

## Article info

Received on: 21.06.2021

Accepted on: 29.07.2021

Published on: 31.07.2021

doi: <https://doi.org/10.52688/ASP34988>

## Research Article

# Strategies planning for power systems maintenance and troubleshooting

Sam Charle Queer<sup>1,\*</sup><sup>1</sup> College of Technology, Mumbai university, Mumbai, India\* [Queersam12@ymail.com](mailto:Queersam12@ymail.com)

## ABSTRACT

The competition in energy market involves development of environment friendly and high scale power output plants. The major types of reliable power generation plants are found to be nuclear and hydropower plants which are manifested a promising source of energy that produce power in large scale. Human errors are mainly occurring during the maintenance, design (planning) and operation phases. Such error are the main causes of performance degradation by imposing economical and technical losses. This paper keen on investigating the human error causes that leads to performance degradation in power plants. It was realized that human errors are mainly caused by bad human resources strategies and faulty materials (monitoring tools) while studying the same over two nuclear and one coal-fired power plants.

**Keywords:** Sustainability, maintenance, human error, RUL, impact factor, availability, criticality

## INTRODUCTION

Power plants are established for supplying the load with known amount of energy in continuous manner. Tradition power plants are basically relying on fossil fuel for energy production; such industries are major and most trusted source of energy. Nevertheless; traditional energy resources manifested in gas, thermal, diesel, atomic, etc. power plants are negatively influencing the environments, it has remained as most reliable resources of energy [1]. Renewable energy resources manifested in wind and solar power plants are promising sources of cheap and environmentally friendly energy [2]. The persisted doubt of possibility of complete switching into renewable energy can be addressed by studying a metrics alike availability and criticality in both resources. Availability is defined at [3] as percentage of continuous power production by the plant without interruption. It is measured in time and reflects the periods that station/plant operational and capable to generate power. Criticality is the period that station/plant is none operational and it occurs during operational faults. Data of availability and criticality is to be collected by the station/plant team in order to put maintenance plans and preparing the required equipments. Through analyzing the data of availability and criticality, station/plant remaining useful life (RUL) can be derived/predicted [4]. RUL represents the period that station/plant will remain operational until the next expected fault occurrence. The prediction of the RUL in power plants is vital factor for the performance and cost. Availability and criticality analysis are achievable using qualitative and quantitative approaches which in turn reveal the future status of plant. Thus, it can be realized from the previous researches that conducted in domain of maintenance scheduling and planning based on Availability and criticality studies. Among that; plenty of researches such as have been made in interest of fossil fueled stations such as thermal plants [5] and gas plants [6]. Such studies are helped for aiding future error occurrences by scheduling robust maintenance plans. From the other hand, good number of researches were deployed those factors in order to estimate the performance of plant in order to optimize the production i.e. (measuring the availability and criticality in wind power plant in order to enhance the power generated from wind more likely by increasing the number of towers or modification the turbine design). In order to highlight the influence of human error in various maintenance process; this paper involves three case studies showing the same over nuclear power plants and coal-fired power plant.

## HUMAN ERROR

In order to prevent devices dysfunctionality, maintenance for the same devices is must. Since power plants are involving numerous costly and highly fault susceptible devices. Perfect maintenance may enhance the cost by preventing the fully defect of the devices and also to return the partially defected devices into service as rapid as possible. Thus, performing of preplanned maintenance is certainly enhancing the plant performance and reliability due to the role it is playing in clearance of malfunctioning in power plants. Defective devices are triggering safety concerns as well as financial losses [b7]. Due to the

---

**\*Corresponding author**

Sam Charle Queer,

College of Technology, Mumbai university, Mumbai, India

e-mail: [Queersam12@ymail.com](mailto:Queersam12@ymail.com)

substantial role of maintenance in tackling plenty of performance degradations factors as well as improving the safety measures in power plants, it is considered as vital contributor in power quality formula [8]. Human error is one of the potential factors that degrade the maintenance irrespective of the serious efforts for perfecting maintenance planning and schedules [9]. Human errors are not avoidable and their bad consequences during maintenance process are popular in industries alike aviation, defence and power plants. Human errors are contributing in almost 60% of errors occurring in industries. More specifically, an error of particular device may trigger multiple errors in the system by whole [10 b1]. According to [11 b2], nuclear reactor unplanned faults are realized associating with maintenance due to human error. In large power plants such as nuclear power plant [12] and hydropower plant [13], it was realized that factors like cost and performance were always targetable during design and planning stages. However, influence of maintenance in both cost and performance is realized to be major. During machinery era where machines are set for performing human tasks and facilitates their lives; human factor could not fully omit. Maintenance is about those process where human can intervene and maintain the required functionality of the machines. Although, large of today's machinery systems are enabled with auto/self-maintenance; human role in in this complex is still required [14]. Human error is the major concern herein where machinery is expected to be maintained perfectly. Such perfection is impossible in practically scenario as human error is unavoidable. With emerging of new man/human machine interface (HMI) systems of user friendly features, it was expected that human error will be reduced [15]. However, human errors were realized in various forms in maintenance degradation [16]. The risks associated with human errors are manifested in equipments premature failure which increase the cost and reduce the performance [17]. Insufficient considerations of the operational errors are main reason behind sudden unexpected errors. Generally, error aids during the designing stages of power plants are merely considering hardware failure which is practically insufficient to rely on due to other errors generating during the operations. Taking another industry (apart from the power generation) it was stated at [18] that human error is participating a 70% of aviation accidents. Another experience in [19] stated that 50% of power outages in coal-power plant is occurring normally during the week days has potentially reduced after scheduling of shutdown maintenance. 60% of losses in domestic plants were realized because of human error. Thus, estimation of human error is vital for tackling the unexpected circumstances during the operations.

## MAINTENANCE OF POWER PLANTS

Planning is essential step any industry for increasing the profitability and consistent under the sever market competition [20]. More specifically, power plants industry is large in terms of investment and also highly susceptible for competitions of energy market. Since energy generation technologies are continuously emerging for kilowatt cost reduction and for creating environmentally friendly systems with less possible emissions. In order to continue plant sustainability (performance in the designed/targeted level), robust maintenance is required. As prescribed above, maintenance is critical for power plant performance; the said maintenance of coal-fired based power plant is realized according to the report of Energy Sector Management Assistance Program (ESMAP) [21] of the World Bank. However, maintenance of such type of plants in Asia Pacific region was realized and the following problems were found:

- a) In the said power plant i.e. coal fired power generation, it was found that such plants are by whole lack for documented maintenance even in case of maintenance of essential and critical parts of the plants.
- b) Ordinary, operational historical maintenance database is found not deployable for extracting data alike average time between the part failures and subsequently no failure model is seen constructed.
- c) Maintenance is conducted according to the fashion cited/inherited from other plants and the planning is made for long times i.e. three years in advance based on the same inputs which led to unexpected shutdown of the plant.
- d) Due to the old age of the mentioned plants, the existed monitoring systems are not being used. even through, its performance is not upto the mark which lead to inadequate maintenance quality.

## CASE STUDY

The framework of the said case study is that bias which can be used to classify the human error. Thus, the consensus among the realized publications/reports of the cases mentioned herewith can be stated as error due to human faults are collected base on the error cause and type of task as well as the circumstances of detection. The framework of the classification is demonstrated in Figure 1.

Such type of errors can be occurred in various type of tasks including: during the designs and planning, during the operation phase and during the maintenance phase. For the research samples CA, CB and CC, the data of human error can be illustrated in Table 1. In order to understand the causes that leads to the so-called human error in power generation industry, we have taken three case studies which represent the causes of human error in two nuclear power plants located in united states of America and India as well as one coal-fired power plant located in India. In further discussions, we are going to term for each mentioned case as CA, CB and CC where CA stands for US based nuclear plant, CB stands for India based power plant and ultimately CC stands for India based coal-fired power plant.

---

### \*Corresponding author

Sam Charle Queer,  
College of Technology, Mumbai university, Mumbai, India  
e-mail: [Queersam12@gmail.com](mailto:Queersam12@gmail.com)

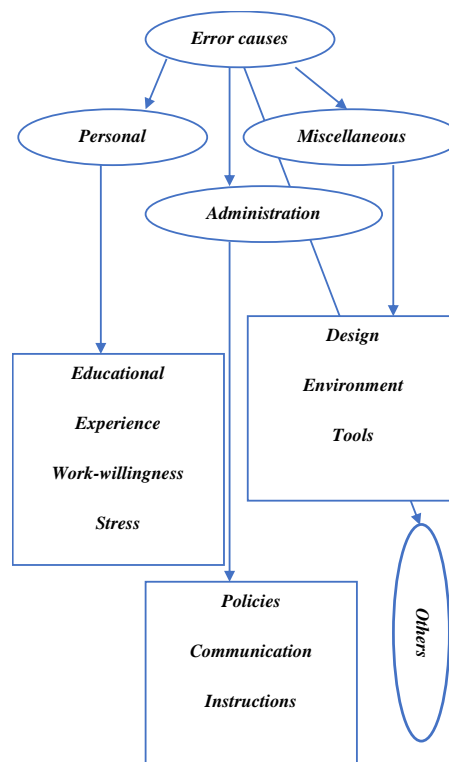
CA: US based commercial boil water reactor suffering from abnormalities occurrences. The data of the same occurrences are reported to the US nuclear regulatory commission (UNRC) and released by them [22].

CB: India based nuclear power plants, data are reported to the reactor control division and released by Bhabha atomic research center [23].

CC: India based coal-fired power plants based in Punjab, Gujarat, Rajasthan, Andhra Pradesh and Tamil Nadu. Data is released by Energy Sector Management Assistance Program (ESMAP) [21].

Thus, Table 1, illustrated the human error causes over various types of power plants including nuclear (CA and CB) and conventional coal-fired power plant (CC). Over the mentioned case studies, it is known that energy generated from nuclear plants are much higher than that of other plants [12]. Considering the cost of production as compared to the coal-fired plants, the later has maintained its position in energy industries. The collection of those samples (cases) was performed after fulfilment the diversity factors in generation type e.g. (nuclear and coal-fired) and the locality (e.g. USA and India). From error assessment point of view, Table 1 brings the consensus of error causes among the aforementioned plants. However, the data is feed into table in form of binary indicators i.e. (zeros and ones) where zeros indicates the none popularity of that error causes in the plant and ones indicated the popularity of error causes.

Results of impact factor for the human error causes as shown in Figure 2 revealed that “experience” and “monitoring tools” errors are having consensus among all the plants i.e. (CA, CB and CC). Thus, experience of the staff is vital for the human error causes from the other hand, faults of monitoring tools such as meters and indicators are also common reason behind the human error in the plants



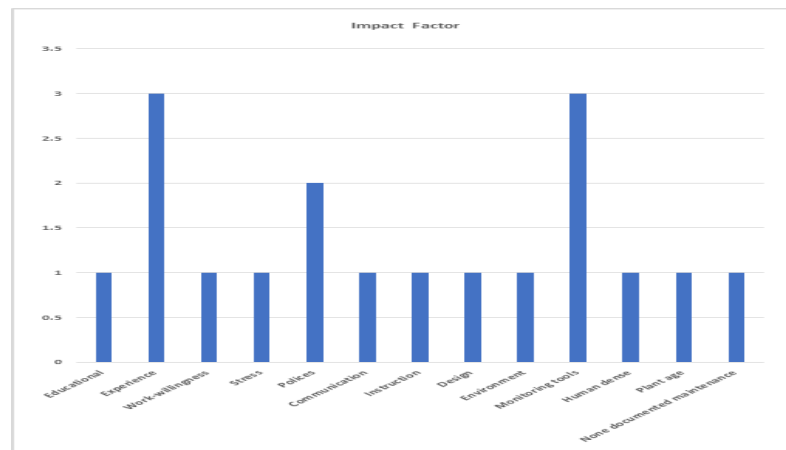
**Figure 1: Classification of the cause of human error in power plants**

**\*Corresponding author**

Sam Charle Queer,  
College of Technology, Mumbai university, Mumbai, India  
e-mail: [Queersam12@ymail.com](mailto:Queersam12@ymail.com)

**Table 1: data formulation from the selected case studies.**

Plants Errors	CA	CB	CC	Impact factor
Educational	1	0	0	1
Experience	1	1	1	3
Work-willingness	1	0	0	1
Stress	1	0	0	1
Polices	1	0	1	2
Communication	1	0	0	1
Instruction	1	0	0	1
Design	1	0	0	1
Environment	1	0	0	1
Monitoring tools	1	1	1	3
Human dense	0	1	0	1
Plant age	0	0	1	1
None documented maintenance	0	0	1	1

**Figure 2: Impact factor of error causes in the power plants (according to the research sample)**

## RECOMMENDATIONS

In order to tackle the human error involved into maintenance degradation, several aspects need to be followed in power plants. Human resources need to be efficiently performed in such way the expert bodies and mostly required profiles are hired. The human resources need to be restructured in such ways all the responsibilities and tasks are clearly defined. Adequate structure of the responsibility involves efficiently fulfillment of four majors in the plants namely, operational an maintenance (O&M), Human resource (HR), Finance and materials. Within maintenance department e.g. (O&M), several responsibilities (profiles) are required; the same is listed in Table 2.

---

### \*Corresponding author

Sam Charle Queer,  
College of Technology, Mumbai university, Mumbai, India  
e-mail: [Queersam12@ymail.com](mailto:Queersam12@ymail.com)

**Table 2: Responsibilities restructure of power plants organizations**

Profile	Required Responsibilities
Operations	Planning the maintenance and human power management.
Maintenance planning	For forecasting the required maintenance tasks.
Station chemistry	Studying of emersions and letouts.
Efficiency and operations	Quality assuring tasks.
Parts maintenance	Assessment of parts and management of spare parts.

## CONCLUSION

Power plants are vital for various performance degradations that influencing the Quality of service. Among that, maintenance performance degradation due to human error. This paper discussed the influencing factors that contributes the expansion of human error in the power plants. The sample of this study is considered three cases namely: CA, CB and CC which stand for two nuclear power plants and one coal-fired power plant. Human error framework was related to three main causes namely: administrative, personal, Miscellaneous and others. Thus, data are collected from the reports published by the specific organizations where the plants are belonging to; the same is gathered from each publication and used to formulate the Table 1. The impact factor of each error cause is being measured and the leading causes of human error was found to be “lack of experience” and “faults of monitoring tools”. Staff experience is responsibility of human resource department which need to recruit the experience professional bodies for operating the plant. From the other hand, faulty tools and monitoring equipments are another cause of human error, the same is realized at all cases of research sample where the faulty monitoring and measurement tools are mainly causing human errors.

## REFERENCES

- [1] H. A. Mahmood and R. K. J. I. J. E. T. Ahmed, "Fiber bragg grating and channel spacing effect in WDM radio over fiber system using DPSK modulation format," vol. 7, pp. 218-22, 2018.
- [2] H. A. Mahmood and R. K. J. I. J. E. T. Ahmed, "Fiber bragg grating and channel spacing effect in WDM radio over fiber system using DPSK modulation format," vol. 7, pp. 218-22, 2018.
- [3] H. A. Mahmood and R. K. J. I. J. E. T. Ahmed, "Fiber bragg grating and channel spacing effect in WDM radio over fiber system using DPSK modulation format," vol. 7, pp. 218-22, 2018.
- [4] A.M. Levenda, I. Behrsin, F. Disano, 2021. Renewable energy for whom? A global systematic review of the environmental justice implications of renewable energy technologies. *Energy Research & Social Science*, 71.
- [5] Simplice A. Asongu, Nicholas M. Odhiambo, 2021. Inequality, finance and renewable energy consumption in Sub-Saharan Africa, 165.
- [6] Shayan Naderi, et al., 2020. Accurate capacity factor calculation of waste-to-energy power plants based on availability analysis and design/off-design performance. *Journal of Cleaner Production*. 275.
- [7] Hanumant Jagtap, et al., 2020. Markov-based performance evaluation and availability optimization of the boiler–furnace system in coal-fired thermal power plant using PSO. *Energy Reports*. 6.
- [8] Shogo Eguchi, et al., Sources of inefficient power generation by coal-fired thermal power plants in China: A metafrontier DEA decomposition approach. *Renewable and Sustainable Energy Reviews*. 110562.
- [9] Shima Yazdani, et al., A comparison between a natural gas power plant and a municipal solid waste incineration power plant based on an emergy analysis. *Journal of Cleaner Production*. 274.
- [10] M. Khalaquzzaman, et al., 2010. Quantification of unavailability caused by random failures and maintenance human errors in nuclear power plants. *Nuclear Engineering and Design*. 240.
- [11] Merve BULUT, Evrencan ÖZCAN, 2021. A new approach to determine maintenance periods of the most critical hydroelectric power plant equipment. *Reliability Engineering & System Safety*. 205.
- [12] Jonas Fausing Olesen, Hamid Reza Shaker, 2021. Predictive maintenance within combined heat and power plants based on a novel virtual sample generation method. *Energy Conversion and Management*. 227.
- [13] Apostolakis, G., Chu, T.L., 1980. The unavailability of systems under periodic test and maintenance. *Nuclear Technology* 50.
- [14] Apostolakis, G., Bansal, P.P., 1977. The effect of human error on the availability of periodically inspected redundant systems. *IEEE Transactions on Reliability* R-26 (3).
- [15] R.M. Ayo-Imoru, A.C. Cilliers, 2018. Continuous machine learning for abnormality identification to aid condition-based maintenance in nuclear power plant. *Annals of Nuclear Energy*. 118.
- [16] Pardeep Singh, 2020. Sustainability of maintenance management practices in hydropower plant: A conceptual framework. *Materials Today: Proceedings*. 28.

---

### \*Corresponding author

Sam Charle Queer,  
College of Technology, Mumbai university, Mumbai, India  
e-mail: [Queersam12@gmail.com](mailto:Queersam12@gmail.com)

- [17] Georgios M. Kopanos, et al., Efficient planning of energy production and maintenance of large-scale combined heat and power plants. *Energy Conversion and Management*. 169.
- [18] Georgios M. Kopanos, 2018. Efficient planning of energy production and maintenance of large-scale combined heat and power plants. *Energy Conversion and Management*. 169.
- [19] Lokukaluge P., et al., 2019. Failure intensity of offshore power plants under varying maintenance policies. *Engineering Failure Analysis*. 97.
- [20] Arthur Henrique, et al., 2018. Criticality-based maintenance of a coal-fired power plant. *Energy*. 147.
- [21] Sarter, N.B., Alexander, H.M., 2000. Error types and related error detection mechanisms in the aviation domain: an analysis of aviation safety reporting system incident reports. *International Journal of Aviation Psychology* 10 (2), 189–206.
- [22] Sandy, D., 2005. Managing human error in maintenance. *Maintenance & Asset Management* 20 (4).
- [23] Nurkhat Zhakiyev, et al. 2017. Optimal Energy Dispatch and Maintenance of an Industrial Coal-Fired Combined Heat and Power Plant in Kazakhstan. *Energy Procedia*. 142.
- [24] Sustainable Development Network, 2009. Strengthening Operations and Maintenance Practices In State-Sector Coal-Fired Power Generation Plants in India. *Energy Sector Management Assistance Program (ESMAP)*.
- [25] Hiroshi UJITA. 1985. Human Error Classification and Analysis in Nuclear Power Plants. *Journal of Nuclear Science and Technology*, 22:6, 496-498.
- [26] Report for technical Committee Meeting Organized By The International Atomic Energy Agency. 1989. Human error classification And data collection.

---

**\*Corresponding author**

Sam Charle Queer,  
College of Technology, Mumbai university, Mumbai, India  
e-mail: [Queersam12@ymail.com](mailto:Queersam12@ymail.com)