ISBN 978-93-84422-80-6
7th International Conference on Advances in Science, Engineering, Technology and Natural Resources (ASETNR-17)
Dec. 27-28, 2017 Pattaya (Thailand)

Assessment of Fire Risk in Electric Power Industry in Thailand

Supapat Phuangkaew[1],Khemcharruch Junsawat[1],Nantakrit Yodpijit[1]*
and Manutchanok Jongprasithporn[2]

[1]Center for Innovation in Human Factors Engineering and Ergonomics, Department of Industrial Engineering, Faculty of Engineering, King Mongkut's University of Technology North Bangkok, Thailand

[2]Department of Industrial Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Thailand

*Corresponding author's email: nantakrit.y@eng.kmutnb.ac.th

***Abstract*:** *The electric power industry is one of the most important businesses in Thailand. Recent report indicates that the rates of fire in power plants is still high and continues to grow even fire safety standards are strictly followed. Recent reports revel that inspections are verified by factories documents and lack of workplace inspection by highly trained safety professionals. Even the factory's structure and equipment parameter still meet the standard, but some safety functions and indicators might be impaired. The main purpose of the current research project is to assess the fire risk from management parameters for electric power plants in Thailand. Indexing methods are used to calculate fire risk levels. Two thermal power plants are randomly selected to investigate in this research project. The has been determined by using fire risk parameters obtained from those two thermal power plant case studies. Findings from the current research project reveal that the average FRI of thermal power plants is 4.3 of 5. Sizes of power plants, types of fuels, and technologies to generate electricity are analyzed with FRI standpoints to identify possibilities for fire safety improvement. Needs of future studies and limitations of this research project are also discussed.*

Keywords: *Fire Risk Assessment, Electric Power Industry, Indexing Methods, Fire Risk Index (FRI), Thermal Power Plants*

1. Introduction

The electric power industry is an important part in the development of a country. The demand for electricity in Thailand is growing every year [1]. To meet the demand, Thai Ministry of Energy has presented a Power Development Plan (PDP2010) that focus on the stability of electricity supply to meet demand. It also encourages the generation of electricity from renewable energy. The 15 years renewable energy development plan also focuses on renewable energy [2]. Therefore, the private sector has become more active to drive the electric power industry, especially as small power plants that used renewable energy. With the support of the government, the number of renewable energy power plants are rising [3]. Unfortunately fire accidents statistics for the last decade related to power plants are also rising [4].

Fire accident data in power plants obtained from Thai government agencies [4, 5] and news articles [6, 7] indicates that the type of power plants accidents is thermal power plants and all of power plants accidents occurred by private power plants. Thus, this research focuses on private thermal power plants. Two power plants have been included in this research. The parameters for this research are composed of two parts. The first part is derived based on Thai building and safety codes [8-10]. And the second part is collected from comment of experts. All parameter weights are set by the experts. This research focuses on actual parameters (such as actual measured walkway size) more than structural parameter (such as the width of building's walkway). Fire risk index was used for this research for comprehensive study of the current situation. Results of this research the differentiate of risks among capacity, fuel, and method to generated electricity. This research also shows lack of compliant personnel that enforce regulations in most of power plants. As a result, the safety were neglected.

https://doi.org/10.17758/ERPUB.ER12174011

2. Methodology

2.1. Fire risk assessments methods

Fire risk assessment has various methods to assess the fire risk such as probabilistic assessment [11, 12], experts are used to assess the risk [13-16]. For fire risk assessment, it is classified in to four categories, checklists, narratives, indexing and probabilistic methods [17]. Checklist is a common format to check against the standard or legality. Narratives may lead to a list of recommendations relevant fire safety. The narrative technique that is known around the world is NFPA [18]. Two techniques mentioned above are classified as qualitative. Two quantitative techniques included probabilistic methods and risk index. Probabilistic methods can calculate risk in number and can be explained mathematically. Tools of probabilistic methods are fault tree analysis, event tree analysis and etc [17]. Probabilistic methods need a well document and excellent fire accidents statistic to accurate calculation [19].

Fire risk index (FRI) is one of the quantitative techniques. Risk index technique is called as semi-quantitative technique, risk ranking, point system and etc [16]. Risk index set a number for each parameter to assess. Value of index for every parameter can be calculated to the risk of what is assessed such as power plants, apartment, and etc. This technique can quickly assess and is widely used for research [16, 20, 21, 22]. Moreover, Hultquist and Karlsson studied to compare between probabilistic methods and indexing methods result indicates that probabilistic methods and index methods have a same resulted for four multi-storey building in Sweden [23]. Finding from initial study, it was indicated that Thailand did not have a good record of accidents. Therefore this research used the fire risk index to assess the risk for power plants in Thailand.

This research classified parameter and calculate fire risk index for every parameter. Collect index values from all parameter to calculate overall fire risk index for power plant. A linear additive model was used to calculate fire risk index as show in eq.1

$$FRI = \frac{\sum_{n=1}^{n} w_i x_i}{\sum_{n=1}^{n} w_i} \tag{1}$$

Where is weight point for parameter i. Weight point shows the important or potential of parameter i if parameter i miscarry. X_i is grade point of parameter i. grade point will be earned from actual visits. i is parameter that was inspected and n is number of parameter.

2.2. Parameter Selection and Weight Configuration

Parameter selection in this research is derived Thai building and safety codes [8-10] and comment of experts. Parameters in this research focus on management because structural parameter always inspect by officer. This study also focuses on the possible deficiencies in management that will be the cause of accidents. A pilot parameter test was used in power plants to ensure that all parameter can be measure. This research has a 25 parameter. Weight point of each parameter was set in 5 levels. Most important are 5 and less importance are 1. Every level was detailed to avoid a difference in the perception among the experts [24] as show in table 1.

Eight safety officers are experts in this research. Experts set a weight for all parameters.Then take the value of average weight assign to parameter. List of parameter are shown in table 2.

TABLE I: Detail of Weight for Parameter

No.	Detail
1	Most important—if not present, very high damage of both life and properties may occur
2	Important—if not present, considerable damage of both life and properties may occur
3	Essential—loss of life may not occur but other losses and injuries are high
4	Essential—loss of properties and injuries are considerable
5	Not essential but preferable

TABLE II: Grade point of management parameter

No.	Parameter	Detail	Weight average
1	Alternate power	Existence of alternative power system	4.25
2	Automatic fire extinguisher	Existence and workability of Automatic fire extinguisher system	4.75
3	Block furniture	Presence of obstacle on corridors or exit doors	3.625
4	Bottleneck corridor	Bottleneck on corridor to exit door	4
5	Chemicals	Chemical management in power plants	4.625
6	Combustible	Existence of combustible material (biomass, gasoline, cotton and etc.)	3.75
7	Command center	Control area of command center	4
8	Communication	Communication between command center to control area	3.625
9	Door swing	Swinging of door	3.875
10	Emergency light	Working condition of emergency lights system	5
11	Exit door	Using condition of exit doors	5
12	Exposed utility inside	Exposed electric steam line or fuel inside power plants	3.75
13	Extinguisher operator	Performances of operator	4
14	Fire announcement	Workability of fire announcement system	4.625
15	Fire damper	Existence and workability of fire damper within ventilation system.	4.25
16	Fire drill	Practice plans	4.875
17	Fire extinguisher	Existence and workability of fire extinguisher	4.625
18	Fire pump access	Accessibility to fire pump	4.25
19	Fire pump protection	Existence of fire pump protection	3.125
20	First aid	Existence of first aid kits for accidents	3.125
21	Gas mask	Existence of gas mask of accidents	2.875
22	lightning protection system	Existence and workability of lightning protection system	3.75
23	Maintenance	Maintenance plan	4.5
24	Occupant load	Number of workers per area or building	5
25	Water for fire	Level of water in tank	5

2.3. Parameter rating schedule

One thing an important in this research is score point. The score is a value that reflects the true safety capabilities of each power plant. This value is obtained from the inspection at the power plant and the measured value is quantitative. The scoring is done by visiting power plants with experts. Some values may not be measurable from vision. It may be necessary to use expert judgment to determine the appropriate score. Generally, parameter can be measured such as fire alarm, water tank, fire extinguishing equipment and etc. Parameter will be measured to compare with regulation or standard to calculate the deviation from standard. This research used methods to grade point for parameter from Huda and Ahmed [25] to considered point as show in table 3

TABLE III: Grade point of management parameter

Weight point		Detail
5	Excellent	Most important—if not present, very high damage of both life and properties may occur
4	Good	Important—if not present, considerable damage of both life and properties may occur
3	Average	Essential—loss of life may not occur but other losses and injuries are high
2	Poor	Essential—loss of properties and injuries are considerable
1	Very poor	Not essential but preferable

Examples of ratings in this study, such as the width of the walkway must be at least 1.5 meters wide. The details of the power plant indicate that the route is 2 meters wide, but walk way can be used only 0.75 meter. Therefore value that was measured is only 0.75 meters. Although the structure of the building is better than the standard, but in the actual use may be impaired. This example, deviation from standard is 50 %. So, the score for this example is 3.

2.4. Collect data

This research indicates that the type of power plants accident in last decade is private thermal power plants [4-7]. Therefore, this research randomly selected private thermal power plant to visit. Data collection will be accompanied by a team of experts to assess and collect the data. The team will check the parameter from the actual place of work. Include document review in the documentation section for some parameters such as fire drill, maintenance. The name of power plants that was visit were not revealed

3. Results

The results of this research are expressed in terms of fire risk index (FRI) of power plants in Thailand. Scale of FRI is 1-5 (5 is maximum). If FRI is high, fire safety level will be high. Two power plants were invested for this research. Power plants in this research have a various fuel (natural gas, and biomass), technology to generate electricity (combine cycle, and steam turbine) and capacity (less than 10 mw to more than 1000 mw). Overview of fire risk index for power plants in this research has a high level at 4.3. It demonstrates that the safety level of electric power industry is good. FRI for two power plants in this research is shown in figure 1.

Figure 2 shows the distribution of grade for two power plants. Figure 2 also indicates that power plants have a good management in many parameters such as automatic fire extinguisher, fire announcement, and maintenance. The safety standard of electric power industry is high, but there are some low grade parameters such as the smoke and fire spread prevention (fire damper), block furniture, and etc.

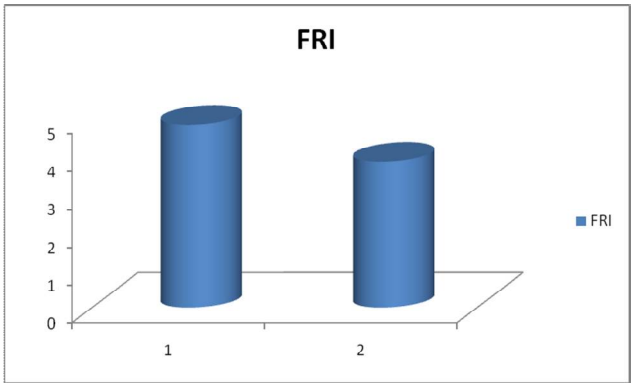

Fig. 1: Overview FRI forms 8 power plants.

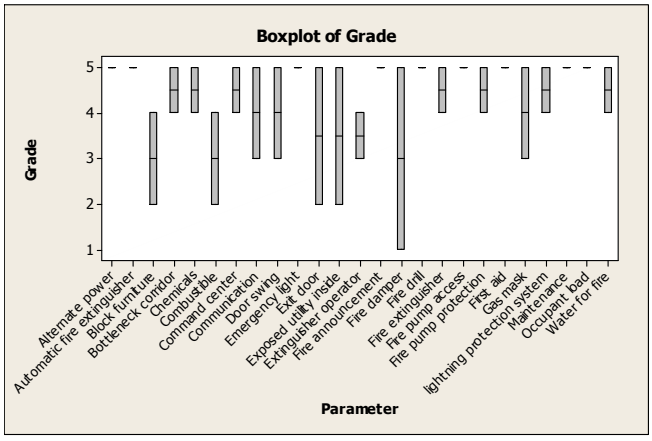

Fig. 2: Box plot of parameter's grade.

The purpose of this research is to provide an overview of the fire safety for power plants in Thailand. Next step, relation between capacity of power plants and FRI were studied. Result indicates that fire risk index for the larger size is higher FRI than smaller size power plants

The relationships between the fuels for generate electricity and fire risk index were studied in this step. Finding from investigation indicates that fuel of thermal power plants in this research is two types of fuel; natural gas, and biomass. Finding also indicates that power plants with high capacity (more than 90 mw) always use natural gas and small power plants use biomass. Therefore, fire risk index for natural gas is higher than biomass fuel.

In addition to study in capacity and fuel, this research also studies in process. Detail of power pants form investigation indicates that technologies to generate electricity for thermal power plants in Thailand are combined-cycle and steam turbine. Result also indicates that fire risk index for power plant with combined-cycle is higher than steam turbine. Results of this research are shown in table 4.

TABLE IV: Results detail

Size	Capacity	Fuel	Technology	Fire risk index
Small	< 90 mw	Biomass	Steam turbine.	3.86
Large	>90mw	Natural gas	Combined-cycle	4.84

4. Conclusions and Future work

This research studied fire risk in Thai power plants. The news articles and record were used in indicates that the power plants fire accidents every year. More over type of power plants that caused the fire accidents is private thermal power plants. The lack of statistics or good record, Fire Risk Index (FRI) is developed to assess fire risk for private thermal power plants in Thailand.

Process of permission to perform power plants is studied and found that power plant has a very good planning, management and structure, because it must be strictly investigated before start operations. There are a limited number of agencies and agencies have to inspect all types of factories in Thailand. Therefore, most of inspection is checking the documents form factory. The information in this document may not reflect actual conditions. Because of the fire that is still happening. So, this research focused on management parameter.

Thai building and safety code and comment of expert is used to develop parameter for this research. Eight experts in this research are safety officer. Weigh point for each parameter is defined by experts. Researcher and authorities goes to power plants to investigate and collect data. The inspection will be carried out with experts to evaluate each parameter of the power plant.

Results of this research indicate that power plants have a good safety level. Average fire risk index for private thermal power plants is 4.3 from 5 (higher is safer). Two power plants have been included in this research. Capacities of power plants in this research are more than 90 megawatts (mw) and less than 10 (mw). Results indicate that high capacity power plants have FRI values higher than power plant with lower capacity. Exit door parameter found that door always open and used as a normal path. Fire damper parameter found that in factories with less capacity, often neglected. Data from these power plants indicates that power plants with capacity more than 90 mw always use fuel natural gas and less than 10 mw used biomass. Therefore, results for fire risk index with fuel are not different from FRI with size. It also concluded that power plants used natural gas has safer than biomass power plants.

Once goal for this research is study relation between FRI and technology to generate electricity. Technology to generate electricity for private thermal power plants in this research is combine-cycle and steam turbine. Result indicates that FRI from two technologies is difference and plants with combine-cycle have higher fire risk index than power plants with steam turbine. It concluded that combine-cycle power plants have a higher level of safety management than steam turbine power plants.

Results of this research concluded that fire risk index for large power plants (more than 90 mw capacity) with natural gas fuel and used combine-cycle to generate electricity is higher than fire risk index for small (less than 90 mw capacity) with biomass fuel and used steam turbine to generate electricity. However, lowest fire risk index from this research is high, but standard of power plants is very high. Therefore, biomass power plants with steam turbine should be supervised and monitored, as well as enforcement of safety standards.

Something that found from all power plants in this research is some parameter always excellent like automatic fire extinguisher, fire announcement, maintenance and occupant load etc. This research has investigated only two power plants. Therefore thirty private thermal power plants are planned to investigated and use statistic to analyze the results data.

5. Acknowledgements

This research was funded by King Mongkut's University of Technology North Bangkok. Contract no. KMUTNB-60-GOV-04

6. References

[1] Electricity Generating Authority of Thailand. Electrical Capacity in Thailand.(Nov. 2016), https://www.egat.co.th/index.php?option=com_content&view=article&id=80&Itemid=116

[2] Department of alternative energy development and efficiency. (2008). alternative energy development plan: AEDP2008.

[3] Energy regulatory commission of Thailand. (2017). SPP/VSPP Database. Retrieved 20 august, 2017, from http://www.erc.or.th/ERCSPP/

[4] Safety Technology Bureau. (2017). accident statistics. Retrieved 25 june, 2017, from http://php.diw.go.th/safety/?page_id=37

[5] Department of Labour Protection and Welfare. (2017). Nnational profile on occupational safety and health of THAILAND. Retrieved 20 august, 2017, from http://www.oshthai.org/index.php?option=com_content&view=category&id=26&Itemid=192&lang=th

[6] Kom Chad Luek (2015) (online) Fire in Ayutthaya biomass power plant, http://www.komchadluek.net/detail/20150227/202104.html. Accessed may 2016

[7] Kom Chad Luek (2015) (online) Fire in Krabi private power plant loss more than 100 million bath,, http://www.khaosod.co.th/view_newsonline.php?newsid=1428469705. Accessed may 2016

[8] Building Control Act B.E. 2543 A.D. 2000, Department of Public Works and Town & Country Planning Thailand.

[9] Notification of Ministry of Industry No.126 Sep 30, 2009 Fire prevention and control in factory. Thailand.

[10] Occupational Safety, Health and Environment Act B.E. 2554. Thailand.

[11] C. Worrell and C. Rochon, (2016). Fire probabilistic risk assessment and its applications in the nuclear power industry. *Fire Technology*, 52(2), 443-467.

[12] J. F. Grobbelaar, N. A. S. Foster and L. J. Lüsse, (1995). Probabilistic fire risk assessment for Koeberg nuclear power station unit 1. *International journal of pressure vessels and piping*, 61(2-3), 571-578.

[13] S. M. Lo, B. Q. Hu, M. Liu and K. K. Yuen, (2005). On the use of reliability interval method and grey relational model for fire safety ranking of existing buildings. *Fire technology*, 41(4), 255-270.

[14] F. Liu, S. Zhao, M. Weng and Y. Liu, (2017). Fire risk assessment for large-scale commercial buildings based on structure entropy weight method. *Safety science*, 94, 26-40.

[15] M. Omidvari, N. Mansouri and J. Nouri, (2015). A pattern of fire risk assessment and emergency management in educational center laboratories. *Safety science*, 73, 34-42.

[16] Z. Wadud, F. Y. Huda and N. U. Ahmed (2014). Assessment of fire risk in the readymade garment industry in Dhaka, Bangladesh. *Fire Technology*, 50(5), 1127-1145.

[17] JM. Watts Jr and JR. Hall Jr (2002) "Introduction to fire risk analysis." In DiNenno PJ (ed) SFPE handbook of fire protection engineering, 3rd edn. National Fire Protection Association.

[18] NFPA (2000) National fire codes. National Fire Protection Association, Quincy, MA.

[19] S. M. Lo, (1999). A fire safety assessment system for existing buildings. *Fire Technology*, 35(2), 131-152.

[20] J. M. Watts and M. E. Kaplan, (2001). Fire risk index for historic buildings. *Fire technology*, 37(2), 167-180.

[21] Z. Wadud, and F. Y. Huda, (2017). Fire Safety in the Readymade Garment Sector in Bangladesh: Structural Inadequacy Versus Management Deficiency. *Fire Technology*, 53(2), 793-814.

[22] L. L. Park, B. D. Kushler, M. J. Serapiglia, L. A. McKenna, E. K. Budnick, and J. M. Watts, (1998). Fire risk assessment for telecommunications central offices. *Fire Technology*, 34(2), 156-176.

[23] H. Hultquist and B. Karlsson, (2000) Evaluation of a fire risk index method for multi-storey apartment buildings, Report 3088. Department of Fire Safety Engineering, Lund University, Lund

[24] F. J. Dodd and H. A. Donegan, (1994). Some considerations in the combination and use of expert opinions in fire safety evaluation. *Fire safety journal*, 22(4), 315-327.

[25] F. Y. Huda and N. Ahmed (2011) "Fire safety rating of garment buildings in Dhaka city." Undergraduate thesis, Military Institute of Science and Technology, Dhaka.