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# Implementation Strategy for DC Fast Charging Stations for Electric Vehicles

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**Abstract.** Adoption of electric vehicles (EV) has been on a rising trend in the recent past. Provision of public DC fast charging infrastructure at strategic points is one of the major drivers towards the adoption of electric vehicles. This paper develops an implementation strategy for DC fast charging stations as an element in transmission and distribution infrastructure at strategic points to supply electrical energy for the recharging of electric vehicles. Kenya Power Ltd., a distribution utility player in Kenya, is a key stakeholder in the e-mobility ecosystem an is keen on opportunities that can take up extra capacity especially off-peak hence smoothening the load curve, maximizing on the use of transmission and distribution infrastructure as well as exposure to new technology. DC fast charging stations encourage the purchase of electrical vehicles and is one-step closer to a low – carbon economy, using clean transport. A SWOT analysis was used to construct an implementation strategy for EVs charging stations. Financial viability of the project was analysed using payback period, cost-to-benefit ratio, net present value (NPV), and internal rate of return (IRR). The financial indicators suggested that the investment is profitable, hence it is worth to consider it for investment.

## 1 Introduction

Kenya's transport sector is a significant and growing contributor to Kenya's GHG emissions. This has a negative impact as the generated gases and particulate matter affect the environment and the health of people. The use of electric vehicles (EVs) is one way to show concern for the environment by encouraging clean transport. However, the adoption of electric vehicles around the world has been slow. With the recent fuel shortages coupled by the price vulnerability of fuel, the number of electric vehicles is growing, especially with measures taken to encourage clean transport. A boom in electric car ownership will correspond with growth in public charging infrastructure which is one of the biggest roadblocks towards widespread adoption of electric vehicles. Encouraging the transition from internal combustion engines (ICEs) to electric vehicles results in lower carbon emissions from the transport sector. Furthermore, the Kenyan market also imports older, more polluting vehicles. Increased concern on the environmental impact of petroleum products, such as GHG emissions, as well as the high cost of petroleum products, combined with government policies encouraging the use of clean energy, have fueled increased adoption of e-mobility.

There has been a lot of interest in solving power quality problems due to DC fast charging using various mitigation measures. A real-time charging navigation framework was proposed in [1] to overcome the impact of fast charging stations (FCSs) on voltage stability. Zhao et al. proposed a management method for FCS operators to regulate the EV's charging behaviour [2]. Mahfouz and Iravani developed and evaluated a system architecture and its control structure that mitigated the impact of DC fast charging on the grid [3]. Gjelaj et al. designed an optimal size of the BES within the DC-fast charging stations with the objective of decoupling the LV grid from the peak load demand from EVs [4]. Phonrattanasak and Leeprechanon [5] developed an Ant Colony Optimization (ACO) algorithm, which is employed to search best location of DC fast charging station on the power distribution system considering traffic constraint of FCS while maintaining power system security of residential distribution system. None of the studies analyzed has a clear implementation strategy on the provision of DC fast charging stations for electric vehicles. This is in terms of grid impact, protection system issues, voltage and frequency regulation problems, policy and regulations governing the possibility of injecting power back to the grid as this may have a negative impact, socio-cultural acceptance and economical or financial issues. Other issues include energy efficiency measures, capacity to meet demand, infrastructure upgrade, availability of resources, skills and expertise and multi-sectoral approach. Public DC fast charging stations require reliable power supply to ensure service uptime. Utility firms are better placed to provide power supply from the grid to DC fast charging stations as these require a significant

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amount of power. Kenya Power being Kenya's sole off-taker can provide power from the national grid to charging stations on highways, street facilities, petrol stations car parks or retail shopping centres

With the emergence of prosumers and growth in alternative sources of power, Kenya Power, who mainly gets its revenue from the commercial and industrial (CI) class of consumers, has been losing out on major business opportunities and consequently, sources of revenue, which negatively affects its profitability [6]. There is need for the company to diversify its source of income and increase its revenues through increased demand. Kenya's load curve has massive differences in the peak and off-peak periods meaning that during off peak hours, there is a lot of idle capacity that ideally could be utilized. The current off-peak demand is 1100MW, against a peak demand of 2132MW and an installed capacity of 3321MW [6]. Adoption of e-mobility is set to raise the off-peak demand to 1500MW. There is need to take up extra capacity especially off-peak hence smoothening the load curve by leveraging on the company's assets, maximizing on the use of transmission and distribution infrastructure as well as exposure to new technology. Adoption of e-mobility shall also create some negative impacts on the grid in terms of power quality. However, there are no clear strategies that guide utilities in the provision of public DC fast charging stations for electric vehicles in Kenya and there is need for such.

This work analyses the existing charging stations, charging technologies, market for electric vehicles, specifically buses and grid impact in the Kenyan scenario. It suggests an implementation strategy for the introduction of DC fast charging stations, as an element in transmission and distribution infrastructure at strategic points, to supply electrical energy for the recharging of electric vehicles. The rest of the paper is organized as follows. Section 2 describes EV charging technologies and impact to the grid while section 3 looks at the design approach. Section 4 discusses the results and analysis while section 5 concludes the work.

## 2 Overview of Electric Vehicle Charging

### 2.1 EV Charging Technology

Charging modes or levels include AC – level 1 and level 2 where the AC supply is connected to an on-board charger, and DC-level 3 where an off-board charger is used to deliver DC supply [7]. Level 1 charging entails using a standard house outlet to charge an electric vehicle. In this level, charging time is longer, an average of 8-12 hours to reach 100% battery state of charge and is mostly used for shorter distances where a full charge is not required. Level 2 charging assigns a 240V/ 400V AC charging and involves the use of chargers that are installed in a garage or private facility. The maximum current is 80A. Charging time is 4 – 8 hours and is mostly used by drivers who require more flexibility. Level 3 charging is also known as DC fast charging, demonstrated by figure 1 Gabbar [8] stated that converters significantly increase the weight and, as a result, interfere with the vehicle performance when installed within an electric vehicle. Charging speed may be limited by the EV's battery management system to protect the battery and ensure its longevity [9].

Fig. 1: CHAdeMO connector (left) and the Tesla Supercharger (right). Source: Gabbar (2022)

### 2.2 Electric Vehicle and the Grid

Adoption of electric vehicles on the market significantly benefits the electric power grid and facilitates the integration of sustainable energy resources. There are three pertinent issues a utility should address before connecting EV charging stations to the grid [7]. These are asynchrony between generation and consumption, insertion of a diverse range of loads into the grid, and grid resilience against power outages. As more people adopt EVs, there will be a significant increase in electricity demand, particularly during peak charging times [10]. This can strain the existing electrical grid infrastructure and may lead to grid congestion, which can cause power outages, voltage fluctuations, and other reliability issues.

The charging patterns of EVs can lead to peak demand on the grid during certain times of the day, which can further strain the grid. If the charging is not managed properly, it could lead to localized overloads and potential outages [11]. For DC fast charging, the direct connection to the medium-voltage (MV) distribution network is preferred to avoid overloading of the low-voltage (LV) network [12]. White and Zhang proposed the use of vehicle-to-grid technology for frequency regulation and peak load reduction [13]. The V2G concept's success is dependent on standardization of requirements and infrastructure decisions, battery technology, and efficient and intelligent scheduling of limited fast-charge infrastructure [14]. Dharmakeerthi et al assumed a unity power factor when modelling and planning of EV fast charging station in power grid [15]. Chatterjey and Harmwill state that reducing losses to an absolute minimum is a priority in fast DC charger designs [16].

Overall, the impact of e-mobility on the grid will depend on several factors, including the rate of EV adoption, charging patterns, and the availability of supporting infrastructure. All parties involved in EV charging would benefit from better charging power management. It will keep the grid stable and ensure power balance between demand and supply. It will be important for utilities and policymakers to plan and invest strategically to ensure that the grid can handle the increased demand and take advantage of the potential benefits of e-mobility. It is important to consider potential negative impacts and develop strategies to mitigate them. This could involve grid upgrades, demand management strategies, and the integration of renewable energy sources to meet the increased demand for electricity from EVs.

## 3 Design Approach

### 3.1 Geographical Study Area

This work focuses on Nairobi City with the main emphasis on Nairobi – Thika highway. Thika is a town in Kenya about 50km from Nairobi. Figure 2 presents a map of Nairobi-Thika highway.

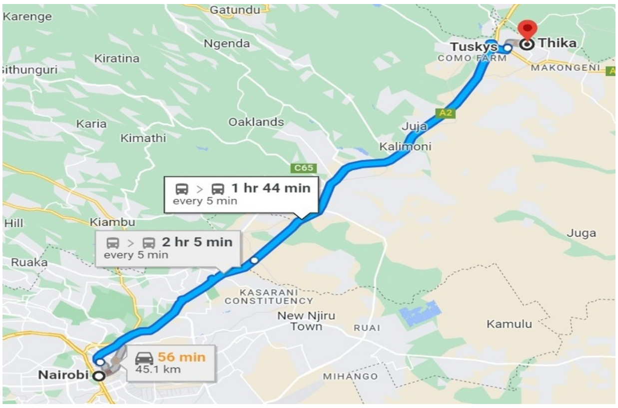


Fig. 2: Map of Nairobi and the Thika Super Highway

Thika super-highway has been considered for investigation in this work as there is a lot of traffic between these two towns, Nairobi and Thika. The plan is to build the fast-charging stations in these towns and also along the highway in case a bus on transit needs to recharge really quick.

### 3.2 Data Collection

This work collected data to determine the approximate number of electric vehicles in the country, specifically buses, and charging stations. It included the capacity of most DC fast charging stations, charging time, efficiency, wiring, power factor, energy management, maintenance and the number of vehicles that can be charged at the same time. The data was collected from EV charging start-ups and expert engineers in the field. A questionnaire was used to collect this data. The study adopted a non- probabilistic sampling method where 3 EV charging start-ups and 3 expert engineers were sampled

Information on the special e-mobility tariff was obtained from Kenya's utility firm and the regulator, EPRA. Data regarding grid readiness such as grid stability and availability within and outside of Nairobi, status of the distribution infrastructure, availability of transformers with the capacity to handle DC fast charging was obtained from Kenya's utility firm. This also included the number of sub-stations and feeders per substation. A map showing energy availability, that is grid lines, between Nairobi and Thika was also obtained from Kenya's utility firm. This data was crucial in determining the need for infrastructure upgrade, reinforcements and grid extensions required, the presence of policy frameworks and standards that support e-mobility and to establish the availability of funding support from banks and other financial institutions engaged in promoting e-mobility.

# 4 Results and Analysis

## 4.1 EV Start-ups

A questionnaire was designed to collect data regarding the provision of public DC fast charging stations for electric vehicles in Kenya. This was shared with several respondents in EV charging start-ups.

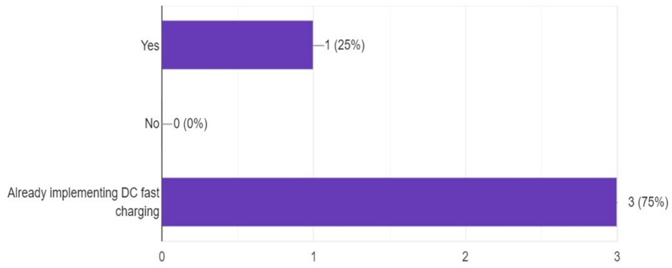


Fig. 3: Percentage of EV start-ups already implementing DC fast charging

It can be seen in figure 3 that about 75% of EV start-ups are already implementing DC fast charging and it's only a matter of time before the rest catch up. Customers want convenience and DC fast charging is the most convenient.

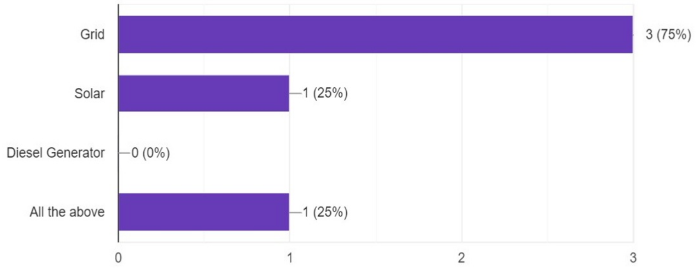


Fig. 4: Percentage of EV start-ups using the Grid

As seen in figure 4, over 75% of EV startups are getting their source of power from the grid. This presents a very good business opportunity for Kenya Power. Table 1 illustrates the responses from EV start-ups using a basis of 50%.

**Table 1.** Statistics from EV start ups

| Data from EV start-ups |
|---|
| Over 50% of EV charging start-ups have been in existence in Kenya for over 5 years |
| Less than 50% of EV charging start-ups have a current customer base of over 200 customers |
| Over 50% of EV charging start-ups are present in more than 2 counties |
| Less than 50% of EV charging start-ups own over 20 DC fast charging stations |
| Over 50% of EV charging start-ups charge more than 10 vehicles in a day |
| Over 50% of EV charging start-ups state that Kenya lacks enough skillset in the EV charging space |
| Over 50% of EV charging start-ups consider regulation or lack thereof, a challenge to the development and implementation of charging stations, to a large extent |
| Over 50% of EV charging start-ups expressed concerns on connection charges, affordable rates, seamless process |

The role of Kenya Power in the provision of public DC fast charging stations for electric vehicles stimulates demand creation thus more revenue and profit. Table 2 illustrates data from respondents regarding the power grid and Kenya Power's readiness to take up e-mobility. Majority of the respondents agree that there is need for an infrastructure and system study and the development of the skillset and culture of proactive maintenance for this specific subset.

**Table 2.** Data regarding Impact to the Grid

| Data | Description |
|---|---|
| **E-mobility Tariff** | Between ksh 15 - 20 |
| **Impact to the Grid** | Majority of respondents state that impact to the grid will be to a less extent since the uptake of EV is still low. Over the medium term, the impact may become more considerable |
| **Grid Readiness** | Over 50 substations in Nairobi County only, with 100% redundancy in the Central Business District |
| **Challenges in cities** | Space and Social Restrictions |
| **Investment requirements** | Infrastructure upgrade, system reinforcements, transformer densification |
| **Kenya's Utility Firm Readiness** | It has technical capacity to handle requirements; the utility can get partners to work with; the EV market can bring about more customers considering the global fuel prices are high and rising |

### 4.2 Evaluation of Time Required to Charge

In this work, data from 17 buses from one of the EV start-ups in is used for analysis. The first step is estimating After Diversity Maximum Demand (ADMD). The ADMD caters for the assumption that all the 17 buses shall be plugged in at the same time. A diversity factor of 0.7 is adopted as standard by Kenya Power. To determine the maximum power demand from the network, a charger rating of 240KW is used.

$$ADMD = Total\ Load * Diversity\ Factor \quad (1)$$

$$ADMD = Total\ Load * 0.7$$

$$ADMD = 240 * 17 * 0.7$$

$$ADMD = 2856\ KW$$

The sum of all the chargers' instantaneous throughput gives the total power demand on the network. This demand can be met comfortably by Kenya Power without resorting to carbon sources. To calculate the total energy consumption, it is assumed that all 17 buses, with a 240kW charger are charged once daily for 20 minutes. The kilowatt-hours per day will enable us to determine the demand and the times of usage.

$$Energy\ Consumption\left(KWh\right) = Total\ Load * Charging\ Time \in hours \quad (2)$$

$$Energy\ Consumption\left(KWh\right) = \frac{240 * 17 * 20}{60}$$

$$¿\ 1360\ kwhrs$$

Total cost of energy incurred in a month assuming a special e-mobility rate of $ 0.11 at peak period. In Kenya, the new e-mobility tariff has been set at $ 0.11 for energy consumption up to 15,000 KWh during peak periods and a time of use tariff of $ 0.056 per KWh during off-peak periods also up to 15,000kWh [17]. Time-of-use (TOU) rates would likely mitigate peak load growth by shifting charging load to low-cost hours

$$Total\ cost\ of\ energy\ incurred\ monthly = Energy\ consumed * Days \in a\ month * e - mobility\ tariff \quad (3)$$

$$¿\ 1360\ kwhrs * 30 * 0.11$$

$$¿\ \$4{,}488$$

The battery size of 1 electric bus is approximately 110kwh with a range of 250km per full charge. The instantaneous power being transferred from the grid to the vehicular batteries cannot be more than the charger rating. Using a charger rated at 240KW, this is less than 30 minutes, allowing more buses to charge. This presents significant energy consumption

$$Time \text{¿} Charge = \frac{Battery\ Capacity}{DC\ fast\ charger\ rating} \tag{4}$$

$$Time \text{¿} Charge = \frac{110}{240} = 0.45\, hrs$$

### 4.3 The Distribution Network

Kenya Power has not only automated the grid but it's also smart with distributed generation and fast restoration incorporating self-healing topology. Kenya Power has 3 66/11KV power distribution sub-stations along Thika Superhighway. These are Roysambu 66/11kv, KU 66/11KV and Ruiru 66/11KV. Figure 5 illustrates a section of the distribution network, including existing transformers, along Thika superhighway. All 3 distribution sub-stations are also located along the highway. Figure 6 illustrates the proposed design of a DC fast charging station. Then AC-DC power electronic stage converts AC into an intermediate DC voltage. DC-DC power electronic stage converts intermediate DC voltage to the voltage required to charge the electronic vehicle battery.

The proposed design shall have a ring main unit (RMU), having an alternative source and a 630KVA transformer for reliability purposes. According to a study done by the World Research Institute and the University of Massachusetts, Nairobi's current power infrastructure can support a 10% switch to electric of Nairobi's fleet, which is currently at 1 million [6].

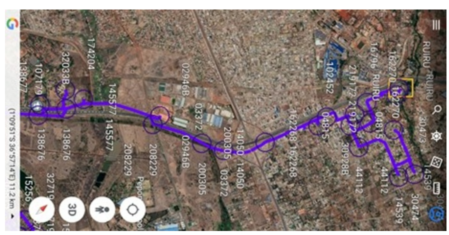

Fig. 5: A section of the distribution network along the highway

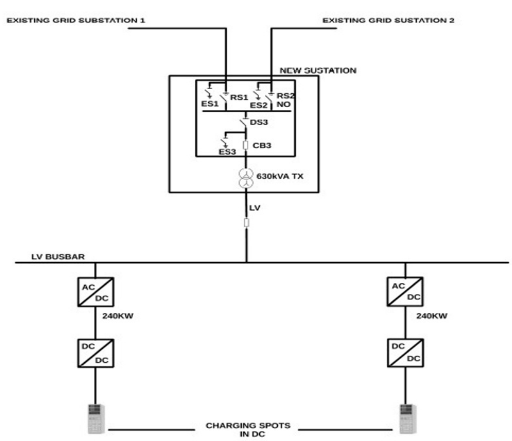


Fig. 6: Design of proposed DC fast charging station

### 4.4 Possible Partnerships

There are a total of 40 petrol stations along Thika superhighway as illustrated in Table 3. A charging station can be incorporated in any one of the petrol stations.

**Table 3**: Number of petrol stations along Thika superhighway

| No. | Outbound Nairobi to Thika | No. of Stations | Inbound | No. | Outbound Nairobi to Thika | No. of Stations | Inbound |
|---|---|---|---|---|---|---|---|
| **1** | River Pangani | 1 | Petrocity Thika | **14** | Ola Ruiru | 14 | Shell garden city |
| **2** | Shell drive in | 2 | Lexo Juja | **15** | Shell spur mall | 15 | shell Pangani |
| **3** | Total drive in | 3 | Total Juja | **16** | Lexo Kimbo | | |
| **4** | Shell mountain mall | 4 | Shell Juja city | **17** | Regnol weighbridge | | |
| **5** | Oilcom mountain mall | 5 | Shell Kimbo | **18** | Delta weighbridge | | |
| **6** | Total thika road | 6 | Rubis Kimbo | **19** | Shell weighbridge | | |
| **7** | Astrol Thika road | 7 | Ola kimbo | **20** | Total Juja city mall | | |
| **8** | Texas Safari Park | 8 | Total kimbo | **21** | Ola juja city mall | | |
| **9** | shell Roysambu | 9 | Rubis Thika Rd | **22** | Rubis Juja | | |
| **10** | Shell kiuguro | 10 | Total ruiru | **23** | Lexo juja | | |
| **11** | Total kiuguro | 11 | Shell kahawa | **24** | Shell Juja | | |
| **12** | Rubis Ruiru Junction | 12 | shell kahawa Junction | **25** | Total Mangu jomoko | | |
| **13** | Astrol Ruiru | 13 | Total safari park | | | | |

**Table 4**: SWOT Analysis for Kenya Power

| Strengths | Weaknesses | Opportunities | Threats |
|---|---|---|---|
| Over 90% of electricity dispatched to the grid comprises of renewable energy | DC fast charging installation is capital intensive and therefore requires high initial investment | The Government is heavily invested in promoting the e-mobility ecosystem in the country | May encounter space restrictions especially if the installation takes place in cities. |
| Kenya Power has enhanced electricity access to over 75% of the Kenyan population, about 9.1 million customers | Construction of a new dedicated line, transformer and other infrastructure upgrades also have high economic costs | Increased interest from local and international stakeholders keen on investing in and developing Kenya's e-mobility sector | Kenya does not have the adequate skill set for EV charging and EV charging installation, operation, and maintenance |
| Kenya Power has a national distribution footprint with a grid length of up to 300,000km. It also has a lot of idle land in urban centers, which can be used to construct a huge field of charging points | Reliability issues due to aged grid components or extreme weather such as storms that may lead to faults on the line | A special e-mobility tariff in place that will assist to take up load during off-peak period thus smoothening the load curve | Lack of a proper e-waste management program to handle spent batteries |
| There's enough generation capacity, 3321MW to meet demand created by the e-mobility ecosystem, hence no need for load shedding to meet this demand | Transition to e-mobility especially DC fast charging is a gradual process and shall require a lot of collaborations | In the recent years, a number of e-mobility companies have been set up with several more start-ups being established | Many EV owners /potential EV owners are discouraged by range anxiety. Moreover, people are still not aware about electric vehicles and their contribution towards a sustainable environment |

| | | | |
|---|---|---|---|
| Kenya Power has not only automated the grid but it's also smart with distributed generation and fast restoration incorporating self-healing topology | Sub-optimal placement of chargers may hinder successful implementation of the project | E-mobility is an opportunity for the company to grow its business and increase its revenues. With increased awareness of the benefits of EVs, demand for them is set to increase and consequently the need for charging | Vandalism of DC fast charging infrastructure. |

The most ideal place will be the Shell petrol station located at spur mall, meaning more people are likely to stop for shopping or eating at the mall, hence they can charge while at a stop. It should be located in the middle of the parking lot to allow more cars to charge. Moreover, it is near Ruiru 66/11KV sub-station limiting distribution losses and reducing line construction costs.

### 4.5 SWOT Analysis

In order to analyze the current situation of the company, a SWOT analysis was carried out. The analysis includes analyzing internal elements, such as the Kenya Power's strengths and shortcomings, as well as external factors, such as market or industry opportunities and threats. This analysis shall be used to construct the DC fast charging implementation strategy. Table 4 illustrates the SWOT Analysis carried out for Kenya Power.

### 4.6 Implementation Strategy

Kenya Power's goal is to sustain profitability and increase the company's shareholder value through the provision of public DC fast charging stations in strategic locations to support the growing number of electric vehicles (EVs) in the country. The reduction of GHG emissions will benefit the environment, with Kenya playing her part in saving our planet and mitigating the effects of climate change. Kenya intends to have at least 5% of all newly registered vehicles, to be electric by 2025. This project will therefore run for 2 years. For Kenya Power to execute this project successfully, the following implementation strategy is proposed as shown in table 5.

**Table 5** : Implementation Strategy for DC Fast Charging

| Strategy | Description |
|---|---|
| E-mobility Planning | Design a model for location optimization of potential public DC fast charging stations to identify where they are most needed. The variables shall be the charging time, number of buses that can be charged at the same time, ADMD, cost of charging infrastructure, battery capacity and state of charge. This should include a mobile application for easier location of these charging spots and use of them. |
| Safety and Security | Charging stations built to high standards and that electric vehicle owners have access to safe and reliable charging such as surge protection and electromagnetic interference. This should include regular maintenance and the introduction of an alarm system to ensure the DC fast charging stations are protected from vandals |
| Government support | Discussions with the Ministry of Energy and Petroleum and other relevant ministries to facilitate the implementation of a policy framework that will support the growth of the E-Mobility industry in Kenya. This will involve consideration to provide tax incentives for electric vehicles. A multi-sectoral approach is critical toward balancing the energy trilemma to provide reliable power, sustainably at an affordable rate. |
| Strategic partnerships | Strategic partnerships between Kenya Power and EV manufacturers, charging equipment suppliers, and financiers to help promote the development of charging infrastructure. For example, partnering with existing petrol stations will lower the initial capital cost by making use of the existing facilities |
| Private investment | Organize annual sustainability expos and conferences to attract private companies and investors entering the market to build and operate DC charging stations. This will also increase e-mobility awareness in the country |
| Network planning | Electric buses require 3- phase power and the faster 240kw DC charging shall require high values of instantaneous power. Analyse capacity per feeder per substation and identify those with almost zero capacity during peak period. Develop a dedicated medium voltage underground line for EV charging, having a Ring Main Unit (RMU) and GMT to ensure availability of an alternative source, to enhance reliability. This should include a more advanced system study to be carried out to analyze possible grid impact and adoption of demand side management measures to mitigate any negative impacts |
| | |

| | |
|---|---|
| Capacity Building | Develop research institutes in e-mobility such as the vehicle-to grid technology to allow for power to be fed back to the grid during peak. This should also be part of the curriculum especially in engineering courses, in universities and various learning institutions |
| Streamlined Service | Set up a department to champion the project within the company tasked to develop a business model, e-mobility system architecture, handle new connections, energy management and efficiency measures, integration with the grid, provision of DRE such solar in small-scale, billing and provision of metering equipment. This should also include the development of a proper e-waste management program to handle spent batteries |
| Coordinated Charging | Having most electric buses charging at night, during off -peak period through the introduction of time of use tariff. This will ensure the company does not need to increase carbon footprint by engaging fossil fuel generating plants/thermal plants, thereby increasing the fuel cost component of electricity |

### 4.7 Cost – Benefit Analysis

This analysis will be carried out using several financial indicators namely, the simple payback period, a cost-benefit ratio, internal rate of return, and the Net Present Value. This will help to evaluate the financial feasibility of DC fast charging. The core market being targeted are bus operators.

**Table 6**: DC fast charging parameters

| Parameter | Value |
|---|---|
| No. of buses that charge at night | 80 |
| No. of buses that charge during the day | 20 |
| Rating of a DC fast charger (kw) | 240 |
| Approximate time of charging (hrs) | 0.5 |
| Average lifetime of a DC fast charging station (yrs) | 10 |
| Discount Rate (%) | 5.5 |

Table 6 assumes a total of 100 electric buses are available for charging and only 20, that is 20% of these buses charge during the day. The lifetime of a DC fast charger depends on several factors such as quality, frequency of use and maintenance but the average lifetime is 10 years. The discount rate has been estimated using the current inflation rate, of 7.5%, and the current lending rate of 13%. So, the real discount rate is: $13\% - 7.5\% = 5.5\%$

**Table 7**: Calculation of PBO, RoR, and CBR

| Parameter | Cost (USD) | Cost (ksh) | Description |
|---|---|---|---|
| **Time of use tariff** | 0.06 | 8 | |
| **Tariff during peak period** | 0.11 | 16 | |
| **Cost during peak period** | 264.83 | 38,400.00 | Rating *No. of buses*Charging time*Tariff |
| **Cost during off peak** | 529.66 | 76,800.00 | Rating *No. of buses*Charging time*Tariff |
| **Total costs** | 794.48 | 115,200.00 | |
| **Annual Cash inflows** | 289,986.21 | 42,048,000.00 | Assuming a total of 100 electric buses are available for charging and only 20 ( 20% )of these vehicles charge during the day for 365 days |

| | | | |
|---|---|---|---|
| **DC Fast Charging station** | 413,793.10 | 60,000,000.00 | Approximate cost of a 240kw DC fast charger is 5million Kenyan shillings. 12 DC fast chargers shall be installed as a pilot. 5 within Nairobi, 2 on transit and another 5 at Thika town |
| **Charging Infrastructure** | 275,862.07 | 40,000,000.00 | Cable, connectors, control and communication unit, billing system |
| **Power supply** | 206,896.55 | 30,000,000.00 | Transformer, cables and associated accessories, electrical panels, switchgear |
| **Network connection costs** | 137,931.03 | 20,000,000.00 | |
| **Initial Investment Costs** | 1,034,482.76 | 150,000,000.00 | |
| **O&M** | 20, 689.66 | 3,000,000.00 | Assuming 0&M cost is 2% of the initial investment |
| **Annual Savings** | 269,296.55 | 39,048,000.00 | Subtracting O&M costs from annual cash inflows |

From table 7, the exchange rate used for financial analysis is Ksh 145 for 1 USD. The simple payback of 3.84 years indicates positive cash flows of the project and a short period required for the investor to recover funds invested in DC fast charging. It assumes constant cash inflows and outflows throughout the years. Any project with a benefit-to-cost ratio above 1 is acceptable. In this case, it was found to be 13.02 as seen in table 8.

**Table 8:** Payback period and benefit to cost ratio

| | | |
|---|---|---|
| Simple PBP | **3.84** | In years (taking the initial investments costs divided by the annual savings) |
| **Benefit-to cost ratio** | 13.02 | Taking annual savings divided by O&M |

While calculating NPV, the sum of the present values is compared to the initial cost of the investment. It has also assumed constant revenue throughout the years. The project is financially viable since it has a positive NPV as seen in figure 7. For calculation of the IRR, it is assumed that the initial investment of the project is realized halfway through the project lifetime, that is 5 years. This was found to be 9.483%, higher than the discount rate, indicating that the project is profitable.

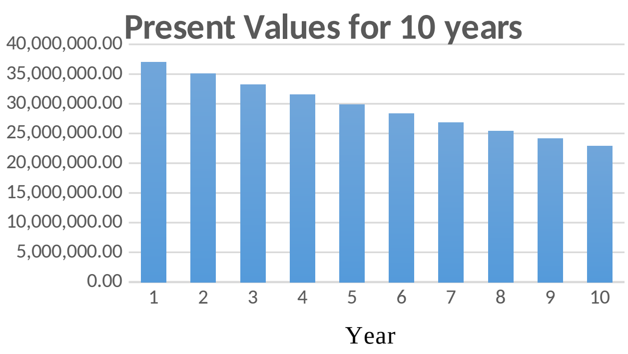


Fig. 7: NPV Calculation

## 5 Conclusion and Recommendation

The financial indicators employed in this study suggest that the provision of public DC fast charging stations is profitable. In this regard, Kenya Power should consider investing in DC fast charging as it is one of the key areas that will help to sustain profitability and increase the company's shareholder value. This shall also improve grid stability and flatten the load curve ensuring Kenya Power is not subjected to high idle capacity charges. Moreover, by investing in e-mobility, the country will significantly reduce dependence on fossil fuels to the benefit of our environment and the health and well-being of the citizens of Kenya. This shall go a long way in reducing the cost of transportation as Kenyans shall not be vulnerable to the fluctuating price of petroleum. The reduction of Green House Gas emissions will help the environment, with Kenya doing her part in saving our planet and mitigating the effects of climate change. This study recommends the introduction of DC fast charging stations, as an element in transmission and distribution infrastructure at strategic points, to supply electrical energy for the charging of electric vehicles at strategic points. This goes a long way to assuage range anxiety and thus encourage the adoption of EVs.

## References

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