Reactor Power Drift in Nuclear Generating Plants

Frank D. Todd, True North Consulting
Bill Kettenacker, Scientech

Presented at the EPRI P2EP Meeting
Savannah Georgia
July 25th, 2008

Background

- Due to margin uncertainty recapture uprates (Appendix K), many plants are operating closer to their license limits sometimes resulting in overpowers.
- Plants that have not implemented improved instrumentation struggle with not knowing if the inputs to their power calculation are drifting due to feed nozzle fouling or other problems.

TRUE NORTH
CONSULTING, LLC

Power Drift

- Power drift occurs mostly from instrument drift over an extended period of time:
  - Power drift can sneak up on you because it is difficult to detect in day to day operation.
  - Do you know any plants that have recently over powered?
  - Are you running over power? Under power?

Monitoring Power - The Challenge

- Each plant thermal power control is unique.
- Power calculations are dependant on several instruments, some of which naturally change over time (fouling nozzles). Also plant performance can degrade influencing calculated power (heaters, steam generators, etc.)
- Often plants will monitor sensors not in the power calculation to detect drift in power (1^{st} stage pressure).
  - ➢ This is helpful but sometimes misleading. Why?

TRUE NORTH
CONSULTING, LLC

Feedwater Flow – The Biggest Influence

- Mid-Presentation Quiz:

  1. When a nozzle fouls, will the flow indicate high or low?

  2. Subsequently what does this do to the calculated thermal power?

  3. A 1% change in feedwater flow has what affect on thermal power?

  4. What causes defouling?

TRUE NORTH CONSULTING, LLC

Sample PWR Power Calculation

$$Qc = \{Msf(hstm - hfw) + Mbd(hbd - hfw)\} + Qmisc - Qp - Qpzr$$

- Qc = Thermal Power
- Qmisc = energy losses to cycle (insulation, letdown)
- Qp = heat input from reactor coolant pumps
- Qpzr = heat input from pressurizer heaters

- Msf = steam flow
- hstm = enthalpy of steam
  - steam pressure
  - steam quality
- hfw = enthalpy of feedwater
  - feed pressure
  - feed temperature
- hbd = enthalpy of blowdown
  - blowdown pressure
  - blowdown temperature
  - blowdown quality

Flow is the big influencer on power!

TRUE NORTH CONSULTING, LLC

Response to a Need

- In response to this need to better track and monitor thermal power and feedwater flow, companies are beginning to develop and promote solutions to assist plant personnel in the early detection of sensor drift or failures that lead to potential over power violations.

- Some solutions will also apply to under power situations that commonly occur following outages (nozzle defouling, etc.).
  - 3 MWth = about 1 MWe

Being down 1 MWe in generation translates into loosing over $250,000/yr!

TRUE NORTH CONSULTING, LLC

Who Would Use These Solutions?

- Thermal Performance Engineers
- System Engineering Managers
- Plant I&C Personnel

Calculation Methodology

- The foundation of these solutions is software and/or services to monitor and constantly validate in real-time the instrument and equipment condition.
- These solutions cover a spectrum of calculation methods to determine the instrument and process health as well as to monitor thermal power.

TRUE NORTH CONSULTING, LLC

Types of Calculation Methods

- **Thermodynamic** – energy balance.
- **Mathematical** – back calculation of thermal power from generation, condenser pressure, etc.
- **Alternate Indicators** – simple relationships (develop curve relating 1st stage pressure and feedwater flow, etc.)
- **Statistical** – numerical methods to analyze the interrelationship of plant instruments and thermal power.
- **Prediction from Learned Operating Data (pattern recognition)** – software that "learns" the characteristics of a healthy system and uses those learned characteristics to evaluate the continuing health of the system.
- **Instrument Behavior** – accurate validation of the sensors that provide data entering the plant power calculation using various technologies.
- **Process Equipment Condition Behavior (neural networks)**– validation of the behavior of the process (i.e. plant power calculation).

Potential Problems

- Calculation Methods
  - ➢ Each have limitations and assumptions.
  - ➢ Almost all methods require periodic tuning or adjustments.
- Accuracy Issues
  - ➢ Human errors with:
    - Not fully understanding the plant thermal power calculation.
    - Problems with development of models.
    - Mining of plant archive data – using bad data!
    - Retuning after plant changes, calibrated nozzles, etc.
  - ➢ Solutions that "Cry Wolf"
    - Presenting "false positives" to plant personnel!

Independent Power Validation – Value

- Two Categories to Monitor:
  - ➢ Dependant Power Sensors
  - ➢ Independent Power Sensors
- In addition to sensors used in the calculation, there is added value to monitor sensors not in the calculation.
  - ➢ Note: The farther the sensor is from the process, the more error.
- Some vendors are offering solutions using both dependant and independent sensors to prevent false positives.

What Makes a Good Solution?

- Results of any of these solutions are only as good as the inputs from the sensors.
  - Sophisticated calculations are worthless without good input data validation!
  - Continuous sensor checking is critical to success to detect dead and drifting sensors.
- The winner of this ballgame of detecting power drift is to:
  - accurately and quickly detect input sensor and thermal power drift.
  - have minimal maintenance.
  - have minimal or no false positives.
    - ✓ Multiple calculation methods insure confidence in results.

TRUE NORTH
CONSULTING, LLC

Summary

- These solutions provide pertinent information that can detect instrument failure that could lead to an over or under power condition.
- Implementation of one of these solutions provides the information to aid engineering and operations in detecting and correcting issues with thermal power long before a problem occurs relating to over power or running under power.

TRUE NORTH
CONSULTING, LLC

Questions & Comments

TRUE NORTH
CONSULTING, LLC

Thank you for your time. Please contact us should additional information be desired.

Frank Todd
True North Consulting
856-391-3347
fdt@tnorthconsulting.com

Bill Kettenacker
Scientech
214-349-5502
wkettenacker@curtisswright.com