ALTERNATIVE ENERGY SOURCES

CONVENTIONAL ENERGY SOURCES

1. <u>Fossil Fuels</u>: These are biochemical fuel sources - derived from the earth's crust. They give out heat energy when burning. Fossil fuels may appear in their natural state in the form of solid-coal, wood, uranium; liquid-petroleum; and gas - natural gas. Here also we will include the synthetic fuels - synthetic gasoline, synthetic natural gas (SNG), liquid hydrogen, gaseous hydrogen, ethanol etc.

The ones we call unconventional energy sources or renewable ~~energy~~ Sources include direct solar energy, wind, tidal, geothermal energy, ~~and~~ nuclear fussion ~~etc.~~ biomas and energy from water falls

2. <u>Hydroenergy Sources</u>: This remains one of the cheapest known source of electricity generation in terms of capital intensiveness during construction and cost of kilowatt per hour (Kw/h) of electrical energy. It does not require highly sophisticated technology but labour. Hydroelectric or hydraulic source of power generation is gaining much ground in the world energy production.

In Nigeria, the Kainji Dam located in the River Nicer of the Niger State has the capacity to supply more than half of the energy need of the country. Countries with abundant natural water resources eg: Egypt, Congo and Angola have a larger potential to generate more energy using hydropower. The use of hydropower may decline due to the introduction of nuclear power stations especially in advanced countries.

<u>Energy and Power from Water-Falls</u>

One of the major characteristics of hydropower stations is that we make use of the energy of water-falls. The height from where the water falls is of paramount importance. This will determine the power rating of the

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40-45 53-56

electrical equipment to be installed when constructing a hydropower plant.

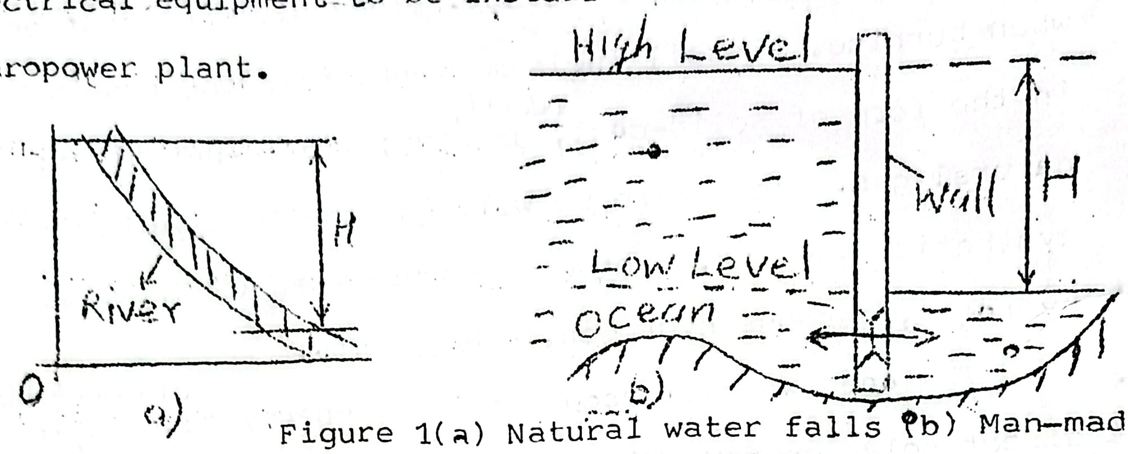

Figure 1(a) Natural water falls (b) Man-made da

In figure 1a, we observe that during a time interval t, second across the diameter 1-1 at a speed of Q, M^3/S we spend some volume of water $v=Qt$, m^3. If we assume that water runs equally for the time interval, then we can calculate the energy of the water fall as

$$E = \rho g Q t H e, \quad wh$$

where V - volume of water; g - acceleration due to gravity, M/S^2; ρ - density of the liquid, Kg/M^3; H-geometrical distance between the highest & lowest water level. Unit of energy generated in one second can be represented as

$$N = \rho g Q H e, \text{ watt}$$

If we take $\rho = 1000 Kg/M^3$ for water and $g = 9.81\ M/S^2$ for a normal slopy river, then we have

$$N = 9.81\ QHe,\ KW.$$

I have to remind you that the value Q is calculated at the end of the water-fall. Of all the parameters of hydroenergy calculation, the quantity Q can be easily regulated to vary power output.

Using the horsepower unit of measurement, we have,

$$\text{Horsepower} = \frac{QHe}{8.8}$$

where Q - water flow in cubic feet per second, H-water head (feet), e - efficiency.

The ~~energy available from a~~ volume of water ~~volume of water in a storage reservior is~~

$$E = \frac{W\,H\,t\,V_e}{K}\ , \quad Kwh$$

~~where W-weight per cubit foot of water (62.5)~~

H - head of available water in the reservior, V - volume of reservior in cubit feet and K - a constant = (2.65×10^6 ft-lb/kwh).

Example 1 : A hydroelectric power station is fed from a water reservior of 60 million cubit meters at a head of 160m. Calculate the available electrical energy if the hydraulic turbine has an efficiency of 82% and the generator driven by the turbine has an efficiency of 92%.

Solution:

$1\,m^3 = 35.31472482$ cuft

$1\,m = 3.28083989$ ft

$V = 60 \times 10^6\ M^3$

$H = 160M$

$E = ?$

There are two efficiencies, so we find their equivalent.

$e_{eq} = e_T \times e_g = 0.82 \times 0.92 = 0.7544$

Bringing all values to the same unit, we have 160 meters = $160 \times 3.33 = 533.3ft$

$60 \times 10^6\,m^3 = 60 \times 10^6 \times 35.70 = 2142.8 \times 10^6$ cuft

$$E = \frac{62.5\ lb \times 533.3ft \times 2142.8 \times 10^6\ cuft \times 0.7544}{Cuft \times 2.65 \times 10^6\ ft - lb/Kwh} = 20334316.45 Kwh$$

$= \cancel{1895845.27\ Kwh}$

Example 2: A synchronous generator at 60Hz was allowed to operate for 45 minutes. If the water volume V = $16400\ m^3$ and the water head H = 20m. What is the quantity of active power P generated? Take machine efficiency 88%, acceleration due to gravity g = $9.81\ m/s^2$ and density of water ρ = $1000\ Kg/m^3$.

Solution:

All parameters are in the same unit.

Generated operated for 45 x 60 sec = 2700 seconds

$Q = 16400/2700 = 6.074 M^3/S$

Energy generated = $\rho gQtHe$

$= 1000 \times 9.81 \times 6.074 \times 2700 \times 20 \times 0.88 =$

$= 2.83161 \times 10^9$ watt x hour

RENEWABLE ENERGY SOURCES

These are the formerly reliable form of energy before the inception of crude oil era. It is expected that these forms of energy can be harnessed and some controlled energy derived from them. They include wind, geothermal, biomas, tidal, wave, running water, direct sunshine and nuclear fission. and nuclear fussion.

(a) NUCLEAR ENERGY

Method of derivation: Nuclear energy is derived from nuclear fission. Nuclear fission is the disintegration of the positively charged uranium nucleus into two relatively heavy nuclei using neutrons. Neutrons are used because they have no charge and are therefore able to penetrate more deeply into the uranium nucleus.

Natural uranium consists of about one part by weight (1 part) of uranium atoms $^{235}_{92}U$ and 140 parts by weight of uranium atoms $^{238}_{92}U$. In a nuclear reaction with natural uranium and slow moving neutrons. If the resulting nuclei are lanthanum $^{148}_{57}La$ and bromine $^{85}_{35}Br$, together with several neutrons, then we have:

Example 3

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{148}_{57}La + ^{85}_{35}Br + 3^{1}_{0}n + \text{Energy}$$

The products of the reaction have a mass

$m = 148 + 84.9 + 3 \times 1.009 = 235.9$ a.m.u.

Now ${}^{235}_{92}U$ and ${}^{1}_{0}n$ together have a mass of $235.1 + 1.009 =$ 236.1 a.m.u.

$\therefore$ energy released = mass difference.

From here $236.1 - 235.9 = 0.20$ a.m.u.

0.20 a.m.u $= 0.20 \times 931$ MeV $= 186$ MeV.

converting this value to joules

$186 \times 1.6\times10^{-13}$ joules $= 298 \times 10^{-13}$ joules.

This is the energy released per atom of uranium fissioned.

In one kilogram of uranium, there are about

$\frac{1000}{235} \times 6.02 \times 10^{23}$ atoms

From here it is obvious that if 1 kilogram of uranium is fissioned, the total energy that will be released is:

$26 \times 10^{23} \times 298 \times 10^{-13} = 8 \times 10^{13}$ joules

this is equivalent to 2×10^{7} Kwh or 2.0×10^{10} wh.

This is the amount of energy released or given out by burning about 300 million kilogram of coal. The energy E produced by a change of mass ΔM is given by the relation

$$E = \Delta MC^2$$

ΔM – mass of uranium atom in grams

where C – speed of light (3×10^{8} m/s)

$1eV - 1.6 \times 10^{-19}$ joules, $1MeV = 1.6 \times 10^{-13}$ joules,

1 a.m.u $= 1.66 \times 10^{-24}$ g $= 1.66 \times 10^{-27}$ Kg.

a.m.u = atomic mass unit.

Uses of nuclear energy

1. In the construction of atomic power stations (APS).
2. In the construction of big ocean vessels.
3. In the construction of sub-marines.
4. Used also in the manufacturing of nuclear weapons of mass destruction.

Control of Nuclear Energy: The aim of the control is to moderate the speed of incident neutrons so that they are "captured" by the nuclei in a mass of uranium. Carbon blocks or cadmium rods are used for the control. The control mechanism is achieved by inserting the rods into the active parts of the nuclear reactor.

Application of Nuclear Energy to Electric Power Generation

The application of nuclear energy to electric power generation is one of the peaceful uses of nuclear power. To do this a nuclear reactor is required in which to start the process of nucleus division of $^{235}_{92}U$ using slow moving neutrons at about 2×10^{3} M/S. I remind you that fast moving neutrons (about 10^{7} M/S) are not desirable because they act equally on $^{235}_{92}U$ and $^{238}_{92}U$.

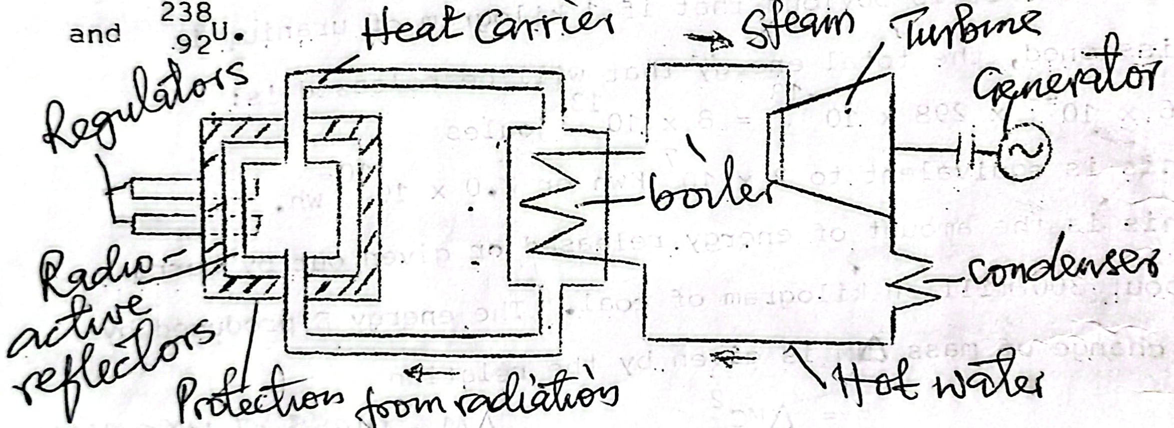

Fig.2 Atomic Power Station (APS).

Working System of the Diagram

This simple disgram illustrates what is called Atomic Power Station. It is in atomic power stations that we apply the heat energy of nuclear reaction for the production of electricity. When the reactor is working, the heat generated is transfered through the heat carrier into the boiler where hot water is quickly turned into steam. The steam so generated is used to rotate the turbine simultaneously with the electric power generator connected to it through a mufti. This system is therefore a mere conversion of heat energy into mechanical and then into electrical energy.

Hydrogen fussion

The process of division of uranium proton (fission) involves heat release. Heat will also be released when Helium is synthesized from Hydrogen isotope, a process which takes place at about 5×10^{7} K. Helium can be synthesized from heavy hydrogen-deuterium and tritium and in the process heat energy is evolved.

$$^{3}_{1}H + ^{2}_{1}H \quad ^{4}_{2}He + ^{1}_{0}n + \text{Energy.}$$

When we synthesize one gram of helium from deuterium and tritium, we get millions of joules of heat energy.

Example 4

Calculation involving heat generated by fussion reaction.

The mass of two deutrons = 2 x 2.015 = 4.03 a.m.u.

mass of helium plus neutron = 3.017 + 1.009 = 4.026 a.m.u,

therefore mass converted to energy by fussion

= 4.03 - 4.026 = 0.004 a.m.u.

0.004 x 931 MeV = 3.7 MeV

$= 3.7 \times 1.6 \times 10^{-13} = 6.0 \times 10^{-13}$ joule

Energy released per deutron = 3.0×10^{-13} joule.

There are 6.02×10^{23} atoms in one mole of deuterium, which is about 2 grams. But we are considering one gram only,

therefore energy released per gram

$= 3.0 \times 10^{-13} \times 3.01 \times 10^{23} = 9.03 \times 10^{10}$ joules.

This quantity of energy ~~cab~~ can be obtained by burning about ten tonnes of diesel.

Hydrogen contains about 1/5000th by weight of deuterium or heavy hydrogen needed in fussion reactions and it can be obtained by electrolysis of sea-water, which is cheap and in plentiful supply.

$$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He + ^{1}_{0}n$$

(b) WIND

Wind is a very important type of energy. The wind-propelled rotors are major source of power generation. In the olden days, it was common to see small electric generators less than one horsepower connected in series and carefully transformed so as to give normal electric current. With the development of new technology, propellers of up to 70m high are now in use. In the USA for example 2x1500kw machines with about 61 diameter blades are under construction with tendencies of increment.

(c) GEOTHERMAL ENERGY

This is the type of energy derived from the slow decay of naturally occuring radioactive elements which are present in the rocks. Geothermal resources are generally classified into four basic types: liquid-dominated hydrothermal, vapour-dominated hydrothermal, petrothermal and geopressured.

Liquid dominated hydrothermal: The term liquid may refer to water or brine solution that is circulated by convection transfer of heat energy from the underlying rock matrix. Liquid-dominated geothermal temperatures are in the range of near-ambient to as high as 360°C. This source of geothermal energy is more abundant than the rest of the other sources.

(d) DIRECT SUNSHINE

The sum exerts energy of varying wavelengths. Here, we are concerned with the radiation in the wavelength range of 0.3 - 3.0 um. This portion includes most of the energy of the solar radiation. It is suggested that fussion reactions supply the energy radiated by the sun. Hydrogen combines to form helium nucleus, the loss in mass during the reaction results in the evolution of energy. This energy is produced in the interior of the solar sphere at temperatures of many millions of degrees centigrade. The radiation of the sun reaches the earth at a surface temperature of about 5762°K.

Usually wind power has better advantage in areas where the national voltage rating is 110 volts. Wind generated power may be used to store pumped water for hydro-stations or used in remote areas where federal grid is inaccessible. One disadvantage of wind electrical power is its unstability.

GAS TURBINES

Description: Gas turbines are turbine set-up, which work by the principle of expansion of heated gas. There are two models of gas turbine: one shaft and two shaft models. One shaft model is made up of the compressor, high pressure turbine, combustion chamber and load. See fig. 20a part A. Two shaft turbine has all the parts of one shaft model including a separate low-pressure turbine and the external load on a separate shaft. One shaft model has only one speed but two shaft model can be driven at variable speed. Liquid helium is mostly used in the combustion chamber.

We have two basic types of gas turbines - radial flow and axial flow. Radial flow gas turbine resembles a centrifugal compressor, are small in size and are not as efficient as axial turbines. On the other hand, axial gas turbines are large, maintains high temperature and are similar to steam turbines. Generally inlet pressure to gas turbines are much lower than those of steam turbines.

Gas Turbine Cycles

There are two ways by which gas turbine works:

(1) Direct cycle: This is by direct expansion of gases in a turbine.

(2) Indirect cycle: By heating another working fluid through a heat exchanger. Therefore, item (1) is normally called "The direct open gas-turbine cycle", and item (2) is "The indirect open gas-turbine cycle".

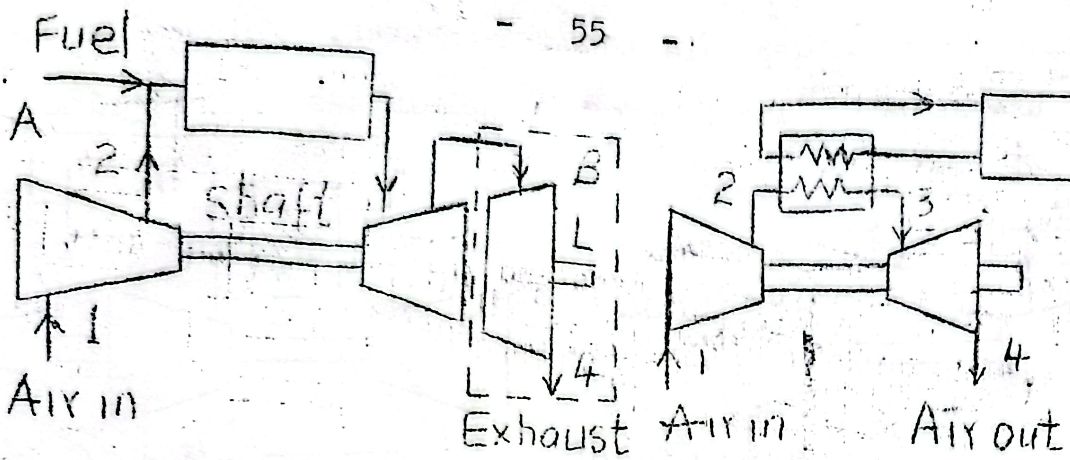

Fig 20a (a) direct open gas turbine cycle, (A) single shaft, (AB) two shaft. (b) indirect open gas turbine cycle

(1) DIRECT OPEN CYCLE: The gas enters a compressor at point 1 and is compressed to point 2. The has then enters the combustion chamber (reactor), where it receives heat at constant pressure and emerges hot at point 3. From there it expands through the turbine at point 4. And from point 4 the hot exhaust air mixes with the atmosphere outside the cycle. The turbine supplies the compressor power.

(2) INDIRECT OPEN CYCLE: Fig (20b), the only difference between this cycle and the direct open cycle is that the air is a secondary fluid that receives its heat from a primary coolant in a heat exchanger.

(3) DIRECT CLOSED CYCLE Fig (21a), the coolant is heated in the reactor, expanded through the turbine, cooled in the heat exchanger and compressed back into the reactor. Ordinary air cannot be used in this cycle. Pressurization is more permissible here and in the indirect closed cycle.

(4) INDIRECT CLOSED CYCLE: Fig (21b), the indirect closed cycle combines the indirect open cycle and the direct closed cycle in that the reactor is separated from the working fliud by a heat exchanger whereas the working gas rejects

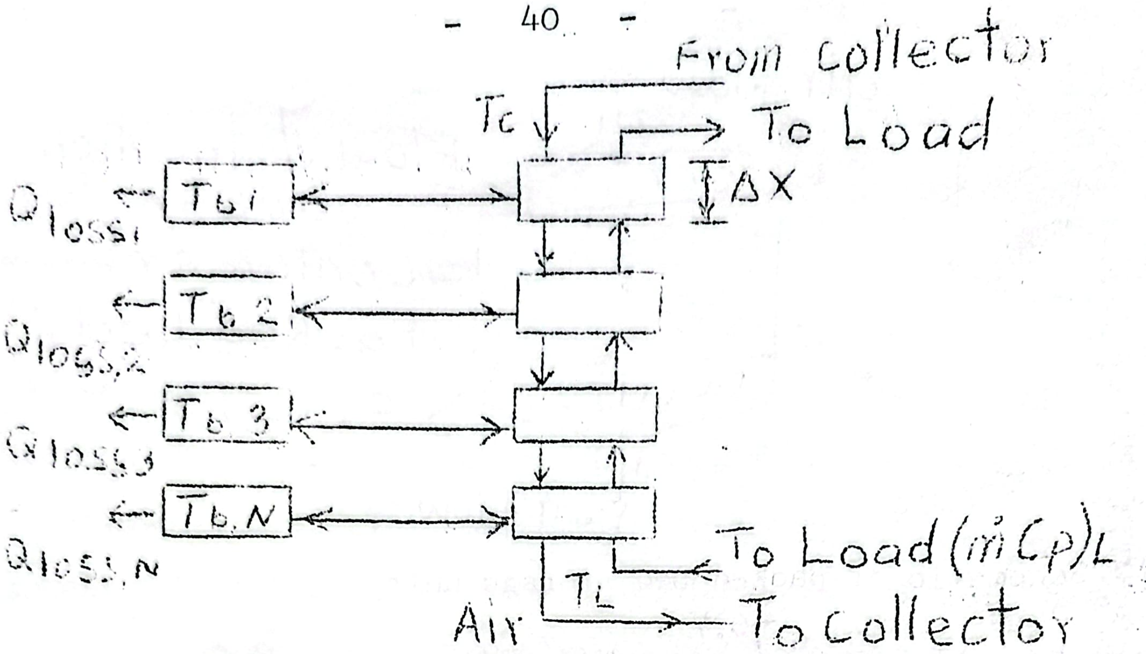

Fig16 Numerical analysis of packed bed.

Magnetohydrodynamic (MHD) generation

This type of electric power generation is unique in that it converts gas plasma into direct electric current. The principle is that gas heated to about (2000 - 3000)$^{\circ}$K with K_2CO_3 as an ionizer, when passed through a magnetic fiels (containing anode and cathode) we will observe flow of current through a load connected at the external terminal.

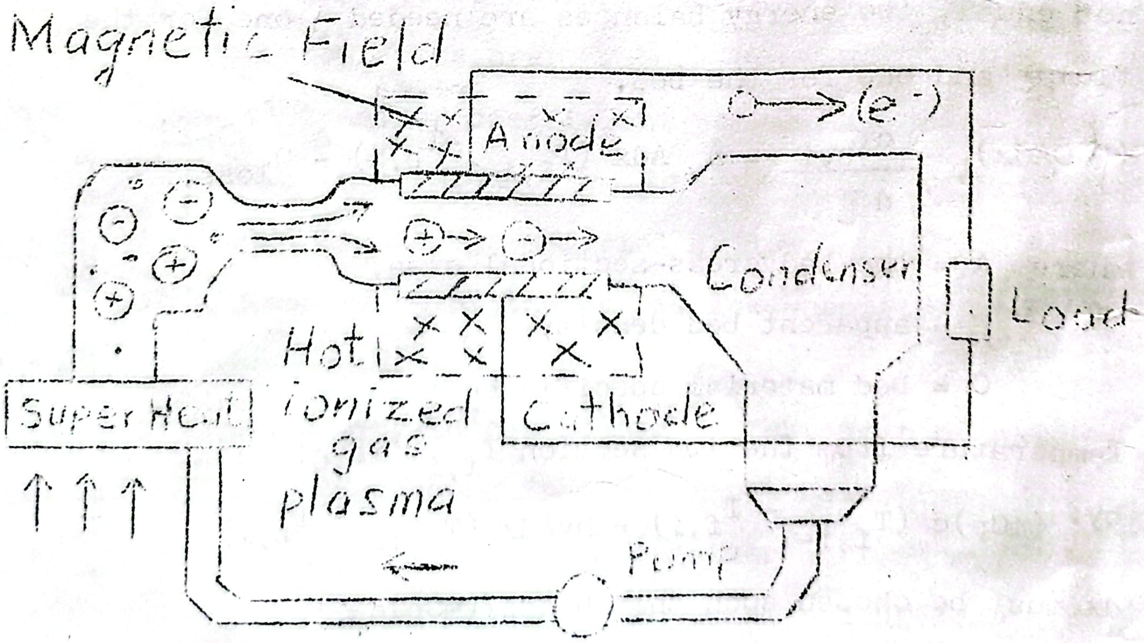

Fig.17 Schematic of an MHD generator.

40-45

This type of MHD generation is a closed circuit system capable of generating about 3000Kw of electrical energy. In the diagram above, four cycles of thermodynamic processes take place. Explanation: Cycle ab - compression of gasses by the compressor, bc - heat intake, cd - conversion of energy of gas expansion in the MHD chamber into electrical energy, da - cooling (removal of heat). The system operates at about 0.85 MPa before entering into the expansion chamber with a gas (natural gas) speed of about 1000 m/sec. In the open circuit system of MHD generation, used gas is thrown into the atmosphere, but with regeneration of ionizers. MHD in future has the capacity to give over 600 Mw per block and can be operated simultaneously with steam turbines. The only problem with MHD is that of high temperature control and being able to raise such innermous temperature required to operate it.

BIOMAS ENERGY

Biomas is an energy resource which includes such organic matters as firewood, waste and animal dung. It is the earliest known source of energy as it accounted for 10% of the world's primary energy consumption. Biomas is a renewable source of energy. In developing countries, biomas is used in cooking and local heat generation but in developed countries, it has gone to the extent of powering heat engines. Biomas energy is perharps the cheapest source of energy today.

Application of Biomas

1. It is a source of fuel for cooking, heating, irrigation and agricultural tasks.
2. It is used to power tractors and heat engines for agricultural purposes.
3. It is a source of fertilizer.

4. It can be used as fuel for boilers in the generation of electricity.
5. In the production of hydrocarbon (Euphorbia trees).
6. In the production of methane for transport and petrochemical industries. Alcohol and paper can be produced from sugar cane, cassava and kelp.

Electromechanical Conversion Systems

1. Water pumps make use of electrical energy to store water for hydropower generation.
2. Different types of Dc/Ac motors are used as electrical grinders.
3. Most quartzite watches transform electrical energy into mechanical.
4. Most on/off relays are set to motion by electrical means.
5. The vibration of accustic systems are caused by electrical impulses.
6. Robbots function only on the application of electricity.
7. Varioustypes of turbines convert mechanical energy to electrical, the power generated as such is capable of driving high powered motors and wind mills.
8. In advanced countries, electricity provides very efficient and reliable means of transport.
9. Other areas of electromechanical transformation include refrigeration, washing machines, pressure pumps, measuring instrument and driers.

Energy Conservation

Definition: This simply means the minimization of wasteful consumption of our energy resource by making use of the potential that still exists within the limits set by natural law. Here, energy may include all forms of energy reserve, Method of electric power generation from solar energy

Some semiconductors improve their conductivity greatly when light strikes them. Examples of such semiconductors include germanium, silicon, lead sulfide, cadmium sulfide and copper oxide. The resistance of cadmium sulfide cell may be over one megohm (1Mom) in the dark and about 100 ohms when brightly lighted.

The "Solar Cell" is an improved type of photovoltaic cell consisting of N-type wafer of silicon doped with arsenic on the surface of which boron has been added to form a transparently thin layer of P-type silicon. When light strikes atoms in the junction layer, energy of the light kicks some electrons out of holes, making the electrons free moving. Some of these electrons uselessly loose their energy by collisions and fall back into a hole.

Some of the energetic electrons usefully wander into the N-type silicon before loosing their energy. Once into the body of the N-type wafer, they can do work flowing through an external circuit rather than gething back home directly through the high-resistance barrier at the junction.

The open circuit voltage of a solar cell is about half a volt. Solar cells operate as dc source. More light produces more current but voltage and efficiency (up to 12%) are fairly independent of the amount of illumination. In some cases, up to 4000 solar cells are connected in series in order to give the required voltage. The sun will give a solar energy constant of about 1353 w/m^2.

THERMOCOUPLE

Unlike solar cells, thermocouple makes use of direct solar heat to produce electricity. Thermocouple is a bimetalic junction in which each end is at a different temperature.

petroleum, natural gas, Biomas, electricity without noticable setback to our economic growth. Energy consumption and economic growth are the two major areas where energy conservation is needed most. The least energy intake per GNP (gross national product) is the optimum value of energy conservation rate. This is because economic activities consume more than 80% of total energy production in the advanced countries. Machine and equipment efficiency have a role to play in energy conservation because this will foster the technological theory that energy is never lost but is transformed from one state into another.

However, energy conservation costs something. Efficiency may mean improved modern technology computerization which is never cheap. But the benefit spreads over a wider range because more people may be enticed to participate in economic activities even locally.

Role of Government in Energy Conservation

Government's role to energy conservation include decisions on price policy and taxes, regulatory measures, standards and quotas. Also Government can provide non-market strategies by providing subsidies, grants and loans as incentives for energy saving investiments. A primary objective for government's regulatory policy on energy conservation is to ensure that the ratio between the percentage growth of energy use and the percentage growth of GNP (known as the energy/GNP elasticity)coefficient is less than one.

Government may also introduce more measures to include:

(a) promoting technical developments for saving energy;

(b) promoting investigations of energy balances to define losses;

(c) introducing national standards for energy-using appliances;

(d) adopting laws for lebelling equipment with information on energy consumption;

(e) subsidizing research and development directly applied to energy conservation.

Problems and limits of energy conservation

1. Machine inefficiency of thermodynamics.
2. Transient processes may increase energy intake at the initial moments of machine operation.
3. Highlife ambition, ignorance of existing laws and economic failure.
4. Many industries do not invest in energy saving due to low level of production capacity.
5. Lack of manpower and adequate information.

Future conservation potential

Energy conservation for the future (till the year 2020) is more significant in the advanced nations. Developing countries (including Nigeria) have not produced enough energy for private and industrial requirement. However, with the present world standard for future energy conservation, it is expected that 44.6% of energy will be reserved to accept the challenges of future development. With better efficiency of machines and technology, more energy could be reserved as much as 50% of the present day energy consumption. Under developed countries may employ different strategy: restrict capital investment rather than energy imputs, as a measure of energy conservation. Overall achievement towards future energy conservation, laws should set mandatory standards for higher efficiency of energy-consuming appliances; energy research should be subsidized to speed the transition of equipment such as solar heaters and heat pumps from the experimental phase into widespread use.

ENERGY POLICY

Energy policy is a political decision of government - a national issue. In Nigeria, government has taken different policies aimed at a sustainable energy supply system. The government has recently undertaken the following measures towards promulgating a unified energy policy initiative.

(1) Massive privatization of the major energy parastatals - NNPC, NEPA, solid mineral mining, the steel sector and others.

(2) Increasing energy price as a conservation strategy.

(3) Transfer of technology and capital resources, importation of energy supply equipment.

(4) Financial and fiscal reforms. Government spends a lot of money in the energy sector - through massive refurbishment of electric power stations, the refineries as well as importation of finished products.

ENERGY DEMAND MODELLING

By the use of energy demand model, it will be possible to forcast energy demand in a particular place or region, within a particular range of time. By the use of "energy coefficient", we may understand energy demand models better.

"Energy coefficient" - percentage change in primary energy consumption/the percentage change in the gross domestic product. The second step towards energy modelling is by distinguishing between supply and demand by introducing the econometric concepts of income and income elasticity as well as price and price elasticity. Mathematically this can be done in the following ways:

$$E(N) + F = \left[E(ST) + F \right] \times \left[\frac{Y(N)}{Y(ST)} \right] \times \left[\frac{P(N)}{P(ST)} \right]^{\beta}$$

where E(N) is the energy demand in year N, F denotes a parameter related to substitutions fron non-commercial energy, Y(N) denotes the regional (or global) gross national product (GNP) in year N (the referred year), denotes the income elasticity with respect to E(N) + F, P(N) denotes the internal price of energy in the region (or in the world) in year N and β denotes the price elasticity, ST - initial starting year.

By logarithmic differenciation, the above formular becomes:

$$\frac{\Delta E(N) + F}{E(N) + F} = \gamma \frac{\Delta Y(N)}{Y(N)} + \Delta \gamma \,.\, \ln \frac{Y(N)}{Y(ST)} + \beta \frac{\Delta P(N)}{P(N)} + \Delta \beta . \ln \frac{P(N)}{P(ST)}$$

Neglecting the non-commercial energy F =0 and income and price elasticities and population may be considered constant ($\Delta \gamma = \Delta \beta = 0$), we rewrite the ongoing equation thus:

$$\frac{\Delta E(N)}{E(N)} = \gamma \frac{\Delta Y(N)}{Y(N)} + \beta \frac{\Delta P(N)}{P(N)}$$

The formula denotes that the demand for energy increases in proportion to income, γ being a factor of about 1.10 $\pm$ 0.15 and decreasing with increasing energy price, β being a factor of about -0.3 $\pm$ 0.05. In other words, a 1% increase in income per capita increases energy demand by 1% while a 1% increase in the price of energy cuts demand by 0.3%.

and β (income and price) elasticity will likely affect our models.

As an illustration:

E(ST) Y (1972) = 4175 P(1972) = 1.00

E(N) Y (2000) = 13479 P(2000)= 1.80

Y (2020) = 28232 P(2020)= 2.17

$$\frac{\Delta E}{E} = \Delta \gamma \ln \frac{Y(N)}{Y(ST)} + \Delta \beta \ln \frac{P(N)}{P(ST)} =$$

$$= 0.15 \ln \frac{13479}{4175} + 0.05 \ln \frac{1.80}{1.00} = 0.2$$

which is about ± 20% inherent uncertainty.

To study the maximum economic growth rates possible under different assumptions, the following conditions may be introduced:

(1) Consistency - equality of demand and supply;

(2) constant fraction - the expenditure for energy should remain a constant fraction of the consumers' budget, and

(3) non-commercial energy is neglected.

Energy demand then becomes $E_{D(t)} = E_0 e^{\gamma z t} \cdot P^{\beta}$.

and energy supply $E_s(t) = E_0 e^{\varepsilon t}$

where z, ε - average annual growth rates of the economy and the potential energy supply respectively.

$$e^{\gamma z t} \cdot P^{\beta} = e^{\varepsilon t} \quad ; \quad P = \exp\left[\frac{\varepsilon - \gamma z}{\beta} t\right].$$

$$\frac{P(t)\, e^{\varepsilon t}}{e^{z t}} = \text{const}, \quad \text{a constant fraction}$$

and solving we have $$\frac{\varepsilon - \gamma z}{\beta} + \varepsilon - z = 0$$

from here $z = \frac{1 + \beta}{\gamma + \beta} \cdot \varepsilon$, a graph of this value is plotted below.

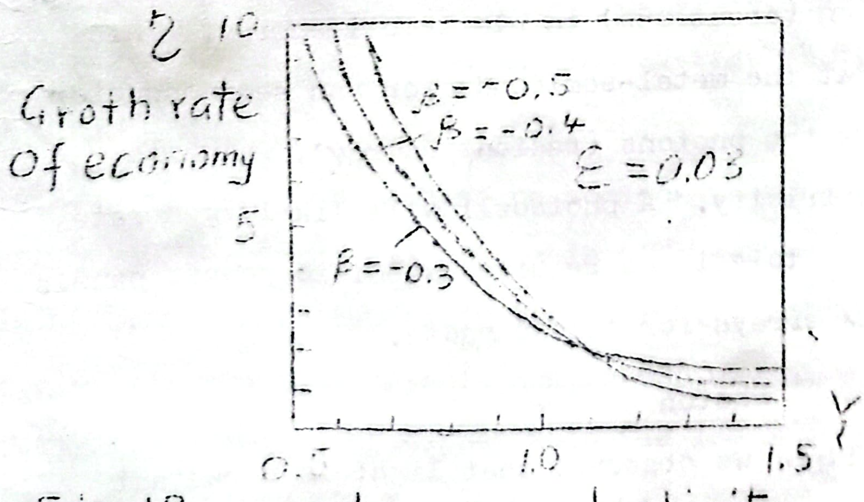

Fig. 18. Income elasticity

For income elasticity below 1.0, around 0.7 the situation becomes different, the economy tends to become less closely dependent on energy, which of course means that factors such as capital, raw materials and labour will pose more severe restrictions on economic growth than does energy availability. The curve is strictly upon adherence to energy demand model. In conclusion, price of energy is related to the price of oil through the formula.

$$P_1(N) = \frac{5P1\ (ST)\ + Po\ (N)}{6\ P_1\ (ST)},$$

where P_1 (N) - initial internal price, Po(N) - external oil price. It is further assumed that there will be a certain delay in the internal energy price response to an increased oil price. The price response factor $_p(N) = P(N)/P(ST)$. This response can be obtained by the use of data as follows:

	1972	1985	2000	2020
Oil price Po (N)	1.0	4.0	8.0	8.0
Internal energy price P (N)	1.0	1.35	1.80	2.17
Price response.	1.0	0.91	0.84	0.79

The prices chosen are only estimates as no forcast is made accurately about future real energy prices.

PHOTOVOLTAIC GENERATION

Photovoltaic generation is the conversion of a fraction of solar radiation (about 15%) to electrical energy. This is usually done at the metal-semiconductor and semiconductor junctions. It is the photons (radiant energy), which is converted to electricity. A photocell will likely generate about 0.5V, and so to get the required specific power, panels are combined into arrays for this purpose.

Photon

In the study of light we observed that light is a radiant energy. Quantum is the smallest piece of light and photon is the quantum of radiant energy. Photon energy $Ep=Kv=K(c/\lambda)$, where $K= 6.62556\times10^{-34}$ j/s or 4.13576×10^{-15} eV/S, V = frequency of radiation (hertz), C = speed of light, 2.997925×10^{8} m/s and λ = wavelength of radiation in meters.