Improvement of Wolsung Simulator including Severe Accident Analysis Models

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Abstract: KHNP is promoting the Wolsung simulator development project that is to adapt severe accident analysis models in the simulator. This project will build a new full scope simulator of a CANDU plant specific to the Wolsung unit 1 plant using L3M Orchid® simulation environment.
For the severe accidents trainings, the Wolsung simulator will include severe accident simulation module using the MAAP4-CANDU. In the early part of a transient, MAAP4 may run slower than real time and much faster than real time at other times. Those problems can be caused instability of simulation system. Wolsung simulator hard ware have built in L3M and for completion of the simulator, the simulator will be validated against a number of acceptance test procedures including normal evolutions, steady state, transient and malfunction tests, severe accidents cases, spare requirements.

Keyword: KHNP, WOLSUNG SIMULATOR, SEVERE ACCIDENT, SIMULATION MODEL

1 Introduction

The purpose of the simulator with severe accident analysis models will allow trainee to simulate normal operations, transient events, design bases accidents, and severe accidents[1]. For the this purpose, the Wolsung training simulator will include severe accident simulation module using the MAAP4-CANDU from Electric Power Research Institute. MAAP4-CANDU performs severe accident analysis for nuclear power plants including assessments of core damage and radiological transport. Wolsung Unit 1 training simulator will be a real-time, high fidelity, repeatable complete plant simulation used for operator training and licensing. Natively MAAP is not designed for real-time simulation as it uses a variable time-step. MAAP4-CANDU may run slower than real time in the early part of a transient and much faster than real time at other times. This creates potential synchronization problems with the other simulator models that must be addressed by both the simulator and MAAP[2] .

During the severe accident simulation, the MAAP models will be used to simulate the following systems: Reactor, NSSS, Containment. The MAAP models for other systems, including emergency core cooling systems, the BOP and I&C will be disabled because they are essentially simplified boundary conditions to the severe accident simulation models of the NSSS and containment. Instead, the simulator models for these systems developed by simulation environment (L3M's Orchid) will be retained and will be interfaced to the MAAP models. Interfacing of existing real-time simulation models and severe accident models has many issues to consider, but we are trying to integration through adjustment and synchronization of boundary condition variables. After completion of the simulator system integration, the simulator will be validated against a number of acceptance test procedures including normal evolutions, steady state, transient and malfunction tests, severe accidents cases, spare requirements.

2 MAAP Interface

The MAAP program is a stand-alone program that simulates serious accidents. The scope of the MAAP program is a reactor, a coolant system, a steam generator, and a containment building. In order for the MAAP program to operate in the simulator, the reactor, steam generator, coolant system, containment building sections must be shut down and replaced by the MAAP. In addition, the boundary systems of the four systems (water supply, main steam, emergency core cooling, etc.) should be linked to the MAAP. The figure below shows the overall connection method.

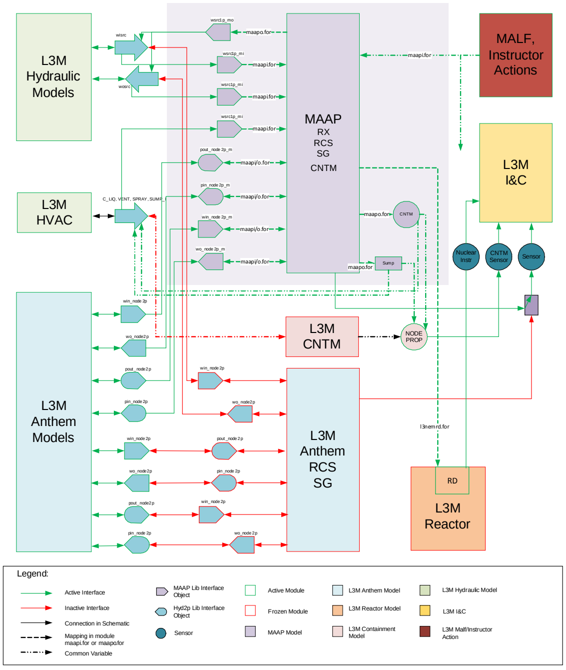

Figure 1. Relationship between MAAP and L3M module

Each object of the MAAP link library is classified according to function, as shown in the following table 1, and all thermal hydraulic linkage is made up of four connections(Flow Source In / Out and Pressure Source In / Out) can be defined. The selection of the flow source and pressure source is determined by what is useful in conjunction with the MAAP. Most flow sources are a typical choice. # 1-6 in the table below are related to the linkage of MAAP and L3M models, and # 7 ~ 8 are related to the setting of Interface Schematic.

Table 1 Objects in the library associated with MAAP

Function group	Object name
1. MAAP and adjacent homo -geneous thermal hydraulic model system (water system etc.)	wsrc1p_mi, wsrc1p_mo, wsrc41p_mi, psrc1p_mi, psrc1p_mo
2. Linkage between MAAP and adjacent ANTHEM model (safety injection system)	win_node2p_m, wo_node2p_m,
3. MAAP containment building results and L3M linkage (HVAC, sensor, etc.)	cntmcv_mo, cntmsump_mo
4. Linkage of MAAP results and measurement control	instr_cdb, selecta_mo, selectb_mo,
5. MAAP valve connection	r_valve2p, rvalve2pl_mi
6. Converting connection point variables for compatibility with past ANTHEM libraries	a42p_m8mo, a4p1p_m8pmi,
7. Generate MAAP standard linkage variable	var_cntm, var_rcs
8. Provides a background image of major facilities in the scheme to improve usability	outline_cntm1, outline_cntm4, outline_prt

2.1 Link MAAP code with L3M model

In case of Homogeneous TH model, the existing 1-phase TH model is connected to the MAAP (ie, four systems of severe accident simulations), it must be connected to the ANTHEM model in normal mode. Therefore, using wisrc, wosrc, pisrc, and posrc, it should be connected the three parts. Fig 2 shows such connecting method about MAAP and flow source In (wisrc, 1-phase) connection & Out (wosrc, 1-phase) connection.

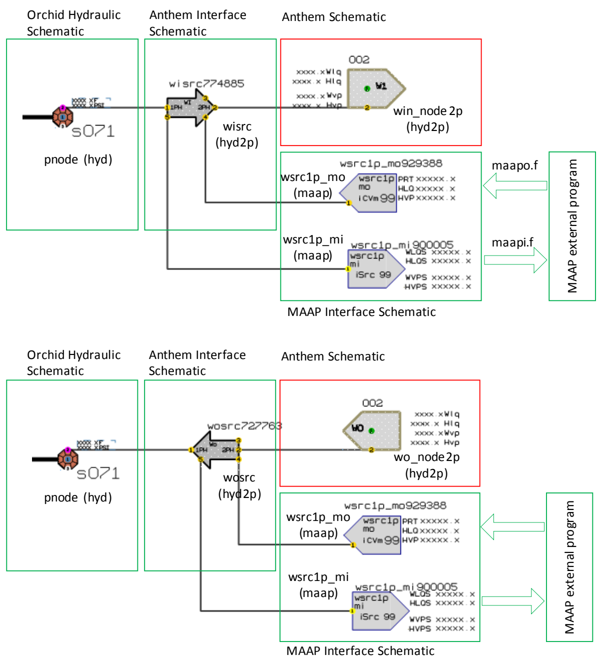

Figure 2. WISRC(or WOSRC) and MAAP linkage

2.2 ANTHEM model

Including the simulation range of MAAP to simulation model, there are various ANTHEM models in the L3M's Model.

a) Connect the MAAP and the flow source In (win_node2p, 2-phase): The win_node2p shown in Fig 3 should be connected to pout_node2p of the existing ANTHEM (RCS, SG, etc).

b) MAAP and flow source Out (wo_node2p, 2-phase) connection: wo_node2p shown in Fig 4 should be connected to pin_node2p of existing ANTHEM (RCS, SG, etc).

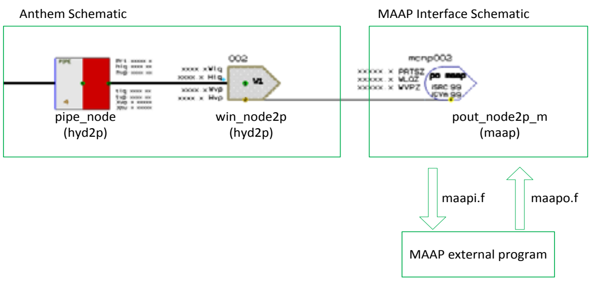

Figure 3. Win_NODE2P and MAAP linkage

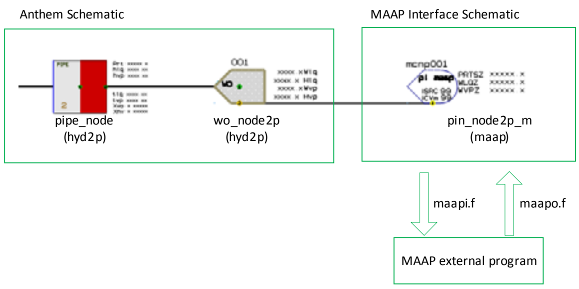

Figure 4. Wo_NODE2P and MAAP linkage

3 MAAP4 Linkage Analysis and Input Deck Comparison Tool Development

3.1 MAAP4 simulator connection

Wolsung project will make three test scenarios (ie, three SAS ICs that can be used by the Instructor) according to the simulator contract, but it is a structure that can increase the IC by creating an additional MAAP4 Input File. This feature shows in Fig 5.

For the Stability and Repeatability perspective, it is necessary to re-execute the data (Input / Parameter File) provided by FAI in the MAAP4 driver to see if the same (or similar) result is obtained. The operator can perform a major accident mitigation while confirming the behavior of the power plant while the IC is running. Due to the nature of the MAAP4-CANDU version, each IC has constraints that must start with 100% output, which is expected to be improved in MAAP5-CANDU (under development). It is necessary to confirm whether the operation will be changed from a driving less than 100% to a severe accident or a DBA to severe accident. In order to mount the MAAP4 on the existing simulator, the similar structure will be most suitable, and the cooperation (interactive information sharing plan) between the FAI and the simulator developer should be derived.

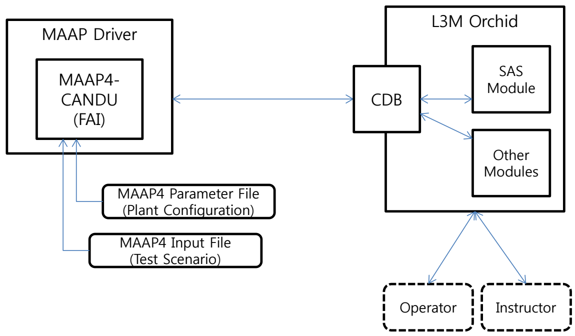

Figure 5. MAAP4-based simulator linkage

3.2 Development of MAAP4 Input Deck comparison function

The purpose of developing of MAAP4 input deck comparison is to derive the difference between input deck for Wolsong 1 and Reference (Wolsung 2,3,4 and Darlington). The reference source is Wolsong 1 (2009), Wolsong 2,3,4 (2001), Darlington (2009). The main function of this feature is to comparison that MAAP code Input deck rules, to distinguish annotation, information, and based on these three different.

3.3 Application plan and main results

In order to improve the quality of input deck and find wrong errors can be verified by checking the differences and common points between Wolsong 1 and Wolsong 2,3,4. It is also possible to accumulate technical information on the configuration system of the input deck. Fig 6 shows the comparison of the input deck (Wolsong 1, Darlington, Wolsong 2/3/4) with the other two shapes based on Wolsong Unit 1.

Figure 6 The comparison of the input deck

	A	B	C	D	E
1	Wolsong #1(Candu-Generic)	Wolsong #2,3,4	Darlington	WS#1 -Darlington	WS#1 -WS#234
2	TAMB 300. ENVIRONMENT TEMP	TAMB 300. ENVIRONMENT TEMP	TAMB 300. ENVIRONMENT TEMP	SAME	SAME
3	TCN0 322. INITIAL TEMPERATURE OF C	TCN0 322. INITIAL TEMPERATURE OF C	TCN0 322. INITIAL TEMPERATURE OF C	DIFF	SAME
4	PAMB 1.D5 ENVIRONMENT PRESSURE	PAMB 1.D5 ENVIRONMENT PRESSURE	PAMB 1.D5 ENVIRONMENT PRESSURE	SAME	SAME
5	QPOWER 2155.9E6 CORE THERMAL POWER	QPOWER 2064.E6 CORE THERMAL POWER D	QPOWER 2651.E6 CORE THERMAL POWER D	DIFF	DIFF
6	PPS0 10.6895E6 INITIAL PRIMARY SYSTEM	PPS0 10.5D6 INITIAL PRIMARY SYSTEM P	PPS0 10.5D6 INITIAL PRIMARY SYSTEM P	DIFF	DIFF
7	PPSNOM(1) 10.6895E6 NOMINAL FULL POW	PPSNOM(1) 10.5D6 NOMINAL FULL POW	PPSNOM(1) 10.5D6 NOMINAL FULL POW	DIFF	DIFF
8	TWPSNM(1) 562.15 NOMINAL FULL POW	TWPSNM(1) 587.7222E0 NOMINAL FULL PO	TWPSNM(1) 587.7222E0 NOMINAL FULL PO	DIFF	DIFF
9	TWPS0(1) 562.15 INITIAL PRIMARY SYSTE	TWPS0(1) 587.7222E0 INITIAL PRIMARY SYS	TWPS0(1) 587.7222E0 INITIAL PRIMARY SYS	DIFF	DIFF
10	PPSNOM(2) 10.6895E6 NOMINAL FULL POW	PPSNOM(2) 10.5D6 NOMINAL FULL POW	PPSNOM(2) 10.5D6 NOMINAL FULL POW	DIFF	DIFF
11	TWPSNM(2) 562.15 NOMINAL FULL POW	TWPSNM(2) 587.7222E0 NOMINAL FULL PO	TWPSNM(2) 587.7222E0 NOMINAL FULL PO	DIFF	DIFF
12	TWPS0(2) 562.15 INITIAL PRIMARY SYSTE	TWPS0(2) 587.7222E0 INITIAL PRIMARY SYS	TWPS0(2) 587.7222E0 INITIAL PRIMARY SYS	DIFF	DIFF
13	WWCP0 1925. PUMP MASS FLOW RATE (	WWCP0 1995. PUMP MASS FLOW RATE (	WWCP0 2741.7 PUMP MASS FLOW RATE (	DIFF	DIFF
14	PDCP0 1.83E6 PRESSURE RISE (Pa) OVER C	PDCP0 1.83E6 PRESSURE RISE (Pa) OVER C	PDCP0 1.83E6 PRESSURE RISE (Pa) OVER C	SAME	SAME
15	ZWPZ0 15.0 PRESSURIZER WATER LEVEL	ZWPZ0 12.48 PRESSURIZER WATER LEVEL	ZWPZ0 5.07 PRESSURIZER WATER LEVEL	DIFF	DIFF
16	MWSG0 3.8D4 INITIAL MASS OF WATER O	MWSG0 3.8D4 INITIAL MASS OF WATER O	MWSG0 8.1814D4 INITIAL MASS OF WATE	DIFF	SAME
17	PSG0 4.7D6 INITIAL PRESSURE ON SEC S	PSG0 4.78D6 INITIAL PRESSURE ON SEC S	PSG0 5.068D6 INITIAL PRESSURE ON SEC	DIFF	DIFF
18	QC0 3.0E6 HEAT LOSS FROM PHTS TO (	QC0 3.0E6 HEAT LOSS FROM PHTS TO	QC0 2.05E6 HEAT LOSS FROM PHTS TO	DIFF	SAME
19	ABB(1) 0.E0 BREAK AREA IN LOOP 1	ABB(1) 0.E0 BREAK AREA IN LOOP 1	ABB(1) 0.E0 BREAK AREA IN LOOP 1	SAME	SAME
20	ABB(2) 0.E0 BREAK AREA IN LOOP 2	ABB(2) 0.E0 BREAK AREA IN LOOP 2	ABB(2) 0.E0 BREAK AREA IN LOOP 2	SAME	SAME
21	FBB(1) 1 ENTER LOOP 1 BREAK LOCATI	FBB(1) 1 ENTER LOOP 1 BREAK LOCATI	FBB(1) 1 ENTER LOOP 1 BREAK LOCATI	SAME	SAME
22	FBB(2) 1 ENTER LOOP 2 BREAK LOCATI	FBB(2) 1 ENTER LOOP 2 BREAK LOCATI	FBB(2) 1 ENTER LOOP 2 BREAK LOCATI	SAME	SAME
23	INBB(1) 6 ENTER LOOP 1 BREAK DISCHA	INBB(1) 6 ENTER LOOP 1 BREAK DISCHA	INBB(1) 1 ENTER LOOP 1 BREAK DISCH	DIFF	SAME
24	INBB(2) 6 ENTER LOOP 2 BREAK DISCHA	INBB(2) 6 ENTER LOOP 2 BREAK DISCHA	INBB(2) 1 ENTER LOOP 2 BREAK DISCH	DIFF	SAME

4 Conclusion

The SAT(Site Acceptance Test) will be performed soon and in this test, the Wolsung simulator will be validated against a number of acceptance test procedures including normal evolutions, steady state, transient and malfunction tests, severe accidents cases, spare requirements. In specially, for the severe accident test, three scenarios & steady state input decks have been developed and we set this steady state to shape A with this initial condition status. Integration with simulation environment of the L3M (MAAP4 works as a separate module, but the information sharing system) is used to reproduce the steady state of the previously set shape A to check the performance (to see the same curve). These results will become the base for the other severe accident scenarios.

The remaining three scenarios are checked for performance, starting from shape B, and set to shapes C, D, and E, respectively. Once all of the above tasks are completed, the operator action is added to the simulation in real time to check the behavior and stability.

References

[1] ANSI/ANS-3.5-2009, "Nuclear Power Plant Simulators for Use in Operator Training and License Examination", American National Standards Institute, 2009

[2] JH Hong, MS Lee and KH Chung, "Application of a Virtual Ovation System to the ShinKori-3 Simulator", Transactions of the Korean Nuclear Society Autumn Meeting Gyeongju, Korea, October 27-28.