PhD in Mechanical Engineering

Research Title:

Combined local and in the cloud battery monitoring for SOC and ageing estimation

Funded by	SILK - FAW

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Context of the research activity	The stringent emission regulations linked to fuel economy, emissions and energy conservation pushed the recent efforts of automotive industry towards the investigation of alternative powertrains. Electric, Hybrid Electric and Fuel Cell vehicles are establishing as reference solutions and are gaining a relevant market momentum. These architectures all rely on batteries as primary or auxiliary energy source. The academic and industrial research is then driven to deeply investigate new optimized battery solutions in terms of chemistry, packaging and management to improve power and energy density property. Typically, the performance of these devices is hardly predictable since they are strongly affected by the number and type of the charge/discharge cycles, and also by environmental factors such as temperature and age. Specifically, the assessment of the level of the remaining available energy indicated by the State of Charge (SOC) as function of the level of ageing suffered by the battery, indicated by the State of Health (SOH) is of major importance. These parameters cannot be directly measured with sensors and must be estimated by means of indirect approaches. Common solutions rely on the adoption of look-up tables, filled with time consuming tests conducted in a laboratory environment. Alternative methods adopt filter-based algorithms (Kalman Filter, Extended Kalman Filter) but may suffer problems related to inaccuracies of the model tuning or lack in the representation of the battery behaviour in all the possible operating conditions. Recently, an increasing attention has been gained by Artificial Intelligence. Specifically, Artificial Neural Networks (ANNs) represent a promising solution since they are not depending on any model and can guarantee a good level of

	accuracy, provided that the training dataset is complete and the network architecture is appropriate. These estimation algorithms are deployed locally on the vehicle control unit or Battery Management System and rely on the measurement acquired on one vehicle only. The proposed research aims to develop a hybrid deployment of the monitoring algorithms, partly on the vehicle control unit, for the SOC estimation, and partly remotely in the cloud, for the SOH estimation. The objective is to enrich the ageing identification with statistical data of the usage of the same battery installed on different vehicles. The SOH estimation data-driven approach would be then in continuous learning during operations guaranteeing higher accuracy. To this end, classification and regression Artificial Neural Networks will be exploited to make the algorithm independent on the chemistry and suitable for next generation batteries, such as GEN 4 solid state batteries. A side advantage is represented by the possibility of performing a remote diagnostic s of the state of the battery, providing an additional monitoring service to the end-user.

Objectives	• In-lab experimental characterizations at cell and module level to create the training and validation datasets. • Development of SOC estimation techniques to be deployed locally on the vehicle and relying on local direct measurements (current, voltage, Temperature, etc…). The algorithm will be based on regression neural networks. • Development of SOH estimation to be deployed remotely on the cloud and relying on data coming from vehicle fleet equipped with the same battery. The algorithm will be based on the combination of regression and classification neural networks. Statistical data will allow to continuously update the algorithm. • The algorithms will be developed on Matlab, Python and C and will be tested in a laboratory environment on connected electronic platforms to simulate the cloud architecture.

Skills and competencies for the development of the activity	The required skills and competencies are: • Basic knowledge of Artificial Intelligence techniques for identification, prediction and estimation tasks with classification and regression architectures. • Basic knowledge of connectivity communication protocols. • Knowledge of Matlab/Simulink environment, Python and C code languages.