ERCIM "ALAIN BENSOUSSAN"
FELLOWSHIP PROGRAMME

Scientific Report

First name / Family name	Sanchari Deb
Nationality	Indian
Name of the *Host Organisation*	VTT Technical Research Centre
First Name / family name of the *Scientific Coordinator*	Mikko Pihlatie
Period of the fellowship	01/09/2020 to 31/08/2021

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

During the ERCIM fellowship, my research at VTT Technical Research Centre, my research mainly focussed on different aspects of charging infrastructure such as planning models for charger placement, charging hotspots computation, machine learning for charging infrastructure planning, charging demand prediction, smart charging etc. The following research activities were conducted:

1. Charging hotspots computation for Helsinki, Finland- Large scale endorsement and adoption of Electric Vehicles (EVs) call for availability of sustainable charging infrastructure. Planning of charging infrastructure to meet the charging needs require identifying the charging hotspots where charging demand will be always relatively high. Also, identifying the charging hotspots in advance will enable distribution network operators to decide whether grid reinforcement is required to support the charging demand. A novel methodology for identifying the charging hotspots for the city of Helsinki was proposed. Home charging scenario as well as charging at workplace, home and shopping centres were considered in this analysis.
2. Review of machine learning for charging infrastructure planning- The ever-growing energy demand and environmental pollution has initiated a paradigm shift towards

Electric Vehicles (EVs) from conventional vehicles. Public acceptance of EVs and large-scale deployment of EVs call for availability of charging infrastructure. Charging infrastructure planning is an intricate process involving various activities such as charging station placement, charging demand prediction, charging scheduling etc. This planning process involves interaction of power distribution as well as road network. The advent of machine learning has made data driven approaches a viable means for solving charging infrastructure planning problem. Consequently, researchers have started using machine learning techniques for solving problems associated with charging infrastructure planning such as charging station placement, charging demand prediction, charging scheduling etc. A comprehensive review of machine learning applications for solving charging infrastructure planning was provided. Further, case studies on charging station placement, and charging demand prediction were reported.

3. Charging demand prediction of e buses of Helsinki by machine learning based approach- Global warming, crisis of energy, and degraded air quality index have compelled electrification of the transport sector. Public Electric Buses (e bus) are the first candidates for electrification as majority of public transport is dependent on them. Electrification of the public e buses will increase the load demand of the power grid thereby creating technological and commercial challenges. The stability and resilience of the power grid may be affected if the charging activities are performed in an uncoordinated manner. Thus, charging load prediction of the e buses is a crucial issue for maintaining smooth and hassle-free operation of the power system. A novel Support Vector Machine (SVM) based and Random Forest based model was proposed for charging demand prediction. The model was validated for predicting the charging demand of e buses for the city of Helsinki, Finland. Simulation results established the efficacy of the proposed approach. Further, a sensitivity analysis was also performed to validate the robustness and efficiency of the proposed approach.
4. Charging demand prediction for private Electric Vehicles- The concern regarding global warming, climate change, fossil fuel depletion has forced mankind to switch to alternate modes of transportation such as Electric Vehicles (EVs). EV chargers increase the load of the power grid that may have severe consequences such as voltage instability, power losses, harmonics, as well as degradation of reliability indices. Thus, the management of the charging load is a critical issue for smooth operation of the power grid. Charging load management calls for accurate prediction of the charging demand. A novel approach based on Bayesian Network (BN) Random Forest (RF) was proposed for charging demand prediction of private EVs. BN was used for creating the historical datasets of the EVs and RF was used for predicting the charging demand. The proposed approach was validated for selected charging hotspots of Helsinki, Finland.
5. Review of smart charging- Electrification of transport has been identified as the one of the significant factors that would increase the power demand Management of charger load has become a matter of concern for the power system engineers. Uncoordinated charging can be detrimental to the smooth operation of the power grid. Smart charging gives certain amount of control over the charging process. Adaptivity of the charging process of EVs in smart charging assists to meet the needs

of power system as well as EV users. Smart charger can adjust the charging power according to the power available to the grid, EV user needs, and also support the grid during emergency. Further, smart charging enables EVs to act as flexible grid resources thereby providing ancillary services to the grid in case of emergencya comprehensive overview of smart charging was conducted thereby explaining its perception, impact, user acceptance, global status and pilot projects.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

1. Deb, S., (2021 June). A Novel Data Driven Methodology for Charging Hotspots Computation for the city of Helsinki. In 3rd International Conference on Electrical, Communication and Computer Engineering (ICECCE) (pp. 1-6). IEEE (accepted)
2. Deb, S. (2021, June). Machine Learning for Solving Charging Infrastructure Planning: A Comprehensive Review. In 2021 5th International Conference on Smart Grid and Smart Cities (ICSGSC) (pp. 16-22). IEEE.
3. Deb, S., (2021). Machine Learning for Solving Charging Infrastructure Planning: A Comprehensive Review. *Energies (*extended version of the 5th International Conference on Smart Grid and Smart Cities paper is selected for publication in Energies)
4. Deb, S., (2021). Charging Demand Prediction of Electric City Buses of Helsinki, Finland by Random Forest. *Scientific Reports* (to be submitted)
5. Deb, S., (2021). Charging Demand Prediction of Electric City Buses of Helsinki, Finland by Machine Learning based approach. *Applied Science* (under review)
6. Deb, S., & Safdarian A., (2021). Charging Demand Prediction of Electric Vehicles by Hybrid Bayesian Network and Machine Learning Based Approach for the city of Helsinki, Finland (to be submitted)
7. Deb, S., & Tammi K., (2021). Smart Charging: A Comprehensive Review. (to be submitted)

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

1. Presented a paper in **IEEE 3rd International Conference on Electrical, Communication and Computer Engineering**
2. Presented a paper in **2021 IEEE 5th International Conference on Smart Grid and Smart Cities (ICSGSC)**
3. Delivered expert lecture in **Energy Modelling 2021 #3**: Sites & software: Solving optimisation challenges for electric vehicle (EV) charging networks
4. Delivered expert lecture in **Online Hands-on Workshop on Emerging Technologies in Electric Vehicle**
5. Attended webinar on Quantum Computing and Programming organized by CSC

IV – RESEARCH EXCHANGE PROGRAMME (REP)

I attended a virtual Research Exchange Programme at Holistic Systems group of SIMULA, Norway where I interacted with Dr Michael Riegler and his research group on real time applications of machine learning. The following topics were discussed:

1. Applications of machine learning for charging demand prediction
2. Applications of machine learning in different fields such as medical, multimedia etc
3. Availability of real-time charging datasets
4. Review of existing EV simulators
5. Design of reinforcement learning based EV simulator