University of Toronto
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Impact of Power Management Strategies on Micro-Grid Dynamic Performance

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Outline

- Definitions
- Assumptions
- Benchmark System(s)
- Investigation Tools
- Power Management and DR Controls
- Study Results
- Conclusions

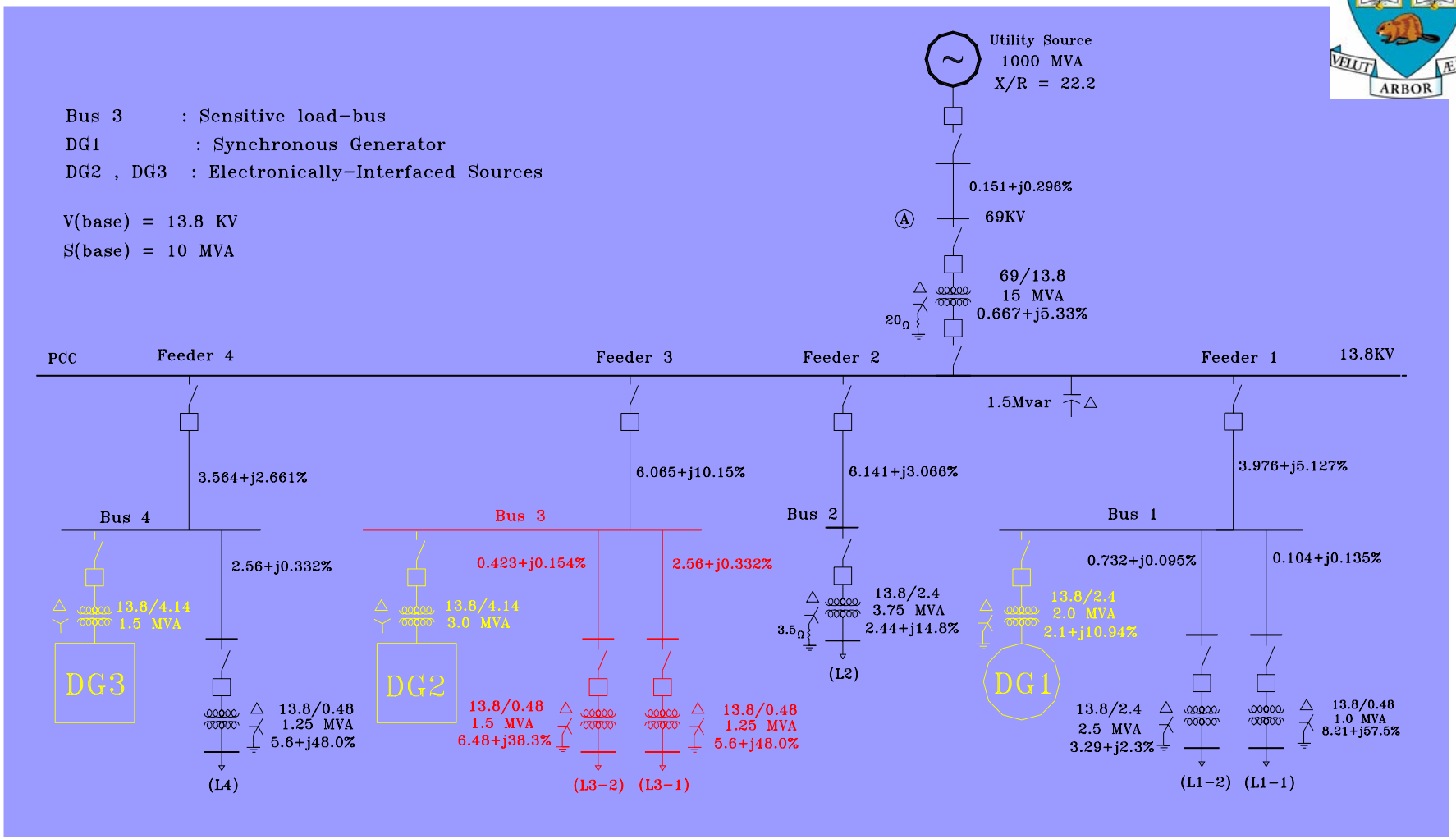
Definitions

- A Distributed Resource (DR) unit includes either a Distributed Generation (DG) unit, a Distributed Storage (DS) unit, or a hybrid of DG and DS units.
- A micro-grid is a cluster of loads and distributed resource units serviced by a distribution grid and capable of
  - operation in a grid-connected mode,
  - operation in an autonomous (islanded) mode,
  - ride-through between the above two modes.

Assumptions

- Radial distribution system
- Dispatchable DR units
- No spinning reserve or back-up units
- No communications
- Frequency deviation (and frequency control) considered

Benchmark System



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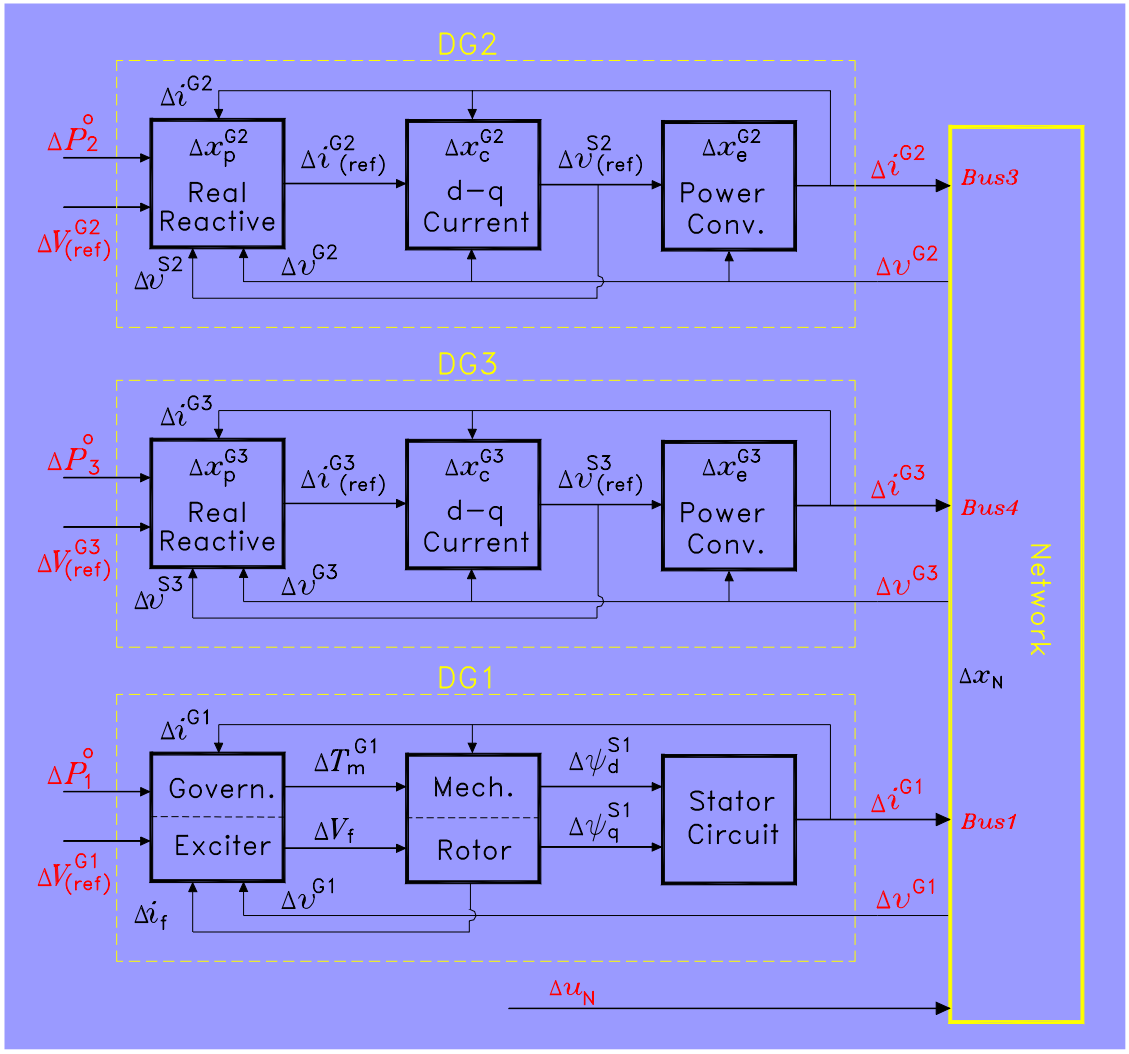
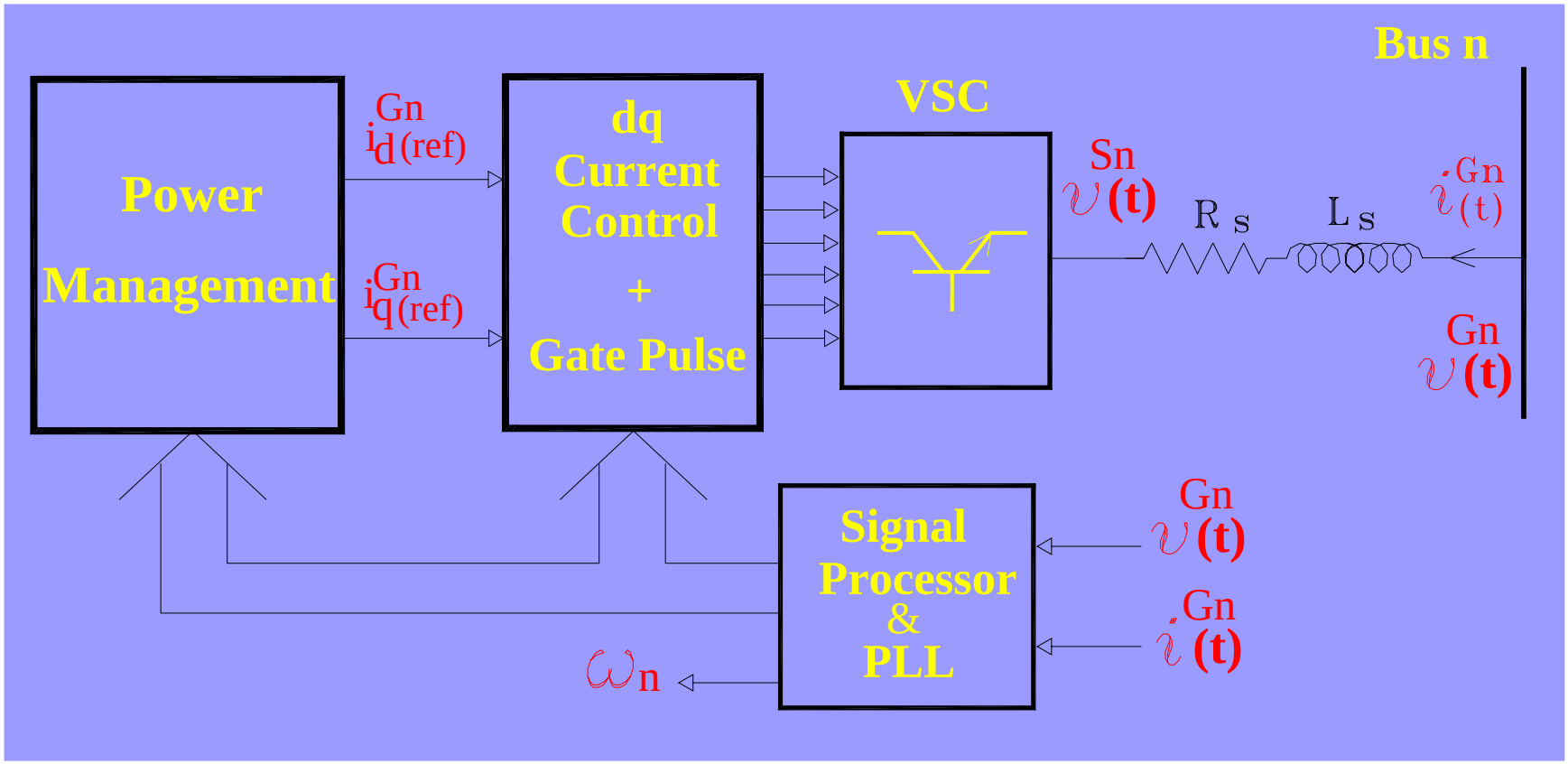
Investigation Methods

- Digital time-domain simulation in PSCAD/EMTDC environment
- Small-Signal dynamic analysis based on eigen analysis in MATLAB environment

Small-Signal Model



Power Management and DR Controls



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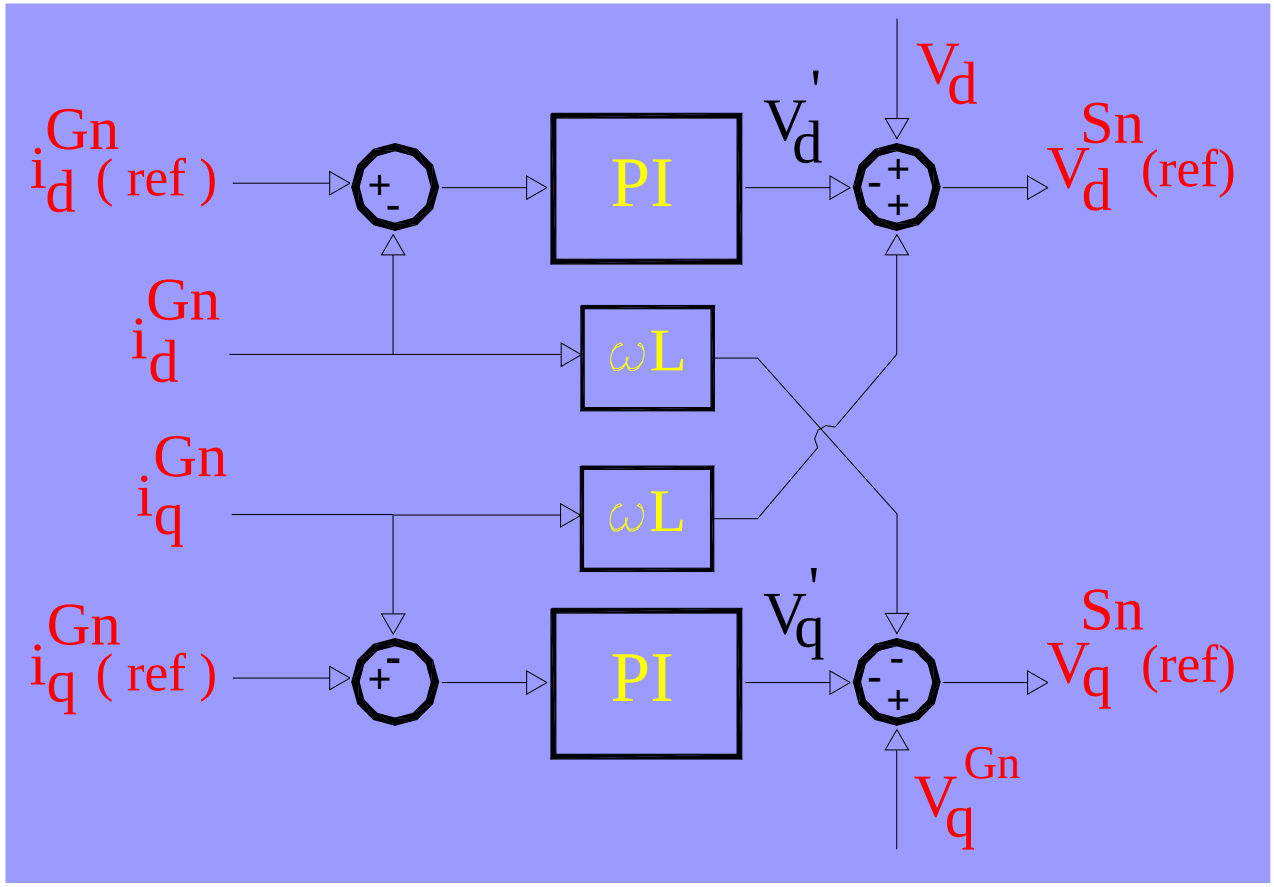
DR Controls

dq current controllers for an electronically-interfaced DG unit

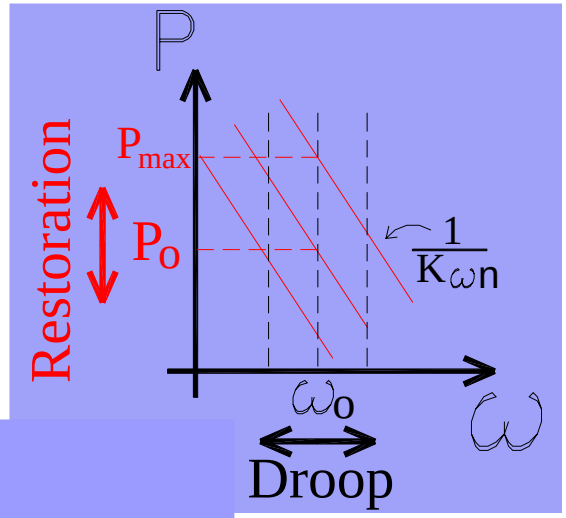


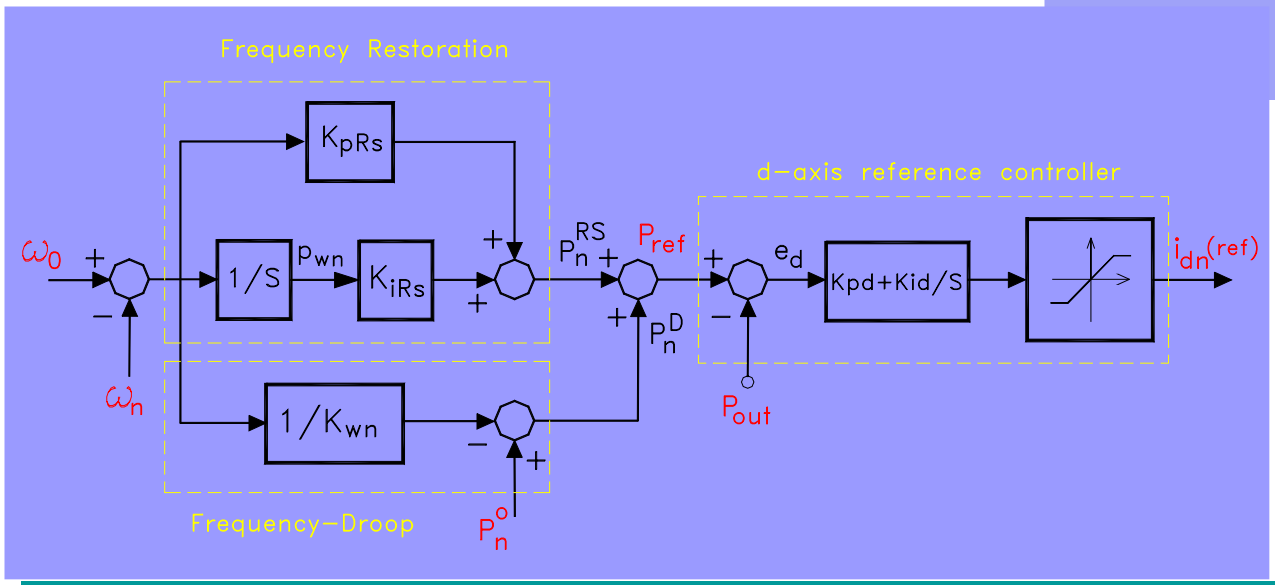
Power Management Strategies

- A Power Management System (PMS) assigns references for real and reactive power components of DR units within a micro-grid to:
  - share real-/reactive-power among DR units,
  - (rapidly) respond to small-signal and large-signal disturbances,
  - determine final operating conditions of DR units to balance power and restore micro-grid frequency,
  - assist in re-synchronization of an autonomous micro-grid to the main grid.

PMS (Real Power)

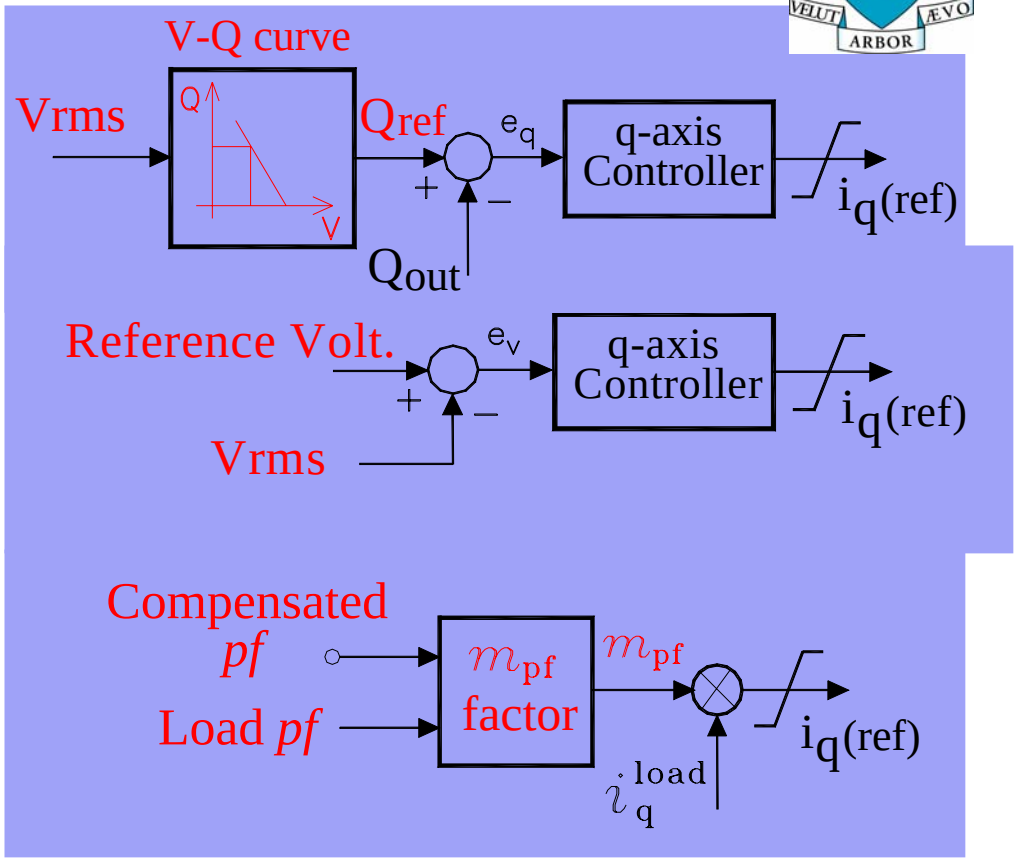
- Frequency-droop characteristic and frequency restoration algorithm





PMS (Reactive Power)

- Strategy I : Voltage-droop Characteristic
- Strategy II : Voltage Regulation
- Strategy III : Power Factor Correction
- Strategy IV : Hybrid of I to III



Case Studies

DG1: 1.47-MW
0.59-MVAr

DG2: 1.87-MW
1.06-MVAr

DG3: 0.96-MW
0.41-MVAr

Total Demand:
4.21-MW/2.79-MVAr

Eigen values	Case I		Case II	
	Real (1/s)	Im. (rad/s)	Real (1/s)	Im. (rad/s)
1,2	- 219.556	± 2164.05	- 2298.7	± 2139.14
3,4	- 366.93	± 1175.57	- 290.0	± 1278.64
5,6	- 18.0	± 725.9	- 62.6	± 706.99
7,8	- 39.56	± 507.59	- 81.71	± 456.86
9,10	- 110.71	± 427.52	- 113.44	± 420.54
11,12	- 1710.09	± 389.43	- 1709.07	± 380.86
13,14	- 748.57	± 380.52	- 747.09	± 377.24
15,16	- 365.37	± 386.08	- 361.29	± 374.22
17,18	- 425.76	± 377.0	- 425.75	± 376.98
19,20	- 56.46	± 336.43	- 143.99	± 291.09
21,22	- 193.0	± 77.35	- 112.32	± 39.41
23,24	- 0.738	± 9.98	- 0.86	± 10.0

- **Case I:**

Real PMS: frequency-droop,

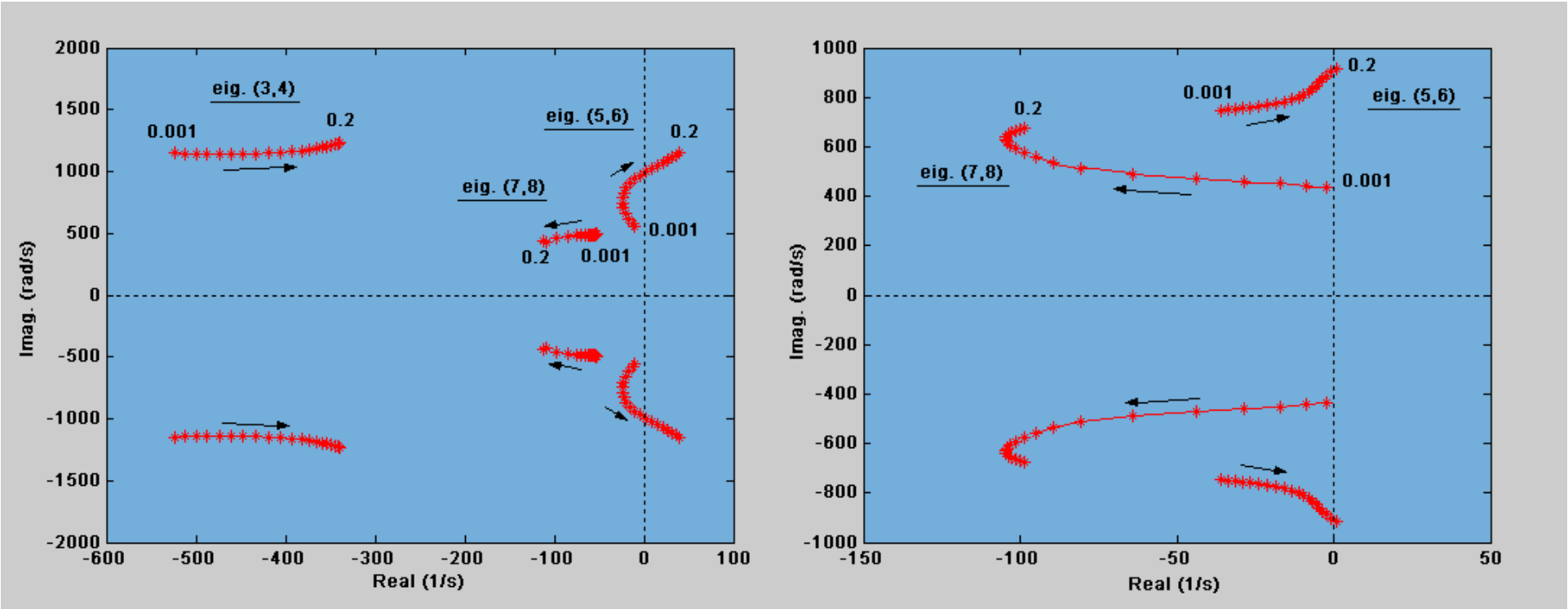
Reactive PMS: voltage-droop characteristics for *DG2* and *DG3*

- **Case II:**

Real PMS: same as Case I,

Reactive PMS: voltage-droop for *DG2* and voltage regulation for *DG3*

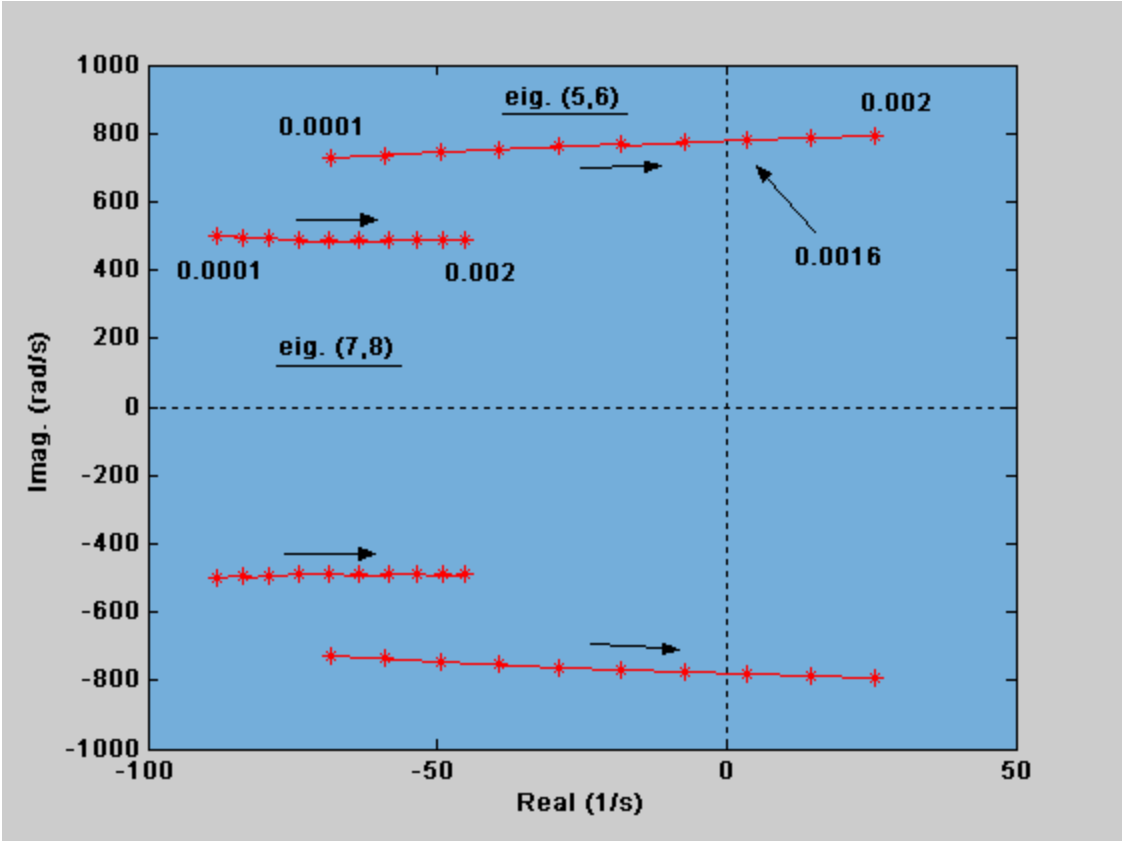
Eigen Analysis



Change in the gain of real power controller for DG2

Change in the gain of real power controller for DG3

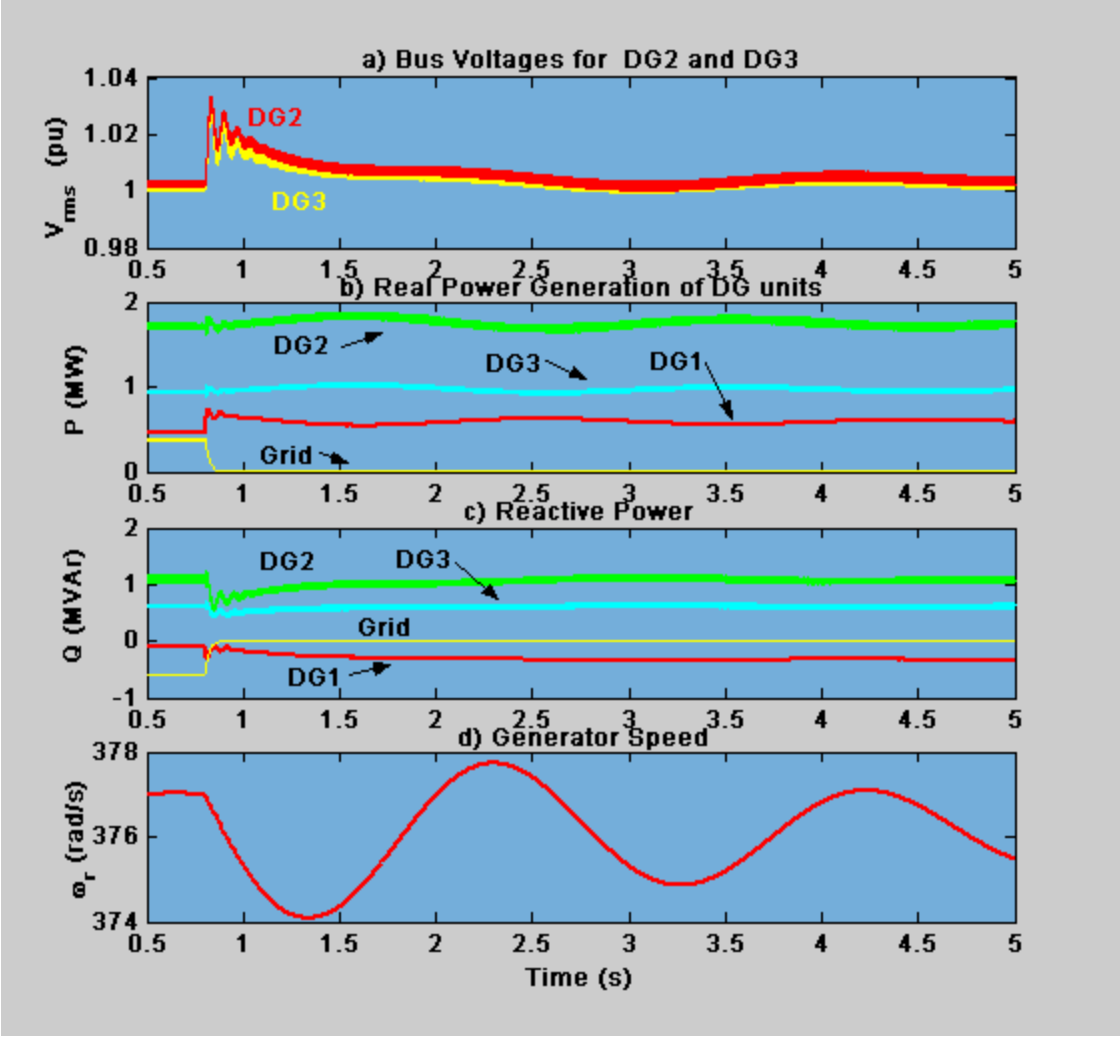
Eigen Analysis



Change in the gain of reactive power controller for DG2

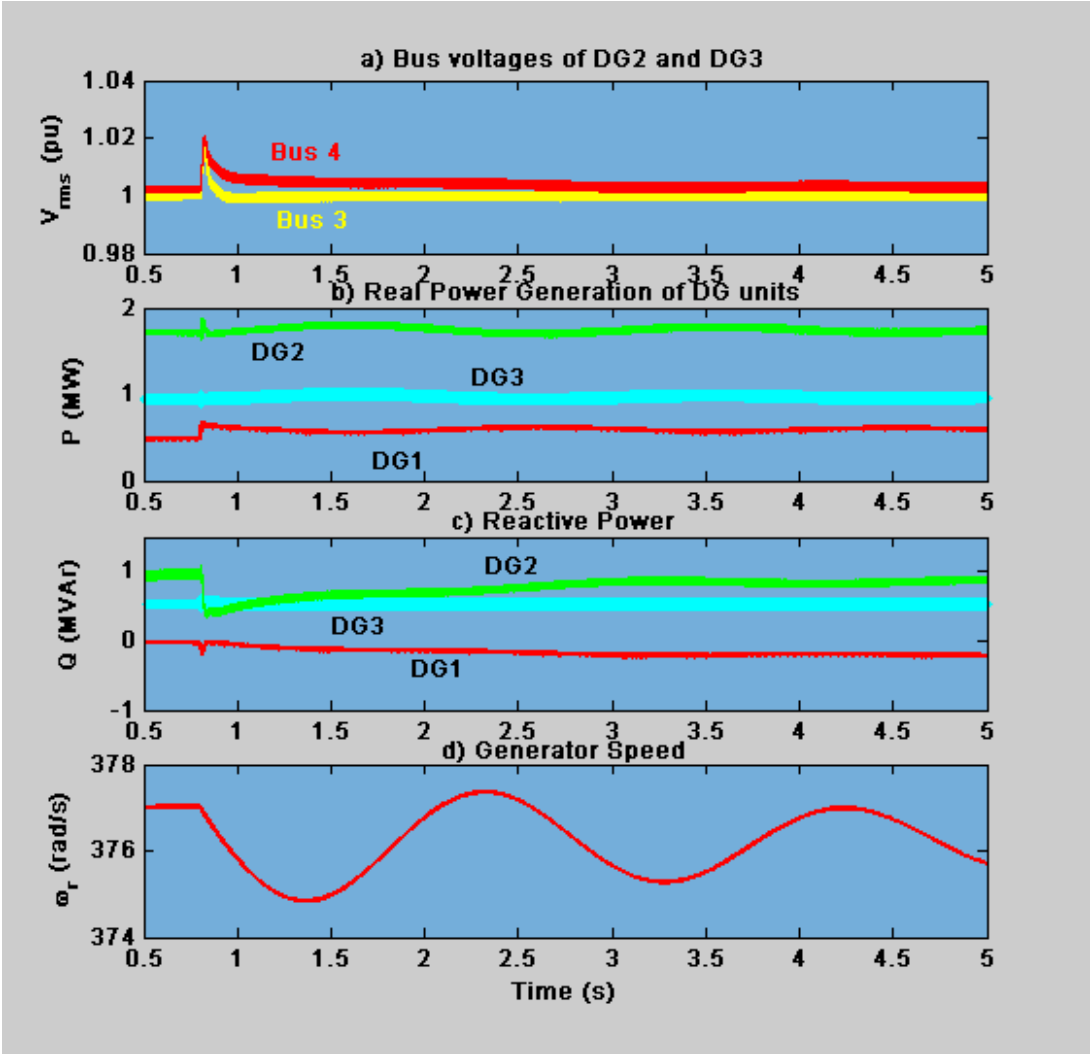
Intentional Islanding

- Intentional islanding, PMS I



Intentional Islanding

- Intentional islanding, PMS **II** and PMS **III**



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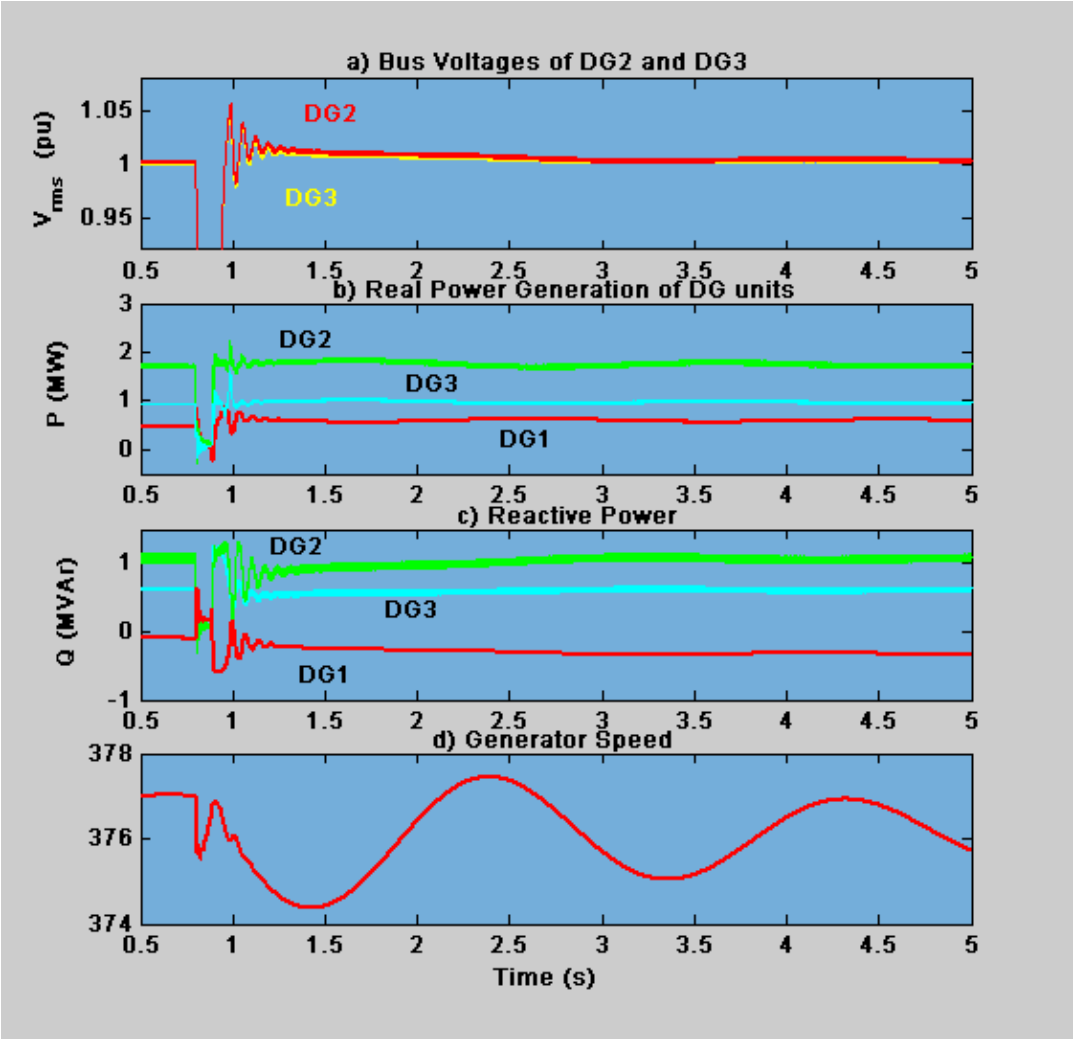
Accidental Islanding (Fault)

- **PMS:**
  PMS **I**
- **Disturbance:**
  3-Phase to ground fault at t=0.8s



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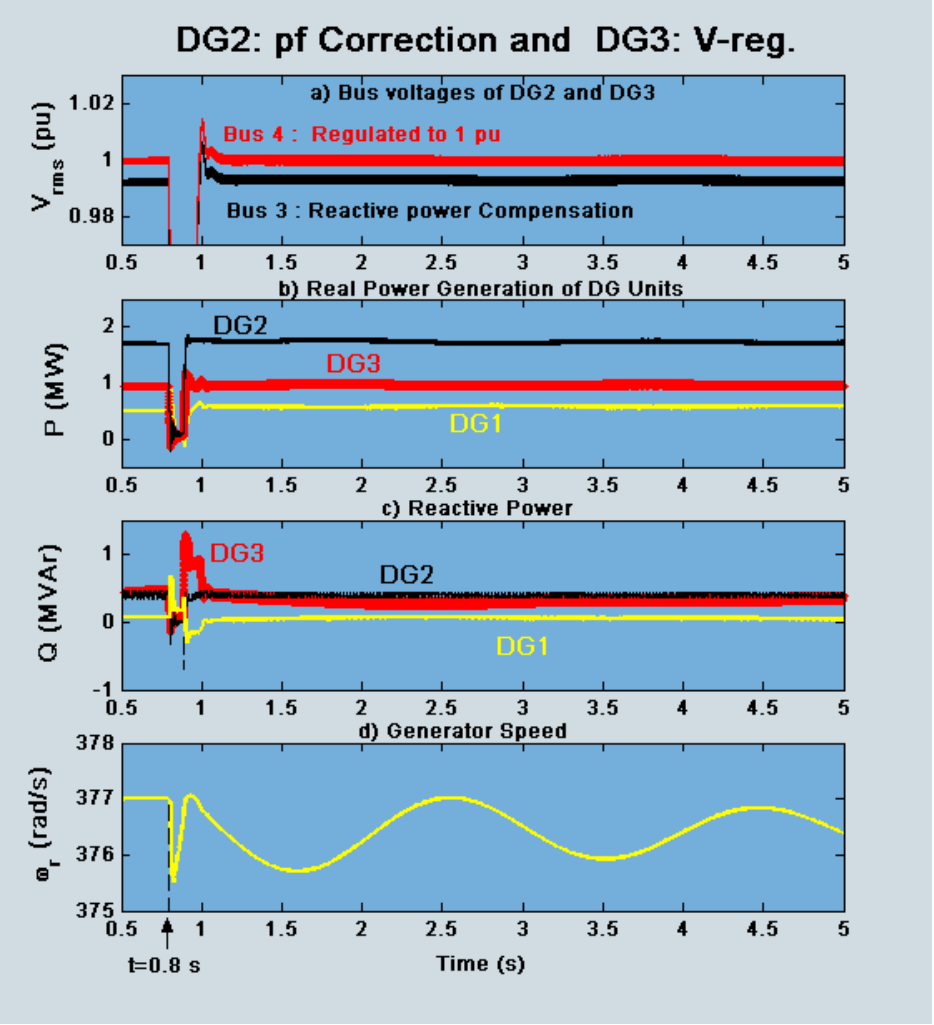

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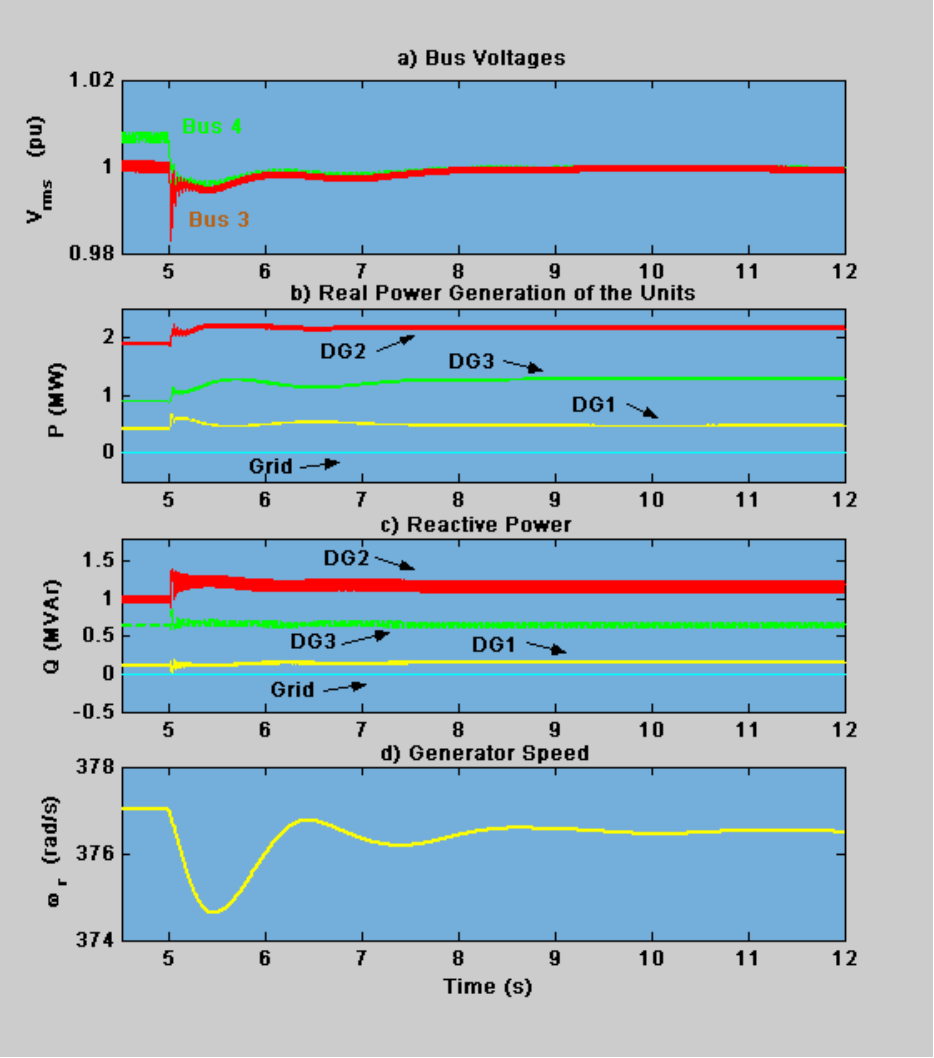
Autonomous Operation

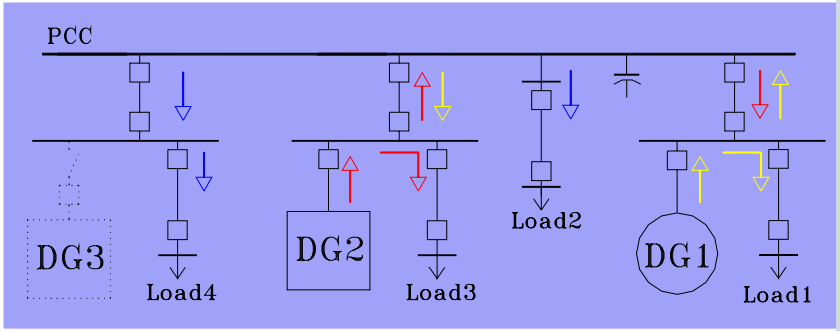
Load Change

- **PMS:**
  Droop characteristics
- **Disturbance:**
  Real power of Load-3 is doubled at t=5s

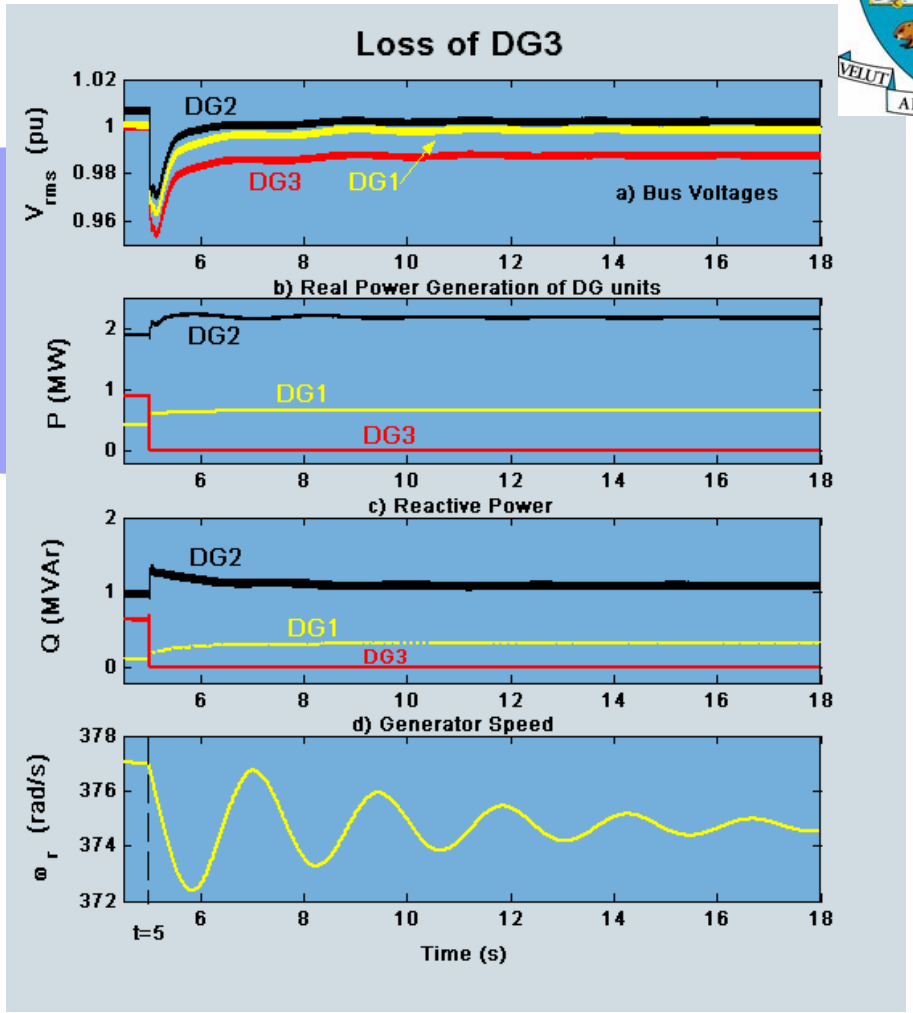


Autonomous Operation

Loss of a Generation Unit



- **PMS:**
  Droop characteristics
- **Disturbance:**
  DG3 is disconnected at t=5s



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Conclusions

- **Optimized controls and PMS parameters of DR units can provide satisfactory performance of the microgrid under both grid-connected and islanded modes of operation.**
- **A hybrid of voltage droop, voltage regulation and power factor correction in conjunction with frequency droop and frequency restoration can minimize dynamic interactions among DR units and and assist in microgrid transition between grid-connected and islanded modes.**