# X SICEL 2021

**Transición energética en la 4ta revolución industrial**

Universidad Tecnológica de Pereira

UNIVERSIDAD NACIONAL DE COLOMBIA

# Analysis of Asset Management Models for a Transformer Fleet in the National Laboratory of Smart Grids (LAB+i)

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# I. Introduction

- Life cycle monitoring
- Asset Management – ISO 55000
- Neural Networks – Artificial Intelligence
- Industry demands
- Research opportunities

Fig 1. Distribution Transformer [1].


Fig 2. Asset lifecycle [2].

# II. Classification method

- Power transformer modeling
  - Thermal, DGA, Frequency, Partial discharges
- Life cycle
  - Consequence factor, failure probability, economic lifetime
- Output indicator calculation
  - Machine Learning, fuzzy Logic, mathematical models
- Measurement and output data frequency
  - Calculation time and output data format

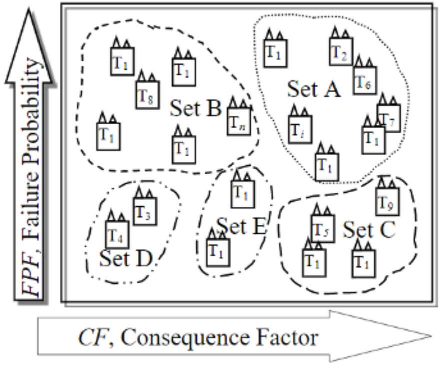


Fig 3. Risk assessment matrix for a fleet of n transformers [4].

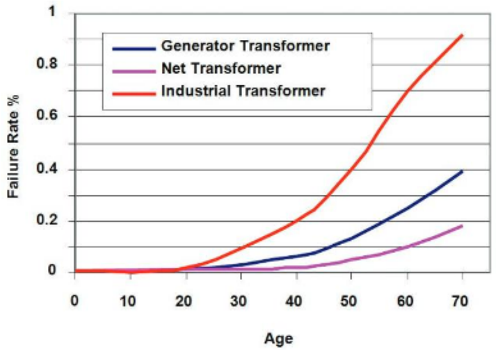


Fig 4. Failure probability versus age [5].

# II. Classification method

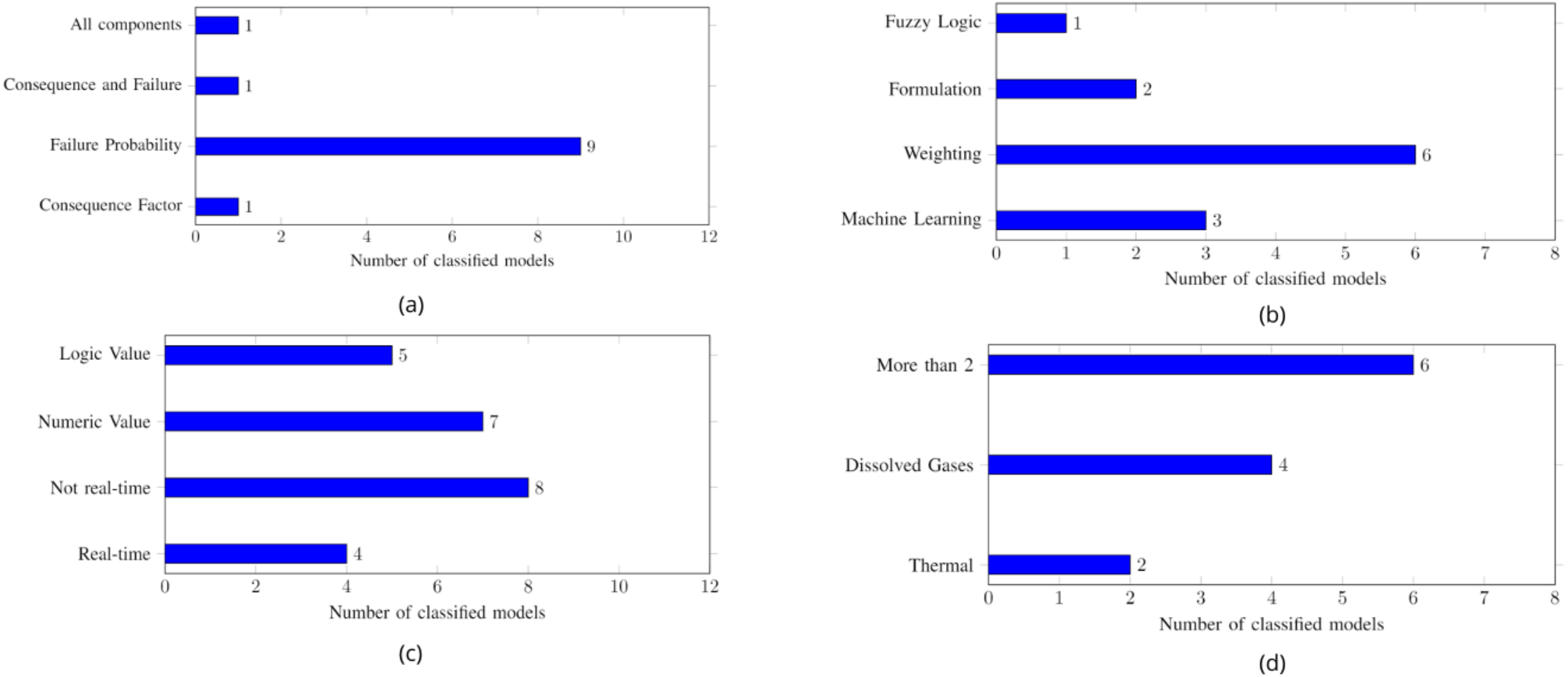


Fig 5. Classification of 12 reference Asset Management models.

# III. LAB+i

- Smart Meters
- Communication through Internet
- Osisoft PI System
- Model construction
  - 33 substations
  - 53 nodes
  - Radial Topology of 3 km
- Smart Grid analysis
  - Viability
  - Demand management
  - Renewable resources
  - Big Data - governance

**LAB+i Laboratory: Matrix Contributions R+D+i**

| | | | Evaluation Criteria | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Function / Scope of Pilot | | | | | Project´s capabilities | | | | | | | | Colombian conditions | |
| | | | Research | Technological development | Innovation | Technology Application | Monitoring and Testing Technology | Interoperability | Open Software | Digital | Resilience | Scalability | Efficiency | Reliability | Customization | Equipment Adaptability | Environmental Conditions |
| Smart Grids - Layers | | | | | | | | | | | | | | | | | |
| 1 | Intelligence | Automated Operation | ✓ | | | ✓ | | ✓ | ✓ | | | | | ✓ | ✓ | | |
| | | Self Healing | ✓ | | | ✓ | | ✓ | ✓ | | | | | ✓ | ✓ | | |
| | | State Estimator | ✓ | | | ✓ | | ✓ | ✓ | | | | | ✓ | ✓ | | |
| 2 | Analysis | City Smart Transportation | ✓ | | ✓ | | ✓ | ✓ | ✓ | | ✓ | | | | ✓ | ✓ | ✓ |
| | | Energy Demand Side | ✓ | | ✓ | | ✓ | ✓ | ✓ | | ✓ | | | | ✓ | ✓ | ✓ |
| | | Building Managament System | ✓ | | ✓ | | ✓ | ✓ | ✓ | | ✓ | | | | ✓ | ✓ | ✓ |
| 3 | Model | Matlab | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | | ✓ | | | ✓ | | |
| | | Simulink | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | | ✓ | | | ✓ | | |
| | | Neplan | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | | ✓ | | | ✓ | | |
| 4 | System | Intelligent Buildings | ✓ | | | ✓ | ✓ | ✓ | | ✓ | | | ✓ | ✓ | | ✓ | ✓ |
| | | Traffic Management | ✓ | | | ✓ | ✓ | ✓ | | ✓ | | | ✓ | ✓ | | ✓ | ✓ |
| | | Energy Efficiency | ✓ | | | ✓ | ✓ | ✓ | | ✓ | | | ✓ | ✓ | | ✓ | ✓ |
| 5 | Communication | Ethernet DNP | ✓ | | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | | ✓ | ✓ | ✓ |
| | | Wireless | ✓ | | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | | ✓ | ✓ | ✓ |
| | | Ethernet TCP IP | ✓ | | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | | ✓ | ✓ | ✓ |
| 6 | Interface | IED | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓ | | |
| | | Sensors | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓ | | |
| | | AMI | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓ | | |
| 7 | Physical | Electric Mobility | ✓ | | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ | | ✓ |
| | | PMUs | ✓ | | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ | | ✓ |
| | | Smart Users | ✓ | | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ | | ✓ |

Fig 6. Contributions R+D+I from pilots in LAB+I Laboratory [6].

# IV. AM implementation

- Thermal Model
    - IEEE Standard C57.91
    - GTC 50
    - Hot spot value
- Three Substations
    - School of Medicine
    - Mathematics Faculty
    - Central Library
- High value of remaining years
- Correlation with overall temperature

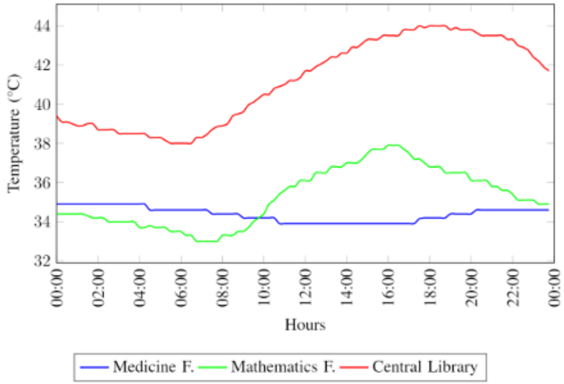


Fig 7. Initial temperature measurements of oil insulation of three substations.

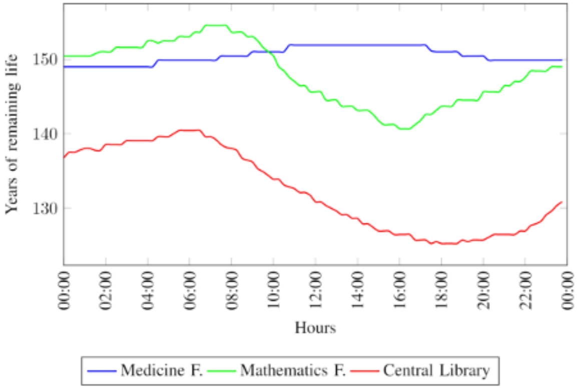


Fig 8. Thermal model results.

# IV. AM implementation

- Fuzzy Logic Model
  - Transformer age
  - Insulating oil temperature
  - Hot spot temperature
- Weighting model
  - Transformer age
  - Transformer load
- Three Substations
  - School of Medicine
  - Mathematics Faculty
  - Central Library

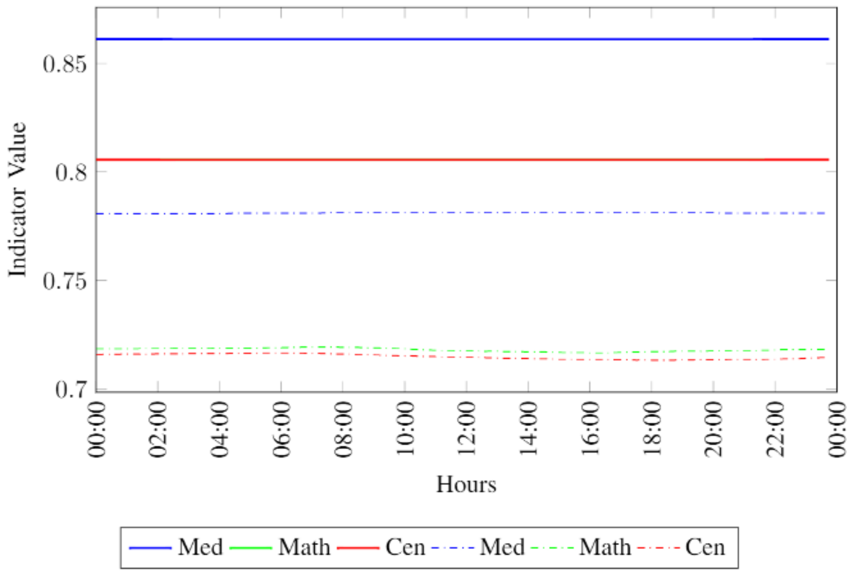


Fig 9. Normalized fuzzy logic and weighting model results.

# V. Results - Classification

- Challenge of establishing a general modeling.
- Data with Asset Management systems.
- Use of new computational tools.
- Applicability within the LAB+I.
- Socialization – Stakeholders.
- Understanding of rules and new models.

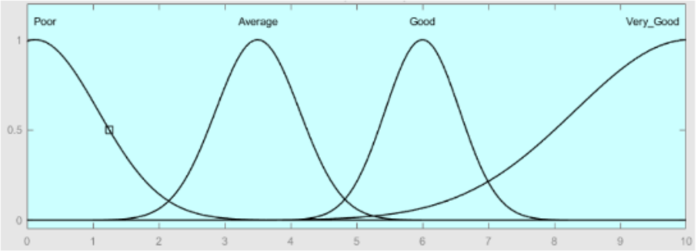


Fig 10. Membership output function for temperature.

# V. Results - Implementation

- Thermal Model
  - Fluctuation in final indicator value.
  - High quantity of years of remaining life.
  - Influence of low insulation temperature.
- Fuzzy Logic Model
  - Stability and confidence.
  - Membership functions and rules
  - Use of limited data.
- Weighting model
  - Use of limited data.
  - Comparison challenges.
  - Low demand related to nominal value of transformers.

Table 1. Transformer categorization.

| Substation | Thermal Model | Weighting Model | Fuzzy Logic Model |
|---|---|---|---|
| Medicine F. | Very Good | Very Good | Good |
| Mathematics F. | Very Good | Good | Good |
| Central Library | Very Good | Good | Good |

Table 2. Indicator standard deviation.

| Substation | Thermal Model | Weighting Model | Fuzzy Logic Model |
|---|---|---|---|
| Medicine F. | 1.06380452 | 1.78568E-15 | 0.002605641 |
| Mathematics F. | 4.22224748 | 1.96425E-14 | 0.01056496 |
| Central Library | 5.5627336 | 1.96425E-14 | 0.015725283 |

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# VII. Questions