An Investigation of the DC Charging System and Electric Vehicle in Relation To Autonomous Distributed V2G Implementation

Amer Himza Almyaly

Email: ameer_almyaly@yahoo.com
The College of Science/Department of Mathematics and Computer Applications/ AL-Muthanna University-Iraq

Abstract-- Vehicle-to-Grid (V2G) forms one of the promising platforms capable of supplying the power system with the distributed spinning reserve. This paper proposes an autonomous V2G control scheme through which user convenience in vehicles could be managed. Also, the proposed system strives to support the management of the power system contribution and battery condition during idle time. To verify the performance of the proposed system’s interface, system efficiency, and communication and control structure, an integrated interface controller, a controllable bi-directional power conditioner, and the test system responsible for electric vehicle battery test bed coordination (with a DC charging port) are used.

1. Introduction
Given the power system of electric vehicles, V2G comes with additional value. In this study, the charging system and the communication and control systems of the electric vehicle are integrated using a smart interface controller. Also, commercial electric vehicles are equipped with the DC quick charging port and the electric vehicle battery test-bed connected with a bi-directional controllable power conditioner. Given the charging system and an electric vehicle, the implementation targets an autonomous distributed V2G control that demands quick and seamless response.

For the charging system and the electric vehicle, the figures that follow illustrate the system structure. Indeed, the figures demonstrate both the respective components’ specifications and a laboratory experimental setup. To ensure that the experiment is conducted indoor and safely, the electric vehicle’s electrical components have a stationary test-bed packaged in them; as well as additional sections such as the quick charging inlet, the electric control unit, the battery management unit, and the battery pack. For the quick charger, the setup is arranged in such a way that its maximum charging power stands at 50 kW while the capacity of the battery stands at 16 kWh.
Figure 1: The charging system and electric vehicle schematic diagram

Figure 2: The charging system and electric vehicle experimental setup

Additional arrangements in the experimental setup are established in such a way that there is communication between the smart interface controller and the electric control unit of the electric vehicle through a control area network (CAN). Also, there is communication between the smart interface controller and the power conditioner through serial communication. To determine the set point of the V2G, parameters that are taken into account include the battery state of charge and the system frequency. Notably, the Discrete Fourier Transform plays a crucial role in determining a precise frequency detection through which the system frequency could be established [1]. The objective of determining the battery state of charge lies in the criticality of establishing electric vehicle propulsion control [2-4]. Through CAN communication, the state of charge is obtained by the controller, with a CHAdeMO protocol on the focus [5].

Apart from the system structure, another section that is noteworthy entails communication and control. For this system, the initial CHAdeMO sequences are developed through the checking of electric vehicle safety, as well as the nature of the charger. To ensure that the electric vehicle is awakened by the smart interface controller, an analog signal is employed. In turn, the CAN communication is better placed to accommodate the information exchange. Upon the successful completion of the compatibility
check, three analog signals are managed to support the operation of the reclosing of the electric vehicle relay, the insulation test, and the connector lock [6]. For every 0.1s, there is an exchange of the charger and electric vehicle’s operating conditions such as the battery state of charge, having accomplished the initial sequences. Should termination conditions be detected by the smart interface, there is consequent execution of the CHAdeMO termination sequences. For the case of the autonomous distributed control, droop characteristics are used to establish the setpoint for V2G and a parameter that plays a moderating effect entails the system frequency deviation. The implication is that as the plug-out time of the users nears, the smart charging has the V2G switched into it to ensure that the scheduled charging is satisfied.

Regarding the case of the centralized control, the battery state of charge needs to be grasped by a load dispatching center for each electric vehicle. This process needs to occur at selected intervals; an example being every 30 minutes. The role of the load dispatching center is to ensure that the required candidates for charging are selected based on the variable of descending or ascending state of charge order. With the state of charge on the focus, the resultant trend of on-off control proves effective relative to the synchronization of the perceived state of charge [6-10]. The eventuality is that for each electric vehicle, the operating state and the state of charge are transferred to the simulator. The platform that supports this transfer entails the UDP/IP communication [9, 10].

Given the experimental set-up described above, one of the categories through which the results are obtained, described, and presented involves the step response. From the previous literature, the evaluation of step responses involves step wise frequency changes arising from AC power sources, which are programmable [2-4]. For the AC current and AC voltage, some of the instantaneous values obtained and other parameters (such as the batter state of charge, active power output, and the system frequency) are summarized as follows:

![Figure. 3: Set up](image)
For the measurements, it can be seen that its sampling time remains at 1 ms. For the current and voltage sensors, the signal processing and specifications are obtained after positive value is used to define the active power at charge.

Specific results demonstrated that a 0.2 s delay accompanied the frequency change, having implemented the frequency detection approach. Given the detected change in frequency, there was a control of the active power. However, this procedure experienced a conversion control power delay, as well as a communication dead time. For the settling time, the total duration was recorded at 1 s. With the CAN communication employed, there was successful determination of the values of the state of charge. As the experiment progressed, it is also notable that the state of charge remained constant. The factor that explained this trend was that the discharge or charge power accumulation corresponding to alterations in the state of charge operated below the minimum state of charge value resolution. Particularly, this value was 0.1 kWh.

Apart from the step response, another aspect that was worth reporting in the experiment’s results involves the autonomous distributed V2G. Particularly, there was a direct interconnection between the charging system (and the electric vehicle) and the power system. In this connection, there was a system frequency fluctuation due to an imbalance in the demand and supply of the real power system. A central assumption through which there was verification of the autonomous distributed V2G was that 30% state of charge was a point at which the electric vehicle was plugged in and that it was after seven hours that the electric vehicle would be plugged out, having achieved a full state of charge. The figure below illustrates the experimental results relative to the investigation of the parameter of autonomous distributed V2G.

Figure 4: Experimental results
From the figure above, readying the emergency departure was preceded by enforcing the smart charging, having ensured that the system stands up. It is also notable that the electric vehicle’s charging was extended to 50% to ensure that a one-third droop gain was supplied to the smart charging. Afterward, there was continuous supply of the charge (by the electric vehicle) followed by discharge cycles produced by the V2G. The process was done for four hours. Eventually, there was the charging of the electric vehicle to the state of charge destination after implementing the second smart charging phase. The destination state of charge stood at 90%. Findings demonstrated that it was within one second (with the time lags included) that the system achieved the total settling time.

2. Conclusion

In conclusion, the proposed system was found to be adequate in following the frequency charge. Also, the system led to the realization of a seamless mode switch. Hence, these findings proved informative for the field of electrical engineering in such a way that it paved the way for the adoption of the proposed methodology of the system integration and the autonomous distributed control schemes due to their feasible nature, hence optimizing the design of electric vehicles in the contemporary, technology-driven world.

3. References

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