Foresight Acoustic Inspection System

Eren Can Gungor

Prof.Brett Smith[1], Prof. Tyrone Fernando[2] & Prof. Herbert Iu[2]
1. Business School
2. School of Electrical, Electronic and Computer Engineering
The University of Western Australia

Aleksandar Klisaric
CEED Client: Northpower

Abstract

Maintaining continuous power generation and a stable network is important. Electrical inspection is the primary tool for maintaining a reliable and stable network. The Foresight Acoustic System (FAIS) that has been introduced by Northpower claims to provide improved performance compared to traditional inspection methods. This project will investigate the benefits of using the FAIS product from both a technical and commercial perspective. The technical focus will consider the advantages and disadvantages of the FAIS over traditional electrical fault inspection systems. The commercial focus is on creating a financial model that investigate the profitability of the FAIS from a commercial perspective.

1. Introduction

With increasing concerns about continuous power generation and network reliability, more and more utility companies and inspection/maintenance service providers have begun to investigate a solution for a more reliable and safer power network (Australian Energy Commission Operators, 2017). According to interviews that were conducted with leading traditional inspection manufacturers, utility companies in Australia are mostly using traditional inspection methods such as thermal imaging, corona cameras, visual inspection and partial detectors to conduct electrical fault inspection. However, traditional inspection systems fail to provide reliable and safer power network (Department of Premier and Cabinet, 2009). One of the main reasons for traditional inspection systems providing inadequate inspection is their poor performance on detecting electrical defects on transmission and distribution lines (Department of Premier and Cabinet, 2009).

This project examines the applicability of an acoustic inspection system, Foresight. A business case for the implementation of Foresight Acoustic Inspection System (FAIS) will be developed from financial and technical performance data.

2 A Study of the Inspection Technologies

The current Australian power network uses several different types of traditional inspection systems.Interviews with leading thermal imaging camera manufacturer and PD Detector revealed that the common inspection systems in use are:

- Thermal Imaging
- Corona Cameras
- PD Detector
- Visual Inspection

2.1 Foresight Acoustic Inspection System

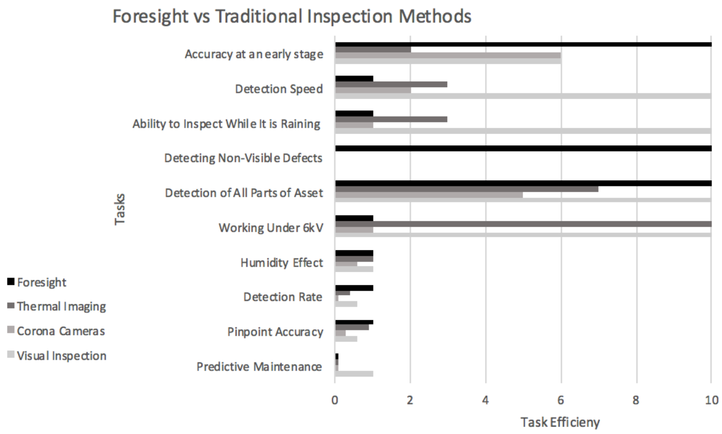
Developed by UIT Networks in 2009 for the Korean Electricity Network, FAIS is a relatively new system. The system uses acoustic inspection to detect electrical defects on substation, transmission and distribution lines. Table one presents the advantages and disadvantages of FAIS uncovered by a comparative study of the technologies.

Inspection System	Working Principle	Advantages	Disadvantages
Corona Cameras	Measures the physical phenomena known as corona discharge	Detect Corona Particles	Only detects corona particle discharges Can not detect defect less than 33 kV Sharp points and flaws can be mistaken for Corona Particles
Visual Inspection	Uses raw human senses such as vision and hearing to conduct ir	Can inspect while it's raining	Open to human error Can only be seen from one distance at a time Unable to detect hiddent or slowly developing defects Slow
Thermal Imaging	Uses IR (Infrared Radiation) to detect the electrical defects	Shows hot spots at joint failures	Primarily works on joints Requires full-load partial discharge detection Detects defects at late stage degradation Low defect detection ratio
FAIS	Uses Acoustic Inspection System to detect defects	Pinpoint Accuracy High Efficiency and fast inspection Directional Method High Defect Detection rate Detect any type of electrical fault	Could not inspect while it's raining Switchboard can be inspected only when they are open

Figure 1 Advantages and Disadvantages of FAIS and Traditional inspection systems.

2.2 Technical Results

A comprehensive technical study has been undertaken to assess FAIS and traditional inspection systems. Figure 1 summarises the most common tasks that inspection systems need to accomplish to provide optimum service. Several tasks and their corresponding task efficiency can be seen in Figure 1 below. Tasks that were selected for the technical results have been chosen based on technical analysis, interviews with several manufacturers and literature review. Task efficiency of the each task represents the technical capability of the inspection to conduct that specific task.



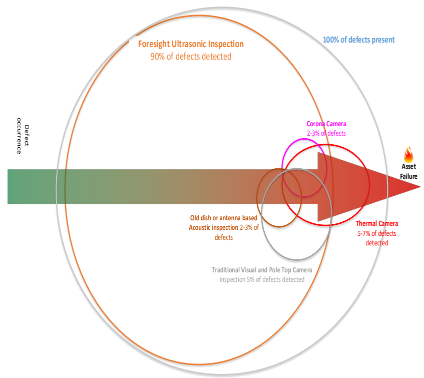


Figure 2/3 Technical Evaluation of Inspection systems.

Figure 2 (left) shows the results from the technical analysis, which show that in all but one area, FAIS performed better than traditional inspection systems. These results are not only important from a technical standpoint but also lays the foundation for financial evaluation of the application of the FAIS.

Figure 3 (right) depicts the comparative capabilities of traditional inspection methods such as corona cameras, thermal imaging camera and visual inspection. Whilst traditional inspections have a limited detection capability of up to 5% of the possible defects (i.e defects around joints), Foresight has the capability to detect wide range of electrical defects such as cable terminations, capacitor banks, lighting arrestors, conductors, midspan joints and insulators along with all the defects detected by traditional inspection methods. Whilst Foresight provides asset owners with an increased pool of defects to assess, often at early-stage of degradation, it also provides an ability to implement a maintenance strategy earlier in a degradation cycle and adopt a preventive maintenance strategy. This in turn results in decreased maintenance cost.

Detection Rate and accuracy will increase the number of defects identified by inspection systems. Detection rate and accuracy will directly correlate with the number of faults. As faults occur from late-stage derogated defects, the increased detection rate of defects prevents the occurrence of faults.

3. A Financial Analysis of an Acoustic Ispection Instrument

In this section a fault probability model is introduced. The model is based on empirical evidence of the fault detection rates by traditional inspection methods and Foresight as well as the probability that a fault will eventuate in a failure on the network (data was collected on a maintenance network and is confidential). The results from the fault probability model permits financial analysis on the two detection methods. The costs considered are inspection costs, asset repair and replacement costs in the event a fault being detect and the risk cost associated with a failure.

Probability of Fault Occurrence has been constructed by following the steps below;

- **Data Collection**
  Current fault occurrence data compromises of number of defects, number of faults, number and number of poles. The data from the client has been collected during a study of 6138 assets, 11kV feeders and number of substation assets, over period of six years using mixture of traditional inspection methods and FAIS. Data has been provided
- **Data Analysis**
  Data will be analyzed by calculating initial probabilities for defects and faults. From there, next fault occurrence will be calculated.
- **Application of Analyzed Data**
  Once the next fault occurrence has been calculated, this fault occurrence can be applied on more sites to draw a general and more reliable result.
- **Applying calculated probabilistic fault value on cost of maintenance, inspection, and cost of repairing fault**

Years	Poles	Site Defects	Faults Calculation per 500 pole	Defect Calculation	Fault Calculation
2011	6138	110	11	0.017	0.1
2012	6138	72	6	0.011	0.0833
2013	6138	124	15	0.02	0.12
2014	6138	108	21	0.0175	0.19
2015	6138	234	11	0.038	0.0017
2016	6138	195	10	0.031	0.0016

Table 1 Defect and Fault data from Client

Table 2 shows the initial setup of the fault occurrence model. It highlights all the given inputs and initial probabilities for faults and defects. Client data uses traditional inspection systems from 2011 to 2016. On years 2013 and 2015, FAIS became main inspection methods for the Client data. A significant decrease in Fault occurrence is evident in 2015 due to higher detection rate achieved using FAIS.

Total cost of inspection system usage will be calculated by following steps;

- Cost of Inspection = Cost of Inspection * Defect Presence Probability (eq1)
- Cost of Detecting Defects =Cost of Detection *Detecting Defect Probability (eq2)
- Cost of Fault = Cost of Repairing * Fault Presernce Probability (eq3)

- Total Cost = Cost of Inspection + Cost of Detecting Defects + Cost of Fault (eq4)

Calculated probabilities and associated costs will be used in the PALISADE Decision Tool and results will be presented schematically as a Tree Diagram. Total cost will be presented under the decision section in the tree diagram.

3.1 Financial Results

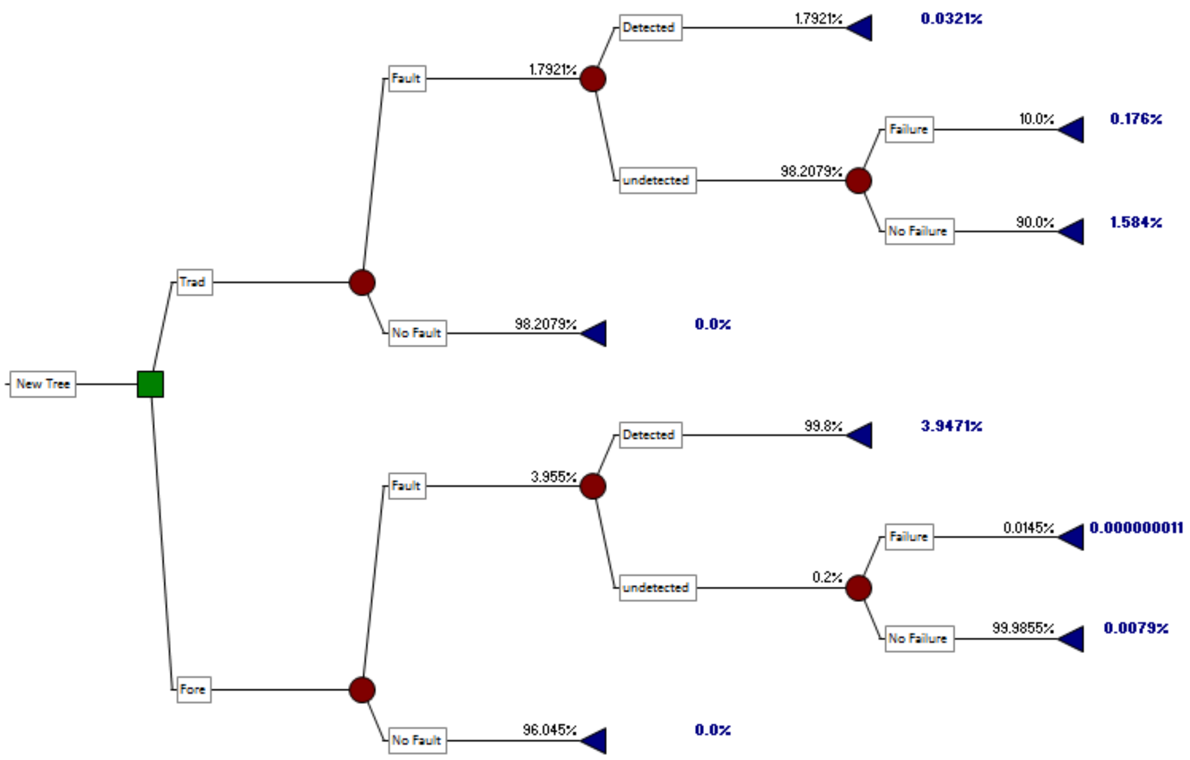


Figure 4 Palisade Decision Tool Next Probability Occurrence and Cost Result.

The decision tree presented in Figure 4 organises the probabilities from table one into branches of conditional probabilities. The joint probability is given in triangle. For example the probability a failure occurs is the product of a fault being present, the inspection instrument not detecting the defect and the defect results in a failure on the network. It can be seen that probability of fault occurrence is nearly 0%. It can be said that the crux of the financial analysis is cost of failure on the network.

The first branch has a possibility of 1.7921% defect presence for given client data. The second branch of the tree diagram has the probability of defect detection. Defect detection probability for Traditional Inspection System is 1.7921%. On the other hand, FAIS for the same branch has 99.8% defect detection rate. . When traditional inspection tools are used the probability of a failure on the network is 0.176 and less than 0.0145 when an acoustic technology is used. Fault probability for Traditional system is 0.176% while it is 0.000000011

Tree-Diagram above which obtained by using PALISADE Decision Tool shows the total cost of using Foresight versus Traditional Inspection Systems. Based on given data by the CEED

Client, early results suggest that Foresight is 46% cheaper to use. This can be mainly attributed to the technical advantages of Foresight Acoustic Inspection System.

4. Conclusions and Future Work

Overall current results demonstrate that FAIS is a financially better option than traditional inspection systems due to pinpoint accuracy and detection rate. Several assumptions have been made while conducting financial analysis. The author assumed that FAIS system would have 0.002% error margin while detecting defects and cost of maintenance for both FAIS and Traditional Inspection Systems. Future work will include more defects and faults data from more sites and cost analysis for fault repair once the cost of the fault has been obtained. Asset Management plan is also not included here. Further savings maybe be made by classifying faults and setting up asset maintenance and replacement programs. This will draw a bigger picture and more precise results for the project. Additionally, the sensitive analysis will be conducted to show breakeven point for the cost of maintenance versus the cost of repair.

5. Acknowledgements

The author would like to express his appreciation for the support from supervisors and client, Herbert Iu, Tyrone Fernando and Brett Smith and Aleksandar Klisaric. Also the author would like to special thanks to Eileen Wiryadinata for constant moral support throughout this project.

6. References

Australian Energy Market Commission. (2014).[online] Available at:http://www.aemc.gov.au/getattachment/c401957a-f86d-43c6-89c8-46d9fe61dee6/Draft-Report.aspx [Accessed 14 May 2017]

Department of Premier and Cabinet. (2017). Final Report. [online] Available at: http://www.royalcommission.vic.gov.au/finaldocuments/summary/PF/VBRC_Summary_PF.pdf [Accessed 2 Sep. 2017]

G. Stojadinovic and I. Woo, "Acoustic Inspection of Transmission and Sub-Transmission Power Lines", in *CEPSI*, Bangkok, 2016

Snell, J. and Renowden, J. (2000) 'Improving results of thermographic inspections of electrical transmission and distribution lines', *2000 IEEE ESMO - 2000 IEEE 9th International Conference on Transmission and Distribution Construction, Operation and Live-Line Maintenance Proceedings. ESMO 2000 Proceedings. Global ESMO 2000. The Pow*, pp. 135–144. doi: 10.1109/TDCLLM.2000.882811

U.S Department of Energy. (2017). *Thermographic Inspections | Department of Energy*. [online] Available at: https://energy.gov/energysaver/thermographic-inspections [Accessed 13 May 2017]