Maintenance Optimization in Power Systems

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Project Overview

Title:	Reliability Optimization in Power System
Start Date:	2018-08-01
End Date:	2019-06-30 (Part 1), 2020-01-31 (Part 2)
PostDocs:	Ebrahim Shayesteh (Part 1 Until 31.10.2018)
	Jan Henning Jürgensen (Part 2 Until 31.10.2019)
Key Persons:	Patrik Hilber (KTH)
	Jenny Paulinder (GENAB)
Sponsors:	ENERGIFORSK, Riskanalysis program
	Göteborg Energi Nät AB

Structure

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2. Optimization Problem
3. Step 1 – Reliability Calculations
4. Step 2 – Component Data
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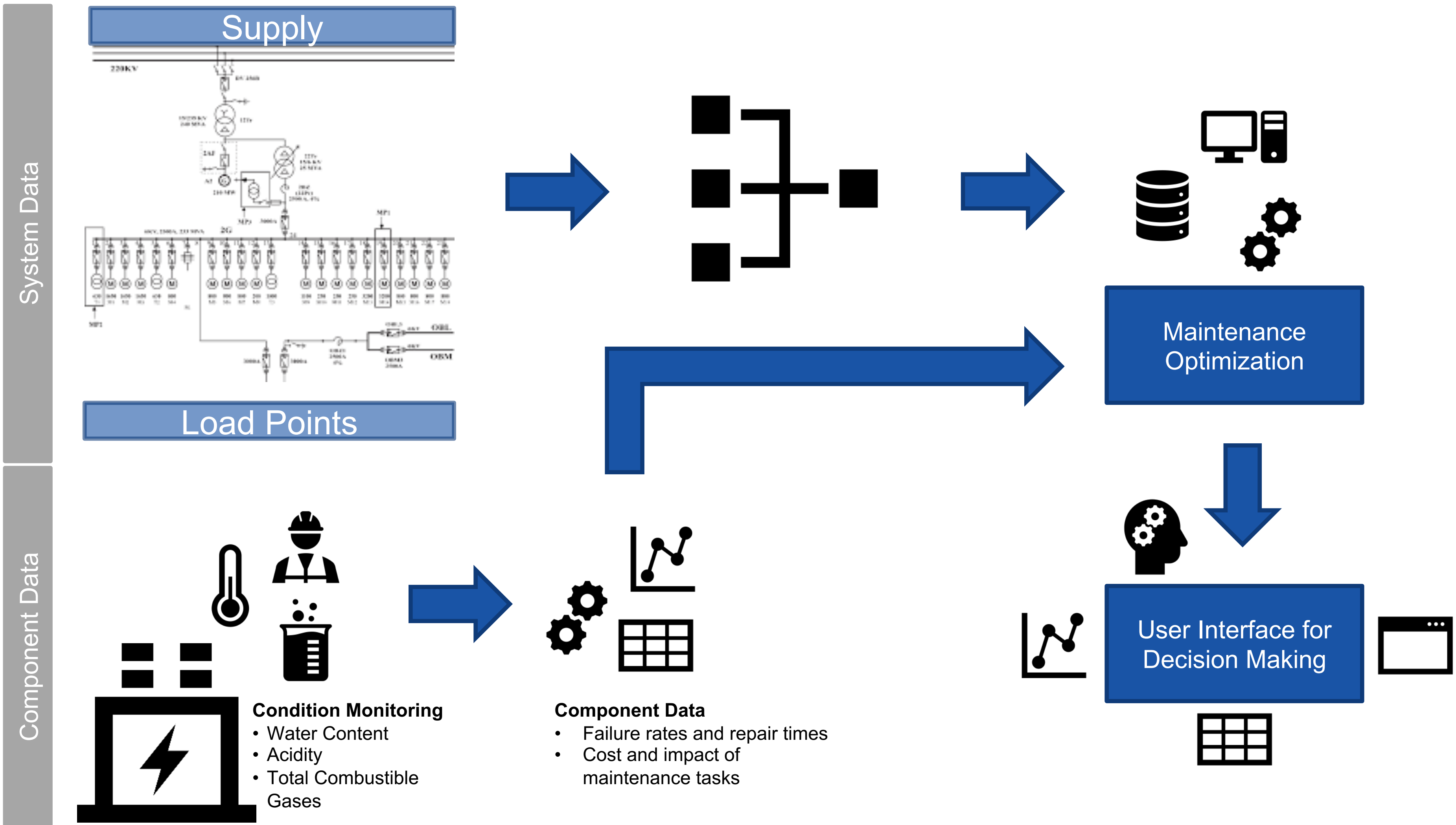
Overview Solution



Optimization Problem

$$min_{\{x_{i,a,t}\}} \quad \sum_{i=1}^{I}\sum_{t=1}^{T}\Delta TC_{i,t}$$

Total variation in all costs of component *i* (¤)

$s.t.$

$$\Delta TC_{i,t} = (1-\omega)\cdot\left[\Delta C_{i,t}^{CM} + \Delta C_{i,t}^{IC}\right] + \omega\cdot\left[\Delta C_{i,t}^{AM}\right]$$

$$\Delta C_{i,t}^{CM} = \Delta\lambda_{i,t}\cdot\beta_i^{CM}$$

Variation in the cost of corrective maintenance of component *i* (¤)

$$\Delta C_{i,t}^{AM} = \sum_{a=1}^{A}\left(\Delta x_{i,a,t}\cdot\alpha_{i,a}^{AM}\right)$$

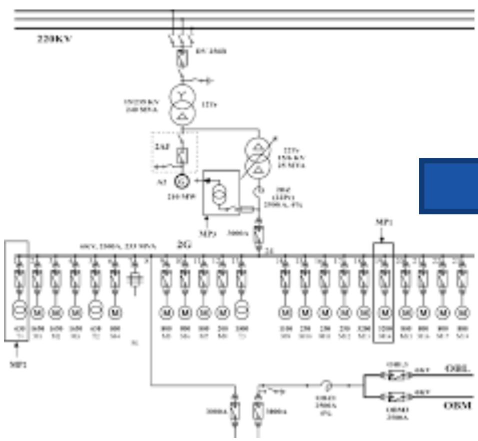
Variation in the cost of preventive maintenance of component *i* (¤)

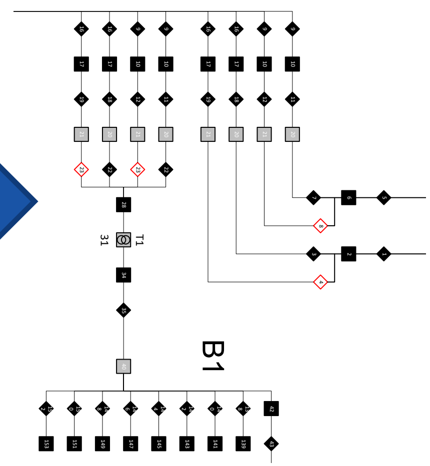
$$\Delta C_{i,t}^{IC} = \Delta\lambda_{i,t}\cdot\overline{I_{i,t}^{H}}$$

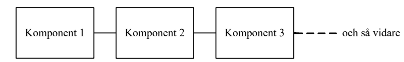
Variation in the interruption cost of component *i* (¤)

Step 1 - Reliability Calculations

Single line diagram of substation
with **reliability block diagram**
to **reliability equations**



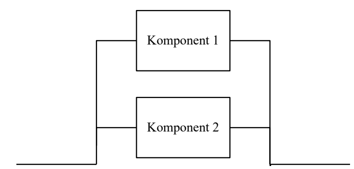




$$U_s \approx \sum_{i=1}^{n} \lambda_i r_i$$

$$\lambda_s = \sum_{i=1}^{n} \lambda_i$$

$$r_s \approx \frac{U_s}{\lambda_s}$$

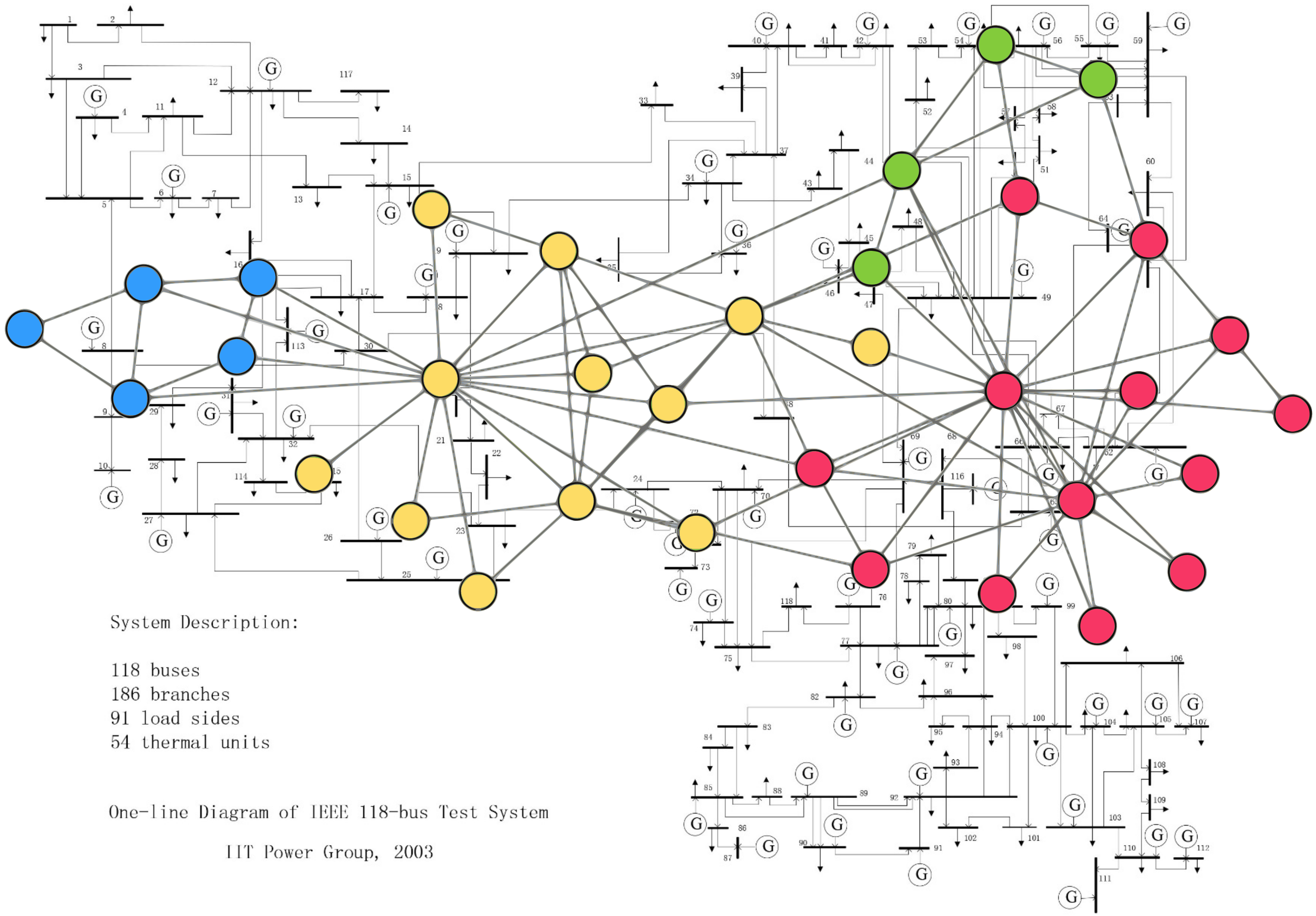


$$U_p \approx \lambda_p r_p = U_1 U_2 = \lambda_1 \lambda_2 r_1 r_2$$

$$\lambda_p = \frac{\lambda_1 \lambda_2 (r_1 + r_2)}{1 + \lambda_1 r_1 + \lambda_2 r_2} \approx \lambda_1 \lambda_2 (r_1 + r_2) = \lambda_1 U_2 + \lambda_2 U_1$$

$$r_p = \frac{r_1 r_2}{r_1 + r_2}$$

Step 1 - Reliability Calculations
Graph Theory



Step 2 - Component Data

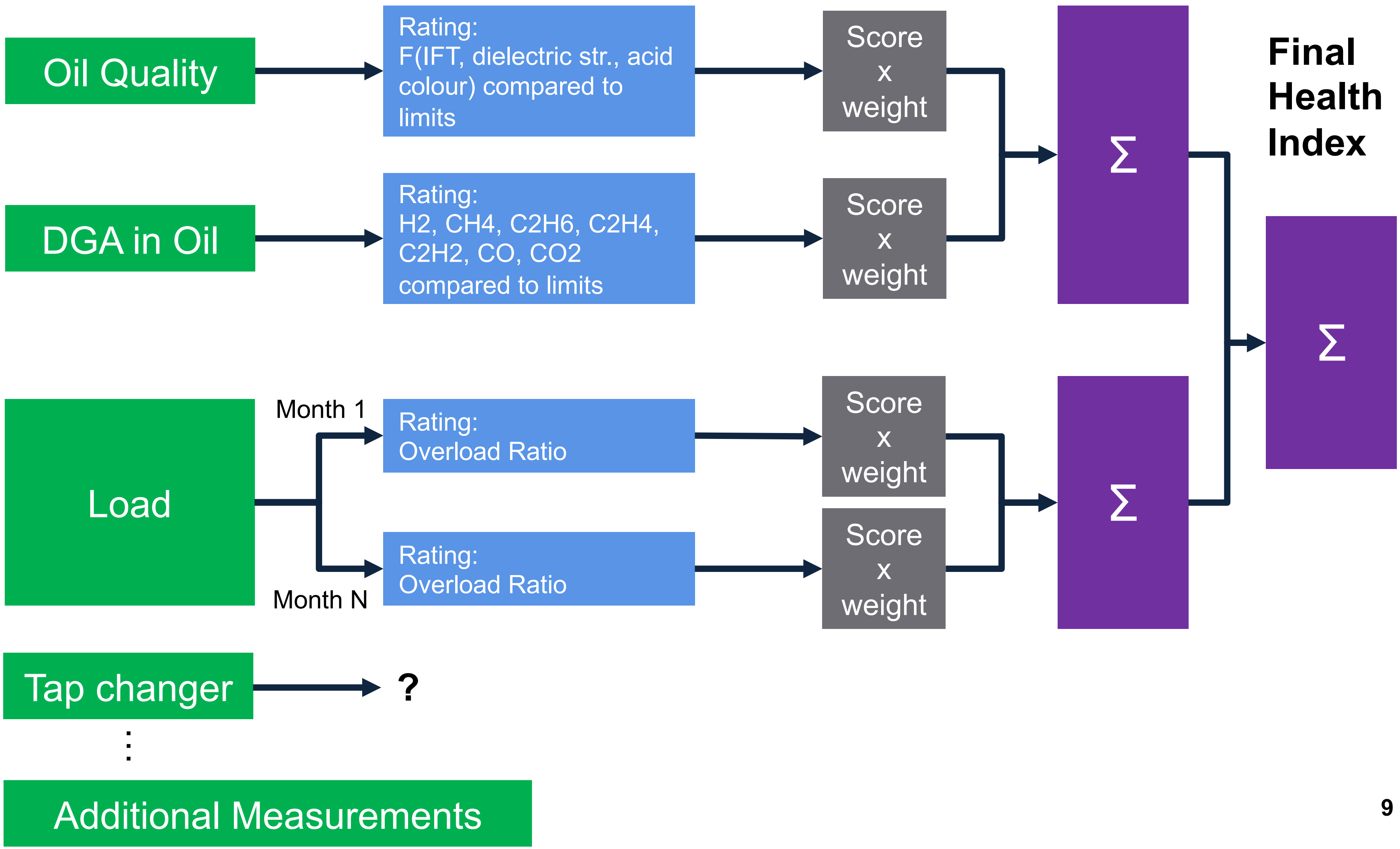
Component Data

- Failure Rates and repair times: Power Transformers, Bus Bar, Circuit Breakers, and Disconnectors
- Determining the component conditions to estimate failure rate
- Determining cost of maintenance tasks
    - Condition monitoring
    - Minor preventive maintenance
    - Major preventive maintenance
    - Component replacement

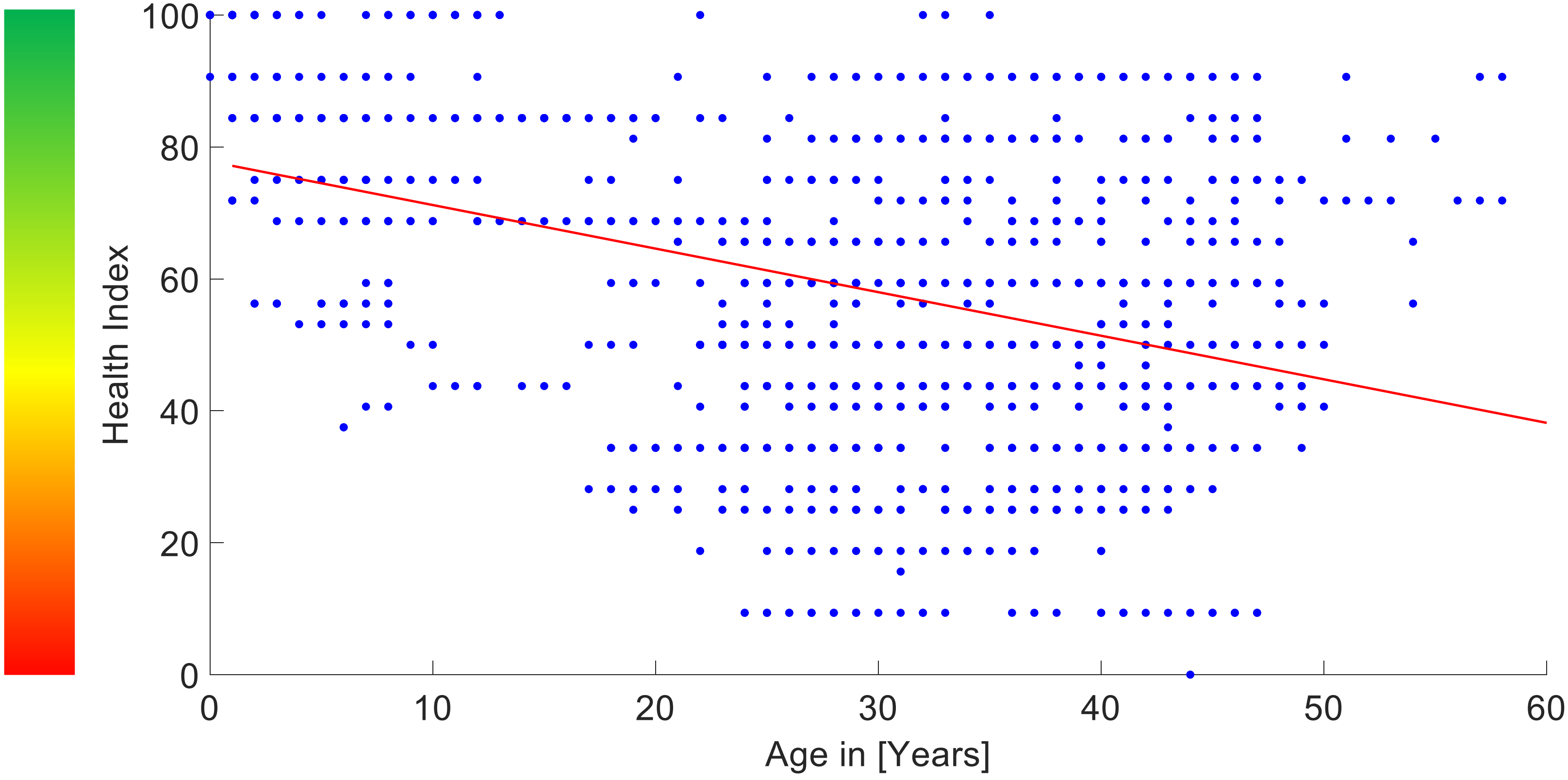
Load Point Data

Load Point	Number of Customers	Interruption Costs	Power at Load Point

Step 2 - Component Data Gathering Condition Monitoring to Health Index

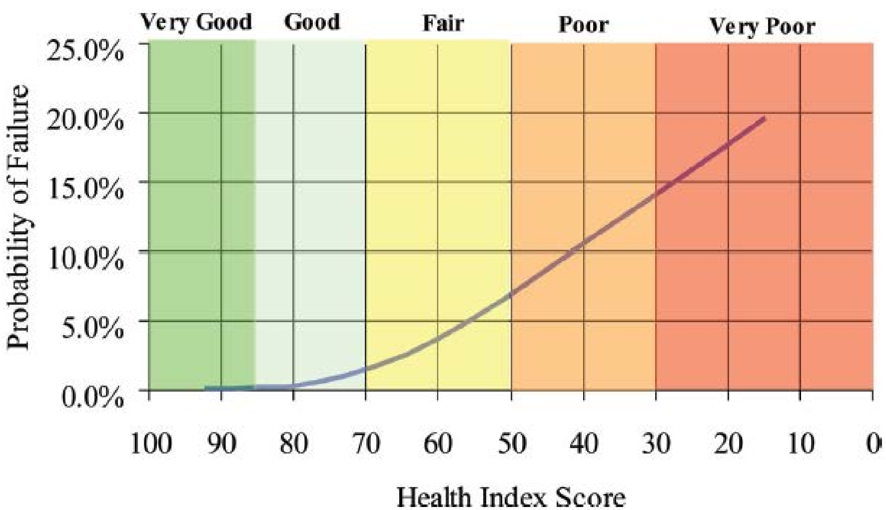


Step 2 - Component Data Estimation Health Index for Population

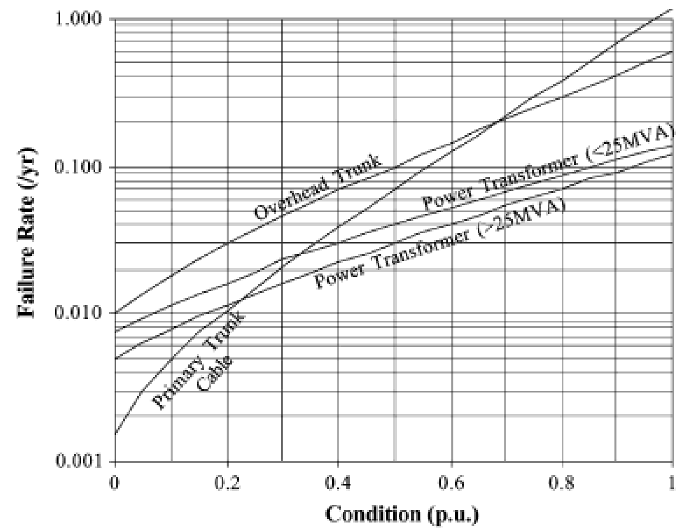


Step 2 - Component Data Estimation Health Index to Failure Rate

Method 1: Expert Approach



Method 2: Based on Historical Data



Functions to translate condition monitoring data or health indices to failure rates

1. Jahromi, A., Piercy, R., Cress, S., Service, J., & Fan, W. (2009). An approach to power transformer asset management using health index. *IEEE Electrical Insulation Magazine*, *25*(2), 20-34.
2. Brown, R. E. (2004, June). Failure rate modeling using equipment inspection data. In *IEEE Power Engineering Society General Meeting, 2004.* (pp. 693-700). IEEE.
3. Jürgensen, J. H., Nordström, L., & Hilber, P. (2019). Estimation of Individual Failure Rates for Power System Components Based on Risk Functions. *IEEE Transactions on Power Delivery*, *34*(4), 1599-1607.

Conclusions

- Data is available
  - Data acquisition is a challenge, which is time consuming
- Implementation with software available, e.g. Excel
- Combining research and industry – practical periods
- New project ideas and research questions

Thank you for your attention!

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