources

Coal is the most abundant fossil-fuel in Canada and in the world. Nearly 90 percent of the world resources of coal exist in three countries: The USSR, The United States, and The People's Republic of China. More than half of the remaining resources (i.e., above 5%) are in Europe.

2.3.1.2 Status of coal-fired power generation technology

The combustion of coal to generate electricity using present technology, is expensive in terms of both fuel and environmental costs. Burning of coal produces particulate, sulphur dioxide and nitrogen oxides. These pollutants have much impact on environment. To control their quantity, suitable means are to be used which lead to higher costs of generation. By the year 2000 A.D., the development of new technologies such as Fluidized Bed Combustion (FBC) and Magnetohydrodynamics (MHD) could produce power from coal more efficiently and with less environmental impacts.

Electricity production in thermal generating stations involves a four-stage conversion process. Chemical energy from combustion is transformed to thermal energy, which is used to raise pressurized steam, which in turn drives a turbine (mechanical energy) that turns a generator to produce electric energy.

In conventional fuel-firing boilers coal is injected by an air blast and burned, and the ashes then fall to the bottom. In Fluidized Bed Combustion (FBC), the fuel is combusted in an agitated bed of inert particles that are kept suspended and in turbulent motion by a rising flow of air. The main advantage of FBC over conventional technology is its reduced emissions. Limestone or dolomite is added to the bed to absorb 85 to 95 percent of the sulphur in the fuel during combustion. The resulting calcium sulphate can then be removed from the bed for recycling or disposal. For the absorbing material to act, combustion temperatures must be lower than in conventional plants, which tends to reduce nitrogen oxide emissions. Higher heat-release and transfer rates mean the size and material requirements are reduced and plant efficiency is improved despite the lower combustion temperatures.

2.3.1.3 Efficiency of energy utilization

The efficiency of any power plant is the amount of electrical energy output per unit of fuel energy input. Conventional coal-fired generation has typical efficiency of approx. 30 percent. It is expected that FBC will have a 5 percent better efficiency than that of conventional plant.

2.3.1.4 Environmental impact of generation method

Burning of coal is one of the worst sources of air pollution, producing particulate matter, sulphur dioxide, and nitrogen oxides. Each of the three pollutants harms human health, creates haze, and damages materials. Sulphur dioxide also affects plant life, while nitrogen oxide plays an important role in the formation of photochemical smog. The amount of emissions from a large 1,000 MW coal-fired plant, running at full capacity for an hour with no controls would be emitting 67,000 pounds of particulates, 32,000 pounds of sulphur dioxide and 8,430 pounds of nitrogen oxide (these figures apply to the so-called low grade brown coal with 10 percent ash content, 2 percent sulphur content and fuel thermal efficiency of 34 percent having general heating value of 10,000 Btu/Kwh).[(6)]

Coal particulates include not only fly ash but also carbon, which results from incomplete combustion of the fuel. In addition, the burning of coal generates small but potentially dangerous quantities of hydrogen floride and hydrogen chloride gases as well as minor amounts of radio-active uranium and thorium.

While illness or death cannot be traced directly to air pollution without laboratory tests, dramatic evidence linking particulates to adverse health effect have been found. Abnormally high levels of particulate coincided with marked increase in fatalities and severe respiratory illnesses, often complicated by heart failure. Beside its impact on human health, particulate pollution contributes in a major way to the aesthetic deterioration of the environment. Soot and ash in the air create haze by scattering and absorbing light, obscuring the brightness of distant objects, and dulling backgrounds. Particulates pollution may also exert far-reaching climatic effects. Larger particulates tend to serve as condensation nuclei and may influence the formation of clouds, rain, and snow.

Coal's sulphur content is the highest ranging from 0.5 to 5 percent. During fuel-burning almost all sulphur is converted to sulphur dioxide gas. Beside acting with particulates to harm human health, sulphur dioxide gas and related compounds cause severe injury to a wide variety of crops, plants and trees, and also many commonly used structural materials. Vegetation damage caused by sulphur dioxide ranges from discoloration and defoliation of individual leaves to the out-right death of entire plants and trees.

Sulphur dioxide in the air is often oxidized to sulphur trioxide which combines with water vapor to form sulphuric acid. The acid may either be converted to sulphate particulates which reduce visibility or it may reach the ground as corrosive sulphuric acid mist or rain, which attacks not only plants and trees but a wide range of structural materials and all valuable property as well. It deteriorates textiles, paper and leather, dissolves paints and dyes, and damages electrical equipment and building materials, such as limestone and marble. It also corrodes most metals.

Nitrogen oxides (NO_x) are gases produced in high concentrations from burning of fossil-fuel at high temperature. They are fundamental in the formation of photochemical smog and, in conjunction with other smog components, have been shown to be harmful to health, vegetation and materials. Unlike sulphur dioxide and particulates which arise from impurities in the fuel, nitrogen oxide is a by-product of the reaction between nitrogen and oxygen in the air used for combustion. At least 90 percent of the NO_x is in the form of nitric oxide (NO) when it leaves the stack. Once in the atmosphere, however, virtually all NO is converted to the more toxic nitrogen dioxide NO_2. From health standpoint, NO_2 exerts its primary toxic effect upon the lungs, resulting in increased acute respiratory disease at all ages. When sunlight strikes air containing NO_2 and hydrocarbons, a chemical reaction takes place, resulting in the formation of photochemical smog. This smog reaction forms other serious air pollutants, oxidants such as ozone which can aggravate asthma, reduce lung function, seriously affect crops and trees, and produce peroxylacetyl nitrate, a powerful eye irritant.(6)

Only 30 to 40 percent of the heat generated by power plants is converted to electricity. Most of the remainder is absorbed by water constantly drawn through the plant's condenser and discharged. This water is considerably hotter than its natural or ambient temperature, and is potentially changed in its ability to support aquatic life. If returned directly to its source, it may have a seriously polluting effect, in some instances significantly raising the temperature of an entire river within the plant vicinity. Changes in the temperature of natural waterways rarely cause spectacular fish kills. However, they may upset reproductive cycles, reduce the available level of oxygen, heighten the toxic effects of pollutants, increase the susceptibility of fish to disease and parasites, and disrupt species balance. Fish may be killed by an abrupt temperature change. A utility financed study of a Pennsylvania stream found that the number of invertebrate species decreased by 54 percent as water temperature rose from 80°F to 87°F and fell another 24 percent as temperature rose to 93°F.(6)

The mining of coal either by strip-mining or by underground mining has great impact on the environment also. The environment hazards of strip-mining are more obvious than those of underground mining. When the overburden of topsoil is removed, rainfall can wash on to the coal and lead to large quantities of acid entering the water supply. Therefore, topsoil must be quickly replaced because soil erosion is very serious.

2.3.1.5 Economic consideration of generation method

Coal is a depletable source. Coal fired generation plants have a very high degree of location flexibility as compared to hydroelectric and nuclear plants. Land requirement for coal-fired plants are higher than that of nuclear plants. Plant lead time is lower than hydroelectric and nuclear plants. Coal-fired units can be built up to 1300 MW and forced outage rates are higher than hydroelectric units. They have an expected lifespan of 30 to 33 years. Larger units are good for base load and the installed plant cost in $/KW is lower than hydroelectric and nuclear plants. Fuel cost is higher than nuclear and has a heating value of 10,000 to 13,000 Btu per pound. It has considerable environmental impact. Cost of energy is competitive as compared to hydroelectric and nuclear.

2.3.2 Crude-Oil-Fired Generation

2.3.2.1 Availability of energy resources

Crude oil resources occur in almost every part of the world to some degree. However, the major commercially valuable resources occur in relatively few locations where geological conditions were appropriate for the formation and storage of the fuel underground.

2.3.2.2 Status of oil-fired power generation technology

The power generation steps in using oil resource are similar to those discussed for the case of coal-fired generation plants. Oil can be used in gas turbine and MHD power plants.

The gas-turbine is essentially the same engine as one used in jet aircraft. Incoming air is compressed and injected into a combustion chamber with the gaseous or vaporized liquid fuel. The high temperature and high-pressure combustion gas expands and drives both the generator and the compressor. A re-generator may be used to transfer heat from the exhaust gases to incoming air.

An important characteristic of the gas turbine is the requirement for a clean (no particulates or corrosive components) gas flow through the turbine. This necessitates either a clean burning fuel or a source of high-temperature thermal energy.

MHD technology is based on the principle that when a gas is heated to a very high temperature, in order of 5,000°C or more, electrons in the gas will be liberated; in the presence of an electric field, negative ions, or electrons, will flow one way while the positive ions that are formed when an electron leaves a neutral atom will flow the other way. If alkali metals, such as potassium or caesium, are seeded in the gas as a catalyst, the desired reaction can take place at much more manageable temperature, in the range of 1,000 to 1,500°C.

Due to corrosive effects that occur at these high temperatures, clean fuels such as hydrogen, natural gas and oil operate best, but the long-term attractiveness of MHD will probably depend on its ability to use coal as a fuel.

2.3.2.3 Efficiency of energy utilization

Conventional oil-fired generation plant has an efficiency in the range of 30 to 35 percent. Gas turbine operates at efficiencies of 25 to 30 percent. MHD generators will operate at efficiency of 50 to 60 percent.

2.3.2.4 Environmental impact of generation method

Burning of oil produces essentially the same kind of flyash having two distinct differences. It has much lower ash content, usually under 0.1 percent and, therefore, is a less polluting fuel source. On the other hand, particulates from oil are much smaller as compared to those from coal, usually less than one micron in diameter, and this size factor tends to magnify their harmful effects on human health and atmospheric visibility. Emissions from a large 1000 MW, oil-fired plant, running at full capacity for an hour with no controls, would be emitting 670 pounds of particulates, 21,000 pounds of sulphur dioxide and 6,930 pounds of nitrogen oxide (these figures apply to the oil with 2 percent sulphur content, thermal efficiency of 34 percent having heating value of 10,000 Btu/Kwh).[6] Sulphur content of oil varies from 0.1 to 3 percent. Therefore, the burning of oil has less environmental impact as compared to coal. Thermal efficiency of conventional fossil-fuel-fired plant is the same i.e., for coal and oil.

2.3.2.5 Economic consideration of generation method

Oil is one of the exhaustable resource. Oil-fired generating plant has a high degree of location flexibility as compared to coal, hydroelectric and nuclear plants. Land requirement is also lower than for coal-fired plants. Units forced outage rates are lower than for coal-fired units and has expected lifespan of 30 to 33 years. The plant lead time is lower than for coal-fired plant. Large units are good for base load as well as for intermittent or peak loads. Installed plant cost is lower as compared to coal-fired but fuel cost is very high having a heating value of 130,000 to 150,000 Btu per gallon. It has lower environmental impact as compared to coal-fired. Cost of energy generated is higher.

2.3.3 Natural Gas-Fired Generation

2.3.3.1 Availability of energy resources

Natural gas is usually found along with oil in almost all oil fields but, at the same time, there are many gas fields where little or no oil is found.

2.3.3.2 Status of gas-fired power generation technology

The power generation steps using natural gas are similar to those in oil and coal-fired generation plants. Natural gas can be used in gas-turbine and MHD power plants.

2.3.3.3 Efficiency of energy utilization

It has almost the same efficiency as described for oil-fired generation.

2.3.3.4 Environmental impact of generation method

Natural gas is the cleanest and most versatile fossil-fuel. On the other hand the production of natural gas may have dangerous impacts on environment; for example, pipeline explosions can present a serious risk to public safety in populated areas. The growing transportation of Liquified Natural Gas (LNG) also can pose potential risks to the public health and safety from accidental release and possible fire or explosion.

2.3.3.5 Economic consideration of generation method

Natural gas is also a depleting source. Like oil-fired, natural gas-fired generating plants have a very high degree of location flexibility. Land requirement is much lower than the coal-fired generating plants. These plants require very low lead time. Unit forced outage rate is lower than coal-fired unit and has expected lifespan of 30 to 33 years. Units are particularly very good for intermittant and peak loads. Installed plant cost is lower than for the coal-fired but fuel cost is higher. Average heating value is 1000 to 1500 Btu per cubic foot. It has low impact on environment.

2.4 Hydroelectric Power

Historically the utilization of the energy from the flowing waters of rivers and streams by means of water-wheels provided the first plentiful and continuous source of energy.

Hydroelectric generation, in most developed countries, is decreasing in availability because feasible sources have already been developed. The ones which are untapped are remote and expensive. However, due to rising cost of fossil-fuels, these potential sites are becoming attractive.

2.4.1 Availability of Energy Resources

Falling water is considered a hydroelectric energy resource when adequate quantity or flow rate occurs together with a suitable elevation difference between the surface of the water storage and the outlet of the turbine discharge. Hydroelectric power is usually affected by weather, seasonal or annual changes in precipitation and can have a major impact on available power.

2.4.2 Status of Hydroelectric Power Generation Technology

Water pressure for generating hydroelectric power may exist as a naturally flowing stream, but a head is most often obtained by building a dam from which the water is then released and this high-pressure water drives a turbine which, in turn, drives one or more generators to produce electricity.

2.4.3 Efficiency of Energy Utilization

The conversion of hydroelectric energy to electric energy involves some losses. Upto 90 percent efficiency can be achieved depending upon the rate of flow of water and the available head. The power produced at any site is proportional to the rate of flow of water times the vertical distance through which it falls. The equipment in a hydroelectric plant is more reliable than in other generation plants like coal, oil and natural gas. It has been found that most installations have actual efficiencies of about 80 percent or more.

2.4.4 Environmental Impact of Generation Method

The energy of falling water is virtually pollution-free and no heat is released, whereas, fossil and nuclear fuel produce polluting by-products along with heat. In the development of hydroelectric schemes, the reservoirs created by damming rivers can act as effective flood barriers and provide continuous water supplies for surrounding irrigation schemes. These reservoirs have become in some cases, tourist and sporting attractions and the habitant for different species of wildlife. Dams also change the water conditions downstream. If little water is released from the reservoir (during off-peak demand periods), downstream water temperatures may increase, making these areas unsuitable for many fish and other biota that are successful in cold waters. An unexpected disadvantage lies in the possible increased spread of disease as a result of the formation of large areas of mosquito, and similar insects, breeding grounds. As an example both the Aswan Dam (Egypt) and Kariba Dam (ZIMBABWE/ZAMBIA) caused such a problem in their neighbouring areas.

2.4.5 Economic Consideration of Generation Method

Most hydroelectric facilities require large expenditure of capital over a multiyear period. In the past, the low costs of fuels and fossil-fuel generating plants have made hydroelectric generation less attractive, but this may not continue in view of the recent increases and further increases expected in fossil-fuel costs.

Hydroelectric units have poor efficiency at low loading and they are generally run at high loadings and shut down completely when not required. This can easily be done with hydroelectric units since they can be started and stopped and loaded and unloaded quickly. Plants may be operated at any mode of generation. Usually small hydroelectric units are suitable for peaking-load requirements.

Hydroelectric stations are often far from load centers and therefore there is a need for long transmission lines. This can increase the overall costs of energy. Average installed costs for hydroelectric stations at present are in the order of between $1,000 to $2,000 per Kw.

2.5 Nuclear Power

Nuclear power has as yet had little impact because of strong anti-nuclear movements pioneered and led by environmentalists in most countries and recently strongly reinforced due to the Three Mile Island's reactor failure in the United States. It is hoped that further research on nuclear waste disposal management and environmental safety can alleviate the current causes of hostility towards nuclear power development. However, due to continual increases in costs of fossil-fuels and depletion of potential hydroelectric sites, nuclear power will have more importance in the generation of electric power.

2.5.1 Nuclear Fission

In a nuclear power plant, the heat energy is derived from the fission of uranium. Several isotopes (u-235, u-233) fission readily when struck by a neutron, breaking into two lighter elements that fly apart at high speed. At the same time, two or more new neutrons are released. The kinetic energy of the lighter elements, the fission fragments, is converted into heat as these fragments collide with surrounding atoms and this heat, in turn can be used to generate steam.

2.5.1.1 Availability of energy resources

Uranium is one of the elements that occurs in nature as a compound. Concentrations of uranium in the ore are low, ranging from 2 to 20 pounds of U_3O_8 per ton with an average of 5 pounds per ton. Natural uranium contains three isotopes, of identical chemical properties, but of different atomic weights, caused by slight differences in the composition of their atomic nuclei. In all natural uranium 99.28 percent of the atoms consist of U-238, 0.71 percent of U-235, and less than 0.01 percent of U-234. The radioactive decay of an atom of U-235 causes the emission of neutrons from its nucleus, these may then collide with another nucleus, of either U-235 or U-238, causing the emission of further neutrons. In the case of neutron collision with a U-235 nucleus, the whole nucleus breaks down into the nuclei of atoms of elements of lower atomic weight, with the emission of more neutrons and considerable amounts of heat.[26]

2.5.1.2 Status of nuclear fission power generation technology

A nuclear power plant is similar, in operating principle to power plants employing fossil-fuels as fuel. Each type generates steam to drive a turbine. The stream pressure is converted into mechanical energy in the turbine, and the generator converts the mechanical energy into electricity.

The CANDU nuclear power reactor system has been under development since 50's by the Atomic Energy of Canada Limited and Canadian Industry. The CANDU reactor uses natural uranium as fuel, that means that it consumes fuel faster than light water reactor system. The CANDU reactor is moderated and cooled by heavy water. Developments are underway on reactors using heavy water as moderator but light water as coolant. The Light-Water Reactor (LWR), which is the most widely used type of reactor in the world, was first developed in the United States. This reactor is fuelled by uranium oxide enriched to a U-235 concentration of about 3 percent. It is moderated by light-water and cooled by either pressurized or boiling light-water.

There is a number of different types of reactors used in the nuclear generation in different countries, such as, the Magnox Reactor, the Advanced Gas-Cooled Reactor (AGR), the High Temperature Gas-Cooled Reactor (HTGR), the Steam-Generating Heavy Water Reactor (SGHWR), Advanced Fuel Cycle Reactor (AFCR), and Liquid Metal Fast-Breeder Reactor (LMFBR).

2.5.1.3 Efficiency of energy utilization

Typical overall efficiency of nuclear plant is about 30 percent. It is expected that it may go upto 40 percent in the near future.

2.5.2 Nuclear Fusion

The most optimistic proponent of nuclear fusion as a source of commercial energy do not expect it to be available until after the year 2000 A.D.

2.5.2.1 Availability of energy resources

If technological and materials problems can be overcome, nuclear fusion could virtually be a renewable source of energy, because it would use the hydrogen that is available in water as a fuel.

2.5.2.2 Status of nuclear fusion power generation technology

In a fusion reaction two light nuclei are fused together to create a more stable, larger nucleus, thereby releasing binding energy in the form of heat. Fundamentally, containment, or control, of the fusion reaction requires the development of materials capable of withstanding temperatures of about 100,000,000°C. At present, two methods of containment have been proposed, for which research and development work is being undertaken. One method uses magnetic field to confine the plasma, and the other uses high-energy lasers to compress a pellet of two hydrogen isotopes, deuterium and tritium.[1]

2.5.2.3 Efficiency of energy utilization

It is expected that the fusion power plants may have 50 to 70 percent efficiency.

2.5.4 Environmental Impact of Generation Method

Tremendous controversy has developed over the potential environmental impact of nuclear power plants. On the positive side they do not burn coal, oil or natural gas, so they produce none of the harmful air pollutants such as particulates, sulphur dioxide, and nitrogen oxide, for which fossil-fuel plants are well known. However, nuclear plants use roughly one half more cooling water than fossil-fuel plants of equivalent capacity, and are apt to produce more detrimental thermal effects unless cooling equipment is installed. But the main controversy surrounding nuclear power involves the safety of the plants due to radioactivity escapes to the environment in normal plant operations, in the transporting of fuel and radioactive waste disposal on possible risk to human, animal and plant life.

2.5.5 Economic Consideration of Generation Method

Uranium like fossil-fuels is also a depleting source. But nuclear fusion could virtually be a renewable source. Nuclear power plant has poorer location flexibility. Land requirement for the plant is much less as compared to fossil-fuel generating plant. It has higher lead time than fossil-fuel plant. Units can also be made upto 1200 MW and have forced outage rates somewhat lower than conventional thermal plants. It has expected lifespan of 30-35 years. Units are primarily used for base load and the installed cost in $/Kw is quite high. Fuel cost, on the other hand, is much lower than the fossil-fuels and has plant average heat rate of above 10,000 to 11,000 Btu per Kwh. Cost of energy generated is thus lower than the fossil-fuel plants.

2.6 Solar Power

Efforts to concentrate the energy from the sun to produce heat or power date from the time of Archimedes, who, about 200 B.C., is said to have used reflecting mirrors to set fire to an attacking fleet of ships. In 1878, Mouchot displayed a working solar-powered water pump at the Paris Exposition. In 1913, an American, Frank Schuman, constructed a 13,000 ft^3 cylindrical trough reflector in Egypt. Schuman's collector produced steam which operated a 55-horse power reciprocating engine. Two solar furnaces capable of producing very high temperatures for materials research have been built in France. In 1968, a 100-thermal kilowatt central receiver was constructed at Genoa, Italy, by G. Francis.(1)

2.6.1 Availability of Energy Resources

The sun radiates energy in a relatively narrow band of wavelengths between 0.22 and 3.3 microns. At the outer limits of the earth's atmosphere, the solar radiation falling on a surface perpendicular to the sun's rays has an intensity of 442.2 Btu per hour per square foot. This quantity, known as the solar constant, is reduced by an average of 54 percent in the earth's atmosphere, where 35 percent is reflected back into space and 19 percent is absorbed and then reradiated to space. The total amount of solar radiation intercepted by the earth is 5.9×10^{17} Btu per hour. But at the surface of the earth, this is reduced to 2.4×10^{21} Btu per year.(11) It is expected that solar energy will have great impact on the countries along the equator.

At any given point on the earth, the amount of intensity of solar radiation varies with season, latitude and atmospheric transparency. Because of the variability of solar radiation, either energy storage or backup power is needed to provide power at night or when the sun is obscured.

2.6.2 Status of Solar Power Conversion Technology

While solar energy can be used for a number of low-temperature heat applications, such as residential heating, it can also be used directly to produce electricity.

Photovoltaics are, essentially, semiconductors whose electrons can be removed by small increases in temperature, thereby producing electricity when sunlight shines on them. The ability to induce current flow in photovoltaic cells depends on the electron behavior and lattice structure of the material. Various types of solar electric cells, or photovoltaics, have been demonstrated. However, availability of the technology on a commercial scale is limited by high manufacturing costs. Solar-thermal power generation is achieved by means of mirrors or lenses that track the sun, directing a concentrated solar flux onto a receiver. In this way temperature in the order of 500°C can be achieved - sufficient to produce high-pressure steam for use with a steam turbine to produce electricity.(1)

2.6.3 Efficiency of Energy Utilization

In discussing efficiency for solar power it is important to recognize that the input energy is free and essentially inexhaustible. Thus, the conversion efficiency has less effect on direct operating costs than it does for conventional fossil-fuel plants. Conversion efficiency does, however, influence the size of the facility required to produce a given amount of energy. As a consequence, it has a great deal to do with capital investment and overhead costs.

When solar energy is used for direct heating, the conversion efficiencies can be relatively high, with a maximum between 60 to 70 percent. The actual value depends strongly on the particular application and the design of the system. When solar radiation is used to generate electricity, the combined efficiency of collectors, storage, heat engines, and the associated electrical equipment is not more than 20 percent.

2.6.4 Environmental Impact of Generation Method

This technology is still at an experimental stage; hence detailed environmental impact has yet to be assessed. As yet, no significant environmental impact has been noted or foreseen.

2.6.5 Economic Consideration of Generation Method

Unit cost per installed KW must be considered speculative at the present time. Further, since large solar arrays are made up of a large number of small concentrators, the effect of cost, in both fabrication and installation, is not entirely clear. At the present, the most generally accepted cost estimates place the cost per installed KW well above that of fossil-fueled plants. Although operating cost of solar power plants are expected to be low.

2.7 Wind Power

For centuries, man relied on the winds to transport goods across the globe. The wind was used to grind grain, pump water, and in the case of Holland to pump water not for convenience, but for the necessity of keeping the country dry. Although somewhat irregular and rather unreliable, in sum total the wind did these tasks well.

2.7.1 Availability of Energy Resources

The world Meteorological Organization has estimated that a little less than 1 percent of the wind energy, that is 175×10^{12} kilowatt hours is available at selected sites throughout the world. The distribution of wind is not uniform over the earth - wind velocities and frequencies are higher in polar and temperate zones than in tropical zones and are generally higher in coastal areas than inland.(1)

2.7.2 Status of Wind Power Conversion Technology

Wind power has its characteristic measures of performance. In the case of conventional wind mills, the output from the rotor is a direct function of the square of the diameter of the blades and the cube of the wind velocity.

The potential range of performance for a wind power system is thus relatively large for only modest changes in size or operating conditions. It is this exponential relationship between wind velocity and output that places such a high premium on identifying sites with continuous high winds.

2.7.3 Efficiency of Energy Utilization

The rotary motion of a conventional windmill represents mechanical energy which may be used to drive electrical generating equipment directly. The maximum theoretical energy recovery for any wind-driven device is about 60 percent of the energy contained in the airstream intercepted by the windmill blades. Blade inefficiencies and mechanical losses reduce the theoretical recovery to a maximum of about 40 percent. The overall wind efficiency of an individual rotor generating system is not likely to be more than 35 percent.[10]

2.7.4 Environmental Impact of Generation Method

Wind power has no significant environmental impact. It produces no waste heat and, for the most part, is compatible with multiple land uses, including farming. It has been suggested that large wind power units be sited along railways and highways, taking advantage of existing rights-of-way and thereby tending to reduce land-use conflicts.

Some restraints may be imposed on the use of airspace over large wind farms, but there seems to be no reason to believe that tower-rotor systems with total heights of 200 to 300 feet will interfere with normal air traffic, except in the immediate vicinity of airports.

2.7.5 Economic Consideration of Generation Method

Most authorities concede that the present day economics of wind-generated electricity are marginal and that wind energy will only be developed on a large scale when energy prices have risen by a considerable amount from the present level. The capital costs are considerably greater than the installed costs of present fossil-fueled power plants.

It should be remembered however, that the wind is not a firm source and the availability factors for wind generations will generally be much lower than those achieved by fossil-fuel plants. Hence, the often considerable costs of storage must be added to the installed capital costs of wind power system.

Because wind power does not cause problems of thermal pollutions, it can be used as a fuel saver, in conjunction with conventional thermal generation, supplying power only when available without storage. The use of wind energy will conserve fossil-fuel resources and reduce atmospheric pollutions.

2.8 Geothermal Power

Generation of electricity from geothermal steam resources occurred for the first time in 1904 at Larderello, Italy. Continuous generation began in 1913 with a 12.5 MW plant. The only commercial geothermal plant in the U.S. is in the Geysers area of California.[7]

2.8.1 Availability of Energy Resources

Geothermal energy is found only where the faults and fractures in the earth's crust contain heat from the interior of the earth close enough to the surface to permit exploitation. The occurrence of such conditions is extremely limited. Geothermal energy can be used for heating or for generating electricity with a steam turbine. The four types of geothermal energy are hydrothermal, hot dry rock, geopressured, and magma-type.

2.8.2 Status of Geothermal Power Generation Technology

Only high-quality vapor dominated hydrothermal reserves are used commercially to generate electricity in North America, but both vapor and liquid-dominated hydrothermal energy are used elsewhere in the world. The two cylces under consideration for liquid-dominated hydrothermal use in steam turbines are flashed steam, whereby steam is formed by sudden pressure reduction, and the binary cycle in which a heat exchanger is used.(7)

2.8.3 Efficiency of Energy Utilization

The overall efficiency of geothermal generation is very low because larger flow of steam is required. The large steam flow required for geothermal plants is a result of the low temperatures and pressures of the steam from geothermal wells. For example, the steam entering the turbine at the Geysers is about 350°F and the pressure is about 125 psi. In contrast, steam conditions in a modern fossil-fuel power plant are about 1000°F and 3600 psi. Typical efficiency of geothermal power plant is in the range of 10 - 15 percent.(7,8)

2.8.4 Environmental Impact of Generation Method

Environmental effects during the preparation and operation phases of a geothermal system are likely to be very site specific and very disperate. The preparation phase consists of land acquisition, active drilling and reservoir development, surface plant construction, and plant startup. The operation phase consists of power generation and any additional drilling or reservoir development required to sustain performance.

Geothermal systems, both liquid and vapor dominating, have non-condensable gases dissolved in varying amounts in the fluid depending on the geochemistry. Experience at the Geysers, for instance, had shown that about 0.5 percent of the dry steam contains carbon dioxide, hydrogen, nitrogen, methane, amonia and hydrogen sulphide. Of these gases, hydrogen sulphide and amonia pose the most serious health problem.[7]

Systems that discard spent geothermal liquids can also result in detrimental effects on the environment. For example, the highly saline geothermal brines pose a potential hazard if they could enter the extensive agricultural irrigation system in that area. In some cases, poisonous materials such as arsenic, mercury and hydrogen sulphide are present in the liquid and constitute a hazard.

2.8.5 Economic Consideration of Generation Method

Geothermal is an exhaustible source. It needs large expenditure of capital. Geothermal units have poor efficiency and poor location flexibility. Operation cost is high, generally plants are far away from load centers. Thus there is a need for long transmission lines, and this increases the cost of the system.

2.9 Biomass Power

Biomass energy, which can be derived from organic materials such as wood and waste products, has considerable potential for the generation of electricity throughout the world.

2.9.1 Availability of Energy Resources

Large-scale utilization of biomass energy is the "energy plantation", in which large areas of fast-growing hybrid poplar would be grown and managed, using advanced agricultural technology.

2.9.2 Status of Wood-Fired Power Generation Technology

Wood is a renewable resource, and with appropriate management it is well suited for a number of energy applications including the direct combustion of wood chips for electricity production, and the conversion of wood into methane or methanol.

Pulp and paper mills could become energy self-sufficient by using mill and forest wastes as fuel to produce steam and electricity.

2.9.3 Efficiency of Energy Utilization

The overall efficiency of biomass energy is very low.

2.9.4 Environmental Impact of Generation Method

Environmental problems associated with energy plantation involve the need for land, water and fertilizer.

It is expected that overall environmental problem of biomass generation will be low.

2.9.5 Economic Consideration of Generation Method

In relation to current electricity prices, the economics of biomass generation scheme are questionable because the overall efficiency of generation is very low and the smaller the output capacity per unit, the smaller the return on investment at present. But its future is promising.

2.10 Tidal Power

2.10.1 Availability of Energy Resources

Tidal power systems, like windmills, have a long history dating back to medieval times. Today large tidal energy schemes are in existance and operating successfully, for example, the 240 MW French scheme at La Rance. The Bay of Fundy between Nova Scotia and New Brunswick is a well-known possible power site.

2.10.2 Status of Tidal Power Generation Technology

The source of tidal energy is the gravitational pull of the earth-moon-sun system. The motion of the moon around the earth, combined with the rotation of the earth, produces tides with a tidal period of 12 hours and 24 minutes in most places.(2)

As the oceans move backwards and forwards under the influence of tides, the energy is dissipated in friction between the water molecules and between the water and the land. Utilization of resource would required construction of dams across the bays and installation of turbines.

2.10.3 Efficiency of Energy Utilization

The efficiency of tidal power plant can be quite high; at La Rance in France, 25 percent of the theoretically available power is generated as electricity.(2)

2.10.4 Environmental Impact of Generation Method

Because of very limited resource availability, the potential environmental and social impacts have not been assessed. There does not seem to be any objectionable or undesirable effects on human, animal and any other objects, etc.

2.10.5 Economic Consideration of Generation Method

In the past, economic analysis has usually found that the estimated cost was too high for the production of power. It does seem that tidal power like hydroelectric power, can contribute a reliable, inexhaustible, power source, not subject to embargo, that should not be overlooked in the future as it has in the past.

2.11 Ocean Thermal Gradient Power

In 1881, the French Physicist, Jacques D' Arsonval, suggested that the temperature differential in the ocean could be used to generate power.

2.11.1 Availability of Energy Resources

The amount of continuous energy available from ocean thermal gradient is inexhaustible but it depends upon such factors as the depth from which the cold water must be obtained, the conversion efficiency of the system, and the transmission losses in getting the electricity to shore.

2.11.2 Status of Ocean Thermal Gradient Power Generation Technology

The surface waters of the ocean change their temperature with changes in climatic conditions. The deep waters do not. Therefore, there is often a temperature difference between the surface and the deep waters, and this temperature difference is utilized to run a steam turbine to generate electricity.

The recovery of energy from temperature differentials in an ocean was demonstrated by Georges Claude in 1931 at Mantanjas Bay in Cuba. Operating on a temperature difference of 14°C, his turbine generator produced 22 Kilowatts, at an overall efficiency of less than 1 percent. Two additional experimental plants of 3500 kilowatts were installed off the Ivory coast in 1956 by the French. But the mechanical failures resulted in abandonment of the plants.[1]

2.11.3 Efficiency of Energy Utilization

Ocean thermal gradient power plants operate, in any event, at relatively low overall efficiency.

2.11.4 Environmental Impact of Generation Method

Ocean thermal gradient power appears to have little direct environmental effect. Removal of thermal energy from the ocean is expected to be balanced by solar radiation to the cold discharge water at the surface. Environmental effects due to the construction and operation of large thermomechanical installation in the ocean are not known.

2.11.5 Economic Consideration of Generation Method

The technology is insufficiently developed at this time for calculating per unit energy cost.

CHAPTER 3

COMPARATIVE ANALYSIS OF GENERATION METHODS

In previous Chapter the different generation methods were described and compared using a common criteria. In this Chapter all those electrical energy generation methods are tabulated for a summarized comparative analysis. From points of view of availability, location flexibility, land requirements, lead time, generator unit size, plant efficiency, forced outage rate, average lifespan, load change, types of load, $ per KW-installed, fuel cost, operation and maintenance cost, environmental effects and acceptability.

TABLE 3.1

ENERGY RESOURCE AVAILABILITY

Generation Methods	Availability Status
Fossil-Fuel-Fired:	
Coal Fired	Exhaustible
Crude Oil Fired	Exhaustible
Natural Gas Fired	Exhaustible
Gas Turbine	Exhaustible
MHD (Magnetohydrodynamics)	Exhaustible
FBC (Fluidized bed Combustion)	Exhaustible
Hydroelectric	Inexhaustible, Restricted
Nuclear:	
Fission	Exhaustible
Fusion	Inexhaustible
Solar	Inexhaustible, Restricted
Wind	Inexhaustible, Restricted
Geothermal	Exhaustible, Restricted
Biomass	Inexhaustible, Restricted
Tidal	Inexhaustible, Restricted
Ocean Gradient	Inexhaustible, Restricted

TABLE 3.2

LOCATION FLEXIBILITY

Generation Methods	Flexibility
Fossil-Fuel-Fired:	
Coal Fired	Flexible
Crude Oil Fired	Flexible
Natural Gas Fired	Flexible
Gas Turbine	Highly Flexible
MHD	Flexible
FBC	Flexible
Hydroelectric	Not Flexible
Nuclear:	
Fission	Not Flexible
Fusion	Not Flexible
Solar	Flexible, Restricted
Wind	Flexible, Restricted
Geothermal	Not Flexible
Biomass	Flexible
Tidal	Not Flexible
Ocean Gradient	Flexible, Restricted

TABLE 3.3

LAND REQUIREMENT FOR TYPICAL 1000 MW PLANT

Generation Methods	Land Requirement (Acres)
Fossil-Fuel-Fired:	
Coal Fired	4000 to 5000
Crude Oil Fired	1000 to 1500
Natural Gas Fired	1000
Gas Turbine	300
MHD	1000 to 5000
FBC	1000 to 5000
Hydroelectric	Depends on reservoir size
Nuclear:	
Fission	300 to 400
Fusion	300 to 400
Solar	7000 to 8000
Wind	N/A
Geothermal	1000
Biomass	4000 to 5000
Tidal	N/A
Ocean Gradient	N/A

Table 3.4

LEAD TIME* REQUIREMENT

Generation Methods	Lead Time
Fossil-Fuel-Fired:	
Coal Fired	Moderate**
Crude Oil Fired	Moderate
Natural Gas Fired	Moderate
Gas Turbine	Short**
MHD	Short to Moderate
FBC	Short to Moderate
Hydroelectric	Long
Nuclear:	
Fission	Long**
Fusion	Long
Solar	Moderate
Wind	Short
Geothermal	Long
Biomass	Moderate
Tidal	Long
Ocean Gradient	Long

*Lead time: Total time from decision to build a plant until it is operating

**Short: 1 to 3 years
Moderate: 3 to 7 years
Long: over 7 years

TABLE 3.5

UNIT SIZE RANGE

Generation Methods	Range*
Fossil-Fuel-Fired:	
Coal Fired	Low to very high
Crude Oil Fired	Low to high
Natural gas fired	Low to high
Gas Turbine	Low
MHD	Low to very high
FBC	Low to very high
Hydroelectric	Very low to high
Nuclear:	
Fission	High to very high
Fusion	High to very high
Solar	Low (depends)
Wind	Low (depends)
Geothermal	Low to high
Biomass	Low
Tidal	Low
Ocean Gradient	Low

*Very low - less than 10 MW
Low - less than 100 MW
High - less than 1000 MW
Very high - over 1000 MW

TABLE 3.6

PLANT EFFICIENCY

Generation Methods	Efficiency*
Fossil-Fuel-Fired:	
Coal Fired	Moderate
Crude Oil Fired	Moderate
Natural Gas Fired	Moderate
Gas Turbine	Low
MHD	High
FBC	Moderate
Hydroelectric	Very high
Nuclear:	
Fission	Moderate
Fusion	High
Solar	Low
Wind	Moderate
Geothermal	Very low
Biomass	Very low
Tidal	Moderate, can be high
Ocean Gradient	Very low

*Very low - less than 10%
Low - up to 20%
Moderate - 30 to 40%
High - 50 to 70%
Very high - 70 to 90%

TABLE 3.7

FORCED OUTAGE RATE

Generation Methods	Outage Rate*
Fossil-Fuel-Fired:	
Coal Fired	High
Crude Oil Fired	High
Natural Gas Fired	High
Gas Turbine	High
MHD	High
FBC	High
Hydroelectric	Low
Nuclear:	
Fission	Moderate
Fusion	Moderate
Solar	N/A
Wind	Low
Geothermal	High
Biomass	High
Tidal	Low
Ocean Gradient	Low

*Low - less than 0.5%
Moderate - 0.5 to 3%
High - 3 to 5%

TABLE 3.8

NORMAL LIFESPAN

Generation Methods	Lifespan
Fossil-Fuel-Fired:	
Coal Fired	Moderate
Crude Oil Fired	Moderate
Natural Gas Fired	Moderate
Gas Turbine	Moderate
MHD	Moderate
FBC	Moderate
Hydroelectric	High
Nuclear:	
Fission	Moderate
Fusion	Moderate
Solar	N/A
Wind	High
Geothermal	Moderate
Biomass	Moderate
Tidal	High
Ocean Gradient	High

*Moderate - 25 to 35 years
High - up to 70 years

TABLE 3.9

REACTION TO SUDDEN LOAD CHANGE

Generation Methods	Sudden Load Change*
Fossil-Fuel-Fired:	
Coal Fired	Moderate
Crude Oil Fired	Fast
Natural Gas Fired	Fast
Gas Turbine	Very fast
MHD	Fast
FBC	Fast
Hydroelectric	Very fast
Nuclear:	
Fission	Slow
Fusion	Slow
Solar	Moderate
Wind	Fast
Geothermal	Moderate
Biomass	Moderate
Tidal	Moderate
Ocean Gradient	Slow

*Very fast - few minutes
Fast - less than one hour
Moderate - less than 10 hours
Slow - over 10 hours

TABLE 3.10

SUITABILITY TO TYPES OF LOAD

Generation Methods	Types of Load
Fossil-Fuel-Fired:	
Coal Fired	Base, Intermittent
Crude Oil Fired	Base Intermittent, Peak
Natural Gas Fired	Intermittent, Peak
Gas Turbine	Peak
MHD	Base, Intermittent
FBC	Base, Intermittent
Hydroelectric	Base, Intermittent, Peak
Nuclear:	
Fission	Base
Fusion	Base
Solar	Intermittent
Wind	Intermittent
Geothermal	Base, Intermittent
Biomass	Base, Intermittent, Peak
Tidal	Intermittent
Ocean Gradient	Intermittent

TABLE 3.11

PRESENT PLANT INSTALLED COST IN $/KW

Generation Methods	Installed Cost in $/KW
Fossil-Fuel-Fired:	
Coal Fired	Moderate
Crude Oil Fired	Low
Natural Gas Fired	Low
Gas Turbine	Very low
MHD	High
FBC	High
Hydroelectric	High, very high
Nuclear:	
Fission	High
Fusion	High
Solar	Very High
Wind	High
Geothermal	High
Biomass	Moderate
Tidal	Very high
Ocean Gradient	Very high

Very low - less than $300
Low - less than $600
Moderate - $600 to $1000
High - $1000 to $1500
Very high - over $1500

TABLE 3.12

FUEL COST

Generation Methods	Fuel Cost (Cents/Million Btu)
Fossil-Fuel-Fired:	
Coal Fired	Moderate
Crude Oil Fired	Very high
Natural Gas Fired	High
Gas Turbine	High
MHD	High
FBC	High
Hydroelectric	Nil or extremely low (only water rental)
Nuclear:	
Fission	Low
Fusion	Low
Solar	Nil
Wind	Nil
Geothermal	Nil
Biomass	Moderate
Tidal	Nil
Ocean Gradient	Nil

Low - less than 100 cents/million Btu
Moderate - 100 to 200 cents/million Btu
High - 200 to 300 cents/million Btu
Very high - 300 to 1000 cents/million Btu

TABLE 3.13

OPERATION AND MAINTENANCE COST

Generation Methods	O & M COST
Fossil-Fuel-Fired:	
Coal Fired	High
Crude Oil fired	Moderate
Natural Gas Fired	Low
Gas Turbine	Low
MHD	Low
FBC	Low
Hydroelectric	Very low
Nuclear:	
Fission	High
Fusion	High
Solar	Low
Wind	Low
Geothermal	High
Biomass	Moderate
Tidal	Low
Ocean Gradient	Low

TABLE 3.14

ENVIRONMENTAL EFFECTS

Generation Methods	Environmental Effects
Fossil-Fuel-Fired:	
Coal Fired	High
Crude Oil Fired	Moderate
Natural Gas Fired	Low
Gas Turbine	Low
MHD	Low
FBC	Low
Hydroelectric	Low
Nuclear:	
Fission	Low
Fusion	Low
Solar	Very low
Wind	Nil
Geothermal	High
Biomass	Low
Tidal	Nil
Ocean Gradient	Nil

TABLE 3.15

SOCIAL ACCEPTABILITY

Generation Methods	Social Acceptability
Fossil-Fuel-Fired:	
Coal Fired	Acceptable
Crude Oil Fired	Acceptable
Natural Gas Fired	Acceptable
Gas Turbine	Acceptable
MHD	Acceptable
FBC	Acceptable
Hydroelectric	Very acceptable
Nuclear:	
Fission	Acceptable (with hesitation)
Fusion	Acceptable (with hesitation)
Solar	Acceptable
Wind	Acceptable
Geothermal	Acceptable
Biomass	Acceptable
Tidal	Acceptable
Ocean Gradient	Acceptable

CHAPTER 4

DISCUSSION AND CONCLUSION

Present methods of generating electricity have proven to be reliable and economical. This suggests that new methods and new energy sources should be selected on the basis of offering an improvement over the way the conventional methods are doing the job till now.

The three fossil-fuels and uranium are the four depleteable resources currently utilized to produce electric power. The conventional turbines for generating electricity from these resources are mature in technology and should continue to improve in performance.

In the case of coal, major technical development is required to harness the energy of coal without producing uncontrolled or unacceptable pollutants in the form of particulates, sulphur compounds and nitrogen oxides. Regardless of the above problems coal still will be a major source of energy for the power generation at least to the end of the century.

The use of crude oil and natural gas for power generation started to decline and it is expected that this decline will continue as society recognizes that these are premium sources of energy which should be utilized at the highest level of efficiency.

The potential impact of MHD and FBC on future power generation requirements is a function of their promised higher efficiency. Many significant technical and engineering problems need to be solved before fossil-fuel MHD and FBC will be a practical and reliable power generation methods.

Hydroelectric energy was the first major source for power generation and has been rapidly developed to the point where very few high capacity factor sites remain to be developed in developed countries. Lowhead hydroelectric sites are available which are very costly to develop at this time. However, future of hydroelectric power is good in view of the recent increases and further increases expected in fossil-fuel costs.

Nuclear power unfortunately, has acquired some very dedicated opponents who are concerned about the safety and potential radiation hazards of nuclear plants. Therefore, the future of nuclear power will face tough challenge from society. The latest report, published by the Department of Energy, Government of Canada, released in the month of August 1981, covers a variety of controversial subjects relating to the nuclear energy industry in Canada. This report says that the nuclear generation could play an increasingly significant role in Canada by 2000, subject to constraints of government policy and public acceptability. But increased use of nuclear energy carries the risk of possible radiation leaks and the possibility of accidents range from inconsequential to catastrophic. The report however emphasizes that the nuclear generation of electrical energy is safer than oil and even safer than coal and natural gas in terms of public and occupational health risk.[12]

Solar power is a major renewable energy resources. Many schemes and concepts have been advanced to use the sun's heat energy to provide heat and even cooling for residential and commercial buildings as well as to power a turbine to produce electric power. A lot more research is needed to bring down the present cost of solar power so as to make this abundant energy source competitive with conventional ones.

Wind power is a renewable resource but it is variable and unpredictable. It requires extensive land use for any significant power production. Some demonstration plants have been built but no significant contribution to power supply is expected.

Geothermal energy has been demonstrated to be practical and competitive at least at the Geysers field in California.

The concept of producing electric power from biomass is promising and will be competitive in near future.

There are three major drawbacks to use tidal power for electric power generation:

1) Capital cost of plant is high,
2) Energy supply varies from hour-to-hour,
3) Major harbours and bays would need to be blocked in order to get sufficient power to be significant.

There does not seem to be a practical solution to any of these problems.

Ocean Thermal Gradient power has also four major drawbacks:

1) Capital cost of plant is high,
2) Plant efficiency is extremely low,
3) Plants are located in ocean where currents are high,
4) Transmission of energy from the plant presents a difficult problem.

Consideration of these problems leads to the conclusion that it will not be a competitive generation method of electric power.

CONCLUSIONS

1. The nuclear generation could play an increasingly significant role by 2000 A.D. A lot more research on radioactive waste management is needed to convince the society to accept nuclear power.

2. The nuclear energy is safer for powering generating station than oil and even safer than coal and natural gas in terms of public and occupational health risk.

3. Lowhead hydroelectric projects should be developed.

4. Coal-fired generation will remain one of the main sources of electric power inspite of its environmental impact.

5. The use of crude oil and natural gas for electric power generation will decline because of its soaring prices.

6. MHD and FBC generation plants yet to solve many technical problems.

7. There should be more research in order to bring down the cost of electricity from solar heat so as to make this abundant energy source competitive with conventional ones.

8. Because of variable and unpredictable nature of wind energy, it seems there will not be much impact of this energy on the generation of power.

9. Geothermal power is restricted to some parts of the world, but its development is worthwhile.

10. The future of biomass is promising.

11. Because of the high cost and restricted sites, tidal power is not much in use at the present. But its developments may be useful in the future.

12. Ocean Thermal Gradient has technical and economical problems which are not easy to be solved.

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