Linear Asset Management: a Case Study of Overhead Transmission Lines

Damjan Maletič, Viktor Lovrenčić, Nenad Gubeljak, Yury Tsimberg, Nuno Marques de Almeida, Ana Lovrenčić & Matjaž Maletič

University of Maribor, Faculty of Organizational Sciences, Kranj, Slovenia, e-mail: damjan.maletic@um.si..

Abstract Linear assets are defined as assets whose length plays a critical role in their maintenance Linear asset owners strive to optimize the value and performance of each asset throughout its lifecycle while meeting all of safety, reliability, quality, performance, and regulatory compliance requirements... A case study is used to present the implementation of linear asset management practices for overhead transmission lines (OHTL). More specifically, the purpose of this paper is to propose an Asset Health Index (AHI) for OHTL using a condition-based method and discuss some other monitoring methods (e.g., robot LineVue with non-destructive in-situ inspection technology for conductors and an integral online approach to ensure tower and conductor integrity - OTLM device and strain gauges). In addition, various issues, and challenges for managing linear assets are also discussed.

1   Introduction

Rapidly changing business environment, strong competition, requirements to minimise losses are some of the conditions in which organisations operate today (Pačaiová et al., 2017). This has prompted asset-intensive organisations to develop new strategies that will enable their long-term survival (Gavrikova et al., 2020). Therefore, organizations are trying to maximize value extracted from their assets by investing efficiently in asset management in order to achieve better returns for their business (Lima et al., 2021). Assets according to the ISO 55000:2014 standard for asset management are items, things, and entities that have value or potential value to the organisation (CIGRE Technical Brochure 787, 2019; ISO 55000:2014). Realising the value of assets is a holistic approach that takes into account the complexity of stakeholder expectations and gives the organisation a competitive advantage (Chattopadhyay, 2021). Physical assets, also known as engineering assets, are important in creating tangible value for an organization in a wide range of industrial settings such as manufacturing, electricity supply, water supply, construction, mining, transportation services, and various other sectors (de Almeida et al., 2021). Asset management begins with understanding the needs of the organisation in line with its business objectives to deliver goods and services reliably, safely, on time and cost-effectively (Chattopadhyay, 2021). It encompasses a wide range of disciplines and processes that cover the life cycle phases of creating, establishing, exploiting and divesting a physical asset in a balanced manner to satisfy the continuum of constraints imposed by business strategy, economics, ergonomics, technical and operational integrity, and regulatory compliance (Amadi-Echendu, 2004).

Recent research (Alsyouf et al., 2021; Lima et al., 2021; Maletič et al., 2018, 2020; Schuman & Brent, 2005) demonstrates that there is a link between asset management and improving organizational performance. However, despite the growing body of literature, there is still a lack of research on various aspects of asset management. It is widely acknowledged that asset management optimization is critical to business performance and profitability in electric power industry (Ma et al., 2014). Deregulation and increasing competition in electricity markets drive energy utilities to review their asset maintenance strategies in order to increase profitability (Côté et al., 2020). How to plan and design, operate and maintain the growing large fleet of OHTL assets in the most cost-effective

D. Maletič, V. Lovrenčič, N. Gubeljak, Y. Tsimberg, N. M. de Almeida, A. Lovrenčič & M. Maletič:
Linear Asset Management: a Case Study of Overhead Transmission Lines

587

manner is the key challenge in improving business performance associated with managing OHTLs. Consequently, the desire to know the actual condition of transmission lines is becoming increasingly more important (Velásquez & Lara, 2018). Moreover, electric utilities that manage transmission lines face challenges in doing so because very little information is available about the useful life of components comprising transmission lines (Tsimberg & Wang, 2016). To fill this gap, first this paper presents the methodology of determining actual stresses applied to the legs of the steal lattice towers of the overhead lines by using strain gauges glued to the tower legs which monitor deformations in the legs (IMOTOL - Integral monitoring of transmission overhead line systems including towers and conductors). Secondly, this paper presents the LineVue™, which uses a non-destructive in-situ inspection technology for conductors. Combining these two technologies allow utilities to have an integrated online approach to ensure the integrity of both tower and conductors.

2 Literature review

The history of asset management begins in the 1970s with the advent of terotechnology (Wijnia & de Croon, 2015). In the 1990s, awareness of the concept of asset management increased. However, there were no formal requirements until 2004, when a formal specification of requirements was developed in the form of Publicly Available Specification on asset management (PAS 55-1:2004), followed by the update version (PAS 55-1:2008) in 2008. After this release the field of asset management was covered by the ISO 55000:2014 series of standards on asset management, which was introduced in 2014 (ISO 55000:2014). ISO 55000:2014 can help organizations establish an asset management system to optimize assets.

Based on ISO 55001 asset management system requirements and review of current situation, organizations can identify gaps, analyse root causes, propose solutions, and continuously improve performance to achieve goals. It encompasses strategies and policies aimed at valuing the assets, including standards, knowledge, assessment methodologies, conceptual models and more, and is responsible for the asset life cycle (Lima & Costa, 2019).

Accordingly, prior research (Maletič et al., 2018, 2020) showed that companies can benefit from implementing an asset management system. Asset management provides many benefits such as: improved financial performance, informed investment decisions, risk management, improved services and outcomes, demonstrated social responsibility, demonstrated compliance, improved reputation, improved organisational sustainability, improved efficiency and effectiveness that directly impact the decision making process (ISO 55000:2014, n.d., p. 55000).

Asset management is an increasingly important research topic (Maletič et al., 2020; Trindade et al., 2019). Accordingly, more and more studies on asset management are also being conducted in the electricity industry in recent years (Figure 1).
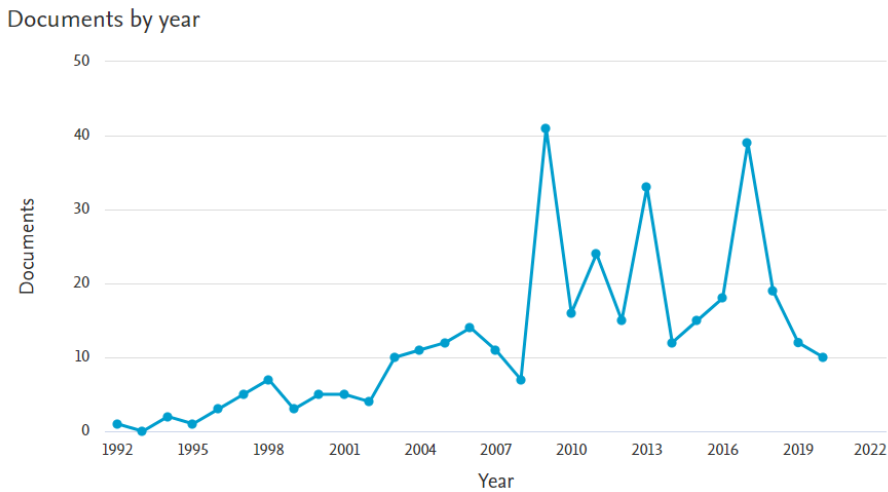
**Figure 1: Year-wise number of articles published related to asset management and
electric power industry (1992-2020)**
(source: Scopus. Search string: "asset management" AND "electric utility")

Over the last two decades, many electrical utilities have adopted asset management in pursuit of optimising value from their asset by balancing cost, risk, and performance (Komljenovic et al., 2021). One should note that in the management of overhead transmission lines (OHTL), the term Linear Asset Management (LAM) is also frequently used. LAM provides functionality that

D. Maletič, V. Lovrenčić, N. Gubeljak, Y. Tsimberg, N. M. de Almeida, A. Lovrenčić & M. Maletič:
Linear Asset Management: a Case Study of Overhead Transmission Lines

589

allows utilities to describe, display, and manage linear assets. It includes the management of the entire life cycle of OHTL from design, construction, commissioning, operation, maintenance, modification, decommissioning and disposal.

Accordingly, linear assets are technical systems with a linear infrastructure whose condition and characteristics can vary from section to section (dynamic segmentation). Transmission lines, as an integral and essential part of the transmission system, are used to transport electrical power over long distances. the main components of transmission lines are conductors, support, and transmission line accessories (Germán et al., 2014).

Transmission system is fundamental to the functioning of an energy market; it consists of the necessary assets to transport the electricity generated from the power stations over long distances to points of consumption, thus enabling the exchange of energy between production and demand (Germán et al., 2014).

Electric utilities face high financial costs in maintaining their OHTL fleet and it is critical to use consistent risk-based decision-making processes to reduce the overall cost of sustaining existing asset base and allow the assets to reach their expected useful life.

Asset management techniques are used to address optimization challenges and manage physical assets in a way that results in the lowest life cycle cost. life (Spatti et al., 2019). The business associated with the process of managing networks, such as the electricity network, is based on possessing good knowledge of the condition of assets used for transmitting, in this case electricity, to the end users so that they deliver expected performance in terms of continuity, security and management efficiency (Bosisio et al., 2019).

Furthermore, by establishing and implementing a proper asset management system, the power grid can manage the risk and continuously improve the performance thus gaining a competitive advantage, which will help improve the social image and reputation of the power grid company (Ma et al., 2014).
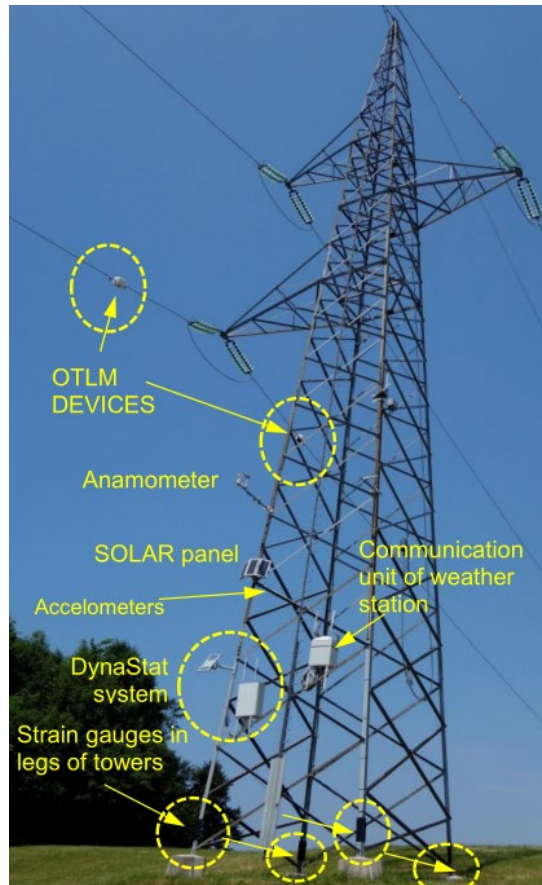
2.1   Asset health index (AHI)

An Asset Health Index (AHI) is a tool that quantifies condition of assets based by processing available condition data. The purpose of AHI is to determine condition of assets at the present time and how it changes throughout their life cycle. These input condition data can be obtained while an asset is in operation or could also come from other sources of information, such as geographic information systems, supplier reliability records, records from relevant external service providers, etc. (De La Fuente et al., 2018).

An AHI is an asset score, which is designed to reflect or characterize the asset's condition and thus, its performance in terms of fulfilling the role established by the organization. Prior studies (De La Fuente et al., 2018; Durán et al., 2020; Serra et al., 2019) have made efforts to define asset health indices. Recently, there has also been a focus on AHI (Gubeljak, Lovrenčić, Bakič, et al., 2020; Naranpanawe et al., 2020; Tsimberg et al., 2016) in relation to OHTL as well.

2.2   Contemporary approaches for monitoring the condition of OHTL

IMOTOL

Figure 2 shows the assembly of the whole IMOTOL system (UM FME has developed system), which includes 2x OTLM device, weather station, DynaStat system and strain gauges. IMOTOL system is installed on the 110 kV OHL Idrija – Cerkno, ELES, in Slovenia at the critical point of mountain peak "Bevkov vrh".

D. Maletič, V. Lovrenčić, N. Gubeljak, Y. Tsimberg, N. M. de Almeida, A. Lovrenčič & M. Maletič:
Linear Asset Management: a Case Study of Overhead Transmission Lines

591

Figure 2: Installation of a measuring system;
Source: (Gubeljak, Lovrenčić, Bakič, et al., 2020)

Towers and conductors, important part of OHTLs, are used, which were made in different periods with different shapes and materials that are difficult to determine traceability. The data on the remaining lifetime of the towers and conductors is crucial for the safe and reliable supply of electricity. In many cases, the data on regular mechanical loads also makes it possible to use the power line securely.

Nowadays, sophisticated information technology, which is supported by various sensors and devices for measuring angles and temperatures, allows for practical monitoring of the state on towers and conductors of the lines. With the help of this technology, the potential for dependence on temperature, wind and other influences is to determine the height of the forces and loads to which the line and the guide are exposed. It is also possible to determine the height of additional loads in the case of gills or other weather phenomena, which can be reliably monitored on critical parts of the OHTL.

OTLM device was developed to measure temperature and current of power lines simultaneously. Temperature is measured directly - at sensor fixing points. The device is equipped with means of attachment to conductor. The current transformer and the supplying unit provide power supply for operation from live conductor without any outside source of power. Last version of OTLM device is equipped with inclinometer (measurement of angle of catenary) and camera (shows the status of OHTL – e.g., conductor, Figure 3).

Figure 3: Camera installed in OTLM device; Source: (Gubeljak, Lovrenčić, Bakič, et al., 2020)

D. Maletič, V. Lovrenčić, N. Gubeljak, Y. Tsimberg, N. M. de Almeida, A. Lovrenčič & M. Maletič:
Linear Asset Management: a Case Study of Overhead Transmission Lines

593

Measurements are transmitted to the control center via available communication channels (GSM, GPRS, UMTS). Communication scheme of the entire measurement system is shown in Figure 4 (ELES, Bevkov vrh).
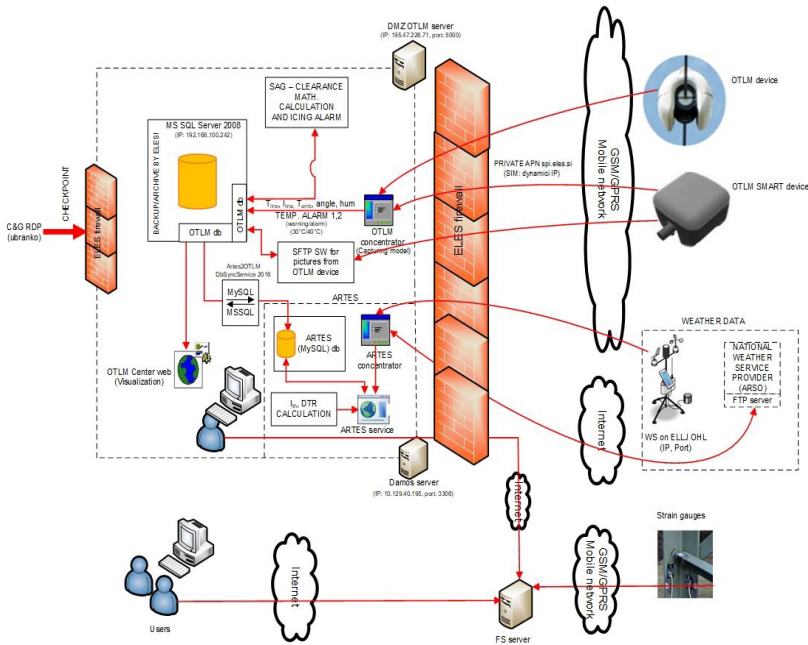

Figure 4: Communication scheme of IMOTOL system (ELES, Bevkov vrh,)
Source: (Gubeljak, Lovrenčić, Bakič, et al., 2020)

The device is equipped with GPS signal receiver. Due to this, temperature and current measurement data is annotated by precise time and X, Y, Z, coordinates of device location. The device enables local and remote access for meter setting, reading of current values, software replacement, etc. Measurements and high-resolution events are transferred to selected computers and the control center (SCADA) via standard IEC protocols. Easy user access is available via LiMa center.

The communication platform for the DynaStat measurement system is designed for a server (FME server), which displays the results of current measurements as well as the results of measurements made up to 24 hours ago, when measurements are taken every 5 minutes. Based on such an integral approach and the analysis of the results of continuous measurements, it is possible to

determine the influence of individual parameters (influence of climatic conditions and current loads) on the behaviour of the conductor (bends, tensile forces). This also applies to the tower (change of own frequencies, condition of the profiles etc.) in order to interpolate these influences over a longer period of time to estimate the actual service life of the mast construction and to ensure operational safety with regard to the external clearances of the overhead line.

At a time when the DynaStat system also measures OTLM devices at the same time measurements and intervals send data to the OTLM center, as shown in the communication scheme in Figure 4.

Robot LineVue™

Kinectrics has developed a new methodology to determine the existing condition of ageing conductors without having to take samples from a line section. It is an "in-situ", non-destructive inspection tool, called LineVue™ that accurately measures the remaining cross-sectional steel of the conductor. It also indicates the extent and severity of corrosion of the steel core wires. Figure 5 shows LineVue™ installed on a transmission line (Tsimberg et al., 2016).
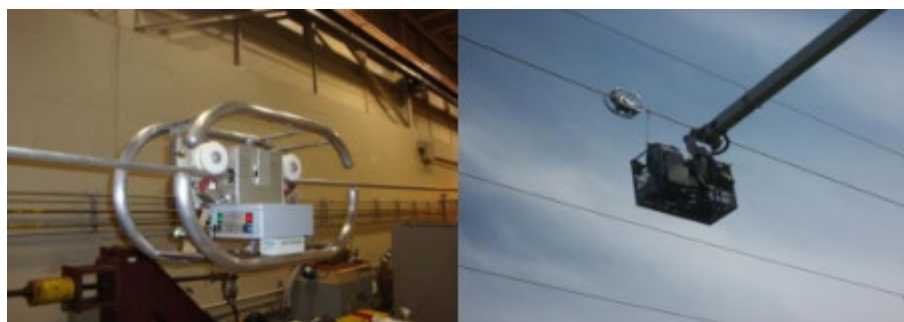

Figure 5: LineVue™ (Tsimberg et al., 2016)

LineVue™ is a non-destructive testing system that "looks through" the aluminium layers and inspects only the ferrous portion of the core (strength element). LineVue™ uses very strong permanent magnets to saturate the steel core with magnetic flux to determine the remaining cross-sectional area of the steel core, as well as to indicate the extent and severity of pitting or other localized defects (e.g., broken steel wire). A such, LineVue™ provides two outputs (Lovrenčič et al., 2020):

D. Maletič, V. Lovrenčić, N. Gubeljak, Y. Tsimberg, N. M. de Almeida, A. Lovrenčič & M. Maletič:
Linear Asset Management: a Case Study of Overhead Transmission Lines

595

1) Loss of Metallic Cross-Sectional Area (LMA) Inspection - quantitatively measures the remaining steel area caused by corrosion and wear,

2) Local Flaw (LF) Inspection - qualitatively detects discontinuities such as broken steel wires and corrosion pitting.

The results are sent by wireless communication to a ground-based computer for processing. Data can be displayed in real time and stored electronically for future analysis (Tsimberg et al., 2016). The evaluation of transmission lines with LineVue™ is performed in the field on energized and non-energized conductors. Conventional methods of assessing the condition of transmission and distribution line conductors are typically time consuming and labor intensive. Field personnel must disconnect the circuit, install safety grounding, gain access, and remove a long section of conductor at the selected location with a bucket truck before taking it to a lab for a series of tests (Lovrenčič et al., 2020). In contrast, LineVue™ represents a reliable non-destructive device that can be used as a live line working tool.

3 Methods

The paper uses a case study approach focusing on the Slovenian company ELES. ELES is the operator of Slovenia's electric power transmission network (TSO). IMOTOL is installed on 110 kV OHL Idrija – Cerkno, ELES, in Slovenia at the critical point of mountain peak "Bevkov vrh" (often problem of icing). Therefore, a case study approach was used in this paper to gain insights into the phenomenon under study (Yin, 2009). Single case study is used. While multiple studies generally provide a stronger basis for theory building (Yin, 2009), it has been shown that a single case study can richly describe the existence of a phenomenon (Siggelkow, 2007).

4 Measurement system (IMOTOL)

The purpose of on-line measurements of stresses in the legs of the tower is to determine the actual stresses at the location of the bonded strain gauges for monitoring deformations in the legs of the towers (IMOTOL).

Knowing the total stresses, which includes the initial residual stress state at the location of the bonded strain gauges, the actual stress state in the legs of the tower can be determined by adding the deformations. The deformations are measured continuously, which allows the degree of utilisation of the tower material to be assessed (Gubeljak, 2020).

Thus, the strain measurements and temperature in the legs of the tower and vibration measurements are made to determine oscillation frequencies. The purpose of these measurements is to evaluate the stress response in the legs of the tower to the mechanical loads on the conductors in relation to the temperature condition of the conductors (Gubeljak, Lovrenčić, Bakič, et al., 2020). This makes it possible to determine the different degree of the tower degradation.

Figure 6 shows an example of measuring residual stresses at the location of the measuring pad with the PULSTEC μ-360. On the same place where residual stresses have been measured, the strain gauges are adhesively bonded and protected as is shown in Figure 6.

Figure 6: Measurement of residual stresses strain gauges mounting place;
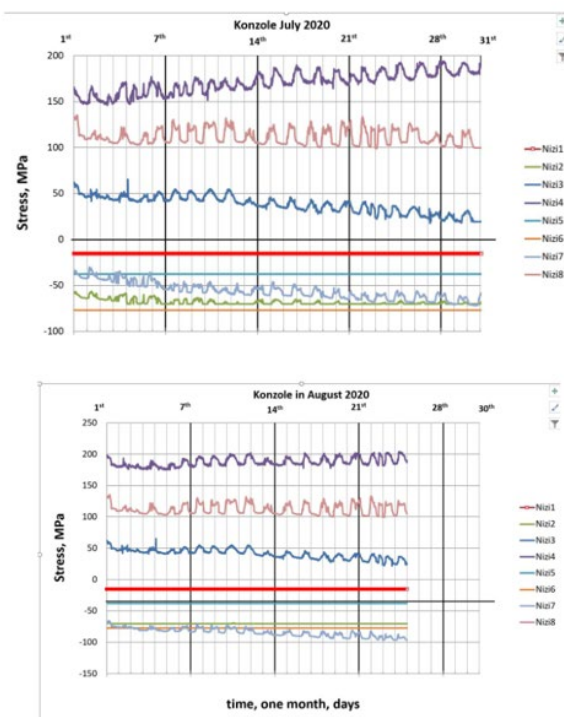Source: (Gubeljak, 2020)

D. Maletič, V. Lovrenčić, N. Gubeljak, Y. Tsimberg, N. M. de Almeida, A. Lovrenčič & M. Maletič:
Linear Asset Management: a Case Study of Overhead Transmission Lines

597

Within the project, the IMOTOL system was developed and installed to measure vibrations and dynamic stress in the legs of the tower and on the tower console, as the most critical part of the SM13 tower on the DV 110 kV Idrija-Cerkno at Bevkov vrh. DynaStat, as an autonomous system with its own power supply, performed a continuous voltage measurement on 16 channels, a vibration measurement and a temperature measurement on the profile in the tower legs. After the measurements, the results are transmitted via the GSM network to the server for remote processing and primary analysis of the results (Gubeljak, Lovrenčić, Ivec, et al., 2020).

Also, when measuring with the DyanStat system, the temperature of the conductor and the angle at the attachment point are measured with the OTLM device at the same time intervals. The OTLM device also performs independent measurements and sends the results via the GSM network to the OTLM center or to the ELES center (Gubeljak, Lovrenčić, Ivec, et al., 2020).

Analysis and presentation of the results can indicate the accumulation of ice on the conductor as well as increased ice on the tower during the winter months. The ice accumulation has an effect on the change in vibration. This was shown by (Gubeljak, Lovrenčić, Ivec, et al., 2020). The aforementioned study included an analysis from December 2019 to February 2020.

The results of the stress measurements on the on console profiles show that in the last months from April to August 2020, the stresses increase and reach 200 MPa. Figure 7 shows the results for last two months (July – August 2020), which may lead to the formation of fatigue cracks.

Figure 7: Stress measurements (July - August 2020)
Source: (Gubeljak, Lovrenčić, Ivec, et al., 2020)

In summary, it was found that the DynStat system successfully measures stress in the legs and indicates the most stressed part of the tower, both in the legs and on the console. By using the stress measurements and vibrations, the dynamic load characteristics of the SM13 tower were obtained. Based on the cumulative number of load cycles in a year, the number of cycles over a longer multi-year period can be predicted. From the dynamic strength point of view, it was found that the legs of the SM13 tower made of steel profiles 100 x 100 x 10 mm are well dimensioned (Gubeljak, Lovrenčić, Ivec, et al., 2020).

The stresses increase continuously from month to month and within each month as the temperature increases, which may be due to loosening of the bolted connections in the console (Gubeljak, Lovrenčić, Ivec, et al., 2020). Therefore, the inspection of the consoles and re-bolting their profiles is suggested.

D. Maletič, V. Lovrenčič, N. Gubeljak, Y. Tsimberg, N. M. de Almeida, A. Lovrenčič & M. Maletič:
Linear Asset Management: a Case Study of Overhead Transmission Lines

599

5   Conclusion

Ensuring that overhead power lines transmit electricity safely and reliability depends on ensuring the structural integrity of the towers and conductors. The towers of the older overhead lines are constructed at different times and are subjected to different mechanical stresses on the same overhead line, resulting in different degradation of the materials and hence different tower life. OHTL conductors and the towers are also exposed to harsh climatic and weather conditions, which can lead to accelerated ageing and the resultant failures of towers or conductors. The purpose of this paper was to present a novel method involving monitoring condition of tower legs using IMOTOL system and determining condition of conductors using in-situ inspections via LineVue™ robot. Both these techniques will enable utility engineers to better manage their OHTL fleet by predicting degradation rates and identifying assets that are approaching their end of life.

Acknowledgements

References

Alsyouf, I., Alsuwaidi, M., Hamdan, S., & Shamsuzzaman, M. (2021). Impact of ISO 55000 on organisational performance: Evidence from certified UAE firms. Total Quality Management & Business Excellence, 32(1–2), 134–152. https://doi.org/10.1080/14783363.2018.1537750

Amadi-Echendu, J. E. (2004). Managing physical assets is a paradigm shift from maintenance. 2004 IEEE International Engineering Management Conference (IEEE Cat. No.04CH37574), 3, 1156-1160 Vol.3. https://doi.org/10.1109/IEMC.2004.1408874

Bosisio, A., Giustina, D. D., Fratti, S., Dedè, A., & Gozzi, S. (2019). A Metamodel for Multi-utilities Asset Management. 2019 IEEE Milan PowerTech, 1–4. https://doi.org/10.1109/PTC.2019.8810812

Chattopadhyay, G. (2021). Asset Management Journey for Realising Value from Assets. In K. B. Misra (Ed.), Handbook of Advanced Performability Engineering (pp. 429–450). Springer International Publishing. https://doi.org/10.1007/978-3-030-55732-4_19

CIGRE Technical Brochure 787. (2019). ISO series 55000 standards: Implementation and information guidelines for utilities. https://e-cigre.org/publication/787-iso-series-55000-standards-implementation-and-information-guidelines-for-utilities

Côté, A., Blancke, O., Alarie, S., Dems, A., Komljenovic, D., & Messaoudi, D. (2020). Combining Historical Data and Domain Expert Knowledge Using Optimization to Model Electrical Equipment Reliability. 2020 International Conference on Probabilistic Methods Applied to Power Systems (PMAPS), 1–6. https://doi.org/10.1109/PMAPS47429.2020.9183620

de Almeida, N. M., Vieira, J., Silva, J. G., & e Castro, C. (2021). The Impact of Asset Management Development Programs in Infrastructure Organizations. In H. Rodrigues, F. Gaspar, P. Fernandes, & A. Mateus (Eds.), Sustainability and Automation in Smart Constructions (pp. 247–258). Springer International Publishing. https://doi.org/10.1007/978-3-030-35533-3_29

De La Fuente, A., Guillén López, A. J., Crespo Márquez, A., Sola Rosique, A., Gómez Fernández, J. F., Moreu de León, P., & González-Prida, V. (2018). Strategic view of an assets health index for making long-term decisions in different industries. Safety and Reliability–Safe Societies in a Changing World: Proceedings of ESREL 2018, 1151–1156. https://doi.org/10.1201/9781351174664-146

Durán, O., Orellana, F., Perez, P., & Hidalgo, T. (2020). Incorporating an Asset Health Index into a Life Cycle Costing: A Proposition and Study Case. Mathematics, 8(10), 1787. https://doi.org/10.3390/math8101787

Gavrikova, E., Volkova, I., & Burda, Y. (2020). Strategic Aspects of Asset Management: An Overview of Current Research. Sustainability, 12(15), 5955. https://doi.org/10.3390/su12155955

Germán, M. O., Molina, J. D., Romero, A. A., Gómez, H. D., & García, E. (2014). Power asset management: Methods and experiences in Colombian power system. 2014 IEEE PES Transmission Distribution Conference and Exposition - Latin America (PES T D-LA), 1–6. https://doi.org/10.1109/TDC-LA.2014.6955209

Gubeljak, N. (2020). On-line Measurement of Stresses in Legs of Towers SM 96, SM 97 in SM 98 at OHL 110 kV Kleče- Logatec 1 for developing of project »INTERRFACE - IMOTOL«. University of Maribor, Faculty of Mechanical Engineering.

D. Maletič, V. Lovrenčić, N. Gubeljak, Y. Tsimberg, N. M. de Almeida, A. Lovrenčič & M. Maletič:
Linear Asset Management: a Case Study of Overhead Transmission Lines

601

Gubeljak, N., Lovrenčić, V., Bakič, K., & Jakl, F. (2020, September 24). An integral approach to ensuring the integrity of the tower and conductors. CIGRÉ e-session 48, Paris.

Gubeljak, N., Lovrenčić, V., Ivec, A., & Kozjek, D. (2020). Pilotski projekt za spremljanje stanja daljnovodov z naprednim OTLM SMART sistemom—Spremljanje deformacij podpor v podpornih stebrih in procesiranje podatkov za oceno stanja med obratovanjem, Končno poročilo »Vzpostavitev sistema za sprotno spremljanje deformacij v nogah in na konzoli stebra SM 13 na DV 110 kV Cerkno – Idrija na lokaciji Bevkov vrh. C&G d.o.o. Ljubljana, št 228/AI/20.

ISO 55000:2014. (n.d.). Asset management—Overview, principles and terminology. International Organization for Standardization (ISO).

Komljenovic, D., Messaoudi, D., Côté, A., Gaha, M., Vouligny, L., Alarie, S., Dems, A., & Blancke, O. (2021). Asset Management in Electrical Utilities in the Context of Business and Operational Complexity. In A. Crespo Márquez, D. Komljenovic, & J. Amadi-Echendu (Eds.), 14th WCEAM Proceedings (pp. 34–45). Springer International Publishing. https://doi.org/10.1007/978-3-030-64228-0_4

Lima, E. S., & Costa, A. P. C. S. (2019). Improving Asset Management under a regulatory view. Reliability Engineering & System Safety, 190, 106523. https://doi.org/10.1016/j.ress.2019.106523

Lima, E. S., McMahon, P., & Costa, A. P. C. S. (2021). Establishing the relationship between asset management and business performance. International Journal of Production Economics, 232, 107937.
https://doi.org/10.1016/j.ijpe.2020.107937

Lovrenčić, A., Peter, Z., Rizzetto, A., & Lovrenčić, V. (2020). Inspection of energized aged conductors using non-destructive, in-situ inspection technology. ICOLIM 2020.

Ma, Z., Zhou, L., & Sheng, W. (2014). Analysis of the new asset management standard ISO 55000 and PAS 55. 2014 China International Conference on Electricity Distribution (CICED), 1668–1674.
https://doi.org/10.1109/CICED.2014.6991990

Maletič, D., Maletič, M., Al-Najjar, B., & Gomišček, B. (2018). Development of a Model Linking Physical Asset Management to Sustainability Performance: An Empirical Research. Sustainability, 10(12), 4759. https://doi.org/10.3390/su10124759

Maletič, D., Maletič, M., Al-Najjar, B., & Gomišček, B. (2020). An Analysis of Physical Asset Management Core Practices and Their Influence on Operational Performance. Sustainability, 12(21), 9097. https://doi.org/10.3390/su12219097

Naranpanawe, L., Ma, H., Saha, T. K., Lee, C., & Ghosal, A. (2020). A Practical Health Index for Overhead Conductors: Experience From Australian Distribution Networks. IEEE Access, 8, 218863–218873.
https://doi.org/10.1109/ACCESS.2020.3042486

Pačaiová, H., Sinay, J., & Nagyová, A. (2017). Development of GRAM – A risk measurement tool using risk based thinking principles. Measurement, 100, 288–296. https://doi.org/10.1016/j.measurement.2017.01.004

Schuman, C. A., & Brent, A. C. (2005). Asset life cycle management: Towards improving physical asset performance in the process industry. International Journal of Operations & Production Management, 25(6), 566–579. https://doi.org/10.1108/01443570510599728

Serra, J., de la Fuente, A., Crespo, A., Sola, A., Guillén, A., Candón, E., & Martínez-Galan, P. (2019). A Model for Lifecycle Cost Calculation Based on Asset Health Index. In International Conference on Smart Infrastructure and Construction 2019 (ICSIC) (Vol. 1–0, pp. 91–98). ICE Publishing. https://doi.org/10.1680/icsic.64669.091

Siggelkow, N. (2007). Persuasion With Case Studies. Academy of Management Journal, 50(1), 20–24. https://doi.org/10.5465/amj.2007.24160882

Spatti, D., Liboni, L. H. B., Araújo, M., Bossolan, R., & Vitti, B. (2019). Efficient Asset Management Practices for Power Systems Using Expert Systems. Application of Expert Systems - Theoretical and Practical Aspects. https://doi.org/10.5772/intechopen.89766

Trindade, M., Almeida, N., Finger, M., & Ferreira, D. (2019). Design and Development of a Value-Based Decision Making Process for Asset Intensive Organizations. In J. Mathew, C. W. Lim, L. Ma, D. Sands, M. E. Cholette, & P. Borghesani (Eds.), Asset Intelligence through Integration and Interoperability and Contemporary Vibration Engineering Technologies (pp. 605–623). Springer International Publishing. https://doi.org/10.1007/978-3-319-95711-1_60

Tsimberg, Y., Peter, Z., & Mogilevsky, C. (2016). Comparison of Different Approaches for Estimating Condition of Overhead Transmission Line Conductors. 2016 CIGRÉ Canada Conference, Vancouver, BC Canada.

Tsimberg, Y., & Wang, F. (2016). Methodology for Developing Transmission Line Components Failure Curves. 2016 CIGRÉ Canada Conference.

Velásquez, R. M. A., & Lara, J. V. M. (2018). Methodology for Overhead Line Conductor Remaining Life Aging infrastructure and asset management. 2018 IEEE PES Transmission Distribution Conference and Exhibition - Latin America (T D-LA), 1–5. https://doi.org/10.1109/TDC-LA.2018.8511752

Wijnia, Y., & de Croon, J. (2015). The Asset Management Process Reference Model for Infrastructures. In J. Amadi-Echendu, C. Hoohlo, & J. Mathew (Eds.), 9th WCEAM Research Papers (pp. 447–457). Springer International Publishing. https://doi.org/10.1007/978-3-319-15536-4_35

Yin, R. (2009). Case Study Research: Design and Methods (4th ed.). Sage Publications, Thousand Oaks CA.