NRC FORM 658
(9-1999)

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DATE OF MEETING
8/16/01

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Docket Number(s) Project 710

Plant/Facility Name General Electric

TAC Number(s) (if available)

Reference Meeting Notice 8/1/01

Purpose of Meeting
(copy from meeting notice) Discuss Part 21 notification on stability related licensing calculations.

NAME OF PERSON WHO ISSUED MEETING NOTICE	TITLE
Robert M Pulsifer	Project Manager

OFFICE

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BRANCH

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DF03

GE Nuclear Energy

Engineering & Technology: Nuclear & Safety Analysis
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NRC Update

Stability DIVOM Curve Non-Applicability

Jason Post and Alan Chung
GE Nuclear Energy
August 16, 2001

Topics

- Stability Detect & Suppress Solutions
- D&S Reload Licensing Methodology
  - DIVOM Curve Description
- Problem Discovery/Root Cause
- Part 21 Notification
  - Affected Plants
  - Actions
  - Final Advice
- NRC Feedback

Stability Detect & Suppress Solutions

- **Stability long-term solutions developed by GE and the BWROG (NEDO-31960-A)**
- **D&S solutions meet the GDC-12 requirement:**

  Anticipated reactor instability reliably and readily detected and suppressed
- **Automatic scram to provide MCPR Safety Limit protection for anticipated reactor instability**
- **D&S solution are Options III, I-D, and II**

Stability Detect & Suppress Solutions

- **Stability Option III:**
  - **Hardware: Oscillation Power Range Monitor**
    - **OPRM signals composed of closely spaced LPRMs**
    - **~30 overlapping OPRM cells per OPRM channel**
    - **OPRM channel trip logic consistent with RPS**
    - **Detects core wide and higher harmonic oscillations**

Stability Detect & Suppress Solutions

- **Stability Option III (continued):**
  - **Software: Each OPRM cell signal individually normalized and processed through 3 algorithms**
    - **Period based algorithm – licensing basis MCPR Safety Limit protection**
      - **Scram when "counts" exceeds N_P and "amplitude" exceeds S_p**
    - **Growth rate and amplitude based algorithms - defense in depth protection**
  - **Reload Licensing: Defined in NEDO-32465-A**
    - **Determine S_p which provides MCPR SL protection**
    - **Maximum value of N_P corresponds to S_P**

Stability Detect & Suppress Solutions

- **Stability Option I-D:**
  - **Hardware: Existing flow-biased APRM flux trip**
    - **Detects only core wide mode oscillations**
    - **Must confirm core wide oscillation is predominate mode for I-D to be applicable**
  - **Software: Trip when unfiltered core average power exceeds flow-biased setpoint**
  - **Reload Licensing: Defined in NEDO-32465-A**
    - **Confirm flow-biased flux trip provides adequate MCPR SL protection**

Stability Detect & Suppress Solutions

- **Stability Option II:**
  - **Hardware: Existing quadrant based flow-biased APRM flux trip**
    - **Detects core wide and higher harmonic oscillations**
  - **Software: Trip when quadrant average power exceeds flow-biased setpoint**
  - **Reload Licensing:**
    - **Methodology defined by each applicant (similar to NEDO-32465-A)**
    - **Confirm flow-biased flux trip provides adequate MCPR SL protection**

D&S Reload Licensing Methodology

- Developed by GE and BWROG D&S Committee
- Documented in NEDO-32465-A, August 1996 (SER date March 4, 1996)
- Purpose
  - Option III: Define OPRM period based algorithm amplitude trip setpoint (S_P) which provides MCPR SL protection
  - Option I-D: Demonstrate flow-biased APRM flux trip provides MCPR SL protection

D&S Reload Licensing Methodology

- **Methodology segregated into three parts:**

1	Hot bundle oscillation magnitude (HBOM)	Hardware dependent	Monte Carlo method (OPRM code)
2	Normalized CPR change vs. oscillation magnitude (DIVOM)	Fuel type dependent*	Relationship developed from TRACG calculations
3	Cycle specific CPR limits and performance	Reload dependent	Cycle specific MCPR SL, MCPR OL, ΔCPR from flow runback (3D nodal simulator)

* DIVOM curve independent of reload in original development

D&S Reload Licensing Methodology

- **HBOM:**
  - **Statistical methodology**
  - **Combination deterministic and statistical inputs**
  - **Determine normalized peak bundle oscillation magnitude when reactor trip has disrupted the oscillation**
  - **Result depends upon LPRM assignment to OPRM cells**
  - **Redo calculation if hardware (e. g., cell assignments) changes**

D&S Reload Licensing Methodology

- **HBOM statistical methodology**
  - **Rank order 1000 trials**
  - **95/95 probability/confidence (non-parametric statistics) corresponds to 39th worst result from 1000 trials**
- **HBOM assumptions:**
  - **Every trial produces an oscillation**
  - **Most responsive OPRM channel fails (Opt III)**
  - **Most responsive APRM channel fails (Opt I-D)**
  - **No LPRM failures (conservative for up to ~50% failure rate)**
  - **Oscillation disrupted when control rods inserted 2 ft into core**

D&S Reload Licensing Methodology

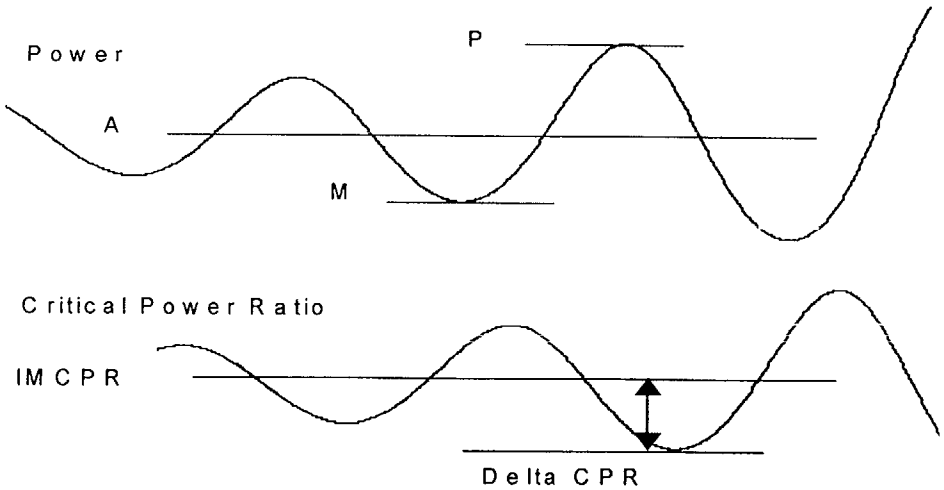
- **HBOM deterministic inputs**
  - **LPRM assignments to OPRM cells/APRM channels**
  - **OPRM/APRM channel failure assumption (most responsive fails)**
  - **RPS trip logic**
  - **Trip setpoint**
  - **Fixed time increment from trip to oscillation disruption**
    - **OPRM/APRM response time**
    - **RPS response time**
    - **Delay for start of control rod motion**
    - **Time for control rods to insert 2 ft into the core**

D&S Reload Licensing Methodology

- **HBOM statistical inputs:**
  - **Oscillation contours**
  - **Oscillation period**
  - **Oscillation growth rate**
  - **Trip setpoint overshoot**
  - **LPRM failure rate (no failures is limiting for design calculations)**

D&S Reload Licensing Methodology

- **DIVOM Curve:**
  - **Normalized CPR change**
    = (Final MCPR – Initial MCPR)/Initial MCPR
    = ΔCPR/IMCPR
  - **Vs. oscillation magnitude = (P-M)/A**



  - **Each power peak produces a DIVOM data point**

D&S Reload Licensing Methodology

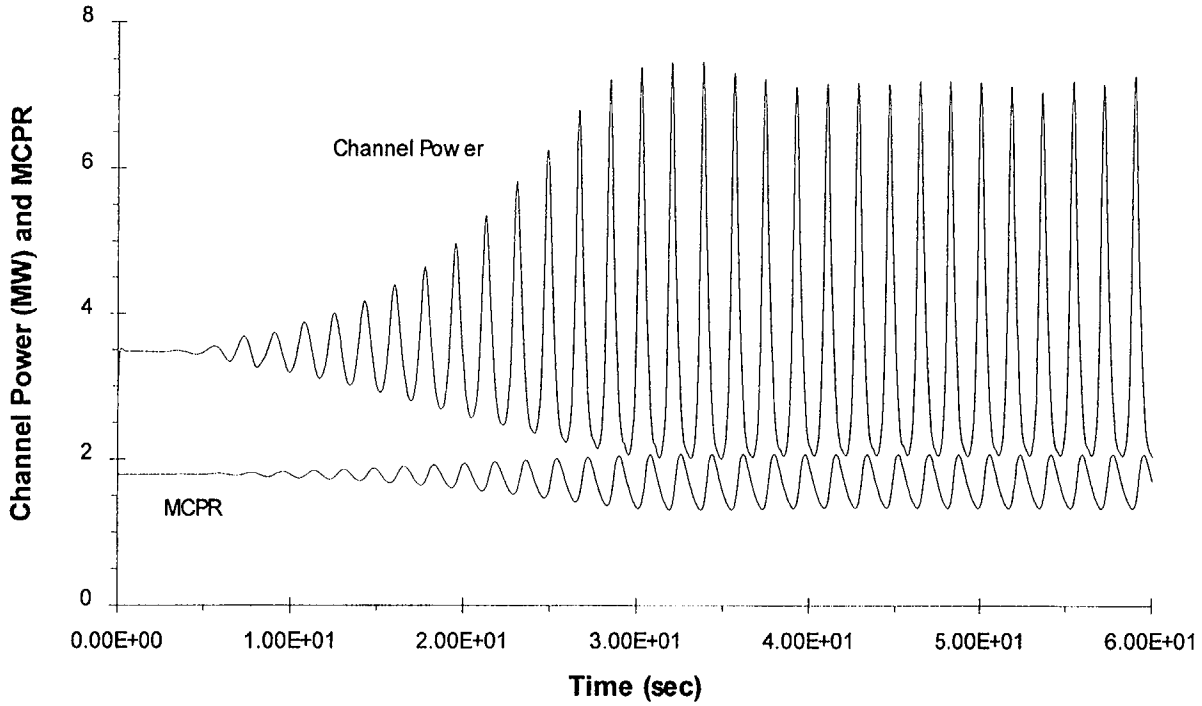
- **Coupled neutronic/thermal-hydraulic oscillation calculated with TRACG**
  - **Detailed core axial model**
  - **Multiple channel groups**
  - **Channel grouping by harmonic contour and radial power distribution**
  - **Each channel produces a set of DIVOM curve data points**
- **Extensive TRACG calculations performed**
  - **Regional mode: 8x8, 9x9, 10x10, mixed core**
  - **Core wide mode: 8x8, 9x9**
  - **Sensitivity studies on fuel design parameters**
  - **Restrictive power/flow statepoints**

D&S Reload Licensing Methodology

- **Core wide mode oscillation:**
  - **Power and flow oscillate in-phase for all channels**
  - **Fundamental mode of neutron flux excited**
  - **Variable pressure drop across core determined by circulation loop dynamics**
  - **Channel flow oscillation coupled to (constrained by) core flow response**
- **Regional mode oscillation**
  - **Power and flow in each half of core 180° out-of-phase**
  - **Harmonic mode of neutron flux excited**
  - **Constant pressure drop across core**
  - **Channel flow oscillation independent of (not constrained by) core flow response**

D&S Reload Licensing Methodology

- **Sample hot channel TRACG calculation:**



D&S Reload Licensing Methodology

- Produced population of hot channel data points from all TRACG runs
- Regional mode:
  - Decoupling from core response produces greater bundle flow oscillation for a given power oscillation
  - Channels with high harmonic location and high RPF produce largest flow oscillation
  - Larger flow oscillation produces larger CPR change and steeper DIVOM curve
- Specified conservative generic core wide and regional mode DIVOM curves at upper edge of all data points
  - Regional: slope = 0.45, intercept = 0.0
  - Core wide: slope = 0.175, intercept = 0.05

D&S Reload Licensing Methodology

- **Generic DIVOM curves**
  - **Valid for all fuel types and vendors**
  - **Reasonably conservative based on data base**
  - **Relied on overall method conservatism to cover some DIVOM curve variation**
- **Conservatisms:**
  - **Highest bundle power at same location as most responsive bundle in oscillation contour**
  - **Developed for large core plant**
  - **Use MCPR SL as acceptance criteria**
  - **Each trial produces an oscillation**
  - **All regional mode oscillations for Option III**

D&S Reload Licensing Methodology

- Cycle-specific CPR inputs and calculations
  - Calculation for two state points:
    - Steady State at 45% rated core flow
      - IMCPR from more limiting of $MCPR_F$ and $MCPR_P$
    - Runback to natural circulation on stability protection line
      - Initiated from MCPR OL
      - ΔCPR from 3-D nodal simulator

D&S Reload Licensing Methodology

- **Option III stability protection line: highest licensed flow control line**
  - **Proximity to setpoint is N/A to normalized signal**
  - **Highest rod line produces limiting conditions**
- **Option I-D (and II) stability protection line: rated rod line**
  - **HBOM is function of proximity to trip line**
  - **Highest licensed rod line is close to trip and gives small HBOM**
  - **Bottom of exclusion zone would give large HBOM, but propensity to oscillate is small**
  - **Rated rod line chosen as reasonable compromise**

D&S Reload Licensing Methodology

- **Algebraic equation to calculate Final MCPR (i.e., lowest MCPR before oscillation is disrupted):**

FMCPR(2PT) = MCPR OL + ΔCPR(runback) - ΔCPR(oscillation)

and

FMCPR(SS) = MCPR(limit at 45% flow) - ΔCPR(oscillation)

- **Confirm FMCPR ≥ MCPR SL**
  - **Option III: S_p is adequate**
  - **Option I-D (and II): flow-biased trip is adequate**

Problem Discovery/Root Cause

- **Deviation Statement: The generic DIVOM curves specified in NEDO-32465-A are not adequate to support current reload licensing analysis**
- **Changes since original development:**
  - **Evaluating more limiting conditions for MELLLA+**
  - **Input a small initial flow perturbation consistent with the harmonic mode allows modeling more limiting conditions**
  - **Discovered importance of peak bundle power for regional mode oscillations**
  - **Realized that original cases were not adequate for current operation**

Problem Discovery/Root Cause

- **Root Cause:**
  - **Inadequate understanding of physical phenomena resulted in underestimating the impact of a key parameter (peak bundle power)**
  - **Limiting radial power distribution cases produced non-symmetric oscillations (until flow perturbation method developed) and were not included in the data base**
  - **Believed that restrictive power/flow conditions, sensitivity studies, and normalization of curves fully addressed current operating conditions**

Part 21 Notification

- GE originally defined as a Corrective Action Request: CAR AI-5313 on 2/19/01
  - Believed that it was only an EPU problem (i.e., DIVOM was applicable for 105% uprate)
  - Overlooked one plant that already had EPU > 105%
- Opened PSC (potential safety concern) 4/19/01 when realized 105% uprates potentially affected
  - Per GE EOPs, 10 working days allowed for PSC resolution
- Opened as a PRC on 5/3/01
  - 60 day clock expired 7/2/01

Part 21 Notification

- Safety perspective:
  - Potential to violate MCPR SL for Option III if:
    - An event initiates from limiting conditions
    - The event results in an oscillation
    - The oscillation is regional
  - Automatic trip still functions
    - Small portion of core might experience MCPR SL violation before trip occurs
  - Not a threat to fuel damage!
  - No threat to public health and safety!

Part 21 Notification

- Safety Communication SC01-01 issued 6/29/01
  - Reportable condition [21.21(d)] for one plant
  - 60 day interim report [21.21(a)(2)] since all potentially affected plants not evaluated
  - Transfer of information [21.21(b)] since GE could not evaluate some potentially affected plants
  - Committed to complete Part 21 notification by 8/31
- To "complete" Part 21 notification:
  - List all affected plants
  - List corrective actions which have been and will be taken
  - Provide final advice related to the defect

Part 21 Notification – Affected Plants

- **Only D&S solutions affected, not prevention solutions (i.e., Enhanced Option I-A, exclusion region calculations)**
- **All plants with Option III installed are affected:**
  - **Hatch 1&2, Fermi-2, NMP-2, Browns Ferry 2&3, Columbia, Perry**
- **Current and upcoming NRC submittals to arm Option III also affected**
  - **Susquehanna 1&2, Peach Bottom 2&3, Limerick 1&2, LaSalle 1&2, Dresden 2&3, Quad Cities 1&2, Hope Creek, Brunswick 1&2**
- **Option I-D (and II) plants not affected:**
  - **Cooper, Duane Arnold, FitzPatrick, Monticello, Vermont Yankee (NMP-1, Oyster Creek)**

Part 21 Notification – Actions

- Notified initial plant when impact confirmed
- Notified all BWRs through BWROG PIRT in advance of SC01-01
- Defined Figure of Merit (FOM) to assess applicability of generic DIVOM curves
  - Regional mode: peak bundle power to flow ratio at ~30% rated core flow
  - Core wide mode: core average power to flow ratio at ~30% rated core flow
- Continued interaction with PIRT after SC01-01 issued

Part 21 Notification – Actions

- Potentially affected plants evaluated vs. FOM
  - Determined which plants are/are not affected
- Each plant with OPRM armed declared the OPRM inoperable
- Plants have different Tech Spec requirements:
  - 120 day/unlimited outage time when OPRM is inop
  - Do/do not have TS 3.0.4 exemption for restart when OPRM is inop
- Produces different plant needs for OPRM restoration to operable

Part 21 Notification – Actions

- GE developed interim regional mode DIVOM curves for higher FOM values
- Detailed reviewed of issue & approach with BWROG
- Calculated interim S_p where requested
- Plant-specific mitigation actions:
  - Load line restriction to maintain plant within FOM
  - Revised S_p based on interim method
  - TS modification
  - Delay implementation

Part 21 Notification – Final Advice

- Participate in BWROG D&S Committee activity
- Plant-specific options:
  - If unlimited outage time: Remain inoperable with trip armed
  - If 120 day limit and/or no TS 3.0.4 exemption:
    - Implement interim S_P and declare operable
    - Consider processing a TS change
  - If OPRM not yet armed:
    - Delay implementation until issued resolved
    - Consider arming and declaring system inop
    - Consider arming and implementing interim setpoint

Part 21 Notification – Final Advice

- **BWROG D&S Committee proposed schedule:**

3Q01:	**Obtain BWROG funding authorization** **Develop and assess existing DIVOM data base, define additional TRACG cases needed**
4Q01	**Complete additional TRACG cases**
1Q02	**Assess TRACG results, develop revised methodology**
2Q02	**Present revised methodology to NRC**
3Q02	**Issue licensing documentation for revised methodology**
4Q02	**NRC approval**

NRC Feedback

- **Discovery/Root Cause**
- **Plant-specific mitigation actions**
- **Part 21 reporting completion**
- **BWROG plans to address**
- **Eventual issue resolution**