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Smart EV Station Aiding Better Demand Side Management

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ABSTRACT: Demand side management and the usage of distributed energy resources are the efficient methods to solve the problem of meeting peak demand which is about 12% in our nation [14]. The number of EVs is expected to grow rapidly in the coming years. However, uncoordinated charging of these vehicles can put a severe stress on the power grid. As a paradigm of the incoming smart grid, vehicle-to-grid (V2G) has been proposed as a promising solution to increase the adoption rate of EVs. The problem of charge scheduling of EVs is an important and challenging problem and has seen significant research activity in the last few years. The existing system consists of ISO, aggregator as a common server to communicate the entire EV station networks. This project tries to eliminate the need of such ISO, aggregator etc. resulting better lifespan of battery by implementing an off-board charging/discharging methodology. The project is physically realised and executed successfully.

KEYWORDS: Electric Vehicle, Vehicle-to-Grid, Grid-to-Vehicle, Demand Side Management, ISO, Aggregator

I.INTRODUCTION

Electric Vehicles (EVs) have received considerable attention in recent times as an eco-friendly and cost effective alternative over conventional vehicles driven by internal combustion engines (ICEs). With the recent concerns about global warming and petroleum-based energy shortages, the number of hybrid electric vehicles (HEVs) and fully electrical vehicles (EVs) is expected to rapidly increase in the coming years. They have lower operating costs with respect to ICE vehicles and can be also charged with locally produced renewable energy sources [1]. However, there exist several challenges to large-scale adoption of EVs. Although their operating costs are less, EVs are still more expensive to buy than ICE vehicles. In addition, access to charging stations is limited, and large capital investment is required for developing a public charging infrastructure [1]. Also EVs consume comparatively high power from the grid during charging. Therefore, uncoordinated charging of a large number of EVs can have an adverse impact on the grid operation [2]. It has been estimated that the total charging load of the EVs in the U.S. can reach 18% of the U.S. summer peak at the EV penetration level of 30% [3]. Furthermore, the EVs may increase the load uncertainties, power outages, unacceptable voltage fluctuations, overload the distribution circuits elements [5], lead to voltage regulation violations [7], and pose potential security threats to both private and public user data [6]. Vehicle-to-Grid is proposed as a solution to cope up with the peak demand problem, i.e. allowing EVs with a minimum sufficient charge to feed power back to grid. The charging stations seen in roadsides, car parking areas are now equipped with the provision of feeding power back to grid. But the existing system uses ISO, aggregator and several communication networks for the whole process [15].

In this paper, we are proposing the idea of self-adaptive control algorithm for the efficient grid interaction by eliminating the need of ISO, aggregator and complicated control over the V2G & G2V process thus facilitating several advantages over EV battery, control easiness, and rather a cost effective solution.

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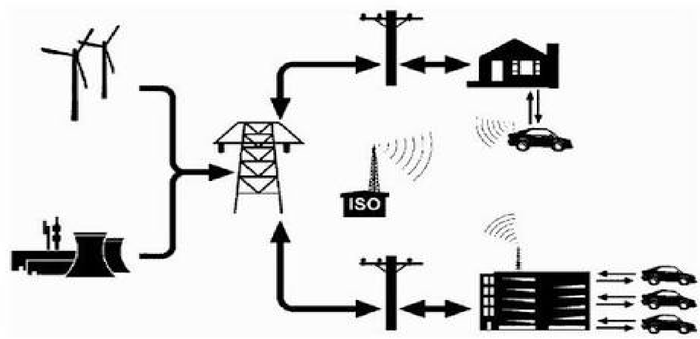
II.SYSTEM CONFIGURATION

EVs are plugged into a charging station to charge or discharge their batteries through charger outlets. Note that an EV can act as a load to the distribution grid (charging), a mobile energy storage (ES) device, and a supplier of electricity to the grid (discharging). Unlike other conventional generating units, vehicle batteries do not have any start-up cost or shutdown cost [7] while discharging power to the grid [4]. Due to lower load, night hours are generally preferred for charging EV batteries (valley filling). The driving profile of an EV is such that it typically travels for 2–3 h a day on an average and is parked for the rest of the time. EVs can be charged overnight at home using AC Level 1(typically 120 V) or AC Level 2 (typically 240 V) charging equipment. Typically, AC Level 1 and AC Level 2 charging can add around 2–5 and 10–20 mi of range per hour of charging time, respectively [4]. EV charging schedule can be coordinated with the operation of other electrical home appliances using a home area network. Although the majority of EVs are expected to be charged at home, conveniently located public charging stations can complement this to increase the daily useful range of EVs [8].

Wireless power transfer techniques have been commercially introduced as a convenient alternative to charging conductively. An example of such a technology is an inductive power transfer (IPT) system [9], [10], which consists of a transmitter coil and a receiver coil that form a system of magnetically coupled inductors. An alternating current in the transmitter coil generates a magnetic field, which induces a voltage in the receiver coil, which is used to charge an EV battery. It operates at power level compatible to AC Level 2. No cables are needed, and charging can start automatically whenever the EV is parked over the system, even for a few minutes. Other techniques for wireless power transfer that have been explored include capacitive power transfer [11], low-frequency permanent-magnet coupling power transfer [4], resonant IPT [4], online power transfer system [4], and resonant antenna power transfer [4].
Illustration of the existing system is as shown below.

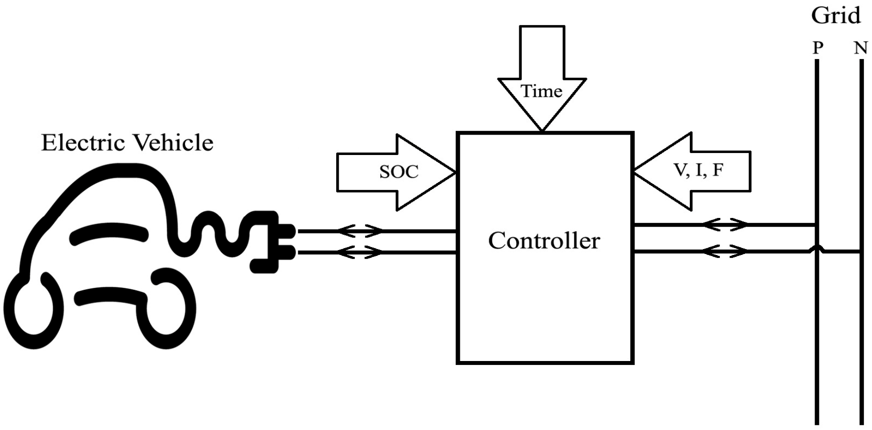


An electric power system is primarily composed of three operational sectors: generation, transmission, and distribution. The generation phase is connected to the transmission phase, which carries electricity to the distribution phase through different substations and transmission lines. The distribution phase dispatches the electricity to the end users through distribution feeders and transformers. An independent system operator (ISO) coordinates, controls, and monitors the operation of the transmission phase.

Majority of the EVs are expected to be connected to the Internet through Wi-Fi, cellular network, or ZigBee communication network [12]. The Internet-enabled communication enables EVs to be clubbed into different groups of varying sizes by aggregators so that each group can be treated as a dispatchable load to the grid. The actual charging decision of each group of EVs is either centrally controlled by the aggregator, or EVs may collaborate with the aggregator in a decentralized manner to decide their charging schedule. When a driver plugs the vehicle into a charging point at a parking spot, a sign-on session is initiated by the aggregator. The vehicle communicates several charging parameters such as location, maximum battery capacity, current state of charge (SOC), desired SOC, maximum and minimum recharge power drawn, and deadline information within which the battery must be charged up to the desired SOC through a secured channel to the aggregator [12]. The aggregator, based on several grid constraints, user constraints, and mobility parameters, determines and communicates the charge schedule to the individual EV to avoid grid overload and balance supply/demand potential of the grid [13]. In centralized charging control, the optimization of

EV charge scheduling is done centrally at the aggregator after collecting information about power requirement of the EVs. The EVs can only communicate their electrical parameters such as maximum battery capacity, SOC, and charge rate to the aggregator. Based on the aggregated power requirement, each aggregator makes a contract with the ISO. On receiving the contracts from different aggregators, an energy management system at the ISO decides the appropriate power share for each aggregator within their contracted boundary considering the other loads, power generation capacity from different generators, and grid constraints. Then, each aggregator executes an optimization routine to schedule the EV charging in such a way that the EVs anticipated energy requirements are met. In contrast, in decentralized charging control, each EV is equipped with some computing capability and the decision to charge or not is taken by each EV in collaboration with the aggregator. Each EV communicates their energy requirements to the aggregator and uses part of this information collected at the aggregator to decide on an optimal schedule [4]. This system operates/controls the integration of more than one no. of vehicles at a time. So there is chance of taking imprecise decisions whether EV is to be charged or discharged. When these conditions are likely to be occur continuously it will lead to the degradation of the EV battery which is the most expensive part of the EV. In addition, management of data of each grid and vehicle is much more difficult, developing a common efficient public infrastructure costs very high, absence of EV owner friendly environment which includes setting the discharge rate, provision for emergency charging, getting incentives for discharging etc. are very considerable difficulties occurred in the existing system.

The proposed system focuses on the modified version of the off-board charging technique used. This system is placed on each station in a bay i.e. it operates for a single EV at a time.



It consists of mainly a self-controlled controller and other electrical & electronic circuits to perform charging and discharging operation. Self-controlling of the controller is purely based on certain parameters like Grid Voltage, Current, Frequency, State Of Charge of Battery and time. Since the aim of the paper is to facilitate DSM, time is set as the main base of the controller operation.

The proposed system generates pulses for the switching of charging and discharging modes. Switching is determined by the parameters taking as the input to the system. Whenever an EV plugged in to the grid through the proposed system, EV only gets charged if the conditions, feasibility of grid voltage, off-peak time, and SOC below100% are satisfied. If the grid voltage is not sufficient during peak time but have an SOC of above 70%, control system switches to discharge mode automatically. The system never allows EVs to discharge at off-peak time even grid voltage is low and never allows EVs to get charged during peak time even grid voltage is feasible. In case of emergency conditions, the owner can press the emergency switch which will allow EVs to get charged irrespective of time and grid conditions. Allotting of DC fast charging circuit during emergency charging is also possible.

III.HARDWARE DESIGN

The hardware design of the proposed system is completed and executed successfully. Hardware consists of mainly a self-adaptive controller and electrical/electronic circuits.

Since the working of the system is a real time process and considering the cost effectiveness, Arduino Microcontroller is taken as the controller board of the system. It is programmed in MATLAB to generate pulses for the mode switching.

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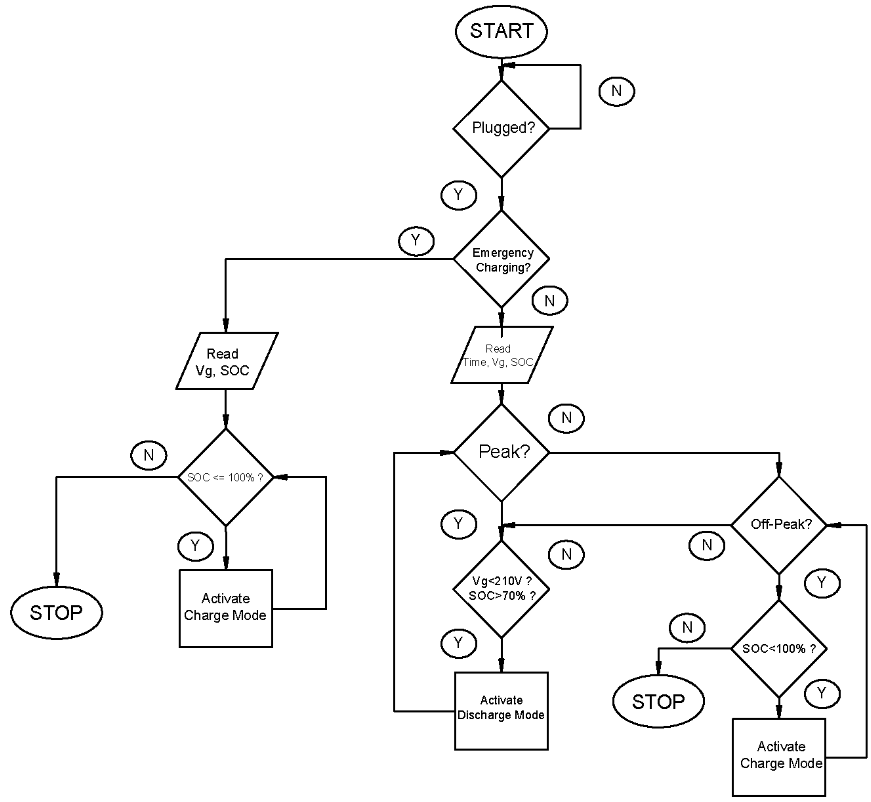
The program facilitates the controller to be self-working; only the owner needs to plug-in the EV to grid through the system. The charging and discharging mode is switched automatically within the system. The microcontroller is synchronised with a RTC module to have the real time computing action. The working flowchart of the proposed system is as shown below.



The flowchart is as explained as follows.

Charging Mode: EVs only get charged during off-peak time except in case of emergency charging i.e. time other than evening 6 to 10 pm. If any of the condition fails alone, system will switches neither charging nor discharging. During charging, the AC grid voltage is stepped down and by using buck converter optimal voltage for charging is attained, which is then rectified to DC voltage and given to EV via cable.

Discharging Mode: EVs are allowed to feed power back to grid when the grid voltage is sufficiently low during peak time and having a battery SOC of at least 70%. Only a defined amount of power is taken from the EV. Like above, if any of the condition fails alone, system will switches neither charging nor discharging. During discharging, the DC voltage is inverted to give AC voltage which is then boosted and stepped up to feed power back. Here, we have considered a micro grid like house as the load. When the discharging is switched, relays will automatically cuts the supply voltage of the load and supplies EV power to the grid.

Emergency Mode: When the user meets with an emergency condition, the switch given is pressed will switches to emergency charging condition. EVs will be charged irrespective of the grid conditions. Fast charging circuit can also be allotted for this.

IV.RESULT

The proposed system is physically realised and executed successfully with MATLAB as its main control platform. The proposed system considers a micro-grid like home as the load for the EV to feed power back. A normal UPS battery was considered as the EV battery. Only the user needs to plug-in the EV cable to the system. The smart EV station worked automatically according to the predefined conditions. The parameter process was seemed successful. Grid integration and bidirectional power flow were also verified to be successful. Algorithm made the EV self-sufficient in

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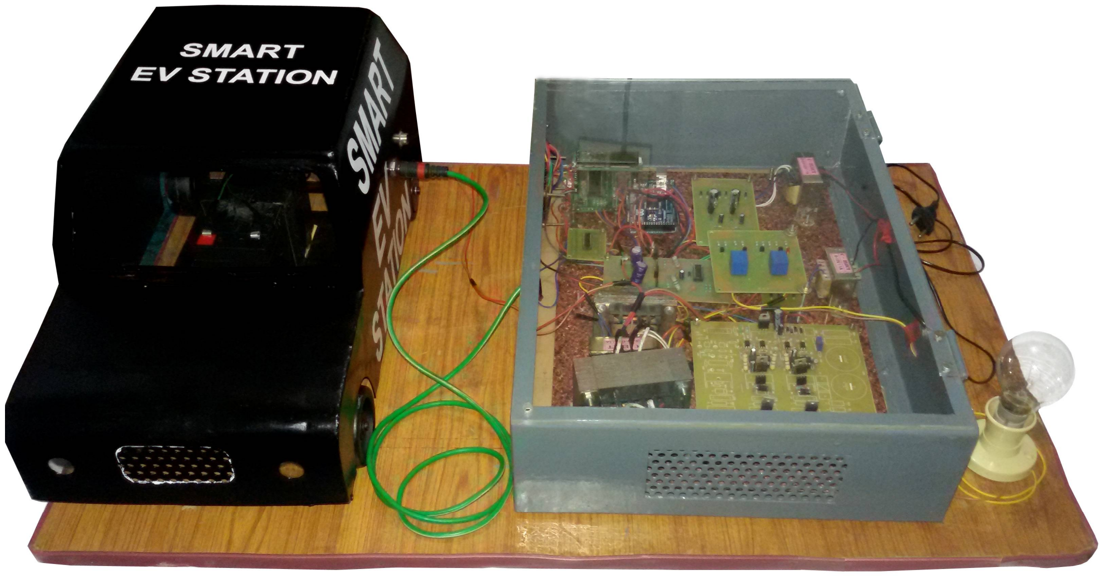
the mode selection and operation and there by facilitated Demand Side Management (DSM), peak shaving and valley filling. User friendly nature of the system is also verified.



V. CONCLUSION

The present day world is now waiting for the mass arrival of the EVs. So a study and implementation of the efficient EV station is inevitable. In this paper, we have attempted to review the existing works on charge scheduling of EVs and its problems, an area that has seen tremendous research activity in the last few years. The existing system is closely observed and several conclusions were made regarding its technical problems. The solution for those problems has found out and physically realised. By the successful realisation of the proposed system, it is hopeful for the world-wide implementation.

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