University of Rwanda

College of Science and Technology

Title of the Project: Feasibility Study of a Solar-Powered Charging Station For E-Vehicles – A Case Study of Car Park Slots at The University Of Rwanda

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In partial fulfillment of the for the requirement for the degree of **MASTERS OF SCIENCE IN RENEWABLE ENERGY**

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DECLARATION

I, Innocent TUYISENGE, The undersigned hereby declare that this dissertation is my original work and that it has never previously been submitted for a degree at the University of Rwanda or any other university . I also declare that all information, sources of materials, and results from other works presented in this paper have been properly cited, acknowledged, and referenced in accordance with academic rules and ethics. No part of a dissertation should be copied without the author's permission. or the University of Rwanda's permission.

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SUBMISSION/APPROVAL

This final with my approval as the University advisor, the dissertation has been submitted for examination.

Thesis Adivisor: Dr Alexis Muhirwa

Supervisor's Signature:

Date: 05/11/2022

DEDICATION

My beloved wife MUKAMAZIMPAKA Marie Thérèse;
My beloved children
My Parents, brothers and sisters;
All UR/ACE-ESD Community;
My classmate in program of Renewable Energy;
Anyone else who is not appearing in this list but whose role is recognized

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May God bless you abundantly!
Mr Innocent Tuyisenge

ABSTRACT

In recent years, electric vehicles (EV) have globally positioned themselves as a respectable substitute for gasoline-powered automobiles. These cars require "fueling up" their batteries in order to operate. Although grid-based charging has always been the standard, using solar chargers has become a desirable option. Clean electricity, which is good for the environment and pollution-free in and of itself, is what these chargers give electric vehicles. We construct an EV charging station for a parking space for a car-sharing service as part of this project. The timings for rental pick-up and drop-off are set in this type of car-sharing service. I develop a linear programming technique that maximizes solar energy while keeping battery levels constant across all electric vehicles (EVs). The performance of the method was evaluated by applying the developed algorithm to a real-world scenario. Where the synthetically generated datasets are used to demonstrate that the available electric charge is distributed fairly among candidate EVs across seasons and demand profiles. Furthermore, when compared to the best effort charging policy, I eliminate 60% of the difference in battery charge levels. I also show that EVs in the 80th percentile have at least a 75% battery charge at the end of their charging session. Finally, I demonstrate that a solar system proportional to the size of a parking lot effectively distributes solar energy to the served EVs.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACE-ESD	African Energy Center of Excellence for Sustainable Development
BEVs	Battery Electric Vehicles
BOS	Balance-of-System
CBE	College of Business and Economics
CoK	City of kigali
COP21	Conference of the Parties, 21st session
d.c.	Direct Current
DCCS	Decentralized Community-based Charging Stations
DoD	Depth of Discharge
E-mobility	Electro-mobility
EMS	Energy Management Systems
ESSP	Energy Sector Strategic Plan
EVs	Electric Vehicles
FC	Fuel Cell
GHG	Green-House Gas
GoR	Government of Rwanda
FCEV	Fuel Cell Electric Vehicles
HEVs	Hybrid Electric Vehicles
HQs	Headquarters
ICE	Internal Combustion Engine
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change
KCC	Kigali Convention Centre
LCPDP	Least Cost Power Development Plan
LHS	Left-hand Side
REG	Rwanda Energy Group
REM	Rwanda Electric Motorcycle company
REMA	Rwanda Environment Management Authority
RES	Renewable Energy System
SEZ	Special Economic Zone

MININFRA	Ministry of Infrastructure
PHEVs	Plug-in-Hybrid electric vehicles
PEM	Proton Exchange Membrane
PEVs	Photovoltaic Electric Vehicles (PEVs)
PV	Photovoltaic
RHS	Right-hand Side
SC	Supercapacitor
SRMs	Switched Reluctance Motors
UNFCCC	United Nations Framework Convention on Climate Change
UR	University of Rwanda
USABC	US Advanced Battery Consortium
VW	Volkswagen
WE	Wind Energy

CHAPTER 1. INTRODUCTION

1.1 Study Background

In today's fast-paced world, Solar systems, for example, can help meet the world's rising energy demand. and environmental concerns. Nowadays, developing new energy conversion and storage systems is becoming imperative due to the high global population growth (≈83M or 1.1% annually) and a concomitant greater survival reliance on energy-based devices. Furthermore, the quick economic growth is extensively bringing about an unprecedented wane in fossil fuel reserves, which is adamantly appended with environmental deterioration that emanates from greenhouse gas emissions. Within this modern area of technological advancements and economic growth, the road traffic is extraordinarily increasing and it is not about to decline because of countries commitment to development, their outnumbering inhabitants and commodities exchange. Almost all vehicles are combustion-fueled, which implies outspread air pollution that directly affects the local ecosystem. The only way to cope with that challenge is to use the fathering source of all renewables that is abundantly spread worldwide. However, the solar energy availability is hourly-sensitive, unequally scattered over the sphere and its storage technology is not yet fully developed to cater for the demand. Hence, many studies are increasingly getting devoted to its effective use.

As a signatory of global treaties such as UNFCCC - Paris Agreement COP21 [1], Rwanda has embarked on the environment protection trail. After climate landmark event, the COP 21 ended up in breakthrough of sealing an all-inclusive unprecedented agreement to stick with a global warming of 1.5°C - 2°C, as to the IPCC recommendations[2]. To that end, various stretch-targeted blueprints (vision 2020, 2050) have been elaborated together with their implementation strategies, such as Rwanda Energy Sector Strategic Plan (ESSP) [3], and the long-term energy vision for high-level targets and achievement approaches[4]. Within that framework, Rwandan traffic sector has been acknowledged as one of highest pollutants in the energy sector that emits sizable GHG in the environment [5].More recently, Rwanda has registered a traffic volume census of 221,000 vehicles (52% being motorcycles and 38% passenger cars), wherein at least 13.5% are located within in Kigali. Until 2050, the car growth rate in Kigali per annum is expected to be between 1.5% and 2.2%; this adapts to the yearly population growth in Kigali that is approximated to lie between 4-6% [6].

Table 1: Transportation Model Estimations for the City Traffic Growth

Macro Model City Wide	Year 2018	Year 2050
Number of Peak Hour Motorbike	47162	111180
Number of Peak Hour vehicle	41235	97420
Sum of vehicle and Motorbike	88397	208600
Growth Rate	-	2,36
Rate per year	-	2,20%

Therefore, Kigali has been tagged as a microcosm of the country's challenges with transport environment deterioration. This is accentuated by the unprecedented yearly increase of vehicles, which has triggered two GoR concerns: (i) Worsened air quality and, (ii) increased fuel import bills [7]. A PV array, charging unit, battery pack, and a bi-directional inverter for load response make up the charging system. Smart EV charging would be necessary to enable EV owners or EV charging facilities to effectively sync with local RES generation, available charging times, growing EV popularity, and knowledge of renewable energy systems (RES), as well as to maximize profitability by accounting for grid pricing variations. The optimized tariff affordability is one of Rwanda Energy Group's priorities, implemented through the Least Cost Power Development Plan (LCPDP) to ensure future 100% electricity access, thus making anticipated industrialization a reality. Recently, Because of the increasing with the increasing reliance on energy-based gadgets for survival, it is clear that new types of energy conversion and storage systems are required. Global population growth and economic growth are accelerating, which is causing fossil fuel supplies to deplete quickly and raising environmental problems like greenhouse gas emissions. Additionally, as a result of the modern era's technological breakthroughs, more electronic equipment are being employed to substitute labor, which results in an additional rise in energy consumption .The term "solar energy" refers to the energy produced by the sun's rays illuminating the earth's surface or atmosphere. There has recently been an emphasis on conducting feasibility studies on solar-powered EV charging stations that generate clean energy. Building solar-powered EV charging stations is a great way to greenfly our transportation needs and make EVs environmentally friendly from the start. thanks to lower solar costs and increased solar efficiency. Generate electricity for charging vehicles. In this thesis, I'm considering constructing a solar-powered charging station for an electric vehicle car-sharing service. Typically, gasoline-powered vehicles are popular in vehicle-sharing services .Because electric vehicles are becoming more popular, These service providers may soon own a greater number of electric vehicles. Tesla electric vehicles are already available through some vehicle-sharing services. Customers who use vehicle-sharing services are typically leased vehicles and billed on a per-use basis. When not in use, the cars can be charged via a power outlet until the next lease begins. The feasibility study of a solar-powered charging station for a car-sharing service raises intriguing questions. First, the solar parking lots must be of sufficient size to provide sufficient power to charge the vehicles. A small PV system, on the other hand Large PV systems may waste energy and provide insufficient energy. Second, solar energy is sporadic because it is dependent on local weather conditions such as temperature and cloud cover to provide power. on any given day. The final step in charging a car is to prioritize exhausted batteries over cells with higher energy levels. Undoubtedly, a car with a higher charge will be preferred over one with a lower charge. To increase consumer satisfaction, charging priority should be given to the vehicle with the lower battery level if one vehicle is 80% charged and the other is 20% charged. Keep in mind that solar energy has a daily peak. As a result, if multiple vehicles are charged at the same time, the best effort equal charge may be suboptimal because it does not prioritize one vehicle over another. An earlier experiment was also conducted on solar cells integrated into E-cars to provide solar energy. They most likely realized that the energy generated by the intergraded PV cells could only be used when the capacity of the battery was less than optimal. Despite the fact that it is a sustainable approach, the capacity of the car's battery saturation point limits the solar energy capture of the PV arrangement. Furthermore, because the vehicle is primarily in motion, optimizing energy capture will necessitate sophisticated systems integrated into the vehicle, which will be costly to operate. and less expensive is to charge solar panels from a parking lot, which is faster and more practical. They may have understood that the energy produced by the intergraded PV cells can only be utilised when the battery's capacity is below optimal that previous experiments on solar cells being incorporated into E- cars to supply solar energy. The capacity of the car's battery saturation point restricts the solar energy capture of the PV arrangement, despite the fact that it is a sustainable approach. Additionally, because the vehicle is primarily in motion, optimizing energy capture will require more sophisticated systems that are integrated into the vehicle, making them expensive to operate It is easier and more convenient to charge via solar panel from a parking lot.

1.2 Problem Statement

In Rwanda we have few charging station some are in Kigali that using grid connection and domestic electricity. They are limitation of E-vehicle, the price of electricity is still high in Rwanda, and challenge of instability in grid electricity the use of renewable energy like solar can be the solution.

Electric vehicles' charging stations are known to cause power system disturbances due to their power electronics system design which brings about the harmonics and voltage shifting, thus requiring more reactive power. The resultant power demand is mostly higher than the available power supply. Therefore, to avoid the overloading the power utility, electric vehicles charging stations need a particular power supply. This in other words means that e-vehicles charging stations should be isolated from the grid. E-vehicles are utilized for transportation, but they can also be used as a backup energy source when renewable energy sources are integrated to meet customer demand, reduce active and power losses, and preserve voltage profiles. The availability of renewable energy sources varies throughout the day, therefore more electricity might be supplied through e-vehicles to satisfy the peak demand. Random integration in e-vehicles may lead to issues with system unbalancing and require a fix. The need to address the fuel efficiency, requirements in emissions and noise pollution, and lower operational expenses has emerged into E-mobility. The latter is in its infancy stage, both in technical perspective and limited market share. Yet many challenges are to be surmounted in order to leverage all pros within the electrical power chain.

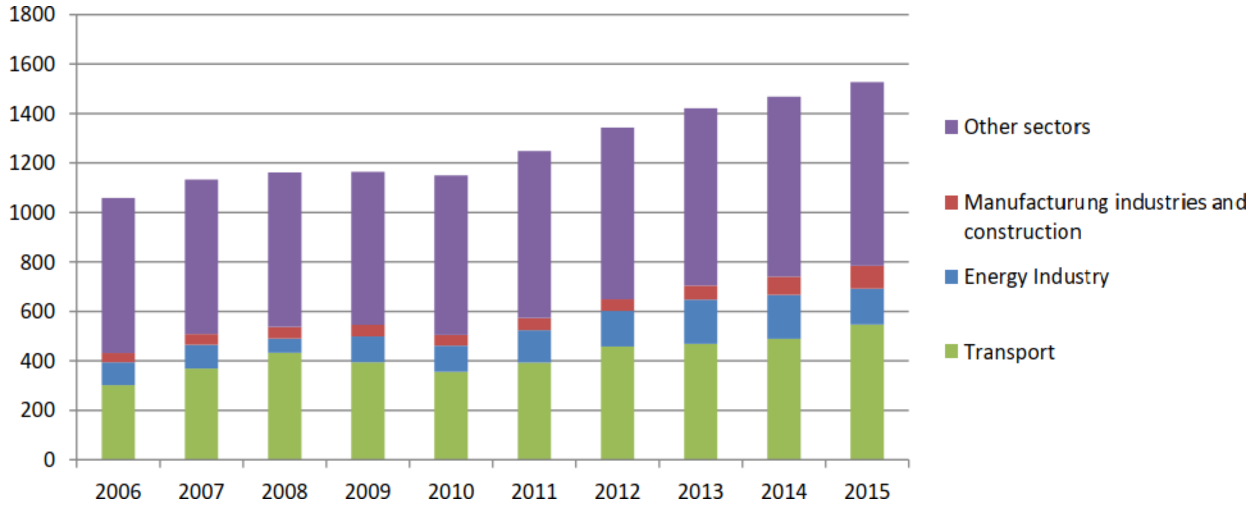

Figure 1: Typical yearly GHG (CO2eq) contributions in Rwanda (1,000 tons)[7]

As illustrated in Fig.1, the commuting/goods traffic is one of the top GHG contributors from the energy sector in Rwanda. Among suggested mitigation alternatives, there are EV-backed transport decarburization and exploitation fuel-efficient systems, so as to start superseding diesel-fueled vehicles since 2020. 2050 projections aim at substituting 150,000 passenger cars with EVs whose average power consumption is 30kWh per 100km each [7]. Thanks to on-going efforts, start-ups initiatives such as Ampersand, Safi Universal Links Ltd, and REM Company, have landed to assemble e-motorcycles or retrofit existing ICE motorcycles. Affordable electric bikes can be bought at $1,300 (<$1,600 for fuel motorcycles), where taxi-moto operators recharge at a cost equal to the one for traditional motorcycles with a capacity to drive for around 70 kilometers. On the other hand; EVs importers, like Volkswagen and Victoria Motors Rwanda Ltd, have a limited number of EVs with two Siemens-operated charging stations located in SEZ and KCC. The rarity of E-cars in the CoK may be attributed to town dwellers not wowed due to various technical and applicability issues or hidebound reasons. The IFC/World Bank is a willing partner to introduce the public transport e- Buses. As of April 2021; 140 e-motors and 40EVs (20 e-golfs, 20 PHEVs) were operative, whereas 60PHEVs were stocked [9, 10] However, The lack of a stable and continuous electrical power supply is one of the main issues with the adoption of PV generators. Such converters suffer from an intermittent and stochastic supply as a result of the constant variations in solar insolation and ambient temperature. Furthermore, the day-night cycle has a significant impact on the ability to use PV sources in standalone configurations, making a PV source a non-dispatchable unit. As a result, various solutions should be implemented in PV systems to balance the electrical grid power flow and provide consistent power to the connected loads. Several studies have been conducted to examine the design of EV charging stations based on hybrid sources, including the storage system. Though energy conversion losses and the initial cost of both battery power banks and solar panels remain issues, Decentralized Charging Stations (DCCS) tailored to sub-community demand prove to be a convenient and sustainable method with low operational costs for achieving carbon-free transportation. The quantity of power available for residential use and other uses diminishes as more electric vehicles draw power from the grid, creating an imbalance in distribution that leads to low power factor and power net instability.

1.3 Research objective

1.3.1 General objective

The general objective is to carry out a feasibility assessment of a Decentralized Community-based Charging System (DCCS) for solar-powered e- vehicles within the car park slots at the headquarters of University of Rwanda (UR).

1.3.2 Specific objectives

The following are the specific objectives proposed to achieve the above-mentioned major goal:

1. To evaluate the locally available irradiation/insolation at university of Rwanda
2. To estimate the daily power demand based on specific user stats
3. To assess and analyze the combination of direct solar PV and battery storage applications
4. To design a model of a Solar PV e-vehicle charging system in accordance with the specific criteria of local insolation and demand.

Our primary research goal is to develop a conceptual Feasibility study based on the usage of solar energy from the sun to charge electric automobiles. We also want to theoretically investigate how existing parking lots may be transformed into solar energy charging stations for the cars. Additionally, We examined the PV panel placement on the parking lot roof . the components that will be used to convert and direct solar energy to storage battery cells and charging stations, as well as the specifications of the charging systems for both car batteries and electric chargers. Finally, we consider how to put the design into practice. at university of Rwanda in our study area.

1.4 The study's significance and expected outcomes

1.4.1 Expected results

The feasibility aspects for low-scale charging spots within specific sub-communities will be approached. All PV-EV charging parameters; such as charging processes, power converter topologies, and control and optimization, will be assessed in accordance to the chosen DCCS features.

1.4.2 Significance of the Study

The road traffic hereafter belongs to eco-friendly, efficient and quiet E-mobility. The transition will require systematic adoption of EV hybrids and renewables ought to be applied energy sources so as to ensure no second-hand GHG emissions from power generation.

Due to the random distribution of the massive solar energy, it is very important to start looking at the feasibility of locally tailored charging systems within a near future. Within populated cities, there are several work/residence-based communities and the energy requirement and availability of such closely located individuals can be assessed to set a Decentralized Community-based Charging Stations (DCCS) whether during in nighttime (Grid connection) or daytime (solar energy supply).Within certain work-based communities, like University campuses and some other public institutions, the number of servants and clients can be fairly regular on a day-to-day basis. Based on averaged daily stats, studies can evaluate the averaged local insolation and users tally with their fuel requirement to tailor a decentralized charging systems.

1.5 Research questions

i) What are the possible ways of making the charging systems sustainably decentralized to sub-community levels?

ii) Is it foreseeable to envision local charging EV stations within institutions that have an almost consistent number of EV users?

iii) What are the main challenges to anticipate in the implementation of zero-emission policy about EVs traffic application?

1.6 Justification

Solar energy systems and other renewable energy sources can assist fulfill the world's constantly rising energy needs. Electric vehicles are a dependable substitute for traditional automobiles due to their technological and environmental benefits. On the other side, renewable energy sources are sporadic. As a result, backup support is necessary. A battery pack is added to the system to help keep the load powered on even when the PV power is insufficient to meet the load's energy needs.

1.7 Scope delimitation

Rwanda has sizable energy potential in various resources; such as solar, hydropower, biomass, methane gas and evident traces of geothermal energy [11]. This study is delimited to the use of solar energy, as an abundantly available resource that mothers all renewables

Though the "University of Rwanda" has been stated in the title for shortening purpose, this study aims a slot within its parking slot located at HQs campus known as College of business and economics (CBE) within a locality that is usually called Mburabuturo. The car parking slot surrounds the building that accommodates the UR Headquarters, as depicted. The site evaluation for efficiency optimization will determine which solar panel placement provide high performance, whether roof-top or ground PV configurations; as shown in the Fig. 2 ,or around the terrain neighboring parking slots.

Figure 2: A satellite panorama of parking slots surrounding UR HQs

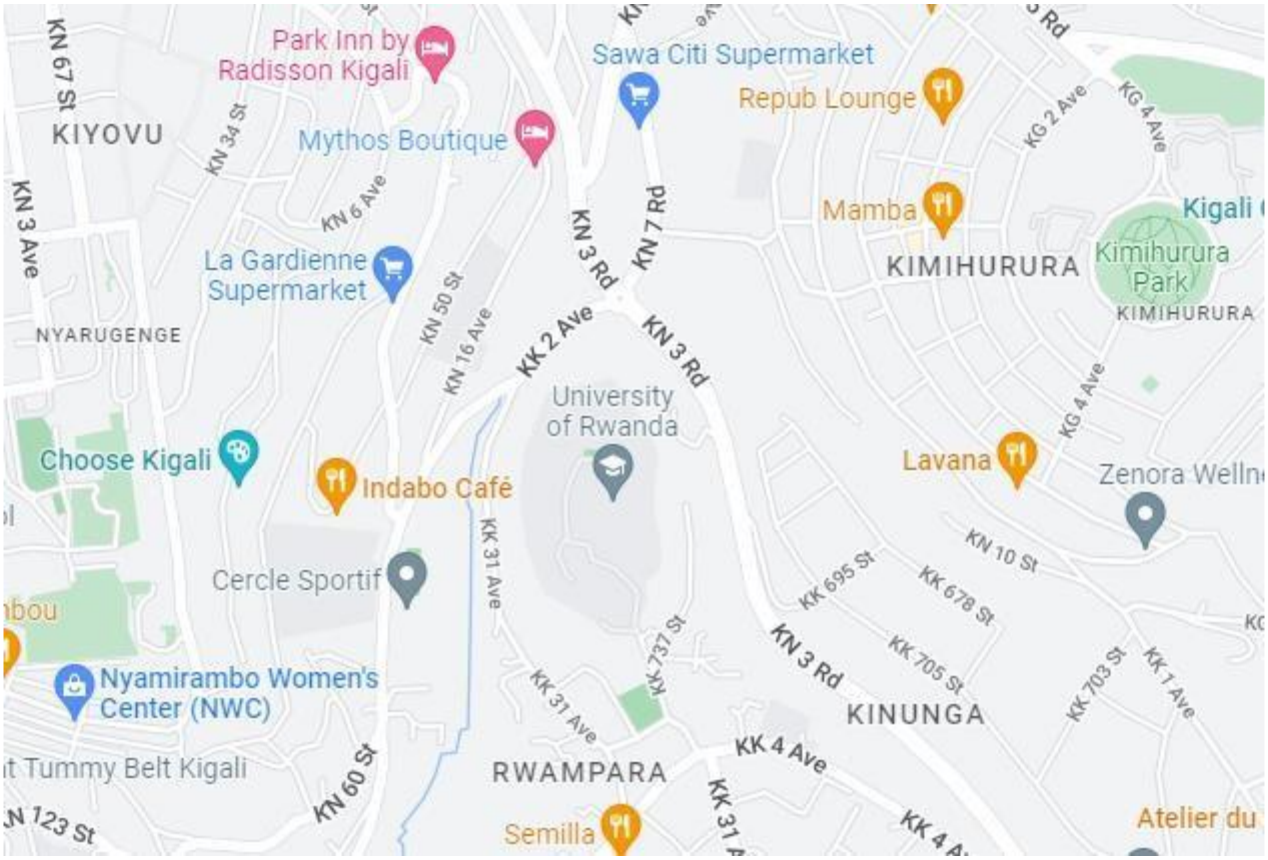

Figure 3: University of Rwanda Headquarter location on Map

Among three main types of E-mobility (BEVs, PEVs, PHEVs), this study is circumscribed to the use of PHEVs due to their flexibility of embedding many power sources, and such transition EVs type have been already introduced in Rwanda by Victoria Motors Rwanda Ltd[9]. Moreover, the battery performance deterioration for PHEVs is not high, since the ICE makes up for the aging-associated degradation.Among the two approaches of PV-charging systems, this project will use the PV-standalone to avoid the operational cost associated with PV-grid charging systems. Moreover, the brake charging feature of PHEVs may supplement the solar-based charging during weak irradiance. Within various renewables that are present in Rwanda, the only renewable resource of solar energy that is free and widely spread will power the DCCS system curtailed to local idiosyncrasies.

1.8. Thesis organization

This thesis' outline is organized as follows: chapter 1; describes introduction of project chapter 2; the literature review, research on related topics is analyzed to choose the best technique for Feasibility study E-Vehicle charging system chapter 3; describes the methodology used for research and chapter 4; Results and discussion, Recommendation and conclusion .

CHAPTER 2: LITERATURE REVIEW

2.1 Historic Account and classification of E-mobility

Electromobility is often misinterpreted as a modern invention, whereas it dates way back in 1867 before the advent of ICE. The first vehicle driven by an electric motor has been introduced towards 19th century end. A Belgian Camille Jenatzy came up with a world record in 1899 of an unprecedented road car able to attain 100 km/h speed. Later on, trains and trams powered from power rails or overhead lines have been commissioned. Though they didn't completely retire from the market, e-vehicles have been downgraded to niche owners due to the convenience and technology advance of ICE. Around 1933, EV's were nearly zero due to their slowness and affordability in comparison to their ICE counterparts.

Thanks to advancement in power electronics in 1960s, the EV technology has witnessed a rebound in motor control; and the 1970s oil crisis maintained the research interest and related founds allocation. Contrived prototypes during those two decades served as a basis to today's EV developments. Mid-1990s marked the apparition of a hybrid model on the market and the Californian Roadster emerged in 2008 as a first e-car appropriate for lengthy highways trips. Since then, EVs have accumulated the interest as an efficient, quiet, and low-emission transport alternative and have been ideally used in taxis, delivery services, and car sharing within cities [12, 13]. E-Mobility stands for a concept of harnessing electric powertrain technologies to enable the vehicles/fleets propulsion. Such technologies encompass full electric-powered vehicles and plug-in hybrids as well as hydrogen fuel cell and photovoltaic electric vehicles (FCEV) that assume hydrogen conversion into electricity[14]. E-Mobility; whether e-buses or e-trucks, electric cars, e-motors, e-bikes or pedelecs; contributes low or zero tailpipe emissions though a rechargeable battery, usually by plugging it into the electricity grid, so as to power an electric motor. As EVs may be entirely or partly driven electrically, three popular classifications are as follows:

(i) Battery Electric Vehicles (BEVs), also often referred to as EVs, are zero-emissions cars (no noxious tailpipe exhaust and pollution-associated hazards), since they are entirely powered by a grid-rechargeable battery pack without ICE. (ii) Both an electric motor and a gas-powered traction engine power hybrid electric vehicles (HEVs).. These regular hybrids cannot be recharged by the grid electricity. However, they retrieve the energy from a battery that is supplied through regenerative braking (usually lost as heat within brake pads & rotors in ICEs) to assist gasoline engine while accelerating. When hybrid cars can benefit from the socket recharging, in addition to recovered electricity while taxing or braking, are termed (iii) plug-in hybrids (PHEVs). For that double recharging source, they have a relatively larger battery [9].

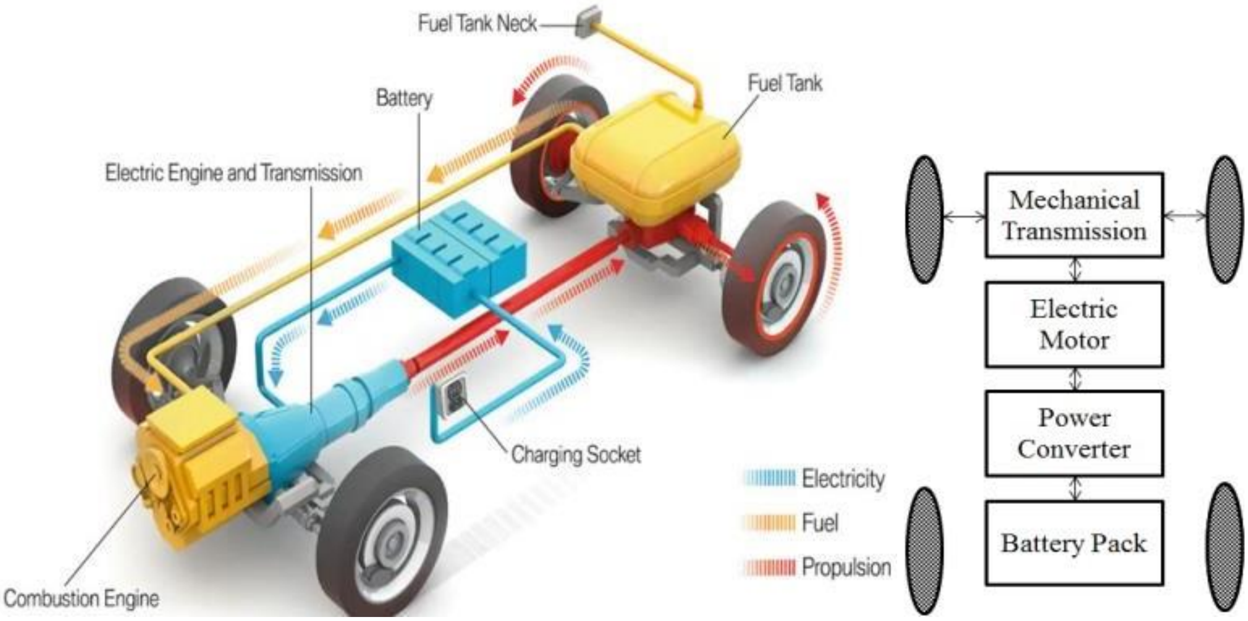

Figure 4 A PHEV Model versus a battery-powered EV schematic [15, 16]

Both hybrids technologies can be considered as the future of auto-industry that bridges the transition from traditional mobility to EVs till an entirely electricity-powered vehicle is developed. Though they both have traction engines, various advantages have been noticed for hybrid vehicles over their ICE counterpart[17].Motor topologies and EVs specifications explain the applications of the d.c. and induction (IM) motors; synchronous types of permanent magnet (SPM) and brushed motor (SBM) motors [18]. The 5th topology is the reluctance motor (RM) that offers more desired characteristics Through achieved technology betterments in battery storages, power converters, motor drives, and EMS; EVs have registered a promising leap forward. However; owing to the challenging technology of recent batteries (i.e. extended charging period, exorbitant initial cost, and restricted passenger/cargo space, limited driving range)[19]; hydrogen fuel cell and photovoltaic electric vehicles (FCEV) have got a boost; since the normal driving distance of usual EVs is comparatively small to result in limited EVs applications[20-22].

2.2. EVs Energy storage systems

Vehicle electrification endeavors strictly rely on accurate and efficient development of energy storage systems. Costly electricity storage and protracted charging time of the battery are shortcomings that hinder the use of zero-emission BEVs, thereby limiting the range of such EVs.

Batteries performance can be distinguished from several aspects, such as the cycle or calendar lifes, the cost per kWh or the energy versus power densities (Fig. 3) [23], Volume and safety, energy efficiency and self-discharge, a trade-off between energy and power density[24, 25]

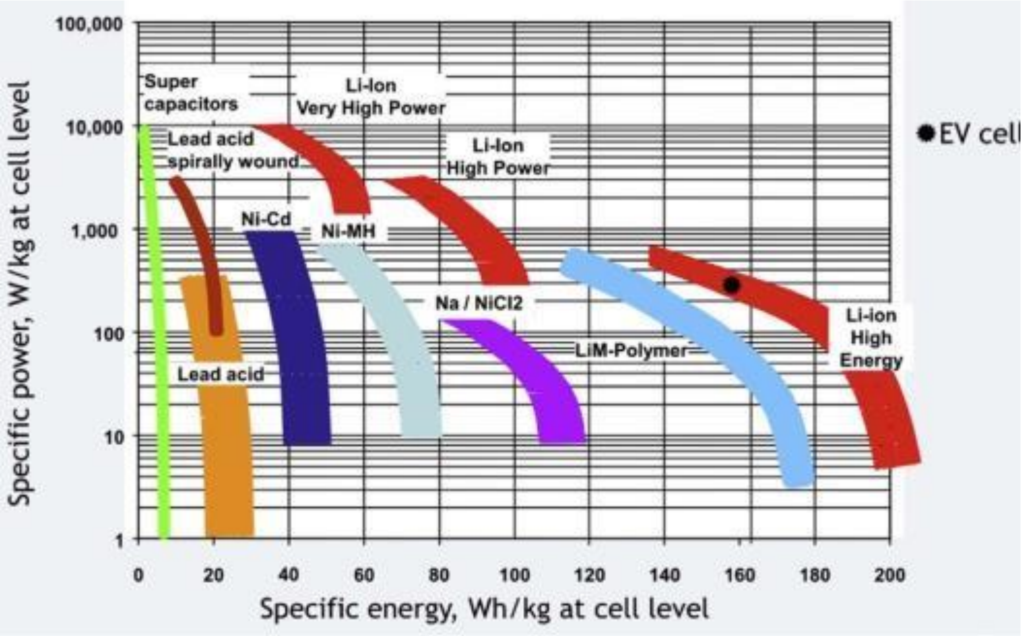

Figure 5 Specific capacity in most popular battery technologies[26]

A goon number of novel batteries technologies have been contrived to be used in hybrids and BEVs. A typical example is the Li-ion technology, one of popular alternatives in advanced EVs. Various chemical compositions have been used to meet specific characteristics [27]. Lithium-ion, nickel-metal hydride (Ni-MH), nickel-cadmium (Ni-Cd), and lead-acid batteries are the most common battery technologies. Table 2 lists typical properties, including energy density (chargeable electric energy per weight of battery pack), power density (the ratio of dischargeable electric energy to charged energy), and cycle life (the number of charging/discharging cycles in a battery's lifetime). According to USABC, a battery cell is said to be dead out if it drops below 80% of its rated capacity or falls below 80% of its rated power density at 80% DoD[28].

Table 2: Technical performance in EVs batteries [29]

	Lead-acid	Ni-cd	Ni-MH	Lithium-ion
Energy density (W/kg)	30-50	45-80	60-120	110-160
Power density (Wh/kg)	180	150	250-1000	1800
Nominal voltage	2V	1.25V	1.25V	3.6V
Overcharge tolerance	High	Moderate	Low	Very low
Self-discharge	Low	Moderate	High	Very low
Operating temperature	-20^0 to 60^0C	-40^0 to 60^0C	-20^0 to 60^0C	-20^0 to 60^0C
Cycle life	200-300	1500	300-500	500-1000

As noticed from Table 2; batteries based on lithium-ion can be made lighter and smaller in both weight and size, since they reflect the best energy efficiency and power density. Furthermore, lithium-ion batteries have fast charge trait, low self-discharge rate, a wide operation range of temperature, with no memory effects and a relatively long cycle life [16]. However; a more advanced EV energy density is being sought in electrochemical energy storage systems. Lithium–Sulphur (Li-S) is one of the later, though its commercialization gets hampered by limitations such as self-discharge that, in addition to cycling, causes capacity wanes [30]. Table 3 some provides lithium-ion battery packs details about manufacturers, specific EV applications, capacity and approximations about normal driving range.

Table 3: Li-ion battery technologies and applications[16]

Cathode material types	EVs developers and EV models	Battery packs capacity [kWh]	Approx. range in normal driving conditions [Km]
Lithium with Cobalt Oxide (LCO)	Tesla–Roadster	56	394.3
	Daimler Benz–Smart EV	16.5	135.2
Lithium Manganese Oxide (LMO)	Think–Think E	23	160
	Nissan–Leaf EV	24	169
Lithium Iron Phosphate (LFP)	BYD–E6	57	400.8
	Mitsubishi–iMiEV	16	160
Lithium Nickle–Manganese–Cobalt Oxide (NMC)	BMW–Mini E	35	241.4

2.3 .Solar PV for EVs application

Charging EV by means of PV involves two techniques: the PV-grid or PV-standalone setting. The former has a flexibility benefit from grid supply over periods of irradiance scarcity or supplement the grid over high irradiance supply (Fig. 4). PV-standalone proves fairly affordable and convenient in rural remote zones, far from utility reach. Partially degraded or second life batteries featured with a maximum power-point tracking controller can enhance the PV-standalone performance [31]

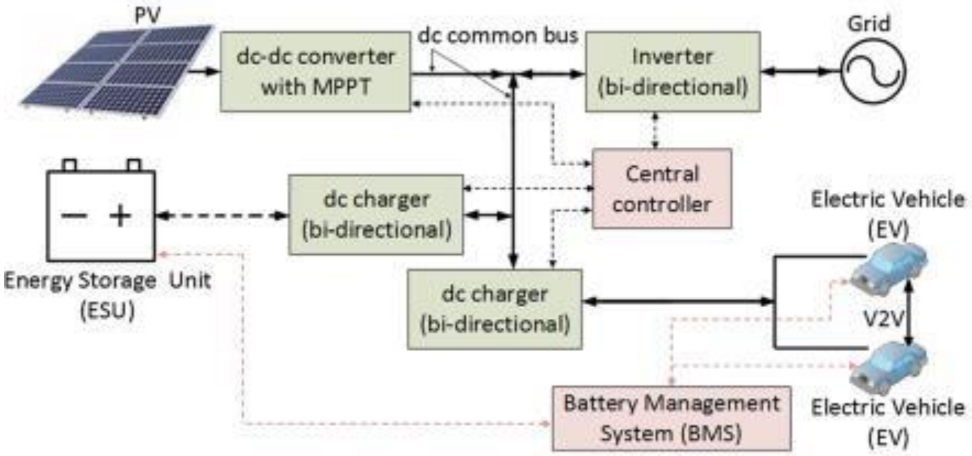

Figure 6: General layout for PV-grid charging settings[32]

The selection of a solar panel application for EVs is mostly guided by the efficiency. The latter is directly correlated with the solar panel material and coverage area, and the expected driving range of EVs. The impact of the efficiency can be easily perceived from PEVs where losses associated with battery energy savings are mitigated. To stretch out the trajectory predictions of EVs, PV panels directly mounted on the vehicle have been tried out to lessen the vehicle reliance on batteries. Under such applications, Switched Reluctance Motors (SRMs) have been a promising option to counteract the issue of massive rare-earth materials and high-performance permanent-magnet (PM) machines[22] that transfer energy from the PV panel to the battery, and eventually, to the SRM. [33]. However, due to the PEVs' roof space limitation, a high-efficiency module (>30%) is required, which result in costly installations[34]. Fig. 5 depicts such efficiency relationships in terms of PV material and area, and the EV driving range.

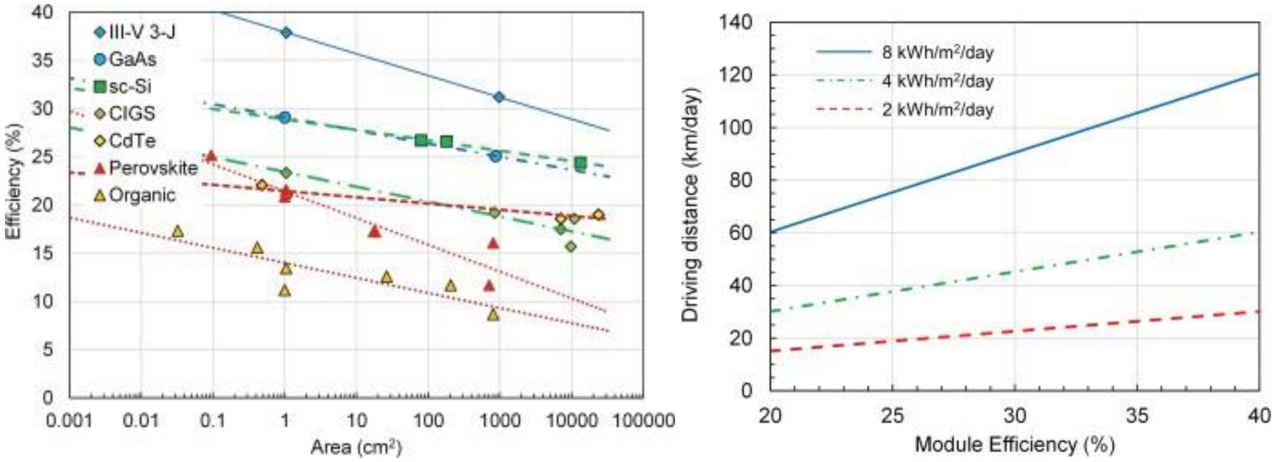

Figure 7: Efficiencies versus various PV solar cells materials and module areas (LHS); and PVEs driving trajectory dependence on a module efficiency and solar irradiation (LHS)[34]

In addition to those efficiency optimization parameters, the PV site design may influence the overall solar cell efficiency. Typically, the angles discrepancies between the PV panel tilt with the solar lay incidence; and shadings set forth by trees or buildings. The latter may be considered as unpredictable solar availability for PEVS or site selection inappropriateness for other EVs [35]. To that end, the mounting structure and other BoS components, such as cabling, regulators, inverters, are to be thoroughly checked [36] This thesis Describes conceptually how to use solar energy to charge a car. By conducting research on each of the subsystems and how they work, we will be successful. Interconnected in this section on literature review.

2.4. The solar panel system

Throughout human history, the sun has played numerous roles. It not only provides energy and light to Earth, but it is also used to study the interactions of other parts of the universe. Despite the fact that the majority of the rays are separated, diffracted, and deflected when they reach the earth's surface, it has been calculated that the total solar irradiance (insolation) that the earth actually absorbs annually is close to 3.8 million exajoules (EJ).

Figure 8: Solar panel

As a result, solar energy produces twice the amount of energy as all other nonrenewable energy sources combined. This causes an abundance of solar irradiance to reach the earth's surface on an hourly basis, which humans and other living things cannot use for a year. As the rays approach Earth, their character becomes more parallel and they lose some of their initial power. According to some authors, the amount of solar energy that can be efficiently harnessed to power electric vehicles is influenced by factors such as location and time of day, in addition to weather. The angle of solar irradiance with the solar panels, the material used to design the PV panels, and the aspect of designing the PV surface are all important considerations. Should all be taken into account. Solar rooftop potential is the amount of rooftops across the entire nation that would be appropriate for solar electricity depending on size, shading, orientation, and location. Rooftop potential does not account for availability or cost, unlike economic or market potential for rooftop solar. Instead, it indicates the maximum amount of solar that can be installed on American rooftops.

2.4.1 Calculation

2.4.1.1. Illumination

The amount of sunshine in Kigali varies substantially due to its high latitude. We must identify the illumination time by calculating the sun's declination angle, together with the solar elevation and azimuth to establish the distance between each PV panel, in order to maximize the function of solar PV modules.is fully and completely exposed to the sun. Then, based on the Kigali city latitude, adjust the inclination of the solar panels so that as much sunlight as possible is vertically irradiated on the solar PV modules, increasing power output. First, we look for Kigali's latitude on the map. Kigali

$\Phi=30\ ^{\circ}$

Then, we collect the declination angle of a few special dates and the entire year.

We can calculate the declination angle using these data.

$\delta = 23.45^{0}\times\sin\ (360^{o}\times\frac{284+n}{365})$

The sunrise and sunset hour angles when n is the number of days in a year

$\cos\tau\ \theta = -\tan\Phi\ \tan\delta$

$\tau\ \theta$= is the angle during sunrise or sunset; positive angles occur at sunset and negative angles occur during sunrise

We can calculate the duration of sunshine for any reason, any day length, and any latitude by using other data.

$T=\frac{2}{15}\ \mathrm{Cos}^{-1}(-\tan\delta\ \tan\Phi)=\frac{2}{15}\tau\ \theta$

Different latitude, different sun irradiation direction angle of the sun to the ground, different inclination of the PV array to obtain much more solar irradiance The installation inclination angle of the PV array can be roughly achieved depending on the local latitude:

When $\Phi= 26^{o}$ to 40^{o} , the installation inclination angle of the

PV array is $Z= \Phi+ (5^{o}$ to $10^{o})$

The latitude in Kigali city is $\Phi= 30^{o}$

Oblique angle $Z= \Phi+10^{o} = 30^{o} +10^{o}= 40^{o}$

2.5 .The Micro controller

Producing the capacity to regulate the peak irradiance at actual solar noon is referred to as solar energy. The electric car battery may be fully charged when the solar intensity is at its highest. Photovoltaic charge controllers are required to convert the energy generated into storage battery cells in order to store this extra energy. Various solar microcontrollers were examined by further researchers. They did emphasize the necessity of on/off, pulse width, modulated, and maximum power tracking microcontrollers in order to increase the efficiency of solar power generation. It is claimed that the on and off microcontrollers can function in both series and shunt modes. Shunt charge controllers direct excess electricity to other loads, whereas series controllers cease charging after the load is fully charged. The more modern methods, such as maximum power point tracker (MPPT) and pulse width modulation (PWM), modify charging rates based on battery level to enable charging closer to maximum capacity. A microcontroller is a small integrated circuit that controls a single operation in an embedded system. On a single chip, a typical microcontroller contains a processor, memory, and input/output (I/O) peripherals. Microcontrollers, also known as embedded controllers or microcontroller units (MCU), are found in a variety of devices such as automobiles, robots, office machines, medical devices, mobile radio transceivers, vending machines, and home appliances. They are essentially simple miniature PCs that are designed to control minor aspects of a larger component without requiring a complex front-end operating system (OS).

Figure 9: Micro controller

How do microcontrollers work?

A microcontroller is a small embedded device that controls only one device function. This is accomplished by interpreting data from its I/O peripherals using its central processor. The microcontroller stores temporary information in its data memory, which the processor accesses and uses to execute instructions. to decipher and apply the incoming data from its program memory Using its I/O peripherals, it then communicates and takes the appropriate action. Microcontrollers can be found in a wide range of systems and devices. Devices frequently employ multiple microcontrollers that work together to complete their respective tasks within the device. A car, for example, may contain a large number of microcontrollers that control various internal systems such as anti-lock braking, traction control, fuel injection, and suspension control. All of the microcontrollers connect with one another to provide information for the proper actions. Some may be able to communicate with the more sophisticated central computer of the car, while others might only be able to do so with other microcontrollers. They deliver and receive data through their I/O peripherals, which they subsequently process to finish the tasks they have been given.

2.5.1. Different type of charge controller

2.5.1.2 MPU controllers

These PV charge controllers are the first of their type to only work in one way. They are made up of closed charge controllers, basic charge controllers, and series regulations. Shunt charge controllers direct extra electricity from a fully charged battery to an auxiliary load, whereas series rules generally prohibit additional current from going into fully charged batteries.

2.5.1.2 Pulse With Modulated (PWM)

PWM simply uses greater voltage spikes to move charged current from solar panels to storage batteries. Some designs have an output voltage that is pre-set but can be changed to match the battery being used. Furthermore, it charges batteries more quickly than on/off controllers.

2.6. Storage Batteries

Batteries used in solar applications must be able to endure the demands of erratic grid energy, including frequent full recharges and significant charging and discharging cycles. You can generate electricity and store it for later use using an energy-storage device, sometimes referred to as a house or solar battery. You might be able to use the electricity your solar panels produce during the day by storing it for use at night. This relatively new technology may be something to think about if you now produce your own energy at home using solar panels but could consume more of it at night or intend to start doing so ,Read on to discover more about different energy-storage options, their costs, and the advantages and disadvantages of batteries. You can also head straight to our display of the newest home batteries. For these unique requirements, a variety of battery types are suitable. Flow batteries, lithium ion batteries, and lead acid batteries are the three main solar energy storage battery technologies that have been researched by others. The ratio of energy actually stored to energy retrieved, the power transfer rate, the time needed to extract the stored energy, the longest duration the battery can be discharged, and efficiency which indicates the ratio of energy released to that stored are all important factors. The cycling capacity, which is the cost determined by operational and investment costs over the specified storage battery's lifespan, disposal effects, which take into account the storage battery's environmental impact after its life cycle is over, and finally, the battery's self-discharge rate, which is the rate at which the battery discharges while in standby mode and the number of times the battery is recharged, are the three factors that go into determining the cycling capacity. discharges as intended after successively charging.

Figure 10: Car battery

2.7 Battery storage installation systems

There are two types of battery installation: DC and AC systems.

2.7.1 DC battery systems

A DC system is directly connected to the energy generation source before the energy generation meter (such as solar panels). You won't need another inverter because this one is more efficient.

Charging and discharging, while less efficient, may have an effect on your feed-in tariff. Retrofitting a battery to an existing PV system with a DC system is generally not advised.

DC systems cannot be charged using the grid, according to the Energy Saving Trust.

2.7.2 AC battery systems

These are connected following the electricity generation meter. To turn the electricity you produce into alternating current (AC) that you can utilize in your house, you'll need an AC/DC power unit (and back again to store it in your battery).

The Energy Saving Trust claims that the cost of AC systems is higher than that of DC systems. Your FIT payments won't be impacted by an AC system, though, because the generation meter can track the entire system output.

2.8. Solar inverters

The solar panel primarily uses direct current energy. This must be converted to alternating current (AC) before it can be used to charge electric vehicles or other automotive devices. Solar inverters convert DC to AC before charging or directing current to off-grid electrical networks.

Figure 11: Solar inverter

A solar inverter, also referred to as a PV inverter, is a type of power inverter that transforms a photovoltaic solar panel's variable direct current (DC) output into utility-frequency alternating current (AC), which can then be used by a local, off-grid electrical network or fed into a commercial electrical grid. The BOS of a photovoltaic system, which permits the use of conventional AC-powered equipment, is a crucial element. For usage with photovoltaic arrays, solar power inverters offer special capabilities including maximum power point tracking and anti-islanding prevention. There have been extensive studies conducted on inverters for strings, solar panels connected in series with a central inverter, micro inverters with independent inverters, and power optimizers, which are similar to micro inverters but involve additional monitoring researched. In order to maintain the system's peak efficiency, power optimizers are employed to continuously adapt and adjust the load tied to the PV panel arrays.

2.9 The vehicle charger

The grid or electric vehicle charging stations must receive the converted alternating current. Here, electric car charging is carried out in accordance with the specifications of the charger, socket, and car and battery kinds.

Figure 12: Vehicle charger

used to keep an electric car moving by recharging its battery. Although most eclectic vehicles' batteries can only be charged using direct current (DC) power, some electric cars (EV) come with a charger that can convert alternating current (AC) electricity into DC and then send that power to the vehicle's charging connection. motives behind car pricing Solar-powered EV chargers like EV arc run solely on solar energy. In these cases, the solar-generated electricity restricts how quickly EV batteries can be charged. In addition, if there are many EVs plugged into a single charging station and there are only so many solar panels available (i.e. the total charging rate of all EVs exceeds the current solar output), The charging station must decide how to allocate the available solar energy among the cars. Cars can be heterogeneous in terms of charge levels. Because maximizing user satisfaction is a key goal in a car-sharing service, a simple best effort charging policy that divides energy equally may not be the best strategy. We consider two goals when allocating solar energy to EVs in a car-sharing service: utilization and fairness. Maximizing solar utilization ensures that the algorithm generates an allocation schedule that delivers the most solar energy while minimizing waste. Fairness ensures The charging station allocates energy to maximize user satisfaction, resulting in fully charged batteries.

2.10 Available Solar PV e-vehicle charging Technologies

A few proposed researches have reviewed various solar PV electric vehicle charging systems based on different parameters as summarised below:

Mehdi Rahmani et al (2016). Because parking lots occupy a significant surface area of a city, conventional grid-supplied PEV parking lots are proposed to be canopied with PV panels in this study to reduce charging costs of plug-in electric vehicles (PEVs). Solar parking lots can also be used to cool electric vehicles, charge their batteries, and even deliver excess energy to the grid. This paper investigates the value of the net benefit of equipping a solar parking lot with PV panels over the life of the PV panels with and without the presence of energy storage. The cost and income terms used here include the investment cost for PV panels, the investment cost for a battery, and the benefit from charging PEVs with free energy generated by the PV panels. Furthermore, the problem is simulated from various starting years while taking into account real PV panel and battery prices. Each simulation calculates the cost-to-benefit transition year. Wei Jiang and his associates (2019). The goal of this study is to optimize EV charging in parking lots by combining an energy storage system (ESS) and a photovoltaic (PV) system. To begin, a smart charging management system is installed. A cost-minimization problem is used to define the charging optimization problem. Following that, the grey wolf optimizer (GWO) is introduced as a method for determining the best solution. An improved binary grey wolf optimizer (IBGWO) is proposed, taking into account the optimization problem's constraint conditions, which can speed up convergence and improve optimization accuracy finally, an EV charging scheduling strategy in real time is presented. IBGWO and short-term PV power prediction are proposed. To evaluate the effectiveness of the proposed strategy, several cases are simulated. In solving the proposed charging scheduling problem, the experimental results show that the proposed IBGWO outperforms other meta-heuristic algorithms. Furthermore, the proposed strategy can increase PV power utilization while decreasing operator electricity costs.G.R.Chandra Mouli and colleagues (2016). This study looks into the possibility of using solar energy to charge battery electric vehicles at work in the Netherlands.In order to produce the most electricity, the ideal PV panel orientation in the Netherlands is determined using data from the Dutch Meteorological Institute. The amount of energy available for EV charging and the need for grid connection are calculated by analyzing seasonal and diurnal variations in solar insolation. Due to the relatively low solar insolation in the Netherlands, it has been discovered that the power rating of the PV array can be 30% higher than the power rating of the converter. Various dynamic EV charging patterns are compared in order to reduce reliance on the grid and maximize the use of solar electricity to directly charge the EV.

There are two scenarios to consider: one in which EVs must only be charged on weekdays, and one in which EVs must be charged every day of the week A priority method is proposed to charge multiple EVs from a single EV-PV charger. The feasibility of incorporating a local store to make the EV-PV charger grid independent is evaluated. The ideal storage size is evaluated to reduce grid dependency by 25%.

Others, including Steven Lee (2016). Electric vehicles (EVs) are gaining popularity as a reliable alternative to gasoline-powered automobiles.

These vehicles must have their batteries "charged" in order to operate. While EV charging has traditionally been done via the grid, solar-powered chargers have emerged as an intriguing option. These chargers provide clean electricity to electric vehicles, which are pollution-free and have a low environmental impact. We build an electric vehicle (EV) charging station for a car-sharing service parking lot in this study. In a car-share program, the pick-up and drop-off times for rentals are predetermined. We create a linear programming method for charging EVs that maximizes solar energy while maintaining consistent battery levels across all vehicles. We evaluate the performance of our algorithm on real-world and synthetic datasets to show that it distributes available electric charge. Fairly among candidate EVs across seasons with variable demand profiles. Furthermore, when compared to the best effort charging policy, we reduce the disparity in battery charge levels by 60%Furthermore, we show that at the end of a charging session, the 80th percentile of EVs have at least 75% battery charge. Finally, we show that a solar installation proportional to the size of a parking lot properly allocates available solar energy generated to the EVs serviced. Pedro Nunes and colleagues (2016). The concept of solar parking lots aims to connect the advancement of electric mobility and clean solar energy. Solar panels generate electricity, which can be used to charge stationary electric vehicles while also providing shade. In a vehicle-to-grid strategy, the vehicles may additionally feed the grid and provide ancillary services to support it.

2.11. Conceptual Study

Figure 13: The example of solar powered charging station for electric vehicle

The conceptual analysis I created helped us to grasp the issues and, consequently, provided a roadmap for finding answers. In order to accomplish our goal of using solar energy to charge electric vehicles, we focused on how to build adapted parking and charging spaces. The study included six subsystems: a solar panel, a microcontroller, a storage battery, inverters, an alternating current network, and a car battery. Because this thesis essentially explains how to charge a car using solar energy, we will concentrate in this section on literature review on research studies on each of the subsystems and how they are related.

When an EV is connected to the battery for charging, the control strategy was created with the intention of maximizing PV power for EV charging and enhancing the interchange of electricity with market and system demand.

Figure 14: solar parking lots chargers

2.12. Recap on related works

A good number of works have been dedicated to EVs charging form a variety of renewable energy resources (RERs)..The more recent works using multi-RERs has been suggested by Mamun, et al. [37]. Various RERs have been used to power the HEV; namely the Solar PV, wind energy (WE), fuel cell (FC) and a supercapacitor (PV + WE + FC + SC) that employs a PEM and a SC to meet high torque demands in order to generate electrical energy. The vehicle was lodging a battery pack supplemented with a SC to respond to the power demand, while the FC was playing the role of the backup supply. The wind energy that springs from the vehicle motion could spin the turbine blade, and the connected alternator had to generate the electricity that charges the battery. Such an amalgamation of RERs was intending at enhancing the efficiency (lightweight EV) while achieving a zero-carbon emission; and use of wheel-embedded motors that cancel out the need for mechanical transmissions. Studies on the solar-powered EVs application to parking lots have been fairly documented. Nunes, et al. [38] could mount solar panels in ceiling-like configuration, thereby acting as parked EVs shelter while charging them. As to rooftop PV applications in charging parking lots EVs[39-41], Osório, et al. [42] have compiled a pertinent survey. Ghotge, et al. [43] used the office packing space to study the demand uncertainties for optimization purpose. In addition to PV-standalone, Zhang and Cai [44] could simultaneously use a PV-grid system to perform optimal charging of EVs parked within the workplace parking lot. This was meant to overcome fluctuations and uncertainty features of the solar supply and the time-inconsistent EV charging requirements,

2.13. The concept of a solar-powered charging station

A solar-powered charging station for electric vehicles has been constructed. A PV array, charging unit, battery pack, and bi-directional inverter for load response are all part of the charging system. The power flow between the various units is controlled by the bidirectional inverter. It has two DC ports for powering the PV panel and storing the battery, as well as two AC ports for charging the battery with the EV charger. The energy management system incorporates solar PV electrical energy projection and EV charging demand projection to optimize the buffer battery state of charging (SOC), Use solar energy as much as possible for EV charging, and avoid doing so during peak hours. The charging station has been open and in use nonstop for a year. by a number of EV consumers. Each minute was recorded.

2.14 Research gaps

As of 3rd July 2020 the number of registered vehicles countrywide is 264,524. The number of charging stations we have: Volkswagen, Victoria Motors Rwanda Ltd, Special Economic Zone, Kigali Convention Centre this charging station is located in Kigali so the is lack of station in Rural area so these are gaps. The amount of power available for home consumption and other activities decreases as more electric vehicles use the grid for power. This results in a distribution imbalance, a low power factor, and power net instability. When parked at a car share service station, vehicles are plugged into charging stations. Furthermore, EV charging stations lack batteries that could be used to store energy and reduce charging time. However, according to my research, storing energy may be a better option. I plan to look into using batteries in a solar-powered charging station.

2.15 PV system modelling

Panels circuits, Boost converter, MPPT techniques, charger controller, DC charger bi-directional)

Problem formulation

Optimize the Energy System Unit

Objective Function Max $P_{out} = V_i * i_j$

S.T $\{V_i > 0, I_j > 6A, I, j > 0\}$

PV Array uses the following equation to calculate the PV array output

$$P = \Upsilon \times \mu \times (Gc / Gs)\,[1+\beta\,(Tc - Ts)]$$

P is the output of the PV array (Kw). ϒ is the PV array's rated capacity, suggesting that its power output is susceptible to unfair test conditions (kw). μ is the PV derating factor, which has a value between 0 and 1, and it is a scaling factor that applies to the power output of the PV array to account for lower output in real-world operating conditions compared to the conditions under which the PV panel is rated , Gc is the current time step's solar radiation on the PV array (kW/m^2); Gs is the solar radiation received by the PV array under standard test conditions (kW/m^2). β is the power coefficient of temperature (% ^{o}c).; Tc is the temperature of the PV cell in the current time step (^{o}c) Ts is the temperature of the PV cell under standard test conditions (^{o}c).

CHAPTER 3 METHODOLOGY

3.1 Introduction

This section investigates the various methods and tools employed in the selection and design of solar PV charging stations for electric vehicles. The high penetration of EVs on the power distribution grid causes significant issues such as power quality degradation, increased line damage, distribution transformer downturn, increased distortion, and higher fault current. One effective way to mitigate the effect is to integrate local power generation, such as renewable energy sources (RESs), into the EV charging infrastructure.

There are two methods for charging batteries: conductive charging and inductive charging. Wireless charging systems are inductive chargers (WCS). WCS can be stationary, which means they can only be used when the car is parked or in stationary modes, such as in car parks, garages, or at traffic lights, or dynamic, which means they can be used at any time. This latter method allows charging of the battery while the vehicle is in motion. In general, WCS can provide some benefits in terms of aesthetic quality, dependability, durability, and user friendliness.

However, inductive chargers are not as widely used and commercialized as conductive ones due to several drawbacks include electromagnetic compatibility (EMC) problems, limited power transfer, bulky and expensive designs, shorter range, and inferior efficiency. Only conductive charging techniques are examined in this research. The genetic algorithm used in references in [62] optimized the output of the boost converter in the solar system charging station. The results were successful, however the genetic method necessitates system reconstruction in the event of a failure.

3.2 Previous Methodology

Others use the offline allocation problem using the linear programming framework, while others use algorithms that maximize the use of solar energy and deliver it to electric vehicles.

The research will be conducted using the following approach in order to meet its unique goals:

-**Methodology approach**: involves researching the methods used in your field as well as the theories or principles underlying them in order to develop a strategy that meets your objectives.

- Data collection: Data collection methods are classified into two types: quantitative methods and qualitative methods.

- **Data analysis**

- Statistical methods are commonly used in quantitative approaches to market research and forecasting demand. These methods forecast demand using previous data. Long-term projections are typically made using these core data collection techniques. Statistical procedures are quite dependable because there is very little subjectivity in them.

- **Qualitative Methods:**

  When no historical data is available, qualitative methods come in handy. No calculations or numbers are required as an alternative. In qualitative research, words, sounds, sensations, emotions, colors, and other non-quantifiable aspects are frequently used. These methods rely on prior knowledge, discretion, instinct, speculation, feeling, and other factors. Methodology proposed. Modeling and optimization, integration, power dynamics, and so on) and the algorithm itself.

  Homer Pro software will be used for simulation, optimization, and evaluation of the proposed system.

3.3 Proposed Method

In order to propose a method, this research first started by reviewing various electric vehiclecharging systems, technology trends and evolution.

The integrated system is made up of a PV system, which serves as the main power source, a converter to help with battery charging, and an inverter to utilize the battery's stored energy to power the load. The battery takes over when the PV system is unable to provide the load with the necessary quantity of electricity. The proposed system's block diagram is shown in Figure 15. Two eventualities can be handled by the system. Case 1: The PV-generated energy is used to power the load directly. Only loads are utilizing all of the power produced in this case. The algorithmic use of illustration 1. Case 2: The PV system generates a lot of electricity, satisfying the load's energy requirements. Assisting the batter, more power is transferred to a converter or battery charger charging.

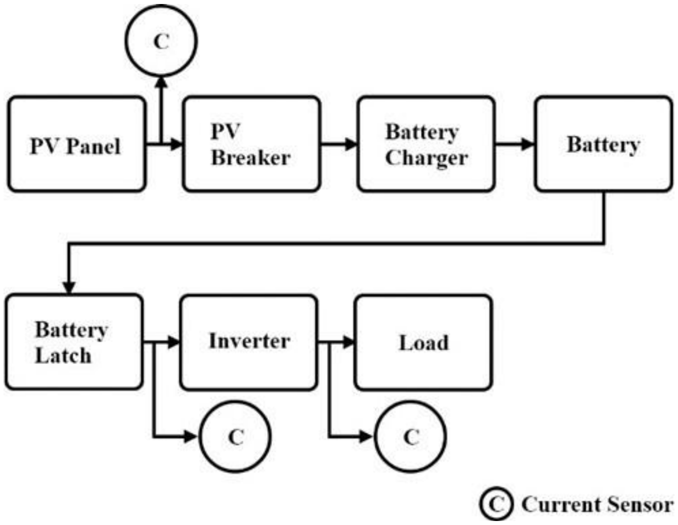

Figure 15: Block diagram of proposed design

The HOMER model developed by the United States' National Renewable Energy Laboratory was used to simulate the physical behavior and economic features of the power system. HOMER models can compare a wide range of design options based on their technical, environmental, and economic merits. It also aids in understanding and quantifying the effects of uncertainty in parameter changes.

Conclusion: The HOMER optimization software was used to calculate the optimal configuration of the components proposed in the energy system based on the PV-EV model developed and data collected from various sources. HOMER evaluates the technical feasibility of energy systems before estimating their NPC and CoE; the technically feasible and cost-effective option will be presented as the optimal solution.

3.4 Conceptual framework

The figure 1.0 below summarizes the conceptual framework for the design of a Solar PVelectric vehicle charging system

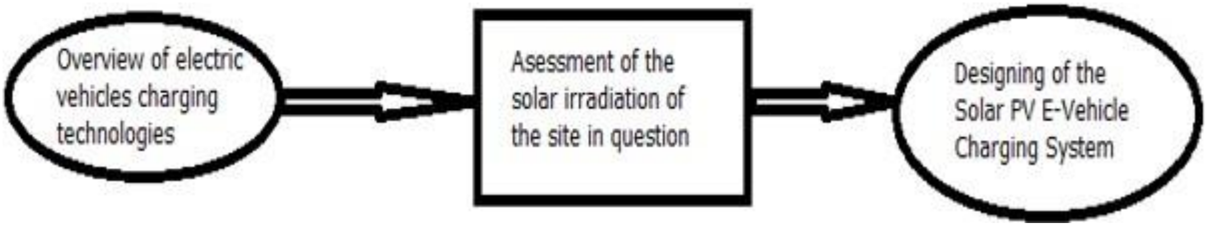

Figure 16: Solar PV E-Vehicle charging system design conceptual framework

3.4 Mapping method to the problem

In this min project research proposal, the problem will be solved by relating all the parameters considered area of the roof for shade, solar irradiation at site, Size of car batteryand Number of vehicles.

Table 4: Mapping the methodology to the problem

Parameters	Methodology	outcomes
Optimize the dc-dc converter	Homer pro	Evaluating designs for both off-grid and grid connected power, optimization and cost effective
Optimize the charger controller	FLC	In the diffuzication, the power losses in charger controller is avoided(minimized a lot)
Optimize the ESU objective Max Pout= V_i*i_j	Integer linear programming	Integer will avoid the oscillation power which induces the losses in charging station

Chapter 4 Results and Discussion

4.1 Introduction

This section gives out the results and discussions for the design and simulation using Homer software based on the parameters discussed in methodology. Section 4.2 Gives the Solar PV charging station for e - vehicles design, section 4.3 discusses the results and finally 4.4 concludes the chapter.

4.2. Solar PV charging station for e - vehicles design

On average, a car battery can maintain about 5amps for ten hours. That makes such abattery a 50amp hour battery. That is equal to around 600-watt hours.

Modern electric vehicles typically have batteries with capacities ranging from 24 to 100 kWh - kilowatt-hours. That is the amount of energy stored in the batteries. One kWh equals 1,000 watts for one hour. A 24 kWh battery can therefore supply 24,000 Watts for one hour.

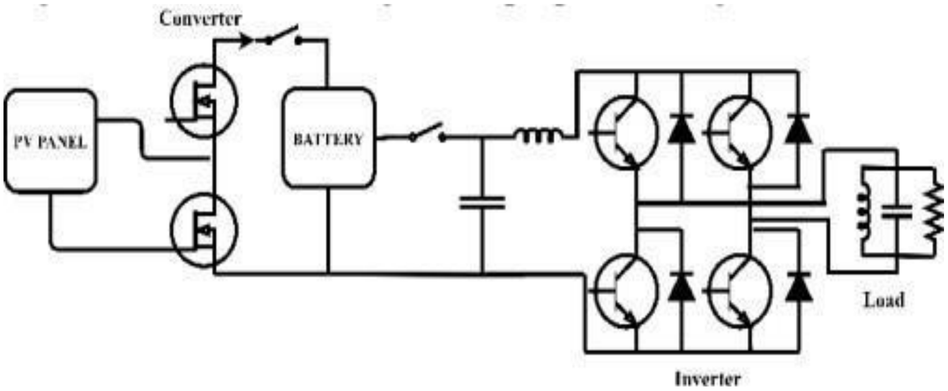

Figure 17: Proposed system design circuit diagram

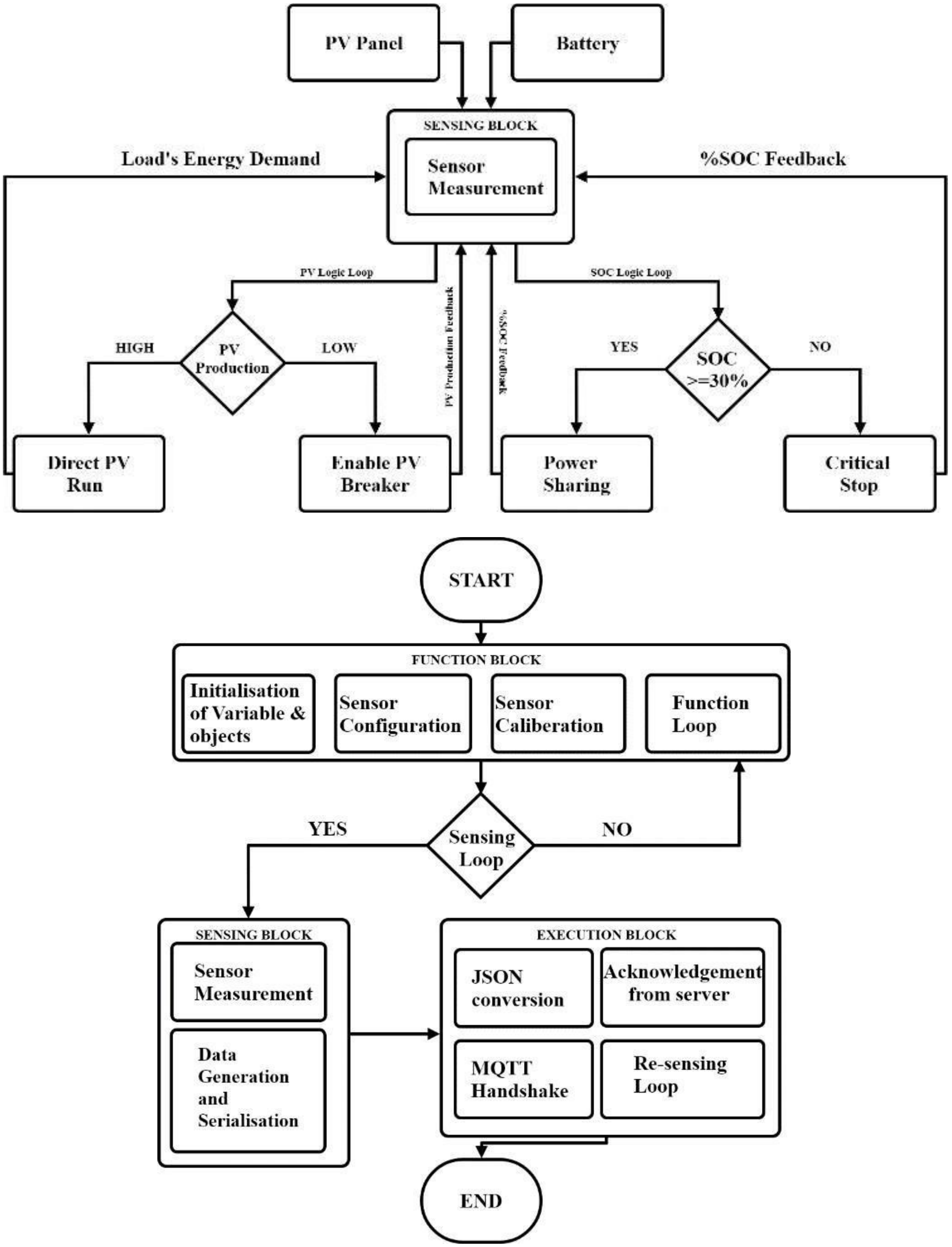

Figure 18: Implementation of smart sensors in the proposed system

The developed algorithm is cloud-based, and IOT enables real-time data transfer from current sensors to the cloud. The algorithm measures the power generated by PV, the power consumed by the load, the state of charge, voltage, and current of the batteries, and sends the generated data to the cloud, where it is used as input by the algorithm. A difference in load values causes a post-call to the sensor, which then sends the data to the server as the load's energy demand rises and falls. When the server receives a push request, it examines the PV panel's power production data as well as the battery's state of charge (SOC) to determine whether the request to continue direct PV operation or seek battery assistance is valid When the sensor's SOC reaches 30%,it sends a post request to the server and sends the data. When the algorithm receives a push request, it interruptsthe circuit until the battery's state of charge (SOC) exceeds a predetermined threshold. depicts the proposed system's current sensor implementation The algorithm looks for changes in the values published by each sensor, which includes real-time information on load energy demand, PV power generation, and battery SOC.

. The PV logic loop and the SOC logic loop handle direct PV run, battery run, or system critical stop until the battery's SOC exceeds the threshold. The PV production and SOC decision block manages the breaker and determines whether the system should run on direct PV, battery, or come to a complete stop. The feedback from the decision is sent to the cloud, and the loop continues. This system is built in the cloud to allow it to operate autonomously and as needed. as part of a smart grid initiative

4.3. Discussion and results interpretation

From the analysis the following results were obtained.

Table 1: Charging System Sizing

Parameters for adopted for design

**System efficiency: 0.8, Available area = 7,350 m^2, Derating factor = 0.8, Full sun hours = 4hrs.

And panel power rating 340W and is of 1.8 m^2 in area is considered for this design.

Site's load calculation for solar powered

We expect the daily load profile to be a constant, straight line because the system is required to supply 20 vehicles with 2.3 kW each for a duration of 4 hours.

Peak Load = Power per vehicle x Vehicle Count = 2.3kW x 20 = 46 kW

Total Load = Peak Load multiplied by the number of duty hours = 46 x 4 = 184 kWh

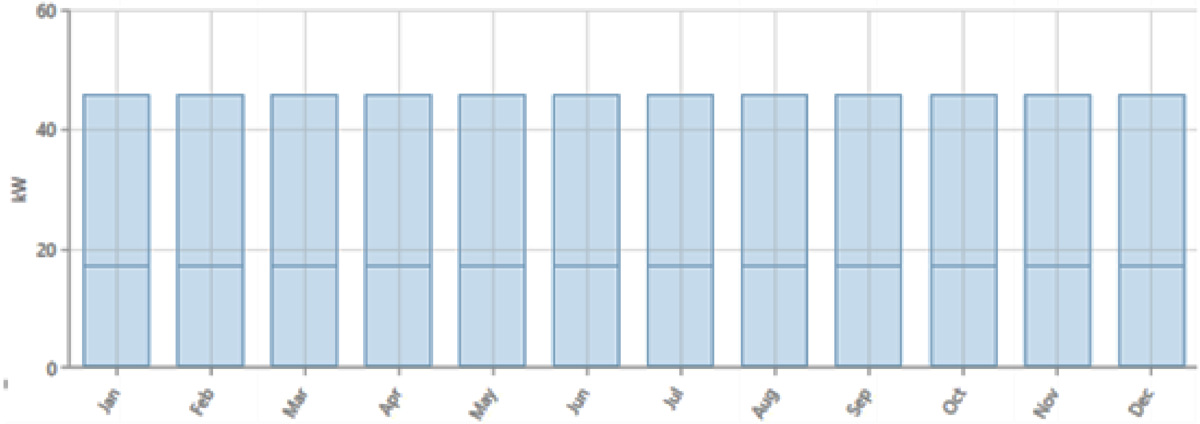

Figure 19: Annual energy needs of the chosen site from HOMER

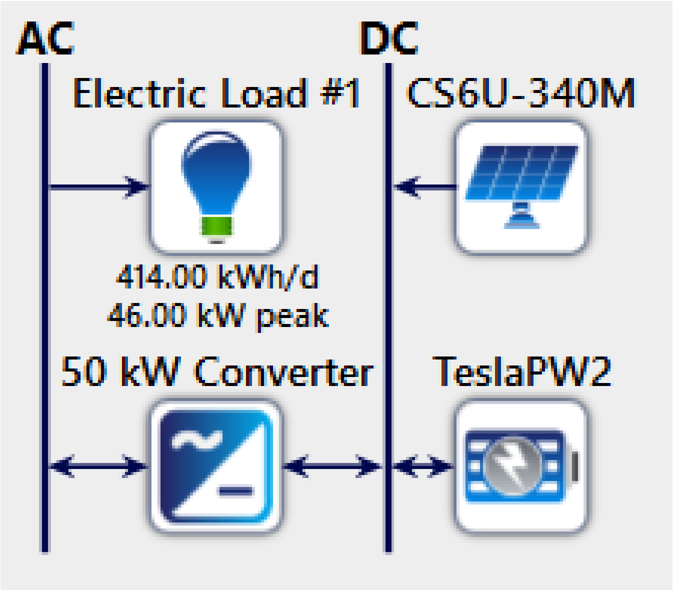

Figure 20: Schematic design from HOMER

For 272 days, the average daily sunlight is 1633 hours, where h is hours. Energy usage per day divided by the number of full sun hours per day equals power output.

$$Power\ Output = \frac{184kWh/day}{4} = \mathbf{46kW}$$

Use a derating factor of 0.8 for PV sizing.= power output / derating

PV array size = total calculated PV capacity / wattage of one panel

$$Number\ of\ modules = \frac{92617}{340} = 272\ modules$$

Table 5: Load calculation from Homer software

Qty	Duration (hr.)	Total kwh	Peak Load(kW)	Total load(kWh)
20	4	2.3kW	46kW	184

Size of PV module	
Adjusted Energy	184kWh
Power output	46kWh
Power output derating	115,771Wh
Power rating of one panel	340W
Number of module	272

Size of inverter	
Adjusted Energy	30,000
Inverter	35,000
Inverter voltage	24V

Size of Battery	
Days of Autonomy	3days
Deep of discharge	40%
System voltage	12V
Ampere hour	12,937.5Ah
Available Battery	200Ah
Number of Battery	216

Charge controller	
Short circuit current	9.74A
Escalation factor	1.3
Size of controller	202.592A

Site’s load calculation for grid powered

Charging is finished

81%

4.16 kWh delivered

0:18:58

Figure 21: Charging process from the grid

Full charging battery in 4hours using single phase and quick charging using three phase take 25min consume 13.8kWh
Total load of 20 vehicles = 13.8kwh×20×4=1104kWh

Table 6: Load calculation of grid connection

Qty	Duration	Total kW	Peak load kW	Total load kW
20	4	13.8	276	1104kWh

3.4 Chapter Conclusion

After compare both systems site’s load calculation For solar powered and grid connection. The research found that solar powered for charging E- vehicle reduce energy consumption and also cost of electricity production and to reduce times spend waiting for charging so that I choice this thesis to help the staff parking at university of Rwanda headquarter.

CHAPTER FIVE: CONCLUSION ANDRECOMMENDATIONS

5.1 Conclusion

The solar parking lot for 20 cars at the University of Rwanda was successfully designed. According to the HOMER solar irradiance map, the solar irradiance index is 4.47 kWh/m^2/day, and the PV panels used were 340W modules producing 115.771 kW and installed in 34 strings of ten panels each. A 50 kW commercial inverter was used in tandem with 216 Tesla Power Wall 2.0 batteries, each with a 240 V and 60 Ah capacity. Regardless, current sensors were critical in the generation of data and its transmission to the cloud via IOT. The system was designed successfully, and the system's driving force, the homer software, runs on the cloud using data transferred by the current sensor via IOT. This homer software's main advantage is its scalability, which allows it to be expanded from a single parking lot to a citywide parking lot. The homer software also provides data on load consumption at all times of day. The cloud hosting of the homer software was done to draw attention to a smart grid initiative. This homer software will function as an application layer, providing data on the load utilization of a single parking lot or multiple parking lots in a neighborhood or city.

5.1 RECOMMENDATION

Further research would be directed toward EV charging routines, extending this thesis the concept of E-Vehicle can be implemented in the designed In order to meet the energy demand of a building, neighborhood, or city, forecasting and scheduling for charging and discharging would be established based on usage patterns.

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