Off-site dose calculation of hypothetical severe accident (SBLOCA) for SMART using MACCS2 code

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1. Introduction

Recently, the Korea Atomic Energy Research Institute (KAERI) had been completed the standard design of SMART (System Integrated Modular Advanced ReacTor) and Reviews for the standard design of SMART has been progressed to achieve the standard design approval by Korea Institute of Nuclear Safety (KINS). Compared with existing commercial reactor, SMART has low electric power capacity and the safety is improved by unique safety features. As seen in the Fukushima Daiich accident, a possibility of the severe accident for nuclear power plants can't be excluded. And its radiological consequences to human and environment are large. Particularly, because SMART could be constructed near the downtown areas due to its various purposes, its consequences are more importance than existing reactors. Therefore, off-site dose was evaluated under hypothetical severe accident conditions for SMART in this paper.

2. Methods and Results

2.1 Introduction of SMART

The power of SMART is designed 330 MWth to supply the energy for electricity generation, seawater desalination, and so on. Its design life is 60 years. The important design concept is to integrate most major components into a single pressure vessel. And SMART has unique advanced safety features such as the passive residual heat removal system, canned-motor reactor coolant pumps, and etc.

2.2 Accident Scenario

As mentioned earlier, SMART is designed as an integrated modular type. Since the steam generators and pressurizer are designed as in-vessel type components, the piping systems connecting within the reactor coolant system could be removed. So, large break loss of coolant accident (LBLOCA) was excluded in accident analyses for SMART.

In this paper, small break loss of coolant accident (SBLOCA) was selected as a representative accident scenario. And failures of all the major safety systems are assumed for conservative analysis.

2.3 Source Term

The core inventory and release fraction are need for MACCS2 code [1] modeling. Firstly, ORIGEN-ARP code [2] was used to evaluate the core inventory for SMART. For the conservative approach, it was assumed that the fuel type is the Westinghouse 17×17 OFA, the fuel burns up continuously during 1095 days (36 months × 2 cycles) without a cooling term, the core thermal power is 23.0 MW per UO_2-ton, and uranium enrichment is 4.8 $^{w}/_{o}$ U-235. And 44-group ENDF library was used for calculation.

Secondly, MELCOR code [3] was used to evaluate the release fraction of fission products for SMART. Existing MELCOR model for SMART which developed to analysis severe accidents for SMART in aspect of regulatory position was used. MELCOR code was executed according to the assumed accident scenario, and a containment isolation failure was assumed to evaluate the release fraction of fission products additionally.

Analysis results of the core inventory and release fraction are shown in table I and II, respectively.

Table I: Core inventory for SMART

Nuclide	Activity (Bq)	Nuclide	Activity (Bq)	Nuclide	Activity (Bq)
Co-58	6.47E+12	Ru-103	4.65E+17	Cs-136	1.48E+16
Co-60	3.70E+13	Ru-105	2.88E+17	Cs-137	4.31E+16
Kr-85	4.54E+15	Ru-106	1.39E+17	Ba-139	6.16E+17
Kr-85m	9.78E+16	Rh-105	2.77E+17	Ba-140	5.98E+17
Kr-87	1.95E+17	Sb-127	2.67E+16	La-140	6.11E+17
Kr-88	2.63E+17	Sb-129	8.46E+16	La-141	5.61E+17
Rb-86	3.87E+14	Te-127	2.64E+16	La-142	5.46E+17
Sr-89	3.62E+17	Te-127m	4.45E+15	Ce-141	5.64E+17
Sr-90	3.56E+16	Te-129	7.92E+16	Ce-143	5.37E+17
Sr-91	4.54E+17	Te-129m	1.52E+16	Ce-144	4.74E+17
Sr-92	4.78E+17	Te-131m	5.91E+16	Pr-143	5.23E+17
Y-90	3.63E+16	Te-132	4.66E+17	Nd-147	2.22E+17
Y-91	4.64E+17	I-131	3.23E+17	Np-239	5.48E+18
Y-92	4.84E+17	I-132	4.75E+17	Pu-238	5.42E+14
Y-93	5.35E+17	I-133	6.83E+17	Pu-239	1.76E+14
Zr-95	5.91E+17	I-134	7.74E+17	Pu-240	1.63E+14
Zr-97	5.80E+17	I-135	6.47E+17	Pu-241	4.44E+16
Nb-95	5.94E+17	Xe-133	6.84E+17	Am-241	5.28E+13
Mo-99	6.21E+17	Xe-135	2.99E+17	Cm-242	7.24E+15
Tc-99m	5.49E+17	Cs-134	3.61E+16	Cm-244	1.19E+14

Table II: Release fraction of fission products

Group	Major Element	Release Fraction
1	Noble Gases (Xe/Kr)	3.08E-01

2	Iodine (I)	5.17E-02
3	Cesium (Cs)	4.29E-03
4	Tellurium (Te)	1.90E-05
5	Strontium (Sr)	5.30E-02
6	Ruthenium (Ru)	1.16E-06
7	Lanthanium (La)	2.84E-02
8	Cerium (Ce)	7.78E-06
9	Barium (Ba)	5.97E-05

2.4 MASSC2 Modeling

The models in MACCS2 are implemented in three modules: ATMOS, EARLY, and CHRONC. Figure 1 shows the progression of a MACCS2 consequence calculation.

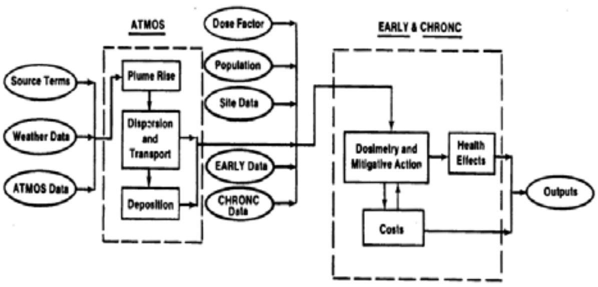

Fig. 1. The progression of a MACCS2 consequence calculation

The standard design of SMART is not consider its construction site. In this analysis, Kori site was assumed as a construction site of SMART. So, meteorological data of Kori site in 2009 was used as MACCS2 input data. It was assumed that release height is zero, heat contents of released flume is also zero. Emergency responses were not modeled conservatively. And most input variables inputted in default values which are recommended by user's manual.

2.5 Analysis Results

The off-site dose calculations were performed using MACCS2 code when the hypothetical severe accident of SMART occurs. Table III shows the analysis results of off-site dose.

Table III: analysis results of off-site dose

Distance (km)	Whole Body Dose (mSv)			Thyroid Dose (mSv)		
	Mean	95th percentile	99.5th percentile	Mean	95th percentile	99.5th percentile
1.0-1.1	489	1380	5210	4240	11900	40500
1.9-2.0	185	483	2080	1430	3310	12300
2.0-3.0	139	312	1140	977	2460	10900
3.0-4.0	88.6	215	546	573	1360	5430
4.0-5.0	63.3	167	418	391	868	3400
5.0-10.0	27.6	66.4	185	147	341	1240
10.0-20.0	8.88	25	42.7	43	99.5	259
20.0-30.0	4.04	10.9	18.4	19	39.2	143
30.0-50.0	1.51	5.02	6.83	6.68	15.3	36.4

According to these results, if a severe accident of SMART such as SLOCA would take place, radiological consequences due to the release of gaseous effluence could be severe by high radiological dose.

3. Conclusions

Although assumptions applied for this analysis was very conservative, calculated dose was so high. And it can be known that off-site dose of SMART would affect seriously on human and environment even under severe accident conditions in these analysis results. So, the emergency plan must be prepared for severe accidents of SMART. Also, detailed off-site dose must be calculated to establish the emergency plan adequately with assumptions of severe accident conditions for SMART.

REFERENCES

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