RISK ASSESSMENT FOR THE PRESSURIZED WATER REACTORS NUCLEAR POWER PLANT

By

Melouk Mohsen Abass

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Risk Engineering

FACULTY OF ENGINEERING CAIRO UNIVERSITY
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Title of Thesis:
RISK ASSESSMENT FOR THE PRESSURIZED WATER REACTORS NUCLEAR POWER PLANT

Key Words: Nuclear PWR, Accidents, Safety, Risk, Control

Summary:

Nuclear power generating plants are one of the most important sources for electricity generation. Nowadays Egypt starts its first nuclear project. One of the main disadvantages of using nuclear energy is the nuclear energy accidents which can spread radiations over a wide area, these radiations harm the cell of the body which can make human death and genetic problems can occur too. So this work tries to decrease the probability and the severity of nuclear accidents by studying the parts of the pressurized water reactor nuclear plant and the sources of hazards in it then find the reason for these hazards and its effect and apply the required control on it to decrease the probabilities and the severities of this hazard on the plant and finally draw the risk matrix for the plant. Also some safety considerations must be applied on the plant to ensure its reliable and safe operation. Finally, nuclear energy is a double edged weapon so it must be handled in careful way.

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in references sections.

Name: Melouk Mohsen Abass Date: 21-11-2018

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Nomenclature

BTRS: BORON THERMAL REGENERATION SYSTEM
BRS: BORON RECYCLE SYSTEM
CRDM: CONTROL ROD DRIVE MECHANISM.
CVCS: CHEMICAL AND VOLUME CONTROL SYSTEM
CR: CONTROL ROD
CCW: COMPONENT COOLING WATER
CSS: CONTAINMENT SPRAY SYSTEM
CSST: CONTAINMENT SPRAY STORAGE TANK
DRPI: DIGITAL ROD POSITION INDICATION SYSTEM
EFWS: EMERGENCY FEEDWATER SYSTEM
FMEA: FAILURE MODE EFFECT ANALYSIS
HX: HEAT EXCHANGER
HHSI: HIGH HEAD SAFETY INJECTION
HDS: HYDROGEN DETECTION SYSTEM
NSSS: NUCLEAR STEAM SUPPLY SYSTEM
RCCA: ROD CLUSTER CONTROL ASSEMBLY
RCS: REACTOR COOLANT SYSTEM
RCP: REACTOR COOLANT PUMP
RCS : REACTOR COOLANT SYSTEM
RFCC: REACTOR CONTAINMENT FAN COOLER SYSTEM
RHRS: RISSIDUAL HEAT REMOVAL SYSTEM
RMW: REACTOR MAKEUP WATER
RWST: REFUELING WATER STORAGE TANK
P: PROBABILITY
S: SEVERITY
R.R: RISK RANKING
SAT: SPRAY ADDIDTIVE TANK
SGBPS: STEAM GENERATOR BLOW DOWN PROCESSING SYSTEM
SIS: SAFETY INJECTION SYSTEM
TTFM: TRANSIENT TIME FLOW METER
VCT: VOLUME CONTROL TANK
WPS(L):WASTE PROCESSING SYSTEM(LIQUID)
WPS(G):WASTE PROCESSING SYSTEM(GAS)

Scientific units:

Bq: Becquerel, SI unit for radioactivity
MBq: Megabecquerel (1 x 10^6 Becquerel)
PBq: Petabecquerel (1 x 10^15 Becquerel)
Sv: Sievert, SI unit for dose equivalent
mSv: Millisievert (1 x 10^-3 Sievert)
µSv: Microsievert (1 x 10^-6 Sievert)

Acronyms:

BEIR: National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation
CTBT: Comprehensive Test Ban Treaty
ECRR: European Committee on RadiationRisks
GRS: Gesellschaftfür Anlagen- und Reaktorsicherheit
(German Society for Reactor Safety)
GS: GesellschaftfürStrahlenschutz
(German Society for Radiation Protection)
IAEA : International Atomic Energy Agency
INES: International Nuclear Event Scale
IRSN: Institut de Radioprotection et de SûretéNucléaire
(French Institute for Radiation Protection and Nuclear Safety)
JAEA: Japan Atomic Energy Agency
MAFF: Japanese Ministry of Agriculture, Forestry and Fisheries
MEXT: Japanese Ministry of Education, Culture, Sports, Science and Technology
NILU: Norskinstitutt for luftforskning
(Norwegian Institute for Air Research)
TEPCO: Tokyo Electric Power Company
WHO: World Health Organization
ZAMG: Zentralanstaltfür Meteorologie und Geodynamic
(Austrian Central Institute for Meteorology and Geodynamics)
NRC: The U.S Nuclear Regulatory commission.

Abstract

Nuclear Energy is one of the most important sources of energy. It is a double-edged weapon, so it must be handled in a careful way. Nuclear power generating plants are one of the major electricity producers. Nuclear energy supplies about 12% of the world electricity. Many countries use nuclear energy to generate one – quarter to one third of their electricity. The nuclear plants produce electricity by boiling water into steam like plants that burn oil or natural gas. The difference is that the nuclear plants use uranium fuel. The steam produced turns turbines to produce electricity.

Egypt started one of its most important projects, which is Dabaa nuclear power plant for electricity generation. Nuclear energy has many advantages, but similarly have some disadvantages. One of its disadvantages is the nuclear power plants accidents, which can spread radiation over a wide area; these radiations harm the body cells, which causes human sickness or even death, illness and genetic problems can occur too.

A nuclear and radiation accident is defined by the International Atomic Energy Agency (IAEA) as “an event that has led to significant consequences to people, the environment or the facility." Some measures to reduce the risk of accidents or to minimize the amount of radioactivity released to the environment have been adopted. Despite the use of such measures, human error remains, and "there have been many accidents with varying impacts as well near misses and incidents".

Our thesis main aim is to achieve to a safe plant so we try to decrease the severity and the probability of the hazards that may occur like natural hazards like earthquakes, tornados…, etc. such as what happened in Fukushima accident or hazards that occur as a result of lack in personal experience (human technical error, like Chernobyl accident or any other hazards).

The plan of this work starts with identifying the different types of nuclear reactors, focusing on pressurized water type. Hence, analyzing the different parts and procedures in nuclear power plant for electricity generation. Finally, the hazards associated with the process, their risk assessment, and mitigation with control methods will be presented.

The aim is to have all activities of the process in the safe zone (green zone in risk matrix).

Chapter 1 : Introduction

Nuclear power generating plants are one of the most debatable electricity producers. Nuclear energy supplies about 12% of the world electricity. Many countries use nuclear energy to generate one – quarter to one third of their electricity. The nuclear plants produce electricity by boiling water into steam like plants that burn oil or natural gas. The difference is that the nuclear plants use uranium fuel. The steam produced turns turbines to produce electricity.

The nuclear reactor main components are:

a) **Fuel:**
The most used fuels are uranium or thorium. Uranium is the preferable one because of its high melting point.

b) **Moderator:**
Moderators reduce the speed of the neutrons to convert it from fast neutron to thermal neutrons. Moderators adsorb energy of the neutrons but do not absorb the neutrons. Graphite, Heavy water and Beryllium are the main materials used as moderators.

c) **Control Rod:**
The control rods are to absorb neutrons to slow down chain reactions or stop it. Control rods are made of steel tubes containing material like cadmium or boron.

d) **Shielding:**
Shielding is used to prevent radiation from spreading outside of the reactor. Lead blocks and concrete are used for shielding. They are several meters thick for complete shielding.

e) **Coolant:**
Coolant absorbs heat produced in the reactor and transfers it to heat exchanger to produce steam. The common coolant material is water, carbon dioxide gas or liquid sodium.

f) **Turbine**:
Steam produced in heat- exchanger passes to turbine. The force of steam and it is converted to mechanical energy.