PREFACE

As non-renewable energy sources are becoming exhausted hastily, there has been a notable surge in the power-sharing of non-conventional energy resources. Furthermore, an increasing number of electrical appliances such as electric automobiles, induction cookers, and heat pumps operated by supply through renewable energy sources are being utilized to replace conventional equipments such as IC engine automobiles, LPG based cookers that requires non-renewable energy sources based fuels. However, in terms of system reliability, the present power system infrastructure cannot withstand a greater penetration of Renewable Energy Sources (RES) such as Electric Vehicles (EVs). The increased usage of renewable energy resources strains the power infrastructure due to new induced demand peaks. The present grid infrastructure will not be able to withstand these developments, and as a consequence, asset deterioration, increased transportation losses, and outages are predicted to occur. The most accessible approach for the distributed system operator, also known as the distribution network's operations manager, is grid expansion. However, it is a costly process, and there are additional viable techniques to minimize grid load peaks, e.g. by adopting alternative charging strategies for EVs.

Uncontrolled charging is the conventional charging approach for EVs. When using unregulated charging, the vehicle's charging begins immediately after connecting to the charging pole. Nevertheless, the intelligent charging strategy can delay the charging moment to a more appropriate time instant in the presence of Time of Use (TOU) electricity rates. Furthermore, the bi-directional power flow capabilities of EV chargers allow the car battery to discharge electricity into the power grid. This research aims to develop an intelligent charging technique that simultaneously offers techno-economic benefits to the system operator and EV owners.

The developed centralized smart charging strategy is based on the Linear Programming (LP) approach. The formulated objective functions in this work consider charging cost minimization and the combination of charging cost and battery degradation cost minimization, under a set of operating constraints. The charging of Plug-in Electric Vehicles (PEVs) in the existing distribution system with both Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) capabilities with the possibility of network re-configuration is also explored. This work has also attempted to study distribution system performance under PEV charging carried out in a re-configured network with Conservation Voltage Reduction (CVR) deployment. The EV owner benefits by shifting the EV charging to off-peak load hours and discharging into the grid during peak load hours are obtained under the TOU-based tariff structure.

In the second part of the work, a framework is developed to provide an optimal charging schedule that minimizes the overall charging cost of the PEVs as well as voltage variability in the network while taking electricity price fluctuations into account. The proposed scheme considers the simultaneous minimization of charging costs of all the EVs along with the deviation of bus voltages from the desired values. The problem is formulated wherein the instantaneous load and electricity tariff is known in advance. The optimization technique provides a re-distribution of the PEV charging load while fulfilling the whole set of constraints. A real-time simulation and validation of the proposed approach are carried out on a Real-Time Digital Simulator (RTDS) and Real-Time Automation Controller (RTAC) platform to reaffirm the efficacy and feasibility in a real-time environment. The RTDS comprising a NovaCor with four licensed cores, a GTNETx2 card and RSCAD FX 1.2 software is used in this work. The simulation is carried out in distribution mode with a simulation time step of 150.0μs. The system variable signals, node voltages, EVs arrival and indicated departure time, initial and desired SOC, and nominal charging and discharging rates are sent by the Transmission Control Protocol (TCP) server (RTDS) and EVs charging schedule is prepared by the client (MATLAB) and dispatched to the server through Socket protocol (SKT). The RTAC is utilized to monitor and check the voltage and frequency limits of the charging stations. The communication between RTDS and RTAC is established using Distributed Network Protocol 3 (DNP3) protocol in GTNETx2 card of RTDS, while trip signals in case of any violations are issued from RTAC using IEC-61850, Generic Object Oriented System-Wide Events (GOOSE) messaging.

The third part of the work is focused on the grid frequency regulation based on EV battery State of Charge (SOC) and frequency deviation. An EV fleet utilized in this work is characterized into various classes depending upon the driving patterns of the EV owners. A number of cases are simulated, causing disturbances in the system in the presence of the proposed controller. Based on the proposed EV model control, aggregated EV charging power is obtained for frequency correction. The proposed controller mitigates the frequency deviations and power interchange in the tie-line between interconnected systems. A Transient Frequency Deviation Index (TFDI) is used to estimate the severity of the contingency.

The last part of the work is focused on the operational aspects of the EVs, wherein the vehicles operating in G2V mode are considered as inverter-based Distributed Generators (DGs). As per the anti-islanding requirements prescribed by IEEE Std. 1547-2018 and UL-1741 Std., in case of separation of the microgrid from the main grid, the islanding event must be detected, and DG must be tripped within 2s. In this context, an improved hybrid Islanding Detection Scheme (IDS) is proposed in this part of the work.

The hybrid scheme uses Modified-Sandia Frequency Shift (M-SFS) as the active and Fast Rate of Change of Frequency (FROCOF) as the passive method. The FROCOF relay activates the M-SFS in case islanding is suspected, and then, M-SFS ascertains the islanding event.