Original Article: Investigating the Introduction of Gas Turbine V94.2

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ABSTRACT

Gas turbines are usually designed in such a way that the pressure of hot gases at the exit of the turbine and after the last moving blade is slightly lower than the atmospheric pressure. Therefore, in order to overcome the ambient pressure, a divergent duct is considered at the gas turbine outlet, and in this way, the exhaust gases, which have a relatively high temperature, are sent to the surrounding atmosphere through the exhaust. The useful output power is transferred to the compressor and then to the generator. Today, the use of gas turbines in power plants and as a generator of electricity is very valuable. In addition, they are widely used in various industries such as space industries, marine platforms, petrochemical industries, etc. These turbines can be useful especially in parts of the electricity industry that require quick installation and commissioning, as well as in cases where the national electricity grid is lost. Speed in construction and installation, low investment cost and low maintenance cost, light weight and the possibility of using multiple fuels are among the advantages of gas turbines compared to other power plants. Current gas turbines are operated with fuels such as natural gas, diesel, low thermal value gases, methane, crude oil, oil. Regarding the disadvantages of these turbines, we can mention the low efficiency and the need for major repairs after fewer working hours and the changes in power and efficiency due to atmospheric changes.

Introduction

This gas turbine was built for the first time by the German company Siemens, and with two nominal powers of 159 and 162 megawatts and an efficiency of 34.9%, it is considered one of the heavy class gas turbines, which is used in thermal power plants to rotate generators. This turbine can also be used in combined gas-steam cycles, and for this reason, it is very popular among power plant users [1-3]. This turbine has 16 compressor stages, 4 turbine stages, two bearings and two vertical combustion chambers. One of the most important economic factors of this type of turbine is the high reliability of efficiency, accessibility, as well as the low cost of construction and repairs against high

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production capacity [4]. The proper temperature of the fluid in the inlet part of the turbine has increased the time intervals of maintenance and on the other hand, it has caused the reduction of service and maintenance costs. Also, the ability to use liquid fuels has made its use independent of the type of fuel, which is an important component in the ability of a turbine.

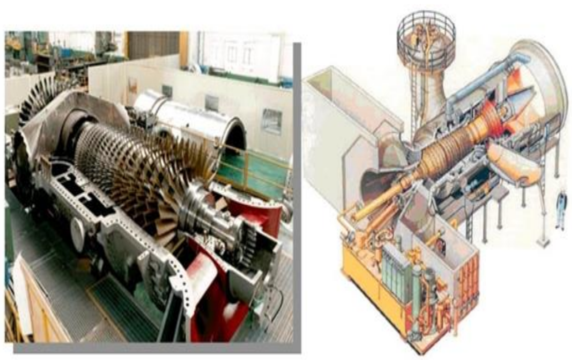

Figure 1. Gas turbine V94.2

In the V94.2 gas turbine, air is the operating fluid and it is compressed by a 16-stage compressor. Fuel is added to hot air in two combustion chambers and then ignited. Each combustion chamber has 8 burners. In the next step, the hot gas expands in 4 rows of turbine and is discharged to the environment with atmospheric pressure. The useful output power is transferred to the compressor and to the generator through the middle shaft [5].

The main components of a gas turbine

1- Air intake system: this part is responsible for receiving, filtering and finally delivering it to the compressor. The air required for the gas turbine must be completely clean and free of suspended particles in the surrounding space. There are usually many suspended particles in the environment, whose diameter decreases with the height above the earth's surface. The presence of these particles on their way through the gas turbine cause many problems for the operation of the device. During storms and when there is a lot of dust in the air around us, the amount and number of these particles will be much higher. Due to the fact that the entry of these particles into the gas turbine can cause problems in its operation, all gas turbines are equipped with several filter systems to clean the incoming air, which is called the incoming air system [5-7].

Figure 2. Air Intake system

Gas turbine compressors

Considering the main task of a gas turbine, which is to convert the energy contained in fossil fuels into mechanical energy and work, in order to provide ideal conditions for combustion reactions and the complete combination of oxygen and fuel, the combustion chamber needs a large volume of compressed air. This air is provided by a compressor. The compressors used in the gas turbine suck air from the atmosphere and increase its pressure to several times the atmospheric pressure. In V94.2 gas turbines, the moving blades of the turbine and compressor are mounted on the rotor.

The rotor is made of a number of discs, each of which includes a row of blades and three hollow axis sections, and all of them are connected to each other by means of a central screw, and they convert the released energy into output torque. Part of this released mechanical energy is used to rotate the compressor and the rest is transferred to a generator through the middle shaft [8].

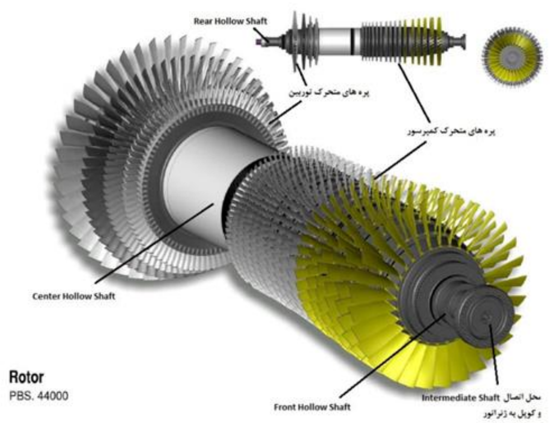

Figure 3. V94.2 gas turbine rotor

The rotor consists of turbine and compressor parts, which rests on two points at both ends, and consists of a number of disks and an intermediate cylinder in the middle. Each disc carries a row of blades. All discs and the middle cylinder are connected to each other by a central rod. The moving vanes of the compressor are mounted on the rotor disks and their task is to convert the received energy into kinetic energy and increase the pressure on the incoming air, and then direct them to the fixed vanes to increase the potential energy of the compressed air along with the fixed vanes. convert air pressure and each moving vane is made of a special material. The profiles of the vanes are optimized according to the flow characteristics and reinforced by considering the ratio of width to length.

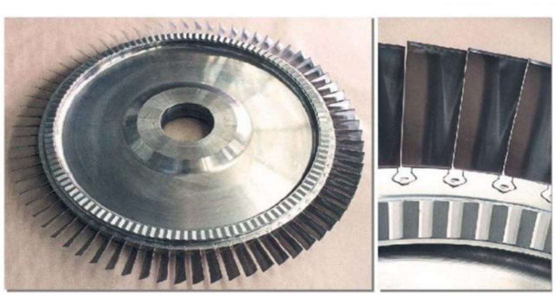

Figure 4. Gas turbine compressor disk V94.2

Each stage of the compressor includes a row of moving vans and then a row of fixed vanes, which increase the pressure on the passing air in each stage.

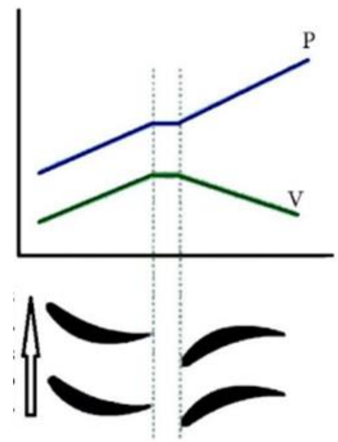

Figure 5. Changes in pressure and speed in passing through the fixed and moving blades of the compressor

Combustion chamber

In fact, in a combustion chamber, compressed air is received from the output of the compressor, and then combustion is performed on the fuel entered into it. After establishing the flame, the mixture of air and fuel is completely ignited and the temperature of the fluid rises sharply. If the fuel does not burn completely in the combustion zone, some of the fuel may enter the dilution section and burn there.

As a result of this action, the temperature of the combustion gases in this section rises and the temperature of the gases entering the turbine section increases. This increase in temperature will cause serious damage to the fixed and moving blades of the turbine. The ratio of air to fuel is 10 to 1 for complete combustion of gaseous fuels and 16 to 1 for liquid fuels. In the designs where there are a number of combustion chambers around the compressor for combustion, two igniters are also placed in two adjacent chambers and two flames are placed at the opposite point.

These combustion chambers are connected to each other by connecting pipes, and after establishing a flame in one of them, the flame is transferred from these connecting pipes to other combustion chambers so that the flame on the opposite side sees the flame and allows it to continue.

Two combustion chambers are located vertically around the turbine and are connected to the turbine shell by side flanges. The compressed air of the compressor entering the combustion chamber cools the outer shell of the hot gas part. In addition, the symmetrical air intake causes a symmetrical temperature distribution with minimal pressure change in front of the first row of rotating vanes. The combustion chamber consists of two chambers inside each other. The inner chamber where the burners are placed in the upper part is called the fire tube. The flame is formed inside it and the hot gas is directed to the turbine blades through it. The outer chamber that houses the fire tube is called the pressure shell [9].

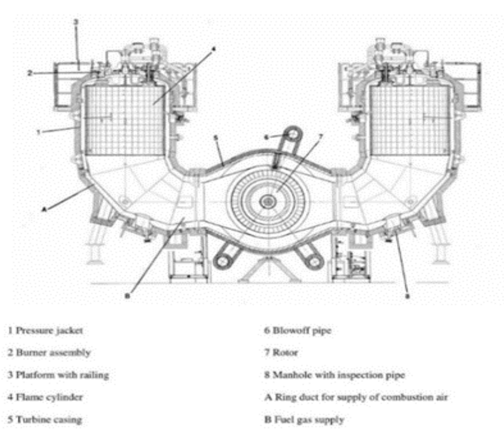

Figure 6. Combustion chamber of V94.2 units

The incoming air creates a layer of air between the firebricks and the inner surface of the fire tube, which protects this body from burns. Each combustion chamber of the V94.2 units consists of 8 burners designed for both gas and diesel fuel. The fuel of the burners operates according to the law of reverse flow, and the excess liquid fuel injected into the burners is returned through the return line built into the burners.

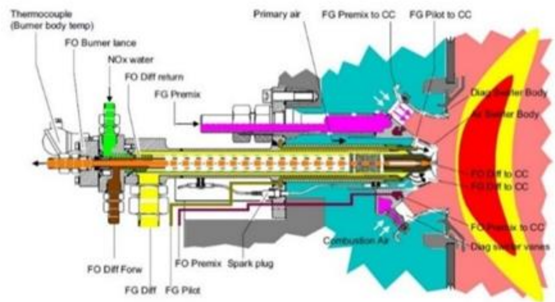

Figure 7. Internal building of V94.2 burner units

Turbine

The main purpose of a gas turbine is to convert the energy contained in fossil fuels into mechanical energy and work. This conversion happens in a part of the gas turbine called the turbine. In this part, most of the energy of the combustion gases is taken and this energy is transferred to the axis of the gas turbine. In fact, the turbine is the part that is placed after the combustion chamber and is responsible for converting the thermal energy of the gases coming out of the combustion chamber into mechanical energy and work.

There are two common types of these turbines: circulating flow turbines and axial flow turbines, whose main difference is in the direction of the fluid passing through them. In fact, in circulating flow turbines, the direction of movement of exit gases is perpendicular to the hot gases entering, and in axial flow turbines, this direction is parallel to the incoming hot gases.

In other words, in turbines with circulating flow, the flow of gases is from the center of the turbine axis outward and radially, which causes the movement and rotation of the turbine. While in axial flow turbines, the gases enter parallel to the central axis of the turbine and hit the blades causing them to rotate and then leave the turbine without changing the direction. In V94.2

gas turbines, the moving blades of the turbine and compressor are mounted on the rotor. The moving turbine blades convert thermal energy into mechanical energy. These blades include airfoils on the surface of the blades and the roots of the blades. The airfoil section is shaped like an airplane wing and is chamfered in order to provide more resistance at the base. These vanes are twisted from the base to the end, the corresponding calculations will be proportional to the fluid velocity that is created along the vane.

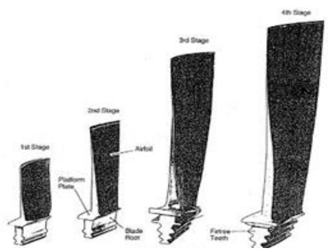

Figure 8. Moving blades of V94.2 turbine

The location of the vanes is a set and includes the protection of the rotating disk against the path of gas and high temperature. On the other hand, the roots of the blades contain a pine-like shape with two or three teeth. The vanes are placed in special grooves on the rotating disc and are locked in place by keys in the axial direction. All moving vans are produced with alloys resistant to high thermal and mechanical stresses [9-12].

Figure 9. V94.2 turbine moving blade disc

The fixed turbine blades have a blade carrier and the blades are mounted in four rows on the blade carrier. The first row of turbine blades are its fixed blades to direct the air in the form of a nozzle with high kinetic energy towards the moving blades.

The pressure energy in the hot gases is converted into kinetic energy in the fixed blades of the turbine. After passing through the fixed blades, the hot gases enter the moving blades of the turbine through the leading edge and apply force to the moving blades both in the form of an impact and in the form of a reaction.

Exhaust

The duty of exhausting the exhaust gases of the turbine to the atmosphere is the responsibility of the exhaust. Hot gases lose all their pressure energy and a large amount of thermal energy while passing through the different stages of the turbine. Gas turbines are generally designed in such a way that the pressure of hot gases at the exit of the turbine and after the last moving vane is slightly lower than the atmospheric pressure, so in order to overcome the ambient pressure and exit through the exhaust, there is a divergent duct at the exit of the gas turbine between the turbine and the exhaust. has it. In this divergent channel, by using the speed of the fluid and converting it into pressure, it overcomes the pressure of the environment, and in this way, the exhaust gases, which have a relatively high temperature, are sent to the surrounding atmosphere through the exhaust.

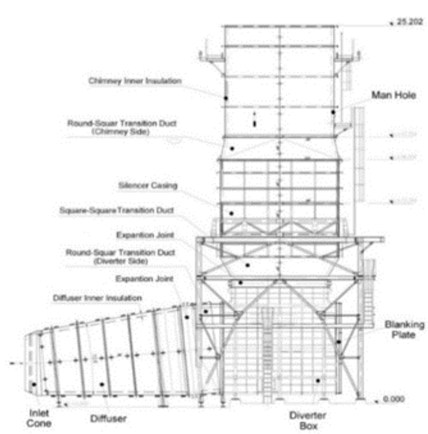

Figure 10. The various exhaust components of the V94.2 unit

Generator

The generator is an electric machine of the synchronous machine type that converts the rotational energy of the turbine into electrical energy. The basis of the work of these machines is based on electromagnetic induction. Current flows in the field circuit and as a result a static magnetic field is produced. As the rotor rotates, the magnetic field produced by the field begins to rotate, creating a magnetic field that varies with respect to location. The magnetic flux leaves the rotor poles and forms a magnetic circuit through the stator. The stator conductors are placed in the stator grooves and according to the Lenz law, an induced voltage is induced depending on the changes in the magnetic field.

Gas turbine peripheral components V94.2

1- Lubrication and jacking oil system: This section is used to supply oil for lubrication and cooling of bearings, supply jacking oil for turbine rotor and generator, and also for injecting oil to rotate the rotor. The lubrication system in gas turbines is responsible for lubrication and also heat transfer or cooling of bearings. The oil is received from the tank by the pump, and after passing through the regulator, it is moved into the filter and cooling unit, and then it enters the bearings, and after lubrication and heating, it returns to the tank for reuse. In order to prevent the oil vapors from leaving the bearings and return the oil to the oil tank more easily, the oil tank includes two fans to create a vacuum. Above these fans, there is an oil extractor to prevent oil vapors from escaping from the fans. The main and auxiliary and emergency pumps of lubricating oil are of centrifugal type due to the need for high flow rates for lubrication and cooling, and jacking pumps are of positive displacement type due to the need to create high pressure. The generator jacking pump is of axial piston positive displacement type and the turbine jacking pump is of vane positive displacement type. A double filter is used to prevent the possible entry of foreign particles with oil into the bearings in the path after the main and auxiliary lubrication pumps. One of these filters is always in the circuit and the other filter is a standby filter, and when the working filter is clogged, the oil passage is changed to the standby filter so that the dirty filter is taken care of and cleaned. In hydrodynamic bearings, an oil film is used as an agent separating the axial surface from the seating surfaces. Therefore, the rotational movement of the axis causes the friction of the oil layers together, which is much less than the friction of metal with metal, and in addition, it causes heat to occur in the oil, which can be easily transferred and cooled. In these bearings, a pump is used to create the desired pressure in the oil in order to create the required pressure to bear the weight of the axis in the oil before the turbine axis reaches the appropriate speed. Jacking pumps have the task of raising the turbine shaft to a certain extent so that the lubricating oil can easily move and flow in the distance between the bearings and the shaft. After the turbine speed reaches the appropriate level, this pump leaves the lubrication circuit due to the creation of an oil film between the bearing and the rotor, which keeps the rotor up and keeps moving. It is worth mentioning that, due to the need for continuous lubrication, the lubrication pump must always be in the circuit. The main task of the lubrication pump is to pressurize and flow the oil. The failure of the oil pump has caused serious damage to the bearings, which in turn will cause a very dangerous destruction of the gas turbine. Therefore, measures have been taken to solve this problem. One of these measures is the use of emergency pumps and the other is the possibility of stopping the gas turbine quickly without the need for an alarm when the oil flow to the turbine is interrupted. If the turbine fails after the oil flow is cut off, the shaft will sit on the bearing and in addition to destroying the shaft and bearings, the blades will also collide with the shell. Therefore, the control system will stop the turbine without any warning in case of oil flow interruption [13-15].

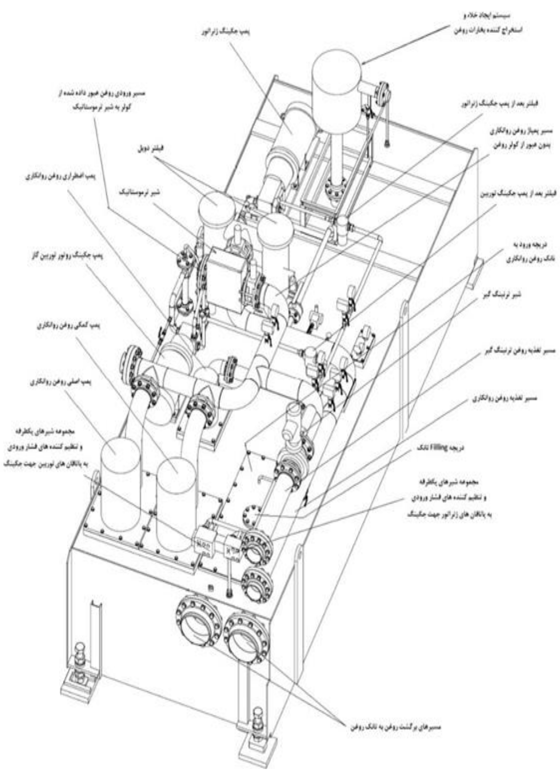

Figure 11. Different components of the lubrication system of the V94.2 unit

2- Hydraulic oil system: This oil is used as an actuator for fuel stop valves (gas and diesel). Valves are opened using hydraulic oil pressure, and as soon as this pressure stops, the valve is closed by force. The reason for using a mechanical actuator when closing is to ensure that the valve closes and thus cuts off the fuel supply in all situations where the hydraulic oil system is not in the circuit, even for a short period of time. This system includes two main and auxiliary pumps for high pressure hydraulic oil injection, and these pumps are positive displacement type due to the need to create high pressure. The hydraulic oil system has two accumulators so that when the hydraulic oil system pressure drops, it can compensate for this pressure drop for a short time.

Figure 12. Various components of hydraulic system of V94.2 unit

A secondary ring is considered for the direction of the oil bag, which includes a centrifugal pump and a fan. With the start of any of the main or auxiliary pumps, the secondary ring pump also enters the circuit and circulates the hydraulic oil in the secondary ring. As the oil temperature rises above the permissible limit (55°C), the fan in the secondary path also enters the circuit and causes the hydraulic oil to cool down to the specified temperature (45°C) and then exits the circuit. The alarm limit for hydraulic oil temperature is 70°C. When the unit is stopped, when the hydraulic oil temperature reaches below the permissible limit (27°C), the main and auxiliary pumps and the secondary ring pump enter the circuit to heat the hydraulic oil, and when the hydraulic oil temperature reaches its normal limit (33°C), all three pumps are turned off.

3- Water cooling system: This system is used to cool the lubricating oil and lifter, as well as to cool the generator. The above system is closed type. In these systems, water passes through generator coolers and lubricating oil coolers, and as a result, the heat produced by the above systems is absorbed by water. In order to prevent corrosion, the water used in the system is tap water to which an antifreeze is added to prevent freezing. The cooling water is introduced to a set of air-water heat exchangers, where the heat stored in the water is transferred to the ambient air. Practically, the super system is intermediate between the heat production systems and the cold source. This system includes two pumps to inject water into the cooling system and four fans are used to cool the water, which enter the circuit based on the set temperatures.


Figure 13. Set of fans and fin tubes of the V94.2-unit cooling system

At any time, one of the pumps is always in the circuit and the other pump is on standby. Both pumps are of centrifugal type and since the inlet of these pumps must never be empty, a water tank is installed next to the fans and at a height that always keeps the suction pumps full of water. When the water level in the surge tank drops below the limit, the cooling pumps will be turned off. The capacity of this tank is 1.5 cubic meters and it is placed at a height of 0.5 meters above the air-water radiator. The said tank has a local level indicator, a level transmitter with low- and high-level alarms and a level switch. The local level indicator allows you to see the tank level. Also, the level transmitter always measures the level of the tank. If the surge tank level decreases and becomes less than 400 mm, the start permission for the cooling system pumps is lost. If the level of the surge tank decreases again and becomes less than the set limit for the level switch, the cooling system pumps will be turned off by the protection command, after which the cooling of the generator will be compromised and the gas turbine will trip due to the high temperature of the generator. There will also be no permission to reboot. The logic of starting the fans of this system is as follows, immediately after receiving the feedback of the Sir Kole pump start, the first fan is started and the second fan is started with a delay of 5 seconds. If the temperature of the water entering the fin fans is below 6 degrees Celsius, the second fan is turned off, and if the temperature of the water entering the fin fans reaches above 14 degrees Celsius, it will start working again. If the temperature of the water entering the fin fans is above 12 degrees Celsius, the third fan will start after 10 seconds from the Sir Kole pump, and it will turn off when the water temperature of the fin fans reaches below 8.5 degrees Celsius. The fourth fan is in standby mode and will be replaced if one of the fans trips, or when the temperature of the water entering the fin fans is greater than 20 degrees Celsius and the difference between the temperature of the water entering the fin fans and the ambient temperature is greater than 10 degrees Celsius, the command to stop the fans is issued automatically in the following cases:

- ✓ when the turbine is not working.
- ✓ Also, when the temperature difference between the output of the generator coolers and the input is less than 1.5 degrees Celsius.
- ✓ Also, when 60 seconds have passed since both pumps were turned off. If the ambient temperature is below zero, the second and third fans will stop automatically.
- ✓ In order to protect the fans against high vibrations, each fan is equipped with a vibration sensor, and in case of high vibrations, it is stimulated and stops the fan.

Other equipment of this system can be mentioned oil coolers. Oil coolers consist of two separate cooler units. Each oil cooler is designed for 100% capacity and one is always working and the other is on standby. These coolers have the ability to be replaced while the system is in the circuit. Changing the coolers is done in order to isolate the cooler in order to carry out repair activities and also to make both coolers work the same and to prevent sedimentation. In addition to the oil coolers, the water cooler line is used in parallel to cool the four generator coolers, which are It is a type of surface heat exchanger and is responsible for cooling the air inside the generator. These coolers include four separate coolers and are located horizontally in the lowest part of the stator body. Each of these four coolers consists of a large number of tubes, and in order to increase the cooling level, each of these tubes has fins on its outer surface. The cooled water flows inside the pipes and the cooling air of the generator are cooled by hitting the outer surface of these pipes and vanes.

4- Liquid fuel system: The liquid fuel system feeds the burners with liquid fuel (diesel) and also controls the amount of fuel injected into the chamber based on the required amounts in startup, operation and shot down, and during shot down and trip, it cuts off the fuel flow quickly and completely. The liquid fuel must have a certain pressure, a certain temperature, sufficient flow and a completely accurate and suitable quality, which is ensured by the use of pumps and filters used in the route and fuel tanks and other equipment, and the liquid fuel is supplied by the pumps in the department. Forwarding is pumped from the tanks to the liquid fuel skid located in the unit. At the beginning of each unit and before the entrance of the skid, there is a 3-way valve that directs the incoming fuel from the forwarding department to the liquid fuel skid located in the unit or returns it to the fuel tanks. There are double filters at the entrance of the skid, one of which is always working and the other is ready to work, so that when the working filter is clogged, the liquid fuel path can be changed to the ready-to-use filter. The function of these filters is to clean the fuel from foreign particles and separate the air bubbles created by pumping from the forwarding section. The liquid fuel system has a high-pressure liquid fuel injection pump. This pump, which is known as injection pump, is a type of positive displacement pump. If the fuel pressure reaches above 85 bar, an alarm will be issued, and if the liquid fuel pressure reaches 100 bar, the gas turbine trip command will be issued.

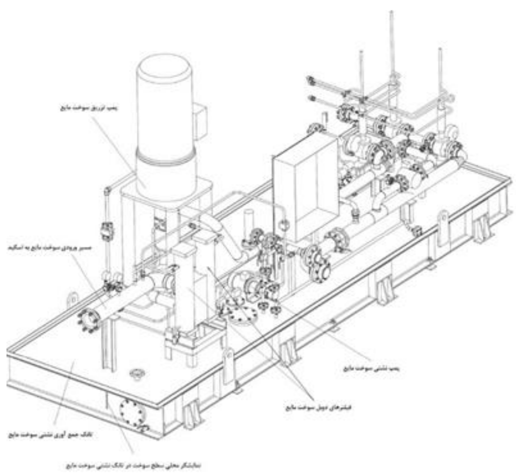

Figure 14. A view of the liquid fuel skid of the V94.2 unit

5- Natural gas fuel system: The natural gas fuel system supplies the gas fuel needed by the burners and controls the amount of gas flow according to the turbine's needs in each of the start, operation and stop stages. In addition, this system is used to cut off the gas path under certain conditions. Regardless of the natural gas fuel supply rate at any time, the natural gas fuel supply pressure should always be almost constant, and it should be dry and clean to prevent corrosion and erosion as well as deposits in the natural gas fuel system components. The natural gas fuel system has a gas filtration skid, which is located upstream of the natural gas skid and before the inlet of the gas turbine unit. This skid is for cleaning and also measuring the amount of fuel fed to the gas turbine. At the inlet of the natural gas skid located in the gas turbine unit, there is a strainer that protects the gas fuel stop valve against the entry of any inappropriate foreign matter that may exist between the fine filter and the strainer. This is important because when the gas turbine trip occurs, the foreign body can prevent the stop valve from closing completely.

Conclusion

Performance characteristics of gas turbines are influenced by several factors. This effect in some cases improves the performance characteristics and in others causes a decrease in performance. Considering these effects and in order to have the same basis, gas turbine manufacturers provide the performance specifications of each gas turbine based on reference and standard conditions. On the other hand, based on the design conditions of the building, they provide correction curves and thus announce the performance according to the design conditions. However, some environmental and operational factors cause the gas turbine to be operated outside this working point, which will change the performance characteristics again. Various factors affect the performance characteristics of the gas turbine. These factors can be broadly classified into two categories. The first category is climatic and environmental factors. Ambient temperature, ambient pressure and ambient humidity are the main climatic factors affecting the performance of the gas turbine. The second category is operational factors that are related to the conditions and how to operate the unit. The operating hours of the unit, the pressure drop related to the inlet and outlet air path, which may be caused by things such as clogging of filters and other equipment installed in the flow path. Fouling of the compressor blades and in general the loss of efficiency of the turbine and compressor, the leaks in the unit, the operating mode of the unit, the fuel quality are some of the factors that change the performance characteristics of the gas turbine. It is important to identify the factors that reduce the performance as well as the factors that increase the energy consumption of these units and prevent these factors in these power plants. Ambient temperature and pressure are climatic factors that will greatly affect the increase or decrease of production power and the increase of heating rate. Ambient pressure has the opposite effect and its reduction will lead to a reduction in production power and an increase in heating rate. Therefore, studying the climatic conditions of the desired areas for the installation of these units and finding the suitable climatic location for installing the gas turbine is of particular importance. In addition to environmental factors, operational factors also affect the performance of these power plants. According to the investigation, the operation of these units in base loads has better performance and reduces their heat rate. Also, by proper planning of repairs and periodic visits on time and by eliminating harmful factors such as pressure drop in the air path and timely washing of the compressor blades, it is possible to reduce the intake air flow rate and the compressor efficiency, which play a significant role in reducing the performance of the gas turbine.

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