REDIN Revista Facultad de Ingeniería Universidad de Antioquia

No.116, pp. 57-65, Jul-Sep 2025

UNIVERSIDAD DE ANTIOQUIA 1803

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Failure-Risk clustering of power transformers

Agrupación de transformadores de potencia según su riesgo de falla

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CITE THIS ARTICLE AS:

J. Zúñiga-Balanta, G. Coria and A. A. Romero-Quete. "Failure-Risk clustering of power transformers", *Revista Facultad de Ingeniería Universidad de Antioquia*, no. 116, pp. 57-65, Jul-Sep 2025. [Online]. Available: https://www.doi.org/10.17533/udea.redin.20241144

ARTICLE INFO:

Received: February 09, 2024
Accepted: November 25, 2024
Available online: November 26, 2024

KEYWORDS:

Asset management; consequence factor; health index; maintenance; power transformer

Gestión de activos; índice de salud; mantenimiento; transformador de potencia consecuencia de falla

ABSTRACT: When assessing the risk of power transformer (PT) failure, routine test results can be used to estimate the condition of each unit and group those that share similar issues. Since the transformer is one of the most expensive and essential components within a power system, this study aims to present a methodology for grouping PTs with similar health problems and Consequences of Failure (CoF). This document presents two grouping options to identify which provide greater benefit in defining the maintenance scheme. To evaluate the CoF, the consequence factor found in the United Kingdom Distribution Network Operators (DNO) methodology is used, which considers factors such as overload to other assets, average load supplied by the unit, critical loads fed, oil volume, proximity to other buildings, and unavailability penalties, among others. This approach is evaluated on a fleet of 39 power transformers. The results show that the combination of the Health Index (HI) and the Consequence Factor leads to consistent indices for risk assessment of the units.

RESUMEN: Al evaluar el riesgo de falla de los transformadores de potencia (PT), se pueden utilizar resultados de pruebas de rutina para estimar el estado de cada unidad y agrupar aquellas con problemas similares. Dado que el transformador es uno de los componentes más caros e importantes dentro de un sistema de potencia, el objetivo de este estudio es presentar una metodología para agrupar PTs con problemas de salud y consecuencias de falla (CoF) similares. En este documento se presentan dos opciones de agrupación para identificar cuál ofrece mayores beneficios a la hora de definir el esquema de mantenimiento. Para evaluar las CoF, se utiliza el factor de consecuencia encontrado en la metodología de gestores de redes de distribución (DNO) del Reino Unido, que considera factores como sobrecargas a otros activos, carga media suministrada por la unidad, cargas críticas alimentadas, volumen de aceite, proximidad a otros edificios y penalizaciones por indisponibilidad, entre otros. Esta propuesta se evalúa en una flota de 39 transformadores de potencia y los resultados muestran que la combinación del índice de salud (HI) y el factor de consecuencia conduce a índices consistentes para la evaluación del riesgo de las unidades.

1. Introduction

Transformers are a crucial component of electrical networks, playing an important role at the generation, transmission, and distribution levels. Power transformers (PTs), which connect transmission and sub-transmission networks, typically have nominal ratings ranging from tens to hundreds of MVA [1]. PT fleets can consist of hundreds of units, each costing approximately 60% of the cost of a transformation bay [1].

Determining the optimal time to replace or maintain a unit before it causes significant failures is essential. This must be done in a timely and efficient manner to avoid unnecessary service interruptions. Various types of maintenance for PTs have been described in the literature, along with estimated optimal time intervals for their execution [2–5]. Performing time-based maintenance at the same frequency for transformers with different conditions can result in unnecessary inspections or unexpected failures, both of which can be costly.

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ISSN 0120-6230
e-ISSN 2422-2844

Therefore, it is important to classify PTs into groups based on their condition.

In [6], the Dissolved Gas Analysis (DGA) is used in a risk matrix to compare the asset condition and the consequence of a potential failure. This comparison is utilized to determine which units require maintenance. Two years later, authors in [7] developed a risk assessment model based on asset conditions using Markov chain analysis. This analysis has also been employed in previous studies [8–11], in which asset condition data is used to determine the future condition of the asset. This method has the advantage of using data from a short period of time for evaluation. By using Markov chains, the optimal time interval for maintenance can be determined, ensuring maximum asset availability.

One method for defining the maintenance scheme is by using weights or weightings. In [12], the value of transformer aging acceleration is calculated using temperature hot spots, the health index (which employs input parameters such as DGA, furans, load history, and transformer age), and the history of failures and maintenance. Each factor is assigned a specific weight. This information is then used to optimize maintenance programs in order to minimize the number of outages and interventions. The weightings are used to optimize maintenance programs that minimize outages and interventions.

In [13], the authors propose a maintenance method based on equipment life cycle cost. The methodology incorporates variable weights reflecting the impact of repairs on the equipment. It allows determining whether to replace or maintain the equipment based on life cycle cost and failure rate.

Moreover, studies have been conducted with the objective of developing maintenance planning strategies that consider both the HI of the transformer and the economic consequences. In [3], an optimization algorithm is employed to determine the most appropriate type of maintenance to perform, considering the time and cost involved and the service output. In contrast, [14] employed DGA to evaluate 950 transformer history data for asset condition determination and to establish the optimal time for performing maintenance.

It is important to note that determining the health status of a transformer is crucial. This is because in the event of a major failure, replacing one of the units that are over 100 MVA can take up to one or two years to produce, depending on the availability of manufacturers, and cost approximately two million dollars [15]. The Condition of Failure (CoF) is crucial in assessing the risk of units in the event of a potential occurrence, similar to the importance of health status.

The paper presents a tool that utilizes clustering with the k-means algorithm and expert criteria to determine optimal solutions. Section 2 outlines the indicators utilized to estimate the overall risk associated with each asset. Section 3 presents the problem and methodology, while Section 4 covers the case study. Finally, section 5 provides the conclusions.

Risk estimation in power transformers

Risk assessment in power transformers involves evaluating the probability of failure and the consequences of unavailability [16]. The calculated value may change over time as the transformer ages and the operating environment of the asset changes.

1.1 Failure consequence factor

The consequence factor aims to assign a numerical value to the potential consequences of a failure from various perspectives, recognizing that all assets will eventually fail. This factor may consider equipment safety, environmental safety, personnel safety, environmental damage, production impacts, delays in meeting objectives, corporate image, and other factors.

1.2 Power transformer health index

The Health Index (HI) is an objective indicator of the functional condition of the power transformers (PTs). It is used to prioritize corrective actions such as maintenance activities or asset replacement. The HI is calculated by processing the data obtained from tests performed on the unit. It serves as a reference value to establish a list of transformers according to their condition.

2. Problem description

The unavailability of PTs can result in reliability issues, failures, and significant costs due to supply interruption, congestion, and instability [17]. Additionally, the acquisition of PTs is capital-intensive, making them critical assets for any power system [18, 19]. In light of the aforementioned considerations, it is possible to define the risks associated with PTs and to implement risk-based management. Several transformers currently in use in electric power systems are approaching or exceeding their expected technical lifetime of approximately 40 years [15, 20], indicating a high risk of failure. In addition to the risk posed by their age, there are other important issues to consider, such as the risk of explosion, environmental problems resulting from oil loss, power losses, and technological obsolescence. To manage risks, it is crucial to know both the HI and the CoF of the units within PTs. The fleets consist of dozens or hundreds of units, making it crucial to classify assets with similar risks for efficient and safe management.

2.1 Evaluation of health index in power transformers

In [21], authors present a tool for determining the HI of units ranging from 69 kV to 230 kV. The tool integrates indicators or measurements related to the condition of the paper oil insulation system. This is because paper insulation is not amenable to any form of maintenance, making it suitable for calculating the useful life of transformers. The same parameters will be employed to determine the HI of each unit. The HI will be calculated based on the weights assigned to each measurement, resulting in a final calculation of the health of each asset. The weights used are obtained from various HI calculation references and are suggested by experts based on the significance of each test in determining the accelerated aging of the PTs.

2.2 Proposed system for estimating the health index

The methodology selected groups three modules to obtain individual health indexes, which are then used to calculate a total health index. Figure 1 describes the tests used to calculate each index.

The HI for physicochemical tests provides information related to the quality of the oil, indicating its physical and mechanical conditions. It is obtained from the following tests:

- Dielectric strength - 2 mm gap [kV]
- Oil moisture content [ppm]
- Acidity [mg KOH/g]
- Dissipation factor - 25 °C [%].

These tests are weighted as shown in Table 1, which is taken from IEEE C57 106-2015 [22]. Equation 1 is used to calculate the oil quality factor (OQF), where Si is the evaluation score of each test result and Wi is the weighting factor associated with its importance.

$$OQF = \frac{\sum_{i=1}^{4} S_i \cdot W_i}{\sum_{i=1}^{4} W_i} \quad (1)$$

For dissolved gas tests, gas concentration is evaluated through DGA using the methodology of linear combination of gases described in Table 2.

The DGA factor is calculated using Equation 2, where Si represents the evaluation score of each test result and Wi is the weighting factor associated with its importance.

$$DGAF = \frac{\sum_{i=1}^{7} S_i \cdot W_i}{\sum_{i=1}^{7} W_i} \quad (2)$$

The degree of polymerization (DP) decreases proportionally with the increase of furan compounds dissolved in the oil, particularly 2-furaldehyde (2-FAL), which accounts for over 90% of the furans and is the primary indicator of transformer solid insulation. Equation 3 presents the Chendong model, which is currently one of the most widely used models to relate the concentration of the furanic compound (2-FAL) to the PD value.

$$DP = \frac{1,51 - \log_{10}(2FAL_{ppm})}{0,0035} \quad (3)$$

Where,
DP = Degree of Polymerization [dimensionless]
2FAL = 2-furaldehyde content [ppm].

For furan testing, IEEE C57.140-2017[23] specifies that oil in good condition should have at least a 2-FAL content of 0.1 ppm (100 ppb), with the acceptance limits for furan content in oil presented in Table 3.

2.3 Evaluation of the consequence factor in power transformers

The consequence factor assesses the CoF for each unit in the transformer fleet across four categories: financial, safety, environmental, and network performance. The estimation methodology for the consequence factor follows the approach outlined by [24], which assumes a reference cost for each type of asset and estimates the impact of its failure. The methodology proposed here adjusts reference costs based on modification factors that consider the condition of the asset. The aforementioned factors are contingent upon the quantity of load affected or the number of connected customers, in addition to the proximity of the transformer to environmentally sensitive areas, such as rivers, streams, and lakes. The methodology is applicable to transformers with maximum voltages of 132 kV and can serve as a reference for equipment operating at higher voltages.

The CoF of a transformer is determined by adding the consequence factor of each category described in Equation 4. This reflects the impact and social cost of a failure.

$$\text{CoF} = \text{Financial}_{CF} + \text{Safety}_{CF} + \text{Environmental}_{CF} + \text{Network}_{CF} \quad (4)$$

The factor produces a monetary value in pounds (£) for listing assets based on their criticality, measured relative

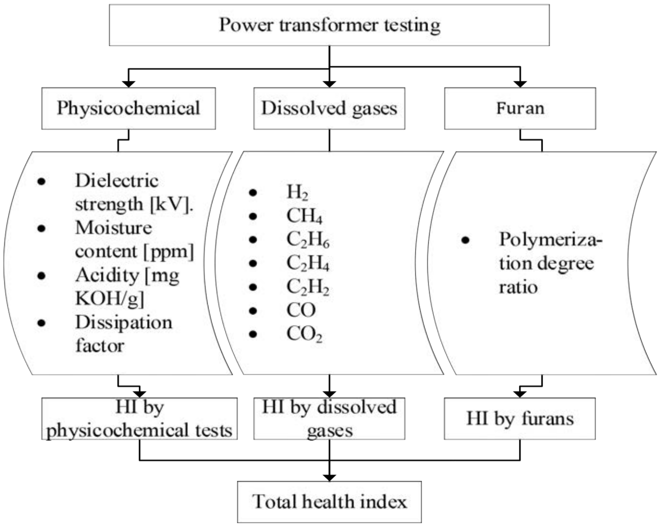


Figure 1 Health index scheme

Table 1 Physicochemical test limits

Tension level	U<=69 kV		69 kV < U < 230 kV		Score (Si)	Weight (Wi)
Dielectric strength - 2mm gap [kV].	>=	45	>=	55	1	
	40-45		47-55		2.5	3
	<=	40	<=	47	4	
	<=	20	<=	10	1	
Moisture content [ppm]	20-35		10-25		2.5	4
	>=	35	>=	25	4	
	<=	0.03	<=	0.03	1	
Acidity [mg KOH/g]	0.03-0.2		0.03-0.15		2.5	1
	>=	0.2	>=	0.15	4	
Dissipation factor - 25 °C [%]	<=	0.05	<=	0.05	1	
	0.05-0.5		0.05-0.5		2.5	3
	>=	0.5	>=	0.5	4	

to the average of assets of the same type using CoF. This calculation is explained in [24].

2.4 Power transformers grouped by risk index

This document proposes two methods for grouping power transformers within the fleet based on the HI parameters and CoF of each equipment. In Case 1, the proposed system evaluates each test individually to obtain the HI (physicochemical, dissolved gases, and furans). The measured values are then normalized, especially since the gas values typically have four or more digits, while oil quality measurements often include decimal values. These normalized values are compared with the consequence factor of each unit in USD to group units with similar measurements. The k-means algorithm is then applied to identify which units have similar measurement results and CoF.

In Case 2, to group similar units, the HI percentages of the physicochemical, dissolved gas, and furan tests are used in addition to the criticality index of the CoFs. These percentages are calculated as follows:

Health index as a percentage of physicochemical tests

Using the data in Table 4 and Equation 1, the Oil Quality Factor (OQF) is obtained. The OQF Score ranges from 1 to 4, with 1 being the best condition and 4 indicating a critical state. To obtain an output between 0 and 100, a mathematical transformation is performed on the HI using Equation 5.

$$HI_{OQF[\%]} = 100 - \left\lceil \frac{(OQF-1)\cdot 100}{3} \right\rceil \quad (5)$$

Health index as a percentage of DGAF

The HI for oil-dissolved gases is obtained using the result from Equation 2 and the information in Table 5

The DGAF score ranges from one to six, with one representing the best condition and six indicating a critical

Table 2 Dissolved gas limits

Gas [ppm]	Score (Si)						Weight (Wi)
	1	2	3	4	5	6	
H2	≤100	(100 – 200]	(200 – 300]	(300 – 500]	(500 – 700]	>700	2
CH_4	≤75	(75 – 125]	(125 – 200]	(200 – 400]	(400 – 600]	>600	3
C_2H_6	≤65	(65 – 80]	(80 – 100]	(100 – 120]	(120 – 150]	>150	3
C_2H_4	≤50	(50 – 80]	(80 – 100]	(100 – 150]	(150 – 200]	>200	3
C_2H_2	≤3	(3 – 7]	(7 – 35]	(35 – 50]	(50 – 80]	>80	5
CO	≤350	(350 – 700]	(700 – 900]	(900 – 1100]	(1100 – 1400]	>1400	1
CO_2	≤2500	(2500 – 3000]	(3000 – 4000]	(4000 – 5000]	(5000 – 7000]	>7000	1

Table 3 Furan content ranges

Condition	2-Fal [ppb]	HI-Furan
Good	≤1000	4
Acceptable	1000 – 2000	2
Bad	≥ 2000	0

Table 4 Oil health index

OQF		
Condition	**Description**	**HI-OQF**
Good	OQF < 1.2	4
Acceptable	1.2 ≤ OQF < 1.5	3
Precaution	1.5 ≤ OQF < 2	2
Poor	2 ≤ OQF < 3	1
Very poor	OQF ≥ 3	0

Table 5 Dissolved gas health index

DGAF		
Condition	**Description**	**HI-OQF**
Good	DGAF < 1.2	4
Acceptable	1.2 ≤ DGAF < 1.5	3
Precaution	1.5 ≤ DGAF < 2	2
Poor	2 ≤ DGAF < 3	1
Very poor	DGAF ≥ 3	0

Table 6 Weights for Transformer Health Index

Index	Weights (Ki)
HI_{DGAF}	10
HI_{OQF}	6
HI_{FURAN}	5

Table 7 Total health index in power transformers

Total transformer health index HI_{TOTAL}	Condition
HItextsubscripttotal > 75	Good
50< HI_{total} ≤ 75	Follow-up
30< HI_{total} ≤ 50	Bad
HI_{total} ≤ 30	Critical

state. To convert the index into a percentage output, a mathematical transformation is performed using Equation 6.

$$HI_{DGAF[\%]} = 100 - \left\lceil \frac{(DGAF-1)\cdot 100}{5} \right\rceil \quad (6)$$

Health index as a percentage of furan

The oil's furan content score can take on values of 0, 2, or 4. Equation 7 is used to calculate the percentage of furan, where RHI-FURAN represents the furan index value and $R_{HI\text{-}fURAN}$ represents the percentage of furan content HI.

$$HI_{FURAN[\%]} = \frac{R_{HI-FURAN}\cdot 100}{4} \quad (7)$$

Total health index as a percentage

The power transformer's overall health index (HITotal[%]) is determined by combining the percentages of the previously calculated indexes for physicochemical tests, dissolved gases in oil, and furan content. Equation 8, which utilizes the weights specified in Table 6, is used to calculate the total HI.

$$HI_{\text{Total }[\%]} = \frac{\sum_{j=1}^{3} K_j \cdot HI_x}{\sum_{j=1}^{3} K_j} \quad (8)$$

Table 7 is used to define the ranges for the power transformer's total health index (HITOTAL). After calculating the $\mathbf{HI_{TOTAL}}$ of each transformer versus the CoF in USD, the grouping of units with similar conditions is performed using the k-means algorithm, which minimizes the sum of the distances between each PT and the centroid of its group, in this case using the Euclidean distance as the grouping criterion.

3. Case study

Following the approach proposed in the previous section, a PT fleet composed of 39 machines has been analyzed. A clustering analysis was conducted on the presented cases for the fleet in question, dividing it into four groups using the Elbow method, as shown in Figure 2a for Case 1 and Figure 2b for Case 2. In both cases, the number of clusters was selected to stabilize the variability, as the units within each group were intended to be homogeneous, but the clusters themselves were heterogeneous. This is consistent with the classification presented in the total health index, which includes categories such as good, follow-up, bad, and critical.

3.1 Results and discussion

After evaluating each case, the clusters of Table 8 for Case 1 and Table 9 for Case 2 are obtained. The following are the results for the four clusters and the number of transformers belonging to each cluster.

Upon analysis of Case 1, it was determined that there were no discernible differences between the four k-means groups with respect to acidity, dissipation factor, and the gases. This indicates that these variables may not be pertinent to the formation of cluster and, as consequence, may not be useful for the individual stratification of transformer risk. This represents a significant degree of uncertainty when using this classification method.

In Case 2, the status of the transformer's evaluated parameters is more discernible, with a p-value of less than 0.001. This indicates that the groups have been correctly formed and that the PTs within each group can be differentiated according to their characteristics.

Figure 3 depicts the divergence between the two groups in Case 1, presented on a two-dimensional plane. The x-axis represents the value of the disaggregated (normalized) tests, while the y-axis depicts the CoF in USD. Case 2 is depicted in Figure 4, where units are grouped by their HI from best to worst (100-HI) and by the consequence of failure in monetary representation as defined by DNO [24]. Figure 3 was created for comparison with Figure 4, allowing for the identification of transformers considered at different risk levels between cases. The grouping is based on state and cost, representing the various failures of each unit. This allows for a more complete understanding of the reasoning behind the clustering of units, with Euclidean distance being one of the determining factors.

These representations provide information on the status and risk of each unit in the PT fleet. They are useful for classifying equipment based on future maintenance needs, identifying units that require immediate attention, and managing future maintenance. The information can be used to plan future maintenance activities.

Table 10 presents the number of PTs identified in different risk levels for Cases 1 and 2. The table illustrates that although PTs in the same risk group exist in both cases, there are significant differences. In Case 1, all tests have equal importance, while in Case 2, each test has a different weight, which is more realistic. Factors such as humidity or the presence of gases are reliable indicators of the aging of these assets.

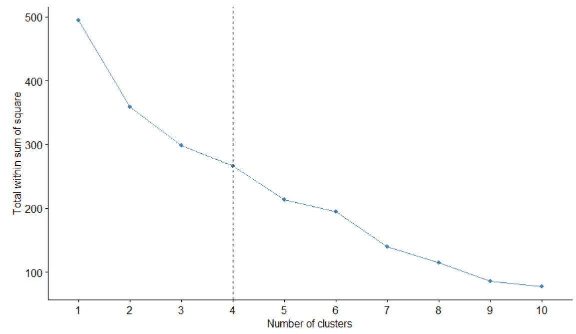
There are three specific cases in which transformers are classified into different clusters. In Case 1, the two transformers in a circle (cluster 1) belong to the same cluster as Case 2. This discrepancy is attributable to the fact that the units have different measurements in H2 and C2H6 gases. However, for the calculation of the HI of Case 2, H2 gas has a lower weight, rendering it less pertinent than other gases. Therefore, they are within the same group (cluster 4). In Case 1, the three assets in square (cluster 3) are located in the same position as in Case 2. However, they differ in the measurements of gases such as CH4 and C2H6, which indicate oil failures, as mentioned in the previous point. In Case 2, the two transformers in Cluster 3 are separated because their failure would have a more significant consequence than that of the other equipment. This prioritizes their maintenance.

The HI of Case 2 accounts for the disparities between gases, as each gas is assigned a distinct weight in the calculation of the HI based on its inherent risk. Therefore, Case 2 incorporates expert considerations that are crucial for appropriate grouping.

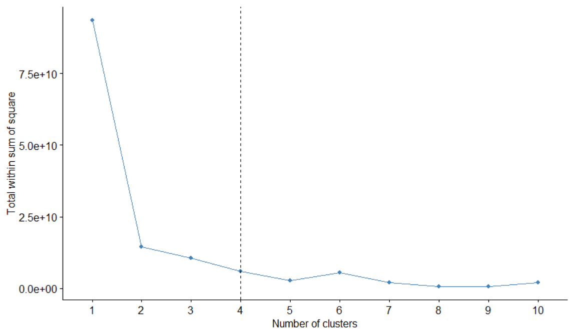
4. Conclusions

This paper evaluates two cases of power transformer clustering within a fleet. The evaluation considers different tests to determine the health status of each unit and the consequences of failure. The first case evaluates each test individually to perform the clustering, while the second case employs the strategy of calculating the HI of each unit prior to clustering.

When evaluating the parameters individually (Case 1), the cluster considers all tests with the same impact on the transformer's health, grouping assets into critical



(a)



(b)

Figure 2 Definition of the number of clusters

Table 8 Case 1 Results

Variable[a]	Cluster 1 (N=2)	Cluster 2 (N=21)	Cluster 3 (N=3)	Cluster 4 (N=13)	P valor
Moisture	8.5 (8.0 to 9.0)	11.0 (7.0 to 13.0)	18.4 (13.0 to 22.0)	21.8 (17.0 to 24.6)	0.001*
Acidity	0.005 (0.005 to 0.005)	0.006 (0.005 to 0.008)	0.007 (0.006 to 0.015)	0.011 (0.008 to 0.035)	0.006*
D. Streng	62.0 (55.0 to 69.0)	64 (57 to 67.5)	39 (26 to 64)	44 (31.5 to 51)	0.004*
Dissipation F.	0.02 (0.01 to 0.02)	0.019 (0.0105 to 0.032)	0.020 (0.017 to 0.136)	0.1088 (0.045 to 0.282)	0.011*
H_2	588.5 (263.0 to 914.0)	21 (9.85 to 30)	18.4 (8.5 to 35)	31 (6.55 to 75.5)	0.124
CH_4	54.0 (45.0 to 63.0)	21 (10.3 to 60)	248 (156 to 361)	7.1 (3.8 to 45.5)	0.008*
C_2H_6	5.7 (3.0 to 8.4)	50 (25 to 75)	545 (398 to 788)	2.5 (1.7 to 18.5)	0.033*
C_2H_4	44.0 (21.0 to 67.0)	4.5 (1.3 to 23.4)	10 (9.3 to 17.2)	25 (12.6 to 120.5)	0.048*
C_2H_2	52.5 (0.0 to 105.0)	0 (0 to 0)	0 (0 to 0)	0.6 (0 to 4)	0.017*
CO	856.5 (624.0 to 1089.0)	646 (439 to 1196)	358 (178 to 691)	246 (4 to 462)	0.087
CO_2	2291.5 (1538 to 3045.0)	4067 (1939.5 to 6244)	4918 (2758 to 5102)	3688 (3005.5 to 4431.5)	0.593
Furans	7 (0 to 14)	0 (0 to 0)	1310 (1302 to 1312)	1415 (1100 to 1671)	<0.001*

a Median and interquartile range are shown. (RIQ); * p valor<0.05.

Table 9 Case 2 Results

Variable[a]	Cluster 1 (N=8)	Cluster 2 (N=6)	Cluster 3 (N=2)	Cluster 4 (N=23)	P valor
Physical-Chemical Index	40.91 (37.5 to 75)	40.99 (31.82 to 57.95)	38.64 (22.73 to 54.54)	86.36 (81.82 to 100)	<0.001*
Dissolved Gas Index	72.22 (66.94 to 91.11)	95.55 (90.83 to 96.66)	84.44 (77.77 to 91.11)	94.44 (86.66 to 97.77)	0.025*
Furan Index	0 (0 to 0)	0 (0 to 12.5)	25 (0 to 50)	100 (100 to 100)	<0.001*
Total Health Index	28.57 (19.04 to 39.28)	52.38 (43.45 to 54.76)	33.33 (19.04 to 47.62)	76.19 (73.81 to 88.09)	<0.001*
CoF	$484911.9 (479711.1 to 487360.3)	$459866.1 (435557 to 462465.9)	$534366.3 (531856.1 t to 536876.4)	$391840.8 (379107.7 to 394351)	<0.001*

[a] Median and interquartile range are shown (RIQ); * p valor < 0.05.

Table 10 Total health index in power transformers

Case 2	Case 1				Total
	Good	Follow-up	Bad	Critic	
Good	21	2	0	0	23
Follow-up	0	0	6	0	6
Bad	0	0	5	3	8
Critic	0	0	2	0	2

risk groups that may not necessarily be critical based on the nature of the test applied. Conversely, when grouping based on the previous calculation of the HI, the classification becomes more discernible. This is because the most relevant tests, such as moisture and furan content, carry greater weight and more clearly express the cause of each unit belonging to a certain risk group.

The contribution of this work is to demonstrate the importance of performing independent calculations of total HI and failure consequences. These calculations are then used as input parameters to estimate the risk associated with each unit. The result is a conclusive

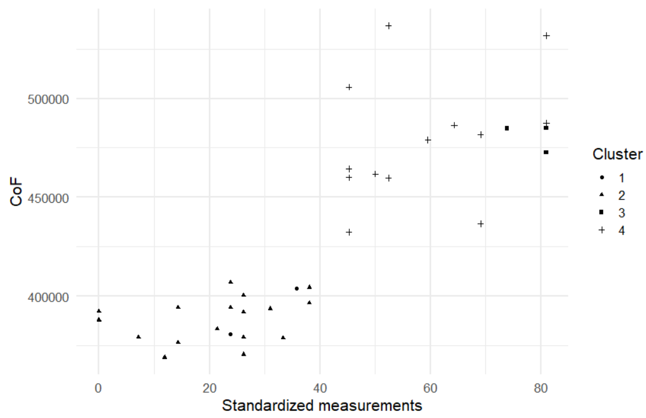


Figure 3 Risk matrix Case 1

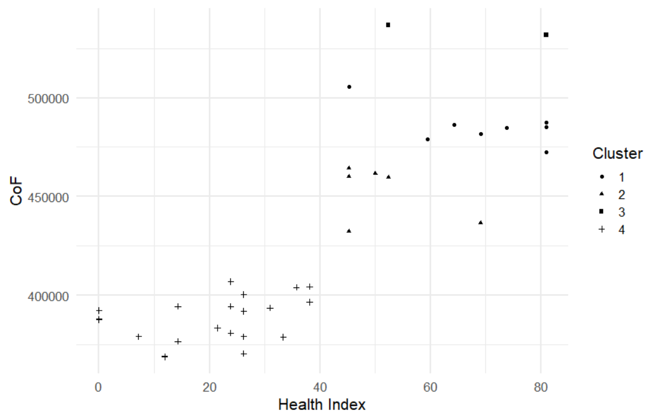


Figure 4 Risk matrix Case 2

classification that considers not only the physical-chemical state of the asset but also the financial consequences of a failure. Factors such as river flows, nearby constructions, and disconnected loads are considered. It is important to emphasize that this classification is objective and based on clearly defined criteria.

The methodology has been validated in a fleet of 39 power transformers. It has been observed that when evaluating each test performed on the equipment, it is challenging to classify the assets within a specific group. This is because units with different measurements that do not necessarily represent a high risk may be grouped together. However, by first evaluating each one by its HI and CoF, it is possible to have better control of the information and classify the assets in a more understandable range.

This work proposes a grouping method to define maintenance strategies based on the risk level of each unit. This approach can assist transformer managers in their fleet management tasks.

Declaration of competing interest

We declare that we have no significant competing interests including financial or non-financial, professional, or personal interests interfering with the full and objective presentation of the work described in this manuscript.

Funding

This research was funded by DAAD and CONICET, as well as the PDTS 2020-2022 project of the UNSJ and SECITI.

Author contributions

Jefferson Zúñiga-Balanta: Conceptualization, methodology, writing—Original draft preparation. Andrés Arturo Romero-Quete: Resources. Gustavo Coria: Resources. All authors have read and agreed to the published version of the manuscript

Data available statement

The authors have confirmed that all data, codes, and results supporting the findings of this study are available and will be provided upon request.

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