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SUBSTATIONS PHYSICAL SECURITY TRENDS

Working Group
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cigré

Substations Physical Security Trends

Working Group
B3-03

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COMITE D'ETUDES B3 : **POSTES**
STUDY COMMITTEE B3 **: SUBSTATIONS**

Substation Physical Security Trends

In response to the growing concern for the security of substation physical assets, CIGRÉ Working Group B3-03 "Air- Insulated Substations" undertook an international survey to assess the use and effectiveness of various security measures for the prevention, detection and control of unauthorized human intervention during the construction, operation and maintenance of substations.

This brochure presents the results of this survey and includes case studies of security measures to prevent unauthorized access to substation property and protect substation assets. With the results of this survey we hope to raise awareness about substation physical security issues and to provide a basis for utilities to develop strategies to ensure public and employee safety and to minimize asset loss.

We wish to thank and acknowledge the many scientists and engineers who were involved in this project as well as the survey respondents for their valuable contribution.

April 2004

Auke Wiersma
Chairman of CIGRÉ SC B3

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SUBSTATION PHYSICAL SECURITY TRENDS

PREFACE

This technical brochure presents the results of an international survey conducted by the CIGRÉ Working Group B3-03 in September of 2002 to examine substation physical security trends in the utility industry. The main objective of the survey was to assess the use and effectiveness of various security measures for the prevention, detection and control of unauthorized human intervention during the construction, operation and maintenance of substations. Key issues addressed include:

- Type and Frequency of Security Threats
- Prevention and Detection of Security Threats
- Effectiveness of Security Measures
- Maintenance of Security Measures
- Security Incident Response

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This brochure was developed for the following target groups:

- **Technical Groups** including equipment suppliers, contractors, consultants, maintenance providers, grid planners and grid engineers.
- **Operators** of power systems, generation, transmission and distribution stations and asset and facility managers.
- **Science, Education and Public Groups** including academic and research institutes, young engineers, managers and others not familiar with the work of CIGRÉ as well as various authorities, the media and NGO's.
- **International Organizations** with similar scope.

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1.0 Executive Summary

Maintaining the security of substation physical assets has become increasingly important in recent years. Inadequate security of substation property can result in a loss in asset value, decreased asset reliability and increased company liability.

Fortunately, there is a range of options available to protect substation physical assets from security threats. The final security solution adopted by a particular utility will depend on local legislation, economic feasibility and company policy.

In September 2002, the Cigré Working Group B3-03 undertook an international survey (Appendix B) to examine how the utility industry is dealing with the increasing need to protect substation physical assets. Specifically, the survey was designed to assess the use and effectiveness of various security measures for the prevention, detection and control of unauthorized human intervention during the construction, operation and maintenance of substations. Key issues addressed in the survey include:

- Respondent Demographics
- Type and Frequency of Security Threats
- Prevention and Detection of Security Threats
- Effectiveness of Security Measures
- Maintenance of Security Measures
- Security Incident Response

2.0 Introduction

Security of substation physical assets has become a growing concern in recent years. Unauthorized access to substation property continues to be a problem for the electric industry. Intrusions can result in loss or damage of equipment or facilities and may create loss in asset value, decreased asset reliability and potential safety and environmental liabilities. Terrorism has created yet another level of concern. In the USA in particular, keeping energy infrastructure safe from terrorist attack has become a key domestic issue.

Unfortunately, transmission and distribution infrastructure is difficult to protect given its expansiveness. Substations are often located in remote areas and are difficult to monitor. Most substations, when originally built were equipped with security measures to protect the general public, discourage vandalism, prevent animal intrusion and subsequent contact with energized equipment, and prevent liabilities associated with the death or injury of an intruder. However, security took a back seat to cost cutting in the late 80's and many security systems were neglected. As utilities become more aware of the need to protect their physical assets they are reexamining their practices and heightening their security measures by adding new cameras and detection systems and working with local law enforcement to put facilities on patrol routes. The real challenge for utilities will be to find a balance between acceptable risk and acceptable expenditure.

The purpose of this survey was to assess the use and effectiveness of various security measures for the prevention, detection and control of unauthorized human intervention during the construction, operation and maintenance of substations. Forty-one electric utilities from around the world participated in this survey. With the results of this study we hope to raise awareness about substation physical security issues and to provide a basis for utilities to develop strategies to ensure public and employee safety and to minimize asset loss.

3.0 Demographics

Forty-one worldwide companies participated in this survey. The size of the companies represented in this survey ranges from 6 to 134,000 employees. Out of 41 participating companies, 40 were electric utilities (**Q1**).

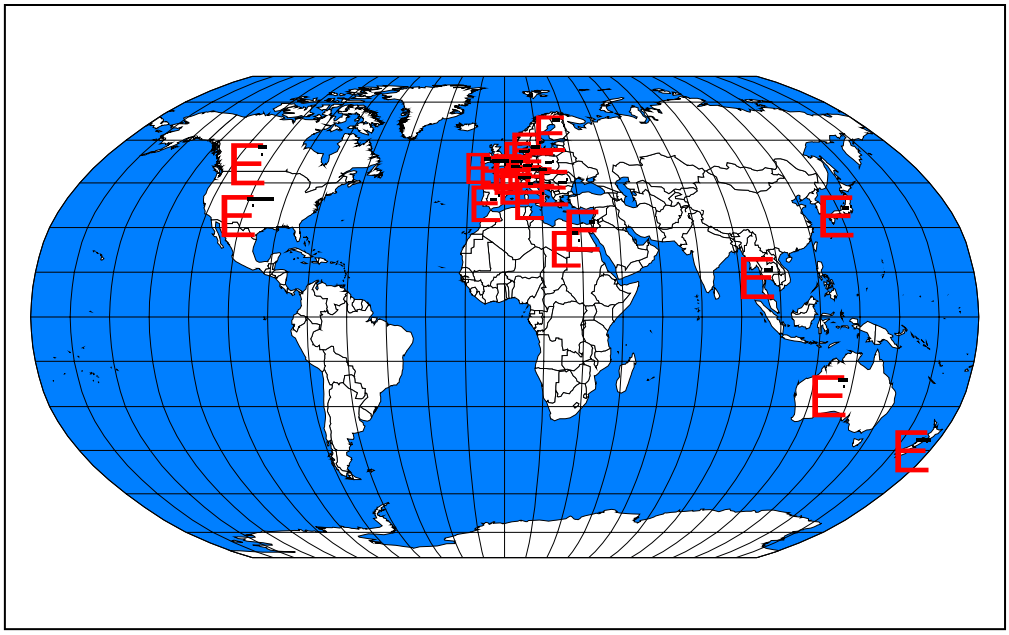


Figure 3.1 *Participating Countries*

Figure 3.1 shows the geographic distribution of the participating companies. The majority of respondents (31 out of 41) were from North America and Europe. Japan and Australia were well represented with 5 and 2 respondents, respectively. Unfortunately, there were no respondents from South America or Central Asia.

3.1 Substation Location

The majority of threats to substation physical security are the result of unauthorized personnel gaining access to the substation. It is not surprising then that the security risk of a substation is impacted by the location of the substation. Substations located in densely populated urban regions are at a higher risk of security threats than substations located in rural areas far from urban centers.

In question 3 (**Q3**) respondents were asked to identify the percentage of substations in their systems that are located in Urban, Suburban, Rural, and Industrial/ Commercial areas. The following figures 3.2 to 3.5 graphically depict their responses.

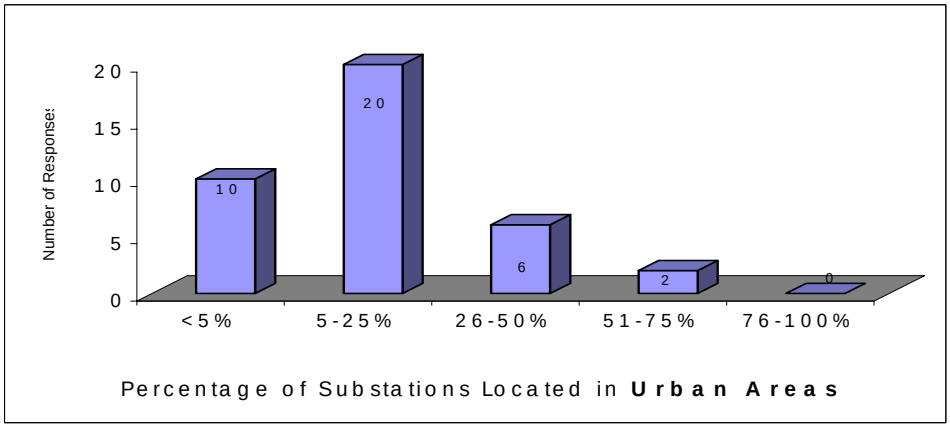


Figure 3.2: *Substations in* ***URBAN*** *Areas*

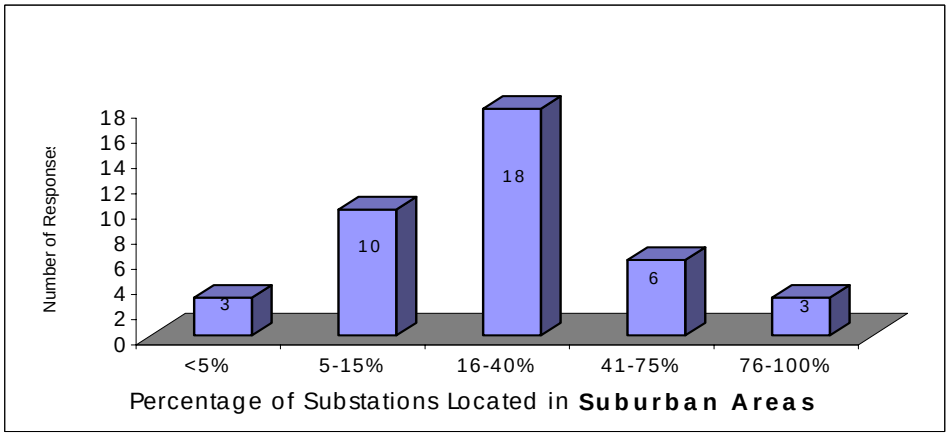


Figure3.3: *Substations in* ***SUBURBAN*** *Areas*

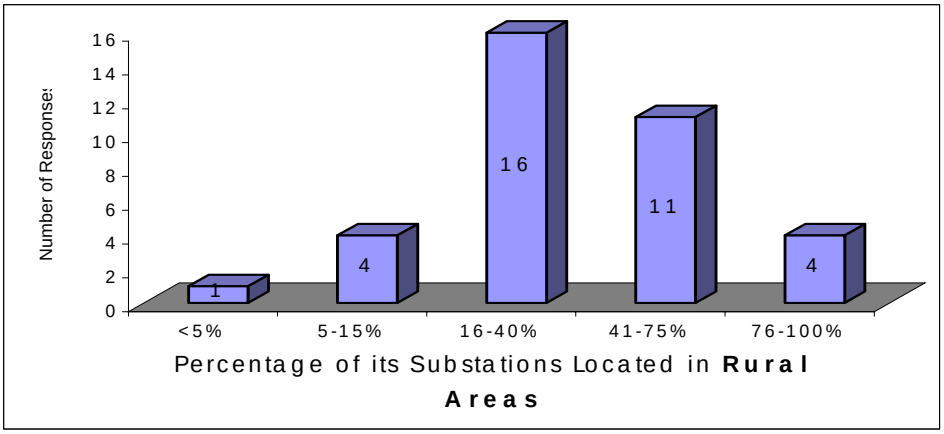


Figure 3.4: *Substations in* ***RURAL*** *Areas*

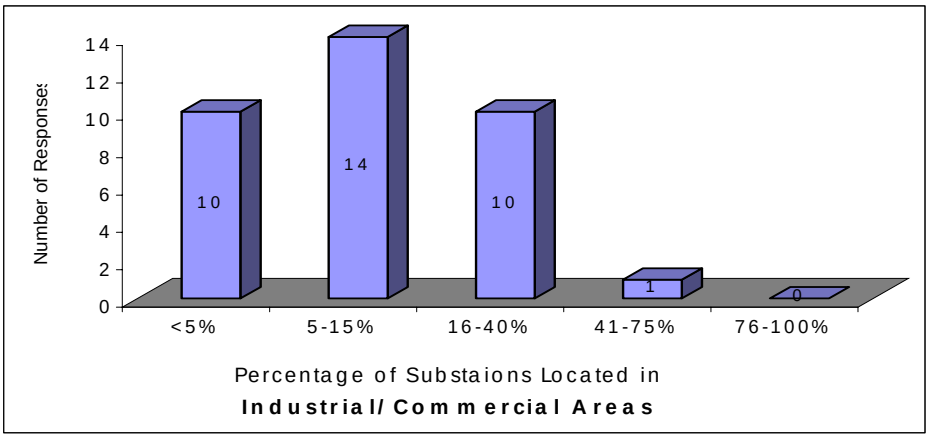


Figure 3.5: *Substations in* ***INDUSTRIAL/ COMMERCIAL*** *Areas*

The majority of respondent companies have substations located in suburban and rural environments. 30 respondents out of 38 (representing 79%) report that fewer than 25% of their substations are located in urban environments. It is important to note that the respondents were not provided with quantitative definitions of terms "urban, suburban, rural, and industrial". As such, these responses should be interpreted in relative terms.

In a typical electrical system, more than 1/3 of the substations are located in rural areas, nearly 1/3 are located in suburban areas and about 1/6 are in the vicinity of urban or industrial areas.

In question 18 (**Q18**), respondents were asked to identify the degree to which substation location generated concern for the physical security of a substation. Respondents were asked to indicate the degree to which their companies are concerned with the physical security of substations located in urban, suburban, rural or industrial/commercial environments.

The results are represented graphically in **Figure 3.6**. More respondents expressed greater concern for the physical security of substations located in urban environments than in rural environments. 32 out of 40 respondents (79%) expressed moderate to extreme concern of the physical security of substations in urban environments and 26 out of 40 respondents (65%) expressed the same degree of concern for substations in rural environments. Overall, the results indicate that utilities are concerned about the physical security of their substations regardless of their geographical location.

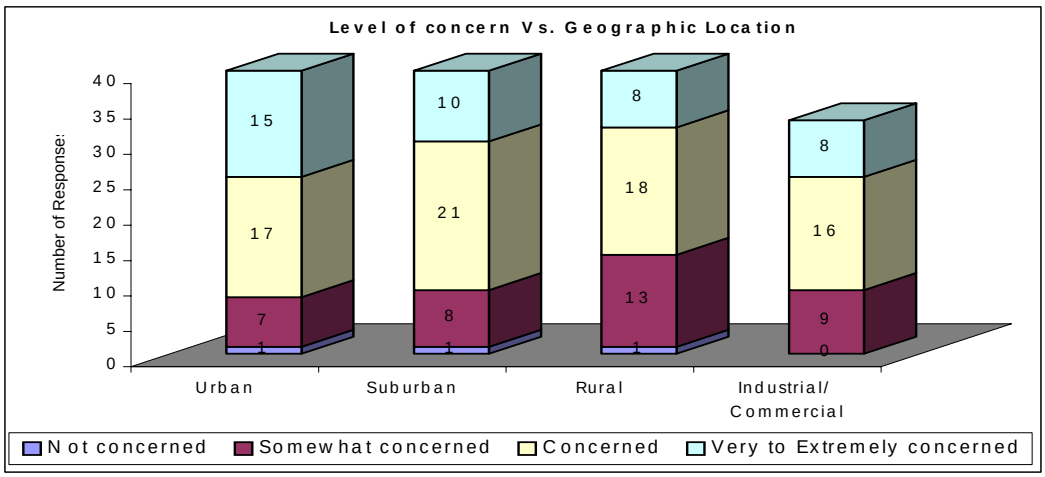


Figure 3.6 : *Security Concern versus Substation Location*

In question 17 (**Q17**) respondents were asked to identify the degree to which geographic location, load criticality, proximity to public places, reliability of the substation, and voltage level influence or drive their company's decisions regarding the need for substation physical security measures.

Each of the five factors investigated (location of the substation, load criticality, proximity to public places, reliability of the station and the voltage level of the substation) appear to be important factors that influence the need for substation physical measures. **Figure 3.7** demonstrates that substation reliability and performance requirements generate the most concern for the physical security of a substation with 87% (i.e. 34 out of 39 respondents) reporting moderate to extreme concern for substations that have high reliability requirements. In descending order, 79% (i.e. 30 out of 38 respondents) report concern for substations with high load criticality, 76% (i.e. 29 out of 38 respondents) report concern for substations with higher voltage levels, 75% (i.e. 30 out of 40 respondents) report concern for substations based on location and 70% (i.e. 28 out of 40 respondents) report concern about substations that are near public places.

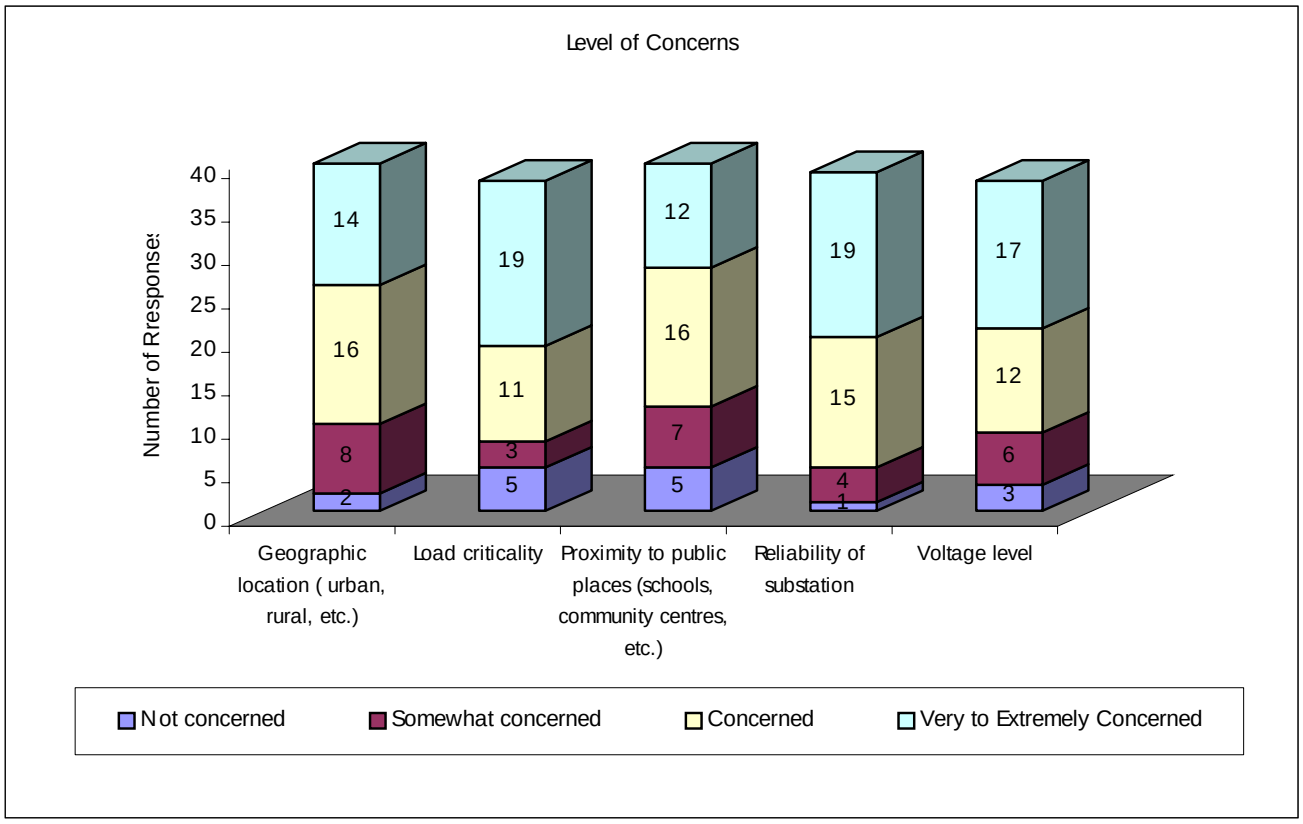


Figure 3.7: *Level of Concern versus Different Reasons for Security Measures*

3.2 Operational Aspects

Of the forty electric utility companies who participated in this survey, 38 respondents classified themselves as Transmission System Operators (TSO), 21 as Distribution System Operators (DSO) and 9 as Generating Companies (GC). In the traditional utility model most companies perform more than one of the operational roles. 55% of the respondents represent Investor-Owned utilities and the remaining 45% represent Government-Chartered organisations.
Figure 3.8 shows the role distribution in detail (**Q2**).

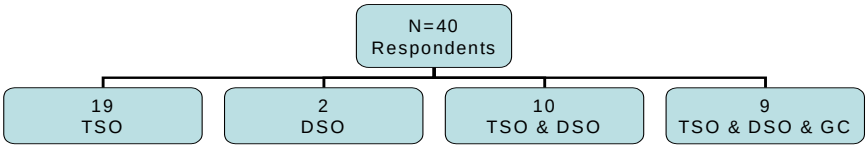


Figure 3.8: *Operational Role of Respondents*

Traditionally, the role of a TSO is related to voltages above 100 kV and the role of a DSO is related to voltages below 100 kV. This is reflected in our sample of respondents as 21 DSO companies responded in fields concerning operating voltages <50 kV and 39 TSO companies responded in fields concerning voltages from 100 to 250 kV.

In question 19 (**Q19**) respondents were asked to identify the degree to which the voltage level of the substation generates concern for the physical security of a substation.

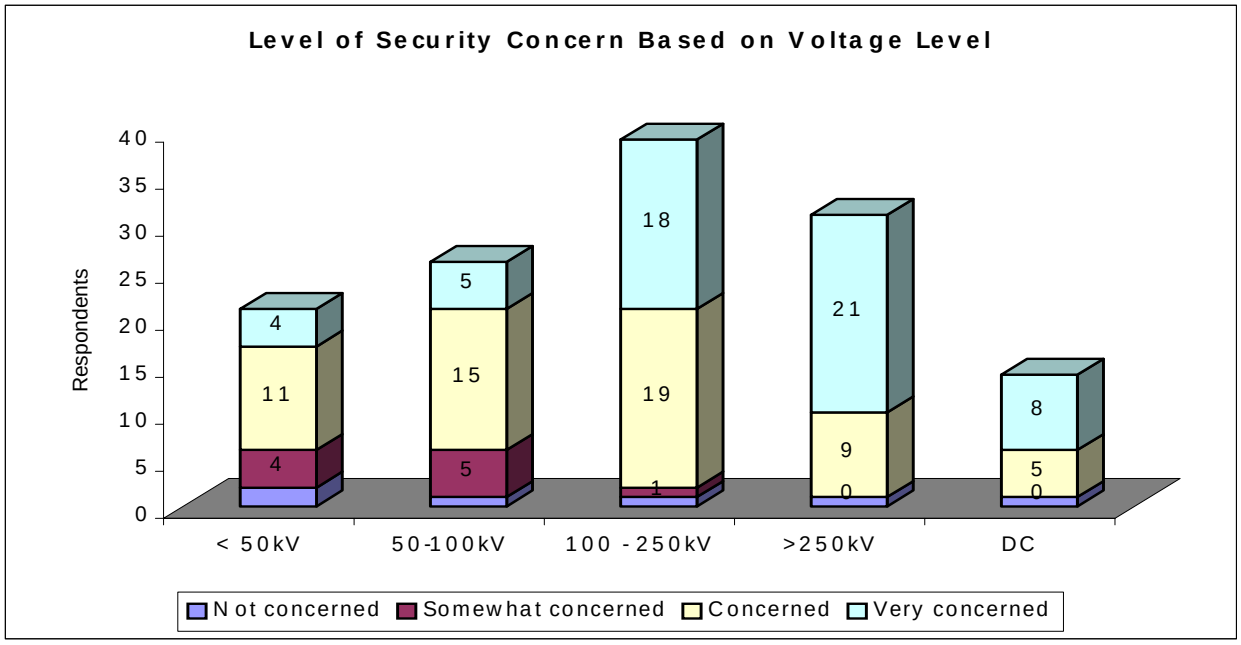


Figure 3.9: *Security Concern versus Operating Voltage*

Respondents expressed greater concern for the physical security of substations with higher voltage levels. Five respondents expressed extreme concern for the physical security of 50-100kV substations, while 21 respondents expressed extreme concern for the physical security of substations rated higher than 250 kV. Eight respondents expressed extreme concern for the physical security of DC substations (**Figure 3.9**).

4.0 Security Threats

4.1 Frequency of Total System Intrusions/ Year

Respondents were asked to identify the average number of ***total system*** intrusions that their company typically experiences on a yearly basis. Respondents were asked to specify whether these intrusions occurred during pre-construction, construction or operation of the substation (**Q8**).

Number of Intrusions/ Year	0	1-5	6-10	11-15	16-20	>20	Number of respondents
Pre-construction	15	9	1	0	0	1	26
Construction	11	14	10	0	0	2	30
Operation	5	23	1	4	3	4	40

Table 4.1: *Number of Total System Intrusions/ Year based on Substation Development Phases*

The results indicate that the majority of substation intrusions occur during the operation of a substation. The frequency of substation intrusions reported by respondents during substation operation is as follows:

- 23 out of 40 respondents (58%) report 1-5 intrusions/year,
- 7 out of 40 respondents (18%) report experiencing between 10 and 20 intrusions/ year
- 4 out of 40 respondents (10%) report experiencing greater than 20 intrusions/ year

Substation intrusions seem to be least common during the pre-construction period. In fact, 15 out of 26 respondents (58%) reported experiencing no intrusions during the pre-construction period. These responses are shown graphically in Figure 4.1.

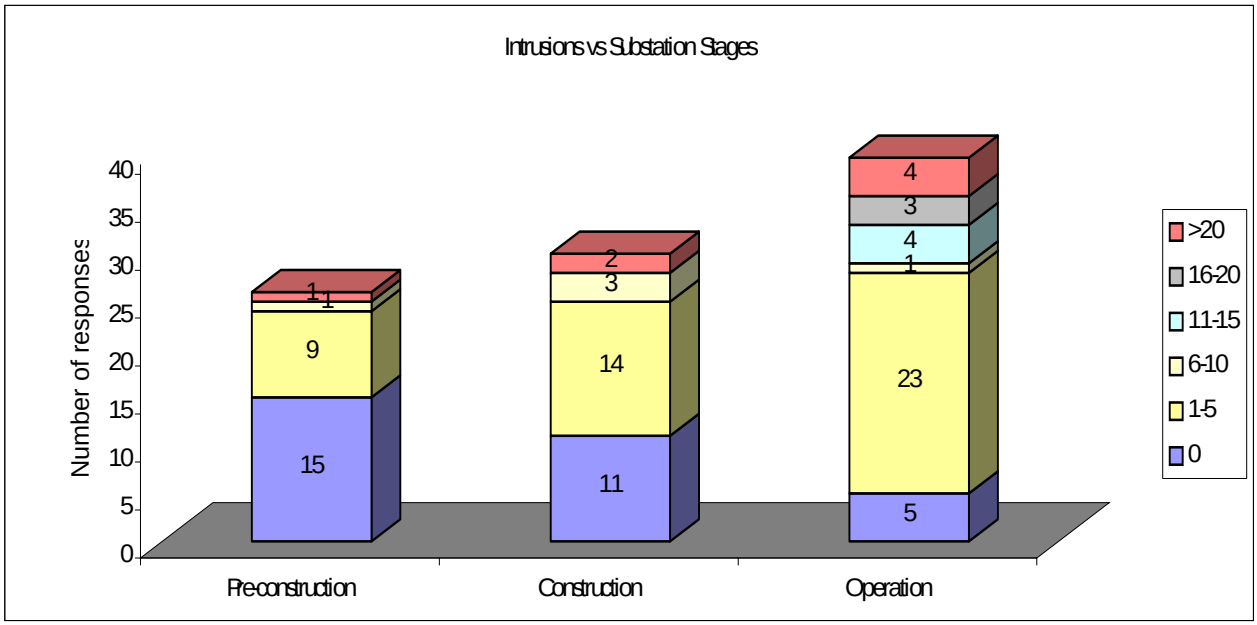


Figure 4.1: *Frequency of Intrusions vs. Stage of Substation Development*

4.2 Type of Intrusions

In question 9 (**Q9**) respondents were asked to identify the type of intrusions their company experienced as a percentage of the total number of intrusions experienced on an annual basis. This question was answered by 37 of the 41 respondents. **Figure 4.1** graphically depicts the type and frequency of intrusions relative to the total number of intrusions experienced annually for all respondents. The most common intrusions reported are those involving theft (32%), unauthorized personnel walking-in or crossing the perimeter fence (21%) and intruding animals (15%).

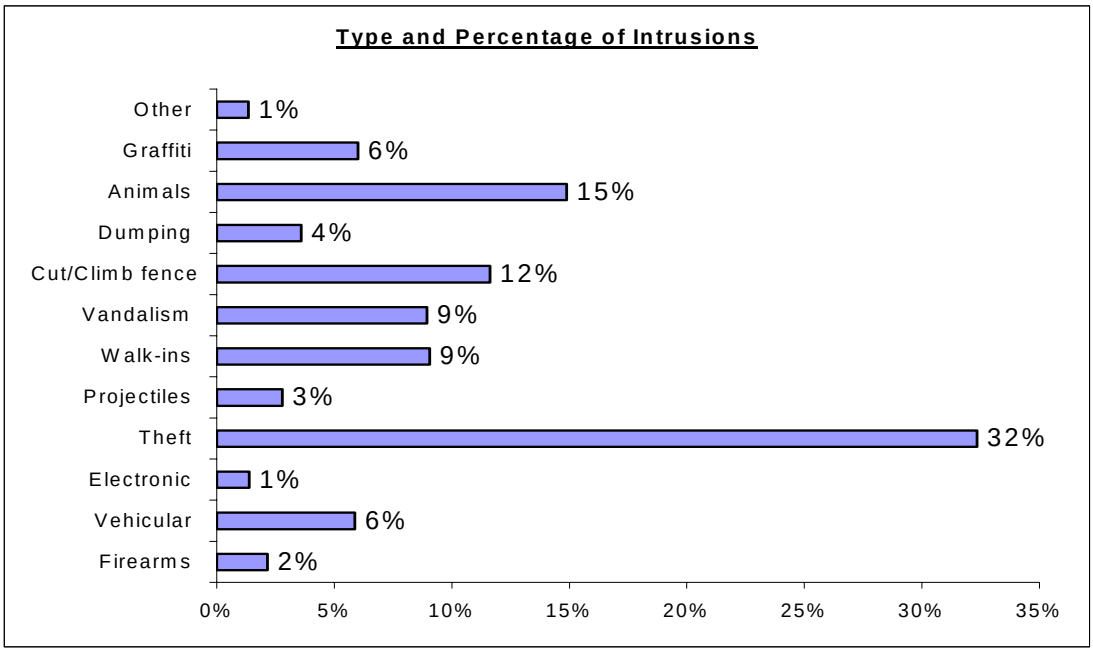


Figure 4.2: *Type and percentage of intrusions*

In order to explore the potential impact of substation intrusions on the operational threat to the substation and its equipment (**Q20, Q21, Q22**), respondents were asked to identify whether they perceived their company to be concerned with incidences of intrusions that resulted in power outages, personal injury or damage to the integrity of substation physical assets.

	Not a problem	**A problem**	**Number of respondents**
Intrusions ⇨ Power Outages	22	**19**	41
Intrusions ⇨ Personal Injury	20	**21**	41
Intrusions ⇨ Damage of Asset	19	**22**	41

Table 4.2: *Impact of Intrusion*

The majority of respondents report that intrusions resulting in damage to substation physical assets and those resulting in personal injury are a significant problem (**Table 4.2).** Intrusions resulting in power outages appear to be slightly less of an issue for respondents. The high frequency of intrusions resulting in theft of substation contents likely contributes to the problem of substation physical asset damage.

4.3 Top Security Concerns

In question 23 (**Q23**), respondents were asked to identify what their company considered to be its greatest substation physical security threat.

Of the 41 respondents who participated in the survey, 7 did not provide an answer to this question and 9 misinterpreted the question and as a result, their responses were not included in the analysis.

Of the 25 respondents who answered this question, 9 listed **terrorism** as their number one security concern, 6 listed **theft**, 5 listed **vandalism**, and 2 listed **sabotage** as their number one concern (**Figure 4.3**). Other security concerns reported by respondents include unauthorized entries (3 respondents), safety of employees (3 respondents), dumping (1 respondent) and power outages caused by animals (5 respondents).

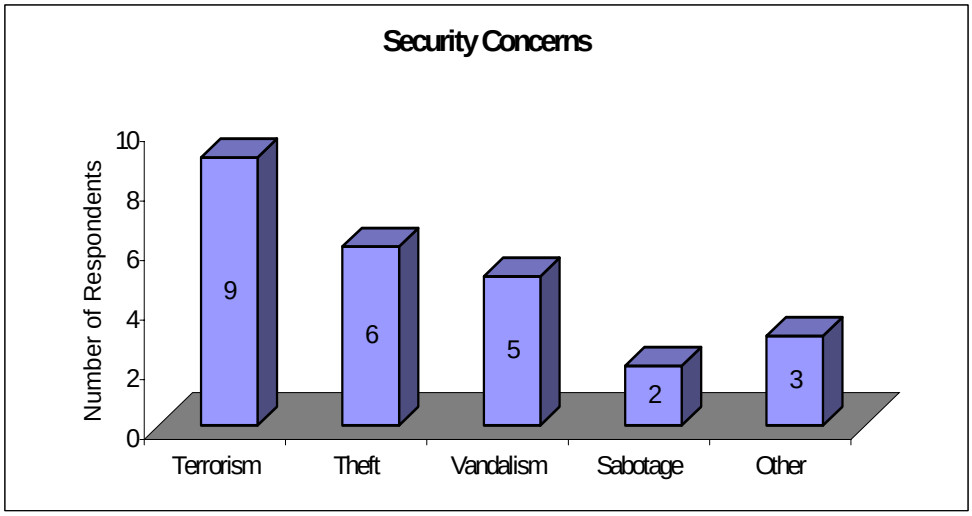


Figure 4.3: *Top Security Concerns*

5.0 Prevention and Detection of Security Threads

Respondents were asked to select from a list provided the measures that their companies use to achieve substation physical security (**Q7**). There were 39 responses to this question.

The most common substation physical security measures used by more than 50% of respondents are: alarm systems, security lighting, signs, chain link fences with barbed wire, higher than normal fences, road gates and locks. Less popular security methods used by only 5% of respondents include plastic barriers, guard dogs and sound detectors.

Respondents were also asked to list other security measures used by their companies that were not listed in the survey. Other security measures used by the respondents include:

- Invasion surveillance equipment using infrared rays
- Indoor AIS/GIS up to 123kV, outdoor AIS with solid buildings for secondary systems
- Laser Ray Systems
- Trench
- Perimeter detection system associated to images
- Passive protection (camouflage)
- Enlist neighbors to monitor substation
- Palisade fencing (replacing chain-link fencing)
- Steel doors
- Crash barriers at gates,
- Windows fitted with security bars
- Concrete walls to protect major transformers

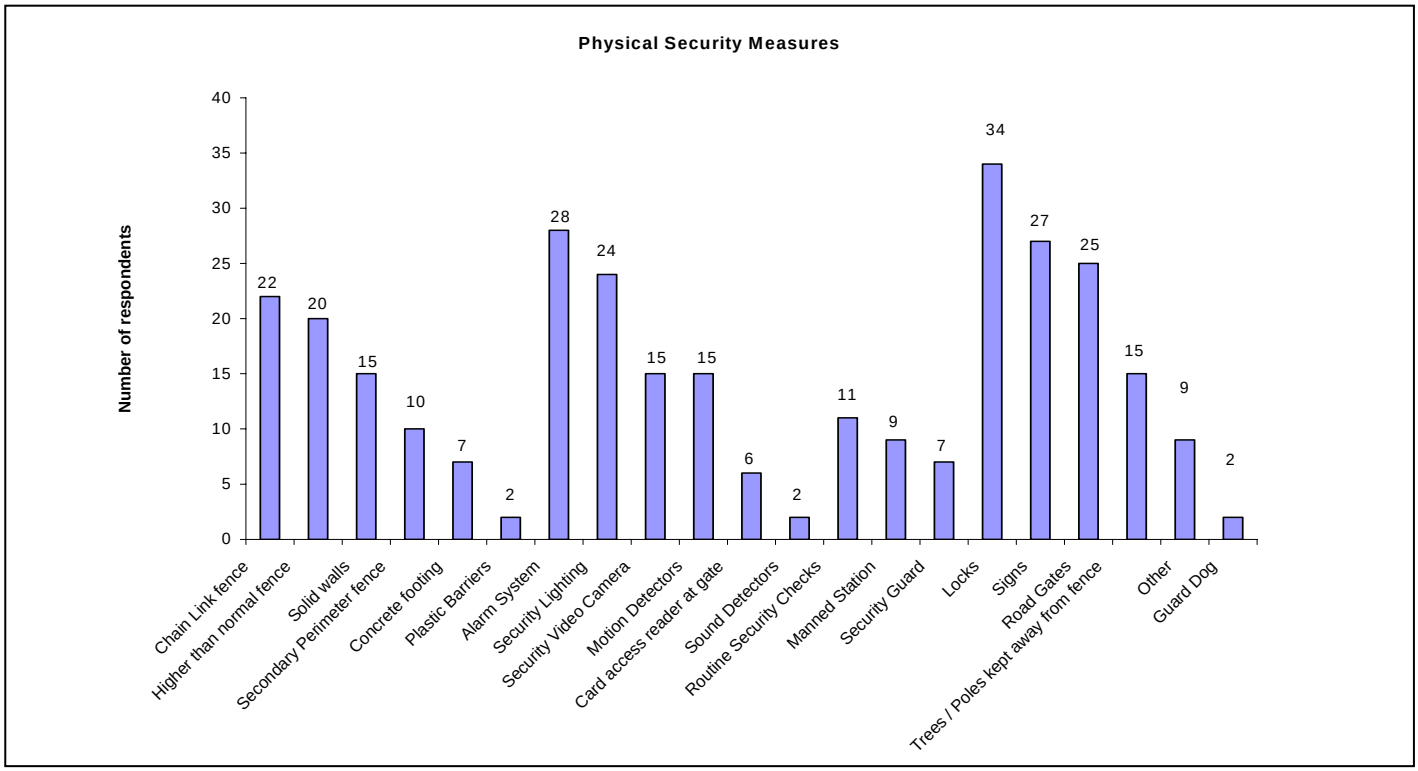


Figure 5.1: *Substation Physical Security Measures*

6.0 Effectiveness of Security Measures

Respondents were asked to indicate the effectiveness of the security measures used by their company (**Q11**).

The survey included a list of several different security measures for the respondents to rate. To facilitate interpretation and analysis of the results, the security measures were grouped into the following four categories:

- **Fencing**: chain link fences, higher than normal fences, secondary perimeter fence, solid walls, plastic barriers, concrete footing around bottom of fence)
- **Electric/ Electronic Systems**: alarm systems, security lighting, card access reader at the gates, security video camera, sound detectors, motion detectors)
- **Human Factor** : security guard, manned stations, routine security checks
- **Other**: signs, road gates, locks, guard dog, trees/poles kept away from fence, and other methods suggested by the survey participants

6.1 Effectiveness of the 4 Categories of Security Measures

The distribution of responses for each of the four categories of security measures was approximately the same. Greater than 68% of respondents rated each type of security measure as either "Effective" or "Very/Completely Effective". Security measures involving some form of on-site supervision (Human Factor) and Electric/Electronic Systems were reported to the most effective, followed by "Other" measures as illustrated in **Table 6.1**.

Figure 6.1 illustrates the effectiveness of the 4 categories of security measures.

	not effective	somewhat effective	effective	very effective to completely effective
FENCING	7%	25%	40%	28%
ELECTRIC/ ELECTRONIC SYSTEMS	3%	21%	42%	34%
HUMAN FACTOR	2%	21%	42%	35%
OTHER	5%	22%	42%	31%

Table 6.1: *Effectiveness of Security Measures*

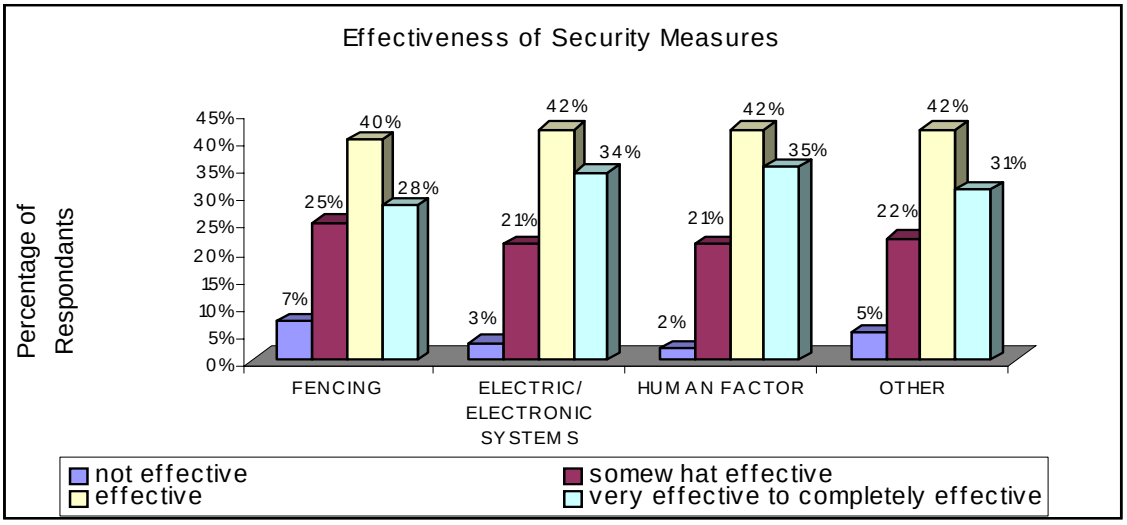


Figure 6.1: *Effectiveness of Other Security Methods*

6.2 Effectiveness of Fencing Methods

Only twenty eight percent of respondents rated fencing methods to be “Very/Completely Effective”. Of the types of fencing methods examined, solid walls were reported to be the most effective (20 of 21 respondents) and plastic barriers were rated as the least effective (3 of 11 respondents). Chain link fences, a popular security measure, was rated as effective by only 15 out of 26 respondents.

	FENCING					
	Chain Link Fence	Higher than Normal Fence	Secondary Perimeter Fence	Solid Walls	Plastic Barriers	Concrete Footing Around Bottom of Fence
Not effective	1	1	0	0	5	1
Somewhat effective	10	5	3	1	3	7
Effective	12	9	9	8	2	6
Very effective to completely effective	3	8	5	12	1	4
Number of respondents	26	23	17	21	11	18

Table 6.2: *Effectiveness of Fencing Methods*

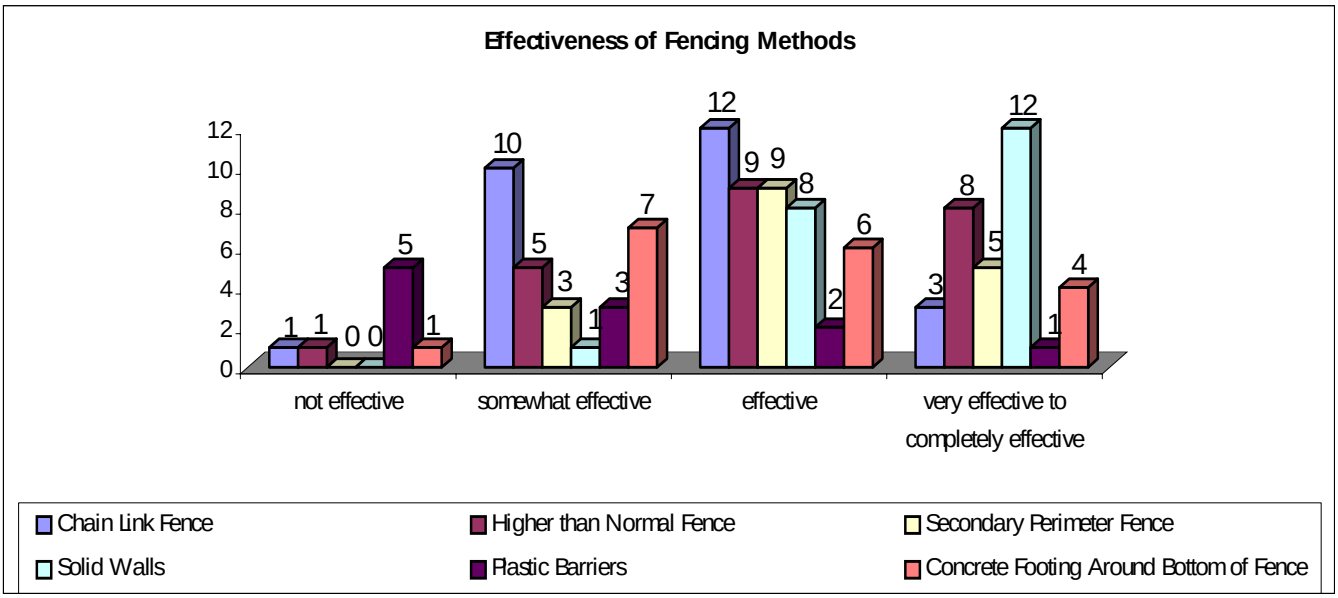


Figure 6.2: *Effectiveness of Fencing Methods*

6.3 Effectiveness Electric and Electronic Measures

For electronic systems, 20 out of 23 respondents rated video cameras to be either “Effective” or “Very/Completely Effective”, and 13 out of 15 rated card readers as an effective security measure. Sound detectors were considered to be the least effective electronic security measure.

	ELECTRIC/ ELECTRONIC SYSTEMS					
	Alarm System	Security lightning	Card Access Reader at Gate	Security Video Camera	Sound Detectors	Motion detectors
Not effective	1	0	0	0	2	1
Somewhat effective	8	8	2	3	4	4
Effective	11	12	8	12	3	12
Very effective to completely effective	16	9	5	8	2	6
Number of respondents	36	29	15	23	11	23

Table 6.3: *Effectiveness of Electric/Electronic Methods*

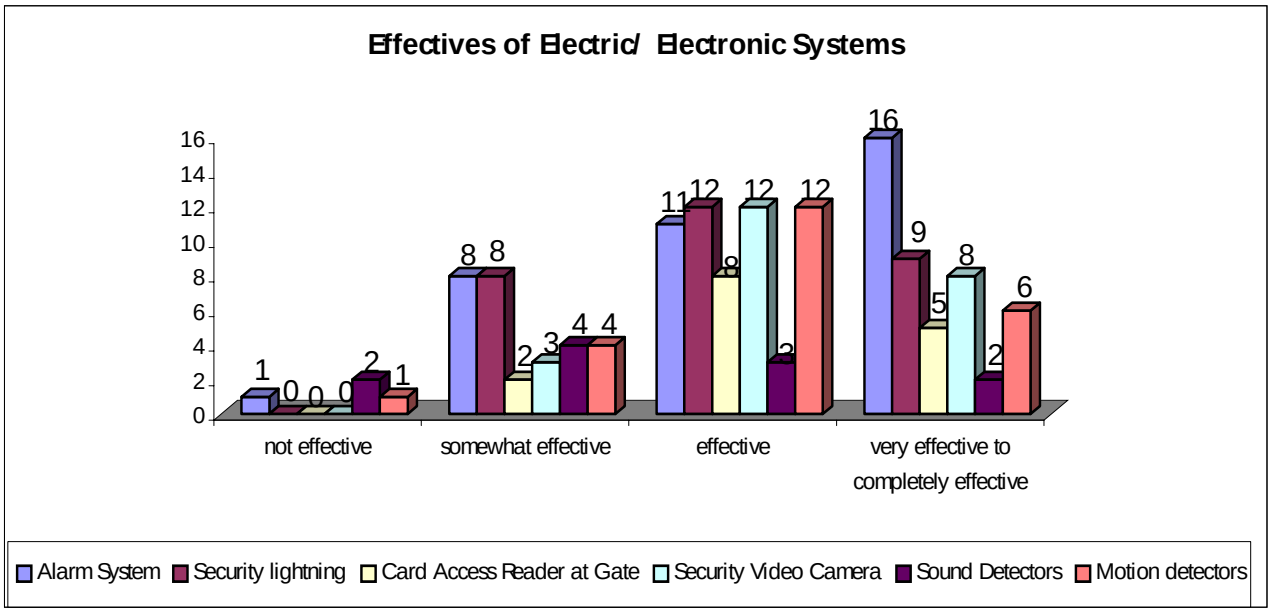


Figure 6.3: *Effectiveness of Electric/Electronic Systems*

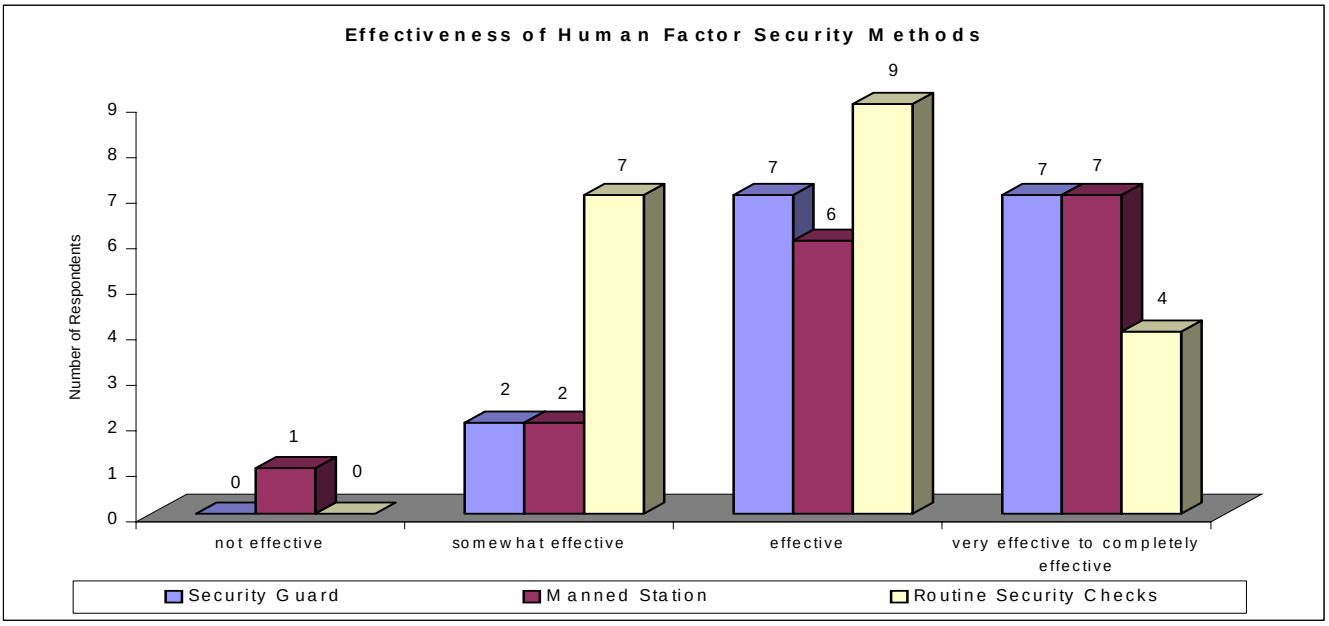
6.4 Effectiveness Human Factor Security Methods

Security measures involving on site supervision were reported to be the most effective type of security measure. The majority (87%) of respondents rated a security guard or a manned station to be equally effective whereas routine security checks were reported to be a less effective security measure.

	HUMAN FACTOR		
	Security Guard	Manned Station	Routine Security Checks
Not effective	0	1	0
Somewhat effective	2	2	7
Effective	7	6	9
Very effective to completely effective	7	7	4
Number of respondents	16	16	20

Table 6.4: *Effectiveness of Human Factor Security Methods*

Figure 6.4: *Effectiveness of Human Factor Security Methods*



6.5 Effectiveness of Other Methods

Security measures in the "Other" category included locks, road gates, signs, guard dogs and trees kept away from the fence line. Of these security measures, locks were reported to be the most effective with 31 out of 34 respondents (91%) considering locks to be Effective or Very/Completely Effective. Road gates were rated by 24 of 29 respondents to be effective and only 15 out of 29 respondents (52%) considered signs to be an effective security measure. Of the 11 respondents who reported using guard dogs, 7 consider them to be Effective or Very/Completely Effective (64%).

	OTHER					
	Signs	Road Gates	Locks	Guard Dog	Trees/ Poles Kept Away from Fence	Other
Not effective	5	0	0	1	1	0
Somewhat effective	9	5	3	3	7	1
Effective	11	15	18	2	7	1
Very effective to completely effective	4	9	13	5	5	4
Number of respondents	29	29	34	11	20	6

Table 6.5: *Effectiveness of Other Security Methods*

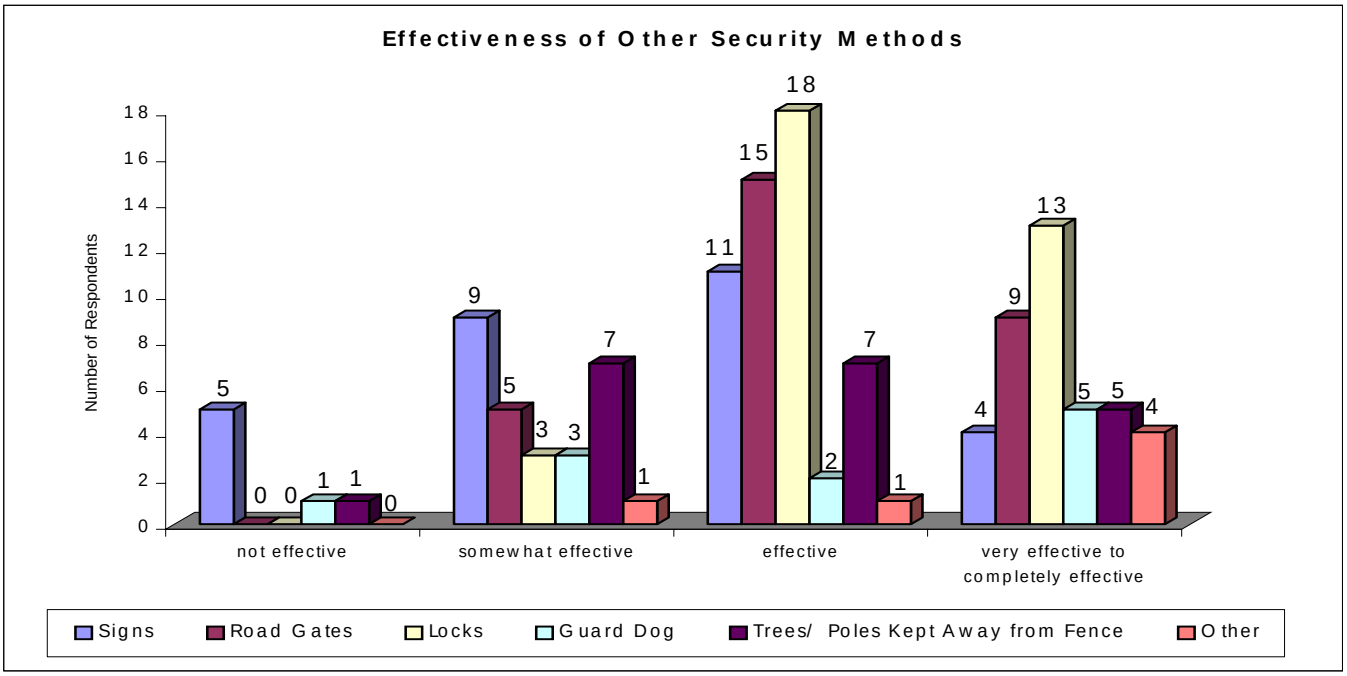


Figure 6.5: *Effectiveness of Other Security Methods*

7.0 Maintenance of Security Measures

Respondents were asked to indicate how frequently their companies assess the condition or functionality of the security measures used (Q12). Respondents were asked to indicate the frequency of security checks based on the voltage level of the substation.

	<50 kV	50-100kV	100-250kV	>250kV	DC
Monthly	5	7	19	12	4
Bi-monthly	1	5	4	4	1
Annually	3	3	7	6	1
Not at all	0	0	0	0	0
Other *	7	7	11	10	6
Number of respondents	16	22	41	32	12
Other* Daily; when workers enter the premises; only corrective actions (when needed to be fixed); every 3, 72, or 6 months spontaneous; weekly; every 2 or 3 years					

Table 7.1: *Frequency of Security Functional Assessment*

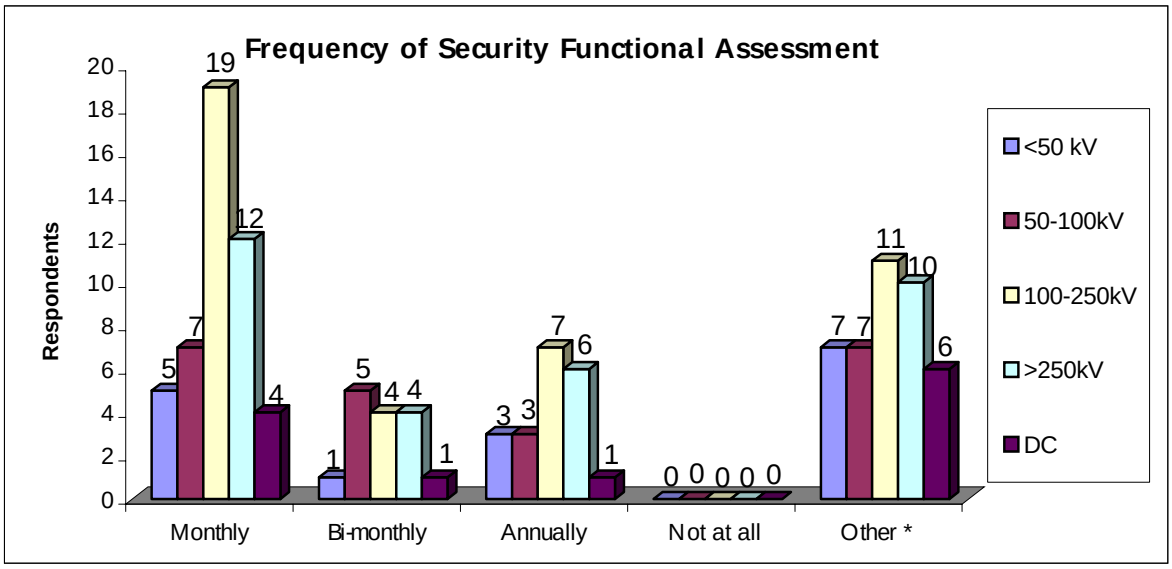


Figure 7.1: *Frequency of Security Functional Assessment*

All respondents reported that their companies assess the condition or functionality of their substation security measures. For substations with operating voltages of 50 kV to greater than 250 kV a monthly check is the preferred frequency. A significant number of respondents reported conducting functional assessments of their security measures at a frequency other than the options listed, ranging from daily, when workers enter the premises, as required, spontaneous, weekly, every 3 or 6 months or every 2-3 years.

8.0 Managing Security Incidents

Respondents were asked to indicate whether their companies have a written policy, plan or guidelines for managing substation incident response and to what degree their security response efforts involved the local law enforcement (**Q13 to Q16 and Q4 to Q6**).

	Existence of policy/plan/guidelines for managing substation incident response	Notification of local law enforcement and emergency services in the event of substation security breach	Partnership with local law enforcement services for automatic intervention in the event of substation security breach
Yes	21	21	14
No	19	19	25
Number of Respondents	40	40	39

Fifty-three percent of the sample (21 of 40 respondents) reported possessing a written policy, plan or guidelines for managing substation incident response. Of these respondents, 10 have an incident response system that includes immediate notification of the local law enforcement in the event of a security breach, resulting in automatic intervention and resolution of the event.

The remaining 47% of the sample do not have a written policy, plan or guidelines for managing substation incident response. However, 5 of the 19 respondents in this category report that they notify the local law enforcement in the event of a security breach and another 4 report having a partnership with the local law enforcement that ensures automatic intervention in the event of a security breach.

Looking at **Q 13 to 16**, through the light of company profile, the survey results show that 61% of the Government -Chartered utilities have a written policy/plan/guidelines for managing substation incident response, while only 41% of the Investor-Owned utilities have such a policy. Also 67% of the Government-Chartered utilities have a system in place to notify the local law enforcement and emergency services if there is a substation security breach, while only 36% of the Investor-Owned utilities have such a system in place.

9.0 References

Oglevie, J. and Rooney, P. ***Physical Security***. In J.D. McDonald (Ed.), Electric Power Substations Engineering (pp16-1 – 16-13). June 2003.

IEEE Standard 1402-2000, IEEE Guide for Electric Power Substation Physical and Electronic Security, sponsored by Substation Committee of IEEE-PES. 2000.