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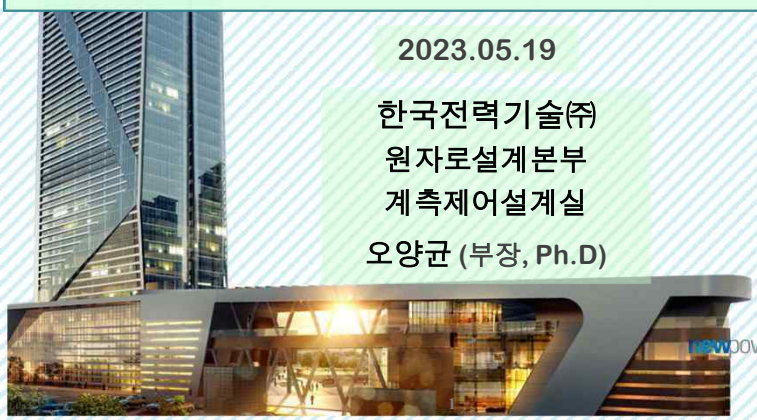
NIMS-IVMS 자료 평가에 의한 APR1400 원자로 노심지지배럴의 진동감시

(Vibration Monitoring of Core Support Barrel in APR1400 Reactor Vessel Based on the NIMS-IVMS Data Evaluation)



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newpower, newstandard

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1. 요지, CSB 진동 vs. NIMS-IVMS 자료 분석

■ 논문 요지

- NIMS-IVMS 자료 평가에 의한 APR1400 원자로의 노심지지배럴 (CSB) 진동감시에 대한 연구를 위해, BNPP 2호기 NIMS-IVMS 자료분석 결과와 연구과정에서 취득한 결론 및 교훈에 대해 토론하고자 함.
- For the evaluation of CSB beam & shell modes of vibration, practical five (5) steps for the NIMS-IVMS data evaluation are developed and applied three (3) steps in this paper based on KEPCO-E&C's engineering experiences, KHNP's site data, and the guidelines of ASME OM Part 5, Inservice Monitoring of CSB Axial Preload in PWR Power Plants.
- As a result, the CSB Beam Mode vibrations are found in the frequency range of 9.0~9.5 Hz based on 180° phase shift, and high coherence value (> 0.75), and a peak value (> 10^{-8}) on NCPSD plot.
- The NIMS-IVMS analysis of coherence plots shows that the CSB Shell Mode vibration is NOT found for the BNPP Unit 2.

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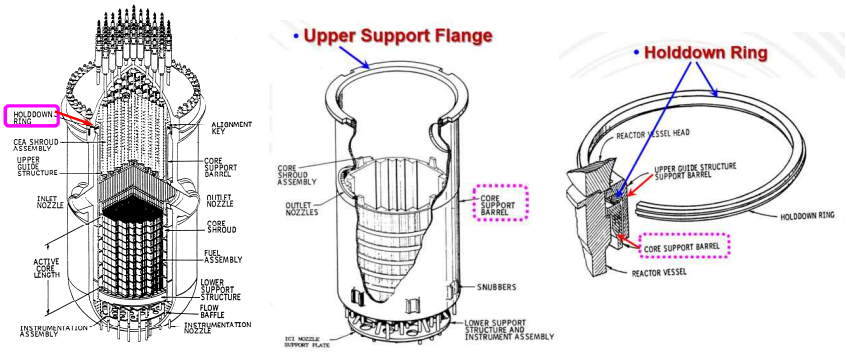
1. 요지, CSB 진동 vs. NIMS-IVMS 자료 분석

■ 원자로, 노심지지배럴(Core Support Barrel: CSB) 및 진동발생



■ CSB의 진동발생 및 후속조치

- CSB 상단의 Upper Support Flange(USF)에서 수직방향의 체결력(Axial Preload)이 상실되면 ➔ 원자로냉각재 유동에 의한 CSB 진동이 발생 ➔ NIMS-IVMS로 CSB의 과도한 진동 여부를 확인 ➔ 평가 후 누름링(Holddown Ring) 교체를 검토

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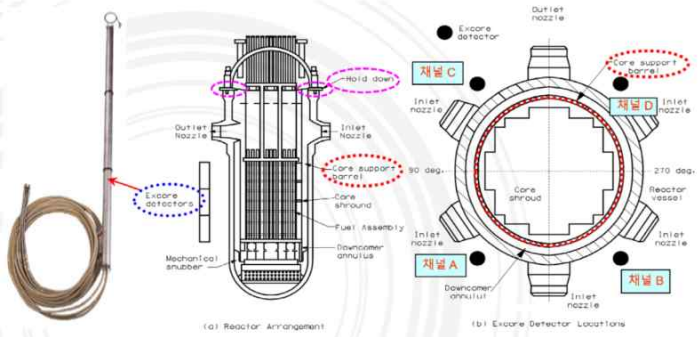
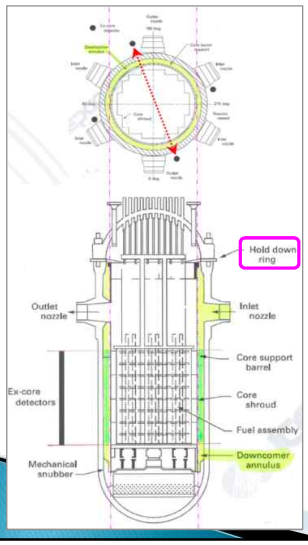
1. 요지, CSB 진동 vs. NIMS-IVMS 자료 분석

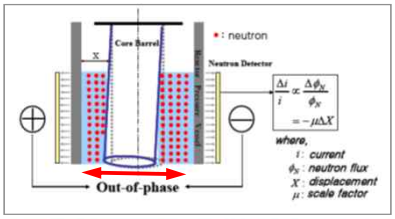
- **NIMS-IVMS 기능**
  - All of the OPR1000 & APR1400 have the NSSS Integrity Monitoring System (NIMS), which has four subsystems as follows:
    - Internals Vibration Monitoring System (IVMS)
    - Acoustic Leak Monitoring System (ALMS)
    - Loose Parts Monitoring System (LPMS)
    - RCP Vibration Monitoring System (RCPVMS)
  - NIMS-IVMS monitors the motions of the CSB, and provide the data that can be used to detect & evaluate the changes of the CSB motions.

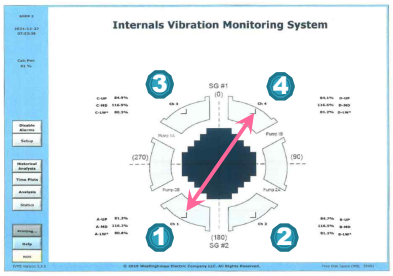


1. 요지, CSB 진동 vs. NIMS-IVMS 자료 분석

- **NIMS-IVMS 기능** (Beam Mode 진동 및 감시방법)
  - 원자로와 주변에 설치된 노외중성자속감시계통(ENFMS) 검출기가 고정된 상황에서, CSB와 노심이 흔들리면 ➔ 노심과 Ex-core 검출기 사이 물-두께가 변화 ➔ 검출되는 중성자속의 변화 ➔ ENFMS 검출기의 전류 변화 ➔ DC 신호에 AC 잡음이 추가된다.







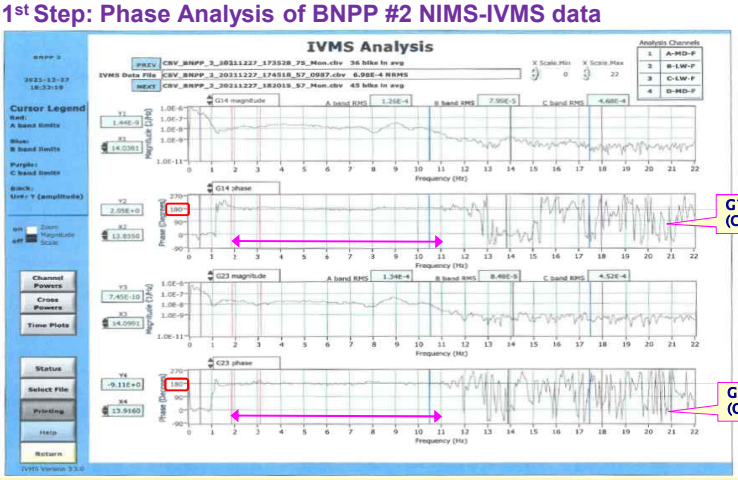
2. CSB 진동감시를 위한 IVMS 자료평가 절차

■ IVMS 자료평가 절차

1. On Phase plot, identify the frequency ranges of 180° & 0° of phase shifts which are corresponding to the Beam Mode (BM) and Shell Mode (SM) of CSB vibration, respectively.
2. On Coherence plot, identify the frequency range of high (0.5 to 1.0) coherence within the phase shift ranges of 180° and 0°, respectively, identified at Step 1.
3. On NCPSD (Normalized Cross Power Spectral Density) plot, identify the frequencies and magnitudes on the NCPSD at the points which are met with the criteria described in above Steps 1&2.
4. Review the results of Step 3, and compare them with previous Baseline Data. Step 4 is not required for plants (e.g. BNPP) of initial fuel cycle.
5. Enter the diagnostic phase based on Step 3&4 results.

3. APR1400 CSB Beam Mode 진동 평가

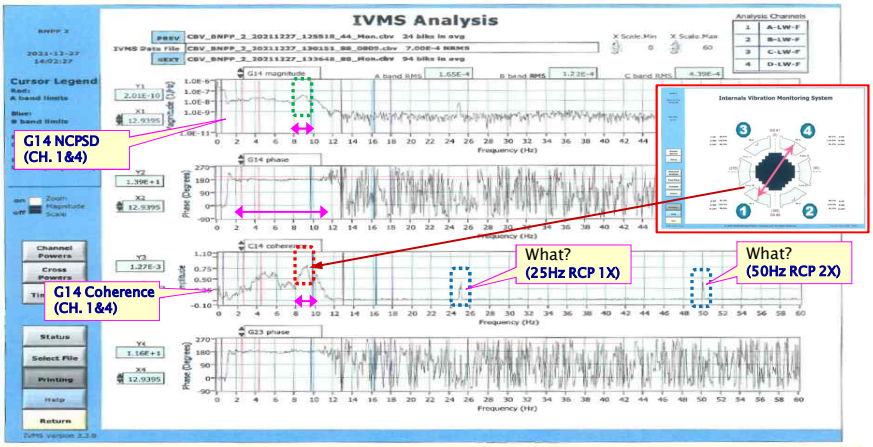
■ 1st Step: Phase Analysis of BNPP #2 NIMS-IVMS data



■ 1st Step Result: Fig. 2 shows the IVMS data which present the 180° phase shifts of signals from the middle (MD) detectors in ENFMS CH.1&4(G14) and from the lower (LW) detectors of CH.2&3(G23) detectors in the freq. ranges of 2 to 11 Hz.

3. APR1400 CSB Beam Mode 진동 평가

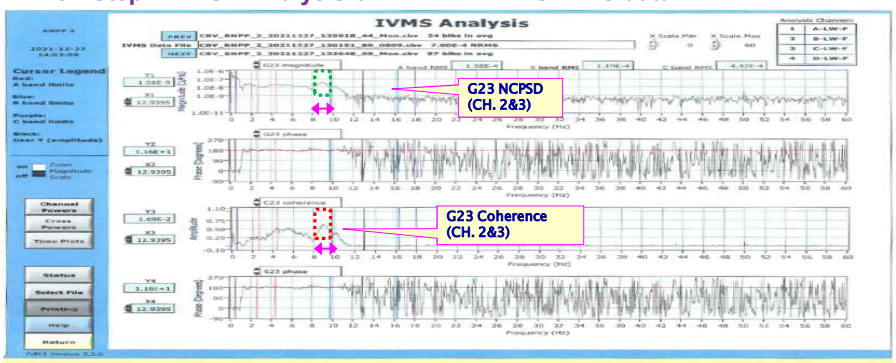
■ 2nd Step: Coherence Analysis of BNPP #2 NIMS-IVMS data



■ 2nd Step Result: The highest value of coherence (more than 0.75) is found at 9.0 to 9.5 Hz within the frequency range of 180° phase shift of acquired signals from the pair of ENFMS channels A&D lower fission chambers.

3. APR1400 CSB Beam Mode 진동 평가

■ 3rd Step: NCPSD Analysis of BNPP #2 NIMS-IVMS data

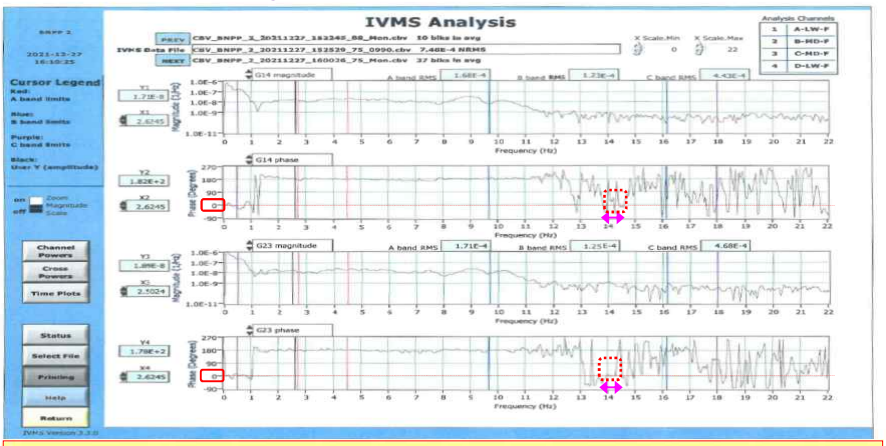


■ 3rd Step Result: There are peaks (more than 10^{-8}) at 9.0~9.5 Hz of frequency in NCPSD plots. Therefore, we can conclude as follows:

- CSB beam mode vibrations are found in the frequency range of 9.0~9.5 Hz.
- The CSB beam mode vibrations in ENFMS detectors 1-4 direction is dominant based on its coherence value (> 0.75). (The CSB beam mode vibrations are found in both directions of ENFMS detectors 1-4 and 2-3.)

4. APR1400 CSB Shell Mode 진동 평가

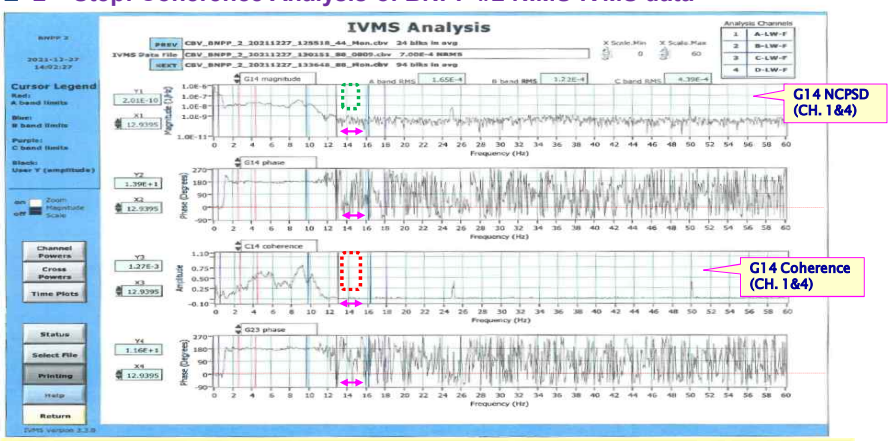
■ 1st Step: Phase Analysis of BNPP #2 NIMS-IVMS data



■ 1st Step Result: Fig. 3 shows the IVMS data which present the 0° phase shifts of signals from middle (MD) detectors in ENFMS CH.2&3(G23) and from lower (LW) detector of CH.1&4(G14) detector in the freq. range of 14.0~14.5 Hz.

4. APR1400 CSB Shell Mode 진동 평가

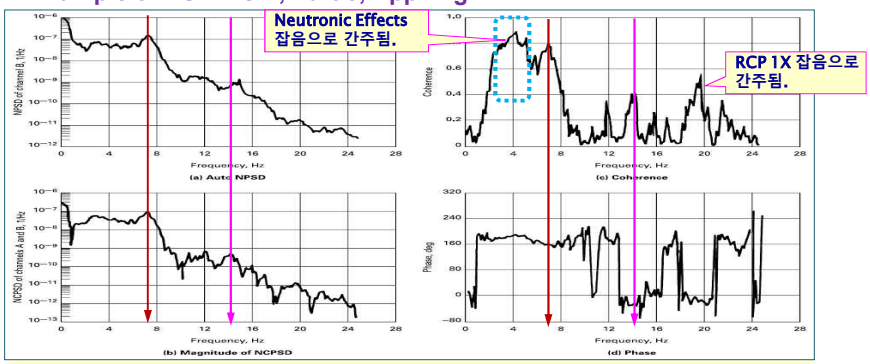
■ 2nd Step: Coherence Analysis of BNPP #2 NIMS-IVMS data



■ 2nd Step Result: There is no noticeable coherence values in the frequency range of 13.5~14.5 Hz. ➔ The NIMS-IVMS analysis of coherence plots shows that the CSB shell mode vibration is NOT found for the BNPP Unit 2.

5. OPR1000 vs. APR1400 CSB 진동 비교

■ Example of ASME OM, Part 5, App. Fig B-1



■ ASME OM P.5 [예] vs. BNPP CSB 진동 특성 차이

- OM P.5 [예] → CSB BM: Frequency 7.0~7.5 Hz, COH 0.8, NCPSD 10^{-7}
- BNPP U.2 → CSB BM: Frequency 9.0~9.5 Hz, COH 0.75, NCPSD >10^{-8}
- OM P.5 [예] → CSB SM: Frequency 13.5~14.5 Hz, COH 0.4, NCPSD 10^{-9}
- BNPP U.2 → CSB SM: Not Found (No significant COH values)

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6. OPR1000 vs. APR1400 CSB 진동 비교

■ Summary of OPR1000/APR1400 CSB BM & SM Vibrations

Table 1: Summary of OPR1000/APR1400 CSB Beam & Shell Mode Frequencies identified by using the NIMS-IVMS data

	CSB BM Freq.	CSB SM Freq.
Hanbit 3&4	8.0 Hz [5]	14.5 Hz [5]
Hanul 3	8.0 Hz [6]	14.5 Hz [6]
Hanul 1&2	8.0 Hz [8][9]	The SM vibration at 20 Hz caused by RCP 1X speed [9].
BNPP 2	9.0 – 9.5 Hz	No significant SM vibration is found.

■ Lessons Learned from the research of the paper

- NIMS-IVMS Beam Mode Filter Freq. Range → 7 ~ 11 Hz
- NIMS-IVMS Shell Mode Filter Freq. Range → 12 ~ 16 Hz
- APR1400 신규 원전의 Shell Mode 진동은 → N/A (없거나 경미함)

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6. 결론, 후속연구 및 질의-응답

- For BNPP unit 2, the CSB beam mode vibrations are clearly found in the frequency range of 9.0 to 9.5 Hz based on 180° phase shift, high coherence value (> 0.75), and a peak (> 10^{-8}) on NCPSD plot.
- For BNPP unit 2, no significant CSB shell mode vibration evidences are found based on the Phase, Coherence, and NCPSD plots.
- BNPP unit 2 is one of the APR1400 plants, and it was just in the stage of initial program fuel cycle (when the NIMS-IVMS data was acquired). Therefore, the results of NIMS-IVMS data and plots shown in the paper are classified as parts of the Baseline Data of the BNPP unit 2, and they should be updated/compared throughout the fuel cycles.
- The results of in this paper need to be further supplemented, with the support of KHNP after the similar researches for other APR1400 plants. *(KEPCO-E&C is prepared to support this kind of similar researches for APR1400 plant sites.)*

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Q&A

알림: 본 논문은 KHNP의 적극적인 지원 덕분에 발표할 수 있게 된 논문입니다. 공저자 정찬준 과장님을 포함하여 KHNP 관계자 여러분께 심심한 감사를 표합니다.

감 사 합 니 다.

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