



Please note that this project is only accepting applications from New Zealand citizens or permanent residents.

Project Title - Supercapacitor assisted low frequency power converters for future DC systems

Host University - University of Waikato

Industrial Partner - Würth Elektronik eiSos GmbH & Co. KG

Academic Supervisor(s)

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Project Description

Current approach to linking renewable energy sources to AC powered buildings use a battery coupled to a DC-DC converter and an inverter synchronized to the AC mains frequency. This system has its disadvantages: (a) efficiency losses due to double conversion (b) short life cycles of battery-banks (c)

pumping renewable energy back to grid at daytime creating grid instability. The project will investigate the efficiency-superiority of supercapacitor-based power converters as a paradigm shifting approach to future DC homes and DC microgrids.

UN Sustainable Development Goal (SDG) 7–Affordable Clean Energy requires that the power electronics linking renewables sources should be super-efficient, low cost and long life. Proposed technique is based on fit-and forget supercapacitor banks as the storage medium with minimal parts for lowering the cost compared to current systems.

With the supercapacitors playing the dual role of energy storage as well as efficient power conversion with an innovative approach, it satisfies the SDG 9–Industry, Innovation and Infrastructure. These converters for future DC homes and DC microgrids (in contrast to current AC grids) will help the SDG 11 (Sustainable Cities and Communities). Given that the prime target of this applied research is to significantly reduce losses in renewable power converters for DC appliances, it naturally supports the SDG 13 (Climate Action).

With two decades of successful postgraduate research on supercapacitor (SC) applications, Waikato Power Electronics Research Group (WaiPER) have a clear picture of the trends of the SC electrochemistry. Group have also developed a new technique family now published as SC-assisted (SCA) techniques for renewable systems culminating many publications and patents. SCA techniques based on 12 completed PhDs have led to a new published-theory, SCA Loss Management (SCALoM), elevating the WaiPER team to the world's leading research group on supercapacitor applications, with their expertise shared in 17 countries. In ongoing research, we have shown that household refrigerators can be made more efficient (approximately 4%) based on our SCARef technique, which also helps reducing electronics inside for cheaper whiteware with longer life.

Both theoretical and experimental research will be in-house at UoW DC laboratory using the solar energy resources and solar energy simulators, while our ongoing collaboration with Würth Elektronik will help deeper experimental validations such as EMC compatibility and type approval tests conducted at Würth laboratories. The partnership will help creating manufacturable prototypes since universities in NZ cannot afford these testing.

This PhD project will help applying the SCALoM theory to develop high-power, battery-free DC-DC converter for future DC systems to minimize or eliminate the three disadvantages indicted in the first paragraph. This Supercapacitor Assisted Loss-less Transformer (SCAL2T) technique will fundamentally remove major barriers for direct DC homes and DC appliances in addition to efficient interconnections to the AC grid. Localised supercapacitor energy storage will eliminate li-ion energy storage which comes with a fire hazard.

SCAL²T is a unique new extension of the patented SC assisted low dropout (SCALDO) converter, by specifically combining two different phases of the SCALDO, with suitable SC banks for energy buffering of renewable inputs.

Student Time Split

University base for student (university, campus, department):

Mainly at School of Engineering, The University of Waikato [Specifically within the DC laboratory and the WaiPER group] together with Department of Electrical and Computer Engineering, University of Canterbury [for high voltage testing of prototypes, as and when required] .

Industry base for student (company, site, address):

Würth Elektronik headquarters, Waldenburg Germany/Würth New Zealand/Local offices of Würth 99 Mclaughlins Road, Wiri, Auckland, 2104

Expected Time Split Between University and Industry Partner (in months):

30 months at University of Waikato /two 11-week periods at Würth- New Zealand and two weeks testing period at Würth Elektronik headquarters, Waldenburg, Germany

Rationale for Time Split:

Research part of the project will be carried out at UoW laboratory with basic prototypes completed via relevant analytical, experimental and simulation work. When high voltage converter version is developed for testing the prototypes student will be placed at University of Canterbury for limited periods of time.

Student will be placed at local offices of Würth as and when required. Once the prototypes are built and tested for functionality and adhering to base specifications, as local universities does not own any labs where electromagnetic compatibility testing or type approval testing can be conducted the student has to carry out these tests at Würth Elektronik laboratories in Germany. PhD student will be sent to Germany to access the EMC and Prototype Test labs of Würth Elektronik.

These test times will be prebooked with Würth Elektronik team in Germany over the second and third years.

As per our on-going collaboration with Würth, we have agreed to develop commercially useful prototypes of any new design techniques we innovate. In this process, Würth will supply free component kits, free access to industrial test labs and free training on specialized testing. We have successfully tried this model and the process in developing a industrially useful version of a DC-DC converter based on our patented (2011) SCA low dropout (SCALDO) regulator technique and completing its EMC compatibility tests successfully in 2024. Currently we are developing a Würth application-note on a SCALDO converter.

Application

To apply for this project please first read the guidance document and then complete the application form on the Applied Doctorates Scheme website.