DigSILENT Modelling of Power Electronic Converters for Distributed Generation Networks

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Outline

– *Introduction*

– **Distributed Generation Unit Modelling**

– **Implementation in DigSILENT**

– **Simulation Models and Results**

  – Distributed Generation Unit

  – Microgrid

– **Recommendations for DigSILENT**

Introduction

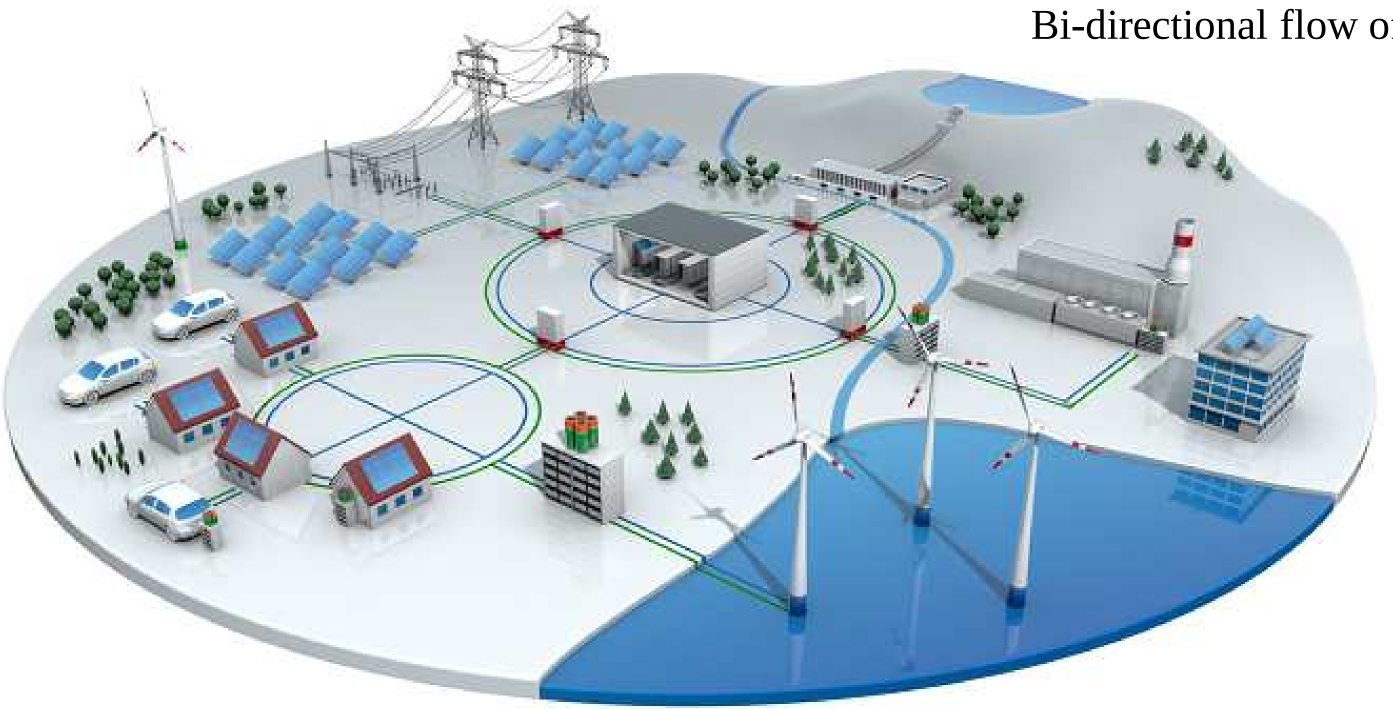
From centralisation … to decentralised systems

- Flow of power in one direction
- Active transmission + passive distribution

Distributed sources:

- Renewables (solar, wind)
- Micro-turbines
- Fuel cells

Bi-directional flow of power



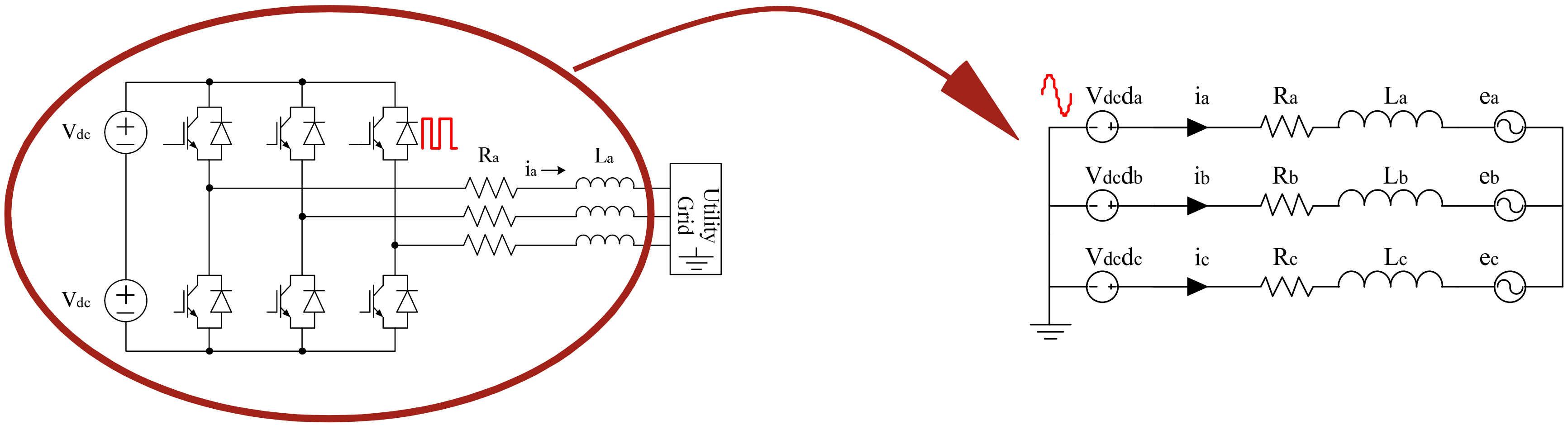
Introduction

- **Distributed Generation can**
  - Cause instability in network voltages and frequency
  - Complicate reactive power flows
  - Raise fault levels
- **Economic issues**
  - Costly changes in network configuration
  - Increased management costs for Distributed Network Operators
- **These are technical and design problems**

Investigating adverse interactions between these DG systems and the grid because of their differing responses to steady state and transient network events

Introduction

- **Simplified "averaged" DG inverter models**
  - Averaged equivalent voltage source behind reactance
  - Similar to conventional rotating machines



- **Ignoring inverter second order effects**
  - Modulation harmonics, sampling delays, closed loop gain settings
  - Presenting real physical inverter system is at best uncertain

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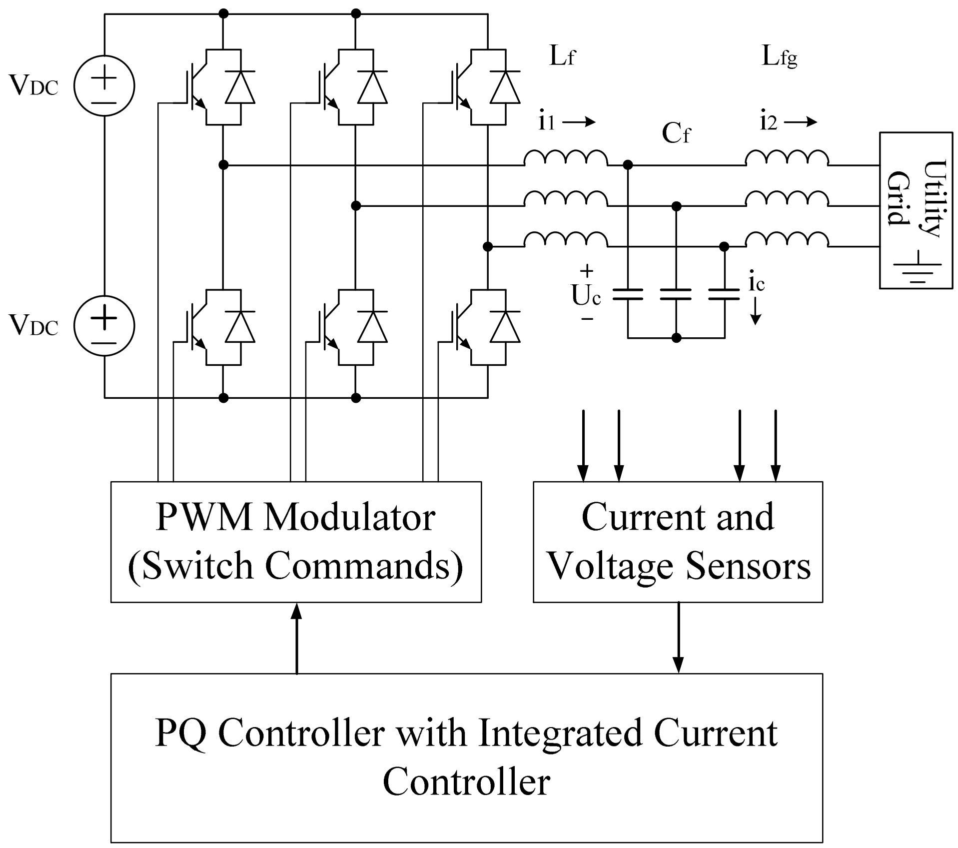
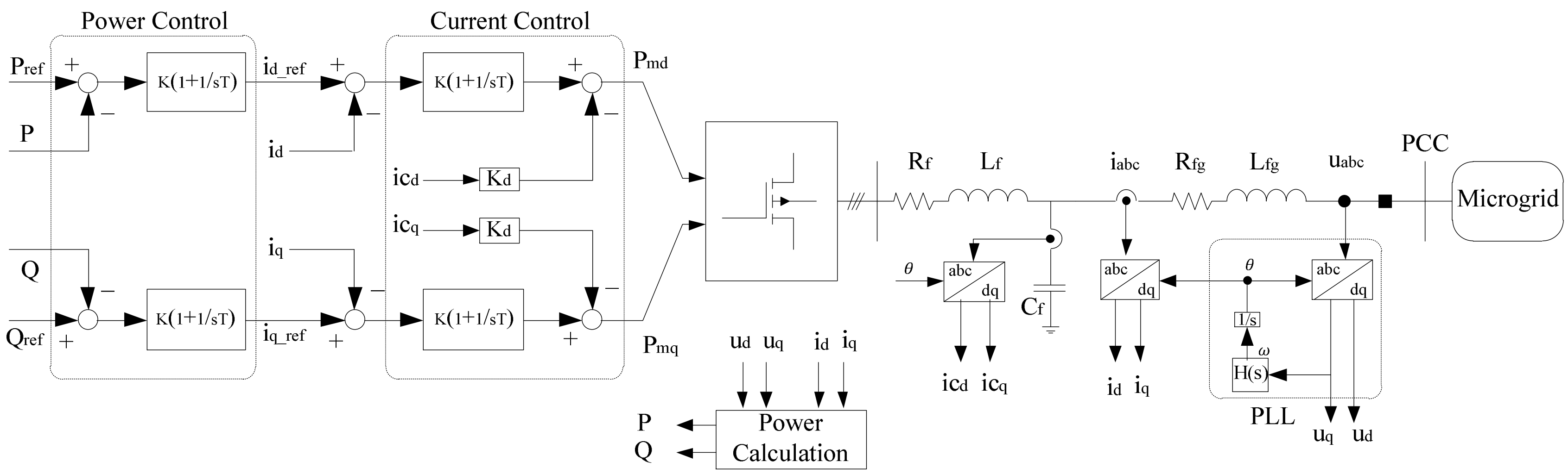
Distributed Generation Unit Modelling



Distributed Generation Unit Modelling



Power Control

- Regulating real and reactive powers injected to the grid system
- PI regulator to reduce transients injected into the distribution system from the converter

Current Control

- PI regulator in synchronous frame
- Active damping with LCL filter
- Achieving better switching frequency harmonic attenuation with reduced size filter components

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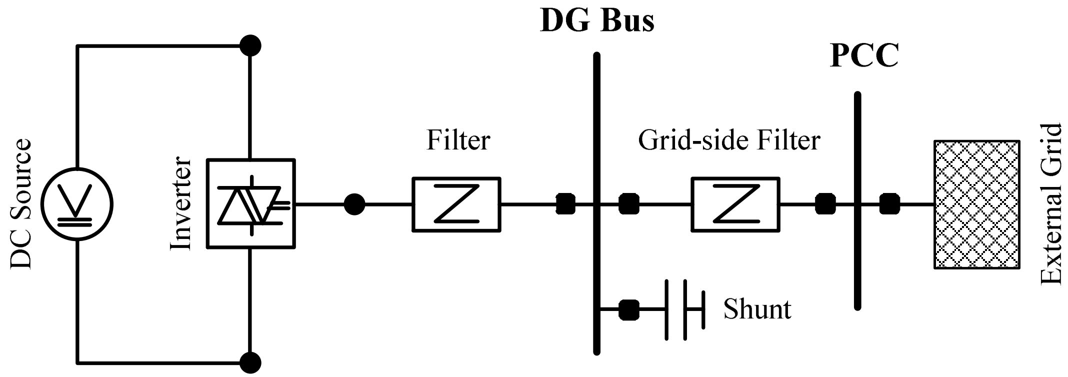
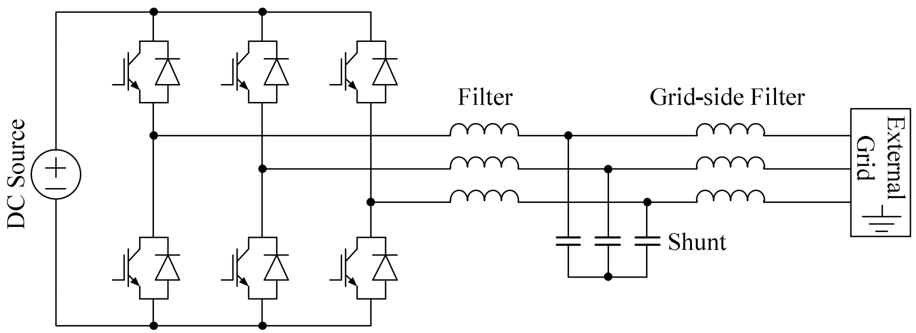
Implementation in DigSILENT

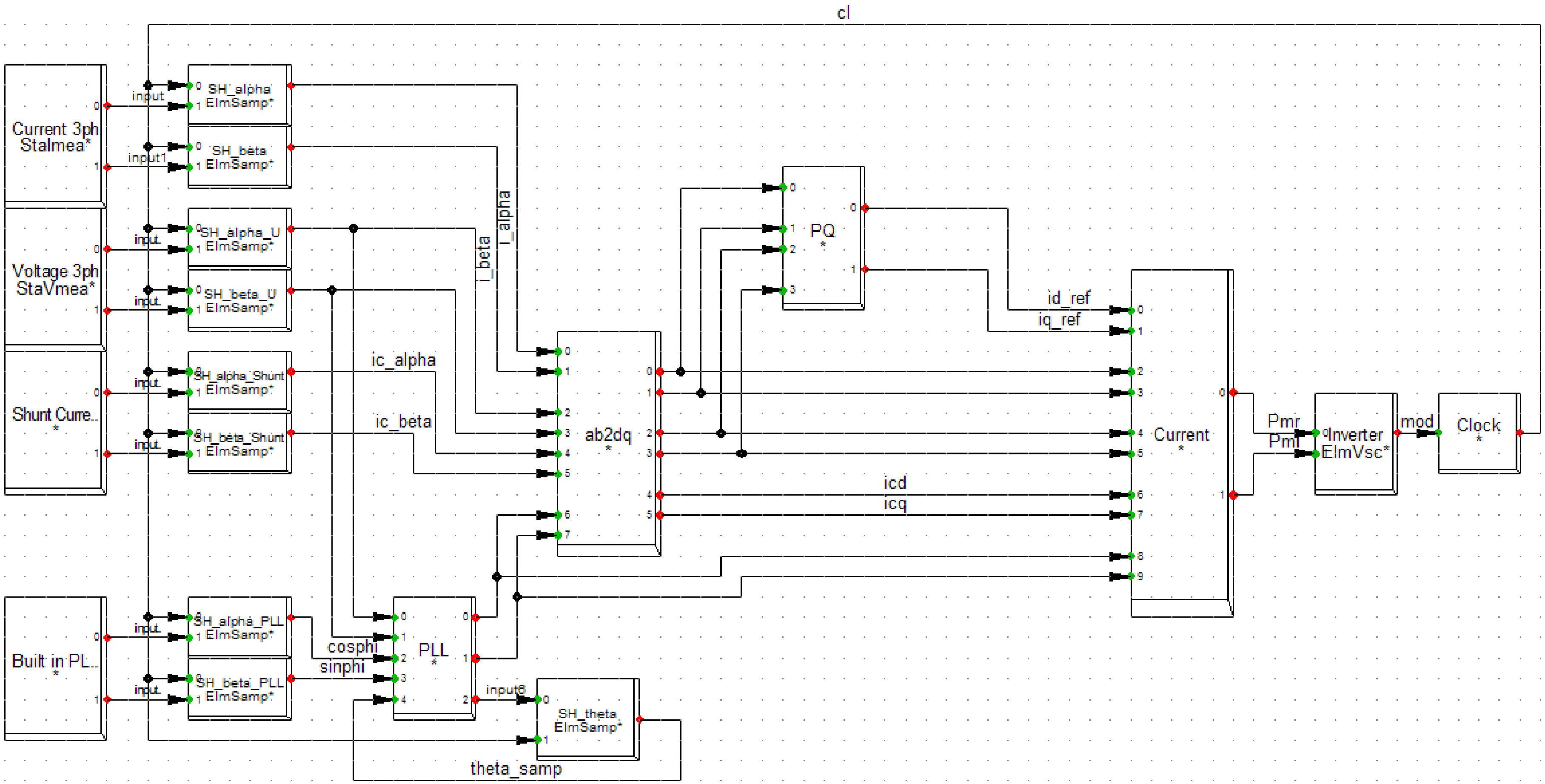
- Inverter modelling based on the "*PWM converter*" model with two DC connections
- DC source to represent the primary source of power
- Using two "*Common Impedances*" for inverter-side and grid-side inductors, and a "*Shunt/Filter C*" located in between these inductances for filter capacitance





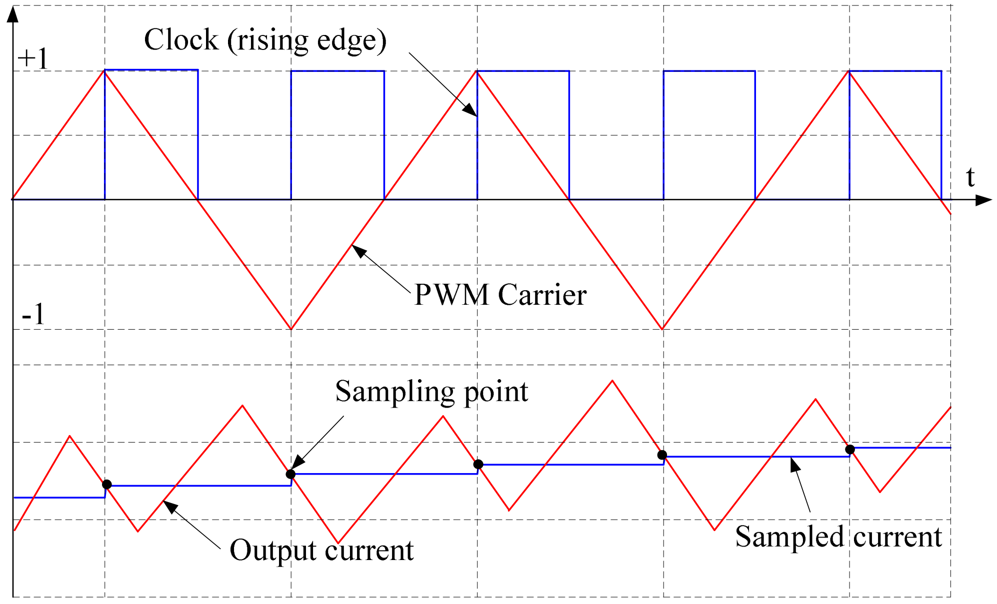
Implementation in DigSILENT

- **Controller Frame**



Implementation in DigSILENT

- **Sampling and Clock Generation**



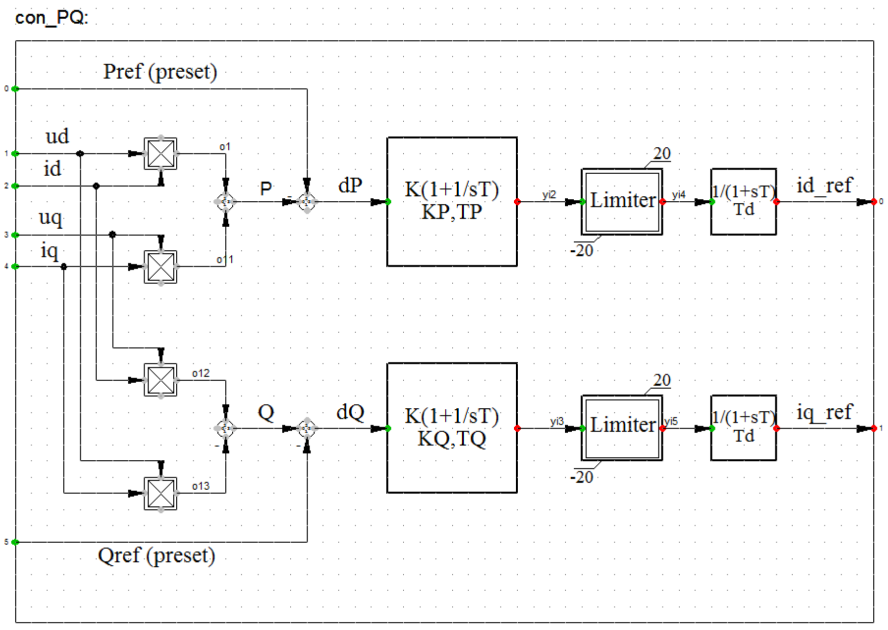
Implementation in DigSILENT

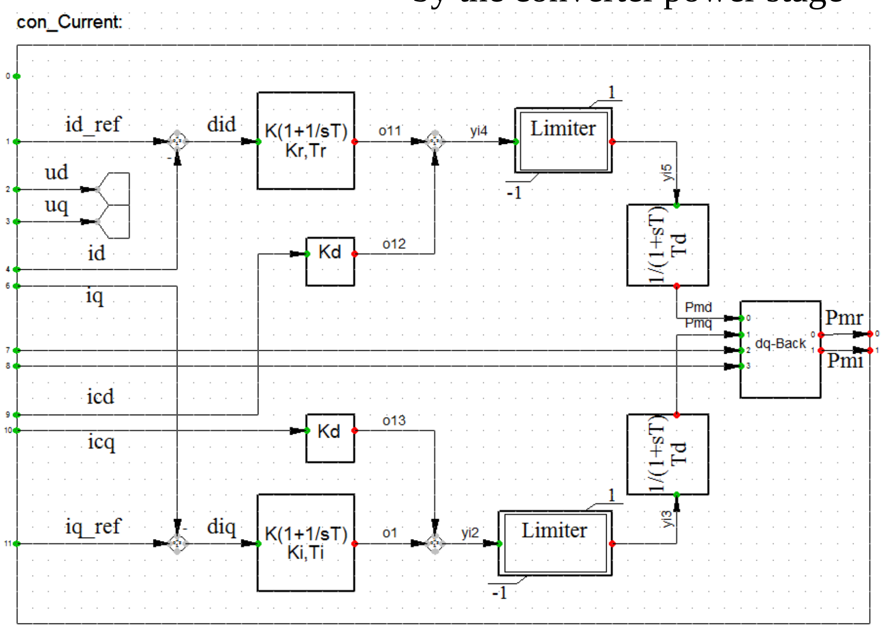
Power Control

- Calculating the actual real and reactive power for the converter $\begin{cases} P = u_d i_d + u_q i_q \\ Q = u_q i_d - u_d i_q \end{cases}$
- Higher level of control generates the power setpoints (P_{ref} & Q_{ref})
- Final outputs $\rightarrow$ i_{d_ref} & i_{q_ref}

Current Control

- State of the art closed loop current regulator [1] $K_p \approx \frac{\omega_c (L_f + L_{fg})}{V_{DC}}$ $\tau_i = 10/\omega_c$
- Capacitor currents added as additional feedback signals after the PI regulators, with a damping gain of K_d
- Final outputs $\rightarrow$ The commanded dq frame voltages, required to be produced by the converter power stage





[1] D. G. Holmes, T. A. Lipo, B. P. McGrath, and W. Y. Kong, "Optimized Design of Stationary Frame Three Phase AC Current Regulators," *Power Electronics, IEEE Transactions on,* vol. 24, pp. 2417-2426, 2009.

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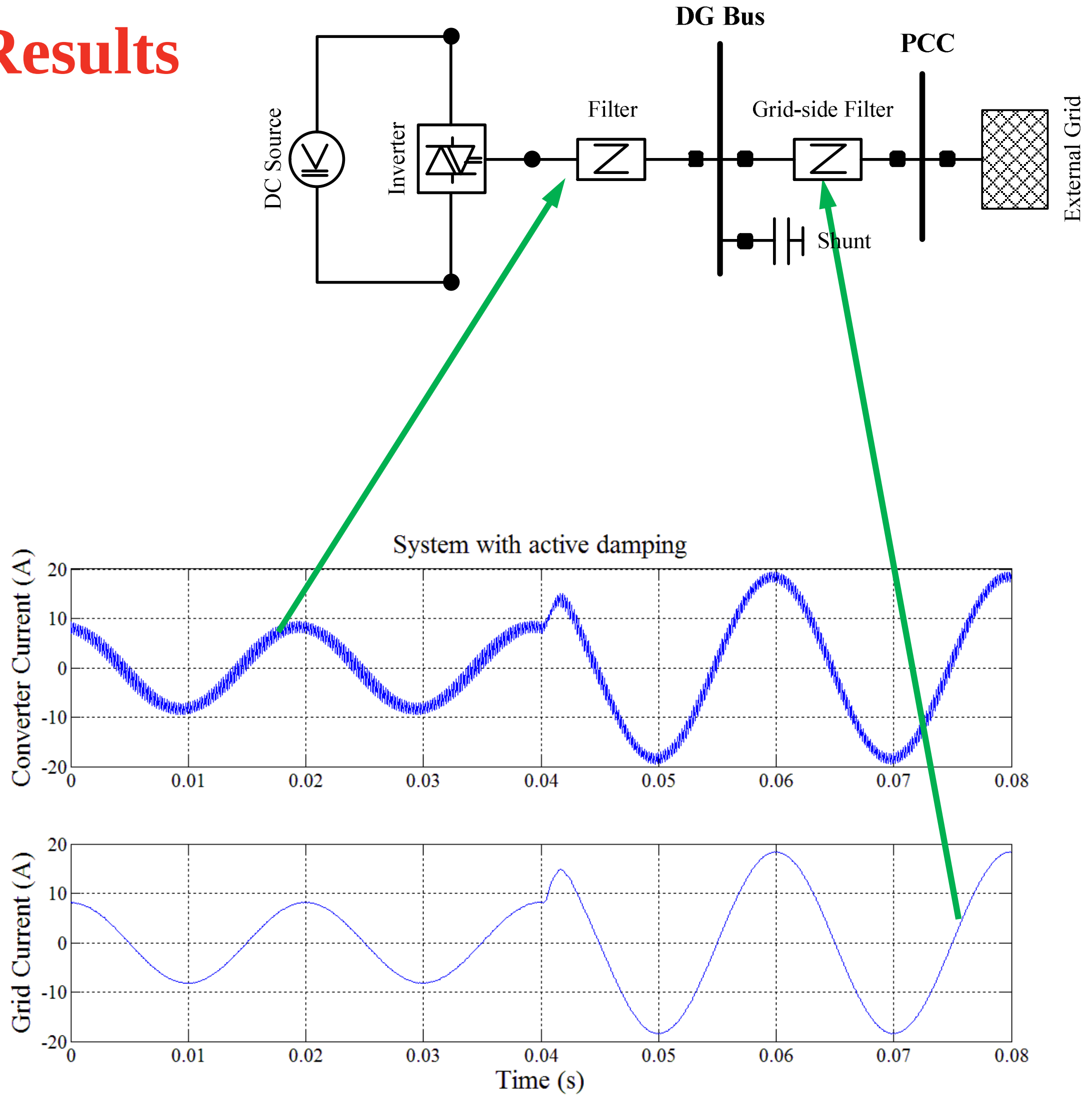
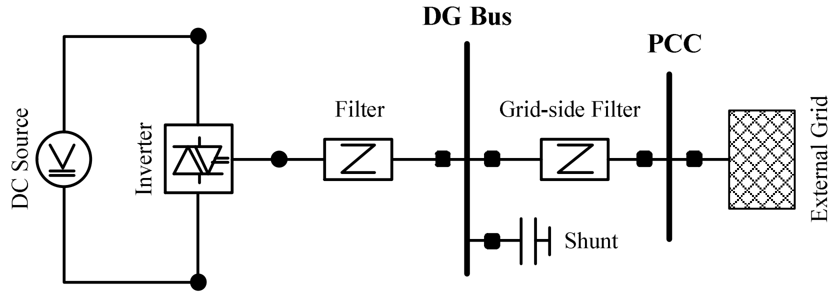
Simulation Models and Results

Distributed Generation Unit

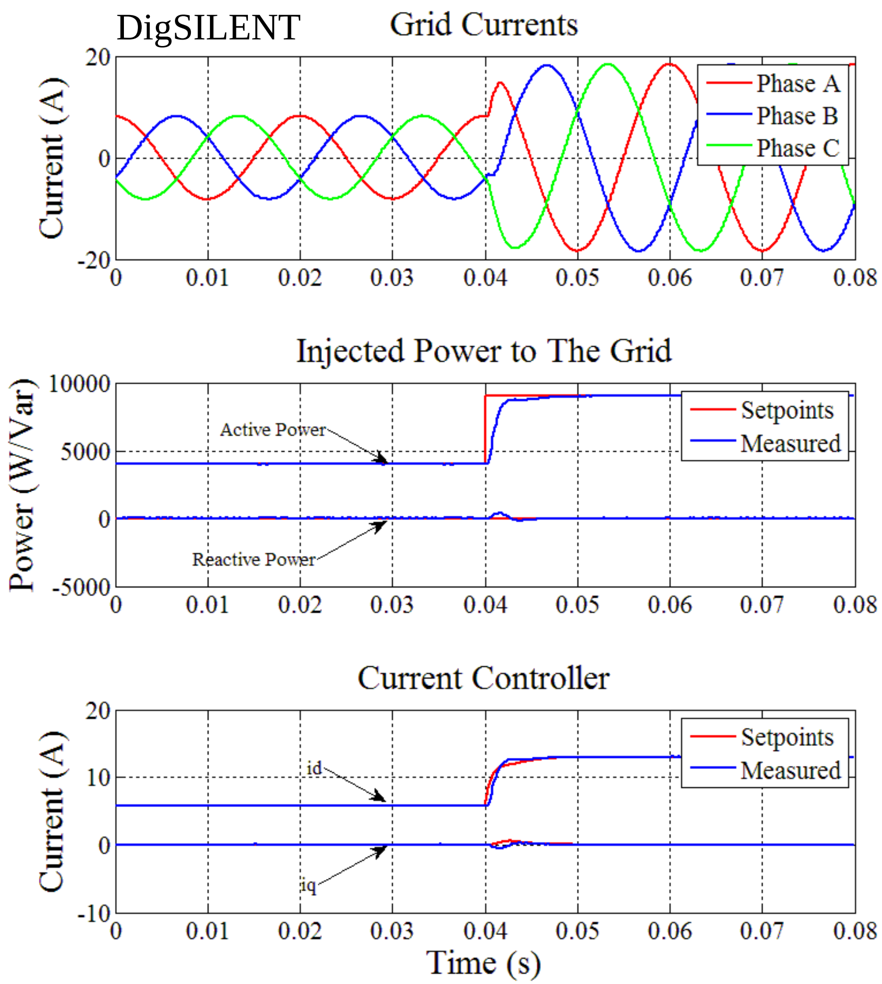


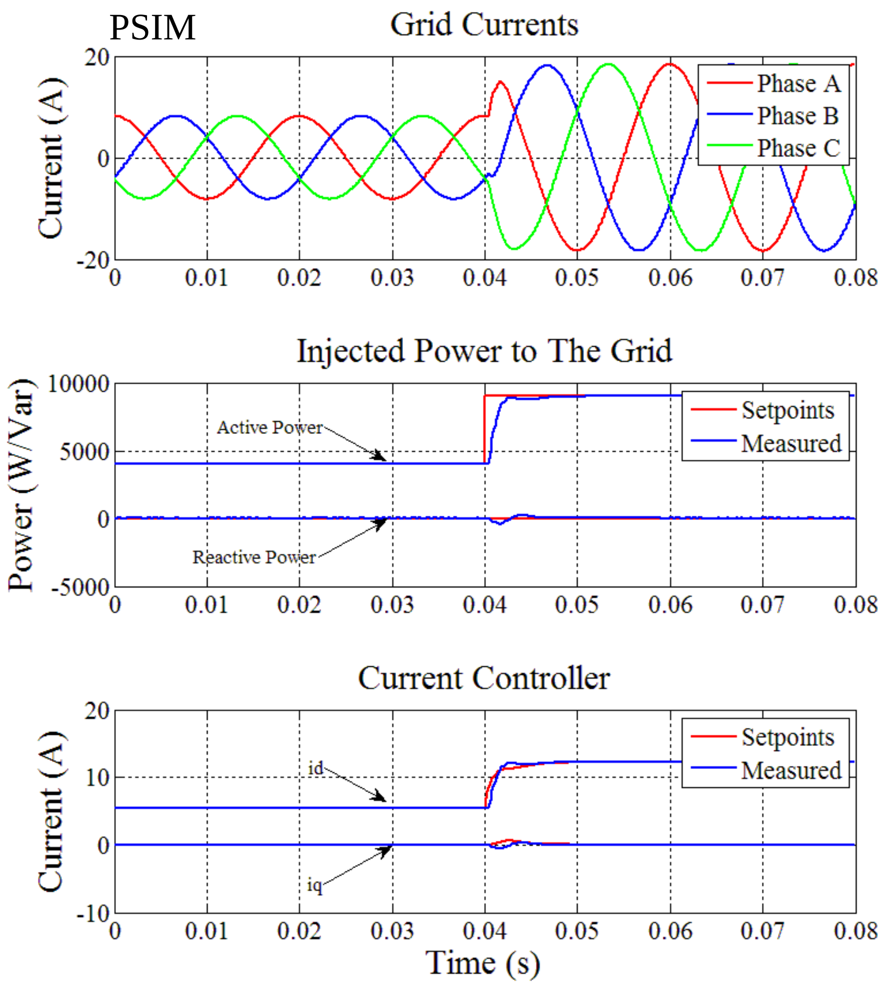
Parameters	Value
Filter (L_f)	12.7 (mH)
Grid-side Filter (L_{fg})	1.27 (mH)
Shunt (C_f)	15 (μF)
Sampling frequency	10 (kHz)
Switching frequency	5 (kHz)
DC Source	1000 (V)
Grid voltage (RMS)	400 (V)
Grid frequency	50 (Hz)
Power rating	10 (kW)

Simulation Models and Results



Distributed Generation Unit





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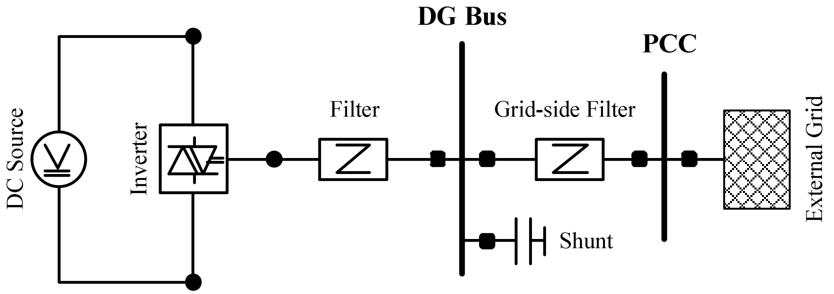
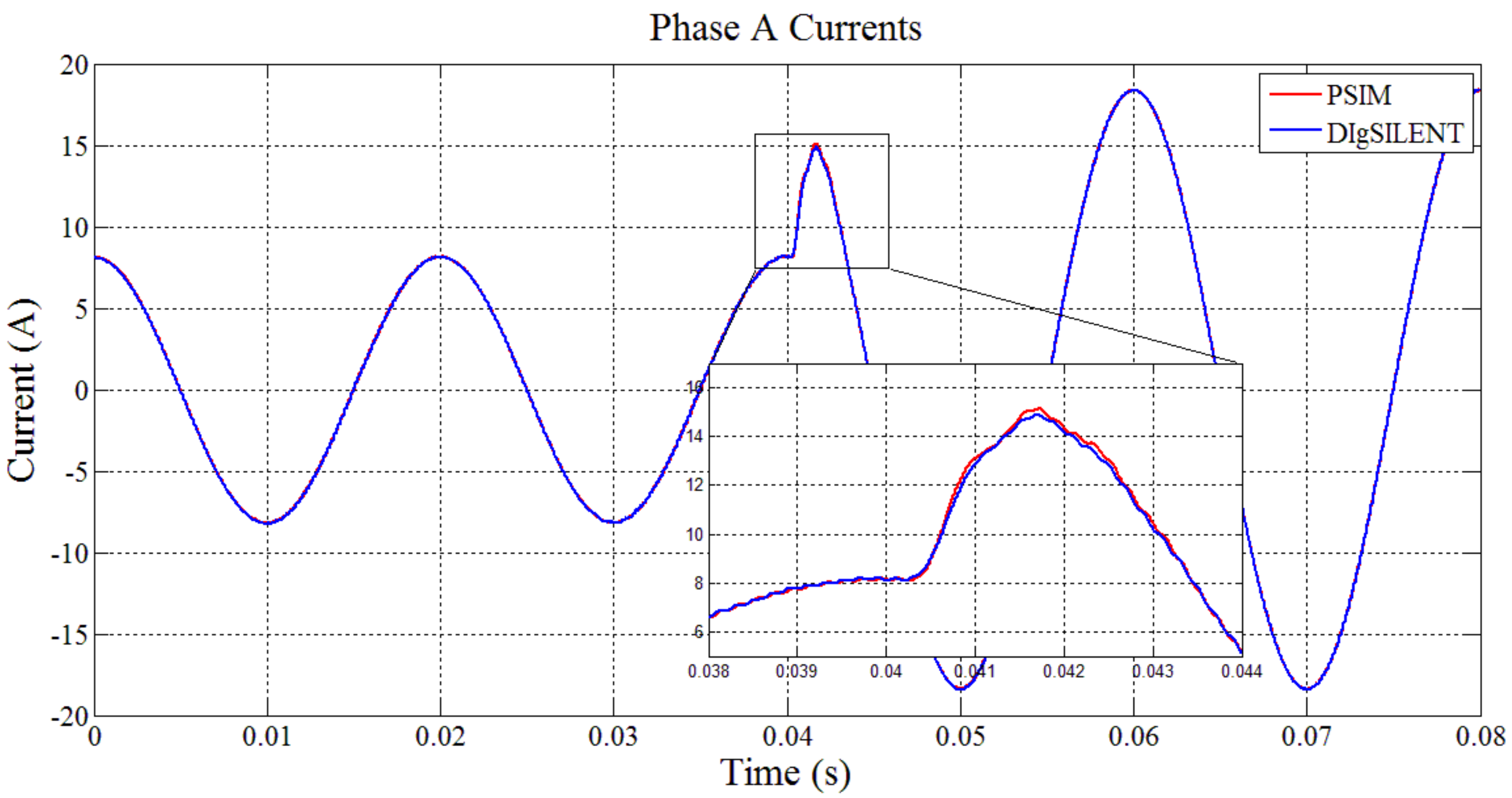
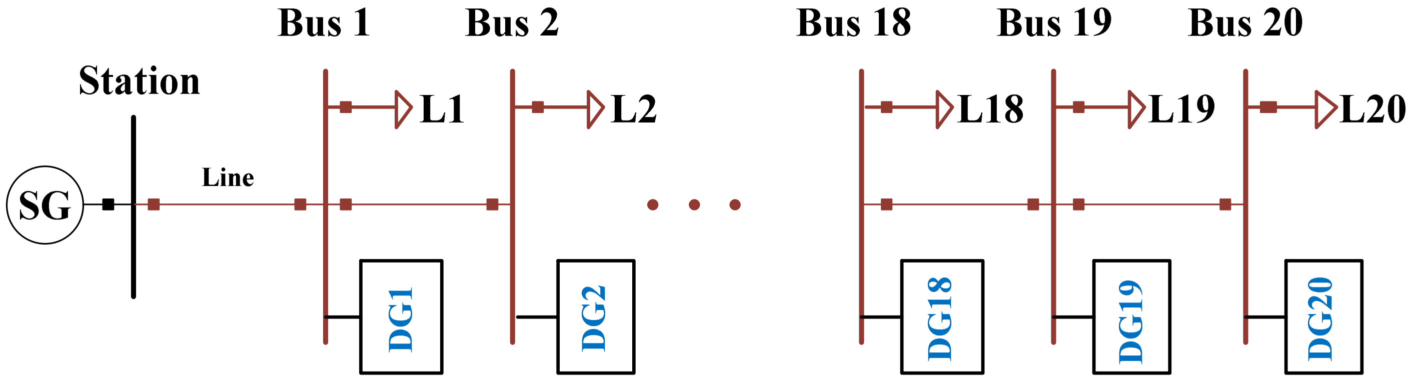


Distributed Generation Unit



Simulation Models and Results

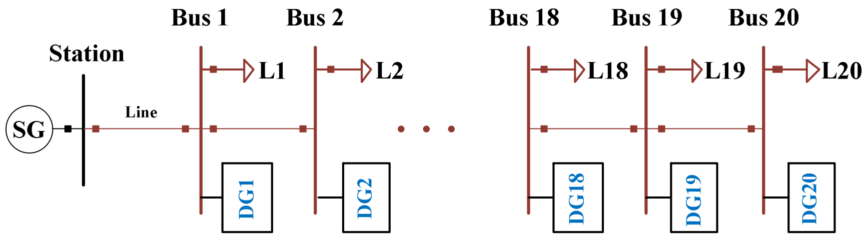
Microgrid



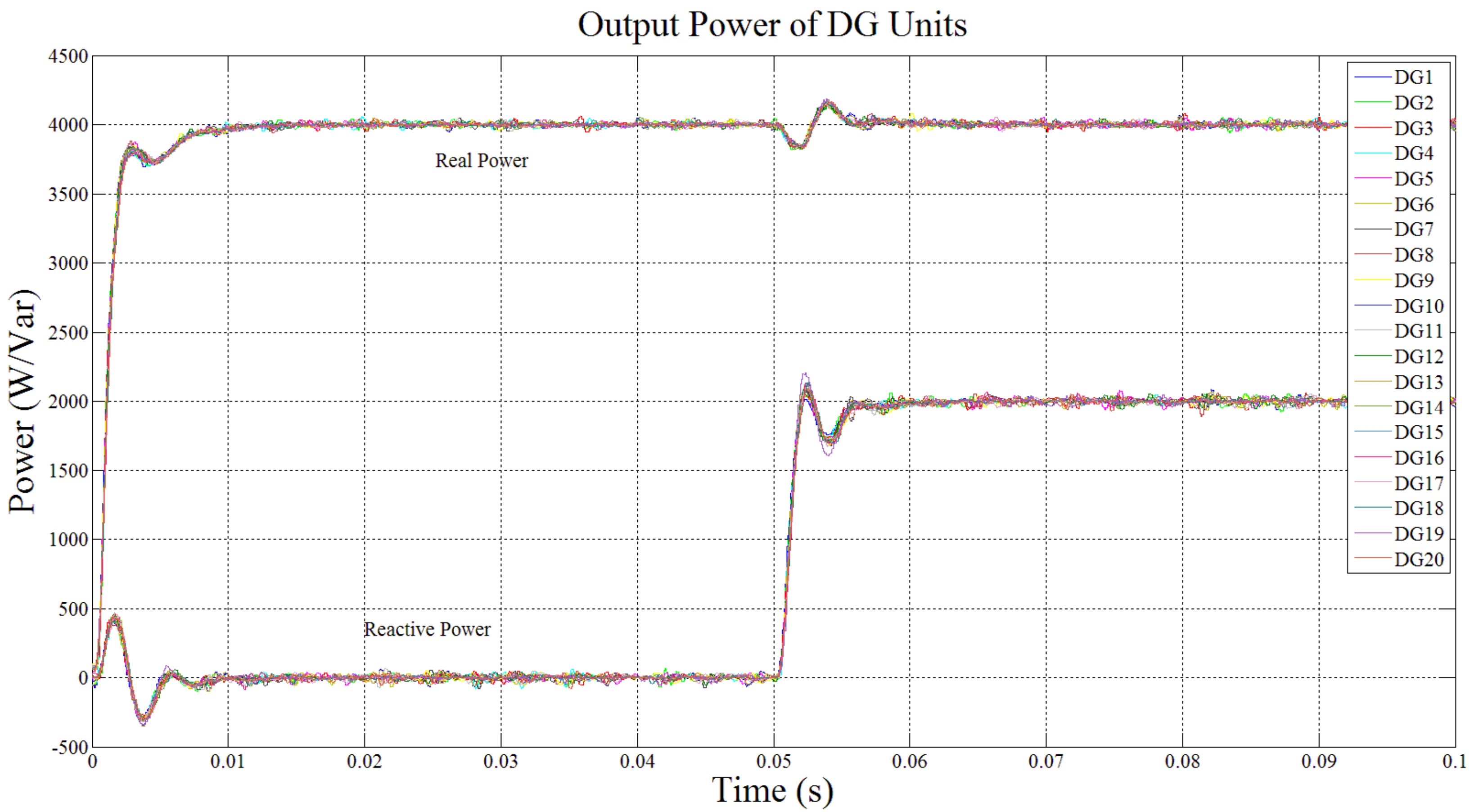
SG Data	Value
Rated power	850 kVA
Voltage rating	400/231 V
Rated power factor	0.8

DG Parameters	Value
Number of DG units	20
Switching frequency	5 – 6 kHz
Total installed load	200 kW – 150kVar
DG penetration	40 % (max)

Simulation Models and Results



Microgrid



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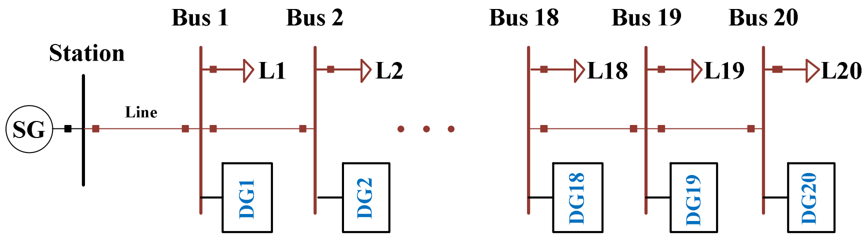
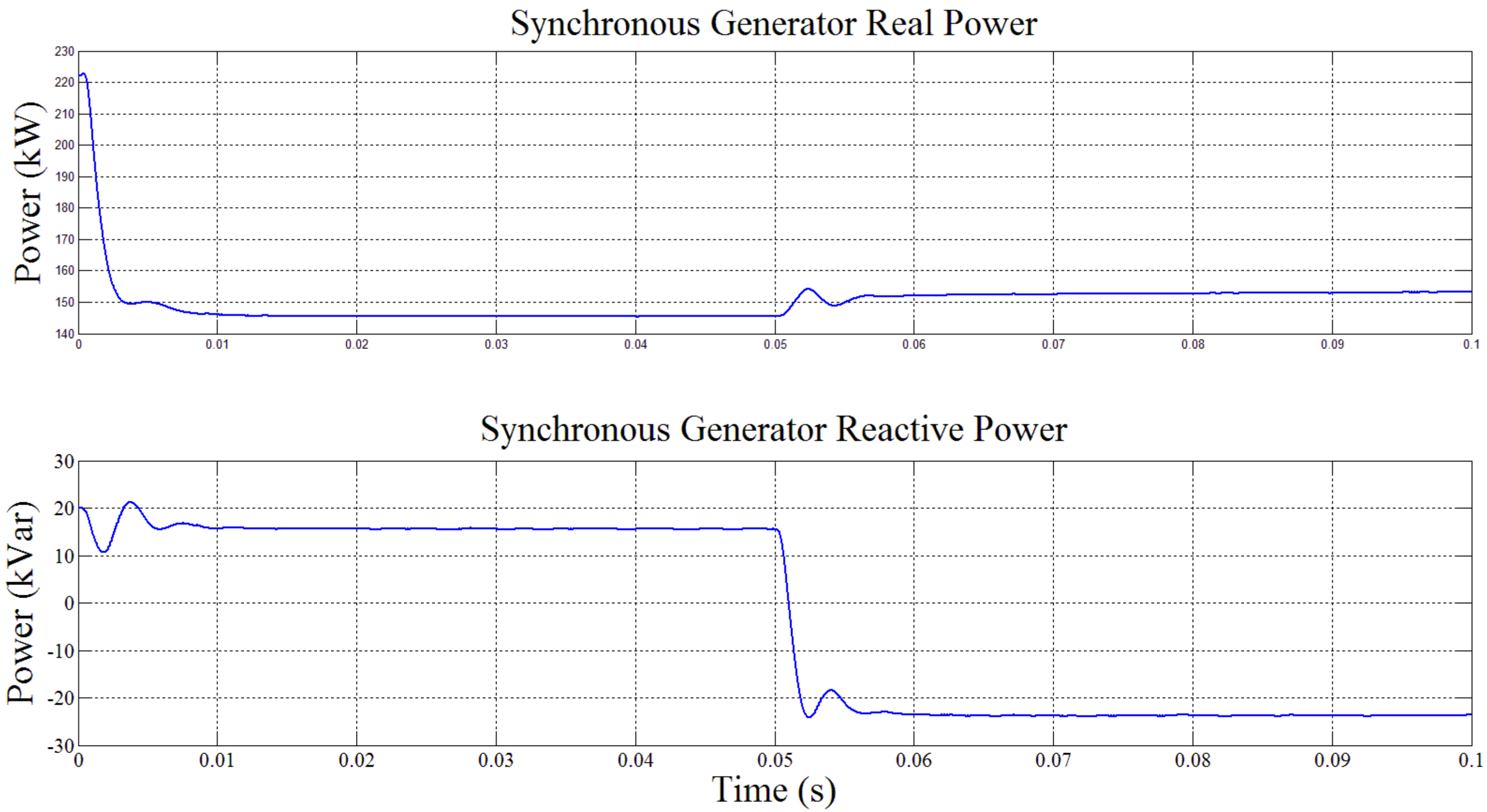


Microgrid



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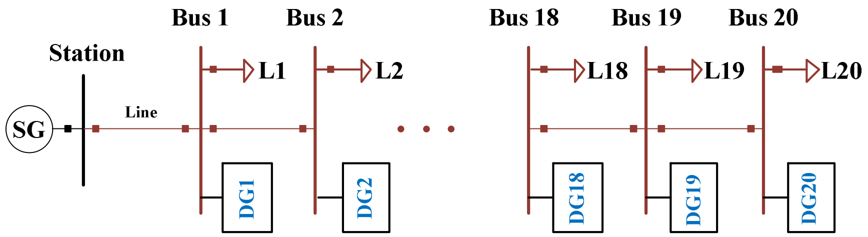

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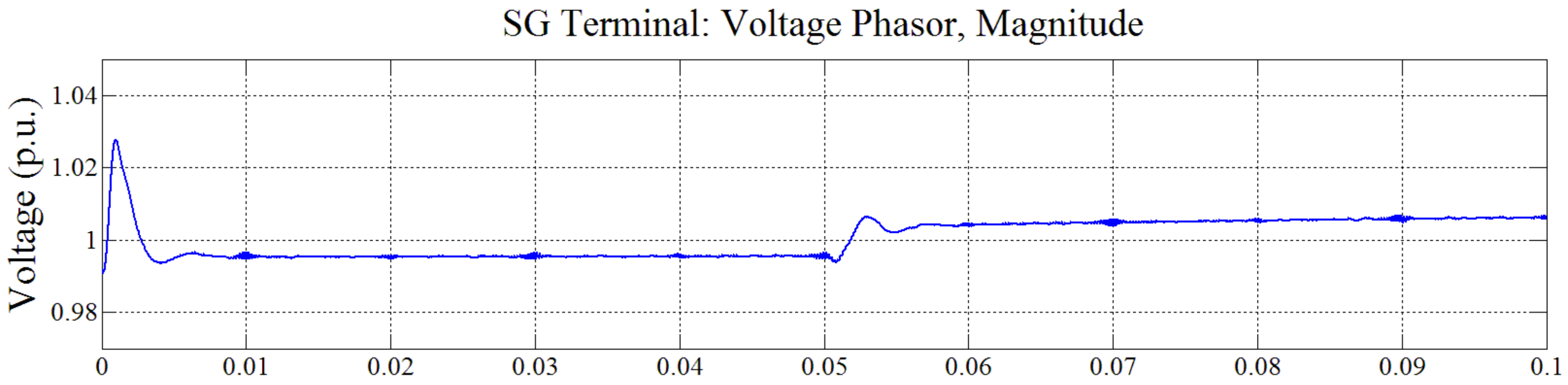

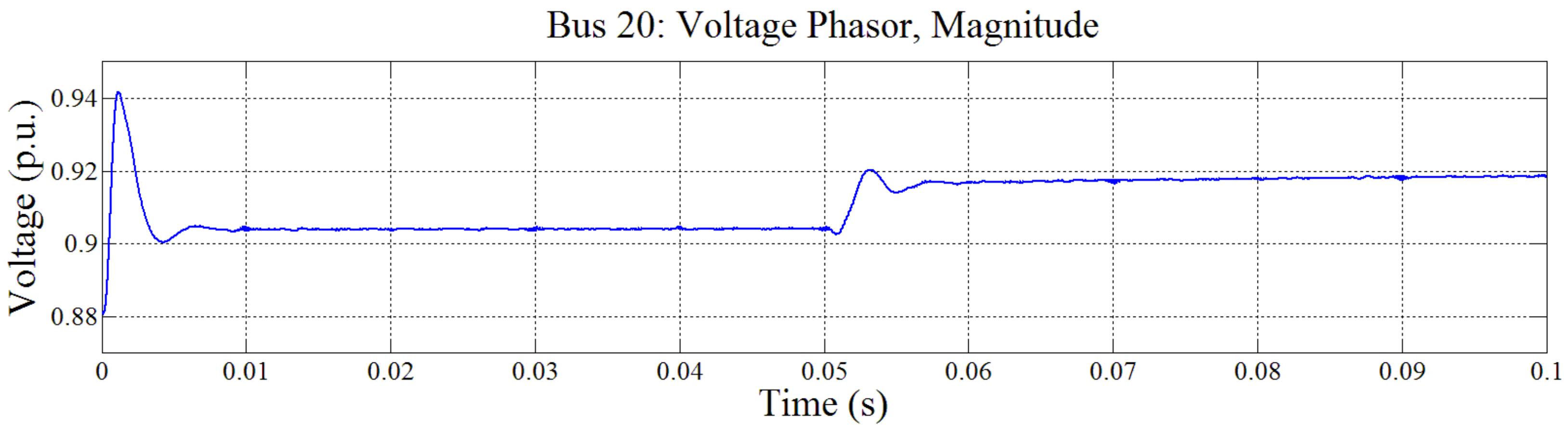

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Recommendations for DigSILENT

- New power elements
  - *Single-phase PWM converter*,
  - *4-leg PWM converter*
- Iteration removal
- Increased numerical stability

Thank you