Arkansas Tech University

Department of Electrical Engineering

Final Report

Faculty Professional Development Grant

Prepared by:

Reza Hamidi

Assistant Professor of EE

September 5th, 2019

A. Summary

This final report presents the results of a Professional Development Grant to fund submission, travel, lodging, and meals during a trip to the 2019 IEEE Power and Energy Society-General Meeting (2019 IEEE PES-GM) in July 2019 in Atlanta, Georgia. The conference was organized by the Institute of Electrical and Electronics Engineers (IEEE).

B. Restatement of the Research Problem

In this research, I developed the theory of multi-agent controls for charging management of electrical vehicles. In this research, a distributed control system was developed in that there is no control center and the electric vehicles only communicate with their neighbors to find out the best charging rate at any given time. This method reduces the establishment costs of a control system, while it provides extensive scalability and resiliency for the electric network.

The mathematical framework for the controller was developed and utilizing Matlab/Simulink tested on a fleet of electric vehicles that randomly integrate and disintegrate to the power system. The results confirmed the applicability of the idea and showed its superiority to the conventional central control systems.

C. Brief Review of the Professional Enhancement Opportunity

The IEEE PES-GM is the largest gathering of power and energy scientists and related industries to present their latest research and development (https://pes-gm.org/2019/). Through the financial support provided by this grant, I had the opportunity to present my latest research, exchange ideas with other peers, and also develop relationships with several researchers in the area of power systems. The PDG let me travel to the conference location, present my accepted research paper (which was mandatory) as well as judging the student poster competition at the conference location.

D. Summary of Findings and Outcomes

The presentation of my research resulted in several discussions with other researchers and developed potential collaborative research with EE faculties at the other universities such as Louisiana State University, Tennessee Chattanooga, University of Nevada-Reno, Washington State University at Pullman, and Western Norway University of Applied Sciences. This increases the probability that I submit successful grants. In addition, ATU was introduced to the audience.

E. Conclusion and Recommendations

Overall, the funds from my ATU professional development grant allowed me to attend the largest gathering in the area of electrical engineering. It made me able to make connections with peers and introduce ATU to a worldwide audience. I received instructive feedbacks on my research that will help my research toward new goals.

Decentralized Control Framework for Mitigation of the Power-Flow Fluctuations at the Integration Point of Smart Grids

R. Jalilzadeh Hamidi, *Member, IEEE*, and R. H. kiany, *Graduate Student, Member*

***Abstract*—In this paper, a decentralized control framework for reducing power-flow fluctuations at the integration point of DC smart microgrids (SMGs) is proposed. The output powers of non-dispatchable renewable energy resources are unpredictable and vary time to time. In this work, plug-in electric vehicles (PEVs) are employed as distributed energy storage systems (DESSs) in order to minimize the power-flow fluctuations at the integration point. In this regards, the proposed control system increases the charging rates of PEVs in excess power generation and reduces the charging rates in power shortage.**

The simulations are performed using Matlab/Simulink. According to the simulation results, the proposed method is able to lessen the fluctuations. It also reduces the dependency of SMGs on the main grid and improves the overall power quality in the main power systems as it minimizes the integration point power-flow fluctuations.

***Index Terms*—**Contingency, cooperative control, electric vehicle, DC grid.

I. INTRODUCTION

PV and wind generation technologies have become mature, and they are widely in use for partially or completely supplying smart microgrids (SMGs). PV- and wind-based generation are favorable as they are more cost-effective in comparison to non-renewable-based DGs. However, the output of these variable renewable energies (VREs) are inherently unpredictable. Therefore, the penetration of these non-dispatchable renewable energy resources (RESs) are limited due to the fluctuations in their output power. The SMGs, which are supplied by only VREs are unreliable [1] and the integration of large shares of VREs results in power system instability due to the fluctuating output of VREs.

Energy storage systems (ESSs) are able to make the SMGs reliable against the mentioned issues with VERs. ESSs store the excessive generation in over-generation periods, and supply the loads during under-generation conditions. Thus, they are able to secure the demand-response in SMGs. However, ESSs are expensive, and it seems that electric utility owners are reluctant to install capable ESSs [2].

Various types of storage systems can be used with different energy densities, costs, charge/discharge power rates, such as ultra-capacitors, battery banks, superconducting magnetic energy storage, and plug-in electric vehicles [3]-[7]. Distributed ESSs (e.g., electric vehicles) compared to central ESSs are more efficient in retaining the power system stable, and at the same time, they are available at a lower cost. The application of ESSs in the reduction of power fluctuations is addressed in [8], however, in that a central controller governs the wind farms and the ESS. In [9], a central controller governs the charging and discharging rates of the batteries in DC smart-houses to reduce the interconnection power-flow fluctuations.

Decentral control systems require minimal communications, and also they are cost-effective in contrast to the central control systems [10] and [11]. The cooperative control method provides large scalability and plug-and-play-ability for the system. It is also capable of managing intermittent communications. Hence, researchers have recognized the decentral controllers suitable for SMGs.

Coordination of ESSs utilizing the cooperative control to reduce power losses as well as maintaining the supply-demand balance is addressed in [12]. A decentralized control framework for balancing the state-of-charge (SOC) of PEVs in DC micro-grids is proposed in [13] and [14].

The practical design and efficiency of bidirectional PEV chargers are described and measured in [15] and [16], respectively. Also, [11] discusses the advances and applications of bidirectional chargers. Therefore, controllable bidirectional chargers are state-of-the-art technologies and they are practically available especially for prototype experiments. The advantages of DC smart grids are elaborated in [17] and [18], and it is concluded that DC smart grids will be superior to AC grids for smart grids with renewable generation to a large extent.

The previous work of the authors presented in [6] is considerably enhanced in this paper. In this regards, a decentralized cooperative control-based controller is proposed to adjust the charging/discharging rates of PEVs for reducing the power-flow fluctuations at the integration point of DC SMGs. The proposed method also lessens the dependency of DC SMGs on the main grid and improves the main grid power quality as it mitigates the power-flow variations at the integration point.

The remaining of this paper is organized as follows: the objectives of the proposed control system and its design are presented in Section II. The test study and simulation

Reza Jalilzadeh Hamidi and Rahman Heidarykiany are with the electrical engineering Department of Arkansas Tech University (emails: reza.j.hamidi@gmail.com and rahman.heidary.kiany@gmail.com).