Improving the teaching of Power Electronics and Sustainable Energy By well-designed Laboratory Experiments

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Background

Energy Crisis, Environmental Pollution, Resource Depletion

PM2.5, Smog, Acid Rain, CO2 Greenhouse Effect, Ozone Layer Destruction, Traffic Jam

Coal vs Wind, Centralized vs Distributed, Energy vs Information

PV system development

- the world’s cumulative installed capacity of PV systems was about 300 MW in 1996, which grew to 1330 MW in 2002 and 102.16 GW in 2012.
- In 2011, there are nine were Chinese companies ranked in the top fifteen solar PV module manufacturers in the world and took a share of 30% in the world .

How to extract the maximum possible power from the installed PV systems is still a challenging problem since the output power of PV modules shows strong nonlinear characteristics, which heavily depend on the weather conditions such as irradiation and temperature.

Power Electronics Education

As one of the key technologies for future energy development, power electronics education has been widely emphasized by most countries.

- the ratio of mandatory sustainable energy in Australia is targeted to be increased to 20% within the next five years;
- In Korea, there is a growing demand on power electronics engineers and the corresponding educations are provided in most of Korean Universities;
- In Europe, research shows that a lack of competent workforce can slow down the development of sustainable energy in European ;
- In China, due to the quick growth of economy, the need for students with power electronics and sustainable energy knowledge is rapidly growing.

the electrical engineering curriculum is expected to be optimized and provide the corresponding state-of-the-art training for electrical engineerings to relevant industry application field

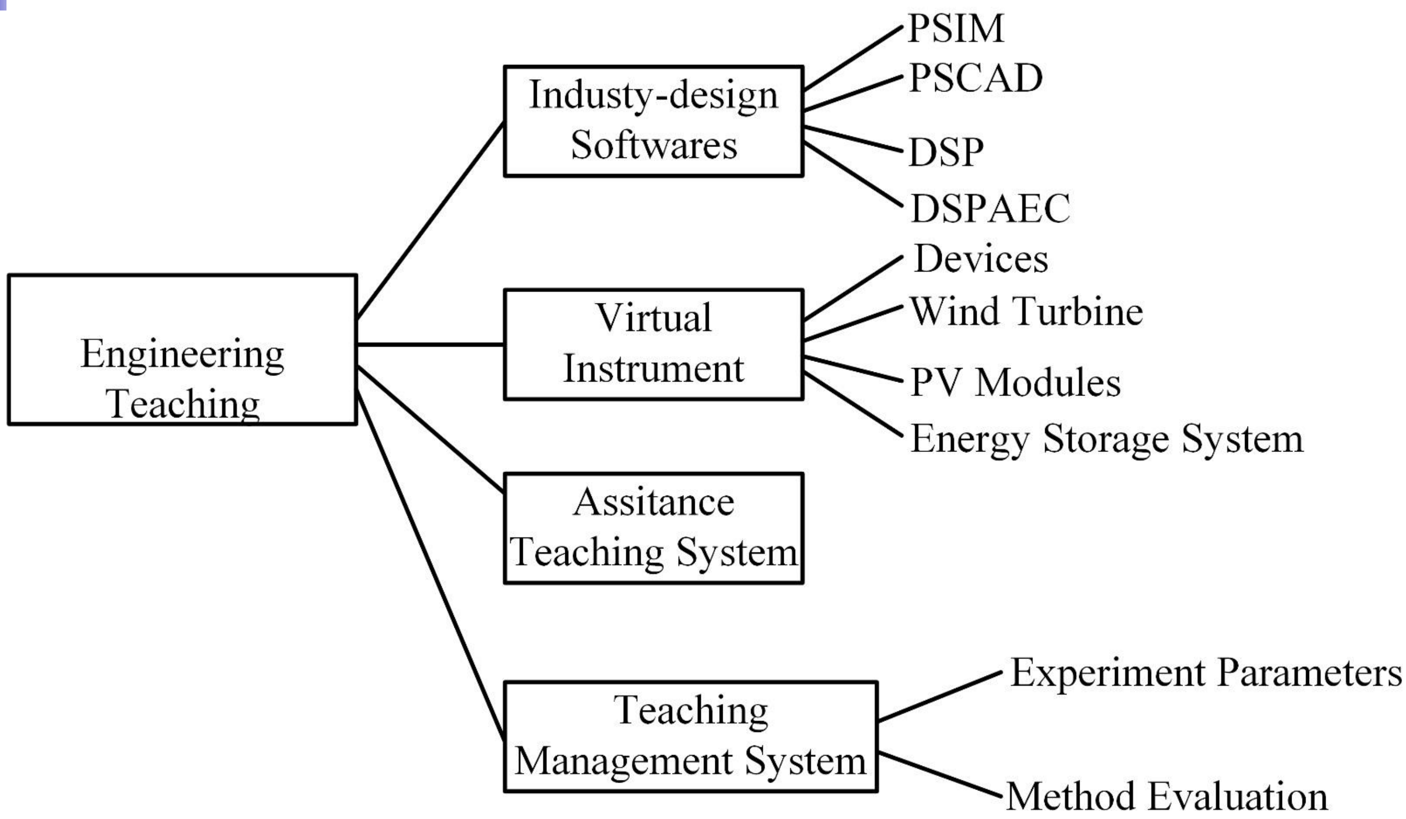
Sustainable Energy Education

- **E-Learning:** the main content of a course will be presented via the internet. This teaching method can be used for the working engineers;
- **Interactive method:** using virtual experiments can be used for lifelong education and self-education; implementation in Labview, a useful tool will be developed for researching and teaching activities in power electronics area;
- **Well-designed simulation and experimental tests**.

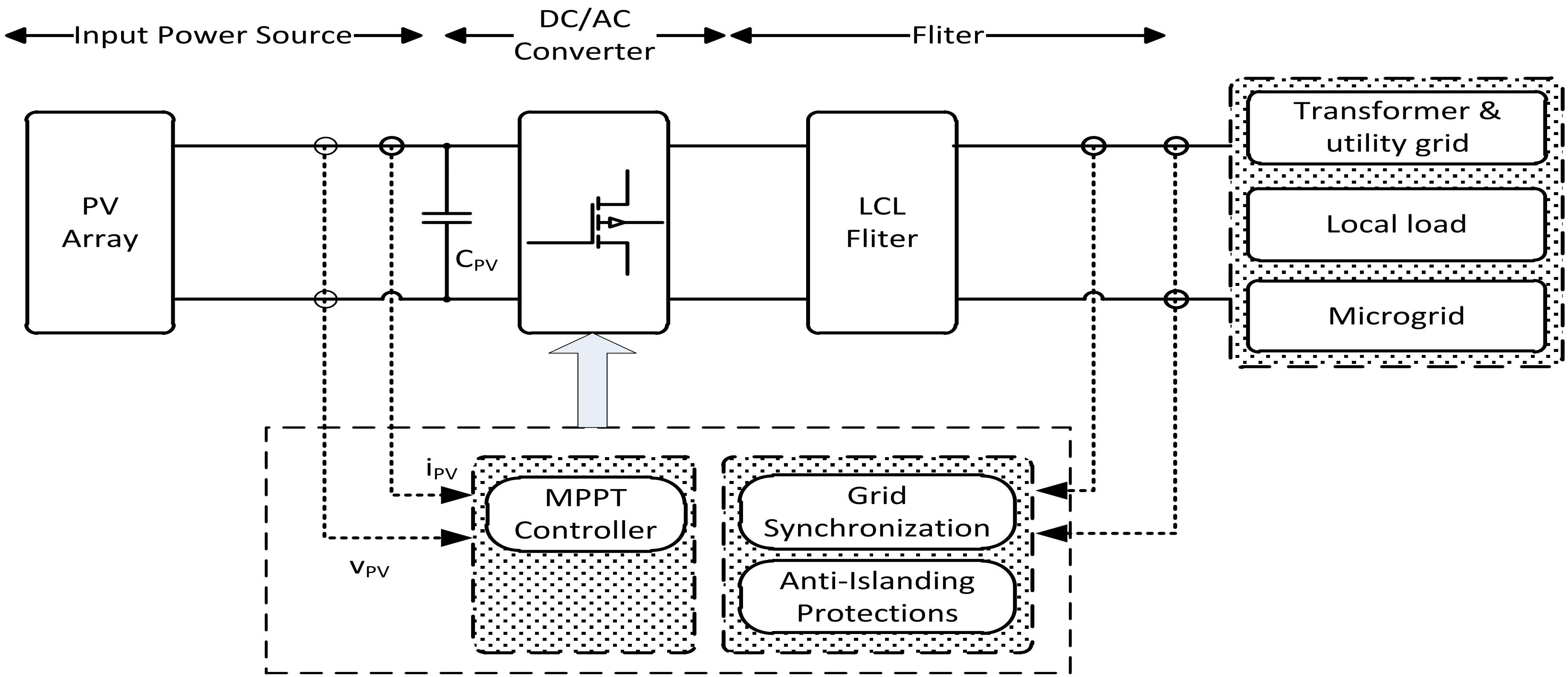
Sustainable Energy Education

- Step-by-step Engineering Education
  - From Components to System
  - From Simulation to Experiments
- Web-based Education
- Video-aided Education
- Interest Motivated Education
- Application-Oriented Education

Power Electronics Education



MPPT System

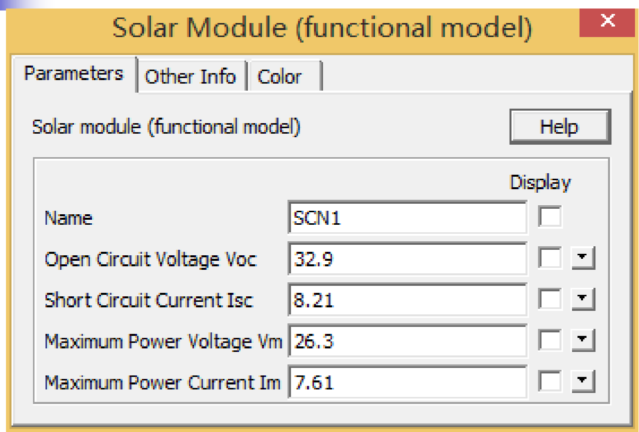


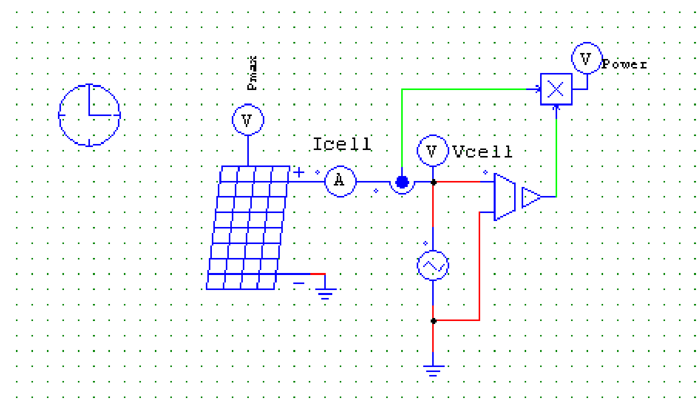
Input Power Source
DC/AC
Converter
Fliter
PV
Array
C_{PV}
LCL
Fliter
Transformer &
utility grid
Local load
Microgrid
i_{PV}
v_{PV}
MPPT
Controller
Grid
Synchronization
Anti-Islanding
Protections

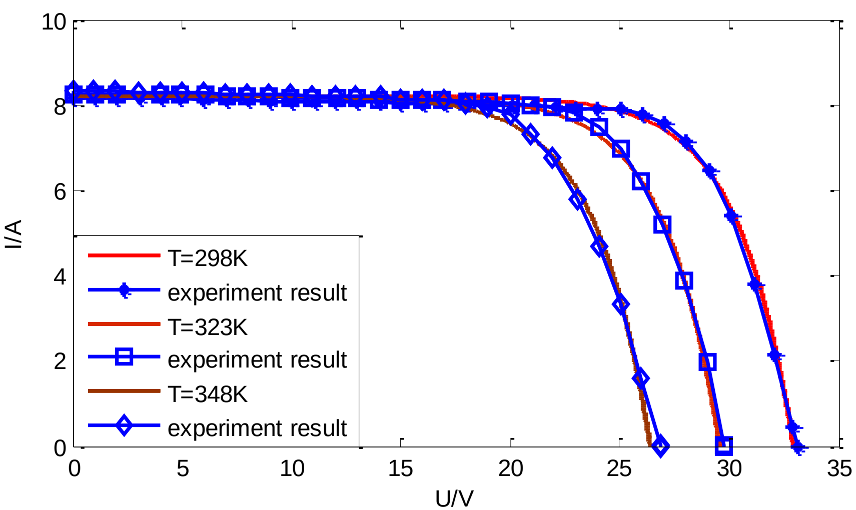
From Simulation to Experiments
PV Modelling

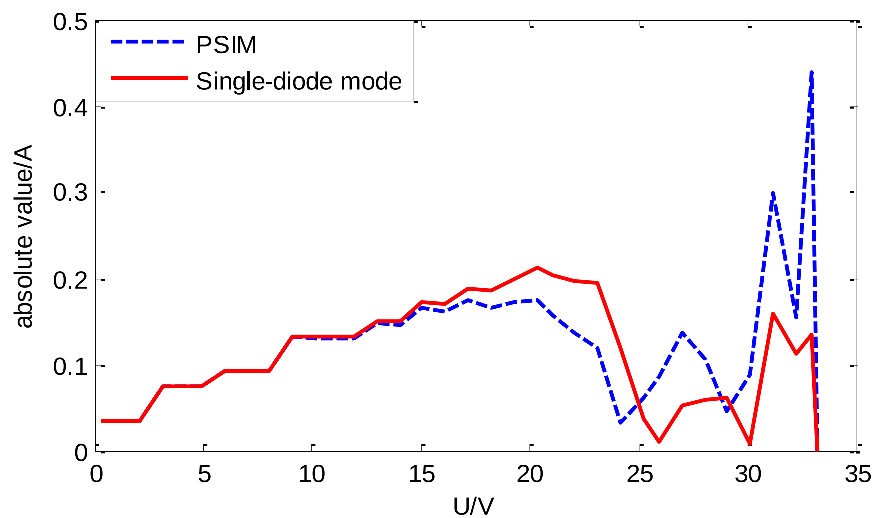
- The electrical power output from a PV module depends on the atmospheric conditions such as irradiance and cell temperature.
- However, PV manufacturing datasheets only provide several electrical parameters
- accurate and easy-to-implement modeling of PV source is very necessary for the prediction energy production from a photovoltaic panel under all conditions, as well as for the design of the MPPT methods.

PV Modelling

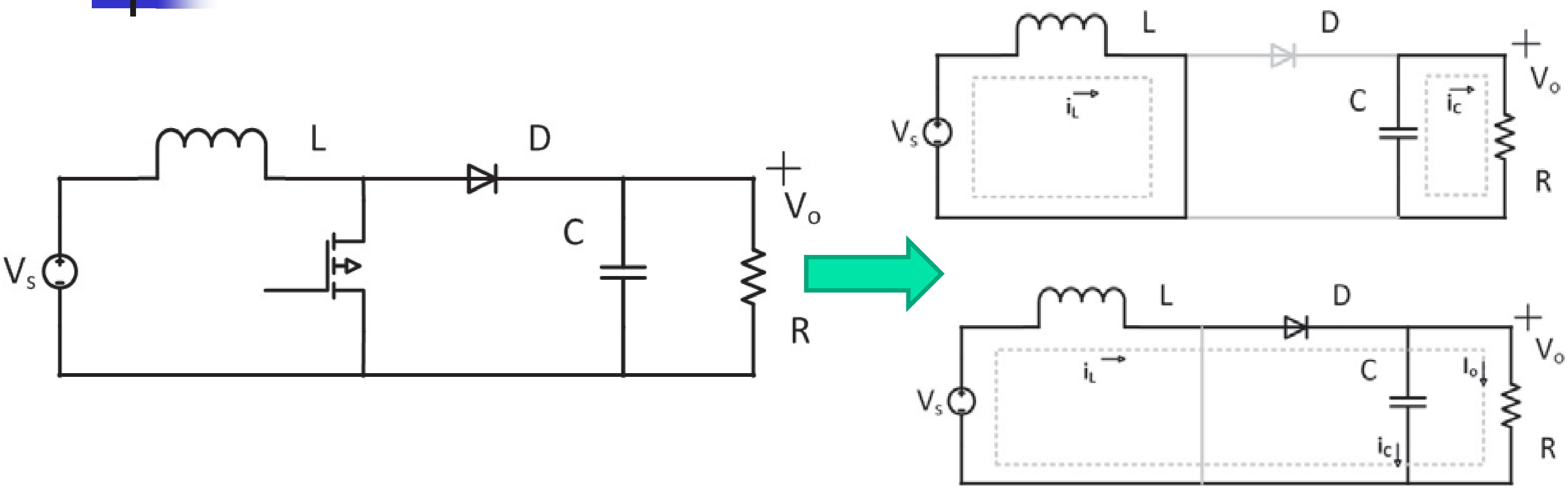








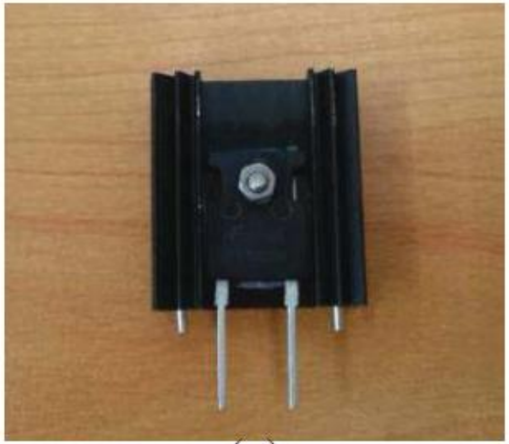
From Component to System
Boost Converter



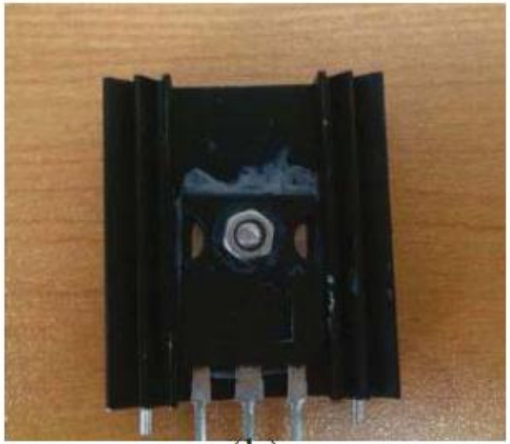
When the boost work is in the continuous conducting mode, we have

$$\frac{V_o}{V_s} = \frac{1}{1-D}$$

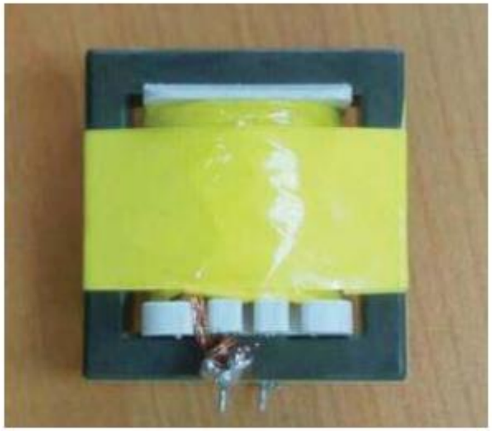
Boost Converter



(a)



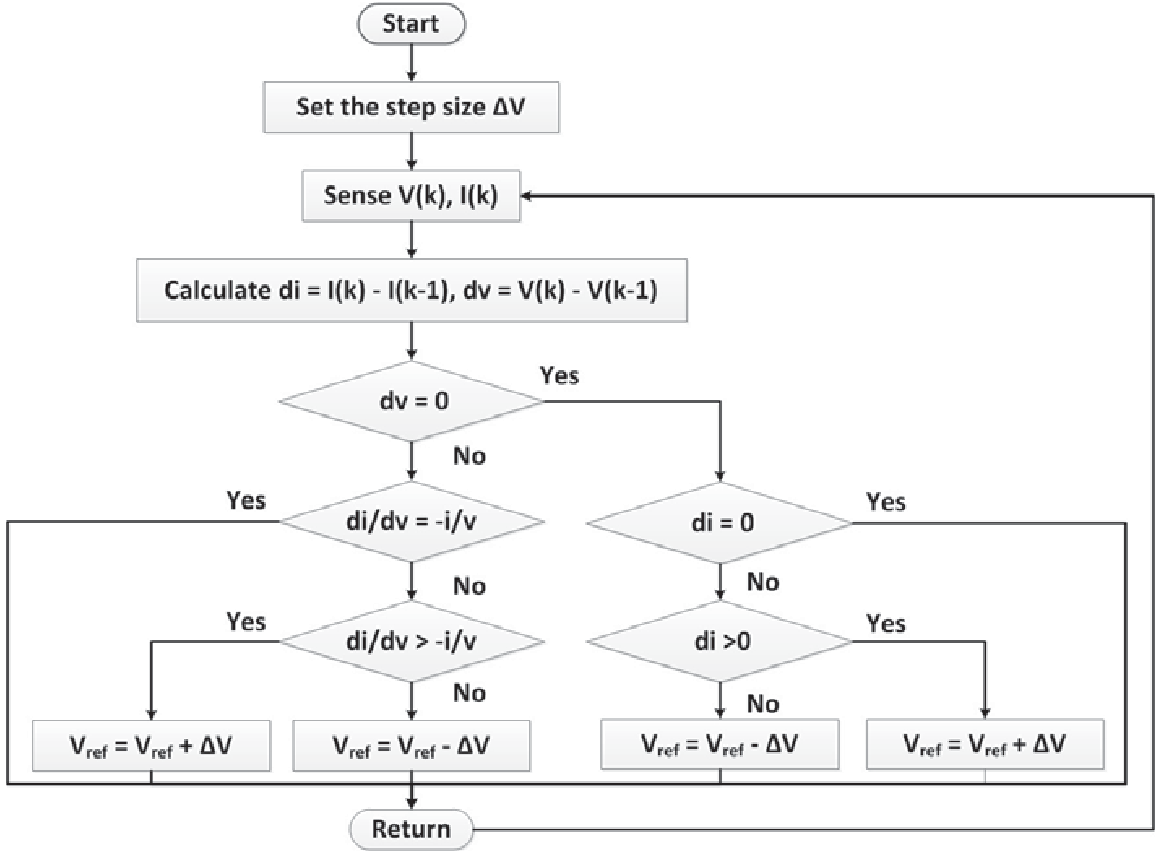
(b)



(c)

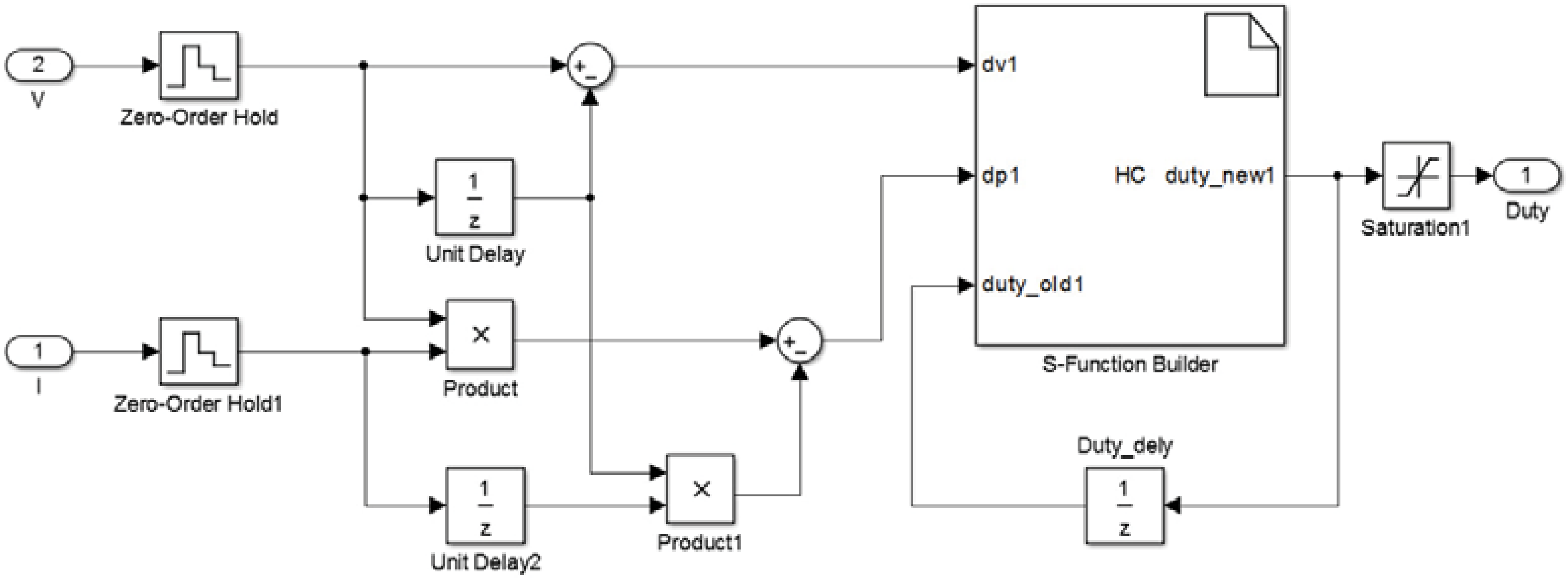
(d)

From Conventional Methods to Innovation MPPT Control



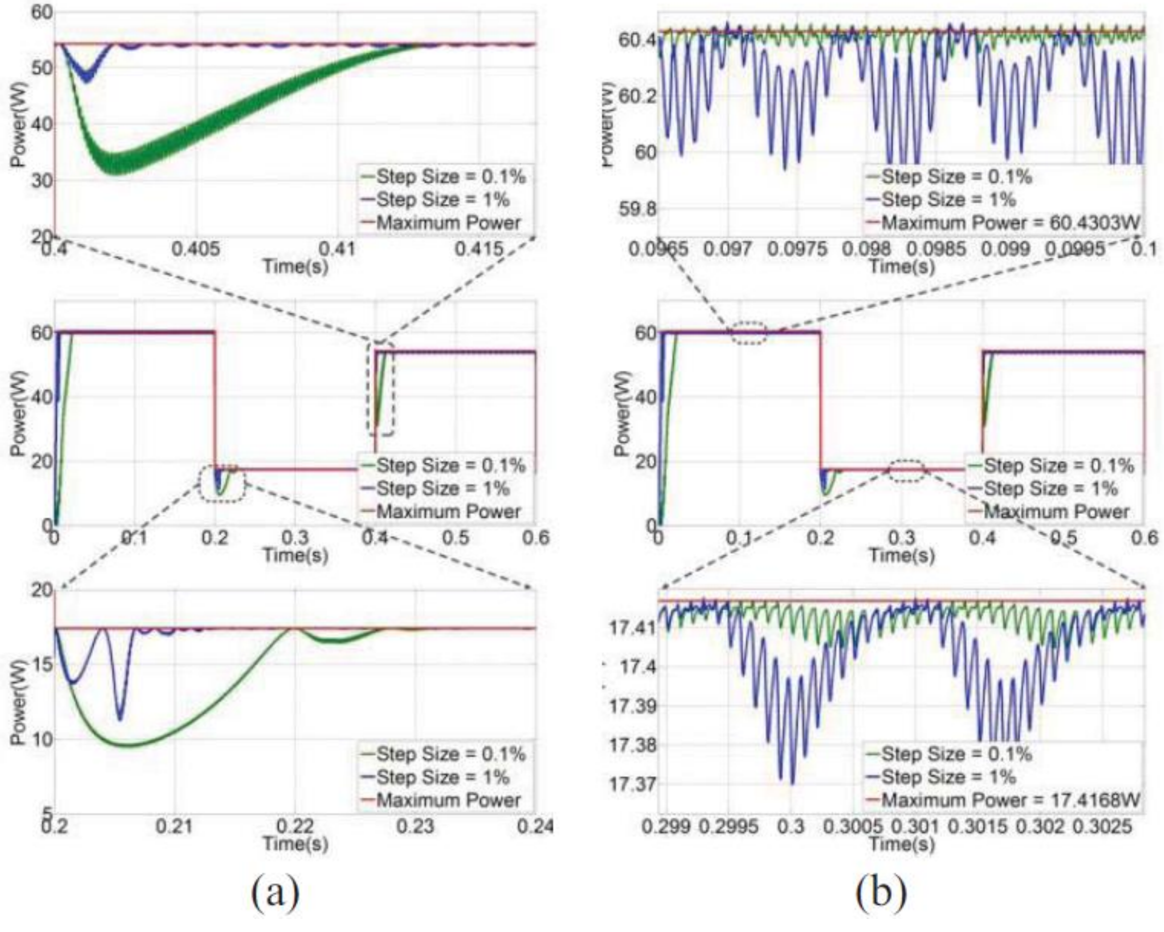
The flowchart of INC method

MPPT Control



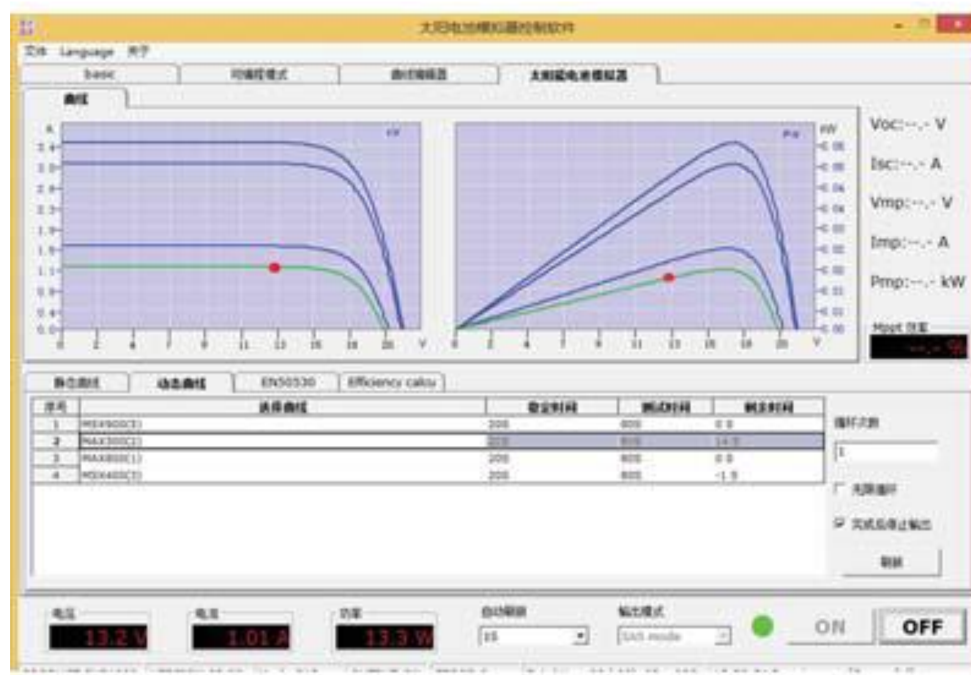
The diagram of MPPT for hill climbing method in Matlab

MPPT Control



The simulation and zoomed results with the HC method

Experiments

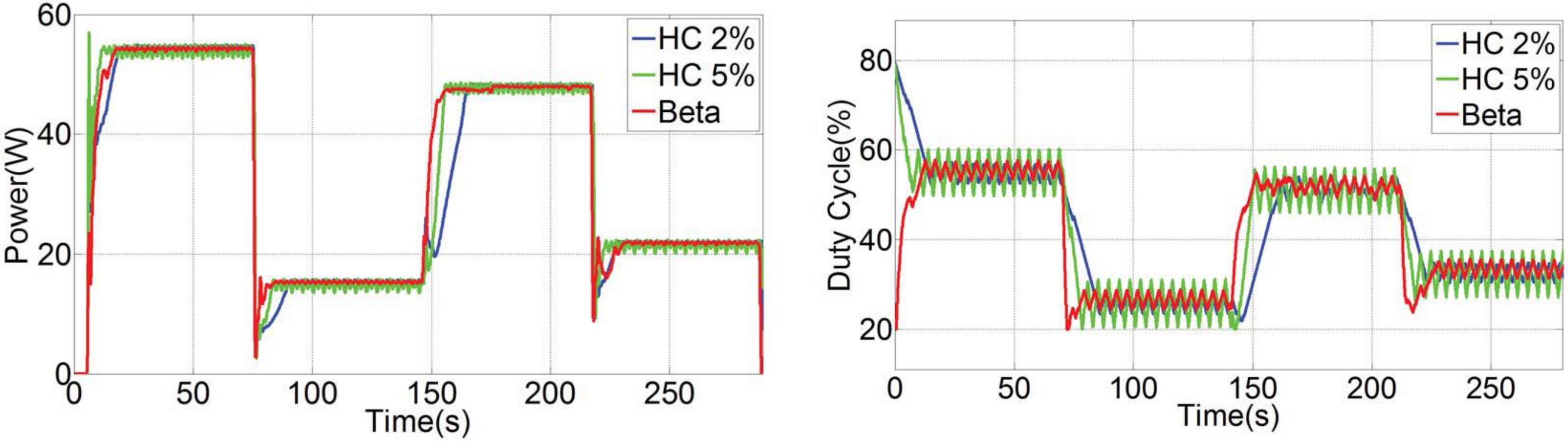


The solar array emulator PVS1000 Series (a) and the user interface of the PVS1000 Series (b).

Experiments

The user interface of the host computer Control Desk Next Generation (CDNG)

Experiments

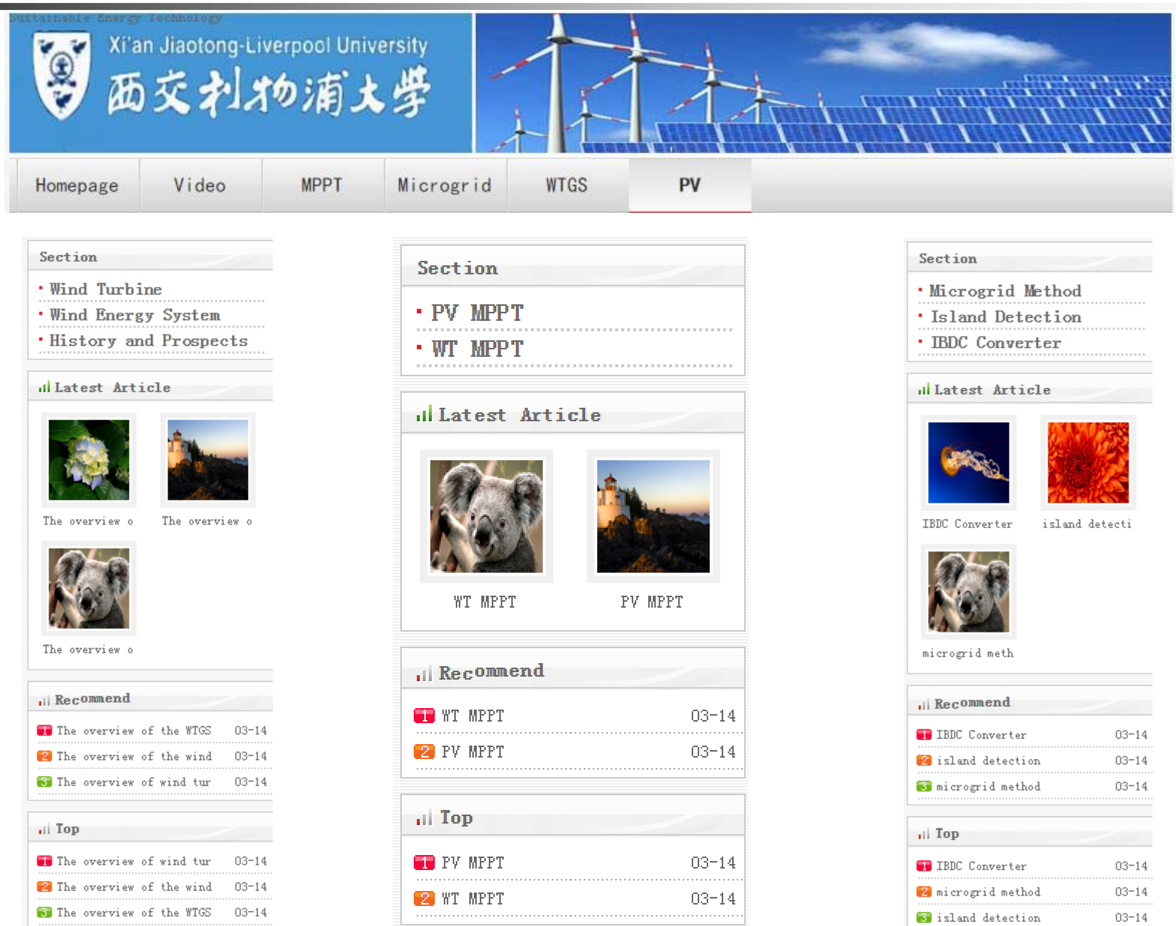


The experimental results for the HC methods and another advanced Beta-parameter based method [19] (a) The power and (b) The duty cycle.

Discussion

Knowledge Points	Conventional Methods	Proposed Method
Be knowledgeable about solar cells	Only basic description	Fully understand the features through simulation
Analyze solar radiation in energy terms.	Basic Level	Fully understand the features through simulation
Design and operation of a photovoltaic system	Knowledge level	Design level through simulation and experiments
Identify and size a photovoltaic system for a given application	Knowledge level	Design level
Tackle some problems of energy conversion using batteries and solar cells.	Knowledge level	Design level with lots of field experience
Describe the fundamentals of photovoltaic energy conversion	Basic Level	Advanced level, clearly know a complicated system

Web-based Education



Bidirectional Communication and Continuous Updating

Interest Motivated Education

PV model: parameters, validation
Micro-inverter: topology, control
DC Optimizer: DC/DC converter
MPPT: steady state vs. dynamics
Partial Shading: analysis phenomenon, pattern, modelling
DMPPT: converter, control
DPP: topology, control
Efficiency and EMI of PV converters: H5, Heric, NPC
ESS(Battery): C/D control, model, converter, internal resistance
Other ESS: flywheel, superconducting coil
MPPT for partial shading
Microgrid: PV, Wind, coordinated control
DC Microgrid: protection, control (drop), pure resistive load, inductive load
AC Microgrid: protection, control (drop), pure resistive load, inductive load
PV powered EV
BIPV (structure, comfortable)
PV cells: structure, material, physics (PN junction)
PLL: distorted, unbalance, phase-jump, frequency-jump
Islanding detection: NDZ
Small-signal model and closed-loop control for PV converters

Wide Topics Recommendation + Students Selection

Application-Oriented Education

Knowledge + Skills + Experience = Future Competitive

Summary

- **Synthesize all kinds of resources at XJTLU for our students** (Hardware, software …)
- **Research-led teaching** (Bridge: Module Study – Project – Job)
- **Innovation – Reality** (extra delivery time or tools, difficult to implement)
- **Student-centered teaching** (meet the needs of students, different cohort students, background, level)
- **Knowledge + Skills + Application**
- **Interesting, Useful, Meaningful** (Boring, Useless, Far away from the real world)

Module Leader is the core

Thanks!