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Optimizing the Maintenance and Repair Program based on Condition Monitoring in Combined Cycle Power Plants

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Abstract

Given the growing dependence on human life and the daily need for electricity, the quality and reliability of this energy is crucial so that it is always available to consumers as a necessity. Since high percentages of electricity are supplied through gas, steam, and combined cycle power plants, combined cycle power plants also play an important role in generating electricity, with high efficiency compared to gas and steam power plants, The main reason for the expansion of their use is due to the high efficiency of the combined cycle power plant because the heat energy generated by combustion in the gas turbine is sent to the steam turbine boiler for use in the steam turbine, because The whole mechanical, combined cycle power plant system It is more complex than a gas or steam power plant, so it is necessary to properly consider and evaluate this complex before it can be significantly available. This availability is strictly related to the maintenance and repair plans of the plant. Since maintenance policies suffer from significant interference and cost overruns, the move to condition-based maintenance and reliability-based maintenance can be justified. In this study, the main components of the combined cycle power plant have been evaluated in terms of reliability, accessibility and economic index and prioritized on the basis of risk index. In the next step, critical cases have been identified and effective remedial measures have been proposed. The implications of these measures have also been discussed.

Keywords: Combined Cycle Power Plant, Reliability, Availability, Condition-Based Maintenance

1. Introduction

Power generation stations, commonly called power plants, are the core of power systems and are responsible for generating power for transmission and distribution to end consumers. As the heart of the power industry, the power plant must be available and reliable at all times, and its components must also be available as the need for reliable power flow. Combined cycle power plants are one of the most common power generation stations around the world, which can achieve 60% thermal efficiency. There are also gas power plants and steam power plants where the efficiency is around 20 to 30 percent. However, thanks to the new technologies used in power plants in recent years, the efficiency of gas turbines has recently been experienced as high as 40%.

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In Sabouhi et al., (2016) focused on the reliability modeling of the combined cycle power plant, they also proposed reliability sensitivity indicators according to the identification of the important components of the units so that the efficient maintenance strategy for the power plant components can be decided. In Ahmadi and Fouladirad (2017) have determined the optimal operating time that can balance some revenue streams and increased costs due to inspections. Optimum operation time is an important parameter that can help maintenance management to decide on subsequent shutdown and repair or replacement. In Zhang et al., (2016) proposed a new method regarding increasing the efficiency of the relative output of combined power. The new cold air production process is to cool the intake air in a combined cycle with liquefied natural gas fuel. The combined cycle power plant works for more efficiency, so its repair and maintenance is necessary so that both gas and steam turbines are active. In Dong et al. (2017) developed a new concept for the maintenance work of gas turbine engines installed in aircraft. In Khaljani et al., (2015) comprehensively studied the heat and power synchronization in a combined gas turbine and hand-made organic cycle. In Biswal et al., (2012) proposed a process model for the hydrogen cooling system of power plants and proposed a scheme to evaluate the availability of the system using fault tree analysis in comparison with the existing system. Using FTA requires a lot of previous data to develop the model. As a pre-awareness tool it may not be intended to detect the current state of components. In Gharakheili et al., (2018) proposed a new support tool based on multi-attribute decision framework in combination with analytic hierarchy process to determine the most important components of power transmission systems. In Kermanpur et al., (2008) analyzed the failure mechanism of Ti6A14V gas turbine compressor blades using both experimental characteristics and numerical simulation techniques. In Hou et al., (2020) discussed that blade failure in gas turbines often leads to the loss of all downstream stages and can significantly affect turbine availability. In this research, condition monitoring techniques have been used in a combined cycle power plant to judge and compare the conditions of different units, so that the importance of condition-based maintenance and repairs can be visualized. With the increasing dependence of social life on electricity, desirable quality, sufficient safety, no power cut and low cost are among the expectations of subscribers. Malfunctions and disruptions in the system sometimes cause irreparable damage to the system or the complex. On the other hand, the continuation of many jobs and the stability of social affairs depend on electricity. This dependence is to the extent that it can be said that a power cut takes life out of its normal routine. Therefore, the aim of the article is to increase the efficiency of the related equipment by reducing the amount of device stops and shutdowns and to reduce the operating costs of the system. Therefore, the issue of maximum reliability of correct and continuous operation is considered as an important issue in the exploitation of distribution networks.

2. Method

2.1 Safety assessment of power plant component failures

Safety is a measure of the probability that a system will perform its function properly as expected or will interrupt its operation in such a way that it will not impair the performance of other subsystems or impair the safety of people with the system (Ramere and Laseinde, 2021). With the above definition, he realizes the fact that, contrary to the hypothesis of the two-state reliability model for each component, the safety model should include three states: the normal state, the unstable state, and the unsafe state. It shows the sensitivity of each component in CCPP from the point of view of electrical safety.

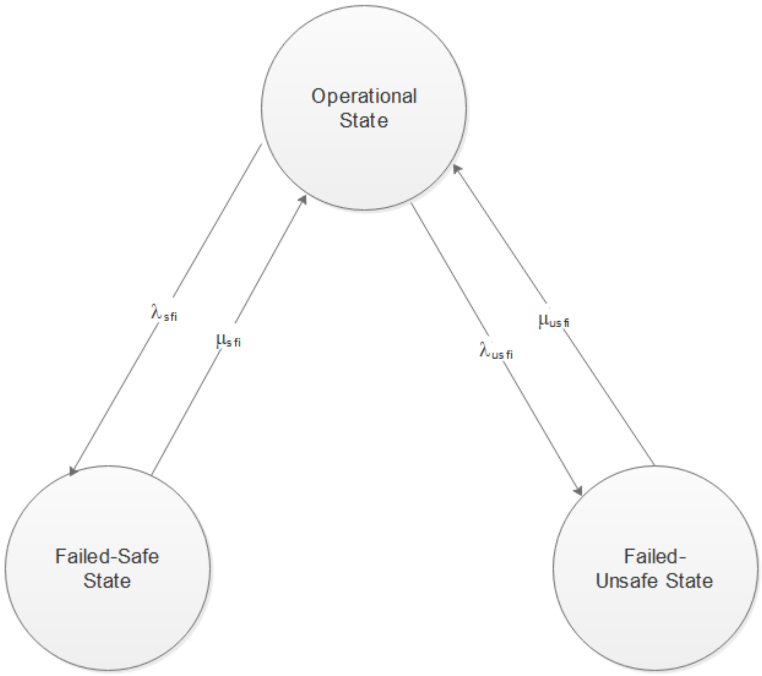

Figure 1: A general three-state Markov model for evaluating the sensitivity of a component

Using the GTPP and STPP models and using the component safety model in the above figure, the MTTUF index, which is determined as the average time it takes to fail between unsafe states, can be calculated using the N matrix in (1).

$$N = (I - Q)^{-1} = MTTUF \qquad (١)$$

where N is the basis matrix that nik averages over the number of times the process is in K state. There are two scenarios for each CCPP component, one considered inside and one outside the system. Compared with the safety index in these two scenarios, the critical factor of each component from the safety point of view is introduced in a normalized form in (2).

$$SCF_i^{CCPP_j} = \frac{\Delta MTTUF^i}{MTTUF_1} = \frac{MTTUF_1 - MTTUF_2^i}{MTTUF_1} \qquad (٢)$$

Evaluation of CCPP components in failure of environmental goals

Environmental impacts are generally related to the use of fossil fuel power plants, which are a constant source that produces a mixture of pollutants that are released into the atmosphere. This combination of fossil fuels in thermal power plants includes: SO_3, CO_2, SO_2, NO_x, CO, carbohydrates (CH) and suspended particles (SPM). In connection with each of the pollutants introduced above, it can be calculated using the emission index.

1-1 Assessment of the cost of imposing CCPP component blackouts

If a specific component in the CCPP fails to operate and thus experiences a void, the cost of failure may be the first sign of financial consequences:

$$OC_i^{CCPP_j} = RP_i^{CCPP_j} \times EF_i^{CCPP_j} \qquad (3)$$

Maintenance costs are other economic terms that must be considered when reporting component depletion. Repair costs can be considered as costs incurred for maintenance and replacement of corrective operations, while maintenance costs may only be for the purpose of preventing imminent failures of CCPP components.

3. Results

Paying attention to the fact that reliability describes the failure characteristics of the components of a system using the analysis of recorded failure data, therefore, failure data is one of the basic requirements for analyzing the reliability of a system. Reliability analyzes performed in power plants are usually qualitative; because the numerical data are determined after the equipment has been working for a certain period of time. Therefore, using the data available in reliable sources is a common and scientific matter in studies. Failure data consists of various types, including field data, general data, and test and inspection data. For the power plants studied in this project, public data and checklists in the power plant archives were used to collect failure data. Considering the number of equipment available in the power plants studied in this project and the lack of required failure data for all components, it is necessary to use the data of several references (Sabouhi et al., 2016; Ren et al, 2021) to collect Failure data collection is used.

Completing FMEA forms (in order to better understand the system)

Completing the FMEA forms and properly summarizing these forms in the form of a general table provides very useful qualitative and quantitative information about the design and performance of the system for engineers and designers and operators and maintenance groups in power plants. Now the failure mode analysis forms and its effects for systems and subsystems must be completed. Due to the high volume of various reasons and modes of failure, in this thesis only the analysis of the modes of failure and its effects has been considered for the lubrication and fueling system of diesel, and then according to the severity, detection and probability of occurrence, Table 1 It has categorized different components according to the amount of risk number. Also, based on the investigation and practical research in the power plant, the root causes for producing errors in the power plant, and considering the abundance of equipment and systems and subsystems in the power plant, the components that had problems and deficiencies and have an important impact on the power plant complex. Below are some of them.

Fuel Forwarding Pump

The duty of these pumps in the diesel refueling system is to transfer diesel from the main tanks to the main filters of the injection pump and perform pumping work with an output pressure of 6 times. In order to calculate the reliability in the components of the sub-systems and systems of the project, we have calculated the risk, the calculation formula of which is as follows:

Risk = Probability of failure x the economic result

Calculating the probability of failure: the number of failures per hours of equipment operation (obtained from power plant documents and archives and operation checklists). Economic consequence: the sum of the costs caused by the direct impact of the equipment failure, which has been inquired and prepared from the documents of the support and procurement department of the power plant.

Table 1: Risk priority number values for power plant components

No.	Sub-system	Failure Condition	Failure Cause	Failure Effects	Control Type
1	The main pump of the diesel fuel system	Abnormal heating	Lack of proper lubrication	Unit shutdown	Visual inspection
2	Main lubrication pump	High temperature of the bearing	Lack of lubrication	Lubrication flux drop + shut down unit	Visual inspection
3	Auxiliary lubrication pump	High vibration + abnormal noise	Line Bearing Failure	Failure of electric motor + unit shut down	Visual inspection
4	The main diesel tank	Diesel leak	Cracking and wear of flexible rubber joints	Economic loss + environmental pollution	Visual inspection
5	Diesel fuel feed pump	Abnormal sound + intense vibration, increasing the temperature of the bearings	Failure of bearings + alignment	Economic loss + unit shut down	Visual inspection
6	Diesel fuel thrust pump	Abnormal sound + intense vibration, increasing the temperature of the bearings	Failure of bearings + alignment	Diesel fuel feed pump	Visual inspection
7	Turbine lifting	Oil leakage from the coupling side	Wear and low quality of internal sealing parts	Economic loss + environmental pollution + + unit shut down	Visual inspection
8	The main filters of the diesel fuel system	Acting ΔP of the corresponding switch	Dirt and blockage of filters	Economic loss + unit shut down	ΔP SWITCH
9	Diesel fuel thrust filters	Acting ΔP of the corresponding switch	Dirt and blockage of filters	Economic loss + depreciation of pumps	ΔP SWITCH
10	Generator lifting	Overheating + abnormal sound	Loss of bearings + impact of gear coupling	Economic loss + unit shut down	Visual inspection

Table 2: Related to the repair costs of the units' diesel fuel feeding pump

No.	Replaced part	Parts number	Cost	Operation time	Required people
1	Bball bearings	2	55	4.5 Hours	2 technicians
2	Rolling bearing	1	25		
3	Mechanical seal	1	90		
4	Seal	2	3		
5	Oil	5.1	5		

The cost of wages is 2 USD per hour for a technician in a power plant and 3 USD for a repair expert. Description of the observed fault: abnormal sound when the pump is working, strong vibration, increased temperature of the bearings Corrective measures have been taken: changing the type of lubricating oil + testing and correcting the alignment Total cost of forwarding pump repairs: 200 USD

Diesel fuel pump electric motor units

Table 3: Related to the repair costs of the diesel fuel pump electric motor of the units

No.	Replaced part	Parts number	Cost	Operation time	Required people
1	Ball bearings	2	55	4 hours	2 technicians
2	Coupling shock absorber	1	3		
3	Dust collector	2	2		
4	Seal	2	3.5		

Total cost of forwarding pump electric motor repairs: 70 USD

Diesel fuel feeding filters units:

The average cleaning is every 48 hours, each pack has 3 filters, and each pack is replaced on average every 16,000 hours of operation.

Table 4: Related to the costs of repairing and replacing and cleaning the filters of the diesel fuel feeding pump of the units

No.	Replaced part	Parts number	Cost	Operation time	Required people
1	Forwarding filter	3	120	6 hours	2 technicians
2	Internal sealing parts	1	125		

The total cost of repairing, replacing and cleaning the filters of the forwarding system: 260 USD.

Main diesel fuel system filters

Table 5: Related to the costs of repairing, replacing and cleaning the main filters of the diesel fuel system

No	Replaced part	Parts number	Cost	Operation time	Required people
1	Cheng over	1	2500000	5 hours	2 technicians
2	Diesel filter	1	3500000		

Sometimes, due to blocking (sudden clogging) of filters and switching ΔP switch; It causes the unit to shut down. The cost of Cheng over repair and service and daily cleaning of diesel filters with their replacement every two years: 200 USD

Risk = $\frac{1}{9300} \times 200 = 0.21$

Fuel Unloading Pump

The duty of these pumps is to transfer diesel fuel (emptied from the fuel tankers to the burial tank) to the main fuel tanks and in some cases circulate the diesel fuel between the tanks. Output and working pressure is 4 bar.

Table 6: related to the repair and service costs of the diesel fuel thrust pump

No.	Replaced part	Parts number	Cost	Operation time	Required people
1	Ball bearings	2	70	4.5 hours	2 technicians
2	Rolling bearing	1	40		
3	Mechanical seal	1	90		
4	Seal	2	2.5		
5	Oil	5.1	5		

Defect description: Abnormal sound when the pump is working, high vibration, increased temperature of the bearings and leakage from the felt bowl. Corrective measures have been taken: changing the type of lubricating oil + testing and correcting the alignment + modifying the chassis of the pump and electric motor set. The total cost of diesel thrust pump repairs: 215 USD

1.3. Diesel fuel thrust pump electric motor

Table 7: related to the repair and service costs of diesel fuel thrust pump electric motor

No	Replaced part	Parts number	Cost	Operation time	Required people
1	Ball bearings	2	60	4 hours	2 technicians
2	Coupling shock absorber	1	3.5		
3	Duster	2	4		
4	Seal	2	2.5		

The total cost of diesel fuel thrust pump electric motor repairs: 80 USD.

Table 8: Related to the costs of repairing, replacing and cleaning diesel fuel thrust pump filters

No	Replaced part	Parts number	Cost	Operation time	Required people
1	Unloading filter	5	285	6 hours	3 technicians
2	Internal sealing parts	1	125		

The average cleaning is every 24 hours, each pack contains 5 filters, and the replacement of each pack is done every 8000 hours of operation. The total cost of repairing, replacing and cleaning diesel fuel propulsion system filters: 430 USD

Main Fuel Pump (Injection pump)

The duty of this pump is to transfer and pump diesel to the turbine burners. The output and working pressure of this pump is 75 bar.

Table 9: Related to the repair and service costs of the main diesel fuel pump

No	Replaced part	Parts number	Cost	Operation time	Required people
1	Ball bearings	1	9450000	6 hours	2 technicians
2	Mechanical Seal	1	29500000		

Defect description: internal leakage from the mechanical location of the flood; Heating of the pump bearing place due to loss of lubricating grease. Corrective actions and suggestions: cutting off and creating corrections in the internal leakage path connected to the leakage tank (considering that one of the flaws in the design of the diesel fuel supply system in these gas units is related to the set of internal leaks, so that in the start-up of the power plant It causes interruptions in the start-up and operation, and the reason for this is that the leakage tank was filled at the same time as the drain valves of the lines connected to the above tank were opened, due to the unresponsiveness and low flow rate of the tank drain pump, it caused diesel to leak from the internal route of the main pump of the diesel fuel system. It goes up towards the pump and causes washing of the lubricating grease of the pump and as a result of increasing friction and causing damage and high cost to the complex, which is proposed to cut off and separate the two separate parts of the mentioned leakage path, this case is solved), submitting a proposal to the manufacturing company based on the changes in the leaky tank drain pump type in the next plans. The total cost of repairing the main pump of the diesel fuel system: 2500 USD.

$$\text{Risk} = \frac{2}{17400} \times 2500 = 0.29$$

The average price of one kilowatt of electricity is calculated according to the presentation in the energy exchange (electricity market) of 0.003 USD, and according to the production capacity of gas units of the power plant (125 megawatts), and the 6-hour duration of the pump repairs, we have: 2250.

Table 10: Related to the repair and service costs of the electric motor of the main diesel fuel pump

No	Replaced part	Parts number	Cost	Operation time	Required people
1	Ball bearings	2	100	6 hours	2 technicians 1 expert
2	Coupling shock absorber	1	5		
3	Duster	2	4.5		
4	Seal	2	7		

The total cost of repairing the electric motor of the main diesel fueling pump: 130 USD

Fuel Oil Relif Valve (Start Up Valve)

Defect description: fluctuating output pressure of the main diesel fueling pump or lack of pressurization of the main diesel fueling pump Actions taken: Service and pressure adjustment of the mentioned valve was done in one hour with two technicians. Total service cost: 2.5 USD.

Risk = $\frac{3}{16850} \times 2.5 = 0.004$

Fuel Oil Control Valves (ESV & RSV)

They perform the task of adjusting and controlling the diesel fuel going back and forth to the turbine burners

Table 11: Related to the repair and service costs of the valves that control the diesel fuel supply route

No	Replaced part	Parts number	Cost	Operation time	Required people
1	Outer seal parts	1	35	3 hours	2 technicians

Defect description: pressure fluctuations in the diesel fuel lines to the burners after the main diesel fueling pump + leakage from the mentioned valves Actions taken: replacement of valve outer seal parts + disassembly and service and cleaning of the internal parts of the mentioned valves Total costs for the actions taken: 40 USD.

Risk = $\frac{1}{15700} \times 40 = 0.003$

Main Oil Pump

It performs the work of pumping oil to lubricate the bearings of the turbine and generator set with an output pressure of 4 bar. In addition, when the turbine is not running, supplying oil to the gear unit is one of the duties of the above pump.

Table 12: Related to the repair and service costs of the main lubrication pump

No	Replaced part	Parts number	Cost	Operation time	Required people
1	Ball Bearing	1	30	8 hours	3 technicians
2	Seal	1	3		
٣	Line Bearing	1	75		

Defect description: severe vibration with abnormal sound when in circuit + heating of the bearing area due to the loss or reduction of the amount of lubricating grease Type of corrective and suggested action: reducing the slack between the Line Bearing and the shaft of the mentioned pump, modifying and changing the type of lubrication (use of oil fluid for lubrication, so that a path for lubrication of the pump's own bearing is built from the charging disc of the target pump to increase the reliability of the lubrication system Pump blaring will go up.) Total repair costs of the main pump of the lubrication system: 135 USD.

$$\text{Risk} = \frac{2}{12300} \times 135 = 0.11$$

Main lubrication pump electric motor

Table 13: related to the repair and service costs of the main lubrication pump

No.	Replaced part	Parts number	Cost	Operation time	Required people
1	Ball Bearing	2	50	4 hours	2 technicians
2	Seal	2	2.5		
3	Shock absorber	1	15		

The total cost of repairing the electric motor of the main lubrication pump: 70 USD. For electric motor and auxiliary pump, due to its similarity and sameness with electric motor and main lubrication pump, all measures and costs are similar. According to the risk calculation for a number of components of lubrication systems and diesel fuel, Table 14 is presented in the order of the risk number.

Table 14: Prioritization of lubrication subsystems and diesel fuel based on risk number

No	Subsystem	probability of occurrence	Cost	Risk number
1	The main diesel fuel pump	$\frac{2}{17400}$	2500	56514.1
2	Lubricating filters	$\frac{2}{21450}$	370	6813.4
3	Diesel fuel feed pump	$\frac{4}{24200}$	185	6005.5
4	The main filters of the diesel fuel system	$\frac{1}{9300}$	200	4288.5
5	Main lubrication pump	$\frac{2}{12300}$	135	4237.1
6	Diesel fuel control valves	$\frac{1}{15700}$	40	488.1
7	Turbine lifting pump	$\frac{1}{18350}$	25	354.4
8	Lubrication pressure regulating valve	$\frac{2}{46300}$	40	304.1
9	Lubricating foot temperature valves	$\frac{1}{28450}$	25	173.8
10	Injection pump pressure valve	$\frac{3}{16850}$	3	808

For subsystems and systems, according to the amount of the risk number, suggestions and solutions are provided for each of them, which will affect the probability of occurrence or the consequences of the work that will be mentioned. Lubrication system filters: It is suggested that due to the importance of the issue of filtration in the lubrication system, as well as the maintenance and quantitative and qualitative value of the lubricating oil, special attention should be paid to this issue, and in this regard, suggestions and plans are presented, including It is possible to mention the use of auxiliary filters with pores (mesh) larger than the main filters in the path between the lubrication pumps and the main filters of the lubrication system. By implementing this plan, some larger particles are prevented from entering the main filters. Failure is effective. It is suggested how to clean and wash the filters from solvents such as gasoline or instant thinner with the air pressure of the auxiliary compressor; It should be used instead of ordinary thinner, which is also effective in the consequences of failure. Diesel fuel feeding pump: change in the chassis carrying the electric motor and pump, which has less resistance in terms of the type of material used, and in short periods of time, it causes misalignment of the electric motor and the mentioned pump, which in some cases causes the fuel supply system to stop. And as a result, the turbine is shot down; It is suggested to use materials with high resistance to affect the consequences of failure. In order to affect the probability of failure, it is possible to suggest the use of high-quality spare parts.

The main filters of the diesel fuel system: the use of auxiliary filters in the distances between the main tanks and the filters of the diesel fuel feeding pump, as well as between the main filters and the feeding pumps of the diesel fuel system, is suggested to affect the consequences of failure and failure. A change in the way of cleaning and washing the filters is also suggested as an influencing factor in the possibility of damage and failure; Because in the current method, washing is done with 160 bar pressure of water with normal (ambient) temperature by car wash from the outside of the filter, while the suggested method of using water with high temperature and pressure is done from the inside of the filter. The main pump of the lubrication system: due to the similarity and the same type of lubrication pumps (main and auxiliary pump), we will offer suggestions and design for the main pump. Lubrication of pump bearings is done by grease, and due to the defects caused due to the reduction in lubrication, the use of discharge oil (output) of the pumps guided by a pipe path to the bearing part, instead of grease, the problem related to the reduction of lubricant significantly It is removed and it also brings cost savings, which reduces the possibility of breakdowns due to lubrication. For abnormal noise and high vibration, it is recommended to change the size between the line bearing and the pump shaft, as well as change the material (in the current type, the distance between the pump shaft and the line bearing is about 1.7 ≈2 mm, the material of the shaft bearing is graphite) that the size changes to 7. ≈1.4 mm and the material from graphic to compressed teflon. In order to align the electric motor and the main and auxiliary lubrication pump, it is recommended to use two holes and retaining screws (instead of one) in the pump coupling and balancing after the above operation.

To test the method of reliability modeling and availability analysis, we combined cycle power plant located in Karaj campus in Iran is used as a system. The CCPP reliability data are presented in the study (Fahmi et al., 2022) and (Qu et al., 2021) to calculate the reliability indices for GTPP and STPP constituting the overall CCPP. Assume that all the components according to the proposed formulations (16) – (1) in the circuit are. The overall basic indicators of CCPP under review are shown in Figure 2 and Figure 3. From Figure 2, it can be seen that CCPP is the one with the highest MTTF and MTTF indicators compared to GTPP and STPP, and when the second STPP is placed in this context. However, it can be concluded from Figure 3 that STPP is the most accessible station compared to GTPP and CCPP and therefore its components. To evaluate the sensitivity of each system component from the reliability point of view, the two scenarios proposed for each component are used and the contribution of component failure to the overall system reliability is investigated.

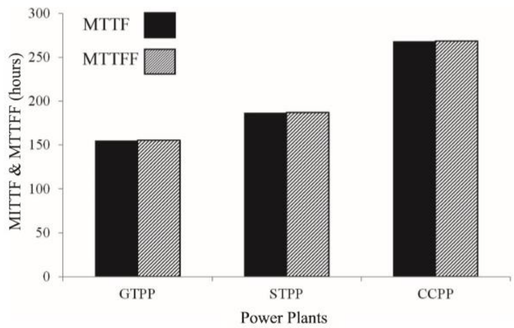

Figure 2: Comparison of MTTF and MTTF of different power plants

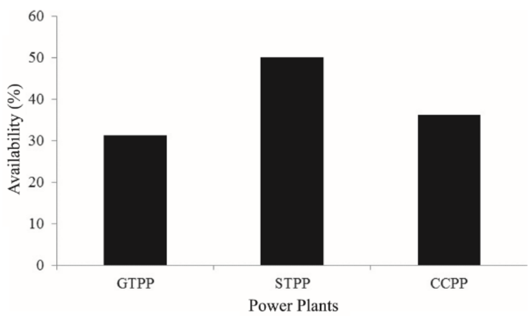

Figure 3: Comparison of accessibility of different power plants

The results are given in Table 15, respectively, for the first ten critical components of the CCPP as an example.

Table 15: Important and critical components of the combined cycle power plant

Component	MTTF (hr.)	MTTFF (hr.)	MCT (hr.)	MDT (hr.)	A (%.)	RCF
Rotor Blade (54)	269.957358	269.957358	440.6602894	170.7029226	36.31628299	0.207400121
Housing (41)	268.9948442	268.9948442	439.7016475	170.706812	36.28459858	0.161967707
Thermocouple (49)	268.4231929	268.4231929	439.126133	170.7029489	36.26619021	0.112784118
Pump (55)	269.7371842	269.7371842	440.4608942	170.7237188	36.30749722	0.076047268
Cooling System (44)	273.3491249	273.3491249	444.2012741	170.8521492	36.41405696	0.039260563
Stator (43)	272.8637683	272.8637683	443.7178097	170.8540414	36.39836771	0.035026174
Housing Bearing (58)	268.755889	268.755889	439.4729152	170.7170262	36.27598778	0.033120758
Stationary Blade (59)	269.9238773	269.9238773	440.6988684	170.7749911	36.30957808	0.02563885
Flame Detector (37)	266.0654564	266.0654564	436.6447579	170.5793015	36.19810016	0.021755295
Governor (53)	271.6516033	271.6516033	442.619113	170.9675096	36.35055733	0.014703444

The analysis shows that the rotor blade (54), reservoir (41), thermocouple (49), pump (55) and cooling system (44) are the most reliable components of CCPP. Component numbers (in parentheses) are used to name subsystems. Grading of system components from reliability, safety, environmental and cost perspective is shown in the following figures.

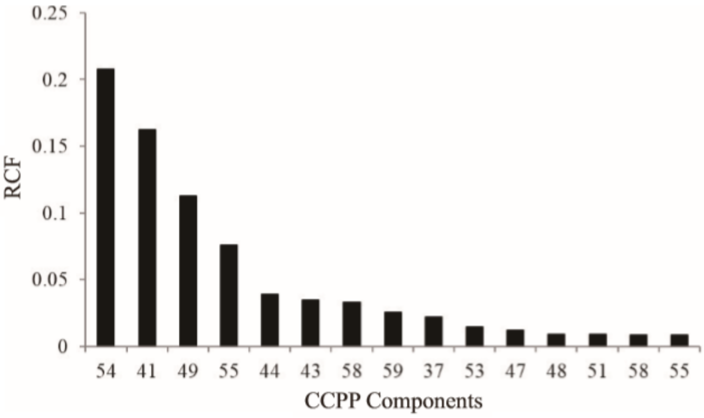

Figure 4: System reliability

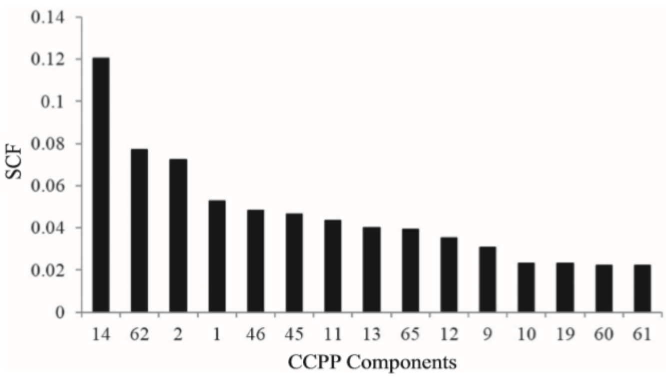

Figure 5: Electrical safety

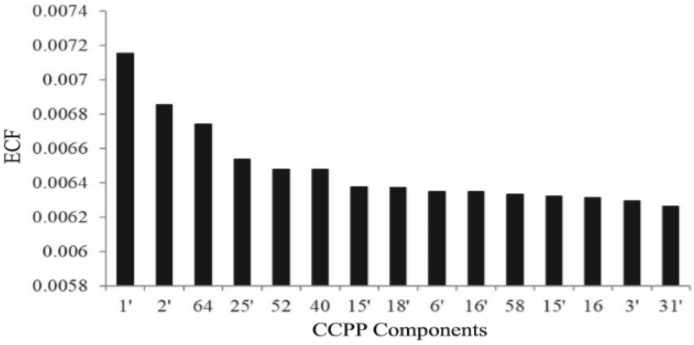

Figure 6: Environment

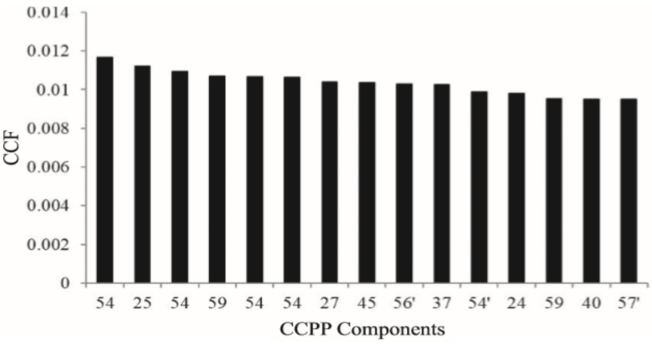

Figure 7: Imposed costs

It can be concluded that the priority of the components is different from different points of view, that the necessity of using the risk factor is calculated for each CCPP component under study, which can be seen in Figure 8.

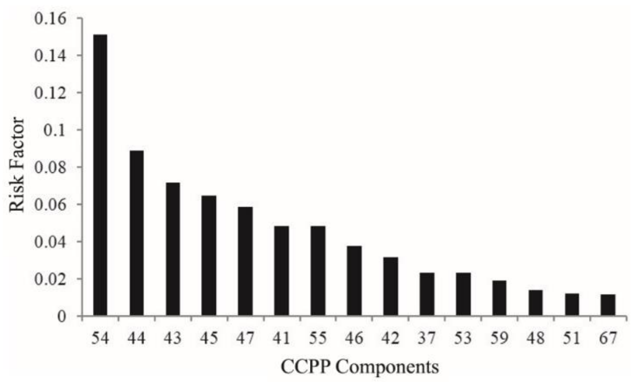

Figure 8: Risk factors for the most important components of the CCPP

The failure probability values in the component are shown in the figure below. The importance coefficients of the result terms in (49) are assumed to be 0.4, 0.2, 0.1, 0.3 for Υ and β and α and η, respectively.

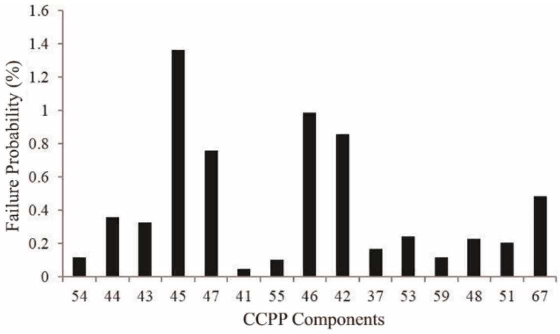

Figure 9: Probability of failure for the most important CCPP components

As seen in Figure 26-3, rotor blades (54), generator cooling system (44), stator (43), rotor (45) and protection system (47) are the most important components of CCPP; Because they have the highest risk factors compared to others. If we are only concerned about the GTPP and STPP components, the proposed framework includes the critical components as a hot steam heater (57), an ejector condenser (29), and a steam condenser outlet (24), a stator (54), an electric motor (30) and bearings (53). For STPP and the rotor blade (54) is the cooling system of the generator (44) and the stator (43) for GTPP. The identified components are those whose failure will have the greatest impact on system performance and at the same time require more due to component-based reliability considerations, such as equipment age mechanism. As a result, maintenance resources can be significantly spread among CCPP components based on risk-based risk determinants. Once the critical components have been identified as the initial focus, the RCM process can be set up for subsequent steps in the CCPP. According to the above research done by (Sabouhi et al., 2016) and observing and using the results; in this research, the border between these two researches is the use of the risk index to identify critical cases and components in this paper.

4. Conclusion

The method described in this research helps in the technological allocation of financial resources for the maintenance of the CCPP component at any time and when necessary, thus ensuring the availability and reliability of power generation to meet the demand is increased. The proposed framework for recognizing critical system components not only initiates the implementation of modern maintenance strategies (such as RCM) but also plays an important role in other applications such as plant health monitoring, spare equipment planning, and investment. Future work could be to develop new formulas for the next steps in the implementation of RCM in the power plant (for example, choosing an optimal maintenance strategy and schedule) that are compatible with the proposed approach and in such a way that the intervention of adequate maintenance measures and necessary recommendations for the maintenance part can be completely taken care of. The implementation of RCM in integrated energy production and transmission systems is also suggested for future studies. The use of fuzzy set theory and other robust probabilistic methods in dealing with the uncertainty involved in the RCM implementation process can also be explored in future work. It is also necessary to state that repair and maintenance with the approach of reliability, time can be cited and planned based on information and data obtained from continuous monitoring and accurate observations, taking into account the totality of conditions and periods. Be specific and special. In the end, it is reminded that the correct and precise implementation of maintenance and repairs based on reliability and accessibility will have the following results:
• Improving the quality of operations and services.
• Preventing the destruction of the environment.
• Increasing the safety of people in harsh and harmful work environments.
• Creating the spirit of cooperation and cooperation and the necessary motivations among the employees.

- Creating an information base based on qualitative and evaluated documents.
- Improving efficiency and effectiveness in operational processes and net costs.
- Extending the economic life cycle of equipment.
- Creating positive habits of thinking, decision-making, consensus, analysis and analysis and finding the root of failures.
- Easier and purposeful performance of periodical and risk-based inspections of RCM standardization.
- Determining a preventive measure for each failure mode of the equipment based on programs and specific time periods (Cycle).
- Reducing costs and energy consumption in environmental protection organization.
- Increasing safety and also accessibility and reliability of devices and finally increasing the level of quality of services and operations.
- Identifying critical and value-added points.
- Strengthening and institutionalizing the culture of prevention in the organization.

References

Ahmadi, R. , &Fouladirad, M. (2017). Maintenance planning for a deteriorating production process. Reliability Engineering & System Safety, 159, 108-118.

Biswal, G. R. , Maheshwari, R. P. , &Dewal, M. L. (2012). System reliability and fault tree analysis of SeSHRS-based augmentation of hydrogen: Dedicated for combined cycle power plants. IEEE Systems Journal, 6 (4) , 647-656.

Dong, X. , Axinte, D. , Palmer, D. , Cobos, S. , Raffles, M. , Rabani, A. , & Kell, J. (2017). Development of a slender continuum robotic system for on-wing inspection/repair of gas turbine engines. Robotics and Computer-Integrated Manufacturing, 44, 218-229.

Fahmi, A. T. W. K., Kashyzadeh, K. R., & Ghorbani, S. (2022). A comprehensive review on mechanical failures cause vibration in the gas turbine of combined cycle power plants. *Engineering Failure Analysis*, 106094.

Gharakheili, M. A. , Fotuhi-Firuzabad, M. , &Dehghanian, P. (2018). A new multiattribute decision making support tool for identifying critical components in power transmission systems. IEEE Systems Journal, 12 (1) , 316-327.

Hou, J. , Wicks, B. J. , & Antoniou, R. A. (2002). An investigation of fatigue failures of turbine blades in a gas turbine engine by mechanical analysis. Engineering Failure Analysis, 9 (2) , 201-211.

Kermanpur, A. , Amin, H. S. , Ziaei-Rad, S. , Nourbakhshnia, N. , &Mosaddeghfar, M. (2008). Failure analysis of Ti6Al4V gas turbine compressor blades. Engineering Failure Analysis, 15 (8) , 1052-1064.

Khaljani, M. , Saray, R. K. , &Bahlouli, K. (2015). Comprehensive analysis of energy, exergy and exergo-economic of cogeneration of heat and power in a combined gas turbine and organic Rankine cycle. Energy Conversion and Management, 97, 154-165.

Qu, Z., Xu, J., Wang, Z., Chi, R., & Liu, H. (2021). Prediction of electricity generation from a combined cycle power plant based on a stacking ensemble and its hyperparameter optimization with a grid-search method. *Energy*, *227*, 120309.

Ramere, M. D., & Laseinde, O. T. (2021). Optimization of condition-based maintenance strategy prediction for aging automotive industrial equipment using FMEA. *Procedia Computer Science*, *180*, 229-238.

Ren, Z., Verma, A. S., Li, Y., Teuwen, J. J., & Jiang, Z. (2021). Offshore wind turbine operations and maintenance: A state-of-the-art review. *Renewable and Sustainable Energy Reviews*, *144*, 110886.

Sabouhi, H. , Abbaspour, A. , Fotuhi-Firuzabad, M. , &Dehghanian, P. (2016). Reliability modeling and availability analysis of combined cycle power plants. International Journal of Electrical Power & Energy Systems, 79, 108-119.

Zhang, G. , Zheng, J. , Yang, Y. , & Liu, W. (2016). A novel LNG cryogenic energy utilization method for inlet air cooling to improve the performance of combined cycle. Applied energy, 179, 638-649.