Gas Turbines- Current Scenario & Future Prospects in India

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Abstract: The gas turbine is the most versatile item of turbo machinery now days. Today, when we talk about the most widely used power generation, we think about the gas turbine technologies because these are the most widely used power generation technologies now a days. Gas turbine could play a key role in future power generation addressing issues of producing clean, efficient and fuel flexible electric power. Gas turbines are the parts of the internal combustion engine in which burning of the air-fuel mixture produces hot gases to run the turbine which therefore produces power. In gas turbines, combustion occurs continuously as compare to the reciprocating internal combustion engines in which it occurs intermittently. Currently the total design capacity of gas turbine power plants in INDIA is about 26699.9MW which is increased by 51.3% as compare to the year 2011 in which it is 13711.27 MW and most of these are installed in Gujarat, Andhra Pradesh, Maharashtra, Tripura, Assam, Uttar Pradesh, West Bengal, Tamil Nadu, Rajasthan, Pondicherry, Karnataka, Kerala, Haryana, Delhi. Hence, in India the gas turbine plays an important role to produce energy3. If we use different types of materials for turbine blades, turbine wheels, compressor blades, materials in combustor, coating materials then we can make the gas turbine power plants more efficient, reliable, and cost effective.

Keywords: Gas Turbine, History, Working Principle, It's scenario in India

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Introduction

When we talk about India's power generation, it is considerably inclined towards power generation which is coal based. As we know that the coal reserves are limited to their natural availability and expansion of coal mining is limited in India. It is the prediction that Indian coal sector will face substantial shortfall in the production of coal in the future and also the use of the coal increases the environmental pollution. When we talk about the gas based power plants, natural gas is a clean fuel as compared to the coal and can be used more efficiently in power generation. Gas based power plants are increasing more and more now a days and government of India is also encouraging gas based power plants because there are many disadvantages of coal based power plants Such as:

- Maintenance and operating costs are high.
- Large quantity of water is required.
- Great difficulty is experienced in coal handling.
- Presence of smoke due to smoke and heat in the plant.
- Unavailability of good quality of coal.
- Problem of ash removing.
- Maximum of heat energy lost.

Therefore, for these reasons and for environmental considerations Indian government is trying to establish more and more gas turbine power plants. In India the production of natural gas is at present at the level of around 132.83 million metric standard cubic meters per day.

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The main producers or suppliers for natural gas in India are Oil &Natural Gas Corporation Limited, JVs of Tapti, Panna-Mukta, Ravva, and Reliance Industries Limited[4]. Hence due to the limitations on the use of the coal for power generation because of its environmental consequences, quality and supply constraints gas will play an increasingly very important role in the power generation sector of India. According to Central Electricity Authority of India as on 30 June, 2011 the total installed capacity of gas based power plants in India is about 13711.27MW which contributes about 10% of the total installed capacity and GAIL is the main source of fuel for most of these power plants.

History of Gas Turbines

1791- In this year the first patent for gas turbine was proposed by John Barber of United Kingdom.

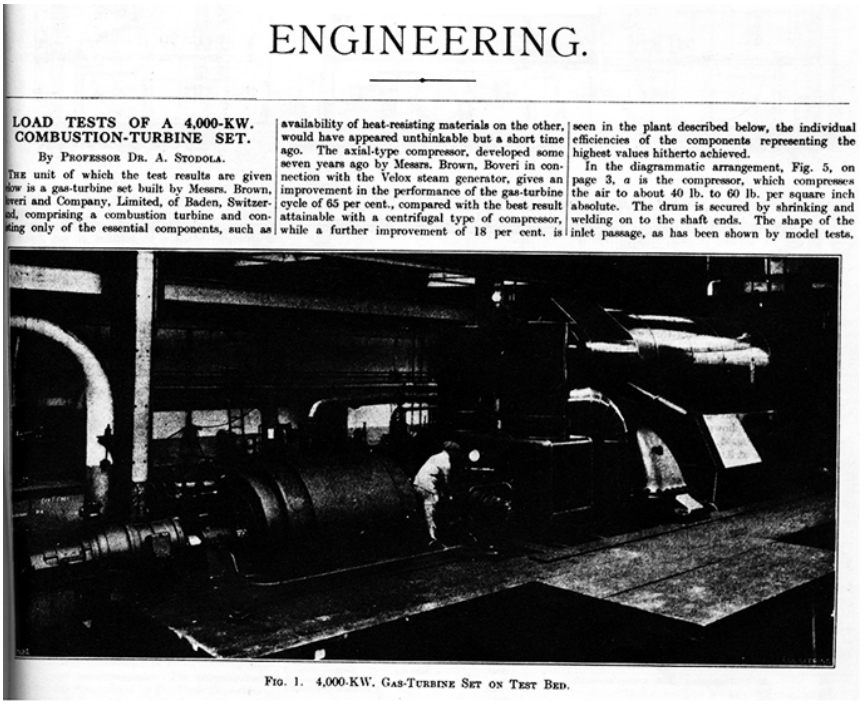
1904- In this year the gas turbine project was done unsuccessfully by Franz Stolze in Berlin.

1906- Gas turbine was developed by Armengaud Lemale in France which comprises of centrifugal compressor and it is of no useful power.

1910- The first gas turbine featuring combustion was discovered of 150 KW (const. volume combustion) by Holzwarth.

1923- First exhaust gas turbo charger was developed to increase the power of diesel engine.

1939- World's first gas turbine for power generation by Brown Boveri Company, Neuchatel, Switzerland (Velox Burner, aerodynamics by Stodola), (figure-1)



ENGINEERING.

LOAD TESTS OF A 4,000-KW. COMBUSTION-TURBINE SET.

By Professor Dr. A. Stodola.

The unit of which the test results are given ow is a gas-turbine set built by Messrs. Brown, veri and Company, Limited, of Baden, Switzer-d, comprising a combustion turbine and con-ting only of the essential components, such as availability of heat-resisting materials on the other, would have appeared unthinkable but a short time ago. The axial-type compressor, developed some seven years ago by Messrs. Brown, Boveri in connection with the Velox steam generator, gives an improvement in the performance of the gas-turbine cycle of 65 per cent., compared with the best result attainable with a centrifugal type of compressor, while a further improvement of 18 per cent. is seen in the plant described below, the individual efficiencies of the components representing the highest values hitherto achieved.

In the diagrammatic arrangement, Fig. 5, on page 3, *a* is the compressor, which compresses the air to about 40 lb. to 60 lb. per square inch absolute. The drum is secured by shrinking and welding on to the shaft ends. The shape of the inlet passage, as has been shown by model tests,

Fig. 1. 4,000-KW. Gas-Turbine Set on Test Bed.

Fig- 1.World's first industrial gas turbine-1939*

*From the paper collection of Eddie Taylor, the first director of MIT GTL (1947–1969)

Paguthan Combined Cycle Power Plant is one of the India's first independent power projects which is of 655 MW gas based combined cycle power plant. Its primary fuel is natural gas and secondary fuel is Naphtha and also it contains the generating units of 3*138 MW of gas turbines and 1×241 of steam turbine. It is located 10 kms from Bharuch in the state of Gujarat[16].

Definition & Working Principle

What is meant by the term 'Gas Turbine'- a proper definition is that it is "a mechanical device operating a thermodynamic cycle in which the working fluid remains in the gaseous phase throughout. The flow processes in the cycle must be substantially continuous and not intermittent."

There are 3 primary sections of the gas turbine- compressor, combustion chamber, and turbine (figure-2). There are 2 types of compressors axial flow and centrifugal flow. Axial flow compressors are most common in use because they have higher flow rates and efficiency and centrifugal compressors are most used in the small engines where simplicity, ruggedness outweigh its properties of less pressure ratio than that developed by axial compressor. The compressed air is mixed with the fuel injected through nozzle and is introduced directly into the combustion chamber where the mixture ignites under constant pressure and then introduced into the turbine where the mixture expands and provides rotation to the shaft which drives the compressor to draw more air in and compress it to sustain continuous combustion. The remaining shaft power is used to drive the generator through which the electricity is produced.

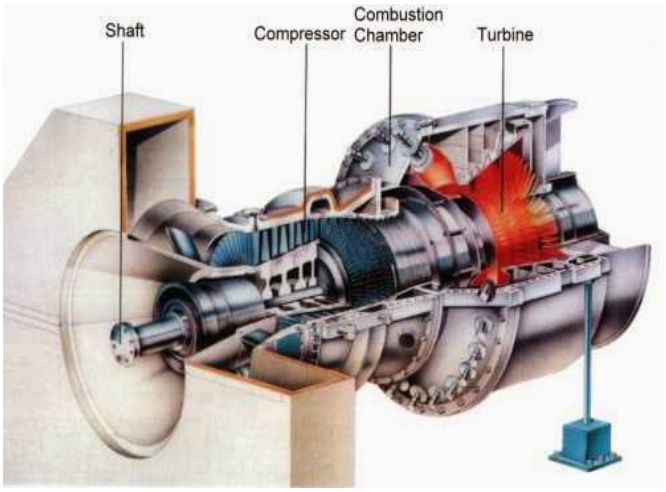


Fig- 2.Turbine engine operation

The thermodynamic process which is used in the gas turbine is Brayton Cycle, (ref. fig.-3). Gas turbines for power generation can be either industrial which is of heavy frame or can be of aero derivative. Aero derivative gas turbines have higher initial cost and more sensitive to compressor inlet temperatures as compared to the industrial gas turbines. There are many parameters on which efficiency of gas turbine depends like at higher temperatures the efficiency is very high[1, 2]. When we use gas turbine power plant with simple cycle its efficiency is about 30 to 40% because there is the large amount of heat remains in the exhaust gas whereas when we use the gas turbine power plant with combined cycle its efficiency is about 55-60% because in this configuration, it recovers the waste heat to produce more work but there are some disadvantages also with combined cycle gas turbine such as its longer startup time, ramp rate to full load, and purge requirements of explosions and fires.

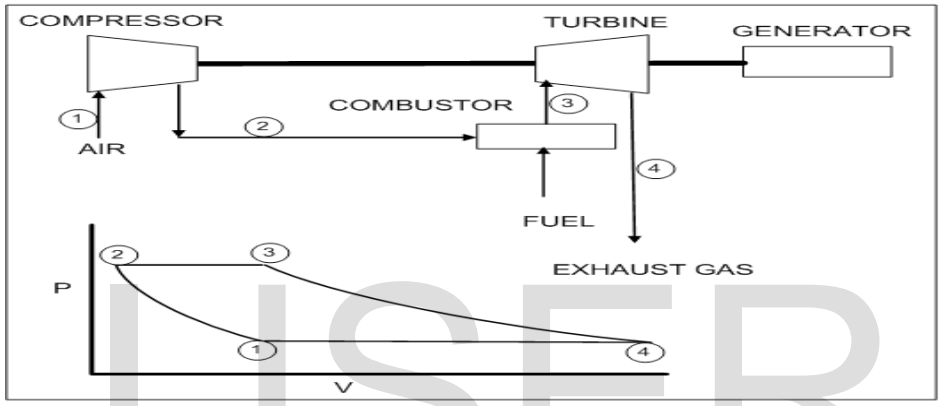


Fig- 3.Gas Turbine based on Brayton Cycle

The term combined cycle means it comprises a steam turbine, gas turbine and a heat recovery generating system where the heat of the exhaust gas is used to produce heat and a generator. The shaft power of the gas turbine and that developed from the steam turbine both run the generator to produce electricity[8]. Combined cycle is the form of cogeneration which means that generation of both heat and work. Combined cycle provides flexible features like low installed cost, high thermal efficiency, flexibility of fuel, short installation cycle, and high reliability.

Advantages of Gas turbines over Power Plants (Diesel and Thermal Power Plants)

- The work developed per kg is large.
- Less vibration due to perfect balancing.
- Capital cost is considerably less.
- The running speed of the turbine is large approximately (40000r.p.m to100000r.p.m) as compare to thermal power plants (1000 r.p.m to 2000 r.p.m) such as diesel power plants.
- Ignition and lubrication systems are simple.
- No ash handling problem.

- Gas turbines can be built relatively quicker.
- Above 550 degree centigrade, the thermal efficiency of the gas plant increases as fast the steam cycle efficiency.
- Storage of fuel is much smaller.
- Because of the low specific weight the gas turbines are particularly suitable for aircrafts.
- Cheaper fuels such as paraffine type, residue oils can be used as compare to diesel power plants.
- Gas turbines plants can be installed anywhere without any difficulty.
- The components of gas turbines can be made very lighter since the pressure used in it are very low approximately 5 bar as compared to the diesel plants which requires pressure around 60 bar.
- The exhaust from the gas turbine is less polluting comparatively since excess of air is used for combustion.

DEMERITS

- With wide operating speeds, the fuel control is comparatively difficult.
- Thermal efficiency of simple turbine cycle is low.
- The gas turbine blades need a special cooling system.
- For the same output the gas turbine produces 5 times the exhaust gases as compare to the other thermal plant.
- Because of the prevalence of high temperature (1000k for blades and 2500k for combustion chamber) and centrifugal force, the life of the combustion chamber and blades is short and small.
- Poor part load efficiency[7].

Applications of Gas Turbine Plants

- To drive generators and supply peak loads in steam, diesel or hydroplants.
- To work as combination plants with conventional steam boilers.
- To supply mechanical drive for auxiliaries.
- Heat recovery feed water heating combustion chamber.

Overview of Energy Consumption

- In 2011, India was the fourth largest energy consumer in the world after China, Russia and U.S.
- In 2013, India has become the third largest energy consumer.
- In 2014, India held nearly about 5.7 billion barrels of proved oil reserves which is mostly in the western part of the country.
- In 2014, India has 47 trillion cubic feet of natural gas reserves located mostly at offshore[6, 11].

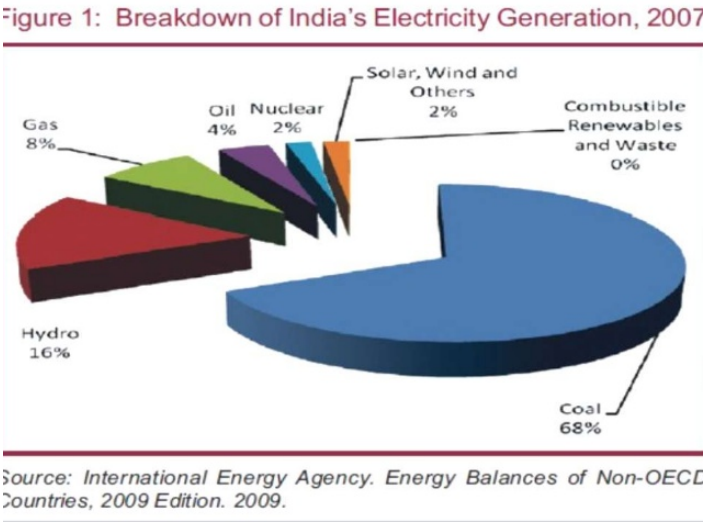


Fig- 4.India's Energy Consumption

Now in 2007, the electricity generation in India is about 68% by coal based thermal power plants, 8% by gas, 16% by hydro power plants and rest of the percentage by oil, nuclear, solar, wind and others (fig.-4)

Now, our country's government promotes the refining sector and India has become the net explorer of petroleum products. India began natural gas pricing reforms and the government has approved the new scheme in which it is working in the sector of natural gas more and more in order to increase the electricity production by gas turbine power plants as the coal production and availability is limited in India and also will become more crucial in the ensuing years[5, 9, 10].

Now, there are the graph shows the energy consumptions by different types of power plants such as coal based, gas based, and others, (fig.-5)

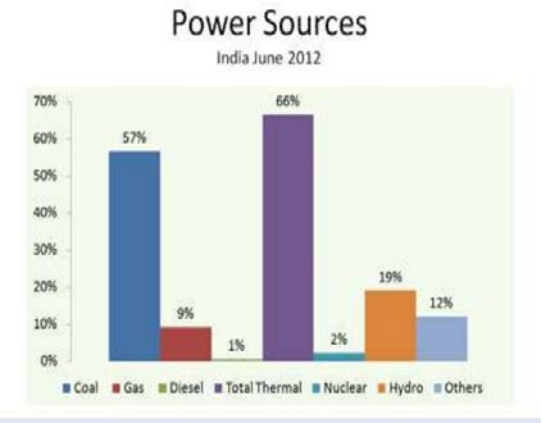
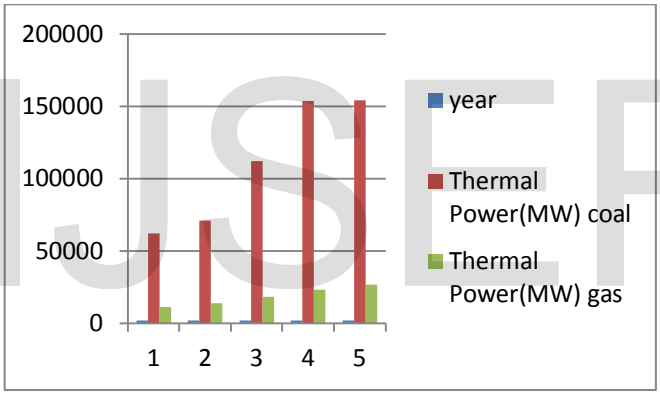


Fig- 5.Power Sources in India

- In terms of fuel, coal fired plants accounts for 56% of India's capacity of producing electricity compared to China's 77%, South Africa's 92%, Australia's 76% and natural gas about 9%[13, 15, 17].
- In India power plants uses .7 kg of the coal per kwh supply to generate the electricity whereas United States uses only .45 kg of fuel. Hence we have to decrease it and built more gas power plants.

year	Thermal Power(MW)	
	Coal	Gas
2002	62131	11163
2007	71121	13692
2012	112022	18381
2014	153571	22971
2015	154170.9	26699.9

TABLE 1: *Sources of electricity in India by installed capacity of coal and natural gas based power plants*



GRAPH-1

From the above graph-1 and table -1, we see India's coal and natural gas based power plants to produce electricity from the year 2002 to 2015.

Conclusion

- Gas turbines could play a key role in future power generation in India as we are focusing towards pollution free or we can say that eco-friendly power plants to produce electricity.
- There are many advantages of using gas turbine as a power plant as compare to other power plants but there are some limitations of gas turbine power plants which has to be overcome such as they are not self-starting, low overall plant efficiency and many more.
- As we see from the latest scenario of India's coal and gas based plants, there is the great increase in the gas based power plants as compare to the coal based power plants between the years of 2014-2015.

- ❖ Al, Ti, Ta, W, Re are the alloys which have been used to increase the levels of strengthening the materials.
- ❖ When the gas turbines are used in cogeneration mode than the efficiency can go up to 60%.

Future Prospects

- ✓ By investigating the advance combustor liners to handle the higher temperatures within the combustor in order to make its lifelong because of the higher temperature combustor life is very short which affects the turbine.
- ✓ By making the combined cycle efficiency with technological advances which includes higher rotor inlet temperature of 1700 degree centigrade or higher blade metal temperature about 1040 degree centigrade.
- ✓ Use materials which have the properties of high stiffness, high tensile strength, high fatigue strength, high resistance to crack propagation. Various alloy used are nickel based alloy, chromium-molybdenum-vanadium alloy, austenitic base alloy and many more. By using coating materials to gas turbine to protect against oxidation, corrosion, and crack propagation.
- ✓ We have to improve the turbine inlet temperature in order to increase the thermal efficiency of the turbine. Thermal efficiency of the gas turbine can be increased by improving the methods of intercooling, reheating, and regeneration.
- ✓ ONGC's mega power project dedicated to nation by our president Mr. Pranab Mukharjee in Tripura. It consists of two units. I unit will generate 363.3 MW and II unit will generate 726.6MW and is expected to operate at the end of 2015. It is the combined cycle gas turbine based mega project.
- ✓ 1500 MW gas power station will be made at Bawana which will fully functional.
- ✓ By using close loop steam cooling system, the firing temperature of the turbines which are high enough can be achieved without increasing combustion temperature and also by using integrated close loop steam cooling system, the amount of chargeable air can be decreased or eliminated for the rotary and stationary airfoils. By doing this, it also increases the few percentage of thermal efficiency of the turbine.
- ✓ By using integrated gasification combustion cycle, the efficiency can be increased very easily. The improvement in efficiency is important as the oil prices are rising and rising of the volatile electricity and also by using Integrated Gasification Combined Cycle with carbon capture and storage technology, we can more drastically reduce the CO_2 emissions.
- ✓ By using the hybrid technology involving fuel cells in gas turbines, the efficiency can be made higher and higher and also by using Ceramic hot gas paths besides compressor or axial flow path can also help in increasing the efficiency of the gas turbine in future.
- ✓ Use of Gas turbine combined cycle (GTCC) is beneficial because in this, heat in exhaust gas when emitted used to produce steam that drives the steam turbine which produces electricity. Without using GTCC, the thermal efficiency is around 40% and by using GTCC the thermal efficiency is around 50-60%.

- ✓ Use of Integrated Gasification Combined Cycle is most beneficial as in this the solid coal is gasified before being fed into the gas turbine which is used to produce energy. Then the exhaust heat is used to generate the electricity by steam turbine and it also helps to restrict the CO_2 and other harmful atmospheric emissions.
- ✓ In future, by using integrated SOLID OXIDE FUEL CELLS with gas turbine and steam turbine in a combined cycle system we can easily reduce the amount of CO_2 emission by approximately 20-30% and increase the thermal efficiency by approximately 70-80%[14].
- ✓ Using IGCC, GTCC, IGCC with carbon capture and storages technologies in future we will have to make sure that in future the turbines in combined cycle need to reach over 65% of efficiency with no emissions to atmosphere and with single cycle need to reach over 40% efficiency[12].
- ✓ Using the bio-fuels obtain from Algae, Butanol, Bio-ethanol, Biodiesel can be used in the gas turbine to make it more and more eco-friendly and decrease its cost.

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