Study Committee D2

Information Systems and Telecommunication

Paper 10182_2022

APPLICATION OF ARTIFICIAL INTELLIGENCE TOOLS FOR OPTIMIZED MAINTENANCE SCHEDULING BASED ON ASSET MANAGEMENT CONCEPTS

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Motivation

Innovative tool for optimized planning, based on:

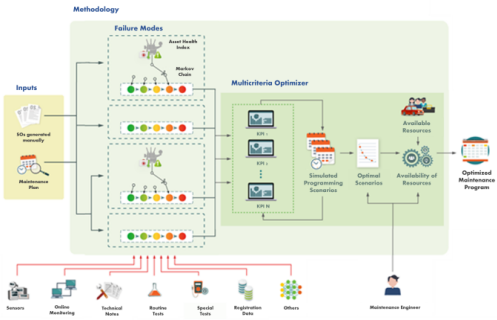
- Asset condition: online data, tests, defects, maintenance, etc.;
- Relative importance: criticality for the system and for the utility;
- Asset management concepts according to ISO 55001 and PAS 55;
- Availability of resources.

Objectives

Methodology and Intelligent Software for optimized maintenance planning of HV substation equipment:

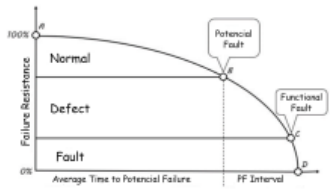
- Optimize and automate the planning and scheduling of Service Orders (SO) scheduling
- Get maximum return from asset functions
- Reduce Operation & Maintenance (O&M) costs
- Increase reliability, availability and security
- Meet regulatory requirements.

Methodology



Asset Condition

- Represented by the state of each of its failure modes, which are modeled by Markov chains and P-F curves:



Risk Indicators

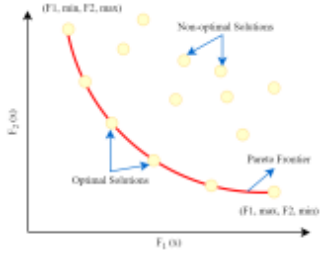
- From the Markov chains it is possible to model Risk indicators, which represent the impact of maintenance actions on organizational goals

$$\bar{C}(\bar{F}) = \bar{C}_{NOR}\bar{F}_{NOR}(\bar{F}) + \sum_{i=1}^{n_{DEFECTS}} \bar{C}_{DEF_i}\bar{F}_{DEF_i}(\bar{F}) + \bar{C}_{FAULT}\bar{F}_{FAULT}(\bar{F})$$

$$I(t_i) = \frac{i_{actual}\,P_{normal}(t_i) + \sum_{i=1}^{n_{intermediate}} i_{intermediate}\,P_{intermediate}(t_i) + i_{final}\bar{P}_{final}(t_i)}{\int_0^{t_i} P_{actual}(t)\,dt}$$

Multicriteria Optimizer

- Find the best “t” values, i.e. the best dates for the next maintenance, with a multi-criteria or multi-indicator optimization problem represented by a Pareto optimal curve:



Resource Allocation

The allocation of resources is then carried out, which considers:

- The priority of each SO, defined by its impact on the indicators;
- The optimal date of each OS, seeking to shift it as little as possible.

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Online Monitoring Pilot

Online Monitoring pilot installation in 4 pieces of equipment distributed in 3 substations:

- 1 transformer with tap changer;
- 1 transformer without tap changer;
- 1 circuit breaker; and
- 1 disconnector switch.

Success Case

- On December 10th, 2020 the installed Bushing Monitor indicated the Tangent Delta Alarm;
- Tests were performed on the bushing and it was found that it really had altered values of tangent delta;
- The bushing was replaced, preventing the defect from evolving into failure with a possible explosion and fire.

Results

- Experimental application in 12 power transformers, programming 24 Service Orders:

Probabilities	Original programming	Optimized programming	Result	
Cost	R$ 202 k/year	R$ 52 k/year	-74%	- 150 k/year
Unavailability	0.8877%	0.2861%	-68%	- 52 hours/year

- Estimated extrapolation for 96 power transformers:

Probabilities	Original programming	Optimized programming	Result	
Cost	R$ 1600 k/year	R$ 416 k/year	-74%	- 1184 k/year
Unavailability	7.1016%	2.2888%	-68%	- 421 hours/year

Software Development Plataform

- Asset Management Plataform Sigma EAM®

Intelligent Software

Conclusion

The innovative products generated in this project provide:

- High impact on Asset Management, allowing intelligent optimization of:
  - ✓ Cost,
  - ✓ Performance and
  - ✓ Risk
- Optimization based on:
  - ✓ Present asset conditions, determined by online monitoring, offline tests and inspections,
  - ✓ Probability of future conditions occurrence based on statistical data and maintenance data,
  - ✓ Key Performance Indicators selected by the utility according to its strategic goals
- High applicability throughout the electricity sector: Distribution, Generation and Transmission assets
- Full compliance with regulatory requirements: Originality, Applicability, Relevance and Reasonability.

This paper presents the main results of the project PD-05160-1804/2018 - Multicriteria Methodology and Intelligent Software for Optimized Maintenance Planning, proposed and financed by Neoenergia Distribuição Brasília and regulated by the ANEEL Program for "Research and Technological Development of the Electric Sector".