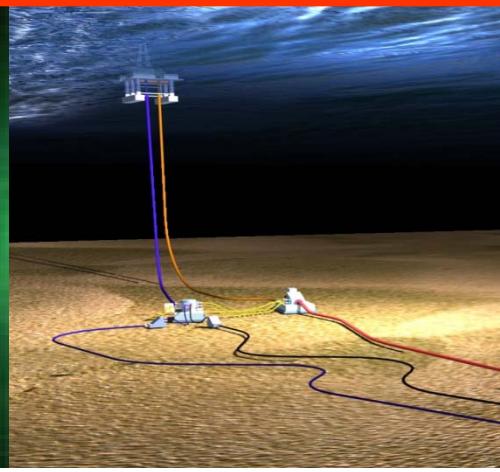
POWER



CABLE MONITORING SOLUTION

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8 - 9 November 2011

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PREDICT WITH CERTAINTY

CLOSE THE
MONITORING GAP

Definition

- DTS: Distributed Temperature Sensor
- DCR: Dynamic Cable Ratings

Contents

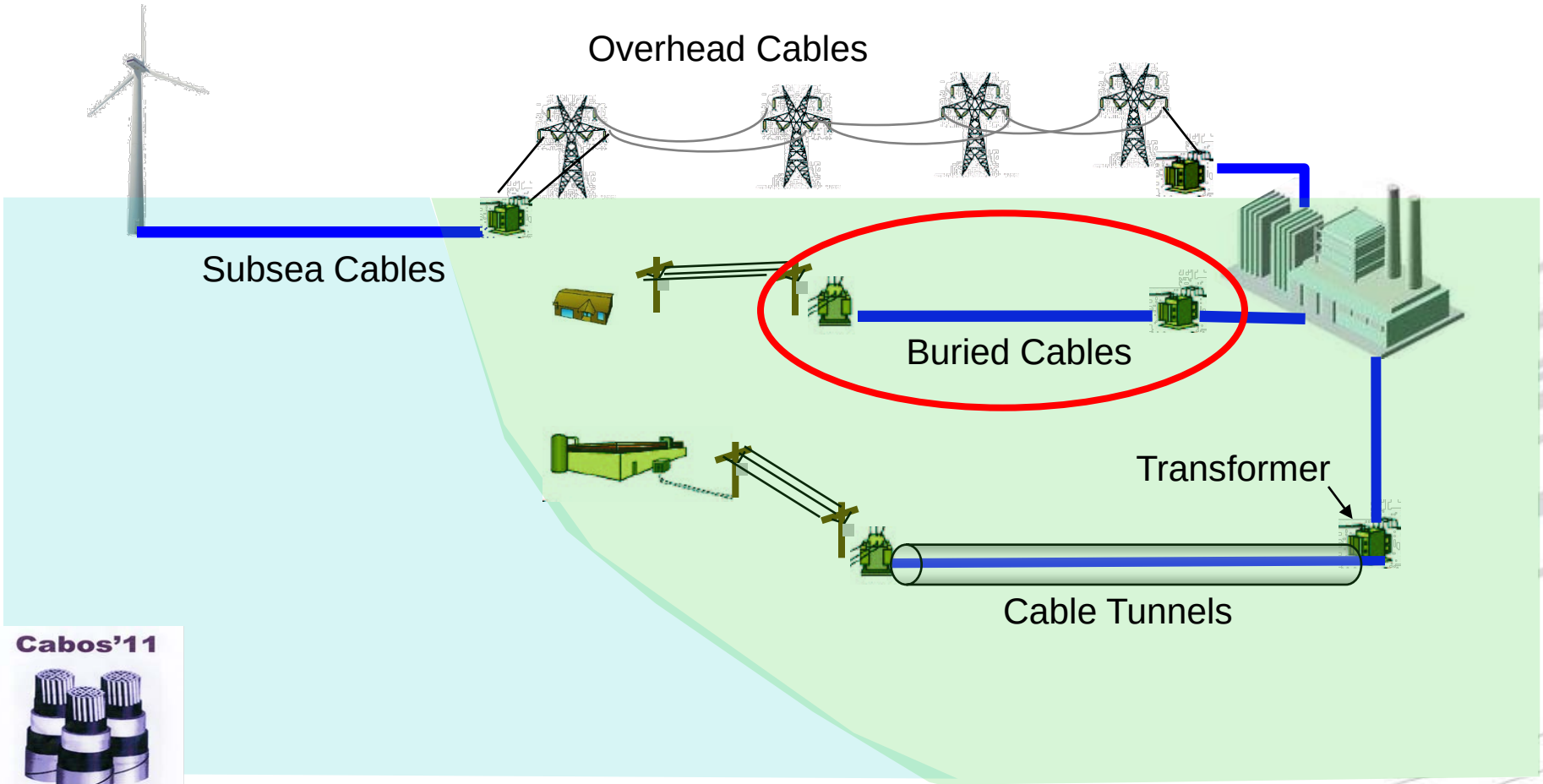
- Issues for Buried Underground Cables
- Technology Principles and cable thermal models
- Case Study
- Further applications
- Speed of real time measurements
- Sensornet Product Range
- Summary

To prevent failures like these

- New York 2003:
  - Current heated up cable, metal cores expand. Line too hot, sagged and short-circuited after hitting tree
- New Zealand 1998:
  - Thermal overheating due to dry summer caused 4 power cables to central business district to fail
    - Power outages for 5 months
    - More than $200m of damage & lost revenues
- UK 1962:

Cable failure in the UK on the Belvedere Sydenham circuit in the Summer due to soil dry out

Power Applications



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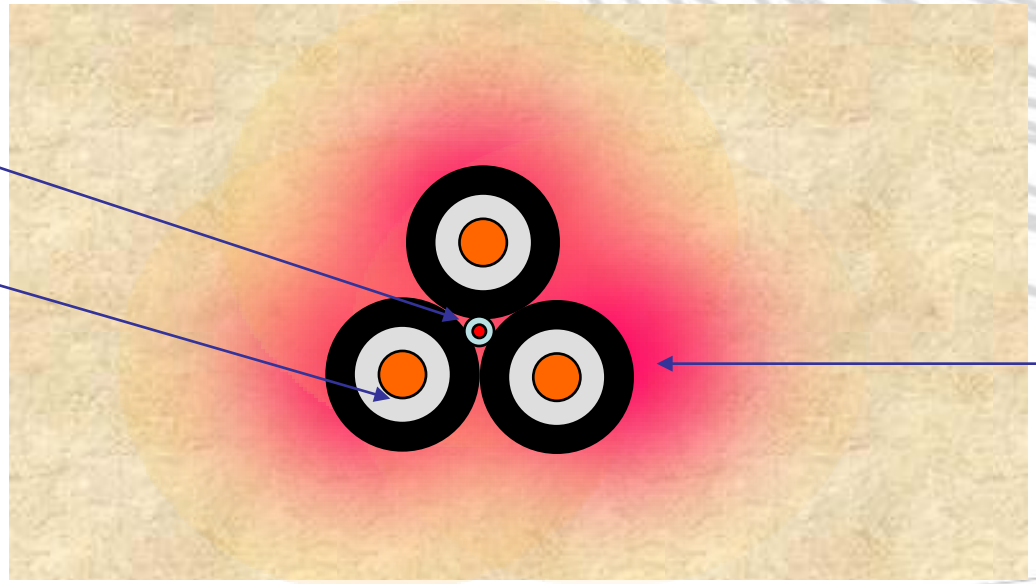
Buried Power Cable

- Cables are rated to thermal calculations based on:
  - Load on cable
  - Thermodynamic properties of cable
  - Thermal Dissipation of Surrounding Environment



Buried Power Cable

- Factors which can lead to lower heat dissipation and cause cable over heating
  - Unknown/changing soil thermal resistivity
  - Dry Weather conditions
  - Surface effects
    - Shallow road crossings
    - Microbes in soil (caused by decomposition)
  - Nearby cables & pipelines
  - Faults in cables/connectors

DTS removes uncertainty & improves safety

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OTDR – Optical Time Domain Reflectometry

Simplicity of measurement – similar to time of flight principle used for RADAR

Standard multi-mode optical fibre

T_1 T_2 T_3 T_4 .....

Backscattered light provides measurement point every 1m

1m pulse of light

$T_{9,995}$ $T_{9,996}$ $T_{9,997}$ $T_{9,998}$ $T_{9,999}$

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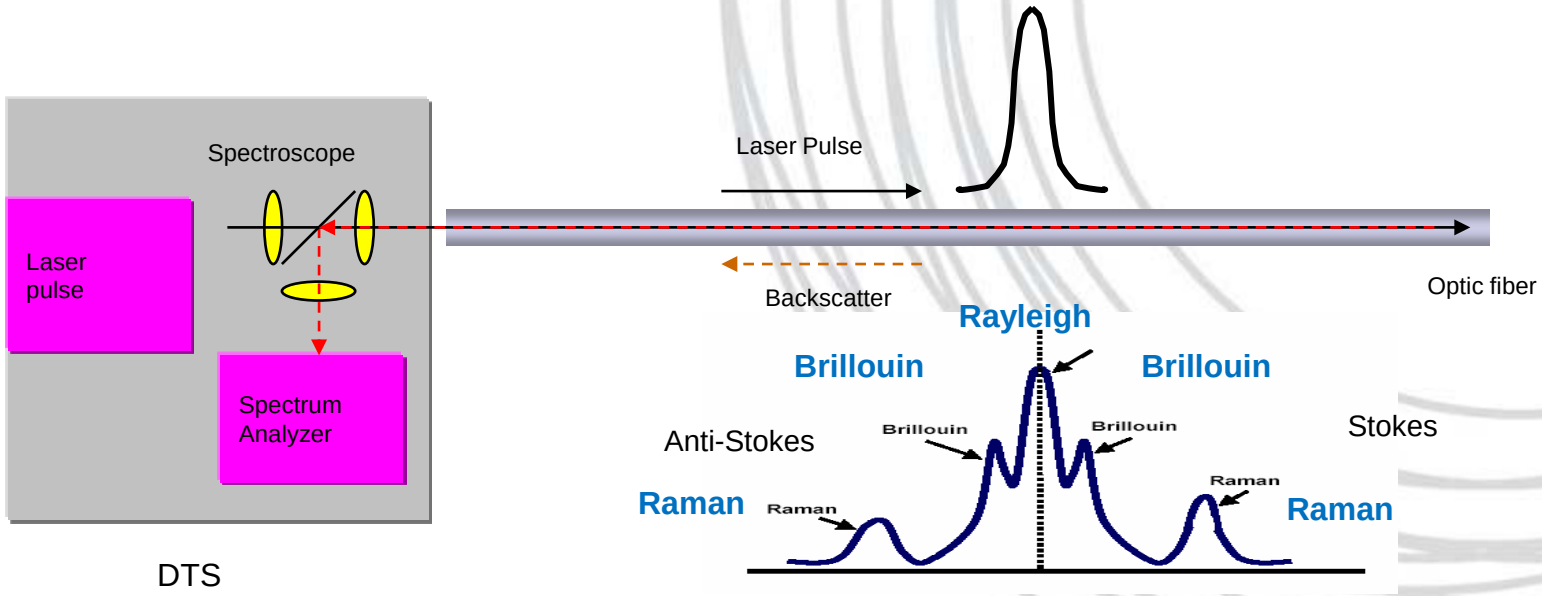
The Technology Principles



- **DTS instruments measure the change in reflected light against time.**
- **Nature of optical reflections change with temperature, strain and pressure**
- **Measure all points along a fibre - distributed.**

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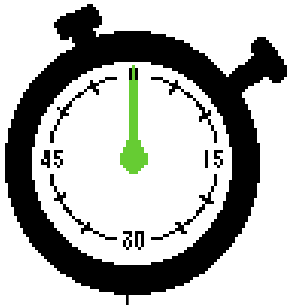
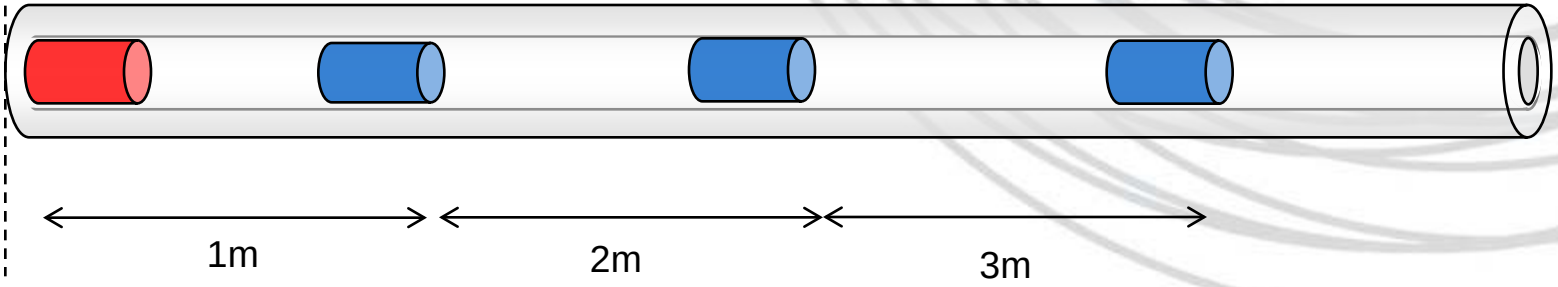
OTDR - Optical Time Domain Reflectometry



Simple principle – similar to time of flight (Radar)



3/100,000 seconds = 3m

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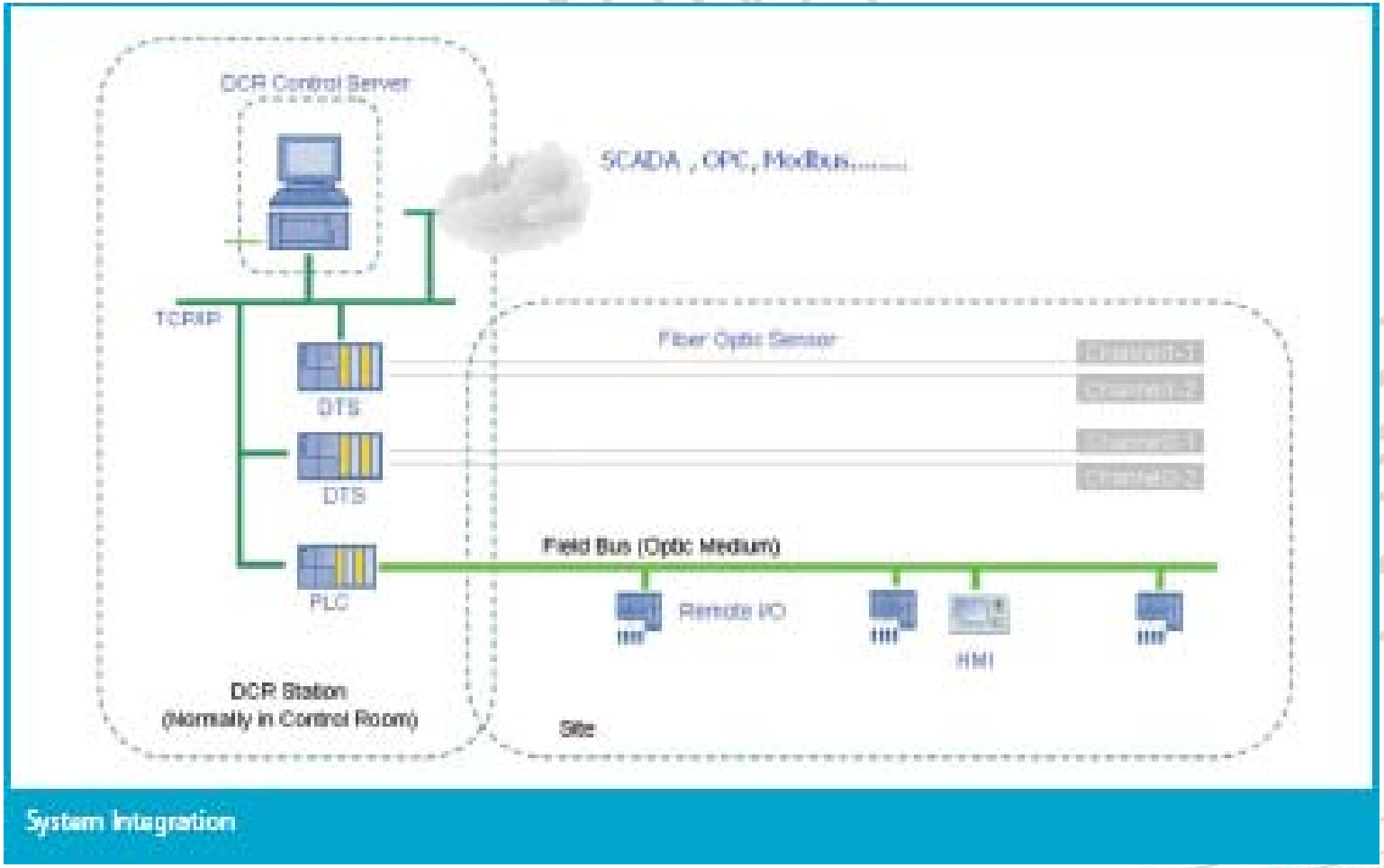
Dynamic Cable Rating System

- To provide the power system operator with cable ratings based in on real-time measurements and a thermal model.
- Using a real-time software system taking inputs from the Power System and Distributed Temperature Sensor (DTS)
- Outputs for user are:
  - Real time power rating (e.g. maximum continuous load cable can sustain without exceeding the thermal rating)
  - Emergency load rating: (e.g. maximum load cable can sustain for a defined period of time – 24 hours, 6 hours, 20 minutes)

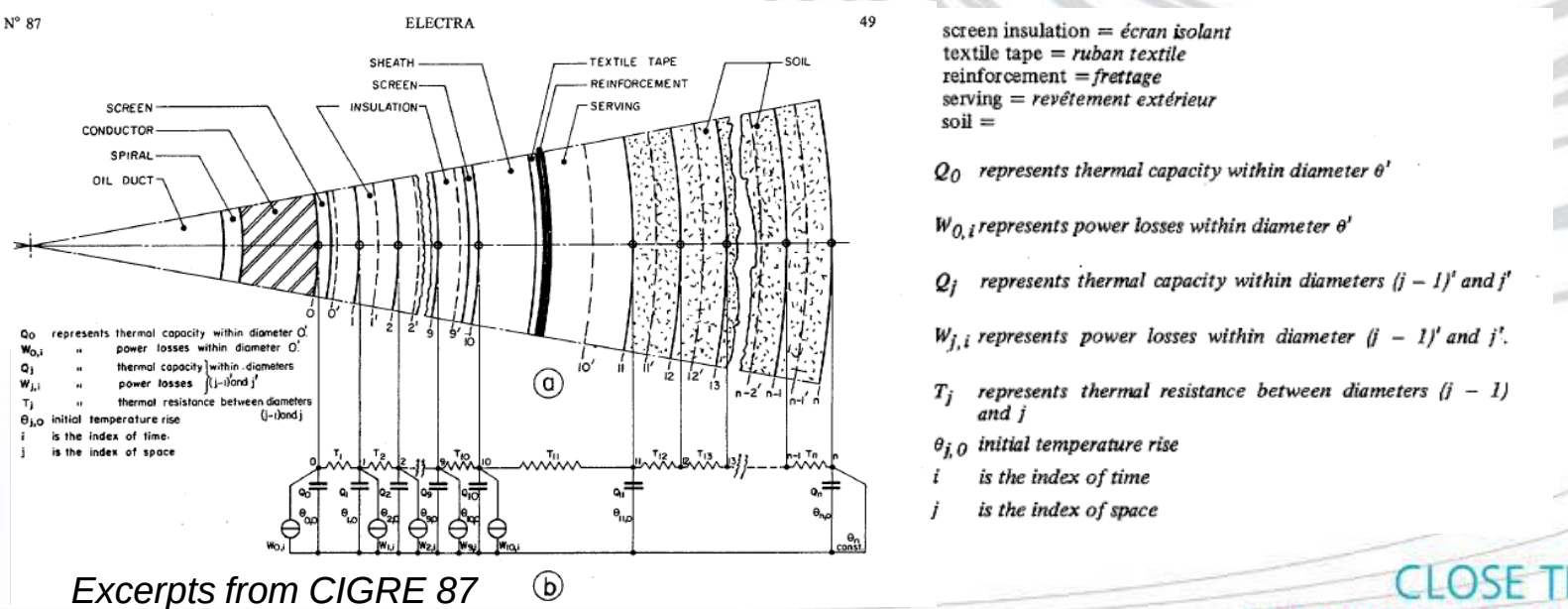
Seamless system integration (e.g SCADA, Ventilation, Relay)

Cable Monitoring SystemArchitecture



Thermal Model used for DCR

- Based on Electra 87 as recommended in IEC60287 & 60853
- Enhancements
  - Unconditionally stable Crank-Nicolson numerical iteration method



Excerpts from CIGRE 87

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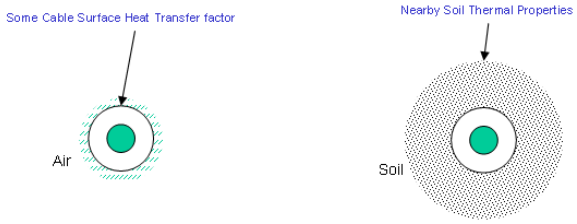
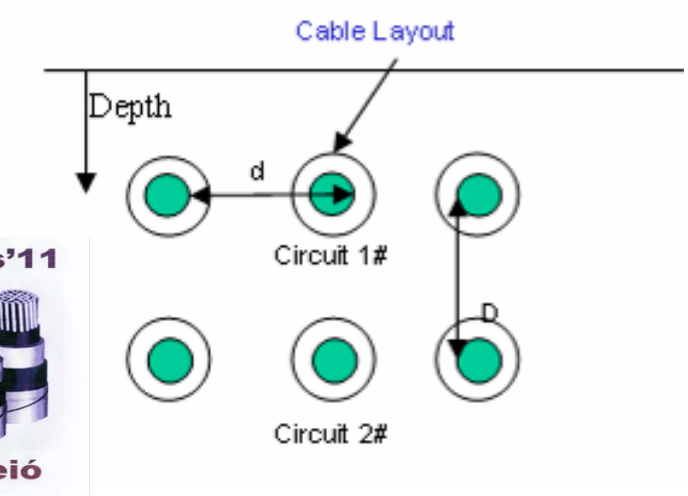
Dynamic Cable Rating



Name	Unit	Description
Nearby Soil Thermal Property	N/A	For Buried Cable: Nearby Soil Thermal Conductivity (W/mK) and Capacity (J/Km³); or Temperature Diffusion Ceoff (m²/s)
Cable Surface Heat Transfer factor	N/A	For Cable In Air: Heat Transfer Coeff(W/Km²)= f (factor, Va, Te)



- Adaptable to environment
  - Buried cables
  - Cables in air
- Multiple cables
- Adaptable to cable geometry

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Case Study: Buried Cable Monitoring

- 33 kV Buried Cable in Trefoil Formation – 4km in length
- Olex Cable - Client Energex

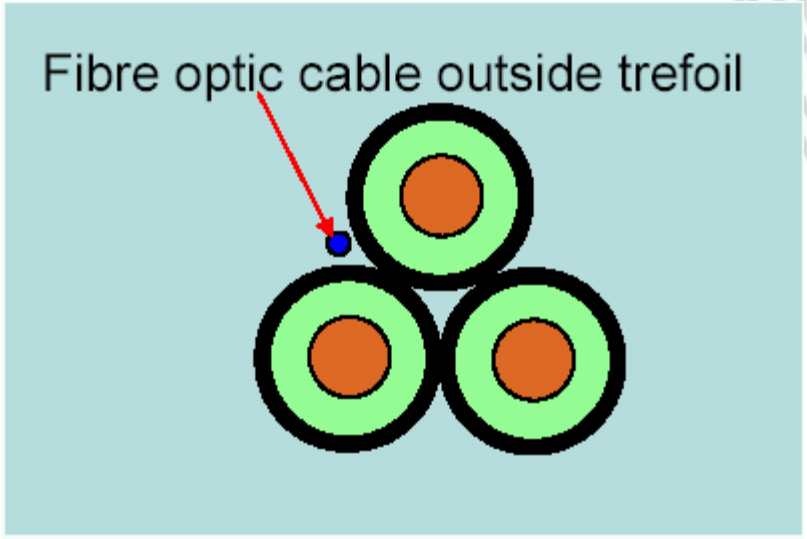

Fig 1 Trefoil configuration

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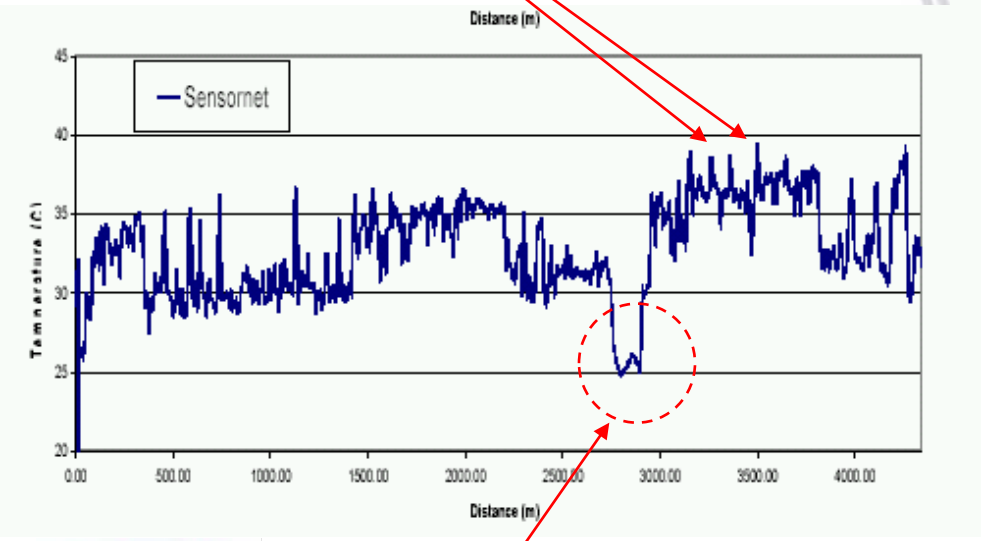
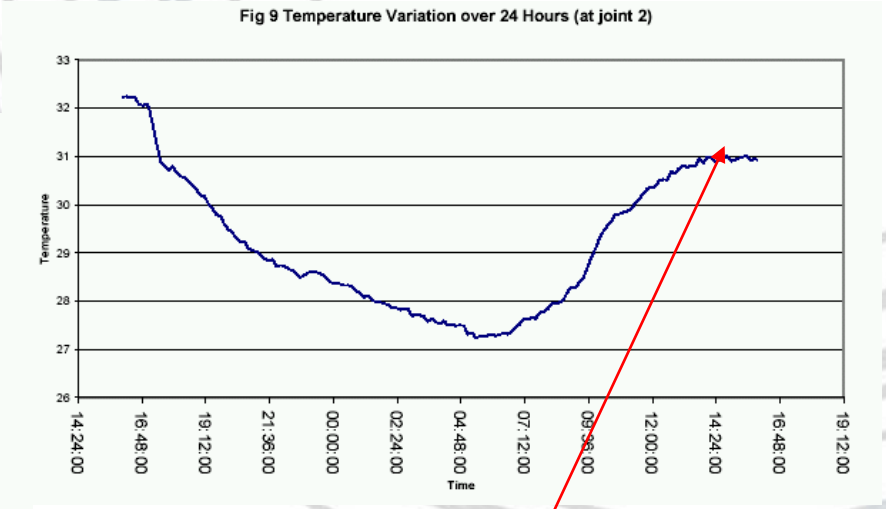
Engergex – Data Analysis over 24 hours

Temperature higher at road crossings





Temperature cooler at river crossing

Temperature at peak loading still well within specifications

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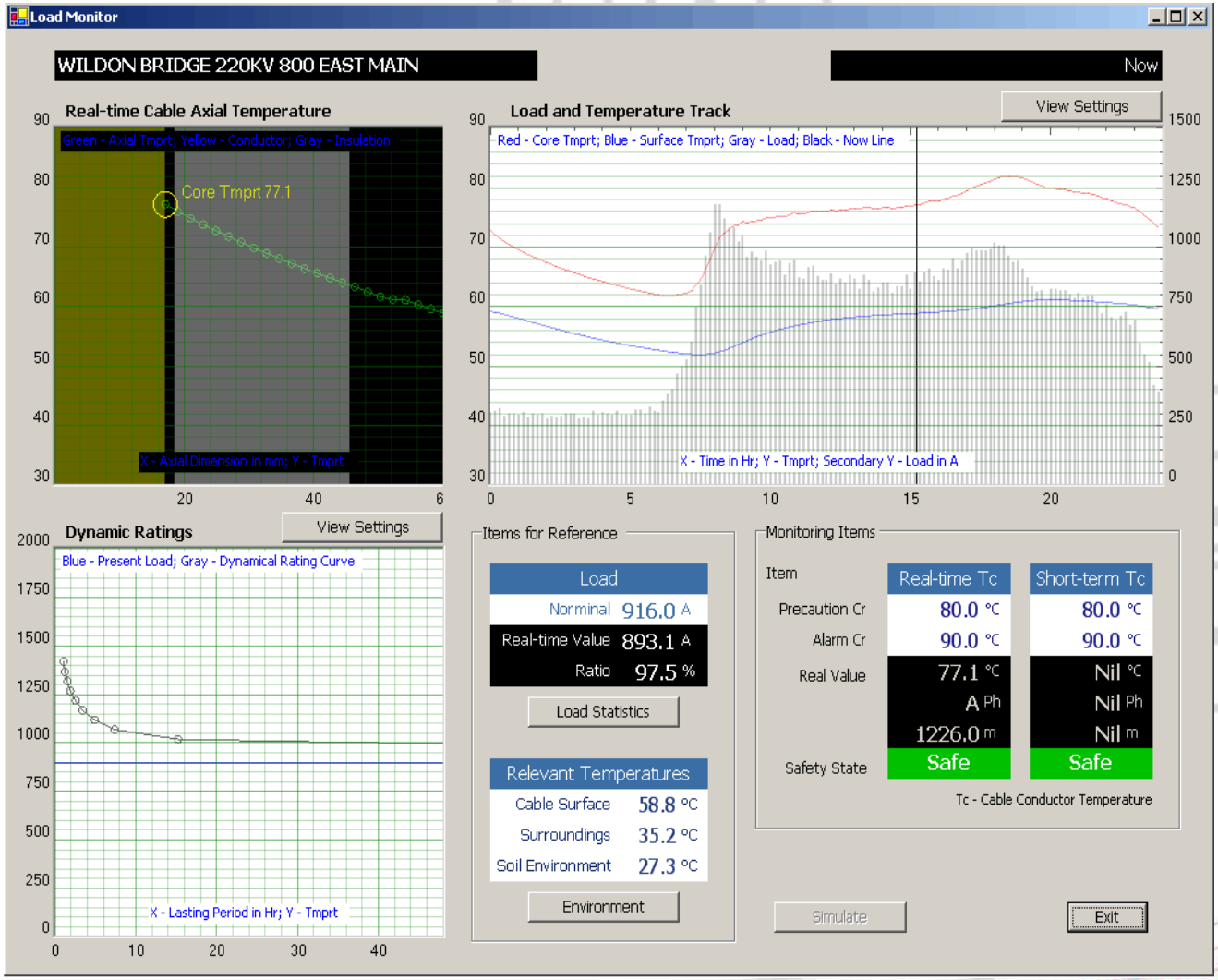
Dynamic Cable Rating - Screenshots



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Network Optimisation using of DTS

Sample calculation using 110 kV cable rated to 50 MW

- Price of power to customer* = $0.11 / kWh Typical cable loading =40%
- Number of peak hours per day = 3
- If cable loading is increased by 5% from (e.g. from 40 to 45%)
  - **Additional revenue per year = $300,000**

** Source: Powergen 2006 ** source: SKM consulting*

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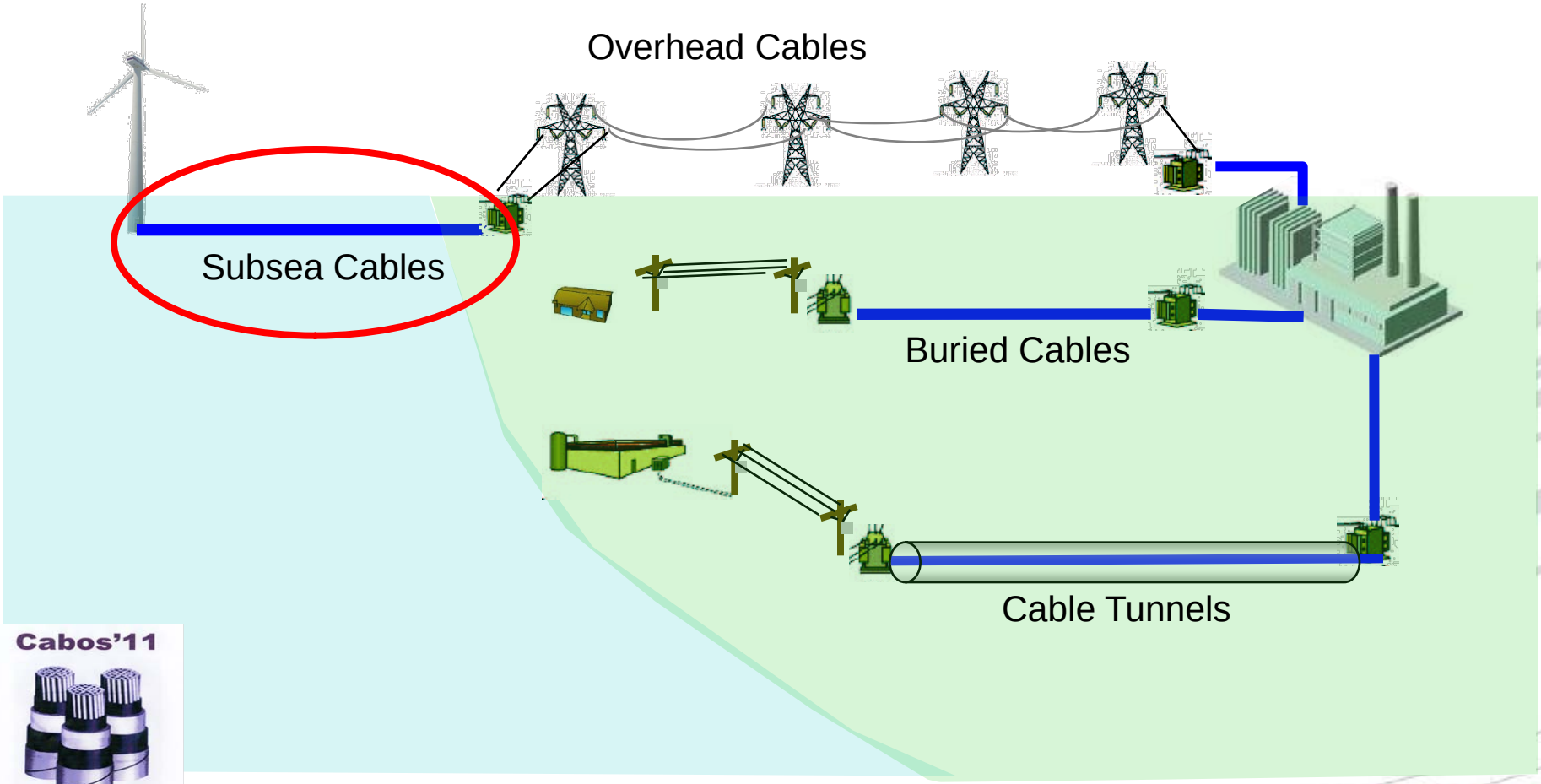
Subsea Cables



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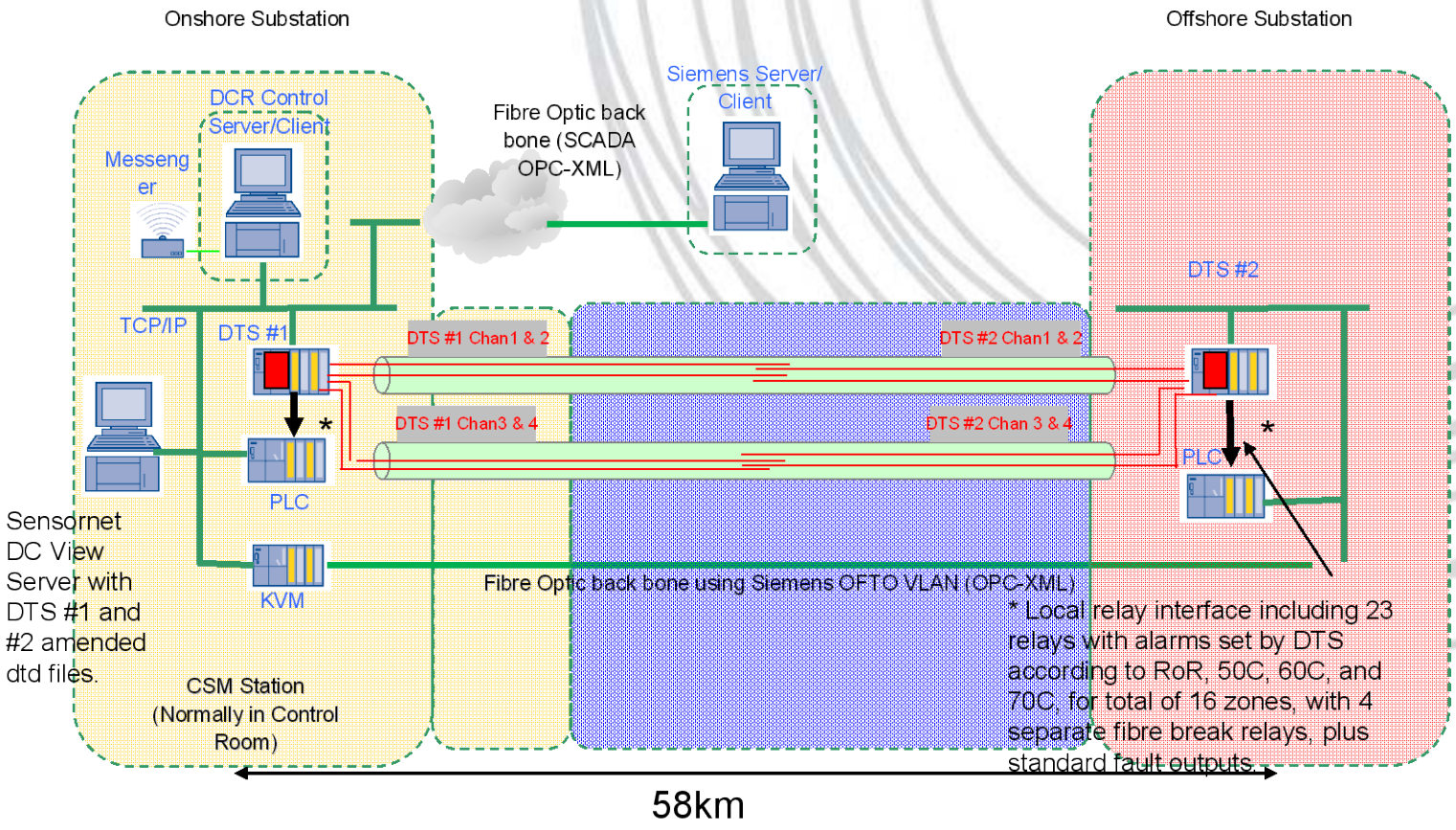
Subsea Cables

- Wind farms, country inter-connectors & Off shore platforms
- Similar to buried transmission cables except:
  - No redundancy => more critical to monitor
  - Longer distances => DTS performance essential
  - Very difficult to access => important to maximize lifetime

Off Shore Wind Farm

Centrica LINCS WF Project:



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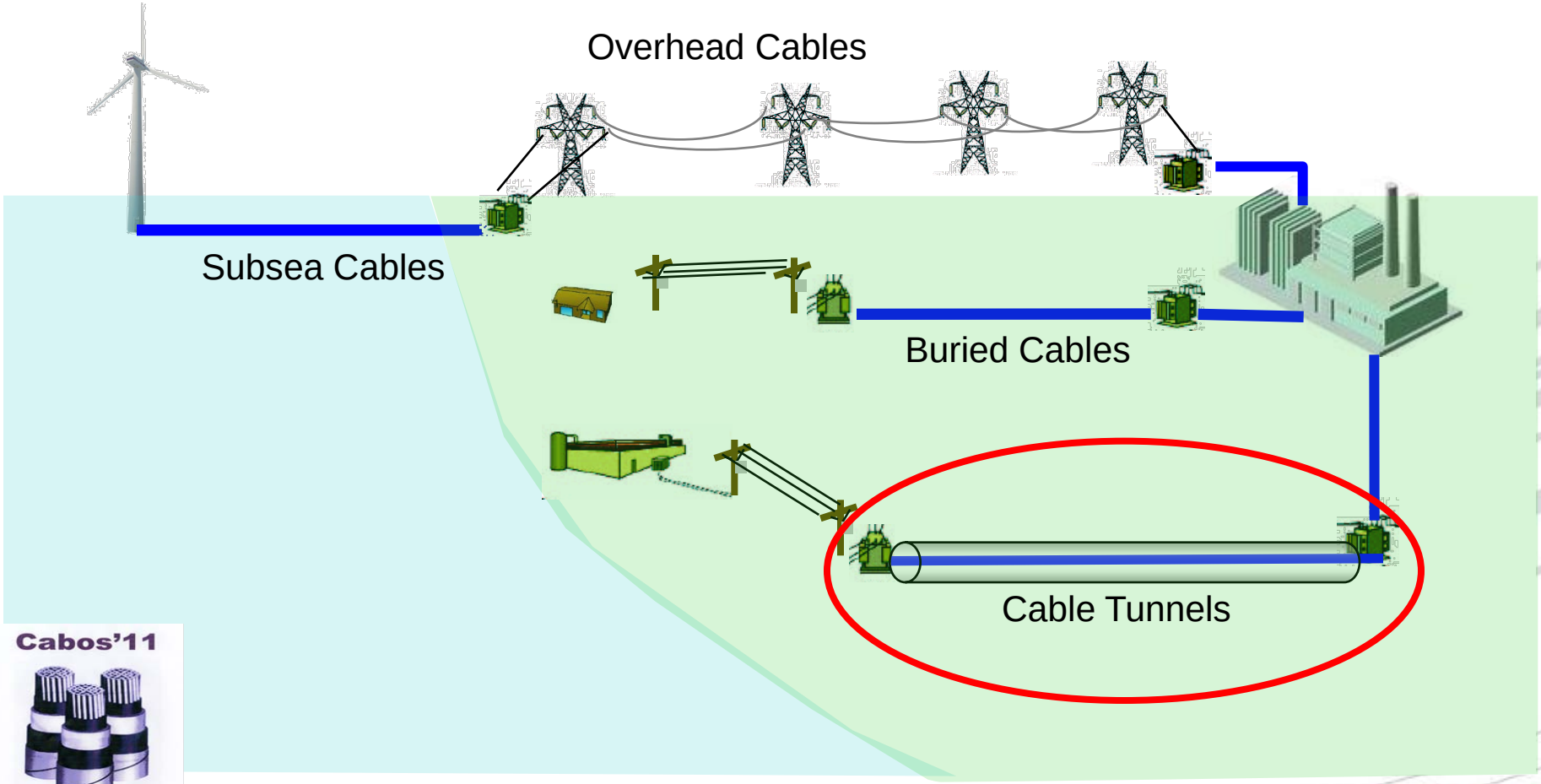
Cable Tunnels



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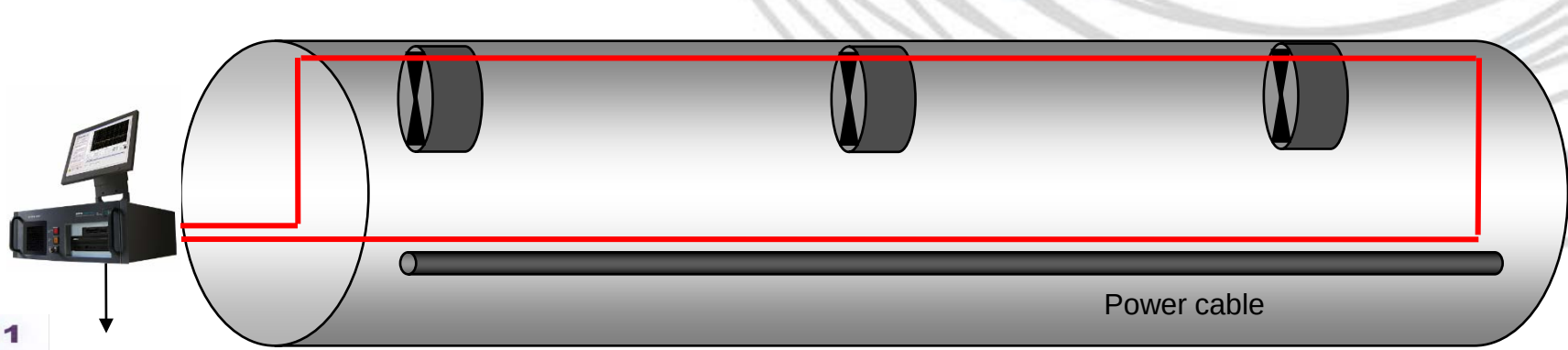
Cable Tunnel Management

- Cable provides 3 monitoring option
  1. Fire Detection: Cable installed in tunnel ceiling
  2. Ventilation Control: Feedback loop to ventilation system
  3. Hot Spot/Cable rating: Fibre attached to power cable



Data output to:
-Tunnel Ventilation Control
- Fire detection system
- Cable monitoring

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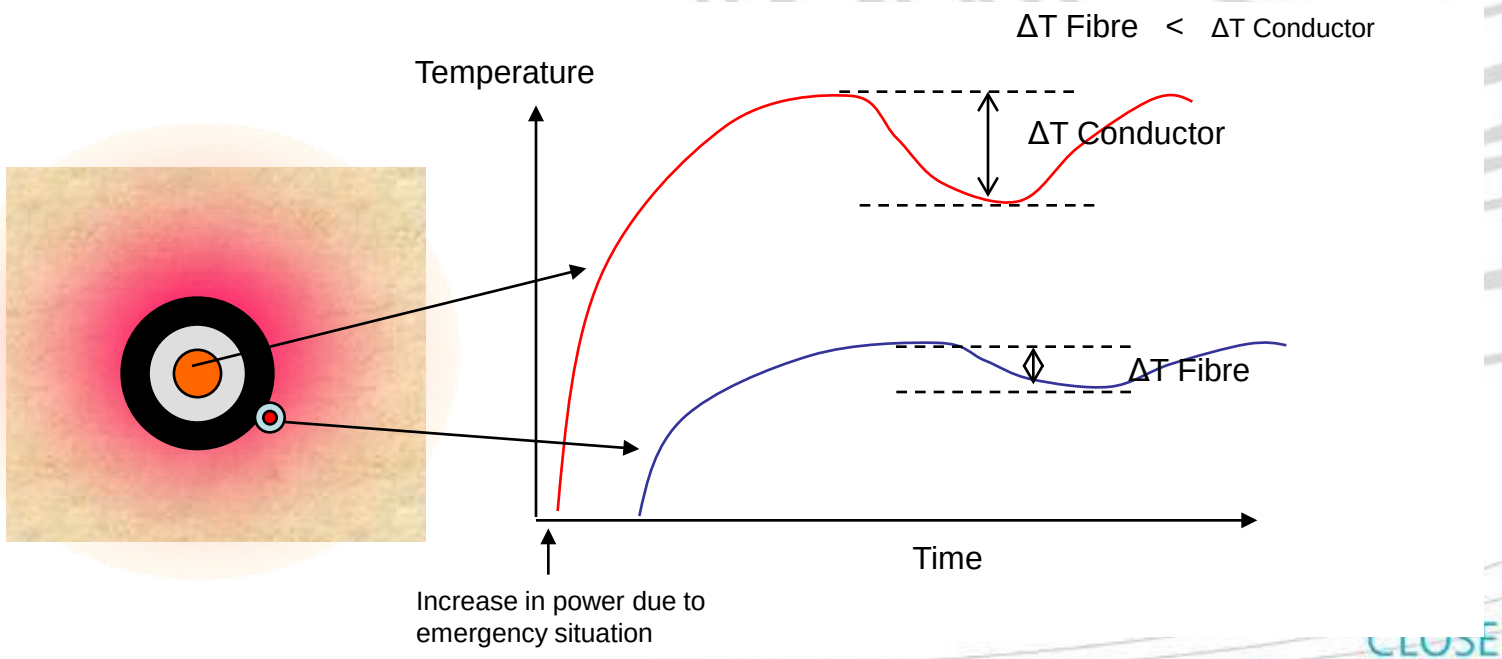
Importance of Speed of Measurement

- DTS must respond more rapidly than thermal environments
- When using multiplexer, DTS interrogates one channel at a time
  - Fast measurement time allow multiple channels without sacrifice of performance
    - More cost effective solution
- In emergency rating situations
  - Important to respond quickly

Importance of Temperature Resolution

- Change of conductor temperature is the vital requirement but is damped as it reaches fibre
  - Therefore high resolution is essential
  - Sensornet can measure down to 0.01°C



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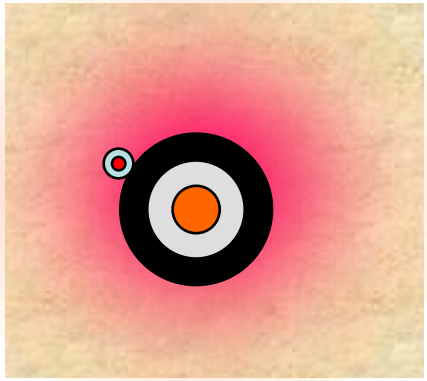
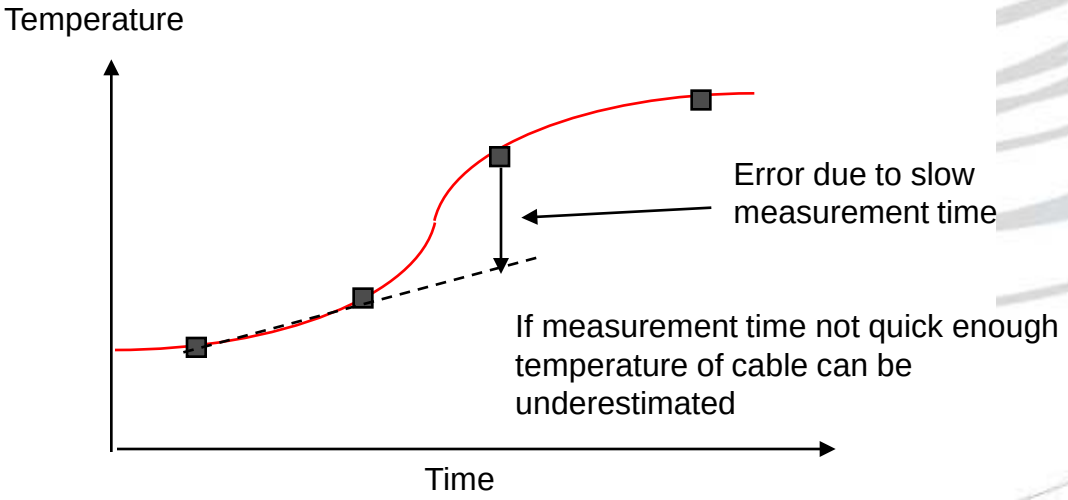
Speed of Response During Emergency Situation

- During emergency rating situation speed of response will be essential to react quickly to temperature changes
- **Sensornet DTS is the fastest response system**
  - **Better than 1°C @ 10km in < 10 seconds**





Where to install the fibre?

- Depending on the requirements, the fibre can be installed either inside the cable or on the outside

Inside Cable

Pros
Close to conductor
Suitable for ducts & subsea

Cons
Difficulty at joints
Greater fibre loss

Outside Cable

Pros
Easy to install
Less optical splices
Lower optical budget
Can install fibre after
Can replace fibre

Cons
Further from core
More critical to model

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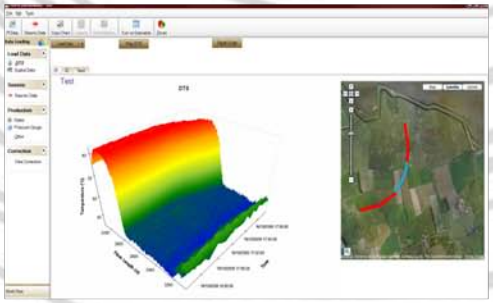
Sensornet Background

- Founded in 1998

– In 2004 backed by Shell Technology Ventures
- Multi-million dollar turnkey solutions to blue chip companies
- 2009 Incorporated as part of Tendeka (Oilfield technology)
- 2011 Acquired by Nova Metrix



- Advanced fibre optic asset monitoring solutions
  - Temperature Sensor (“DTS”)
  - Distributed Strain Sensor (“DSS”)
  - Distributed Acoustic Sensor (“DAS”)

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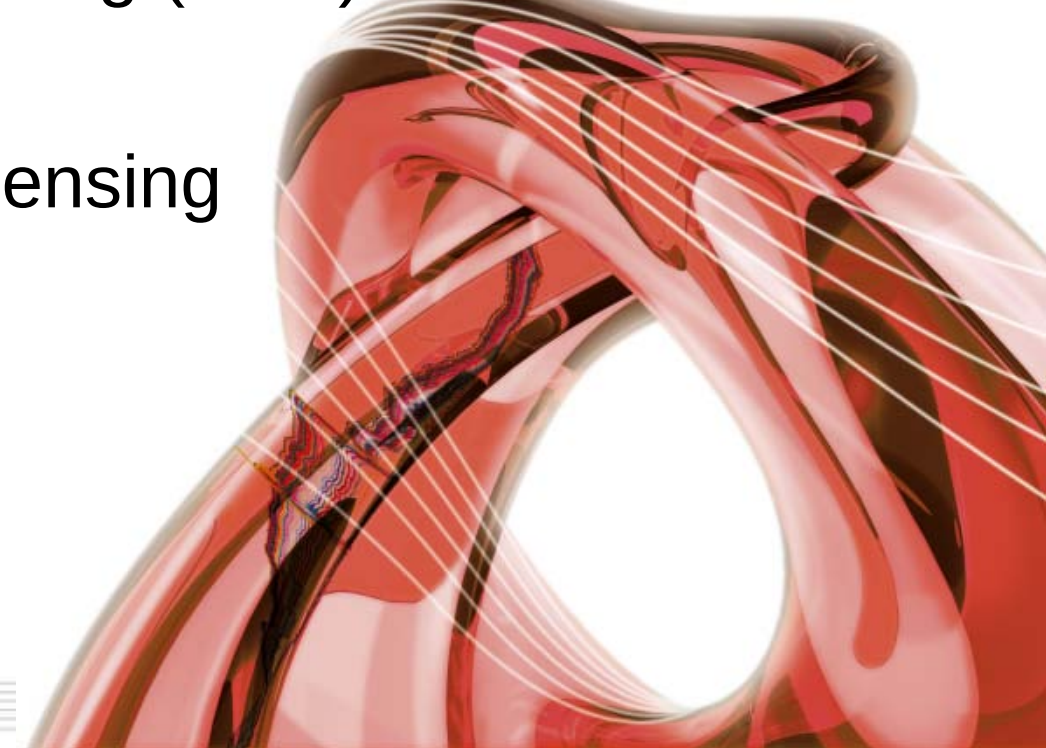
Product Range

- Distributed Temperature Sensing (DTS) <45km
- Distributed Strain Sensing (DSS) <24km
- Distributed Acoustic Sensing (DAS) <50km

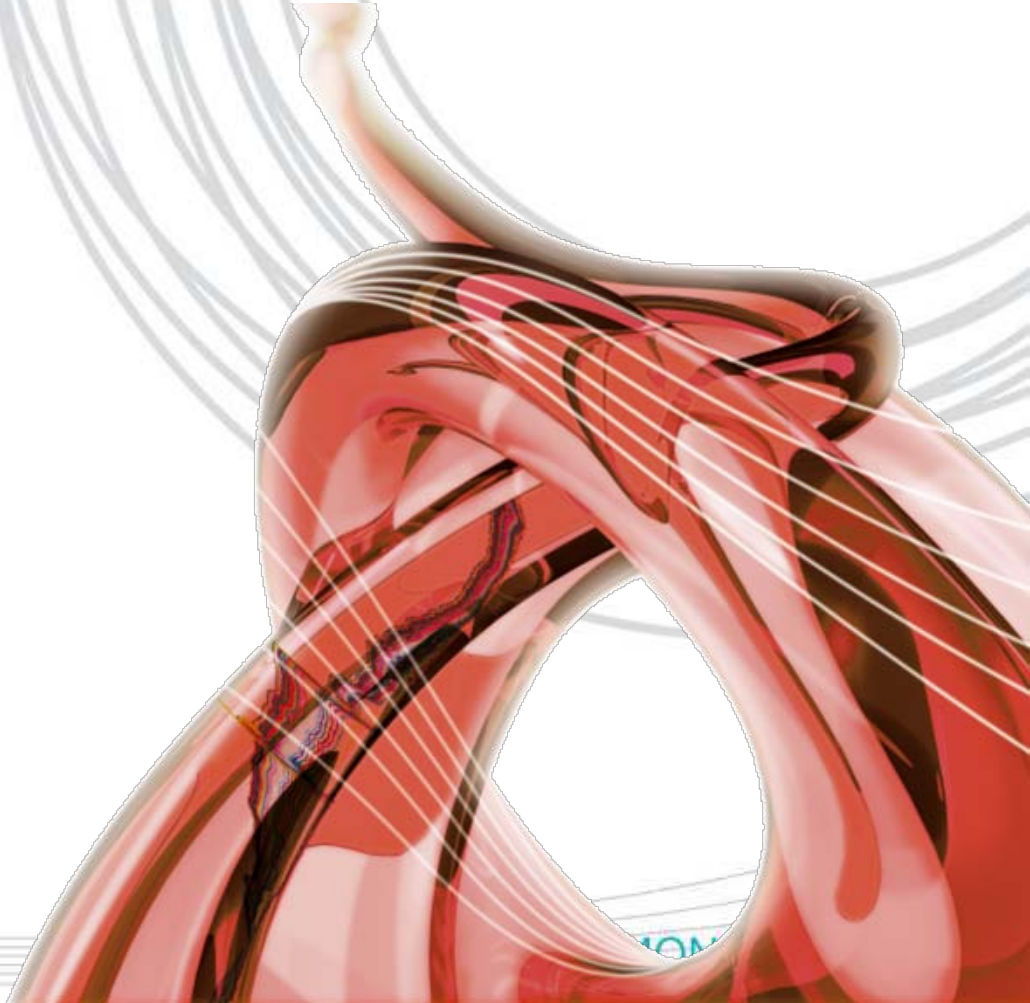


Summary

- Hot spot and fault detection
  - DTS can locate hotspot to within 1m
- Network optimisation
  - Run cables at higher rating safely
  - DTS plus DCR (dynamic cable rating)
- Asset Lifetime calculations
  - Knowledge of actual thermal stresses
  - DTS plus DCR
- Cable movement / TPI
  - Distributed Strain Sensor / Distributed Acoustic Sensor

KNOWLEDGE = POWER

Obrigado



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