UNIVERSITÀ DI PISA

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Dottorato di Ricerca in Ingegneria dell'Informazione

Doctoral Course

Supercapacitor Techniques for DC Microgrid and Renewable Energy Applications

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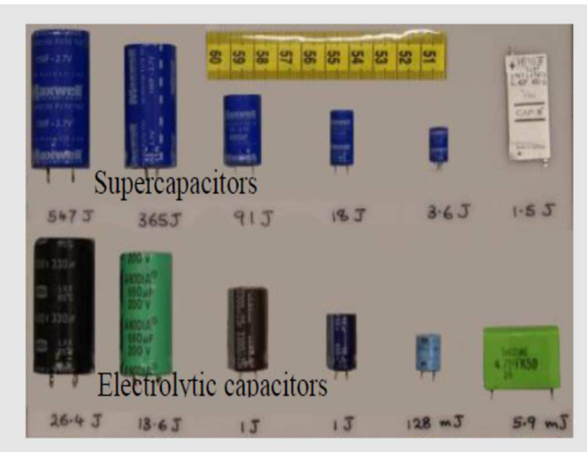
Short Abstract During the last two decades, electronics industry has seen many commercial versions of electrical double layer capacitors (EDLC), which are also known as ultra-capacitors and supercapacitors (SC), with the aim of complementing or replacing electrochemical batteries. EDLCs come in single-cell capacitance values from 0.2 to 7500 farads, with the limitation of very low DC voltage ratings from 0.7 V to 4 V. A general observation is that for the same device volume of an electrolytic capacitor, an EDLC gives an approximately one million times larger capacitance as pictorially shown below. Recently some SC manufacturers have introduced a novel family of 'supercap-batteries' where capacitance has gone up to 70,000 F. Compared to conventional capacitors with large DC voltage ratings, EDLCs offer one to two order greater energy density and approximately twice the power density. Based on these facts, supercapacitors can be used for unique and novel circuit topologies to achieve: significantly high energy efficiency in DC-DC converters; surge protection; rapid energy transfer; loss minimised sub modular inverters and renewable energy converters with DC-UPS capability.



Seminar will present an in-depth discussion on how to develop unique solutions to well-known issues in power electronics with examples of developing many patented or patent pending SC assisted (SCA) techniques such as SCA low dropout regulator (SCALDO), SCA surge absorber (SCASA), SCA temperature modification apparatus (SCATMA), SCA Sub modular inverter (SCASMI) and SCA light emitting diodes (SCALED). Industrial applications of these SCA techniques will be

Course Contents in brief:

1. Capacitors and their limits
    - Capacitor fundamentals
    - Capacitor types and their properties
    - Capacitors' application scope and limits
    - Electrolytic capacitors vs Supercapacitors
2. Energy storage device families and Ragone plot
    - Energy storage in electrical systems
    - Compressed air energy storage
    - Superconductive magnetic energy storage
    - Rapid energy transfer requirements and fundamental circuit issues
    - Technical specifications of energy storage device
    - Ragone plot
    - Types, construction and characteristics of EDLCs, hybrid devices and capa-batteriesHistorical background
    - Electrical double-layer effect and device construction
    - Pseudocapacitance and pseudocapacitors
    - Hybridization of electrochemical capacitors and rechargeable batteries
    - Modelling and equivalent circuits
    - Testing of devices and characterization
    - Modules and voltage balancing
    - Capa-batteries
3. Traditional applications of EDLCs
    - Automotive and transportation applications
    - Power quality applications
    - Portable products
    - Theoretical framework for non-traditional Supercapacitor assisted (SCA) circuit topologiesReview of the simple RC circuit loop theory
    - Modification of the traditional RC circuit, by an over-rated DC source, and a pre-charged exponentially large capacitor
    - Inserting a useful load into the loop with a supercapacitor
    - Efficiency advantage of the modification
    - SCA low dropout regulator (SCALDO) technique for high efficiency linear DC-DC convertersDC-DC converters and DC power management
    - Supercapacitor assisted low dropout regulator (SCALDO) technique

- SCALDO implementation examples
- Comparison between SCALDO regulators and charge pumps

4. SCA surge absorber technique and an example of a commercial application
    - Lightning and inductive energy dumps in electric circuits and typical surge absorber techniques
    - Supercapacitor as a surge absorption device: summarized results of a preliminary investigation
    - Design approaches to a supercapacitor-based surge protector
    - SCA temperature modification apparatus (SCATMA) for rapid heating of fluids
    - Problem of traditional heating from direct AC mains supply and heating system specifications
    - Commercial solutions for eliminating water wastage due to storage in buried plumbing
    - SC-based solution with pre-stored energy
    - Results from an ongoing prototype development exercise
5. SCA sub modular inverter (SCASMI) for renewable energy applications
    - Reduced losses and efficiency advantage in inverter design
    - Basic principle of SCASMI technique
    - Generalised principle and operating modes
    - Implementation details of SCASMI inverters
6. SCA light emitting diodes (SCALED) technique for DC Microgrid applications
    - DC operation of LED units – 12 V and higher voltage DC operable flood lighting units
    - Supercapacitors for short term Dc-UPS capability to overcome solar energy fluctuations
    - Replacing battery banks with supercapacitors – issue of MPPT implementation
    - SCALED topology and its theory related to high efficiency LED lighting
    - An overview of a pilot project at Ports of Auckland Jetty area

Total # of hours of lecture: 16-18 hours

References:

[1] (2015) Kularatna, N., ***Energy Storage devices for Electronic Systems: Rechargeable batteries and Supercapacitors***, Elsevier Academic Press, 2015, 267 pages.

[2] (2016) Kularatna, N., *Supercapacitors Improve the Performance of Linear Power-Management Circuits*, IEEE Power Electronics Magazine, March 2016, pp 45-59

CV of the Teacher

Nihal Kularatna

DSc, BSc Eng (Hons)

FIET (London), FIPENZ, Senior Member IEEE (USA)

Nihal Kularatna is an electronics engineer with over 43 years of contribution to profession and research. He has authored eight books for practicing electronic engineers including the two consecutive IET Electrical Measurement Series books titled *Modern electronic test & measuring instruments* (1996) and *Digital and analogue* i*nstrumentation- testing and measurement (2003/2008)* and three Elsevier (USA) titles. His recent research monograph on energy storage systems, titled *Energy storage devices for electronic systems: rechargeable batteries and supercapacitors,* was published by Elsevier in 2015, summarizing his applications oriented research during the last five years, supervising many PhD students at the University of Waikato, New Zealand. He was the winner of **New Zealand Innovator of the Year 2013 Award**.

From 1976 to 1985 he worked as an electronics engineer at Sri Lankan airports and digital telephone exchange systems in Saudi Arabia. From 1985, he had a 16+ years of a successful engineering career at the Arthur C Clarke Institute for Modern Technologies, where he was appointed as the CEO in 1999. From 2002 to 2005 he was a Senior Lecturer at the Department of Electrical and Computer Engineering, University of Auckland.

In the 1990s, he was an active consultant for a few US companies, including the Gartner Group, Technology Dynamics, NJ and many Sri Lankan organizations. He acts as a member of the on-demand expert reviewer panel of the Ministry of Business Innovation and Enterprise, New Zealand and in 2014 he was appointed the Vice Chair of the Energy Efficiency and Literature committees for the upcoming IEEE DC at Home Standard.

A Fellow of the IET (London), Fellow of IPENZ and a Senior Member of IEEE (USA) and a graduate from the University of Ceylon, during his long career at ACCIMT he was a winner of Presidential Awards for Inventions-1995, the Most Outstanding Citizens Awards-1999 and a TOYP Award in 1993. In 2011 he was elected as an affiliated member of the Power Sources Manufacturers Association, USA.

He is currently active in research in non-traditional supercapacitor applications, power supply topologies, transient propagation and power conditioning. He has contributed over 150 papers to learned journals and international conferences. His work on supercapacitor assisted (SCA) circuit topologies/techniques such as SCALDO, SCASA and SCATMA culminated numerous US, NZ and PCT patents and several more are pending.

He is presently employed as an Associate Professor in the School of Engineering, the University of Waikato, New Zealand. At international IEEE conferences and industry trade shows he frequently delivers invited tutorials, workshops and lectures on subjects he is passionate about, including the area of innovation and commercialization. His hobbies are gardening and car-grooming.

Room and Schedule

Room: *Aula Riunioni del Dipartimento di Ingegneria dell'Informazione, Via G. Caruso 16, Pisa – Ground Floor*

Schedule:

Day1 – 9:00 – 12:00

13:30- 16:30

Day2 – 9:00 – 12:00

13:30- 16:30

Day3 – 9:00 – 13:00