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ENERGY MANAGEMENT SYSTEM BASED ON CHARGE AND DISCHARGE IN ELECTRIC VEHICLE APPLICATIONS

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Abstract -An electric vehicle charge-discharge management framework for the effective Utilization of photovoltaic (PV) output through coordination based on information change between home energy management system (HEMS) and grid energy management system (GEMS).The HEMS controls the EV charge discharge according to the demined plan and real-time monitored data, which is utilized for mitigating the negative effect caused by forecast errors of power profiles. The hardware results show the effectiveness of our proposed Framework from the view point of reduction of the residential operation cost and PV curtailment.

Index terms -Visual Cryptography, Extended Visual Cryptography Scheme

I. INTRODUCTION

Reduction of CO2 emissions to prevent global warming is a worldwide challenge. Electricity will account for almost a quarter of the final energy consumption by 2040. the power sector is needed to lead the way toward a decarbonized energy system. In Japan, in addition to co2 emissions, primary energy self-sufficiency is a large issue. Energy self-sufficiency has stayed at only 6% after the Great East Japan earthquake and the Fukushima Daiichi accident in 2011. In order to break down this emergency, the government is aiming to increase it to approximately 25% by 2030. On the other hand, the amount of CO2 emissions was 201 million only in the household sector in 2013, and the aim is to reduce this volume by 39.3% by 2030. To overcome these energy issues, the government is developing newly constructed houses with zero average emissions for deployment by 2030, so-called net-zero energy houses (ZEHs), which have an annual net energy consumption of zero or less, is receiving considerable attention. To achieve ZEHs, utilization of residential photovoltaic (PV) systems is essential; besides, the energy storage systems should be deployed in households to flexibly utilize electricity from the PV systems. Additionally, home energy management system (HEMS) is expected to become an important component in realizing ZEH in Japan, and could be introduced in all (approximately 50 million) households by 2030.

Electric vehicles (EVs) can be used for energy storage to effectively utilize PV, while it is originally used for driving. Connecting EVs to the power grid with renewable energy sources (RESs) will lead to various cost advantages in terms of energy management, but the power flow tends to be complicated; the power flow derived from EVs has large and temporally unexpected variation compared with conventional flows. Therefore, in the energy management of EVs, the impact of EV charge-discharge on the grid must be addressed, along with the effective utilization of RESs. There are many previous studies on EV charge-discharge management. These works can be classified by the connection system to the grid, i.e., vehicle-to-grid (V2G), which is the connection system through public charging stations, and vehicle-to-home (V2H), which is the connection system through houses. The classification of previous studies in terms of the connection system, consideration of EV charge-discharge impact on the grid, and penetration of the RESs.

Many previous studies focus on V2G, particularly on EV charging management schemes in parking lots. The coordination scheme of autonomous EV parking has been proposed for utilizing the EV batteries to support various V2G services. The minimization of electricity cost and maximization of profit for the aggregators in parking lots has also been considered. In these reports, the allocation of EV parking lots and impact of EV charging on the grid is evaluated in terms of voltage violation, total system loss, and peak system load. However, the RESs are not penetrated in the grid; therefore, the effective utilization of the RESs supported by EV management is not discussed. The authors of proposed an EV charging scheme managed by the aggregator. The aggregators should manage EV charging to maximize their profit and mitigate the impact on the grid. In these cases, RESs, such as PV and wind power generation, are effectively utilized for EV charging, and the cost is reduced without increasing the negative impact on the grid.

On the other hand, for a V2H system, discharge management, in addition to the charge management, has been considered in terms of home energy management, based on human activity and the electricity rate. Several studies have focused on HEMSs integrated with EVs. The HEMSs proposed to maintain residential convenience by managing several home appliances, including the EV, while the consideration of the impact on the grid and the RESs penetration are not included. The authors of proposed energy management schemes that use EVs to minimize the residential operation cost of home energy management. In these schemes, each EV charging plan is optimized for satisfying individual objectives, and the aggregator coordinates the plans to minimize the impact of EV charging on the grid. However, the potential for RES utilization has not been evaluated. HEMSs with PV and EV. These schemes manage the EV charge-discharge to minimize the residential operation cost by selling the surplus PV output. However, the researches mainly focus on the optimization in the houses, and the impact on the grid has not been assessed; therefore, the profit reduction expected to be caused by PV curtailment under the voltage constraint has not been considered.

To minimize the residential operation cost, the EV should be charged when the PV is not generating and discharged when it is generating for covering the residential electricity consumption and selling as much surplus PV output as possible under the Feed-in Tariff (FIT) Program. However, in this case, PV curtailment in order to mitigate the overvoltage caused by the reverse power flow from the surplus PV output will become the main issue; the expected profit from selling the surplus PV output cannot be earned. Therefore, for effective utilization of PV output in V2H scenarios, an EV charge-discharge management framework for reducing PV curtailment by the voltage constraint in the grid is required.

Although, the authors have studied the EV charge-discharge framework based on information exchange between HEMS and grid energy management system (GEMS) for reduction of the residential operation cost and the amount of PV curtailment, the influence caused by the uncertainty of the forecasted power profiles utilized for the charge-discharge planning has not been considered. An extension of our previous work, and we propose the coordinated EV charge-discharge management under the condition with uncertainty of PV forecasting. In the proposed method, the coordination is also based on information exchange between the HEMS and GEMS. The HEMS determines an EV charge-discharge plan for minimizing the residential operation cost, without disturbing EV usage for driving, on the basis of the voltage constraint information in the distribution system (DS) obtained from the GEMS. The planning is also based on the forecasted profiles of PV output. When the EV charge-discharge control is carried out according to the determined plan based on forecasted profiles with significant deviation from the actual values, the charge-discharge amount will be larger or smaller than the ideal amount so as to reduce the residential operation cost and PV curtailment. In order to mitigate the negative impact of forecasting error, i.e., the opportunity loss of selling surplus PV and unnecessary electricity purchase, our proposed method adopts a following control scheme, which monitors the residential electricity consumption and PV curtailment and controls charge-discharge amount following to these values, after the planning. We carried out numerical simulations using a DS model and evaluated the effectiveness of our proposed EV charge-discharge framework from the viewpoint of the residential operation cost and the amount of PV curtailment.

II. PREVIOUS WORKS

A. SMART ENERGY

Asmart energy system is a cost efficient system which utilizes green renewable resources. It is a system in which energy production, storage, distribution, transmission and consumption are integrated intelligently.

Closely related to the continuously increasing energy consumption trend; environmental, economic and sustainability challenges are present all over the world. Fossil energies are becoming more expensive as they approach to the end of their possible exploitation, and the pollution caused by fossil-based energy are becoming less and less acceptable by the society and unbearable for the ecosystem.

Energy efficiency and sustainability can only be improved via facilitating and increasing usage of distributed and renewable energy generation (e.g. solar, wind, geothermal, biomass) near or at the consumption sites, in order to avoid energy losses from long-distance energy transmission, conversion and distribution.

Information and Communication Technology (ICT) based solutions will play an important role for collecting the data, controlling, monitoring and coordinating energy networks, which can be characterized by low-carbon generation, storage, efficient distribution/transmission system, and optimized consumption. However, it should be kept in mind that since the decentralized small-scale renewable energy resources, such as solar and wind power have uncontrollable natures, it is of utmost importance to use the storage technology in order to balance supply and demand.

ICT and automation market players will undertake a major role for enabling and supporting the new smart energy value chain via provisioning of digital services, ICT and automation infrastructure, enabling the smart energy infrastructure for the energy market players. At the same time, digital service providers will guide the energy market players to stimulate the cost efficient streamline to their business processes and to expand their business with new services for consumers. New services will also enable consumers to play roles that are more active in energy consumption.The existing “energy value chain” is designed in a unilateral way and based on a hierarchical system from top to down, in other words, from producer to consumer. It was not constructed in for a bi-directional traffic. In order to fulfill the rapidly changing society needs, current energy market needs to be more democratic by all means.

B. SMART GRID

Smart grid upgrades today’s inefficient and centralized power grids into smart and quick responsive electricity networks that offers new technological services for the energy industry. Smart Grid has some tempting key features for all the players in the market.

Decentralization of Power Generation (DPG) supports end node participation, not only for the consumption side but also for the generation. Energy is produced close to the place where it will be used. By this way, small size local generators are prefered rather than the national large size power plants. This will also help to reach the low carbon emissions that are set by the EU, and is going to reduce the transmission losses too.

Demand Response (DR) is another important aspect of the smart grid. DR manages consumption of electricity in response to supply conditions, such as having customers reduce their consumption at critical times or in response to market prices. It is also related with load shifting that deals with unstability of demand. Total demand can vary from time to time. Smart grid can

convince customers to temporarily reduce their consumption during peak demand periods to match balance between total supply and demand in the power grid.

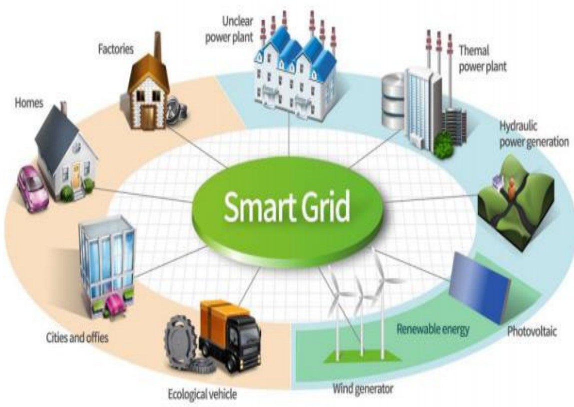

Fig. 1.1 Smart Grid

Smart Meter (SM) provides customers to learn their real time energy usage and cost information. Before the smart meter application, it was very hard to determine which activities were high energy consumption activities. By using smart phone, tablet or any smart device applications, customers can track their energy consumption and with their available historic data they will be able to carry out numerous analysis.

The advantages of the Smart Grid are; more efficient operations that reduces management costs, reduction at energy prices from the consumer’s side, allowing consumers to play a pro-active role in the operating system, efficiency and transparency at electricity transmission or distribution, repairing itself, ensuring power quality and harmonics, smart metering and feedback, reducing peak demand, better integration of all factors, better integration of large scale renewable energy systems (RES), better integration of residential power generations and better security.

C. DEMAND RESPONSE

Demand Response (DR) programs provide effective means of control to customers within the Smart Grids (SG). Customers have an opportunity to monitor, reduce, or shift the associated consumption to achieve the minimum consumption payment. Public tariff/tax regulations and DR programs indirectly lead to Peak-to-Average Ratio (PAR) decline, which is a key indicator reflecting efficiency of the entire generation, transmission, and distribution hierarchy. While the public enterprises manage demand and supply in a more coordinated and efficient way, the customers benefit from the financial incentives of the program. There are two types of DR programs.

Price based DR programs, dynamically change electricity prices (selling or buying) to effect the customer energy consumption behaviour. Block price is a type of program in which block period is determined and fixed. Critical peak pricing is a pricing policy applied on critical peak periods. Variable peak pricing is based on “time of use” and “real time pricing”, which is the commonly used program where pricing vary by hourly basis. Real market conditions determine the prices of energy.

In Incentive based DR programs, grid operators give customers financial incentives or rewards. Direct load control is a program where power companies or smart grid operators can run or shut down customer’s devices, such as air conditioners or water heaters during periods of peak demand in exchange for lower electricity bills. Interruptible service is another program where a firm contract between customer and grid operators can be designed in order to achieve the incentives. For example, a penalty system may be put into operation if the required energy consuption cannot be reached. In the emergency price program, during emergency situations, customers accept to lower their energy consumption in order to take the incentives.

D. MICRO GRID

Microgrid is a localized group of electricity sources and loads that normally operates connected to and synchronous with the traditional centralized electrical grid (macrogrid), but can also disconnect to "island mode" and function autonomously as physical and/or economic conditions dictate.
The main aim is to supply autonomous, reliable, continous, high quality and secure energy for all communities; commercial, industrial, and rural customers. Like the normal (macro) power grid, it has a generation unit, a distribution system, a thermal storage, voltage and frequency regulation, storage, smart meter and distributed controllable loads. It integrates with distributed energy resources (DER), mainly renewable energy resources, solar and wind power, combined heat and power (CHP) generator, hydro and geothermal systems.

Microgrid allow customers to make decisions about consumption, time and quantity adjustment. Demand response programs are based on the agreements between the microgrid operator and load owner, household or the factory owner.

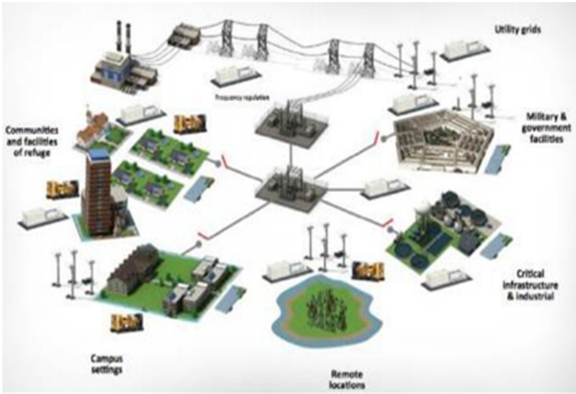

Fig. 1.2 Micro Grid

There are many cases, mostly in developed and developing countries where microgrids are designed and used at university campuses, industrial parks, military bases, residential areas and farms (Fig. 1.2). Each entity has its own peculiarities such as the military based microgrid needs more cyber security whereas the green farm microgrid uses more solar panel or residential microgrid uses more CHP based energy solutions including both electricity and thermal energy delivery.

E. 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 Artifical 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.

F. 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 enviromental perspective; decreasing gas emission per person is an important achievement when combined with decreasing energy consumption, using clean renewable energy resources and electrical vehicles. HEMS is also accessible through home inside panel, home computer, tablet or smartphones. It increases the energy effectiveness of smart house and has various advantages.

It minimizes energy consumption, electricity bill and maximize customer's comfort. It shows and predicts electricity usage considering the price of the energy bought from the electricity grid, the amount that the customer sells to grid in real time, the amount of energy generation from renewable energy resources, the devices that are on/off, the amount of energy each device uses etc. In addition, it views and tracks the 'flow of energy' from generation to consumption phases, home energy costs and revenues. It provides energy saving tips giving insights to the customer. Using optimization models, it schedules devices and storages, gives reliable advice to home users to change their consumption behaviour, may even give tips to improve it. HEMS optimization model focuses on inside of a smart house (see Figure 1.4); namely, smart home devices, such as the dishwasher, washing machine, lighting system, garden irrigatiton system plus the storage, electrical vehicles, renewable energy resources, solar panels/wind turbines, heaters and the air conditioners.

HEMS needs to model some characteristics of these house items in order to arrange a balance between the energy usage and the household's comfortable lifestyle. While carrying out such a task, some questions must be kept in mind with concrete answers: "How much energy is consumed for operating this device? How often does the household use these devices? What are the minimum and maximum energy levels for the energy storages available in home? How much energy will be produced in solar panels if the next day would be sunny? Can the arrival and departure times of the household's electrical cars determined/controlled daily? etc."

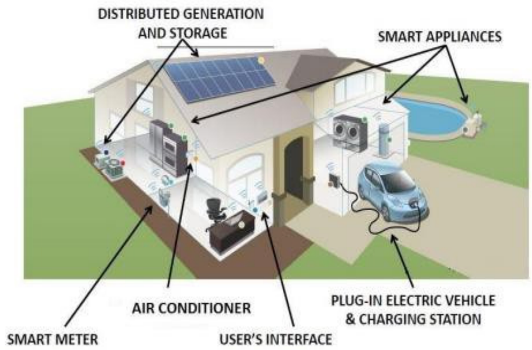

Fig. 1.3 Home Energy Management System

HEMS technology is not only developing rapidly and steadily in terms of technology but also gaining popularity towards large mass of people. While for the consumers, HEMS means extra savings and tranquility; for the energy institutions, device manufacturers and connected home platform providers, HEMS means extra growth and possible market opportunities.

G. 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 CO_2 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 the market 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.

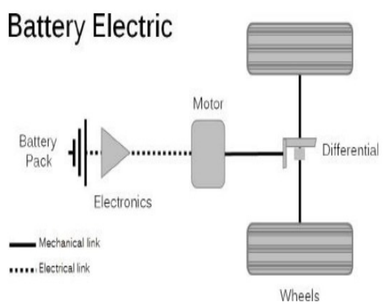

Fig. 1.4 Electric vehicle architecture

III. BASIC ENCODING IDEA

The encoding ability of a VCS with regard to a secret image R could be specified by a set of two n × m binary basis matrices B0 and B1 for white and black pixels, respectively, in R. The basis matrices should meet two requirements:

a) *contrast condition*: the number of black sub pixels in the “or” result of any group of k rows in $B1$ is more than that of the same rows in $B0$.
b) *security condition*: that of pair any group of less than k rows in $B1$ is equal to that of the same rows in $B0$.

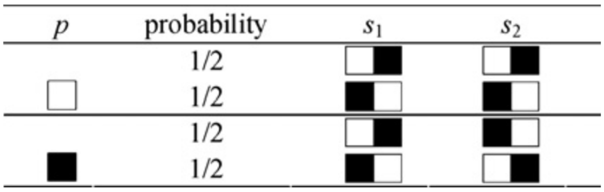

Figure.4. Basic scheme of visual cryptography

In the above basic VC scheme each pixel 'p' of the secret image is encrypted into a pair of sub pixels in each of the two shares. If 'p' is white, one of the twocolumns under the white pixel in Fig. 1.4 is selected. If p is black, one of the twocolumns under the black pixel is selected. In each case, the selection is performed randomly such that each column has 50% probability to be chosen.

Then, the first two pairs of sub pixels in the selected column are assigned to share 1 and share 2, respectively. Since, in each share, p is encrypted into a black–white or white–black, if 'p' is white it always outputs one black and one white sub pixel, irrespective of which column of the sub pixel pairs is chosen during encryption. If 'p' is black, it outputs two black sub pixels. In this paper,we re-define n-RIVCS in a more flexible way and design a general construction using linear programming to obtain efficient basis matrices with a less pixel expansion.

IV. PROBLEM SPECIFICATIONS AND PROPERTIES

A. 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 about5MW 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.

B. 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.

C. PV ENERGY SYSTEMS FOR PORTABLE APPLICATIONS

This energy generation system consists mostly of capacities below
100W. They have a huge range of applications ranging from powering calculators, educational toys, solar lamps, traffic signals, mobile chargers, etc. They are usually made up of poly crystalline material of solar cells due to their higher energy density over a small area and fits in the portable applications. However, this system is not highly commercialized due to battery technology required to store the power generated and high cost of poly crystalline silicon solar cells. They generally use lithium ion batteries to store energy due to its high energy capacity and light in weight. These systems come handy when power is required on move and has a potential to revolutionise the current era of electronics with free power on move.

The simple mobile charger based on PV energy system consists of a small solar module generally made of poly crystalline silicon, connected to the electrical load through a buck/boost converter for regulation of voltage at the load end. This regulation is usually done using a feedback loop that senses the output voltage and tries to keep it at the desired output voltage required.

V. FUTURE SCOPE

Investigation of the effects of our proposed framework considering the movement of the EV in the expanded large-scale DS model is remained on a future work. With regard to the EV driving schedule, here assumed that the EV owner added the driving schedule to the HEMS. With regard to the EV driving schedule, we assumed that the EV owner added the driving schedule to the HEMS.

The HEMS should conduct the operation considering the effect on the forecast error in the future work. In the GEMS, focused on an OLTC, but the proposed coordination framework could be similarly implemented in the HEMS and GEMS using other voltage regulators such as capacitor banks and step voltage regulators.

VI. CONCLUSION

Thus, proposed a coordinated EV charge-discharge management framework. The coordination is based on the information exchange between the HEMS and GEMS. The proposed framework determines a daily EV charge-discharge plan on the basis of the exchanged information and day- ahead forecasted power profiles to ensure the adequate free capacity for charging the curtailed PV during the daytime and the charged capacity for the scheduled EV drive. Here also proposed a following control scheme. The scheme controls the EV charge-discharge amount following to the real-time monitored data for mitigation of the deficiency and excess of charge- discharge amount caused by the forecast errors. The effectiveness of the proposed framework was evaluated using a DS simulation model from the viewpoint of the residential operation cost and the amount of PV curtailment. The simulation results implied that the proposed framework achieves to reduce the residential operation cost and the PV curtailment by the information exchange and the following control.

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