



On-line monitoring of transformer health using gas analysis

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Changing the World's Energy Future

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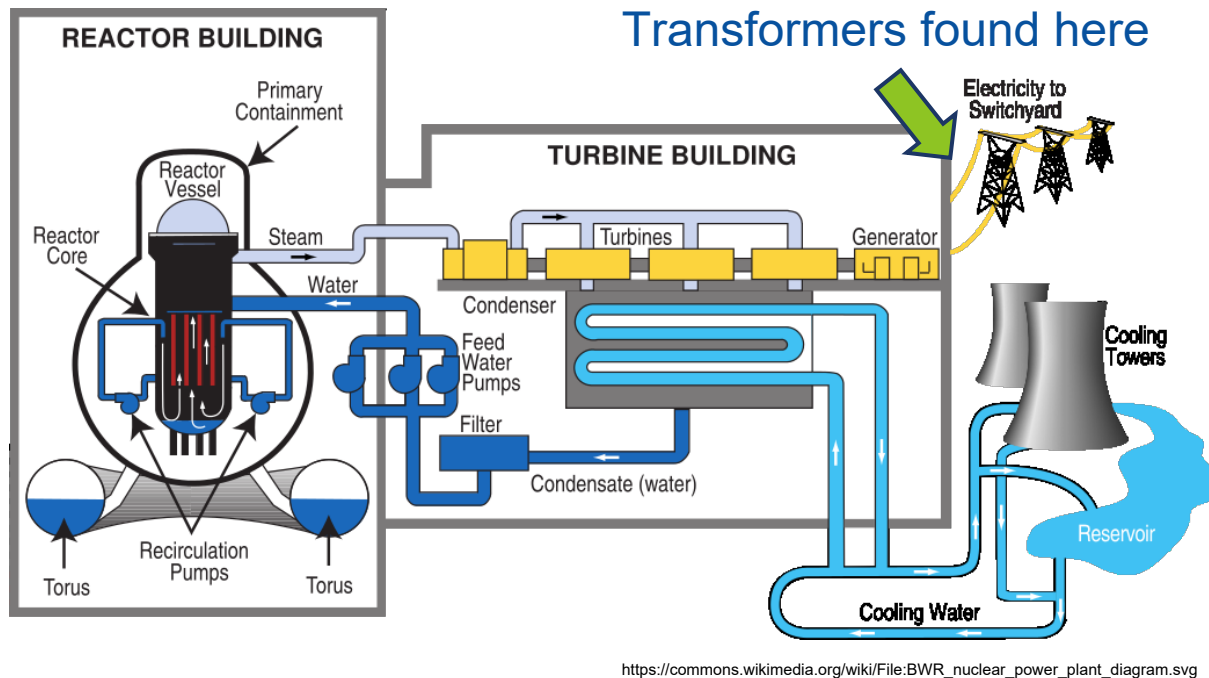
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On-line Monitoring of Transformer Health Using Gas Analysis

As a transformer ages, different gases are created that indicate the type and severity of the degradation.



- Transformers take the electricity generated from a plant and supply it to the load.



Posted Anne Bailey, 8/3/2017,
<https://www.alineeds.com/blog/large-transformer-recycling-at-nuclear-facility.aspx>

5 Functions to Monitor Transformer Aging

Transformer Health Monitoring

22-50091_R0

1. Chendong Model
2. Parameter Estimation
3. Thermal Life Consumption Model
4. Diagnostic Model
5. Prognostic Model

Chendong Model

Inputs: 2-Furaldehyde level

Outputs: Degree of polymerization & remaining useful life

Thermal Life Consumption Model

Inputs: Ambient temperature & load

Outputs: Accelerated aging factor & remaining useful life

Diagnostic Model

Inputs: Gas generated in oil

Outputs: System status & cause of potential fault

Prognostic Model

Inputs: Current gas concentrations

Outputs: Future gas concentrations



Chendong Model

- Relates 2-Furaldehyde (measured infrequently) to degree of polymerization and its significance.

$$DP_t = \frac{\log_{10}(2FAL) - 1.51}{0.0035}$$

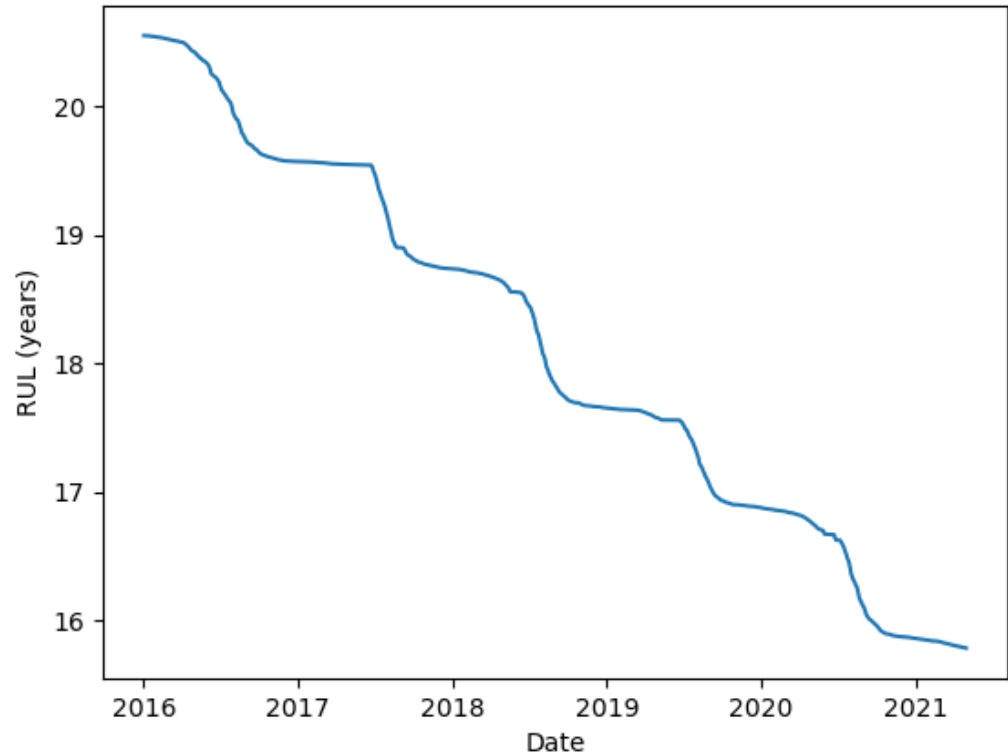
Description	DP_t
healthy insulation	700–1200
moderate deterioration	450–700
extensive deterioration	250–450
end-of-life criteria	<250

Parameter Estimator

- Not all variables within the **Thermal Life Consumption Model** were known, so we needed to estimate them.
- Function sets the problem up as a constrained optimization problem then tries to minimize it to find the solution.
- Works with multiple missing variables.
 - Requires further bounding.

Thermal Life Consumption Model predicts how hot-spot temperatures age the transformer more quickly.

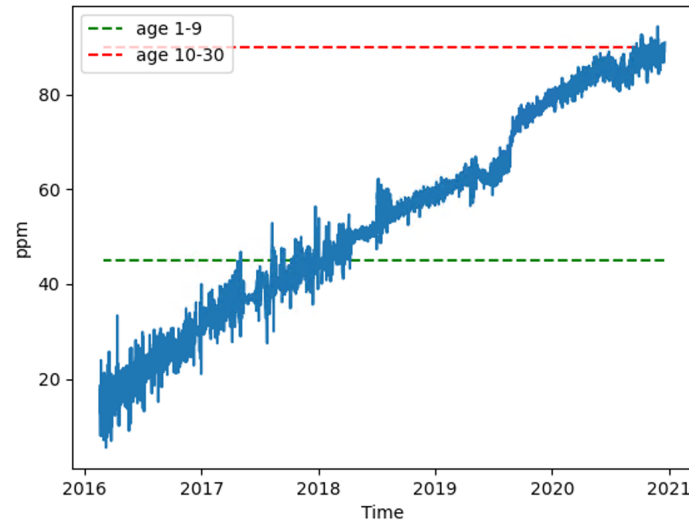
- The Thermal Life Consumption Model estimates an aging acceleration factor through the calculation of the thermal hot-spot temperature using ambient temperature and other plant parameters.
- Higher temperature and larger loads lead to increased accelerated aging factors and a quicker decline in the Remaining Useful Life (RUL).



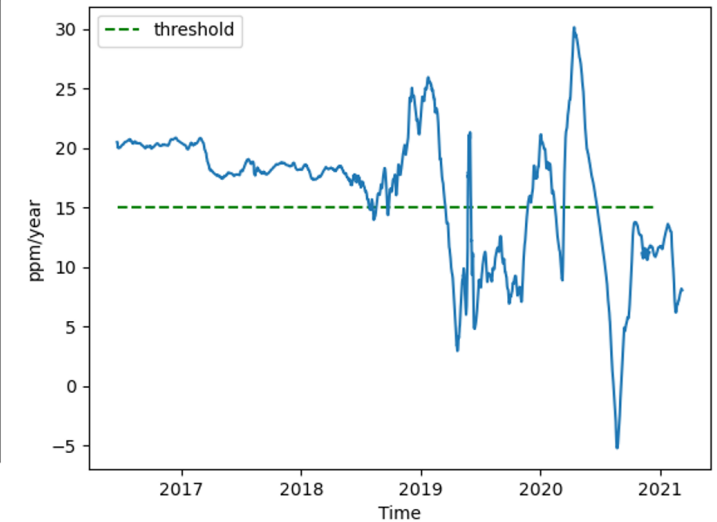
- Remaining useful life decreases more rapidly in summer than winter.

Diagnostic Model determines the type of fault as a warning signal.

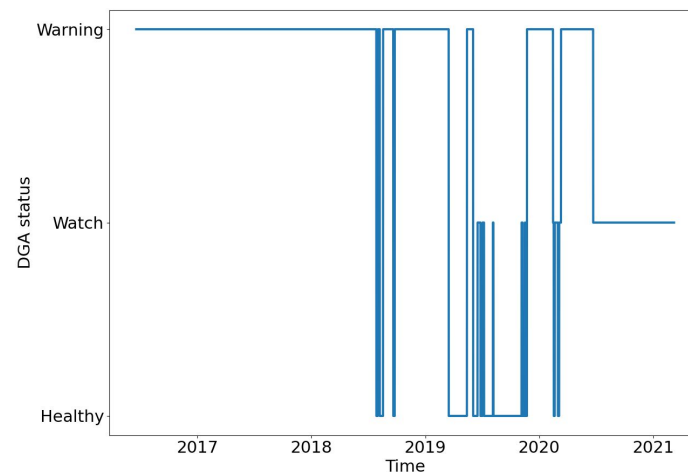
- The Diagnostic Model consists of a Dissolved Gas Analysis (DGA) Model and a Duval triangle.
- The DGA model focuses on the gas concentrations, production rates, and transformer age to determine transformer condition.
- If deemed unhealthy, the Duval triangle can determine potential causes based on certain gas concentrations.



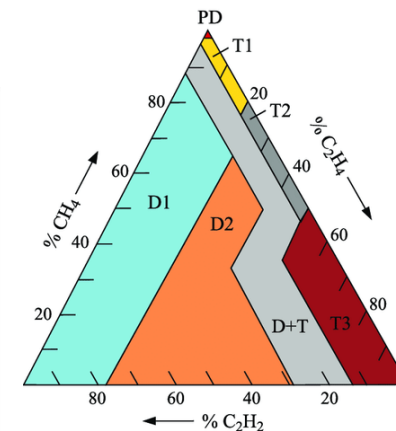
Gas Concentrations



Production Rates



Determine condition



PD: partial discharges
D1: discharges of low energy
D2: discharges of high energy
T1: thermal faults (temperature < 300 °C)
T2: thermal faults (300 °C < temperature < 700 °C)
T3: thermal faults (temperature > 700 °C)
D+T: mixtures of thermal and electrical faults

Identify potential cause

Prognostic Model predicts when in the future that specific variables will cross a failure threshold.

- The **Prognostic Model** uses historic dissolved gas data to predict future gas accumulated.
- This process uses Autoregressive Integrated Moving Average (ARIMA) to make these predictions with the upper half of the 95% confidence interval.
- This model is purely data driven, not physics or coupled with other signals.

