Increasing Network Capability through a Review of Asset Ratings

Dr Darren Spoor
Operations Technical Support
TransGrid

Presented on the 14th Nov 2013 to the Joint Electrical Institutions Sydney - Engineers Australia, IEEE, IET

References:

- Similar presentations:

IEEE PES Conference on Innovative Smart Grid Technology, Asia (ISGT2011)

IEEE – Celebrating 125 Years of Engineering the Future

13-16 November 2011,
Pan Pacific Hotel, Perth Australia

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The conference organizing committee invites researchers and practitioners worldwide to submit papers for review and possible presentation. General conference papers are invited on these and other smart grid related topics:

- Smart grid skilling needs
- Standards for smart grid and grid codes
- Regulatory aspects and market operations
- Cyber and physical security systems and information and communication technology
- Asset management, system reliability and diagnostics
- Intelligent monitoring and outage management
- AC and DC transmission and distribution system planning, operation and security
- Protection and phasor measurement unit applications
- Grid integration of renewable energy sources
- Utilization and control of power electronic controllers and energy storage
- Grid solutions for plug-in electric vehicles and low-carbon transport
- Sensors, communication and advanced metering infrastructure
- Energy management, efficiency and end user benefits

Leading practitioners and researchers that wish to lead and assist in the organisation of Tutorials, Special Interest Paper Sessions or Panel Sessions are encouraged to submit expressions of interest to the Technical Program Chair.

Important Dates

- Expressions of Interest for Special Sessions 1st June, 2011
- Full Paper Submission Deadline: 18th July, 2011
- Author Notification of Acceptance: 1st September, 2011
- Final Paper Submission (if revision is requested): 1st October, 2011
- Early-bird Registration Deadline: 1st October, 2011

Submission and Review

- Complete manuscripts are to be submitted by email to the Technical Committee. Presented papers will be published in the IEEE Xplore digital library.
- Full papers will be peer reviewed by an appointed Reviewer Pool. Volunteer reviewers can submit expressions of interest to the Technical Committee.
- Papers must be formatted to the IEEE PES template which can be downloaded at http://ieee-pes.org/templates-and-sample-of-pes-technical-papers. Papers not conforming to the IEEE PES template will not be considered.
- Submitted papers should be written in English, and in PDF file format. The maximum size of the file is 2 MB. Papers may not exceed 8 pages in length.
- Name your file as follows: Family Name_First Two Words of the Paper's Title (e.g. Wolfs_Smart_Grid). Use only the English alphabet A-Z.
- An acknowledgement of receipt, and all correspondence, will be sent to the corresponding author's email address only.
- All papers must be converted into an IEEE Xplore compatible PDF format through IEEE PDF eXpress. The conference ID is ISGTAsia11x .
- Authors must sign and submit the IEEE copyright form upon submission of the final version of the paper. The copyright form is available at http://www.ieee.org/publications_standards/publications/rights/copyrightmain.html.

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cigré – Managing Substations in the Power System of the Future

Trends in Technology, Design, Materials and Diagnostics

International Study Committee Meeting and Colloquium 2013
Study Committee B3 (Substations) and Study Committee D1 (Materials and Emerging Test Techniques)
Hosted by Cigre Australia

Brisbane, Australia – September 8-13, 2013

Introduction

A 2-day Colloquium will be held in Brisbane on 9 - 10 September 2013. The Colloquium theme, "Managing Substations in the Power System of the Future - Trends in Technology, Design, Materials and Diagnostics" has been designed to align with Cigre's major strategic focus on the Power System of the Future.

The Colloquium will be held in conjunction with the annual meeting of Study Committee B3 (Substations) and D1 (Materials and Emerging Test Techniques).

The event date has also been chosen to coordinate with the CIGRE Auckland Symposium to be held on September 16-17, 2013, titled "Best Practice in Transmission and Distribution in a Changing Environment".

Leading international experts in the fields of substations, high voltage materials and substation testing and diagnostics will attend the Colloquium and will provide an opportunity for authors and attendees to demonstrate and be exposed to international trends and experience.

Preferential Subjects

1: Latest Developments in Substation Design:

- The application and development of IEC61850, NCIT's and new types of communication protocols, equipment and systems and integration into existing substations
- Old issues but new approaches - minimising fire risk, oil containment, substation security, non-standard layouts, new switchgear types for space restrictions
- Environmental management, stakeholder awareness and public sensitivity issues including global warming, SF_6 management and replacement
- Hybrid HVDC and AC substation design and operation challenges

2: Impact of Modern Materials and Emerging Test Techniques on Substation Equipment:

- New developments and performance of environmentally friendly solid and liquid insulating materials and gas mixtures in substation applications
- Materials for HVDC applications and diagnostic methods related to DC voltage stress (e.g. PD measurement under DC voltage stress)
- Experiences with UHVAC and UHVDC equipment including in-service, laboratory and on-site testing

3: Life Cycle Management and Maintenance:

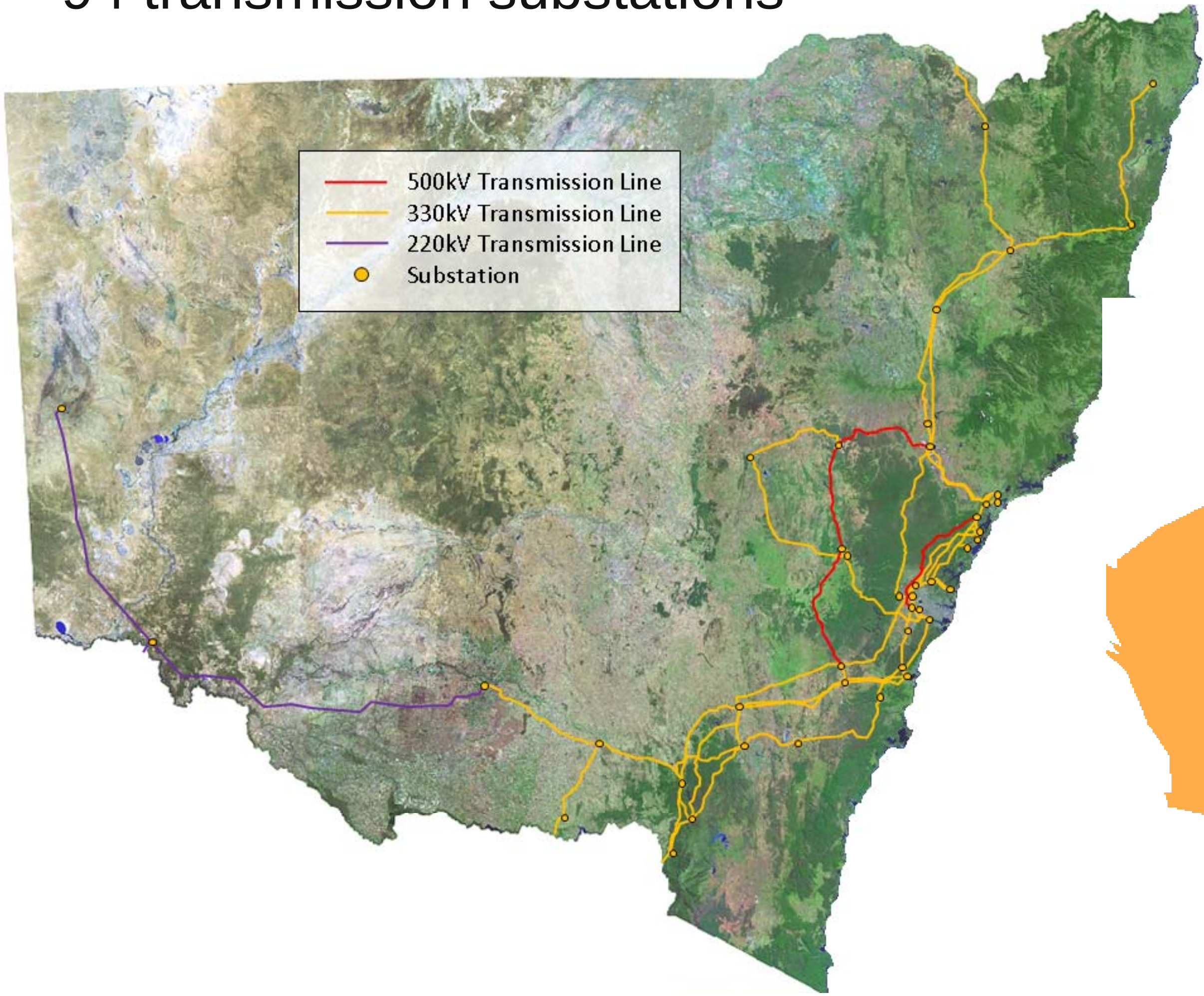
- Substation up-rating, upgrading and extension approaches and experience
- Maintenance optimisation, life assessment and extension methodologies and experiences
- Substation equipment performance improvements and reliability of monitoring, diagnostics and testing equipment and systems

Overview

- Impact of Ratings in a Network
- Network Limitations in NSW
- Available improvements to Thermal Ratings
- Applications of Thermal Inertia:
  - Primary Equipment:
  - Secondary Equipment
- Improvements in Network Utilisation

TransGrid's Network

- 12,800 kilometres of high voltage lines and cables,
- 94 transmission substations

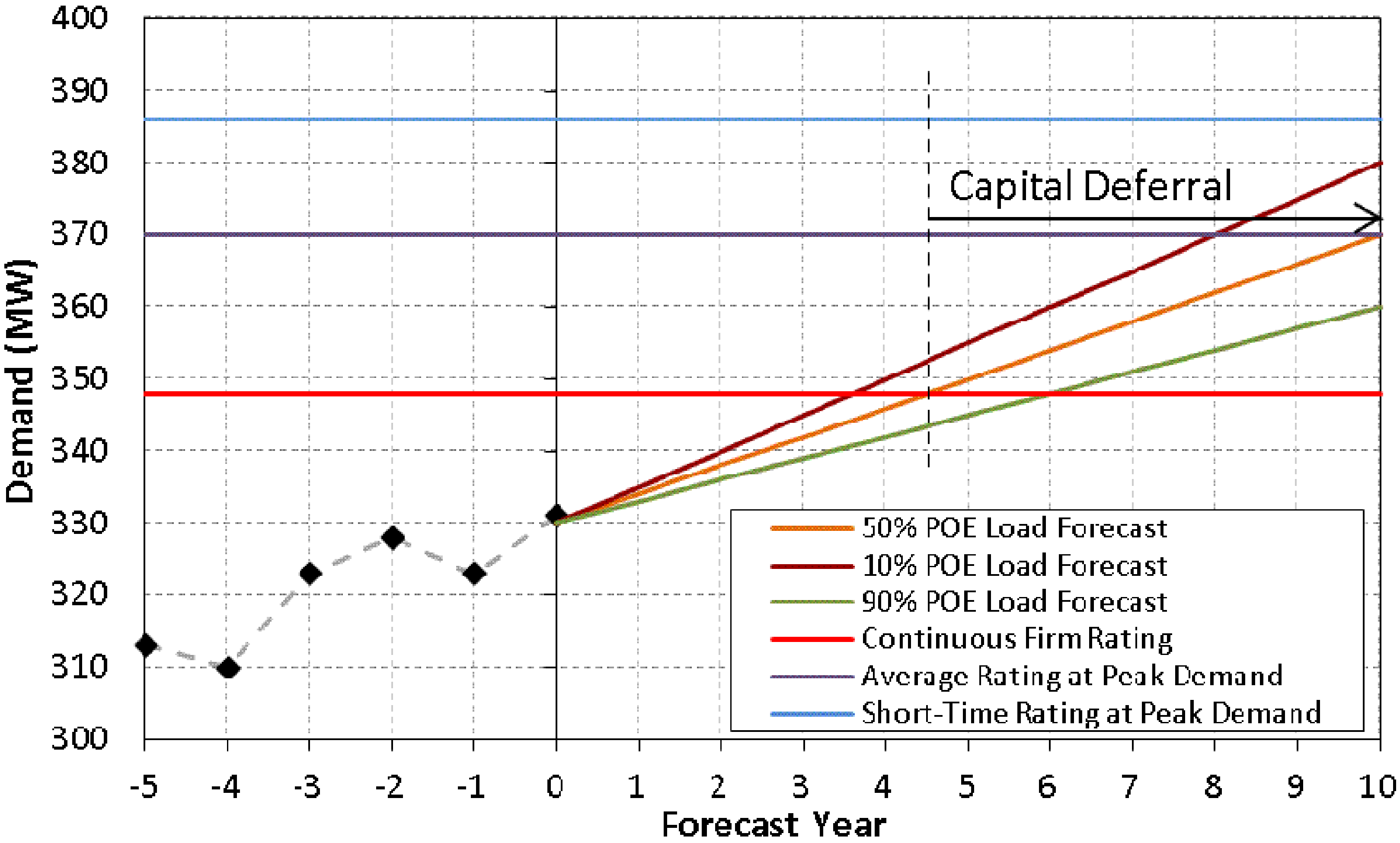


The Current Climate

- Current Objectives
  - Minimising Capital Expenditure
  - Maintaining Customer Reliability

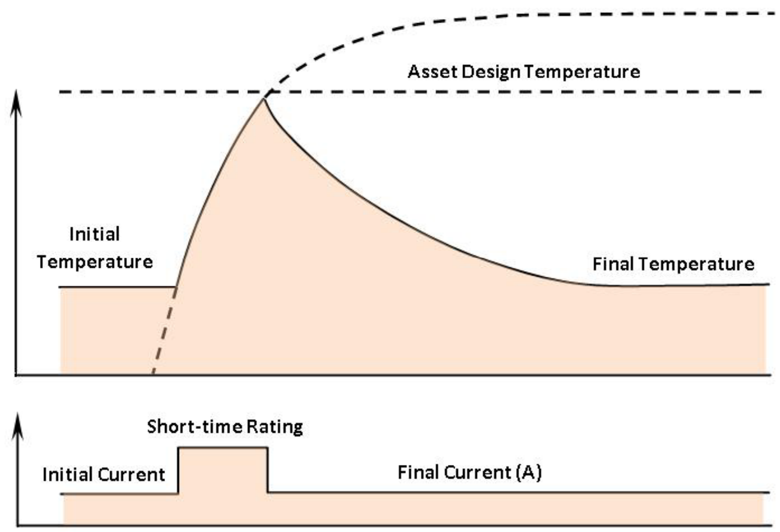
- This can be achieved through
  - Demand Management
  - Routine review of load forecasts
  - Post-contingent Load Transfers
  - A review of rating calculations
  - Short-time or real-time ratings

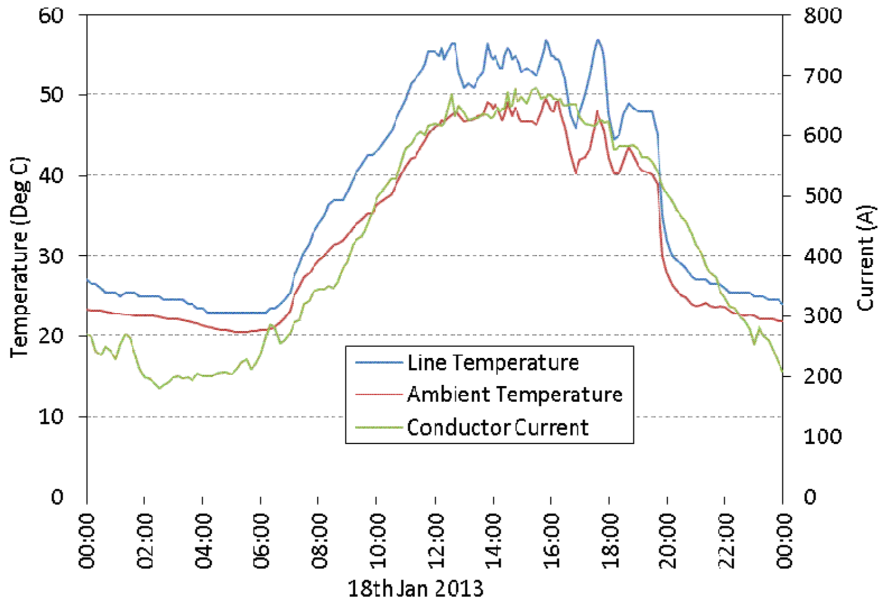
Financial Impact of Ratings



What Are Thermal Ratings?

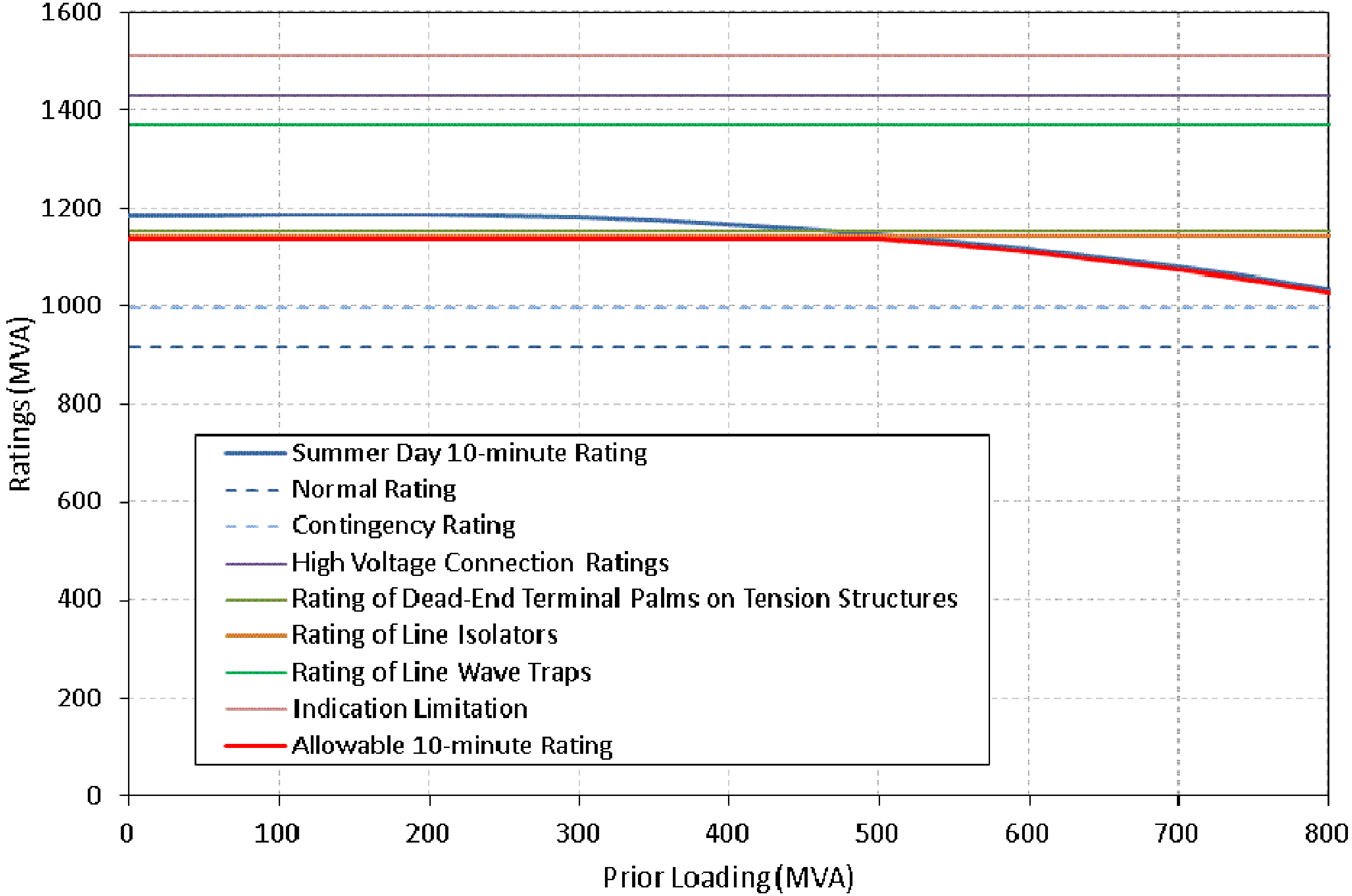
- Normal Ratings
  - Allowable continuous current
- Contingency Ratings
  - Continuous current during lengthy emergencies.
  - Generally less conservative
- Short-Time Ratings
  - Current rating for a short duration (5, 10, 15 min)
- Real-Time Ratings
  - Current rating for the ambient conditions and prior loading





Coordination of Thermal Ratings

- Substation equipment should not restrict the use of short-time or real-time transformer or transmission line ratings



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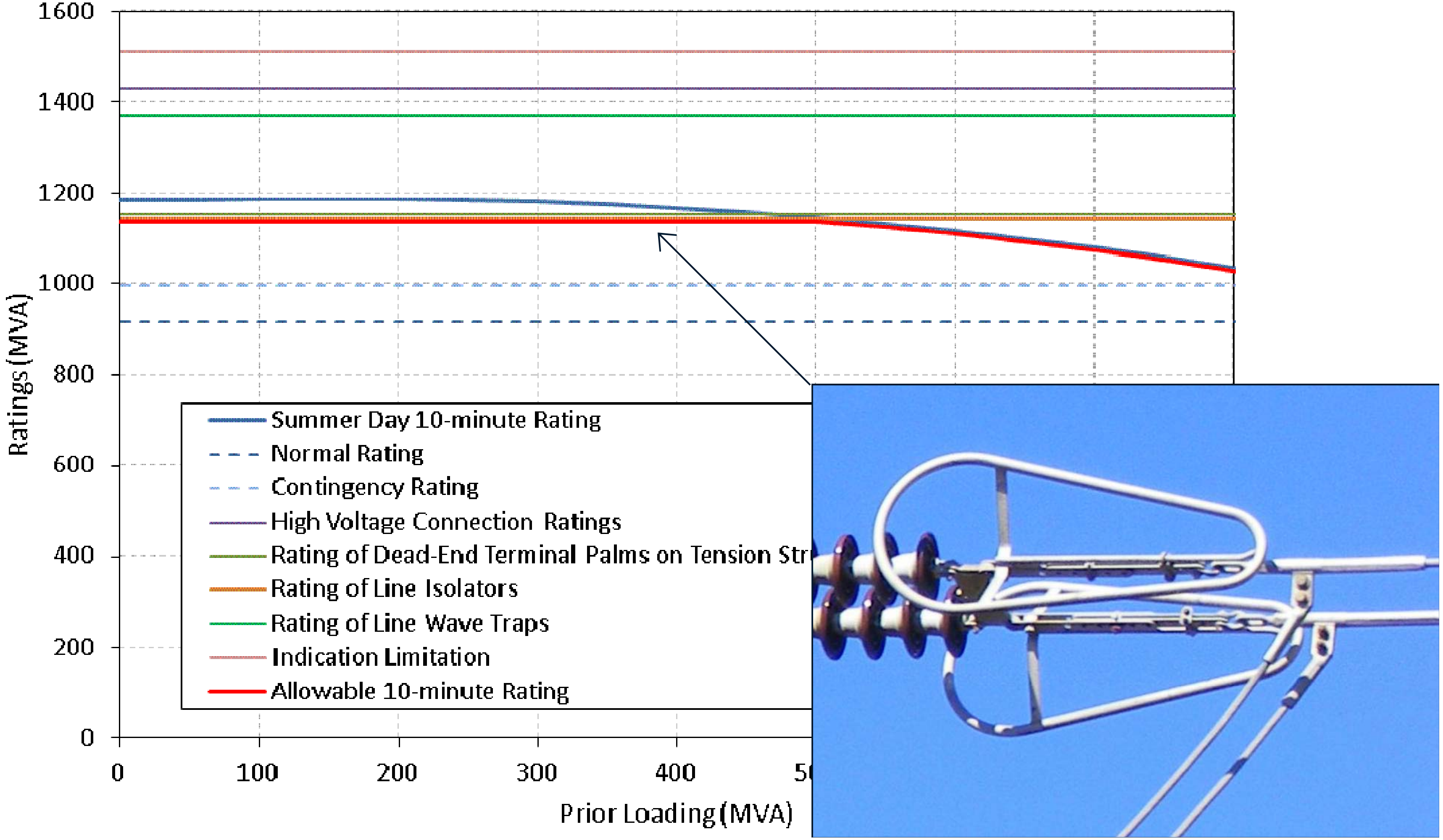
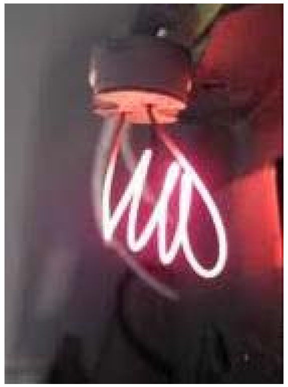
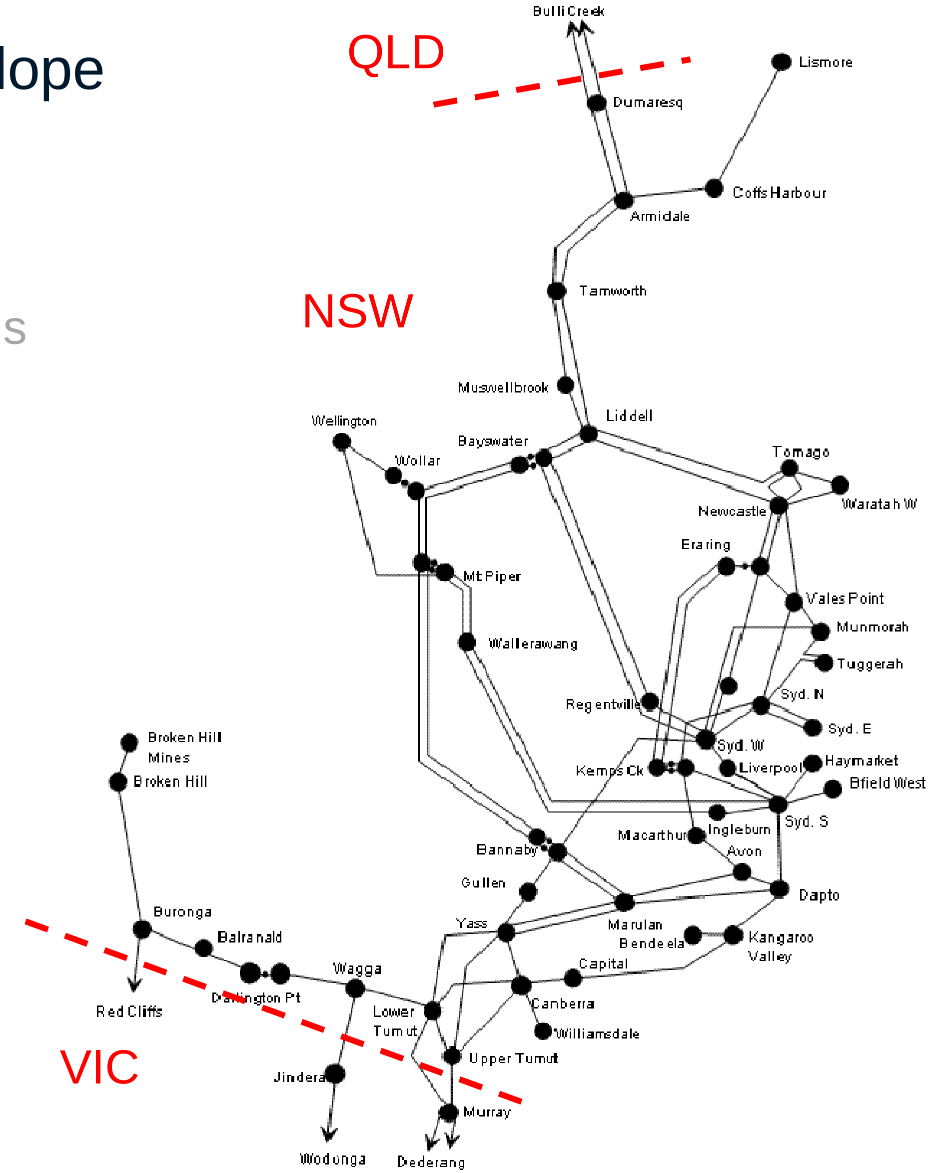


Transmission System Operating Envelope

- Technical Operating Envelope can be Affected by:
  - Thermal ratings
  - Allowable voltage thresholds
  - System dynamics





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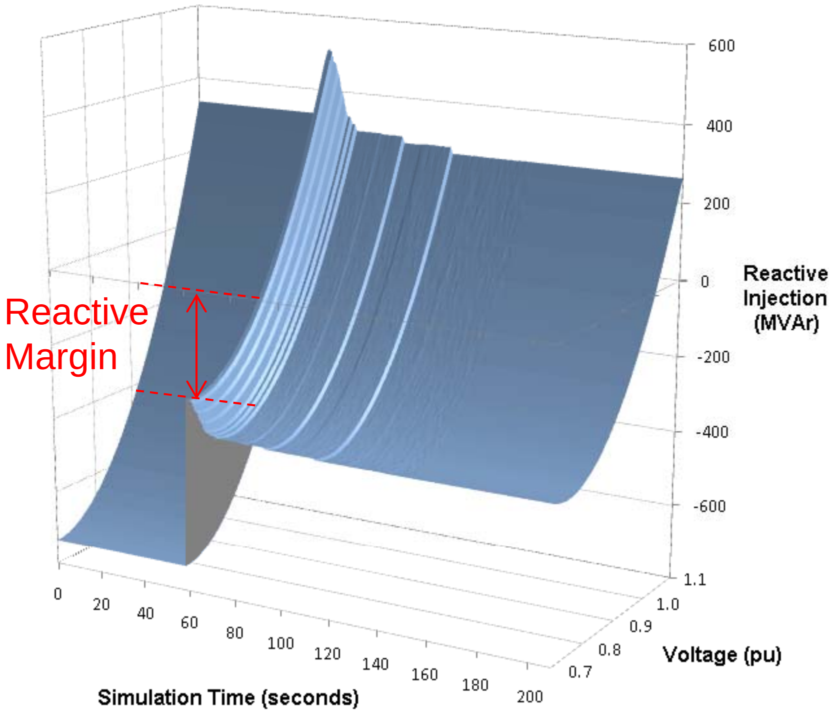

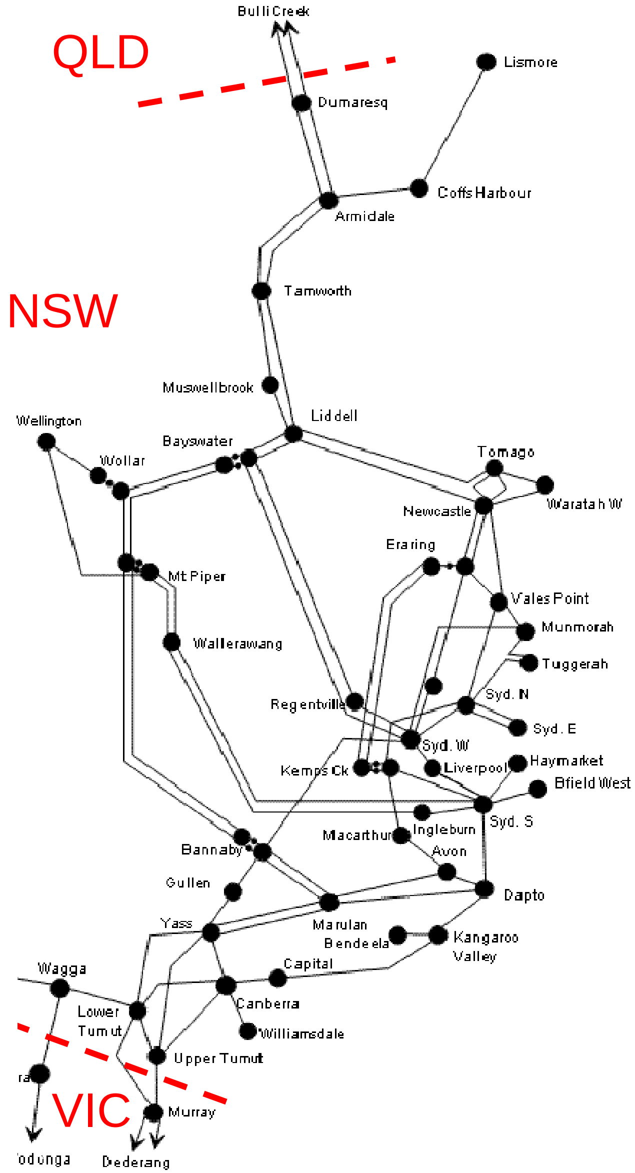

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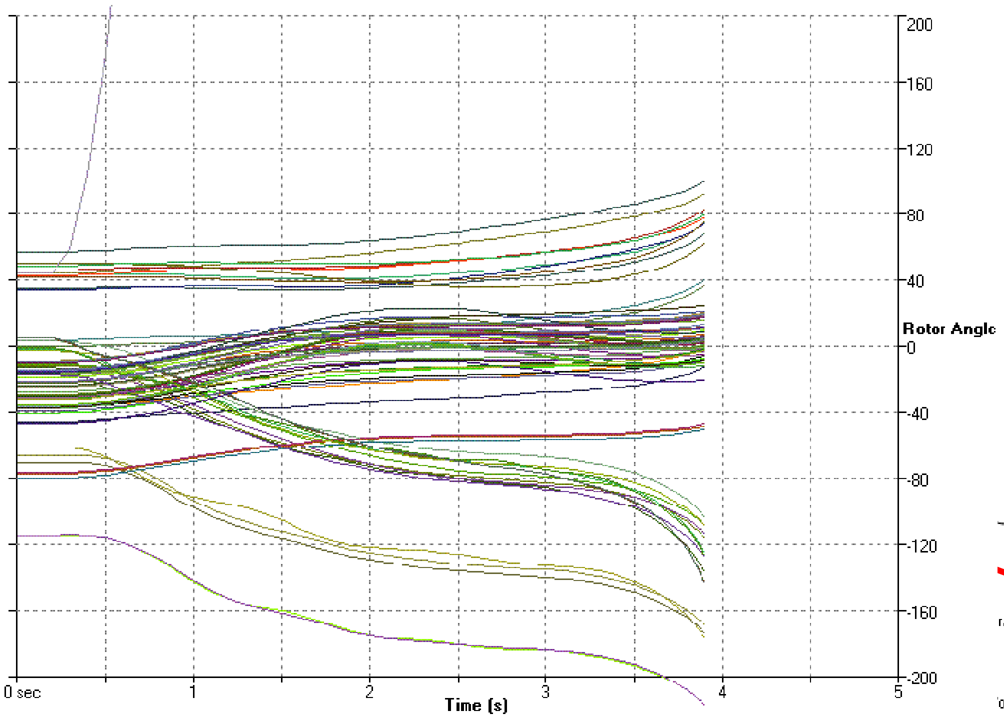
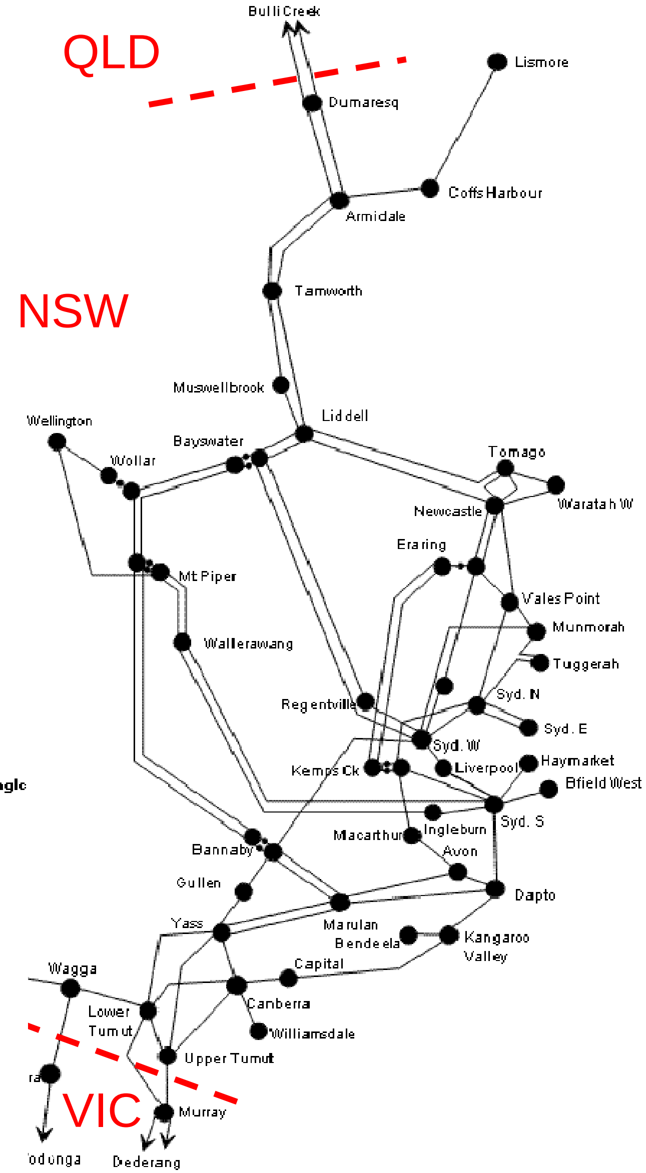
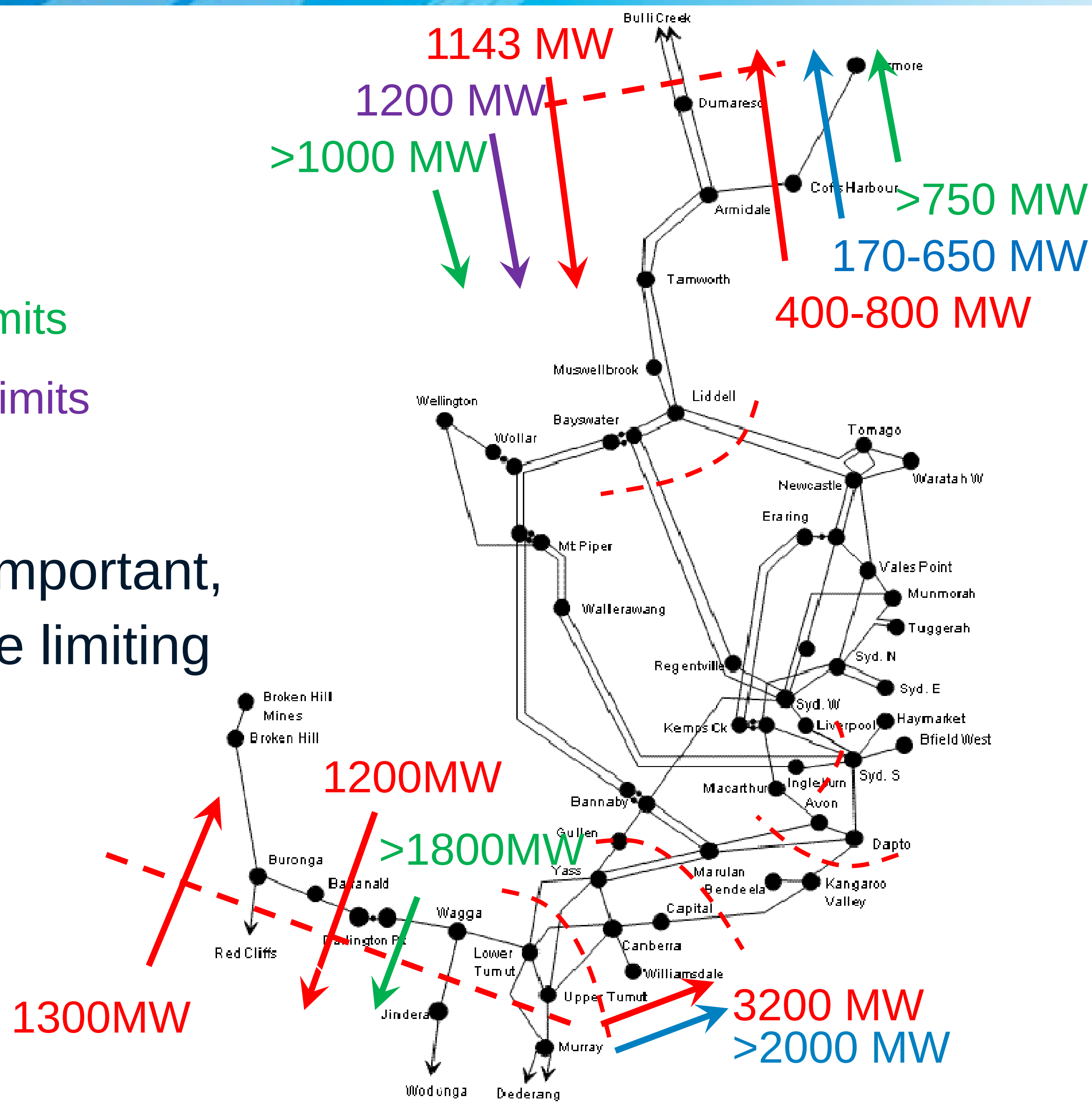




Transmission System Operating Envelope

- Market Constraints
  - Thermal Limits
  - Voltage Limits
  - Transient Stability Limits
  - Oscillatory Stability Limits

- Thermal ratings are important, but are not always the limiting factor

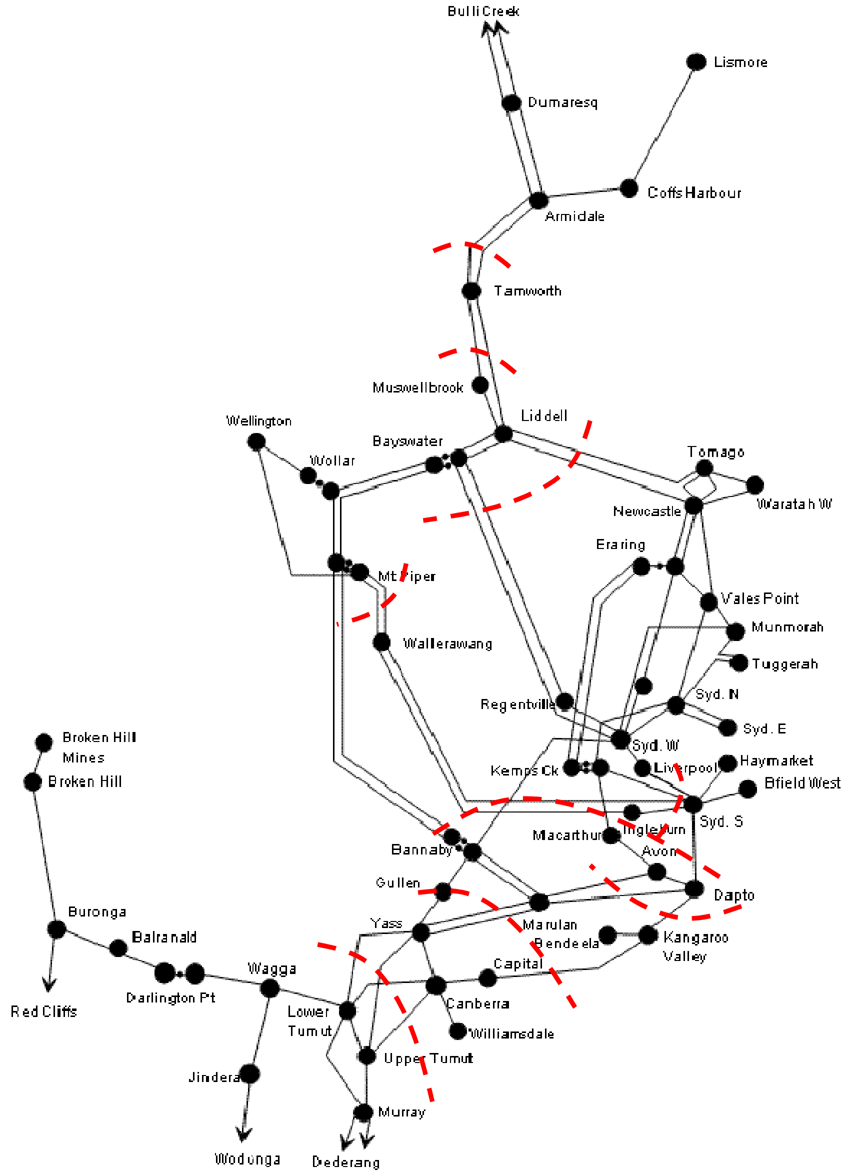


Transmission System Operating Envelope

TransGrid

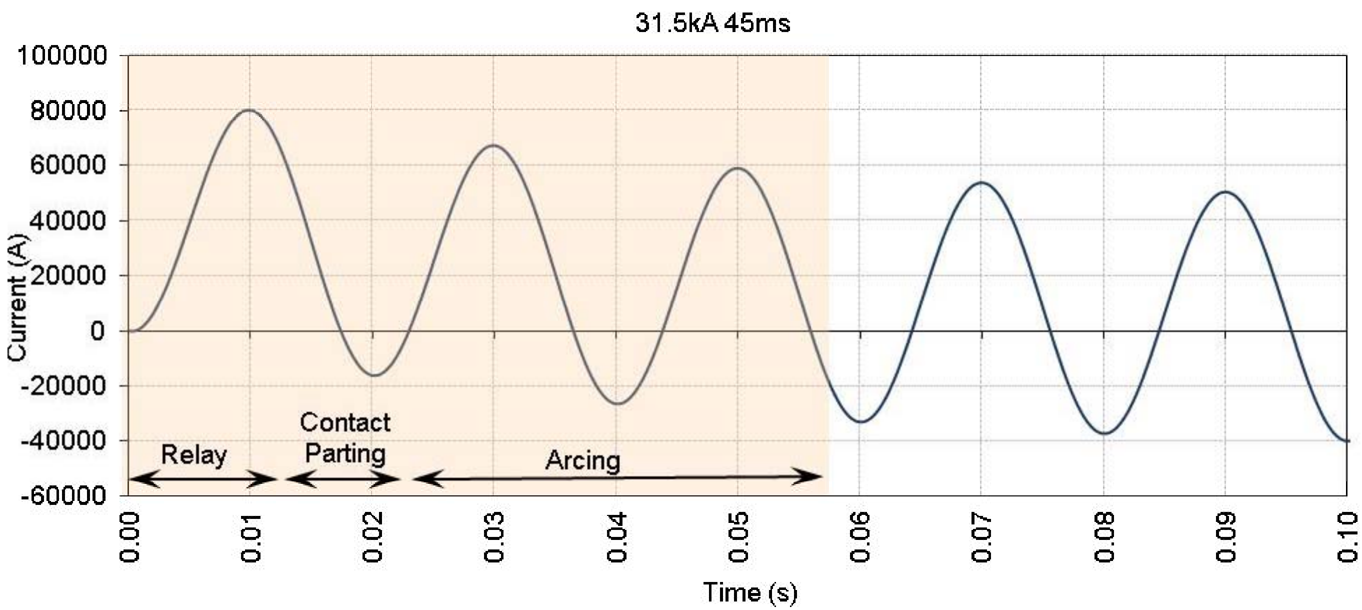
- Market Constraints
  - Thermal Limits
  - Voltage Limits
  - Transient Stability Limits
  - Oscillatory Stability Limits

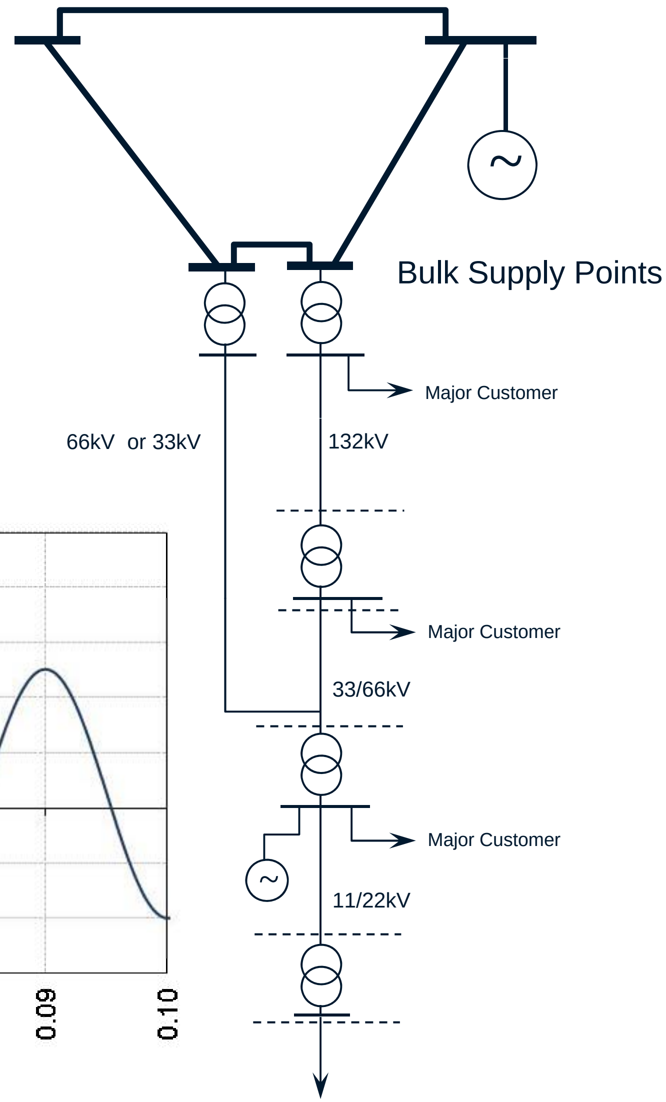
- Additional limits apply during planned outages



Distribution System Operating Envelope

- Distribution System Operating Envelope is Usually Affected by:
  - Fault Ratings
    - Switchgear requirements
    - Earthing requirements





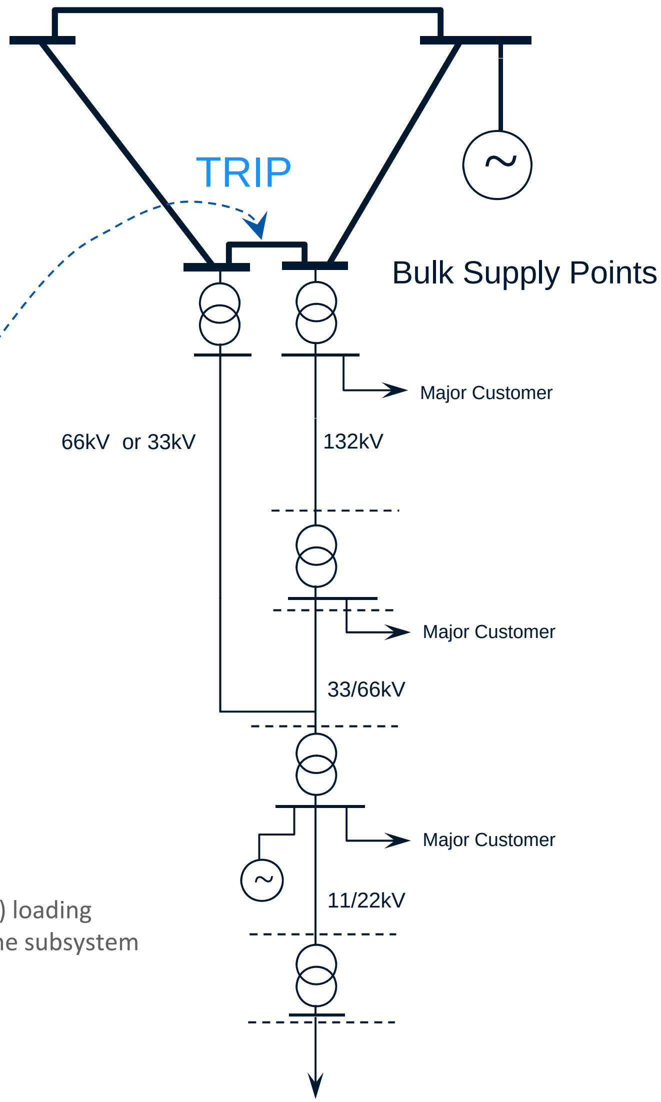
Distribution System Operating Envelope

- Distribution System Operating Envelope is Usually Affected by:
  - Thermal ratings
    - Diversified peak demands
    - Application of planning criteria
    - Voltage Angles between BSP's
  - Thermal Equations:

$$Load \approx A.L_{PRE} + B.\delta + C$$

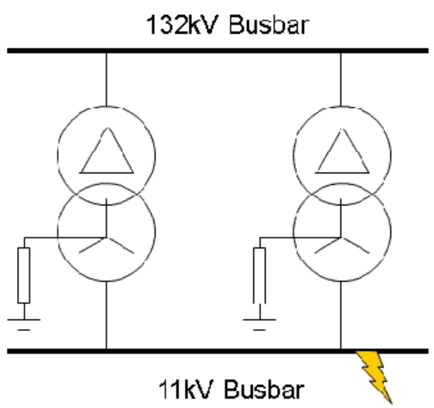
$$\delta = (\delta_A - \delta_B) \approx \frac{180}{\pi}\left[\frac{X\ P_X}{100\ V_A V_B}\right]$$

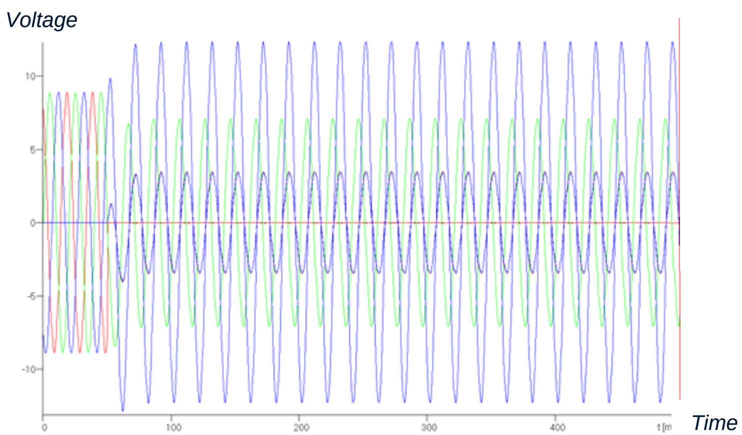
δ_A	is the voltage angle at busbar A
δ_B	is the voltage angle at busbar B
X	is the reactance of the line
P_X	is the power flow on the line
V_A	is the HV voltage at busbar A
V_B	is the HV voltage at busbar B
Load	is the estimated (post contingent) loading
Lpre	is the pre contingent loading in the subsystem
A	is a regression coefficient
B	is a regression coefficient
C	is a constant

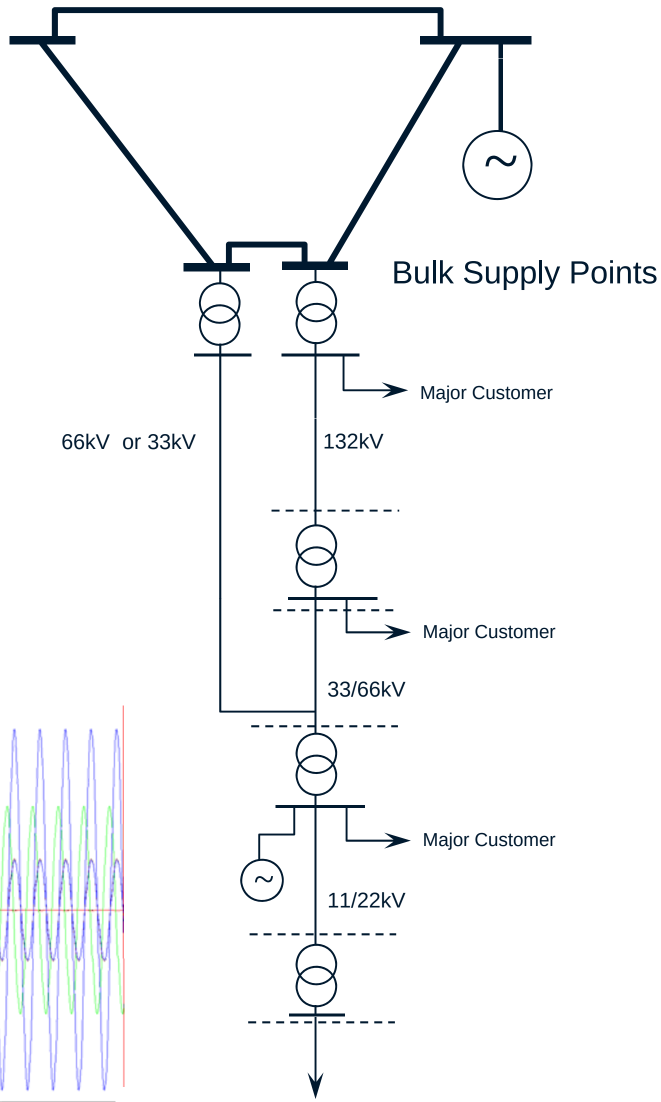


Distribution System Operating Envelope

- Distribution System Operating Envelope is Usually Affected by:
  - Allowable voltage thresholds
    - 230V ±10%
      - IEC 60038 and AS61000.3.100
    - Transformer Tapping Ranges
    - Step voltage changes
      - AS61000.3.100
    - Temporary over-voltage limits

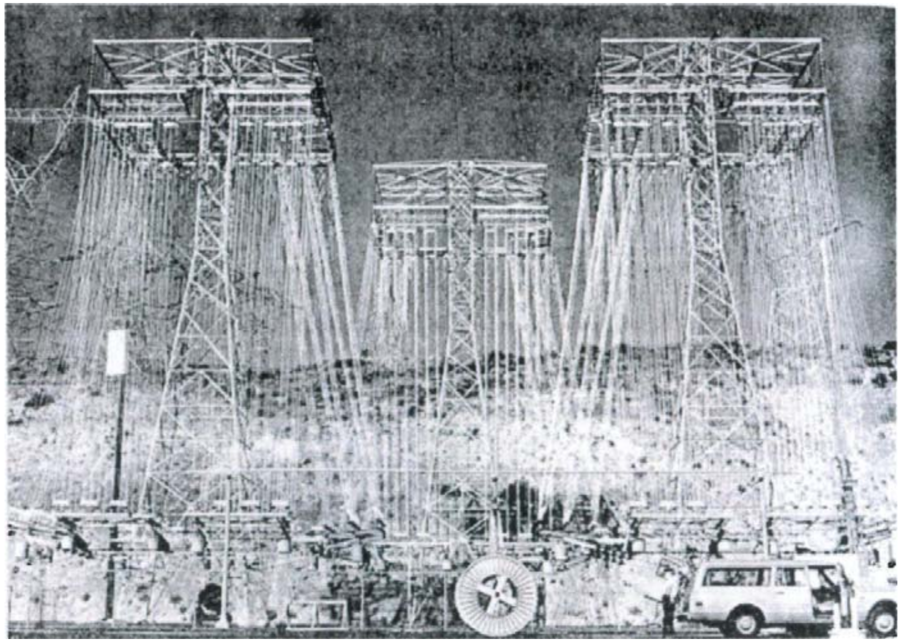






Corrective Actions

- Voltage Limits:
  - Network augmentation
  - Reactive plant
  - LV and MV voltage regulators
- Transient Stability Limits
  - Improved Fault clearing times
  - Braking resistors
  - Series capacitors
  - Generator control systems
- Oscillatory Stability Limits
  - Generator control systems
  - Tuning Power System Stabilisers
- Thermal Limits
  - Application of short-time ratings
  - Review of underlying assumptions



M.L. Shelton, et al "Bonneville Power Administration 1400-MW Braking Resistor" IEEE PES Summer Meeting & Energy Resources Conf., Anaheim, Cal., July 1974

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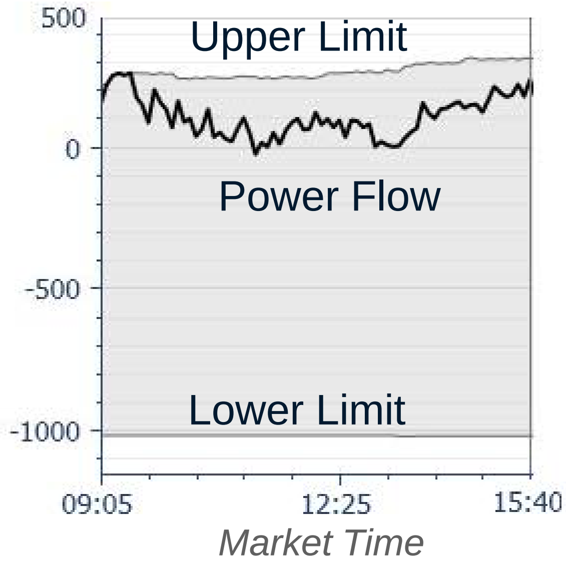


These can done at minimal cost

Common Thermal Limitations

- Primary Equipment:
  - Transformers
  - Overhead Lines
  - Underground Cables

Large Thermal Time Constants

- Terminal Equipment
  - Busbars
  - Terminal Palms
  - Circuit Breakers
  - Isolators
  - Wave Traps
  - CT Primary Windings
- Secondary Equipment
  - Protection circuits
  - Metering Circuits
  - Indication Circuits

Common Thermal Limitations

- Primary Equipment:
  - Transformers
  - Overhead Lines
  - Underground Cables
- Terminal Equipment
  - Busbars
  - Terminal Palms
  - Circuit Breakers
  - Isolators
  - Wave Traps
  - CT Primary Windings
- Secondary Equipment
  - Protection circuits
  - Metering Circuits
  - Indication Circuits

Short Thermal Time Constants

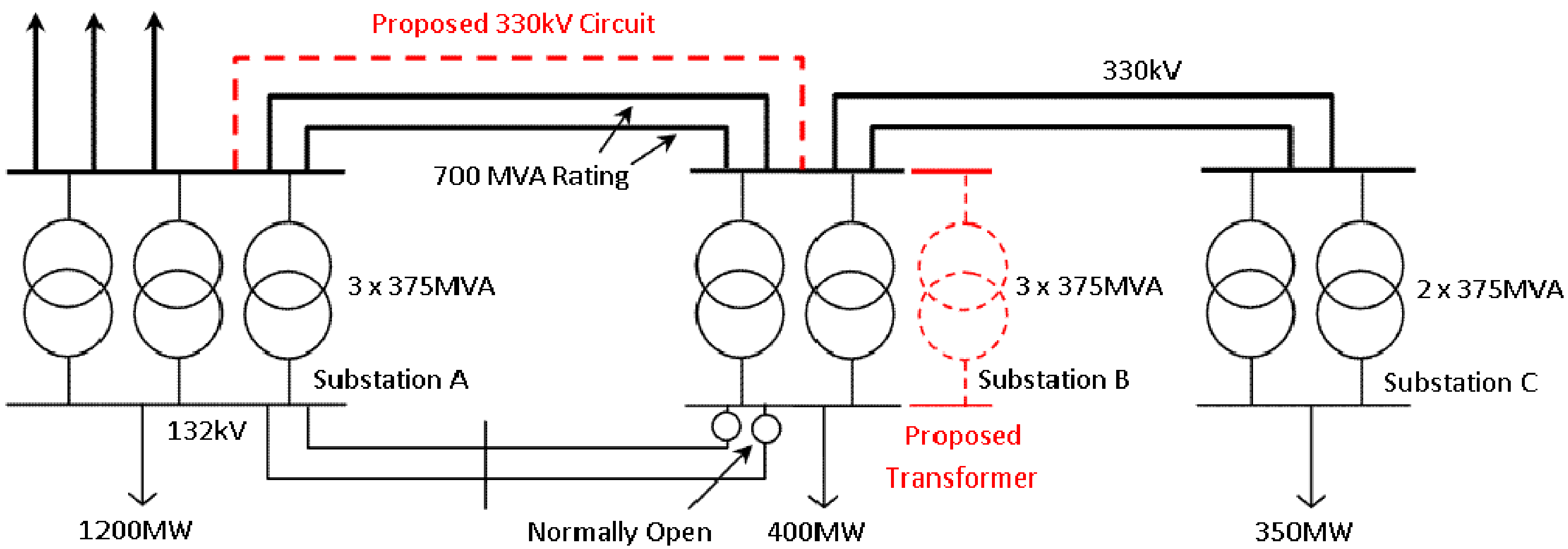
Common Thermal Limitations

- Primary Equipment:
  - Transformers
  - Overhead Lines
  - Underground Cables
- Terminal Equipment
  - Busbars
  - Terminal Palms
  - Circuit Breakers
  - Isolators
  - Wave Traps
  - CT Primary Windings
- Secondary Equipment
  - Protection circuits
  - Metering Circuits
  - Indication Circuits

Some Limits can be waived

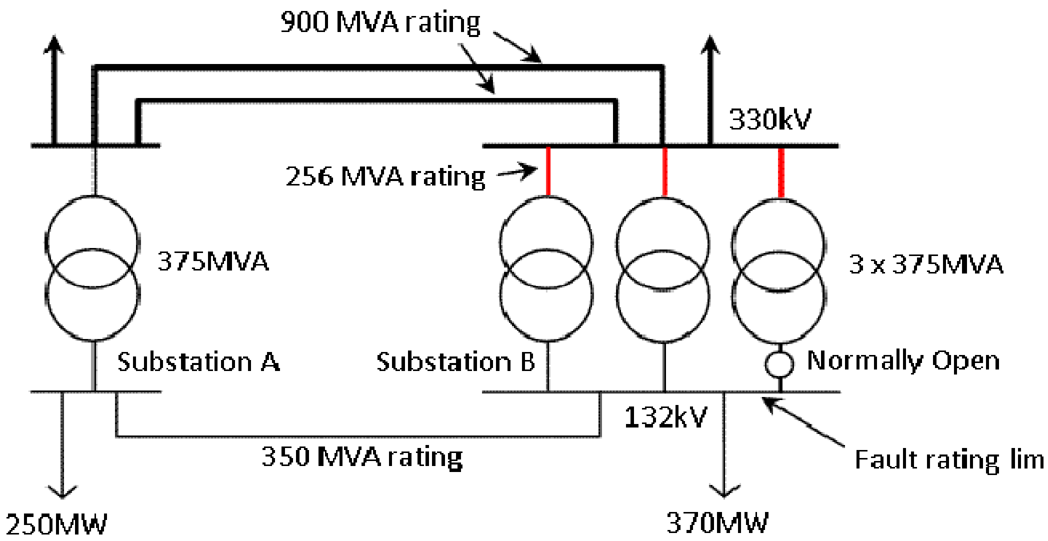
Application of Short-Time Ratings

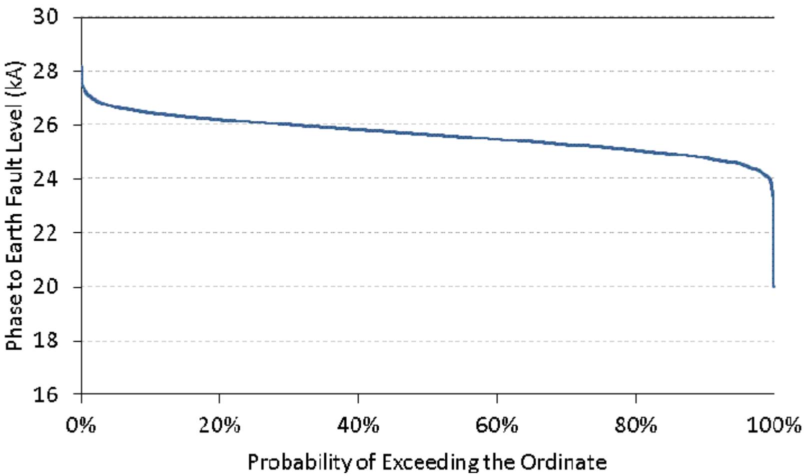
- Post Contingent Transfers:
  - There is a planning requirement for two projects
  - These could be avoided by utilising the short-time ratings
  - 50 MW could be transferred back to Substation *A* after a contingency
  - Several years worth of capital expenditure deferral



Application of Short-Time Ratings

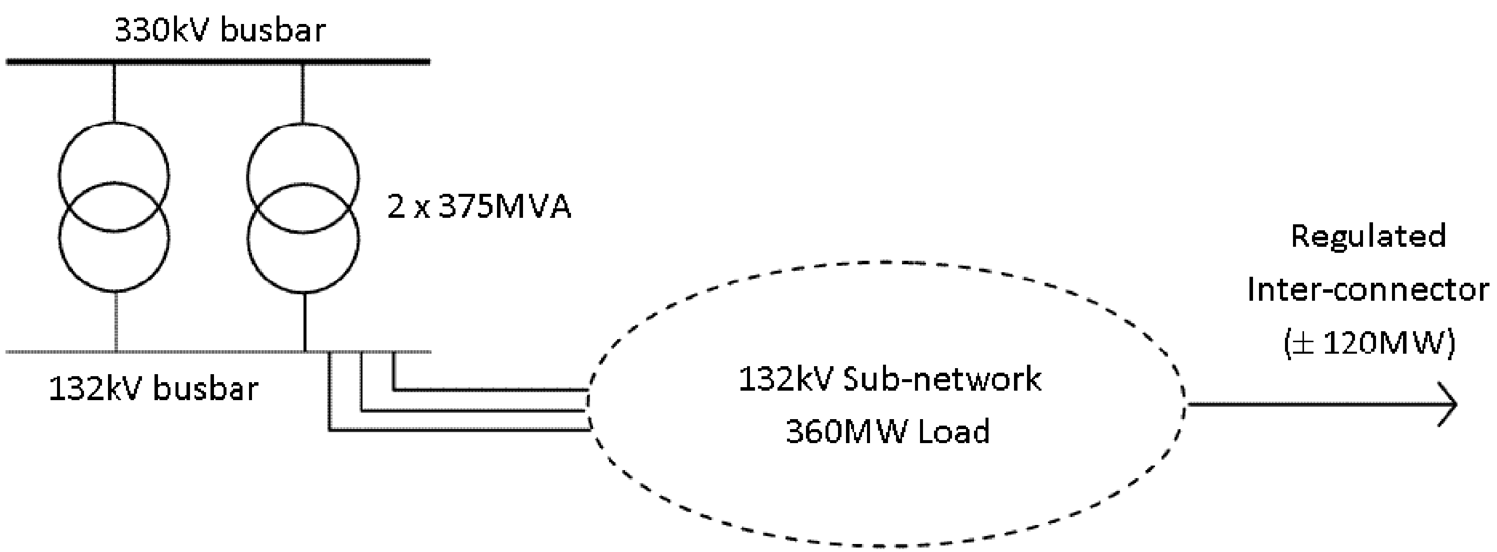
- High Voltage Connections:
  - There is a 330kV dropper and HV connection limitation
  - A five-minute rating of 320 MVA has been derived
  - This provides the opportunity to place the third transformer on load after another transformer trip.
  - Another approach is to consider the real-time fault levels at this site





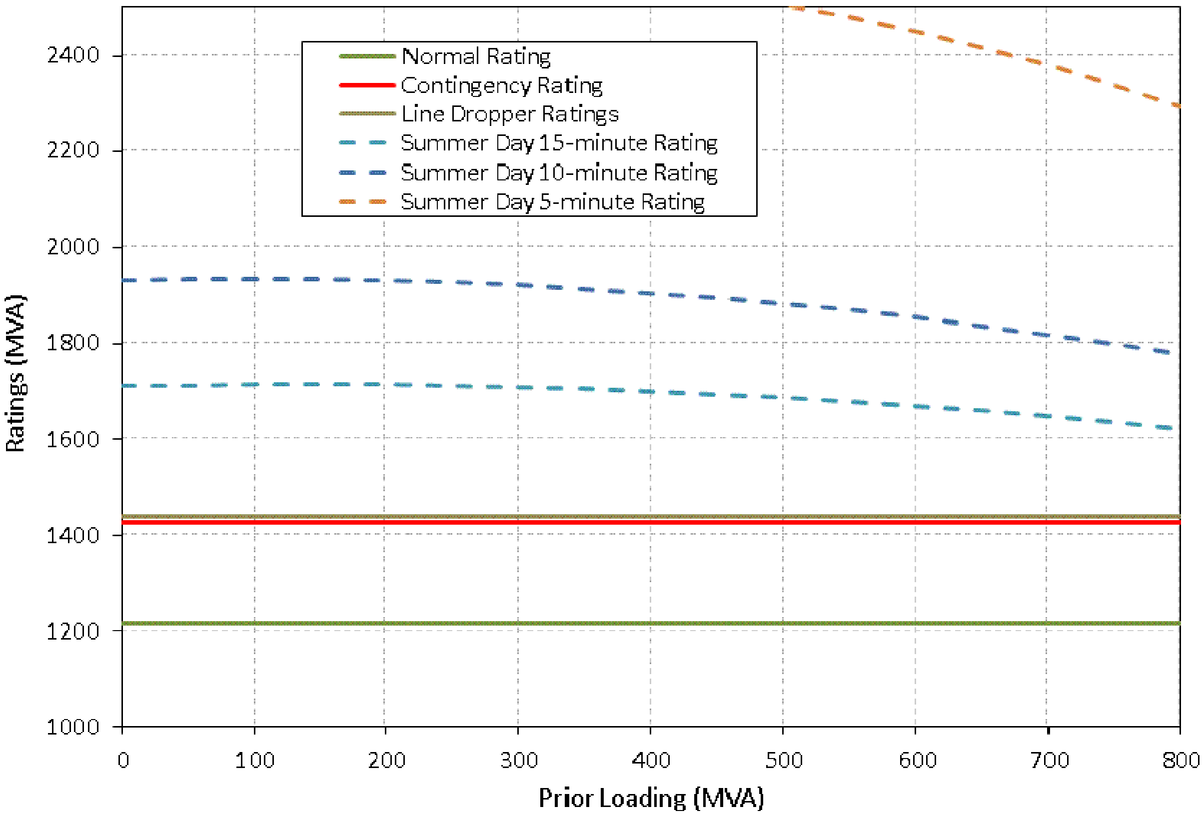
Application of Short-Time Ratings

- Alleviating Market Impacts:
  - A 132kV sub-network with a peak demand of 360MW
  - A regulated interconnector can appear as a load of 120MW
  - A contingent trip of a transformer can result in loads of 480 MW through the remaining transformer.
  - A four-hour rating of 511MVA applies for these transformers



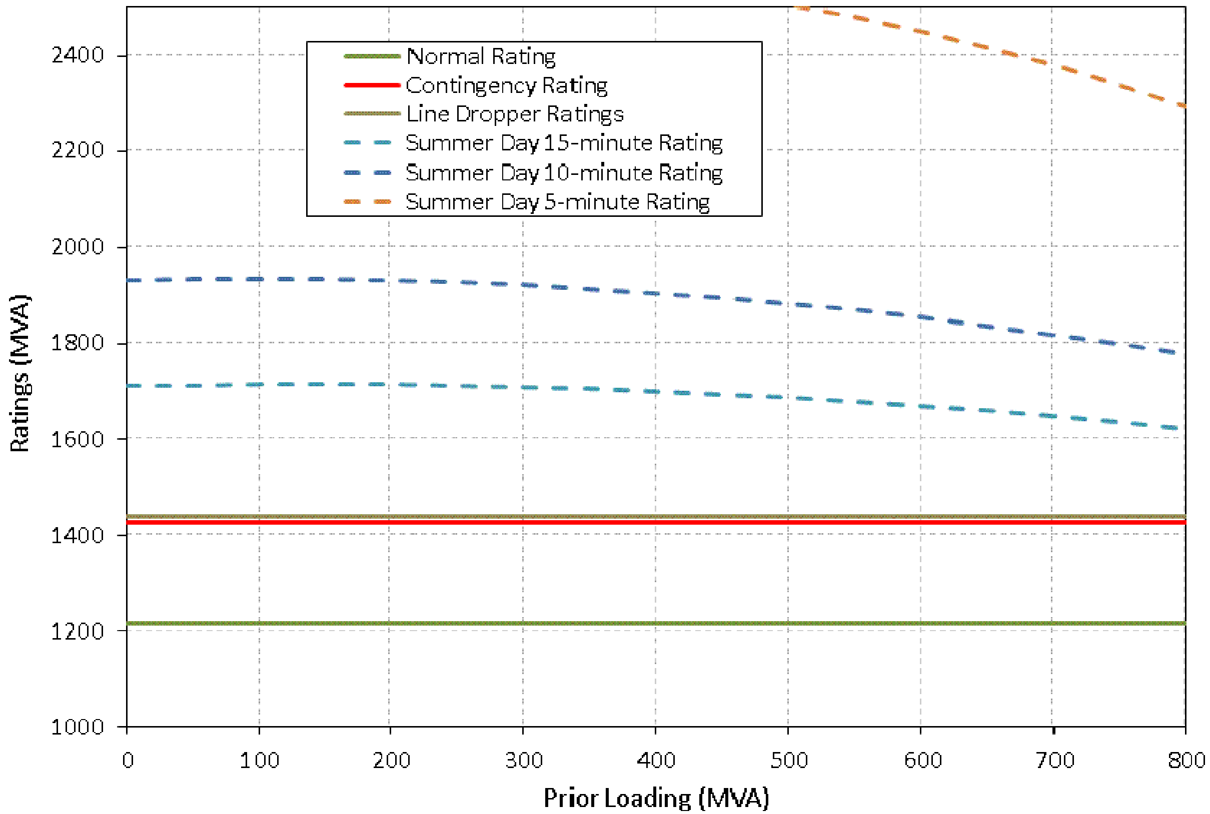
Coordination of Thermal Ratings

- An example of poor coordination:
  - A substation provides a summer day rating of 1430MVA
  - This matches the contingency rating of the 330kV lines
  - This design failed to consider the available short-time ratings

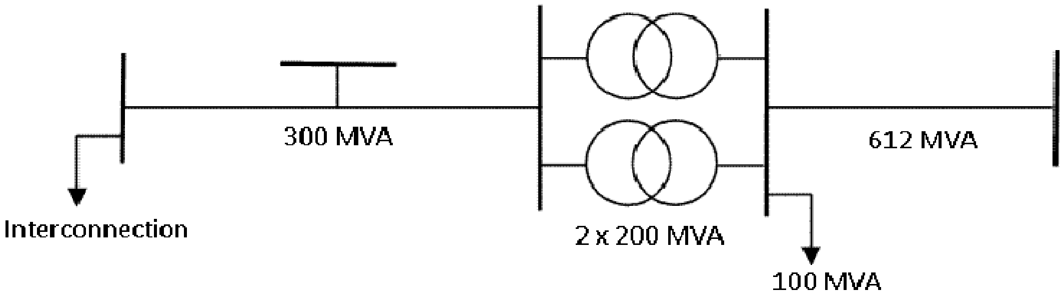


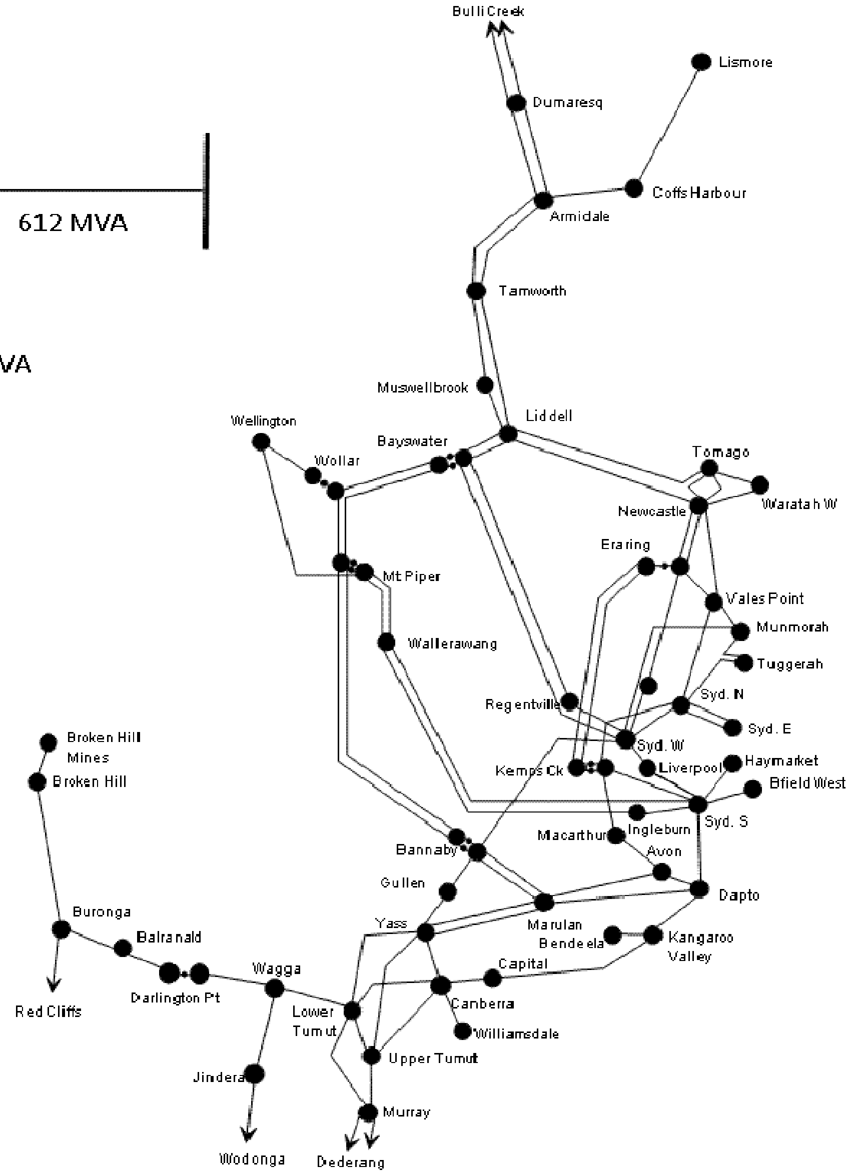
Coordination of Thermal Ratings

- Transmission line bays should be capable of carrying loads greater than 150% of the transmission line normal rating.
- Transformer bays should be designed to carry loads of at least 130% of the transformer normal rating



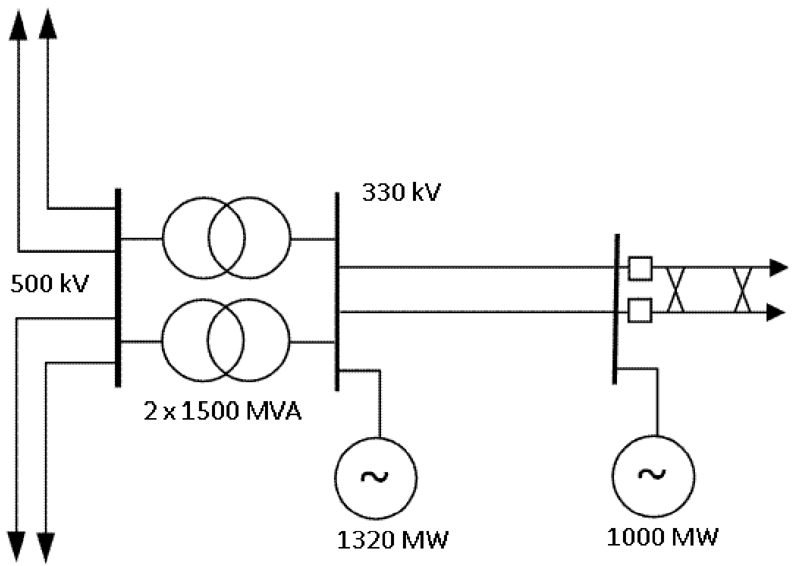
Transformer Short-Time Ratings

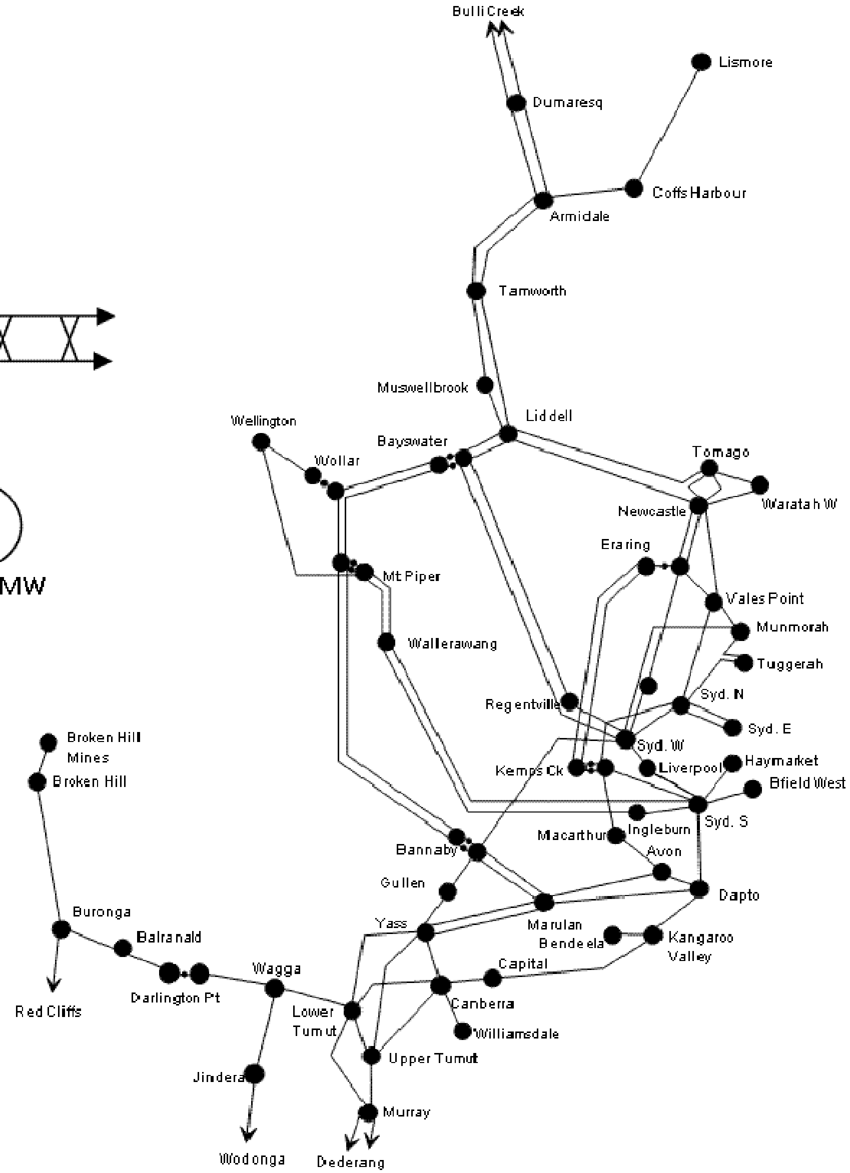




- Transformer rating
  - 60 min rating of 260-300 MVA
  - This depends on ambient conditions
- Market constraints
  - Can be applied post-contingent
  - Usually require 15 min for implementation

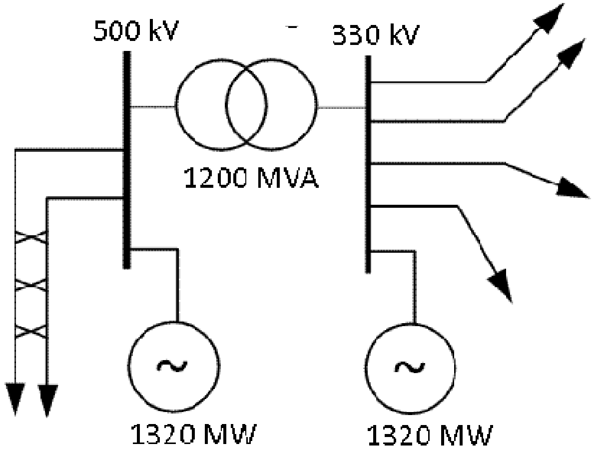
Transformer Short-Time Ratings

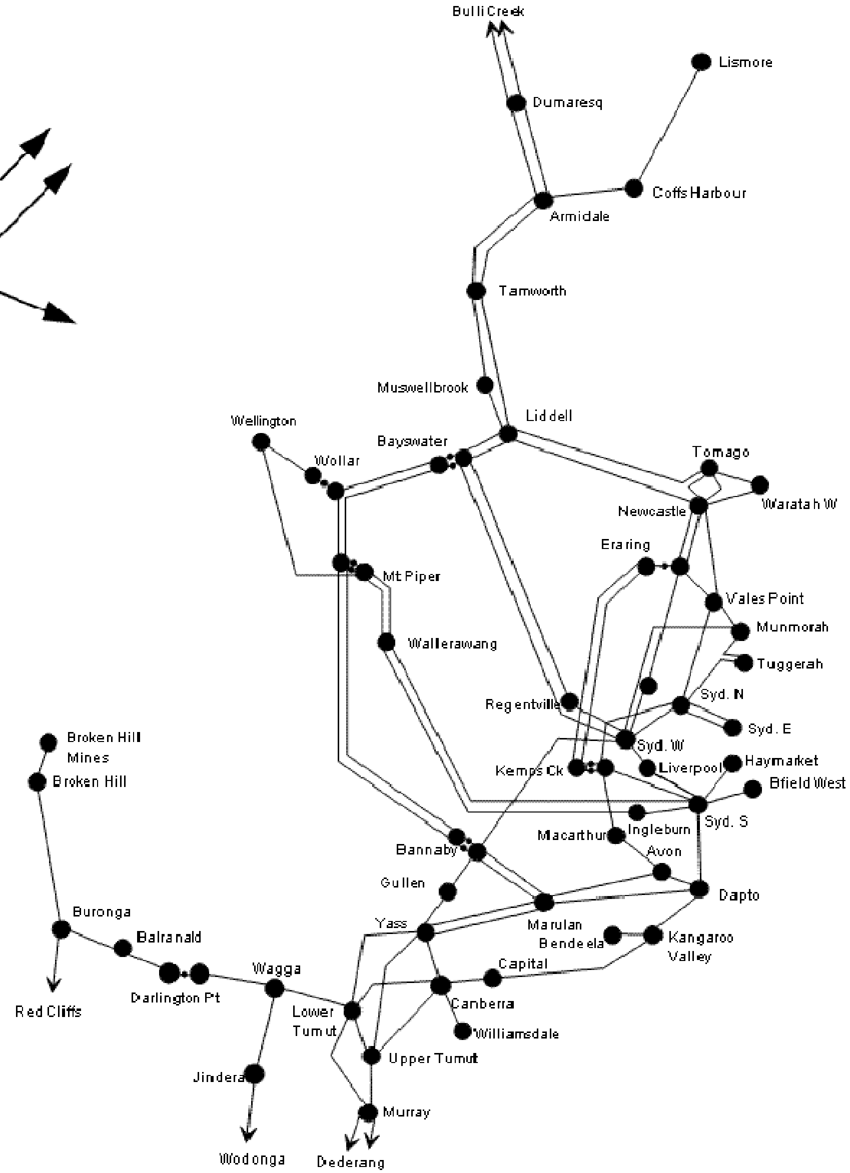




- Transformer ratings
  - Short-time transformer ratings avoid market constraints during double circuit outages.
  - Constraints can be applied as a post-contingent measure

Transformer Short-Time Ratings

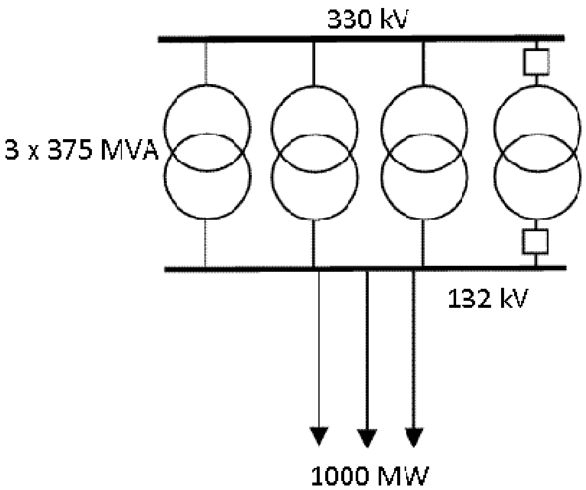




- Transformer ratings
  - Short-time transformer ratings avoid market constraints when double circuit faults are considered credible.
  - Constraints can be applied as a post-contingent measure

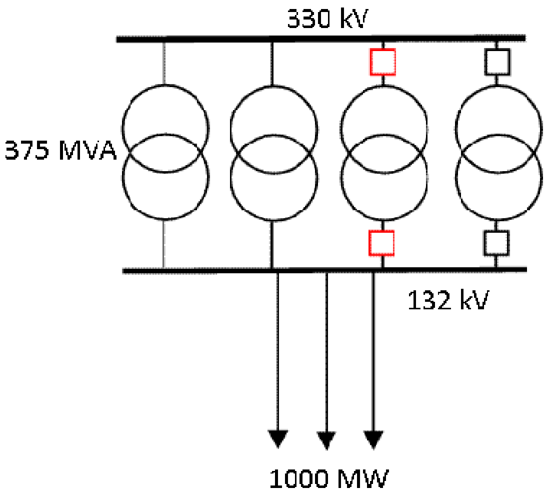
Transformer Thermal Inertia

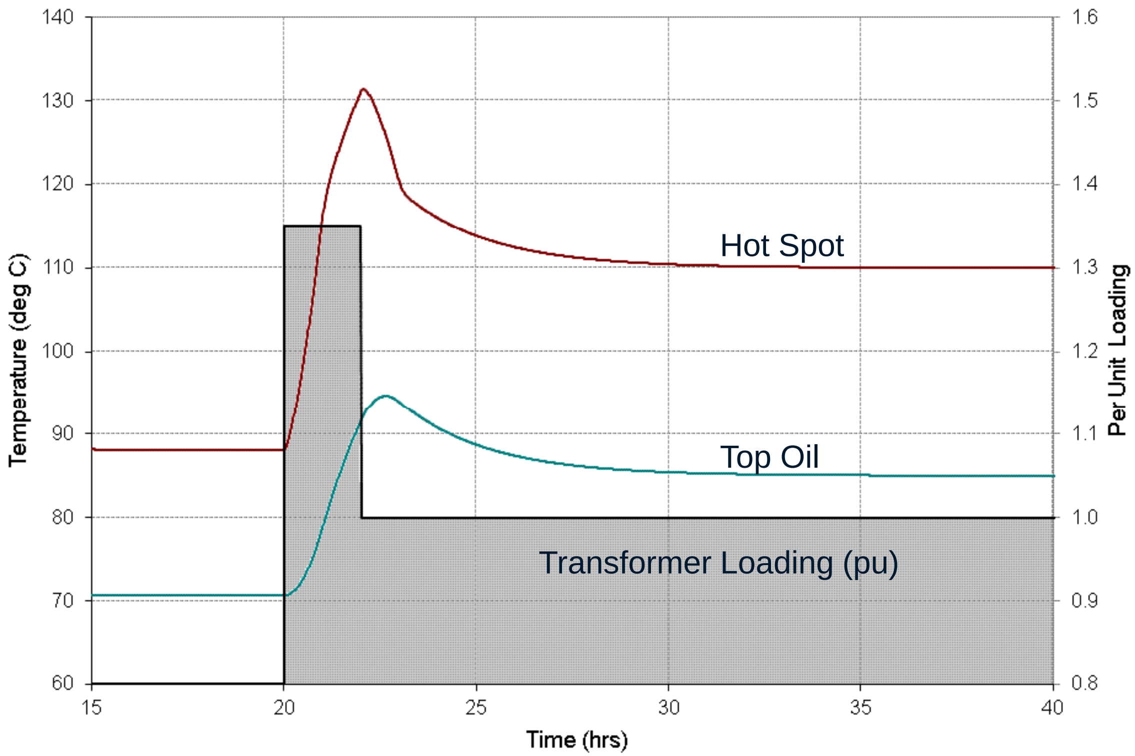
- Transformer thermal inertia
  - Is quite large and constant
  - The effective time constants depend on how quickly heat is removed from the transformer
- Consider a Bulk Supply Point:
  - Four 375 MVA transformers
  - A planned or forced outage of one transformer
  - Substation loading of 1000 MW



Transformer Thermal Inertia

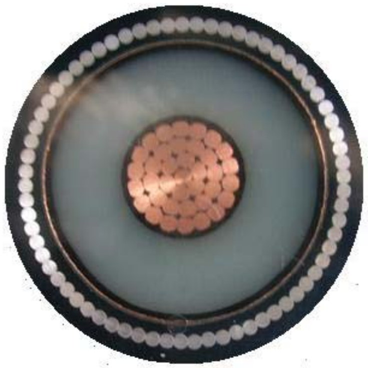
- A Transformer Trip
  - The next credible contingency
  - Transformers at 133% of rating
  - Adequate time to transfer load

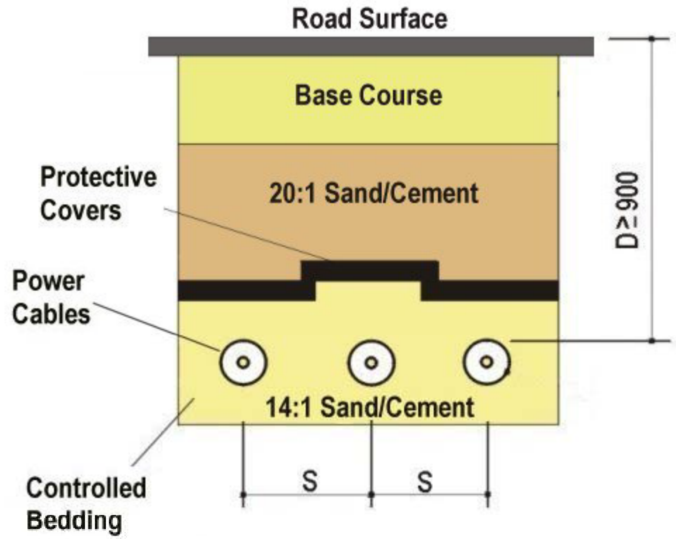


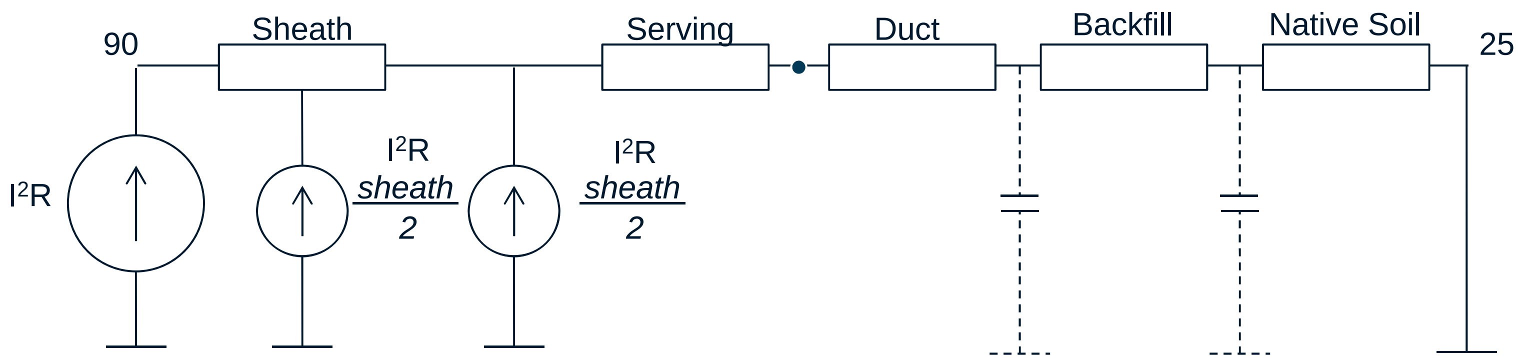


Cable Thermal Inertia

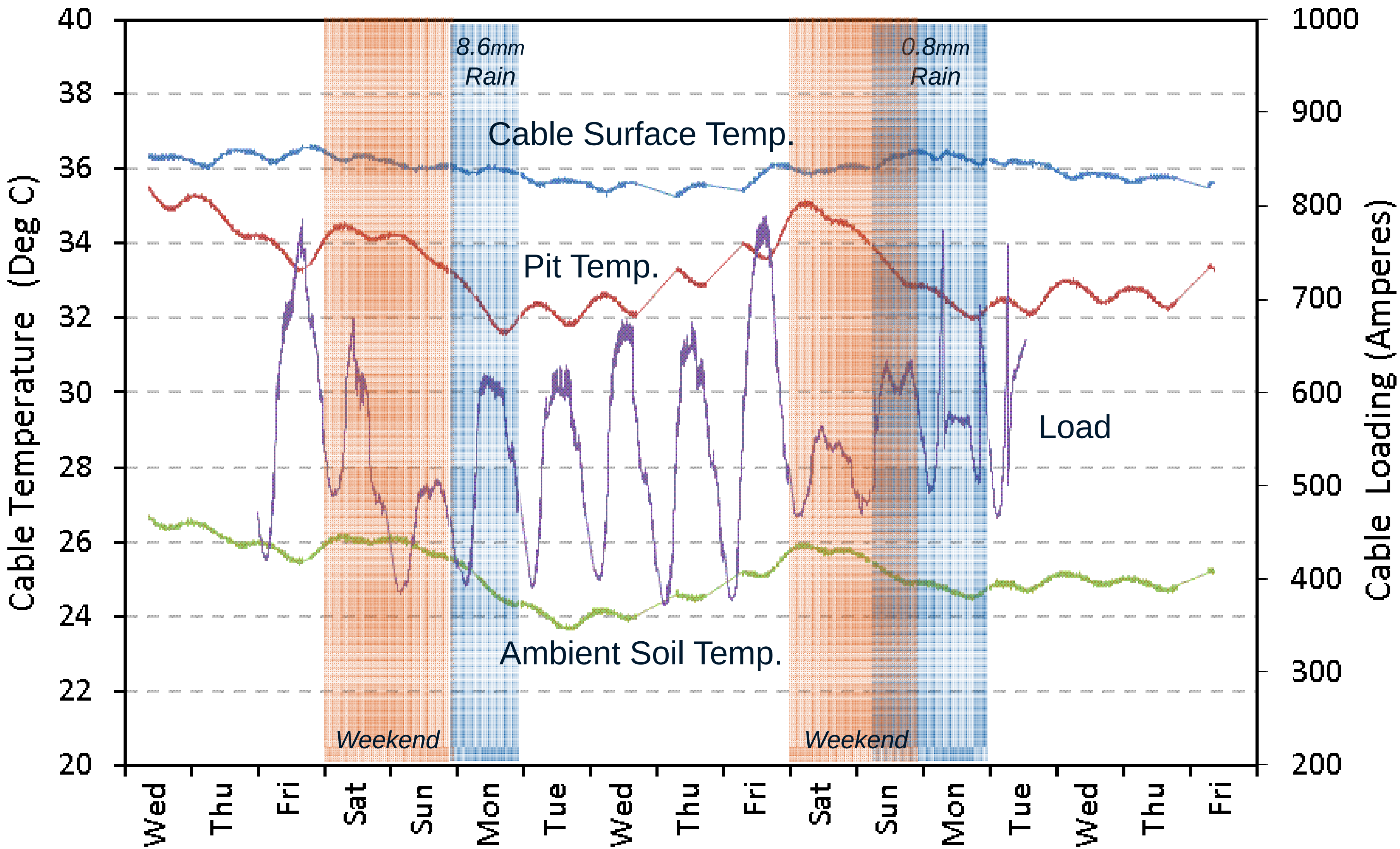
- Electrical Analogue
  - Heat sources are current sources (IEC 60287)
  - Voltages correspond with temperatures
  - Higher T_R exists outside the trench



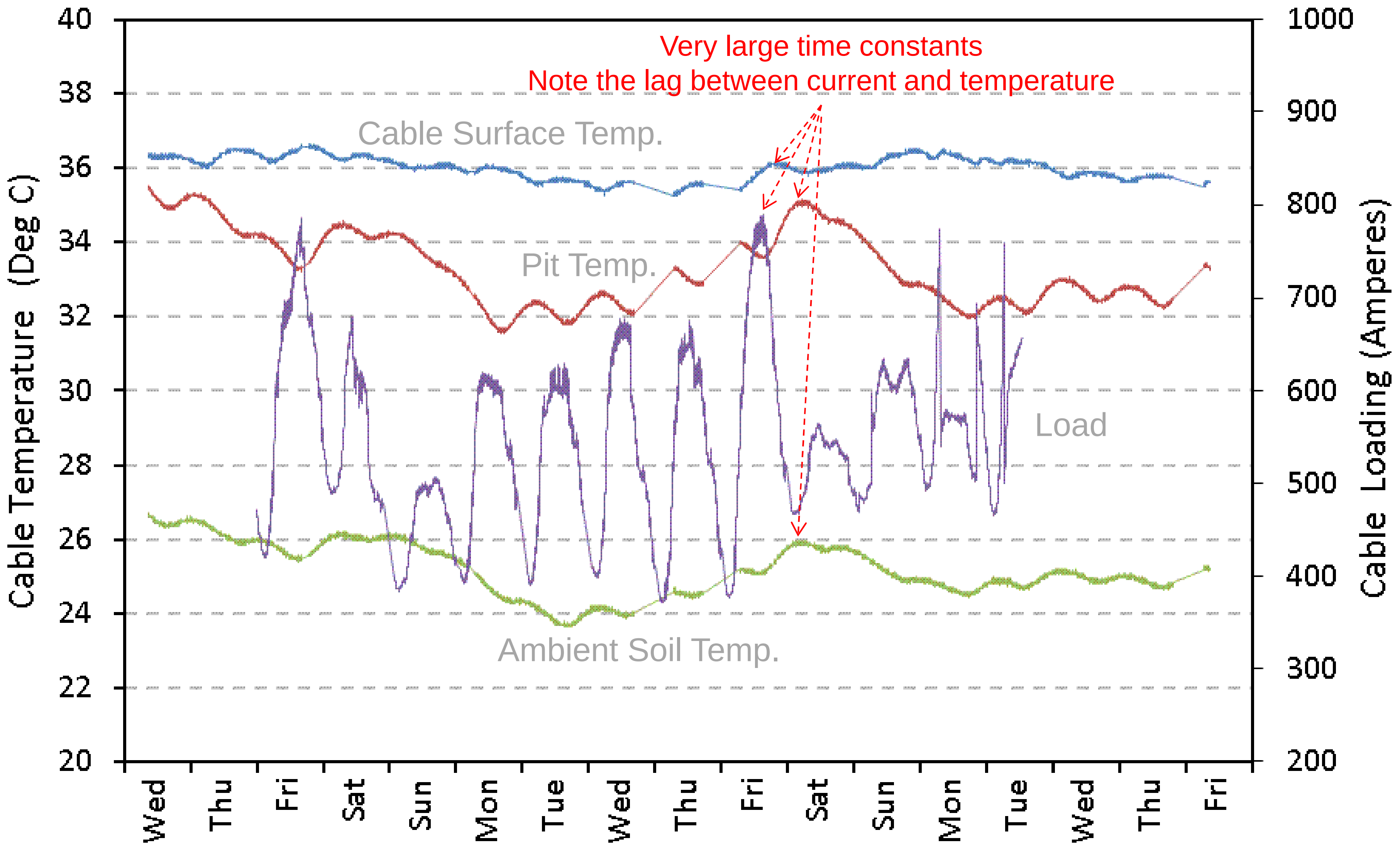




Cable Thermal Inertia

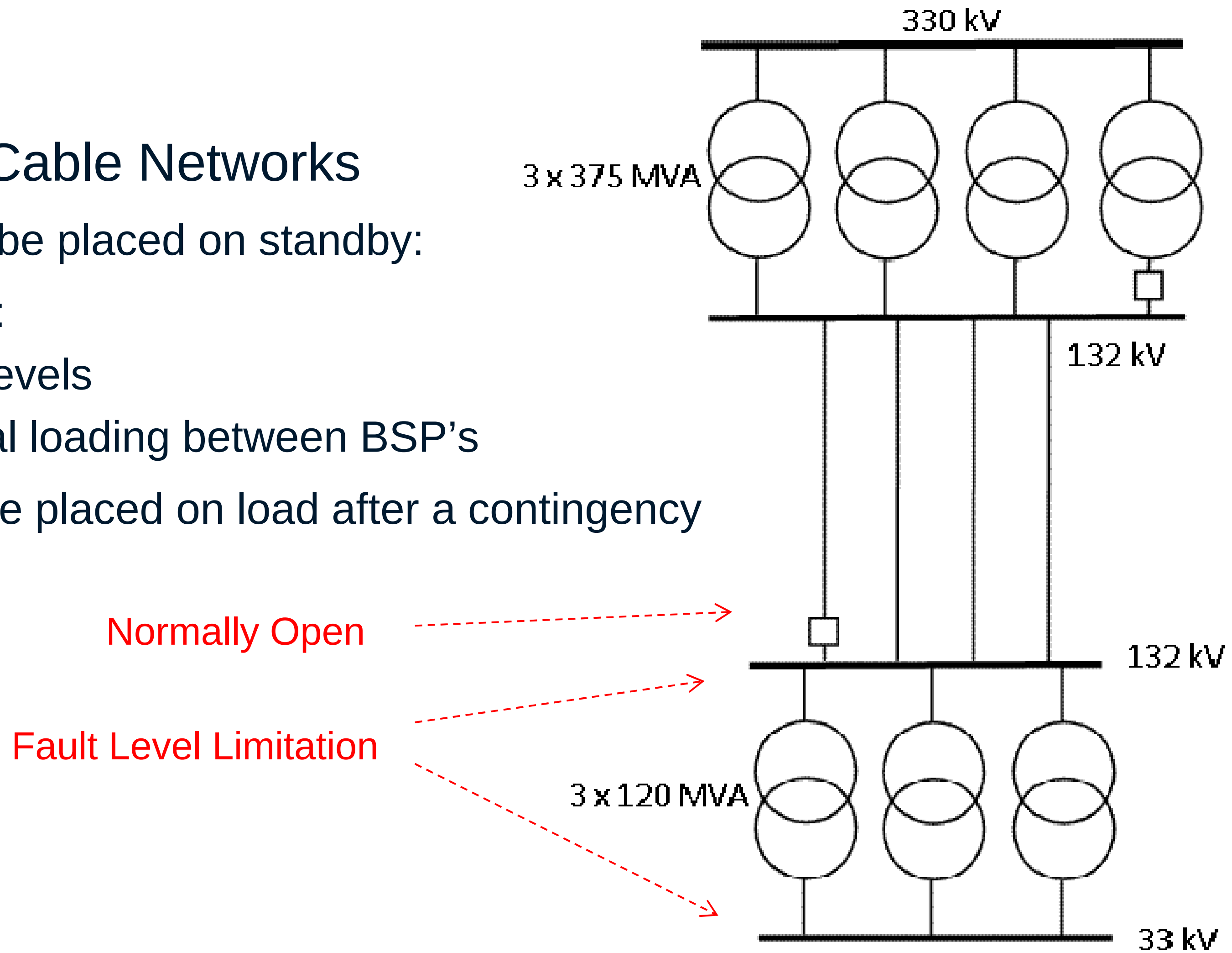


Cable Thermal Inertia



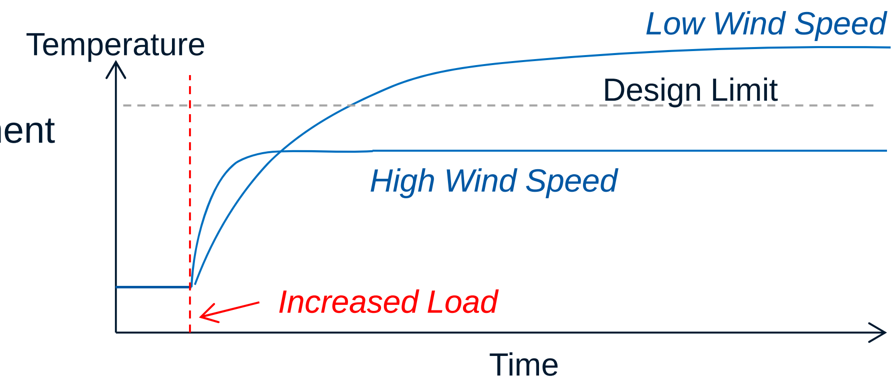
Cable Thermal Inertia

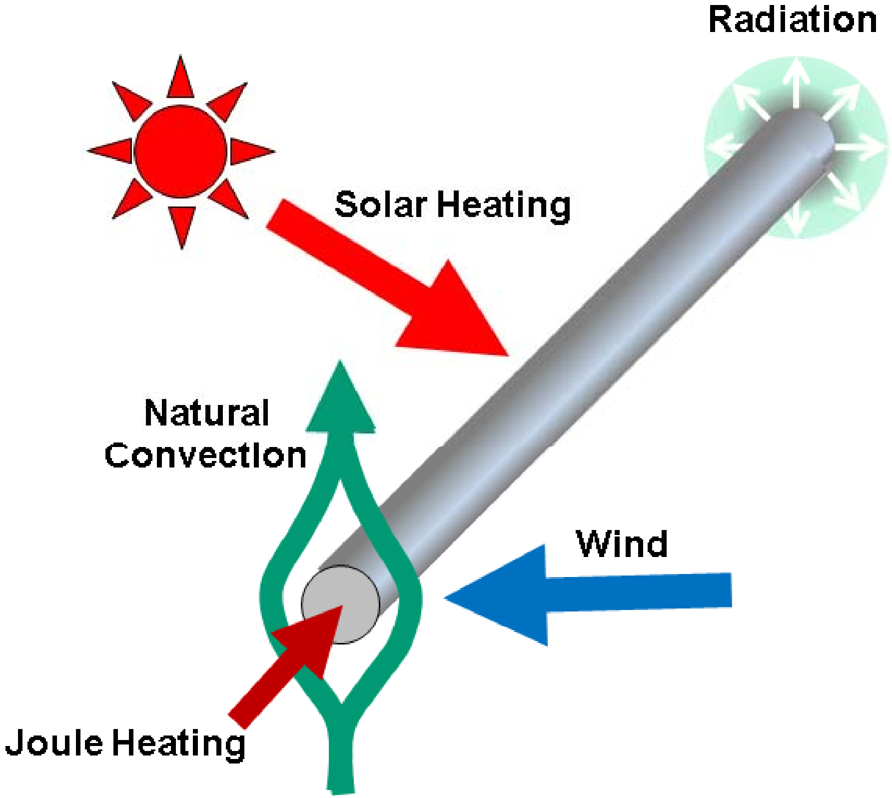
- Operation of Cable Networks
  - Cables can be placed on standby:
  - Assists with:
    - Fault Levels
    - Thermal loading between BSP's
  - Cable can be placed on load after a contingency

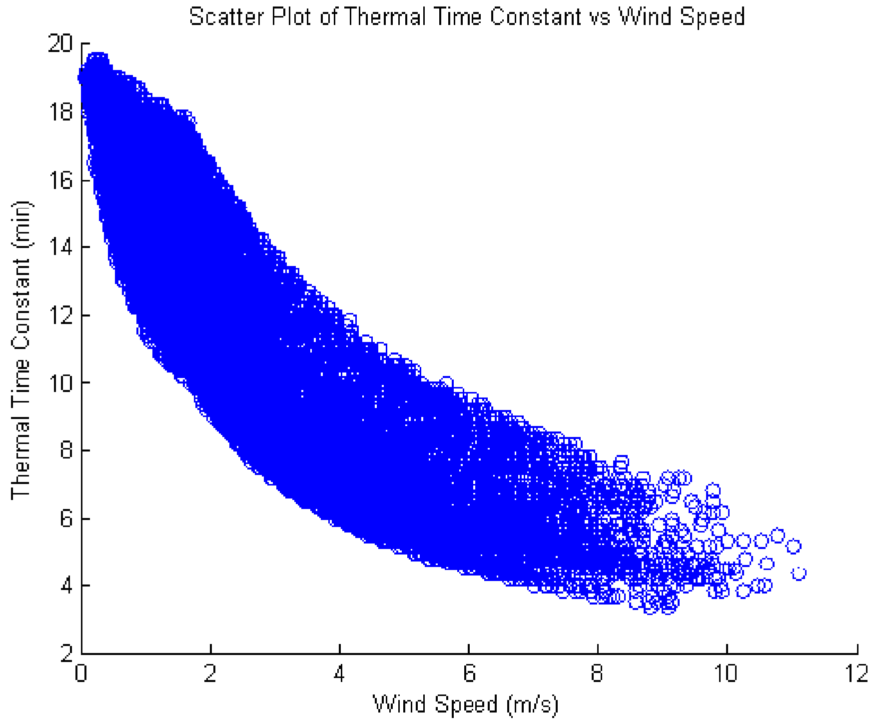


Transmission Line Thermal Inertia

- Overhead Transmission Lines
  - Temperature is dependent on the environment
  - Thermal inertia is constant
  - Thermal time constant varies
    (primarily with cooling efficiency)

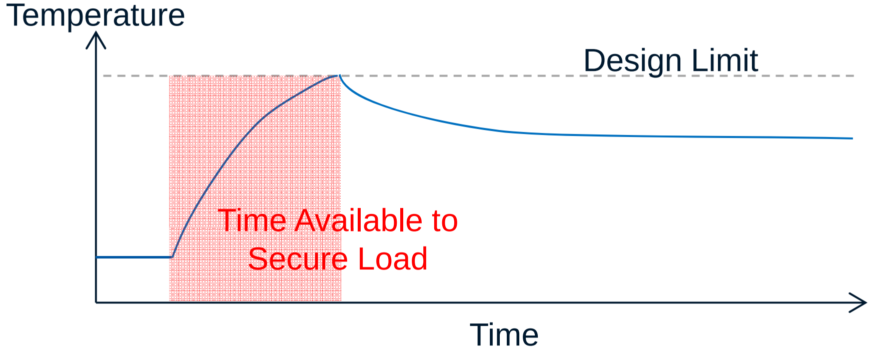


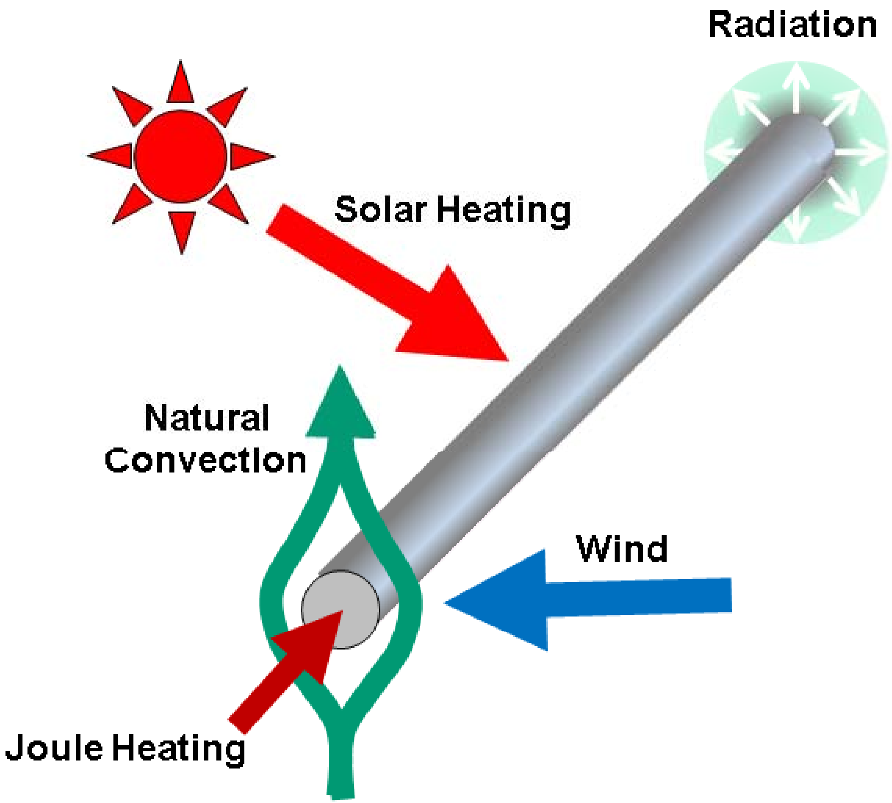


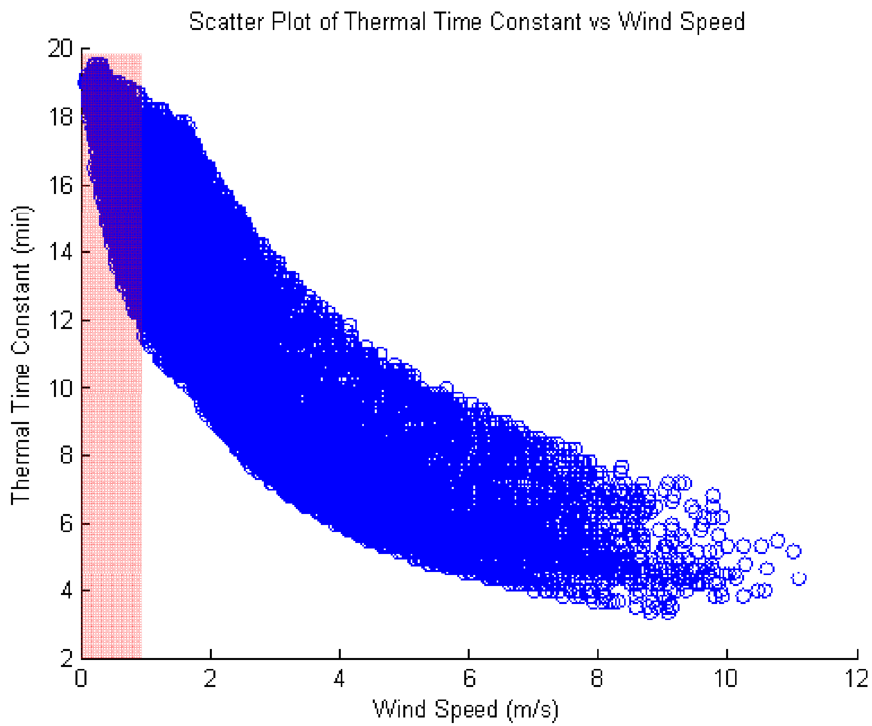


Transmission Line Thermal Inertia

- Overhead Transmission Lines
  - We are interested in low ratings
  - This corresponds with low wind speeds
  - Relatively Large Thermal Time Constants





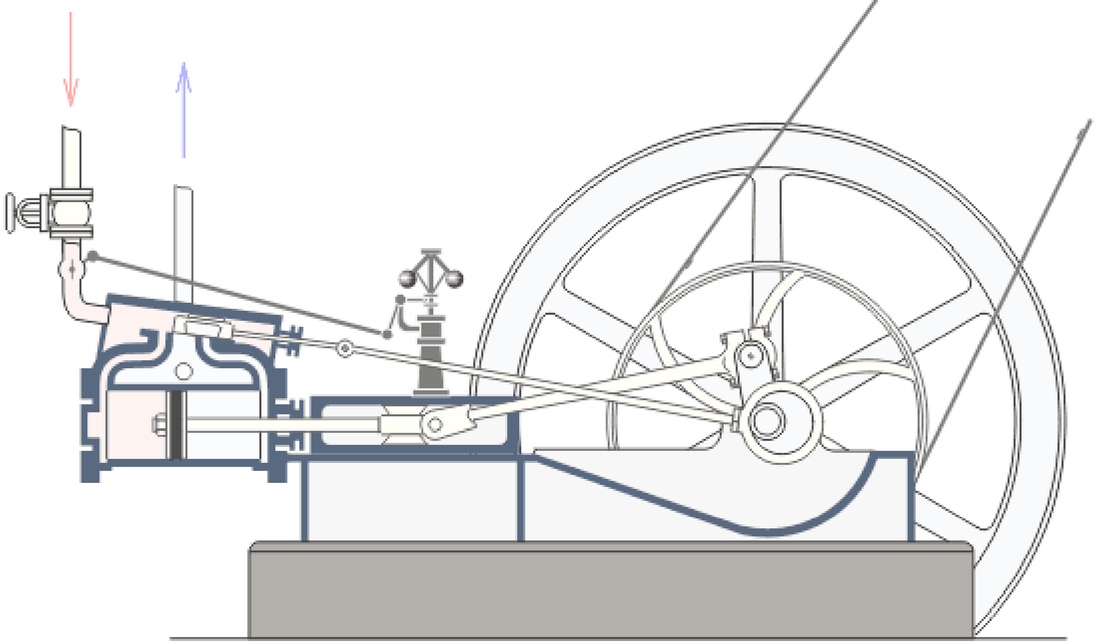


Transmission Line Thermal Inertia

- Wind Speed Variability
  - A simply conductor analogy is an old steam engine:
  - The engine transfers power once (or twice) a cycle – with each stroke
  - The machine can maintain a constant angular speed if the inertia is high
  - Variations in mechanical load do not significantly affect the angular speed

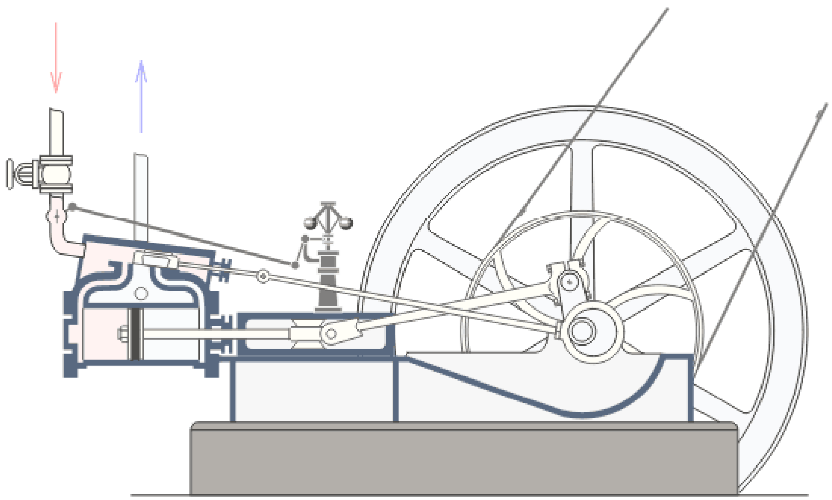
Mechanical Load is analogous with the Wind Speed

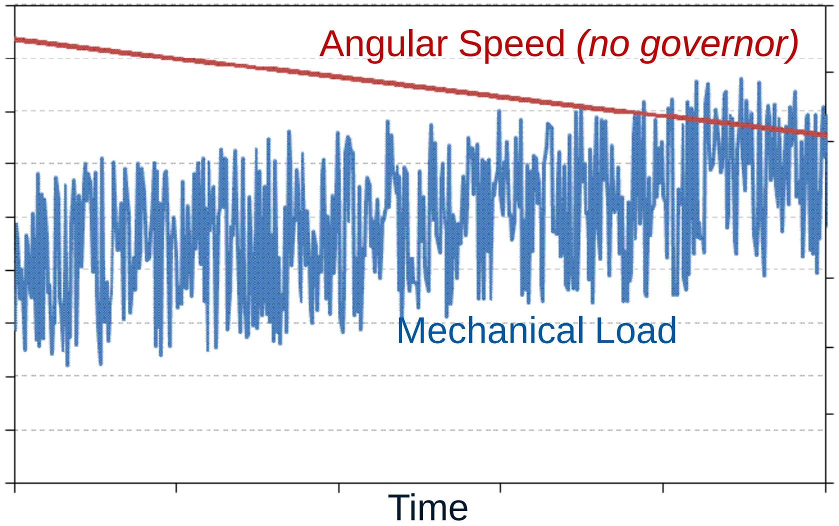
Conductor Temperature is analogous with Angular Speed

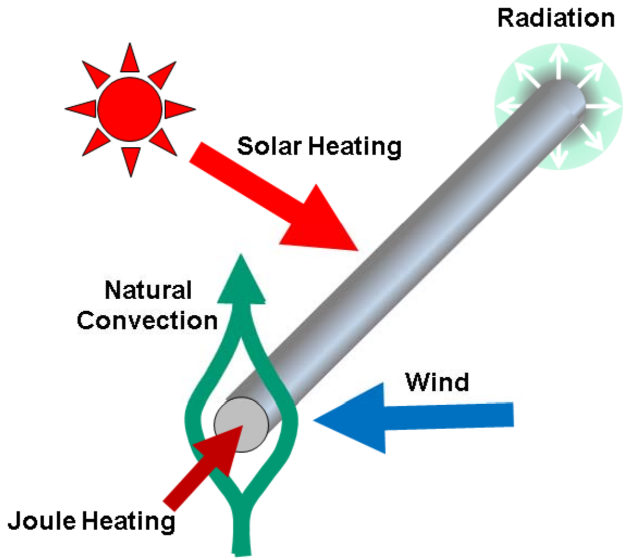


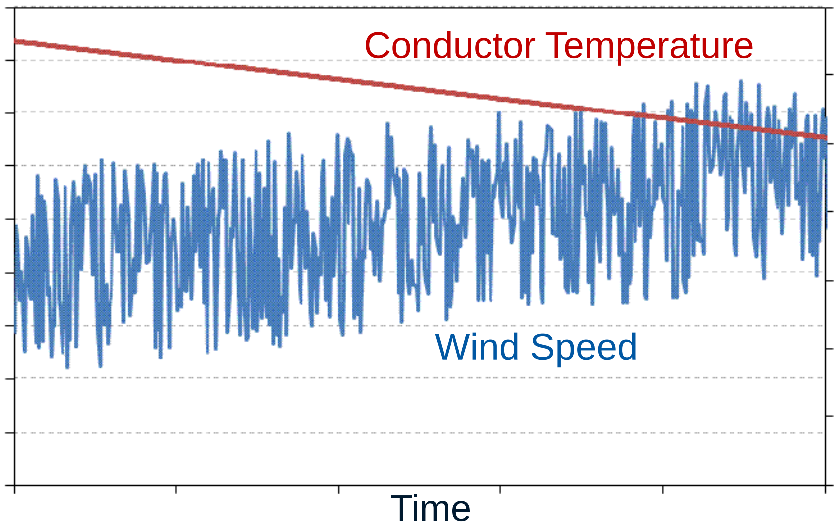
http://mi.eng.cam.ac.uk/IALego/steam.html

Transmission Line Thermal Inertia



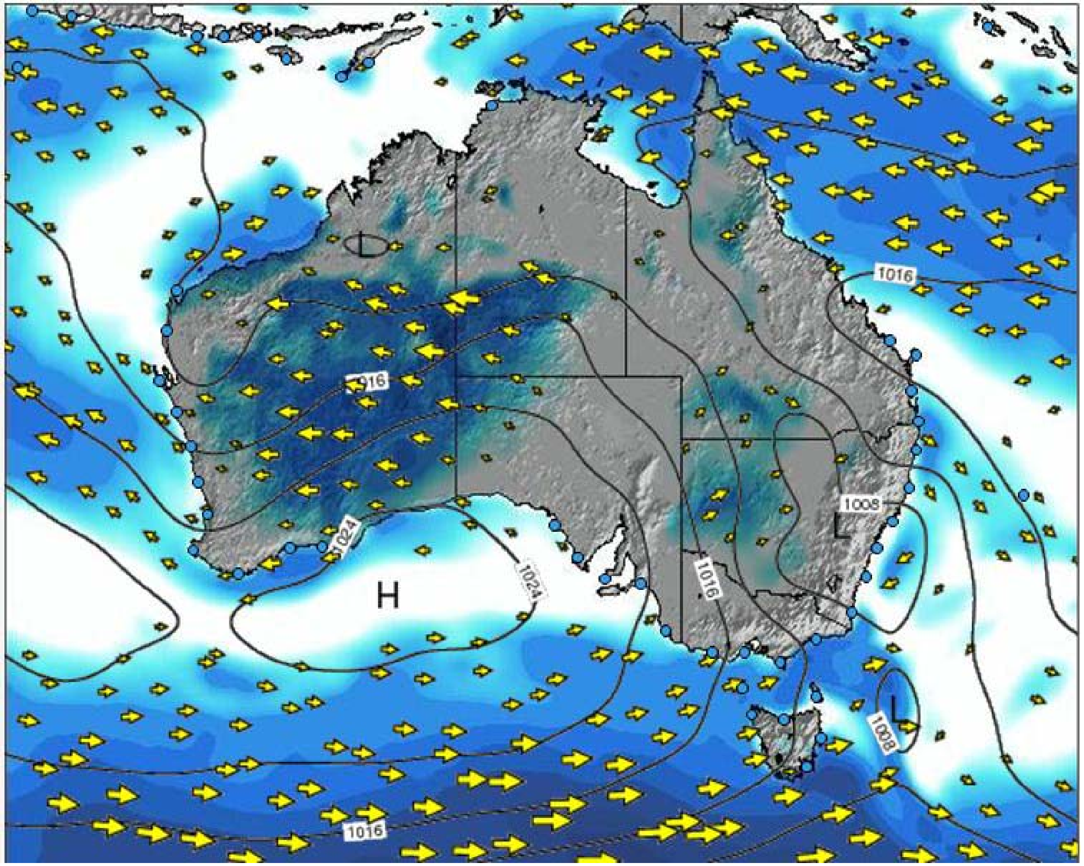






Transmission Line Thermal Inertia

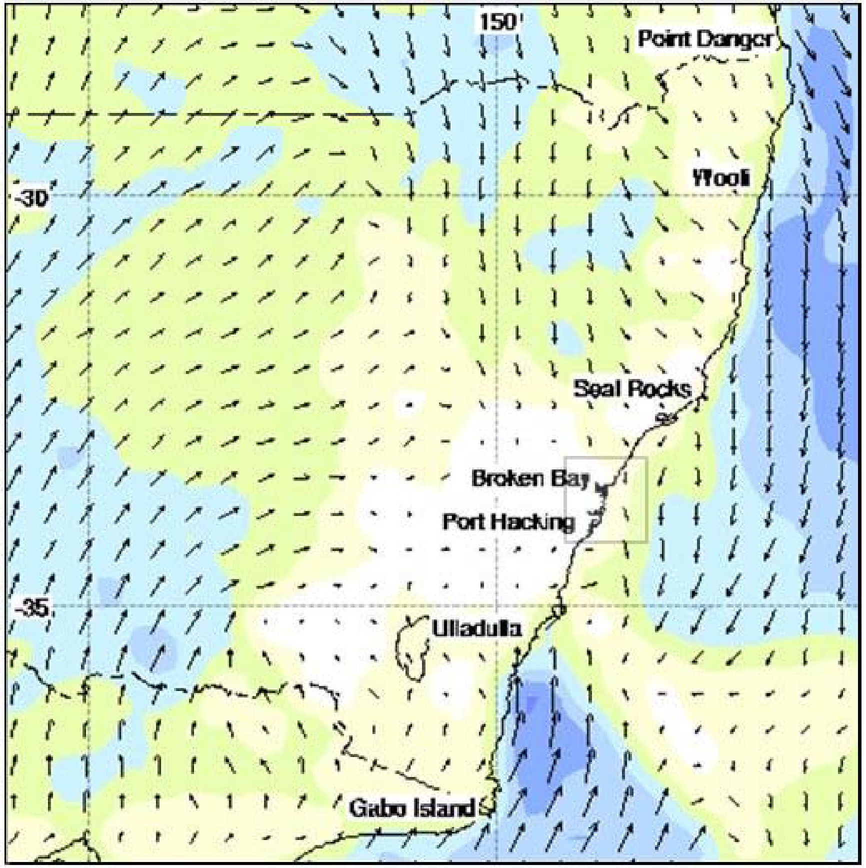
- Wind Speed Variability
  - Wind speed is not uniform
  - High variability in magnitude and direction



http://www.surf-forecast.com/weather_maps/Australia

Transmission Line Thermal Inertia

- Wind Speed Variability
  - Thermal inertia of the conductor smooths these variations
  - It is sometimes possible to apply single measurements over a large geographic area
  - Many references refer to a 30km range over uniform terrain



http://www.bom.gov.au/marine

Transmission Line Thermal Inertia

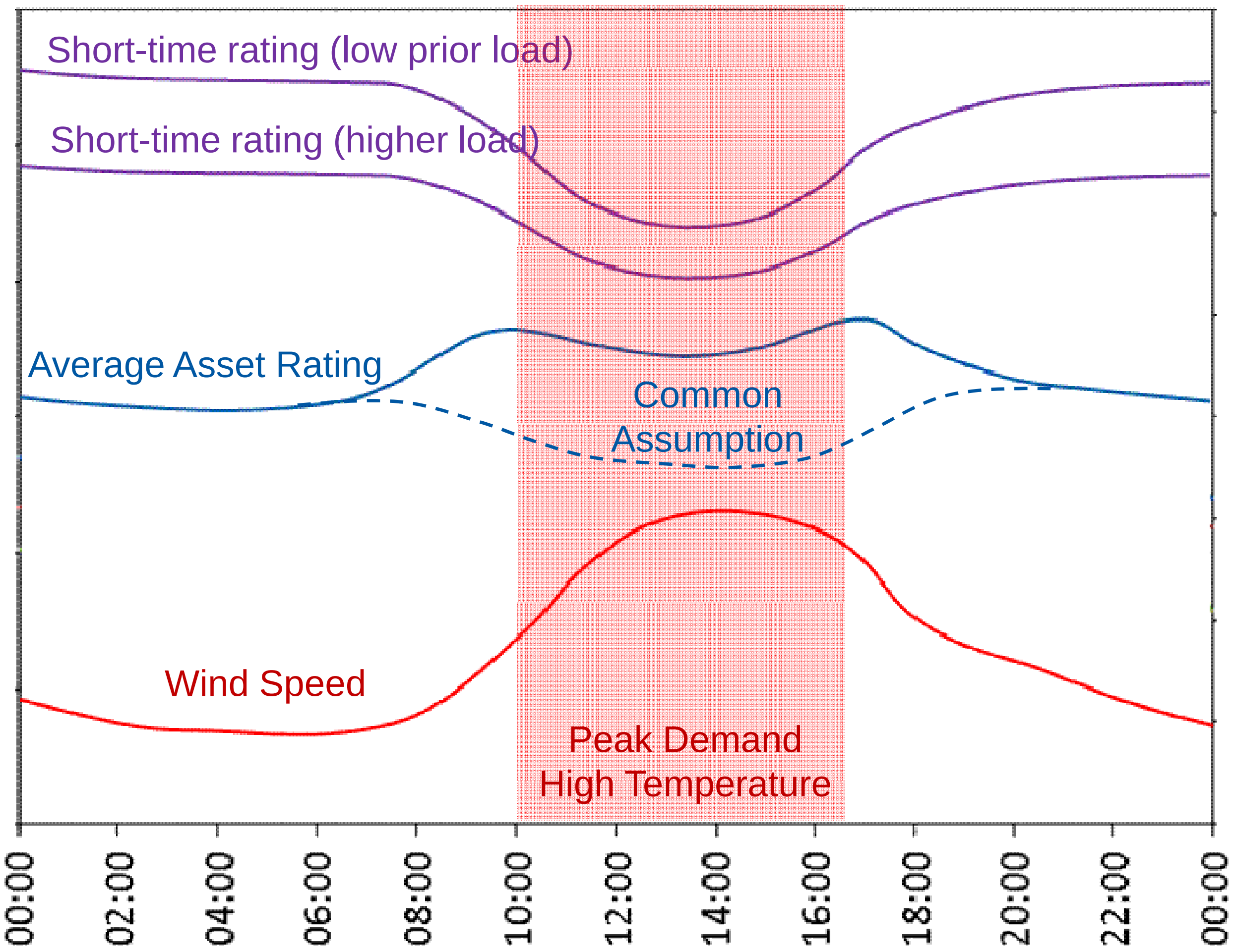
- Wind Speed Measurements
  - Taken at conductor elevations
  - Hardware installed in accessible and locations for maintenance

Transmission Line Thermal Inertia

- Wind Speed Measurements
  - Taken at conductor elevations
  - Hardware installed in accessible and locations for maintenance

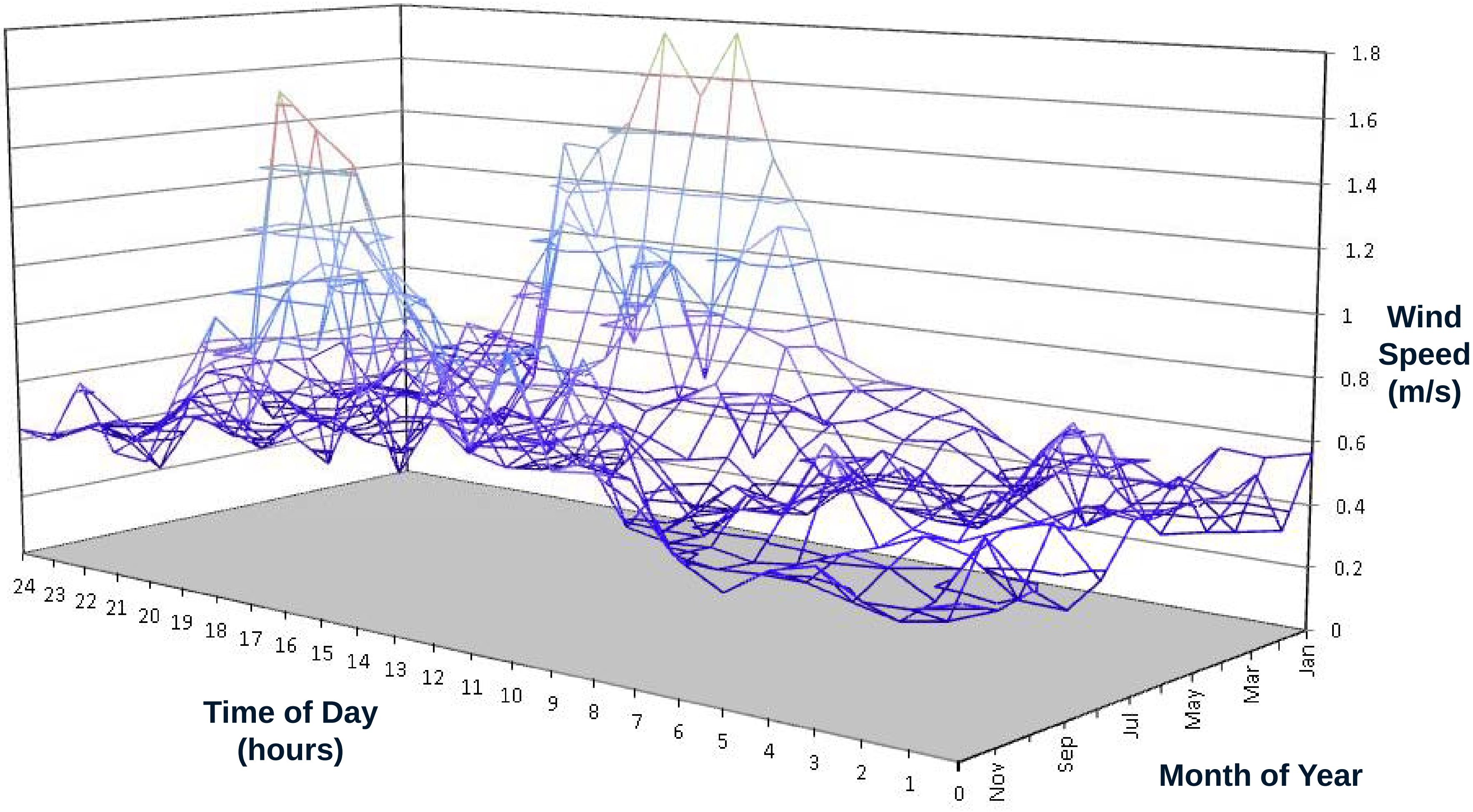
Transmission Line Thermal Inertia

- Use of Short-Time Ratings
  - Can provide the most benefit during low or moderate wind speeds



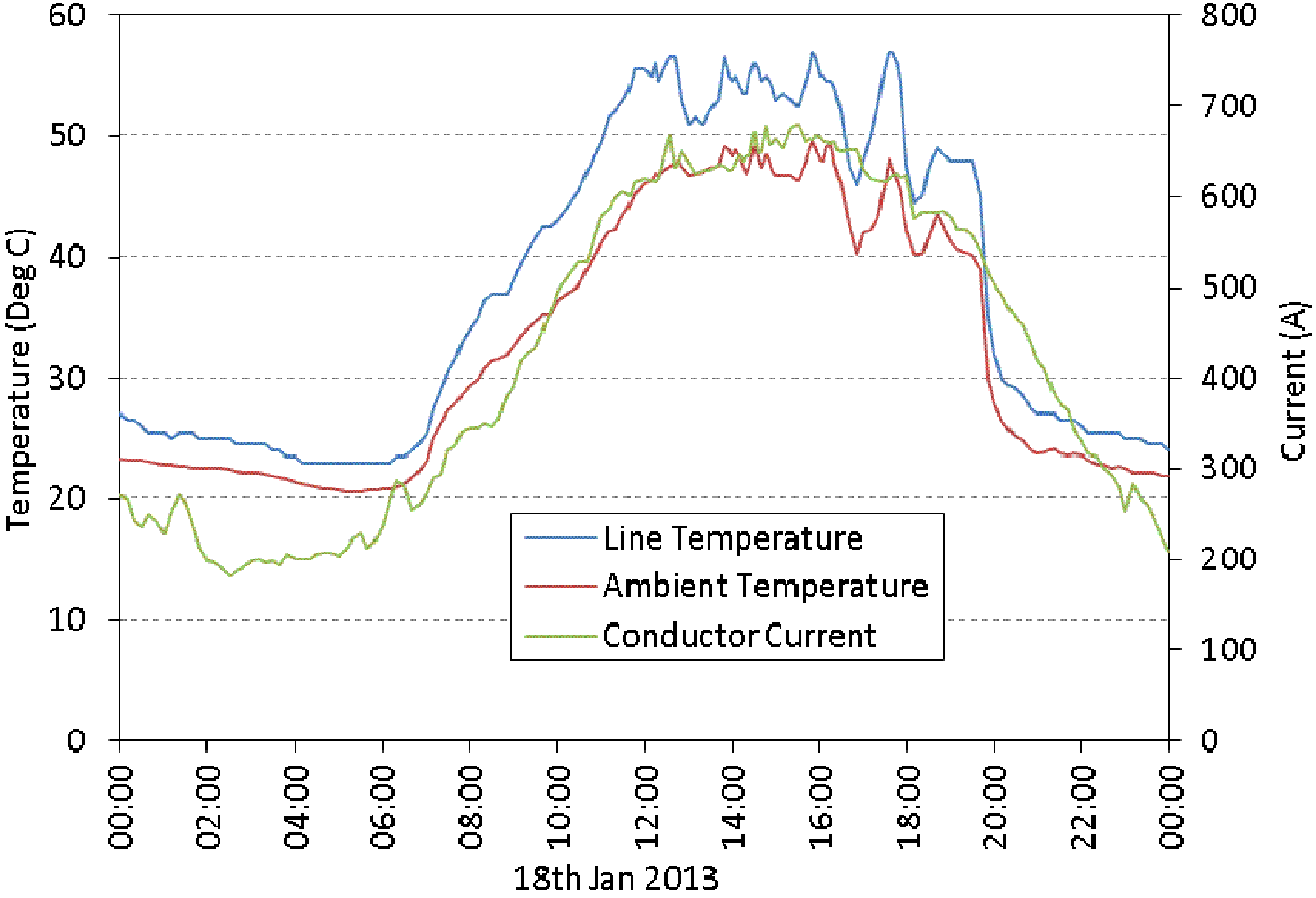
Transmission Line Thermal Inertia

- Four Year Minimum Effective Wind Speeds
  - Good short-time ratings are available



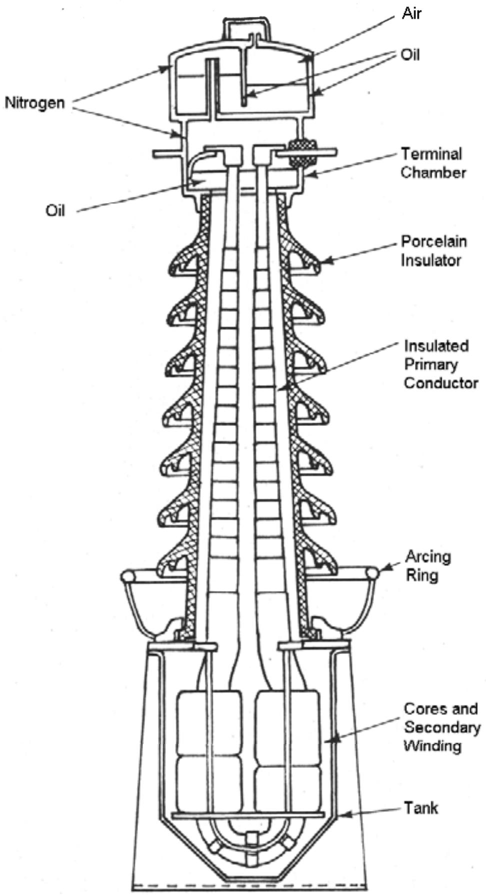
Transmission Line Thermal Inertia

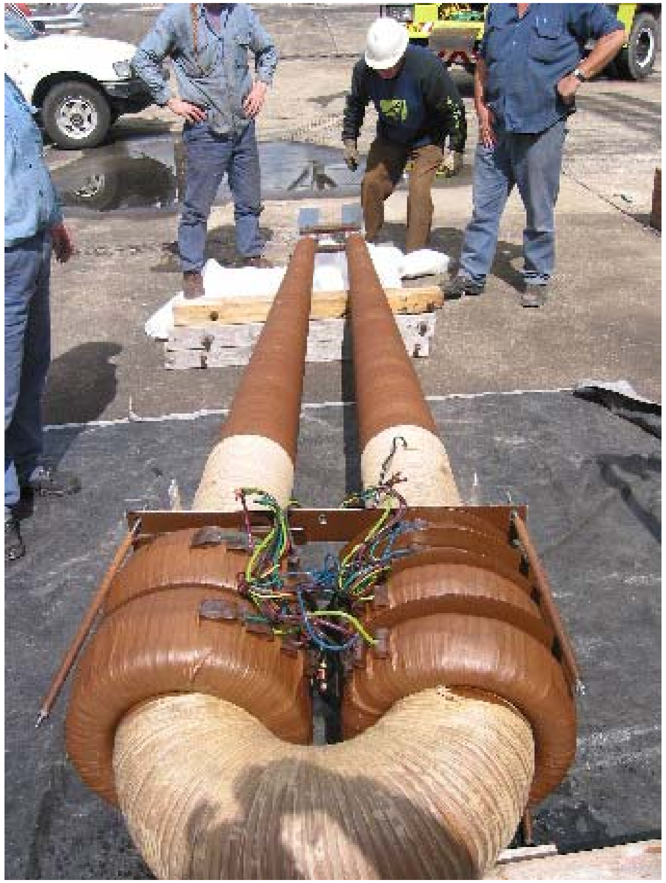
- High Ambient Temperatures
  - Good wind speeds during periods of high demand
  - Conductor temperatures are close to ambient conditions prior to a contingency

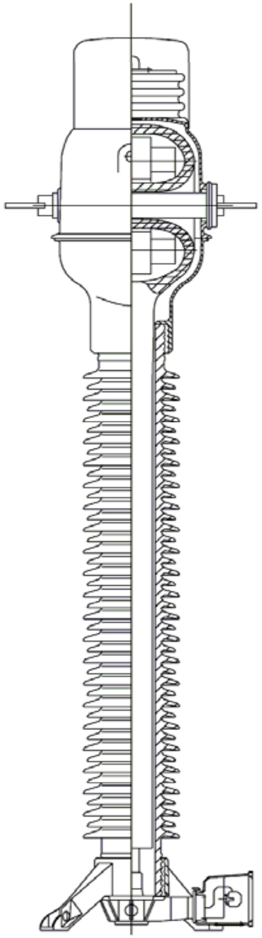


Secondary Equipment

- Current Transformers
  - Usually have a primary rating of between 500 - 3000 A
  - Often have a thermal rating of 2 A in the secondary windings

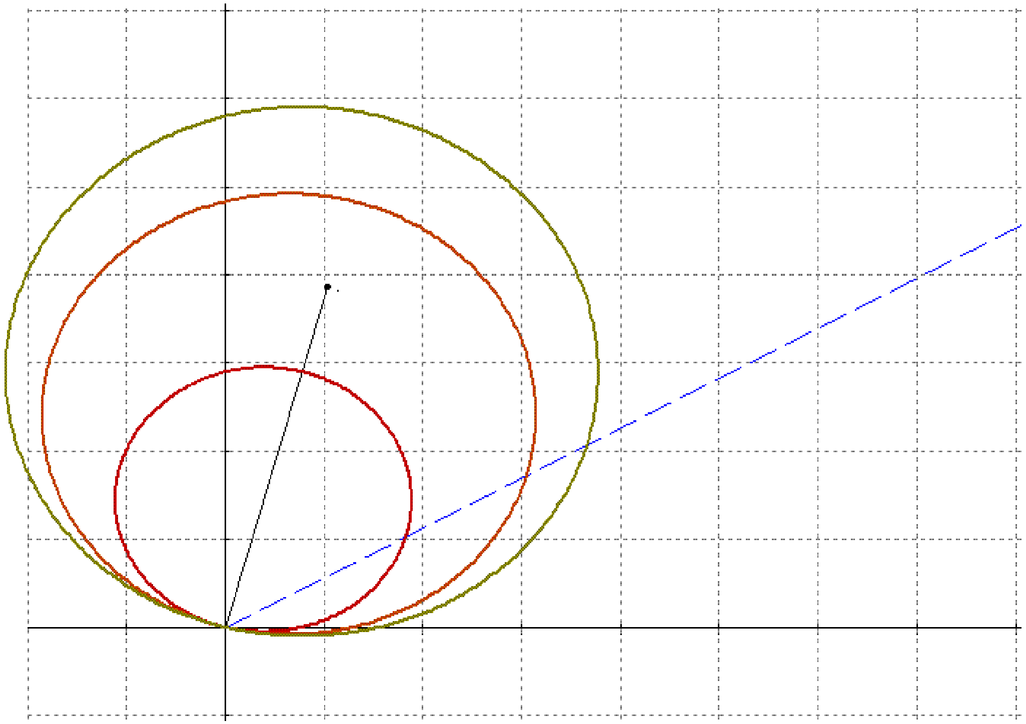






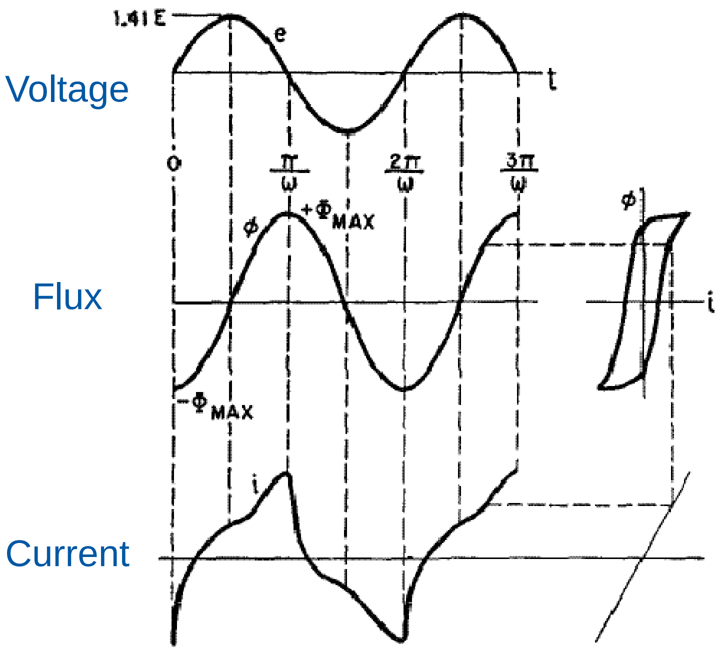
Secondary Equipment

- Protection Circuits
  - The thermal rating of protection relays is rarely a limitation
  - Protection secondary limit is normally 2A.
  - Limits associated with distance relays:
    - Zone 3 limits can be alleviated by <u>changing relay type or relay angle</u>
    - Thermal limits can be resolved using <u>interposing transformers</u>



Metering Circuits

- Revenue Metering
  - The normal rating is often 1.2A
  - Contingency rating is 2A
  - This assumes that a small loss of accuracy can be accepted in an emergency
  - backup metering used to correct errors
- Indication Metering
  - The normal rating is often taken as 1.25A
  - A contingency rating of 2A can be used if indication is available elsewhere



Secondary Equipment

- Indication Transducers
  - The normal rating is often taken as 1.25A
  - The 1.25 factor is also to avoid CT saturation leading to high harmonic distortion.
  - This ensures that correct indication is available for operator action in an emergency.
  - A contingency rating of 2A can be used <u>if indication is available elsewhere</u>

Conclusion

- Careful application of short-time ratings can defer expenditure
- Many thermal ratings are based on conservative parameters
- A detailed review of these parameters can increase utilisation

Useful References:

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- Tech Report 207 “Thermal Behaviour of Overhead Conductors” CIGRE WG 22.12, Aug 2002
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- IEC60943 “Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals” Edition 2.1, March 2009
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- Cigre Brochure 006 – “The Mechanical Effects of Short Circuit Currents in Open Air Substations.” 1987.
- ENA EG(0) Power Systems Earthing Guide – Part 1 Management Principles, February 2010.

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- G. J. Anders – Probability Concepts in Electric Power Systems. Wiley. 1990. ISBN: 0-471-50229-4.

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Questions?