Turkish Journal of Nuclear Science (2018), Cilt.30, No.1.
http://www.turkishnuclearscience.com http://dergipark.gov.tr/tjins

CONSEQUENCES OF SPENT FUEL POOL ACCIDENT DUE TO LONG TERM STATION BLACK OUT AT VVER-1200

Kemal DOĞAN
Turkish Atomic Energy Authority, Çankaya Ankara, Turkey, 06510
k.dogan@taek.gov.tr

VVER–1200 SANTRALİNDE UZUN SÜRELİ SANTRAL KARARMASI NEDENİYLE KULLANILMIŞ YAKIT HAVUZU KAZASININ RADYOLOJİK SONUÇLARI

Abstract:

Natural disaster occurred at Japan Fukushima Daiichi Nuclear Power Plant (NPP) in March 2011 showed that combination of natural disasters with a long term station black out which is not accepted as a design basis accident till that day could be very dangerous. In this study, inventory calculation in the spent fuel pool, calculation of source term from inventory, atmospheric dispersion calculation of source term and consequently the possible radiation doses of persons in vicinity of the NPP area and emergency interventions were investigated, in case of long term black out accident that can occur in the AES 2006 design VVER-1200 type NPP planned to be built in Turkey.

Özet:

Mart 2011'de Japonya Fukushima Daiichi Nükleer Güç Santralinde (NGS) gerçekleşen doğal felaket nükleer çevrelere o güne değin tasarıma esas kaza olarak kabul edilmeyen uzun süreli santral kararmasının doğal afetler ile birleşince ne denli tehlikeli olabileceğini gösterdi. Bu tez çalışmasında Mersin, Akkuyu'da kurulması planlanan AES 2006 tasarımı bir VVER–1200 tipi NGS'de gerçekleşebilecek uzun süreli santral kararması kazası durumunda kullanılmış yakıt havuzundaki envanter hesabı, envanterden kaynak teriminin hesabı, kaynak terimin atmosferik dağılım hesapları ve sonucunda NGS sahası yakınlarında bulunan kişilerin alması muhtemel radyasyon dozları ve acil durum müdahaleleri incelenmiştir.

Keywords: AES 2006 design VVER – 1200, long term blackout accident, spent fuel pool, Mersin Akkuyu NPP, PCCOSYMA, ORIGEN-ARP.

Anahtar kelimeler: AES 2006 tasarımı VVER – 1200, uzun sureli santral kararması kazası, kullanılmış yakıt havuzu, Mersin Akkuyu NGS, PCCOSYMA, ORIGEN-ARP.

1. Introduction

On 12 May 2010 in Ankara an intergovernmental agreement has been signed between Turkish Republic and Russian Federation to construct a NPP with four units of VVER 1200 type (AES 2006 design, a third generation pressurized water reactor) which has 4800 MWe installed capacity at Mersin, Akkuyu site.

In this study, radiological consequences of a possible accident that may occur in the spent fuel pool of a VVER 1200 type NPP during a long term station black out accident is investigated.

The analyzed accident involves failure of diesel generators due to the external events along with the loss of off-site power.

Makale Gönderim Tarihi:17/04/2018
Makale Kabul Tarihi:05/06/2018

2. Material and methods

2.1. Inventory & Source Term Calculations

ORIGEN-ARP software is used for inventory calculations (Oak Ridge National Laboratory, 2002). For calculations, typical AES 2006 design data presented in Environmental Impact Assessment Report of Akkuyu NPP are used (Akkuyu Nükleer A.Ş., 2014). Technical parameters used for AES 2006 design VVER 1200 type power reactor inventory calculations are shown in Table 1.

Table 1. Technical parameters for NPP

Nuclear Power Plant Life Time	60 yrs
Thermal Power	3200 MWth
Average burn up ratio	55.5 MWday/kg U
Average enrichment of the fuel assemblies placed in the core	% 4.79
Number of fuel assemblies in the core	163
Number of fuel assemblies changed every load	42
Uranium amount in 42 fuel assemblies	19768 kg
37 of 42 fuel assemblies residence in the core for 4 years 5 of 42 fuel assemblies residence in the core for 3 years	
Average time of residence in the core of 42 fuel assemblies	1330 days
Amount of water in the spent fuel pool	1529.3 m^3 + 750 m^3

It is reported that capacity of the spent fuel pool used of the NPP is sufficient for the spent fuel of 10 years of operation in addition to all the fuel in the core (Akkuyu Nükleer A.Ş., 2014).

In this study, it is assumed that spent fuel pool is full and all the fuel in the core is in the pool during the accident.

According to the accident scenario, it is assumed that all the water covering the fuel is evaporated and the integrity of the fuel clad is lost. At the result of the calculations, decay heat released by the spent fuel in the pool leads to the evaporation of the water and the uncovery of spent fuel in the pool starts in 2.29 days after initiation of the accident.

The residence period of the fuel in the spent fuel pool is taken into account for the inventory calculation. Additionally, spent fuel uncovery period which is 2.29 days is also used for this calculation.

Since radionuclide specific release ratios are not available for the containment outer boundary of VVER-1200 NPP, methodology and numerical values of Nuclear Regulatory Commission (NRC) NUREG 1150 report are utilized in this work (U.S. Nuclear Regulatory Commission, 1990).

Makale Gönderim Tarihi:17/04/2018
Makale Kabul Tarihi:05/06/2018

According to NRC NUREG 1150 report radioactive isotopes are divided in to 9 groups according to their chemical and physical behaviors to calculate the release ratios. These groups and release ratios are given in Table 2.

Table 2. Isotope groups and release ratios

Groups	**Release Ratio**
Noble Gas Group (Xe, Kr)	0.95
Halogen Group (I)	0.35
Alkali Metal Group (Cs, Rb)	0.25
Tellurium Group (Te, Se, Sb)	0.15
Barium Group (Ba)	0.04
Strontium Group (Sr)	0.03
Cerium Group (Ce, Pu, Np)	0.01
Rutenium Group (Ru, Co, Rh, Pd, Mo, Tc,)	0.008
Lanthanum Group (La, Zr, Nd, Eu, Nb, Pm, Pr, Sm, Am, Cm, Y)	0.002

Source term calculated by using release ratios given in Table 2 and core inventory is listed in Table 3.

Table 3. Source Term

Isotope	**Activity (Bq)**	**Isotope**	**Activity (Bq)**
Kr85	1.04E+17	Sr89	9.15E+16
Kr85m	4.72E+12	Sr90	2.92E+16
Kr87	3.94E-01	Sr91	4.32E+14
Kr88	1.10E+10	Ce141	5.01E+16
Xe131m	3.70E+16	Ce143	9.81E+15
Xe133	4.73E+18	Ce144	4.62E+16
Xe133m	1.02E+17	Pu238	5.27E+14
Xe135	4.01E+16	Pu239	3.50E+13
I131	8.54E+17	Pu240	5.43E+13
I132	8.09E+17	Pu241	1.38E+16
I133	1.71E+17	Np239	2.20E+17
I134	8.65E-09	Ru103	3.64E+16
I135	5.29E+14	Ru105	9.20E+10
Cs134	2.48E+17	Ru106	1.66E+16

Makale Gönderim Tarihi:17/04/2018
Makale Kabul Tarihi:05/06/2018

Cs136	3.28E+16	Rh105	5.43E+15
Cs137	3.43E+17	Mo99	2.08E+16
Rb86	1.21E+15	Tc99m	2.02E+16
Te127	2.78E+16	La140	1.06E+16
Te127m	6.93E+15	Zr95	1.06E+16
Te129	1.41E+16	Zr97	4.38E+14
Te129m	2.19E+16	Nb95	1.10E+16
Te131m	1.39E+16	Am241	2.10E+13
Te132	3.36E+17	Cm242	2.40E+14
Sb127	2.28E+16	Cm244	1.25E+14
Sb129	4.62E+11	Y90	1.95E+15
Ba140	1.90E+17	Y91	8.02E+15

3. Results and Conclusions

For atmospheric dispersion calculation PCCOSYMA software based on Gaussian plume model was used (Jones et al., 1995).

For 15 different atmospheric conditions, calculations were performed for effective doses. In all calculations, day time and summer season conditions were assumed. Additionally, doses were calculated for two days. Release height is assumed as 100 meters. Atmospheric conditions used for calculations were given in Table 4.

Table 4. Atmospheric conditions used for calculations

Condition	**Stability Class**	**Wind Speed (m/s)**	**Condition**	**Stability Class**	**Wind Speed (m/s)**
1	A	1	9	C	7
2	A	2	10	D	4
3	B	1	11	D	6
4	B	2	12	D	7
5	B	4	13	E	2
6	C	2	14	E	4
7	C	4	15	F	2
8	C	6			

The results of atmospheric dispersion calculations performed for 15 different atmospheric conditions, for each condition effective doses approximately at 5 km, 10 km, 15 km and 20 km were given comparatively at Table 5.

Makale Gönderim Tarihi:17/04/2018
Makale Kabul Tarihi:05/06/2018

Table 5. Comparison of effective doses at various distances for different atmospheric conditions

Conditions	**Stability Class**	**Wind Speed (m/s)**	**Effective dose at ≈ 5 km (mSv)**	**Effective dose at ≈ 10 km (mSv)**	**Effective dose at ≈ 15 km (mSv)**	**Effective dose at ≈ 20 km (mSv)**
1	A	1	4.386	1.809	1.315	0.8986
2	A	2	2.539	0.9697	0.7435	0.5169
3	B	1	5.505	2.290	1.538	1.094
4	B	2	3.246	1.288	0.8892	0.6492
5	B	4	1.733	0.7126	0.4907	0.3706
6	C	2	4.746	1.812	1.274	0.8767
7	C	4	2.610	1.032	0.7169	0.5116
8	C	6	1.796	0.7310	0.5193	0.3626
9	C	7	1.554	0.6379	0.4553	0.3243
10	D	4	4.176	1.433	0.9958	0.7125
11	D	6	2.880	1.018	0.7257	0.5173
12	D	7	2.493	0.8895	0.6379	0.4680
13	E	2	15.18	4.224	2.949	2.023
14	E	4	8.484	2.435	1.690	1.207
15	F	2	37.84	8.082	4.701	2.943

The presented results involve uncertainties since release ratios from containment used for the calculation of source term from inventory are not specific to VVER-1200 type NPP and accident.

The most important assumptions made for the atmospheric dispersion calculations were the constant wind direction and the single release of source term. In reality, noble gas group which is very important part of the source term would be released from containment rapidly but it would spread over time for the release of heavy isotopes. From this point of view the assumptions made are conservative.

According to the results of the calculations, except for the conditions of the most conservative stability classes E and F with wind speed of 2 m/s, it was observed that beyond 20 km annual dose limits for population were not exceeded. In these two conditions where dose limits were exceeded, short term sheltering would be enough to prevent excessive doses.

For conducting a specific study to the VVER-1200 type Akkuyu NPP which will be built in Turkey, design data which are presented in Akkuyu Nuclear Power Plant Safety Analysis Report and site parameters which are presented in Akkuyu Nuclear Power Plant Site Parameters Report are required. Since these data do not exist and they are classified as confidential, calculations in this study were made as conservative as it could be.

Considering the results obtained with conservative assumptions, it can be concluded that effective dose values beyond 20 km would not exceed annual public dose limit if Akkuyu NPP design data and realistic site parameters were used.

Makale Gönderim Tarihi:17/04/2018
Makale Kabul Tarihi:05/06/2018

4. Bibliography

1) Akkuyu Nükleer A.Ş. (2014). Environmental Impact Assessment Report of Akkuyu Nuclear Power Plant Project, Ankara: Akkuyu Nükleer A.Ş.

2) Jones, J.A., Mansfield, P.A., Haywood, S.M., Hasemann, I., Steinhauer, C., Ehrhardt, J. & Faude, D. (1995). PC COSYMA (Version 2): An Accident Consequence Assessment Package for Use on a PC, EUR Report 16239.

3) Oak Ridge National Laboratory. (2002). ORIGEN-ARP: Isotope Generation and Depletion Code, Oak Ridge, Tennessee: Oak Ridge National Laboratory.

4) U.S. Nuclear Regulatory Commission. (1990). U.S. Nuclear Regulatory Commission Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants, NUREG-1150, USA, Washington: U.S. Nuclear Regulatory Commission.

Makale Gönderim Tarihi:17/04/2018
Makale Kabul Tarihi:05/06/2018