



DEPARTMENT OF ENERGY TECHNOLOGY  
AALBORG UNIVERSITY

## PhD Public Defence

- Title:** Distributed Control Strategies applied to Parallel-Connected Three-Phase  
Modular UPS Inverters
- Location:** Pontoppidanstræde 105, room 3.115
- Time:** Monday 23 October 2017 at 13.00
- PhD defendant:** Baoze Wei
- Supervisor:** Professor Josep Guerrero
- Moderator:** Associate Professor Sanjay K. Chaudhary
- Opponents:** Professor Remus Teodorescu, Dept. of Energy Technology, Aalborg University  
(Chairman)  
Professor Parthasarathi Sensarma, IIT Kanpur, India  
Associate Professor Francesc Guinjoan, UPC, Barcelona, Spain

**All are welcome. The defence will be in English.**

**After the defence there will be an informal reception  
in Pontoppidanstræde 111 (coffee room).**



## Abstract:

To provide a more reliable and higher quality power for critical loads, Uninterruptible Power Supplies (UPSs) play an important role in many industrial and commercial applications, such as distributed generation (DG) systems, high power electric drives, high speed elevators, and data base center that cannot afford power loss.

The modular design concept of UPS appeared at later 1990s. The basic idea is that in a modular UPS, it contains several converter modules working in parallel to feed power to the loads. The modular concept has some advantages, such as increasing the power capacity regardless the rating limited of switching devices, increasing the flexibility, reliability and maintainability of power supply systems to meet the requirements of customers. And some redundant power modules can be put in a modular UPS to ensure high availability: When one power module fails, another one can take over to continue supplying power to loads.

My PhD project is mainly associated with a modular UPS project which is cooperated with a UPS design and research company named Salicru in Barcelona, Spain. This project is named TROY. The aim of this project is to design a drawer type modular UPS using Neutral Point Clamped (NPC) three-phase three-level voltage source frequency converter. Control strategies based on distributed control concept are developed in the thesis for the modular UPS.

Some key issues related with control are considered in the project. First contribution of the thesis to the project is the current limit control under over load or short circuit condition in order to protect the hardware and the safety of human being. If the protection algorithm is under well operation, the other tests can be performed safely.

In a modular UPS, the converter modules work in parallel with each other, one of the other important topics that should be looked at is the average power sharing. Worse power sharing performance will lead to serious circulating current problem and cause different current stress on the switching devices. And in some worse cases, if the circulating current is large enough, it will lead to negative current to threaten the safety of DC link and significantly diminish the lifetime of higher power output modules. So the second contribution of the thesis is to provide two different control methods to enhance average power sharing performance. One is founded on the adaptive virtual impedance; another is based on a modified droop control. And what's more, another circulating current suppression method is also given which is likewise suitable for modular UPS and verified by three-phase two-level inverters in the microgrid laboratory in Aalborg University.

Since in the control diagram, the virtual impedance is applied with droop control, a secondary control is needed to recover the voltage and frequency. The third contribution of the thesis is to develop an improved distributed secondary control to guarantee a good dynamic performance.

In the thesis, a whole control diagram of a modular UPS (inverter side) will be discussed. The developed control method for current limit, distributed secondary control, average power sharing under different condition are given. And the proposed methods are verified both with simulation and test on modular UPS platform in Salicru.