Evolution of Electrical Power System: Changing Trends in Power Generation

Shambhu Ratan Awasthi
Professor, Rabindranath Tagore University, Bhopal (M.P.) India.

ABSTRACT
The paper deals with the conventional sources of energy viz. fossil fuels, hydro and nuclear to generate electricity along with the historical development of electric power system comprising of power generation, transmission, and utilization. The growth of conventional electric power in India will be discussed. The depleting fossil fuel deposits and serious climate change concerns due to the emission of green house gases caused by the burning of fossil fuels have compelled to adopt the environment friendly renewable sources of energy. The paper gives evolution of renewable sources of energy and its present status. Finally, the futuristic renewable energy technologies have been briefly discussed.

Key words: Conventional power, renewable energy, power system

I INTRODUCTION

Energy is an essential need in our daily life and is a backbone for social and economic development. The per capita electricity consumption is considered as an indicator of economic development of a nation. The per capita energy consumption in India was 16.3 kWh in December 1947. Table 1 gives growth in per capita electricity consumption.

Table No. 1
Growth in per capita electricity consumption in India [1]

Status as on	Per capita consumption (kWh)
31Dec 1947	16.3
2005-06	631.4
2006-07	671.9
2007-08	717.1
2008-09	733.5
2009-10	778.6
2010-11	818.8
2011-12	883.63
2012-13	914.41
2013-14	957
2014-15	1010
2015-16	1075
2016-17	1122
2017-18	1149
2018-19	1181
2019-20	1208

II GROWTH OF CONVENTIONAL POWER IN INDIA

Power Sector in India has grown significantly since independence both in the installed electricity generating capacity, transmission/distribution and utilization. The total power generating capacity in India has increased from 1362 MW in 1947 to 370,048 GW (including renewable energy) by March 2020.

(a) Conventional power generation - The conventional power projects are based are fossil fuels, water or nuclear fuels. The major sources of energy for power generation and transportation have been the fossil fuels i.e. coal, oil, and natural gas. The fossil fuels are the buried deposits of organic materials i.e. dead plants and animals for lakhs of years in the earth. These materials are plants and animals which were subjected to heat and pressure and got converted into crude oil, coal, and natural gas. The utilization of fossil fuels has enabled large-scale industrial development which largely replaced burning of wood for heating.

Hydroelectric power is a renewable source of energy and has been adopted by several countries as a part of water management system for flood control, domestic use, irrigation, industries, fishing, recreation etc. It uses potential energy of water which is converted into kinetic energy and is used to rotate turbine. The hydropower projects are environment friendly and are generally multi-purpose.

Globally, the nuclear energy is based on controlled fission process in which the heavy atoms of fissionable materials, either uranium or plutonium are split into 2 or 3 parts to release huge amount of energy. Nuclear fission is considered as clean source of energy in spite of radiation hazards, health issues and in disposal of radioactive wastes. The stringent standards and practices evolved over the decades have minimised the risk of accidents.

The growth in installed power capacity in India is given in Table 2.

Table No. 2
Growth of installed conventional power capacity in India [2]

Status as on	Thermal (MW)				Nuclear (MW)	Hydro* (MW)	Total (MW)	Growth# (%)
	Coal	Gas	Diesel	Total				
31Dec 1947	756	-	98	854	-	508	1362	-
31Dec 1950	1004	-	149	1153	-	560	1713	25.77
31 Mar 1956	1597	-	228	1825	-	1061	2886	68.48
31 Mar 1961	2436	-	300	2736	-	1917	4653	61.23
31 Mar 1966	4417	137	352	4906	-	4124	9030	94.07
31 Mar 1974	8652	165	241	9058	640	6966	16664	84.54
31 Mar 1979	14875	168	164	15207	640	10833	26680	60.11
31 Mar 1985	26311	542	177	27030	1095	14460	42585	59.61
31 Mar 1990	41236	2343	165	43744	1565	18307	63616	49.39
31 Mar 1997	54154	6562	294	61010	2225	21658	84893	33.45
31 Mar 2002	62131	11163	1135	74429	2720	26269	103418	21.82
31 Mar 2007	71121	13692	1202	86015	3900	34654	124574	20.46
31 Mar 2012	112022	18381	1200	131603	4780	38990	175373	40.78
31 Mar 2017	192163	25329	838	218330	6780	44478	269588	53.72
31 Dec 2018	197452	24937	638	223027	6780	45399	275206	2.08
31 Mar 2019	200704	24937	638	226279	6780	45399	278458	1.82
31 Mae 2020	205345	24955	510	230810	6780	45699	283289	1.73

*Hydro power plants of above 25 MW capacities are only considered.
#Growth is calculated over the previous value of total conventional installed power capacity.

The year 2016-17 was significant as for the first time, new installed power capacity of renewable energy in India surpassed installations based on fossil fuels. This trend continues year after year since then. The Central Electricity Authority (CEA) declared on 29th March 2017 that for the first time India become net exporter of electricity. During April 2019 to January 2020, India exported 8,015 GWh energy to neighbouring countries, against an import of 6,166 GWh.

(b) Transmission - The transmission of electricity was started with DC but it was suitable for short distances. Subsequently, with the advent of transformers, DC power was universally adopted with AC. However, for very long distance transmission of electric power, high voltage direct current (HVDC) is preferred in which transmission losses are minimised.

(c) Utilization - In the beginning, the use of electricity was mainly for battery charging, lighting, heating, gramophone etc. Since, then very large number of usages of electricity have been developed in all the sectors, viz. domestic, commercial, industrial, irrigation etc.

III DEVELOPMENT OF ELECTRIC POWER SYSTEMS

The evolution of electric system is a result of dedicated efforts of the scientists and engineers. Since early civilization static electricity and magnetism were experienced but they could not be distinguish as two different entities. A Greek philosopher Thales of Miletus around 600 BC discovered the phenomena of attraction when amber was rubbed with cloth. It was due to static electricity. The gradually acquired knowledge of magnetism, electricity and the interaction between them led to revolutionary inventions.

The history of historical developments in generation and transmission technologies and their usages are given next:

- 1492 - Christopher Columbus, an Italian Navigator discovered variation in declination of compass needle around the globe.
- 1729 - Stephen Gray, a British chemist, experimentally discovered electric conduction and insulation.
- 1733 - Charles Francois, French, discovered two types of electric charges, named positive and negative. He established that similar charges repel each other and opposite charges attract.

- 1752 - Benjamin Franklin, USA proved that electric charges and lightning were the same. He invented lightning rod for protection of buildings from lightning strikes.
- 1800 - First electric battery was invented by Alessandro Volta, an Italian. The unit of electric potential is named 'Volt' in his honour.
- 1808 - Humphry Davy, a British chemist invented an 'arc lamp'. The 4-inch arc was created between carbon rods that glowed when electric power was supplied by a battery.
- 1820 - Independent experiments conducted by Hans Christian Oersted - a Danish, A.M. Ampere – a French Physicist, and a French physicist Francois Arago. It established the relationship between electricity and magnetism.
- 1820 - Ampere developed a formula, known as Ampere's law, to calculate magnetic field strength when an electric current flows through a conductor.
- 1821 - The first electric motor was invented by Michael Faraday, a British.
- 1826 - Georg Ohm, a German physicist, defined the relationship between power, voltage, current and resistance in 'Ohm's Law'. The unit of resistance is named 'Ohm' in his honour.
- 1831 - Michael Faraday, a British proved that electromotive force (EMF) is induced by changing electromagnetic field. Faraday's experiments demonstrated working of an electric generator.
- 1832 - Based on Faraday's principles, a French instrument maker Hippolyte Pixii built the first 'dynamo' capable of delivering power to industry.

Fig. 1 Michael Faraday, A great scientist [3]

- 1833 - Russian physicist Heinrich Lenz formulated Lenz's law for electromagnetism that upholds the principle of conservation of energy.
- 1835 - Joseph Henry, USA invented an electromagnetic relay.
- 1837 - Thomas Davenport, USA invented the electric motor, an invention that is used in most electrical appliances.
- 1839 - Sir William Robert Grove, a British developed the first fuel cell, a device that produces electrical energy by combining hydrogen and oxygen.
- 1841 - James Prescott Joule, a British showed that energy is conserved in current flowing electrical circuits, thermal heating, and chemical transformations. The unit of thermal energy, 'Joule', was named after him.
- 1853 - William Thomson, a British mathematically formulated R-L-C circuit.
- 1860s - James Clerk Maxwell, a Scottish published mathematical theory of electromagnetic fields. His four equations unified magnetism, electricity and light which led to the invention of electric power, radios, television, and communication.
- 1876 - Charles F. Brush, Ohio, USA invented the 'open coil' dynamo that could produce a steady electric current.
- 1878 - Joseph Swan, a British invented the first incandescent light bulb. His light bulb burned out quickly.
- 1878 - Charles Brush developed an arc lamp that could be powered by a generator.
- 1878 - Edison Electric Light Co. was founded in New York by Thomas Alva Edison.
- 1879 - Thomas Edison, USA invented an incandescent bulb and continued experiments to extend its life.

- 1879 - Electric lights (Brush arc lamps) were first used for street lighting, in Cleveland, Ohio.
- 1879 - California Electric Light Company Inc., San Francisco: the first company to sell electricity to public. The company supplied power to arc light lamps.

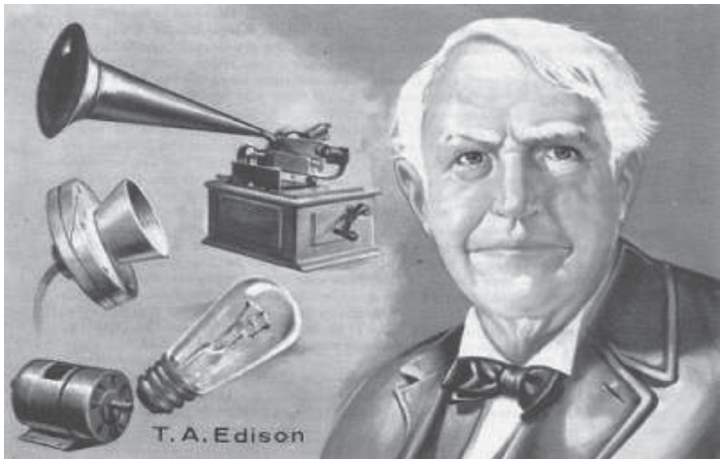

Fig. 2 Thomas Alva Edison: A great scientist [4]

- 1882 - Coal fired power plant: Pearl Street Station, Manhattan, New York built by Edison Illuminating Company was the first electric power plant of the world. The station was powered by custom-made Porter-Allen high-speed steam engines designed to provide 175 HP at 700 rpm. It was the first **cogeneration** power plant also as the steam was supplied to the local manufacturers and warming the nearby buildings in the same block. It was a direct current (DC) power system and could supply power to light about 500 customers.
- 1882 - The first hydroelectric station of the world: 1 x 12.5 kW Vulcan Street Plant on Fox River was commissioned on 30th September in Appleton, Wisconsin, USA.
- 1882 - First 2 kV, 57 km long DC transmission line between Munich-Miesbach was commissioned.
- 1883 - Nikola Tesla, a Serbian-American invented the 'Tesla coil'. It is a resonant transformer circuit which produced high-voltage, low-current, high frequency alternating-current.
- 1884 - Nikola Tesla invented an electric alternator that produced alternating current (AC).
- 1884 - Steam turbine generator for bulk power generation was invented by Sir Charles Algernon Parsons.
- 1886 - William Stanley, USA developed first practical transformer which spurred the development of AC power. He also developed an improved electric meter.
- 1888 - Nikola Tesla for the first time demonstrated complete 'poly-phase' electrical system of power generation. Westinghouse Electric Company, USA obtained the patent rights of AC system.
- 1891 - First 3-phase AC power transmission line was commissioned between Lauffen and Frankfurt, Germany.
- 1893 - The Westinghouse Electric Company used an alternating current (AC) system to light the Chicago World's Fair.
- 1893 - A 22 mile (35 km) AC power line was commissioned to transmit electric power from Folsom Powerhouse in California to Sacramento.
- 1896 - First power line, 11 kV, 3-phase, 20 mile (32 km) transmission line was commissioned between Niagara Falls to Buffalo, New York.
- 1897 - India's first hydroelectric power station: 2 x 65 kW Sidropong Hydroelectric Power Station, Darjeeling, was commissioned.
- 1899 - India's first thermal power project: Emambagh Lane was commissioned (The Calcutta Electric Supply Corporation Limited).

Fig.3 Hydro power station at Darjeeling [5]

- 5-MW turbine for Fisk St. Station, Chicago, USA was commissioned.
- 1902 - World's longest and highest voltage transmission line: 50 kV, 136 km from Shawinigan Power Station to Montreal was commissioned.
- 1909 - First pumped storage plant was commissioned in Switzerland.
- 1912 - First 110 kV-overhead power transmission line was commissioned.
- 1921 - Lakeside Power Plant in Wisconsin became the world's first power plant to burn only pulverized coal.
- 1923 - World's first 220 kV transmission line was commissioned between hydroelectric plants in the Sierra Nevada to the San Francisco Bay Area.
- 1923 - Big Creek – Los Angeles lines were upgraded to the 220 kV.
- 1925 - Peat fired power plant: 1,500 MW Shatura, Russia, the highest capacity in the world was commissioned.
- 1936 - Highest steam temperature of 900 degrees Fahrenheit was attained in early 1920s.
- 1936 - Boulder (Hoover) Dam was completed.
- 1936 - A 287 kV, 266 miles (428 km) transmission line was laid to transmit 240 MW power from Hoover Dam to Los Angeles.
- 1938 - Nuclear fission process: discovered by Otto Hahn and Fritz Strassmann, German radio-chemists
- 1939 - First industrial gas turbine: 4 MW was commissioned at Neuchatel, Switzerland. It was manufactured by Brown Boveri.
- 1942 - World's first nuclear fission reactor with controlled chain reaction was designed and developed by Enrico Fermi in USA.
- 1953 - First 345 kV, 3-phase AC transmission line was commissioned by American Electric Power, USA.
- 1954 - World's first Obninsk nuclear 5 MWe reactor supplied power to grid in Russia on 27 June.
- 1954 - First high voltage direct current submarine cable transmission in Sweden (20 MW, 100 kV, 96 km) between Vastervik and Yagne on Gotland island.
- 1957 - Shippingport Atomic Power Station in Pennsylvania became the first nuclear power plant to provide electricity to customers in USA.
- 1967 - Highest transmission voltage: 765 kV line was commissioned in Russia, USA and Canada.
- 1973 - Oil shale fired power plant: 1,615 MW, the largest capacity in the world was commissioned in Estonia, Europe.
- 1977 - Nuclear power plant: 6384 MW, the largest in the world was commissioned at Bruce, Canada.
- 1979 - Run-of-the river power plant: 2,620 MW, the largest in the world was commissioned at Chief Joseph, USA.
- 1982 - First 1,150 kV transmission line between Elektrostal and power station at Ekibastuz, Soviet Union was commissioned.
- 1985 - Pumped Storage hydro power plant: 3,003 MW Bath County, USA, the largest in the world commissioned
- 1987 - Coal fired power plant: 4,760 MW Vindhyachal, Madhya Pradesh, the largest in India was commissioned
- 1988 - Natural gas power plant: 5,597 MW Surgut-2, Russia, the largest in the world commissioned
- 1992 - Coal fired power plant, 5,500 MW Taichung, Taiwan, the largest in the world was commissioned.
- 1999 - First 1,000 kV transmission line with double circuit between Kita and Iwaki, Japan.

- 1999 - Oil refinery: 1,97,000 m^3/day, Jamnagar, India, the World's largest commissioned
- 2012 - Hydro power plant: 22,500 MW, Three Gorges, China, the largest in world commissioned
- 2013 - Concentrated solar thermal generating system: 377 MW, Carolina, South Mojave desert. Ivanpah, California, the largest in the world commissioned
- 2013 - HVDC line: 600 kV, 7.1 GW, 2385 km, Rio Madeira transmission link, Brazil, the longest in the world
- 2014 - Oil fired power plant: 5,600 MW and desalination complex at Shoaiba in Saudi Arabia, world's largest commissioned
- 2014 - Zero emission coal power plants: 229 MW GutureGen 2.0 Illinois, USA, the first in the world is under construction (retrofitting the old Meredosia Power Station).

IV OIL SHOCKS AND CLIMATE CHANGE

An oil embargo in 1973 imposed by members of the Organization of Arab Petroleum Exporting Countries (OAPEC) led to fuel shortages and sky-high prices. In the wake of oil shocks, self-sufficiency in energy was identified as the major driver for the development and adoption of new and renewable sources of energy. It led to the formation of a Commission for Additional Sources of Energy (CASE) under the Department of Science & Technology in March 1981. A new department, named Department of Non-Conventional Energy Sources (DNES) was created in 1982. In 1992, a new ministry named, 'Ministry of Non-Conventional Energy Sources' was formed which was re-named as the Ministry of New and Renewable Energy in October 2006.

Climate change is a threat to sustainable development. Increasing temperatures, rising sea levels and frequent weather extremes have become a global and regular phenomenon. Rapidly changing climate puts many coastal areas, food security, human health and ecosystems at risk and may intensify further. To avoid such devastating consequences, the international community has committed itself to limit the mean global temperature rise to 2° C above pre-industrial levels. In agriculture sector, methane and nitrous oxide are emitted which have 25 and 298 times warming potential than carbon dioxide. Natural sources of GHG emission are forest clearing and waste decay in landfills. A relation amongst energy, land and climate is depicted in Figure 4.

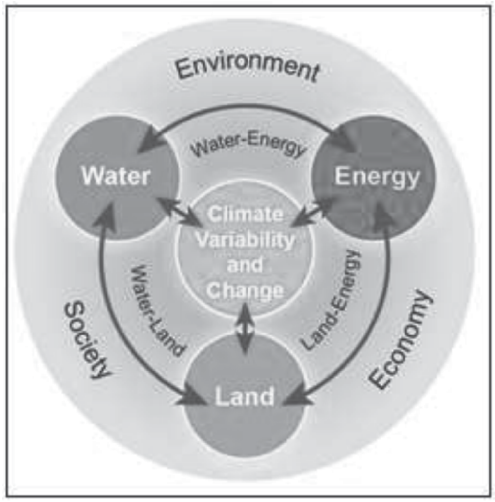

Fig.4 Energy, water, land and climate [6]

V RENEWABLE SOURCES OF ENERGY

The trends in the usage of energy sources have been changing since the beginning of the human civilization. Shift in the usage of energy sources is directly linked with the economy and technological developments. The trend has been to adopt the sources available locally with higher energy density.

The trend in the 21st century is undergoing major shifts in energy sources. The pace of fossil fuel based power generation is subsiding with a focus on efficient 'clean coal' technologies whereas the share of renewable sources of energy is picking-up rapidly.

Sun is the ultimate source of energy for earth. Sun is a star and is powered by the fusion reaction of hydrogen isotopes taking place in the sun and forming the heavier atoms. In the fusion process, hydrogen atoms combine to form helium atoms and release huge amount of energy. The fusion reaction continues till fusion material gets exhausted. After all the hydrogen atoms are used up, the fusion of helium atoms starts. The solar energy is radiated in all directions in the forms of heat, visible light and UV radiations. Even after travelling hundreds of kilometres through atmosphere, solar radiation reaches earth with adequate energy. The average solar insolation entering the atmosphere is 1,366 W/m^2. The major portion of the solar radiation is absorbed by earth, clouds, and atmosphere whereas remaining is reflected back. The average insolation that reaches earth's surface is 684 W/m^2.

The renewable sources of energy are direct (solar heat and light) and indirect (wind, water, etc.) which are originated by the solar energy. The solar energy warms the earth's surface and oceans and causes weather patterns, air flow, and ocean currents. The evaporation of water caused by solar heat energy initiates the water cycle causing rainfall. The potential energy of the stored water in reservoirs is converted into electrical energy in a hydroelectric power plant.

(a) Water power and wind power - The watermill was invented about 2,500 years ago. Using watermills, men managed to master the water power to produce flour, oil, tanning of leather, smelting of iron, sawing the wood, and so on. Later in the first century AD, windmill was invented and was used for various applications such as milling (grinding), rolling, or hammering. These processes were used in the manufacture of paper, textiles, rolling, wire drawing, and metal products.

(b) Biomass - During evolution of human civilization, wild grains were collected and eaten. Agriculture was a revolutionary milestone in the history of mankind. Agriculture began in different parts of the world independently and included diverse crops. The food grains like wheat, barley, peas, vetch, lentils, chick peas, rice, and flax were cultivated initially. The cultivation of sugarcane, sorghum, bananas, cotton, and some root vegetables were developed later.

The agriculture resulted in food security and paved the way for permanent human settlements. The animals were used for agriculture also and hence, domestication of animals increased. The agricultural wastes are the main sources of biomass which are used for power generation. Similarly, animal waste is an important source of biogas for cooking and power generation.

VI EVOLUTION OF RENEWABLE ENERGY: PAST AND PRESENT

The evolution of electrical engineering and electrical power system are a result of dedicated efforts of the scientists and engineers. Since early civilization static electricity and magnetism were experience but they could not distinguish between the two. A Greek scientist around 600 BC discovered the phenomena of attraction when amber was rubbed with cloth. It was due to static electricity. The gradually acquired knowledge of magnetism, electricity and the interaction between them led to revolutionary inventions.

The landmark achievements in electric power generation from renewable sources of energy are given next:

- 1888 - The first wind turbine to generate electricity of 12 kW was developed at Cleveland, Ohio, USA to charge the batteries.
- 1904 - World's first geothermal power plant was commissioned at Larderello, Italy.
- 1921 - Geothermal power plant: 1517 MW, The Geysers, California, USA, the largest in the world was commissioned.
- 1974 - Solar Photo Voltaic cell for harnessing light energy of sun was developed by Joseph Lindmayer, USA.
- 1980 - The first wind farm of the world with 20 turbines each 30 kW was commissioned in New Hampshire, England.
- 1981 - Solar One, commissioned first large scale, 10 MW pilot solar thermal power plant in Daggett, California.
- 2001 - Biomass power station: 265 MW Alholmens, Finland, the world's largest commissioned
- 2008 - Wave power plant: 2.25 MW Agucadoura Power Plant, Portugal, the largest in the world
- 2008 - The largest onshore wind park with the capacity of 1500 MW was commissioned at Muppandal, Tamil Nadu.
- 2011 - Tidal power plant: 254 MW Sihwa Lake, South Korea, the largest in the world was commissioned
- 2011 - Solar PV Concentrated power plant: 60 MW Golmud-2, China, the largest in the world
- 2013 - Concentrated solar thermal generating system: 377 MW, Carolina, South Mojave desert. Ivanpah, California, the largest in the world commissioned
- 2014 - Offshore wind farm: 630 MW London Array, United Kingdom, the largest in the world commissioned

- 2015 - OTEC (Ocean Thermal Energy Converter) power plant: 100 kW, Hawai, USA, the largest in the world

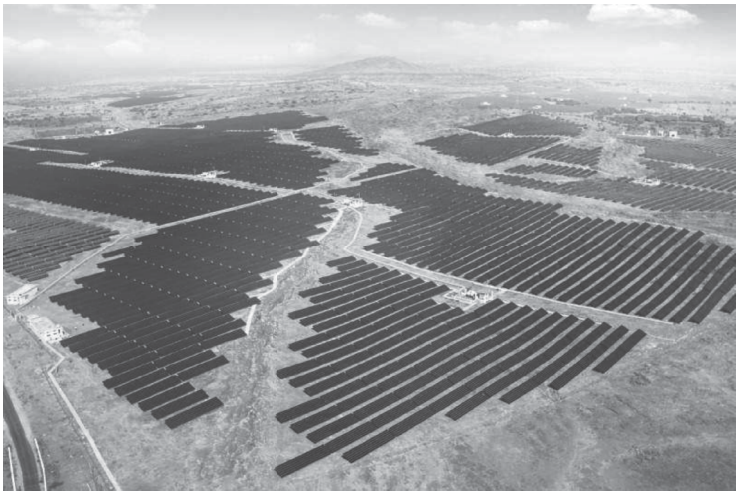

Fig. 4 Largest solar power plant of the world at Bhadla, Rajasthan [7]

- 2016 - Largest unit rating wind turbine: 8 MW of MHI Vestas model V164-8.0 MW for offshore is the largest unit rating turbine in operation. It has a 164 m rotor diameter and a hub height of 138 m. Two turbines were installed in Esbjerg, Denmark.
- 2016 - Solar PV Power Plant, 1547 MW Tengger Desert Solar Park, Zhongbei, Ningxia, China commissioned, the largest in the world.
- 2017 - The largest capacity offshore floating wind farm of the world rated 30 MW was commissioned at Hywind Project, Scotland.
- 2018 - World's largest onshore wind park with present installed power capacity of 7,965 MW (to be expanded to the planned capacity of 20,000 MW) was set-up in Gansu, China
- 2018 - Walney Extension Wind farm was set up which is world's largest offshore wind farm. It comprises of 87 turbines (40×8.25MW MHIVestas+47×7MW Siemens-Gamesa) spread over 145 km^2 in Irish Sea, North-West coast, England.
- 2019 - Onshore Wind Park with around 8,000 MW at Gansu, China is the largest in the world. The ultimate planned capacity is 20,000 MW.
- 2019 - World's largest MHI-Vestas make wind turbine model V164-9.5MW, 9.5 MW was commissioned in January 2020 in the 209 MW offshore wind power project at Northwester-2, Belgium.
- 2020 - Hornsea One is world's largest offshore wind farm with the capacity of 1218 MW. It comprises of 174 floating foundation turbines (each 7 MW), Siemens-Gamesa model SWT-7.0-154 spread over 407 km^2 Sea at 20-40 m depth. It is off the coast of Yorkshire, southern North Sea, U.K.
- 2020 - Solar PV Power Plant in the world, 2245 MW Bhadla, Jodhpur district, Rajasthan, India commissioned.

Table No. 3
Installed renewable power capacity (June 2020) [8]

GRID-INTERACTIVE POWER (MW)	
Wind power	37829.55
Solar power –ground mounted	32305.15
Solar power –roof top	2817.15
Small hydro power	4688.16
Biomass (bagasse) cogeneration	9200..50
Biomass (non-bagasse) cogeneration/captive power	679.81
Waste to power	148.84
Total	**87669.16**
OFF-GRID/CAPTIVE POWER (MW0	
Waste to energy	200.5
SPV system	980.8
Total	**1181.3**

VII EMERGING TECHNOLOGIES

Coal fired power generation is mainly responsible for climate change but it cannot be stopped suddenly but could be gradually phased out. Clean coal technology aims to reduce GHG emissions by adopting well developed super-critical technology for generation and technology to capture the SO_X and NO_X gases.

The nuclear fusion process and technology are being developed in which lighter atoms join to form heavier atom and release huge amount of energy. The fusion is quite safe and being developed jointly by few countries including India. A 500 MW experimental fusion reactor is being developed for installation in France.

In the Indian context, fast breeder reactor is very important as its fuel, thorium' is abundantly available indigenously. A 500 MW indigenously developed prototype fast breeder reactor 'Bhavini' has been installed and is under commissioning at Kalpakkam in Tamil Nadu. It will operate with uranium as a nuclear fuel and its experience will be utilised in developing thorium based fast breeder reactor.

Hydrogen has great potential as a source of energy but safety hazards in transportation and storage are the main hurdles. Once these hurdles are overcome, hydrogen will play vital role in transportation sector with the use of fuel cells instead of batteries and small power generating stations. The fuel cells overcome the drawback of batteries of low energy storage capacity.

Extraction of bio-diesel from ethanol obtained from sugarcane bagasse and biodiesel from Jatropha, Karanj, Pine etc. are likely to become an important source of green energy in transport sector.

The future trend is for hybrid wind-solar power plants with energy storage for optimum utilization of land and also to take care of the variability of solar and wind resources to enhance reliability of power supply.

In order to capture high wind at heights, flying turbines are being developed which do not need tower and yawing mechanism. However, several challenges are to be overcome.

VIII CONCLUSION

The paper discussed the conventional sources of energy viz, fossil fuels, hydro and nuclear for generation of electric power and their growth in India along with the historical development of electric power system. The paper explains as to how the depleting fossil fuel deposits and serious climate change concerns due to global warming caused by the green house gases emissions on burning of fossil fuels have forced to adopt the environment friendly renewable sources of energy. The paper summarises the evolution of renewable sources of energy. The futuristic renewable energy technologies have been briefly mentioned. Hydropower is eco-friendly and has special significance as it s a part of water management.

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