MOBILE SOLUTIONS FOR COST EFFECTIVELY CAPTURING ELECTRICAL ASSETS OF MUNICIPALITIES

Author & Presenter: T Rajakanthan MSc, Technical Director of Ciber Terrasoft
Co-author: B McLaren from Eskom
Co-author: GJ Mafrika MSc, a Eskom IDM Manager & Chair of EnerKey Programme
Co-author: J Forson of Forson Consulting

1. Introduction

Power outages in networks occur in both rural and urban areas due to age, excessive demand, recent extensions, premature failure, lack of maintenance, *wear and tear* [1]. Approximately 50% of the networks require immediate attention or major refurbishment/replacement [2]. The electricity distribution grid is suffering from a lack of investment and recapitalisation of its ageing infrastructure, resulting in an industry in crisis [2].

"*Asset Management (AM) is a process of maintaining asset performance at a required level of service while minimizing total life cycle cost* [3]". André Bekker of Eskom stated that "*A sustainable approach to the management of an electrical supply network can only be found in organisations that fully embrace all the principles of Asset Management* [4]". Dr. Willie de Beer formerly of EDI Holdings has also clearly stated the business case and need for Asset Management at various forums [2-8]. Municipalities require Information Technology (IT) software systems to support an AM strategy such as following:-

- GIS (Geographic Information Systems) – eg. ArcInfo, SmallWorld, GeoGraphics, etc.
- ERP (Enterprise Resource Planning) and EAM (Enterprise Asset Management) systems such as SAP, JD Edwards, Maximo, PeopleSoft, Accpac, etc.
- Financial/Accounting systems, Billing systems, etc
- PSA/PSS (Power Systems Analysis/Simulation) eg. DigSilent, PSSE/PSSU, etc.

However, these software systems require large volumes of data for municipalities to successfully implement an AM strategy.

1.1. Municipal challenges

The current state of distribution network assets and lack of sufficient data about those assets means that municipalities are **unable** to perform the following:-

1. Comply with NRS 093-1:2009 and GRAP (Generally Recognised Accounting Practice) 17 which focuses strongly on the compilation of the asset register for immovable assets. "*An asset register is a complete and accurate database of the assets that is under the control of a municipality and that is regularly updated and validated.*" National Treasury: Final Asset Management Guide – 2008. *The compilation of an asset register is therefore a legislative requirement [9].* "*According to the MFMA (Municipal Finance Management Act) 63 (2) (c)**,** an accounting officer must take all reasonable steps to ensure that the municipality has and maintains a system of internal control over assets [9]*". This includes the use of the asset register in the preparation of financial statements in accordance with GRAP.
2. Comply with all legal requirements for archival-records storage of up to date as-built/record drawings of the entire network infrastructure. Many as-built drawings are out of date, been damaged or have been lost over time. Generally, the accuracy and content of as-built drawings decreases with voltage when considering infrastructure from 400kV down to 230V.
3. Guarantee continuity and quality of service [2]. The *NRS047: Quality of Service* and *NRS048: Quality of Supply* specifically do not address assets or the use of PSA/PSS to explore network power flow scenarios to cater for demand, stability, reliability, faults, protection, etc. However, it

would be difficult to achieve compliance without applying solid asset management principles [5] and conducting appropriate simulation studies.

4. Ensure public safety as required by the *Occupational Health and Safety Act No. 85 of 1993* (OHS) which requires maintenance of infrastructure for safe continued use [4]. Apart from lack of maintenance issues, tampering and illegal connections are further compromising safety. Alarmingly, lack of experienced and effectively trained contractors is continuing to cause safety and quality challenges [7].
5. Consolidate the capturing process so that it is done in full only once. Presently, different personnel are used to capture specific and limited information (such as customer coordinate, meter information) only, sometimes with duplication. This approach is costly for utilities.
6. Development of annual funding profiles for maintenance, repair, rehabilitation and replacement of assets [6] based on the present assessed level of impairment. Reliable information is required for policy makers to determine long-range funding needs [6] which must incorporate results from power simulation studies (using PSA/PSS).
7. Efficiently provide electricity to an estimated 600,000 connections by 2014 [10] and government's 3 million new houses units over next 15 years [11]. Historical data is required so that engineers can not only analyse the performance of infrastructure rolled in the past but also understand those components that are repeatedly or prematurely failing (whether it be due to poor workmanship and/or quality). The analysis of historical data will enable engineers to effectively
    - better optimise infrastructure for performance (energy efficiency) based on improved load modelling
    - refine construction standards to maximise return on investments while minimise total lifecycle costs
8. Demand growth exceeds the loading capacity of many of the networks which will amongst others pose a significant risk to the effective introduction of Energy Efficiency Strategies [2]. Implementing energy efficiency strategies such as Demand Side Management and Smart-grids also require substantial data about the customers and their consumption patterns/requirements.
9. The current severe shortage and retention of experienced technical staff at all levels of the industry (i.e. planning, design, asset creation, operation and maintenance) is a major contributor to the current unsatisfactory state of the infrastructure and poses a real threat to the electrical industry [2, 7].

1.2. Asset Data

While accuracy of data for HV/MV/LV (400kV to 230V) feeder lines and substations varies, it generally decreases with voltage. To be able to meet the challenges stated above, municipalities require raw detailed accurate asset and customer data including:-

- Precise geographical location (GPS (Global Positioning System) coordinate of all equipment and customers)
- Technical data (ie. date of commission of equipment, type, ratings/capacity, etc)
- Present condition of equipment (level of impairment)
- Interconnectivity data (how each asset connects/relates to others, match customer to transformer, ability to trace through a network, etc)

1.3. Non-electrical data

Though not part of the explicit compliance requirements, other proximity related non-electrical data (such as structures (buildings), servitude, terrain, structures, vegetation, etc) is also required for the overall maintenance of the network to minimise power interruption as well as ensure public safety. A few examples of these are given below:-

- management of vegetation to ensure clearance and fire prevention
- ensuring that servitude and property fences are in order for access restriction,
- monitoring conductor clearances over/near structures, road reserves and rivers,
- risk mitigation for assets located in areas that could be affected by extreme weather/natural disasters (eg. conductor blowout due to wind, structures being submerged due to flooding, etc)
- basic terrain data for planning future transmission line routes (prefeasibility studies)

- customer data such as location, income, appliances, etc for demand modelling and energy efficiency strategising

2. Problem Statement

GRAP notes that "*Most municipal Assets Registers in respect of infrastructure assets are inadequate*" [6, 9]. Municipalities tend to focus on fulfilling onerous compliance requirements rather than critical issues of service delivery and enhancing performance [6, 12]. Why then is compilation of asset registers such a challenge for municipalities?

The only way to gather extensive accurate raw data to compile an asset register is to conduct a complete network audit. Currently, the costs for conducting network audits are expensive for the following reasons:-

1. Paper, pen and standalone GPS receivers are used to compile paperwork. Experienced engineers (usually outsourced) or senior clerks-of-works are typically used because they can mange onerous paperwork at the required quality.
2. When the paperwork is returned to the office, more time is required to manually re-enter data into a suitable software system. This activity is prone to human-error and legibility issues which affects the quality of the data.
3. Producing up to date as-built/record drawings also requires more time and skilled resources.
4. Municipalities tend to send their internal staff to gather limited mission critical information at any given point in time (eg. determine the conductor type). This approach costs time and money particularly since personnel are required to travel to distant locations to acquire the information.
5. The work of capturing of larger volumes of data is outsourced to skilled resources who are able to manage the complexity and assure the quality. The remuneration for outsourced data is on an attribute by attribute basis which means that the scope of the data captured is still insufficient for compliance requirements (eg. identify pylon top structures and equipment). This means that at sometime in the future, personnel will have to be sent out again to capture all the information (including foundation and installation) which has long-term cost implications.

It should be noted that it is not economically feasible to use survey teams (who will focus on terrain and node positions) or practical to use aerial imagery (cannot provide adequate resolution of the network components) to acquire the necessary volume of data. Thus the problem is summarised as follows, "How can municipalities capture extensive infrastructure asset data accurately, rapidly and cost-effectively?" In addition, the asset data must be sufficient to meet the challenges stated above.

3. Approach

The focus of this paper is to address the abovementioned challenge in two ways.

- Provide suitable technology that enables the capturing of extensive infrastructure asset data. The technology will significantly reduce time and costs for acquiring the data.
- The availability of tools will not require skilled resources to manage onerous paperwork. This means that the skill level used for capturing can be done by clerks-of-works (instead of senior clerks-of-works or consultants).

However this cannot be done in isolation and must be used in conjunction with a suitable implementation approach as discussed in the following subsections.

3.1. AM Strategy

Asset management strategies/plans and appropriate systems do not exist across the industry [7]. Following the Electricity Distribution Maintenance Summit in 2008 and in support of the National Response Plan to the electricity emergency, EDI Holdings developed a new Approach to Distribution Asset Management (ADAM) [6]. The ADAM Turnaround Program is a comprehensive, multi-year initiative, targeted at addressing maintenance, refurbishment and strengthening backlogs while addressing funding gaps. Though the EDI has been disbanded Dr. de Beer and his team proposed an *Approach to a South African Pilot* at the AMEU conference in September 2010 [8]. They had already developed a roll-out process, data collection questionnaire and database to conform to regulatory standard. They had also identified an initial target group for a pilot project which included 6 Metro's and 12 Secondaries (Drakenstein, Stellenbosch, Centelec, Buffalo City Municipality, Umfuleni, Mogale City, Klerksdorp, Tlokwe, Msunduzi, Umthlathuze, Polokwane, Rustenberg). Even though, funding and skills shortages have limited these efforts, ADAM can serve as the basis for municipalities to commence with a turnaround strategy without concerned about the REDs (Regional Electricity Distributor) restructuring.

3.2. Asset Register

Part of the AM strategy involves the compilation of the asset register. In its simplest form, an asset register may be a manual document or a spreadsheet stating all assets owned by a business. Management must ensure that certain minimum information is contained within the asset register as stated in the GRAP Implementation Guide to Municipalities [9]. To ensure a unified approach to tackling asset management issues, Dr. de Beer recommended that an AMEU workgroup on AM be formed [6]. To ensure a uniform compilation of asset registers, this workgroup should "design" the asset hierarchy [12]. It must take into account all the asset types that will be encountered in that specific municipality, and consider the most appropriate way for information to be aggregated for reporting purposes [12]. Furthermore, the level of detail of data (e.g. at facility, asset, component, or sub-component level, the extent of information on each element and impairment) to be gathered should be guided by the intended use of the information [12] (eg. simulation, maintenance, safety, etc). Obviously, the asset register must also provide for recording the level of impairment as well as issues that compromise safety.

3.3. Derive Questionnaires

Once the asset register structure (content) has been defined, a corresponding set of questionnaires can be derived for use when data capturing. A questionnaire is simply a question to which the answer will directly correspond with a field within the asset register. To prevent inappropriate responses and incorrect spelling, all possible answers must be listed for each and every question. For example, the question "*What is the transformer installation?*" will have three predefined responses; *Inline*, *Out of line* and *Platform*. Thus the user may only choose one of these responses which mean that it is impossible to select an invalid response. In the event that the user is required to specify a value, a range for acceptable values should be specified. A collection of questionnaires should be logically grouped into check sheets based on a theme/topic (such as transformer, fuse, pylon, etc). Thus data collection at any given node will involve the capturer working though a series of check sheets corresponding to each piece of equipment, each with multiple questionnaires.

To simplify and speed up this process, it is recommended that the workgroup address the network based on voltage (eg. focus on HV first, then MV and so on). This means that the asset register and the questionnaires can continually developed while the field staff commence with the data capturing. This approach also provides more time for the workgroup to also establish standards for equipment replacement, useful life and valuations.

The workgroup may also need to establish questionnaires for gathering other non-electrical data (such as servitude, terrain, structures (buildings), rivers, road reserves, vegetation, etc) which is also required to effectively maintain the network.

3.4. Extend IT systems

As the workgroup establishes the structure for the asset register, the municipalities' respective IT personnel must ensure that their IT systems (GIS, ERP, EAM, PSA, spreadsheet, etc) can accommodate that data. The modification of the IT systems should occur independently of the data capturing process guided only by the established structure of the asset register.

3.5. Skills Challenges

At a minimum, artisans at the level of a clerk-of-works (N6 and apprenticeship or equivalent with experience and competencies) are required to capture networks because they have the knowledge and experience to critically assess the network installation, configuration and condition. There is no alternative but to provide formal training with theory and practise to produce artisans. In addition to formal courses and in-field training, appropriate skills retention policies need to be implemented.

While skilled artisans are technically competent, they should **not** be burdened with the following:-

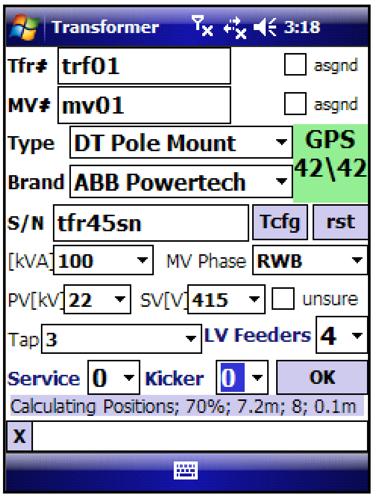
1. Filling out onerous paperwork with the inherent risk of missing out information and legibility issues. Paperwork can be easily lost or damaged due to the elements (such as wind and/or rain).
2. Recording network interconnectivity.
3. Concern about noting GPS coordinates to 6 decimal places. Accuracy is essential for locating the nodes in the future to fix specific faults.
4. Manual data re-entry back at the office into the municipalities' respective software systems.

Gathering of non-electrical data such as servitude, terrain, structures (buildings), vegetation, etc can be done either by artisans or by personnel who have experience with managing vegetation and ensuring safety.

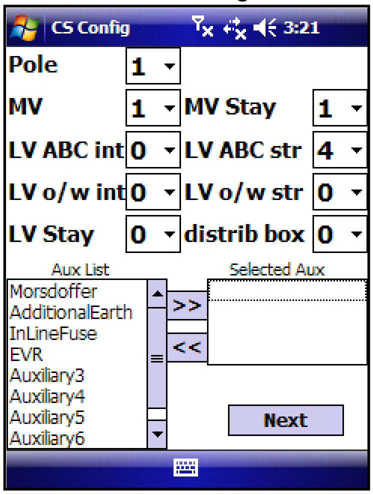
4. Solution

4.1. Asset Data

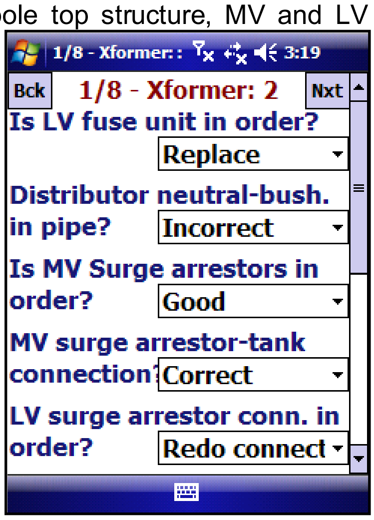
The second aspect of reducing data capturing costs is through the use of productivity enhancing technology. A mobile device based software was developed for data capturing in collaboration with Eskom and consultants. It was designed to be a flexible so that it could be customised to confirm to the data standard that was established by the workgroup. This means that artisans can systematically, rapidly and accurately document network data in the field by replacing standalone GPS receivers, paper and pen. The software runs on a rugged mobile device [13] with built-in GPS receiver (sub 5m accuracy) and uses the Windows Mobile® Operating System. This provides the user with a similar experience to working with the Windows OS based PC.



The use of the software is described through an example of capturing an LV network starting at the transformer. The software will instruct the artisan to locate the transformer. At the transformer, the artisan will be prompted for information as shown on the diagram on the right. This information not only uniquely identifies the transformer type but also makes it possible to conduct simulations on the network. While this information is being entered, GPS readings are recorded in the background without concerning the artisan. When artisan completes filling in the data, the software calculates an average GPS reading and stores it with the data.

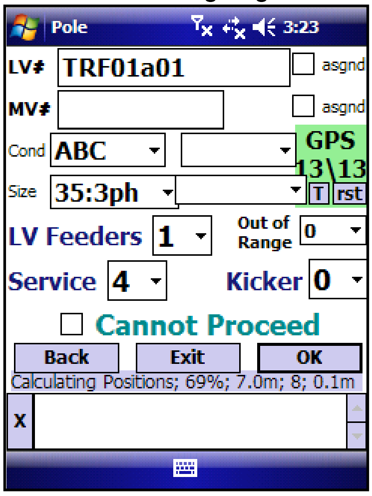


Once the electrical data has been captured, the next step would be to identify all the structures and equipment located at this node. The software will prompt the artisan to specify all equipment (such as number of poles, MV and LV pole top structure, MV and LV anchors, auxiliary devices, etc) as shown on the diagram on the left. Based on these entries, the software will present the artisan with the corresponding check sheets. On each check sheet, each questionnaire is posed with an adjacent dropdown boxes. The respective dropdown box will list all possible answers related to the adjacent question as shown in the diagram on the right. Research has shown that selecting an answer from an available list minimises the chances of incorrect responses being selected ensures correct spelling. There is limited provision for typing in data such as the year of manufacture and additional fault comments that were not covered by the questions. Numeric entries such as the date is verified to ensure no out of



range responses. A response to each questionnaire is required before the software permits the artisan to proceed to the next questionnaire.

While answering the check sheet data, the artisan is encouraged to use at least a 10x zoom camera with image or optical stabilisation to capture images of any issues observed to support the data captured. In the field trials, this features proved particularly useful when the answers were not discrete (ie combination of responses). There are no limits to the number of images or video clips that can be captured other than the memory limitation onboard the external camera. Though the mobile device has a built-in camera the zoom capability is insufficient for revealing fine details at a distance of over 5m and the memory is limited. Once all the data has been captured, the software will instruct the user to proceed to next pole. The user must simply choose one of the outgoing feeders and proceed to the next pole.



The artisan will click on the screen to notify arrival at the first pole/node. The GPS readings will commence in the background while the artisan enters the information as shown in the diagram to the right. When completed, the software will then allow the artisan to specify all the equipment before working through each and every check sheet similar to what was done at the transformer. Upon completion, the software will instruct him to capture each and every service connection.

The artisan can then proceed to the first dwelling and capture information about the meter. After entering the meter information, the software will automatically present the customer check sheet for the artisan to complete. When the artisan has completed, he is expected to proceed directly to the next dwelling. Once all the dwelling serviced by this pole is completed, he can move on to the next pole.

Capturing can also be done on HV lines or start at an MV source and include multiple transformer zones.

4.2. Non-electrical data

The capturing of non-electrical data is much simpler. The software enables the capturer to select a point feature type (eg, tree, vegetation, etc) and then fill-out the corresponding check sheet. Line features, such as servitudes, river boundaries, terrain can also be captured by walking the route. GPS coordinates are logged in the background without concerning the capturer.

4.3. Features and Benefits

This solution offers the following features and benefits as listed below.

1. The use of the mobile software is designed to enable an artisan to work in an intuitive and systematic manner without getting confused. Artisans do not require prior knowledge of computers or reading GPS and therefore training only takes a matter of days. The artisan is only alerted if the GPS signal is poor and the device is unable to calculate the present location. This is often resolved by simply moving around within the vicinity of that node (between obstacles such as buildings, trees, etc) to enable the device to receive a line-of-sight signal from the satellites to calculate the current position.

2. The software captures the network interconnectivity automatically as long as the network is captured in the direction of flow of power. When a feeder route is completed, the software will direct the artisan back to the last branch for capturing the remaining feeders, thereby ensuring that no part of the network is accidentally omitted.

3. This solution promotes the vision of sending artisans out once to document all the required information without duplication which has significant time and cost savings. Unlimited users can capture data simultaneously making it possible to gather data quickly. This also means that the data capturing process can be consolidated to further reduce capturing costs.

4. Given the skills shortages, artisans can be trained to correctly assess field equipment. Senior clerks-of-works will manage teams of appropriately trained artisans to capture data. The senior

clerks-of-works will review captured information with images for not only quality assurance purposes but also to enforce process discipline amongst the staff when gathering data.

5. Makes it possible for all field staff to capture large volume of network asset data, rapidly, systematically, accurately and uniformly. When the artisan returns to the office, they will be able to plug in to a desktop and download the data and images. Municipalities can be confident of quality of the data received because they have been compiled using standardised check sheets (questionnaires). The data can be readily uploaded into their IT systems (GIS, ERP, EAM, PSA, spreadsheet, etc) which can amongst others be used to compile so the asset register. Trials showed cost savings of over 70%.
6. Over time, the AMEU workgroup will change the layout of the municipality's asset register to meet to meet the evolving needs of the industry. A major feature of this solution is that corresponding questionnaires can then be added, modified or deleted accordingly on the mobile device with version control.
7. Since the built-in camera on the rugged mobile device is limited, an external 10x zoom (minimum) camera can be used to obtain supporting high-resolution images which will also serve as quality assurance. Safety regulations do not permit personnel to climb poles or pylons.
8. This software also has a desktop based component that enables it to generate as-built drawings in MicroStation *dgn* format (and export to AutoCAD *dwg*/*dxf* format). These drawings can be archived to not only fulfil legal obligations but for them to be used when designing extensions, network rehabilitation and strengthening. Using custom tools, the engineer can simply click on a node to view all the data captured for that node and review the corresponding images. The attribute data can also be used to generate reports and charts using Microsoft Excel© as well as produce a high-level cost estimate to correct the faults that were found on site.
9. Engineers can be able perform analysis of historical network asset data to understand the effectiveness of design philosophies, construction standards, workmanship and recurring issues. The analysis will enable organisation to refine the way that the new networks are rolled out in the future by:-
    a. Improving load demand predictions and optimise new designs accordingly (ie not over or under design the network which has cost and performance implications)
    b. Optimise construction standards for optimised lifecycle costs
    c. Identify and provide appropriate training to eliminate workmanship related problems
10. Gather much needed non-electrical data required to support infrastructure maintenance.

5. Job Creation

The task of compiling asset registers has been avoided in the past due to the prohibitive costs. The advent of new technology means that clerks-of-works with sufficient experience can now undertake this work, cost effectively. The re-deployment of clerks-of-works to focus on data capturing will automatically create opportunities for personnel to move up within the organisations hierarchy. This movement should then create gaps at the lowest level for the employment of matriculants and graduates. Working with electrical asset infrastructure requires not only technical knowledge but also experience to do so in a manner that is safe. This approach will give new employees exposure to the industry, opportunities to learn and become safety conscious should they wish to pursue this career. The need for electrical infrastructure guarantees lifelong careers in this industry and further educational institutions are encouraged to develop skills in this area. Eskom and EnerKey are developing long-term programmes to address issues of turning non-graduates into skilled artisans while addressing the issue of non-employment [14].

6. Conclusions

A significant component of asset management is the compilation of the asset register. However, all of the municipalities lack sufficient network layout and detailed asset data. Acquiring this data has been a major challenge for municipalities because costly skills (often outsourced) are required to manage the volume and quality. Working with consultants and Eskom, a mobile device based software was developed to facilitate data capturing of large volume of data in a systematic manner without overwhelming the user. This approach has the following benefits:-

- Improve accuracy and reduce time.
- Consolidate the capturing efforts so that personnel are sent out once to each location to capture all the required information.
- The questionnaires posed on the device are entirely configurable by the municipality so that it can conform to one uniform questionnaire standard. There are no limits to the number of questionnaires that can be posed. These questionnaires can also be changed and managed over time.
- Eliminate time required for manual data re-entry back at the office
- Record network interconnectivity
- Decrease the need for high-end skills down to clerks-of-works by managing the large volume of data that needs to be captured. There is no need to fill out onerous paperwork.
- Reduce costs for outsourced data capturing given the availability of appropriate technology.
- Users need not be computer literate or be familiar with GPS. Therefore the time required for training is a matter of few days.
- Overall cost savings were over 70%.

The data gathered would need to be uploaded into the municipalities' respective IT systems. This would make the data available to the entire organisation enabling them to fulfil the following obligations:-

- Comply with NRS 093-1:2009 and GRAP through the compilation of asset registers. This will also enable municipalities to prepare financial statements as required by PFMA.
- Ensure archival storage of as-built/record drawings.
- Guarantee continuity and quality of service through compliance with NRS047 and NRS048.
- Ensure public safety though compliance with Occupational Health and Safety Act.
- Produce high accuracy long-term plans for the maintenance, refurbishment and extension of infrastructure based on actual condition of assets and results from power simulations. These plans can then be used to derive precise funding profiles for financial assistance and revenue through appropriate tariffs.
- Use historical data gathered on past networks to improve load modelling and optimisation of newer networks so that they can perform at their designed capacities.
- Use the data to develop suitable energy efficiency strategies.

The objective of this solution is to make it economically viable to record all the assets, connectivity and their level of impairment so that municipalities can develop appropriate plans to maintain networks over the next few decades. Thus, the data will pave the way for the adoption of a suitable AM strategy (such as ADAM) to ensure long-term business sustainability and provide reliable power supply to support our economy.

The solution creates opportunities for training and the promotion of staff within their respective organisations. This should then create gaps at the lowest levels for sustainable employment of aspiring youth within the electrical industry.

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