

# PHYSICAL SECURITY FRAMEWORK FOR POWER PLANTS IN YEMEN

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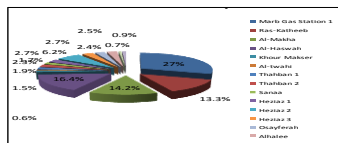
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## Graphical abstract



## Abstract

This study aims to design a framework for physical security measures for Marib power plant in Yemen to protect it from the physical attacks. Power plants are very important infrastructures and electricity is very essential in all aspects of human life, and it is obvious that power plants must have a good security protection from attack. Physical security is the first layer in power plants security. In Yemen, there are 18 power plants that generate around 1268.05MW of electricity, such that 835.5MW is generated using steam and gas and 432.55 using Diesel. Marib Power Plant is the largest station in Yemen, it is providing 341 MW and 27% of the electricity. Moreover, Marib Power Plant supplies electricity to Sana'a, the capital city of Yemen, and other neighboring areas. However, Marib Power Plant faces many physical attacks, which are the local armed tribesman, bombing and sabotage. According to the reports from Ministry of Electricity, these attacks caused many social, political and economic problems for the citizens and government. Therefore, this study shows that (Deterrence, Detection, Delay, Response and Army role) can be effective factors to reduce the attacks on Marib Power Plant. The validation of this framework was conducted in two ways: firstly by conducting an interview with experts in Marib Power Plant, and secondly by hypotheses testing between the components of the framework.

Keywords: Physical security, security model, power plant

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## 1.0 INTRODUCTION

Environment for computing system has moved from a safe environment to an environment that is less secure and the possibility of physical attacks has become much easier than other attacks. Therefore, attacks on physical security have increasingly occurred [1].

Physical security becomes essential if a security module is directly accessed, especially in an unprotected environment [2]. In addition, physical security has become one of the most important issues due to the worldwide distribution of explosives and illicit drugs [3]. Therefore, physical security is the first layer of security and plays an important role in protecting all the assets that are responsible for the storage and data processing because physical access means getting access to the information easily [4]. To reduce these

attacks, there is an urgent need to strengthen the protection of critical assets (radioactive components and fissionable material) at high-security facilities, such as nuclear plants, or military bases [5].

This is because the primary objective of physical security is to secure or protect a high value asset (or a set of assets) against theft, sabotage and other malevolent attacks [6]. However, a strong physical security system should be designed to detect the attack earlier in order to protect the critical assets and sensitive information, especially critical infrastructure like power plants.

Power plants supply electricity to all aspects of our lives; for instance, hospitals, factories and for telecommunication and internet services. And, the electric grid is arguably the world's largest engineered system. Vital to human life, its reliability is a major and

often understated accomplishment of humankind. It is the motor of the economy and the major driver of progress [7]. To implement a good protection for power plants, the facility managers should be involved in developing a good physical security plan. That is because their duties are planning and managing the building and infrastructure security and thus, they are able to identify the real risks and take appropriate reaction that reduces or eliminates such risks [8, 9].

After Tsunami and the attacks of September 11, 2001 the physical security of power plants and their vulnerability was elevated and categorized as national security issues. Nuclear Regulatory Commission (NRC) published a series of security regulations that are required to be applied to power plant facilities such as: preparing cyber security plans, developing strategies for dealing with the effects of aircraft crashes, strengthening access controls, improving training for security personnel and take other new security measures. The strategic improvements in security is very significant as it can make it more difficult for attacks on such facilities to succeed and can reduce the impact of attacks that may occur [10]. In addition to strategic security enhancements, tactical security improvements can be rapidly implemented as another line of defense to deter, mitigate, or neutralize potential attacks.

Thus, protection of power plants is a serious problem in the world, especially in the developing countries that face many physical security threats. For example, earthquakes and Tsunami are challenges for power plants in Japan; earthquakes, hurricanes, tornadoes, floods, terrorist threats are the main threats on power plants in USA; and terrorism is one of the attacks on UK infrastructure.

In Yemen, local armed tribesmen, bomb attacks (terrorism attacks) and sabotage attacks are a frequent occurrence on power plants. Therefore, this paper determined the factors that influence physical security to enhance the protection of power plants in Yemen.

## 2.0 PHYSICAL SECURITY ISSUES IN POWER PLANTS IN YEMEN

Figure 1 showed that Yemen has 18 power plants that generate around 1268.05 MW of electricity, 835.5MW using steam and gas and 432.55 using Diesel. Electricity lines in Marib feed the Dhahban power station, the main source of electricity for Sana'a [11]. Marib gas station is the largest station in Yemen which cost around \$159,016,000 and provides 341 MW, the equivalent of 27% of electricity output in Yemen.

Therefore, any problem in this station causes interruptions in different Yemeni cities which means a huge area will be plunged into darkness. In addition, many companies, factories and government organizations will be forced to stop working. Recently, Marib power plant faced significant security issues even

before 2011 and had one of the highest levels of tribal conflict. Because of the lack of government control, militant groups used Marib as a staging ground for attacks, which are responsible for several high-profile attacks on electricity and oil resources in Marib in 2010, as well as frequent attacks on government officials and security forces [11]. Power plants in Yemen faced a big obstacle concerning the infrastructure and some facilities in the past few years as its towers, facilities and power plants became the target of attacks, specifically in Marib province.

The Yemeni News Agency reported that the total number of attacks that affected the power transmission lines Marib - Sana'a reached 141 which cost over 33YR billion including the cost of spare parts, repairs and interrupted power [12]. In addition, the Yemeni Minister of Electricity and Power stated that the ministry agreed on Friday 22 June 2012 to stop working in Marib gas-operated power station to draw attention to the government to provide complete protection for transmission lines. Also Dr. Saleh Somai, the Minister, mentioned that "the Ministry chose to stop Marib gas plant because of the repeated attacks by vandals and will remain out of service until the army and security do their duty in protecting the lines. The national electric grid would be destroyed completely if the repeated attacks on electric power transmission lines continued and we did nothing" [13].

The frequent electricity shut down led to many problems in the Yemeni citizen's life [14], including:

- **Business problems:** the daily shut down leads to the destruction of much of the merchandise, especially in retail, and stopped many daily businesses
- **Tourist problems:** leads to giving a bad picture of the infrastructure in Yemen and thus, decline in tourism and investment
- **Investments problems:** many investors choose to leave Yemen as a result of poor infrastructure, and some might found that most of the investment projects have their own sources of electricity.

- **Security problems:** repetitive shut down of electricity at night leads to the risk of theft and burglary and increase of various crimes in dark alleys and streets.

However, the electricity infrastructure in Yemen faces a major issue according to the reports from of Electricity and Power because the attacks that occurred caused many problems for the government (Social, political and economic).

This paper presented physical security framework to protect the biggest power plant in Yemen, which is Marib Power Plant.

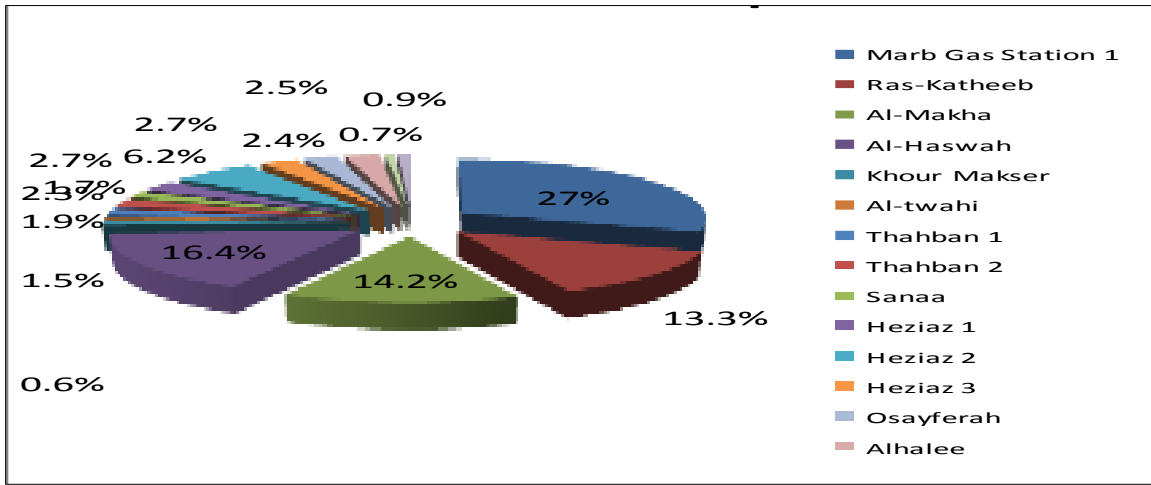


Figure 1 total rate unified power plant in Yemen

### 3.0 METHODOLOGY

There are three processes that were followed to conduct this study, starting from reviewing the previous studies in order to come up with the related measures that were used in physical security, and then review the attacks and threats that threaten power plant in Yemen.

The second step is matching the measures with the attacks and threats to come up with the proposed framework. Finally, design the interview and questionnaire to validate the measures. The methodology processes are shown in Figure 2.

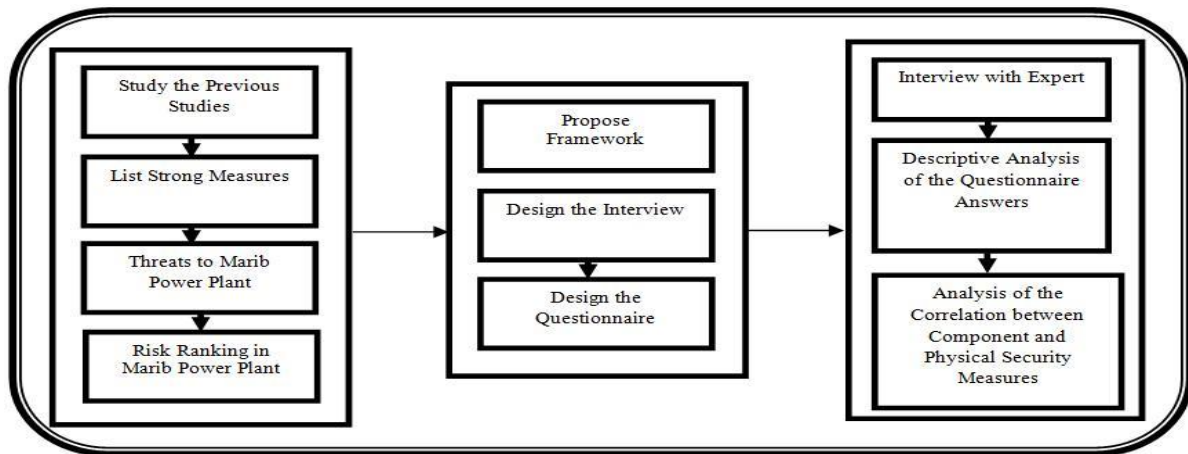


Figure 2 Methodology process

According to the previous studies, different counter measures were used to mitigate the physical security attacks. Consequently, a list of countermeasures that is used to mitigate the physical security threat was identified. Six physical security frameworks were discussed as shown in Table 1 and the common measures that are used in all frameworks were identified. Then, the strengths of each framework were determined to be compared with others and the common components were identified in order to use it in the proposed physical security framework for

power plant. A comparison between different studies is shown in Table 1.

The common measures in the previous studies that shown in Table 1 are the Deterrence, Detection, Delay and Response, which were used to design the proposed framework of physical security measures to mitigate the physical security threats. Through the determination of their weaknesses and the strengths in terms of Marib power plant location and based on the study that was conducted by [11], it was found that the threats come from the attackers using arms and guns and the researcher suggests one additional

measure that will reduce these attacks which is Army Roles.

In this paper, both qualitative and quantitative methods were used to evaluate and validate the conceptual framework. The authors tried to map the

interview and questionnaire questions with each factor of the framework in order to have accurate results.

**Table 1** The common physical security measures used with six authors

Measures/Authors	Detection	Delay	Response	Assess	Communica te	Intelligenc e
Anderson (2001)	√	x	√	x	x	x
Long (2005)	√	√	√	x	x	x
Alach (2007)	√	√	√	x	x	x
Galisson (2009)	√	√	√	x	x	x
American (2007)	√	√	√	√	√	√
Smith and Rooks (2013)	√	√	√	x	x	x
Measures/Authors	Audit	Alarm	Deter	Deny	Access control	Identificati on
Anderson (2001)	x	x	√	x	√	√
Long (2005)	x	x	√	√	x	x
Alach (2007)	x	x	x	x	x	x
Galisson (2009)	x	√	√	x	x	x
American (2007)	√	x	√	x	x	x
Smith and Rooks (2013)	x	x	√	x	x	x

The framework consists of five independent variables which are Deterrence, Detection, Delay, Response and Army role. The hypotheses for this framework are:

- The researchers assume that there is a positive relationship between deterrence and physical security measures to reduce the attacks on Marib power plant.
- The researchers assume that there is a positive relationship between physical protection system functions (detection, delay and response) and physical security measures to reduce the attacks on Marib power plant.
- The researchers assume that Army Role is positively related to the physical security measures to reduce the attacks on Marib power plant.
- The researchers assume that Army Role is positively related to increase Deterrence to reduce the attacks on Marib power plant.

- The researchers assume that Army Role is positively related to increase physical protection system functions (detection, delay and response) to reduce the attacks on Marib power plant.

The correlation using SPSS was applied to test the above hypotheses. Correlation between variables is a measure of how well the variables are related. The most common measure of correlation in statistics is the Pearson Correlation (technically called the Pearson Product Moment Correlation or PPMC), which shows the linear relationship between two variables.

The research population consists of 25 persons. Therefore, the appropriate method to study this population is to investigate all respondents as recommended by statistical experts [15-17].

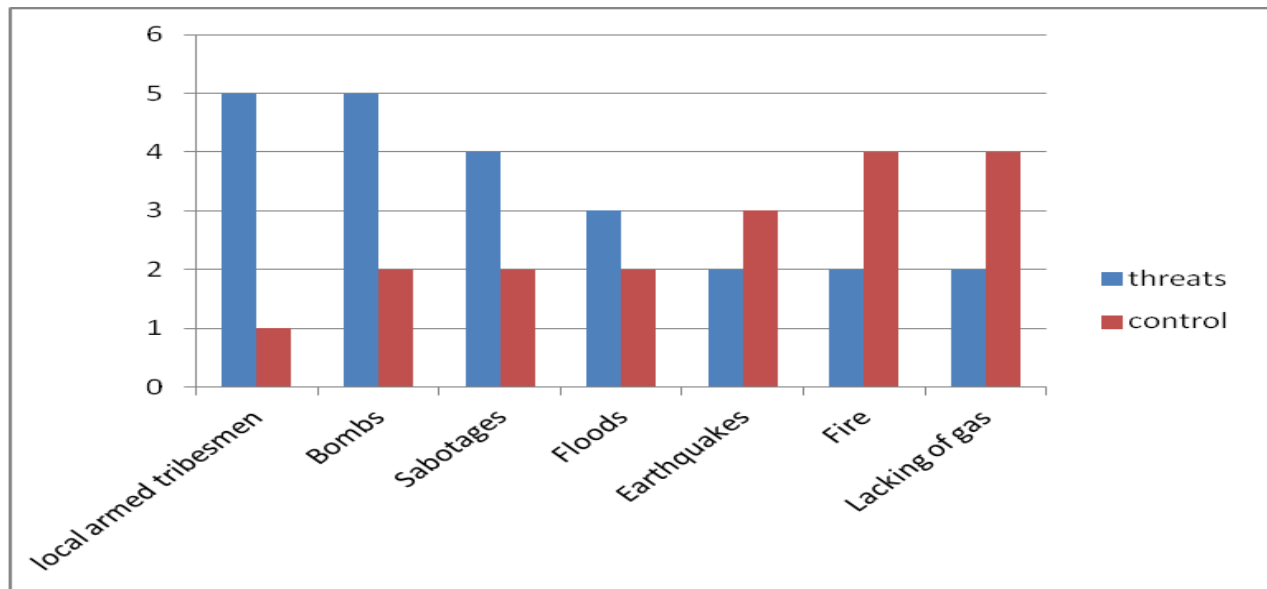


Figure 3 Level of risk threats and control in marib power plant

#### 4.0 FRAMEWORK IMPLEMENTATION

The review of security breaches shows that the most-expensive and important attacks that annually cause serious harm toward Marib power plant come from local armed tribesmen, bomb attacks (terrorism attacks) and sabotages which are indicated as strong threats and prevention is weak against these attacks as shown in Figure 3.

Terrorists or so-called local armed tribesmen could cause cascading failures and damage to parts that would take months to repair or replace. Although this threat is very likely, no steps have been taken to address the problem. The proposed framework should mitigate or at least reduce the threat of attack. Mitigation should use perimeter security concept, i.e., it should be taken through deterrence, detection, delay, response, and corrective actions.

The described threats and attacks are traditional types of attacks which indicate the level of corruption that the country has falling into, the degree of illiteracy and retardation among tribesmen, and the low level of government prestige and law enforcement. These simple attacks can be easily addressed by following the proposed framework to solve these challenges.

##### 4.1 Deterrence

Due to the absence of law enforcement and security forces, armed tribesmen are encouraged to continue attacking the power plants. Both security forces and law enforcement can perform strong deterrence to stop or reduce the attacks. For example, applying dissuasive penalties against criminals can form one important factor to discourage them or others to

violate or attack power plants. Furthermore, the absence of polices and clear plans to address the problem leads to increase the attacks.

In this paper, deterrence will be referred to as law enforcement and regulation. Strong law enforcement will help to warn potential attackers and punish the violators. Punishment leads to guarantee that the attackers will not repeat the attack as well as increase law prestige.

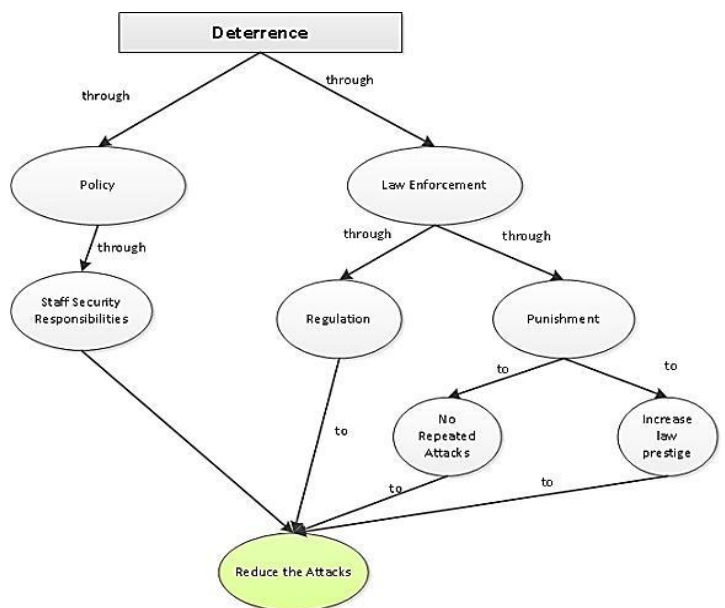


Figure 4 Deterrence to reduce the attacks on Marib power plant

Deterrence through law enforcement will significantly increase the physical security against the attacks in Marib power plant as shown in Figure 4.

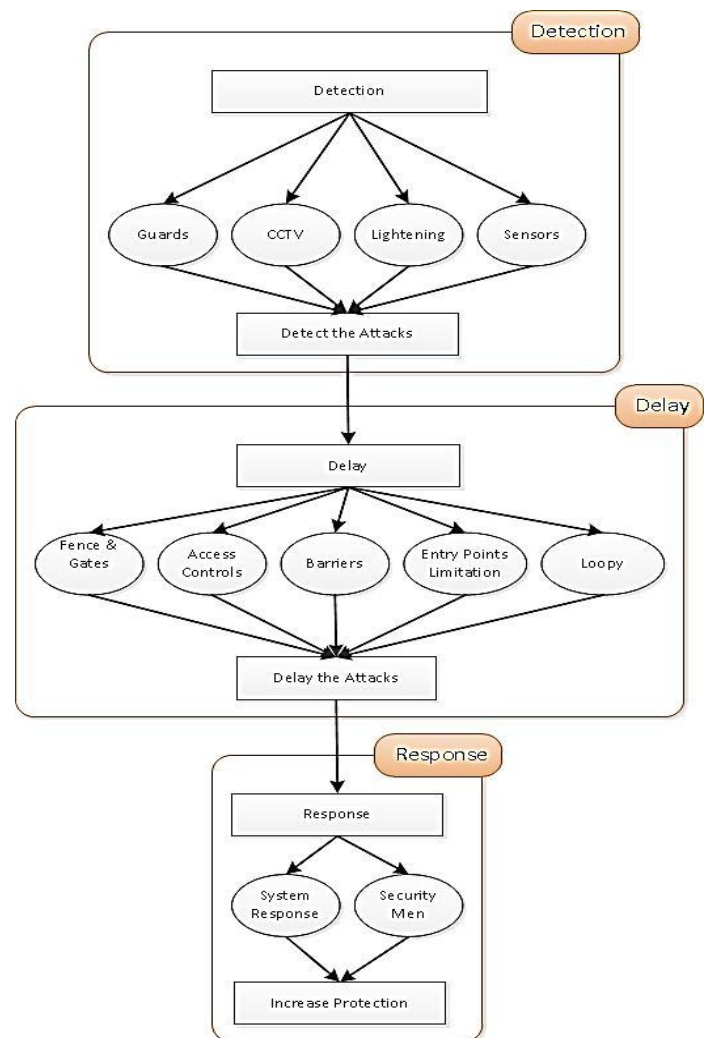
#### 4.2 Physical Protection System Functions Development

Poor physical security such as detection mechanisms, delay and response has contributed to help the attackers to achieve their objectives. It is obvious that the existing mechanisms are not suitable for attacks made by humans such as terrorism, political conflicts or corruption. By investigating threats in Marib power plant, it is clear that terrorist armed tribesmen, bombing, and sabotage are not slated for protection during the early phases of the constructions. Bomb, sabotage, and armed tribesmen attacks are high likely, but no action has been taken to address the problem. Therefore, the proposed framework should consider this issue.

Detection is necessary as terrorists could violate the law and deterrence mechanisms. By investigating the root cause of the attacks, when an attack is imminent, then the possible detection processes should be activated. Delaying the attack is another important requirement as the tribesmen are less educated and work outside of the team concept. Delaying will be an effective key to implement physical security. The delay will be determined by the duration needed to respond to the event. A rapid response is crucial due to the hazardous environment that the attacks occur in.

In physical security systems, detection, delay and response always come straight to protect the organization. There is no value for the protection without knowing the type of the potential attack.

This will be done by detection systems such as security guards, surveillance cameras, sensors and lights. All these systems lead to the discovery of an attack before it occurs and sends alerts to those responsible for security. The role of delay which is one of the most important types of physical security comes after the disclosure of the attack. Without the delay, detector systems have no value because the response needs time to react to the attack before it happens. These systems come in one level because they are integrated with each other. Figure 5 showed the process for implementation of the physical security system.



**Figure 5** Physical protection system functions to reduce the attacks on Marib power plant

#### 4.3 Army Role:

Yemeni people, especially in Marib, possess many types of weapons including heavy ones. These weapons cause many conflicts among people and government. The presence of any critical infrastructure in these areas is threatened by armed tribesmen. Moreover, the absence of government control leads Marib becoming an important destination for terrorist groups. In Marib, there are many critical infrastructures such as oil and natural gas fields as well as the most important power source in Yemen (Marib Power Planet).

Recently, Marib power plant has been attacked many times by so called armed tribesmen and terrorists. The security forces cannot address these groups, because the attackers are sheltered by the tribes. These attacks put the government in a critical situation in terms of cost and control. Due to this issue, army role will play a significant part to enforce the tribes to deliver the attackers to court.

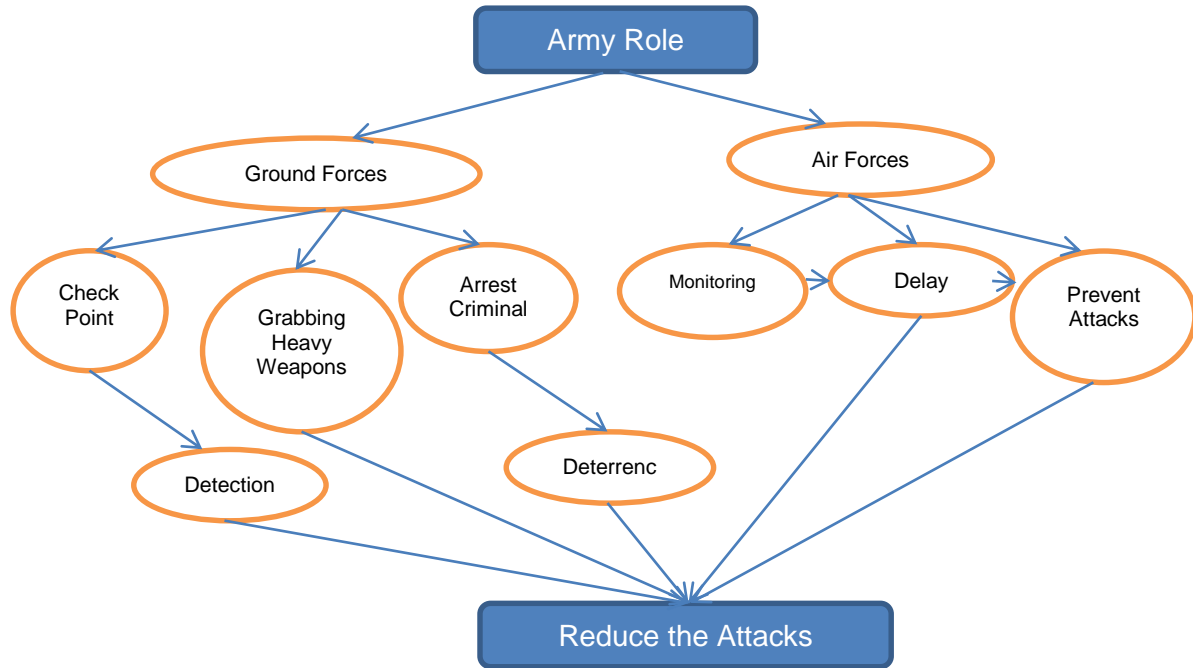


Figure 6 Army role to reduce the attacks on Marib power plant

The proposed solution is to use both ground forces and air forces. Ground forces will conduct checkpoints to monitor and prevent the carrying of weapons in critical areas. Moreover, seizing heavy weapons from the tribes is a crucial requirement to prevent attack. This will help to detect and deter criminals and reduce attacks accordingly. In addition, the air force will be used to provide cover to the ground forces, monitoring, delaying and prevent the attacks. Figure 6 depicts the army role.

The army role might be an important significant component of any solution developed to address the physical security attacks in Marib power plant. Thus, physical security is measured in various ways. The framework shown in Figure 7 highlights the most important measures employed to protect Marib power plant from the previously discussed threats. To the best of the researchers' knowledge, this is a pioneering study in this area in the context of Yemen.

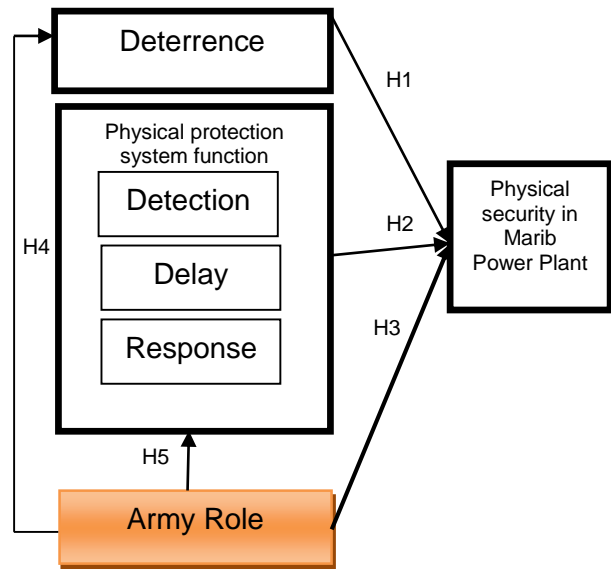


Figure 7 Proposed physical security framework for Marib power plant

## 5.0 FRAMEWORK VALIDATION

Verification is required to study the relationship between the physical security measures and components in the framework; the researchers tested the relationships between the framework components and the physical security measures in Marib power plant as discussed in the below sub-sections.

### 5.1 Interview

The vice manager of Marib power plant (Eng. Mohammed Syolan) verified that the components of the physical security measures framework are quite important to Marib power plant to mitigate the threats. Also he augmented the framework components with the following suggestions:

Protecting transmission lines is a very important issue for Marib Power Plant. The government must not give the attackers what they wish, because it encourages them to continue with the attacks.

Also, the government must provide electricity services to each village in Marib province.

### 5.2 Correlation Analysis

The framework consists of five independent variables which are Deterrence, Detection, Delay, Response

and Army role. To test hypotheses in the framework, the researcher used correlation in SPSS. The most common measure of correlation in statistics is the Pearson Correlation.

In this paper, the researcher tested the relationships between the components of the framework and the physical security measures in Marib Power Plant and arrived at the following results:

All hypotheses in the framework have been tested and the current study results show that these factors have significant effect on the physical security measures. Therefore, the researchers recommend that Marib Power Plant should pay more attention to the factors that influence physical security measures, such as the use of new devices that uncover and stop attacks before they happen. Also, army role can play significant role to reduce the attacks on Marib power plant.

Overall, the results indicate that the physical security measures, which include all components in the framework, have a significant effect on the physical security measures in Marib power plant as shown in Table 2. Therefore, the researchers suggested that this framework should be applied to mitigate the threats and prevent the attacks in Marib power plant.

**Table 2** Correlation analysis results

hypotheses	Pearson Correlation	Relationship States	Notes
Correlation between Deterrence and Physical Security Measures to Protect Marib Power Plant	.482	Positive	If deterrence increase, the physical security attacks in Marib Power Plant will decrease.
Correlation between Physical Protection System Functions (Detect, Delay & Response) with Physical Security Measures in Marib Power Plant	.505*	Positive	Marib Power Plant needs ( Detection, Delay and response) to reduce the attacks and threats.
Correlation between Army Role and Deterrence	.525	Positive	Army Roles will increase the deterrence role to protect Marib Power Plant
Correlation between Army Role and Physical Security Measures to Protect Marib Power Plant	.617**	Positive	Army Role associated positively with Physical Protection System Functions (Detect, Delay & Response)

## 6.0 PHYSICAL SECURITY MEASURES FRAMEWORK FOR MARIB POWER PLANT

Based on the statistical analysis of results and review of the literature, the researchers found that the variables included in this framework play a significant role in providing overall physical security. Therefore, this framework is suitable to reduce and mitigate the attacks in Marib power plant because it includes common variables that existed in previous studies in this domain which are deterrence, detection, delay and response. In addition, the researchers added

Army Role as a new variable to the framework. All the above components of the framework are compatible with threats that face Marib power plant in Yemeni. According to the information available to the researchers, the framework that is illustrated in Figure 6 is considered the first study that is conducted in Yemen for this area.

## 7.0 CONCLUSION AND FUTURE WORKS

Physical security researches in Yemen are still in the initial stages. It has not received high academic



attention. Therefore, more attention should be given to this area to understand the potential factors that may affect physical security. This paper developed a new framework based on the previous studies in physical security, including all important variables which are Deterrence, Detection, Delay and Response. In addition, this study added new variable, which is the Army role to investigate a set of antecedents that have an influence on physical security of Marib power plant in Yemen.

The result of this framework could be used to determine the important factors that influence physical security to enhance the protection of Marib power plant in future. Therefore, additional variables should be investigated on a larger scale by future researchers, i.e. examining more antecedents or factors that influence physical security threats in Marib power plant. These variables may include economic, political, and reduced infrastructure service in Marib city which are quite important factors according to an interview with the vice manager of Marib power plant (Eng. Mohammed Syolan).

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