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# VEHICLE-TO-GRID TECHNOLOGY IN A MICRO-GRID USING DC FAST CHARGING ARCHITECTURE

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## ABSTRACT

Electric Vehicle (EV) batteries can be utilized as potential energy storage devices in micro-grids. They can help in micro-grid energy management by storing energy when there is surplus (Grid-To-Vehicle, G2V) and supplying energy back to the grid (Vehicle-To-Grid, V2G) when there is demand for it. Proper infrastructure and control systems have to be developed in order to realize this concept. Architecture for implementing a V2G-G2V system in a micro-grid using level-3 fast charging of EVs is presented in this paper. A micro-grid test system is modeled which has a dc fast charging station for interfacing the EVs. Simulation studies are carried out to demonstrate V2G-G2V power transfer. Test results show active power regulation in the micro-grid by EV batteries through G2V-V2G modes of operation. The charging station design ensures minimal harmonic distortion of grid injected current and the controller gives good dynamic performance in terms of dc bus voltage stability.

***Keywords: G2V, V2G, EV, power transfer, micro grid, DC fast charging.***

## I INTRODUCTION

Vehicle-to-Grid (V2G) technology is an innovative concept that revolutionizes the way we think about energy management within micro-grids. In this context, we'll explore the introduction of V2G technology in a micro-grid using a DC Fast Charging architecture, which holds significant promise for enhancing the efficiency, resilience, and sustainability of localized energy systems.

**1. Micro-grid Overview:** A micro-grid is a self-contained energy system that can operate independently or in conjunction with the main power grid. It typically serves a localized area, such as a community, industrial facility, or campus, and is characterized by its ability to generate, store, and distribute electricity efficiently. Micro-grids are increasingly recognized for their potential to improve energy resilience and reduce carbon emissions.

**2. Introduction to V2G Technology:** V2G technology is a groundbreaking innovation that bridges the gap between electric vehicles (EVs) and the power grid. It allows EVs to not only consume energy but also become active participants in the grid ecosystem. Through bi-directional charging, electric vehicles can feed excess energy back into the grid during peak demand periods, effectively transforming them into mobile energy storage units.

**3. DC Fast Charging Architecture:** Incorporating a DC Fast Charging architecture within a micro-grid is a critical component of the V2G system. DC Fast Charging stations are known for their ability to rapidly charge electric vehicles, making them a popular choice for both urban and rural areas. These stations are more efficient and time-effective compared to traditional AC chargers, and they are ideally suited for V2G applications.

**4. Benefits and Implications:** Introducing V2G technology within a micro-grid using DC Fast Charging has numerous advantages:

**Load Balancing:** V2G-enabled EVs can provide excess power to the micro-grid during peak demand, reducing strain on the grid and lowering electricity costs.

**Resilience:** In the event of grid outages, V2G-capable EVs can act as backup power sources for critical infrastructure.

Renewable Integration: V2G helps absorb excess renewable energy when generation exceeds demand, promoting the integration of green energy sources.

**Reduced Carbon Footprint:** By utilizing electric vehicles for grid services, the carbon footprint of the micro-grid is further reduced.

**5. Challenges and Future Prospects:** While V2G technology holds immense promise, there are challenges to overcome, including regulatory, infrastructure, and interoperability issues. However, as technology and policy evolve, the potential for V2G integration in micro-grids will only grow, offering a glimpse into a more sustainable and resilient energy future.

## II LITERATURE SURVEY

A literature survey on Vehicle-to-Grid (V2G) technology in a micro-grid utilizing DC Fast Charging architecture provides valuable insights into the state of research, current trends, challenges, and future prospects in this rapidly evolving field. Below, I present an overview of some key studies and findings related to V2G technology within micro-grids using DC Fast Charging architecture:

These studies collectively emphasize the significance of V2G technology and its integration with DC Fast Charging architecture in micro-grid settings. They provide a holistic view of the challenges, benefits, and ongoing research efforts, contributing to the development of more sustainable and resilient energy systems. Researchers and practitioners in the field can draw valuable insights from this body of literature to advance V2G technology in micro-grids.

## III METHODOLOGY

Energy storage systems are important components of a micro-grid as they enable the integration of intermittent renewable energy sources. Electric vehicle (EV) batteries can be utilized as effective storage devices in micro-grids when they are plugged-in for charging. Most personal transportation vehicles sit parked for about 22 hours each day, during which time they represent an idle asset. EVs could potentially help in micro-grid energy management by storing energy when there is surplus (Grid-To-Vehicle, G2V) and feeding this energy back to the grid when there is demand for it (Vehicle-To-Grid). V2G applied to the general power grid faces some challenges such as; it is complicated to control, needs large amount of EVs and is hard to realize in short term [1]. In this scenario, it is easy to implement V2G system in a micro-grid. The Society of Automotive Engineers defines three levels of charging for EVs. Level 1 charging uses a plug to connect to the vehicle's on-board charger and a standard household (120 V) outlet.

This is the slowest form of charging and works for those who travel less than 60 kilometers a day and have all night to charge. Level 2 charging uses a dedicated Electric Vehicle Supply Equipment (EVSE) at home or at a public station to provide power at 220 V or 240 V and up to 30 A. The level 3 charging is also referred to as dc fast charging. DC fast charging stations provide charging power up to 90 kW at 200/450 V, reducing the charging time to 20-30 mins. DC fast charging is preferred for implementing a V2G architecture in micro-grid due to the quick power transfer that is required when EVs are utilized for energy storage. Also the dc bus can be used for integrating renewable generation sources into the system. In majority of the previous studies, V2G concept has been applied in the general power grid for services like peak shaving, valley filling, regulation and spinning reserves.

The V2G development in a micro-grid facility to support power generation from intermittent renewable sources of energy is still at its infancy. Also, level 1 and level 2 ac charging is utilized for V2G technology in most of the works reported. These ac charging systems are limited by the power rating of the on-board charger. An additional issue is that the distribution grid has not been designed for bi-directional energy flow. In this scenario, there is a research need for developing technically viable charging station architectures to facilitate V2G technology in micro-grids.This work proposes a dc quick charging station infrastructure with V2G capability in a micro-grid facility. The dc bus used to interface EVs is also used for integrating a solar photo-voltaic (PV) array into the micro-grid. The proposed architecture allows high power bi-directional charging for EVs through off-board chargers. Effectiveness of the proposed model is evaluated based on MATLAB/Simulink simulations for both V2G and G2V modes of operation.

## DC FAST CHARGING STATION CONFIGURATION FOR V2G

The configuration for dc fast charging station to implement V2G-G2V infrastructure in a micro-grid. EV batteries are connected to the dc bus through off-board chargers. A grid connected inverter connects the dc bus to the utility grid through an LCL filter and a step-up transformer. The important components of the charging station are described below. For dc fast charging, the chargers are located off-board and are enclosed in an EVSE. A bidirectional dc-dc converter forms the basic building block of an off-board charger with V2G capability. It forms the interface between EV battery system and the dc distribution grid. The converter configuration is shown in Fig. 2. It consists of two IGBT/MOSFET switches that are always operated by complimentary control signals. Buck mode of operation ( charging mode): When the upper switch is operating, the converter acts as a buck converter stepping down the input voltage to battery charging voltage. During the on state, current flows through the switch and inductor to the battery. This is the charging operation, where the power flow is from the grid to vehicle (G2V). When the switch is off, the current takes its return path through the inductor and diode of lower switch and completes the circuit.

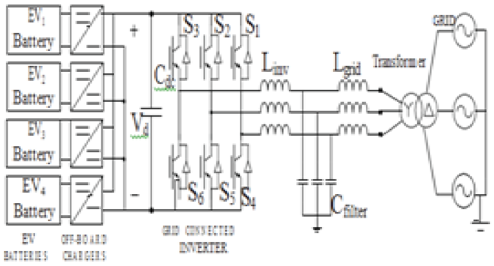

Fig.1 EV Charging station for fast dc charging

## IV SIMULATION RESULTS

During a simulation, Simulink updates the states and outputs of a model's blocks once per time step. The order in which the blocks are updated is therefore critical to the validity of the results. In particular, if a block's outputs are a function of its inputs at the current time step, the block must be updated after the blocks that drive its inputs. Otherwise, the block's outputs will be invalid. The order in which blocks are stored in a model file is not necessarily the order in which they need to be updated during a simulation. Consequently, Simulink sorts the blocks into the correct order during the model initialization phase.

In order to create a valid update ordering, Simulink categorizes blocks according to the relationship of outputs to inputs. Blocks whose current outputs depend on their current inputs are called direct feed through blocks. All other blocks are called non direct-feed through blocks. Examples of direct-feed through blocks include the Gain, Product, and Sum blocks. Examples of non direct-feed through blocks include the Integrator block (its output is a function purely of its state), the Constant block (it does not have an input), and the Memory block (its output is dependent on its input in the previous time step). Simulink allows you to assign update priorities to blocks. Simulink updates higher priority blocks before lower priority blocks. Simulink honors the priorities only if they are consistent with its block sorting rules.

Some of SIMULINK blocks, which are used in this thesis, are given below.

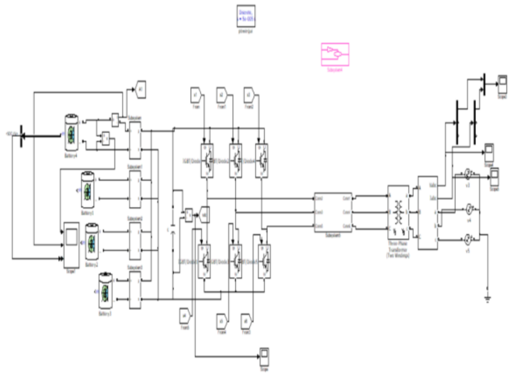

Fig.2. Proposed circuit configuration

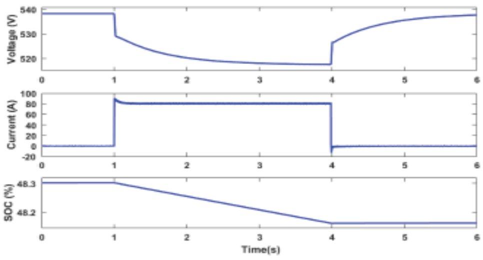

Fig.3.Voltage, current and SOC or EV1battery during V2G operation

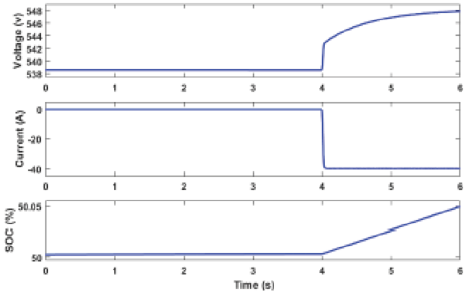

Fig.4.Voltage,current and SOC or EV2 battery during G2V operation

The active power contribution from various components of the system is shown in Fig. 8. The grid power changes to accommodate the power transferred by the EVs. The negative polarity of the grid power from 1s to 4s shows that the power is being fed to the grid from the vehicle. The change in polarity of grid power at 4s shows that the power is supplied by the grid for charging the vehicle battery. This demonstrates the V2G-G2V operation. Also, the net power at PCC is zero showing an optimal power balance in the system.

The dc bus voltage is regulated at 1500 V by the outer voltage control loop of the inverter controller and is shown in Fig. 9. This in turn is achieved by the inner current control loop tracking the changed d-axis reference current as shown in Fig. 10.

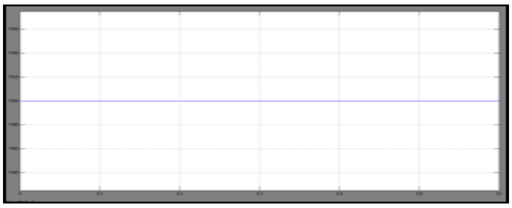

Fig.5.Variation in dc bus voltage

The grid voltage and current at PCC are shown in Fig. 11. Voltage and current are in phase during G2V operation and out of phase during V2G operation showing the reverse power flow.

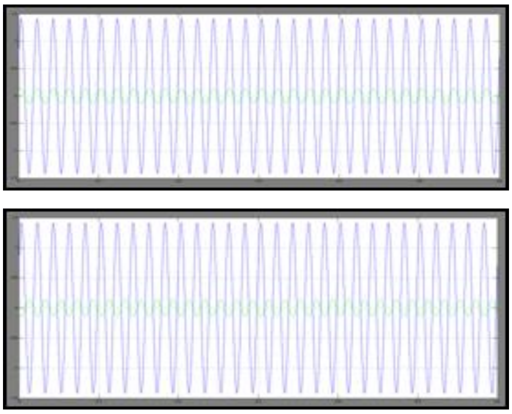

Fig.6.Grid voltage and grid injected current during V2G-G2V operation

Total harmonic distortion (THD) analysis is done on the grid injected current and the result is shown in Fig. 12. According to IEEE Std. 1547, harmonic current distortion on power systems 69 kV and below are limited to 5% THD. The THD of grid- injected current is obtained as 2.31 % and is achieved by the judicious design of LCL filter.

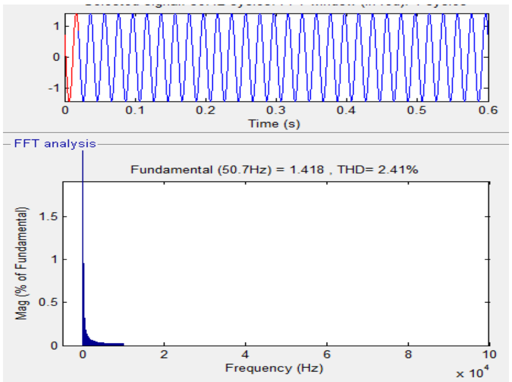

Fig.7.Harmonic spectrum and THD of grid-injected current PI controller:

Integrating a fuzzy logic controller (FLC) into Vehicle-to-Grid (V2G) technology within a micro-grid using a DC Fast Charging architecture is a sophisticated approach aimed at optimizing the performance of the V2G system. Here, I'll provide an overview of how an FLC can enhance the operation of V2G systems in micro-grids with DC Fast Charging:

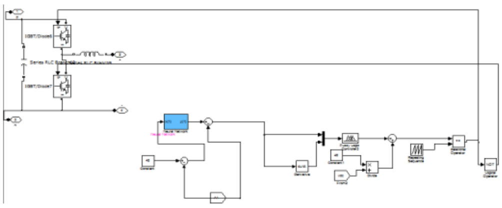

Fig.8 Constant current control strategy for battery charger

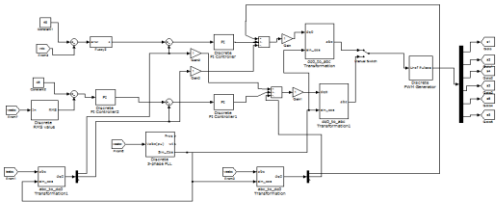

Fig. 9. Inverter control system

### 1. Fuzzy Logic Controller (FLC):

Fuzzy logic is a computational approach that allows for handling imprecise and uncertain information. FLCs are well-suited for complex, non-linear control systems, making them a valuable tool in V2G applications.

### 2. V2G System Overview:

V2G technology enables electric vehicles (EVs) to interact with the micro-grid, not only drawing energy from it but also returning surplus energy back to the grid when needed.

### 3. Benefits of Integrating an FLC:

Optimized Charging and Discharging: An FLC can adapt the charging and discharging rates of EVs to match the micro-grid's energy supply and demand in real-time. This ensures efficient and balanced energy exchange.

**Grid Stability:** FLCs can help maintain grid stability by regulating the power flow from EVs, preventing sudden fluctuations in voltage and frequency within the micro-grid.

**Energy Cost Reduction:** By intelligently controlling the timing and rate of energy transfer between EVs and the grid, FLCs can minimize energy costs by charging during off-peak hours and discharging during peak demand.

**User Prioritization:** FLCs can consider user preferences, vehicle schedules, and grid requirements to determine when and how to utilize EVs for V2G services.

**Fuzzy logic results:**

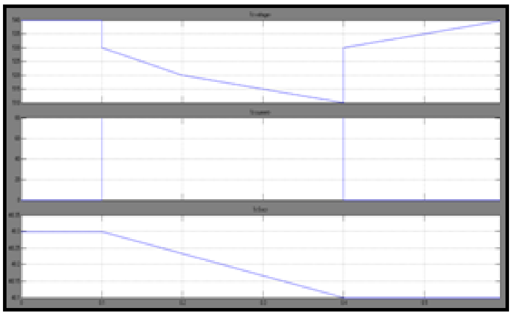

**Fig.10.Voltage, current and SOC or EV1battery during V2G operation**

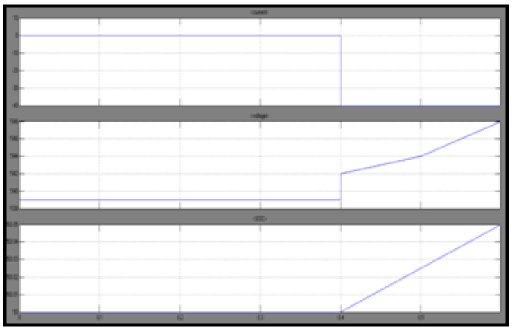

Fig.11.Voltage,current and SOC or EV2 battery during G2V operation

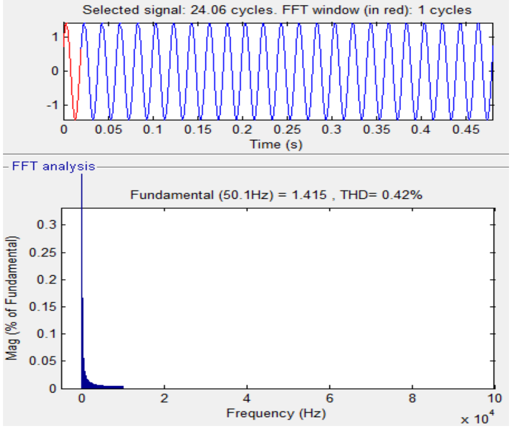

Fig.12.Harmonic spectrum and THD of grid-injected current Fuzzy logic controller

## CONCLUSION

Modeling and design of a V2G system in a micro-grid using dc fast charging architecture is presented in this paper. A dc fast charging station with off-board chargers and a grid connected inverter is designed to interface EVs to the micro- grid. The control system designed for this power electronic interface allows bi-directional power transfer between EVs and the grid. The simulation results show a smooth power transfer between the EVs and the grid, and the quality of grid injected current from the EVs adheres to the relevant standards. The designed controller gives good dynamic performance in terms of dc bus voltage stability and in tracking the changed active power reference. Active power regulation aspects of the micro-grid are considered in this work, and the proposed V2G system can be utilized for several other services like reactive power control and frequency.

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