Renewable Based Battery Protective Electric Vehicle Charging Management System

Praisy Roselin.S [1] and Mrs. C. Gnanathilaka M.E, Ph.D.[2]

[1,2]*Department of Electrical and Electronics Engineering, Ponjesly College of Engineering.*

Abstract— ***The adoption of Grid-connected Electric Vehicles (GEVs) brings a bright prospect for promoting renewable energy. An efficient Vehicle-to-Grid (V2G) scheduling scheme that can deal with renewable energy volatility and protect vehicle batteries from fast aging is indispensable to enable this benefit. This project develops a novel V2G scheduling method for consuming local renewable energy in microgrids by using a mixed learning framework. It is the first attempt to integrate battery protective targets in GEVs charging management in renewable energy systems. Battery safeguard strategies are derived via an offline soft-run scheduling process, where V2G management is modeled as a constrained optimization problem based on estimated microgrid and GEVs states. The Extreme Learning Machine (ELM) algorithm is used to train the established online regulator by learning rules from soft-run strategies. The online charging coordination of GEVs is realized by the ELM regulator based on real-time sampled microgrid frequency. The effectiveness of the developed models is verified on a U.K. microgrid with actual energy generation and consumption data. This project can effectively enable V2G to promote local renewable energy with battery aging mitigated, thus economically benefiting EV owns and microgrid operators, and facilitating decarburization at low costs.***

***Index Terms—Electric Vehicles, renewable energy, microgrids, Extreme Learning Machine algorithm*.**

I. INTRODUCTION

The adoption of Grid-connected Electric Vehicles (GEVs) brings a bright prospect for the promotion of renewable energy. However, an efficient Vehicle-to-Grid (V2G) scheduling scheme that can deal with the volatility of renewable energy and protect vehicle batteries from fast aging is indispensable to enable this benefit. Many studies have investigated V2G management under local renewable energy penetrations. The real-time online decision-making model is one of the most commonly used V2G scheduling methods for its merits in dealing with the volatility of renewable resources. In online V2G scheduling, the behaviors of GEVs are scheduled based on real-time sampled grid status instead of predictions or historical information. A fuzzy-logic algorithm was used to manage the penetration of GEVs by real-time sampled grid voltage and battery energy states. Experiment results indicated that the established regulator could schedule the V2G behaviors of GEVs in real-time to improve power quality. In, an intelligent optimization approach is developed for the optimal vehicle charging/discharging scheduling in a grid-connected charging station and a smart building based on multimodal approximate dynamic programming. The proposed strategy exhibits a robust behavior in the presence of stochastic arrival and departure times as well as different pricing models and renewable energy production. An online V2G coordination method using a two-stage rule-based decision-making model.

In online methods, the charging behaviors of each GEV can be dynamically scheduled because the established control models are free of complex optimization processes. The rapidity makes it possible to respond to the volatility of renewable energy. However, predictive information and GEVs cooperative optimization mechanism are not employed in most online methods, and batteries may undergo extra aging cycles because of uncoordinated scheduling. According to without properly designed safeguard scheduling mechanisms, V2G service may rapidly exhaust vehicle battery life. In a quantitative study, battery useful life could be decreased to 65% after participating in bi-directional V2G management. The concerns with accelerated battery aging have become the main reason that keeps GEV customers from participating in V2G services. The studies carried out by the University of Oxford and the University of Washington indicate that battery aging occurs with its operation but can only be detected and mitigated on a large time scale. With the development of communication and computation technologies in recent years, many efforts have been made to reduce battery aging by using optimization-based scheduling methods. A heuristic algorithm-based V2G scheduling method is developed to schedule the charging behavior of GEVs in the microgrid. The V2G scheduling is modeled as a multi-objective optimization problem under a 24-hour time scale, and the battery aging is mitigated by constraining the Number Of Cycles (NOC) and Depth Of Discharge (DOD). In, V2G scheduling is modeled as a stochastic optimization problem, and the mitigation of battery aging is realized by setting NOC constraints. Simulation results indicated that the total economy of the integrated transportation-energy system could be significantly improved. The optimization-based V2G behavior management model achieves optimal scheduling but is not able to be deployed online. The scheduling period is as long as 5 min even the most advanced computing equipment is adopted.

The recently developed computationally efficient approaches bring a bright perspective for ensuring V2G scheme optimality and real-time performance. The Broad Learning System (BLS) and Extreme Learning Machine (ELM), are both least squares-based supervised learning algorithms with fast learning and strong generalization ability. The BLS paradigm has recently emerged as a computationally efficient approach in big-data scenarios to supervised learning. The ELM algorithm mainly focuses on dealing with common regression problems with relatively small datasets. Compared with BLS, ELM has better computational efficiency and stability for conventional regression problems. It has been widely used in engineering applications, including industrial processes, complex system modeling, and fault diagnosis. In the proposed V2G scheme can be simplified to a multiple-input and single-output system. Therefore, the most basic and commonly used supervised learning method: ELM is employed to solve the learning problem.

III. PROPOSED SYSTEM

A. Renewable Based Battery Protective Electric Vehicle Charging

A microgrid that consists of local renewable, conventional generator, GEVs, and domestic load is employed to verify the developed V2G scheduling method. Photo Voltaic (PV) array and wind generator are connected to the microgrid ac bus through inverters, while household loads and conventional generators are connected to ac bus directly to sustain power balance states. Based on the real-time sampled microgrid frequency state information, the charging and discharging behavior of GEVs are coordinated by the V2G scheduling system. The corresponding V2G strategies are realized by the smart charging pile between GEVs and microgrids. In this article, targets of V2G scheduling are assumed to absorb local renewable generation and mitigate vehicle battery aging. Therefore, the effect of the power purchase from the main grid is not considered and the microgrid is assumed to operate under off-grid mode.

The characteristic of conventional power plants is simulated by the dynamic model presented and the generators are modeled by linearized swing equations. The energy consumption and renewable power generation states of the microgrid are simulated based on the open-access power system operation data provided by Western Power Distribution, U.K. The national household travel survey data is employed to simulate the charging behavior of V2G participants, and the Monte Carlo simulation model is used to simulate GEVs availability states. The power conversions processes between the energy generation, consumption and storage devices are modeled as a steady-state conversion model is described. The power flows between different sectors in the microgrid are simulated to verify the effectiveness of the developed V2G management method. The proposed work is implemented on a high-performance workstation equipped with 2×E5-2690v4 processors. The softrun model and the training of the online regulator are programmed with MATLAB, and the real-time V2G regulation is realized in Simulink to facilitate its hardware deployment.

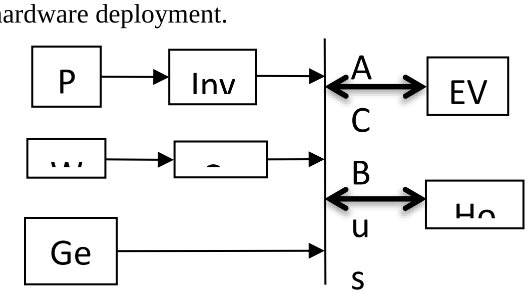

Fig. Proposed Block Diagram

B. Smart Home

For the last couple of decades humanity took a huge leap in terms of technology when it is compared with the previous centuries. In the near future, the devices will have more intelligence, they will understand our emotional state and needs and may even speak with us. Internet of Things (IoT) and Artificial Intelligence (AI) will change everything. When an ordinary home is considered, smart lighting reacts automatically or in response to one's voice, TV opens and lighting color changes according to the TV's content etc. Smart home is a technological platform that consists both hardware and software components. Hardware primarily acts as a communications base. Home-Area Network (HAN), that connects digital devices into a common network by wireless or wired technology, provides a gateway to the other WAN or smart grid networks. Home controller and automation system gives access to control devices from remote, anywhere that has the internet connection. It has the capability of programming and scheduling activities for the home applications that are connected to the home area network, such as start or stop commands of a washing machine at pre-determined time period that is related with the energy prices. Another example is the situation where a device or events trigger another device by setting designed activity based on the customer preferences. For example, at an emergency case, lighting system turns on immediately, arranges the power in critical position, open/unlock all doors and activates the emergency telephone.

C. Home Energy Management System (Hems)

Home Energy Management System (HEMS) makes all of the decisions at a smart house. 'Smart house' and 'home energy management system' is used in place of one another interchangeably in practice. In order to prevent this confusion, it is of utmost importance to define both concepts thoroughly.

Basically; smart home deals with the infrastructure side, whereas HEMS deals with the decision support side. Not only smart home means more infrastructure, base platform and hardware concepts but also home energy management system simply works on smart house infrastructure as a decision support system. Thus, the home user can make better decisions about reducing energy consumption, managing energy resources by changing energy consumption behavior. HEMS is the interface that allows the user to monitor, control and manage household electricity consumption and generation efficiently. From the public institutions' point of view, it reduces peak demand load and prevent blackouts by demand response program. On the other hand, from the environmental perspective; decreasing gas emission per person is an important achievement when combined with decreasing energy consumption, using clean renewable energy resources and electrical vehicles.

D. Electric Vehicles

The automotive sector is going through profound changes in the coming years where the EVs are an important factor to consider in the development of the future electricity grid, the SG. In 2030, the automobile sector will have modifications compared to the one we know since the beginning of the 20th century: thermal vehicles, although still numerous, will use very little oil, and could even be restricted in the centers of large metropolises because of their local nuisances (pollution, noise). At the same time, the sector's economic model will be disrupted by the gradual disappearance of the ownership link between user and vehicle: rental and car-sharing could become more common.

This evolution is made unavoidable by three major factors: The energy crisis: the dependence of transport on oil poses economic problems (trade deficit) and geopolitics (risks on oil supplies) that will only increase. The environmental crisis: the transport sector is one of the main contributors in terms of CO2 emissions and it represents one quarter of our emissions, an increase of 22% since 1990.The crisis of the current economic model of the sector: it is based on a rapid renewal of vehicles, whose utility is questioned by customers today in times of crisis, and tomorrow for ecological reasons. Although the EVs is not a new concept, prototypes have existed since the end of the 19th century, the progress made on batteries and autonomy, changing attitudes and political incentives have allowed the EV market to become more attractive. For the grid, EV can be perceived in two ways, as a load, or as a means of storing energy. In the first case, charging control consists of shifting the consumption of EVs over time, in order to limit power peaks on the grid, or to make recharge coincide with periods of high production of renewable energy resources. In the second case, it is a question of using the battery of EVs to absorb or supply energy according to themarket prices, the availability of the RERs or the consumption of the individual. This is the concept of the "Vehicle to Grid (V2G)".

Technical levels of recharging power for EVs exist, corresponding generally to the available power with circuit breakers of 16, 32 and 63 amperes:

- 16 A single phase = 3 kVA, considered as "normal recharge";
- 32 A three-phase = 22 kVA allowing "accelerated charging";
- 63 A three-phase = 43 kVA allowing "fast charging".

The increase of the recharging power makes it possible to decrease in proportion the duration of recharging for an electric battery. Thus, for a battery of average capacity (for example 25 kWh / ~ 160 km of autonomy), the complete recharge of the battery has a theoretical duration of approximately 8 hours for normal recharging (3 kVA) to about 30 minutes for fast charging (43 kVA). The architecture of an EV is presented in Fig. 1.4.

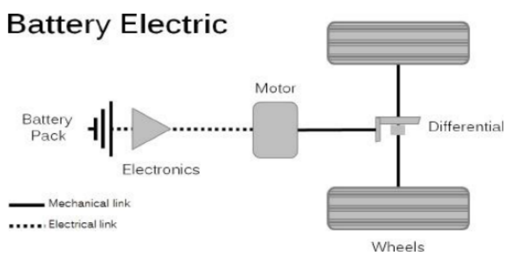

Fig. Electric vehicle architecture

E. PV Energy Generation Concepts

Grid-Connected Applications

In this mode of solar power generation, the solar arrays are used in huge capacities of the order of MW to generate bulk power at the solar farms, which is coupled through an inverter to the grid and feeds in power that synchronises with the conventional power in the grid. The grid connected solar power operates at 33KV and at 50 Hz frequency through inverter systems, whereas the solar farms generate the average power output of about 5MW each. Owing to very high power generation, the batteries are not used to store power as in case of isolated power generation for economic concerns. 53 grid-connected solar projects were selected up to the end of 2010 comprising of total capacity of 704MW.

NTPC Vidyut Vyapar Nigam (NVVN), the trading subsidiary of NTPC, was identified as the implementing agency for grid connected solar power generation. NVVN was allowed to purchase solar power from the project developers and bundle with power from the cheaper unallocated quota of the Government of India (Ministry of Power) out of the NTPC coal based stations and selling this "bundled" power to Distribution Utilities. NVVN invited Expressions of Interest in August, 2010 to select 150 MW of Solar PV projects and 470 MW solar thermal projects, which yielded huge response by way of an offer of more than 5,000 MW.

Stand Alone Applications

This mode of energy generation from solar consists of systems which are not connected to the grid, i.e. off-grid applications (captive power). It is done especially in the north-eastern states and several districts of Rajasthan, where there is scarce of electricity from the conventional sources. These stand-alone systems have a solar array, coupled with a power conditioning devices such as an inverter that converts the power from DC to AC to suit the load requirements such as home power and a battery to store the solar energy harnessed during the day to consume it in the absence of solar energy. These decentralised systems of PV array operate at below 33KV and 50Hz through the inverter. However, the larger capacities of the order of KW usually sell the power to grid and get paid with attractive tariff. The heating systems concentrate the sun rays on heating water which can be used for cooking, washing, power generation, etc. About 8.2 lakhs solar lanterns, 6.7 lakhs solar home lighting systems, 1.2 lakhs solar street lighting systems, 7,495 solar water pumping systems, stand-alone and grid connected Solar PhotoVoltaic (SPV) power plants of about 4MWp capacity, about 3.97 million square meter solar water heater collector area and 6.39 lakhs solar cookers have been distributed/installed in the country, as on 31.01.2011.

f.. Methodology

Grid load, solar generation, and wind generation power profiles within 30 working days in the studied microgrid system are shown in Fig. 3.2. The first peak appears in the period of 08:00 to 10:00, and the maximum grid load level reaches 3.5 MW at around 09:00 because of the rise of commercial power consumption, as shown in Fig. 3.2 (a).The second peak is from 17:00 to 20:00 because of the aggregated use of cooking and heating appliance in households. Without energy storage capacity, microgrid needs to trade with the main grid frequently to satisfy the power requirement of consumers. The solar generation profiles are shown in Fig. 3.2(b), most of which peak in the period of 11:00 to 12:00 when the valley of grid load profile appears. Without GEVs penetration, the generated power cannot be fully consumed by the grid and the abundant power will be wasted. The wind profile is not as regular as solar profiles, as shown in Fig. 4(c); however, the power generation value in the evening is generally higher than that of in the daytime.

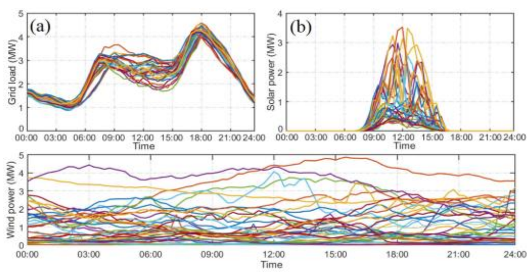

Fig. Microgrid (a) load (b) solar generation, and (c) wind generationpower profiles within 30 working days.

The objective of V2G management is to maximize the Renewable Energy Absorption (REA) rate in the scheduling period. Fluctuation of renewable power generation impacts of scheduling algorithm performance directly. REA rate of the developed mixed learning method is compared with conventional optimization-based method under different renewable generation forecasting error states. Both the optimization-based and mixed learning models achieve satisfactory performance with accurate prediction information. The REA rates reach 98.4% and 97.2%, indicating the effectiveness of V2G scheduling. The optimization-based model and mixed learning model can keep stable before the forecasting error reaches 4%, and the REA rates are generally kept above 92%. However, with the prediction error further increasing, the REA rate decreases dramatically. When forecasting error reaches 10%, the REA rate in the optimization-based method is only 60.7%. The microgrid REA rate can still be kept to 90.2% in the mixed learning method, validating its robustness under uncertain renewable generations and power consumption.

IV. SIMULATION RESULTS

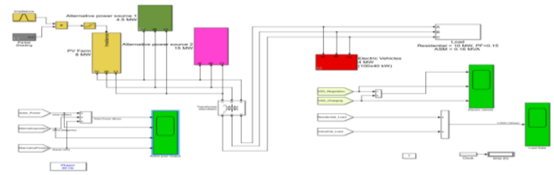

Fig. Circuit Diagram

The above circuit diagram shows a coordinated framework of the EV charge-discharge management for reduction of residential operation cost and PV curtailment by effectively charging the expected PV curtailment to the EV. The HEMS determines an EV charge-discharge plan for minimizing the residential operation cost on the basis of the forecasted PV output and expected PV curtailment due to the voltage constraint informed from the Grid.

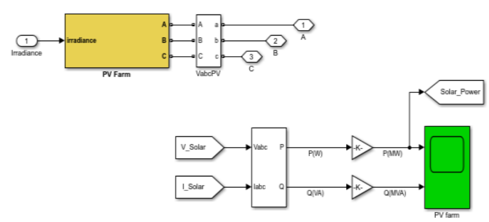

Fig. Photovoltaic Farm Block

The above figure shows the photovoltaic farm block to analyze the simulation results to understand the performance of the PV farm such as power output, voltage regulation etc.

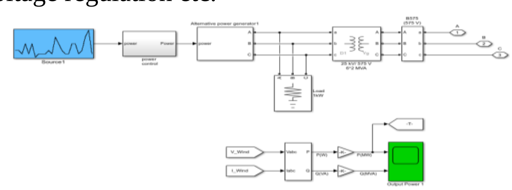

Fig. Alternative Wind Power Source Block

The above figure shows the alternative wind power source block to analyze the simulation results to understand the performance of the wind power system such as power output, efficiency, grid integration, etc.

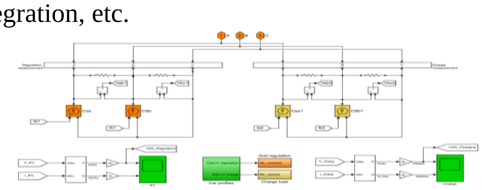

Fig. Electric Vehicle Circuit Block

The above figure shows the electric vehicle circuit block to analyze the performance of the electric vehicle in terms of energy consumption, range, acceleration, etc.

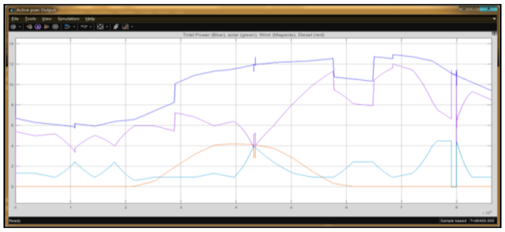

Fig. Simulation Waveform for Active Power Output

The above figure shows the simulation waveform for active power output. Pink color wave is defined as the power output of solar. Blue color wave is defined as power output of wind. Sky blue color is defined as power output of diesel generator. Finally, total power is defined as orange color.

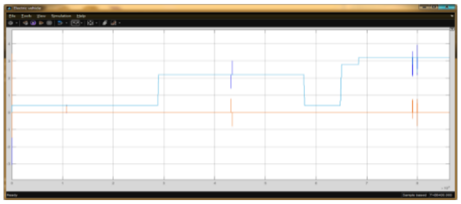

Fig. Simulation Result for Electric Vehicle Regulation and Charging

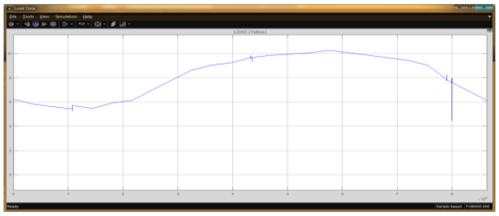

Fig. Simulation Results for Residential and Industrial Load Output Waveform

V. CONCLUSION

Thus, proposed a battery safeguard V2G scheduling method was developed for managing GEVs charging in microgrids with local renewable energy penetrations in this article. The consumption of volatile renewable energy and the mitigation of battery aging are addressed by establishing a mixed learning V2G scheduling framework. The optimal online GEVs charging strategies were derived from the cooperation between the soft-run optimization model and online V2G power regulator. Through extensive simulations on a microgrid system with real power generation and consumption data, the key findings are as follows. 1) Benefiting from the cooperative optimization mechanism, the battery antiaging strategy was derived from the softrun V2G behavior management model. The established ELM algorithm-based regulator can accurately reproduce the derived strategies in the soft-run model. Compared to the conventional online scheduling method, battery aging cycles was effectively mitigated in V2G service. 2) The built online V2G power regulator schedule the charging power of GEVs in real-time for responding to the volatility of renewable power generation. Compared to the optimization-based method, the REA rate was significantly improved.

Large-scale wind and solar power plants connected to transmission networks are also of great significance to improving microgrid security and efficiency. Future work will be conducted on V2G scheduling that considers energy mobility and trading between the microgrid and the main grid.

REFERENCE

[1] Amini .M.Hand Islam .A.(2014), "Allocation of electric vehicles' parking lots in distribution network", pp. 1–5.

[2] Definition of ZEH and future measures proposed by the ZEH Roadmap Examination Committee, (2015)" Energy Efficiency and Conservation Division/Agency for Natural Resources and Energy/Ministry, Trade and Industry.

[3] Deilami .S, MasoumC A.S, Moses P.S, and Masoum M.A.S.(2011), "Real-time coordination of plug-in electric vehicle charging in smart grids to minimize power losses and improve voltage profile," IEEE Trans. Smart Grid, vol. 2, no. 3, pp. 456–467.

[4] Dubey.A and Santoso.S.(2015), "Electric vehicle charging on residential distribution systems: Impacts and mitigations," IEEE Access, vol. 3, pp. 1871–1893.