Development of a Visualizer for Severe Accident Phenomena

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1. Introduction

In case a severe accident occurs in a plant, we should rely on severe accident management to mitigate the accident consequences. But for most of the operating plants, performing the accident management efficiently seems to confront difficulties because we cannot aware of the accident progression conditions in containment or in reactor vessel. Diagnosing the condition of the containment atmosphere is one example of difficulties we will have. To spray the containment and thus to manage the hydrogen risks we need to measure the concentrations of steam, oxygen and hydrogen. But measuring the concentrations of steam and of oxygen is not possible and even measuring the concentration of hydrogen is reliablel in the most operating plants. To overcome this shortcoming, we need a good plant simulator to diagnose the progression of accidents in real time. As a first step in developing the simulator we have developed a visualizer for severe accident phenomena using ATLAS and MELCOR.

2. Tools and Results

In this section we will introduce briefly the tools and methods used in developing the visualizer and some results of the visualization applied to APR1400 reactor for large break loss of coolant accident (LBLOCA) scenario.

2.1 ATLAS

ATLAS is a multi-purpose tool used in developing nuclear plant analyser and was developed by GRS in Germany. The development of ATLAS was initiated from the need for visualization of ATHLET analysis result to prove input deck quality, error check and also to develop nuclear plant analysers for different german NPPs. It is now running on PC under Windows NT, 2000 and XP operating system with a simplified graphical editor which allows the user to create various graphics. ATLAS is linked with most of the severe accident analysis codes now in use such as ATHLET, ATHLET-CD, COCOSYS and of course MELCOR. This means, for example, that the analysis results of MELCOR code can be visualized with the help of various graphics provided by ATLAS.

2.2 MELCOR Severe Accident Analysis Code

MELCOR[1] is a fully integrated, engineering-level computer code that models the progression of severe accidents in light water reactor nuclear power plants. MELCOR is being developed at Sandia National Laboratories and a broad spectrum of severe accident phenomena in pressurized water reactors can be treated by the code. The code has been verified against many experimental data and has been proven to be sufficiently reliable, but to present the analysis results in graphical forms takes time and more extra efforts. Thus linking the ATLAS with the MELCOR and thus showing the results easily and clearly can broaden the spectrum of MELCOR's application domain.

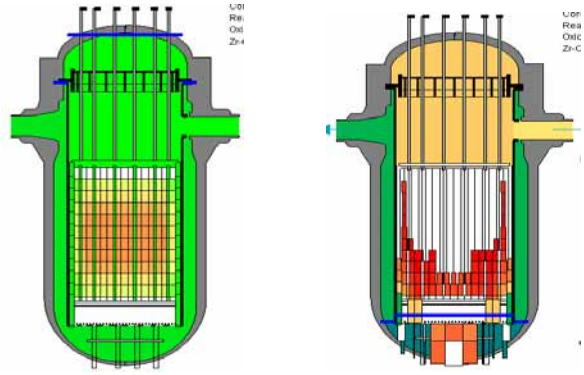
2.3 Accident Scenario of APR1400 to visualize

At first we have linked the ATLAS with the MELCOR analysis results and thus developed a visualizer for APR1400 reactor. The accident scenario to be shown is a LBLOCA caused by 10" cold-leg break. The progression of accident is summarized in the following.

Time (sec)	Accident Development
0	LOCA, Rx Trip
52	Core uncovered
163	Injection of SIT
303	Inventory of SIT exhausted
4,316	Fuel starts to melt
6,125	Core Dryout
7,377	UO2 relocates to lower head
8,516	RPV breached

2.4 Visualization of Reactor Core

The figure 1 below is the result of visualization for APR1400. Figure 1(a) shows the reactor core operating at steady state of 100% full power. Temperature is distinguished by color. As the color becomes more red, the temperature becomes more hot. We can see that the center of the core is hotter than the peripheral region, axially and radially. The green color says that the core is filled with coolant. Figure 1(b) is a picture of core at time 8,500 seconds just before reactor breach. The melted fuels have relocated to the vessel lower head and a large cavity in the core has occurred. With the help of this visualizer we can follow the whole process of core melting with as much detail as we want.

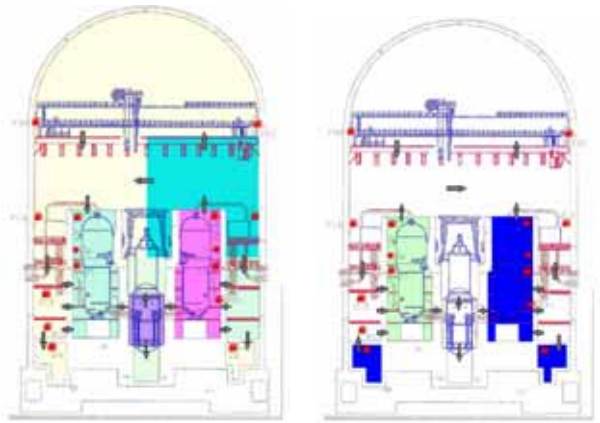


(a) (b)

Figure 1. APR1400 reactor core, (a) at time 0 second and (b) at time 8,500 seconds.

2.5 Visualization of Containment Condition

The figure 2 below shows the condition of containment atmosphere with time. Figure 2(a) shows the steam concentration in the containment at time 10 seconds. It shows clearly that the break has been occurred in the S/G compartment on the right. Figure 2(b) shows the concentration of the liquid aerosol in the containment at time 10,000 seconds. Liquid aerosols are accumulated in the IRWST and in the right S/G compartment where the pipe has broken. We can also represent the concentration of fission products, hydrogen, oxygen etc.. These kinds of information would be surely critical in successfully performing the severe accident management and thus improving the mitigative capability of the operating NPPs against severe accident.



(a) (b)

Figure 2. containment conditions ,(a) the steam concentration in the containment at time 10 seconds and (b) the distribution of liquid aerosol at time 10,000 seconds.

3. Conclusion

We have developed a visualizer for severe accident phenomena. It is a first step to a development of a severe accident simulator and was developed linking the MELCOR analysis results with the ATLAS graphic tool. The developed visualizer will serve in training courses, in checking the errors of the MELCOR inputs and thus improving the analysis quality. But the final goal is to develop a severe accident simulator which will serve as an essential tool for the national radiological emergency preparedness.

REFERENCES

[1] R.O. Gauntt et al., MELCOR Computer Code Manuals, NUREG/CR-6119, SAND2000-2417, 2000
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