A DEMATEL Technique to Analyze the Drivers for Affecting the Efficiency of Steam Turbine

T. Sivageerthi, S. Bathrinath and M. Uthayakumar

Abstract*: The global warming is a major thread in recent days. Industrial pollution is a prime contributor to global warming especially pollution due to coal fired power plants. In global electrical power scenario, maximum portion of required electrical energy is produced from coal fired thermal power plants. Steam turbine is major equipment in it, which converts heat energy in to mechanical energy. The energy conversion efficiency is most important one. Reduction in efficiency means wastage or loss of energy and leads to increase the cost of generation. Here, case study is conducted in the topmost coal fired thermal power plant in south India. The objective of the study is to recognize and evaluate the most influential drivers in the coal fired thermal power plant. If the most important drivers which highly influencing steam turbine efficiency are identified. In this paper, to recognize the most influential drivers for affecting steam turbine efficiency by using DEMATEL technique. The outcomes of the paper expose that steam pressure (D1) is the most influential driver in the coal fired thermal power plant and they need more focus to control it.

***Keywords*: DEMATEL, Global warming, India, Steam turbine.**

I. INTRODUCTION

Due to some reasons like age and continuous operations, each and every power plant losses their efficiency. In olden days everything develops with time. Latterly, some plant will be no longer at the operation. Carbon dioxide emission increases due to its reduction in efficiency. As on February 2019, electricity has 351GW capacity in India. By utilities electricity generation was 1303 TWh and the total generated electricity was 1,486 TWh in the year 2017-2018 and consumption in the electricity was 1149 kWh/capita. In India, the electricity total Installed Capacity is 3,50,162 MW (As on 28.02.2019) upon which total thermal power installed capacity is 2,22,927 MW, it is 63.7% of total installed capacity. It is difficult to control the drivers for affecting steam turbine efficiency and also it is a key problem for every power plant. The objective of the paper is to identify and analyze the drivers for affecting steam turbine efficiency in coal fired thermal power plant by using DEMATEL technique. For the implementation of efficiency in steam turbine, the industrial managers and practitioners will use the outcomes. Recently many researchers have explored the problems related to efficiency of steam turbine [1-3].

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II. RELEVANT LITERATURE

The relevant literature is sorted into two sub-segments namely (A) To identify the drivers for affecting steam turbine efficiency (B) Literature Gap

A. To identify the drivers for affecting steam turbine efficiency

Anjali and Kalivarathan et al. [4] followed the maintenance strategy and suitable operation for the power generation and does not need power plant with effective design and through the cycle efficiency of energy conservation still higher. Fu and Liu [5] investigated on the three dimensional flow fields has different parameter influences in the low-pressure steam turbine of a power station. Under various conditions of inlet, both full and small scale turbine exhaust systems have complex flows and they simulated. On the flow fields and performance of aerodynamics, the effects of fluid properties and both inlet Mach and Renault number were examined. Ion and Codrut [6] explained that efficiency of turbine has negative influence on efficiency of steam power plant. 47.7% thermal efficiency for the rated K 200- 130-1 steam turbines. Since 1968, the turbine is operational so the evaluation efficiency can focuses its current condition of the technical one. Spencer et al. [7] identified a forecasting technique for steam turbine-generators performance with the capacity of 16.5MW.

B. Literature gap

Based on the relevant literature, so far there is no research papers related for the analysis of drivers for affecting steam turbine efficiency by using MCDM method like DEMATEL. This paper examines the drivers by using DEMATEL technique. From the industrial experts and literature, drivers are recognized and exhibited in Table 1.

Table- I: Categories of drivers

S.No	Drivers	Notation
1	Steam pressure	D1
2	Steam Temperature	D2
3	Exhaust pressure/ vacuum	D3
4	water rate/ steam flow rate	D4
5	Inter stage seal clearance	D5
6	Vibration	D6

7	Thermal insulation	D7
8	surrounding Temperature	D8
9	Regenerative heaters performance	D9
10	Reheater performance	D10

III. FLOW DIAGRAM OF THE PAPER

The flow diagram of the paper is presented in Figure 1.

IV. METHODOLOGY

In this paper, to analyze the drivers for affecting steam turbine efficiency in a coal fired thermal power plant by using DEMATEL method. Figure 1 depicts the flowchart of the paper.

A. DEMATEL

It is a method for recognizing the factors and shows the relationship of cause and effect and also it is used to solve complicated problems [8]. Many researchers used the DEMATEL method for solving the industrial problems recently [9-11].

The DEMATEL method procedures are discussed below [12-14].

Phase 1: To compute the direct relation matrix ‘E’

Based on the inputs from decision makers, to compute the ‘E’ by analyzing and comparing the factors with each other. Equation (1) depicts the numerical expression of ‘E’.

$$E = \begin{bmatrix} 1 & e_{12} & e_{13} & \cdots & e_{1(n-1)} & e_{1n} \\ e_{21} & 1 & e_{23} & \cdots & e_{2(n-1)} & e_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ e_{(n-1)1} & e_{(n-1)2} & e_{(n-2)3} & \cdots & 1 & e_{(n-1)n} \\ e_{n1} & e_{n2} & e_{n3} & \cdots & e_{n(n-1)} & 1 \end{bmatrix} \quad (1)$$

This method used the linguistic scale for rating and exhibited in Table 2.

Table- II: Linguistic scale

Mutable	Impact score
Very high impact	4
High impact	3
Medium impact	2
Low impact	1
Very low impact	0

Phase 2: Normalize the ‘E’ matrix

To normalize the ‘E’ by using equations (2) and (3). Between 0 and 1 where all the components should lie.

$$C = \frac{1}{\max_{1 \le i \le n}} \sum_{j=1}^{n} E_{ij} \quad (2)$$

$$F = C \times E \quad (3)$$

Phase 3: To compute the Total relation matrix ‘G’

To acquire the ‘G’ from the ‘F’ by using equation (4), where I indicates Identity matrix.

$$G = F(I - F)^{-1} \quad (4)$$

Phase 4: To compute the summation of rows and columns

To compute the summation of rows and columns by using equations (5) and (6) and are depicted as r_i and s_i correspondingly.

$$ro_i = \left[\sum_{j=1}^{n} g_{ij} \right]_{n \times 1} \quad (5)$$

$$co_i = \left[\sum_{i=1}^{n} g_{ij} \right]_{1 \times n} \quad (6)$$

Phase 5: To build the graph for cause and effect (CEG)

By using the phase 4 of DEMATEL method, the CEG is generated. To draw the graph by using both and value as the axis of horizontal and vertical axes correspondingly.

V. CASE STUDY

The proposed technique is used for analyzing the drivers for affecting steam turbine efficiency. For the past 10 years, many drivers affecting the efficiency of steam turbine based on the reports gathered from the industries. It increases the cost generation and affects the process of the industry as well as environment. The case industry is topmost coal fired thermal power plant in south India with the yearly income of more than 100 crores. In this particular industry, more than 2000 workers are employed. It is vital to analyze the drivers in the industry for the improvement of efficiency of steam turbine. The findings of the paper will surely help the industrial managers and practitioners to understand what are the risk drivers involved in the firm, how to diminish it and also it is used for implementation. For illustrating the proposed method, there are three stages that need to be followed and are detailed below.

VI. RESULT AND DISCUSSIONS

Basically, many factors are influencing the efficiency of steam turbine. Among them the most important factors are taken into consideration for this analysis. At the initial phase, the steam turbines give their maximum efficiency nearest to its designed values. After prolonged operation, day by day they lose their efficiency. Periodical and preventive maintenance are carried out to manage the fast deterioration of turbine efficiency. Such as monitoring critical parameters related to turbine performance and preventive maintenance taken then and there. Normally, the maintenance and operation engineers have given equal importance to all of their works such as watching all parameters and executing periodical and preventive maintenances. If the most important work to be done are found out for influencing the efficiency of the steam turbine, it will greatly helpful to all the power engineers to concentrate in the particular important factor. This paper elaborately discusses the relationship between 12 important factors with the help of the DEMATEL. Based on the causal diagram (Figure 2), an analysis result was discussed and the drivers are sorted into both cause and effect group. The cause group consists of seven factors such as steam pressure (D1), Inter stage seal clearance (D5), Steam temperature (D2), Thermal insulation (D7), surrounding temperature (D8) and Re-heater performance (D10). Based on the causal diagram this study was conducted and shown in Fig 2.

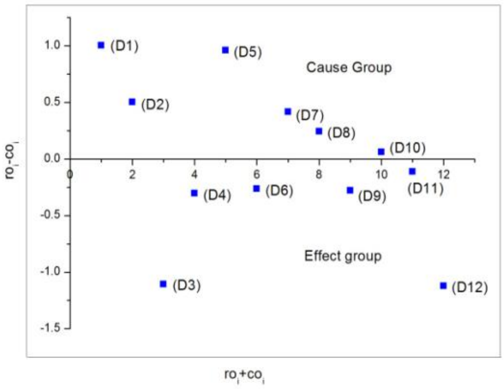

Fig. 2. Causal diagram

A. Discussion of cause group drivers

The effect group has six factors such as load (D12), exhaust pressure / vacuum pressure (D3), water rate / steam flow rate (D4), Regenerative heater performance (D9), Vibration (D6), Gland sealing performance (D11). The cause diagram pin pointed that main steam pressure (D1) is the most important influencing driver when compared with the other important influencing drivers. The steam inlet pressure is a most important criterion for achieving the rated steam turbine efficiency. If the actual main steam pressure is less than the designed main steam pressure then it will affect the turbine efficiency in a great manner. In some situation like, excessive steam consumption in turbine and boiler puncture, we cannot maintain the main steam pressure to its design value. At this stage, the steam turbine efficiency will reduce drastically. So this criteria (D1) steam pressure is essential. The $(ro_i + co_i)$ value shows that the relative influence of each criterion in table 8. Hence, this highest $(ro_i + co_i)$ values should be consider. Based on the preference values $(ro_i + co_i)$ in Table 8, water rates / steam flow rate (D4), load (D12), and exhaust pressure / air compressor (D3) occupy top 3 ranks among 12 essential influencing drivers but the criteria vibration (D6) has least important priority. The efficiency of steam turbine will not greatly affect with vibration (D6).

A. Discussion of effect group drivers

Even though, the cause criterions has greater influence on turbine efficiency, there is a need to give great attention as the $(ro_i - co_i)$ values are optimistic that means the most influential impact ro_i is greater than the degree of influential impact co_i. Meaning that the degree of influential impact ro_i is greater than but under cause group. The ability to provide degree of influenced impact co_i but consider cause group that main steam pressure criteria comes first. It reflects that the mainstream pressure plays important role in steam turbine efficiency. The energy available in main steam greatly depends upon the pressure and temperature of the main steam. High pressure steam naturally provides high power. In real time, modern supercritical power plants are having higher efficiency than the subcritical power plants. The criteria (D12) have lowest priority value (-1.12) revealed from the causal diagram. According to the result, the load has very least criteria and it will not significant influence on the steam turbine efficiency. Now a day all the coal fired power plants in flexible load operation to accommodate the green energy incoming in to the grid. The criteria (D3) steam temperature has least important and it comes next least important to the load (D12). In actual practice the coal burner in boiler is tilted down to produce more steam and tilted up to for rising the steam temperature. So, the changes in steam temperature will not create the grate impact on steam turbine efficiency.

The criteria water rate/ steam flow (D4) has least important next to the criteria steam temperature (D3) if the steam floe rates is reduce , the load reduce and the reduction in steam turbine efficiency is very low hence it comes lower most criteria in the first three ranking criteria.

VII. CONCLUSION

In India, all the thermal power plants have a problem in steam turbine efficiency because many risk drivers affecting the process. They need more attention to control and eliminate the drivers. They use some conventional methods for analyzing the drivers of steam turbine efficiency because of the time constraints and also it is difficult to manage. In this paper, to solve this issue DEMATEL technique is used. By using this method, it is easy to analyze the interrelationship between wastes and identifies the most influential drivers in the thermal power plant. Fig 1 shows the Steam pressure (D1) is the most influential drivers between others in the steam turbine efficiency and they need to control it. The industrial managers will use the results for the implementation of steam turbine efficiency. For the future point of view, this paper has some drawbacks and it can be explored later. For example, some drivers are not good bonding relationship with others. These features are not deliberated in this paper. To overcome these drawbacks, some MCDM methods like ELECTRE, AHP and TOPSIS have the features of good relationship between drivers as well as participation of number of decision makers is limited.

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Table- III. Initial DRM

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
D1	0	0	4	3	3	1	0	0	2	1	3	4
D2	1	0	3	3	1	0	4	2	1	1	0	3
D3	0	0	0	3	1	1	1	0	2	1	0	3
D4	0	0	4	0	3	2	1	1	4	3	2	4
D5	4	0	4	4	0	1	0	0	3	4	1	3
D6	0	0	0	1	1	1	0	0	0	0	1	3
D7	0	3	2	3	0	0	0	4	2	2	0	2
D8	0	2	3	1	0	0	4	0	1	1	0	2
D9	0	3	4	3	0	0	2	0	0	0	3	3
D10	0	4	3	3	0	0	0	0	3	0	0	3
D11	1	0	0	1	0	0	0	3	1	0	0	2
D12	0	0	3	3	0	3	0	1	2	2	0	0

Table- IV: TRM

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12
D1	0.02	0.029	0.221	0.188	0.124	0.078	0.029	0.03	0.143	0.09	0.127	0.227
D2	0.041	0.043	0.193	0.184	0.061	0.04	0.162	0.1	0.11	0.09	0.029	0.19
D3	0.008	0.025	0.068	0.149	0.051	0.061	0.051	0.02	0.112	0.068	0.024	0.155
D4	0.019	0.048	0.233	0.113	0.118	0.107	0.069	0.063	0.206	0.15	0.098	0.237
D5	0.135	0.046	0.249	0.237	0.047	0.083	0.036	0.029	0.19	0.184	0.081	0.224
D6	0.007	0.006	0.032	0.06	0.04	0.05	0.007	0.011	0.025	0.02	0.041	0.122
D7	0.008	0.134	0.16	0.174	0.027	0.033	0.055	0.153	0.131	0.11	0.026	0.156
D8	0.006	0.096	0.161	0.102	0.019	0.025	0.155	0.034	0.085	0.07	0.016	0.132
D9	0.011	0.118	0.202	0.171	0.028	0.036	0.098	0.041	0.068	0.049	0.114	0.179
D10	0.009	0.151	0.18	0.171	0.028	0.035	0.043	0.028	0.154	0.045	0.028	0.178
D11	0.034	0.017	0.045	0.065	0.012	0.017	0.022	0.104	0.059	0.021	0.014	0.1
D12	0.005	0.027	0.154	0.149	0.024	0.119	0.025	0.045	0.111	0.093	0.025	0.075

Table- V: Sum of influences given and received on criteria

Drivers	ro_i	co_i	ro_i+co_i	ro_i-co_i
D1	1.307	0.302	1.609	1.004
D2	1.244	0.741	1.985	0.503
D3	0.792	1.899	2.691	-1.107
D4	1.461	1.764	3.224	-0.303
D5	1.540	0.579	2.119	0.961
D6	0.421	0.685	1.106	-0.263
D7	1.167	0.752	1.919	0.415
D8	0.902	0.659	1.561	0.243
D9	1.116	1.395	2.510	-0.279
D10	1.051	0.989	2.040	0.062
D11	0.509	0.621	1.130	-0.112
D12	0.852	1.975	2.827	-1.123

Table- VI: Relative vector ($ro_i - co_i$)

Rank	**Cause group**	**ro_i-co_i**
1	D1	1.004
2	D5	0.961
3	D2	0.503
4	D7	0.415
5	D8	0.243
6	D10	0.062
Rank	**Effect group**	**ro_i-co_i**
1	D12	-1.123
2	D3	-1.107
3	D4	-0.303

4	D9	-0.279
5	D6	-0.263
6	D11	-0.112

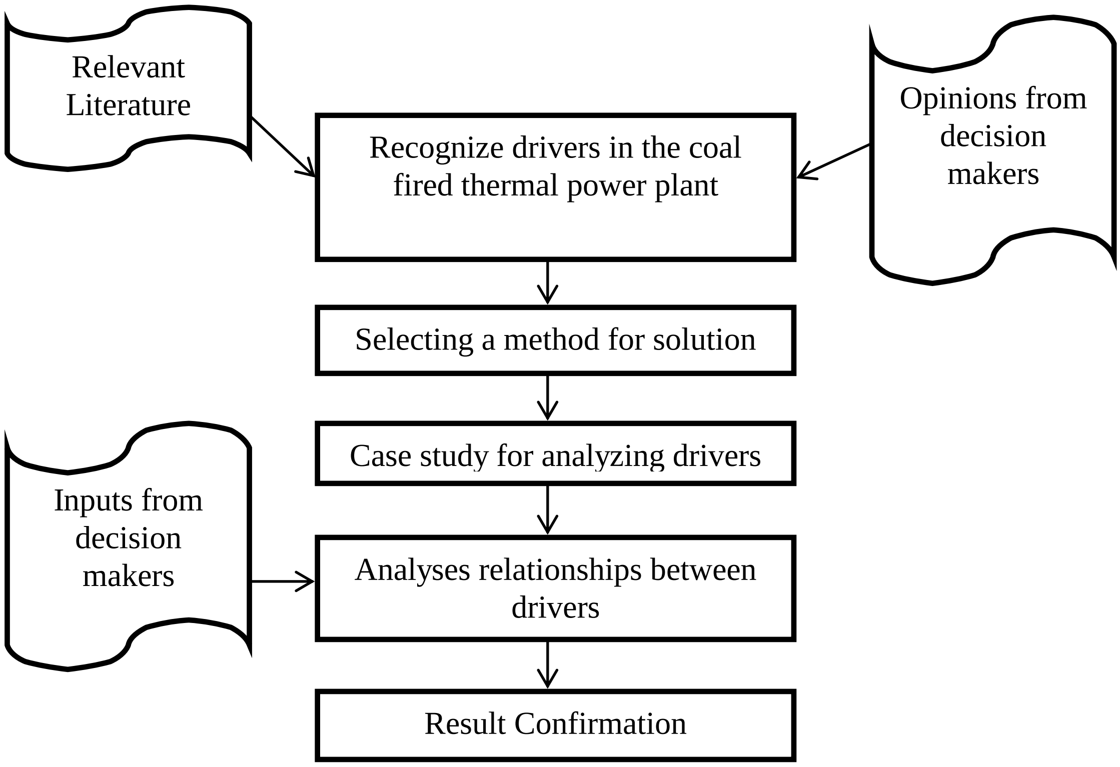

Fig. 1. Flow diagram of the paper