

Investigation Various Types of Power Plants from Economic, Technical and Environmental Aspects

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Abstract

Energy plays a special role in economic growth, social welfare, improving the quality of life and security of a society. Power plants are one of the world's major energy suppliers, a set of industrial facilities that use other energy sources to generate electricity. Power plants use other forms of energy to generate electricity, such as fossil fuel energy, chemical energy, renewable energy, nuclear energy, and gravitational potential energy. There are different types of power plants, the main of which are: steam power plant, gas turbine power plant, combined cycle power plant; nuclear power plant, hydroelectric power plant and wind power plant, in this study, their advantages and disadvantages from economic, technical and environmental aspects were compared and analyzed. In general, the results showed that each of the mentioned power plants has its own characteristics, so their selection should be based on technical, economic and environmental conditions in each city or country. For example, among these power plants, although hydropower plants have the highest efficiency (about %80) and are environmentally friendly, but their construction cost is high, or combined cycle power plants and nuclear power plants, although relatively good efficiency is about %35, but due to their technological complexity, there are restrictions on their use.

Keywords: Power plant, advantages, disadvantages, economic aspects, efficiency

INTRODUCTION

Energy plays a special role in economic growth, social welfare, improving the quality of life and security of a society. Global research shows that there is a direct relationship between a country's development and the amount of energy it consumes, and therefore the access of developing countries to new types of energy sources is particularly important in order to improve and improve their economic situation. Meanwhile, electricity is one of the main and underlying factors for the growth and prosperity of industrial, economic and social sectors, so that it can be said that one of the indicators for evaluation and development of countries is the index of increasing electricity generation and distribution capacity. Various power plants and technologies are used to generate electricity [1–3].

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A power plant is a set of industrial facilities that use other energy sources to generate electricity. Power plants use generators to convert energy into other forms, such as fossil fuel energy, chemical energy, renewable energy, nuclear energy, gravitational potential energy, and electrical energy (in fact, these rotary energy machines Convert mechanical to electrical energy).

The history of the power plant dates back to 1878, when Sigmund built it. This power plant has 24 dynamos that are driven by a steam engine that

was used to light the cave. It was an initiative of Thomas Edison, organized and managed by his colleague Edward Johnson. The electricity was supplied at a location that could reach power cables under the railroad without digging the road, which was monopolized by the power company. The first power plant in New York in September 1882, the Pearl Street Power Plant, was built by Edison for lighting on Manhattan Island. Which was destroyed by fire in 1890 [4–7].

There are different types of power plants, the main of which are: steam power plant, gas turbine power plant, combined cycle power plant; nuclear power plant, hydroelectric power plant and wind power plant (Figure 1). The main purpose of this research is to study different types of power plants benefits and advantages from economic, technical and environmental aspects.



Steam power plant



Gas turbine power plant



Combined cycle power plant



Nuclear power plant



Hydroelectric power plant



Wind power plant

Figure 1. The main types of power plants.

Steam Power Plant

The difference between a steam power plant and other power plants is in how steam is generated. Whatever method is used to generate steam, a large amount of heat must be used to operate the steam turbines, which reduces the efficiency of the steam power plant. The thermal efficiency of the steam power plant increases significantly. Therefore, in all places where in addition to electrical energy, a large amount of thermal energy is needed, a steam turbine is used so that the remaining heat can be used after electrical work. In steam turbines, the steam released from the last stage of the turbine is directed by pipes for industrial and thermal uses [8–10].

Ways to increase efficiency and reduce losses in the heating plant:

1. Improve the efficiency of machines and devices by changing their structure and increasing their power.
2. Reduce the internal consumption of the power plant by using the machines and devices correctly.
3. Reduce heat loss by recovering heat from distilled water and turbine steam losses.
4. Improve thermal efficiency.

Thermal efficiency can be increased as follows:

- a. Reduce the pressure inside the condenser
- b. Raising the pressure and temperature of fresh steam
- c. Frequent heating of steam
- d. Preheating of feed water by steam drawn from the turbine

The disadvantage of this type of power plant is the production of abundant carbon dioxide, nitrogen oxides, sulfur, etc., which are left in the ground and pollute the environment. The maximum efficiency of this power plant is 41%, which can be achieved with all available facilities today [11–14].

Gas Turbine Power Plant

A gas power plant is a power plant that operates on the basis of gas cycle and thermal cycles, ie fluid is the cause of gaseous work and the transfer and conversion of energy is gaseous like air, but in steam power plants it is the transfer of liquid vapor [15–18]. Gas power plants can also be built from 1 Mw up to over 100 Mw.

Advantage of gas power plant:

1. Its simplicity: all equipment is mounted on one shaft.
2. Cheap: because its equipment is low.
3. Installation is fast.
4. It is small: In oil rigs, which require a lot of electricity generation, gas power plants should be used to take up less space.
5. Does not need water: In the main cycle of the power plant, water is not needed, but in ancillary equipment, for example, to cool the hydrogen used to cool the generator at high speeds, water is needed.
6. The commissioning of this power plant is fast.

A steam power plant should not be turned off after commissioning, but a gas power plant is such that it can be turned on in the morning and turned off late at night. Also, a gas power plant is very suitable for a peak load, but a steam power plant is not suitable for a peak load.

Disadvantages:

1. Environmental pollution
2. Short life: Turbine and compressor wear
3. High depreciation: turbine blade, compressor blade

4. Low efficiency

Reasons for low efficiency:

- a. Exhaust smoke with high temperature
 - b. About 1.3 turbine power is spent on compressor. Therefore, it is not allowed for long-term use in a gas power plant because the cost of fuel consumption is expensive.
5. It is not possible to use solid fuel. (Like coal) because the rotor blades are removed immediately.

If the operation time is more than 2000 hours per year, steam power plant, if the operation time is more than 5000 hours per year, hydropower plant is used. In Iran, the main electricity consumption is domestic electricity (60%) and about 30% is industrial electricity. As a result, 50% of the country's power plants must be turned on every night; Therefore, most of our electricity generation should be of the gas power plant type. Gas power plants can also be used in factories due to their cheapness. Gas power plants are also used in nuclear power plants and are used to cool the reactor, which provides hot and compressed air to the gas power plant, which supplies electricity to the nuclear power plant.

In gas power plants, they adopt methods to increase efficiency.

1. With the exhaust smoke, it heats the air entering the room: the cycle is more complicated, but the efficiency goes up.
2. Using a two-stage compressor

The highest efficiency is about 35% when the power plant has a two-stage compressor, a two-stage turbine and a preheater.

Gas turbines play an important role in energy production in today's era, so many studies have been done to optimize various components such as air intake, turbine and compressor, combustion chamber, atomizers [19–23]. In addition, gas turbines are widely used in other industries such as aerospace industries, which has made them doubly important [24–31].

Combined Cycle Power Plant

One of the most widely used power plants in our country are combined cycle power plants: This power plant is a combination of two thermal and gas power plants [32–34]. A combined cycle power plant is far more efficient than a thermal power plant, and another good feature is that it enters the circuit very quickly! Neka power plant in the north of the Iran-Shahid Rajaei Qazvin power plant-Shazand Arak power plant-Qom power plant is among these power plants. In addition to having high efficiency and power, combined cycle power plants also have other advantages:

1. Flexibility
2. Quick starter
3. Suitability to provide base load and periodic performance
4. High efficiency in a wide range of load changes
5. The possibility of using coal and other fuels

The obvious disadvantage of the hybrid cycle is its complexity, because basically two different types of technology are used in the hybrid cycle.

Hydroelectric power plants, which is one of the combined cycle power plants and is part of strategic power plants, and energy production in this power plant is such that the production of these power plants is never permanent and only depends on the time of water leaving the dam mouth! The production capacity of these power plants is usually low and their only advantage is that they do not need to spend on raw materials economically! And they actually work with water. Due to their constant production, these power plants are usually used to control the network frequency! Combined cycle power plants with an efficiency of more than 50% have the highest efficiency [35, 36].

Nuclear Power Plant

A nuclear power plant is in many ways shared with a fossil fuel power plant. Both require water vapor to run the steam turbine, the only difference being that nuclear power plants use steam reactions instead of fossil fuels.

On the other hand, it can be claimed that the nuclear power plant is the most economical power plant that is being built in the world today. There are other reasons for using a nuclear power plant to generate electricity, the most important of which are the cleanliness of this method, the lack of greenhouse gas emissions and other environmental pollutants. Fossil fuels, such as coal, release significant amounts of pollutants such as carbon and sulfur into the environment, which are harmful to human health. Nuclear energy is extremely efficient compared to other sources of electricity. The only major problem is the provision of equipment and devices for uranium enrichment and its use to generate electricity, and today this technology is more available to industrialized countries. One of the disadvantages of this power plant is that the nuclear power plant is very unfavorable for the production of peak power and should be used only for the production of basic electricity. The efficiency of nuclear power plants is about 35%.

One of the problems of a nuclear power plant is its construction cost, which includes the cost of building a reactor, the cost of security issues, the cost of building mining centers, the cost of building nuclear fuel conversion centers, the cost of building nuclear rehabilitation centers and nuclear storage facilities for nuclear waste. Each nuclear power plant costs an average of \$ 10 billion to \$ 15 billion.

Nuclear power generation costs in 2007 were about \$ 0.0176 per kilowatt hour, compared to \$ 0.0247, \$ 0.0678, and \$ 0.026 for coal, natural gas, and oil, respectively [37–40].

Hydro Power Plant

Hydropower plants use gravity and solar power to generate electricity. Water evaporates due to ambient heat, the main cause of which is the sun, and rises in the atmosphere. It then collapses in the form of rain and snow. Water is poured on the heights and flows in the form of small streams and then larger intestines, and then after passing some distance, its gravitational potential energy is converted into kinetic energy [40–44].

In hydropower plants, either the high state exists naturally, or we create the high state by creating a dam and accumulating water and increasing its height behind the dam.

Today, the use of hydropower plants is the best option to improve the environment and reduce pollution. Hydroelectric power plants have a very high efficiency of about 80%.

In 2015, the hydropower plant generated 16.6% of the world's total electricity and 70% of the total renewable electricity and is expected to grow by about 3.1% per year for the next 25 years.

Hydropower plants are produced in 150 countries around the world. In 2013, the Asia-Pacific region generated 33% of the world's hydropower. China is the world's largest producer of hydropower, generating 920 terawatt hours in 2013, accounting for 16.9% of its domestic electricity consumption.

The cost of hydropower is relatively low, making it a competitive source of renewable electricity.

Among the benefits of hydropower:

1. Use of natural resources.
2. High compatibility with the environment
3. The life of this power plant is long

4. Meeting the major needs of the agricultural sector
5. Environmental reform one of the disadvantages of hydropower plants or something that limits the use of hydropower for energy production is the high cost of facilities, so in developed countries, hydropower plants are used only in special circumstances.

Wind Power Plant

One of the methods of generating electricity in the world is the use of wind; wind power plant has been built for this reason to provide some of the electricity we need. With the development of environmental attitudes and cost-effective strategies in the exploitation of non-renewable energy sources, the use of wind energy has increased compared to other energy sources in many countries around the world. The use of wind turbine technology for the following reasons can be a good choice compared to other renewable energy sources [45–50].

1. No need for water
2. No environmental pollution
3. No need for wind turbine fuel
4. Creating a sustainable energy system
5. Low price of wind turbines compared to other forms of new energy

One of the biggest obstacles to harnessing wind power is its environmental impact. Many people believe that wind turbines are unpleasant in appearance and noisy; Especially because they are located in beautiful areas outside the urban areas, the continuous sound of wind turbine tower turbines is an important issue for those who are close to them. The overall efficiency of this power plant is 33%.

In Figure 2, the efficiency of different types of power plants can be compared:

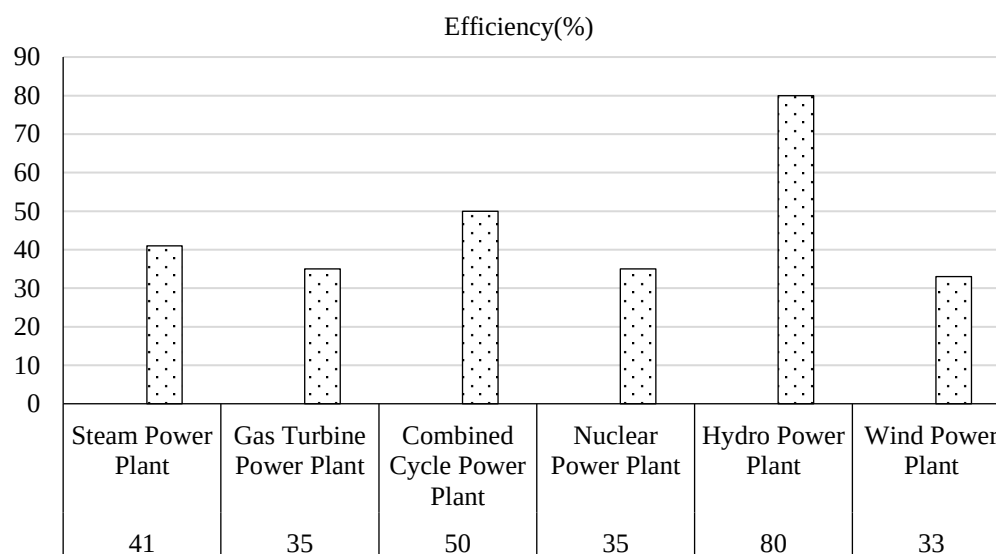


Figure 2. Efficiency of different types of power plants.

CONCLUSION

Energy plays a special role in economic growth, social welfare, improving the quality of life and security of a society. Power plants are one of the main suppliers of energy in the world. There are different types of power plants, the main of which are: steam power plant, gas turbine power plant, combined cycle power plant; Nuclear power plant, hydroelectric power plant and wind power plant. In this study, the advantages and disadvantages of different types of power plants from economic, technical and environmental aspects were compared and analyzed. In general, the results showed that each of the mentioned power plants has its own positive and negative characteristics, so their selection

should be based on technical, economic and environmental conditions in each city or country. For example, among these power plants, although hydropower plants have the highest efficiency and are more environmentally friendly, but their construction cost is high, or combined cycle power plants and nuclear power plants, although they have a relatively good efficiency but due to their technological complexity, their use has limitations.

REFERENCES

1. Chestney, Nina (2021-05-14). "Factbox: Getting out of gas - the sold and scrapped projects". Reuters. Retrieved 2021-11-27.
2. Mohammad Sadegh Vafakhah. (2022). [online] Available at: <http://eng-msv.blogfa.com/>.
3. "What would a world powered entirely by offshore wind look like?". The Economist. 2021-11-04. ISSN 0013-0613. Retrieved 2021-11-27.
4. Thompson, Silvanus Phillips (1888). *Dynamo-electric Machinery: A Manual for Students of Electrotechnics*. London: E. & F. N. Spon. p. 140.
5. "Hydro-electricity restored to historic Northumberland home". BBC News. 27 February 2013.
6. Jack Harris (14 January 1982), "The electricity of Holborn", *New Scientist*.
7. "Data & Statistics". International Energy Agency. Retrieved 25 November 2021.
8. "How electricity is generated - U.S. Energy Information Administration (EIA)".
9. <https://ntrs.nasa.gov/api/citations/19780073904/downloads/19780073904.pdf>.
10. *Fundamentals of Steam Power* by Kenneth Weston, University of Tulsa
11. Babcock & Wilcox Co. (2005). *Steam: Its Generation and Use* (41st ed.). ISBN 0-9634570-0-4.
12. Thomas C. Elliott, Kao Chen, Robert Swanekamp (coauthors) (1997). *Standard Handbook of Powerplant Engineering* (2nd ed.). McGraw-Hill Professional. ISBN 0-07-019435-1.
13. Air Pollution Control Orientation Course from website of the Air Pollution Training Institute.
14. Energy savings in steam systems Archived 2007-09-27 at the Wayback Machine Figure 3a, Layout of surface condenser (scroll to page 11 of 34 pdf pages)
15. Bakken, Lars E et al., p.83-88. "Centenary of the First Gas Turbine to Give Net Power Output: A Tribute to Ægidius Elling". ASME. 2004
16. Aminjan, K. K., Rahmanivahid, P., & Heidari, M. Effects Of Thermodynamic Parameters On Performance of Gas Turbine Cycle With Regenerator.
17. Eckardt, D. and Ruffli, P. "Advanced Gas Turbine Technology – ABB/ BBC Historical Firsts", *ASME J. Eng. Gas Turb. Power*, 2002, p. 124, 542–549
18. Zarepour, G., & Aminjan, K. K. (2018). Modeling the Thrust and Specific Fuel Consumption for a Hypothetical Turbofan Engine. *International Journal of IC Engines and Gas Turbines*, 4 (1), 1, 10.
19. Bobbitt, Malcolm (2007) [1994]. "III – Gas-Turbines and the Jet Era". *Rover P4 Series* (revised ed.). Dorchester, UK: Veloce Publishing. pp. 84–87. ISBN 978-1-903706-57-2. Retrieved 17 October 2014.
20. Aminjan, K.K., Heidari, M., & Rahmanivahid, P. (2021). Study of spiral path angle in pressure-swirl atomizer with spiral path. *Archive of Applied Mechanics*, 91 (1), Pp 33–46.
21. Khani Aminjan, K., Kundu, B., & Ganji, D.D. (2020). Study of pressure swirl atomizer with tangential input at design point and outside of design point. *Physics of Fluids*, 32 (12), 127113.
22. Khani Aminjan, K., Heidari, M., Ganji, D.D., Aliakbari, M., Salehi, F., & Ghodrat, M. (2021). Study of pressure-swirl atomizer with spiral path at design point and outside of design point. *Physics of Fluids*, 33 (9).
23. Doustdar, M.M., & Aminjan, K.K. (2019). Modeling the Thrust and Specific Fuel Consumption for a Hypothetical Turbojet Engine. *International Journal of IC Engines and Gas Turbines*, 5 (1), Pp 45–52.
24. Parhrizkar, H., Aminjan, K.K., Doustdar, M.M., & Heydari, A. (2019). Optimization of S-Shaped Air Intake by Computational Fluid Dynamics. *International Journal of Fluid Mechanics & Thermal Sciences*, 5 (2), Pp 36.

25. Aminjan, K.K. (2018). A Review on the Change Process and the Evolution of Aircraft Engine Air Intake. *International Journal of Mechanics and Design*, 4 (1), Pp 15–22.
26. Aminjan, K.K., Heidari, M., Rahmanivahid, P., Alipour, H., & Khashehchi, M. (2021). Design and Simulation of Radial Flow Turbine Impeller and Investigation Thermodynamic Properties of Flow in LE and TE.
27. Ali Kamranpay, Alireza Mehrabadi, Numerical Analysis of NACA Airfoil 0012 at Different Attack Angles and Obtaining its Aerodynamic Coefficients, 2019. *Journal of Mechatronics and Automation*. 6 (3).
28. Agrawal, Giri L. (2 June 1997). Foil Air/Gas Bearing Technology–An Overview. ASME 1997 International Gas Turbine and Aeroengine Congress and Exhibition. pp. V001T04A006. doi:10.1115/97-GT-347. ISBN 978-0-7918-7868-2. Retrieved 23 July 2018.
29. Aminjan, K.K. (2018). Aerodynamic Analysis of NACA 65–2012 Airfoils at Different Attack Angles with Computational Fluid Dynamics (CFD) Method. *International Journal of Mechanical Handling and Automation*, 4 (2), Pp 9–16.
30. Mahmoodi, M., & Aminjan, K.K. (2017). Numerical simulation of flow through sukhoi 24 air inlet. *Computational Research Progress in Applied Science & Engineering (CRPASE)*, 3.
31. Ali Kamranpay, Review on Main Equations for Measuring Spray Properties in Centrifugal Injectors, *Journal of Industrial Safety Engineering*, Vol 8, No 3 (2021).
32. "HA technology now available at industry-first 64 percent efficiency" (Press release). GE Power. December 4, 2017.
33. "Levelized cost of electricity renewable energy technologies" (PDF). Fraunhofer ISE. 2013. Retrieved 6 May 2014.
34. Yahya, S.M. Turbines, compressors and fans. Tata Mc Graw Hill. pp. chapter 5.
35. "US Patent for Parallel-compound dual-fluid heat engine Patent (Patent # 3,978,661 issued September 7, 1976) - Justia Patents Search".
36. "Combined-cycle, gas-fired unit costs coming in below expectations: Duke | S&P Global Platts". 2015-08-11.
37. Release, Press. "New modification of Russian VVER-440 fuel loaded at Paks NPP in Hungary".
38. "PRIS – Home". Iaea.org. Retrieved 11 January 2022.
39. "World Nuclear Power Reactors 2007–08 and Uranium Requirements". World Nuclear Association. June 9, 2008.
40. "Table A.III.1 – Cost and performance parameters of selected electricity supply technologies" (PDF). The Intergovernmental Panel on Climate Change. Retrieved 20 December 2021.
41. Hill, Donald (2013). *A History of Engineering in Classical and Medieval Times*. Routledge. pp. 163–164. ISBN 9781317761570.
42. Bartle, Alison (2002). "Hydropower potential and development activities". *Energy Policy*. 30 (14): 1231–1239. doi:10.1016/S0301-4215(02)00084-8.
43. Howard Schneider (8 May 2013). "World Bank turns to hydropower to square development with climate change". *The Washington Post*. Archived from the original on 22 July 2013. Retrieved 9 May 2013.
44. Munoz-Hernandez, German Ardul; Mansoor, Sa'ad Petrou; Jones, Dewi Ieuan (2013). *Modelling and Controlling Hydropower Plants*. London: Springer London. ISBN 978-1-4471-2291-3.
45. Holttinen, Hannele; et al. (September 2006). "Design and Operation of Power Systems with Large Amounts of Wind Power" (PDF). IEA Wind Summary Paper, Global Wind Power Conference 18–21 September 2006, Adelaide, Australia. Archived from the original (PDF) on 26 July 2011.
46. Abbess, Jo (28 August 2009). "Wind Energy Variability and Intermittency in the UK". *Claverton-energy.com*. Archived from the original on 12 January 2011.
47. "Harvesting the Wind: The Physics of Wind Turbines" (PDF). Archived from the original (PDF) on 24 August 2015. Retrieved 10 May 2017.
48. "COP26: How much is spent supporting fossil fuels and green energy?". BBC News. 15 November 2021. Retrieved 24 November 2021.

49. What are the pros and cons of onshore wind energy? Archived 22 June 2019 at the Wayback Machine. Grantham Research Institute on Climate Change and the Environment. January 2018.
50. "Wind Power – Analysis". IEA. Archived from the original on 23 November 2021. Retrieved 23 November 2021.