Case study on Designing a Comprehensive Fire Protection System for KY Power Station

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Abstract. The KY Power Station relies on two gas turbines to generate electrical energy. In addition, fuel storage is also required to ensure uninterrupted power supplies. As a power generation plant and the existence of fuel storage, an efficient fire protection system is essential. This paper presented a comprehensive review of the existing research on fire protection systems. Utilising the reviewed as basis, this paper also described the five types of KY Power Station fire protection systems as the case study. Specifically, the five fire protection systems are: Water Spray Fixed System, Foam Protection System, Automatic Carbon Dioxide Extinguishing System, Pressurized Fire Hydrant and lastly Automatic Fire Detection and Alarm System. Even though a station may require more than one fire protection systems as illustrated by the case study, this paper observed that the existing researches focused mainly on designing the individual system of different fire protection system according to standard. This paper found that there is lacked of research on optimising these individual fire protection systems. The optimisation usually requires development of mathematical model. Therefore, there is a need for development of mathematical model for the individual fire protection system. These different types of fire protection systems are independent but they are equally important. Thus, there is also a need to look into global optimisation in designing the fire protection system.

Keywords: Storage Tank, Transformer, Fire Code and Standard

1. Introduction
The KY Power Station is one of the industrial utilities located at Sabah, Malaysia. The KY Power Station generates electricity from primary energy [1]. Like most of the power plants, the KY Power Station uses generators to convert mechanical energy into electrical energy and then supplies the power to the electrical grid to feed the community electricity needs. The KY Power Station relies on two gas turbines to generate electrical energy. At the same time, as the gas turbine get their power from the burning fuel in the combustion chamber and then drive the turbine that have the sharing shaft with the generator that generates electricity, fuel storage is required inside the power station to ensure uninterrupted power supplies, which eventually can cause a power cut. Electricity powers that generates by the gas turbine will travels out to the transformer inside the same power station. This transformer step-up the electricity to a very high voltage as it leaves the power plant and entering the electrical grid to move along power lines to homes and businesses.
Figure 1. Relationship between hazard in KY Power Station

As a power generation plant and the existence of the fuel storage, an efficient fire protection system is essential. Therefore, question related to the safety precaution designed for the KY Power Station arises as many accidents involving storage tanks and power stations recorded around the world up till now. For instance, on August 11, 2016 an explosion was reported at a power station in Hubei, China that killed at least 21 people and 5 injured. A day before another giant explosion was reported to be happened in the northern port city of Tianjin that caused 165 people to died [2]. It was also reported that investigation has been made to identify the cause of the explosion. However, according to the press, industrial accidents that happened in China were considered common as China practice a low standard of safety precautions.

Recorded as one of the worst explosions happened [2], a study was carried out by Gui Fu, Lin Zhou, Jianhao Wang and Meng Shi [3] to identified the cause and what lesson learned from the said accidents. It was confirmed that accidents has caused of total 22 people killed and 4 injured and it was caused by the explosion of a high-pressure steam pipeline. Their analysis revealed that unsafe acts performed by the staffs contributed the power plant to be in the unsafe conditions. Specifically, the staff’s inadequate safety knowledge, staff weak safety awareness and lastly staffs bad safety habits led to this disaster. Therefore, to prevent similar incident from happening in the future, they recommend effective training and education for the staffs, awareness programs, and lastly monitor of all the unsafe acts and correct them time by time to avoid the unsafe work habits.

Meanwhile in New York, Dave Maclean [4] has reported an explosion happened at a New York City power plant that forced LaGuardia Airport to temporarily shut down because of the power disruption. The accident happened on the 28th December 2018 night that originated from the blow-up transformers at the power plant. Fortunately, no lives lost in the accident and only caused the sky above become a bright blue-green. While, in another unfortunate incident at the Enron Plant in Redcar at Teesside, the transformer explosion caused 2 people died and the other two seriously injured.

According to Grobler and Maphanga (2018) [5], explosion in the power station should not happen as the explosion will lead to a loss of life, injury, and as well as massive damages to equipment that can cost up to billions. The energy expert believes that the explosion might be caused by the equipment failure, failed of protection devices to function properly, and poor maintenance or staffs lack of skills. However, it is hard to know the actual reason as there are number of issues usually unknown.

In view on these accidents, Nwabueze (2016) [6] conducted a research related to the fire hazard management entitled ‘Liquid Hydrocarbon Storage – How Prepared is your Facility?’. Focusing only facility with storage of liquid hydrocarbons tank (oil and fuel), he conducted a research concerning the preparation taken in every facility, which may consequentially lead accident to happen. He considered characteristic of the tanks, facility logistics, codes limitations, foam quality and lastly emergency preparedness practice by the facility. Not limited only to the storage tanks, he stressed that for any
organization or operator to successfully respond on fire emergencies, adequate attention must be paid to the fire pre-planning, staff training, emergency preparedness reviews and lastly perform the regular testing on emergency response plans.

The incidents and studied presented before showed that it is very important for every power station to have a safety precaution to be properly designed and installed. Not only in preventing any losses, and most importantly preventing any harm to all power station staffs. For the KY Power Station, there are five (5) types of fire protections system proposed and later installed on site by considering all the assets to be protected. In this paper all the systems will be discussed and explained as all the system works together to protect the KY Power Station.

2. Literature Review

There are several papers studied issues related to the fire-fighting systems for a power station. These fire-fighting systems are designed to protect different functional or sections within the power station such as the storage fuel tanks, transformers and electrical equipment.

For the storage tanks, for instance, Alimohammadi et al [7], in paper titled ‘A novel method to design water spray cooling system to protect floating roof atmospheric storage tanks against fires’, studied the total water demanded or required to extinguish fire using the linear density method. The quantity of water demanded was then used to calculate the storage tank dimension. They compared all the average methods including National Fire Protection Association (NFPA) and Institute Petroleum (IP) standards with their new proposed linear density method. They concluded that their method is better in protecting the tanks. Whereas Xu-qing, Quan-zhen and Hong [8] did a study on the current fire fighting system applied in China for the fuel storage tanks in their research titled ‘Study of Fire Fighting System to extinguish full surface fire of large scale floating roof tanks’. By comparing the current design with the American Petroleum Institute (API) codes, they concluded that the current design needs to be raised up 6-10 times to be properly protecting all the storage tanks.

Adapting the same system for the transformers, Duarte [9] done a study on the usage of standard and codes in design the water spray fixed system for high voltage power transformer. In his paper titled ‘Aspect of Transformer Fires in Brazil’ he explained the transformer fire happened in Brazil and came out with a way in preventing fire to happen at the transformer. He stated that the used of standards and codes in the form of good practice helps to avoid hazards from happening. Constantatin et al [10] called these current standards and codes in guiding the transformer as the old fire-fighting system. Constantatin et al [10], in their paper ‘Transformer Protection and Fire Fighting Systems used in High Voltage Power Stations’, proposed a new system called the Sergi Nitrogen Injection System to be used in protecting the transformer. Focusing in protecting the high voltage power transformer, they did a comparison between both the proposed Sergi Nitrogen Injection System with the water spray fixed system (old system) through the analysis on advantages and disadvantages of the systems. They concluded that the proposed modern system, which name as the Sergi Nitrogen Injection System, is more reliable system compare to the older fire-fighting system.

In the fire-fighting system, apart from the water spray fixed system, fuel storage needs another protection known as Foam System. The foam system is used to cover the oil surface in case of fire to immediately extinguish the fire by preventing the oxygen, which aids the burning. Most of organization sets the activating foam system manually to keep it as the last decision to be made, which otherwise may cause a huge total loss to them. However, Afaq Ahmed et al [11] in their paper ‘Design of Automated Fire and Safety System in Tanks and Vessels’, monitored the functionality of the thermocouple and peripheral interface controller (PIC) system in operating flow to control valve for the foam system. They found that many tanks fire can be avoided by using the automated foam system, which in fact can be adapted in both small and large tanks.

Apart from the fuel tanks and transformers, a set of power station also requires electrical equipment to control and monitor the whole power station system in generating electricity. All the electrical equipment will be placed in a room, which is normally known as electrical control room. According to Raj et al [12] in their study on electrical control room, carbon dioxide snuffing system should be
designed and engineered to protect the components and equipment in electrical room from causing massive damage due to fire. However, carbon dioxide extinguishing system can be harmful to human in the same space or room. Carbon dioxide extinguishing system will create a probable health risk for people inside the room. Therefore, the use of clean agent as extinguishing system is introduced as it poses a much lower health risk to people compared to carbon dioxide [13]. There are several types of gases that classified as clean agents namely as FM-200, FE-13, Novec 1230, INERGEN and etcetera. These gases are generally safe to be discharged even with the human present. Besides, the clean agent is also known able to extinguish faster up to 10 seconds or less. It was also more effective to be used in electrical rooms as clean agents as they are electrically non-conductive and non-corrosive. Hence, there will be no damage to all electronics and delicate mechanical devices or equipment. Most importantly, there will be no cost of clean up after extinguished as the clean agent will rapidly vaporizes to gas during discharge and evaporates cleanly without leaving any residue behind.

A power station also requires a full time monitoring in case fire might happen. The full monitoring can be performed using the fire detection and fire alarm systems. However, as mentioned by Festag [14] in his paper titled ‘False alarm ratio of fire detection and fire alarm systems in Germany – A meta analysis’, a false alarm might be happened to the fire alarm system. He outlined three possible reasons, which are technical defect, deceptive alarm and lastly because of malicious and good intent. He used a meta-analysis to analyse all the possible causes that happened in Germany. Despite the research was focused in studying the cause of false alarm, Festag [14] keeps emphasizing the facts that fire detection and fire alarm systems are useful means to reach the objectives of fire protection. The fire detection and fire alarm systems can provide an early alert that can reduce property damage considerably and more importantly, save human lives. Following that, Dong et al [15] proposed a wireless fire alarm system instead of wired type that commonly used. They compared between wired and new wireless automatic fire alarm panel and concluded that wireless automatic fire alarm system requires only low power consumption, real-time transmission and have low error rate. Thus, they concluded that the wireless type of fire alarm can help improve the fire safety level of 3 in 1 place such as multi-property street shops, brick and wood relics and ancient buildings, temporary buildings and etcetera.

Lastly, to protect the power station parameter, pressurized hydrant was also required to be installed. As mentioned in article ‘Pressurized Systems’, Eckman [16] stated that the quality of pressurized system in fire protection system is determined by the amount of water in storage, the maximum production rate, the distribution system, and the installation and maintenance of fire hydrants. Therefore, he has listed eight (8) things to be considered in designing a pressurized system for firefighting system. The things to be considered are designing water supply, available flow, distribution system, distribution system, system design, emergency operation, hydrant operation, hydrant maintenance and operation and lastly, fire department responsibilities.

3. Case Study
The KY Power Station, which is built on an 11,325 m² area, is completed in 2017 and able to generate total power of 32MW to the surrounding community. The power is generated by using two gas turbines with the help of two power transformers, which controls the voltage before the power is released to the electrical grids and serves homes and businesses. Knowing that lots of people require a power supply to support in their daily routines, has forced the organization to install the essential fire protection systems onto the power station parameter. The fire protection systems will minimize the possibility of any power interruption. Regardless, the KY Power Station still keeps safety as significant and essential to be incorporated in the power station fire-fighting design. Meanwhile, to ensure that the gas turbines are running smoothly without shortage supply of fuel oil, numbers of storage tanks are located at the KY Power Station compound. MV Room, LV Room and Battery Room, which are located at the power house, are parts of electrical rooms to support the whole system of the power station.
As shown in Figure 2, the KY Power Station requires large area to run the power station and to keep providing electrical power to the community. It is almost impossible to have a person to fully guarding the KY Power Station compound and informing any hazards happen or reporting it directly to the Local Fire and Rescue Department to ask for help instantly. There will be a possibility that accidents have occurred badly before the Fire and Rescue Department arrived. Even worse, fire might destroyed everything both assets and human lives before they could arrive. Therefore, ‘Automatic Fire Detection and Alarm System’ has been proposed to this Power Station in order to have a better guarding, which only requires 24 hours manned in control room.

However, it is important to know that all the proposed and then installed fire protection systems in the KY Power Station. The fire protection systems were designed while considering or fulfilling numbers of Design Codes, Standards and Regulations of fire fighting either locally or internationally. First of all, “Uniform Building By-Law 1984” [17] was referred to ensure the fulfilments of the building requirements for ‘Power Station’ type of building in term of protection. As the KY Power Station was not totally categorized as a building the “Guide to Fire Protection in Malaysia (2006)” [18] was referred. However, the guide focused only on a common protection whereas the KY Power Station require more than just a common protection. Therefore, reference was shifted to the National Fire Protection Association (NFPA) [19] codes and standards, which provides all the guidelines in designing fire protection thoroughly whether as a common or special fire protection system. This fire protection system can also be installed at different type of organizations. Nevertheless, due to the
certain reason, the water spray system for the storage tanks was developed using the Institute Petroleum (IP) [20] codes for the design.

There are five main types of fire protection system required for the KY Power Station based on mentioned fire codes and authority requirements. The five types of fire protection system namely are; water spray fixed system for transformer and fuel storage tanks, foam protection system for storage tanks and bund area, automatic carbon dioxide extinguishing system for electrical rooms, pressurized fire hydrant for the parameter protection and lastly automatic fire detection and alarm system for monitoring the whole power station. However, to ensure all the proposed fire protection systems to be functioning, the systems need support from a set of water pumping system with total capacity of water storage.

3.1. The Existing Fire Fighting Water Storage Tank and Water Pump Set

Before the KY Power Station was established in 2017, that site was an abandoned power station about more than five years with most of fire protection still existed including the hydrant pipeline, water tanks and also the water pump set. When the owner decided to rehabilitate the place, due to the cost constraints both of the water tanks and water pump set was reused. This scenario required the contractor to refurbish and maintain the equipment. Therefore, for the new power station, the new fire protection system was designed by the engineer with consideration of both existing water tanks and pump set capacity.

As stated in “Guide to Fire Protection in Malaysia (2006)” [18], for every fire protection system that used water based as a fire extinguisher, the owner is required to store water for a total of one hour pump operated with continuously supply from local water supply authority, which is in this case was the Jabatan Air Department.

As the system consists of various types of fire protection, to confirm that the storage capacity meets the requirements, the worst-case scenario will be applied with assumption that fire would not happen simultaneously. For the KY Power Station, there are total three types of fire protection systems that require water in their operations. The systems are the fire hydrant that protects the power station parameter, the water spray fixed system for storage tanks, and also for transformers. By referring to the location and condition of all the hazards in the KY Power Station, the worst case scenario consisted of three numbers of fire hydrant was used [18] and three water spray fixed systems at the fuel storage tanks were activated. With the current two water storage tanks as shown in Figure 3, the system can support a total 1.28 hours of total water storage, which fulfils the local fire department requirement.

Meanwhile, usually a system was designed and calculated before the pump capacity was identified. In contrast, all the new fire protection systems for the KY Power Station was design to suit the capacity of the pump by altering the pipe sizing in order to match with the existing pump head and
flow rate. A set of fire-fighting system must be equipped with one motor-driven firewater pump, one diesel engine driven firewater pump as standby pump and one set of jockey pump.

3.2. Water Spray Fixed System (Transformer & Fuel Storage Tank)

According to the National Fire Protection Association (NFPA), the fuel storage tanks and transformers need to be protected by the water spray fixed system, which also performs as the cooling system for the storage tank and extinguisher for the transformer. For both hazards, NFPA15 [19] recommends applying fire water application rate of 10.2 L/min/m². However, the Energy Institute Part 19 [20] standard recommends the used of 2.0L/min/m² fire water application rate. Due to this reason, the KY Power Station fire water application rate is set at 2.0L/min/m², which allows the use of existing water storage capacity.

3.2.1 Fire Protection Measures for Fuel Tanks

In the KY Power Station, there are four 600m³ fuel tanks, a 327m³ fuel tank and a 120m³ fuel tanks, which used to store all the fuels that serve the Gas Turbine. These fuel tanks are provided with the fixed water cooling system and the foam fire protection system. In the case of a fire breakout around the tank, the heat from the fire will break the sprinkler bulb that is connected to wet fixed pipe. The decreasing of pressure shall then open the water deluge control valve to initiate water flow to water side spray nozzles. The sprayed water then cools the fuel tanks.

![Fuel Storage Tanks protected by Water Spray Fixed System](image1)

![Deluge Valve outside the Storage Tank bund area](image2)

Even though Alimohammadi et al [7] found that the linear density method works better than common method recommended by the NFPA or other common standard, it still cannot be applied to
the new system design. This is because the linear density method has never been certified by any fire organization or association either locally or internationally. The problem of utilising of uncertified method has been emphasised by Xu-Xing, Quan-zhen and Hong [8]. They showed how in China the uncertified method was far from the international certified standard and required enhancement. Therefore, it is important to refer to the certified and testified standard as NFPA to make sure that the hazards are properly protected.

3.2.2 Fire Protection for Transformer

In the KY Power Station, supporting the operation of two gas turbines, there are two sets of power transformers and two sets of unit auxiliary transformers. These transformers are located outdoor and are protected by the water fixed system and external fire hydrant. Applying the same concept of operating as installed in fuel storage tank, a cage made of the water piping will be trapping the transformer to give full protection as shown in Figure 6.

![Figure 6. Transformer was caged with Water Spray Fixed System](image)

However, Constatantin et al [10] stressed that using the water spray fixed system to protect the transformer is not reliable. They proposed a new system known as the Sergi Nitrogen Injection System. However, considering the possibility of fire might happen is low compare to the installed cost and maintenance cost required this new system is considered to be not economical to be installed at the KY Power Station.

3.3 Foam System (Fuel Tank)

All the fuel storage tanks are required to be protected by the foam system. The foam protection system, which if compared to water spray system, was initiated manually by trained personnel in charge to deplete any fire appear inside the tank. The reason behind manual operation is because the owner tries to prevent the foam from ruining all the stored fuel. This may lead to a high total lost cost. Therefore, the water spray system should do the cooling as much as possible. Only if failed and cause a fire inside the tank, then the foam system will be activated inside the tank. While for any raging fire within bund area, the foam monitor will take the task in extinguishing it with the helps of external fire hydrants around the area.
While most of the power station owner prefers to locate the valve for the foam system activation closed to the bund and tank area, AfidAhmed et al [11] argued that it is better to have automated system for activating the foam system. The automated system was a better option as it would not require human monitoring or human to open the valve. However, as long as total lost cost is still the main reason to be considered, the automated system might be not an option as it will directly throw the foam inside the tank without the owner knowledge.

3.4 Automatic Carbon Dioxide Extinguishing System (Electrical Rooms)
Electrical rooms in the KY Power Station are all located inside the power house. The electrical rooms consist of three rooms, which are known as the MV Room, LV Room and Battery Room. Even though these three rooms are located next to each other, they have their own carbon dioxide fire protection system complete with individual panel and detection system. The fire protection system provided shall be activated by smoke and heat detectors available in every room.

Carbon dioxide system was harmed to human once the gas was release and can cause a death [21]. Following that, the clean agent gas was introduced as it harmless to human and also able to prevent any damage to the electrical equipment inside the room. Only with these two advantages itself, it is
strongly recommended to use the clean agent system even though the cost is twice from that the carbon dioxide system.

3.5 Automatic Fire Detection and Alarm System (Power House)

The KY Power Station has a very wide area that requires a full time monitoring in case fire. With such area, it almost impossible to have a human to fully monitor all the hazards area including storage tanks, transformers and also electrical rooms. Because of that, main fire alarm system installed complete with all the detection devices in every protection area according to the standard.

For every fire protection system installed in the KY Power Station, there are detection devices included that act as an informer. These detection devices are linked with the fire alarm panel that located at the control room, which is manned 24 hours. These detection devices will transmit the signal and notify staffs that fire happen at the hazard they are assigned to protect while the fire alarm panel was connected to SPKA system that linked with the local fire and rescue department. Figure 9 showed the main fire alarm panel that is completed with the SPKA system that located at the control room. Meanwhile Figure 10 showed the repeater fire alarm panel that was located inside the guard house for their immediate action if alarm was activated.

As mentioned by Festag [14], by installing the automatic detection that link to the alarm panel, lots of false alarm may be recorded. These false alarms may cause hassled as they may be thought as fire really happened. As in KY Power Station, since the alarm panel link to local fire and rescue
department, numbers of false alarm might cause them to be sceptical if actual fire may happen. However, this would not be a reason not to install the fire alarm panel.

3.6 Pressurized Fire Hydrant

The external hydrant pipe is linked throughout the KY Power Station boundary and provided with outdoor hydrants within less than 90m radius. This outdoor fire hose cabinets complete with two hoses and nozzles at each hydrant position.

![Image of Fire Hydrant complete with hose cabinet](image1)

Figure 11. Fire Hydrant complete with hose cabinet

Fire hydrant system is designed with consideration of minimum three hydrants active during fire outbreak. The fire water pressure shall be designed starting from fire water pump outlet to furthest three hydrant points.

![Image of Pressurized Fire Hydrant around the Power Station](image2)

Figure 12. Pressurized Fire Hydrant around the Power Station

Figure 12 showed the pressurized hydrant. It requires a lot of consideration in designing the pressurized hydrant as it also served the water to all the fire protection systems for both fuel storage tanks and transformers protection which is water spray fixed system. Apart from that, the design also considered the existing pump supplied flow rate that affecting the selection of pipe size to control the operation flow rate of every outlet. Eckman [16] outlined four qualities that are required for the pressurized hydrants. He also listed eight things to be considered in designing the pressurized hydrant.
In conclusion, not only limited to the five protection systems stated in the literature, the portable fire extinguisher was also provided inside the KY power house as an early protection that did not require the active system to activate. Thus, with all total of five types of fire protection system proposed and then installed at the KY Power Station, testing has been run and inspected by the local fire department before the power station was approved to begin its operation. Based on that fact itself, it is proven that the designed fire-fighting systems and then installation were performed according to the standards and codes mentioned previously.

4. State of the art in fire prevention systems
Extensive review indicates that the current researches focused mainly on designing the individual systems according existing codes or standard. However, the review indicates that there is lacked of research on optimising these individual systems. The optimisation usually requires development of mathematical model for the individual system. Therefore, there is a need for development of mathematical model for the individual fire protection system.

At the same time, the different types of fire protection systems may exist in a power station as illustrated by the case study. Each of these fire protection systems may work independently from one to another in protecting the power station. However, despite being independent, each of these fire protection systems is equally important. Thus, there is also a need to look into global optimisation rather than individual (local) optimisation in designing the fire protection system. As each of these fire protection systems has their own objective functions, the global optimisation may require special approaches such as the multi-objectives optimisation. The multi-objective optimisation may enable the mathematical models representation of the overall (global) systems, which is also currently not available.

5. Conclusion
With a lot of fire accidents recorded at power station worldwide, it raised a lot of concern from the organization in maintaining the safety of the KY Power Station while preventing the fire accidents from happened. Therefore, engineer was hired to propose and design the fire prevention system around the power station with guidance from the Design Codes, Standards and Regulations of firefighting either locally or internationally. Specifically, the five fire protection systems are; Water Spray Fixed System, Foam Protection System, Automatic Carbon Dioxide Extinguishing System, Pressurized Fire Hydrant and lastly Automatic Fire Detection and Alarm System. As a result, the KY Power Station has implemented adequate firefighting and prevention systems around the power station to ensure continuous supply of power needed by the surrounding community.
As future improvements on the KY Power Station, the foam system should be activated automatically instead of manually, electrical room to be installed using the clean agent instead of using carbon dioxide system and lastly to adapt the wireless fire alarm panel to improve the fire safety level. Not limited to system itself, trained staffs are also required in handling the system. The staffs also need to be educated and aware of every system installed in the KY Power Station.

In term of review of literature, this paper observed that the existing researches focused mainly on designing the individual system of different fire protection system according to standard. This paper found that there is lacked of research on optimising these individual fire protection systems. The optimisation usually requires development of mathematical model. Therefore, there is a need for development of mathematical model for the individual fire protection system. These different types of fire protection systems are independent but they are equally important. Thus, there is also a need to look into global optimisation in designing the fire protection system.

ACKNOWLEDGEMENTS
The authors would like to express gratitude to the Universiti Malaysia Sabah and KY Power Station for the support given throughout the project.

References
[1] Afework B, Hanania J, Stenhousen K and Donev J 2019 Energy Education – Power Plant
[2] AFP 2016 China power station explosion kills at least 21: Xinhua New Straits Times
[3] Fu G, Zhou L, Wang J and Shi M 2018 Analysis of an explosion accident at Dangyang Power Plant in Hubei, China: Causes and lessons learned Safety Science 102 134-143
[4] Stevens M, Rojas R and Fortin J 28 December 2018 New york sky turns blue after transformer explosion The New York Times A21
[5] Grobler R and Maphanga C 11 October 2018 Explosion at Eskom power station should not have happened – Expert News24
[6] Nwabueze D 2016 Liquid hydrocarbon storage tank fires – How prepared is your facility? Chemical Engineering Transactions 48 301-306
[7] Alimohammadi I, Nourai F, Daryalaal M and Ghasemi A 2014 A novel method to design water spray cooling system to protect floating roof atmospheric storage tanks against fires Iranian Journal of Health, Safety & Environment 2 pp 235-242
[8] Xu-qing L, Quan-zhen L and Hong G 2011 Study of Fire Fighting System to Extinguish Full Surface Fire of Large Scale Floating Roof Tanks Procedia Engineering 11 189-195
[9] Duarte D 2012 Aspects of Transformer Fires in Brazil Open Journal of Safety Science and Technology 2 63-74
[10] Vilceanu R and Surianu F 2016 Transformer protection and fire fighting systems used in high voltage power stations International Journal & Engineering 3 107-112
[11] Jamadar A, Adam R, Shabbir S, Danish I and Saahil M 2018 Design of Automated Fire and Safety System in Tanks and Vessels International Research Journal of Engineering and Technology (IRJET) 5 3139-3142
[12] Raj A, Palaniswamy E and Venkatesan 2018 Carbon Dioxide Snuffing System International Journal of Engineering Science and Computing 8 16864-16867
[13] Koorsen 2017 Determining which type of Fire Protection System to use Koorsen Fire & Security
[14] Festag S 2016 False alarm ratio of fire detection and fire alarm systems in Germany – A meta analysis Fire Safety Journal 79 119-126
[15] Dong W, Wang L, Yu G and Mei Z 2016 Design of Wireless Automatic Fire Alarm System Procedia Engineering 135 413-417
[16] Eckman W 1995 Pressurized Systems Fire Engineering
[17] Jabatan Bomba dan Penyelamat Malaysia 2012 Uniform Building By-Laws 1984
[18] Hock S C 2000 Guide to Fire Protection in Malaysia Kuala Lumpur Fire and Rescue
Department

[19] National Fire Protection Association 2005 Edition
[20] N.A 2003 Institute of Petroleum Energy Institute United Kingdom
[21] N.A 2019 Ten people killed by a fire extinguishing system International Association of Fire and Rescue Services