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Направление подготовки 14.04.02 Ядерные физика и технологии
Отделение школы (НОЦ) Ядерно-топливного цикла

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Тема работы
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MASTER’S THESIS

Topic of the work
Physical protection system (Nuclear security)

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For the Master's Thesis completion

Master's Thesis

(Master's Thesis)

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Topic of the work:

Physical protection system (Nuclear security)	
Approved by the order of the head (date, number)	No1882//c at 19.03.2018

Deadline for the completion of Master's Thesis:	04.06.2018

TERMS OF REFERENCE

Initial data for work **(***the name of the objective of research design; performance or load; mode of operation (continuous, periodic, cyclic, etc.);type of raw materials or material of the product; requirements for the product, product or process; special requirements to the features of the operation of the object of product in terms of operation safety, environmental impact, energy cost, economic analysis, etc)*	Physical protection system (Nuclear security) Plans for the implementation of nuclear program in Ghana was reviewed and suitable places were analysed for the construction of nuclear power plant. Threats and vulnerability analysis was conducted and based on that, the nuclear facility was designed and categorised. The physical protection system was also designed according to international and local standards (IAEA, DOE, ROSATOM)
List of the issues to be investigated, designed and developed *(analytical review of literary sources in order*	Analysis of places to build NPP in Ghana. Description of the hypothetical object (VVER 1000/1200).

to elucidate the achievements of world science and technology in the field under consideration, the formulation of the problem of research, design, construction, the content of the procedure of the research, design, construction, discussion of the performed work results, the name of additional sections to be developed; work conclusion).	Threats and vulnerability analysis. Requirements for equipping PPS with engineering and technical equipment within the framework of accounting and control. Designation of nuclear facility and physical protection system in accordance with the requirements of normative documents.
List of graphic material **(***with an exact indication of mandatory drawings)*	N/A
Advisors on the sections of the Master's Thesis *(with indication of sections)*	
Chapter	**Advisor**
One: Literature Review	Roman Laas
Two: Methodology	Roman Laas.
Three: Results	Roman Laas
Four: Financial management, resource efficiency and conservation	Timur R. Rakhimov
Five: Social Responsibilities	Verigin D.A.

Date of issuance of the assignment for Master's Disertation completion according to a line schedule	

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"FINANCIAL MANAGEMENT, RESOURCE EFFICIENCY AND RESOURCE CONSERVATION"

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Education Level	Masters	**Direction / specialty**	Nuclear Physics and Technology

References for "Financial management, resource efficiency and resource conservation":	
1. The cost of research: Logistics, energy, financial, information and human	*According to manual provided*
2. Norms and standards resource consumption	*According to manual provided*
3. used the tax system, tax rates, deductions, discounting and credit	*According to manual provided*
The list of questions for study, design and development:	
1. Evaluation of commercial and innovative potential STI	**Implement** at least 1 option from the list (1-3) below: 1. Potential consumers of research results 2. Analysis of competitive technical solutions from the perspective 3. Technology QUAD 4. SWOT-analysis **Perform** • Evaluation of the project readiness for commercialization • Methods for the commercialization of scientific and technological research
2. Development of the charter of scientific and technical project	• Objectives and outcomes of the project. • The organizational structure of the project. • Identification of possible alternatives
3. Project management planning: the structure and schedule of the budget, risk and procurement organization	• The structure of the work within the framework of scientific research • Determination of the complexity of work • Scheduling scientific research • The budget of the scientific and technical research (STR)
4. Defining resource, financial, economic efficiency	• Integral financial efficiency indicator • Integral resource-efficiency indicator • Integral total efficiency indicator • Comparative project efficiency indicator
List of graphic material	
1. *Segmentation of the market* 2. *Estimation of competitiveness of technical solutions* 3. *SWOT Matrix* 4. *Schedule and budget of the project* 5. *Assessment resource, financial and economic efficiency of the project*	

Date of issue of assignment	

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ASSIGNMENT FOR THE SECTION "SOCIAL RESPONSIBILITY"

For student

Group	Full name
0АМ6И	Adams Benjamin Addo

School	Nuclear Science and engineering	**Division**	Nuclear Fuel Cycle
Level of education	Masters	**Direction / specialty**	Nuclear Physics and Technology

Initial data to the section "Social responsibility"	
1. Description of the workplace (working area, technological process, equipment used) for the case of occurrence of:	• Description of the workplace of the engineer who performs calculations on the PC, for the occurrence of: ○ harmful factors of the production environment: an increased level of electromagnetic radiation. ○ Hazardous factors in the production environment: the likelihood of a fire, the likelihood of electric shock.
2. List of legislative and normative documents on the topic	Familiarization with legislative and normative documentation.
List of issues to be investigated, designed and developed:	
1. Analysis of factors of internal social responsibility: *- the principles of the organization corporate culture;* *- the system of labor organization and its security;* *- development of human resources through learning programs and training and development programs.*	• Analysis of identified hazards: ○ increased level of electromagnetic radiation. ○ means of protection.
2. Analysis of external social responsibility factors: *- assistance in environmental protection;* *- interaction with the local community and local authorities;* *- preparedness to participate in crisis situations, etc.*	• Analysis of identified hazards: ○ Electrical safety (including static electricity, protective equipment); ○ Fire and explosion safety (causes, preventive measures, primary fire extinguishing means)
3. Legal and organizational issues of ensuring social responsibility: *- Analysis of legal norms of labor legislation;* *- analysis of special legal and regulatory legislative acts;* *- Analysis of internal regulatory documents and regulations of the organization in the field of research activities.*	• GOST 12.1.038-82 SSBT. electrical safety • PPB 01-03. Fire safety rules in the Russian Federation
List of graphic material:	N/A

Date of issuance of the assignment according to a line schedule	

The task was issued by the Advisor:

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Ministry of Education and Science of the Russian Federation

Federal Independent Educational Institution

"NATIONAL RESEARCH TOMSK POLYTECHNIC UNIVERSITY"

School: School of Nuclear Science and Engineering

Direction of training (Specialty): 14.04.02 Nuclear Physics and Technology

Level of education: Master's Degree

Division of Nuclear Fuel Cycle

Period of completion (fall/spring semester 2017/2018)

Form of presenting the work:

Physical protection system (Nuclear security)

(Master's Thesis)

SCHEDULED COURSE ASSESSMENT CALENDAR

for the Master's Thesis completion

Deadline for completion of Master's Thesis:	04.06.2018

Assessment date	**Title of section (module) / type of work (research)**	**Maximum score of the section (module)**
09.02.18	Literature Review and Methodology	
04.03.18	Design of nuclear facility and vulnerability analysis	
02.04.18	Design of physical protection system	
01.05.18	Financial management and Social Responsibility	
29.05.18	Compilation of the dissertation (full report)	

Made by:

Position	**Full name**	**Academic degree, academic status**	**Signature**	**Date**
Assistant Lecturer	Roman Laas	-		

Agreed:

Position	**Full name**	**Academic degree, academic status**	**Signature**	**Date**
Nuclear Power Installations operation	Verhoturova V.V	PhD		

Expected learning outcomes

Result code	The result of the training (the graduate should be ready)	Requirements of the FSES HE, criteria and / or stakeholders
professional competencies		
LO1	To apply deep mathematical, natural scientific, socio-economic and professional knowledge for theoretical and experimental research in the field of the use of nuclear science and technology	FSES HE Requirements (PC-1,2, 3, 6, UC-1,3), Criterion 5 RAEE (p 1.1)
LO2	Ability to define, formulate and solve interdisciplinary engineering tasks in the nuclear field using professional knowledge and modern research methods	FSES HE Requirements (PC-2,6,9,10,14 UC-2,3,4, BPC1,2), Criterion 5 RAEE (p 1.2)
LO3	Be able to plan and conduct analytical, simulation and experimental studies in complex and uncertain conditions using modern technologies, and also critically evaluate the results	FSES HE Requirements (PC-4,5,6,9,22 UC-1,2,5,6), Criterion 5 RAEE (p 1.3)
LO4	To use the basic and special approaches, skills and methods for identification, analysis and solution of technical problems in nuclear science and technology	FSES HE Requirements (PC-7,10,11,12,13 UC-1-3,BPC1,3), Criterion 5 RAEE (p 1.4)
LO5	Readiness for the operation of modern physical equipment and instruments, to the mastery of technological processes during the preparation of the production of new materials, instruments, installations and systems	FSES HE Requirements (PC-8,11,14,15, BPC-1), Criterion 5 RAEE (p 1.3)
LO6	The ability to develop multivariate schemes for achieving the set production goals, with the effective use of available technical means	FSES HE Requirements (PC-12,13,14,16, BPC-2), Criterion 5 RAEE (p 1.3)
cultural competencies		
LO7	The ability to use the creative approach to develop new ideas and methods for designing nuclear facilities, as well as modernize and improve the applied technologies of nuclear production	FSES HE Requirements (PC-2,6,9,10,14, UC-1,2,3), Criterion 5 RAEE (p 1.2,2.4,2.5)
basic professional competencies		
LO8	Independently to study and continuously to raise qualification during all period of professional work.	FSES HE Requirements (PC-16,17,21, UC-5,6, BPC-1), Criterion 5 RAEE (p 2.6) coordinated with the requirements of the international standard EURACE & FEANI
LO9	Actively own a foreign language at a level that allows you to work in a foreign language environment, develop documentation, present results of professional activity.	FSES HE Requirements (BPC-3, UC-2,4), Criterion 5 RAEE (p 2.2)

LO10	To demonstrate independent thinking, to function effectively in command-oriented tasks and to have a high level of productivity in the professional (sectoral), ethical and social environments, and also to lead the team, form assignments, assign responsibilities and bear responsibility for the results of work	FSES HE Requirements (PC-18,20,21,22,23 UC-1,4, BPC-2), Criterion 5 RAEE (p 1.6,2.3) coordinated with the requirements of the international standard EUR-ACE & FEANI

Abstract

The final qualifying work contains 156 pages, 31 figures, 22 tables.

Key words: nuclear facility, nuclear material, physical protection system, complex of engineering and technical means of physical protection, physical protection engineering and technical equipment, vital zone, limited zone, protected zone, threats, vulnerability analysis, nuclear power plant, drones, unmanned aerial vehicles, intruder, adversary, hypothetical object, VVER 1000/1200, perimeter.

The subject of the study are insider threats, outsider threats, insider in collusion with outsider threats, nuclear power plant vulnerabilities, analysis of threats that unmanned aerial vehicles (drones) impose on nuclear power plant, design of hypothetical nuclear facility for VVER NPP, categorization and analysis of the most vulnerable areas of this facility, accounting and control of nuclear materials, the design and functions of PPS.

The purpose of the final qualifying work is to design the PPS with the elements of the complex of engineering and technical means of physical protection of the inner zone and the protected zone (Physical protection system).

In the course of the work, an analysis was carried out of normative and legal documents on the organization and functioning of the physical protection system and the system for accounting and control of nuclear materials at the nuclear facility. The formulation of requirements for equipping the complex of engineering and technical means of physical protection of important and protected areas was also carried out.

As a result of the work, an integrated physical protection system was designed for the protection of nuclear facility from terrorist activities.

List of abbreviations

DBT	-	Design Basis Threat
DFO	-	Distillate Fuel Oil
DPF	-	Dangerous Production Factors
ECCS	-	Emergency Core Cooling System
FA	-	Fuel Assembly
FITs	-	Feed In Tariffs
GAEC	-	Ghana Atomic Energy Commission
GHA	-	Ghana
GNPPO	-	Ghana Nuclear Power Programme
GoG	-	Government of Ghana
GRIDCO	-	Ghana Grid Company
HEU	-	Highly Enriched Uranium
HPF	-	Harmful Production Factors
IAEA	-	International Atomic Energy Commission
IPP	-	Independent Power Sources
ISIS	-	Islamic State of Iraq and Syria
IT	-	Information Technology
LCO	-	Light Cycle Oil
MESTI	-	Ministry of Environment, Science, Technology and Innovation
MW	-	Megawatt
NM	-	Nuclear Material
NMAC	-	Nuclear Material Accounting and Control
NPP	-	Nuclear Power Plant
NRC	-	Nuclear Regulatory Commission
PPETF	-	Physical Protection Engineering and Technical Facilities
PPS	-	Physical Protection System

RCCAs	-	Rod Cluster Assemblies
VVER	-	Water -Water Energy Reactor
SNF	-	Spent Nuclear Fuel
SNFS	-	Spent Nuclear Fuel Storehouse
TCP	-	Town and Country Planning
UAV	-	Unmanned Aerial Vehicles
URC	-	Unacceptable Radiological Consequence
WAGP	-	West African Gas Pipeline

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Introduction

Nuclear energy is currently the most promising and efficient branch of energy. In connection with the development of nuclear power, the number of dangerous fissile materials and nuclear equipment is increasing, and the number of countries possessing them is also increasing.

Nuclear materials and nuclear facilities are of great interest to terrorist organizations, and as a result, there is a high probability of a terrorist threat, which means that nuclear safety and non-proliferation should be widely considered at nuclear facilities. The seizure, disabling of nuclear installations or disruption of the operation of such facilities is fraught with catastrophic consequences that can cause large and irreparable damage to the state, society.

The number of fissile materials at nuclear facilities is increasing due to the accumulation of spent nuclear fuel. In this regard, the attractiveness of nuclear facilities from intruders (violators) is increasing. Nuclear materials need a thorough and reliable protection of the perimeter, storage and use of nuclear materials. To address these issues, there are two main systems.

Safety of nuclear energy use and security of nuclear materials at nuclear facilities is ensured by the State Physical Protection System. The physical protection system is a set of organizational and technical measures carried out at a nuclear facility, its administration, security service, and security units using engineering and technical means of physical protection to prevent unauthorized actions at a nuclear facility. To maintain the effective functioning of the physical protection system, it is necessary to update it or improve it, as modern terrorists (violators) are sufficiently well trained, aware, armed. Therefore, they must be confronted with highly effective protective measures. As measures to prevent terrorist attacks, the PPS should jointly perform the functions of detection, delay and timely response.

Implementation of these functions is possible only when creating automated physical protection systems. An automated system is understood as a set of technical, software, other tools and personnel actions designed to automate the security processes of an object. Therefore, for the effective functioning of the PPS, staff training, creation and application of modern, effective engineering and technical complexes means of physical protection that can complement each other must be done.

There are many systems that perform various security tasks. However, none of them is able to guarantee full and reliable protection of objects of and information from the full range of possible threats. The solution to this problem lies in the development of integrated systems that integrate various security subsystems with common technical means, communication channels, software, databases, etc.

The main advantage of integrated security systems is that all subsystems are interconnected, and in response to an event in one subsystem, a corresponding action takes place in the other. There is an opportunity to set the required scenarios of reaction of any complexity to different events.

Access control based on biometric readers or cards also helps in increasing the security level of the most vulnerable places on the site. At the same time, security is provided not by any one element of the system, but by a set of organizational measures and technical means of the PPS. To avert or prevent terrorist from unauthorized access to limited and vital areas of the organization, it was necessary to design and create a security system.

To solve non-proliferation issues, there is a system of state accounting and control of nuclear materials. The system of state accounting and control of nuclear materials is an element of the system of state regulation of nuclear energy and is designed to perform such important tasks as the maintenance of accounting and reporting documents, and prevention of unauthorized actions with respect to nuclear material.

The purpose of this master's thesis is to design a physical protection system for a hypothetical object (VVER) in order to address actual threats. To achieve this goal, the following tasks were formulated:

- Analysis of places to build NPP in Ghana.
- Description of the hypothetical object (VVER 1000/1200)
- Threats and vulnerability analysis
- Designing of hypothetical nuclear facility for the VVER 1000/1200 to be built in Ghana, categorization and analysis of the most vulnerable areas of this facility.
- Requirements for equipping PPS with engineering and technical equipment within the framework of accounting and control were reviewed.
- Designation of PPS and equipping the system complex with engineering and technical means of physical protection in accordance with the requirements of normative documents.
- The resource, financial, budgetary, social and economic effectiveness of the study was carried out.

1 Nuclear energy in Ghana

1.1 Plans for the implementation of the nuclear program in Ghana

1.1.1 Brief overview of Ghana

Ghana became a self-governing nation on 6th March 1957. Ghana practices a multiparty system of democracy, based on the 1992 constitution. The country is located about 750 km above the equator on the west coast of Africa. It lies between latitudes 4 44' and 11 11' north and longitudes 3 15' west and 112' east. Longitude 0 or the Greenwich Meridian passes through the port city of Tema, which is to the east of the country. The total area of the country is about 238,540 km. The 2010 Population and Housing Census estimated the country's population at about 24.66 million. The backbone of the country's economy has been the agricultural sector. Ghana's landscape is drained by a number of rivers and streams. The major rivers include the Black Volta, which has its origin in Burkina Faso and then flows along the north-western boundary of the country with La Cote d'Ivoire, before entering the country at its midsection; the White Volta, which also has its origin in Burkina Faso, then flows into the country at the middle of the northern boundary; and the Oti River, which flows from Togo and enters the country along the northeast of the country. These rivers, flowing from the north, merge at about the middle of the country to form the Volta River. There are other rivers in the west, like the Pra, Ankobra and Tano rivers, with origins in the highlands of the country. Two hydropower plants have been constructed on the Volta River, at Akosombo and Akuse and a third hydropower plant at Bui on the Black Volta. There are also a number of coastal lagoons: Lake Bosomtwi, created by a meteorite, and the huge manmade Volta Lake, created after the construction of the hydroelectric dam at Akosombo. [1]

The country has several Airports (International and Local) which include Kotoka International Airport, Kumasi and Sunyani Airport. It also has major sea ports which comprises of the port of Sekondi-Takoradi, Port of Tema and the fishing harbor at Tema through which goods are imported.

Ghana's economy growth decelerated sharply to an estimated 4.2% in 2014, down from 7.4% in 2013. Gas supply interruptions from Nigeria, disruptions in power supply, rising inflation, and decline of the Cedi were the key drivers of the slowdown. Compared to regional countries with similar energy and oil & gas investment opportunities, Ghana is well-ranked as an investment location, as a consequence of its long history as a stable democracy and an attractive investment climate. With the commissioning of Bui hydroelectric plant, Ghana's total system installed capacity is 2,837 MW, with electricity reaching about 74% of the population nationwide. However, the firm or dependable capacity would be 2,515 MW. The generation capacity increased in the third quarter of 2014 by another 240 MW after the commissioning of the Kpone thermal power plant, bringing the total installed capacity to 3,077 MW. Expanding Generation capacity, extension of the distribution network, reliability of the power supply, reduction of technical and commercial losses, and access to natural gas feedstocks are areas of focus in the power and energy sectors for the Government of Ghana (GoG) to maintain economic growth. Total energy generation, consumption, and peak demand are increasing in Ghana due to population and technological advancement. The projected Electricity Coincident Peak Demand for the year 2014 was 2,179.5 MW. This represented an increase of 236.6 MW and a growth of 12.2% over the 2013 actual peak which was 1,942.9 MW. The increase occurred as a result of mines, industrial customers, residential and new loads emanating from rural projects. Hydroelectric generation represents about 55% of dependable capacity, with the remaining 45% largely made up of thermal generation. Solar energy contributes less than half percent of total capacity. The Government of Ghana-owned power generation stations are shown in Table 1.1 below.

Table 1.1 - Government of Ghana installed generation capacity

Facility	MW	Percentage of Capacity	Type	Fuel Type
Akosombo	1,020	37.5%	Hydro	Water
Kpong	160	5.9%	Hydro	Water
TAPCO (T1)	330	12.1%	Thermal	LCO/GAS/DFO
TICO (T2)	220	8.1%	Thermal	LCO/GAS/DFP
T3	132	4.9%	Thermal	LCO/GAS/DFO
MRP	80	2.9%	Thermal	DFO
Siemens Plant	49	1.8%	Thermal	Gas/DFO
Total	1,993	73.3%		

Table 1.2 - Quasi-Independent Power Producers (IPP)

IPPs	MW	Percentage of Total Capacity	Type	Fuel Type
BUI Power	400	14.7%	Hydro	Water
Sunon Asogli	200	7.4%	Thermal	Gas
CENIT	126	4.6%	Thermal	LCO/Gas
Total IPPs	726	26%		
TOTAL GHANA	2,719	100%		

Reliability of energy supply in Ghana is affected by inadequacy of available generation capacities to meet the projected demand under all system conditions. Also, poor planning and untimely schedule of maintenance and retrofit upgrades to power plants affects the reliability of energy. Security of fuel supplies such as natural gas supply from the West African Gas Pipeline (WAGP), Ghana Gas, and adequate stocks of Light Cycle Oil (LCO) and Distillate Fuel Oil (DFO), Potential of the WAGP not being able to meet contractual quantity of gas, Possible delay in the completion of the Ghana Gas Project and Low water level for the hydro power plants are also factors contributing to the unstable energy in the country. This lead to the shedding of minimal power during off peak and peak periods as a result of worsening in power supply. Economic development in Ghana is constrained by inadequate generation capacity which, in turn, is limited by the insufficient supply of natural gas. Estimates by the GoG prepared in 2013, to sustain the country's current rate of economic growth, some 200 MW of additional generation capacity will be required per annum over the next 20 years (an additional 4,000 MW).

Ghana's electricity market has undergone significant restructuring and reforms, including the on-going unbundling of assets and the opportunity for increased private sector participation through IPPs. Tariff rates have increased significantly in the past years, making them more cost reflective. In an effort to keep pace with inflation, currency devaluations (Cedi to the US Dollar), and rising fuel costs, a quarterly adjustment mechanism has been put in place beginning January 1, 2014. There are wide opportunities for private investment in the energy sector in the form of IPPs and under Feed In Tariffs (FITs) for renewable energy projects. The GoG target of 5,000 MW by the end of 2016 coupled with the estimated requirement of an additional 4,000 MW of capacity over the next 20 years, will require significant foreign investment, private capital, and technical expertise. The rapid demand for energy over the years necessitate the introduction of nuclear power into Ghana's energy mix as a base load. [2]

1.1.2 Energy sector of Ghana

Until the discovery of oil and gas in the country, hydropower potential used to be the largest indigenous commercial energy resource. It has been estimated that the country has about 2,500 MW of hydropower potential, about 60 % of which was exploited by the end of 2013. The major exploited hydropower potentials are the 1,020 MW Akosombo Hydropower, 160 MW Kpong Hydropower plants on the Volta River and a third 400 MW Bui Hydropower plant on the Black Volta. Hydropower systems sometimes suffer from low capacity utilization due to perennial droughts. Extreme weather patterns will pose a lot of danger to the development and sustainability of mini and small hydropower facilities, as most of them could dry out completely in the dry seasons. Extreme weather patterns will pose a lot of danger to the development and sustainability of mini and small hydropower facilities, as most of them could dry out completely in the dry seasons [3].

Other extreme weather conditions which affect hydropower generation include observed rise in mean surface temperatures, which has led to increased evaporation of water from the 8,500 sq km surface area of the Volta Lake. This results in the loss of high volumes of water which could have been used for hydro generation. On the other hand, there have been severe rainstorms, especially in the catchment area of the Volta River. These rainstorms lead to excessive water inflows in the Volta Lake, which tend to threaten the safety of the dam. In November 2010, the Volta River Authority was forced to spill water from the dam when the water level in the reservoir reached a height of 277.1 ft (the maximum height is 278 ft).

The development of renewable energy sources like wind, solar and biomass-based electricity generation, which depend so much on weather patterns, could also be threatened by climate change and by extreme weather variability.

The country's domestic energy resources are crude oil, natural gas, hydropower, and other renewable energy sources like wind, solar and traditional biomass. [4]

1.1.3 Electricity policy and decision-making process

The main policies that govern the electricity sector are formulated by the Ministry of Energy. The Ministry is also responsible for the monitoring and evaluating of policies, programmes and projects in the electricity sector. The Energy Commission, a quasi-independent body established by the Energy Commission Act 1997 (Act 541), is the government's energy policy advisor and makes national energy policy recommendations to the Minister of Energy. The Commission advises the Minister of Energy on national energy policies for the efficient, economic and safe supply of electricity and natural gas, having due regard for the economy. In addition, the Commission is to formulate national policies for the development and utilization of indigenous energy resources, in particular renewable energy: solar, wind and biomass.

The planning of the electricity sector system is the responsibility of the Energy Commission. The Commission has been given the mandate to prepare, review and periodically update indicative national energy plans, to ensure that all reasonable demands for energy are met. The Commission has undertaken the Strategic National Energy Plan (2006-2020) and Planning for Sustainable Energy Development – Ghana Country Study (2004-2030) studies and is currently in the process to Updating the Strategic National Energy Plan. The Energy Commission and the Ghana Grid Company have also undertaken a Generation Master Plan Study for Ghana.

Two power system planning studies have taken place in the recent past. The Energy Commission and other stakeholders under the IAEA National TC project GHA/0/008 undertook “Planning for Sustainable Energy Development – Ghana Country Study”. The other study, “Generation Master-plan Study for Ghana”, was undertaken by Tractebel Engineering on behalf of Energy Commission and GRIDCo Ltd. These two studies were based on Bui Hydropower plant coming online in 2013, the use of natural gas from Nigeria imported through the West African Gas Pipeline, and domestic Jubilee Fields for electricity generation. Actual, proposed and generating master plan for sustainable energy was estimated and shown in figure 1.1 below.

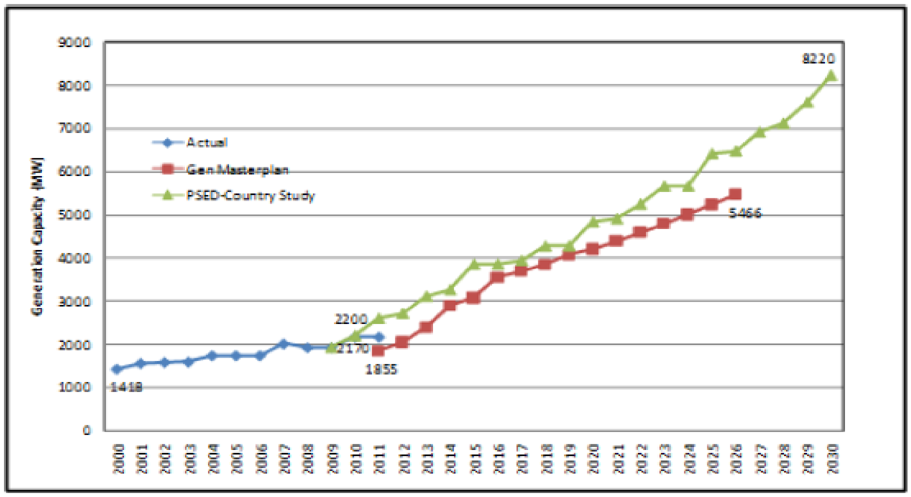


Figure 1.1 – Actual and Projected Electricity Generation Capacity

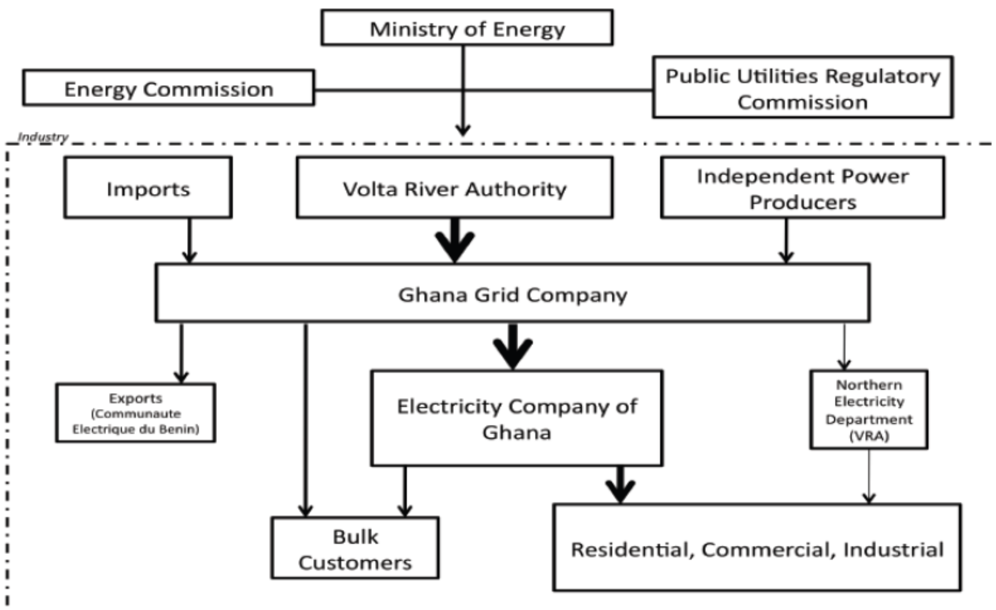


Figure 1.2 – Structure of Ghana Electricity System

Figure 1.2 shows the hierarchical order of decision making and planning of the energy sector from the ministry of energy till final consumers.

1.1.4 Current organizational chart

The organizational structure envisaged for the implementation of the country's nuclear power programme and the relationships between the various stakeholders.

ORGANIZATIONS EXPECTED TO BE INVOLVED IN THE VARIOUS TASKS					
Energy Commission, Media, Ghana Institute of Engineers, Ghana Nuclear Assosciation,	Ministry of Education, Ministry of Environment, Science and Technology, Universities, Polytechnics,	Energy Commission, GRIDCo, PURC, Utilities	Attorney General's Department, Legal Section of GAEC,	GAEC, EPA, Energy Commission, Geological Survey Dept, Ministry of Trade & Industry	NDPC, Ministry of Finance and Economic Planning, Energy Commission

Figure 1.3- Working Groups to undertake various aspects of TCP GHA/0/011

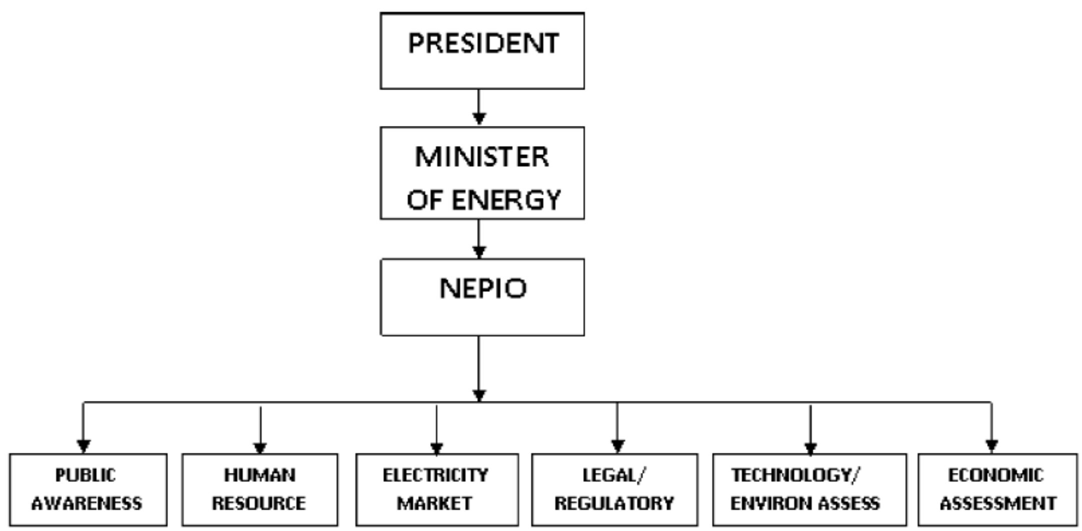


Figure 1.4- Organizational chart of Ghana

The Ghana Atomic Energy Commission (GAEC) is expected to play a leadership role in the implementation of the country's nuclear power programme. The Commission has established four institutes and a school. And now, the Nuclear Power Institute has been established to initiate and monitor day to day progress of the procedures to obtain a nuclear power plant. The institutes are the Radiation Protection Institute (RPI), Biotechnology and Nuclear Agriculture Research Institute (BNARI), Radiological and

Medical Research Institute (RAMSRI) and National Nuclear Research Institute (NNRI). They are intended to research into peaceful and safe applications of nuclear energy, science and technology, and biotechnology, in sectors such as agriculture, energy, environment, geology, health and industry. The Ghana Atomic Energy Commission, acting on behalf of the government, submitted a proposal to the International Atomic Energy Agency for support in undertaking a study to evaluate the role nuclear power will play in the country's future electricity generation.

1.1.5 National Laws and Regulations

The Ghana Atomic Energy Commission and stakeholders, with assistance from the International Atomic Energy Agency, have drafted the Ghana Nuclear Energy Bill, 2009 to pave the way for peaceful uses of nuclear energy in Ghana. The Bill, which has been submitted to the Cabinet for consideration before being laid before Parliament, proposes the establishment of Ghana Nuclear Regulatory Authority. The Ghana Nuclear Energy Bill presented to parliament include the following; Introductory Provisions, The Ghana Nuclear Regulatory Authority, Regulatory Activities, Provisions for Reactors, Transportation of Nuclear Materials, Safeguards and Prohibitions, Provisions on Mining and Processing, Provisions on Nuclear Liability, Inspection and Enforcements, Offences, Penalties and Appeals, General Provisions. The bill was considered by cabinet and approved by parliament.

In 1993, the Provisional National Defence Council Law 308 established a twelve-member Radiation Protection Board and issued concurrently a Legislative Instrument LI 1559, which prescribed the mandate and responsibilities of the Board as a licensing and regulatory Authority for the purpose of Radiation Protection and Waste Safety. Hence, to facilitate the mandate of the Board, the Ghana Atomic Energy Commission, in pursuit of Ghana Atomic Energy Commission Act, 2000: Act 588, established the Radiation

Protection Institute (RPI) in February 2002. The organizational chart of the Radiation Protection institute is shown below.

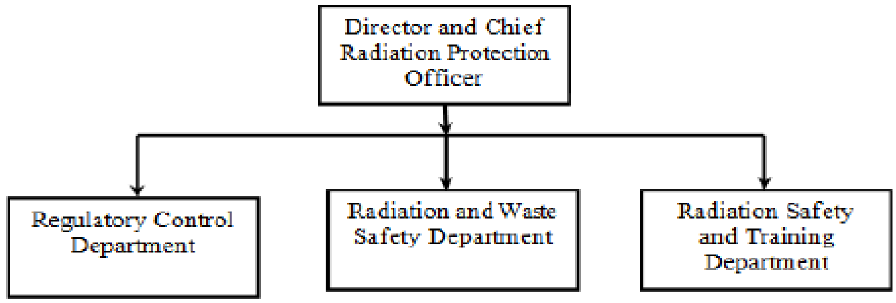


Figure 1.5- Structure of Radiation Protection Institute (under the Radiation Protection Board, now Ghana Nuclear Regulatory Authority)

The Radiation Protection Board issues licenses to persons who purchase, manufacture, acquire imports, sell or deal in, store, use, dispose of or export, any kind of irradiating device or radioactive material, or any other source of ionizing radiation. The Ghana Nuclear Power Programme Organization (GNPPO) is an organization mandated with the task of coordinating, overseeing and administering the phase-to-phase implementation of the Nuclear Power Programme in Ghana until the commissioning of Ghana’s first nuclear power plant.

Ghana's Power Ministry and ROSATAM have signed an agreement for cooperation in peaceful use of the nuclear energy in the Republic of Ghana. The document of the agreement signed between Russia's ROSATOM and Ghana's Ministry for Energy and Petroleum establishes legal framework for cooperation in the field of peaceful application of atomic energy between the two countries. The two sides plan to jointly develop atomic energy infrastructure, and also, the plan is to construct reactors, including research reactor facilities in the Republic of Ghana. This is a framework agreement. Being signed, the document allows for development of the necessary contractual and legal framework for cooperation in the nuclear area between Russian Federation and Republic of Ghana. Within the agreement, the parties are intended to develop cooperation in design and construction of power and research nuclear reactors; exploration and production of uranium deposits; nuclear fuel cycle services; production of radioisotopes and their application in industry, medicine and agriculture; education, training and retraining of experts for the nuclear energy industry.

1.1.6 Nuclear power development strategy

The country was awarded a national TCP GHA/0/011: "Evaluating the role of nuclear power in Ghana's future electricity generation mix". The successful implementation of the IAEA TCP GHA/0/011: "Evaluating the role of nuclear power in Ghana's future electricity generation mix" is expected to present the framework for developing the country's nuclear power development strategy. A Nuclear Energy Programme Implementation Organization has been established to manage the activities of seven working groups. The seven working groups will address issues with regards to the following:

1. Siting Grid Infrastructure Assessment

This working group is expected to undertake a series of studies to develop a strategy for the determination of potential sites, evaluation of these sites for characterization, and final determination. It will also assess the national grid and its interconnection with the West African Power Pool and develop a strategy for nuclear power operation suitable for the national grid or in the context of the West African Power Pool. A preliminary potential site mapping has been undertaken as part of the implementation of IAEA national TCP GHA/0/011: "Evaluating the role of nuclear power in Ghana's future electricity generation mix". The working group dealing with siting issues is expected to undertake further assessment of the sites that have been mapped out for characterization, to determine such factors as source of cooling water, transport and grid infrastructure, for the ranking of the nuclear power plant site.

2. Techno-economic Assessment, Financing and Procurement

This working group is expected to review future electricity generation expansion plans to determine the role of nuclear power and undertake a comprehensive techno-economic assessment of these plans. The group is also expected to develop a strategy for funding the nuclear power programme, long-term spent fuel handling and final disposal, waste management and decommissioning of the nuclear power plant. The government is funding all activities related to the implementation of the nuclear power programme. The Techno-economic Assessment, Financing and Procurement working groups are expected to develop a strategy for funding the nuclear power project.

3. Legal and Regulatory Issues

This working group will address all legal and regulatory issues pertaining to the country's nuclear power programme. A Nuclear Bill has been drafted, which proposed the establishment of a Nuclear Regulatory Authority to be in charge of licensing nuclear power plants and all nuclear related facilities and in charge of undertaking nuclear regulatory activities. The Bill has been submitted to Cabinet, it was approved and the Nuclear Regulatory Authority was established.

4. Technology Assessment

This group is expected to undertake the assessment of specific technologies suitable to be adopted for the country's nuclear power project for electricity supply and for a policy for nuclear fuel acquisition. It is also expected to develop a strategy for management of the various levels of nuclear waste.

5. Human Resource Development

This working group is expected to undertake assessment of human resource requirements at all stages of the nuclear power programme, and to develop a strategy for human resource development.

6. Nuclear Power Project Management

This working group is expected to develop the nuclear power project framework, activities and time scales. It is also expected to develop best strategy or type of contract for securing a nuclear power plant e.g. turnkey, split package or multi packages.

7. Stakeholder Involvement

This working group is expected to develop a comprehensive Communication Strategy for public awareness campaigns and for ensuring the involvement of all stakeholders. [5]

1.1.7 Developing a National Position towards a Nuclear Power Plant

A national position is the outcome of a process that establishes the governmental strategy and commitment to develop, implement and maintain a safe, secure and sustainable nuclear power programme [6]. This process results in a national decision that clearly communicates the Country's national policy, as well as its commitments in accordance with all international obligations, norms and standards.

1.1.8 Conditions required for national position in phase one

In line with the IAEA milestone approach for the development of nuclear infrastructure, a newcomer country can be considered to have satisfied national position requirements when the following are met.

When a long-term commitment and the importance of nuclear safety, security and non-proliferation have been duly recognised. This condition is demonstrated with a clear statement by government of its intent to develop a nuclear power programme with a strong commitment to safety, security and non-proliferation [7].

A nuclear energy programme implementation organisation is established and staffed: with a clear mandate to see to the development of the programme; be recognised by all relevant ministries as having that role; report to a senior minister or directly to the head of government; have the required funding, resources and expertise, and involve all relevant stakeholders, including the country's major utilities, the regulatory body for security and radiation safety, relevant government agencies, decision makers.

A national nuclear energy strategy has been defined. This defines and justifies the national strategy for the role of nuclear power in a country's energy mix. Among others, this may include: an analysis of energy demand and energy alternatives; an evaluation of the impacts of nuclear power on the national economy, e.g. GDP and employment; a preliminary technology assessment to identify technologies that are consistent with national expectations consideration of siting possibilities and grid capacity; consideration of financing options, ownership options and operator responsibilities; consideration of long-term costs and obligations relating to spent fuel, radioactive waste and decommissioning, and considerations of the human resource needs and external support needs of the regulatory body and owner/operator [8].

Currently, Ghana has a nuclear power plant program going on and has attained success in all the nineteen (19) infrastructural issues to be considered prior to the commencement of the operation of a Nuclear Power Plant (NPP).

This shows a completeness of the first of the three phases of the International Atomic Energy Agency (IAEA) mandatory milestone approaches for every newcomer state to accomplish before the development of a national infrastructure for nuclear power. [9] In February 2018, the Ministry of Environment, Science, Technology and Innovation (MESTI), through the Ghana Atomic Energy Commission (GAEC), under the Nuclear Power Project, signed a Memorandum of Agreement with ROSATOM for the construction of a Nuclear Power Plant which will have the Russian design VVER-1000/1200 power units in Ghana. [10]

1.1.9 Hypothetical nuclear facility in Ghana

1.2 General siting considerations

A good site for a nuclear power plant should diminish the plant's impact on the environment. The site should be in such a way that the amount of radioactive releases to the public are minimal in case of an accident. A great amount of heat released to the environment should have small effect on aquatic life, or, if cooling towers are used, their consequence on the micro-climate must be within acceptable limits. The characteristics of the site which include population distribution, meteorology, hydrology, should be such that the effects of accidents are within tolerable limits (IAEA 1982).

The main conditions that need to be considered when selecting a site for nuclear power plant includes seismology, geology, hydrology and grid infrastructure. Since most available reactors are cooled by water, they have to be built close to a large water body. The quantity of water needed depends on the type of a cooling system to be used, that is, whether it is a once through type or recirculation with cooling towers or cooling ponds. A plant of 1000MW may need a water coolant flow rate of approximately 100 m^3/s (IAEA 1982). If recirculation is used, make-up water of 2%-5% is needed. Additional significant factor to watch out for in the site's search is ground shaking during earthquake. In principle, nuclear reactors have to be designed in such a way that it would be able to withstand any ground shaking intensity, if the subsurface material is suitable. Seismic designs which are above ground shaking with the peak ground acceleration of 0.2 g where g is acceleration due to gravity are, somehow expensive with the cost increasing more than linearly with intensity. Shown in the figure below are the relationship between the ground shaking intensity for plant safe shutdown and the percentage of plant cost in the Africa. The closeness of population to a nuclear plant site is another factor to be considered. There is a general principle controlling the population distribution around a nuclear facility and is such that it will allow a feasible emergency plan to move individuals away from areas that has been affected in case of an accident. Shown below is a map of showing the earth zones of Africa.

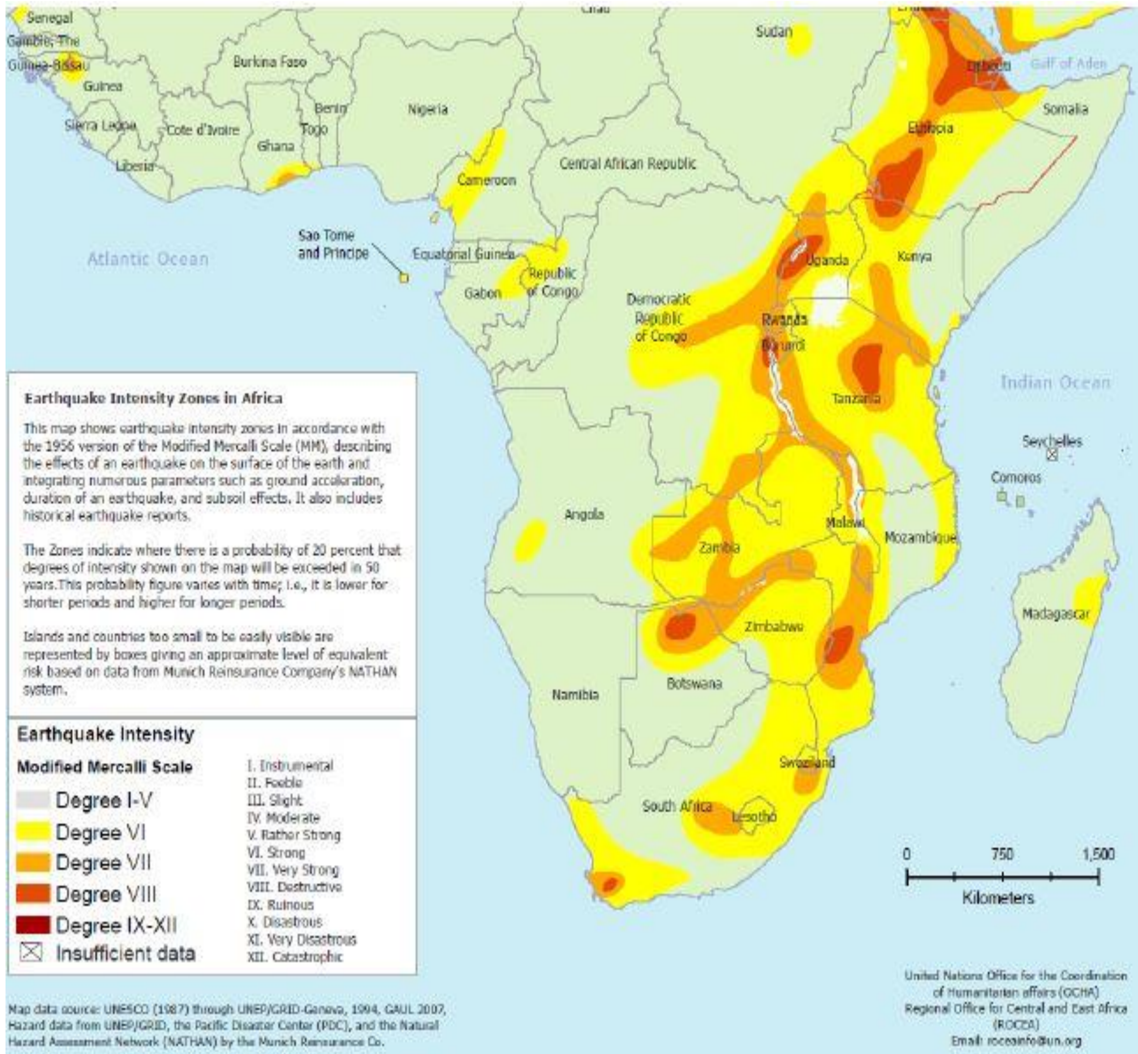


Figure 1.6- Earthquake intensity zones of Africa.

An area called an exclusion zone is therefore set around the reactor's facility, where there is restriction to public access. Also, there is no permitting of permanent residence in the exclusion area. Several factors determine the size of the exclusion zone and differs from country to country.

For example, in the U.S, the size of the exclusion area is designed in such a way that an individual, situated at any point on its boundary for about two hours immediately following the onset of assumed fission product release, would not receive an accumulated radiation dose to the whole body in excess of 25 rem, that is, 0.25 Sieverts or an accumulated radiation dose in excess of 300 rem, that is, 3 Sieverts to the thyroid from exposure to iodine (US NRC 2012). In several countries, the exclusion zone around a nuclear power plant is about 0.5 kilometer to 1 kilometers and may even be more in some other countries (IAEA 1982).

The Possibility of life-threatening natural events such as flooding, volcanic eruption, and earthquakes are also considered in the process of site selection. The main phenomenon which is of major worry in the case of earthquake is surface faulting. It is the displacement of the ground during severe earthquakes caused by the faults that created the earthquake (capable faults). This kind of displacement may reach several meters. As it is very difficult and challenging task to design plants against such a phenomenon, the ultimate solution is to situate the plants far away from the fault. Furthermore, plants have to be situated far away from areas which are prone to volcanic eruptions as a result of the emission of lava flows and burning clouds. It also has to be protected from static and dynamic effects of flooding. Therefore, in principle, it is necessary not to situate plants in areas or zones where flooding is severe. Building of Nuclear power plants along rivers and other waterbodies have to be protected against flooding due to precipitation and other forms of actions such as failure of water controlling structures such as dam collapse. Nuclear power Plants along the coast have to be protected against tsunamis, surges, and wind induced waves. The subject of flooding has led to world-wide attention as a result of the Fukushima accident that occurred in March, 2011, when a 14-m tsunami wave swept through a nuclear plant site in Fukushima in Japan damaging and destroying emergency generators and pumps. This resulted in the loss of the coolant flow leading to the partial melting of fuel rods (IAEA 2011). Adding up to the natural phenomena, nearness to installations that can handle military installations, aircraft flight paths, explosions etc., must also be taken into consideration. Nearness to existing grid network load centers is also a factor to be put into consideration when looking for a site. The purpose of this is to minimize electricity transmission losses and, consequently, transmission cost. There have been overwhelming earthquakes recorded in 1862 and 1939. Both of these earthquakes with magnitudes of 6.5 created immense destruction in Accra, the capital city of Ghana. The 1939 earthquake resulted in 17 fatalities and 133 injuries. The computed peak ground acceleration ranges from 0.14g to 0.57g corresponding to VII to IX on the modified Mercalli scale. The history of earthquake in Ghana is given in the Table below. Several fault lines are present within the major earthquake zones of Ghana. These comprises of the Eastern Boundary fault, Akwapim fault, the Coastal Boundary fault, and Western Boundary fault.

Table 1.3- Peak ground acceleration collated with intensity scales

PGA(g)	MODIFIED MERCALLI	INTENSITY
> 0.025	> = IV	> =IV
0.025	V	V
0.05	VI	VI
0.10	VII	VII
0.20	VIII	VIII
0.40	IX	IX
> 40	X	X

Table 1.4- History of earthquake events in Ghana

Year	Magnitude	Remarks
1615	-	Felt in Elmina
1636	5.7	Felt in Axim. Buildings as well underground workings of Portuguese mines collapsed
1862	6.5	Every building in Accra was razed to the ground. The OsuCastle and Forts were rendered uninhabitable. The shocks were felt in Togo where water in the Mono river fell much below its normal level.
1906	5.0	Many buildings in Accra particularly castles and forts were cracked. The earthquake was felt in other areas as far as Togo
1939	6.5	Intensity was greatest in areas between Accra, Weija, Gomoa Fete, and Nyanyanu. The computed peak ground acceleration ranges from 0.14g to 0.57g corresponding to VII and IX on the modified mercali scale. In Accra 16 people were Killed with 133 injuries
1964	4.5	Felt mainly in Akosombo
1969	4.7	Felt mainly in Accra
1997	3.8	Felt mainly in Accra
2003	4.8	Felt in some parts of Accra

With respect to drainage, there are a number of rivers in Ghana, most of which flow into the sea in the south. This comprises of the Pra, the Ankobra, and the Tano. It also has an artificial lake that is the Volta Lake which was formed as a result of the creation of the first hydro-electric dam on the river Volta. The water volume of this lake is 187 km^3 and with a total surface area of 8500 km^2. This surface area makes it the biggest man-made lake in the world. The country also has a 539-km coastline as its southern boundary. The likelihood of existence of tsunamis in Ghana was out for discussion due to the Fukushima accident, which took place in Japan in the month of March, 2011. So many experts are of the view that the likelihood of existence of such kind of event in the Ghanaian seas, which are part of the Atlantic Ocean, is remote.

1.2.1 Geographical features of Ghana

Though Ghana is distant away from the major earthquake sectors in Africa and some parts of the world, it is slightly seismically active along its coast in the south. The figure below shows the Earthquake epicenters. As shown in Figure, the intensities of earthquake generally range from level V to VI on the modified Mercalli scale. This is similar to the peak ground acceleration of 0.05g to 0.1g using the conversion given in Table 1 above. The country "Ghana" has some earthquake data for investigation to a reasonable degree.

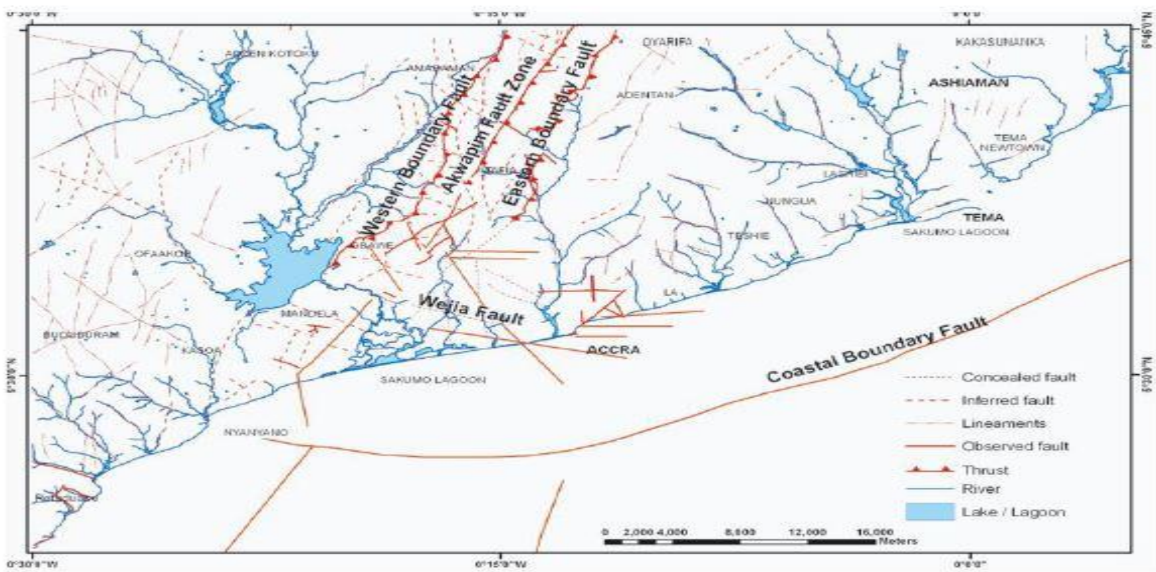


Figure 1.7- Fault map of the Greater Accra Metropolitan Area.

The process involved in the selection of sites consist of several activities which can be divided into two main stages. These include site survey and site qualification. Site survey comprises the universal studies of the whole country to identify suitable sites. The sites identified which are selected are then subjected to systematic analysis to make sure that they meet at a substantial level for the laid down characteristics involved in selecting suitable sites during the site qualification stage. The work in the siting process in Ghana is the site survey stage, where lands nearer to water bodies inland and coastal areas are being screened to become possible sites for the construction of nuclear power plant.

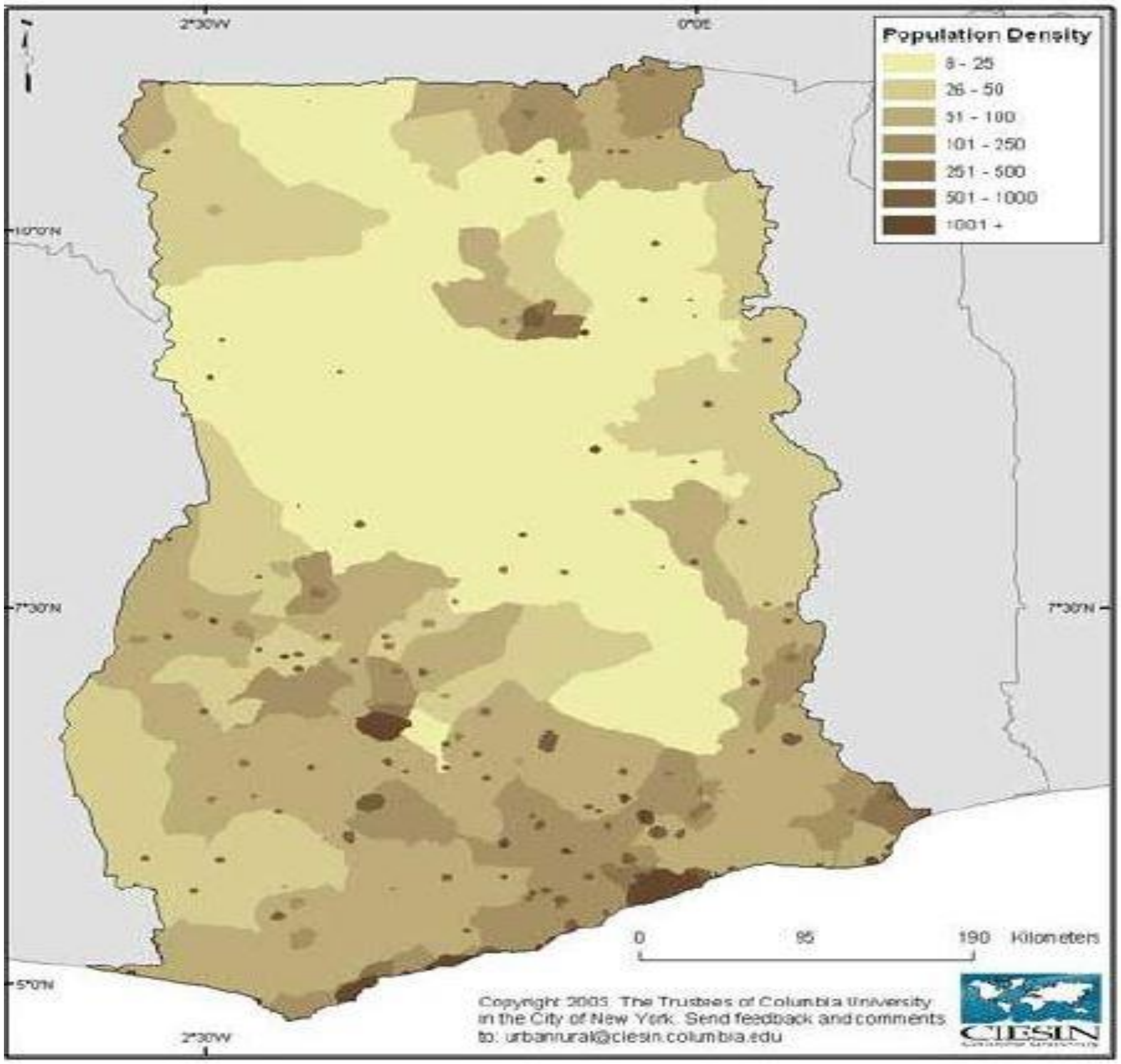


Figure 1.8- Population Density of Ghana

Bearing in mind the country's seismicity and related fault lines, areas around the eastern part of the Akwapim fault are considered inappropriate. These comprises of Accra and its surrounding areas. Locations around the Volta Lake are considered to be attractive as a result of their low seismicity and population density. The siting of a nuclear power plant along the Lake Volta has, raised discussions and arguments among stake holders. The main reason being that, since the lake is a fresh water body, it will be contaminated by radioactive substances in case an accident occurs and will lead to the creation of serious environmental issues or problems. This opinion has also been opposed by the fact that, there is a likelihood of Burkina Faso deciding to build a nuclear power plant in the near future and if this happens, it will certainly be built in the Volta basin due to fact that it is a land locked country and has no large rivers. The subject of pollution also arises in this situation in case of an accident. However, the universal view between national planners and environmentalists is that the fresh water bodies require protection, hence any effort and decisions made to situate nuclear power plants around fresh water bodies have a probability to meet stiff disagreement. The situation of reactor or nuclear plant sites around water bodies will also be rejected since they are also fresh waters. Moreover, there has to be the assurance that the rivers or water bodies will not dry up due to periodic droughts during the working life of the nuclear power plants.

Most of the nuclear power plants existing in several countries are licensed to function for 40 years, and a number of them have received extra time to work for further 20 years. This means that there should be no drying up of water bodies or rivers within the expected 60-years functional life time of the plant. With regard to the effects of climate changes, the immense losses of water in rivers is very possible. Several studies have revealed that a lot of rivers in Ghana will lose about (30 % to 40 %) of water by 2050 as a result of climate change. Accumulating all these features together, location of site has been limited to areas or zones around the west coast of the Akwapim fault. The zone, which lies in the middle of 0^{o} 23’west and 3^{o} 06’west, is being screened to obtain candidate sites. The activities to be considered during the conduction and screening process include detail seismic studies and analysis, meteorology, population distribution, social issues, protection of historical artefacts, and land acquisition issues. [11]

Figure 1.9- Drainage map of Ghana. [12]

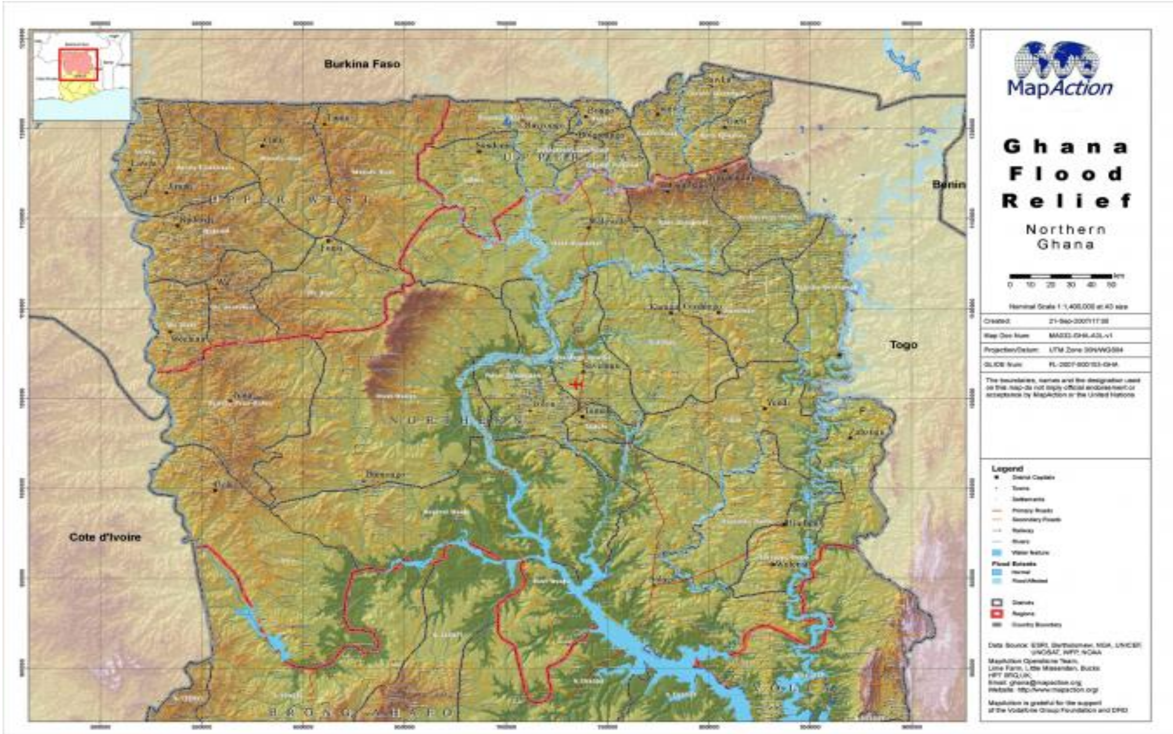


Figure 1.10- Ghana flood relief [13]

From the figure 1.10, it indicates that the upper half of the country suffers from flood sometimes in the rainy season. This is due to the opening of some dam gates in the upper neighboring country called Burkina Faso. Therefore, it wouldn't be advisable to site a nuclear reactor close to Burkina Faso and the Northern part of the country.

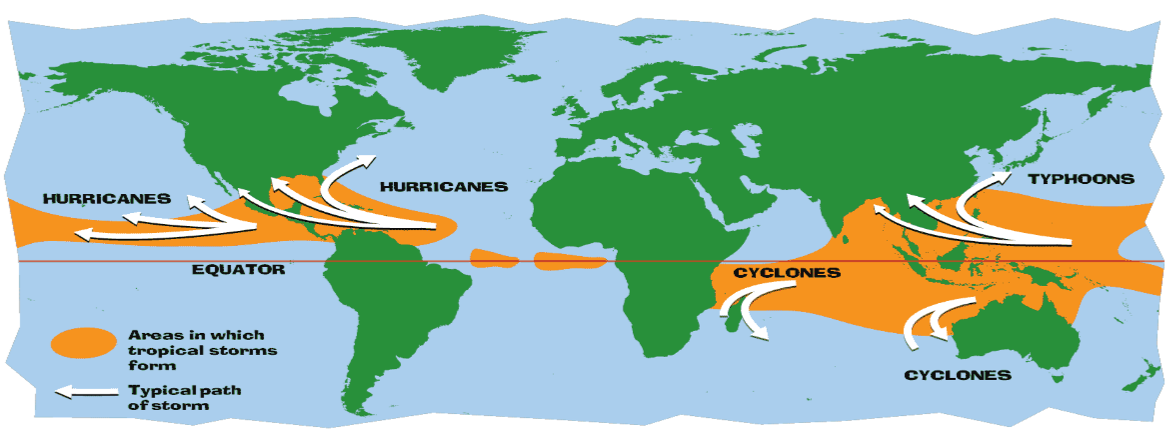


Figure 1.11- Hurricanes, typhoon and cyclonic view of Africa. [14]

Also, from figure 1.11, it confirms absolutely that Africa in general is free from violent natural disasters such as the hurricanes, typhoons and the cyclones. Hence Ghana as a country is free from these disasters.

1.2.2 Considerable site for NPP unit types in Ghana

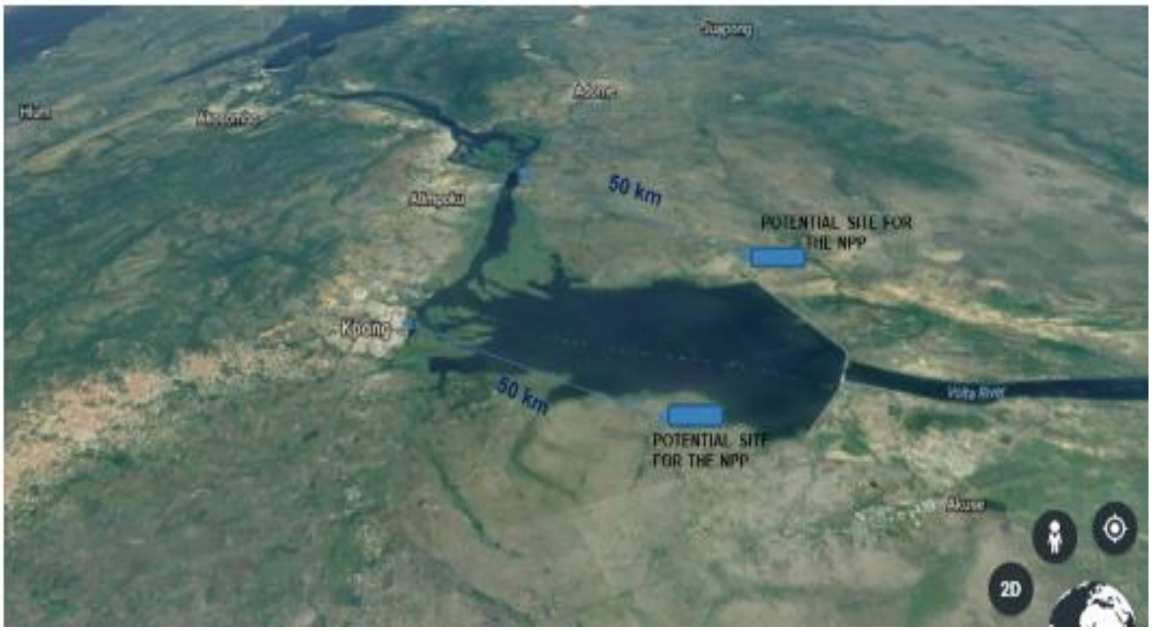


Figure 1.12- A hypothetical site selected for the construction of nuclear power plant in Ghana.

The figure 1.12 is a hypothesized choice of area and sites selected for the proposed nuclear power plant to be constructed in Ghana upon successfully consideration of all safety measures regarding site selection such as meteorological, seismology, hydrology etc. These factors have been carefully studied before considering Kpong as the appropriate choice of the site. The population density of this area is less and it is also close to a river. The area is also free from surface faults. From the figure, it is clear that the potential sites for the nuclear power plant are 50 km from the Kpong township. However, roads and railway will be constructed to reach the selected site for smooth transportation of materials and engineering machines to the selected area.

Figure 1.13- Map of Ghana showing Kpong

1.2.3 Analysis of Corruption, Theft and Terrorism in Ghana

The country "Ghana" has for the past years been experiencing corruption and dangerous armed robbery of all kinds. These armed robbers who make use of sophisticated weapons have become so brave that they even operate in broad daylight, demonstrating total disregard for the police or the other law enforcement agencies in Ghana.

There have been many instances where Ghanaian residents abroad who have returned home for holidays or to invest their monies have been targeted and robbed. A disturbing phenomenon of their activities is carjacking and highway robbery previously unknown in Ghana. Armed robbers boldly snatch cars from their owners, waylay traders on the highways and rob them of their monies and personal belongings. In some cases, they even murder their victims in cold blood and many others.

Ghana, which used to be the most peaceful country in West Africa, is now getting a bad name as a result of the actions of these armed robbers. The doings of these armed robbers have left many Ghanaians to live in fear. [15]

Furthermore, Ghanaian leaders and the people themselves are so corrupt that they can do anything to earn quick money without working for it. For example, in Ghana, policemen and custom officers take bribes from people and make them occupy positions which they are not qualified for all because of their selfish gain and the love of money which has now made the country to earn a bad name because of the corrupt nature of its citizens.

Also, the U.S. department of state has assessed Accra as being a medium-threat location for terrorist activity directed at or affecting official U.S. government interests.

Though there exists an increasing threat of terrorism, Ghana has been spared a direct terrorist attack, but it does remain vulnerable due to porous borders and regional instability. [16] Nevertheless, Ghana is at a higher risk of experiencing Terrorism in the near future due to the presence of the "Boko Haram" group in Nigeria which is a neighboring country to Ghana.

Boko Haram begun as an Islamic anti-corruption group that became a violent, IS-affiliated movement whose rebellion has threatened stability in the Lake Chad region. Boko Haram, whose name loosely translates from the Hausa language as "Western education is forbidden", aims to create a hardline Islamic state in northeast Nigeria. Its rebellion has cost at least 20,000 lives since 2009.

Boko Haram was very peaceful before its leader "Mohammed Yusuf" was killed in custody in 2009 by the Nigerian police after an uprising in Maiduguri, which prompted a military assault which led to the killing of some 700 people and left the group's mosque and headquarters in wrecks.

Abubakar Shekau, Yusuf's right-hand man, replaced him as leader, and begun to wage masses of deadly attacks on schools, mosques, churches, state entities and security services. Among the group's most notorious acts was the April 2014 kidnapping of more than 200 school girls from the remote town of Chibok.

A total of 106 have since been released, found or escaped: 113 remain captive.

The mass kidnapping brought world attention to the insurgency at a time when Boko Haram was seizing territory across the northeast, threatening Nigerian sovereignty.

Eight years of violence have forced 2.6 million from their homes, destroying property and farmland in the mainly rural northeast, sparking a humanitarian crisis and acute food shortages.

Several thousands of people have lived under the threat of scarcity of food and are reliant on aid agencies for food, water, shelter and healthcare. [17]

Therefore, looking at these scenarios, since these two countries are neighbors, if should in case the "Boko Haram" group makes any attack on a nuclear facility in Nigeria, it may lead to the release of radiations or loss of radioactive material which will lead to mass destruction in some part of Nigeria and might also go a long way in affecting some surrounding areas in Ghana.

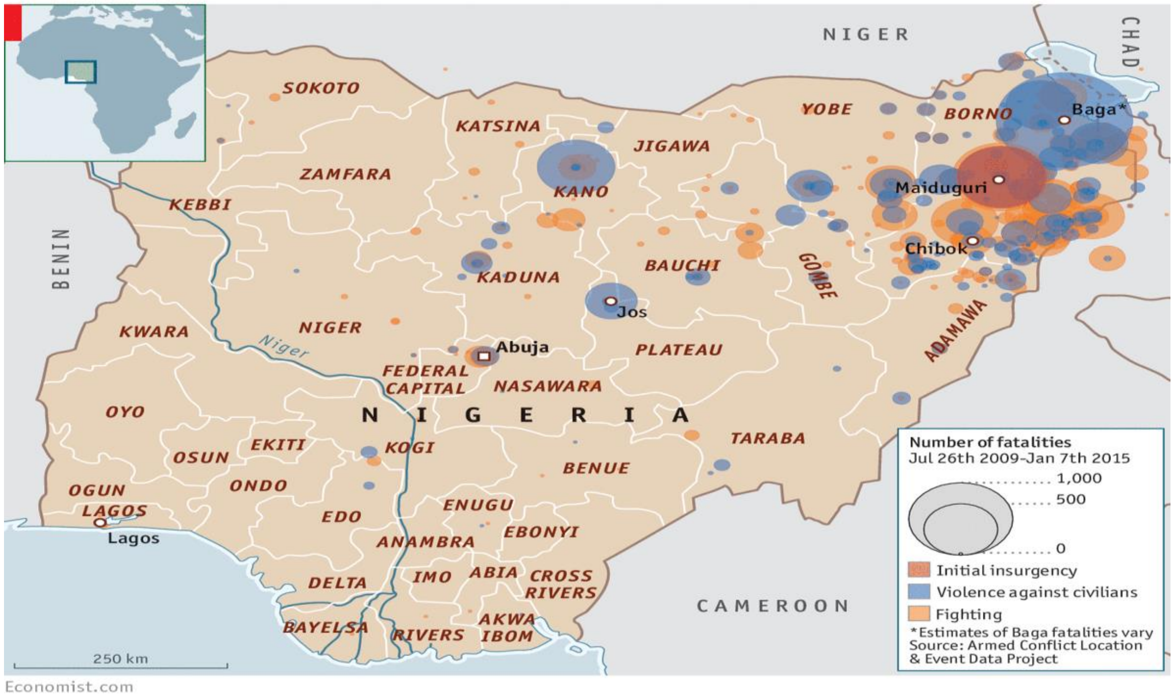


Figure 1.14- Map showing Areas of Boko Haram terrorist attack in Nigeria

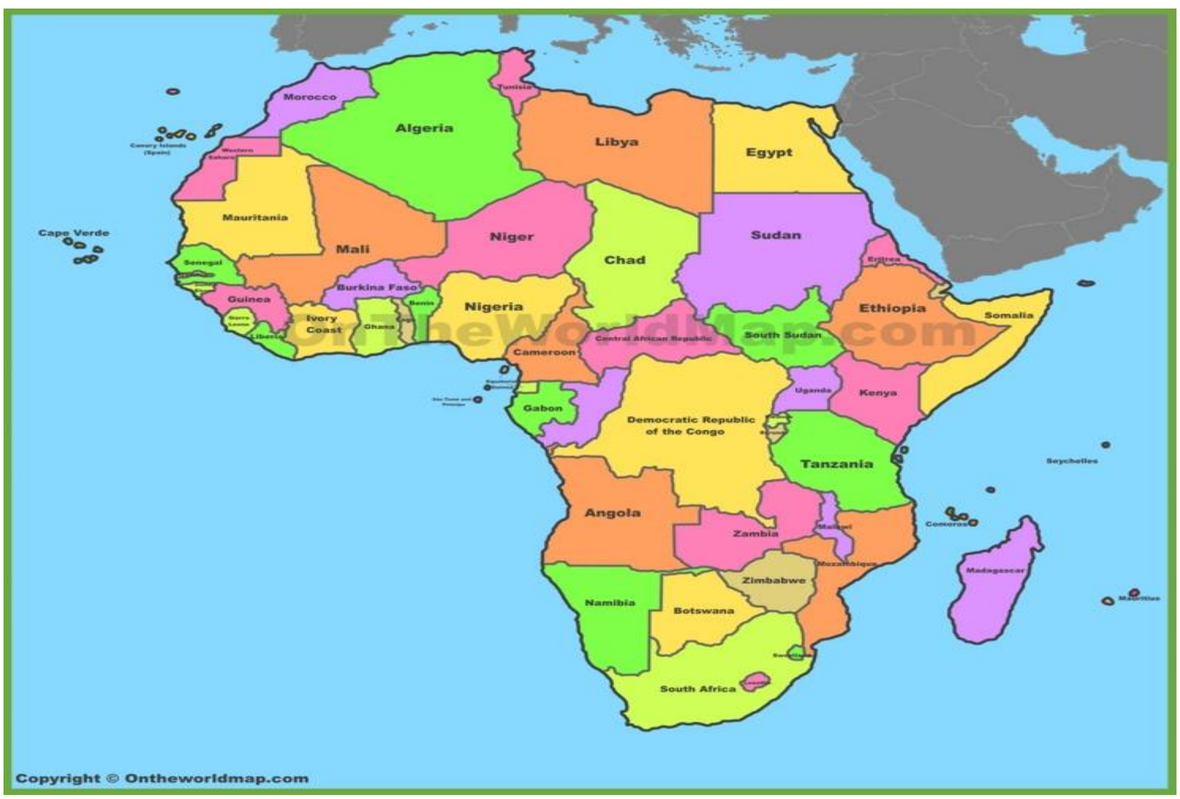


Figure 1.15- Map of Africa showing the closeness of Ghana and Nigeria

1.2.4 Description of the hypothetical object to be constructed in Ghana

The country has agreed on constructing a pressurized water reactor (VVER–1000/1200). The VVER-1200 is a Generation 3+ with V–491 reactor plant which is a development of the VVER–1000 design which uses light water as coolant and moderator reactor and has proved a long-time operation. The comprehensive realization of the NPP safety is achieved through the principle of defense-in-depth which is based on the application of a system of barriers in the way to the possible circulation of the radioactive substances and ionizing radiation into the atmosphere and the surrounding environment as well as on the application of a system of the engineered safety features and organizational measures to ensure the integrity of these barriers. The reactor consists of 121 rod cluster control assemblies (RCCAs) and are positioned inside the core as compared to 41–61 in other PWRs. They are designed for quick chain reaction suppression, maintaining power at given level and its level-to-level transition, axial power field leveling, xenon oscillation suppression. The material for the construction of the reactor is an alloy of Steel with compositions 15H2NMFA. The frequency of core damage is less than $1.000*10^{-6}$ /Reactor–Year and an occupational radiation exposure less than 0.39 Person–Sv/RY. [18]

VVER is a thermal neutron reactor with pressurized water as both coolant and moderator. It has a two-circuit steam generating system with four cooling loops, main circulation pump, pressurizer, relief and emergency valves on steam pipes, and accumulator tanks of the emergency core cooling system (ECCS). Hence, VVER-1200 has a reliability of time-proven engineering solutions with a set of active and passive safety systems compliant with post-Fukushima requirements.

The presence of spent fuel pool inside the containment, inter-containment space ventilation filters, a core catcher with a sacrificial concrete layer, an unparalleled passive heat removal system, and other cutting-edge technologies merged into VVER-1200 design certainly makes it a Generation 3+ reactor. The ECCS also features innovative technologies, and one of them is cold boric acid which is stored under pressure in special tanks. In case of containment or pipeline rupture, valves open and boric acid is injected into the reactor core to bring the chain reaction to a stop and cool down the reactor. ECCS in combination with other systems assures an extreme degree of the reactor safety. [19]

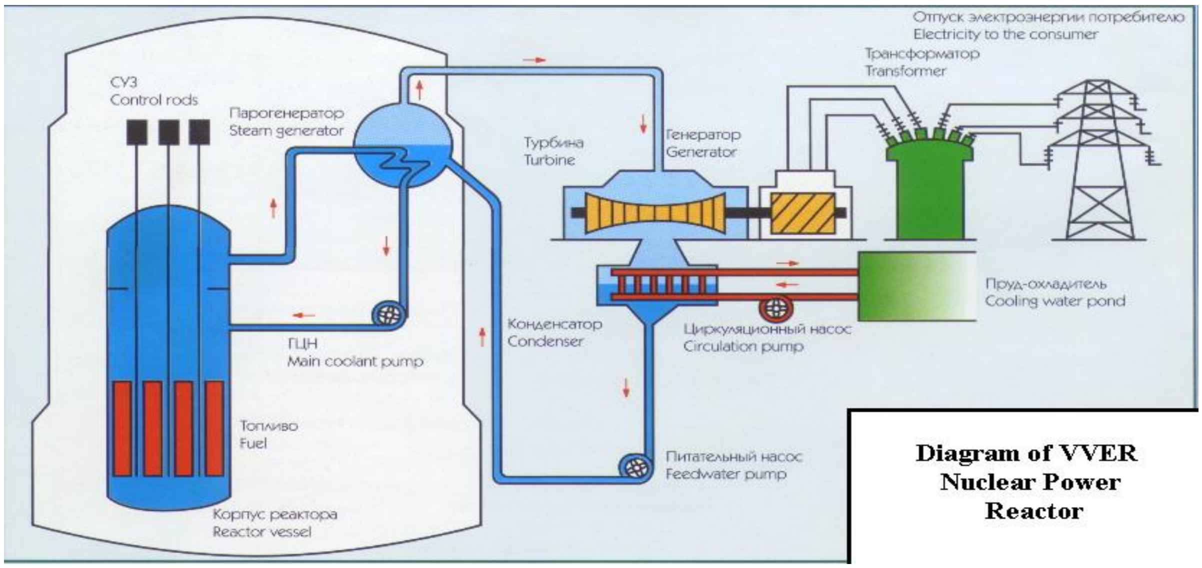


Figure 1.2.1- Diagram of VVER nuclear power plant [20]

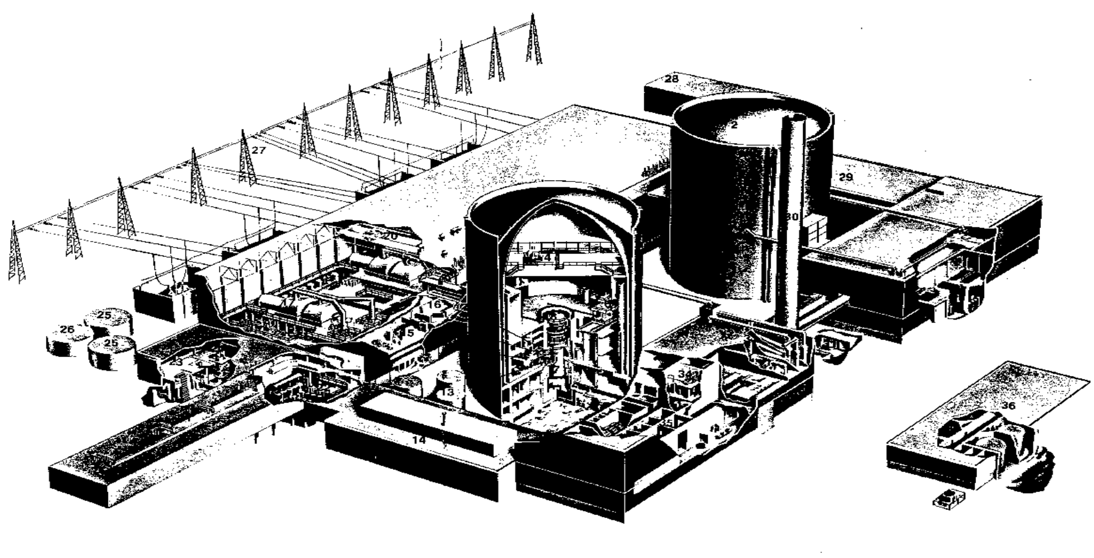


Figure 1.2.2- VVER Plant Layout

1. Reactor building Unit 1
2. Reactor building Unit 2
3. Steel containment
4. Polar crane, 250 tons
5. Ice condenser
6. Refueling machine
7. Reactor pressure vessel
8. Control rod drives
9. Primary circuit (6 loops)
10. Main circulation pump
11. Main shut-off valve
12. Steam generator
13. Tank area
14. Laboratory building
15. Computer room
16. Main control room
17. Turbo-generators
18. Moisture separator-reheater
19. Condensate purification plant
20. Two turbine hall
21. Office building
22. Demineralization plant
23. Cooling water pumping plant Unit one (1)
24. Main coolant pump
25. Demineralized water tanks
26. Drain tank of secondary circuit
27. Switchyard
28. Cooling water pumping plant Unit two (2)
29. Service building
30. Ventilation stack
31. Auxiliary building Unit 1
32. Auxiliary building Unit 2
33. Exhaust air conditioning center
34. Evaporators of active water treatment plant
35. Machine repair shop
36. Liquid waste storage [21]

1.2.5 Reactor core and fuel design

The reactor core comprises of 163 fuel assemblies which are identical in design, but different in the enrichment of fuel. The TVSA fuel assembly (FA) is taken as a base version of fuel assembly design and as an alternative version which is TVS-2. Both versions of FA are interchangeable and are of reference character. The design of the core is developed for the generalized version of FA design both TVSA and TVS-2 providing its operability in using several FA types. Both FA designs comprises of the following components which are top nozzle; bundles of fuel rods (fuel rods and Gd fuel rods); bottom nozzle. FA top nozzle provides necessary force of FA compression in the core. There is a skeleton for the bundle of fuel rods and it houses 312 fuel rods (Gd fuel rods). The skeleton comprises of guiding channels and spacing grids and provides the following throughout the FA service life.

The FA bottom nozzle offers conjugation of FA lower part with the support of the reactor core barrel and presents a guiding device for coolant supply into fuel rod bundles and Gd fuel rods. Below are images showing the general views of the TVSA and TVS-2.

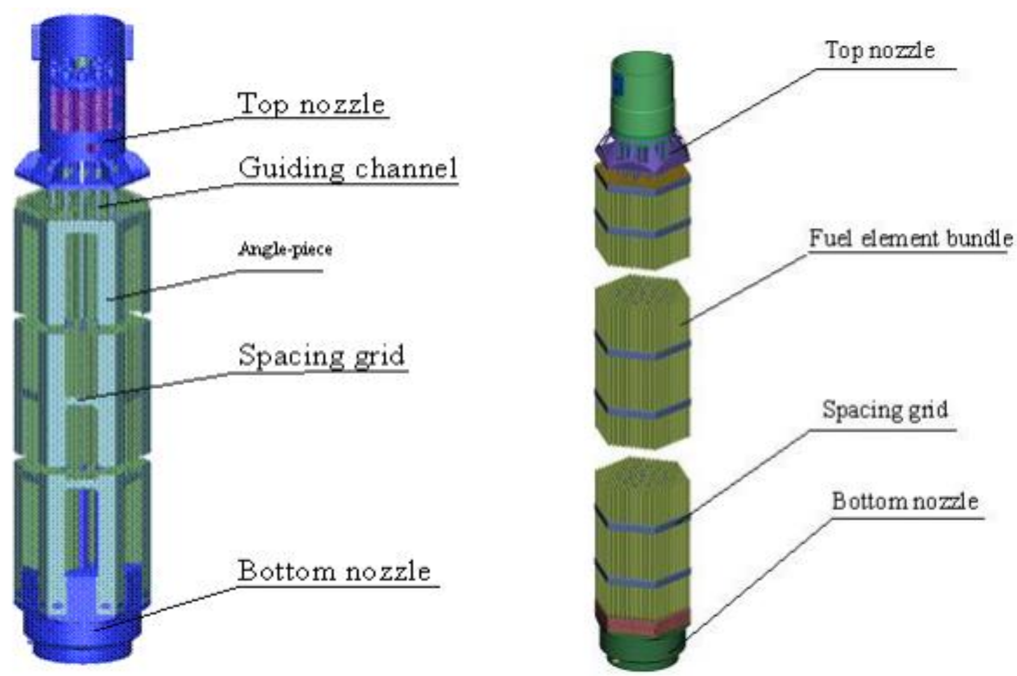


Figure 1.2.3- TVSA and TVS-2 VVER fuel Assembly designs

The rod control cluster assembly (RCCA) comprises of 18 absorbing elements (AEs), the grip head and springs of an individual suspender.

The RCCA AE is a tube of outer diameter 8.2×10^{-3}m and wall thickness 0.5×10^{-3}m which is filled with absorbing material and sealed with end pieces by means of welding. The absorbing material used are Boron carbide B_4C and dysprosium titanate (Dy_2O_3 TiO_2). Dysprosium titanate in the AE lower part permits to extend RCCA service life under maintenance of sufficient worth of emergency protection. The basic characteristics of the equilibrium fuel cycle are given in the table below.

Table 1.5- Main characteristics or parameters of the equilibrium fuel cycle

Characteristic	**Value**
Number of loaded fresh FA, pcs. - total	42
Average enrichment of make-up fuel in U235, % wt.	4.45
Duration of reactor operation between refueling, effective days.	325
Burn-up of unloaded fuel, MWD/kg U:	52.8

1.2.6 Fuel handling systems

The complex of systems used for refueling and nuclear fuel storage represents a set of systems, devices, components intended for storage, loading, unloading, transportation and the inspection of nuclear fuel. This systems for refueling and fuel storage provides:

- Receiving, storage and incoming inspection of a fresh nuclear fuel before loading into the reactor
- Nuclear fuel reloading in the reactor core
- Storage of spent nuclear fuel in spent fuel pool of NPP reactor building
- A long-term storage of spent nuclear fuel in the storehouse at NPP site
- On-site transportation of nuclear fuel on NPP territory starting from receiving a special transport with fresh fuel and finishing with a long-term storage of spent nuclear fuel in SNFS (spent nuclear fuel storehouse). [22]

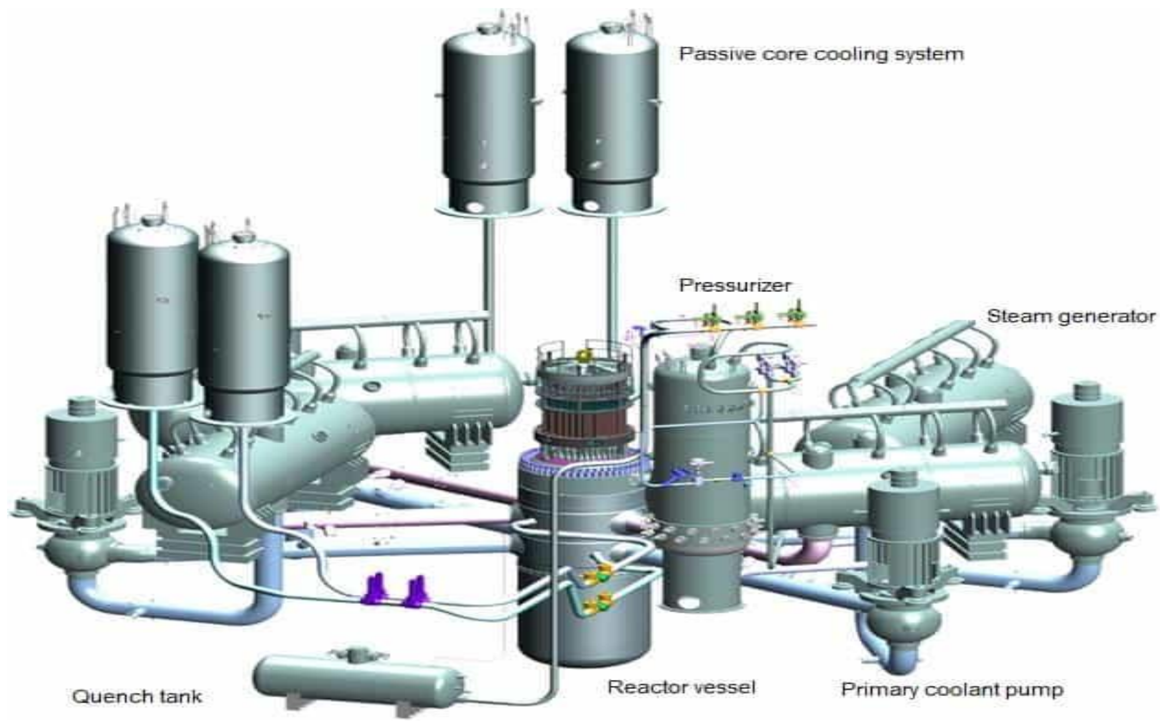


Figure 1.2.4- Nuclear reactor and Primary circuit of VVER-1200 plant [23]

1.2.7 VVER-1000/1200 reactor fuel, fuel rods and fuel assembly

Both VVER-1000/1200 uses bundles fuel rods with zirconium-alloy as claddings material. These bundles of fuel rods are filled with fuel pellets of uranium dioxide. In some cases, the fuel rods are filled with pellets containing gadolinium oxide to improve upon its physical characteristics and safety. The VVER fuel Assembly has hexagonal design.

Besides fuel rods, fuel assembly has a number of structural elements: cap, tailpiece, spacing grids and in some cases a shroud tube. A cap is designed for gripping during load-unloading operations, and a tailpiece ensures the FA placement in to the reactor and provides channel for coolant for fuel rods.

A VVER-440 FA is composed of 126 fuel rods. A VVER-1000 FA has 311-312 fuel rods. There are different modifications of fuel for this type of reactors, designed for 3, 4, or 5-year fuel cycles.

At present, two designs of fuel assemblies for VVER-1000 reactors – TVSA and TVS-2 - with a higher rigidity skeleton. This strengthened skeleton is the key feature of the fuel assemblies. In TVSA it is formed by spacers and 6 angles joined by spot welding that provide higher rigidity and strength of the structures. In TVS-2 the skeleton is formed by spacers spot-welded to guides to provide more rigid and strong structure.

Depending on fuel pellet material, uranium fuel rods and gadolinium fuel rods are distinguished. The former use uranium dioxide (UO2) and the latter are fitted also with an integrated burnable poison – gadolinium oxide (Gd2O3).

There are makes of VVER-440 and VVER-1000 reactor fuel assemblies which are different in a uranium-235 and gadolinium oxide content in the said fuel rods, which are designed for four- and five-year operating cycles. [24]

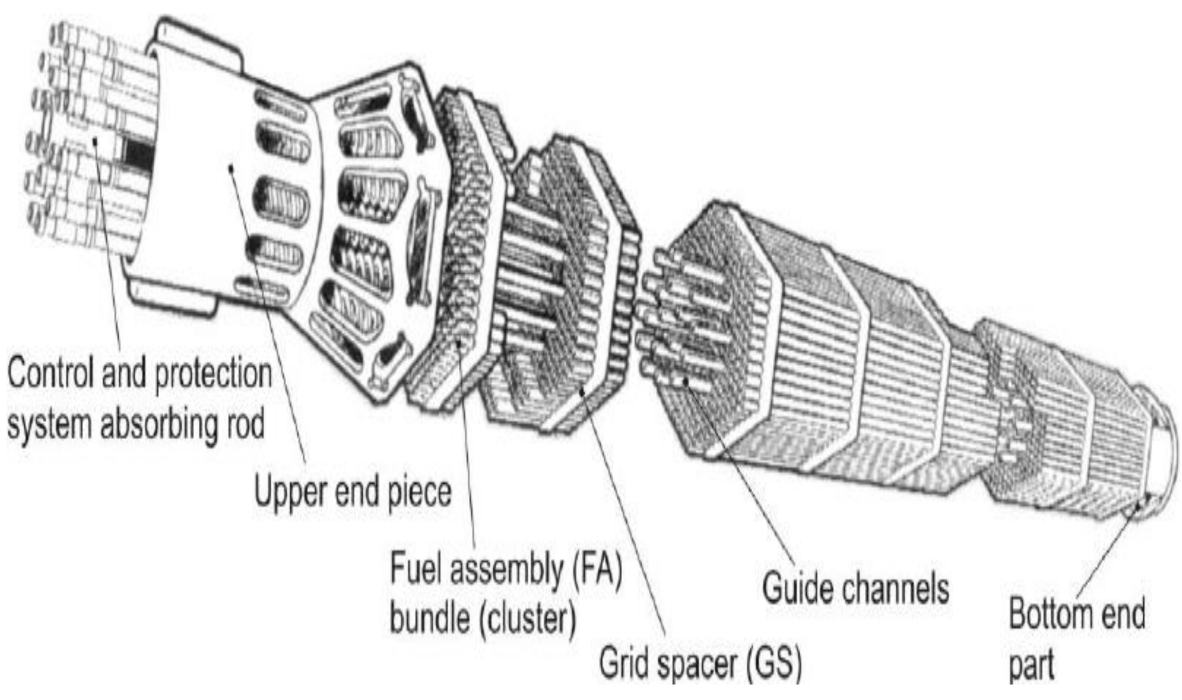


Figure 1.2.5- VVER fuel Assembly [25]

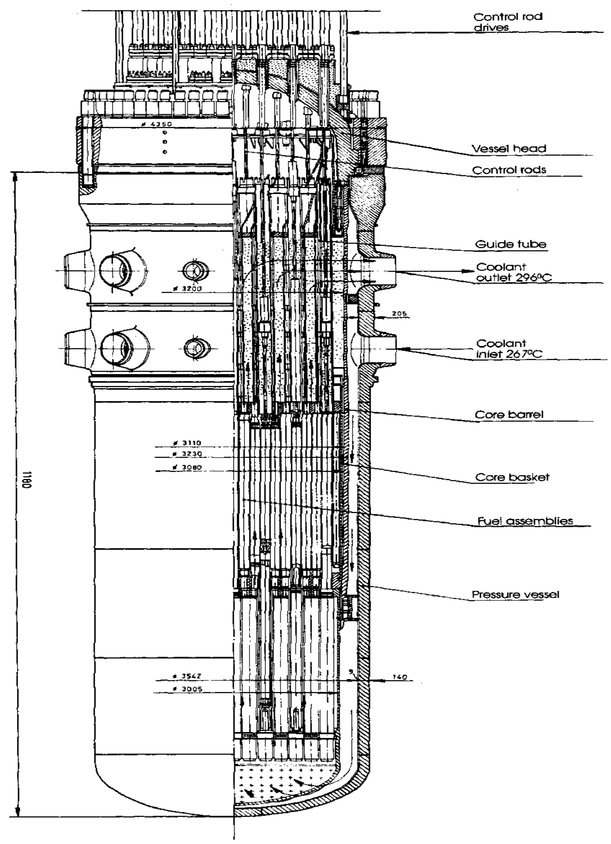


Figure 1.2.6- VVER Reactor Vessel [26]

1.2.8 General criteria for designing of nuclear fuel

- In the determination of the criteria for designing of nuclear fuel, the properties which include physical, chemical and mechanical phenomena that affect the strength or durability of the nuclear fuel during functional and accidental conditions will be broadly evaluated. The evaluation will cover all design basis scenarios.
- In the determination of the criteria for designing of nuclear fuel, the material and structural properties that are related to final disposal and the long-term safety of final disposal will also be considered.
- The designing of a nuclear fuel assembly shall be done in such a way that its components maintain their position in all functional conditions and that they are not

permanently removed during postulated accidents. The nuclear fuel assembly must withstand all design-basis scenario loads in such a way that reactor shutdown and coolability are not endangered.

- Irradiation-induced changes that affect the properties of the nuclear fuel will be taken into consideration in the determination of the limits for safe use of the nuclear fuel, including the effects on the final disposal of spent nuclear fuel. Burn-up limits to be applied to nuclear fuel shall be presented, and they shall be based on experimental data. If irradiation affects heat transfer between cladding and coolant it shall be taken into account also in correlations used for evaluating the heat transfer crisis.
- Control rods shall withstand wear and other stresses during operation in order that their normal function is not endangered. The control rods will retain their capability to absorb neutrons when the reactor is in operation in compliance with the assumptions of the Safety Analysis Report of the plant unit.
- The normal functional process of control rods must not be prevented by distortions of a fuel rods or fuel assembly.

1.2.9 Criteria for designing of nuclear fuel for normal operational conditions

In normal operational conditions, the fuel shall accomplish the following conditions:

- There will be no melting in the fuel pellets.
- The Cladding temperature will not significantly exceed the temperature of coolant.
- There will be no collapsing of fuel rod cladding.
- The fuel rod internal pressure will not rise to the level that the deformations of the cladding caused by it would negatively affect the heat transfer between fuel pellets and coolant (lift-off).

The deformations in the control rod and fuel assembly components or parts shall remain so negligible that:

- There will be no substantial increase in power in the fuel rods
- No coolability of nuclear fuel is not endangered
- There will be no obstruction of the reactor scram or other movement of control rods.
- There will be no hampering in the handling of fuel rods.

The likelihood of a fuel failure caused by mechanical interaction among fuel pellet and cladding will be very low. In order to ensure this, functioning limits for variations in power and the rates of change will be determined for nuclear fuel, taking into consideration the stress and corrosion of the cladding.

1.3 Nuclear fuel design criteria for anticipated operational occurrences

In anticipated operational occurrences, the fuel shall accomplish the following conditions:

- There will be no melting in the fuel pellets.
- There shall be adequate cooling of the cladding. The cooling of the cladding is taken to be adequate if there is a 95% likelihood at 95% confidence level that the hottest fuel rod does not reach heat transfer crisis. Alternatively, it may be verified that the total number of rods attaining heat transfer crisis does not exceed 0.1% of the total number of fuel rods in the reactor.
- The likelihood of fuel failure that is caused by mechanical interaction between fuel and cladding will be very low. [27]

2 Security

2.1 Nuclear Security and Physical protection system

Physical protection consists of a number of actions to defend nuclear facilities and material contrary to sabotage, robbery, diversion, and other malicious acts. [28]

Physical protection system is one of the primary systems used at nuclear facilities for protecting these facilities by providing defense against terrorist attacks, likelihood of bombing, sabotage, and theft. Physical protection or security is defined as that part of security concerned with physical actions designed to protect personnel; to avert illegal access to equipment, installations, material, and documents; and to safeguard against surveillance, sabotage, damage, and theft. A system may be defined as a collection of objects or elements designed and constructed to achieve an objective according to a procedure. The designer of any physical protection system must have the system's main objective or aim in mind. The main objective of a PPS is to stop radiological sabotage and robbery of nuclear materials or amenities existing within the nuclear facility. Robbery and sabotage of the nuclear facilities may be averted in two ways either by deterring or by defeating the adversary. Deterrence occurs by employing a PPS that is seeming by possible adversary as very tough to be defeated; it makes the facility an unattractive target.

The main Physical Protection System (PPS) functions include Detection, Delay and Response. [29] Detection is a process in a physical protection system that starts with sensing a potentially malevolent or otherwise unlawful act and that is completed with the evaluation of the cause of the alarm. Delay is the component of a PPS intended to increase the penetration time of an adversary for entry into and/or departure from the nuclear facility or transport. Response refers to the persons, on-site or off-site, who are armed and appropriately equipped and trained to counter an attempted unlawful removal or an act of sabotage. [30] Physical protection detection systems can include active infrared sensors, infrasonic sensors, capacitance proximity sensors, electric field sensors, and radiation sensors. [31] The conventional PPS combines two substantial surrounding fences with a clear zone in between and consist of several advanced sensors and interconnecting communications. Physical protection systems (PPS) at diverse locations are rarely identical due to vast the differences in facilities, targets, and threats. The elementary design for PPS is quite well recognized but substantial engineering and design tailoring is often required for each site. [32]

Nuclear security refers to the prevention and recognition of, and response to theft, sabotage, unlawful access, illegitimate transfer, or other malicious acts involving nuclear material, other radioactive materials or their associated facilities. [33]

Nuclear security and protection system Promotes the advancement and implementation or employment of technology and systems for the physical protection of nuclear materials and facilities. [34] The three distinct steps of nuclear security include:

- Defining the requirements
- Designing the physical protection system based on the requirements, and
- Evaluating the physical protection system to assess or evaluate whether it meets the performance requirements.

Adversaries can be classified into three distinct groups. These include outsiders, insiders, and outsiders in collusion with insiders. For each group of adversaries, the full range of tactics or strategies including deceit, force, stealth, or any combination of these must be well thought-out.

Deceit is the attempted defeat of a security system by using false or incorrect authorization and identification; force is the unconcealed, forcible attempt to overcome a security system; and stealth is the attempt to defeat the detection system and enter the facility secretly. Vital capabilities for the adversary comprises of his knowledge of the PPS, his level of motivation, any skills that would be useful in the attack, the speed or swiftness with which the attack is carried out, and his ability to carry tools and weapons.

Because it is not often possible to test and assess all possible capabilities of an unknown adversary, the designer and analyst must make assumptions. These assumptions can be based on published information about human performance and the tested vulnerabilities of physical protection elements. [35] The most tough adversaries to address or tackle using the PPS are terrorists, but activists and demonstrators are also hard due to the ambiguity of their actions and intents.

The insider threat is a global concern for nuclear security since an adversary with a colluding insider is very treacherous or dangerous. [36] The main objectives of physical protection or nuclear security are:

- **To defend or protect against unlawful/unauthorized removal**

Protecting against stealing and other illegal taking of nuclear material

- **To locate and recover missing nuclear material**

Ensuring the employment of rapid and wide-ranging measures to locate and, where appropriate, recover stolen nuclear material.

- **To protect or defend against sabotage.**

Protecting nuclear facilities and nuclear materials against sabotage.

- **To lessen the effects of sabotage.**

Mitigating or reducing the radiological consequences of sabotage. [37]

2.1.1 Requirements of a Physical Protection System

2.1.2 General requirements of physical protection system

The general requirements of a physical protection system are:

- The physical protection system should be operating at the during period of supply of nuclear materials at a nuclear facility.
- During decommissioning or dismantling of a nuclear and storage facility, the physical protection system should be operating till final extraction of nuclear materials from the storage and nuclear facility is done.

- The physical protection system should operate under normal conditions and in situations of a nuclear facility in which normal conditions were breached due to unauthorized act on it, causing injury to working personnel (population), giving rise to threat to the life of personnel (population), and also possible damage to the environment.
- In the physical protection system, there should be data protection, including confidentiality of data or information about the arrangement structure and functioning of the physical protection system, its integrity and approved access to it, of which if breached, may decrease the efficiency of the whole physical protection system or of its discrete elements.
- At a nuclear facility, there should be defense not relating to nuclear installation or storage facilities, a nuclear facility communications and elements, for which in the process of vulnerability analysis, the need to avoid unlawful activities was identified.
- In exceptional cases when it is impossible to completely put in place the requirements for the physical protection system at a nuclear facility established by the existing Federal rules and regulations, compensatory structural and technical procedures should be adopted. The adequacy of procedures taken should be confirmed by an assessment of the effectiveness of the physical protection system. [38]

2.1.3 Physical protection requirements for nuclear facilities

Nuclear materials that need physical protection include nuclear reactors, fuel cycle facilities, and spent fuel storage and disposal facilities. The physical protection programs for these nuclear materials and facilities include the following important features:

- **Threat assessment**: This evaluation is done to determine how much physical protection is sufficient.

- **Physical Protection Areas:** These areas graded to provide defense-in-depth with fences, barriers and controls for the Exclusion, Protected, Vital, and Material Access Areas.
- **Intrusion Detection:** This makes use of intrusion detectors to notify the site's security force of a potential intruder.
- **Intrusion Alarm Assessment**: This is an evaluation done to distinguish between false or nuisance alarms and actual intrusions and to initiate response.
- **Armed Response** to protect public health and safety and the common defense and security, by defending nuclear material or a nuclear facility against an intrusion or attack.
- **Regulatory Initiatives**: These are taken to ensure that the Nuclear Regulatory Commission's(NRC’s) Domestic Safeguards Regulations, Guidance, and Communications continue to effectively protect and defend the Nation's nuclear facilities and material in different threat environments.

2.1.4 Physical protection during transit

Conveyance or transportation of spent or used nuclear fuel and other high activity shipments need physical protection. Important features of physical protection for transportation include:

- Use of NRC-certified, structurally rugged, shipment overpacks and canisters. Fuel within canisters is dense and in solid form, not readily dispersible as respirable particles.
- Advance planning and coordination with local law enforcement along approved routes.
- Protection of information about schedules.
- Regular communication between transports and control centers.

- Armed escorts within heavily populated areas.
- Vehicle immobility measures to protect against movement of a hijacked shipment before response forces arrive. [39]

2.1.5 Design and evaluation process outline

The design of an active PPS includes the determination of PPS purpose or objectives, the initial design or characterization of a PPS, the assessment of the design, and in many cases, redesign or modification of the system. To develop the objectives, the designer must initiate by collecting information about facility operations and conditions, such as a full description of the facility, working states, and the physical protection requirements.

The designer then needs to describe the threat. This involves considering features or characteristics about potential adversaries, such as class, capabilities, and range of strategies or tactics.

Next, the designer ought to identify targets. Targets may be physical possessions, electronic data, people, or anything that might impact business operations. The designer now knows the aims of the PPS, that is, what to protect against whom.

The next step is to design the new system or characterize the existing system. If designing a new system, people, procedures, and equipment must be integrated to meet the objectives of the system. If the system already exists, it must be characterized to establish a baseline of performance.

After the PPS is designed, it must be analysed and assessed to ensure it meets the physical protection objectives. Assessment must permit for features working together to guarantee protection rather than regarding each feature separately. Due to the complex nature of protection systems, an assessment generally involves modeling techniques. If any vulnerability is found, the original system needs to be restructured to correct the weaknesses and a re-evaluation conducted.

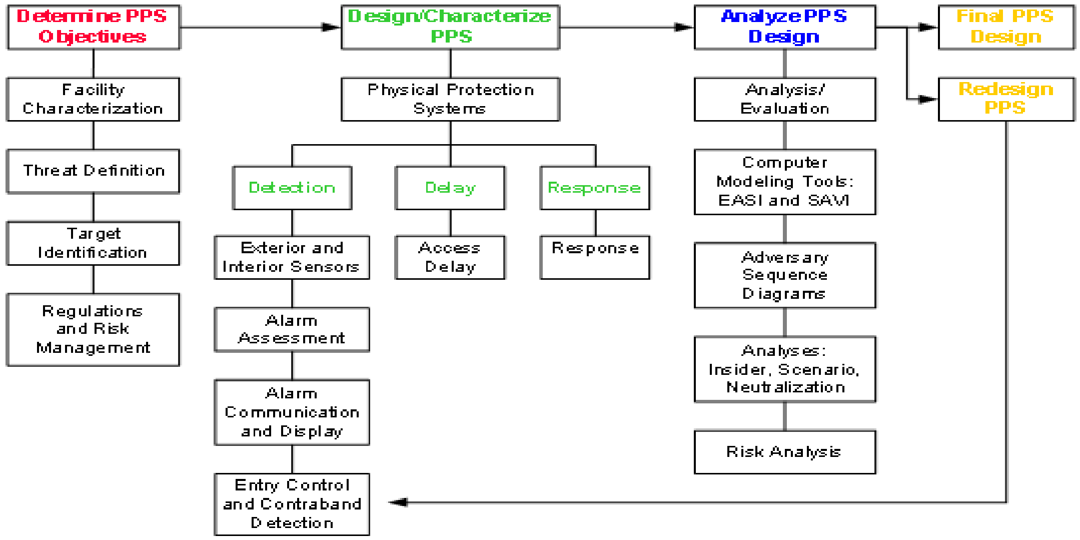


Figure 2.1- Design and evaluation process outline

2.1.6 Determination of Physical protection system objectives

The first step in the development of a PPS design is to determine the objectives of the PPS. To formulate these objectives, the designer must understand a facility's operations and conditions, define the threat, and identify the targets.

Facility operations and conditions that describe a facility include: the location of the site border, building location, building internal floor plans, and access points. A description of the activities taking place within the facility is also required, as well as identification of any existing physical protection features

2.1.7 Threat definition

Next, a threat definition for the facility must be made. Information about an adversary's tactics and capabilities must be collected. Adversaries can be divided into three groups: outsiders, insiders, and outsiders in collusion with insiders. For each group of adversaries, a full range of strategies should be well thought-out such as: deceit, force, stealth, or any combination of these. Important capabilities for the adversary include:

- knowledge of the PPS, level of motivation, any skills that would be useful in the attack, the speed with which the attack is carried out, and ability to carry tools and weapons.

2.1.8 Target identification

Finally, identifying potential targets within the facility should be performed. The attractiveness of the target determines the measure and method of protection that will be applied to the facility. [40] Target identification provides the basis for the PPS design by focusing on what to protect, while PPS design addresses how to protect.

Target identification is an evaluation of what to protect without consideration of the threat or the difficulty of providing physical protection. In other words, target identification determines areas, assets, or actions to be protected and generally are those that have undesirable consequence of loss to the enterprise. The danger to these objects, and the comfort or difficulty of protecting the objects against a particular treat is considered after the objects are identified.

Asset refers to any target of an adversary attack. Main targets may consist of physical resources, electronic data, people, or any other thing that could influence business operations. Secondary targets can also include PPS components that can be attacked to reduce system effectiveness and facilitate an attack. Identification of both types of assets is often required depending on the threat goals, capability, and motivation and the consequence of loss of the assets. [41]

2.1.9 Design of a physical protection system

The required functions of an effective PPS include Detection, delay and response. These functions have to be performed in order and within a period of time that is less than the time required for the adversary to execute his mission. An effective PPS has several specific characteristics.

A well-made system provides defense-in-depth, diminishes the consequence of component failures, and exhibits balanced protection. Moreover, a design process based on performance criteria rather than feature criteria will select elements and procedures according to the contribution they make to overall system performance. The procedures of a Physical Protection System have to be compatible with the procedures of the facility. Security, safety, and operational objectives must be accomplished together at all times. [42]

Physical protection of nuclear materials and facilities must include elements of deterrence which consist of signs, lighting, visual robustness, etc., detectors which include exterior sensors, door and interior intrusion sensors, television surveillance, personnel access control systems, material screening systems, alarm stations, etc., delay objects which include fences, gates, vehicle barriers, doors, walls, and dispensable delays, etc., objects of response including unarmed and armed guards, highly skilled special response forces, local law enforcement officers, in some cases detachments of the military, etc., and mitigation strategies which include ways on how to minimize the consequences or effects if theft or sabotage acts are successful. The sequential connection of these functions, which must all be present, makes the system stronger.

Defense-in-depth for detection, delay, and response is a good practice. The presence of these multiple layers requires an adversary to avoid several protective devices in sequential order to be successful. For example, an adversary might need to breach two or more distinct barriers before gaining access to a reactor control room. The defense-in-depth notion adds to a PPS overall reliability by abolishing dependency on one barrier or system. Furthermore, it deters the adversary by adding uncertainty, requiring different procedures and tools, and creating supplementary steps.

Deterrence is impossible to measure and the design and assessment process is aimed at creating a measurable level of risk. Mitigation is significant in minimizing the consequence or effect of the overall accomplishment of the adversary, but the main accountability of the PPS is to prevent the adversary from being successful. Still, mitigation is important, and if it is affected by working procedures at a facility, the consequence or effect of a successful adversary attack might be significantly minimizing. [43]

Detection refers to the sensing and identification of an intrusive act at any point in the protection system and it is often reported by an intrusion sensor and broadcasted through the alarm communication sub-system.

The intrusion alarm has to be followed by evaluation; if appropriate, the response force will then be alerted.

The discovery of an intrusion or an attempted intrusion into a protected area is one of the primary functions of a PPS.

It is important to make follow up when there is a detection as early as possible after the start of the intrusive action in order to provide the ample time for evaluation and response. [44]

Intrusion detection must be carried out at the physical barrier surrounding the protected area and timely assessment or evaluation should also be performed. Clear areas should be provided on both sides of the boundary of the protected area with illumination adequate for assessment. To protect against illegal access or malicious acts, special attention should be given to all points of potential access. The boundary of the protected zone should normally include a physical barrier in addition to and outside the building walls. In aspects where the walls of a building are of a specially solid construction, these walls may be seen as being the perimeter of the protected area under conditions specified by a security survey. [45]

2.3 Delay

It is an element for decelerating an adversary progress. Delay can be achieved by personnel, barriers, locks and activated delays. Response force personnel can be well thought-out as components of delay if they are in static and well secured positions.

The measure of the effectiveness of delay is the time required by the adversary after discovery, this delay is no value to the effectiveness of the Physical Protection System, since it does not provide extra time to respond to the adversary. Delay before detection is basically a deterrent.

2.3.1 Response

The response function comprises of the tactics taken by the response force to stop adversary accomplishment. Response can include both interruption and neutralization.

Interruption is defined as the adequate number of response force personnel arriving at the right location to stop the adversary's advancement. It includes the announcement to the response force of precise information about adversary actions and the distribution of the response force. Neutralization defines the actions and success of the responders after interruption. The principal measure of response effectiveness is the time between receival of a communication of adversary's actions and the disruption of their activities.

Response time is the key measure as responders must be at the right place in order to counteract the adversary. At locations where there is no abrupt response, it is presumed that the asset or object can be lost and this is an acceptable risk.

In these cases, the primary response may be after-loss-event investigation, recovery of the asset and criminal prosecution.

Deployment defines the actions or movements of the response force from the time communication is received until the force is in position to interrupt the progress of adversary. The effectiveness measure of this function is the probability of distribution of response force to the adversary's location and the time needed to organize or position the response force. [46]

A longer or lengthier response time is needed if personnel have to rush to the area or zone. In that case, we may have to design layers of perimeter security such as an outer fence with barbed wire offsets, then bundles of coiled razor wire, and inner fencing. [47]

Security force personnel provide the response actions or movements to interdict and counteract adversaries. The response force usually includes skillfully trained primary and secondary responders and patrolling security forces who augment the engagement by primary and secondary responders. [48]

The duty of a response force in a PPS is to accomplish the roles necessary to avert theft or sabotage of nuclear materials and facilities. Response force personnel are used to resolute incidents that involves use of force options up to the use of lethal force if required to stop a threat. All or part of the response force may be situated on-site or off-site and may consist of site personnel or local police forces, regional police forces, national police forces, or military forces. They may be dedicated to the site or pulled from other duties to form a response in the event of an incident at a nuclear facility. In any event, security guards and response forces must use as appropriate, and they must be trained, equipped, and assessed to ensure they execute their roles effectively against the threats defined in the design basis threat or assessment and in accordance with state laws and regulations.

The ultimate objective of all response forces at a nuclear facility is to prevent an adversary from gaining access to a nuclear material from a site or sabotaging a nuclear facility. [49]

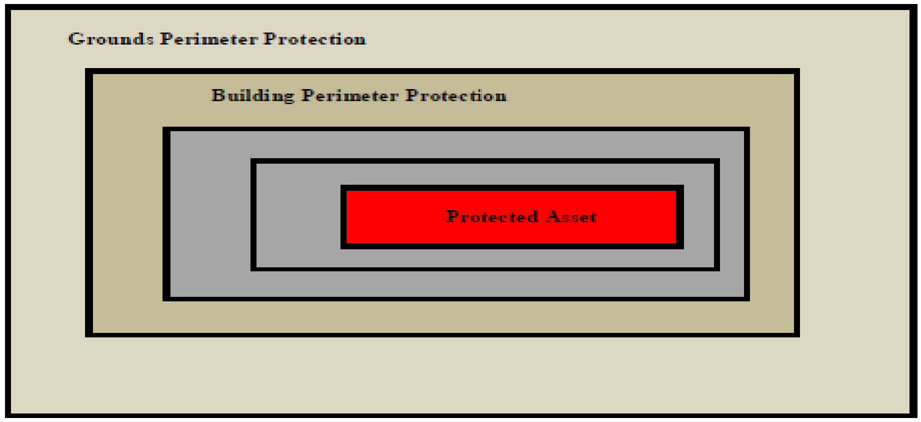


Figure 2.2- Image showing defense-in-depth [50]

2.3.2 Evaluation of the physical protection system design and effectiveness

Analysis and assessment of the security system design commences with the analysis and detailed understanding of the protection objectives the designed system must meet. This can be accomplished simply by making inspection of essential features of the system such as intrusion detectors, entry control, access delay, response communications and a response force. The security system will yield high performance results only when all of those features work together to assure adequate levels of protection.

The result of this phase of the design and evaluation process is a system vulnerability assessment. Evaluation of the system design will either find that the design successfully accomplished the protection objectives or it will detect weaknesses. If the protection objectives are accomplished then the process is finalized. Periodic assessment is required to make sure that the original protection objectives continue to be effective and that the physical protection system continues to meet them. If the PPS is found to be ineffective, vulnerabilities in the physical protection system must be identified. This leads to modification or redesigning of the initial protection system to correct its vulnerable parts. [51]

The PPS capability to withstand a potential attack and avert an adversary from achieving his objectives is usually considered as PPS effectiveness. The assessment of effectiveness serves as a basis for evaluating whether a Physical Protection System meets its intended objective. The Physical Protection System is well-thought-out to active only when it is possible to withstand the threat, resulting from a potential attack on an object, to an acceptable level.

The assessment of PPS effectiveness is anticipated to be an essential part of the development and design process of any PPS to show that the recommended system meets set requirements. It is important to assess the effectiveness each and every time the system design or the conditions of use changes significantly. The analysis of PPS effectiveness is at any rate quite a difficult duty, because the PPS ability to survive a potential attack depends not only on PPS features, but also on adversary abilities.

In view of the info put above it could be stated that the purpose of the assessment of PPS effectiveness is mainly to:

- Verify whether the PPS is designed and implemented so that it could observe specified requirements determined by a PPS user or a relevant executive power (a state or a final control element).
- Discover possible imperfections in PPS design or implementation which are to be removed in order to accomplish the requirements.
- Analyze the results of changes in the PPS design and improvements.
- Verify regularly the PPS effectiveness to analyze possible changes in PPS or threat.
- Evaluate the effectiveness of the expenditures on single PPS measures.

The assessment of effectiveness is a basic condition for having active, economically satisfactory physical protection, as it enables us to determine the weaknesses of the PPS which are to be strengthened, and also points at the locations where the system is designed ineffectively bringing high financial needs and not having appropriate influence to physical protection effectiveness. Usually, when assessing the effectiveness, qualitative as well as quantitative analytical measures might be used. [52] Systems that are designed to protect high-value critical assets normally require a quantitative analysis. Examples include the PPS of residential buildings, offices, smaller shops, restaurant, etc., while systems protecting lower-value assets may be analysed using less rigorous qualitative techniques. Examples include high-security systems in nuclear power plants, nuclear weapons etc. The latter or final are more appropriate for lower consequence loss assets and so will be better able to resist loss or damage of that asset. With a qualitative analysis, the analyst has to define the threats and targets and analyze system performance, but these should be tailored to meet the budget and time constraints of the analysis. [53]

For most analyzing models, objectives and antagonist paths must first be identified. The analyst must then take into consideration the adversary's objective: to complete the path.

The following three closely interrelated methods or techniques are based on detection of path with lowest cumulative probability of detection up to critical point of detection and are proposed for assessment of technical effectiveness of nuclear facility security. They utilize central division of security sectors with one sector containing protected asset in middle of whole system and are based on intruder's familiarity with the security system.

The path with lowest cumulative probability of detection up to critical point of detection is called critical path or path with lowest cumulative probability of interruption. Detection before critical point of detection is called timely detection.

2.3.3 EASI method (Estimation of Adversary Sequence Interruption)

Allows the computations of probability of interruption only on one predefined path.

2.3.4 ASD Method (Adversary Sequence Diagram)

This is a technique for graphic depiction of possible or potential intruder paths in security system. ASD describes facility and its security system as layers that isolates external intruder from his target inside facility. Individual physical areas are divided by protective barriers that include everything that may delay or detect intruder.

2.3.5 SAVI method (Systematic Analysis of Vulnerability to Intrusion)

Combines EASI and ASD methods and evaluates every possible path to central zone from the viewpoint of probability of interruption and creates a list of ten most vulnerable paths according to their possibilities of interruption. If values of probability of interruption are equal, it lists paths according to total length of attack. Main SAVI program is accompanied by extensive database of delay and detection parameters of most commonly used protection elements. SAVI method implements also sensitivity analysis. Given that most critical parameter is time required for response, for sensitivity analysis SAVI uses different values of response force time. Output is of course probability of interruption.

From the viewpoint of modeling, the main technique or method of evaluation of effectiveness or calculation of probability of interruption may be identified as suitable, but models do not completely reflect demands of systems for protection of persons and property from the viewpoint of modeling of protected area. Stated disadvantage (even from viewpoint of nuclear facilities) is absence of probability of intruder elimination calculation. [54]

2.3.6 Redesign of the physical protection system

The result of the analysis phase is system vulnerability assessment. If the system is found to be ineffective, vulnerabilities in the system must be identified. This leads to modification or redesigning of the initial physical protection system to correct its vulnerable parts. It is possible that the PPS goals or objectives would also need to be reevaluated. A re-evaluation of the redesigned system is done to check vulnerability corrected.

2.3.7 Design Basis Threat/ Threat assessment

The likelihood that terrorists, criminals, or protestors might try or make effort to sabotage a nuclear facility, steal nuclear material, or perform other unauthorized actions within the nuclear industry has to be taken into consideration in the protection of nuclear facilities. Physical Protection Systems (PPS) are created in order to counter the defined threat to ensure maximum physical protection of nuclear facilities. The development of PPS involves balancing security requirements with resources that are available. The threat affects both of these aspects. In several or most cases, the threat must be assumed, due to the fact that it has not been demonstrated in frequent attacks on nuclear facilities. In cases where threat information is not available, postulates must be made regarding the threat in order to create a comprehensive set of PPS requirements and prioritize financial and additional resources. An organized or structured analysis of the capabilities and intentions of potential threat capabilities and intentions provides a sound basis for making such assumptions.

The Assessment of Threat is considered to be an independent effort that is not constrained by considerations of budget or policy. The threat assessment bounds the threat problem to support the subsequent DBT development effort. [55]

The design basis threat (DBT) defines the general features or characteristics of adversaries that nuclear power plants and nuclear fuel cycle facilities must protect or defend against in order to prevent radiological sabotage and theft of special nuclear material. The NRC licensees makes use of the DBT as the basis for implementing highly defensive approaches at specific nuclear plant sites through security plans, safeguards contingency plans, and guard training and qualification plans. [56]

The description of a DBT comprises four important themes. These are:

- **External and/or Insider adversaries** – A potential adversary is a group of individuals or people considered to have the intent and the capabilities to conduct a malicious malevolent act.
- **Malicious acts** leading to unacceptable consequences – Measures has to be taken to avoid malicious acts, such as the illegal removal of nuclear material or sabotage and protect against their unacceptable consequences.
- **Attributes and characteristics** – The attributes and characteristics of potential adversaries describe their capabilities to carry out a malicious act. Capabilities may include weapons, explosives, tools, transportation, insiders and insider collusion, skills, tactics, and number of individuals. These capabilities help determine the detection, delay, and response criteria for design and evaluation of an effective physical protection system.
- **Design and evaluation** – A DBT, defined at the State level, is a means used to help in the establishment of performance requirements for the design of PPS. A DBT is as well used to help State authorities and operators evaluate the effectiveness of the systems to counter adversaries by assessing the systems' performances against their skills and capabilities which are described in the DBT.

The DBT outlines the set of adversary features or characteristics for which the State organizations and operators both have protection responsibility and accountability. The division of these responsibilities might differ according to different States. The Design Basis Threat is used to describe or define the requirements given to the operators and to clarify the protection functions that are the responsibilities of the State's Authorities.

It's very important to recognize that the specific competences or capabilities contained in a Design Basis Threat are autonomous of which organizations (Operator alone, State and Operator together, or Operator in association with another organisation) are intended to use it. A country or State may wish to have several DBT either to reflect the various targets (for instance, radioactive and nuclear materials) and the protection needs according to different types of facilities (for instance, research reactors and nuclear power plants), different adversary objectives (for instance, theft or robbery, sabotage, economic disruption), or different geographic regions. This differences or distinction points out the importance of clarifying the planned use of a DBT prior to developing it. [57]

A DBT gives or provides:

- A basis for confidence or assurance that the PPS developed in a State is effective and appropriate.
- A basis for PPS design and a consistent standard for evaluating the tolerability or adequacy of the system.
- A baseline criterion against which the necessity for changes in physical protection can be assessed.
- A basis for assigning or allocating responsibilities between organizations involved.

The Design Basis Threat can allow or permit adaptation of the PPS to address special or unique characteristics or features of the nuclear facilities or materials. The DBT can also help avoid unnecessary protection being given or applied to materials and facilities while making sure that those materials or facilities for which a malicious act could lead to high consequences get the required protection they need. In this way, the use of the Design Basis Threat approach to physical protection can help to minimize the arbitrariness that might otherwise exist in establishing requirements for the physical protection of nuclear facilities and materials under State jurisdiction.

Specifying a Design Basis Threat is one of the technique for a country or State to establish the required performance level for new or already existing physical protection systems (PPS). The DBT helps in ensuring that physical protection systems (PPS) are effective against possible threats without overdesigning them. A state DBT can also give or provide a reliable or consistent basis for requirements across all nuclear facilities within a nation. [58]

Threats on storage site and nuclear facilities can be in the form of sabotage or theft of nuclear materials. Sabotage may include:

- **With people (outsiders, insider or outsiders in collusion with insiders)**

- **Without people (the use of flying objects such as drones)**

Sabotage refers to any form of deliberate act directed towards a nuclear material or facility in use, storage or transport which could jeopardize the health and safety of workers, and the general public by exposing them to radiation or release of radioactive substances." [59]

Insider threats are probably the most dangerous and serious challenges that nuclear security systems face. All of the cases of robbery or theft of nuclear materials where the circumstances of the theft are identified were committed either by insiders or with the assistance or help of insiders; given that the other cases involve majority of the material stolen secretly without the awareness of anyone knowing the material was missing, there is every reason to believe that they were committed by insiders as well. Similarly, resentful employees from inside nuclear facilities have committed many of the known events or incidents of nuclear sabotage.

2.3.8 Threats and vulnerability analysis

Vulnerability analysis is a necessary step in creating an effective security system. Based on its results, design options and technical security complexes are developed or created. The vulnerability analysis is carried out in order to determine the possible consequences in case of an attack on a nuclear facility, identify weaknesses and shortcomings of the security system or considered design variants of the system, and in the end the best choice or version of the security system for a particular facility is created.

Procedure for the analysis of the vulnerability of a nuclear facility is established by departmental or interdepartmental normative legal acts. When preparing a report on the analysis of vulnerability of nuclear object is also recommended to take into account the requirements of regulatory legal acts of the atomic energy management authority and documents operating organization, determining the order and content of the analysis vulnerability of a nuclear facility.

2.3.9 Analysis of insider threats

Insider threat is a general term for a threat to data or security of an organization that comes from within. Such kinds of threats are mostly attributed to employees or former employees, but may also result from third parties, including temporary workers, customers or contractors.

Insider threats can be of several forms, but threats can be considered as either accidental or malicious.

Accidental threats refer to circumstances or situations in which damage or loss data arises as a result of an insider who has no malevolent or malicious intent. For instance, a worker or an employee might accidentally delete an important or vital file, fall victim to a phishing attempt or unintentionally share more data or files with a business partner than is consistent with organization’s policy or legal requirements.

Malicious threats refer to deliberate attempts by an insider to access and potentially harm an organization's data, systems or IT infrastructure. These forms of insider threats are usually attributed to resentful employees or formal employees who believe that the company or organization mistreated and or wronged them in some way, and hence feel justified in quest of revenge. Insiders may also become threats when they are subverted by malicious outsiders, either through financial enticements or through blackmail.

A malicious insider can also be a hacker, also called a black hat or cracker, that is, an employee of a rival organization or company or a member of a terrorist group that opposes the organization. In these circumstances, there would-be attacker infiltrates the company, either by looking for employment or by pretending to be an employee, vendor, delivery courier or other trusted third-party. As soon as the threat actor gets physical access to the facility, he or she looks for various ways to carry out an attack. [60]

Insider threats pose dangers to anybody who handles information that is top-secret or proprietary, material that is extremely important or valuable or hazardous, people or individuals who must be protected, or facilities or equipment's that might be sabotaged. [61]

Insider threats are the major security breaches and are so expensive to remediate and so difficult to deal with. The main reasons been that:

- **Insider threats can go undetected for years** – The longer you take to detect a breach or a leak, the more remediation expenses go up. Insider threats can be very tough and difficult to detect, which is why they are the costliest to remediate.
- **It is difficult to differentiate or distinguish harmful actions from regular work** – This is why insider threats are so difficult to detect. When an employee is working with sensitive data or information, it is virtually not possible to know whether they are doing something malicious or not.
- **It is easy for employees to cover their actions –** While it's not easy to detect malicious activities when they occur, it can be virtually not possible to detect them post-factum. Any tech-savvy employee will know how to clean up after themselves by removing, editing or deleting logs to cover malicious action.
- **It is difficult to prove guilt** – Even if you do succeed in detecting malicious actions, employees can simply claim that it was a mistake they made and get away with it. It is virtually impossible to prove guilt in such cases.

Insider threats are very dangerous or unsafe and can be caused by any of these groups below:

- **Privileged users** – These are often the most trusted workers in an organization or company but they also have the most opportunities to misuse your data, both deliberately and inadvertently.
- **Third parties** – Isolated employees, subcontractors, third-party vendors and partners all frequently or regularly have access to your system. Since you don't know anything about the security of their systems and often even about the very people accessing your data or information, you should treat them as a security risk.
- **Terminated employees** – Equivalent to the case cited at the beginning of this article, workers or employees can take data or information with them when their appointment is terminated. Even more importantly, occasionally they can access your data even after their termination, either through malware or backdoors or by retaining their access since nobody was worried about disabling it.

The core reason why malicious insiders conduct such wrongdoings includes:

- **Acting on opportunity** – A worker or an employee sees an opportunity to make use of organization data for personal gain or to steal and sell it, and then makes decisions to act on it, such actions are infrequently preceded by long-term planning and preparation. They mostly occur relatively spontaneously.
- **Taking revenge for perceived injustice** – Resentful workers or employees can steal data or simply leak it online or destroy it in order to get back to you for a supposed injustice.
- **Making a statement** – Sometimes, a worker or an employee wants to make a social or political speech or statement and leaks data online or causes damage to it in order to do so.

- **Doing competitors bidding** – Business or corporate espionage is a thing, and even truthful or trustworthy employees or workers can be approached and offered a deal which they would be find difficult to refuse. This usually involves bribery and/or blackmail.
- **Seeing themselves as a future competition** – Some workers and employees may want to establish their own competing business and make decisions to get ahead by using your data or information. They may contact clients and steal or make changes in your client list or even offer their services while still working. [62]

2.4 Analysis of outsider/outsider in collusion with insider threats

Outsider threats involves the possibility that people or individuals carrying weapons or groups from outside a nuclear facility gain access and steal weapons, weapon components or fissile material.

The vulnerability of nuclear power plants to deliberate attack is of concern in the area of nuclear security and safety. Civilian research reactors, nuclear power plants, certain naval fuel facilities, uranium enrichment plants, fuel fabrication plants, and even potentially uranium mines are vulnerable to attacks which might lead to widespread radioactive pollution or contamination. The attack threat is of several general types which include commando-like ground-based attacks on equipment which if disabled might lead to the meltdown of reactor core or dispersal of radioactive substances; and attacks from external sources such as an aircraft crash into a reactor complex, or cyber-attacks.

Terrorists might target nuclear plants in order to release nuclear and radioactive materials into the community or environment. If terrorist groups could sufficiently cause damage to safety or security systems in an attempt to cause melting down of the reactor core at a nuclear power plant, and/or sufficiently cause damage to spent fuel pools or cooling system, such an attack may result in a widespread of radioactive substances. [63]

The likelihood that armed individuals or groups may gain access, and sabotage a nuclear facility, steal components or fissile material involves the threat from outsiders. The outsider's objective is to gain control of these objects or items for their own use or to allocate them to another state or to another state actors. Terrorist might attempt to capture such components or fissile or radioactive materials when they are being transported. To increase the chances of causing serious damage, attackers or terrorist would dedicate substantial effort to employ or recruit insiders, as they would have more knowledge about the detailed operations and vulnerabilities at these places. Thus, the "insider collusion" would serve as a multiplier effect for terrorist or outside attackers. Experts or skilled and highly trained insiders such as nuclear engineers would have knowledge on how to disable or deactivate emergency sources of power and cooling systems. Such deactivation would increase the possibility of a reactor core meltdown and release radiations and radioactive substances. Insiders could sabotage other important or vital plant systems while outside attackers hold the security guard or forces under obstruction or siege. [64]

The primary attraction of civil nuclear-energy objects or facilities as terrorist targets lies in the potential for creating a release of radioactive materials large enough to cause significant casualties or fatalities, land and water contamination. Destruction of a vital piece of energy-supply setup in the targeted country and the likelihood that a successful attack would result in the shutdown of nuclear-energy facilities worldwide might be seen as collateral "benefits" by terrorist group.

Nuclear-terrorism dangers can be classified into three groups:

- dirty bombs, which means conventional explosives or incendiary devices that disperse radioactive materials
- attacks on nuclear-energy or nuclear-weapon facilities, and
- terrorist acquisition and use of nuclear-explosive weapons.

Additionally, the mere declaration or assertion of the capability to carry out any of these categories of attacks or a clear threat to do so at a specific time and place may assist terrorist purposes, even if an attack does not happen or occur. The community or public's deep-rooted fear of nuclear weapons, radioactivity and nuclear radiation tends to increase not only the impact if an attack occurs, but also the dreadful effect of threats to do so.

Of all the three classes of nuclear-terrorism dangers, the dirty bomb is the easiest for terrorists to perform or execute. In most situations or circumstances, a dirty bomb would cause a quite few immediate mortalities or fatalities beyond those caused directly by the chemical high-explosive used. A possible exclusion could be the use of an incendiary device to cause a dispersion of a potent radionuclide into the aeration or ventilation system of an office building. The major effects of most dirty bomb actions or events would be in property damage, the costs of temporarily abandoning and cleaning up the polluted or contaminated areas and in the fear and depression created in the public.

Victory in the second group of danger, that is, attacks on nuclear-weapon or nuclear-energy facilities would be very difficult for terrorists or attackers to achieve but could produce significantly higher casualties. The effect of such an attack could involve several hundreds or thousands of immediate mortalities, several thousands of delayed deaths from radiation-induced cancers, and massive economic damage from the contamination of the area or territory. Victory in the third category, that of acquiring and discharging a nuclear weapon is probably the most difficult for attackers or terrorist group to achieve. However, such an attack could lead to several hundreds or thousands of immediate deaths resulting from the effects of blast and burns of explosions in the central part most important city, as well as several other casualties from fallout and vast property damage.

Nuclear-explosive weapons are those where most of the energy is released from nuclear reactions other than chemical high-explosives. [65]

A nuclear weapon refers to any kind of weapon that derives its incredible destructive force from the sudden release of the energy created by a self-sustaining reactions of nuclear fission and/or fusion. Fission-based weapons obtain their energy from the splitting of atoms, which comprises of all first-generation U.S. nuclear weapons, including the bombs which were dropped on the Japanese cities of Hiroshima and Nagasaki. Current nuclear weapons are even more destructive and obtain some or most of their explosive yield from a process called fusion. Fusion is conceptually the converse of fission, joining rather than splitting atoms. When two or more light atoms fuse, a large amount of energy is released. [66]

Considering all the terrorist threats facing the world, perhaps the severest is the likelihood of terrorists creating or obtaining a nuclear weapon and discharging it in a town or city. If an attacker or terrorist group exploded just one nuclear weapon, several hundreds or thousands of people could die due to the fact that, there is no effective protection against a nuclear explosion, one important remedy is to prevent terrorists from gaining access to nuclear bomb materials or weapons in the first place. Countries or nations are devoting inadequate attention to this problem and, in some cases, following and or pursuing policies that increase the risk of terrorists gaining access to nuclear weapons.

A nuclear weapon requires either highly enriched uranium (HEU) or plutonium. Luckily, these materials are not found in nature and are not easy to produce. Therefore, it means there are only two reasonable ways for attackers or terrorists to gain access nuclear weapons. Primarily, they could steal a complete nuclear weapon from existing arsenals or buy a stolen weapon. Also, terrorists could purchase the material needed to build a nuclear weapon and acquire the expertise to construct a bomb from this material.

Since only a relatively small quantity of Highly Enriched Uranium or plutonium is required to construct a bomb, terrorists could feasibly steal sufficient material to build one or more nuclear weapons. A crude nuclear weapon would use forty to fifty (40-50) kilograms, that is, (88-110 pounds) of Highly Enriched Uranium; a more sophisticated design would need twelve (12) kilograms, that is, 26 pounds of HEU or four (4) kilograms, that is, nine (9) pounds of plutonium. The robbery or theft of Highly Enriched Uranium would be very worrisome, because it is relatively straight-forward to construct a bomb using this material.

Highly Enriched Uranium (HEU) is used to fuel more than 100 research reactors in many of countries all over the world. Most of these facilities are used for academic or industrial purposes with insufficient security making them even more attractive targets for terrorists looking for nuclear weapons materials.

Hundreds or thousands of these so-called tactical nuclear weapons, many of which are relatively small and do not have electronic locks to avert their unauthorized use are kept in some countries and in poorly secured locations or areas.

Even in countries such as the United States, Japan, and France, safety and security measures for defending or protecting weapon-usable materials from stealing are probably insufficient to protect against modern terrorist threats. [67]

2.4.1 Preventive measures against insider and outsider threats

It is therefore significant that a list of the sensitive positions and possible insiders is checked or conducted to avoid the insider threat happening and reduce the possibility of outsiders working in collusion with employees. Some of the preventive measures that can be taken include:

- Identification, verification, authentication and confirmation of staffs or employees.
- Trustworthiness assessment, which refers to assessing or evaluating an employee or personnel's integrity, honesty and reliability during non-regular and regular employee routines.
- Escort and surveil infrequent staff and visitors.

- Improve security awareness.
- Improve the security information on nuclear materials and nuclear facilities.
- Create or establish a quality assurance policy program and good organization culture.
- Clearly demarcating critical areas with access control and procedural activities to limit access to the nuclear facility and materials data easily by an insider.
- Strict law and disciplinary actions to punish criminal or offending insiders.
- The use of detection, delay and response functions for the deterrence and prevention of malicious intrusion acts, to mitigate or lessen the consequences. [68]

2.4.2 Nuclear power plant vulnerability

Huge amounts of radioactive fission products are contained in nuclear power plants which, if dispersed, could pose a direct radiation hazard, pollute or contaminate soil and vegetation, and be consumed by humans and animals.

High levels of human exposure to radiation can cause both immediate illness and death, and longer-term deaths by cancer and other diseases.

To avoid the dispersal of radiations and radioactive material, nuclear fuel and its fission products are enclosed in metal cladding within a steel reactor vessel, which is located inside a concrete "containment" structure. The remaining or residual heat from the radioactive fission products could possibly melt the fuel-rod cladding even if the reactor were shut down. The most important concern in the operation of a nuclear power plant, in addition to controlling the nuclear chain reaction, is making sure that the core does not lose its coolant and "melt down" from the heat generated by the radioactive fission products inside the fuel rods. Therefore, even if the operators of a nuclear power plant shut down the reactor as they are supposed to during the events of a terrorist attack, the hazard or threat of a radioactive release would not be eliminated.

The containment structures of commercial reactors made of steel-reinforced concrete, several feet thick are intended to prevent the dispersion of most of a reactor's radiations or radioactive material in the event of a loss of coolant and meltdown. Without any fissure in the containment, and without the dispersal of some source of energy such as a chemical explosion or fire, the radioactive fission products that escaped from the fuel cladding which is melting would mostly remain where they were. The two meltdown accidents that took place in power reactors, both at Three Mile Island in 1979 and at Chernobyl in the Soviet Union in 1986, demonstrate this phenomenon. These two occurred from a combination of operator error and design flaws. At Three Mile Island, the accident occurred due to loss of coolant which caused the fuel to melt, but there was no explosion or fire, and the containment prevented the escape of significant amounts of radioactive materials. At Chernobyl, which had no shielding material or containment, a hydrogen explosion and a fierce graphite fire caused a significant part of the radioactive core to be blown into the atmosphere, where it polluted large areas of the surrounding countryside and was noticed or detected in smaller amounts in neighboring countries.

2.4.3 Vulnerability from Air Attack.

Nuclear power plants are intended or designed to withstand earthquakes, hurricanes, and other life-threatening events, but attacks by large aircrafts loaded with fuel, such as those that crashed into the World Trade Center and Pentagon, were not anticipated when design requirements were considered or determined. A recorded interview revealed on Arab TV station Al-Jazeera, September 10, 2002, a statement which contains that Al Qaeda initially decided or planned to include a nuclear power plant in its 2001 attack sites, intensified concern about airplane crashes.

In light of the likelihood that an air attack might breach or penetrate the containment structure of a nuclear power plant, some interest groups have recommended or made a suggestion that such an event could be followed by a meltdown of a reactor core and extensive exposure to radiation. Nuclear industry spokesmen or representatives have countered by pointing out that relatively small, low-lying nuclear power plants are tough targets for attack, and made arguments that, the penetration of the containment structure is unlikely, and that even if such penetration happens it probably wouldn't reach the reactor vessel. They suggest that a continual fire, such as that which caused the melting of the structures in the World Trade Center buildings, would be not be possible unless an attacking plane completely penetrates the containment, including its fuel-bearing wings. Newly completed NRC studies "confirm that the possibility of both damaging the core of the reactor and releasing radioactive materials that could affect community or public health and safety is low. [69]

2.4.4 Drones

In technological or technical context, A drone is an unmanned aircraft. More officially, drones are known as unmanned aircraft systems (UASes) or unmanned aerial vehicles (UAVs). Basically, a drone is a hovering mechanical device or flying robot. It may be remotely controlled or can fly freely through software-controlled flight plans embedded in their systems working together in combination with onboard sensors and GPS.

In the recent past, Unmanned Aerial Vehicles were most often connected with the military, where they were initially used for anti-aircraft target training or practice, intelligence gathering and then, more controversially, as weapons stands or platforms. Now drones are also used in a wide range of civilian activities, ranging from search and rescue, traffic monitoring, surveillance, weather monitoring and firefighting to personal drones and business drone-based photography, as well as videography, agriculture and even delivery services. [70]

Drones are used in circumstances where manned flight is considered as too dangerous or difficult. They provide troops with a 24-hour "eye in the sky", seven days a week. Each aircraft can stay aloft for up to seventeen (17) hours at a time, moving or loitering over an area and sending back real-time description or imagery of events on the ground. [71] They are known for their “accuracy” and “stealth features”. Monumental tasks have been carried out with the help of drones by preventing terrorist attacks and capturing or arresting important Taliban leaders, including the observation or surveillance of the infamous and notorious “Osama Bin Laden.” [72]

2.4.5 Components and operation of drones

A typical Unmanned Aerial Vehicle is made of composite materials which are not heavy to decrease weight and increase maneuverability. It can be equipped with a several diverse equipment, which may include cameras, Global Positioning Systems (GPS), GPS guided missiles, navigation systems, sensors or detectors, and so on. Drones can be controlled by remote control system or a ground cockpit.

Drones come in various sizes, with the large drone frequently used for military purposes such as the Predator drone, other smaller drones which can be launched by hand, to other unmanned aerial vehicles which require short runways. An unmanned aerial vehicle system consists of two main parts, the control system and the drone itself.

All the sensors and navigational systems are present in the nose of the unmanned aerial vehicle (UAV). The remaining part of the body is complete innovation since there is no loss for space to accommodate less weight and humans. The engineering materials used to construct the drone are very complex composites which can absorb vibration which minimizes the noise produced. [73] There are differences in the frame and creation of drones, but the crucial components that every drone must possess is a waterproof motor frame, flight and motor controllers, motors, transmitter and receiver, propellers, and batteries or any other source of energy.

These small aerial devices are able to pack a lot of equipment's or accessories into their plastic or metal frames. Most drones are ready-to-use, however, some individuals or people like constructing drones by themselves using kits.

The property that makes these unmanned aircraft extraordinary is their great flight capability. Drones have ultra-stable flight, and they can fly around or hover and perform various acrobatics in the air. How far and higher a drone can fly depends on the space you are flying it, and also the line of sight. A drone can certainly fly beyond the line of sight, but it increases the risk of hurting or causing injury to someone, crashing the drone, or causing damage to someone's property.

In terms of drones for entertainment, they have a short control distance and can fly for just few minutes. On the hand, advanced drones which are used in the military or mapping are able to fly around or hover for hours in the air and be controlled from a long or great distance.

2.4.6 Classification of drones

Classifying of drones may sound to be impossible, based on the fact there are different variety of models, with different properties or features, sizes, and price. The only way we can categorize them is by size.

- **Nano and mini drones**

The smallest form of drones on the planet are members of these groups. They can be grouped into two categories which are "Nano and Mini drones".

The smallest are the Nano drones which usually have the same sizes as insects but on the other side, mini drones can be up to 50cm in length and they have more powerful electric motors and better properties or features than Nano drones.

Universally, all models from both groups are used by the military, in spying and smaller tasks, as a result of the fact they can be easily maneuvered and they can reach remote areas or locations. On the other way round, there are quite a number of models on the market that are available to ordinary consumers. Nano or micro quadcopters have a very small radius, between 1 and 3 km and they cannot hover or fly for more than 10-20 minutes.

- **Drones with small sizes**

Drones from this group have dimensions between 50 cm and 2 m. They don't have powerful motors so they must be thrown into the air, in order to start flying.

These products are also very popular on the market because they have great features and they are more affordable than bigger drones.

These drones are also the most common type of drones available to average customers. Simply said, most drones that you can see on the market are members of this group. All of them have a radius of 5 km and they can fly between 20 and 40 minutes.

- **Drones with medium sizes**

Drones that has a wingspan between 5 and 10 m falls into the medium class or category. They can carry up to 200 kg of weight and they have powerful motors.

Also, only one person cannot carry a drone from this group, so they are not a common choice of ordinary people.

Medium size drones are usually used for the transportation of goods to remote locations, and by the military. Remember that these drones are still smaller and lighter than other light aircraft. They can hover up to 50 km and their hovering time can be as long as 6 hours.

- **Bigger drones**

Drones with a wingspan of more than 10m is a member of this category. In general, these drones have the same sizes as smaller aircraft and they are used by the army. A civilian or a normal citizen cannot buy this drone, owing to the fact it is treated as an aircraft. Most of these drones are equipped with weapons and missiles, so they are used in strategic or tactical attacks. It is believed that these big drones will entirely replace the aircraft that require a pilot in the near future.

Owing to the fact that there are different forms of drones from this group, they can be classified in these smaller, groups:

- Short range models: They can hover up to 150 km and more than 11 hours.
- Drones withy medium range: They can have a range of 650 km and they are usually used in weather forecasting.
- Drones with the longest radius: Drones from this category can hover up to 30.000 ft. above the sea level and can stay in the air for more than 36 hours. The main goal or objective of these drones is to reach remote distances. [74]

Figure 2.3- Image of a drone [75]

2.4.7 Drone/UAV Applications at Present and in the Future

Drones applications are not restricted to the military world only, rather they serve a big part of economy with unconventional or advanced mechanisms and remarkable capabilities. The rising interests of users in the drone technology have established new fields of application for it. At present, drones are employed in so many areas and with continuous developments in technologies, these devices or machines are going to be more robust and beneficial in the near future too. They are now able to convey massive loads and can serve users with lengthier or longer flight times as compared to their previous versions. With increasing technology, many new detectors or sensors are being added to drones or unmanned aerial vehicles so that their operation can be highly improved and they can work for dedicated applications with high level of performance.

Drones are now employed in all fields where people use to operate; you can find them in agriculture industry as well as in the world of internet. Other fields where drones are made use of include aerial photography, search and rescue operations, shipping and delivery, engineering, 3D mapping, surveillance, research and nature science, etc. [76]

2.4.8 Analysis of threat of UAV or drones to nuclear facilities

The current world is rapidly changing with the advancement of new technologies constantly emerging and transforming methods or approaches to several tasks. Together with substantial benefits, many ways of using technology for malicious purposes have come up.

Unmanned aircraft are not an exception to this trend. The entertaining or recreational and commercial use of Unmanned Aerial Vehicles (UAV) is on a steep increase. UAVs are being dynamically used for numerous recreational activities, such as videography, photography, and the complete enjoyment of flight. They are also becoming popular with commercial organizations. United States Federal Aviation Authority (FAA) as of January, 2016 had registered over 300,000 UAV owners in the United States. Also, companies and organizations, like Amazon, are looking at employing UAV technology for package delivery, to provide Wi-Fi services, and so on.

UAVs are hired by civilian contractors and engineers for seismic risk assessments, transportation planning, disaster response, and construction management. Furthermore, in the nuclear industry, new uses for UAVs to fulfill or achieve operational, safety and environmental monitoring tasks are constantly being explored, which includes taking physical, chemical, and radiochemical measurements extending human safety capabilities by monitoring in environments where humans cannot go and, expanding the deployment of traditional security detection (e.g., sensors and cameras) and perimeter monitoring systems. While developments in Unmanned Aerial Vehicle technology found enormous applications and brought numerous benefits or assistance to humanity in general, the possible threat of the misappropriation of this technology should not be discounted.

Lately, the world experienced or witnessed a number of security events or incidents involving UAVs, some of which were related to nuclear facilities. Several instances of these events or incidents include:

- Washington, D.C., in January 2015, a civilian UAV flew over the White House fence and crash-landed on the lawn but this incident did not cause any injuries or damage to property. The operator of this UAV was ‘‘an intoxicated employee of a government intelligence agency who was off-duty’’ and the UAV was a famous commercially available ‘quadcopter’.
- The UAE, in January 2015, all air traffic at the Dubai International Airport was brought to a stop for 55 min by an entertaining or recreational UAV. No damages were caused to aircrafts or passengers, but it was a significant disruption which resulted in economic or financial consequences.
- In July 2016, Unmanned Aerial Vehicles were seen hovering the over Savannah River Site (SRS) in the USA. In late June and early July 2016, eight (8) Unmanned Aerial Vehicles (UAV) were spotted by the protective force and professional staff at the facility. The event or incident prompted an investigation by federal agencies. The reason for the UAV flights and the identity of the operator is currently unknown at the time of this writing. [77]

So many unknown drones flying over French nuclear power plants in October 2014, have caught the attention of the general public and of authorities. These flights had taken place either late in the evening, during the night or early in the morning. For instance, on 19 October, these drones had flown over four NPPs situated far from each other, and on the next day over three other NPPs, signifying that this was a well-coordinated act. According to the media, the drones were sometimes only 20 to 30 centimeters wide, but sometimes two meters wide and therefore could possibly carry smaller quantities of explosives. Even after France's interior minister declared that special units of the Gendarmerie, deployed for the surveillance of NPPs since 2007, had received orders to "neutralize" these hovering or flying objects, anonymous drones still flew over French NPPs numerous times.

A drone is an aircraft that hovers without a human pilot on board and must be controlled with the help of a remote from a great or far distance or programmed before it leaves the ground to hover one or numerous routes.

Essentially, a drone is a reusable, unmanned carrier system that can be armed or equipped with weapons and sensors.

In their military applications, drones have assumed increased importance as an instrument for reconnaissance and monitoring potential opponents. In that aspect, drone technology has made swift advancement in recent years. Till today, there has not been any military application of smaller, easily transportable drones with "standard" armament or that are equipped with, for example explosive munitions.

Civilian mini-drones are already available for purchase in greatly varying models. Civilian drones are usually called "multicopters". Though civilian drones that could convey quite a few kilograms of explosives are rare, they are already

commercially available. For instance, the hexacopter, a drone with 6 arms and 12 motors altogether, can convey and transport loads weighing up to 8kg.

Drones also pose a danger or threat if they are used, like the military, for reconnaissance. Drones can send or transmit comprehensive images of an NPP's grounds, its resources and the tactics or strategies used by its security forces. This might greatly increase the possible success of an attack and make it more "attractive" for attackers or terrorist group.

A study which was carried out in 2014 on behalf of Greenpeace Germany investigated whether there are possible terror incidents or scenarios supported by the drones that make a core meltdown almost inevitable. The purpose was not to speculate about who deliberately carried out the drone flyovers in France, and for what reason. Instead, the inquiry is on whether these drone flyovers pose a danger or threat if a terrorist group are responsible for them. The outcome of the study is that, contrary to what officials and operators state, there has been series of threats from drone flights over French nuclear power plants since the commencement of October 2014. Not only the drone overflights themselves but also the failure of security officials to explain and avert such activity are matters or issues for concern.

In most times the threat of terrorist attacks on nuclear power plants (NPP) is deliberately played down. It is often argued that nuclear power plants are adequately protected but for secrecy or confidentiality reasons no details can be released or exposed. These arguments are opposed by the drone overflights. For one thing, it seems that workers or operators and officials are helpless or powerless to stop the overflights and for another, it must now be assumed, after potentially successful reconnaissance flights, that prevailing security measures or procedures are now known. [78]

Also, more threatening, according to the telegraph reports, British Prime Minister David Cameron has cautioned world leaders that Islamic State terrorists are presently making plans to fly drones over the skies of Western countries and spray nuclear material in an attack. Cameron revealed his worries and concerns to other world leaders in a Nuclear Security Summit meeting, in which he emphasized ISIS could possibly end up with nuclear material in its hands. The threat, he said, was "only too real." That threat is not just an outlandish imagination. Already, videotape has revealed ISIS militants or activist using drone technology. Combining drone technology with nuclear material is a frightening enough situation or scenario that world leaders are mapping out war games in response. [79]

In considering all the various instances above, it is clear that UAV tech can pose new threats or challenges for security and safety systems at nuclear facilities.

2.4.9 Integration of Physical Protection System

A Physical Protection System is an amalgamated system of detection, delay, and response measures. The Physical Protection System must be integrated and active against both unlawful removal and sabotage. [80] Single Physical Protection System subsystems may be joined and connected to each other.

A perfect Physical Protection System design procedure takes into combination four disciplines which include operations, safety, physical protection, Nuclear Material Accounting and Control, and computer security in a well-adjusted approach to meet all requirements. The design process should improve the general operation of the nuclear facility and help meet all requirements in the most active and cost-efficient manner. However, each of these four disciplines has different objectives:

- **Operations:** the events and systems required at the nuclear facility to attain or accomplish the facility mission. The aim is to accomplish the facility objectives most effectively and efficiently.
- **Safety:** the actions and systems that protect the personnel of the facility, the surrounding or environment from harm or destruction caused by accident, equipment malfunction, and natural disasters or hazards. The aim is to make operations as safe as possible.
- **Nuclear Material Accounting and Control:** the activities or actions and systems to maintain precise information on nuclear material existing at the nuclear facility. The main aim is to maintain knowledge of the nuclear material quantity and location, and to detect any unauthorized handling or movement. [81]
- **Physical protection:** the events and systems that protect or prevent nuclear material and nuclear facilities against illegal or unlawful removal and sabotage. The main

aim is to protect or prevent persons, assets, society, and the public, community or environment from malicious acts involving nuclear material and other radioactive material. [82]

2.5 Operations

Operational requirements are aligned with the mission or objective of the nuclear facility. The requirements include work hours, number of people requiring access to certain locations of the facility, throughput of security area access control points, number and nature of entrances into a protected area such as a vital area. These requirements will have effect the Physical Protection System and must be considered in the design phase of the PPS.

2.5.1 Safety

Effectively managing the interface between safety and security is an important element of both programmes, to ensure appropriate physical protection of nuclear material and nuclear facilities and health and safety of workers and the public. [83]

It is necessary to make sure that physical protection does not compromise safety and vice versa.

One area where there is a need for close interaction between physical protection and safety specialists within a nuclear facility is sabotage target identification and subsequent protection of these targets. This must be achieved or attained using a graded approach, in a way which does not compromise safety requirements and arrangements but permits for effective protection of the targets. Every nuclear facility must perform analyses to:

- Determine whether or if the radioactive fission products or materials (inventory) at each location inside the facility has the possibilities to result in

Unacceptable Radiological Consequences (URC), as determined by the State, using a graded approach;

- Identify equipment, systems or devices and also the sabotage of which could directly or indirectly lead to Unacceptable Radiological Consequences; and
- Identify computer-based instrument and control systems important to safety and security.

Following such target identification, there is a necessity to design or upgrade the Physical Protection System to be more effective against credible sabotage scenarios or incidents derived from the applicable the Design Basis Threat (DBT) or threat assessment. This procedure needs to be performed every time there is an alteration in the threat assessment, an alteration in the State determination of URC or a significant change in the inventory of the facility. The procedure includes identification of vital or protected areas which contain radioactive material, equipment, systems and devices, and also the sabotage of which could lead to high radiological consequences, while taking into consideration engineered safety systems which are already present. [84]

At the design stage of a facility, the amalgamation of safety and security requirements at the same time may allow a benefit from synergies. For example, for nuclear safety and security reasons, redundancy and segregation of redundant equipment or systems may provide benefits for safety and for safety. On the other hand, making provisions for redundancy only for safety reasons without providing for segregation may be useful for safety but not for security. The isolation of redundant equipment can also provide security protection against sabotage by requiring more preparation, more equipment and more time for an adversary to complete a malicious act. Thus, they could be very effective to deter, prevent or delay acts of sabotage or to mitigate or minimize the radiological consequences. [85]

Other examples of safety systems that can be used to promote security are continuous air monitors or glove box negative pressure alarms that provide protection for operator personnel, which may be used to generate alarms for potential sabotage or illegal removal. These safety systems could be amalgamated for safety and security protection by creating technical or automatic alarm communications between safety and security disciplines for certain operational or incidental conditions.

The presence of radiation protection measures such as thick concrete walls or shielding barriers provide safety procedures for personnel and may increase adversary delay time to target locations.

Nuclear power plants are generally designed and constructed to handle extreme external and internal loads such as vibration, heat, overpressure and impact in the interest of safety. IAEA guidance provides a procedure for evaluating the ability of a certain subset of a nuclear power plant’s safety related structures, systems and components to survive a sabotage induced event. [86] This guidance includes evaluation of engineered safety features for the protection of nuclear power stations against sabotage, including stand-off attacks.

2.5.2 Nuclear material accounting and control (NMAC)

At every enterprise that has nuclear materials, the accounting and control of these nuclear materials is an obligatory part. In the light of NM, the definition of the actual quantities of NM in the enterprise is understood, for which a set of measures and technical means is organized. The NM accounting and control system provides continuous access to information on the available NM quantity and location.

A robust NMAC programme, at a nuclear power plant aids in deterring and detecting illegal removal of nuclear material by maintaining an inventory of all nuclear material and implementing control measures to maintain continuity of knowledge of the nuclear material and its location. It must have the ability to generate an alarm and to initiate a response if the system specifies that nuclear material may have been removed without permission or approval or is being used in an unlawful manner. An active nuclear accounting and control system can detect malicious insider activity involving nuclear material or nuclear material accounting and control (NMAC) records and support the correct assessment or evaluation of an irregularity involving nuclear material. [87] Hence it is important that the Physical Protection System and NMAC system function in a balanced and complementary manner in order to defeat a wide range of adversary attacks or threats.

There is an IAEA guidance concerning the establishment of a nuclear material accounting and control system for nuclear security at a nuclear facility. [88] This guidance can be used to help ensure an effective interface between the facility Physical Protection System and the nuclear material accounting control system.

2.5.3 Categorization of nuclear material

In determining the level of physical protection to be implemented for nuclear materials in use and storage or during transport, account should be taken of the possibility that the unauthorized removal of plutonium, highly enriched uranium or uranium-233 could lead to the construction of a nuclear explosive device by a technically competent group. The primary factor for determining the physical protection measures against unauthorized removal of nuclear material is the nuclear material itself.

Within a nuclear facility records, the operator has to specify the material and list by location, the type, that is the element contained and, for uranium, the enrichment and composition; depending on IAEA requirements. According to IAEA document on the physical protection of nuclear material and nuclear facilities INFCIRC/225/Rev.5, the nuclear materials that will be present when operating NPP with VVER are:

- plutonium
- Uranium enriched above natural but less than 10% U-235
- Irradiated fuel including depleted or natural uranium, thorium or low enriched fuel (less than 10% fissile content)

These nuclear materials fall under category II according to IAEA requirements and must be protected in agreement with careful or prudent management practice. [89]

2.5.4 Sensitive information Protection

Adversaries wanting to perform any malicious acts against a nuclear facility may gain access to important or sensitive information. Sensitive information may exist in various forms, including software where the unlawful disclosure, modification, alteration, destruction or denial of use could compromise physical protection. Prior to commencement of the designing a PPS, operators need to launch internal guidelines, policies, plans and measures for protecting the confidentiality, integrity and availability of the sensitive information they hold or handle, in agreement with national security policy and the relevant national laws and requirements. [90]

Computer security is a vital element of Physical Protection System design and must be taken into consideration in design stages of the PPS. [91]

2.5.5 Physical protection equipment measures

Physical protection measures include people, procedures, and equipment. These measures are implemented and sustained using management systems.

The aim, objective or goal of a Physical Protection System is to protect against illegal removal of nuclear material and sabotage of nuclear facilities. A Physical Protection System achieves these purposes using the functions of detection and assessment, delay, and response. [92]

A Physical Protection System is designed to meet the fundamental principle of defense-in-depth by the creation of concentric security or layered security areas. The term ‘security areas’ is used to generally to refer to limited access areas, vital areas, inner or protected areas and the concept of a strong room within an inner area.

The design of PPS is usually a difficult and complex process or task. It is advisable that designers create Physical Protection System design and equipment selection with national experts. Further support or assistance, if desired, may be gotten via bilateral cooperation with other States, or from the IAEA. [93]

2.5.6 Risk Based Physical Protection System and Measures

Risk management requires assessing the threat and the potential consequences of the malicious acts, and then developing a legislative, regulatory and programmatic framework which ensures that appropriate effective physical protection measures are put in place.

According to IAEA Nuclear Security Series No. 13, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5), the risk of

- unauthorized or illegal removal of nuclear materials with the intent to construct a nuclear explosive material
- unauthorized removal of nuclear materials which could lead to subsequent dispersal and sabotage

can be managed by:

- **Reducing the threat:** The risk or threat may be reduced, for example, by the use of robust physical measures as deterrence, or through the confidentiality of sensitive information.
- **Improving the effectiveness of the physical protection system:** The physical protection system's effectiveness may be increased, for example, by implementing defense in depth or establishing nuclear security culture.

- **Reducing the potential consequences of malicious acts:** This can be achieved by modifying specific contributing factors, for example, the amount and type of nuclear material and the design of the facility. [94]

2.5.7 Physical Protection Engineering and Technical Equipment (PPETF)

Technical and engineering equipment must be included in the designing and creation of PPS to ensure the achievement of its objectives or goals.

The Physical Protection Engineering and Technical Facilities must ensure:

- consistent and nonstop operation in all operation modes stated or specified.
- monitoring for the existence of faults or malfunctions such as loss of video signal, equipment rupture, attempts to access communication lines, etc. and alerting or sending notification to the operator about this and archiving this information.
- remote monitoring of the operational competences or abilities of the PPETF.

Furthermore, the physical protection engineering and technical facilities must:

- maintain the operational capabilities during disconnection of the main power supply, which ought to be provided by back-up power supplies or systems and performed by automatic switching of the main power supply to the back-up power supply.
- display info to the proper Local Control Unit (LCU) and Central Control Unit (CCU) with required registration of transfer of physical protection engineering and technical facilities or their components over to back-up power supply.

Also, the complex of the physical protection engineering and technical facilities must carry out the following functions:

- collection, processing, analysis and control of all signals, messages and information received.
- provide the possibility of assessing an alarm situation in real time.

- generate and transmit of set signals or messages to the security guard and response units, and to command centers of the physical protection system.
- provide information exchange between central control unit and local control unit.
- develop control actions on the managed physical barriers and means on providing the operations of the physical protection system.
- supervising or monitoring of the status and operational abilities of the physical protection engineering and technical facilities.
- supervising the activities and location of personnel when they are working with nuclear materials, at nuclear installations, and at storage facilities.
- storage and delivering information on the operation of the PPS, attempts or efforts to overcome it, and illegal actions against protected facilities and at the PPETF.

The requirement and technique of information interaction of the physical protection engineering and technical facility complex with systems of nuclear, radiation, environmental, technical and fire safety of a nuclear facility must be stated in the technical specifications for designing and construction or improvement of the PPS.

The physical protection technical facilities (PPTF) are elements or components and devices included in the following key operational or functional systems:

- Intrusion Detection System (IDS)
- alarm system
- Access Control System (ACS)
- Access Monitoring Control Systems
- Opto-Electronic Surveillance and Situation Assessment System (OESS)
- Rapid Communication and Warning System which includes wire and radio communications
- Tele-Communication System (TCS);

- Information Security System (ISS)
- Power supply and lighting Systems

2.5.8 Intrusion Detection System (IDS)

The intrusion detection system is intended to notice efforts of illegal activities and must report these events or actions to the physical protection personnel and other functional systems within the PPS for performance of appropriate and adequate actions, and automatically issue the essential control commands to the activating mechanism and controlled physical barriers.

2.5.9 Access Control Systems (ACS)

They are designed or created for emergency call for response forces, for announcement about commission of unlawful actions, for issuance of signal of coercion on the part of the lawbreaker or intruder, for control of essential functions of the security guard on duty, and for control of passage of patrol along predetermined route.

2.6 Access Monitoring Control Systems (AMCS)

These are designed to control and provide access of workers or personnel to nuclear facility, seconded officials, visitors and passage of vehicles to rooms, buildings, structures, guarded areas, at the territory, and exit from them in accord with the passage regime established at the nuclear facility.

2.6.1 Opto-Electronic Surveillance System (OESS)

The opto-electronic surveillance system is intended for remote supervision of approach avenues, streets or lane to protected areas, boundaries and other perimeters in order to assess the current situation, monitor actions and activities of intruders, direct the actions of the physical protection personnel, as well as to keep a video record.

2.6.2 Rapid Communication and Warning System (RCWS)

Intended or designed for the voice communication and information exchange among the physical protection personnel's in order to provide controlled actions on protection of a nuclear facility in normal and emergency cases.

2.6.3 Tele-Communication Systems (TCS)

It is designed to provide a reliable and accurate information exchange between systems that are part of the physical protection system. The telecommunication systems must transfer precise information, provide continuousness of operations, provide strategically acceptable time of message or signal delivery, systematize, document and store information on TCS functioning, and exchange data with other components systems of different types of safety of the nuclear facility.

2.6.4 Information Security System (ISS)

The information security system is an essential component of an automated PPS. At any level of control and stages of operation of the PPS which include collection, transmission, processing, scrutiny, storage, and transfer of control commands, data or info must be protected or secured using a set of devices and implementation of procedures intended at preventing or avoiding leakage of information or at preventing influence on it via technical channels, or at prevention of unintended or intentional software and hardware impacts with the aim of breaching the integrity, that is, the destruction and distortion of information during its processing, transmission and storage, or interruption of the operational competence of technical equipment.

2.6.5 Power Supply and Lighting Systems

The power supply system is intended to give uninterrupted power supply to the engineering and technical facilities of the PPS. The power supply to the engineering and technical elements must come from two different power sources backing up each other. Transition to backup power system have to be automatic. Information on transition of engineering and technical elements to back-up power must be displayed on the relevant local control unit and central control unit with compulsory recording. Power supply systems and cable networks must be protected against unofficial actions intended at bringing them out of operation.

2.6.6 Physical barriers and engineering equipment

Physical barriers and engineering equipment of the guarded areas and guard checkpoints are also included in the Physical protection engineering and technical facilities.

The engineering systems must:

- obstruct the activities of intruders or offenders when making an illegal intrusion.
- create signals of impact on controlled physical barriers.
- designate the boundaries of guarded areas.
- protect the personnel on duty at control stations of the PPS, personnel on duty at check posts, duty guards at patrol posts and personnel of the security guard units in carrying out responsibilities on prevention of unlawful activities and detention or imprisonment of criminals or lawbreakers.

Physical barriers are created to stop passage of people and automobiles into protected areas and also to hinder or slow down the process and actions of intruders.

Physical barriers are engineering constructions of a nuclear facility and it includes walls, floors, gates, and doors. They are also specially designed and constructed structures which include fences, anti-ram devices, grids, reinforced doors, containers, etc. Natural barriers such as trees along avenues to protected areas are also considered as physical barriers.

In the event of a nuclear facility linking an area of water, actions must be taken to protect and fight against intrusion of offenders through the water area. This may include the installation of networks or other special equipment such as patrol boats if the shoreline makes it impossible to equip the forbidden zone.

The fences of nuclear and storage facilities are intended to stop the passage of people and automobiles to and from protected areas bypassing the check posts or checkpoints. Fences are created along the boundary of protected zones.

The main fence runs along the perimeter of the protected area. A forbidden zone must be located along the boundary of the protected area. The inner and outer fences of the prohibited zone pass through its borders. The fences which have been constructed must meet the following requirements which include:

- the design must have no elements that make it easier to overcome barriers
- there must be minimum number of fractures.

2.6.7 Artificial Obstacles

Artificial obstacles are devices and constructions installed or arranged in a protected area, on approach avenues to buildings, structures protected of protected nuclear installations, storage facilities in order to hinder the movement of offenders and create favorable conditions for their prompt detention by security guard units within the prohibited zone or on approach avenues to buildings and structures.

Artificial obstacles can be permanent and portable, and used for hindering (slowing down) intrusion (movement) of people or vehicles.

The design of artificial obstacles should meet the following requirements:

- hinder the movement of offenders deeper into a nuclear facility for a time sufficient for his prompt detention by security guard units.
- not interfere with normal operation of detection devices.

- provide condition for the safe conduct of duties by the personnel of the security guard units.

The adequacy of artificial obstacles on the perimeters of protected areas should be supported by calculations in evaluating the effectiveness of physical protection system and by the results of exercises.

For the movement of security guard units on vehicles, roads within the territory of a nuclear facility, nuclear installations, storage facilities, as well as special roads (security guard roads) that can be built in a prohibited zone or outside depending on the width of the prohibited zone should be used. Security guard roads should run outside the operation range of detection devices and have a minimum number of intersections with roads and railways existing at nuclear installations and storage facilities. They should be equipped with signs as stipulated by road traffic regulations. Extension should be constructed on the road for U-turn and patrol with oncoming vehicles. Their width and installation frequency should be determined by local conditions.

Warning signs with the inscription: “Prohibited zone. Passage is prohibited (closed)” should be installed along the obstacle line in order to warn about prohibition of passage to prohibited zone. In separate cases, there should be a warning sign with the inscription: “Passage is prohibited for unauthorized persons”. The inscription should be in Russian language, and in some cases – in Russian and in the respective national language. Warning signs should be placed on the inner and outer fences of the prohibited zone, using fencing poles or separate columns. Warning signs should be installed on bends (corners) of a prohibited zone, in wickets and gates to prohibited zones. [95]

3 Categorization and assessment of nuclear facility

3.1 Design layout of nuclear facility to be used in Ghana

Based on the threats and vulnerabilities described above, below is the hypothetical nuclear facility designed for the construction of NPP in Ghana.

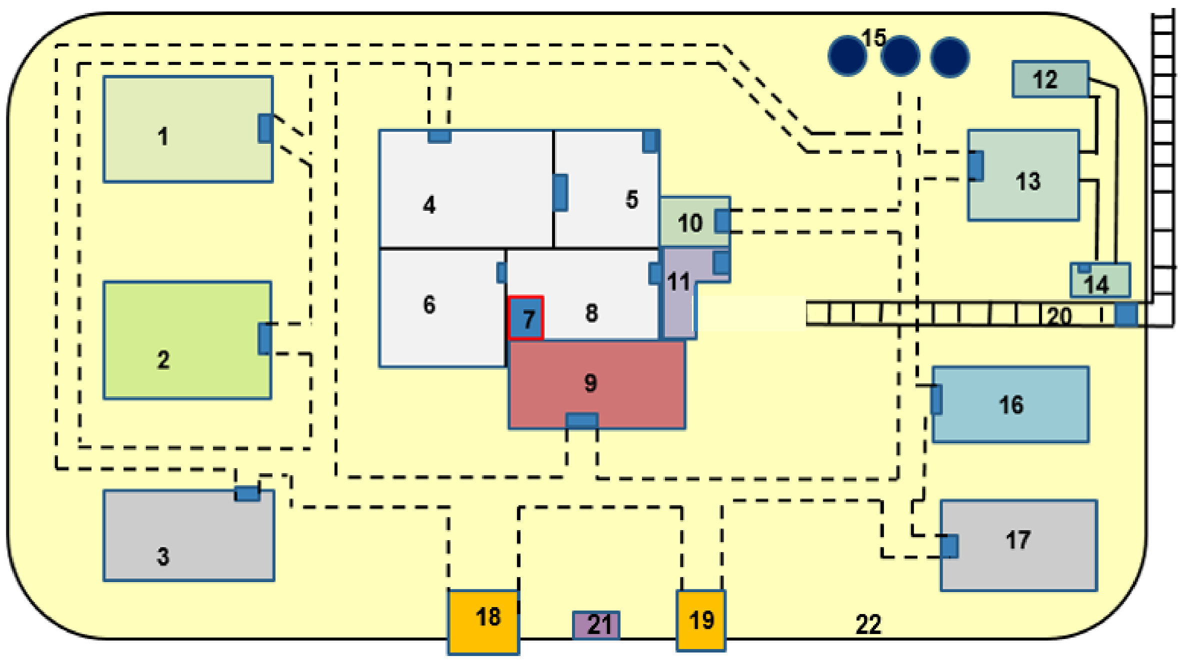


Figure 3.1- A hypothetical site arrangement and Layout plan for the construction of VVER 1000/1200 nuclear power plant in Ghana

1. Transformer yard, 2. Electrical building, 3. Parking field, 4. Turbine building, 5. Service building, 6. Radioactive waste/control building, 7. Fresh fuel building, 8. Reactor building, 9. Diesel generator building, 10. Guard house 1, 11. Vital area main pass/entrance, 12. Service water-pump house, 13. Circulating water-pump house, 14. Guard house 2, 15-Cooling Towers, 16-Spent fuel pool, 17. Main office building, 18. Vehicle checkpoint, 19. Human checkpoint, 20. Railway spur, 21. Main security checkpoint, 22. Outside passive fence

By considering the illegal activities that goes on in Ghana and the existence of the terrorist organization "Boko Haram", the main threats that may arise when operating a nuclear power plant will be theft of nuclear material. Other threats may include sabotage and terrorism.

Based on these activities, the most vulnerable areas of this site are the nuclear waste and control building, spent fuel pool and the transformer yard.

Considering the endemic corruption in Ghana, the radioactive waste and control building could be vulnerable due to the fact that some of the security men tasked to protect the stored radioactive waste from the nuclear power plant might succumb to the blandishments of sundry terrorist groups worldwide and give them access to the radioactive or nuclear waste which they are guarding. These terrorists may use the nuclear waste for the construction of nuclear weapons which may be used to cause mass destruction of the environment.

Also, the spent fuel pool may also be vulnerable. This is because the spent fuel pool is more susceptible to certain terrorist attacks like deliberate aircraft crashes since it is located outside the reactor containment. Terrorist attack on the spent fuel pool may cause leakage of water from the pool and this will cause the fuel rods to heat up the remaining water in the pool, and finally lead to boiling and evaporation. If the water that leaks or boils away is not quickly replenished, the water level will drop, exposing the fuel rods. Once the fuel rod is exposed, it could become very hot and cause the metal cladding encasing the uranium fuel to rupture and catch fire, which will in turn heat up the fuel until it suffers damage. This kind of incident could release large quantities of radioactive substances into the surrounding environment. This can lead to thousands of deaths caused by cancer and billions of dollars in decontamination costs and economic damage. This would begin in current discharged spent fuel, which is hotter than fuel that has remained in the storage pool for a long period of time. Terrorist may attack the spent fuel pool just to cause fear and panic in the surrounding areas.

Furthermore, armed men or terrorist groups in collaboration with private companies which provide power to some parts of the country might sabotage the government by attacking power grids and other utilities which would lead to several days of blackout in some areas or parts of the country in order for the government to allow them to still operate and supply power to those areas, hence the transformer yard is also vulnerable.

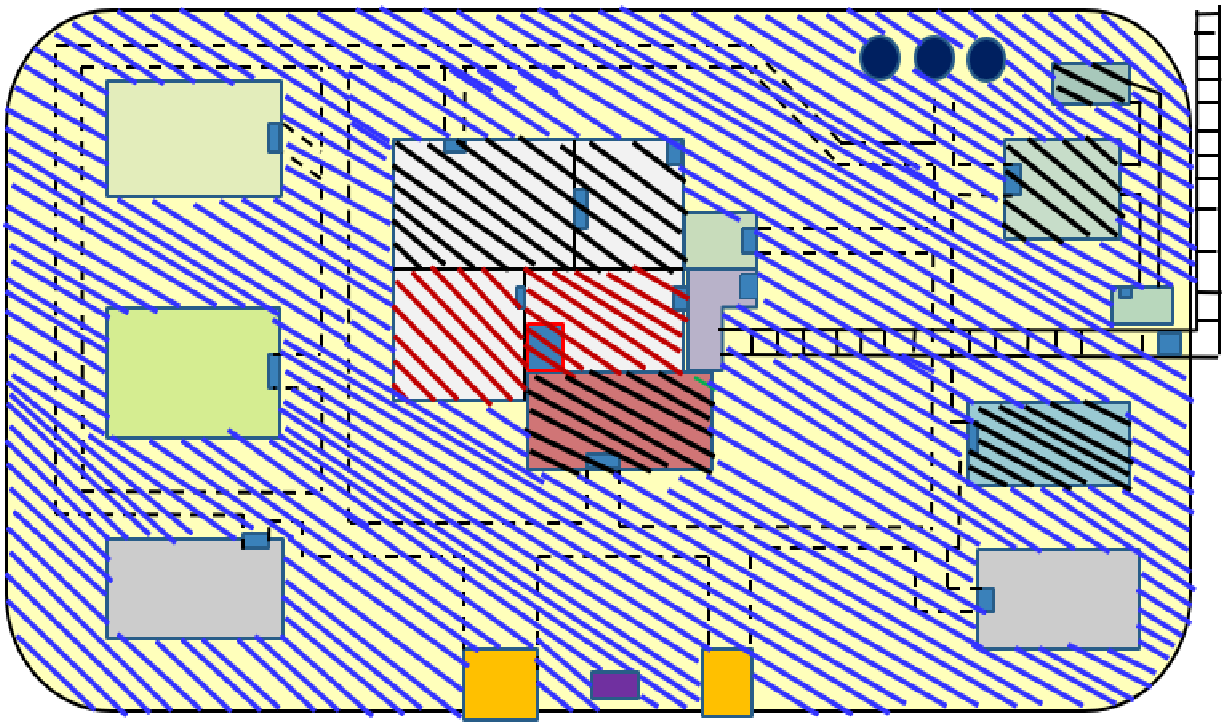
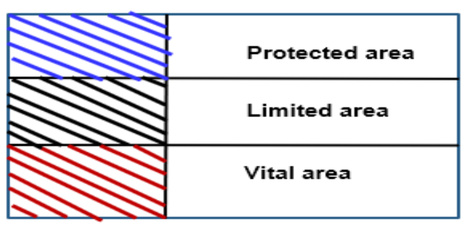


Figure 3.2- Illustration of protected, limited and vital Areas



3.2 The model and scenario of the offender's actions

The intruder model is drawn up to determine the requirements for the PPS. It is a combination of qualitative and quantitative characteristics of the offender. This model illustrates the route that the offender will take in order to get access to the vital and other important areas of the facility. The offenders are expected to be many and fully armed hence lots security guards or forces are expected to arrive at the premises on time to counter the attack.

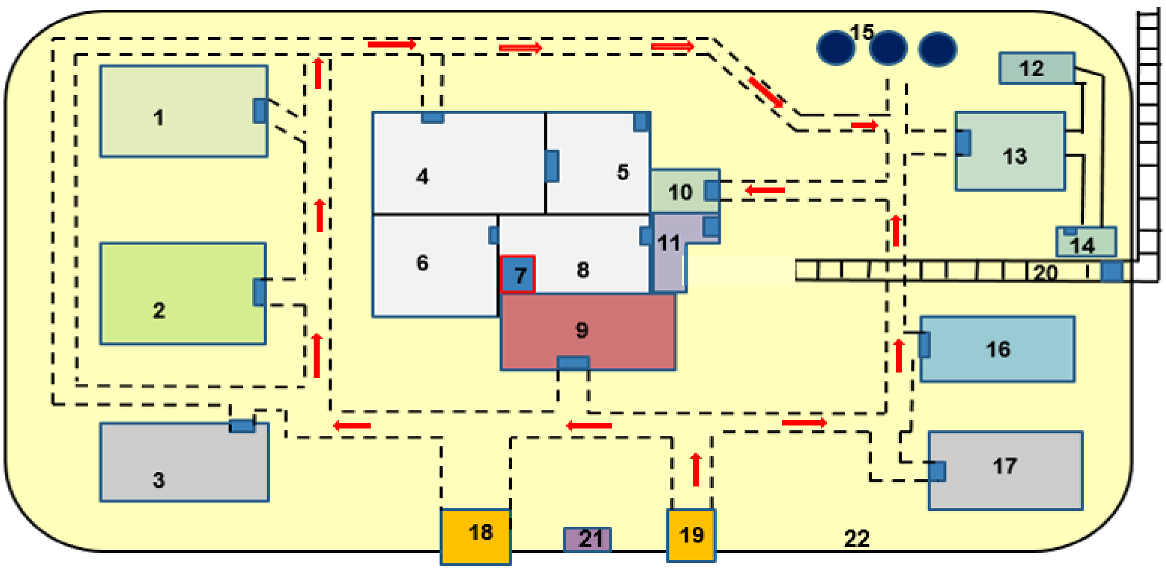


Figure 3.3- Route of offender

3.3 Equipping the checkpoint of human, transport and the protected area

According to IAEA document INFCIRC/225/Revision 5, nuclear Security Series No.13 and TECDOC-1276, in the protected area, there should not be sections of boundaries that are not available for observation. The means of detection must be installed in such a way as to avoid this. The area adjacent to the border of the nuclear facility must be cleared of shrubs.

Approaches to the perimeters of the protected area and the transport checkpoint are equipped with detection devices, watchtowers, monitoring pit, fences, ditches, concrete blocks, and the road is designed in such a way that a steep turn and other options are provided to exclude the possibility of transport over speeding necessary for a breakthrough. For the location of security personnel, a room is provided for security personnel, which is also equipped with surveillance cameras, and alarm-ringing devices. Access to the premises of the protected area is possible only for individuals with a set password.

In the main hall, the access of passing persons is controlled with the use of full-height blocking-type access devices, which ensure reliable detention of persons who do not have access rights or who attempt to carry prohibited items. The hall is also equipped with optoelectronic surveillance system and body scanners with automatic alarm-ringing devices which helps in the detection and prevention of prohibited objects or substances into the premises.

Perimeters of the protected area are equipped with active infrared detector, bi-static microwave detector, capacitance sensors, surveillance or video cameras and communication and alarming devices which are capable of providing detection of unauthorized access, emergency call of reaction forces and presentation of information for assessing the situation, as well as ditches and tongs that delay the violator or slow his progress. Boundaries of the protected areas are designed to provide delay long enough for guards to respond.

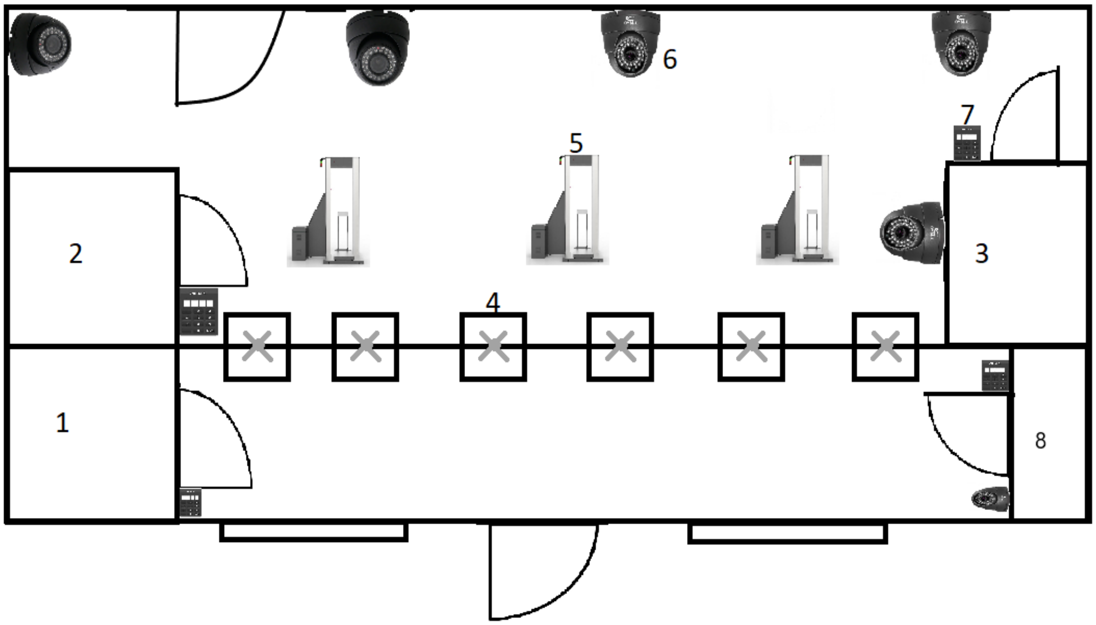


Figure 3.4- Human checkpoint

1. Office of passes
2. Room for personal examination
3. Security personnel room 2
4. Full-height blocking-type access devices
5. Body scanner
6. Surveillance cameras
7. Pin-code keyboard
8. Security personnel room 1

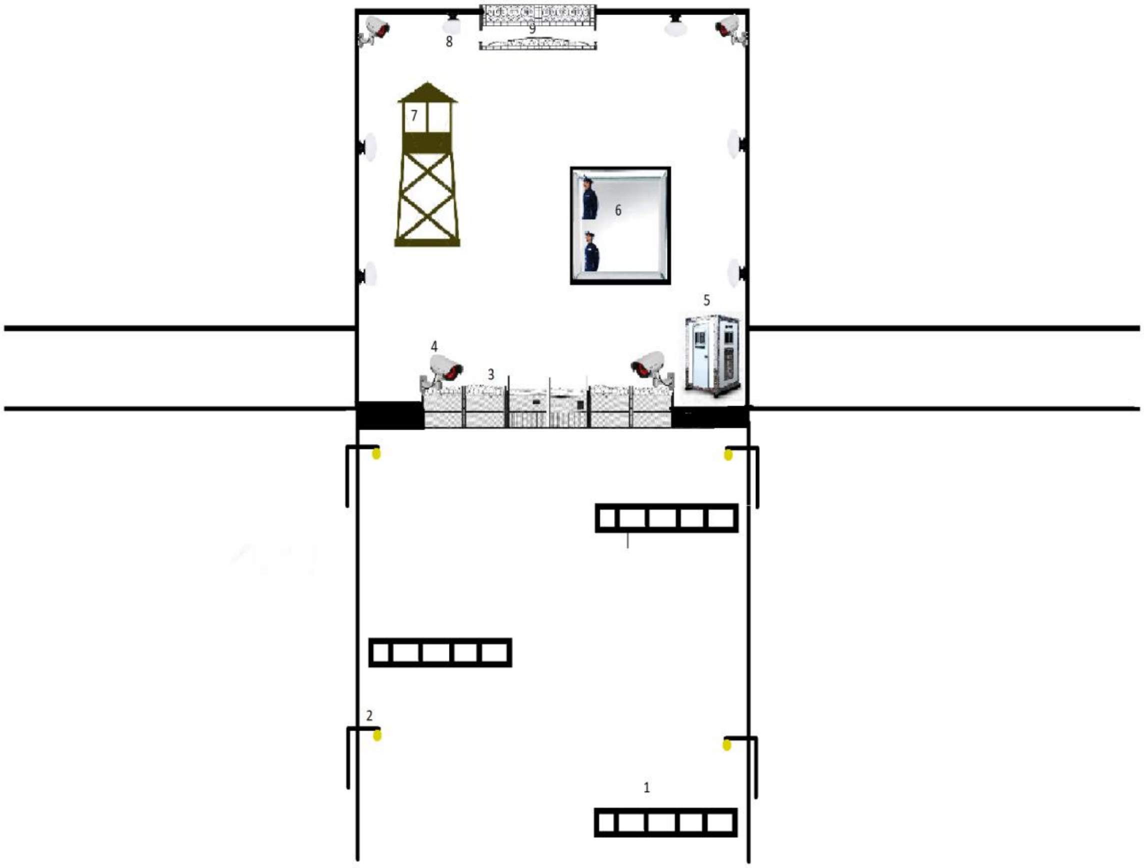


Figure 3.5- Transport route and checkpoint

1. Barriers
2. Street Lights
3. Transport Entrance/Checkpoint
4. Surveillance Cameras
5. Guard house
6. Monitoring pit
7. Watchtower
8. Compound Wall Lights
9. Facility Entrance

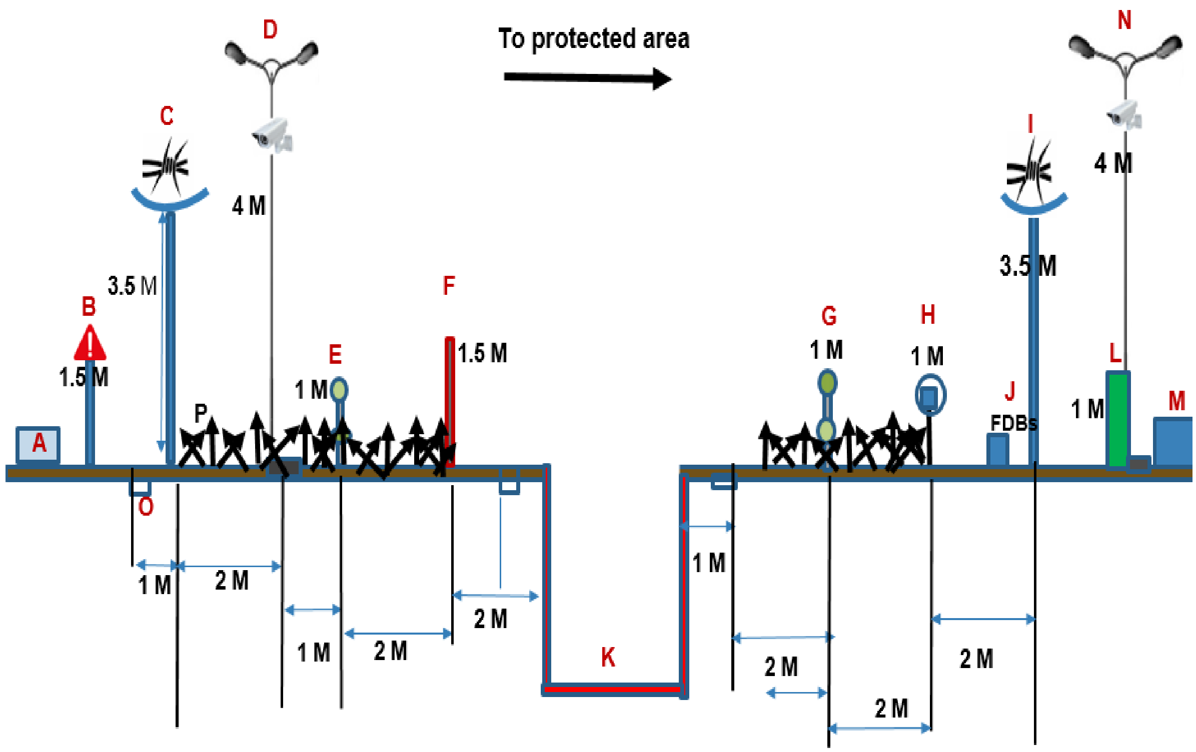


Figure 3.6- Physical protection system

A. Off-Site	I. Inner Area Fence
B. Warning Sign	J. Field Distribution Box (FDB)
C. Outside Passive Fence	K. Ditch/Pit
D. Outside Camera Tower/Light	L. Concrete Block (solid, separate)
E. Bi-static Microwave 1	M. Protected Area
F. Active Infrared	N. Inner Area Camera Tower/Light
G. Bi-static Microwave 2	O. Buried-line Sensor
H. Capacitance Sensor	P. Tongs

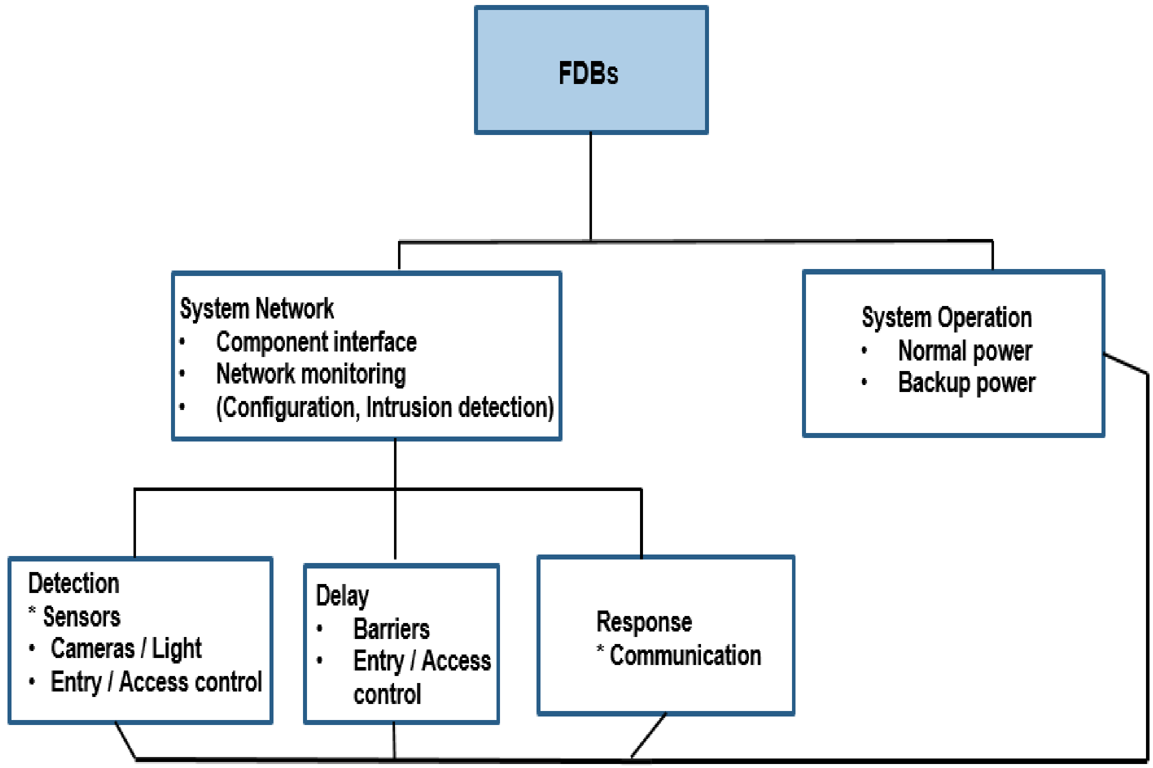


Figure 3.7- Field Distribution Box (FDBs) showing the various components of the PPS

Financial management, resource efficiency and resource conservation.

4.1 Financial Management.

Financial Management refers to planning, organizing, directing and controlling the financial activities such as procurement and utilization of funds of an organization. It is the application of general management principles to financial resources of an organization. [96]

4.1.1 Potential consumers of project results

A potential consumer of PPS is any country that has NPP or an organization that owns Nuclear Material (NM), but for each NPP its own PPS is projected, duplication is excluded. Thus, in the territory of the Russian Federation, both Rosatom and private entrepreneurs that own NM can act as consumers. Also, through Rosatom, it is possible to supply a project abroad, but complete transfer of information to other states is prohibited.

Also, hospitals and industries in Ghana and other countries that makes use of radiation can also be potential consumers of the designed PPS.

4.1.2 Analysis of competitive technical solutions using QuaD technology

Physical Protection System (PPS) can solve one important task, that is, increasing the level of security of most of the protected areas on the site. At the same time, security is provided not by only one element of the system, but by a set of organizational measures together with other engineering and technical facilities.

4.1.3 QuaD technology

This technology is a flexible tool for measuring the characteristics of a new development and its prospects in the market. For greater clarity, this analysis was carried out using the evaluation map presented in Table 4.1.

Table 4.1 - Evaluation card for comparing competitive technical developments

Criteria for evaluation	The weight criteria	Points	Maximal score	Relative Value (3/4)	Weighted average value (3x2)
1	2	3	4	5	6
Indicators for assessing the quality of development					
1.Convenience in operation (meets the requirements of maintenance personnel)	0,05	80	100	0,80	4,00
2. Reliability	0,25	90	100	0,90	22,50
3. Safety in operation	0,05	85	100	0,85	4,25
4. Possibility of improvement	0,12	65	100	0,65	7,80
5. Efficiency	0,22	95	100	0,95	20,90
6. Complexity	0,10	90	100	0,90	9,00
7. Ability to connect to a computer network	0,10	90	100	0,90	9,00
8.Repairability	0,10	95	100	0,95	9,50
Indicators for assessing the commercial development potential					
9.Product Competitiveness	0,01	75	100	0,75	0,75
Total	1	1180	1500	11,80	87,70

Assessment of quality and prospects for QuaD technology is determined by formula:

$$\Pi_{cp} = \sum B_i \cdot b_i \qquad (4.1)$$

Where $\prod_{cp}$ is the weighted average of the quality and prospects indicator scientific development; B_i is the weight of the indicator (in fractions of a unit); and b_i is the weighted average of the i-th index.

If the value of the indicator was from 100 to 80, then this development is considered promising. If from 79 to 60, then the prospects are above average. If from 59 to 40, then the prospects are average. If from 39 to 20, then the prospects are below average.

For the developed project, the value of the indicator is equal to 87.70, which is included in the range of values, which makes it possible to say that this development is promising.

4.1.4 SWOT Analysis

SWOT (Strengths, Weaknesses, Opportunities and Threats) is a comprehensive analysis of a research project. SWOT analysis is used to study the external and internal environment of the project.

Strengths are factors that characterize the competitive side of a research project. Strengths indicate that the project has a distinctive advantage or special resources that are special in terms of competition. In other words, strengths are the resources or opportunities that project management has and that can be effectively used to achieve the goals.

In this work, the designed system has a defense-in-depth plan which makes it complex thereby making it very difficult for adversary to defeat it, hence providing a multi-level protection for the nuclear materials or facilities. It is also designed in such a way that it can easily be modified or adjusted in order to fight new threats.

Weaknesses are a shortcoming, omission or limitation of a research project that hinders the achievement of its objectives. This is something that is poorly achieved within the project or where it has insufficient capabilities or resources compared to competitors.

The main weaknesses of the designed system may arise from human factors such as employee security violations and theft by employee in collusion with outsiders. Also, another weakness of the system is that the modes of it operation has to be kept secret from some of the workers and the general public (privacy).

Furthermore, ageing of some equipment of the complex system such as the information security system (ISS) or entrusting wrong people in charge of ISS can also be a source of weakness.

Opportunities include any preferable situation in the present or future that occurs in the environment of the project, for example, a trend, change, or perceived need that supports demand for project results and allows project management to improve their competitive position.

The use of existing and future IAEA document (IAEA safeguards) on nuclear security which gives recommendations on physical protection of nuclear material, for example applying the rule of two or three persons in the organization can be used as a measure to protect nuclear materials and other vital information. This document also gives ways or measures on how to upgrade the PPS in order to withstand new threats.

Also, the concept of zones can be used as a guide when designing of PPS for use in nuclear facility site. The use of obstacles at the interface of security zones can be used as one of the protection lines when designing a security system which will prevent or delay unauthorized access in order to provide the security organization and authorities to undertake counter measures with sufficient time.

Furthermore, by making analysis of threats that has occurred worldwide (International experience) from human actions will give an idea on how the system should be modified or adjusted in order to counter such threats in the future.

A threat represents any undesirable situation, trend or change in the project environment that is destructive or threatening for its competitiveness in the present or future.

The main threats in the nuclear industry are terrorism, information leakage or loss, and changes of the requirement of normative legal documents.

Some insiders may violate the security of the organization by colluding with outsiders (terrorist), give out passwords and other security pin codes to adversary in order for them to easily defeat the system and get access to vital areas such as the radioactive waste and control room to steal nuclear waste that they can use for nuclear weapon proliferation.

The ageing of information security system can lead to breakdown of these system which may lead to loss of useful information of the organization. Entrusting wrong people in charge of information security systems can also lead to the leakage of vital information.

The change of requirements of normative legal documents is a threat due to the fact that the organization may not have enough funds to modify the system anytime there is an upgrade or adjustment of the requirement on how to design security system based on new threats.

Below are some measures that can help to reduce the threats and weaknesses of the designed system based on comparison of the SWOT described above.

Adding of protection levels such as the use of biometrics as form of identification and access control can help to limit or control terrorist access to information systems and protected areas since the use of body parts is what can enable them to gain access to those systems and areas.

Adaptation of all levels of protection such as upgrading or making changes in rapid response plan and tactics to counter new threats anytime there is a change in legal requirements of how to design a security system will also help to increase the security level in the organization.

Reservation of information security systems can be made in order to be able to recover lost information in case there is a breakdown of the old equipment. Only trusted people in the organization must be given the authority to have access to information security system. This brings about confidentiality since only authorized persons gets to read vital information thereby preventing the leakage of information. It also ensures that information and programs are changed only in a specified and authorized manner (Integrity).

Table 4.2 presents the interactive project matrix, which shows the correspondence of strengths to capabilities, which allows for more detailed consideration of the development prospects.

Table 4.2- Interactive matrix of the project

	S1	**S2**	**S3**	**W1**	**W2**	**W3**
O1	+	+	-	+	-	-
O2	+	+	+	-	-	-
O3	-	-	+	+	-	-
T1	+	+	+	+	-	-
T2	+	+	+	+	+	+
T3	-	+	+	-	-	-

Based on the result of the SWOT analysis above, a final SWOT-analysis matrix is presented in Table 4.3.

Table 4.3-SWOT Analysis

	Strengths: S1- complex S2 - multi-level protection S3 - adaptability	**Weak sides:** W1 - dependence on the human factor. W2 – privacy. W3 – Ageing of information security systems/ wrong in charge of information security systems
Capabilities: O1 - IAEA safeguards O2 - Concept of zones and the use of zones within one another. O3 - use of international experience	O1S1S2- Compliance with IAEA recommendations. O2S2S3- Use of obstacles at the interfaces of zones as one of the protection lines. O3S3- Adapt the system against new threats	O1W1- Applying the rule of two or three persons. O3W1- Analysis of international experience for threats from human actions.
Threats: T1 – Terrorism T2 – loss/ leakage of Information T3 - change of requirements of normative legal documents	O1T2S1S2- Adding protection levels, Information control. T3S2S3- Adaptation of all levels of protection for changes. O1S3- Rapid response and adaptation to new terrorist threats. T2S3- Improvement	O1W1- Biometrics T2W1W2- Control of access to information. T2W3. Reservation of information security systems

4.1.5 Evaluation of the Project Readiness for Commercialization

Table 4.3 - Assessment of the Readiness of the Research Project to Commercialization

S/No	Criteria	Degree of elaboration in the research project	Level of developers existing knowledge
1	Scientific and technical potential is determined.	5	5
2	Promising areas of commercialization of scientific and technological potential are identified.	5	5
3	Industries and technologies (products and services) to offers on the market are identified.	5	5
4	Commodity form (product form) of the scientific and technical basis for the presentation to the market is determined.	4	4
5	Author is identified and protection of their rights is secured.	4	5
6	Assessment of the value of Intellectual Property is done.	4	5
7	Marketing research of potential markets is carried out.	5	5
8	Business plan for commercialization of scientific development is developed.	4	4
9	The ways of promoting scientific development to the market.	5	5
10	The strategy (form) the implementation of scientific development is developed.	4	5
11	International cooperation potential and access to foreign markets are studied.	5	5
12	Use of infrastructure support services to receive benefits is studied.	4	5

13	Funding issues commercialization of scientific development is formed.	4	4
14	Team for the commercialization of scientific development is formed.	3	5
15	Arrangements for the implementation of a research project are made.	3	4
16	Total points (B_{sum})	64	71

Readiness Assessment research project to commercialization (or the level of existing knowledge from the developer) is defined by the formula:

$$B_{sum} = \sum B_i \tag{4.2}$$

where B_{sum} is the total number of points in each direction; and B_i is the point on the i-th indicator.

The value of B_{sum} suggests the extent of readiness of scientific development and its developer to commercialization. For example, if the value of B_{sum} turned out between 75 and 60, such a development is considered promising, and the developer of knowledge sufficient for successful commercialization. If 59 to 45, it means that the prospect is above average. If 44 to 30, it means average prospect. If 29 to 15, it means that the prospect is lower than average. If 14 and below, it means the prospect is extremely low.

Hence the evaluation concludes that the volume of investment in the ongoing development and direction of further development is considered promising, and developer of knowledge sufficient for successful commercialization.

4.1.6 Planning for the management of the scientific and technical project

The organizational structure of the project is the most appropriate a temporary organizational structure that includes all its participants and is created to successfully achieve the project's objectives.

Development of the organizational structure of the project includes:

- Identification of all organizational units
- Defining the roles of project participants and their interaction,
- Definition of responsibility and authority
- Distribution of responsibility and authority between organizational units of the structure
- Development of instructions regulating interactions in the structure and working procedures.

The organizational structure of the project is a dynamic structure, which is undergoing changes in the project implementation process. These changes depend on the phases of the life cycle of the project, the types used in project contracts, and other conditions for the implementation of the project.

The Project stakeholders and Participants include:

- Research Institute (Performer: Heads, Supervisors and Students)
- Business company dealing with radiation monitoring and Nuclear fuel use activities (Head of Company, Engineers and Consultants)
- Educational Institutions (Head, Engineers and Consultants)

4.1.7 Structure of work under the project

In the process of creating the hierarchical structure of the project, the content of the entire project is structured and defined. The planning process group consists of the processes performed to determine the overall content of the work, clarify the objectives and develop the sequence of actions required to achieve these goals. Work breakdown Structure (WBS) - detailing of the enlarged work structure: the division of the entire volume of the planned work into small operations so that they correspond to the level at which the way of performing the planned actions would be clear, and the operations would be evaluated and planned

Table 4.4- Morphological matrix for research implementation alternatives

Characteristics	Alternatives		
	1	2	3
Entity	University	Research Institute	Business Company
Executives	Supervisor	Head of institute	Head of Company
Materials	Free	Bought	Bought
Equipment	Free	Bought	Rented
Software	General	Special	Special
Software access	Free	Free	Free
Facilities	Classroom	Lab	Office
Facilities access	Free	Bought	Rented

4.1.8 Project plan

As part of the planning of the research project, a calendar schedule was constructed. In this case the Gantt chart was used to map the distribution of the work carried out. Gantt chart is a type of bar charts which is used to illustrate the planned schedule of project, in which the works can be shown the extensive length of time, characterized by the dates of beginning and end of the implementation of these works.

The graph is constructed and shown in table 4.5 below by month and seven-day working periods during run-time of project. The difference in the length of the distribution of each working period largely depends on the task needed for a particular work. The task performed are written and shown in appendix. The work on the topic is represented by long stretches of time, characterized by the dates of commencement and completion of work. The linear graph is presented in Table 4.6.

Table 4.5- Stages of work and executors

Main stages	Duration, days	Work content	Position performer
Development of technical specifications	3	Drafting and approval of technical specifications	Supervisor
Choice of direction research	90	Selection and study of materials on the topic	Engineer
	90	Conducting patent research	Engineer
	5	Choice of Research Directions	Supervisor Engineer
	5	Scheduling of work on the topic	Supervisor Engineer
Theoretical research	5	Consideration of similar crimes	Engineer
	5	Selection of Physical protection engineering and technical equipment, Categorization of nuclear facility	Supervisor Engineer
	10	Conducting a vulnerability Analysis	Engineer
	15	MC & A organization	Engineer
Carrying out of modeling			
Development of technical documentation and design	15	Drawing up the plan of the object	Supervisor Engineer
	20	Designing of PPS and calculation of PPS effectiveness	Supervisor Engineer

Table 4.6 - Work schedule

work Number	Type of work	Performers	Tк, cal, days.	Duration of work execution														
				Feb			March			April			May			June		
				1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	Drafting and approval of technical specifications	Supervisor	3															
2	Selection and study of materials on the topic	Engineer	90															
3	Conducting patent research	Engineer	90															
4	Choice of Research Directions	Supervisor Engineer	5 5															
5	Scheduling of work on the topic	Supervisor Engineer	5 5															
6	Consideration of similar crimes	Engineer	10															
7	Selection of Physical protection engineering and technical equipment, Categorization of nuclear facility	Supervisor Engineer	15 15															

8	Conducting a vulnerability analysis	Engineer	10															
9	MC & A organization	Engineer	5															
10	Drawing up the plan of the object	Supervisor Engineer	15 15															
11	Designing of PPS and calculation of its effectiveness	Supervisor Engineer	20 20															

	Supervisor
	Engineer

4.1.9 Budget of scientific research

When planning the research budget, it must be ensured that full and reliable reflection of all types of costs associated with its implementation. In the process of budget formation, cost like material costs, costs for special equipment for scientific work, additional salaries among others were calculated. The scientific work was carried out under a budget allocated to a supervisor and one student of the university. The supervisor is allocated 300 Rub per hour and the engineer has 100 Rub per hour. The total cost incurred during the cost of the project was then calculated and shown below. The main costs in this research are costs for electricity and purchase of office supplies. The cost of electricity is calculated by the formula:

$$C = T_{el} \cdot P \cdot t = 6 \cdot 0.5 \cdot 600 = 1800 \tag{4.3}$$

where T_{el} - tariff for industrial electricity (6 rubles per 1 kW · h);

P - capacity of equipment, kW;

t - time of use of equipment, h (120×5).

The cost of electricity amounted to 1800 ruble

4.2 Raw materials, purchased products and semi-finished products

This item includes the cost of all kinds of purchasing materials, components and semi-finished products necessary for the implementation of works on the subject. Number of required material values determined by the norms of consumption.

Material cost calculation is carried out according to the following formula:

$$C_m = (1 + K_{tr}) \cdot \sum_{i=1}^{m} p_i \cdot N_i \tag{4.4}$$

Where m – number of types of material resources consumed in carrying out scientific research;

N_i – the number of physical resources i-th species, planned to be used in carrying out scientific research (pieces, kg, m, mon.);

P_i– acquisition unit price i-th species consumable material resources (rubles / pc, rub / kg, rub / m, rub / m etc.....);

K_{tr}– coefficient taking into account transportation and procurement costs.

Calculating the expenses of material costs based on the current price list or negotiated prices. The expenses of material costs include transportation and procurement costs (15-25% of the price). In the same item, includes the expenses of paperwork (stationery, copying materials). The results of this term are presented in the Table 4.7 below.

Table 4.7 - Raw materials, components and semi-finished products

Title	unit	Quantity			Price per each, ruble			The sum, ruble		
		Atl 1	Alt 2	Alt 3	Atl 1	Alt 2	Alt 3	Atl 1	Alt 2	Alt 3
Electricity	-	600 kW°hr	620 kW°hr	640 kW°hr	6	6	6	1800	3100	3120
Paper	SvetoCopy	1 packet of 500 sheets	1 packet of 500 sheets	1 packet of 500 sheets	0.54	0.54	0.54	270	270	270
Printing	-	400	420	430	2	2	2	800	840	860
Pen	Stabilo	4	4	4	30	30	30	120	120	120
Access to the Internet	-	4 months	4 months	4 months	350	350	350	1400	1400	1400
Total of materials								4390	5730	5770
Transportation and procurement expenses (15%)								659	860	866
Total items $C_м$								**5049**	**6590**	**6636**

4.2.1 Calculation of costs for special equipment for scientific

This item includes all costs associated with the acquisition of special equipment necessary for work on specific topic. In this research work on special equipment, necessary for carrying out experimental work is a personal computer which costs 26,000 rubles, with a life service of 4 years.

Table 4.8 - Budget cost for the purchase of special equipment for scientific paper

#	Name of equipment	Number of units of equipment			unit price of equipment, ths. Rub.			The total cost of equipment, ths. Rub.		
		Atl 1	Alt 2	Alt 3	Atl 1	Alt 2	Alt 3	Atl 1	Alt 2	Alt 3
1	computer	1	1	1	26000	36000	40000	26000	36000	40000
Total:								26000	36000	40000

4.2.2 The basic salary of the performers of the topic

The article includes the basic wages of employees, directly involved in the implementation of the project (including bonuses, co-payments) and additional wages.

The item includes basic wages of workers directly involved in the implementation of the project (including premiums, bonuses) and additional wages.

Table 4.9 – Calculation of basic salary

#	Executives	Work, person-days.			Salaries per one person-days, ths. Rub.			Total salaries at the rate (salary), ths. Rub.		
		Atl 1	Alt 2	Alt 3	Atl 1	Alt 2	Alt 3	Atl 1	Alt 2	Alt 3
1	supervisor	36	-	-	2760	-	-	99360	-	-
2	Head of Lab	-	42	-	-	3680	-	-	154560	-
3	Research Director	-	-	48	-	-	4600	-	-	220800
4	student	120	-	-	920	-	-	110400	-	
5	Specialist	-	50	-	-	2760	-	-	138000	-
6	Engineer	-	-	70	-	-	1840	-	-	128800
Total								**209760**	**292560**	**349600**

4.2.3 The main salary of the performers of the topic

The article includes the basic wages of employees, directly involved in the implementation of the project (including bonuses, co-payments) and additional wages.

The item includes basic wages of workers directly involved in the implementation of the project (including premiums, bonuses) and additional wages.

$$S_t = S_b + S_{ad} \tag{4.5}$$

where S_b – basic salary;

S_{ad} – additional salary.

Basic salary can be calculated, based on hourly labor rates:

$$S_b = S_h * 8 \quad (4.6)$$

where S_h - basic salary of one employee per hour, rub/hour; Hourly labor rate may vary depending on the type of executive in the research project.

4.2.4 Additional salary of performers of the topic

Costs for additional pay for the performers of the topic allowance for the amount of additional payments foreseen in the Labor Code of the Russian Federation for deviation from normal working conditions, as well as payments related to guarantees and compensation.

The additional salary is calculated on the basis of 10-15% of basic salaries of employees directly involved in implementation of the topic:

Calculation additional salary conducted according to the following formula:

$$S_{ad} = k_{ad} * S_b \quad (4.7)$$

where kad - factor of additional salary (taken at the design stage at 0.12 - 0.15).

We take the coefficient of additional salary equal to 0.15 for the supervisors while 0.12 for an engineer, student and specialist. The results of calculating the main and additional wages of performers of scientific research are presented in Table 4.10.

4.2.5 Contributions to social funds (insurance contributions)

In Russian Federation, employees pay insurance payments for state social insurance fund (SIF), the Pension Fund (PF) and medical insurance fund (MIF). Employers on behalf of the employees make these payments. Contributions to these funds determined based on the following formula:

$$S_f = k_f * (S_b + S_{ad}) \quad (4.8)$$

where k_f - coefficient for payments to funds (SIF, PF, MIF).

In 2018 the size of insurance payments was set at the level of 30%. Yet for institutions engaged in educational and scientific activity the reduced rate of 27,1% is used. Social funds contributions have been calculated and tabulated in Table 4.10

Table 4.10 Contributions to social funds

Artist	basic salary, rubles.			Additional salary, rubles.		
	Alt.1	Alt.2	Alt.3	Alt.1	Alt.2	Alt.3
Supervisor	2400			360		
Head of Lab		3200			480	
Research Director			4000			600
Student	800			120		
Specialist		2400			360	
Engineer			1600			240
Ratio of contributions to social funds	27,1%	27,1%	30%	27,1%	27,1%	30%
Total amount of social fund payments						
Alternative 1	997					
Alternative 2	1745					
Alternative 3	1932					

4.2.6 Overhead costs

This article includes the costs of management and maintenance, which can be attributed directly to a particular topic. In addition, this includes expenses for the maintenance, operation and repair of equipment, production tools and equipment, buildings, structures, etc. The calculation of overhead costs is carried out according to the following formula:

$$C_{ovh} = C_{total} * k_{ovh} \qquad (4.9)$$

Where C_{total} – Total costs of the above cost items in 1 – 7 and

k_{ovh} – Overhead coefficient, which can be taken at a rate of 16%.

Table 4.11 - Overhead Expenses

	Alt 1	Alt 2	Alt 3
C_{total}	241806	336895	398168
K_{ovh}	38689	53903	63707

The calculated value of the costs of research work is the basis for the formation of the project cost budget, which, when forming an agreement with the customer, is protected by a scientific organization as the lower limit of the cost of developing scientific and technical products.

The definition of the cost budget for a research project for each option is shown in Table 4.12.

Table 4.12 – Calculation of the expenditure budget of the research project

S.No	Name of the item	Amount, Rubles		
		Alt 1	Alt 2	Alt 3
1	Material costs of the study	5049	6590	6636
2	Expenses for special equipment	26000	36000	40000
3	Costs for the salaries of the performers of the topic	209760	292560	349600
4	Contributions to social funds	997	1745	1932
5	Overhead expenses	38689	53903	63707
6	Research Cost Budget	**280495**	**390798**	**461874**

4.2.7 Effectiveness and efficiency of resources

The definition of efficiency is based on the calculation integral indicator of the effectiveness of the scientific research and this can be related to the definition of two weighted averages; financial efficiency and resource efficiency.

Integral component cost-effectiveness research obtained during budget cost estimates three (or more) variants of scientific studies (see Table 4.13). To do this, the most integral indicator of the implementation of the technical problem is taken for the calculation base (the denominator), which relates to the financial value of all the embodiments.

Integral financial efficiency indicator development is defined as:

$$E_{\mathrm{fin}}^{\mathrm{alt.i}} = \frac{TC_i}{TC_{max}} \tag{4.10}$$

where $E_{\mathrm{fin}}^{\mathrm{alt.i}}$ – an integral index of financial efficiency;

TC_i – Total cost of the i-th alternative;

TC_{max} – the maximum total cost of research project (including analogs).

The obtained value of the integral financial indicator of the development reflects the corresponding numerical increase in the development costs budget in times (value greater than one), or the corresponding numerical reduction in the cost of development in times (the value is less than one, but greater than zero).

Since the development has one execution, then;

$$E_{fin}^{alt.1} = \frac{TC_1}{TC_{max}} = \frac{280495}{461874} = 0{,}61$$

For analogues respectively:

$$E_{fin}^{alt.2} = \frac{TC_2}{TC_{max}} = \frac{390798}{461874} = 0{,}85$$

$$E_{fin}^{alt.2} = \frac{TC_2}{TC_{max}} = \frac{461874}{461874} = 1$$

Integral resource-efficiency indicator of research alternatives can be determined as follows:

$$E_{\text{res}}^{\text{alt.i}} = \sum a_i \cdot b_i \quad (4.11)$$

Where $E_{\text{res}}^{\text{alt.i}}$ – an integral indicator resource for i-th embodiment of the development;

a_i – weight factor of i-th research alternative;

b_i – a score of i-th execution of development options is set by an expert in the chosen scale of assessment;

n – number of parameters comparison. Calculation of the integral indicator resource is recommended in tabular form (Table 4.13).

Table 4.13 - Comparative evaluation of characteristics of the project alternatives

Criteria	Weighting coefficient of the parameter a_i	b_i Score		
		Alt.1	Alt.2	Alt.3
1. Convenience in operation (meets the requirements of maintenance personnel)	0,05	3	3	5
2. Reliability	0,25	5	4	4
3. Safety in operation	0,05	4	5	4
4. Possibility of improvement	0,12	4	5	5
5. Efficiency	0,22	4	5	4
6. Complexity	0,10	4	5	4

7. Ability to connect to a computer network	0,10	4	5	5
8. Repairability	0,10	3	4	4
9. Product Competitiveness	0,01	4	5	5
Total	1			

Alt.1 = 0,05*3+0,25*5+0,05*4+0,12*4+0,22*4+0,1*4+0,1*4+0,1*3+0,01*4=4,50

Alt.2= 0,05*3+0,25*4+0,05*5+0,12*5+0,22*5+0,1*5+0,1*5+0,1*4+0,01*5=4,55

Alt.3 = 0,05*5+0,25*4+0,05*4+0,12*5+0,22*4+0,1*4+0,1*5+0,1*4+0,01*5=4,28

Integral total efficiency indicator of alternatives is determined based on the integral resource and financial efficiency by formula:

$$E_{\text{total}}^{\text{alt.i}} = \frac{E_{res}^{\text{alt.i}}}{E_{\text{fin}}^{\text{alt.i}}} \tag{4.12}$$

Hence

$$E_{total}^{alt.1} = \frac{\mathrm{E}_{\text{res}}^{\text{alt.1}}}{\mathrm{E}_{\text{fin}}^{\text{alt.1}}} = \frac{4{,}50}{0{,}61} = 7{,}38;\ E_{total}^{alt.2} = \frac{\mathrm{E}_{\text{res}}^{\text{alt.2}}}{\mathrm{E}_{\text{fin}}^{\text{alt.2}}} = \frac{4{,}55}{0{,}85} = 5{,}35;\ E_{total}^{alt.3} = \frac{\mathrm{E}_{\text{res}}^{\text{alt.3}}}{\mathrm{E}_{\text{fin}}^{\text{alt.3}}} = \frac{4{,}28}{1} = 4{,}28$$

Comparison of the integrated indicator of the effectiveness of the current project and its analogues will determine the comparative effectiveness of the project. Comparative efficiency of the project:

$$E_{\text{comp}}^{\text{alt.i}} = \frac{E_{total}^{\text{alt.i}}}{E_{\text{total}}^{\text{min}}} \tag{4.13}$$

The result of calculating the comparative efficiency of the project and the comparative effectiveness of the analysis are presented in Table 4.14.

Table 4.14 Comparative development effectiveness

№ p / p	Indicators	Alt.1	Alt.2	Alt.3
1	Integral financial efficiency indicator	0,61	0,85	1,00
2	Integral resource-efficiency indicator	4,50	4,55	4,28
3	Integral total efficiency indicator	7,38	5,35	4,28
4	Comparative project efficiency indicator	1,72	1,25	1,00

Comparison of the values of integral performance enables to understand and select most effective alternative for solution of the technical problem in the research taking into account financial and resource efficiency. Therefore, Alternative one is proved to be more efficient compared to the other two alternatives.

Social Responsibility

The creation and implementation of an integrated Occupational Safety and Health (OSH) management system is an integral part of the successful conduct of preventive work to reduce the level of injuries in the workplace and reduce the percentage of occupational morbidity. This system is implemented at all stages of the production process by creating a unified system of targeted actions by combining all ongoing measures for labor protection.

Occupational safety is a system of socio-economic, legislative, therapeutic and preventive and other measures and means that ensure the preservation of health, safety and human health in the work process.

In order to develop a safe working environment and avert accidents of people during process of work, rules are introduced for occupational safety and health, which are obligatory for engineering and technical workers, employees and supervisors.

A dangerous factor or industrial hazard is a factor whose impact under certain conditions leads to trauma or other sudden, severe deterioration of health of the worker [97].

A harmful factor or industrial health hazard is a factor, the effect of which on a worker under certain conditions leads to a disease or a decrease in working capacity.

5.1 Harmful and hazardous production factors Analysis

It is necessary to take into account the dangerous production factors (DPF) and harmful production factors (HPF), which arise when working on a computer. Identified DPF and HPFF are presented in Table 5.1. It should be noted that under the conditions in which the work was carried out, there is no influence of DPF.

Table 5.1 - The main elements of the production process, forming DPF and HPF

Name of work types and parameters of the production process	Factors in accordance with GOST 12.0.003-74 SSBT		Regulations
	Harmful	Dangerous	
Work on a computer	The impact of radiation (microwave, UHF, VHF, HF, etc.)	–	SanPIN 2.2.2 / 2.4.1340-03 Sanitary-epidemiological rules and regulations. "Hygienic requirements for PC and organization of work"
	–	Electricity	GOST 12.1.038-82 SSBT. Electrical safety
	–	Fire safety	GOST 12.1.004-91 SSBT. Fire safety.

5.1.1 Organizational arrangements for work on a computer

All personnel’s working on a computer must strictly observe the safety rules. Training of personnel of safety and industrial sanitation involve induction training and Education at the workplace, conducted by the responsible person.

Testing of knowledge of safety rules by the qualification commission is conducted by personnel after training at the workplace.

Persons engaged in servicing the electrical installation should not have bruises or injuries, medical contraindications that interfere with production work. The medical examination determines the health status of persons engaged in the production process.

5.1.2 Technical measures

The workplace must be planned in such a way that a clear order is provided, items, tools and documentation must have a permanent placement. Objects necessary for the performance of work must be placed in the easy reach of the workplace as shown in figure below.

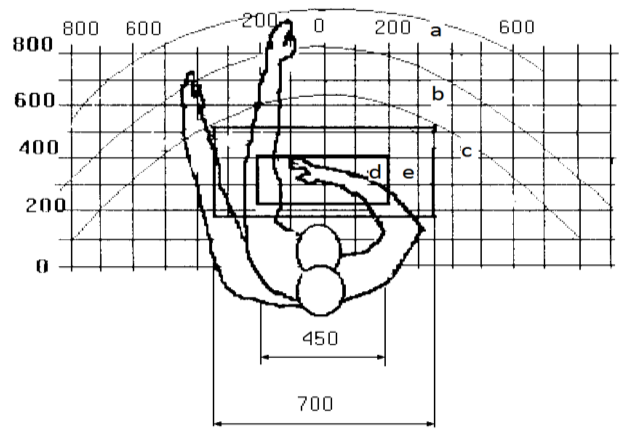


Figure 3.9 - Hand reach zones in the horizontal plane

a. Zone of maximum reach of hands;

b. reach zone of fingers with outstretched arm;

c. easy reach zone of the palm;

d. Optimum space for fine handmade work

e. the optimum space for rough manual work

The optimal placement of objects of labor and documentation in the reach of hands are described below.

- the display is located in zone a (in the center)
- keyboard - in the area of e / d
- the system unit is located in zone b (on the left)
- the printer is in zone a (right)

The documentation is placed in the easy reach of the palm - in (left) - literature and documentation necessary for work; In the drawers of the table - literature that is not used constantly.

The desk for writing should be designed taking into account the following requirements:

- The height of Working table is 680-800 mm;
- Working table width is not less than 700 mm and the length is not less than 1400 mm.
- the height of the legroom is not less than 600 mm, the width is not less than 500 mm, the depth at the level of the knees is not less than 650 mm.
- The work chair must be chosen in such a way that it is up and down and that it is possible to adjust the height and angle of the seat and backrest.
- The recommended seat height is (420-550 mm) above the floor. The width and depth of the seat surface should be at least 400 mm, and the seat surface should be with a recessed front edge.
- The computer monitor should be located at the eye level of the operator at a distance of (500-600) mm.
- The level of contrast and brightness of the image on the screen should be chosen in such a way as to reduce the irritating effect on the visual apparatus of the operator. Also, for convenience and compliance, when selecting a computer, it should be possible to adjust the position of the screen.
- The keyboard should be located on the surface of the table at a distance from the edge of 100-300 mm. The normal position of the keyboard for work is its placement at the level of the operator's elbow with an angle of inclination to the horizontal plane of 15 degrees. The most convenient for work are keys having a concave surface, a quadrangular shape with rounded corners. The keyboard should be chosen so that the color of the keys is contrasted with the color of the panel.
- At work, which requires intensive mental or physical tension, shades of warm tones that excite human activity are recommended.

5.1.3 Safe working conditions

The main parameters that characterize working conditions are noise, microclimate, electromagnetic field, vibration, illumination, radiation.

The creation of a microclimate (air in the workplace) of industrial premises is based on parameters such as temperature, air speed and relative humidity.

The optimal and permissible values of the microclimate characteristics are given in Table 5.2.

Table 5.2- Optimal and permissible parameters of the microclimate

Period of the year	Ttemperature, °C	Relative humidity (%)	Air velocity, m/s
Cold and Transitional	23-25	40-60	0,1
Warm	23-25	40	0,1

Among the activities for the improvement of air quality in the workplace include: proper organization of ventilation and air conditioning and heating facilities. Ventilation can be in the form of natural and mechanical means. The rooms of the premises or buildings must have the following amounts of outside air: the volume of the room must be up to 20 m^3 per person or not less than 30 m^3 per hour per person; when the volume of the room is more than 40 m^3 per person and there is no emission of harmful substances, there shall be natural ventilation.

The heating system must provide adequate, consistent and uniform heating of the air. In areas with high demands for clean air must use water heating system. Parameters used in the climate laboratory governed by a central heating system and have the following meanings: humidity of 40%, air velocity of 0.1 m / s, and temperatures in the summer of 20-25 ° C, winter temperature is 13-15 ° C. The laboratory uses natural ventilation. The air enters and leaves through the slits, the windows, the doors. The main problem of such a ventilation that supply air enters the room without purification and heating.

In the course of work, harmful and disturbing factors can include vibration, noise, and other worsening working conditions which have a harmful effect on the human body and on the hearing organs through the central nervous system.

Due to this, the response is reduced, attention is weakened, the number of errors increases, and memory deteriorates. The noise level at the workplace when working on a PC should not exceed 50 decibel (dB). in the frequency range 2 kHz - 400 kHz - 25 nT.

System units and the computer screen produce EMR. The main sources of radiation are the system unit and video cable. According to [98], the intensity of the electromagnetic field at a distance of 50 cm around the screen along the electrical component should be no more than:

- in the frequency range 5 Hz - 2 kHz - 25 V / m
- in the frequency range 2 kHz - 400 kHz - 2.5 V / m

The magnetic flux density should be no more than:

- in the frequency range 5 Hz - 2 kHz - 250 nT

To protect against EMR, you need:

- Increase the distance from the operator to the source (the screen should be at least 50 cm from the user)
- apply screen filters, special screens and other PPE, i.e. the use of pre-screen filters, special screens and other personal protective equipment.

Computer screens or display produces non-ionising Radiation. Under the influence of non-ionising radiation in the body, various biological effects and complications can arise, which may include violations of normal blood coagulability, radiation sickness, etc. The irradiation dose of the operator at a distance of 20 cm to the display is 50 microR/ hour. According to the norms [98], the design of the computer produces radiation, the equivalent dose of which is equal to 100 μR / h.

Weakness of the organs of vision can be caused by factors such as insufficient lighting or illumination, excessive lighting and wrong direction of light.

5.1.4 Electrical safety

The risk of associated with electric shock to a person can be maximize or minimize, depending on the conditions provided in the room. Work with computers in high humidity, high temperature (more than 35 ° C), the presence of conductive dust, conductive floors should not be.

When working on a computer, there is a danger of electro-impact when touching non-conductive parts, when touching the floor, walls exposed to voltage, with a short circuit in the power supply.

The actions to ensure the electrical safety of electrical installations include:

- disconnection of voltage from current-carrying parts, on which or near which work will be carried out;
- preparation and posting of posters that indicate the place of work;
- earthing of the housings of all installations;
- covering the conductive surfaces of tools with reliable insulation
- inaccessibility of current-carrying parts of equipment (the conclusion in the case of electroporating elements, the conclusion in the body of current-carrying parts) [99]

5.1.5 Fire and Explosive Safety

According to [100], depending on the characteristics or features of the substances used in the production, and their quantity, for fire and explosion hazard, the premises can be characterized by categories A, B, C, D. As the room is classified in category B according to the degree of fire and danger (room with solid combustible substances), it is essential to provide for a number of preventive measures. Possible causes of fire can be:

- malfunction of current-carrying parts;
- work with open electrical equipment;
- short circuits in the power supply;
- Failure to comply with fire safety regulations, etc.

Fire prevention actions are classified into regime, organizational, operational and technical.

Organizational procedures comprise of proper maintenance of buildings and territories, operation of equipment, firefighting of workers, training of personnel in fire safety rules, etc.

Technical measures usually include compliance with fire regulations and rules for the construction and design of buildings electrical wires and equipment, heating, ventilation, lighting, etc.

Technical procedures or measures usually include compliance with fire regulations and rules for the construction and design of buildings electrical wires and equipment, heating, ventilation, lighting, etc.

The regime measures can be attributed to fire prevention measures and the establishment of rules for the organization of work. To avert the occurrence of fire from short circuits, overloads, etc. It is obligatory to follow the fire safety rules described above.

In the event of an emergency, it is necessary:

- notify the management (duty officer);
- Call the appropriate emergency service or Emergency Situations Ministry at 112
- take measures to eliminate the accident in accordance with the instructions.

Conclusion

The dissertation was done in a period of four (4) months with the help of a scientific advisor.

During the performance of the final qualification work, the plans for the implementation of nuclear program in Ghana was considered. From the analysis conducted on places to build NPP, Kpong was chosen to be the best site to build NPP in Ghana.

Also, based on the threat and vulnerability analysis conducted, it was realized that the main threat is unauthorized removal or theft of nuclear material due to the existence of armed robbers and terrorist organization “Boko Haram” with trained armed forces and may try to obtain nuclear materials. Nuclear material of VVER-type NPP may be attractive for the terrorist groups because it can be used to produce nuclear and radiological weapons. Moreover, spent nuclear fuel contains plutonium.

Hence, the physical protection system and the boundaries of protected areas were designed according to international and local legal framework (IAEA, DOE, ROSATOM) to provide delay long enough for guard’s forces to respond.

The budget spent for the project implementation is 280494.70 rubles.

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