Transformer Program

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ELECTRIC GENERATION
ISSUES, TRENDS, and PRACTICAL SOLUTIONS

Overview of Calpine

- Established in 1984
- One of the largest Independent power producers in the U.S., capable of delivering more than 27,000 MWs of electricity
- 92 power plants in operation or under construction

Overview of Calpine (Cont'd)

- Fleet of combined-cycle and cogeneration plants
- Use both natural gas and steam to produce electricity
- Cogeneration plants also produce steam for industrial use
- Commitment to environmental excellence in power generation
- Operates the largest single renewable geothermal power resource in the world at The Geysers

Calpine Transformer Program

- Calpine owns 635 transformers including over 200 generator step-up units (GSU)
- WHY PERFORM ASSET HEALTH REVIEW?
  - Transformer related issues significantly impacted fleet reliability and increased overall operation costs
  - Review of test results was in three separate groups: electrical, oil and infrared (IR) thermography results
  - Inconsistent test results or lack of test data

Calpine Transformer Program

- WE NEEDED TO BETTER UNDERSTAND THE OVERALL HEALTH OF OUR CRITICAL TRANSFORMERS

Calpine Transformer Program

- What is our goal?
  - Determine the health of our critical transformers
  - Improve our Transformer Fleet Reliability Performance
  - Consistent updating of information for strategic planning and maintenance
  - Have a documented assessment to drive maintenance and planning

Calpine Transformer Program

Dedicated Calpine Program Manager

- Provides management of National Contractors
- Responsible for the schedule of testing each year. Keeps master schedule detailing what has been tested and the plan for the coming year
- Reviews all test results (Electrical, DGA and Infra Red) with service partners

Calpine Transformer Program

- Responsible for management of unplanned emergency work (must be prepared to respond to site within hours)
- Primary point of contact for Key Service Partners
  - Alstom Grid (RB Watkins) - Electrical Test Contractor
  - SD Meyer - Oil Analysis
  - Doble Engineering - Transformer Condition/Health Assessment

Calpine Transformer Program

- Alstom Grid (RB Watkins) Electrical Test Contractor - Electrical Testing and Inspection Program
- Nationwide contractor selected to perform all testing including GSU, station service, unit auxiliary, and excitation transformers (635)
  - Overall Power Factor
  - Excitation Current
  - Winding Resistance
  - Transformer Turns Ration (TTR)
  - Bushing Power Factor Testing (C1 and C2 or Hot Collar)
  - Surge Arrestor Testing
- Determining the health of our transformers with limited internal resources

Calpine Transformer Program

SD Meyer - Oil Analysis

- Comprehensive oil sampling program administered by SD Meyer
  - GSU's sampled quarterly
  - Station services and auxiliary transformers sampled annually

Calpine Transformer Program

- Analysis includes
  - Visual Inspection
  - Liquid Power Factor
  - Karl Fisher
  - DGA
    - Hydrogen, Methane, Carbon Monoxide, Carbon Dioxide, Ethane, Ethylene, Acetylene and Total Combustible Gas
  - Inhibitor
  - Corrosive Sulfur
  - Metals in Oil
  - Furans

Calpine Transformer Program

- Doble Engineering - Transformer Condition / Health Assessment
- We had three separate groups reviewing the electrical, oil and IR results Consultants, SD Meyer, PdM Group (RTSI & SKF)
- Complete history of test results including factory testing if available
- Complete maintenance history if available

Calpine Transformer Program

- Manually input all test data into one xml.file with comments
- Drop maintenance history, reports, IR scan, electrical and oil test results (complete history) into a Doble FTP Site for entry into DOBLE DTAWEB
- GSU Assessment performed by Doble all other performed internally by Calpine with Doble's assistance if needed

Calpine Transformer Program

- Transformer Condition Assessment
- Overall transformer code based on asset health review
- Top level rating based on diagnosis of all information
- Transformers rank 1 – 5 with 1 being the worst and 5 being the best
- Having a 5 point code allows for refinement of comments and management information
- Three main condition colors Green, Orange, Red
- Forth color Blue, to identify information is missing

AEGIS

Calpine Transformer Program

CONDITION CODE		
Code	Description	Explanation
0	No Data	Overall Transformer Code = 0 if no oil test or electrical test data. Individual test codes = 0 if no data available for that test.
0MP	Missing Partial Data	Not assigned to the Overall Transformer Code. Indicates data provided but not complete to make assessment.
1	Unacceptable	Strong indication that there is a problem. Requires immediate attention or considered unacceptable to be returned to service.
2	Poor	Data indicates there likely is a problem. Requires attention in the very near future.
3	Good	Data indicates there may be a problem but it is not clear, usually need further investigation or trending of data.
4	Very Good	Data is not within expected limits, maybe some noteworthy trends but indicates there is not likely a problem. Typically further investigation is recommended.
5	Excellent	Data does not indicate any problem conditions.

Calpine Transformer Program

- Mitigating concerns from the start
- Doble support for
  - Design specification
  - Design review
  - Factory inspection
  - Witness key stages in manufacturing process
  - Factory Acceptance Test (FAT)

Calpine Transformer Program

When things go wrong: Bushing Failure on 165 kV,300 MVA GSU

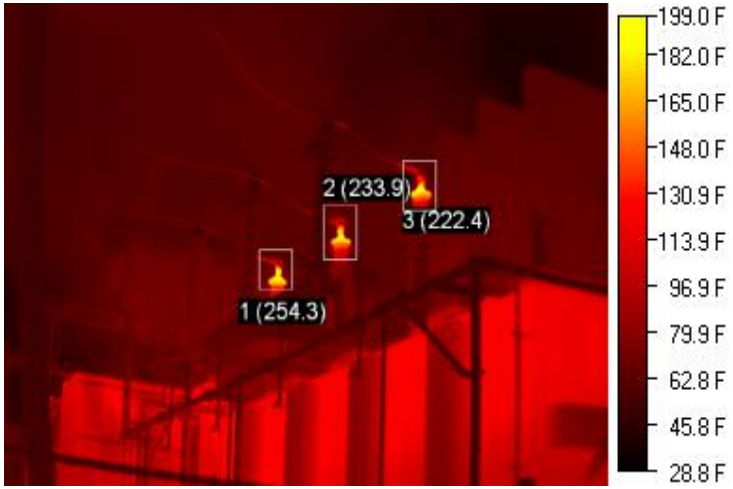
Calpine Transformer Program

- Split Conductor 165kV 750kV BIL Top Bushing Oil Analysis
- The result of the Dissolved Gas Analysis (DGA) identified two bushings had unacceptably high levels of Hydrogen, Methane and Ethane
- The bushings were immediately taken out of service
- The production of Methane & Ethane is commonly assoc. with overheating
- Hydrogen is associated with overheating and partial discharge arcing
- All bushings were stripped down and new “passive” components installed

Calpine Transformer Program

- Identified before failure

Transformers	Bushings
- Infrared thermal imaging - Ultrasonic – corona - Corona camera – as needed - Visual (motors, fans, controls)	- Infrared thermal imaging - Ultrasonic – corona - Corona camera – as needed - Visual (oil level)



Generator Step Up Transformer Bushings (All three phases)

Temperatures above 250°F observed and reported at the top of the transformer bushings

Further investigation revealed internal bushing connections were not properly made

Calpine Transformer Program

- Calpine estimates our cost avoidance for the events below to be approximately $6M

Unit/Location	Machine/Area Description	Method of Detection
CT-1	CTG 1-GSU T-10	Testing/Inspection
CT-2	CTG 2 GSU T-20	Testing/Inspection
SST Aux A, B and C	Aux Transformers	Testing/Inspection
ST-1	STG-GSU	Oil Analysis
BP	TRF-02	Oil Analysis
CT -3	CTG 3 GSU	Oil Analysis
STG –A-XF SUS	Aux Transformer NLTC	Oil Analysis
Unit 2	#2 Cooling Tower Transformer	Oil Analysis

Calpine Transformer Program

- GSU Spares Program
  - Lead time for Transformers 12 – 14 months
  - Identify critical spares with the fleet
  - Design spares for multiple use
  - Nationwide heavy haul contractor selected
    - Based on storage location developed heavy haul plan
- 2012 Spares Coverage (Approx. 40% of the fleet)

Calpine Transformer Program

- Additional units added in 2012/2013
  - 230 MVA 18/118 kV
  - 100 MVA 13.8/69/138 kV
  - 73 MVA 13.8/115 kV
  - 230 MVA 13.8/18/533 kV
  - 250 MVA 15/352 kV
  - 230 MVA 13.8/15/230 kV
  - 333 MVA 16/145 kV
- All available June/July 2013
- 2013 Spares Coverage (including industry rental unit) is approximately 92% of the fleet

Calpine Transformer Program

- Fleet-wide review of Protection Relay Coordination and Settings
- All protection relay settings from 480V to 500kV will be reviewed for accuracy, suitability and compliance with industry standards
- 3 - 5 year program to complete the review
- Settings will be reviewed in an ongoing program
- Relays that become obsolete, unreliable or unsupported by the OEM will be scheduled for replacement
- DC Battery systems

Program Enhancements Under Construction

- Develop relationship with a Transformer OEM(s) for future purchases and support
  - The aim of the relationship building is to reduce lead time for replacement transformers by jointly agreeing to standard design requirements
- Develop transportation plan to move transformers from storage to the plants
- Potentially add other HV equipment to this Program in the future
  - Testing the transformer requires HV circuit breaker, disconnects, and cables to be de-energized. Programming the maintenance of the HV equipment with the transformer outage could increase

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QUESTIONS ?

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