Control and Protection Requirements for Microgrids

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Outline

- Definitions
- Microgrid Control
- Microgrid Protection
- A Signal Processing Module for Microgrid Integrated Control and Protection
  - Application Example
  - Study Results
- Conclusions

Definitions

- Distributed Resource (DR) Unit:

  is either a distributed Generation (DG) unit, a Distributed Storage (DS) unit, or any combination of DG and DS units that can be operated as either a “dispatchable” or a ”non-dispatchable” entity.

- Dispatchable DR Unit:

  is a unit that its output instantaneous real-power and/or reactive-power components are controllable, for a pre-specified time interval.

- Microgrid:

  is a cluster of DR units and loads services by an electric power grid (usually at a distribution voltage class), and capable of:

  – operation in a grid-connected mode,
  – operation in an islanded (autonomous) mode,
  – transition between grid-connected and islanded modes,
  – ride-through for each DR unit in either grid-connected and islanded modes.

Microgrid Control Functions:

- Control of DR units (based on locally and/or remotely measured signals)
  - excitation and governor controls of Synchronous Machine (SM) based DR units
  - direct- and quadrature-axis variables controls of VSC-coupled DR units, i.e.
    - current-controlled VSC (CC-VSC)
    - voltage-controlled VSC (VC-VSC)
    - hybrid or hierarchical of VC-VSC and CC-VSC
  - imposition of limits for each controller

- Coordination of DR unit controls
  - Coordination of controllers of DR units for real-power management, for example based on frequency-droop (and frequency restoration) method
  - Coordination of controllers of DR units and reactive-power sources for voltage control, for example based on (a) voltage-droop, (b) voltage regulation, (c) power factor correction, (d) or any combination of these methods
  - Coordination of limiters

A scenario that causes excursion of a microgrid out of the acceptable operational region, should be counteracted by activating:

(a) either another set of controls, e.g. based on a “discrete event control strategy”

(b) or microgrid protection.

Coordination of controls requires fast “detection” capability.

Microgrid Protection Functions

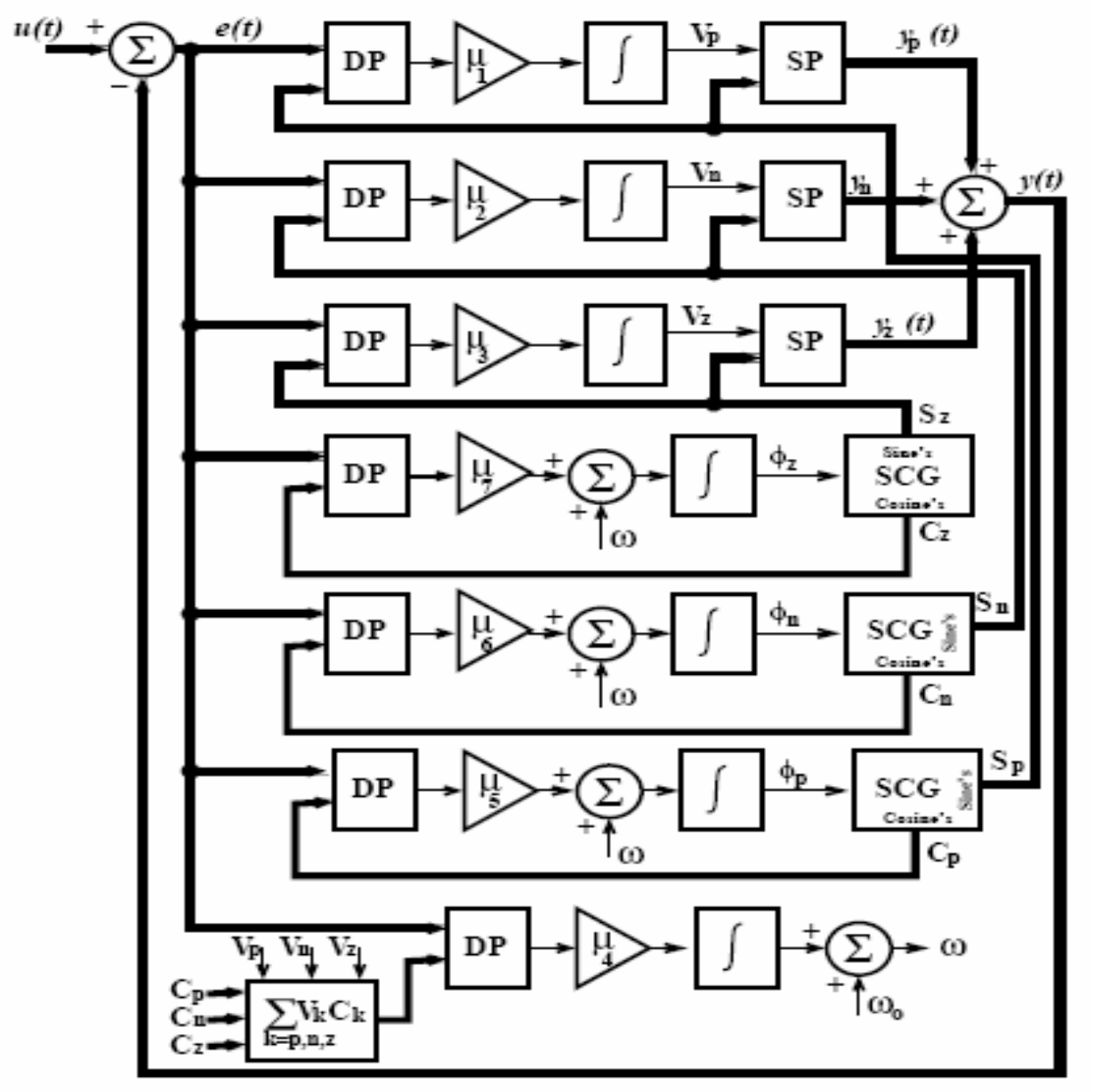
- Protection against "***fast transient events***" which are beyond the speed of response and/or range of operation of continues controls, for example:
  - surge arrester operation in response to transient over-voltages
  - fuse operation due to faults
  - fast current limiter operation subsequent to faults

- Protection against "***dynamic events***" for which fast controls of a microgrid can participate either to reduce the impacts or mitigate the phenomena, for example:
  - over/under voltage protection
  - over/under frequency operation

Microgrid Protection Functions (Continued)

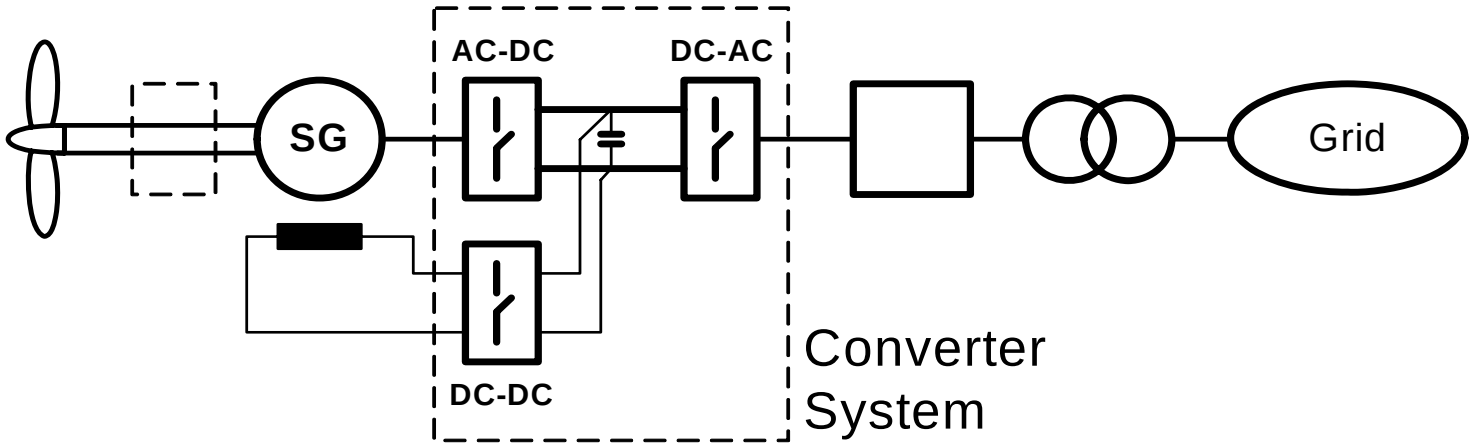
- The latter case requires "integration" of protection and control functions either through (i) change of control mode/strategy (e.g. CC-SVC to VC-VSC mode), (ii) dynamic change of control parameters, (iii) activating auxiliary controls, or (iv) a combination of (I) to (iii). Application example are to:
  - enhance ride-through capability of DR units during microgrid faults,
  - enable fast islanding detection to prevent DR tripping,
  - provide ride-through capability subsequent to single-phase load energization,
  - enable transition between grid-connected and islanded modes.

Integration of Control and protection functions requires fast "detection" capability.

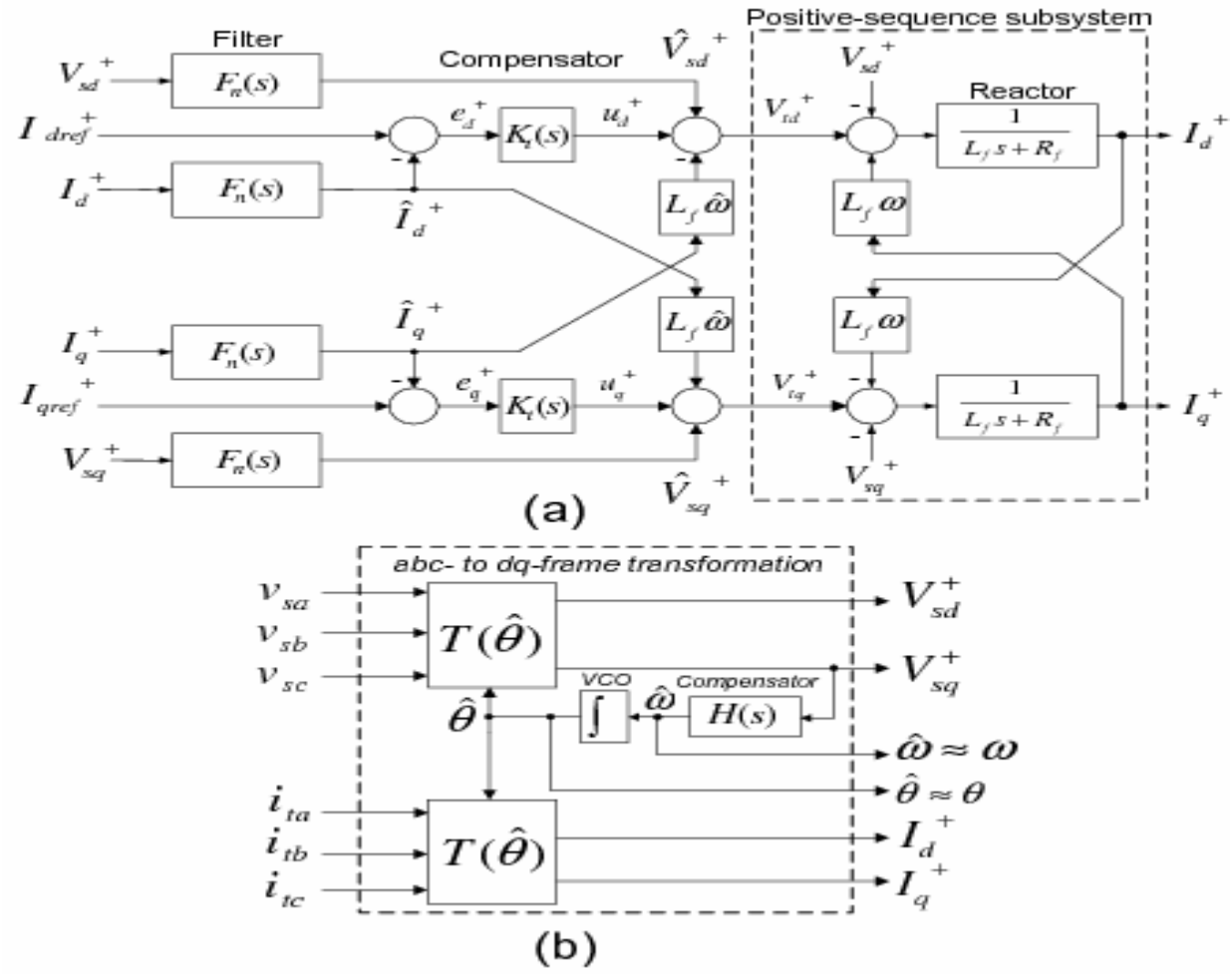


Block diagram representation of the **U**nified **T**hree-phase **S**ignal **P**rocessor (UTSP)

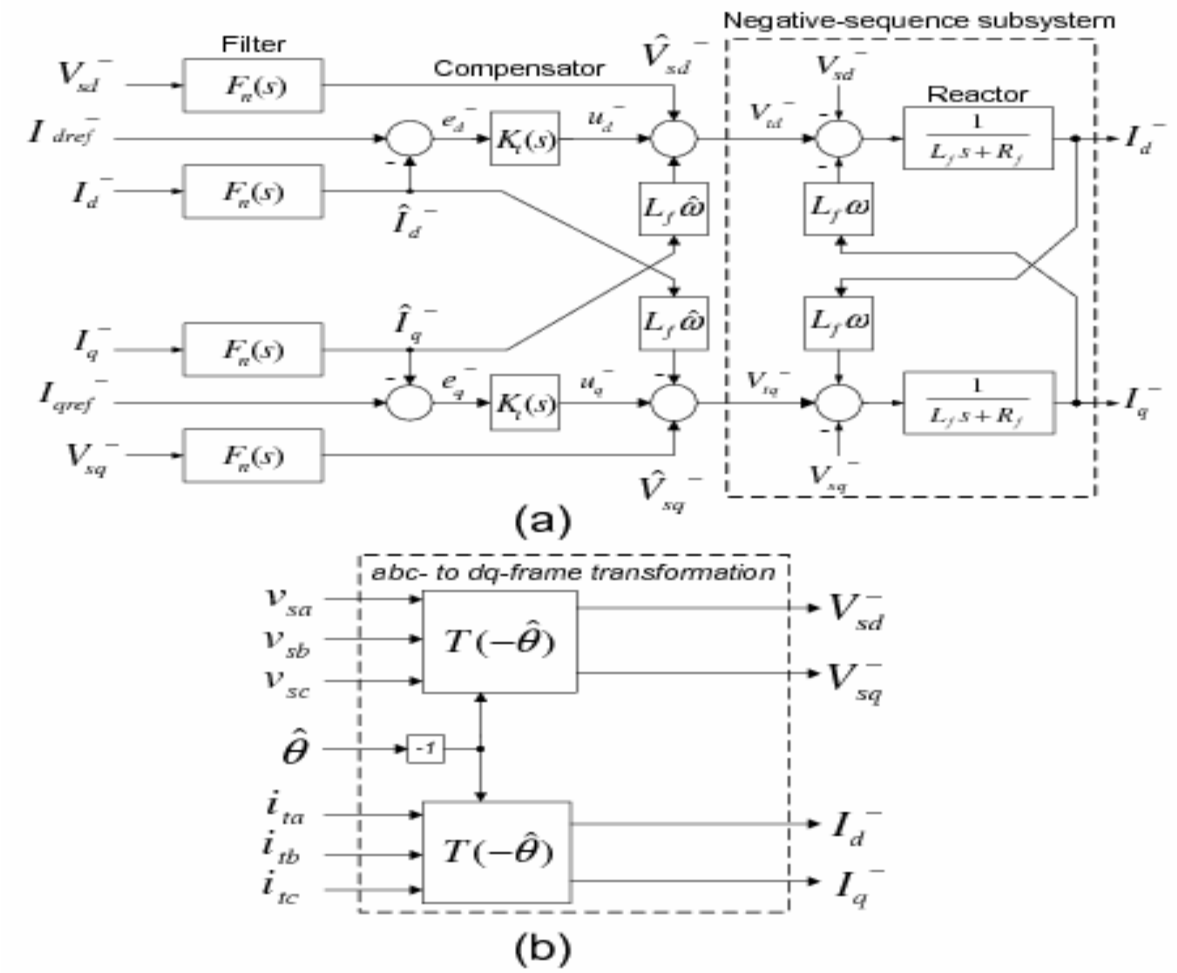
DG unit: variable-speed, direct-drive wind unit



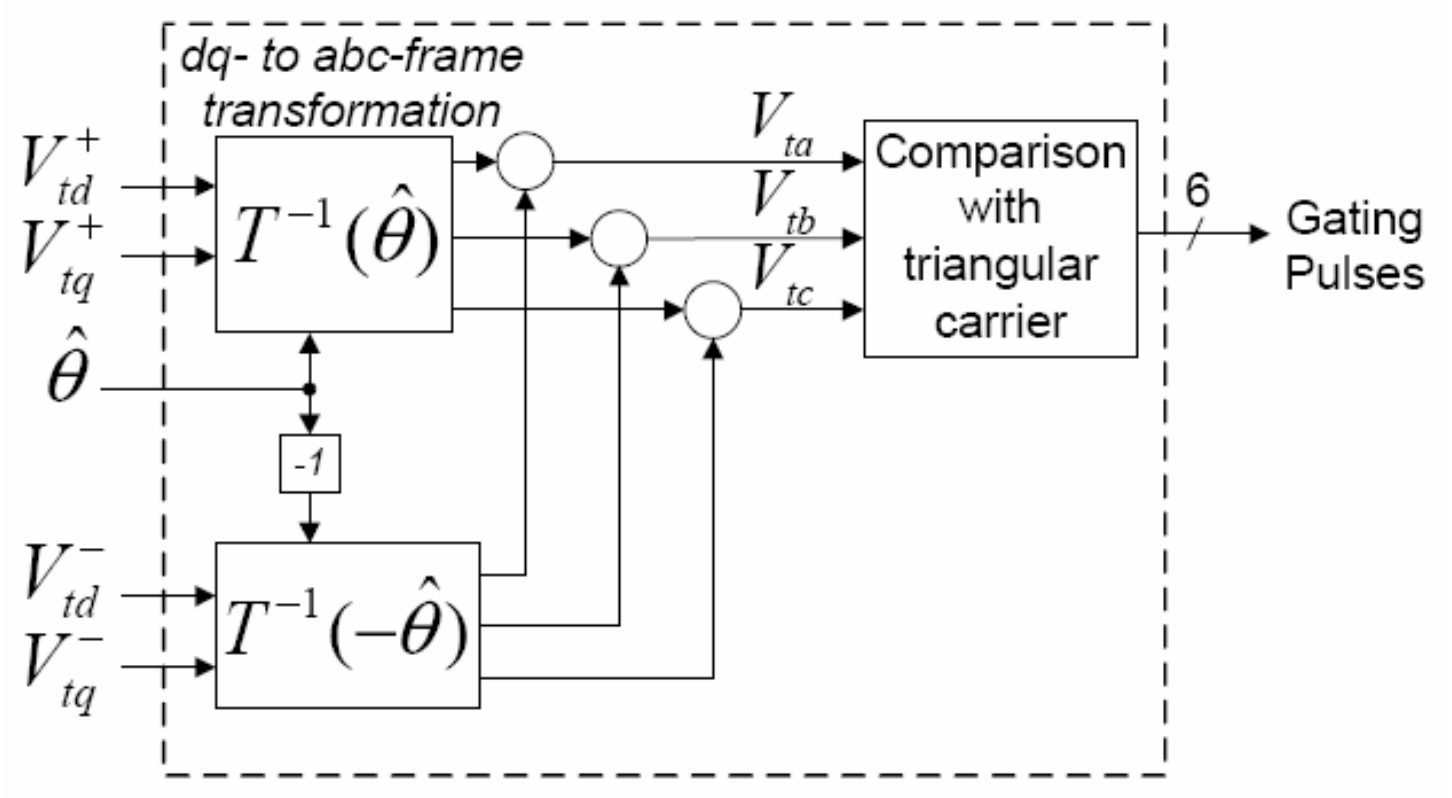
- Rated Power of Unit: 1000 kW
- Converter Technology: IGBT switch
  two-level converter
  2400 Hz switching frequency
- Generator Technology: field-controlled SG
  27 rpm, 84-pole
  690 Volt



(a) positive-sequence current controller and (b) positive-sequence voltage/current resolver with embedded PLL

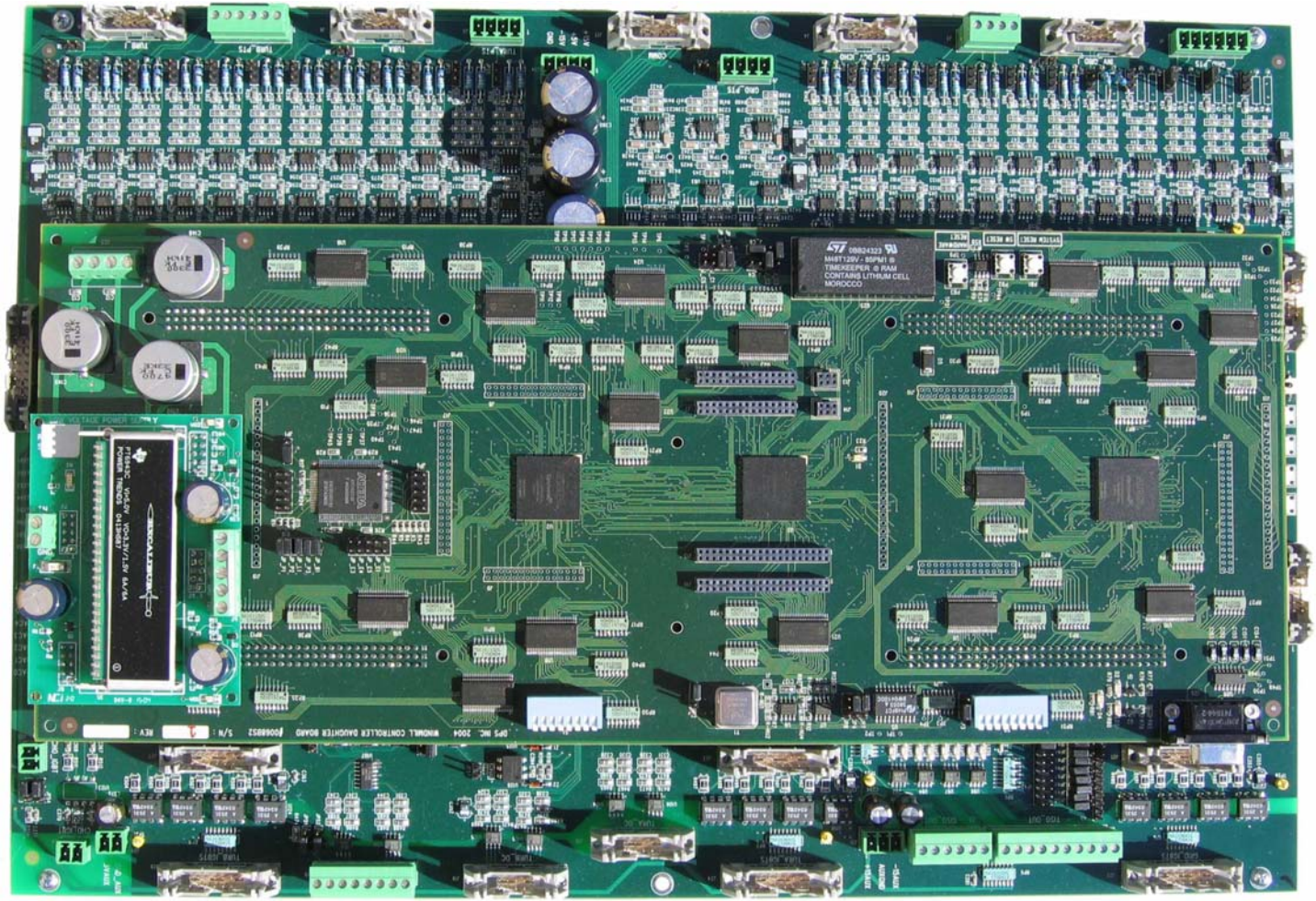


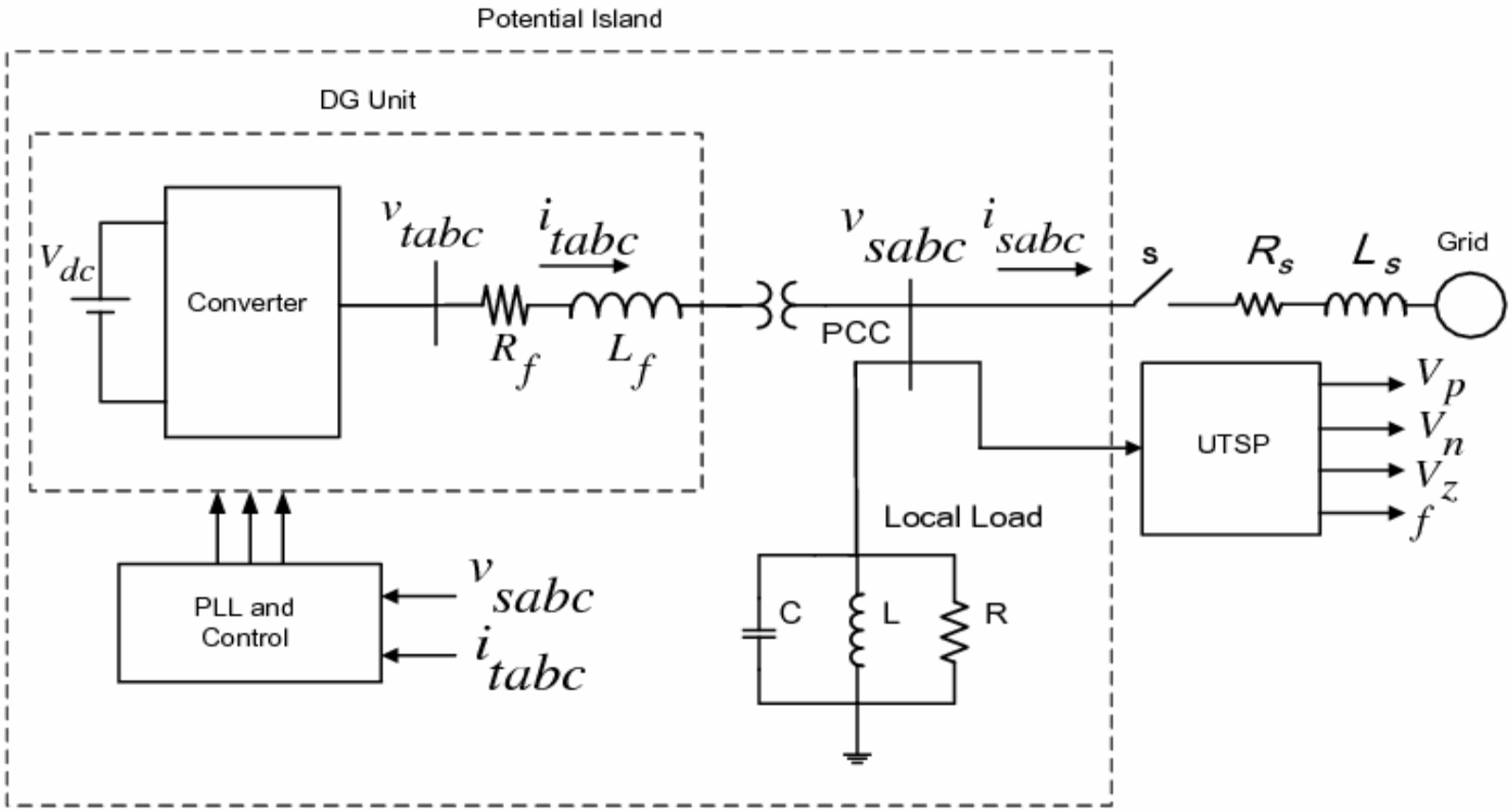
(a) negative-sequence current controller and (b) negative-sequence voltage/current resolver



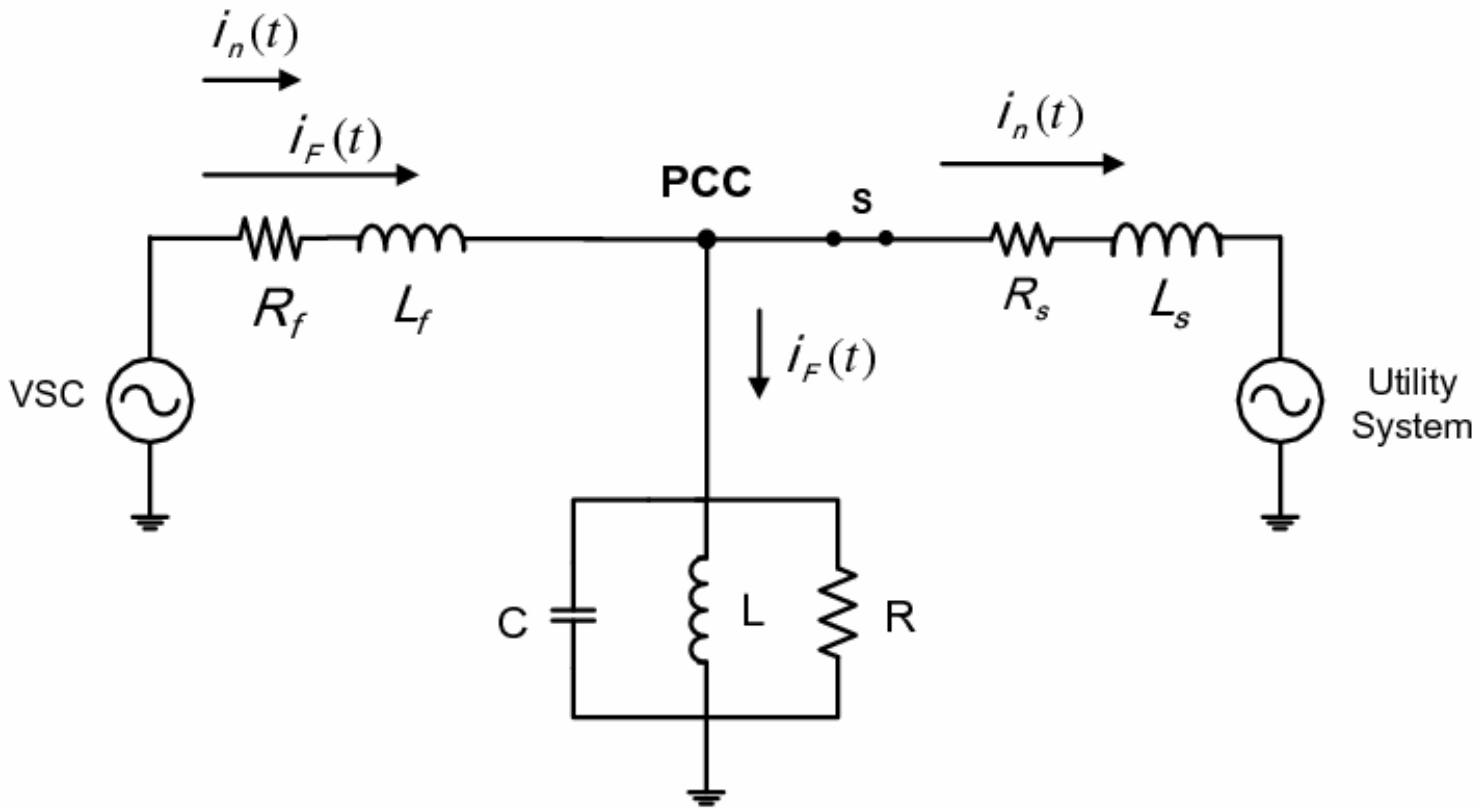
Block diagram of the converter PWM signal generator

Control Protection platform of the DG Unit including UTSP

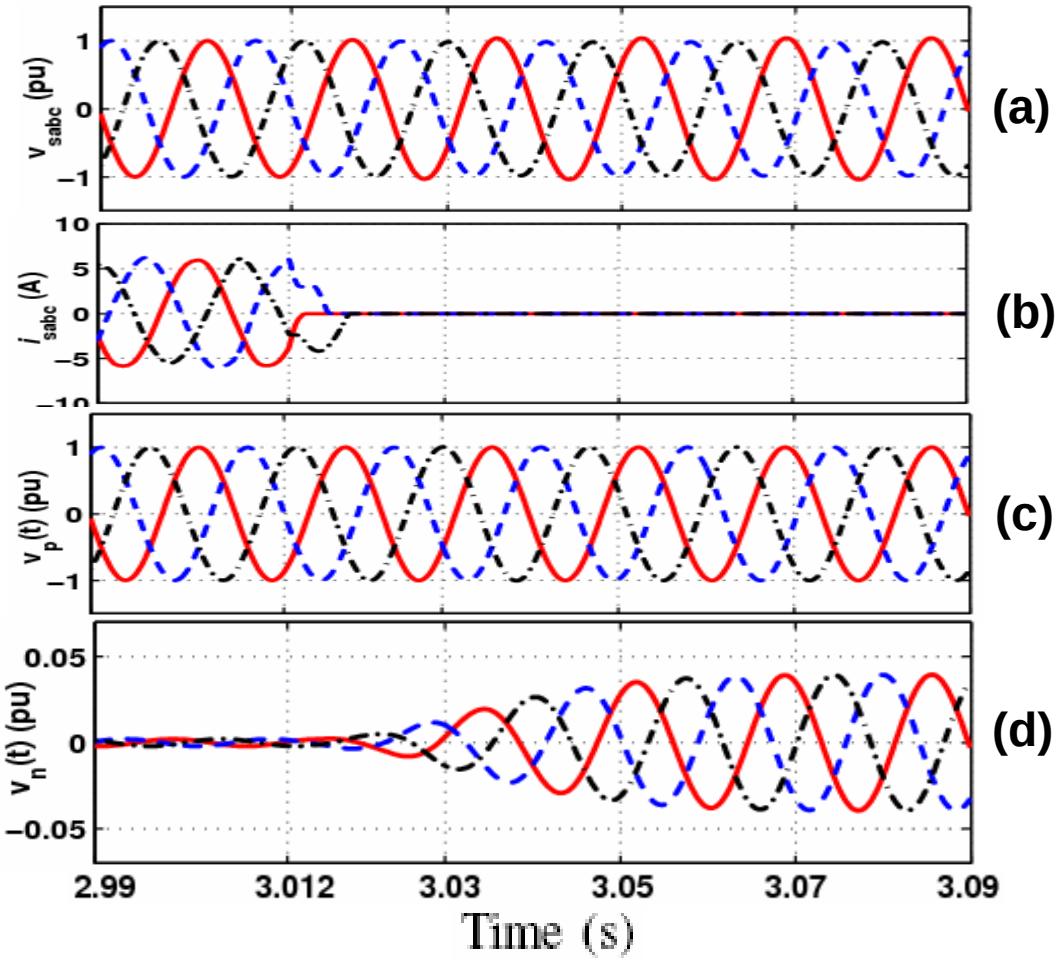




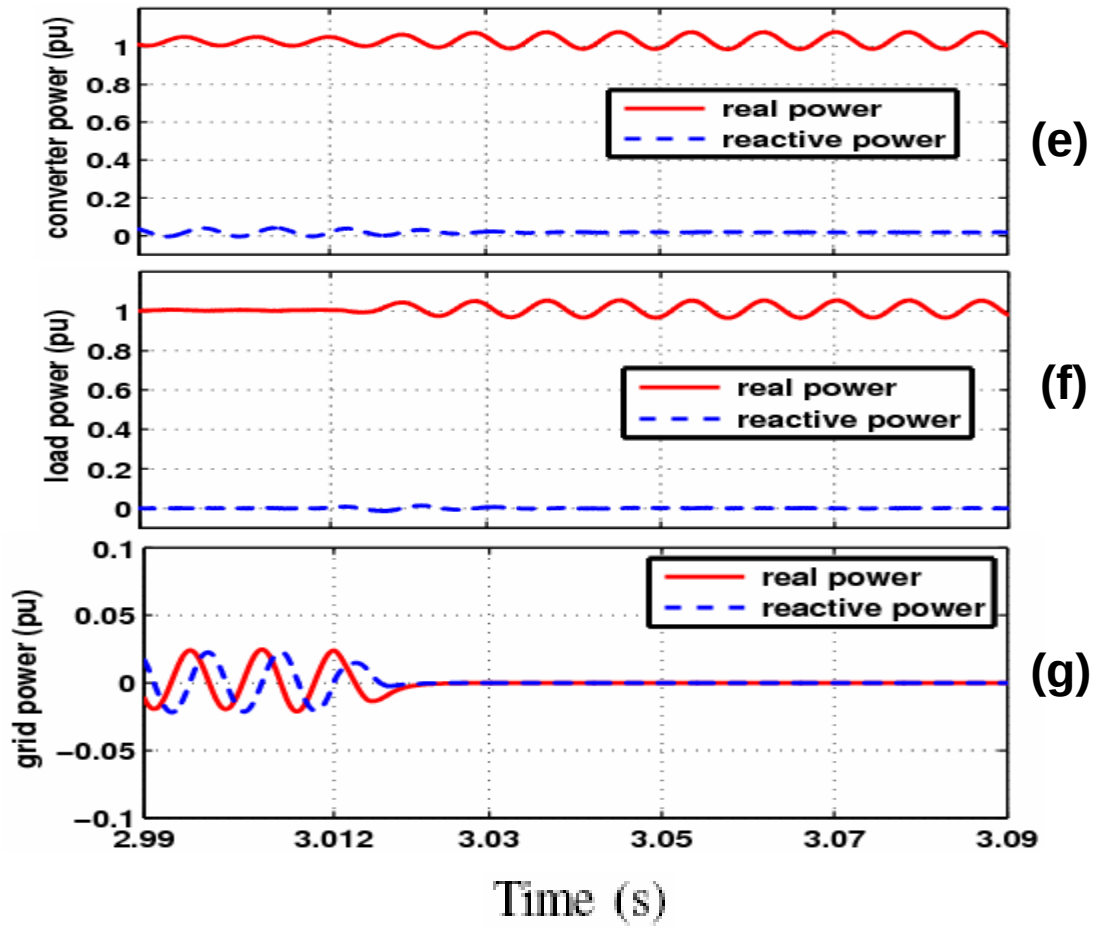
Schematic diagram of the DG unit under UL1741 anti-islanding test condition



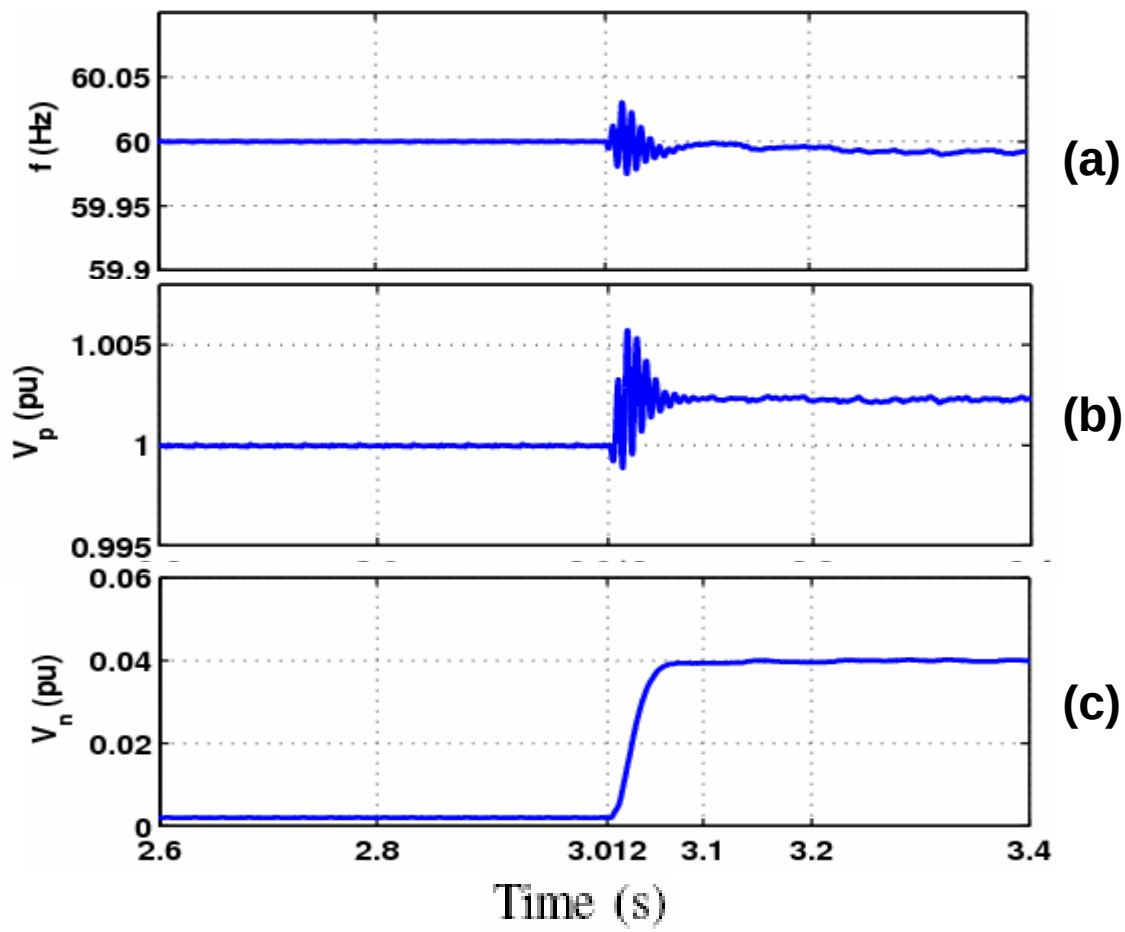
Schematic diagram of the DG system illustrating positive- and negative-sequence current injection for islanding detection



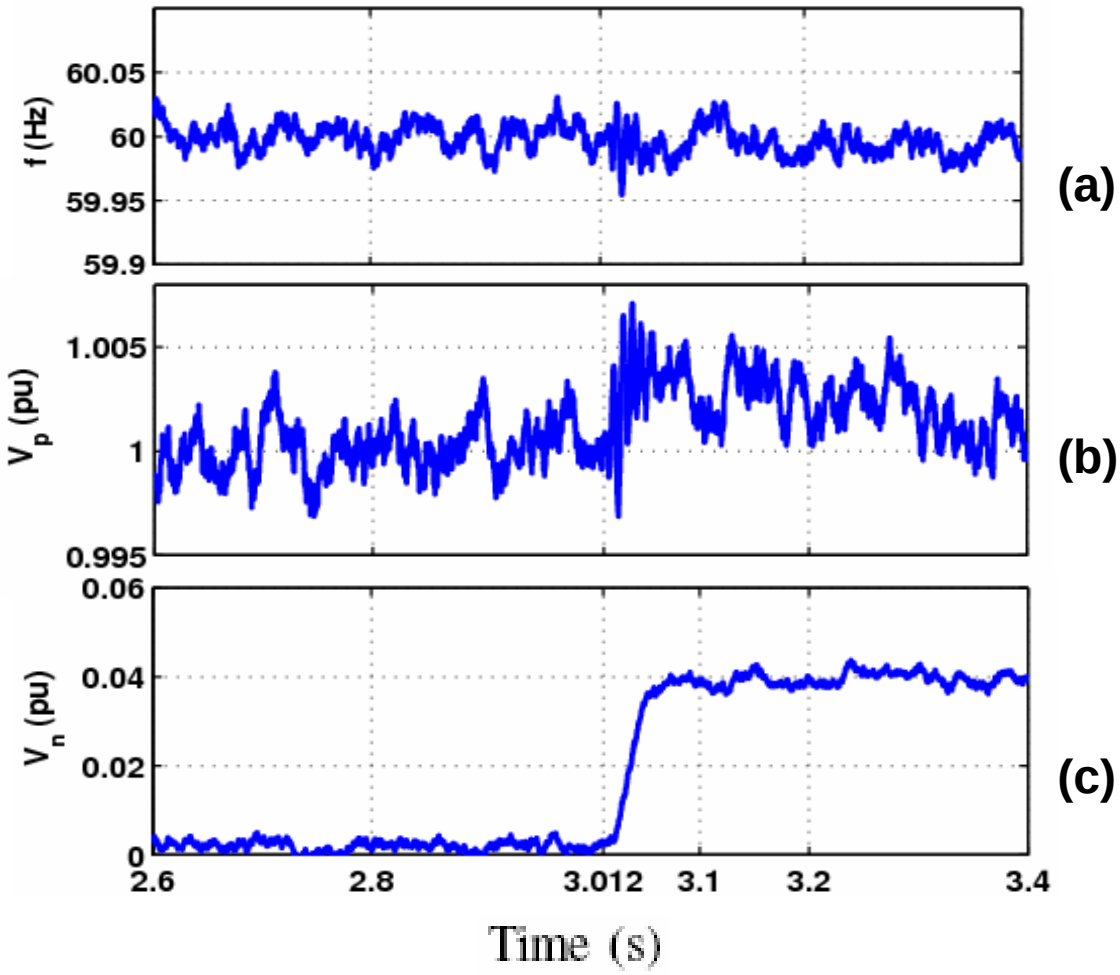
UTSP and the test system signals under UL1741 test conditions
(a) PCC voltages, (b) grid currents,
(c,d) PCC instantaneous positive-, and negative- sequence voltages



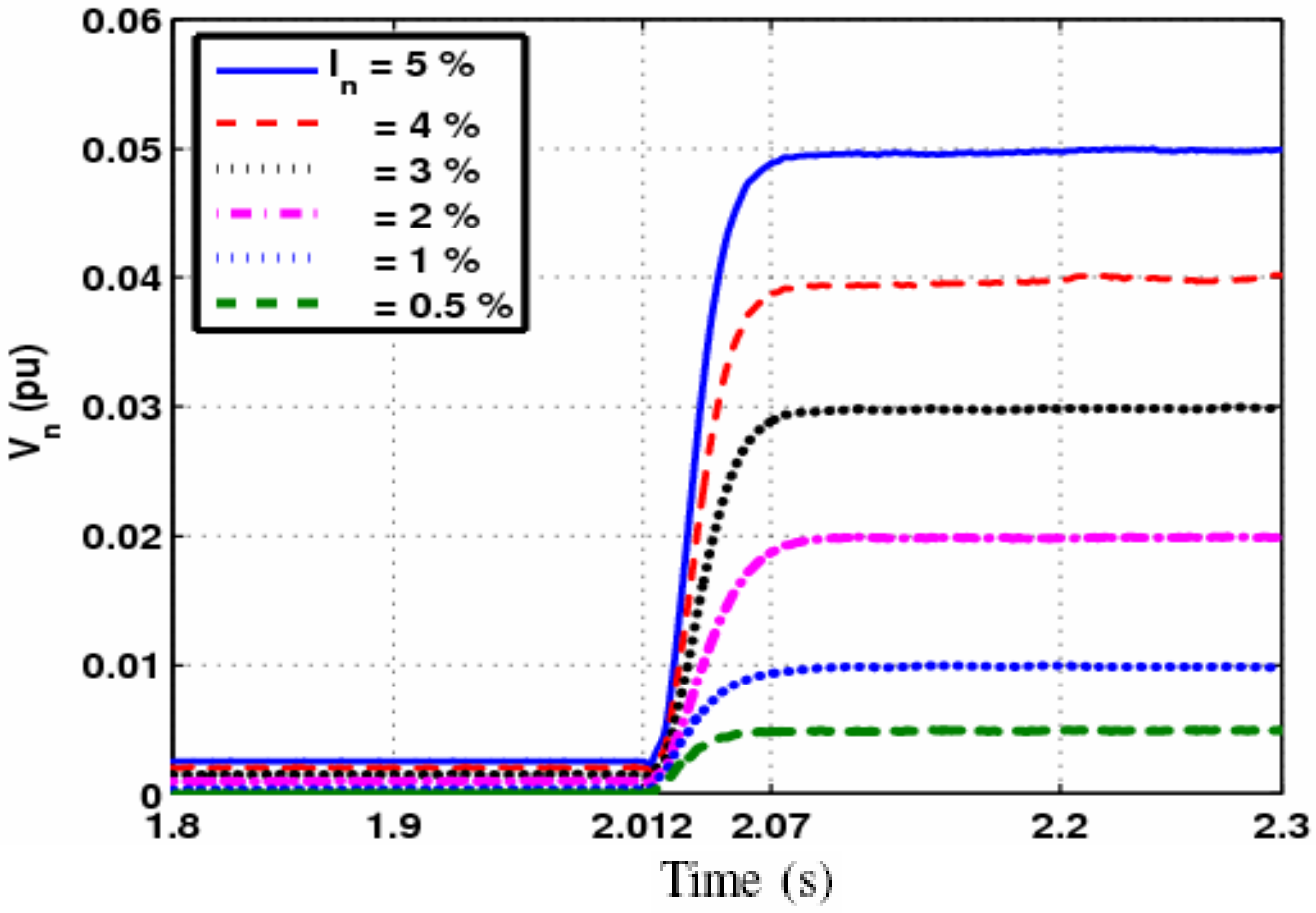
Instantaneous power components of converter, load, and grid



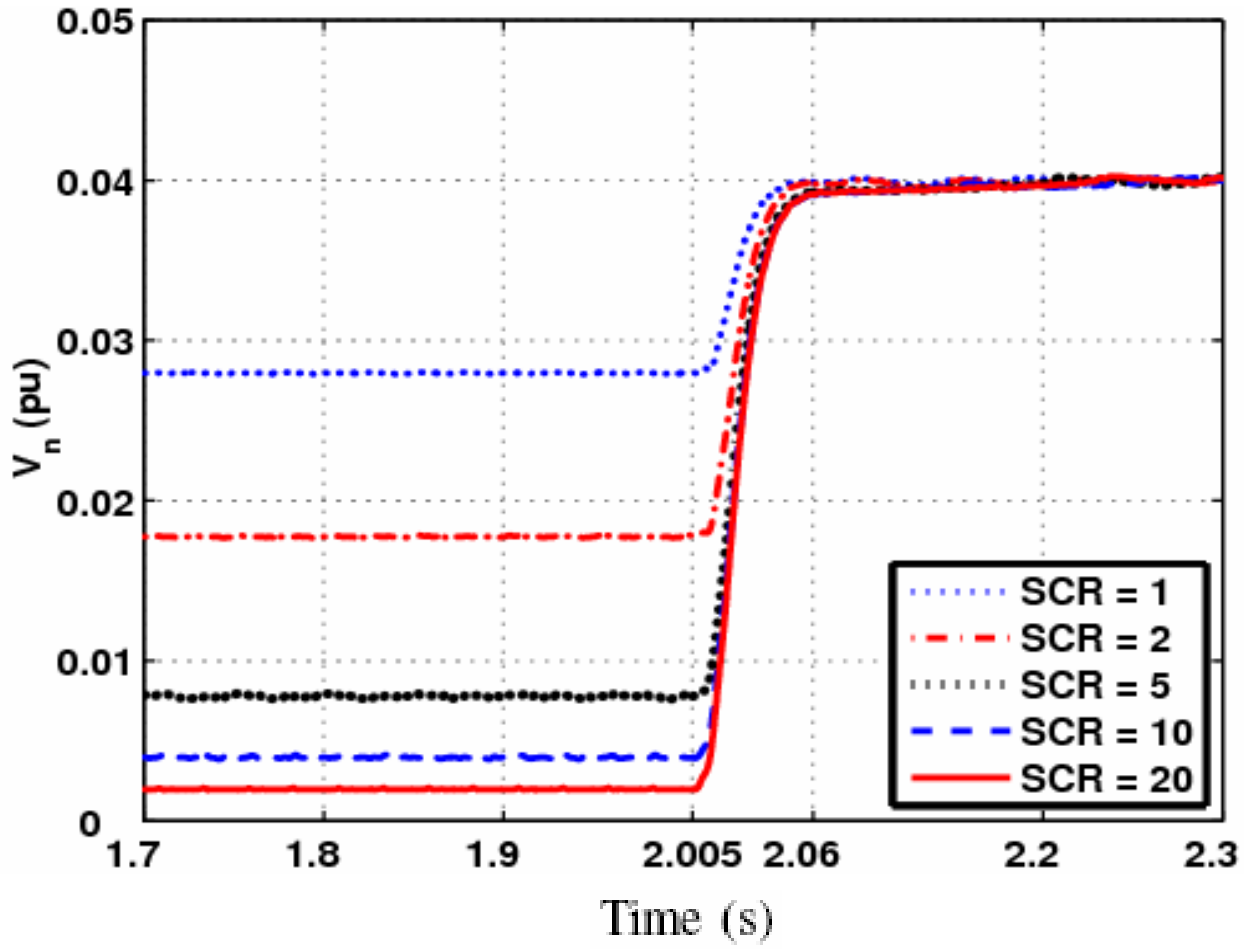
UTSP simulated output signals under UL1741 test conditions (a) estimated frequency, (b,c) PCC estimated magnitudes of positive-, and negative-sequence voltages



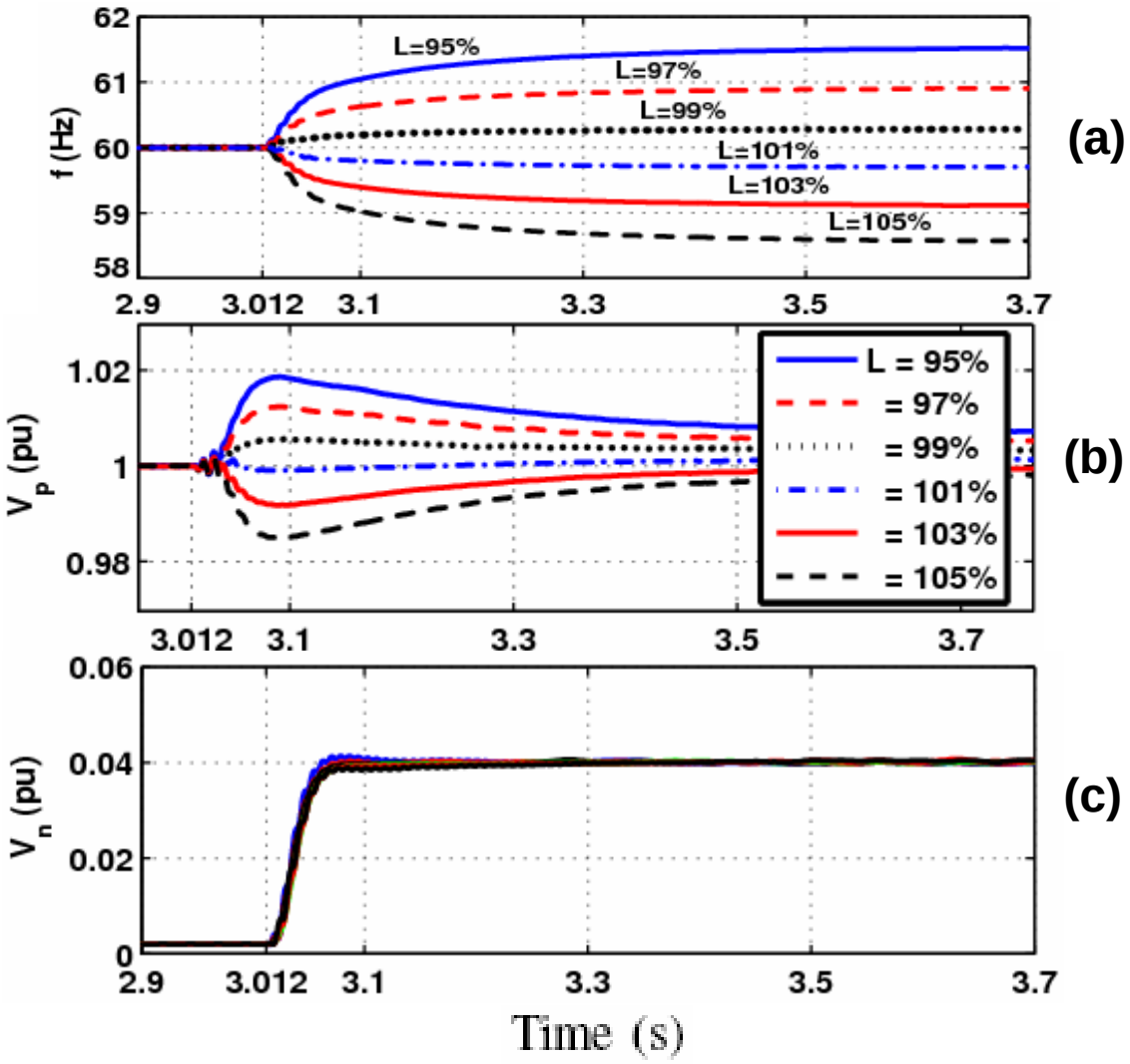
UTSP output signals under UL1741 test conditions
(a) estimated frequency, (b,c) estimated magnitudes of positive-, and negative-sequence PCC voltages



Estimated magnitude of the negative-sequence of PCC voltage for different levels of injected negative-sequence current



Estimated magnitude of the negative-sequence of PCC voltage for different SCR values



UTSP output signals when *L* changes from 95 to 105% of rated value
(a) estimated frequency, and (b,c) estimated magnitudes of positive-, and negative-sequence PCC voltages

Summary and Conclusions

- Operation of a DR unit in a microgrid requires coordinated control and protection strategies that can handle:
  - grid-connected mode of operation,
  - islanded (autonomous) mode of operation,
  - transition between grid-connected and islanded modes,
  - ride-through transients in grid-connected and islanded modes.

- Coordination of control and protection of a DR unit requires fast and reliable detection of type and severity of microgrid disturbances.

- A detection method was presented and it its analog implementation and digital hardware realization were illustrated.

- Application of the detection method for islanding detection of a DG unit, under UL1741test conditions, was demonstrated.