June 5, 2013

MEMORANDUM TO: Ronaldo V. Jenkins, Branch Chief
Licensing Branch 3
Division of New Reactor Licensing
Office of New Reactors

FROM: Tekia Govan, Project Manager **/RA/**
Licensing Branch 3
Division of New Reactor Licensing
Office of New Reactors

SUBJECT: REGULATORY AUDIT SUMMARY FOR THE REVIEW OF DTE ELECTRIC COMPANY'S SASSI2010 VERIFICATION AND VALIDATION DOCUMENTATION FOR FERMI 3

DTE Electric Company has procured SASSI2010 to be used for Soil Structure Interaction (SSI) analyses in support of the Fermi 3 Combine License application. On March 19, 2013, the U.S. Nuclear Regulatory Commission staff conducted an on-site audit at the Sargent and Lundy office in Chicago, Illinois. The purpose of this audit was to review the SASSI2010 verification and validation documentation to confirm that the SASSI code is adequate for the Fermi 3 site conditions and SSI analysis cases. The detailed results of the audit, and entrance and exit attendance sheets are provided in the attached Enclosure.

Docket Nos.: 52-033

Enclosures:
As stated

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cc w/encl: See next page

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DATE	6/4/13	5/31/13	6/4/13	6/5/13

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AUDIT SUMMARY

Fermi 3 COL Application

SASSI2010 VERIFICATION AND VALIDATION

Dates of Audit: March 19 - 21, 2013

Audit Location: Sargent and Lundy, 55 E. Monroe Street, Chicago, IL

Nuclear Regulatory Commission (NRC) Review Team: Tekia Govan (NRC Project Manager), Manas Chakravorty (NRC Technical Reviewer), Carl Costantino (BNL), and Manuel Miranda (BNL)

Audit Scope

Sargent & Lundy (S&L) procured the SASSI2010 program to perform soil-structure interaction (SSI) analysis in support of the Fermi 3 Combined License application (COLA).

The purpose of the audit was to review the SASSI2010 Verification and Validation (V&V) documentation prepared by S&L, to verify the applicability of the SASSI2010 program to the Fermi 3 site conditions and SSI analysis cases. Generic test problems were reviewed only to the extent that they address the program features used in the Fermi 3 SSI analysis cases and related to Fermi 3 site conditions.

List of S&L Calculations Available for Review

Calculation Number	Revision	Date	Title
SVVR03.7.316-1.0-250USER-M01	1	3/18/2013	Validation of SASSI2010 Version 1.0-250USER-M01

Audit Summary

Representatives from S&L, DTE Electric Company, NRC, and Brookhaven National Laboratory (BNL) were present during the audit. A list of attendees at the entrance and exit meetings is provided in Enclosures 2 and 3 respectively.

After introductions and a review of the agenda, NRC staff made some introductory remarks regarding the audit background, scope, and objectives. Following these remarks, S&L presented a brief overview of the 45 test problems and related calculations that are documented in the V&V package.

Next, the staff conducted a detailed review of a selected subset of test problems. The staff focused on the following aspects during the review:

- Acceptability of computed solutions up to highest frequency of interest at the Fermi site.
- Acceptability of computed solutions for full range of Poisson's ratios of interest at the Fermi site.
- Sensitivity of computed solutions to location of half-space interface, as applicable to Fermi site.
- Acceptability of computed solutions for case of sharp contrast in stiffness between adjacent soil layers, as applicable to the Fermi site.
- Acceptability of computed solutions for the types of elements that may be used in the model, aspect ratio, minimum dimension, or maximum distortion of the 3D solid elements that will be used to model excavated volume at the Fermi site.

The staff only reviewed SSI analysis performed using the Direct Method (DM) of SASSI.

As a result of the review, one issue was identified as needing additional V&V work. This issue was discussed with S&L and a path forward was identified. Details of the review and discussions are given in the following section.

The audit concluded with an exit meeting that summarized the discussions and the disposition of the issues raised during the audit, which are summarized in Table 1.

<u>Detailed Review and Discussions</u>

<u>Acceptability of computed solutions up to highest frequency of interest at the Fermi site</u>

Problem 42 considers a 64'x48'x64' (base x width x height) box-type structure embedded 16' in a layered stiff soil/rock profile. The passing frequency of the model is 50 Hz, using SASSI guidance. Two horizontal input motions are considered: (a) an input motion with negligible energy content above 16 Hz, and (b) a Fermi site-specific input motion with non-negligible energy content up to 50 Hz.

Structural response in terms of 5 percent-damped acceleration response spectra (ARS) is presented for the two input motions. The ARS for the Fermi input motion show increased magnitude at certain high frequencies, which coincide with the high frequency peaks in the transfer functions. This implies that the Fermi input motion (richer in high-frequency energy content) is being correctly convolved with the transfer functions that are representative of a stiffer soil/rock site (which have relatively higher peaks at higher frequencies).

However, the staff noted that the computed transfer functions are not validated independently of SASSI. The problem, therefore, only tests the convolution of the transfer functions with the ground motion inputs. The issue of validation of the transfer function is further reviewed below under the discussion of Problem 1 and Problem 2.

Problem 1 considers a superstructure represented by a lumped-mass stick model supported on a circular footing (130' diameter, 10' thick) overlaying a homogeneous soil medium (surface-mounted conditions). **Problem 2** is very similar to Problem 1; the main difference is that the soil medium is layered and the circular footing is 96' in diameter. The passing frequency of the models is 18 Hz for Problem 1 and 20 Hz for Problem 2, using SASSI guidance.

Horizontal and rocking impedance functions corresponding to Problems 1 and 2, computed using SASSI, compare favorably with results obtained using the in-house program DIMFU and analytical solutions by Luco (1976). However, the comparisons are only performed for a range of the non-dimensional frequency parameter a_0 between zero and approximately 3.7 for Problem 1, and between zero and approximately 5 for Problem 2. For the Fermi site conditions, by contrast, the maximum a_0 should be in the order of 8 to 10.

Based on the above observations, the staff concluded that test Problems 1, 2, and 42 do not test the SASSI solutions, in terms of transfer functions or impedance functions, for the full frequency range of interest at the Fermi 3 site (up to 50 Hz). The staff could not identify any other relevant test problems in this regard.

S&L indicated that additional test Problems 46 and 47 will be implemented, as described in Table 1, to demonstrate the acceptability of the SASSI solutions for the frequency range of interest at the Fermi site. The staff will issue a new RAI to document the results of the additional investigation.

Additional clarifications regarding test Problem 2 are listed in Table 1.

<u>Acceptability of computed solutions for full range of Poisson's ratios of interest at the Fermi site</u>

Problem 43 considers the SSI model of the Fermi RB/FB embedded in a layered rock profile that is similar to the Fermi site conditions, but with no backfill above the rock. The passing frequency of the model is 50 Hz, using SASSI guidance. Fermi site-specific input motions are used. The Fermi upper bound s-wave velocity profile for the rock is used together with three different Poisson's ratios: 0.3, 0.4, and 0.48 (S&L indicated 0.48 will be the upper limit in the Fermi COLA analysis for saturated backfill layers).

Results in terms of transfer functions generally show stable solutions for the three values of Poisson's ratios considered. Deviations for the 0.48 case are evident in the transfer functions for vertical response due to vertical input, which is expected since vertical response largely depends on the p-wave input.

In some instances, the transfer functions for horizontal response due to horizontal input appear to be sensitive to the 0.48 case, above approximately 25 Hz. S&L explained that these deviations are due to the effect of rocking, which is not important in the Fermi COLA analysis because rocking is known to be minimal.

Based on the above observations, the staff confirmed the numerical stability of the SASSI solutions up to the upper limit of Poisson's ratio of 0.48. The staff also indicated that verification of limiting the Poisson's ratio to a value of 0.48 (upper limit) in the Fermi COLA analysis for saturated backfill layers will be performed as part of staff's review of the SSI and SSSI analysis results to be documented in the COLA FSAR.

Additional clarifications regarding test Problem 43 are listed in Table 1.

Sensitivity of computed solutions to location of half-space interface, as applicable to Fermi site

Problem 44 considers the SSI model of the Fermi RB/FB embedded in a layered rock profile that is similar to the Fermi site conditions, but with no backfill above the rock. The passing frequency of the model is 50 Hz, using SASSI guidance. Fermi site-specific input motions are used. The Fermi upper bound s-wave and p-wave velocity profiles for the rock are used. The half-space interface is considered at three different distances below the bottom of the RB/FB basemat: 112.2 m (reference case), 142.2 m, and 192.2 m.

Results in terms of transfer functions and ARS show insignificant differences between the three different cases considered. Based on these observations, the staff concluded that the location of the half-space interface in the Fermi COLA analysis (reference case in the test problem) is acceptable. Improvements in the SASSI solutions due to additional layers below the reference location of the half-space interface appear to be minimal.

Additional clarifications regarding test Problem 44 are listed in Table 1.

Acceptability of computed solutions for case of sharp contrast in stiffness between adjacent soil layers, as applicable to the Fermi site

Problem 45 considers the SSI model of the Fermi CB embedded in a layered rock profile that is similar to the Fermi site conditions, but with no backfill above the rock. The passing frequency of the model is 50 Hz, using SASSI guidance. Fermi site-specific input motions are used. The Fermi upper bound s-wave and p-wave velocity profiles for the rock are used.

An additional 1.28 m layer of soil with s-wave velocity equal to 343.5 m/s is considered overlaying the rock, to investigate whether the computed SASSI solutions are affected by a sharp contrast in stiffness between adjacent layers (the ratio of s-wave velocity between adjacent soft and stiff layers = 1/7.3). Since the additional soil layer is thin in comparison to the underlying rock layers, the computed SASSI solutions should remain essentially unchanged.

Results in terms of transfer functions and ARS show insignificant differences between the reference case and the case with the additional soil layer. Based on these observations, the staff concluded that the SASSI solutions are adequate for an SSI model that contains a sharp contrast in stiffness between adjacent layers.

Acceptability of computed solutions for the types of elements that may be used in the model, aspect ratio and minimum dimension of the 3D solid elements that will be used to model excavated volume at the Fermi site

Element size in the excavated soil volume is dictated by the 50 Hz passing frequency requirement, using SASSI guidance, for both horizontal and vertical directions.

Problems 31, 36, and 41 address the aspect ratio of the solid brick elements used to model the excavated soil volume as well as thick shell elements used to model the basemat and walls of the structure. Results in terms of transfer functions and ARS show that the aspect ratio needs to be limited to 1:3 in the horizontal and vertical directions for both thick shell and brick elements in the excavated soil volume. The staff will verify limiting the aspect ratio for these elements to 1.3 as part of its review of Fermi 3 SSI analysis model.

TABLE 1

Summary and disposition of issues raised during the audit

Issue	Disposition
Provide descriptions of in-house programs DIMFU and DYNAS	Program descriptions were provided (see Attachment 1)
Incorrect references to SASSI2000 in the V&V documentation	Typos will be updated in the next revision of the V&V documentation
Problem 2 states that the radius is the same as Problem 1; however, Problem 2 has a radius of 24 ft and Problem 1 has a radius of 65 ft (pg. 54, 56, 58).	Problem 2 will be revised as follows: • Section 4.2.2 will be revised to clarify that the model radius is 48 feet • Section 4.2.4 will be revised to state radius of 48 feet instead of 24 feet • Note 3 of Table 4.2-2 will be revised to delete footing dimension description • Figure 4.2-2 will be revised to include the SL-SASSI2010 data point for frequency of 128.9 Radians/Second
Problem 42 considered an SSI model with discretization such that the passing frequency is 50 Hz, using SASSI guidance. The transfer functions presented have not been validated independently of SASSI. The problem, therefore, only tests the convolution of the transfer function with the ground motion inputs. Problems 1, 2, and 7 compute impedance functions for different geometries and soil conditions. They compare the SASSI solution with results obtained using the DIMFU program (Problems 1 and 2) and Wong and Luco's analytical formulation. The comparisons presented are limited to a frequency range of 0 to 20 Hz (a_0 = 0 to ±3.7). Since the test problems do not appear to test the SASSI solutions in terms of transfer function or impedance functions for the full frequency of interest for the Fermi 3 site (up to 50 Hz), please explain how this is addressed.	The following additional three-step investigation will be performed by S&L: Step 1: Using the least equivalent shear wave velocity from the rolling average of the Fermi 3 layered soil properties, determine the maximum a_0 value (based on 50 Hz passing frequency) for which the accuracy of the impedance functions should be addressed Step 2: Repeat test Problem 1 (New Problem 46) as follows: • Adjust the shear wave velocity of the homogenous soil layer as required so that the model has a passing frequency of 50 Hz • Compare the SASSI2010 impedance functions up to a_0 value from Step 1 against those obtained from DIMFU program Step 3: Repeat test Problem 2 (New Problem 47) as follows: • The layered soil shall be that of Fermi 3 with the shear wave velocities adjusted by a factor as required to satisfy 50 Hz passing frequency requirement • Compare the SASSI2010 impedance functions up to a_0 value from Step 1 against those

Issue	Disposition
	obtained from DIMFU program The staff will issue a new RAI to document the results of the additional investigation for New Problem Numbers 46 and 47
Problem 7, Figure 4.7-4 (pg. 145) shows deviations between the solution developed by SASSI and published analytical results of Luco (1978). These deviations appear to be significant above $a_0 = 2$.	Problem 7 considers inclined (45 degrees) wave propagation, which is not applicable to Fermi 3 SSI analysis cases
Problem 43, Fig. 4.43-4, Transfer Functions for Poisson's Ratio of 0.3 and 0.4 track well; Poisson's Ratio equal to 0.48 deviates above 29Hz.	Section 4.43.5 will be revised as follows: • The bullet for comparison of horizontal transfer functions will be expanded to explain the reason for the deviations above 29 Hz being due to rocking effects; this is not applicable to Fermi 3 SSI analysis cases because rocking is known to be minimal
Problem 44, discuss relative number of interaction nodes for CB vs. RBFB	In Problem 44 (RB/FB) model there are 1575 interaction nodes and in Problem 45 (CB) there are 2835 interaction nodes. RB/FB excavated volume has larger plan dimensions and embedment depth than the CB. Plan dimensions for CB model elements are much smaller than RB/FB (1.17m vs. 3.5m), which gives larger number of interaction nodes in CB as compared to RB/FB.
Problem 37, Section 4.37.5, clarify the meaning of "substructure direction method is used…"	Section 4.37.5 will be revised to read, "substructure direct method is used…"
Problem 37, verify that the spurious spikes in Figures 4.37-7, 10, 12, and 13 are due to interpolation	Additional frequencies will be included to verify that the spurious spikes are due to interpolation
Problem 9, Figure 4.9-4 the transfer functions for rocking motion show deviations	Problem 9 considers inclined (45 degrees) wave propagation, which is not applicable to Fermi 3 SSI analysis cases

Fermi 3 SASSI2010 V&V Audit
Entrance Meeting
March 19, 2013

Name	Organization
Tekia Govan	NRC/NRO
Manas Chakravorty	NRC/NRO
Carl J. Costantino	CJC&A
Manuel Miranda	BNL
Ryan Pratt	DTE Electric Co
A. K. Singh	S & L
C. E. Ruth	S & L
Joe Petrich	S & L
Randy Kurtz	S & L
Paula Scholl	S & L
Delfo Bianchhini	S & L
Michael O'Leary	S & L
James McIntyre	S & L
Mike Brandon	DTE Electric Co
Garid Berry	S & L
Surendra Singh	S & L
Ming Yang	S & L
R. W. Harris	S & L

Enclosure 2

Fermi 3 SASSI2010 V&V Audit
Entrance Meeting
March 21, 2013

Name	**Organization**
Mike Brandon	DTE Electric Co
James McIntyre	S & L
Surendra Singh	S & L
Ming Yang	S & L
Javad Moslemian	S & L
R. W. Hooks	S & L
Tekia Govan	NRC/NRO
Manas Chakravaty	NRC/NRO
Carl Costautine	CJC&A
Farid Berry	S & L
Manuel Miranda	BNL
A. K. Singh	S & L
Clay Ruth	S & L
Joseph Petrich	S & L
Paula Scholl	S & L
R. L. Kuntz	S & L
Eric Weyhnch	S & L
Jim Xu	NRC/NRO
Teleconference Participants	
Peter Smith	DTE Electric Co
Adrian Muniz	NRC/NRO
Ryan Pratt	DTE Electric Co

Enclosure 3

ATTACHMENT 1

DIMFU, Dynamic Impedance Functions :

DIMFU computes the dynamic impedance functions for a rigid circular foundation on a layered viscoelastic half-space using Luco's method (Reference 1). The impedance functions are computed at requested frequencies.

Reference 1: J. E. Luco, "Vibration of a Rigid Disc on a Layered Viscoelastic Medium", Nuclear Engineering and Design, No. 36, 1976.

DYNAS, Dynamic Analysis of Structures

DYNAS (Dynamic Analysis of Structures) is designed to perform dynamic analysis of structures which can be idealized as three-dimensional space frame and/or rigid slabs connected by translational or torsional springs. The program considers the combined effects of translational, torsional, and rocking motions of the structure. The program uses three methods of analysis: response spectrum, time history (support motion), and forced vibration methods. All methods use the normal mode approach. For the time history and forced vibration analysis, the decoupled differential equations of motion are integrated numerically using Newmark's method. For the time history analysis, the base motion can be applied simultaneously in two orthogonal directions. For the time history and forced vibration analysis, response spectrum can be generated as specified slabs or joints. For the response spectrum method, the response from all nodes of the system can be included. The program can also perform a static analysis using the same analytical model as in the dynamic analysis.