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ASSESSMENT OF RADIOACTIVE GASEOUS EFFLUENT RELEASED FROM NUCLEAR POWER PLANT NINH THUAN 1 UNDER SCENARIO OF INES-LEVEL 5 NUCLEAR ACCIDENT

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Abstract. *Based on guides RG 1.109, RG 1.111 published by United States Nuclear Regulatory Commission (USNRC) our research concentrates on assessing radiation doses caused by radioactive substances released from the nuclear power plant (NPP) Ninh Thuan 1 to the environment under scenario of an INES-level 5 nuclear accident caused by two incidents of the station black out (SBO) and loss of coolant accident (LOCA) using software RASCAL4.3 provided by the Emergency Operations Center of USNRC. The plant Ninh Thuan 1 is assumed to use the VVER-1200 technology with a total power of 2400 MW$_e$. The input data for the model calculations is based on building the accident scenario, the technical parameters of VVER-1200 technology and the meteorology. The meteorological data on dry and rainy seasons, which are typical for the Ninh Thuan region was also considered.*

The X/Q (s/m^3) quality and the maximum dose values were calculated within an area of 40 km radius from the NPP site, where X/Q (s/m^3) is the ratio of activity concentration to release rate. Based on the obtained results on dose distribution the necessary measures for nuclear emergency preparedness have been proposed according to the IAEA recommendations.

Keywords: station black out (SBO), loss of coolant accident (LOCA), reactor coolant system (RCS), source term, radioactive release, maximum dose value, nuclear power plant (NPP) Ninh Thuan 1, international nuclear event scale (INES), RASCAL4.3..

I. INTRODUCTION

Currently, Vietnam is actively preparing infrastructure for the first two nuclear power plants (NPP) projects in the Ninh Thuan province, in which the plant Ninh Thuan 1 is planned to use the VVER-1200 technology with a total power of 2400 MW$_e$. When going into operation, the NPP will release radioactive nuclides into the atmosphere. The radioactive effluent undergoing dispersion in air and deposition on the ground will impact to the environment and human, especially for occurrence of a nuclear accident. Therefore, the studies of transport and dispersion of radioactive

substances in atmosphere, and assessment of radiation dose to the public are of essential requirement for an NPP project. In addition, the calculation results will provide the necessary data for the Environmental Impact Assessment (EIA) and support for regulatory organization in reviewing the Safety Analysis Report (SAR)

Radioactive releases from various nuclear facilities, in general, may contribute to radiation exposure through two main pathways: (1) External exposures by direct radiation from radioactive plumes or from radioactive nuclides deposited on the ground, and (2) Internal exposure due to inhalation and ingestion of radioactive substances. The magnitude of exposure is dependent on atmospheric dispersion and deposition processes [1].

In this work we concentrate in assessing maximum radiation doses as a result of radioactive release from a nuclear accident with wider consequences assumed to occur at the NPP Ninh Thuan 1. The magnitude of the accident was evaluated at level 5 defined by the International Nuclear Event Scale (INES) [2]. The scenario of the accident was built based on two incidents: the Station Black Out (SBO) and the Loss of Coolant Accident (LOCA) induced by a rupture in the Reactor Coolant System (RCS) for the nuclear reactor. The accident leads to consequences starting from the damage of the reactor core to failure of the containment, and eventually the release of radioactive substances to the environment. The assessments for the accident have been performed using RASCAL4.3 developed by the Emergency Operations Center of USNRC [2,3]. Building the input for the model calculations consists of describing the accident scenario, the technical parameters characteristics of the VVER-1200 technology and the meteorology. The obtained calculation results include the released radioactive nuclides and distribution of X/Q value and the maximum value of organ doses within 80 km radius from the NPP site.

II. RASCAL4.3 AND BUILDING DATA INPUT

For modeling a NPP accident the Source Term to Dose model in RASCAL4.3 is used to evaluate the projected radiation doses from the plume of the released radioactive substances to people downwind based on entering information about the plant conditions. The dose pathways consist of cloud shine from the plume, inhalation from the plume, and ground shine from the deposited radioactive nuclides.

Building the data input for the model calculations includes:

a. Meteorology

Meteorological data is needed to the model behavior of the radioactive plume in the atmosphere. The minimum required data includes wind speed and direction, atmospheric stability, precipitation, air temperature. The goal is to provide the best representation of the weather conditions for the model run in both time (up to 48 hours starting from the release) and space (up to a distance of 50 miles or 80 km from the plant site). The RASCAL4.3 requires the initial weather data to be entered within a 2 hour window before the start of the release.

In this work the assessment for the radioactive dispersion and consequence of the accident was carried out at two times of the year: on the days of 17^{th} January and 26^{th} September 2013 which are typical for the weather of the dry and rainy seasons in the Ninh Thuan region. Short descriptions for the observed meteorological data are summarized in Tables 1&2.

Table 1. The observed meteorological data on 17^{th} January, 2013 at Ninh Thuan

Summary of data at release point	Type	Direction Degree	Speed (m/s)	Stability Class	Precip.	Temp. (˚C)
2013/01/17, 03:00	Obs	327	2	C	None	23.0
2013/01/17, 04:00	Obs	0	5	C	None	23.2
2013/01/17, 05:00	Obs	0	3	C	None	23.0
2013/01/17, 06:00	Obs	23	4	C	None	23.8
2013/01/17, 07:00	Obs	0	4	C	None	24.8
2013/01/17, 08:00	Obs	0	4	C	None	26.9
...						
2013/01/19, 00:00	Obs	0	5	C	None	22.9

Table 2. The observed meteorological data on 26^{th} September, 2013 at Ninh Thuan

Summary of data at release point	Type	Dirdeg	Speed (m/s)	Stability Class	Precip.	Temp (˚C)
2013/09/26, 03:00	Obs	225	1	D	None	26.0
2013/09/26, 04:00	Obs	225	0	D	None	26.0
2013/09/26, 05:00	Obs	335	1	D	Rain	25.9
2013/09/26, 06:00	Obs	295	2	D	Light rain	25.8
2013/09/26, 07:00	Obs	245	3	D	None	25.6
2013/09/26, 08:00	Obs	270	2	D	Light rain	26.1
...						
2013/09/28, 00:00	Obs	270	0	D	None	24.8

b. Description of accident scenario

Due to a Station Black Out (SBO) incident at the NPP Ninh Thuan 1 the LOCA phenomenon occurred and led to the reactor core to be uncovered. In this scenario it is assumed that there was a rupture in the Reactor Coolant System (RCS) and this made the LOCA to be occurred more quickly. For the evolution of the accident it is assumed that the reactor was shutdown at 0:00 on 17 January 2013, the core was uncovered at 3:00 and recovered at 5:00. During two hours the core was uncovered the fuel rods was heated up and melt down due to the decay heat. This caused release of the fission products from the core to the reactor containment via the rupture in the RCS and consequently makes it possible to increase temperature and pressure in the containment. In this state it is assumed that the integrity of the containment was maintained within two hours before the leakage occurred. After that, the containment has failed and caused the radioactive release to the atmosphere which is assumed 1% per day in this scenario. The data on the VVER-1200 technological characteristics needed to build the input for the RASCAL4.3 calculations is summarized in Table 3 [4].

Table 3. The VVER-1200 technical parameters assumed to use at NPP Ninh Thuan 1 [4]

Event Type	Nuclear Power Plant
Location	Phuoc Dinh
Name:	Ninh Thuan 1
City, country, state	Ninh Phuoc, Ninh Thuan (South Central Coast), Vietnam.
Lat/Long/Elev:	11.3963^{o}N/ 109.0037^{o}E/ 20 m
VVWR-1200 Reactor parameters	
Reactor power	3,200 MWt
Peak rod burn-up	60,000 MWd/MTU
Containment type	PWR Dry Ambient
Containment volume	2.50E+06 ft^3
Design pressure	72.52 lb/in^2
Design leak rate	0.2%/day
Coolant mass	2.9E+05 kg
Assemblies in core	163
Steam generator	U-type
SG water mass	52,220 kg
Source term	
Type	Time core is uncovered
Shutdown	2013/01/17 at 0:00
Core uncovered	2013/01/17 at 3:00
Core recovered	2013/01/17 at 5:00

III. RESULTS AND DISCUSSION

For each scenario of the NPP accident the RASCAL4.3 calculations give two main results: (1) Source term for radioactive nuclides released to the atmosphere, and (2) Distribution of maximum dose values (rem, mSv) up to 50 miles (80 km) from the plant. For the scenario described above for the NPP Ninh Thuan 1 there may have up to 60 radioactive nuclides that can be predicted by the RASCAL4.3 for the released source term. All these nuclides are used to consider the radioactive dispersion and assess (the) maximum dose distribution due to the NPP accident. However, only the radioisotopes that have been detected in two accidents Chernobyl and Fukushima

are used to evaluate the magnitude (level) of accident defined by the INES [2]. In this work the radioactive nuclides which were used to evaluate the level of the accident are presented in Table 4.

Table 4. The radioactive nuclides used to evaluate the magnitude of the accident described above for the NPP Ninh Thuan 1

Nuclide	Activity, A_i (Ci)	F_i	Nuclide	Activity, A_i (Ci)	F_i
^{140}Ba	1.4E+3	none	^{106}Ru	6.6E+1	6
^{144}Ce	3.6E+1	none	^{132}Te	2.7E+3	0.03
^{134}Cs	2.4E+3	3	^{133}Xe	1.4E+5	0
^{137}Cs	1.7E+3	40	^{89}Sr	7.3E+2	20
^{131}I	1.1E+4	1.0	^{90}Sr	1.1E+2	20
^{99}Mo	1.3E+2	0.08	^{241}Am	1.2E-6	8000

In principle, the magnitude of a nuclear accident is evaluated as follow: Firstly the activity A_i of each released radionuclide has to be attributed to the equivalent one of radioisotope ^{131}I by multiplying with factor F_i, and then a total released radioactivity (A_{total}) is summed from all the obtained equivalent ones [5]. Therefore, from the data shown in Table 4 the total value of the released radioactivity is calculated as:

$$\begin{aligned} A_{total} =& \Sigma(A_i \times F_i) \\ =& 10.35 \times 10^4 \text{ Ci} \sim 38.26 \times 10^{14} \text{ Bq} = 3826 \text{ TBq} \end{aligned}$$

where: A_i is activity of the released radionuclide; F_i is conversion factors for radiological equivalence to ^{131}I.

This is the radiological equivalence to ^{131}I for release to the atmosphere. This value shows that the accident could be graded at the INES level 5: Accident with wider consequences [5].

Based on the obtained result for the released source term the distributions of maximum dose values within a radius of 50 miles (80 km) around the plant were calculated as a function of dispersion time at 3, 10, 20, 30, 40 and 48 hours starting from the release. The obtained results showed that for the dispersion time less than 10 hours the maximum dose values increase slightly with respect to time. After this time up to 48 hours the maximum dose values remain unchanged. So, for discussion, we show in Tables 5 and 6 the maximum dose distributions typically for the dry and rainy seasons at the dispersion time of 10 hours, respectively.

The annual limits of the total EDE for occupational and public exposures are, respectively, 50 and 1 mSv guided by USNRC and Vietnam regulations [6, 7]. From the obtained calculation results shown in Table 5 we can see for the dry season: (1) the total EDE at several kilometers from the plant site is less than the limit value of 1 mSv for public, and (2) the dose rate in the dispersion time of 10 hours is approximately 0.05 mSv/h, i.e. about four times less than the limit value of 0.2 mSv/h specified by Appendix 2 of Circular 25/2014/TT-BKHCN [8]. This means that the procedure for radiation emergency preparedness, for instant temporary evacuation, is not

necessary to implement for public. However, within 20 km radius the dose rate is about 1 μSv/h, the consumption of food and milk must be immediately stopped until getting the results of sample testing [8]. It is noted that the information on the accident, including the cause, the evolution of the accidents and the dose evaluation has to be updated and inform fully to the Emergency Response Authority of the Ninh Thuan province.

Table 5. Calculation results for distribution of maximum dose values (mSv) at the dispersion time of 10 hours for the dry season up to 25 miles (40 km) from the plant

Distance	Mile	3	5	7	10	15	20	25
from release	Km	4.8	8	11.3	16.1	24.1	32.2	40.2
Dose (mSv)	Total EDE	4.8E-1	2.8E-1	1.2E-1	8.5E-2	3.1E-2	1.1E-2	***
	Thyroid CDE	4.1	2.4	9.9E-1	7.2E-1	2.9E-1	1.0E-1	1.5E-2
	Inhalation CDE	3.6E-1	2.1	8.6E-2	6.2E-2	2.3E-2	***	***
	Cloud shine	1.3E-2	***	***	***	***	***	***
	4-day ground shine	1.2E-1	6.8E-2	2.9E-2	2.1E-2	***	***	***
	Inter Phase 1^{st} Yr	2.0	1.2	4.8E-1	2.5E-1	1.4E-1	5.1E-2	***
	Inter Phase 2^{nd} Yr	1.1	6.7E-1	2.8E-1	2.0E-1	8.0E-2	3.0E-2	***

*"***": the dose value* $< 1.0E-2(0.01)$ *mSv.*

Table 6. Calculation results for distribution of maximum dose values (mSv) at the dispersion time of 10 hours for the rainy season up to 25miles (40 km) from the plant

Distance	Mile	3	4	5	7	10
from release	Km	4.8	6.4	8	11.3	16.1
Dose (mSv)	Total EDE	2.3	1.80	1.7	1.5	6.2E-1
	Thyroid CDE	8.4	6.3	5.8	4.1	3.0
	Inhalation CDE	6.7E-1	5.0E-1	4.3E-1	3.0E-1	2.0E-1
	Cloud shine	2.7E-2	2.0E-02	1.8E-2	1.2E-2	***
	4-day ground shine	1.6	1.4	1.3	1.2	4.3E-1
	Inter Phase 1^{st} Yr	35.0	31.0	28.0	29.0	8.2
	Inter Phase 2^{nd} Yr	21.0	18.0	16.0	17.0	4.8

*"***": the dose value* $< 1.0E-2(0.01)$ *mSv.*

For the calculation results shown in Table 6 on the maximum dose distribution for the rainy season we can see at the distance of less than 6 kilometers from the plant the total EDE is from 2 to 2.5 times higher than the limit value. In this case it is requested to inform and coordinate closely with the Emergency Response Authority of the Ninh Thuan province in order to follow the evolution of the accident and issue timely the appropriate response measures. The procedure for radiation emergency preparedness and people evacuation should be considered and implemented under the guidance of Circular 25/2014/TT-BKHCN [8].

IV. CONCLUSION

Based on two incidents of the Station Black Out (SBO) and Loss of Coolant Accident (LOCA) we proposed the scenario of a nuclear accident assumed to occur at the NPP Ninh Thuan 1. The source term of the released radioactivity, dispersion and consequences of the accident were calculated using the RASCAL4.3 code developed by the Emergency Operations Center of US-NRC.

The data input for the code calculations was built consisting of the technical parameters of the VVER-1200 technology assumed to use for the Ninh Thuan 1 NPP project, the evolution of the accident and the meteorology within 48 hours before and after the release. The calculations on the maximum dose distributions were carried out up to 25 miles (40 km) from the plant site for two meteorological conditions on the dry and rainy seasons which are typical for the annual weather in the Ninh Thuan region.

The obtained result on released source term made it possible to classify the considered accident at the INES level 5: The accident with wider consequences.

For the dry season the obtained maximum dose distribution at several kilometers from the plant is less than the limit value for public and, therefore, it is not requested to implement any emergency preparedness measure. However, within 20 km radius the consumption of food and milk must be immediately stopped until getting the results of sample testing.

For the rainy season the obtained maximum dose distribution within 6 km radius is from 2 to 2.5 times higher than the limit value for public, therefore, it is requested to implement the radiation emergency preparedness and people evacuation.

In both considerations for the dry and rainy seasons, it is requested to inform and coordinate closely with the Emergency Response Authority of the Ninh Thuan province in order to follow the evolution of the accident. The communication to public and the proposed response measures have to be implemented under the guide of Circular 25/2014/TT-BKHCN.

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