WELCOME TO A

COMET 2017

TECHNICAL PAPER PRESENTATION
“ONLINE THERMAL MONITORING FOR PARALLEL POWER TRANSFORMERS.”

BY SEAMUS ALLAN
Seamus is the Product Portfolio Manager for Dynamic Ratings and is based in Dynamic Ratings’ headquarters, in Sussex, Wisconsin. Seamus has recognized subject matter expertise in many areas including transformer and electrical apparatus monitoring for Dynamic Ratings.

He has worked for Dynamic Ratings since 2008, moving through various roles (around the world) including software development, on-site commissioning and product development. His team provides direction and engineering support to the field, sales, and development engineering teams for power transformers and online condition monitoring.
The electricity network is changing. Forecast load growth is minor, and the corporate and regulatory landscape is turbulent resulting in tight budgets. Ever increasing penetration of distributed energy resources and gradual closure of large synchronous generation is resulting in unexpected peak loading and system stability difficulties for network operators. On the other hand, technology is advancing at a tremendous rate with advanced condition monitoring coming of age and acceptance, and novel energy storage and control schemes being introduced into the system.
The Electricity Network is changing

- New renewable technologies
- Deeper penetration of renewables
- Distributed and/or intermittent in nature
- Battery storage systems

Subsequently: Load Flows are changing

Transmission and distribution operators are utilizing new technologies
  - Battery storage on sub-transmission
  - Power electronics
  - Novel control schemes
ORIGINAL SYSTEM

Historic electricity network design, (loosely) radial energy distribution: generation connected at transmission level voltages

NEW GENERATION

More economical for newer (typ. smaller) distributed generation to be connected at sub-transmission level
SITUATION IN AUSTRALIA

ElectraNet is experiencing this issue, acutely in the South East of South Australia

WIND GENERATION ON 132 KV
280 MW wind farm, 80 MW thermal (gas) plant and 63 MW thermal (gas) generation connected onto 132 kV sub-transmission network

POWER FLOWS REVERSED
During certain conditions (cool windy days in South Australia, hot weather in neighboring Victoria), power flow at interconnector

THERMAL CONSTRAINTS
Thermal limits on transformers at interconnector site constrains power flow and can invoke limits on generation dispatch
SYSTEM OPERATOR CONSTRAINTS

Australian Electricity Network Operator (AEMO) uses constraint risk model to set wholesale pricing and determine generation dispatch.

**S>>V_NIL_SETX_SETX**
Constraint is invoked if throughput exceeds capacity of transformers at South East interconnector substation

**CONSTRAINT INVOKED**
Limits export across interstate interconnector
Constrains off generation at locally connected generation

**MARKET IMPACT**
evaluated using Marginal Value – increase in wholesale price due to constraint being invoked for given number of hours annually

<table>
<thead>
<tr>
<th>Year</th>
<th>Marginal Values</th>
<th>Hours</th>
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<tbody>
<tr>
<td>2011</td>
<td>$97,376</td>
<td>207</td>
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<tr>
<td>2012</td>
<td>$169,769</td>
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<tr>
<td>2013</td>
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<tr>
<td>TOTAL</td>
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SYSTEM PLANNING CONSIDERATIONS

**INTERSTATE CONNECTOR UPGRADE**

Heywood Interconnector (between states of South Australia and Victoria) reviewed as capacity was regularly being exceeded (in both direction depending on load flows). Upgrade project included new 500 kV transformer, series capacitors and line upgrades.

**SOUTH EAST SUBSTATION IMPACT**

Thermal constraints at South East substation impacted load flow through interconnector due to parallel 132 kV sub-transmission from Tailem Bend to South East.
REQUIREMENTS

REVISED N-1 SUBSTATION RATING
Substation capacity ratings for various time intervals (particularly AEMO LDSH rating of 15 mins), based on lower of 2 transformer ratings

TIME FOR LOAD
Time for load for each transformer, given total SS load

IMPLEMENTATION

DYNAMIC RATINGS ENGINEERED COMPREHENSIVE MONITORING SYSTEM

Online thermal modelling / dynamic rating

Asset condition health assessment including bushing monitoring and partial discharge

Upgraded thermal model (IEC 76-7)
ONLINE THERMAL MODEL

Dynamic Ratings E3 Transformer Monitor performs continuous online thermal modelling of monitored asset for real time and predictive calculations

† REAL TIME THERMAL MODEL
• Top Oil calculated for model verification
• Winding temperatures for control, ageing, alarms

‡ “WHAT IF” CALCULATIONS
• Time for load
• Load for time

[Graph showing thermal model for transformer]

OPTIMIZATION OF PARAMETERS

INITIAL CONFIGURATION
- Model is configured using transformer heat-rise test data

OPTIMIZATION
- Mathematical regression techniques used to generate revised parameters for thermal model
- Based on real world data measured on the monitoring system
- Improves model accuracy
- Gives confidence for derived results
COMPREHENSIVE MONITORING

WHY?

- **OVERLOADING INCREASES RISK**
  Running (older) assets above nameplate rating elevates ageing mechanisms and increases risk of acute failure modes.

- **CRITICAL TRANSFORMERS**
  Critical transformers deserve close attention to decrease risk.

WHAT?

- **THERMAL MONITORING**
- **INSULATION AGEING**
- **INTEGRATION OF ONLINE DGA**
- **BUSHING HEALTH**
- **PARTIAL DISCHARGE**
- **TAP CHANGER HEALTH**
SITE PHOTOS
INITIAL OBSERVATION PERIOD 12 MONTHS

- System in operation for 1 year, collecting data.
- Analysis showed significant headroom on TX
  - Large thermal mass
  - High loading occurs during cool, windy conditions
- After review of data, the 160 MVA transformers AEMO “LDSH” rating increased to 208 MVA
- This rating improves the RHS of the AEMO constraint equation
  \[ S >> V_{NIL\_SETX\_SETX} \]
RESULTS OF NEW RATINGS

AEMO equipment ratings increased and contingency re-rate to nameplate put in place. Review of constraint impact after trial period of new ratings.

**LSHD RATING AND RAMP DOWN**

- Pre-contingent rating 208 MVA
- Post-contingent 160 MVA rating remains

**INCREASED EXPORT / IMPORT CAPACITY**
EFFECT ON CONSTRAINT BINDING HOURS

- After the implementation of the revised static rating (late 2014), significant drop in constraint binding hours
- It is likely that a fully dynamic 15 minute rating would reduce binding hours to zero

May have been possible to achieve result using offline cyclic models, however unlikely given:
- Complex load profile (intermittent wind)
- Lack of thermal characteristics of transformers
- Online solution trialed for data gathering
- Side benefit of condition monitoring
CONCLUSION

Transformer project at South East substation, coupled with interconnector upgrade at Heywood.

- 500 kV INCREASED SECURITY OF SUPPLY
- INCREASED RENEWABLE GENERATION DISPATCH
- REAL-TIME MONITORING OF AGED TRANSFORMERS UNDERGOING NEW LOADING

These technologies will become more commonplace due to the changing networks we work in.

- EVOLUTION OF THE ELECTRICITY SYSTEM
- CHANGES TO OPERATION OF NETWORKS (BUDGETARY, REGULATORY)
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