High Efficient Design for Electric Vehicle Charging Station

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Abstract- **One major step towards the sustainability of a society is that the Electrification of different sectors.In the case of transportation sector electrification will lead to several advantages, such as: reduce consumption of oil, reduce emissions and integrate renewable energy resources into the grid. Implementation and installation of efficient electric vehicle charging stations (EVCS) is essential to encourage large adoption of Electric Vehicle (EV) as it will reduce 'range anxiety' concern regarding the distance the EV could travel before the battery runs out. In this work,it shows how we can design an electric vehicle charging station in an optimal way that integrates Renewable distributed generation (DG) which causes cost and emission reduction. EVCS with grid connection and without grid connections are studied here, where energy sources such as PV, wind, and diesel generator are considered to compensate supply for the EVCS demand.**

1. INTRODUCTION

Sustainable transportation system can be made by the use of electric vehicle that promising lots of benefits. From an economical point of view, it EV is somehow costlier than internal combustion engine vehicle (ICEVs). But this can be compensated by the high efficiency of an electric motor that reduces the operation cost compared to the ICEVs. From an environmental point of view, electric motor due to its high efficiency it will reduce the total CO2 emissions even within an electricity system with a high fraction of fossil fuel generation. From the point of view of the electric grid, it can also play a major factor in the integration of renewable energy into the existing electricity system.

The International Energy Agency have a target to implement about 20 million EVs on the road by 2020. With this EV market growth, it is expected that it will affect the performance and efficiency of the electric grid. Extra investment is required in the generation and transmission capacity, due to an increase of peak loads under simple charging strategy.

The main impact of EV on electric distribution networks are: power quality issues, transformer and line saturations and increase on electrical losses . For this reason, it is necessary to integrate a high penetration of plug-in electric vehicle (PEVs) into grid safely network reinforcements, embedded generation and EV charge management strategy which is called as coordinate charging . The lack of accurate PEV charging data has led to a lack of robustness in coordinate charging. This could improve more in the years to come when the penetration of the PEVs will increase to a high level. Until then uncoordinated charging PEVs need to be accommodated. This selection of upgrading the infrastructure to accommodate the uncoordinated PEVs is costly and will take time. Also,the uncoordinated PEVs supplying method through conventional generation will lead to a shift in the emissions from the transportation sector to the generation sector. For that, a renewable DG as a source to accommodate the growth of uncoordinated PEV loads should considered . Several contributions have been presented in the literature in the area of combining renewable energy resources (RES) with PEVs. A survey conducted shows that EVCS with renewable provide about 433% increase in the usage of these stations by EV drivers. The benefit of adopting these different types of renewable generation at EVCS was confirmed in through simulation. An algorithm has been designed to accommodate high penetrations of PEVs through renewable DG. This algorithm will be better idea for the local distribution companies (LDC) to plan for the location, size, and year of installation of renewable DG units while minimizing the costs and emissions and enabling higher percentages of PEV integration. In a grid-connected solar powered EVCS with Vehicle2Grid was designed and tested experimentally. It has proved in this work that the EVCS can generate enough electricity to charge EV on a sunny day, and it is capable of balance load demand in the local grid during cloudy days. It is also a similar study in case wind energy. Grid-tied PV-Wind EVCS for stadiums was proposed and analyzed in terms of cost, validity, and usefulness

Diesel generation,PV and batteries were considered for the optimization in design of EVCS. The wind was not taken in consideration. Two cases need to be studied in term of economics and environmental impacts and they are EVCS without (isolated)and with grid-connection. The main addition of this work are as follows:

1. Wind energy is taken as a source option
2. The carbon dioxide emission penalties has been discussed for the optimization problem

2. PROBLEM DEFINITION

The objective of this work is to design an efficient EVCS that ensures supplying the load while minimizing the cost and emission of the system. The work presented in this paper will be done using a software called Hybrid Optimization Of Multiple Electric Renewables platform (HOMER), which is a simulation tool to help in the designing, planning and evaluating of a renewable energy microgrid.It also help to minimizing the net present cost (NPC) and emissions.

The system architecture have mainly three elements,and they are: input, model, and output. The input includes mainly EVCS electric and thermal load profile, EVCS available supply options and the related sizing, costs and other parameters of the components. The following constraints will be measured:

- The annual load should met all the time.
- The charging station should operate without renewable resources.
- If the load demand suddenly increases or renewable generation suddenly reduces,The operation reserve is determined by the addation of four values inorder to ensure that the electricity will be supplied :

1. 10% of load per hour, to ensure serving up to 10% unwanted increase in the load.
2. The reserve requirement doesn't depend on the peak load as the percentage is assumed to be 0%
3. 50% of wind turbine power output will be added to the operation reserve, i.e the system must ensure enough operating reserve to supply the load even if the wind turbine output unexpectedly reduced by 50%.
4. 50% of solar power output, i.e the system must gives enough spare capacity operating to supply the load even if the PV array output unexpectedly decreases 50%. Since the proposed method is multi objective the following should be also considered

- A. System Costs

The aim of this methodology is to minimize the total net present cost (NPC) which is the difference between current value of all the costs that afford within the project lifetime and the present value of all the income that it gains over its lifetime.

- B. System Emissions

One of the primary objective of this project is to minimise emmision.Emission penalties can control these upto a certain limit.

3. SYSTEM MODEL

The proposed system model has 4various source components

- EVCS load
- Thermal load
- Solar
- Wind

A. EVCS load

The EVCS load profile used in this paper is similar to that used in , which is a real load obtained from Drive-4-Data. Where Drive-4-Data is an initiative by Waterloo Institute for Sustainable Energy (WISE) at the University of Waterloo, that motivate an EV driver to attach Datalogger to their vehicle to collect data such as, PEVs speed as a function of time, drive cycle and powertrain information, such as vehicle acceleration, battery SOC and the vehicle's driving routes and location. The PEV charging demand profile was generated from 2013 Chevrolet Volt drive cycles from May 2013 to May 2014 with 16 kWh battery capacity. Where 20 PEVs assumed to arrive for EVCS.

B. Thermal load

The thermal energy demand is considered in this work to be 10% of the EVCS electric energy demand. Thermal load is used in EVCS in cold countries to heat facility services available at the charging station. The thermal load will be supplied by the boiler, or by recovered waste heat from the diesel generator and the excess energy from renewable resources.

C. Solar resource

This study is made based on data for Waterloo, Ontario. From practical and theorotical part solar resources are more beneficial during summer.

D. Wind resource

Wind resource are also taken from NASA Surface Meteorology and Solar Energy website for Waterloo, Ontario. The annual average wind for this area is 5.08 m/s.

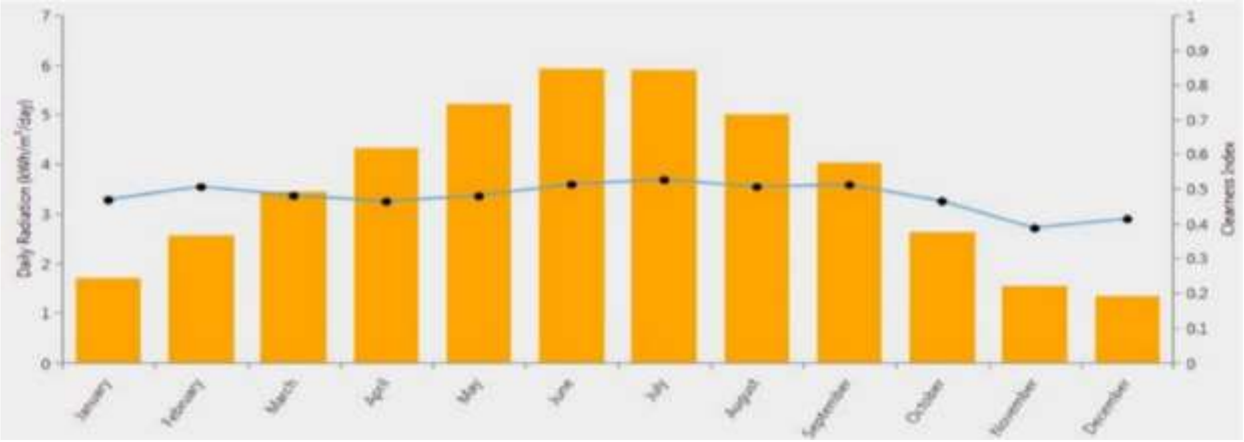

Fig 1 Solar radiation profile

CASE STUDIES: case studies that will be considered for analysis are

1 Diesel dependent EVCS
2 Renewable-based EVCS
3 Diesel-renewable mixed EVCS
4 EVCS connected to external grid

4. RESULTS AND DISCUSSION

A. Comparison of various cases

1) Optimal EVCS configurations and cost components:

The optimal EVCS design shown in Fig. 2 was obtained from the above mentioned software (homer) for the different cases. The detailed analysis of the optimal EVCS is presented in Table 1 for each case. It is clear from Table 1 that while the diesel-dependent EVCS (Case-1) required 50 kW of diesel capacity, the renewable-based EVCS (Case-2) completely depended on solar PV, wind, and battery storage generation. The diesel renewable mixed EVCS (Case-3) reduces fuel requirements and diesel generation capacity to 25 kW, battery string and renewable capacity. In Case-4, it is realized that when the EVCS have the option of withdrawing energy from the grid, it depends on the grid to an elevated level. When compared to EVCS without an external grid connection it is found that diesel-renewable mixed EVCS is most economical as well efficient as it is shown in Table 2. Since, in most of the time, an external grid will be available for connection with the islanded EVCS then this option can be considered.

TABLE 1.OPTIMAL EVCS DESIGN

Components	case1	Case2	Case3	Case4
Diesel KW	50	0	25	0
PV KW	0	100	50	0
Wind KW	0	100	10	10
Converter KW	50	10	30	30
Battery, no.s	0	1500	150	10
External grid, KW	0	0	0	1000

TABLE 2 COMPARISON OF COST COMPONENT

Parameters	Case1	Case2	Case3	Case4
NPC(M$)	0.897	0.687	0.542	0.313
Levelised cost of energy ($/kWh)	0.5859	0.4471	0.350	0.193
Operating cost (M$/yr)	0.0628	0.0113	0.0245	0.0213

However, the connectivity distance should be considered. This will be discussed in the later in the following. It can be realized from Table 2 that the levelized cost have the highest value in Case-1, while it reduces in Case-2 to 0.4471 $/kWh, which is higher than Case-3. Fig. 3, 4 and 5 can explain this variation in cost.

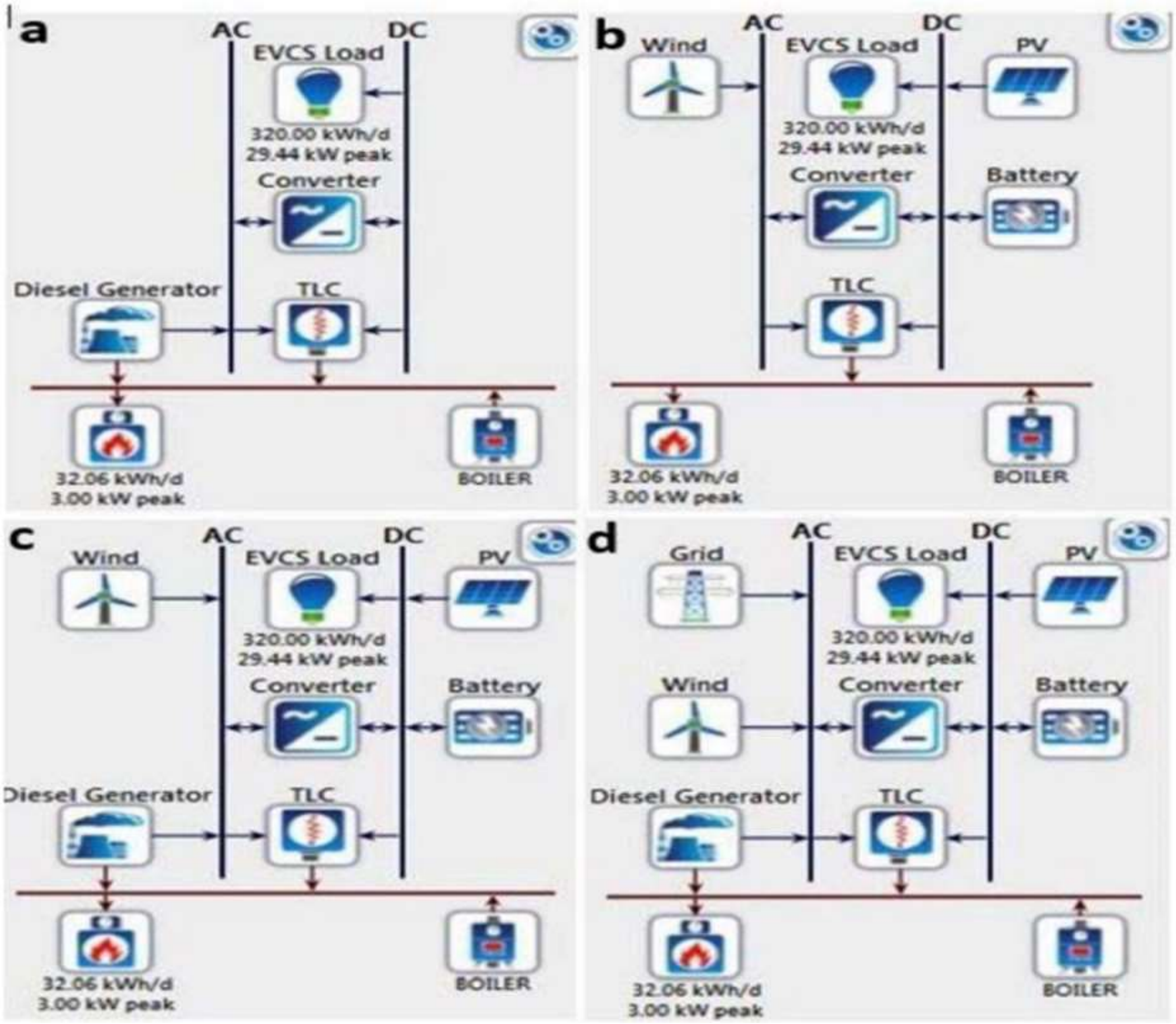

Fig 2 Optimal EVCS configuration case1 (a), case2 (b), case3 (c), case4(d)

As it is shown in Fig. 3 the fuel of the diesel generator plays a major factor in increasing the cost of the system as the system is dependent on the diesel generator only. In the renewable based EVCS, the fuel has a minor effect, while the major cost comes from the capital cost as there is a need to install the components of the system, this is clearly shown in Fig. 4. While in the Diesel-Renewable mix EVCS both the fuel and the capital cost will contribute in raising the cost as is shown in Fig.5; however, the cost will be lower than both previous cases. In Case-4,shown in fig 6, the significant cost component is the operation cost which is mainly due to the power purchased from the grid. At the beginning of the project the diesel generator and the inverter incur a capital cost, while in year 15 the inverter will incur a replacement cost.

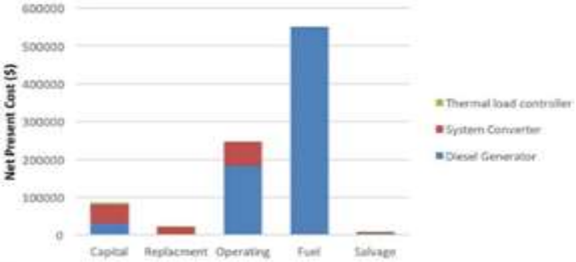

Fig. 3. Cost component for Case-1

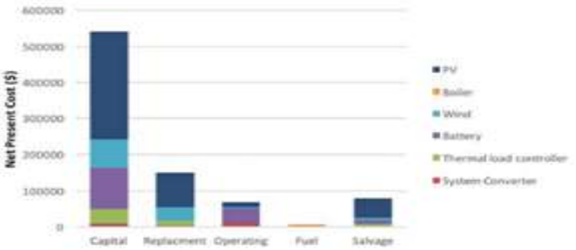

Fig. 4. Cost component for Case-2

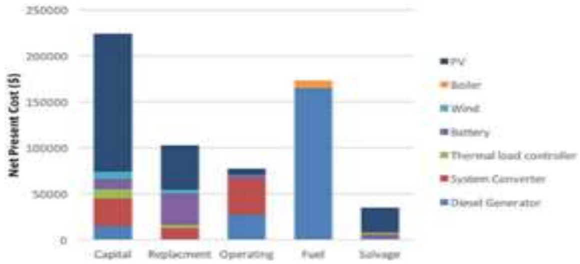

Fig. 5. Cost component for Case-3

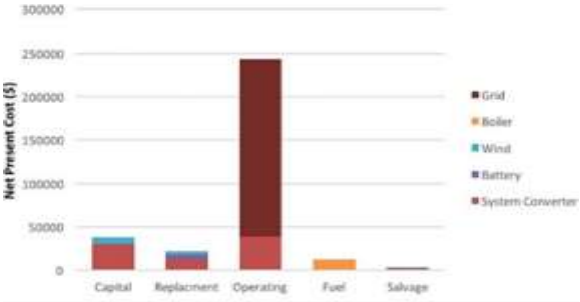

Fig. 6. Cost component for Case-4

The system will also require a regular stream of fuel and operation & maintenance costs. While in renewable based EVCS (Case-2) the system will incur an initial investment cost that is higher than Case-1 due to the cost of renewable components. Inverter and wind generators will require a replacement cost at year 15 and 20 respectively while other costs will play a minor effect. Case-3 will have the same pattern as in Case-2, with an addition of regular stream accounting for the fuel and operation cost. Case-4 will require a small investment cost at the beginning as the system will already be existing and the cost of operation will be distributed through the system, while in year 15 an additional cost will be present which is the cost of replacing the inverter.

2)Production profiles in various EVCS Configurations :

The electric energy production and consumption for the four different EVCS configuration have been considered and presented in Table 3 and Figs. 7-10. It is clear from Table 3 that renewable based EVCS (Case-2) has the highest production amount as well as the highest excess energy dump to dump load. This is expected due to the intermittent and non-dispatchable characteristics of the renewable energy. Therefore, relying on only renewable energy to operate the EVCS is a risk, and the capacity needs to be higher. It can be realized in the diesel-renewable based EVCS (Case-3) both the production and the excess energy have been reduced. This is due to the availability of the diesel generator and the storage source. In Case-4 there is no excess energy as the EVCS sells all excess energy back to the grid.

However, it is clear from Fig. 10 that the renewable energy contribution has been reduced dramatically as compared to Case-2 and 3 as per Fig. 8 and 15.

TABLE 3. PRODUCTION AND CONSUMPTION IN VARIES EVCS CONFIGURATIONS

Component	Case-1	Case-2	Case-3	Case-4
		Production, MWh/yr		
Diesel generator	174.436 (100%)	0	59.399 (44%)	0
Solar PV	0	138.085 (63%)	69.042 (51%)	0
Wind	0	79.394 (37%)	7.939 (6%)	7.939 (6%)
External grid	0	0	0	135.139 (94%)
Renewable energy contribution	0%	100%	57%	6%
Total	174.436	217.497	136.381	143.079
		Consumption, MWh/yr		
EVCS electrical load energy served	116.800	116.800	116.800	116.800
EVCS thermal load energy served	11.7	11.7	11.7	11.7
Energy sold back to grid	0	0	0	3.580
Excess energy to dump load	37	91	1.7	0

Fig. 7. Case-1 power production

Fig. 8. Case-1 power production

Fig. 9. Case-1 power production

Fig. 10. Case-1 power production

3) Effects of EVCS configurations on environmental emissions

As one of the main goals of this work is to lessen the emission of the system, it makes sense to expect that the renewable based EVCS (Case-2) will have the lowest emission. This is shown in Table 4 While Case-3 emits more than renewable based EVCS, it will still have lower emission than diesel-based EVCS.

TABLE 7 . COMPARISON OF EMISSION

Pollutant	Case-1	Case-2	Case-3	Case-4
Emissions, kg/yr				
Carbon dioxide	159351	1947	50133	86847
Carbon monoxide	995	0	298	0
Unburned hydrocarbons	44	0	13	0
Particulate matter	6	0	2	0
Sulfur dioxide	322	4	101	368
Nitrogen oxides	935	0	280	176

4) Component costs and sizing option

The sizing options together with other associated parameters of the supply components are showed in Table 1, while the costs are presented in Table 5.

TABLE 8 SIZING OPTIONS AND OTHER PARAMETERS

Options	Options on size and unit numbers	Life	Other information
Solar	1, 10, 50, 100, 150, 200, 300, 500 kW	20 years	De-rating factor =90%
Wind (10kW)	0,1,10,50,100,500 unit	15 years	Weibull distribution with K=1.83
Battery	10, 50, 100, 150, 200, 500, 1,000, 1500 unit	(Lifetime throughput) 845 kWh	Nominal capacity 225 Ah
Converter	0, 10, 30, 50, 100, 200, and 500 kW	15 years	Converter efficiency = 90% Rectifier efficiency = 85%
Grid Extension	10, 25, 50, 100, 500, 1000 kW	-	Purchase= $0.12/kWh Sellback= $0.39/kWh [20]
Diesel Generator	0 to 500 kW	500,000 h	Minimum load ratio = 30% Heat recovery ratio = 10%
Diesel Fuel	-	-	Price = $0.70/L Density of 820 kg/m3 Carbon content 88% Sulfur content 0.33%

B. Sensitivity analysis

1) Effect of CO2 penalty in the NPC and the share of renewable energy

According to the penalty on carbon dioxide emission that was studied. Fig.11 shows that as the penalty on CO2 increases the NPC increases. The renewable energy fraction stays unchanged for a small amount of penalty below $30/ton. However, as the penalty increases above $30/ton amount the fraction of renewable energy increase until it reaches 84% of renewable fraction at a penalty of $45/ton where it stays unchanged even for higher penalty.

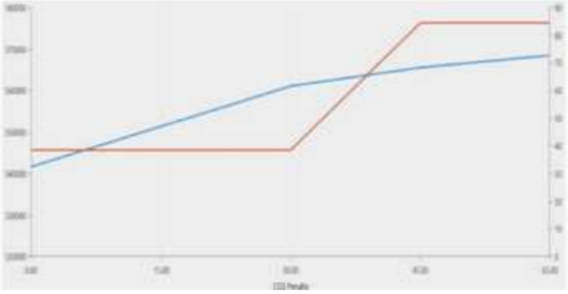

Fig. 11. Effect of CO2 penalty in the NPC and renewable fraction renewable Net fraction Present Cost $

2) Optimal break-even distance

As it has been shown in previous analysis that from the island EVCS, Case-3 was the most economical. If we assume that this case may be connected to the external grid due to the availability and reliability of grid connection, then the distance of the EVCS will play a key role in the NPC. Fig. 12shows that the NPC with a grid connectivity option increases as the distance increases between the grid and the point of connection but it has a lower cost compared to the one without an external grid option for up to 17.9 km in this case.

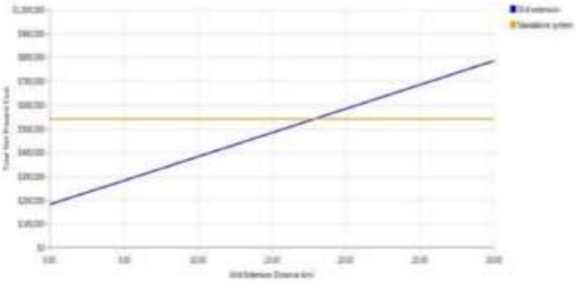

Fig. 12. Effects of grid connectivity distance in NPC

5. CONCLUSION

An optimal design configuration for EVCS was discussed in this paper. Various supply options were considered such as: PV, wind, diesel generator and battery. The analysis has been done using HOMER software with different case studies. The results indicate that the most economical islanded EVCS is the diesel renewable mix. Although this option has higher emission than the renewable based EVCS, still the emission is lower than the diesel based EVCS. It has also shown that as the penalties in the emission increase that will lead to an increase in the percentage of renewable energy used in the system. The possibilities of relying on the external grid have been studied in this paper, and it was shown that with this option the excess of generated energy from renewable resources can be sold back to the grid. Analysis has been made to find the breakeven extension distance.

REFERENCES

[1] I. Zamora , J.I.SanMartín , F.J.Asensio , V. Aperribay J. García-Villalobos, "Plug-in electric vehicles in electric distribution networks:A review of smart charging approaches," Renewable and Sustainable Energy Reviews, vol. 38, pp. 717–731, OCTOBER 2014.

[2] Jackson John Justo, Eun-Kyung Kim,Ton Duc Do, Jin-Woo Jung Francis Mwasilu, "Electric vehicles and smart grid interaction:A review on vehicle to grid and renewable energy sources integration," Renewable and Sustainable Energy Reviews, vol. 34, pp. 501–516, JUNE 2014.

[3] V. K. Ramachandaramurthy,JiaYingYong Kang Miao Tan n, "Integration of electric vehicles in smart grid:A review on vehicle to grid technologies and optimization techniques," Renewable and Sustainable Energy Reviews, vol. 53, pp. 720–732, JANUARY 2016.

[4] I. A. N. a. Y. Qiu, "Economic and environmental impacts of providing renewable energy for electric vehicle charging – A choice experiment study," Applied Energy, vol. 180, p. 256–268, 2016.

[5] L. X. R. S. a. V. W. S. W. Woongsup Lee, "Electric Vehicle Charging Stations with Renewable Power Generators: A Game Theoretical Analysis," IEEE TRANSACTIONS ON SMART GRID, vol. 6, no. 2, pp. 608-617, MARCH 2015.

[6] H. Fathabadi, "Novel wind powered electric vehicle charging station with vehicle-to- grid (V2G) connection capability," Energy Conversion and Management, vol. 136, pp. 229-239, 2017.

[7] H. J. V. a. K. Kusakana, "Design of a photovoltaice wind charging station for small electric Tuk Tuk in D.R. Congo," Renewable Energy, vol. 67, pp. 40-45, 2014.