South African Electric Vehicle Analysis

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***Abstract*— Ten Nissan Leaf electric vehicles were leased and the vehicles used on a daily basis, gathering information for a period of three years. The vehicles were allocated on a rotational basis to Eskom staff for a limited period of time. The usage patterns of the vehicles as well as the distances travelled on a daily, weekly and monthly basis and the charge and discharge characteristics (e.g. the time of day etc.) was logged. The commuting costs using electric vehicles, the electricity usage per km and the cost per km (i.e. maintenance etc.) were also recorded. Other parameters such as customer perceptions, experiences and what people would pay for an Electric vehicle was recorded. Comparison of an ICE vehicle versus an EV in terms of performance and cost and environmental value chain was calculated.**

***Index Terms*—Electric vehicles, charging stations, charging infrastructure**

I. INTRODUCTION

Eskom has been researching the development of electric vehicles for many years. Although the formal electric vehicle development programme has been closed down as it was felt that manufacturing EVs would never be part of Eskom's core business for strategic reasons, the research into the impact of electric vehicles (EV) on the Eskom grid has continued. Thus it is not so much the manufacture of e-vehicles that is of primary interest to Eskom, rather from a SMART grid perspective it is the impact and interface of EVs on the grid that requires further research. The volume of electric vehicles entering the market, their charging characteristics, charging methodologies as well as intelligent data exchange between Eskom and the EV fleet is being investigated.

The impact of EVs on Eskom is not to be underestimated. Although growth in this area is not expected to be rapid, the 'fast charge' facility for many vehicles, combined with rapidly increasing battery capacities, means distribution networks can be severely overloaded during certain times of the day. Two modes of charging exist for charging EVs, which are either normal-charge (8 to 12 hours) or fast-charge (less than 30 minutes). Each of these modes has implications for the energy provider. Also, at the moment, no special tariffs or charging facilities are available in South Africa. It is important for Eskom to evaluate and determine what tariffs would be required and how a charging network would be established.

When the project was initiated in 2013 the only pure 100% electric vehicle available in South Africa was the Nissan Leaf. The locally produced Joule from Optimal Energy was not released as Optimal Energy has closed business. BMW launched their range of electric vehicles into South Africa in March 2015. BMW's vehicles are the i3 pure electric, the i3 Rex hybrid and the i8 hybrid electric vehicles. The Chevy Volt is not yet available. Other vehicles such as the Prius are known as hybrid vehicles i.e. a mix of electric and petrol/diesel and do not have as profound an effect on the grid.

To evaluate the Nissan product, Eskom Research Testing and Development Department decided to lease ten such vehicles for evaluation. The vehicles were to be used on a daily basis, gathering information for a period of three years.

II. OBJECTIVES

The objectives were to evaluate the usage of electric vehicles in the South African environment and for their widespread use within Eskom. One of the critical aspects that needs to be evaluated is the impact EVs will have on the electrical network, as the establishment of an EV charging infrastructure or the additional load associated with charging EVs will have a direct influence on the grid. This will also be influenced by the charging characteristics, i.e. time of charge, mode of charge and frequency of charge. In order to influence these factors, it is important for Eskom to evaluate and determine what tariffs would be required to ensure stability of the network.

III. RESEARCH APPROACH

Ten Nissan Leaf electric vehicles were leased (figure 1) and the vehicles used on a daily basis, gathering information for a period of three years. The vehicles were allocated on a rotational basis to Eskom staff for a limited period of time.

Data logging equipment was installed in the vehicles to record and store relevant data. The following information was captured from the data loggers (quantitative data), as well as from a questionnaire that was developed for the purpose of this study (qualitative data):

- The usage patterns of the vehicles,
- The distances travelled on a daily, weekly and monthly basis,
- The charge and discharge characteristics (e.g. the time of day etc.),
- Commuting costs using electric vehicles,
- Electricity usage per km,
- Cost per km (i.e. maintenance etc.),
- Monitoring of customer perception,
- What would people pay for an Electric vehicle,
- Capturing peoples' experience and perception on EV's with regards to the performance, range capabilities etc., and
- Comparison of an ICE vehicle versus an EV in terms of performance and cost and environmental value chain.

The interface possibilities between Eskom and EVs need to be considered. Eskom explored the possibility of discharging energy from the vehicles battery (not necessarily these vehicles but for the future) into the grid and pay the vehicle owner for the power during peak demands. This could also assist with electrical grid planning studies in terms of their capabilities of handling the extra load EV's will place on the grid and their possible expansion/upgrade if required.

Figure 1. Nissan Leaf Electric Vehicle

The information from on-board system in the Nissan EV was used for the first year of the study but was found to be insufficient for the purposes of the study. An international logging unit that plugs into the controller area network (CAN) bus of the vehicle was brought in by a local development company. Only data from one vehicle was monitored and logged during this first year.

A local data logging system was developed locally for the Nissan EV. This was built locally and installed in the 10 vehicles. These units were installed in February 2014 and used to collect data from the vehicles.

A questionnaire was developed in order to capture the driver experience when driving the EVs. This formed part of the qualitative research component.

During this same period Frost & Sullivan were contracted to determine the expected impact on MV and LV networks (LV and MV line/cable loading, MV/LV transformer loading, MV and LV voltage regulation, technical losses) for different EV uptake levels and charging scenarios for typical representative networks.

Eskom provided the source data for a residential suburb's demand profile, which had to be modelled (winter and summer weekday) on a per hour daily demand curve. Frost & Sullivan then used the expected additional EV demand and superimposed it on the base demand to obtain a cumulative demand load profile. The impact on the grid is then portrayed in a visual fashion, with load curves reflecting overall demand and substation level demand increases.

Following this step, Eskom would require localised knowledge of their local network planners who have detailed insight into the particular network composition and capacity constraints of each individual residential network and feeder system. By showing the graphics to the local network planner, he/she would be able to predict the specific network impact and local analysis.

IV. Analysis of Results

The data retrieved from each vehicle was evaluated and analysed. A consolidated analysis was also conducted which combined the data for all the vehicles to provide a holistic view.

The combined report for the 12 month period from 1 April 2015 to 30 April 2016 is depicted in Figure 2 below. The Time of Use graph shows that most of the charging on the ten vehicles was spread between 06H00 to 00H00 with 1450kWh being the highest between 08H00 to 10H00. This graph shows that the vehicles were charged throughout the day showing a slight drop between 17H00 to 18H00. The least amount of charging for all vehicles occurred between 00H00 and 06H00.

The trip distances chart shows that about 720 short trips between 0 to 5 km long and approximately 420 trips for ranges of 5 to 20km were done in total during this period. The rest of the trips varied showing a declining number of trips with an increase in range.

On average the trips started with 76% charge in the battery and ended with 62% charge left in the battery.

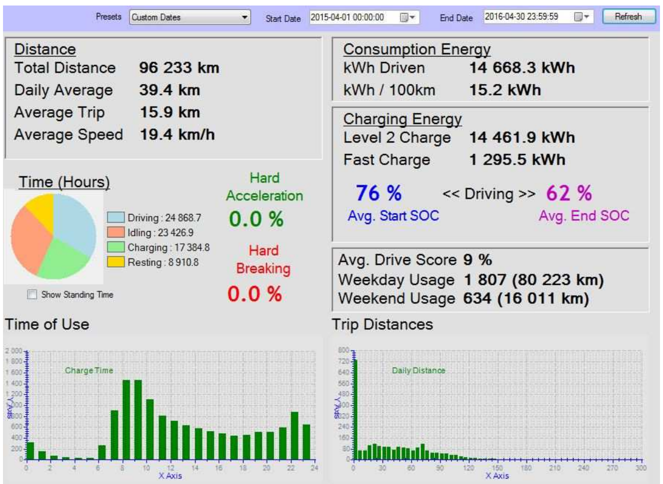

Figure 2. Data Captured for Ten Vehicles for 12-Month Period

The overall total results for the period September 2013 to April 2016 indicate the following. The ten vehicles covered a distance of approximately 281 819km, which equates to an electricity cost of R59 836.94. To cover the same distance using an internal combustion engine vehicle with a consumption of 8L/100km would have cost R306 928.00 using a pump price of R13.00 per litre. This is 5.1 times more than the electricity costs for the electric vehicle to cover the same distance. This equates to an 80% saving in fuel costs. In terms of CO_2 the saving by driving electric was 68 120.43kg.

From a customer behaviour component, it is seen that the most common period for charging the vehicles was between 08h00 to 10h00 in the morning. This could mainly be due to staff plugging the vehicle to charge as soon as they arrive at the office. This is however during the peak period, which will ultimately have a negative impact on the grid if multiple vehicles are sold to the South African market as this may be a common tendency for customers to adopt this behaviour.

It should also be noted that the range of the vehicles reduced over the 3 year period. Trips that could originally be made without charging midway were and are no longer possible due to the reduction in battery performance.

Based on the data collected and evaluated it can clearly be seen that the savings in using an electric vehicle are significant.

The feedback from all participants in the study was very positive. Although there were instances of range anxiety most were comfortable to use the vehicle and drive according to the range limitations.

There are several factors that have a potential influence on the network when considering EVs. These factors can be separated to distinguish between EV factors and network factors, and these are as follows:

- EV factors:
    - Number of residential properties with at least one EV per household that need to be catered for;
    - Number of EVs per residential property;
    - Type of EVs purchased;
    - Battery charging requirements of the above EVs;
    - Usage and driving patterns of the EV end-user;
    - Charging modes; and
    - EV age.
- Network factors:
    - The age of the network; and
    - Network composition.

The practical realities added complexities in completing an international benchmarking study and best practices in terms of impact studies. These practical realities were purely due to the composition of the South African networks differing significantly not only by province, but also per metropolitan area, as well as per residential area. Different feeder lines in residential area often differ substantially, based on urban development patterns, age, demand requirements, and maintenance practices. Therefore, a generic network impact analysis could not be done as the impact on a particular residential network will be highly dependent on a local scenario and would add more value when done on an individual case-by-case rather than a generic unrealistic analysis.

Based on this, a model was developed that combined the EV market figures, EV segmentation, usage patterns, and charging patterns. Source data for a residential suburb‘s demand profile and the expected additional EV demand was used to produce a per hour daily cumulated demand curve for both winter and summer weekday. The impact on the grid is then portrayed in a visual fashion, with load curves reflecting overall demand and substation level demand increases. This information enables the local network planners to predict the specific network impact as they have detailed insight into the particular network composition and capacity constraints of each individual residential network and feeder system.

Various scenarios were considered and modelled for the purpose of showing the possibilities to consider in the future. From this the following observations were made:

- Over the short term (1-3 years), medium (3-5 years) and longer term (5 years plus) the impact of EVs on the macro / overall South African grid will be nominal.
- The impact on the residential grid over the same period is expected to be minimal – subject to several factors, as indicated above.
- It is expected that with current EV uptake levels, the residential grid should be stable over the next 10 years, but this is subject to change if certain factors change.
- The factors can be managed by Eskom and the metropolitan municipalities to ensure that the grid remains stable.

In order to increase the uptake of EVs, various practical issues need to align, such as a reduction in price of vehicles, increase in consumer awareness and also business models need to be streamlined in order to obtain consumer confidence. A master plan is required that accommodates for an uptake in EVs.

Based on the South Africa network composition (segmented in HV, MV and LV) it is expected that the largest impact on the grid will be felt in the residential sector. The industrial and commercial networks are expected to be able to withstand moderate levels of EV uptake.

There are various means available to Eskom / metropolitan municipalities to manage consumer charging behaviour, including time-of-use tariffs and staggered charging.

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