SEVERE ACCIDENT CONSEQUENCE ASSESSMENT FOR CHINSHAN NPP IN TAIWAN USING MELCOR2.1 AND WINMACCS

YU CHIANG, RONG-JIUN SHEU, SHAO-WEN CHEN, SHAO-SHUAN CHEN, YU-TING KU
Institute of Nuclear Engineering and Science, National Tsing Hua University,
No.101, Sec. 2, Kuang Fu Rd., Hsinchu, Taiwan 300, R.O.C.

JONG-RONG WANG, CHUNKUAN SHIH
Nuclear and New Energy Education and Research Foundation,
No.101, Sec. 2, Kuang Fu Rd., Hsinchu, Taiwan 300, R.O.C.

WEN-SHENG HSU
Nuclear Science and Technology Development Center,
No.101, Sec. 2, Kuang Fu Rd., Hsinchu, Taiwan 300, R.O.C.

ABSTRACT

This study completed a methodology of the consequence analysis of Nuclear Power Plant (NPP) in Taiwan. The consequence analysis sometimes need large amount of paper works. By the methodology in this study, the MELCOR2.1/SNAP calculated the reactor behavior during the accident and combined to WinMACCS using MELMACCS code. The analysis from reactor accident to dose calculation were all included and the post-processing was simplified by a graphic interface. There were three cases considered in this study which the venting path was different. The analysis results showed that the release fraction was very different of three cases.
This study successfully built a method of consequence analysis of Chinshan NPP and the results can help the decision making of mitigation strategy during a NPP accident.

1. Introduction

After Fukushima event, researchers did lots of safety analysis and procedure improvement of the nuclear power plants (NPPs) in Taiwan. For a beyond design basis accident, the heat removal of containment and suppression pool became the most important issue. The venting strategy in this kind of accident could have chance to cause the release of radiation nuclides from damaged core. So the different consequences of different events of NPPs were calculated in this study. By using MELCOR2.1 and WinMACCS, this study can help the decision making in Taiwan to cope with the beyond design basis accident.

In this research, the latest version MELCOR2.1 was used and combined with Symbolic Nuclear Analysis Package (SNAP). In this combination, MELCOR was used with a graphical user interface (GUI) that users can easily modify any detail of the model. Also, the results of MELCOR calculation can be shown in an animation model. Which means the detail results such as water level, pressure, hydrogen generation, valve status, release of radiation nuclides, etc. can be shown clearly in a five minutes animation. WinMACCS is a Windows interface version of MACCS2 code (MELCOR Accident Consequence Code System version 2) for the released radiation nuclides calculations. The consequences calculations of WinMACCS included the wind directions, wind speeds, wash out, evacuation in the emergency region, cancer risk, food chain pollution, etc.

The detail flow chart of this study is shown in Figure 1. There were few steps in this research. First, an accident event of Chinshan NPP was calculated by MELCOR2.1. Chinshan NPP is a BWR/4 reactor with MK-I containment. The MELCOR2.1/SNAP model of Chinshan NPP was built in previous work[1]. Second, the MELCOR results was input to an animation model built by SNAP. The MELCOR calculation was shown in detail in this animation model. Third, the released source term calculated by MELCOR were input to MELMACCS for converting the results to WinMACCS input type. Finally, the WinMACCS calculation based on weather, population were done and the results were discussed in detail combined with the venting strategy of Chinshan NPP. The WinMACCS results were shown in a self-made graphic interface program built by our lab and the dose near Chinshan NPP was shown clearly through this program.

By the combination between codes and the graphic output in this study, the decision making through consequence analysis will be more intuitive and strength the mitigation strategy in a NPP accident.

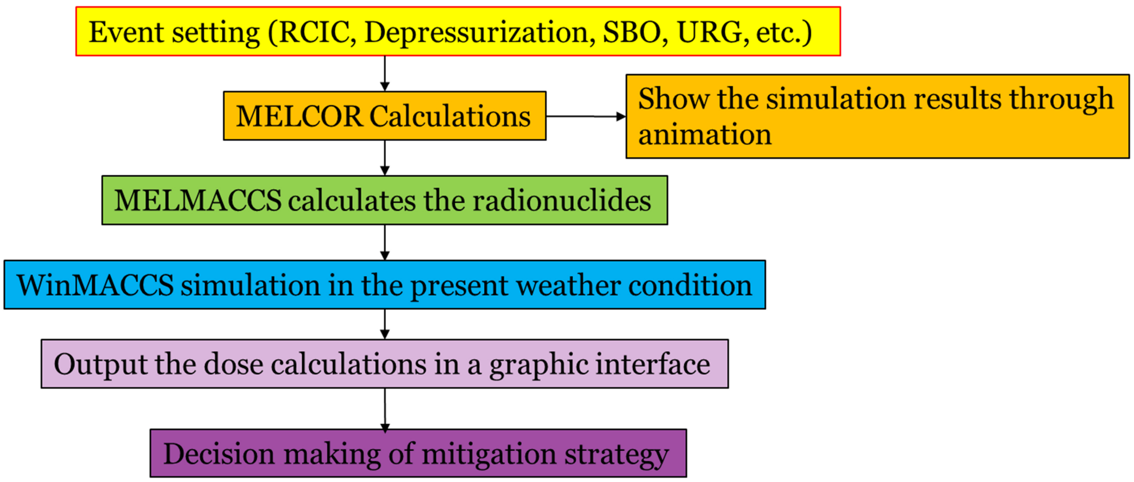

Fig 1. Flow chart of accident consequence assessment model

2. Methodology

In [1], the model establishment of MELCOR2.1/.SNAP was introduced and this model was compared to MAAP5.0 code for the model verification. Figure 2 shows the MELCOR model of Chinshan NPP. In this study, three cases were considered and set into MELCOR model. All three cases were in a situation of long term Station Blackout (SBO) and all the water injection system were assumed to be failed. Table 1 shows the detail setting of these cases. The leakages between containment, reactor building and environment were also set in this model. In [2], Sandia National Lab had a conclusion that the bolts of drywell head of MK-I containment may pulled by the high pressure in drywell and caused a leakage to reactor building. In the other hand, the leakage between reactor building and environment was 0.5% per day in the MELCOR model[3]. There were three venting strategies in this study. In case A, the drywell venting automatically started through the rupture disc when the containment pressure was over 50psig (0.34MPa)[4]. Rupture disc was an auto depressurization valve in MK-I containment. The radiation nuclides in containment will flow to environment through the stack after the break of rupture disc. In Case B, the rupture disc was still functional. But the venting strategy was changed from drywell to wetwell. In case C, the rupture disc was set to be failed. The containment pressure kept building up and increased the reactor building pressure through drywell head leakage. The reactor building failed at 1.5 atm.[4] and cause the release of radiation nuclides. Figure 3 shows the detail flow path settings for case A, B and C.

	Case A	**Case B**	**Case C**

Event	SBO without RCIC	SBO without RCIC	SBO without RCIC
Drywell head leakage	Yes	Yes	Yes
5F leakage rate	0.5% per day	0.5% per day	0.5% per day
Rupture disc	Available	Available	Failed
Venting method	Through rupture disc (Drywell venting)	Through rupture disc (Wetwell venting)	Reactor building failed because of over pressure

Tab 1: Detail settings of two cases

After the calculation of MELCOR, the results of MELCOR calculation was input to the program called MELMACCS. MELMACCS can generate the WinMACCS input for further consequence calculations. The WinMACCS interface was shown in Figure 4. The weather was set to be northeast wind during the accident, which is the most frequent wind direction in the winter around the area of Chinshan NPP. The population settings were followed by the emergency plan of New Taipei city[5]. After the consequence calculations of WinMACCS, the analysis results were input to a self-made program and the post-processing process can be shorten. This program can help the decision making of mitigation strategy in a very short time.

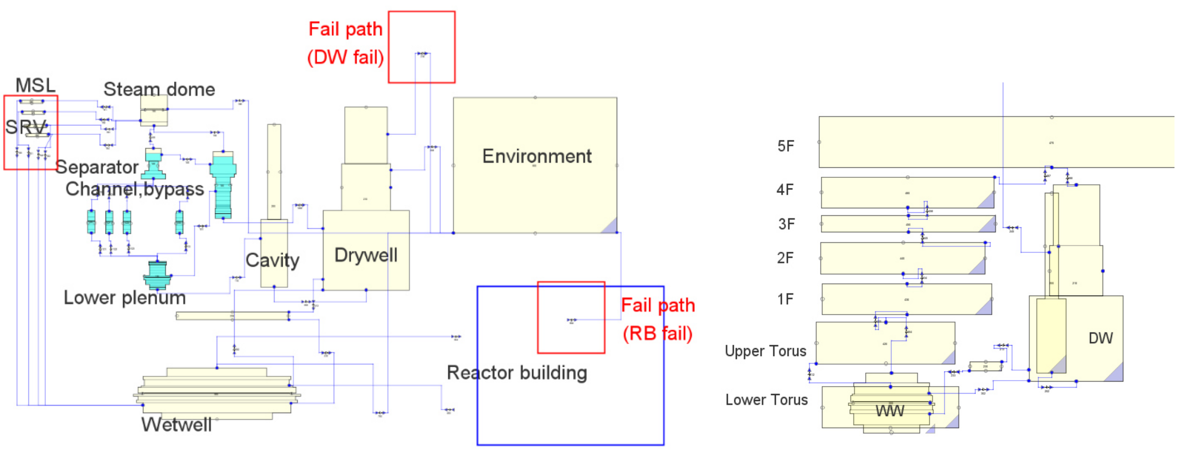

Fig 2. Chinshan NPP MELCOR model

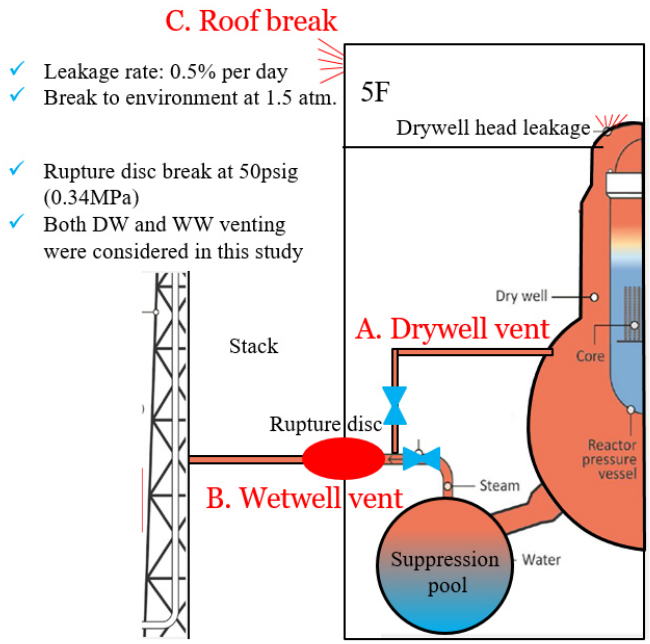

Fig 3. Detail setting of case A, B and C

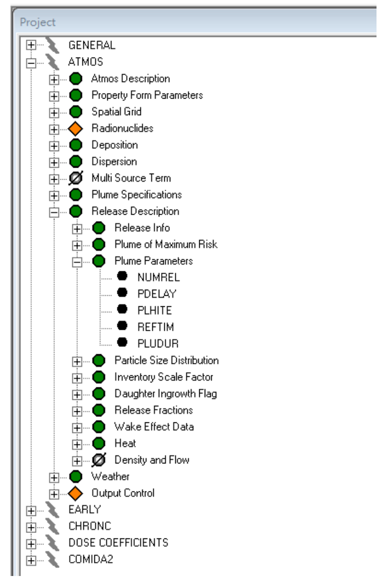

Fig 4. WinMACCS interface

3. Results and discussions

In all three cases, the SBO event started at 0s. The water level kept going down because of decay heat and the cladding temperature rose due to uncover. Figure 5 shows the water level and cladding temperature of three cases. The cladding temperature rose and the cladding failed before 100 minutes. Water dried out at 400 minutes and caused the failure of Reactor Pressure Vessel (RPV). Figure 5 also shows that there was no difference between case A, B and C in the early stage of the accident. After the cladding temperature reached 1088.7K, the hydrogen generated rapidly due to the zirconium-water reaction. The hydrogen flowed into suppression pool through SRVs and the pressure of wetwell started rising. The vacuum breaker between wetwell and drywell opened and balanced the pressure of them. Figure 6 shows the containment pressure in the accident. Also, the results were the same in the early stage of the accident. The hydrogen generation make the pressure rise at 100 minutes. RPV failed at 400 minutes and generate a pressure peak in Figure 6. The results of case A and case B show that the rupture disc was opened at 1500 minutes and the pressure decreased due to the open flow path to environment. For case C, the containment pressure kept building up because the rupture disc was not opened. Figure 7 is the pressure of reactor building fifth floor. At first, the pressure was increase due to the leakage of drywell head. At about 1200 minutes, the pressure rose immediately because of the hydrogen burn in fifth floor. The pressure reach the setting point 1.5 atm. and the fifth floor broke to the environment at this time.

After the calculations of MELCOR, the release of radiation nuclides was input to MELMACCS for generating the WinMACCS input. Table 2 shows the release fraction of radiation nuclides in the MELCOR calculations. In addition, the SOARCA analysis of Peach Bottom[6] was also shown in Table 2. The case of SOARCA was an SBO event without RCIC. The containment was failed because of over pressure.

	Release fraction								
	Xe	Cs	Ba	I	Te	Ru	Mo	Ce	La
SOARCA	0.947	0.017	0.095	0.115	0.104	0.009	0.002	0.000	0.000
Case A	0.8838	0.0051	0.0012	0.0259	0.0559	0.0000	0.0020	0.0000	0.0000
Case B	0.8724	0.0053	0.0013	0.0276	0.0613	0.0000	0.0019	0.0000	0.0000
Case C	0.4082	0.0026	0.0001	0.0080	0.0097	0.0000	0.0009	0.0000	0.0000

Tab 2: Release fraction of radionuclides

For case A, B and SOARCA, containment was failed and released the radiation nuclides. There was over 90% of noble gas release to the environment. The rupture disc was break in case A, B and caused the release of containment. The trend of the release fraction were consist with the case of SOARCA. Not like the containment failure case in SOARCA, the venting in both case A and B were through a long venting pipe and stack. So the release fraction was lower than SOARCA in this study. The results of case A and case B were very close. But this two cases were different in the venting strategy and the “Scrubbing effect” should be observed in the case of wetwell venting. The reason of this similar results was maybe because of the high generation of hydrogen in the early stage of the accident. In the animation model can see this situation clearly. The large amount of hydrogen flowed into wetwell and caused the pressure rose rapidly. Some of the water was pushed into drywell at this time. So the radiation nuclides drop into water right after the PRV failure and scrubbing at that time and decreased the release fraction case A. In case C, the radiation nuclides were stuck inside the containment and only released through the drywell head leakage. So the release fractions were lower than case A, B and SOARCA.

After all the calculations of MELCOR2.1/SNAP, MELMACCS, WinMACCS, the results were showed in an animation model. Figure 8 shows the animation model done by SNAP. The thermal-hydraulic results of MELCOR calculation were shown in detail in this animation model. Figure 9 was the animation results of case A. The pressure of containment was very low because of the open of rupture disc. The stack was shining and showed the release of important radiation nuclides. The core relocation and hydrogen burns can also be seen in the model. Figure 10 was the result of case C. The drywell was in a red color because of the high pressure of containment. The rupture disc was not open in case C and caused the high pressure of containment. Case C contained more radiation nuclides than case A and B.

The WinMACCS calculations were imported to a self-made program and showed the consequence calculations directly. Figure 11 is the case A results of Thyroid dose and Figure 12 is case B. The dose located in southwest near Chinshan NPP because of northeast wind. Although the release fraction of case A and B were very close. The dose effect calculated by WinMACCS shows that case A had a more severe result. The dose effect not only counted on the release fraction, but the release time, release height, etc. can still affect the dose results around the NPP. By the combination between codes and the graphic output in this study, the decision making through consequence analysis will be more intuitive and strength the mitigation strategy in a NPP accident.

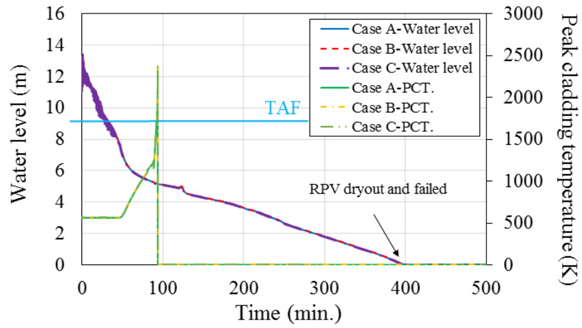

Fig 5. Water level and PCT. of MELCOR calculations

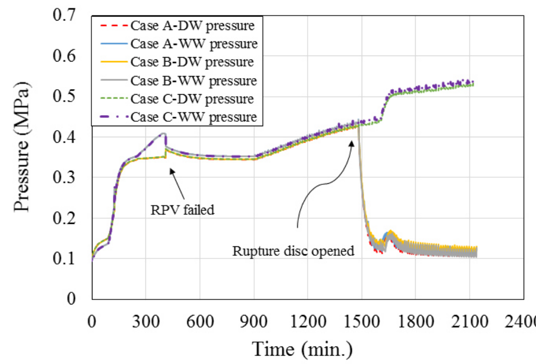

Fig 6. Containment pressure of MELCOR calculations

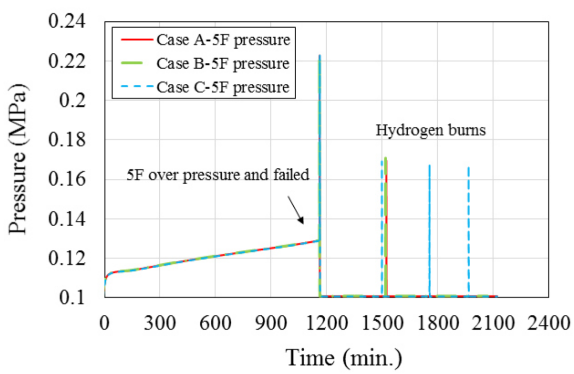

Fig 7. Pressure of reactor building fifth floor

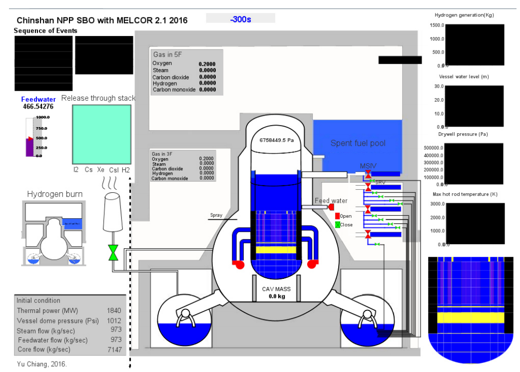

Fig 8. Animation model of MELCOR2.1/SNAP

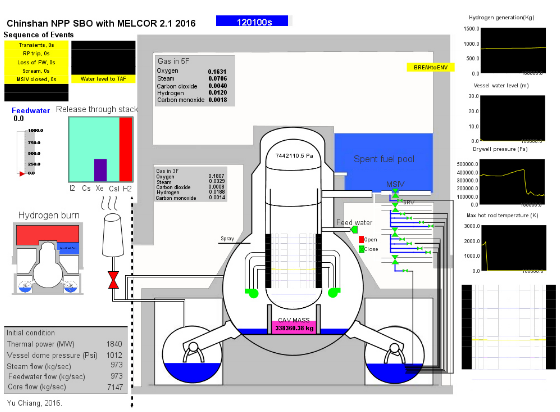

Fig 9. Animation model of MELCOR2.1/SNAP-Case A

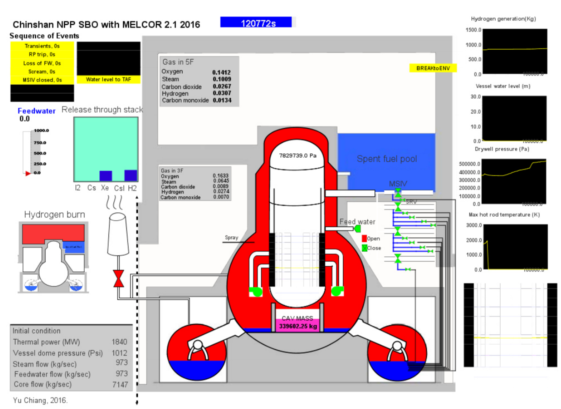

Fig 10. Animation model of MELCOR2.1/SNAP-Case C

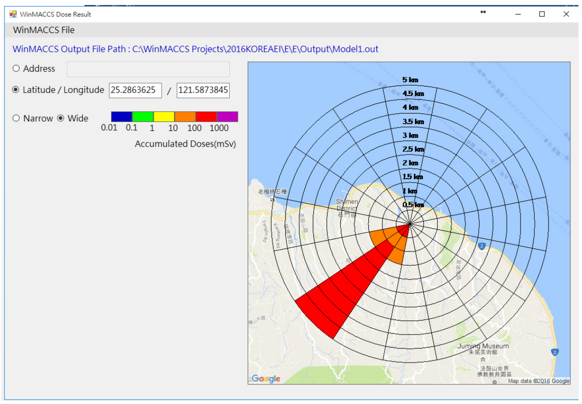

Fig 11. WinMACCS output by self-made program (Polar dose of thyroid)-Case A

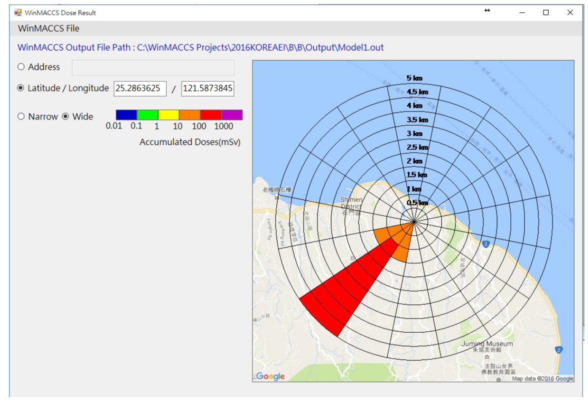

Fig 12. WinMACCS output by self-made program (Polar dose of thyroid)-Case B

4. Conclusions

By using MELCOR2.1/SNAP and WinMACCS, this study has developed a method to simulate the consequence analysis of Chinshan NPP. Several conclusions are as follows:

- The SNAP interface can help the user to modify the MELCOR model more intuitive.
- An animation model can be built by using SNAP interface. The animation can show the results of any MELCOR calculations easily.
- The release fraction was very different of different venting path.
- The release fraction of the radionuclides in this study was consist with the SOARCA simulation.
- The self-made program can show the consequence analysis of WinMACCS directly.
- This study successfully built a method of consequence analysis of Chinshan NPP and the results can help the decision making of mitigation strategy during the NPP accident.

Reference

[1] Chiang, Y., Wang, J.R., Lin, H.T., Chen, H.C., Shih, C., 2015. Methodology Using MELCOR2.1/SNAP to Establish an SBO Model of Chinshan BWR/4 Nuclear Power Plant NURETH-16.

[2] Randall Gauntt, D.K., Jeff Cardoni, Jesse Phillips, Andrew Goldmann, Susan Pickering, Matthew Francis, Kevin Robb, Larry Ott, Dean Wang, Curtis Smith, Shawn St.Germain, David Schwieder, Cherie Phelan, Fukushima Daiichi Accident Study (Status as of April 2012). 2012.

[3] Tai Power Company, Final Safety Analysis Report of Chinshan NPP.

[4] Taiwan power company, Teaching material of Chinshan BWR/4 Training (2007).

[5] Emergency plan of New Taipei city, 2014.

[6] Nathan Bixler, Randall Gauntt, Joseph Jones, Mark Leonard (dycoda LLC), State-of-the-Art Reactor Consequence Analyses Project Volume 1: Peach Bottom Integrated Analysis.