Power Oscillations

GE BWR/4 Technology Course
R-504B – 4.3

Objectives

1. Recognize the potential consequences of unstable power oscillations.
2. Recognize why it can be difficult to detect power oscillations.
3. Recognize the regulatory requirements for BWRs (GDC 12).
4. Recognize the plant conditions that can result in power instability and what can cause these conditions to occur.

Objectives

5. Recognize the approaches used at BWR plants to prevent and/or respond to neutron flux oscillations.
6. Define the following terms:
   - Fuel Time Constant
   - Decay Ratio
   - Limiting Cycle Oscillation

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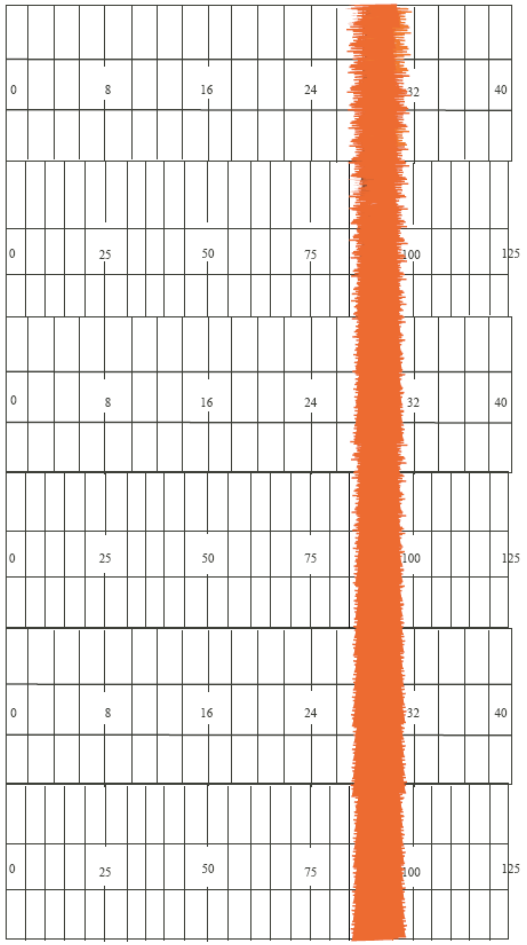
7. Recognize how the following Oscillating Power Range Monitor (OPRM) algorithms produce alarms and trips
   a. Period Based Algorithm (PBA)
   b. Amplitude Based Algorithm (ABA)
   c. Growth Rate Based Algorithm (GRBA)
8. Identify when OPRM trips and alarms are automatically bypassed

Normal Power Oscillations

- These constant Oscillations do not challenge Thermal Limits, they're considered stable.



Term Review

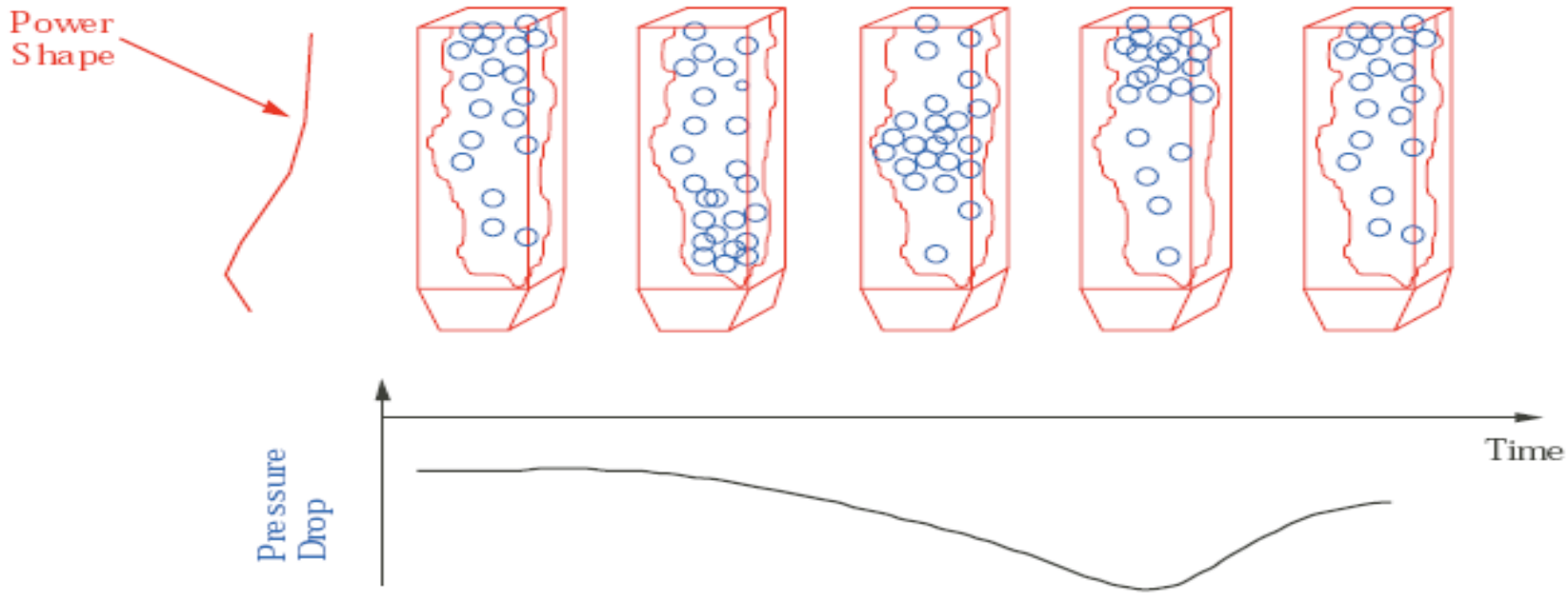
- Fuel Time Constant
  - Before the power generated in the fuel can effect the moderator density, it must change the fuel temperature and transfer heat to the coolant.
  - The fuel in BWRs responds relatively slowly with a time constant between 6 and 10 seconds
- Decay Ratio
  - Decay ratio is the measured stability of an oscillating system and is the quotient of the amplitude of one peak in an oscillation divided by the amplitude of the peak immediately preceding it

Term Review

- Limit Cycle Oscillation
  - A limit cycle oscillation is one with a decay ratio > 1. This causes the amplitude of the oscillations to diverge and become unstable. The oscillation amplitude continues to grow until it reaches a saturation value. At the point the system is said to be in a limit cycle.

Thermal Hydraulic, Neutronic, Density Wave, Instabilities

- Basic mechanism – Density Wave

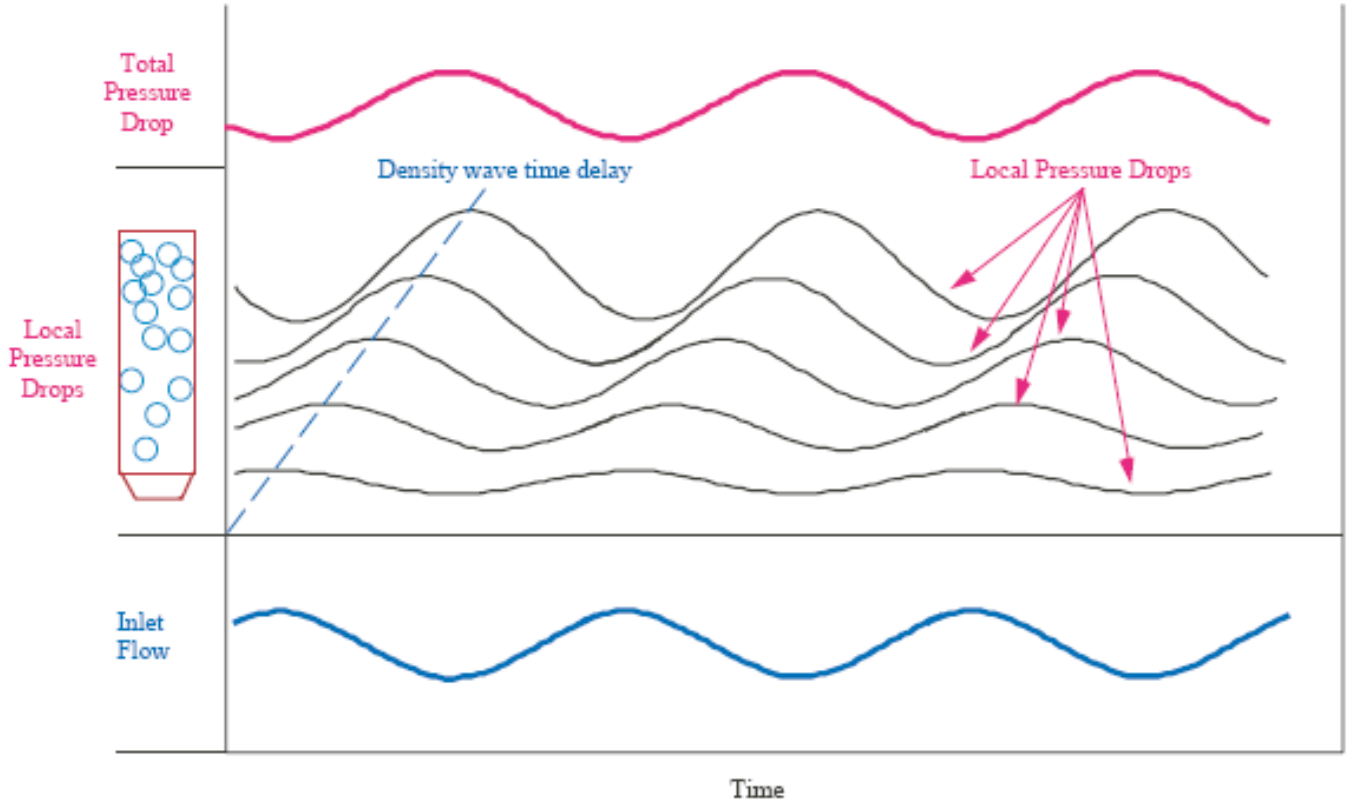


NOTE: The effect of a power pulse is seen up to 2 seconds later in the channel pressure drop due to void propagation delay.

Instability factors

- void fraction
- fuel time constant
- power level
- power shape
- feedwater temperature and
- core flow

As inlet flow drops, the d/p goes up



As d/p goes up inlet flow goes down

If the decay ratio >1 then the bundle flow is unstable

If Bundle flow is unstable, then so is Pressure, and so is Power

- The most likely conditions to cause an instability
  - High Power
    AND
  - Low Flow

Core Wide Power Oscillations or Bundle Oscillations

- The entire core can oscillate together

  OR

- A single bundle may have Oscillations

In Phase or Out of Phase

- The entire core can Oscillate in phase

  OR

- One part of the core can be increasing in power while another part is decreasing in power (out of phase)…difficult to detect

In-phase and out-of-phase Oscillations

- The out of phase oscillation is important because it is more difficult to detect.
- APRMs sample power both radially and axially in the core
- Oscillation may be masked by the cancellation between out of phase LPRMs that provide signals to the same APRM channel.

Safety concern

The primary safety concern regarding unstable power oscillations during normal operations is the ability of the reactor protection system to detect and suppress oscillations before they can challenge the fuel safety limits (Minimum Critical Power Ratio).

Unstable Oscillations

- Can occur at Power or in Conjunction with an ATWS
  - Stable oscillations have a decay ratio < 1
- Primary Safety Concern
  - The ability of RPS to detect and suppress oscillations prior to challenging the MCPR thermal limit.

General Design Criterion 12--

- *Suppression of reactor power oscillations*. The reactor core and associated coolant, control, and protection systems shall be designed to assure that power oscillations which can result in conditions exceeding specified acceptable fuel design limits are not possible or can be reliably and readily detected and suppressed.

GE Service Information Letter (SIL) 180

- 1984 – Identified the High power/Low flow part of the P/F map as region of least stability
- Recommended that if entered:
  - insert rods to < 80% rod line and
  - monitor for oscillations.

GE Service Information Letter (SIL) 180

- Recommendations were largely ignored
  - March 1988 – LaSalle event
  - NRCB 88-07 Supplement 1– NRC required plants to implement GEs recommendations and asked to take steps to ensure MCPR margin.

NRCB 88-07 Supplement 1

- Divided plants into 2 groups
- Different actions recommended for exiting the exclusion region
  - Same actions recommended for both groups to exit the restricted region

NRC/BWROG Agreement

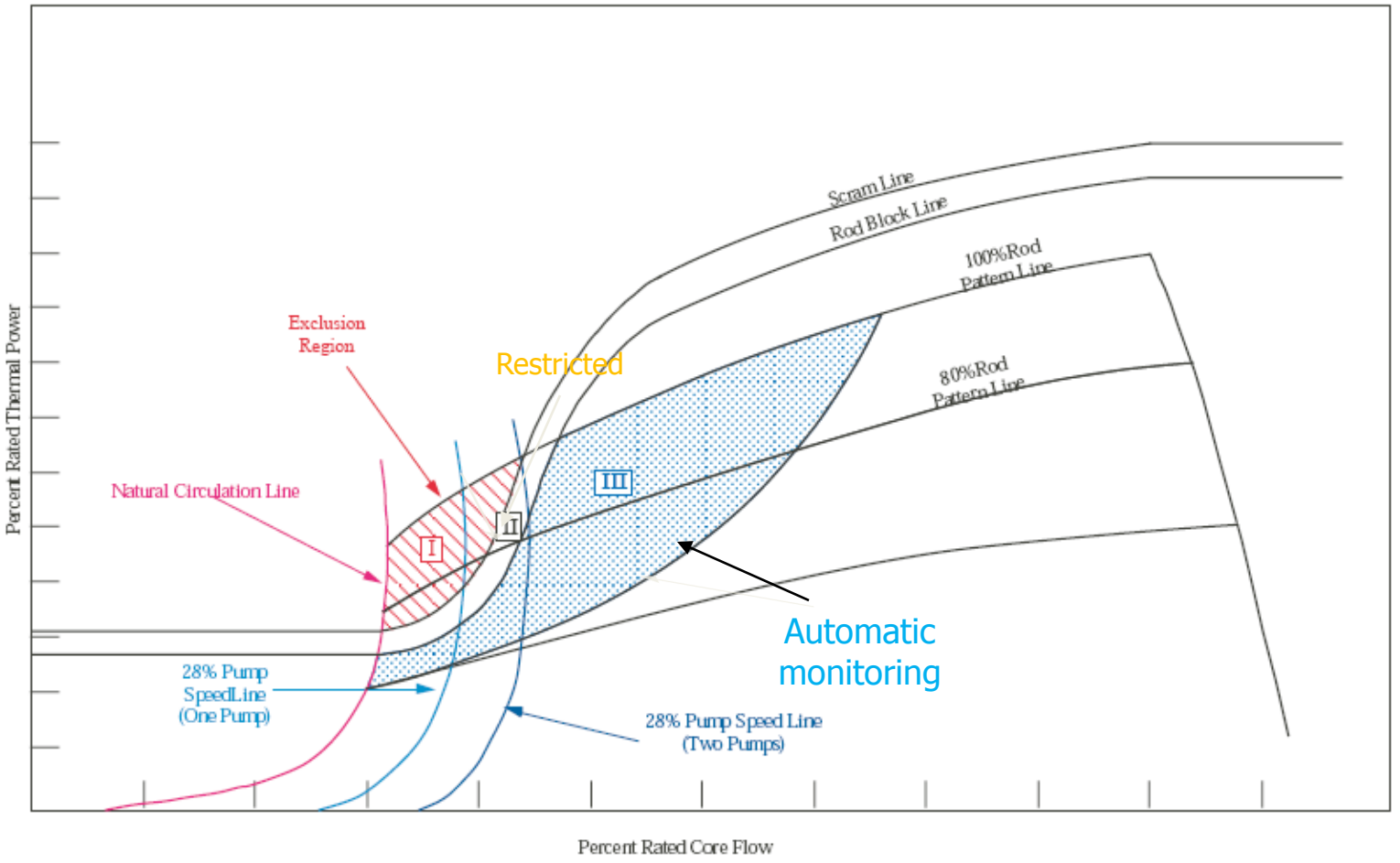
- Desire to avoid exceeding MCPR SL
- Agree to three plausible options

BWROGs Long Term Stability Solutions

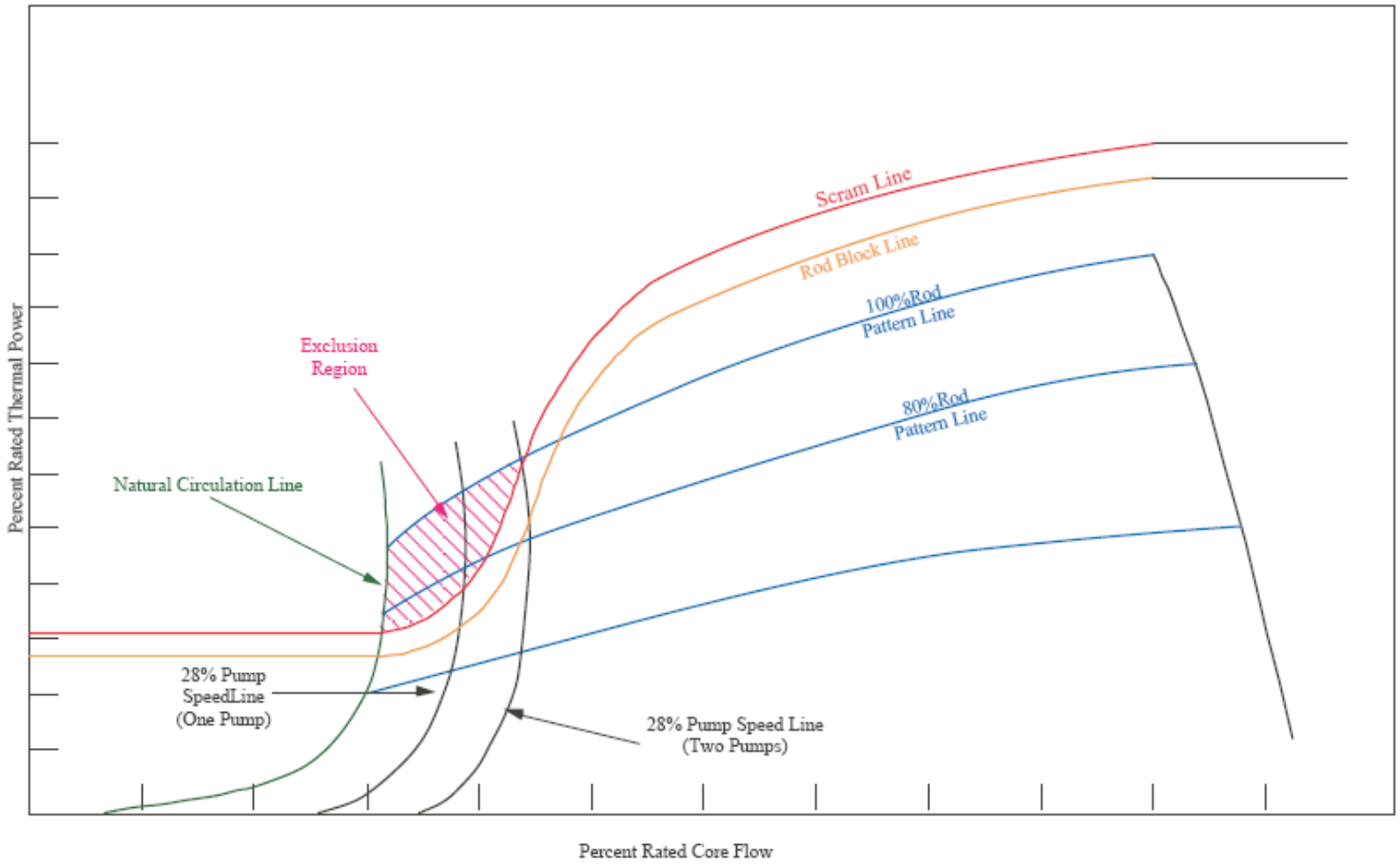
OPTION 1 – Exclusion Region

- I-A Immediate action (Scram) when enter exclusion region. OPRMs used to monitor
  - Grand Gulf, River Bend
- I-D Smaller core uses existing unfiltered flow biased APRM (entry administratively controlled)
  - Duane Arnold, FitzPatrick, Monticello, Cooper and VY

Option I-A


Scram Line
Rod Block Line
100%Rod Pattern Line
80%Rod Pattern Line
Exclusion Region
Restricted
Natural Circulation Line
I
II
III
Automatic monitoring
28% Pump SpeedLine (One Pump)
28% Pump Speed Line (Two Pumps)
Percent Rated Thermal Power
Percent Rated Core Flow

Option I-D


Scram Line
Rod Block Line
100%Rod
Pattern Line
80%Rod
Pattern Line
Exclusion
Region
Natural Circulation Line
28% Pump
SpeedLine
(One Pump)
28% Pump Speed Line
(Two Pumps)
Percent Rated Thermal Power
Percent Rated Core Flow

BWROGs Long Term Stability Solutions

OPTION 2 – Quadrant Based APRM Scram

- BWR2 - OC and NMP1

BWROGs Long Term Stability Solutions

OPTION 3 - LPRM Based Detect and Suppress (OPRM)

- LPRM signals analyzed by 3 algorithms to detect instability and auto scram the reactor.
- 24 plants
  - Hatch1/2, Brunswick1/2, Fermi 2, PB2/3, Perry, Hope Creek, NMP2, Quad1/2, Dresden2/3, LaSalle1/2, Limerick1/2, Clinton, Susq1/2, WNP2, Browns Ferry2/3

OPRM Algorithms

Amplitude Based Algorithm - establishes a setpoint at some value above 100% power.

- In order to cause a scram the signal must:
  - First pass through the setpoint with a positive slope
  - Then pass through the setpoint with a negative slope
  - Then pass the setpoint a second time with a positive slope.
- When the setpoint is set well above the random fluctuations that occur in reactor operation, this algorithm will prevent scrams that would otherwise result from single spikes.

OPRM Algorithms

Growth Algorithm - is designed to detect the presence of oscillations as they grow above the level of normal random noise.

- If the amplitude of an oscillation is greater than the previous oscillations amplitude by a predetermined amount, a scram signal will be generated.

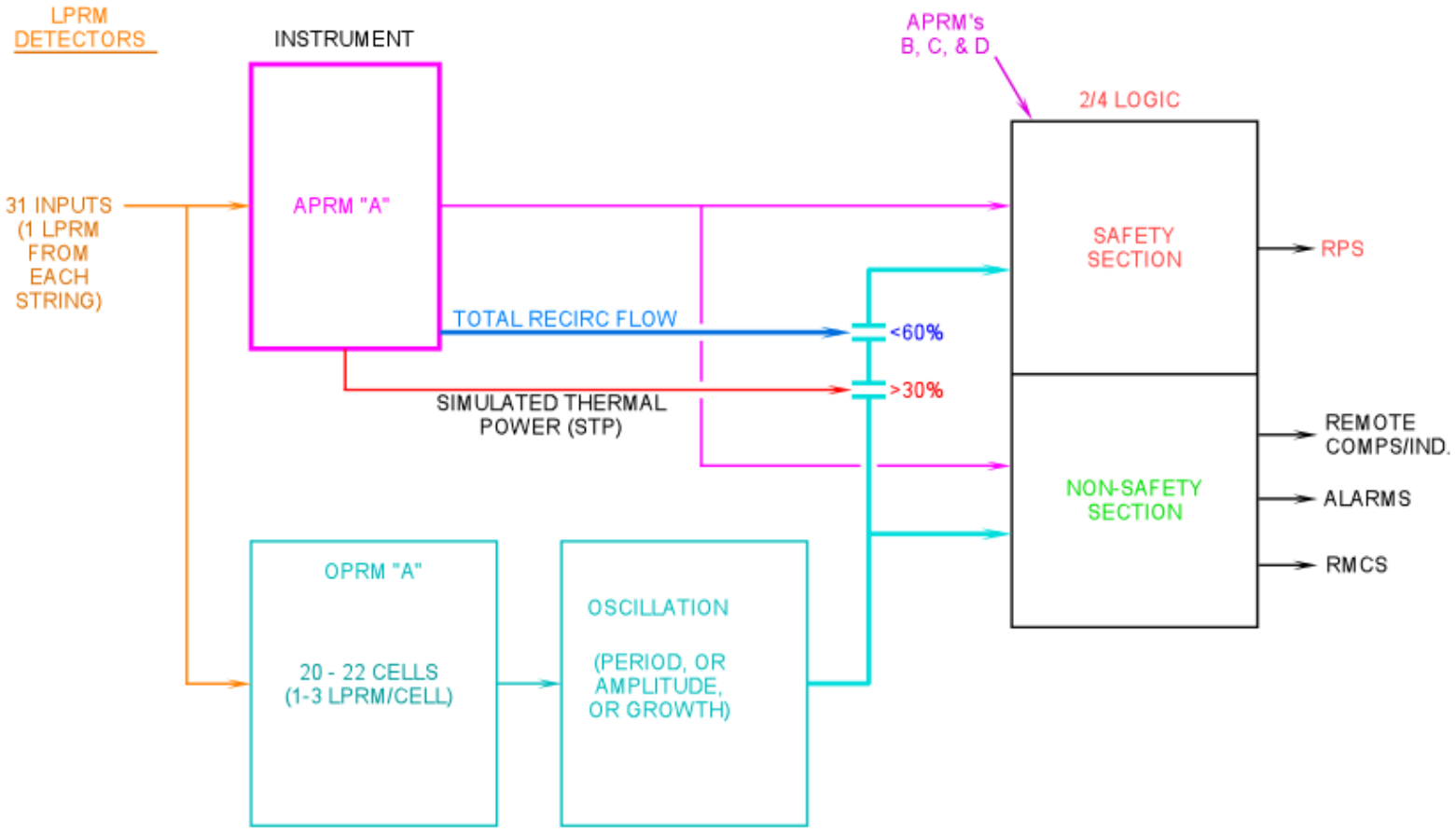
OPRM Algorithms

Period-Based Algorithm - Detects the "periodicity" of the signal by maintaining statistical data of the intervals between consecutive peaks.

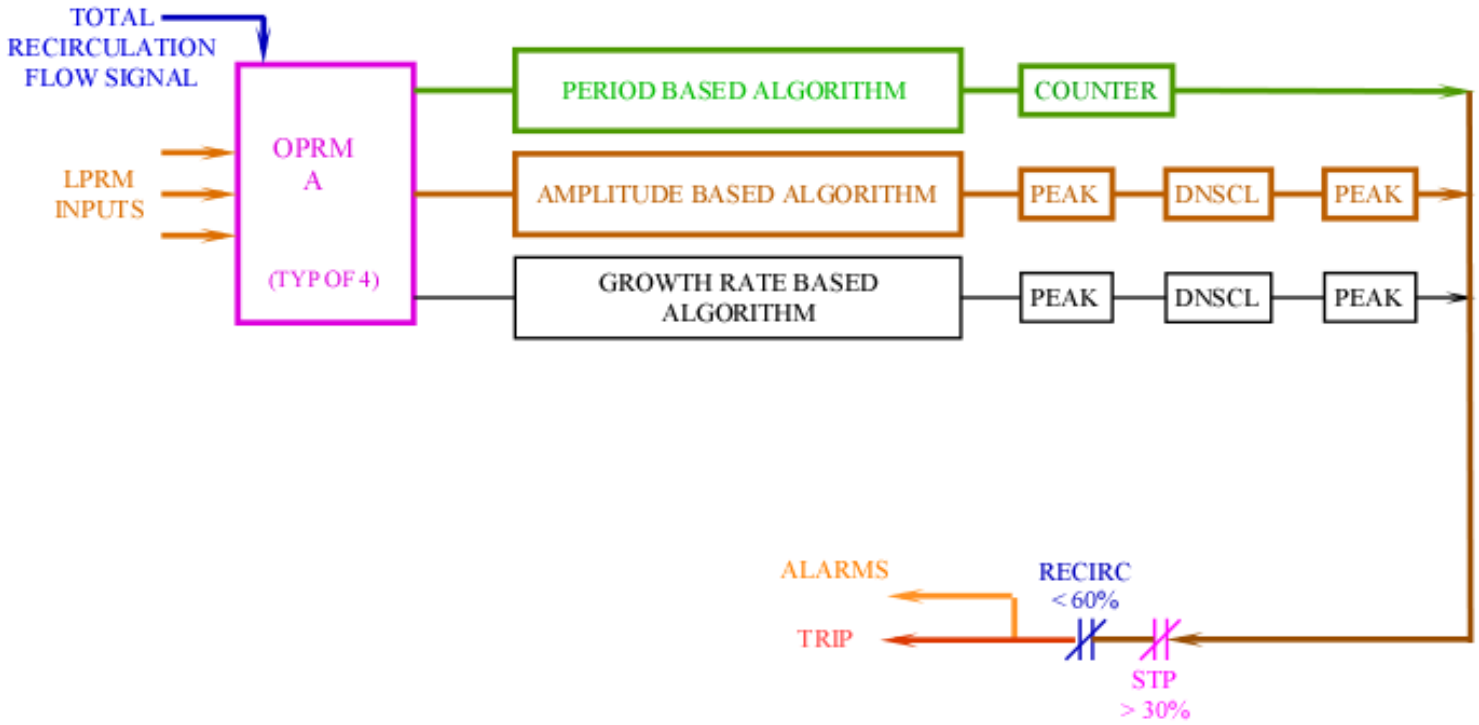
- When the "periodicity" is high, the reactor is considered to be approaching instability.

OPRMs

Enabled at > 30% Power AND < 60% Flow



OPRM Logic


TOTAL
RECIRCULATION
FLOW SIGNAL
LPRM
INPUTS
OPRM
A
(TYP OF 4)
PERIOD BASED ALGORITHM
COUNTER
AMPLITUDE BASED ALGORITHM
PEAK
DNSCL
PEAK
GROWTH RATE BASED
ALGORITHM
PEAK
DNSCL
PEAK
ALARMS
TRIP
RECIRC
< 60%
STP
> 30%

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