Plug-in Electric Vehicle Connected to Nano-Grid without Storage System

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Abstract: **Vehicle-to-Grid (V2G) describes a system in which plug-in electric vehicles, such as Battery Electric Vehicles (BEV), Plug-in Hybrid Electric Vehicles (PHEV) communicate with the power grid to sell demand response services by either returning electricity to the grid or by throttling their discharging rate.V2G storage capabilities can also enable EVs to store and discharge electricity generated from renewable energy sources such as solar and wind. When the vehicles are parked in a parking-slot, the power can be sent from Vehicle to the DC bus-bar or to the grid. From each Electric-vehicle the voltage level and State of Charge (SOC) information is uploaded to the CLOUD on a regular basis. Fuzzy-Logic shall determine the participation factor/ranking of each vehicle and is communicated to the CLOUD. The Central Controller will receive the uploaded data and depending upon the load requirement the best vehicle(s), to be connected to the grid, is/are shortlisted. The selection information is then informed to the respective electric vehicle, through cloud, so that power is sent from V2G**.

Index Terms: Electric vehicles, Fuzzy logic, Electric Storage, Internet of Things **Cloud, Frequency regulation, Nano-grid, Vehicle to Grid**

I. INTRODUCTION

The increase in population has also increased the demand for power generation. The traditional way to generate electricity is by using hydro, coal, fossil fuels, biogas etc. Depletion of these energy sources cause future generation to suffer from electricity scarcity. So, with the advancement in technology renewable energy sources like solar energy, wind energy, wave energy, etc. are being used for the generation of electricity. Release of carbon emissions into the atmosphere by burning fossil fuels from thermal plants, industries, motor vehicles cause global warming, increasing the temperature of the earth's surface and ocean causing melting of polar ice, rise in sea level, desertification. So, countries are encouraged to go for renewable resources

Penetration of renewable energies have become one of the most promising technologies. Though the renewable sources are abundant and economical, but not possible to utilize them completely for rising power demand. It causes a mismatch between the supply and the load that makes the grid unstable. So, to solve above issues a new technology has been introduced recently is the Vehicle to grid(V2G). V2G is the exchange of power between the storage of

TABLE I.
CONTROL TECHNIQUES USED IN LITERATURE

1	Charge Control and Operation of Electric Vehicles in Power Grids: A Review	Paper presented the control and optimization strategies for managing the charging/discharging EVs	-
2	Research on Vehicle-to-grid Technology	To strengthen the regulation and operation management for electric vehicles.	-
3	Integrating E-Vehicle into Power System by the execution of Vehicle-to-grid (V2G) Terminology- A Review	Survey of V2G innovation	-
4	Fuzzy Logic Control of Electric Vehicles: Design and Analysis Concepts	Nonlinear model-based analysis is performed	Fuzzy logic control
5	Load Frequency Control in Isolated Micro-Grids with Electrical Vehicles Based on Multivariable Generalized Predictive Theory	To improve the system frequency stability with complex operation situations	Multivariable Generalized Predictive Control (MGPC)
6	Vehicle-to-grid Bidirectional Energy Transfer: Grid Synchronization using Hysteresis Current Control	To achieve a flow of power between the power grid and the electric vehicle the in both the directions	Hysteresis Current Control method
7	Time of Use Price based vehicle-to-grid Scheduling of Electric Vehicle Aggregator for Improved Market Operations	To optimize EVs coordinated charging and earn monetary benefits for EV owner and System Operator	Price-based Demand Response Program (PBDRP) is proposed to enhance the value of EV owners

electric vehicles and the grid during high peak demand on the load side. Thus, contributes the clean and green environment. Electric vehicles can adjust their charging and discharging behavior based upon the load and State of Charge (SOC).

Electric vehicle is a vehicle that converts the electrical energy stored chemically in a battery to mechanical energy to move the vehicle. The types of electric vehicles available in the market are

1. Battery type electric vehicles which store energy electro-chemically in the battery like lead-acid, lithium-ion, nickel metal- hydroxide, etc. They must be plug-in to charge their battery and unplug to drive the vehicle.

2. Hybrid electric vehicles are vehicles that have more than one power source. The battery and the motor will drive the vehicle.

3. Fuel cell electric vehicles consist of two electrodes separated by electrolyte. The chemical reaction between the fuel and an oxidant directly converts the chemical energy of the fuel into electrical energy.

Electric vehicles can operate in two modes,1. Grid to Vehicle and 2. Vehicle to Grid modes of operation. In mode-1, the vehicle battery is charged from grid whereas in mode-2, the energy stored in the battery is given to the grid.

Authors of [9] Samy Faddel, Ali T. Al-Alwami has presented a review on charge control methods and operation of Electric vehicles in power grid. The objective of EV and HEV is that they help in reducing the CO_2 emission from the vehicle and help in reducing the dependency of oil in transportation. The EV as controllable load provides more flexibility to the system operator by Valley filling and peak shaving and to increase the efficiency in the demand side management system. Many strategies are introduced to control the EV charging to prevent the negative impact on the grid. They are classified into centralized, decentralized and autonomous charging controllers. Centralized EV charge control requires a good communication infrastructure. The decentralized charge controller has limited communication requirements. Whereas the autonomous charge controller is communication free. Among these strategies, the autonomous controller will reduce the communication traffic to the V2G aggregator. The different charge control strategies were overview based on real-time EV charge dispatch.

Paper [11] aim to improve the regulation and operation management of EVs. This paper explains the concept, scheme, and functioning of V2G. To reduce the greenhouse gases, an increase in oil prices of petrol or diesel and dependency on oil are the major reasons that made to develop EV. They have become more popular because of less pollution, low noise, and high efficiency. They also discussed the types of Electric Vehicles – Battery Electric Vehicle, Hybrid Electric Vehicle, and Fuel Cell Electric Vehicle available in the market. V2G will provide the peak power balancing, auxiliary storage (spinning reserve) and regulation service to balance the load frequency to the generation frequency and renewable energy sources storage and backup. The power sends to the grid in 2-ways, one way is that vehicles are joined to the distribution system at homes and the other way is vehicles are aggregated and joined to the transmission system in aggregation.

The authors of [15] Awais Hashmi and Muhammad Talha Gul have presented the survey on the latest innovation of Vehicle-to-grid. This V2G enables the two-way flow 'tween the EV and the grid. The structure of transport distribution network changes with the idea of V2G and solves the issues like filtering of current harmonics, balancing of load, control of power, etc. The vehicle will sit ideal for about 20-22 hrs. in a day and it will run for about 2-4 hrs. So, the maximum time it is at rest, at this time the vehicle can be connected to the grid to transfer its power from its battery to the grid to balance the grid storage/energy. They also explained the integrating of wind energy with EV for charging the EV battery so that the vehicle owners can save money and there will be no carbon emission from the vehicle into the atmosphere. They also explained the working principle of EV and the important sections like a storage unit, control unit, and impetus unit. Benefits and barriers for integrating V2G are also discussed briefly.

As EVs are complex electromechanical systems described by non-linear loads, so they have complex design and analysis. Jemma J Malaygiorgou and Antonio T. Alexandridis in [7] used the FLC system to control the inputs d & q components which are duty ratios of VSC, and boost converter and the external inputs are internal battery voltage and torque on car wheels. d- Component of VSC duty- ratio and boost converter duty- ratio is driven internally by fuzzy logic controllers to have optimum PMSM flux extraction and to determine battery operation and the externally driven component of a fuzzy logic controller is q- component of VSC duty-ratio input. Steady-state equilibrium is obtained when external uncontrolled inputs become constant. They proved that the EV scheme is Lyapunov stable for any bounded control inputs and the simulated results are verified with the theoretic analysis.

In a power system, deviation in frequency is one of the major reasons to cause power imbalances. The frequency changes in the system due to disturbances in load or fluctuations in renewable sources, for this reason, it is hard to maintain the desired frequency range in the system. In paper [6], Jun Yang and Zhili Zeng presented the V2G model as a solution for LFC. The EV is being used as a storage to provide energy to the grid during high load demand. Also, a controller is proposed based on Multi-Variable Generalized Predictive Control (MGPC) theory in load frequency control, to achieve Load frequency control the EV and the diesel generator are combined.

This paper [13] presents the two-way energy flow between the vehicle and grid enabling the V2G technology. EVs are used to transfer energy to the grid at peak time and extract from the grid at an off-peak time to charge the battery. Power converters like ac-to-dc and dc-to-dc converters are used to transfer power from G2V and V2G technology. The output from the inverter is synchronized by using a hysteresis current control method before feeding to the grid. Ac-to-dc converter acts as a rectifier in G2V mode and acts as an inverter in the V2G mode of operation,

whereas the dc-dc converter acts as boost converter during battery discharge and as buck converter during the battery charging. The mode of operation either V2G or G2V is decided by the availability of SOC of the battery. If SOC is greater than the reference value, then it will be in V2G mode and if SOC is less than the reference value then it operates in G2V mode. All these observations are seen in Simulink software and the harmonics while power transfer is eliminated using LC filters. The main reason to use/develop Electric Vehicle is given here under.

Global population which is 6 Billion may increase to 10 Billion by 2050. Vehicles in use may increase from 700 Million in 2000 to 2.5 Billion by 2050.If all the vehicles are Internal Combustion Engine Vehicle (ICEV)then there will be extreme air pollution. So, sustainable transport is to be used like zero emission vehicles and that promotes public transport so that less vehicles on the roads. For charging these electric vehicles use renewable energy sources. Advantages of using Electric Vehicles with conventional vehicles are given here under.

A.   Comparison of Energy sources used for transportation
▪ Fuels available in liquid form are petrol and diesel have similar energy content means having same specific energy. Compared to petrol, diesel has high density per unit volume, and it is economical.
▪ Fuels available in gaseous form are CNG - Compressed Natural Gas have low energy density compared to liquid fuels and hydrogen. Compared to liquid fuels and CNG, hydrogen has very high-power density.
▪ Batteries store energy in chemical form and give out energy in electrical form. With advancement in technology the size of the battery is reduced and have high capacity storage.
▪ Ultra-capacitors store energy in biostatic form have limited storage and ultra-flywheel store energy in mechanical form at high energy which are less reliable.

B.   Pollution and Greenhouse gases
From vehicles many pollutants are released through smoke and termed as greenhouse gases that cause air pollution. They are
◆ Gases CO, CO_2, CH_4, NO_X (N_2O, NO and NO_2) are known as greenhouse gases. Due to the presence of these gases the infrared radiation is trapped in the atmosphere and causes greenhouse effect leads to climate change and global warming.

CO-carbon monoxide is poisonous gas that cause respiration problems in the humans and high amounts of CO2- carbon dioxide gas is released by ICE vehicles.NO_X are released into the atmosphere by diesel engines and can be minimized by using urea filters.
◆ SO_X(SO_2)- Sulphur dioxide gas is released into the atmosphere by coal based thermal power plants. When this gas reacts with the oxygen and water present in atmosphere produces sulfuric acid causes acid rains. By selecting coal with low Sulphur content for electricity production can be a solution for reducing SO_2levels.Total hydro carbons and SO_X gases will build ozone layer at the ground level which is very dangerous for human. It causes lung infections.

Therefore, emission of BEV is very less compared to ICEV and HEV lies between ICEV & BEV.

C.   Energy diversification
ICEV use liquid fuels as fuel either oil or natural gas. PEV such as PHEV, BEV, FCEV uses electricity or hydrogen as energy carrier. The sources required for producing electricity can be oil, natural gas, coal or from renewable energy sources like hydro, solar, wind, tidal etc. Among all these vehicles PHEVs are most energy diversified and can run by both liquid fuels and electricity.
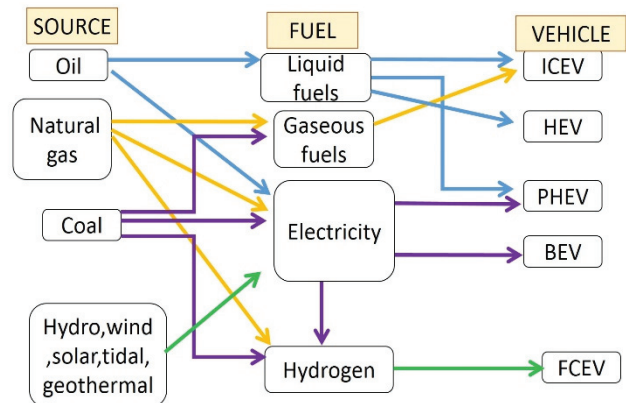

Figure 1. Energy Diversification Diagram

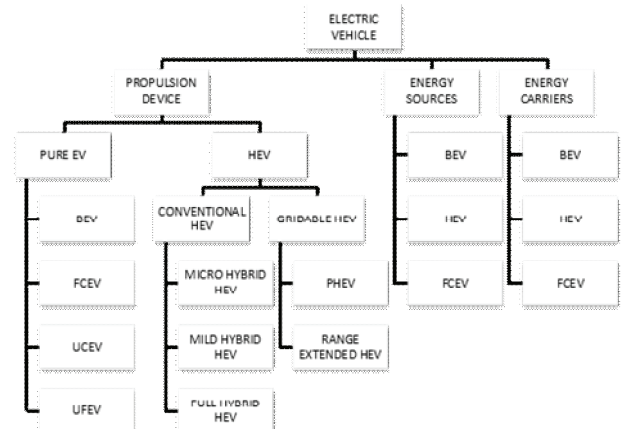## II. OVERVIEW OF DIFFERENT ELECTRIC VEHICLES

Figure 2. Electric vehicle Classification Tree

Electric vehicles based on **propulsion device** are classified into two types. They are as follows:
a) Pure electric vehicles and b) Hybrid electric vehicles

A.   Pure electric vehicle
It is a vehicle that uses electric motor for propulsion. They are again classified into
1.   Battery ElectricVehicle (BEV)- has battery as propulsion device.
2.   Fuel Cell ElectricVehicle (FCEV)- consists of battery and fuel cell. The battery here used for absorbing regenerative power.

3. Ultra Capacitor Electric Vehicle (UCEV)- consists of battery and ultra-capacitor. They have high specific power and stores limited energy.

4. Ultra Fflywheel Electric Vehicle (UFEV)- consists of battery and ultra-flywheel. They store energy in mechanical form at high energy and are less liable.

In above electric vehicles, battery is the common source. In FCEV, UCEV and UFEV battery is used as a hybrid source while battery in UCEV and UFEV is used for storing electrical energy since low specific energy.

B. Hybrid Electric Vehicle

It is a hybrid vehicle that uses both battery electric vehicle and IC engine as propulsion device. It offers refueling (petrol/diesel), consumes less fuel. These are classified into

(a). *Conventional hybrid electric vehicles* provide different capabilities to the system.
These are again classified into

1. Micro HEV
In this type, when the vehicle is at rest ISG supports starting and stopping of IC engine's enables recovery of regenerative energy during braking and ISG used here have low power capacity, voltage between 14-42 volts and are connected using belt-driven system.

2. Mild HEV
ISG here used has power capacity of 7-15kw and voltage between 100-150v which is slightly higher than Micro HEV type. It enables start-stop to feature, regenerative braking and power sharing during normal operation means ICE rating can be reduced.

3. Full HEV
This type offers more versatile operation and has a combination of ICE and motor to drive wheels. It requires electronic variable transmission (EVT) for 50-60kW at voltage 500-600v.It enables start-stop to feature, regenerative braking, power sharing and electric launch. Since Full HEV operates in various modes, ICE can operate in OOL (Optimum Operation Line).

Integrated Starter Generator (ISG)-is an electrical machine can be connected to IC Engine as Belt driven ISG or Crankshaft mounted ISG.

(b). *Grid-able hybrid electric vehicles* are vehicles that can be connected to the grid for power exchange between the vehicle and the grid during high load demand. These are again classified into

1. Plug-in hybrid electric vehicles
These vehicles are derived from Full HEV operates in blended mode. They require higher battery bank than Full HEV and battery will charge using charging probes.

2. Range extended hybrid electric vehicles
These vehicles are derived from Battery Electric Vehicle and mostly operate in Pure electric mode.

The difference between conventional HEV and grid-able HEV is, conventional HEVs can be refueled only at filling station or petrol bunk whereas, grid-able HEVs can be refueled electrically at filling stations enables direct charging of batteries by plug-in.

Electric vehicles classification based on energy sources are as follows:

a) Battery electric vehicle- In this vehicle, the battery is used as an energy source. b) Hybrid electric vehicle- In this vehicle, a combination of liquid fuels and battery is used as an energy source. c) Fuel cell electric vehicle- In this vehicle, a combination of fuel cell and the battery is used as an energy source.

Energy carrier is a medium to transfer energy from source to propulsion device. Electric vehicles classification based on energy carriers are as follows:

a) Battery electric vehicle uses electricity to transfer energy.

b) Hybrid electric vehicle uses both liquid fuels and electricity to transfer energy.

c) Fuel cell electric vehicle uses Hydrogen as energy transfer.

III. CHALLENGES FACED BY DIFFERENT ELECTRIC VEHICLES

A. Conventional HEV
The challenges faced by the electric vehicles are
1. They are non-zero emission vehicles.
2. Low energy diversification because oil and natural gases to be refilled after every use.
3. It has a complex system.
4. It requires variable transmission because it has its own transmission loss, creates noise and requires regular lubrication.
5. The system is quite heavy and bulky.

B. Grid-able HEV
1. These vehicles face all the challenges of conventional HEV.
2. These are high-cost vehicles as it requires high battery capacity.
3. In some vehicles they require installation of on-board charger.

C. Fuel cell EV
1. They have high initial cost since fuel cell cost is more.
2. Lack of hydrogen fuel infrastructure since it is not available.
3. Storage of hydrogen is very challenging. Hydrogen can be stored in 3 ways as
(a). Gaseous form-compressed hydrogen gas
(b). Liquid form- liquid nitrogen
(c). Solid form- metal hydroxide
4. High safety concerns because of its explosive nature.

D. Ultracapacitors / Ultra flywheel EVs
1. They have a high cost.
2. They have low specific energy and cannot be used as a sole energy source as it requires a battery as HEV.
3. Ultra flywheel E Vs stores mechanical energy at high speed of flywheel often have high safety concerns.

E. Battery electric vehicle
1. They have a limited driving range.
2. High initial cost because battery size is more and limited life cycle.
3. Lack of charging infrastructure.

IV. FUZZY LOGIC CONTROL SYSTEM

Fuzzy Logic

Fuzzy logic is a multi-value system for its member elements in the range between 0 and 1. In traditional typeset we have Boolean types of answers either YES or NO, or TRUE or FALSE which is a true value logic. But in fuzzy logic we have partial cases between TRUE and FALSE.

A FLC consists of five functional blocks as indicated in fig.3. The rule base, the database, the fuzzifier, the inference engine and defuzzifier.
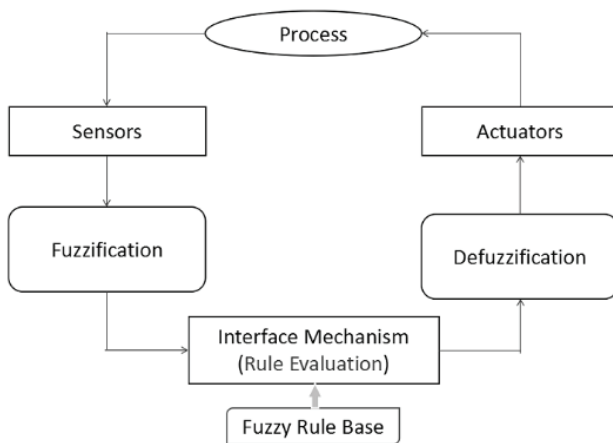

Figure 3. Fuzzy Logic Control

The fuzzy logic controller has sensors, actuators, fuzzification, inference engine and defuzzification. The input to the controller is given in word form or in sentence called as linguistic variables for example age, temperature cost.

Now a days age is defined by infant, young, old, very old and the cost is defined by very cheap, cheap, expensive these are termed as linguistic values to the given input.

Membership function represents the degree of truth in fuzzy logic and tells whether the elements present in the system are continuous or discrete. It is represented in graphical form. The Number of linguistic values is equal to the number of membership functions.

Before the inputs are given to the controller they are normalized.

1.   Normalization:

 Normalization is a procedure where the input values are normalized in a specific range.

2.   Fuzzification:

Fuzzification is a process of converting normal values/crisp values to fuzzy values (linguistic variables). Based on membership functions apply membership function to normal values so it becomes fuzzy membership values.

(a) Fuzzy set: It defines the value between 0 and 1.

(b) Crisp set: It defines the value is either a 0 or 1.

Membership functions are selected and assigned based on the input and nature of input variable. Next fuzzy values are provided to the inference engine for controlling the further applications. This process of selecting membership

functions and applying them on input is called as knowledge base. The membership functions for the input and output are given in fig. 4, 5 and 6
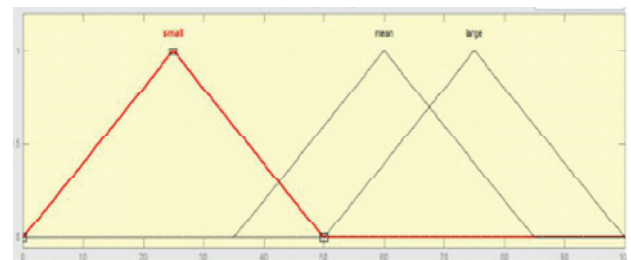

Figure 4. Membership function for SOC

It is the main part of the controller works on rules provided by the programmer. Fuzzy inputs are given to the inference engine and it selects the appropriate rules which are predefined and satisfies the fuzzy input values then applies the rule to get the fuzzy output. This process is called rule base system (it is also called as the heart of the system). The rules are written in 'IF'(antecedent) and 'THEN'(consequent) statements.
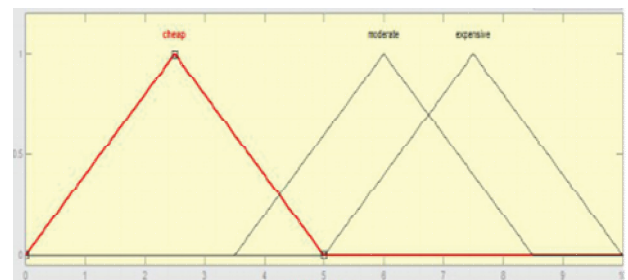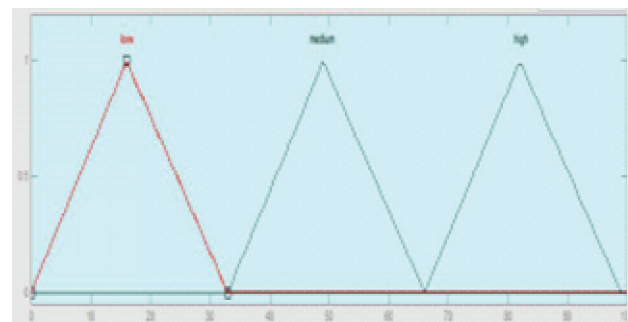

Figure 5. Membership function for COST

Figure 6. Membership function for EV Rating

3.   Inference Engine:

It is the main part of the controller, works on rules provided by the programmer. Fuzzy inputs are given to the inference engine and it selects the appropriate rules which are predefined and satisfies the fuzzy input values then applies the rule to get the fuzzy output. This process is called rule base system (it is also called as the heart of the system). The rules are written in 'IF'(antecedent) and 'THEN'(consequent) statements.

4.   Defuzzification:

Defuzzification is a process where fuzzy output values are now converted to crisp values. These values portray the actions taken by the fuzzy controller in individual control cycles. And the final output from defuzzification is given to the system. Defuzzification is also called as "rounding it off".

We have many types of inference mechanisms like Mamdani, Takagi Sugeno, etc. Among this Mamdani inference mechanism is chosen for its simplicity and easy to use. This is a direct adaptive mechanism where controllers are designed directly based on fuzzy rule base.

V. DESCRIPTION AND BLOCK DIAGRAM OF EV CONNECTED TO NANO GRID

The block diagram consists of 3-electric vehicles EV-1, EV-2 and EV-3 each composed of fuzzy logic controller and a battery are connected to a DC bus-bar through switches S-1,S-2 and S-3 respectively. Load is connected to the DC bus bar.
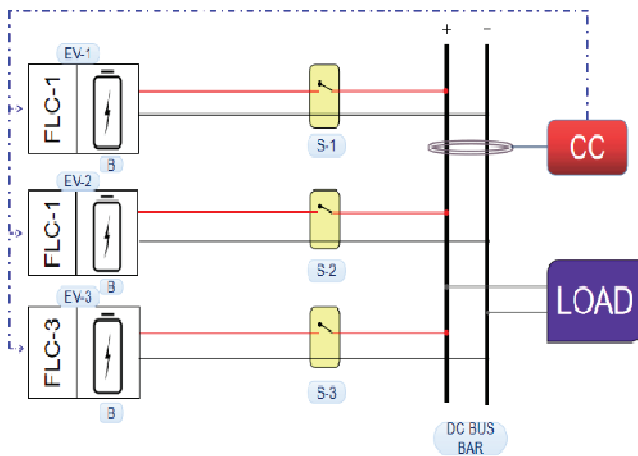

Figure 7. Block diagram of EV connected to Nano grid

The central controller will function as an information exchange between the vehicle owner and the Cloud. The information is based on the state of charge, tariff and voltage level of the battery. Cloud is a source of information storage. The voltage from the DC bus is taken as a reference voltage. If the threshold voltage is less than the reference voltage, then number of vehicles are connected to the circuit and if the threshold voltage is greater than the reference voltage then vehicles are not connected to the circuit. The fuzzy logic controller present in each vehicle will decide the ranking of the vehicle depending upon the state of charge, tariff and voltage level. The information of the vehicles with high SOC, voltage and low tariff are preferred from the central controller and this information is given to the fuzzy controller to give ranking for the vehicles. The detailed working procedure of the fuzzy controller is given in Section-IV. Once the ranking is given the vehicles are connected to the bus bar through switches. The flowchart corresponding to the implementation of the methodology is mentioned in figure 9.
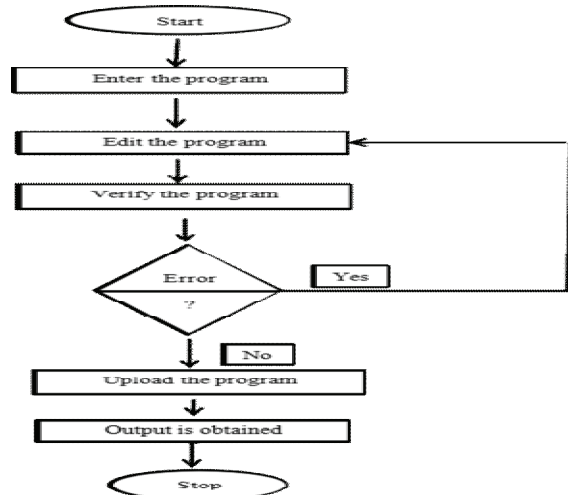

Figure 8. Membership function for SOC

VI. RESULTS

The EVs that are parked can be connected to the power grid to send their battery power to balance the peak demand. The cost per unit and SOC of battery of each EV is given to the central controller through CLOUD.

The proposed topology is implemented and tested on a hardware kit shown in fig.9
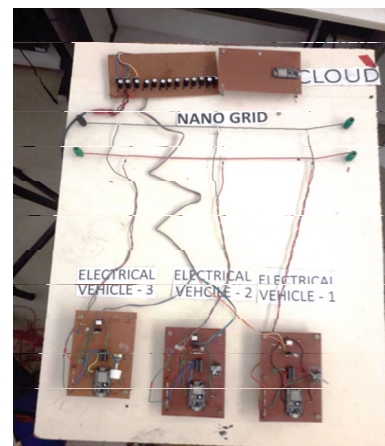

Figure 9. Hardware implementation of ELECTRIC VEHICLE

The kit is tested using fuzzy logic controller in MATLAB Software version 2015b. This fuzzy logic controller will compare the measured values from the EVs with the reference values and decide the ranking/participation factor/rating of the EV. Once the rating is obtained, it is given to the EV through central controller via CLOUD.

The output values are shown below table 2.

TABLE II.
OUTPUT VALUES OF COST, SOC AND EV RATING

COST	SOC					EVR
	50	60	70	80	90	
1	14	13	12	12	11	10
2	17	16	15	14	13	12
3	17	16	15	14	13	12
4	13	12	12	11	10	10
5	22	21	20	19	19	18
6	30	29	29	28	27	27
7	34	33	32	31	31	30
8	33	32	31	30	30	29
9	40	39	38	37	36	35
10	40	39	38	37	36	35

It can be observed from the above table when the cost is low and SOC is high, EV rating is high. The central controller will choose the EV to be connected is based on high rank i.e. low cost and high SOC of battery.
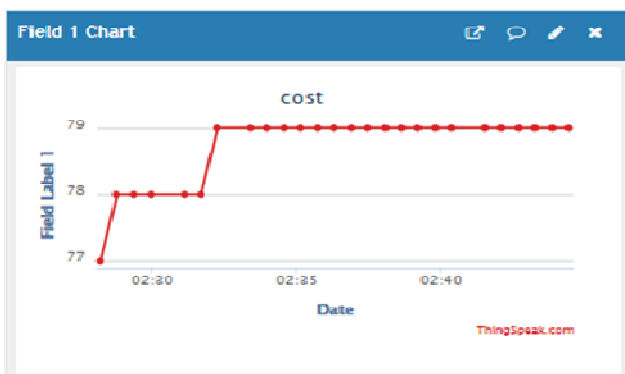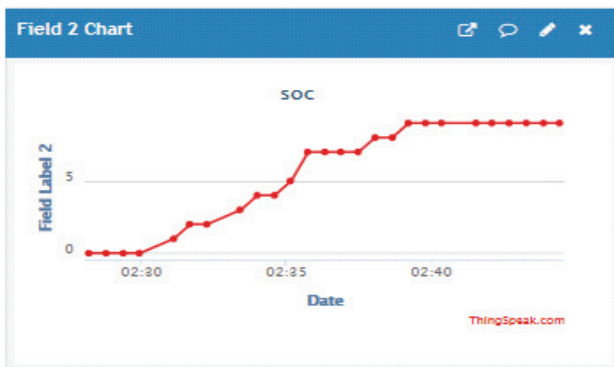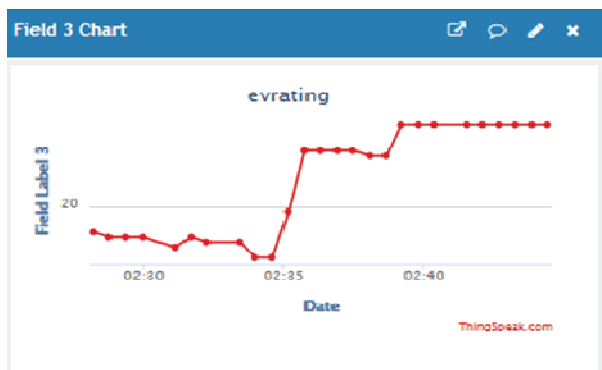

Figure a) cost

Figure b) soc

Figure c) EV rating

Figure 10. Outputs of a) COST, b)SOC and c)EV Rating in IoT

VII. CONCLUSIONS

Vehicle-to-grid (V2G) describes a system in which plug-in electric vehicles, such as battery electric vehicles (BEV), plug-in hybrids (PHEV) communicate with the power grid to sell demand response services by either returning electricity to the grid or by throttling their discharging rate.V2G provides ancillary services like reactive power support, load balancing, frequency control and enhancing renewable energy penetration to the grid. From each Electric-vehicle the voltage level and State of Charge (SOC) information is uploaded to the CLOUD on a regular basis. Fuzzy-Logic shall determine the participation factor/ranking of each vehicle and is communicated to the CLOUD. The Central Controller will receive the uploaded data and depending upon the load requirement the best vehicle(s), to be connected to the grid, is/are shortlisted and this information is given to the EV owner to connect his vehicle to the grid to transfer the power. By sending power from V2G, the EV owner will benefit economically.

In future, by connecting inverters the DC voltage from the EV can be converted to the AC voltage and the aggregate of this power could be given to the AC grid using wireless transmission.

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