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Power System Support From Photovoltaic Systems

Wednesday, 15 November 2023 | Technical Topic Webinar

Presented by

Dr. Hossein Dehghani Tafti
EIT Lecturer

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Agenda

1	Welcome and Introduction
2	High Penetration of Renewable Energy Systems
3	New Standards and Regulations
4	Flexible Power Point Tracking
5	Flexible Power Point Tracking under Partial Shading Conditions
6	Power System Frequency Support from Photovoltaic Systems
7	Modelling of Renewable Energy Systems for Power System Studies
8	Conclusion and Q&A

Introduction - Presenter

Hossein Dehghani Tafti

- Lecturer at EIT
- Research Fellow at The University of Western Australia – Magellan Powertronic Pty Ltd
- Senior Research Associate at UNSW Sydney
- Research Fellow at Nanyang Technological University
- PhD in Power Electronics and Power Engineering (2018) from Nanyang Technological University, Singapore
- MSc in Power Engineering from Amirkabir University of Technology, Iran (2011)
- BSc in Power Engineering from Amirkabir University of Technology, Iran (2009)

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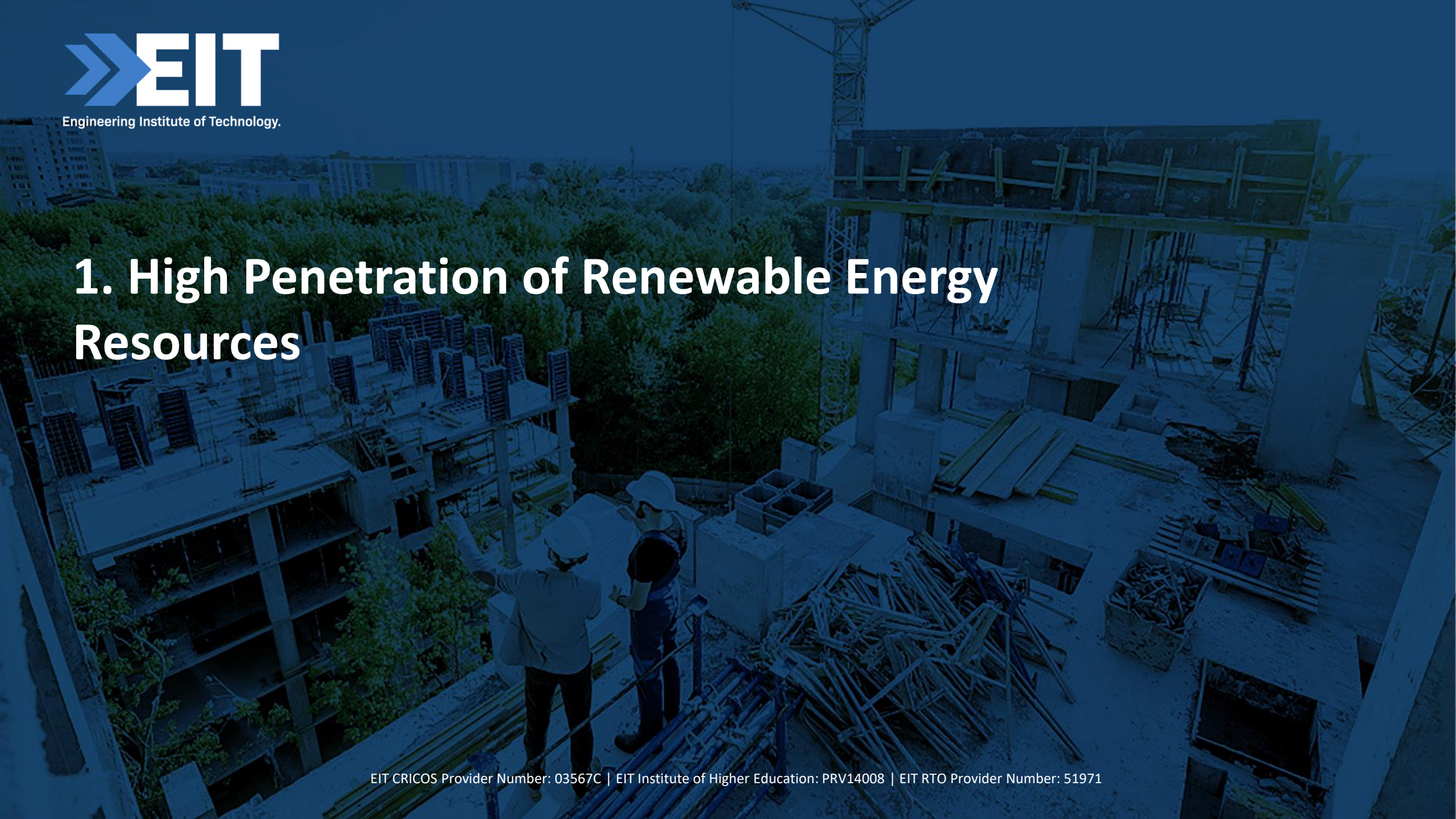
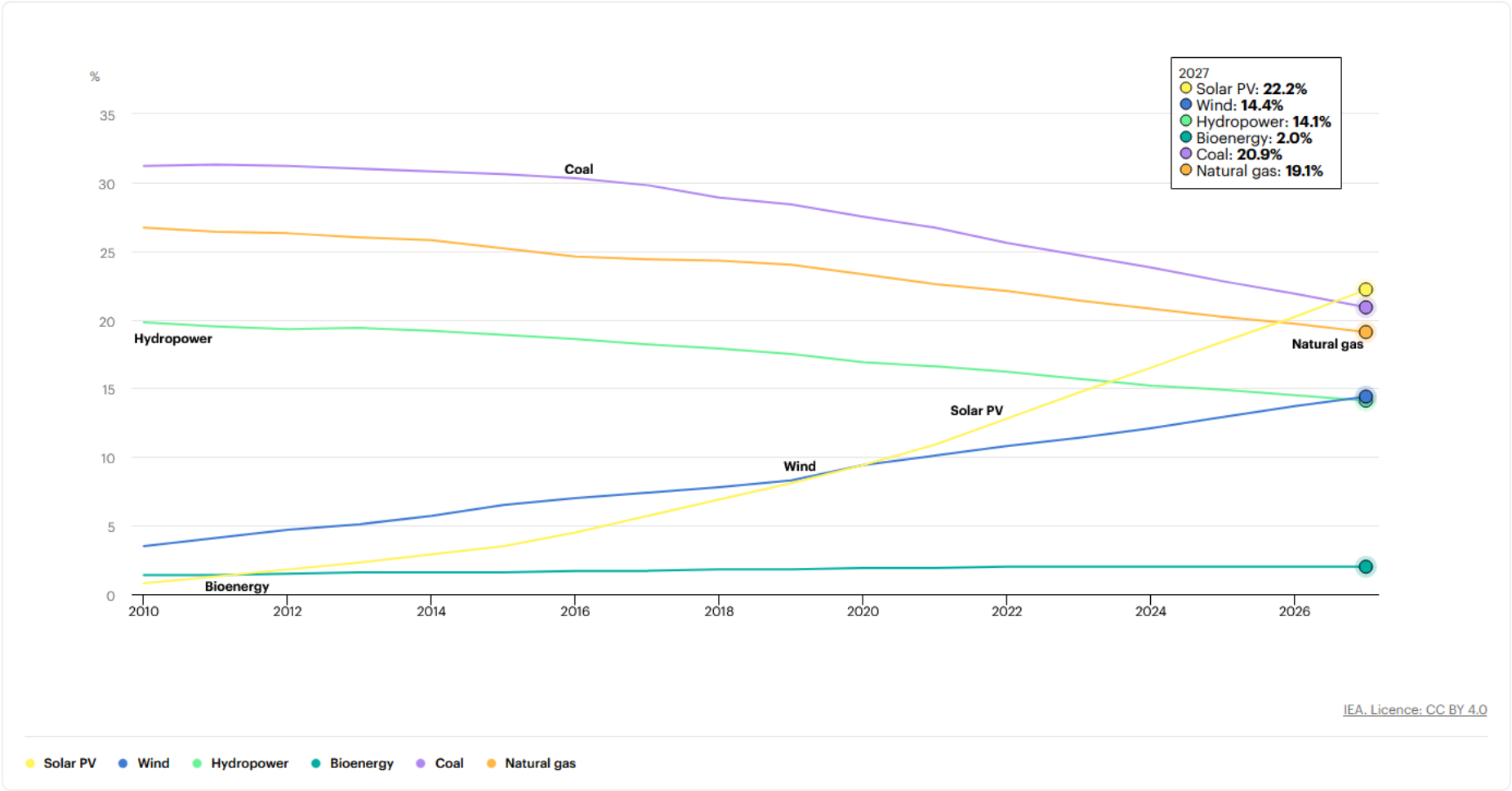
1. High Penetration of Renewable Energy Resources



High Penetration of Renewable Energy Resources



High Penetration of Renewable Energy Resources Challenges

- Environmentally dependent power output
- Low inertia
- Lack of visibility of operation to power system operators
- Lack of central control
- …

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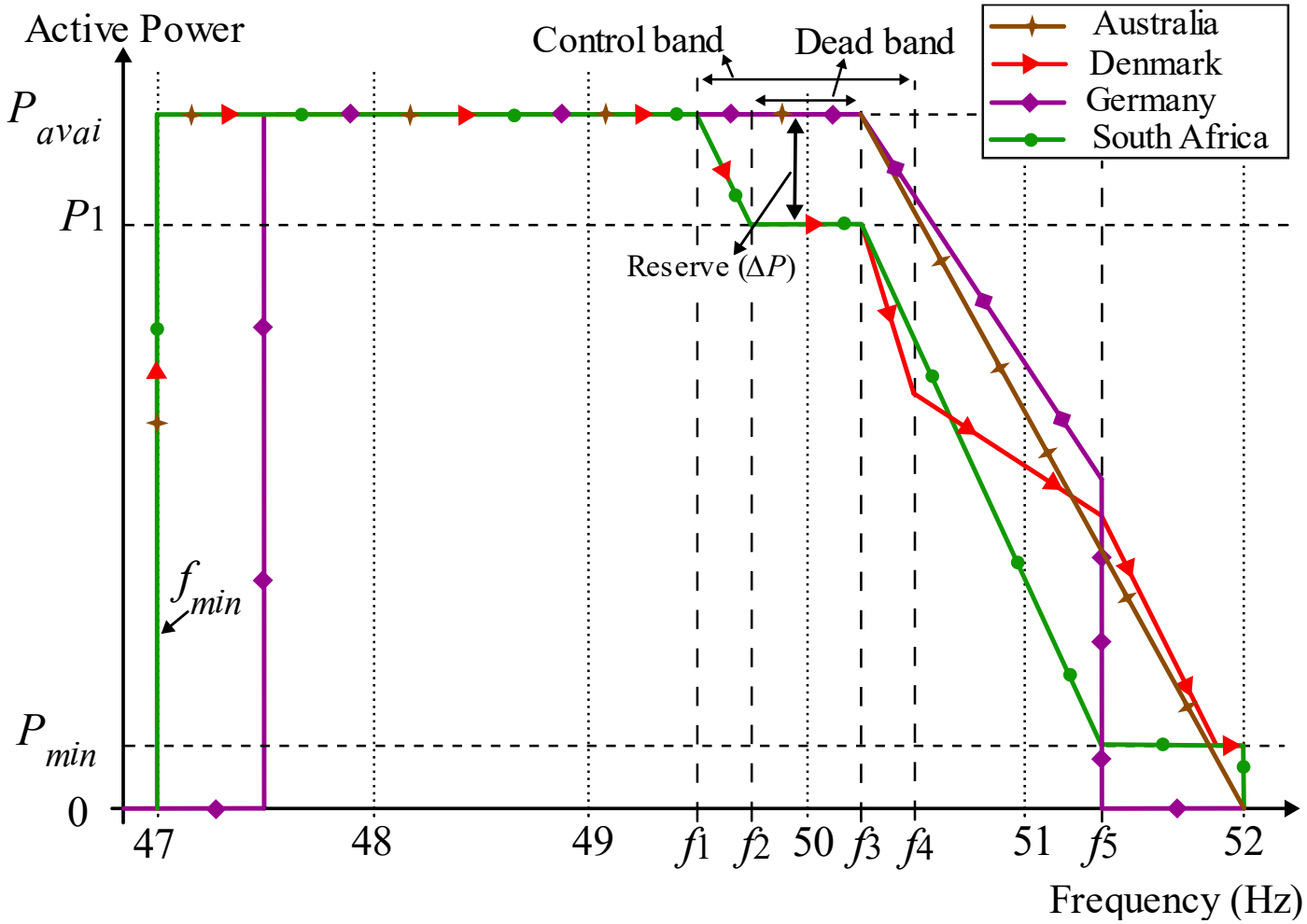
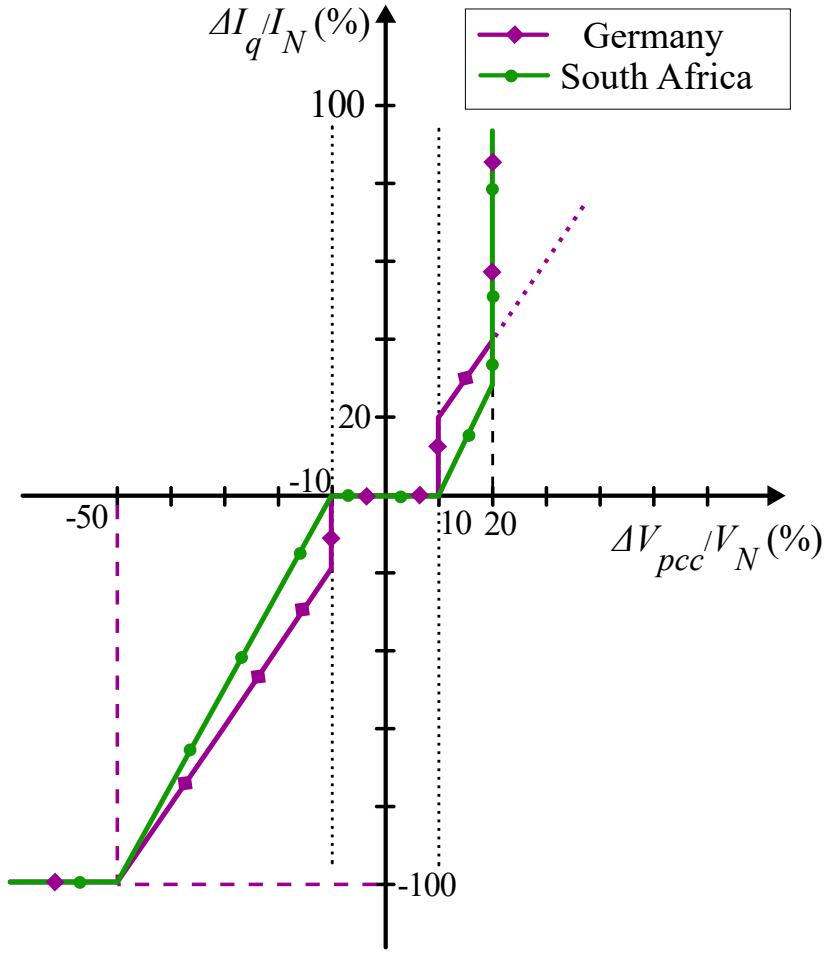
2. New Standards and Regulations

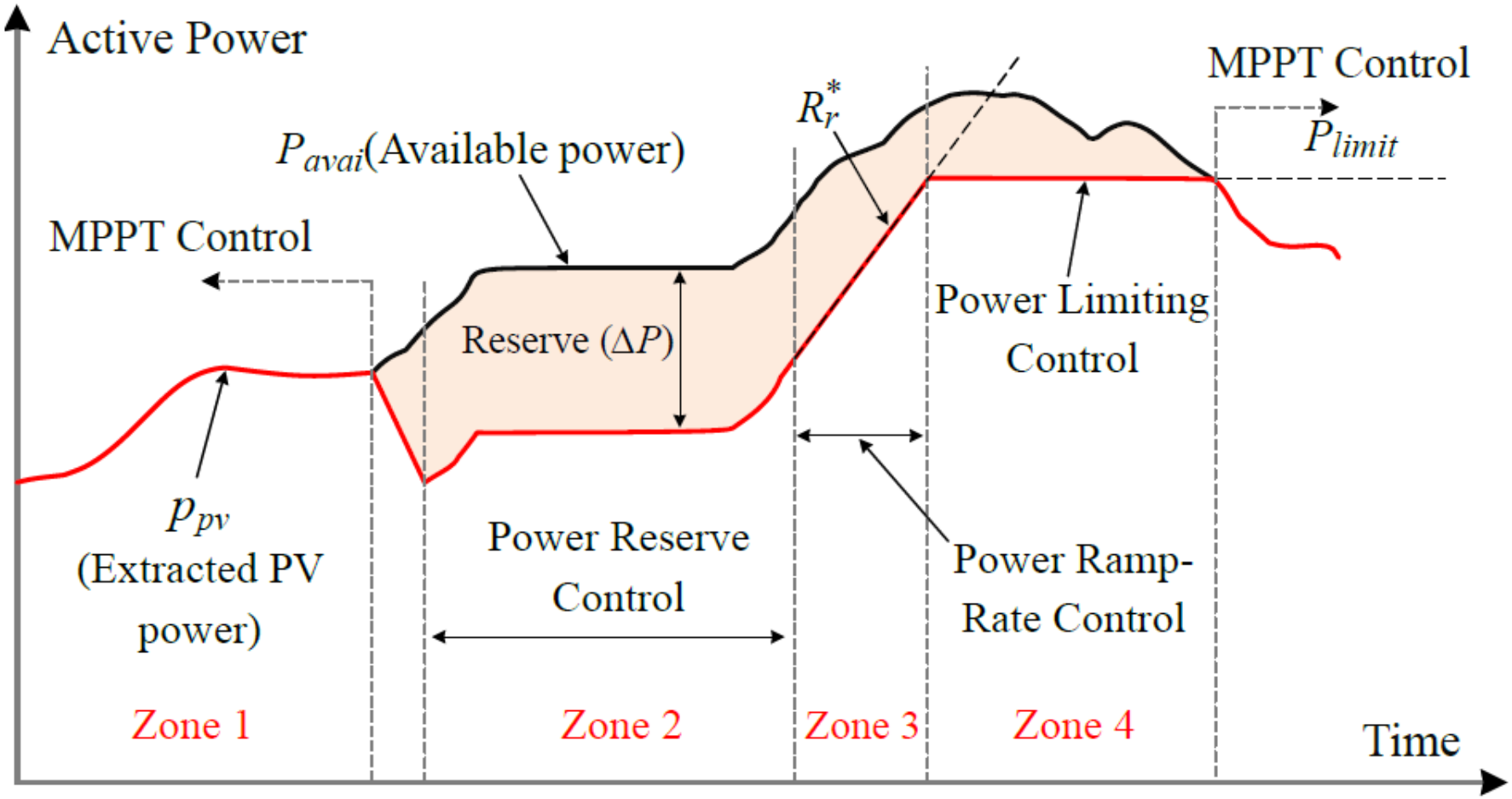
Frequency Support



Voltage Support



Different Types of Requirements



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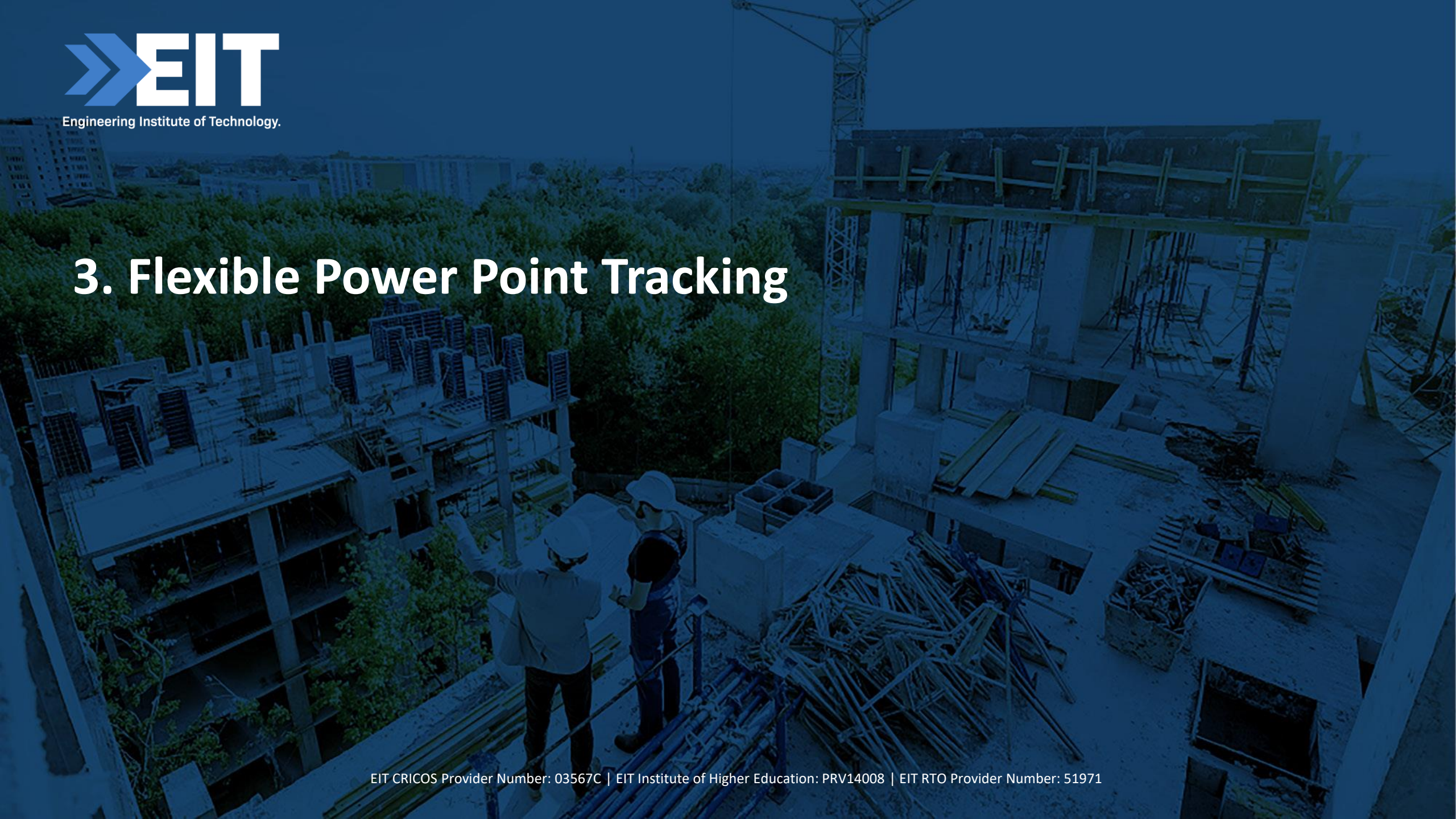
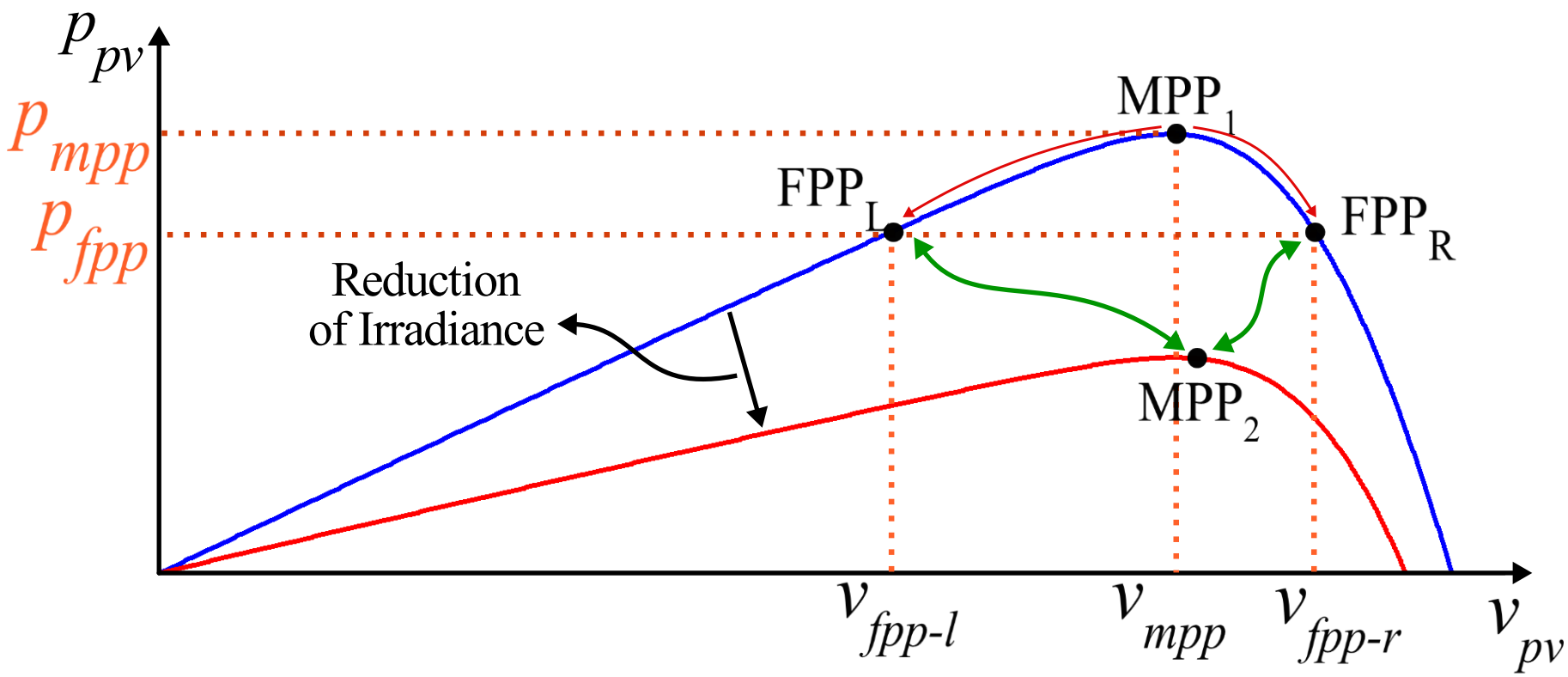
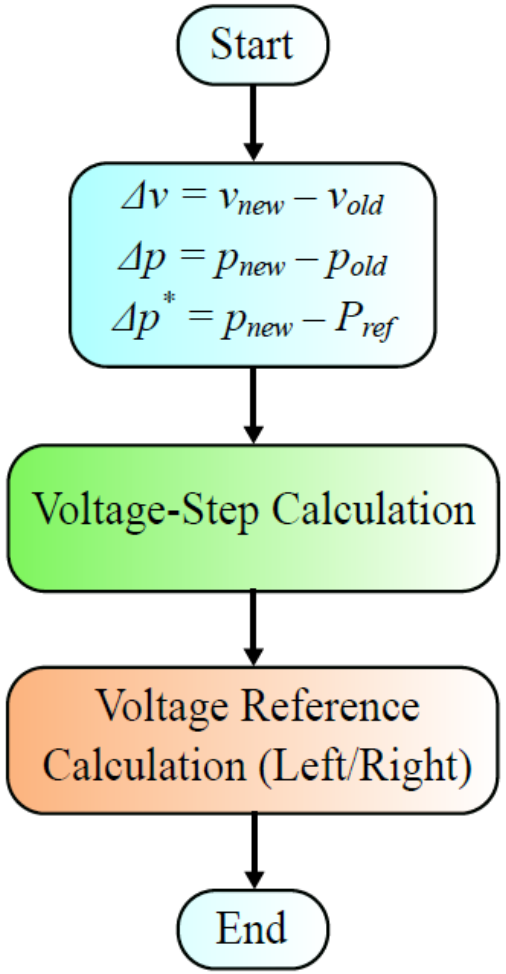
3. Flexible Power Point Tracking

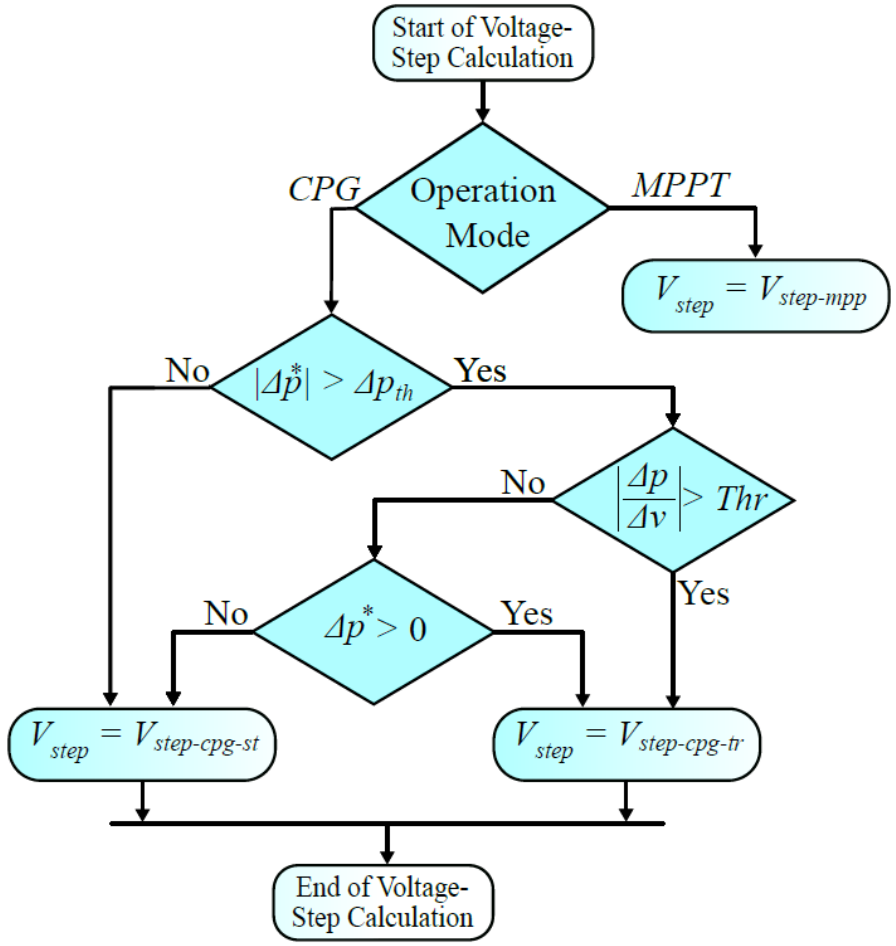


Flexible Power Point Tracking



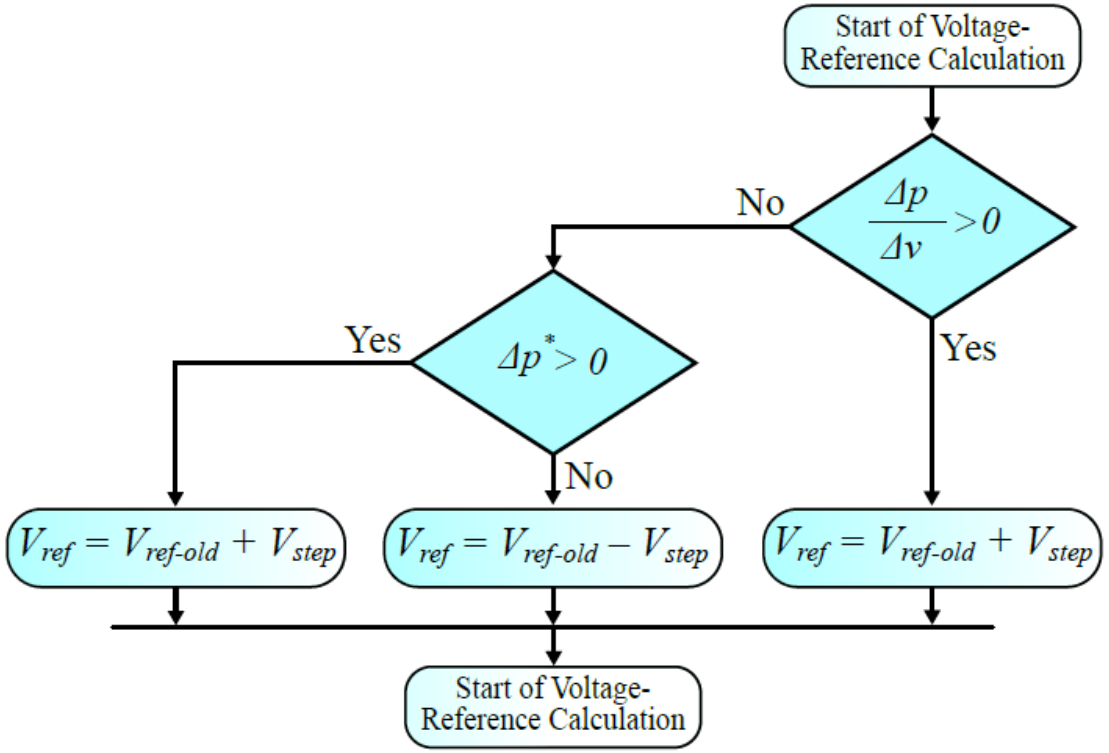
Flexible Power Point Tracking



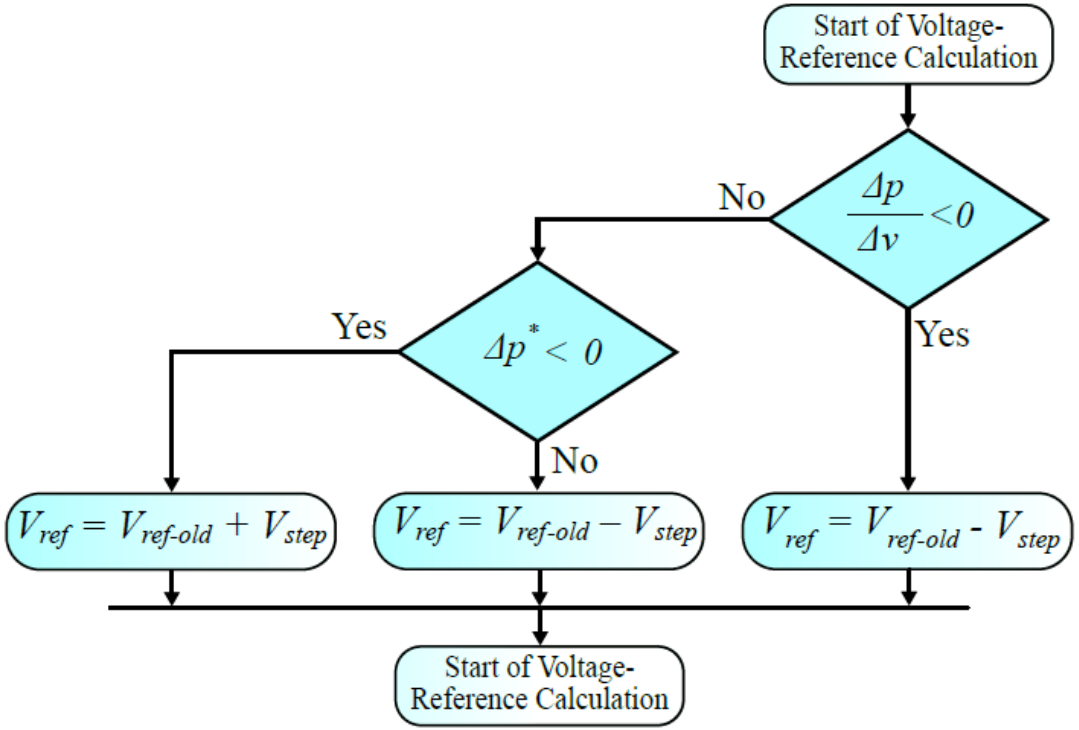


Flexible Power Point Tracking

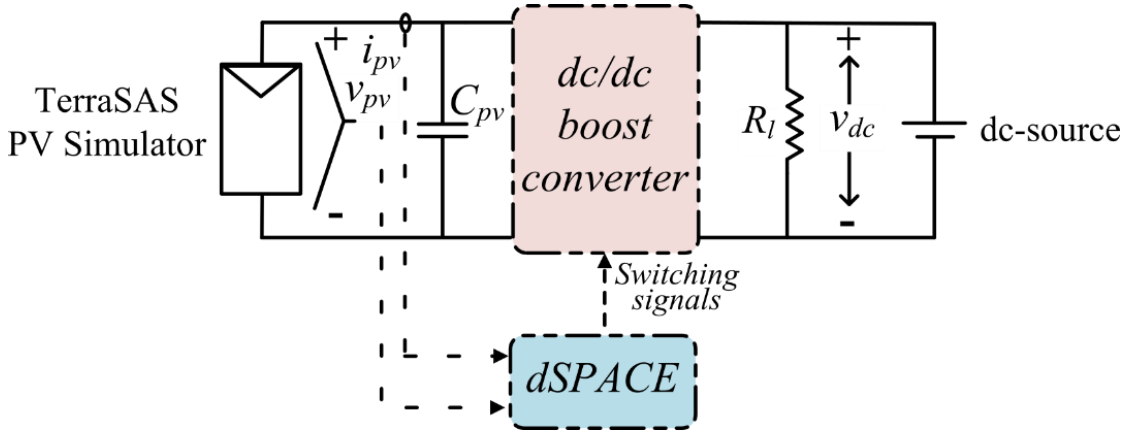
Right-side of MPP

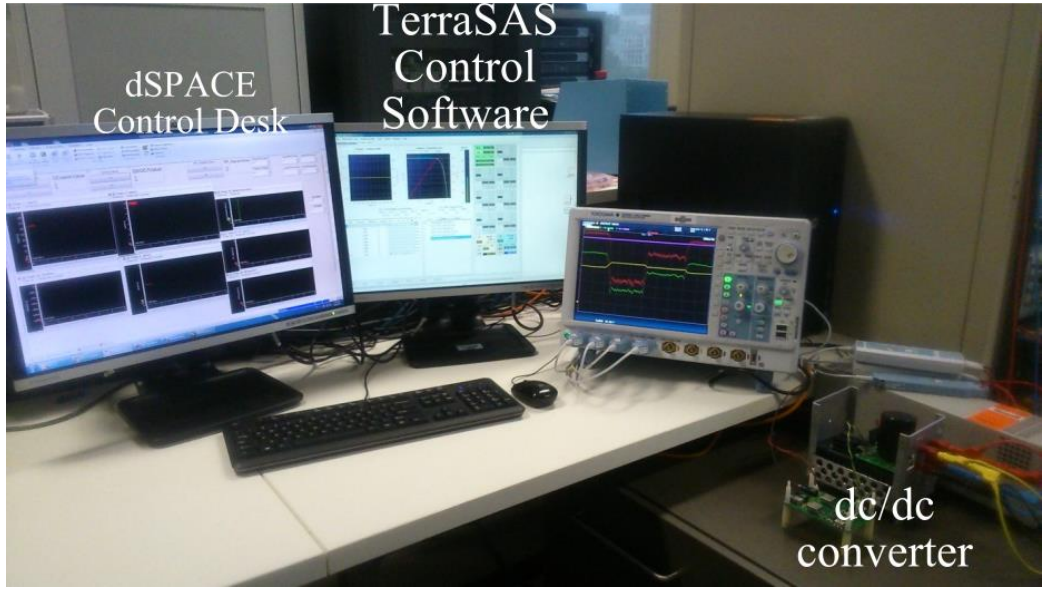


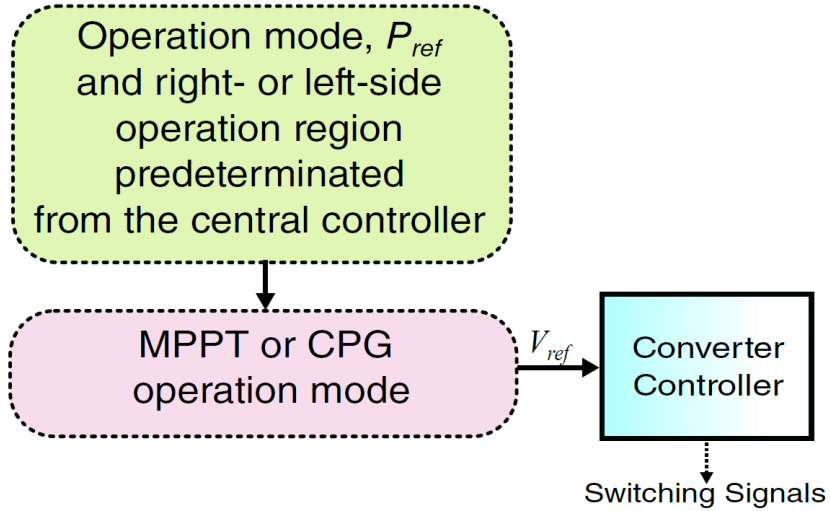
Left-side of MPP



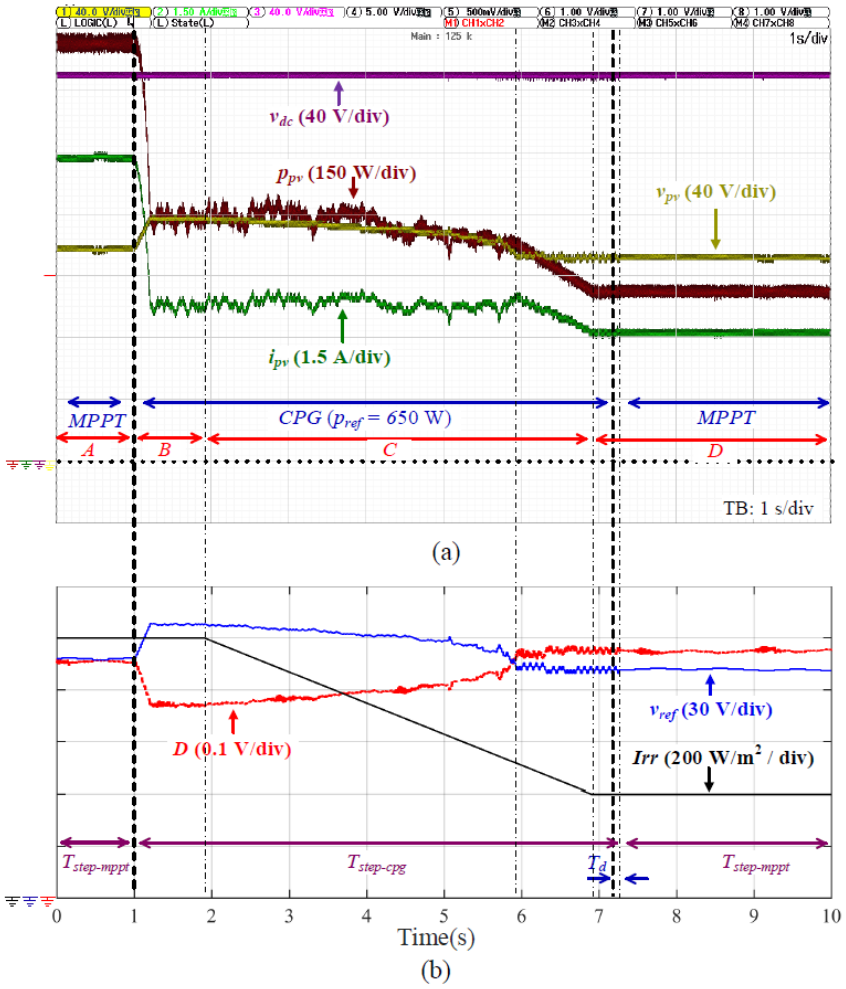
Experimental Validation

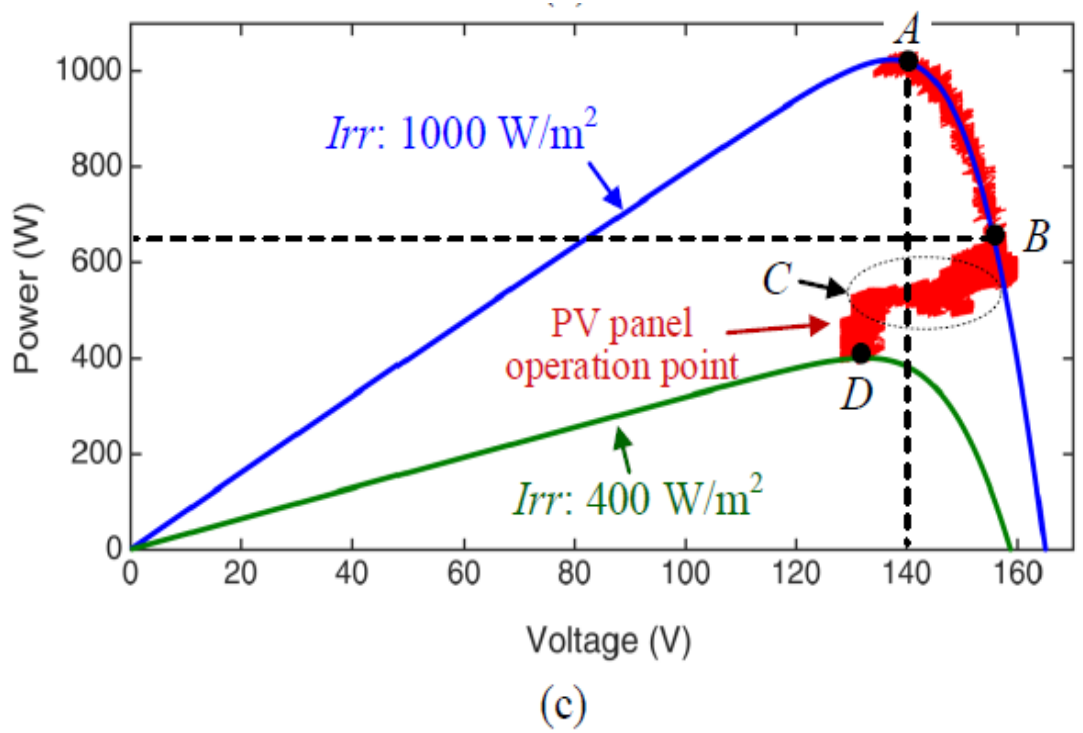






Experimental Results



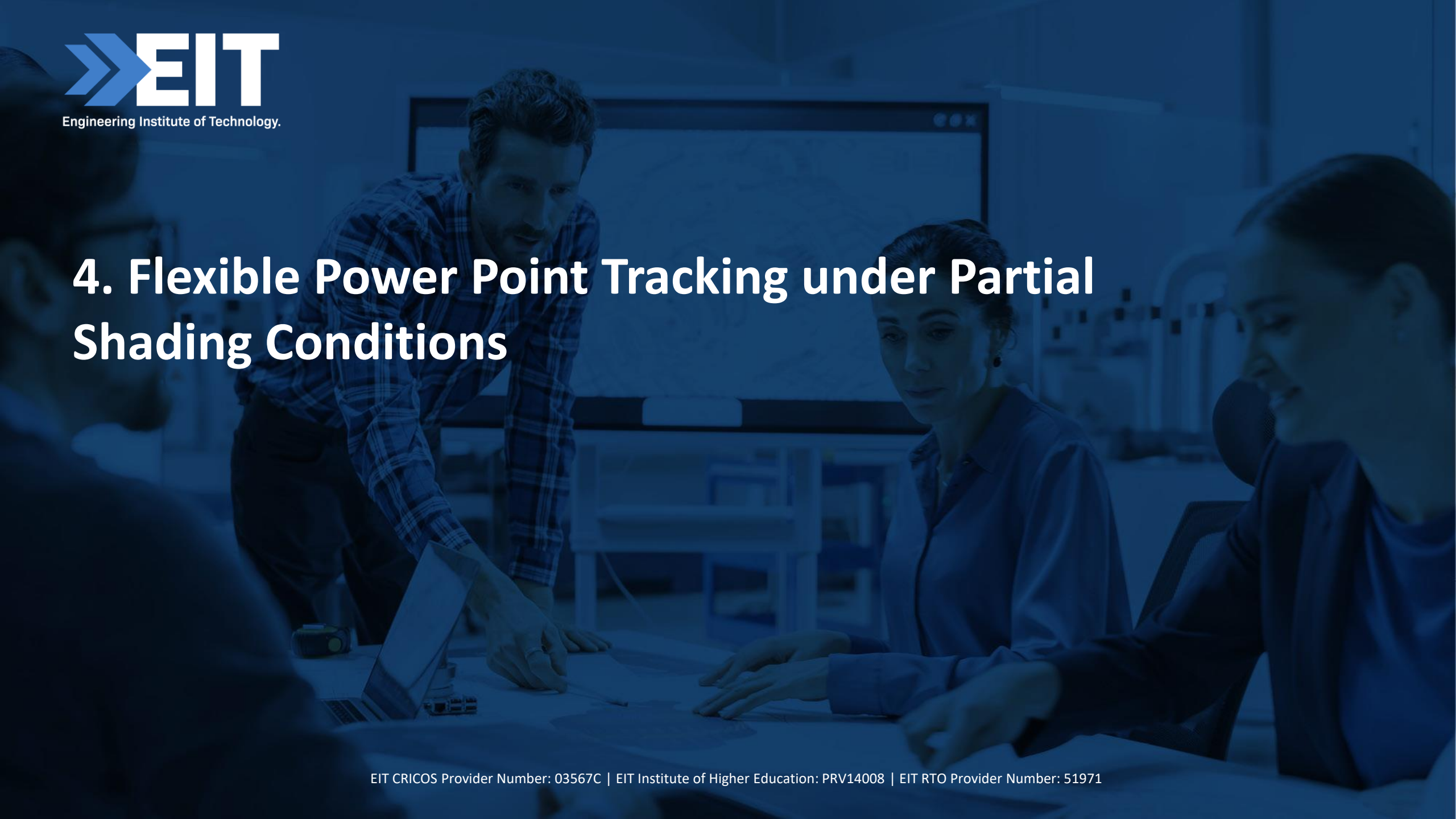


Change of irradiance:

a) PV panel voltage, current, power and dc-link voltage,
b) Voltage reference and dc-dc converter duty cycle,
c) PV panel operation point

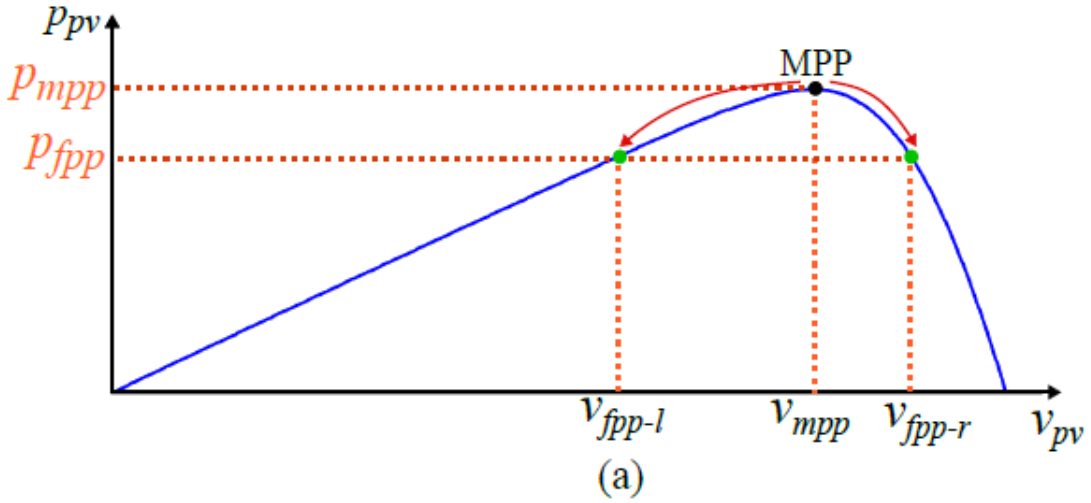
Remarks

- Applicable in both maximum point tracking (MPPT) and reduced power point tracking (RPPT) operation modes
- Flexibility of the proposed algorithm to move the operation point to the right- or left-side of maximum power point
- Applicability for both single- and two-stage photovoltaic power plants
- Fast dynamic response and low power oscillation

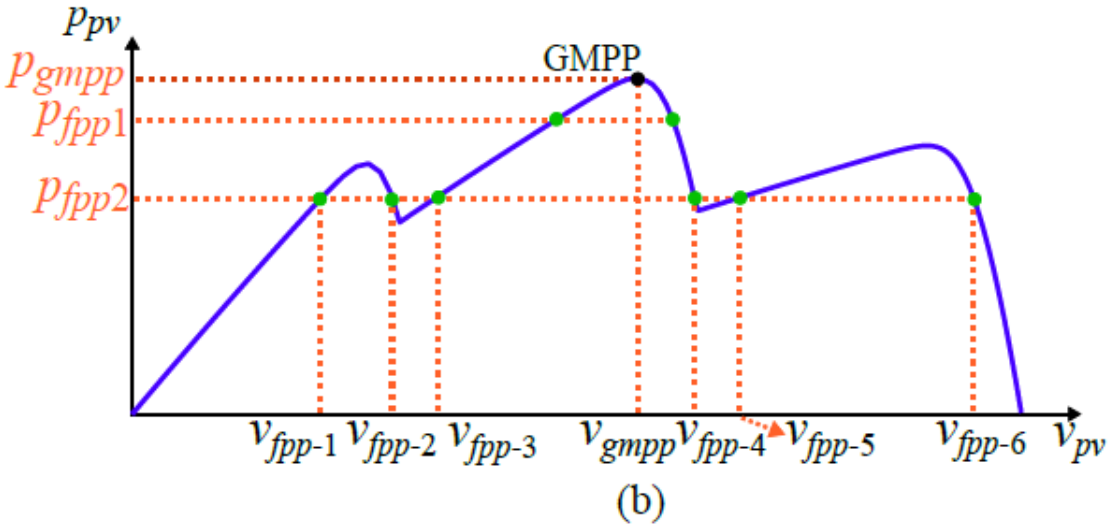


4. Flexible Power Point Tracking under Partial Shading Conditions

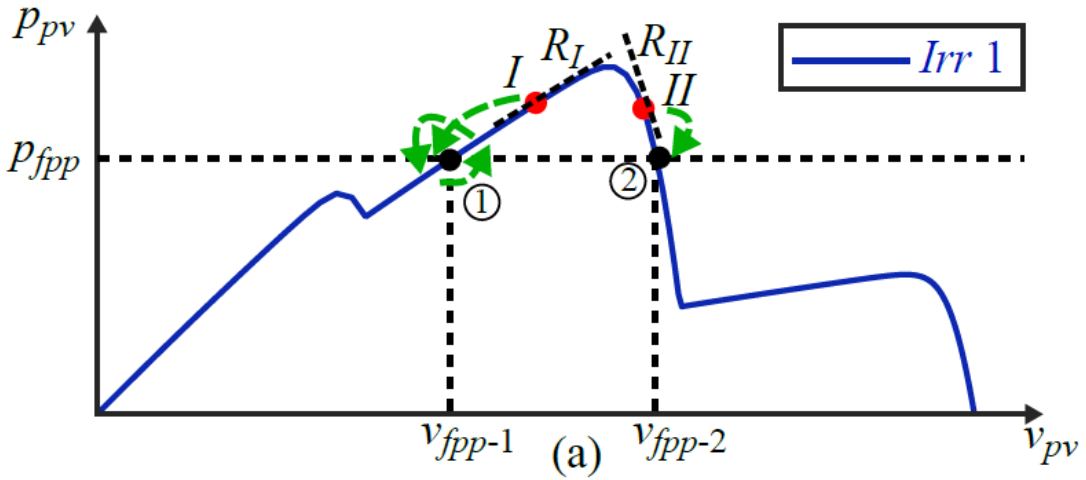
Flexible Power Point Tracking Under Partial Shading Conditions



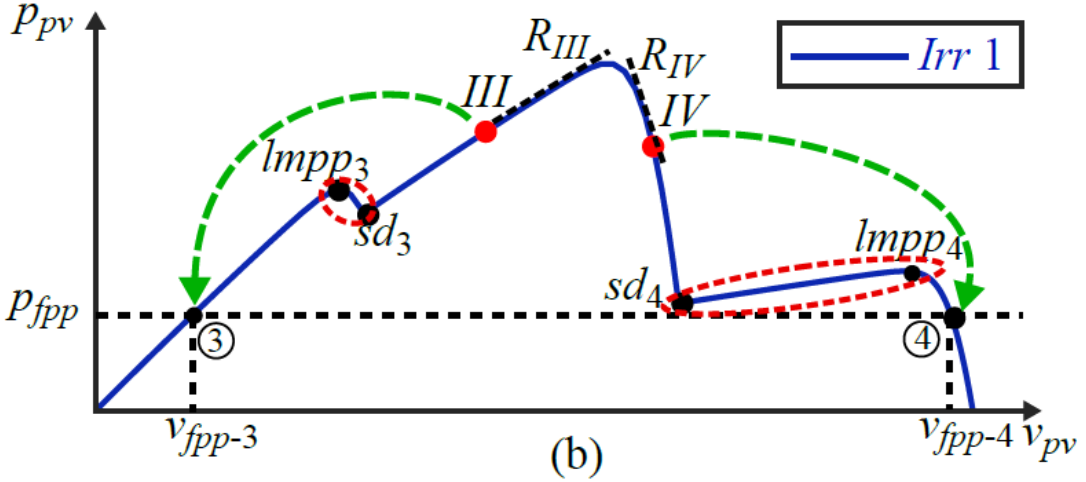
(a)



(b)

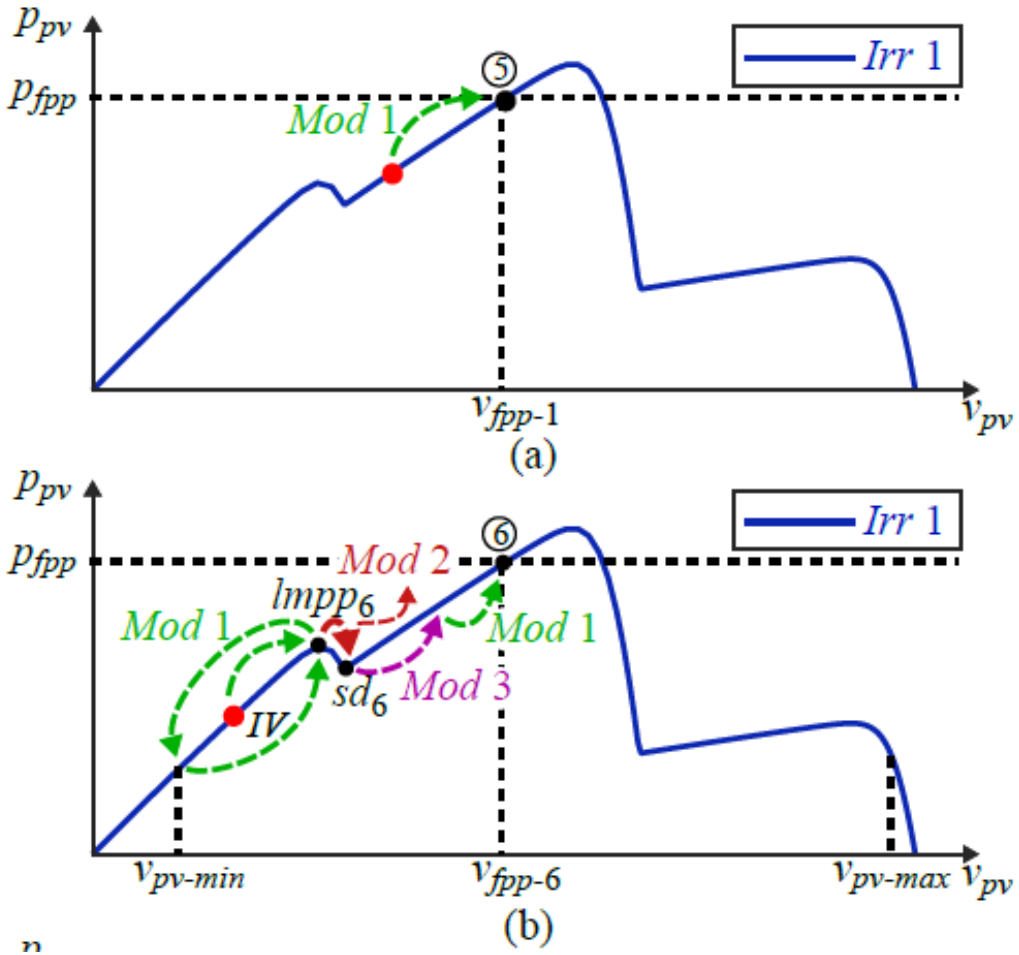


(a)



(b)

Flexible Power Point Tracking Under Partial Shading Conditions



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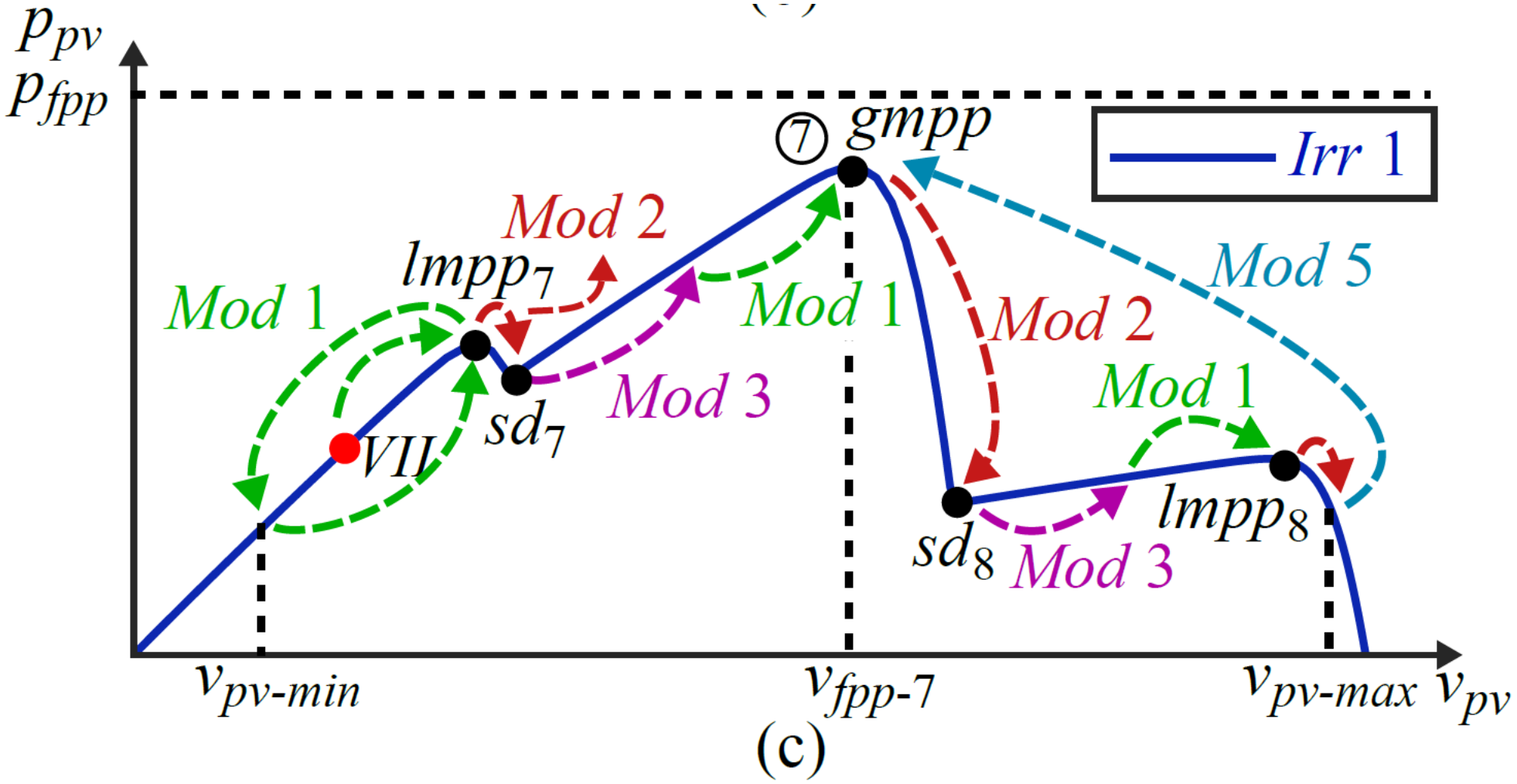
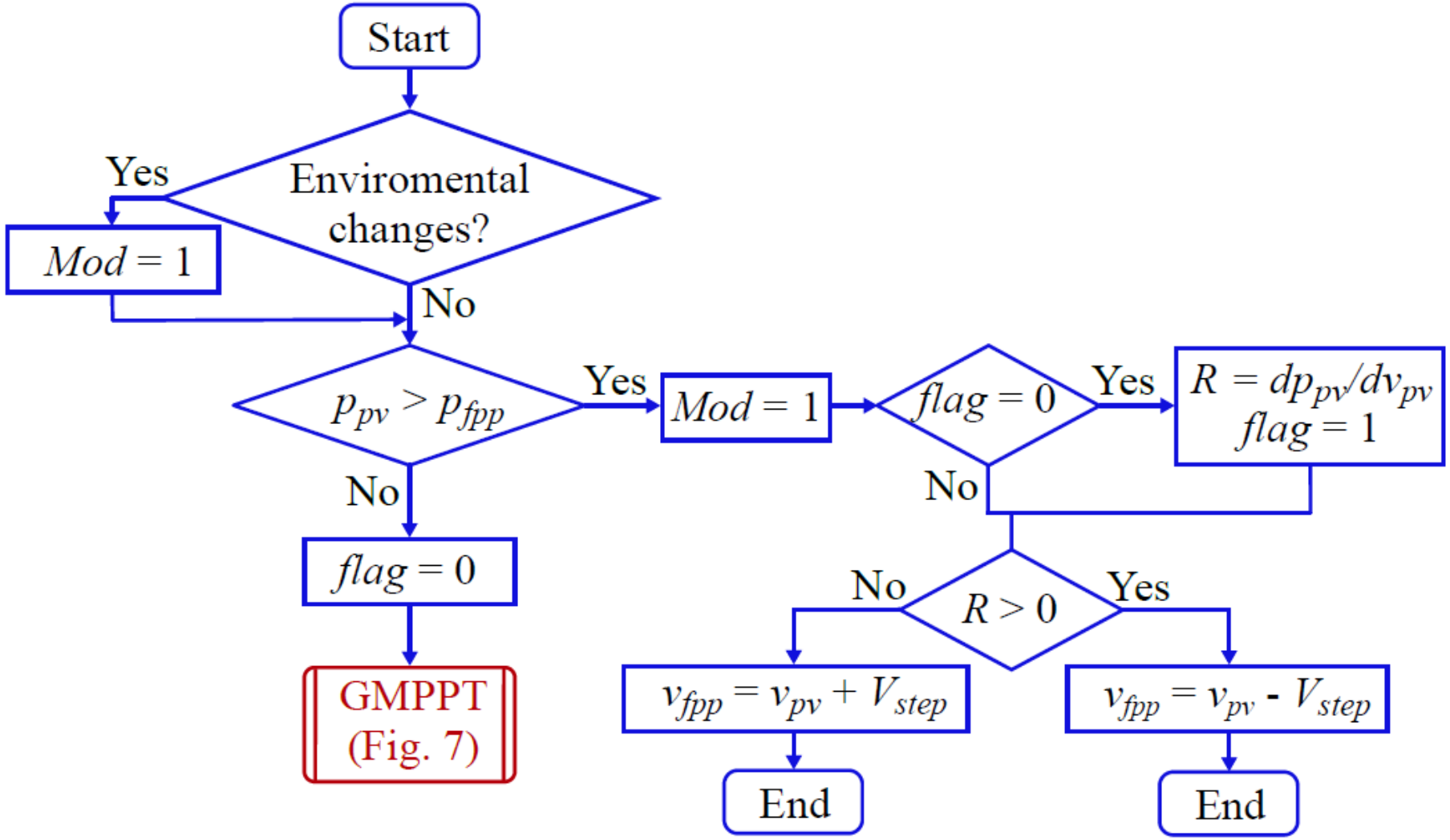


Flexible Power Point Tracking Under Partial Shading Conditions



Flexible Power Point Tracking Under Partial Shading Conditions

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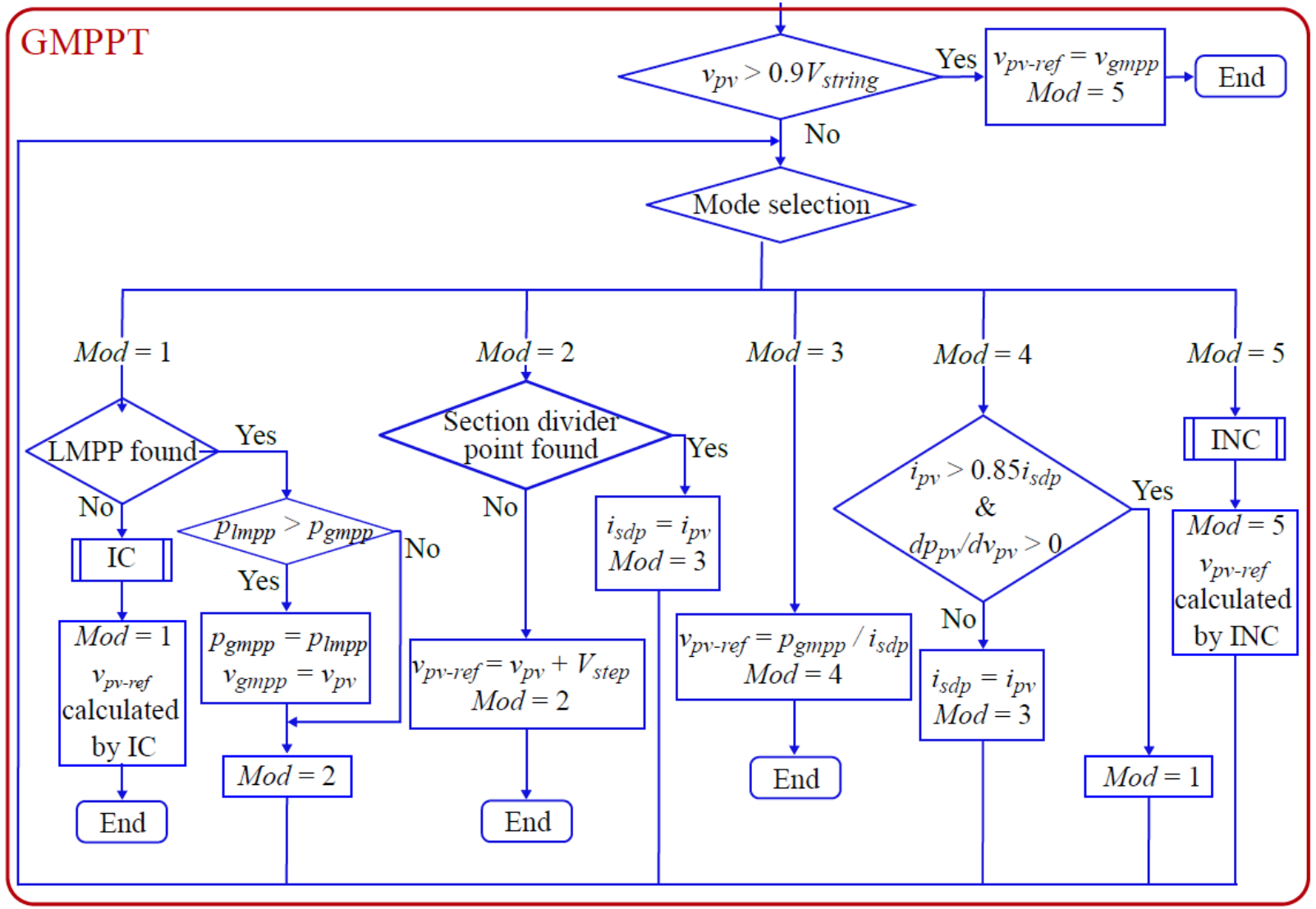

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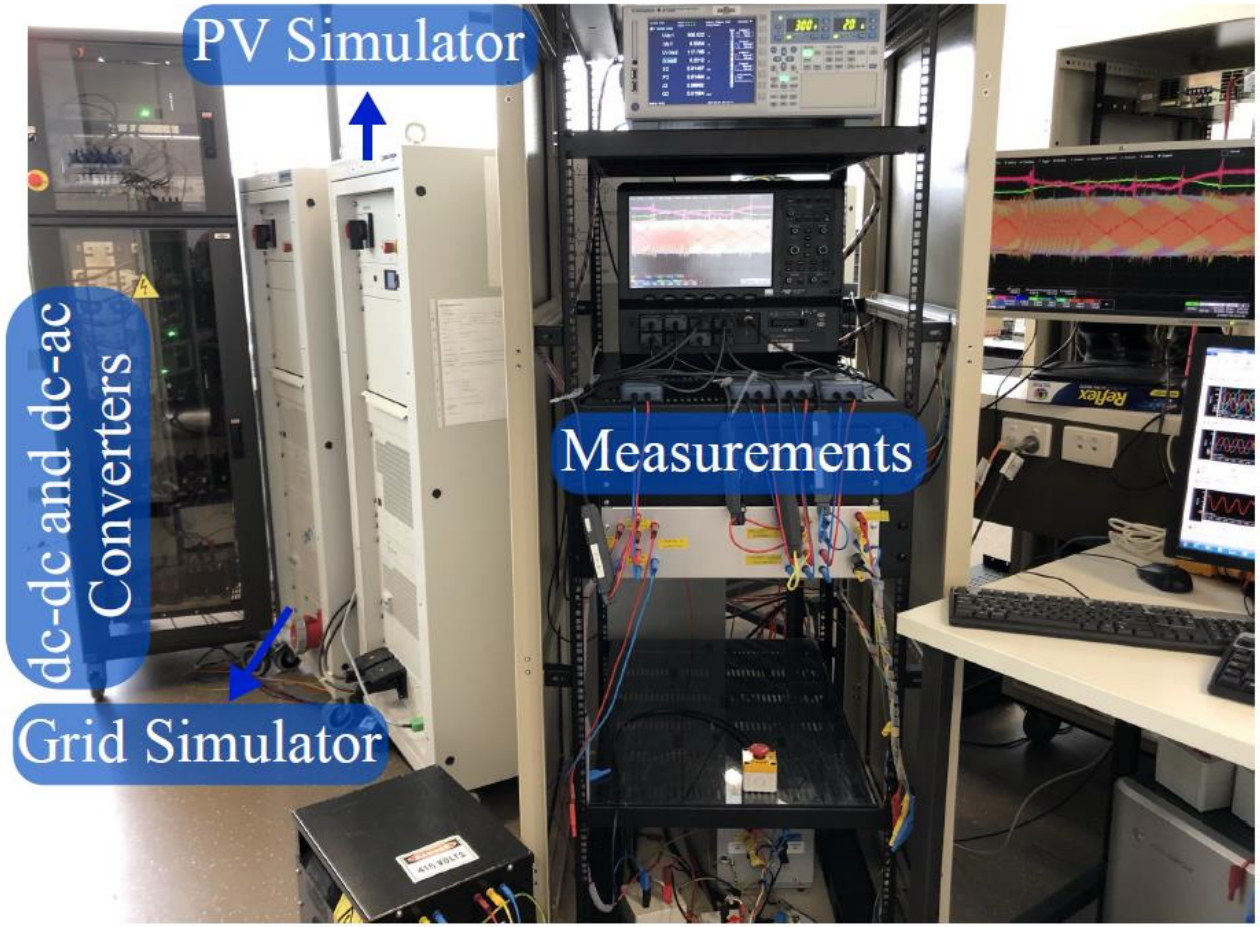
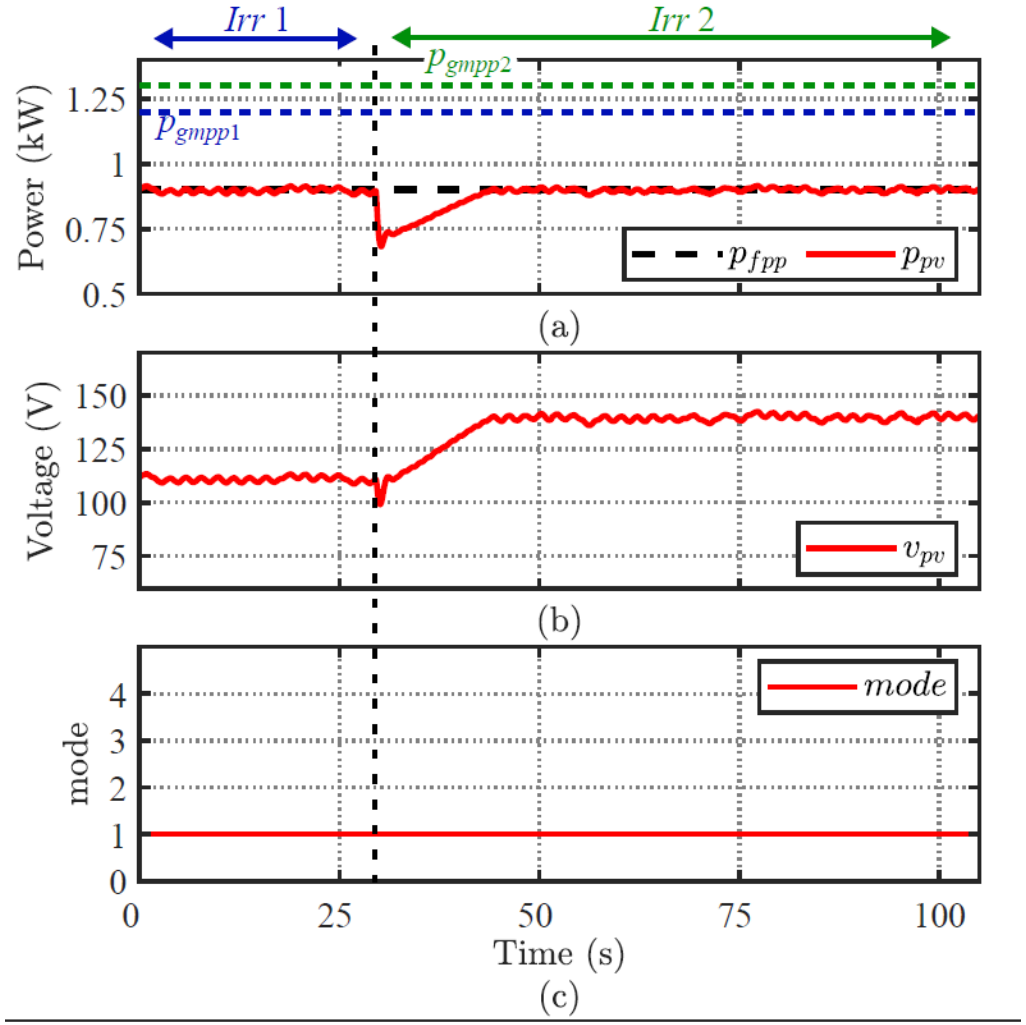
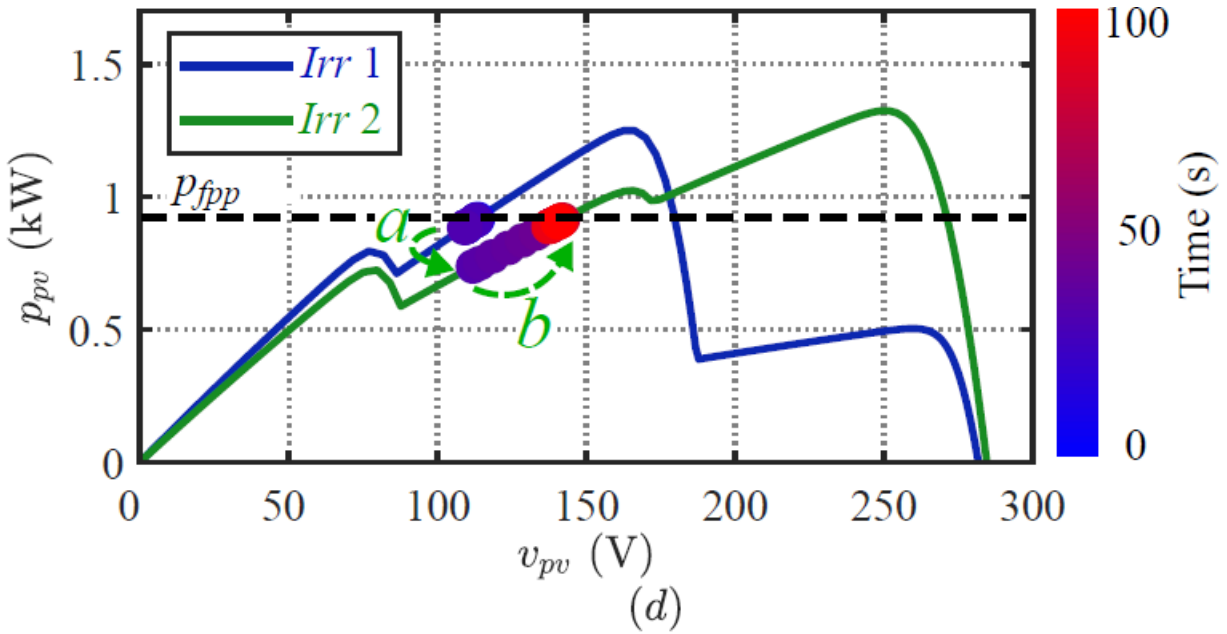


Experimental Results





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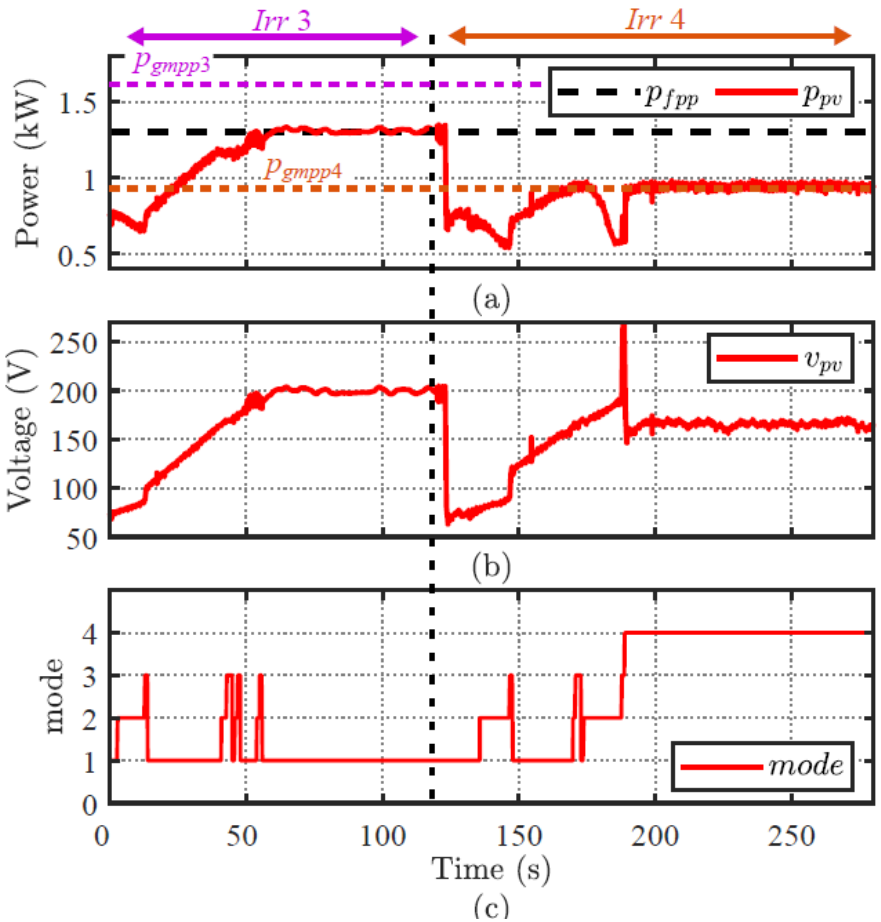

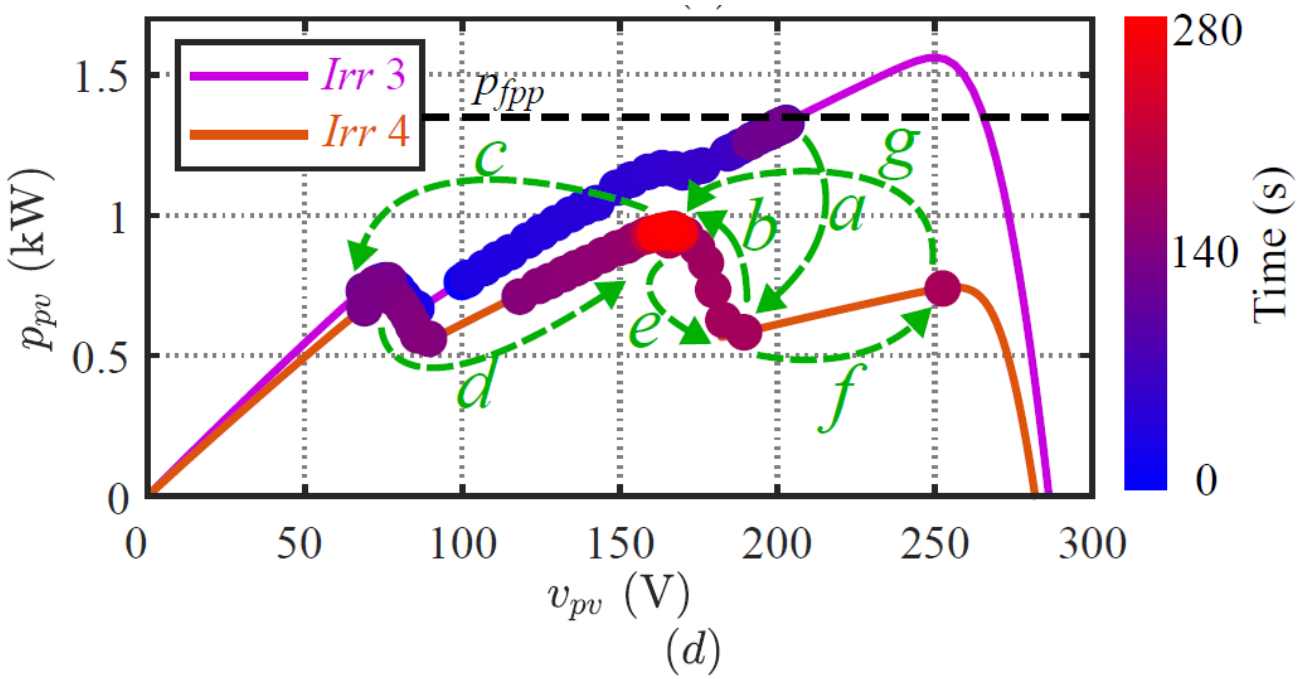

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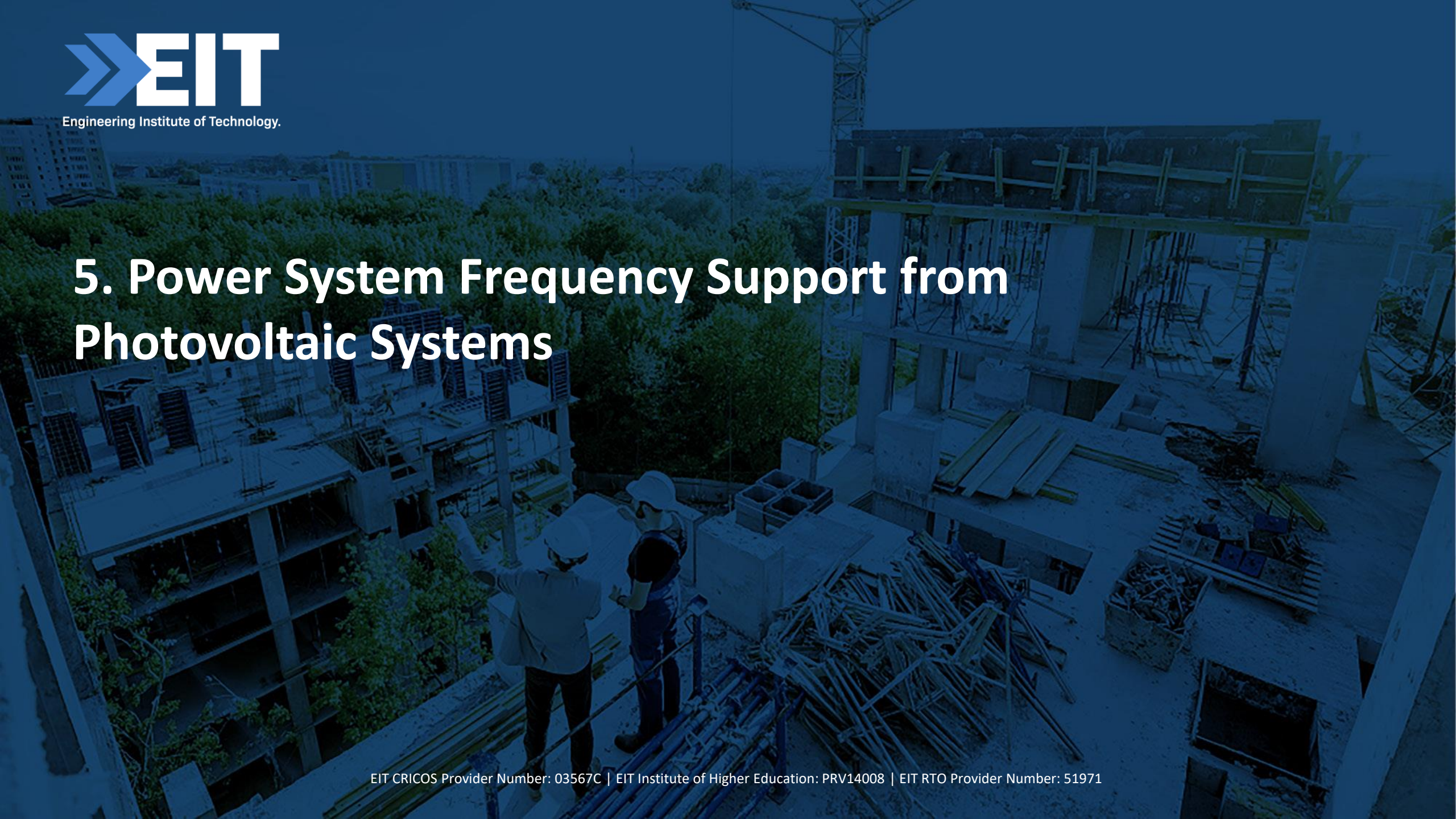
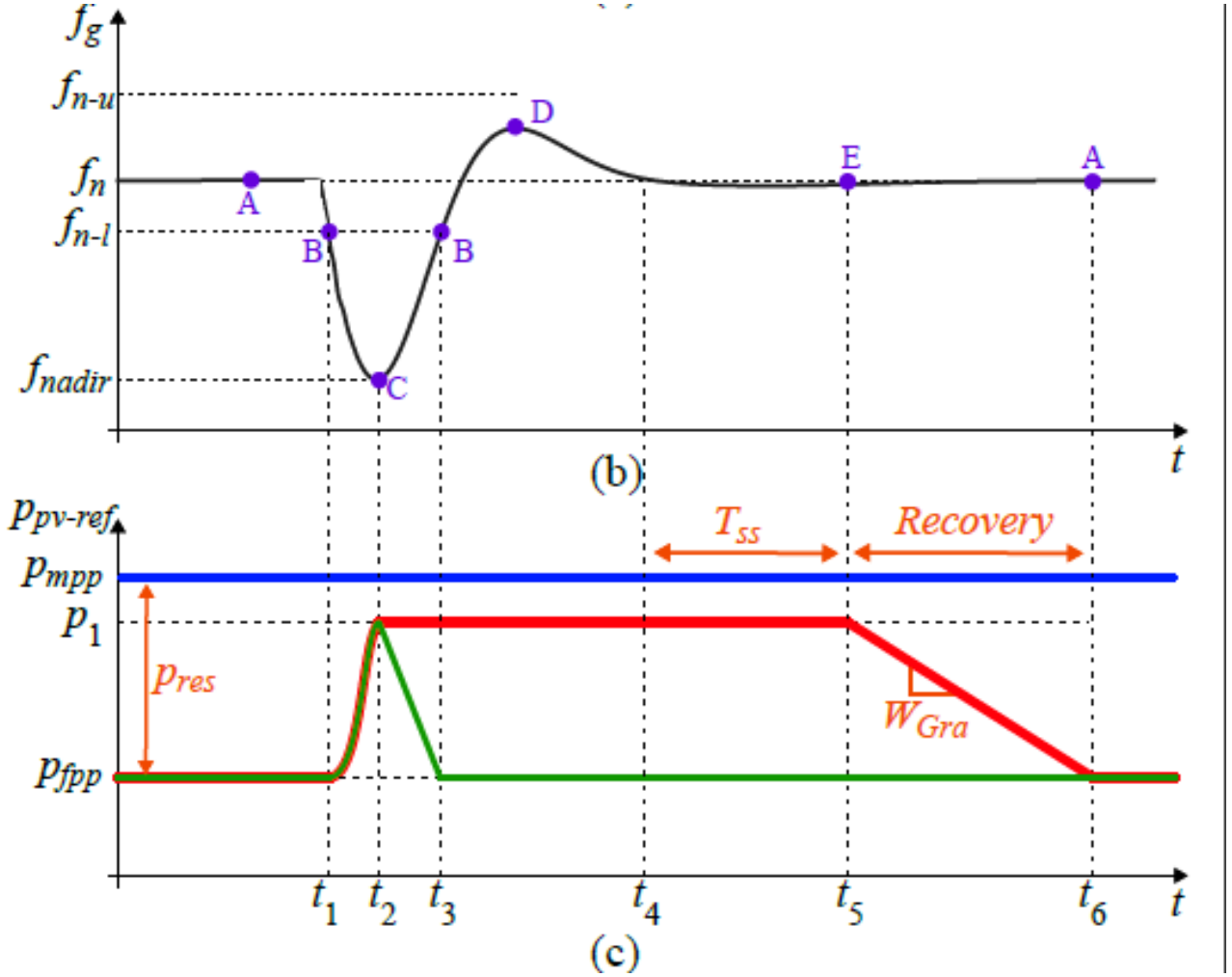
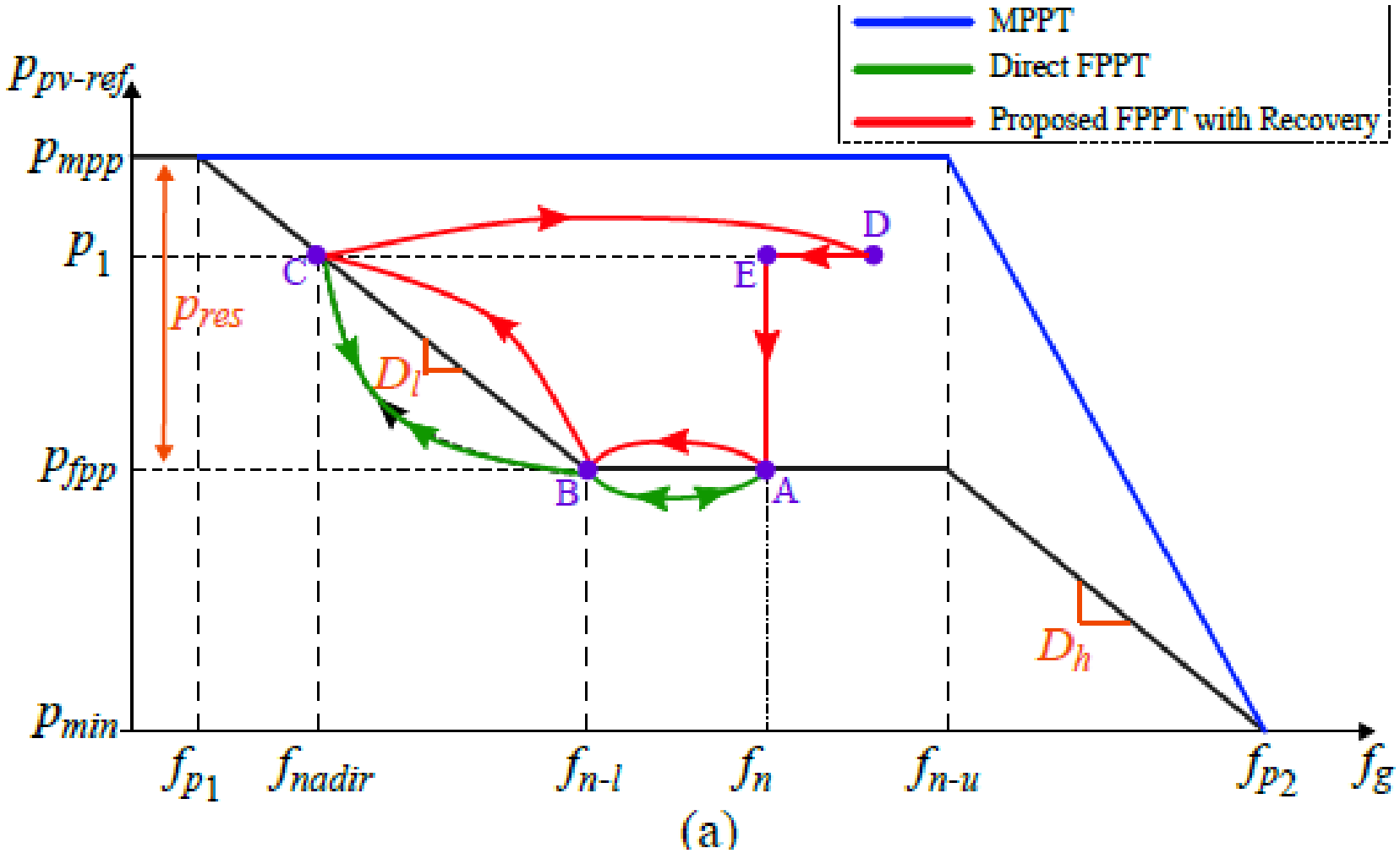
5. Power System Frequency Support from Photovoltaic Systems



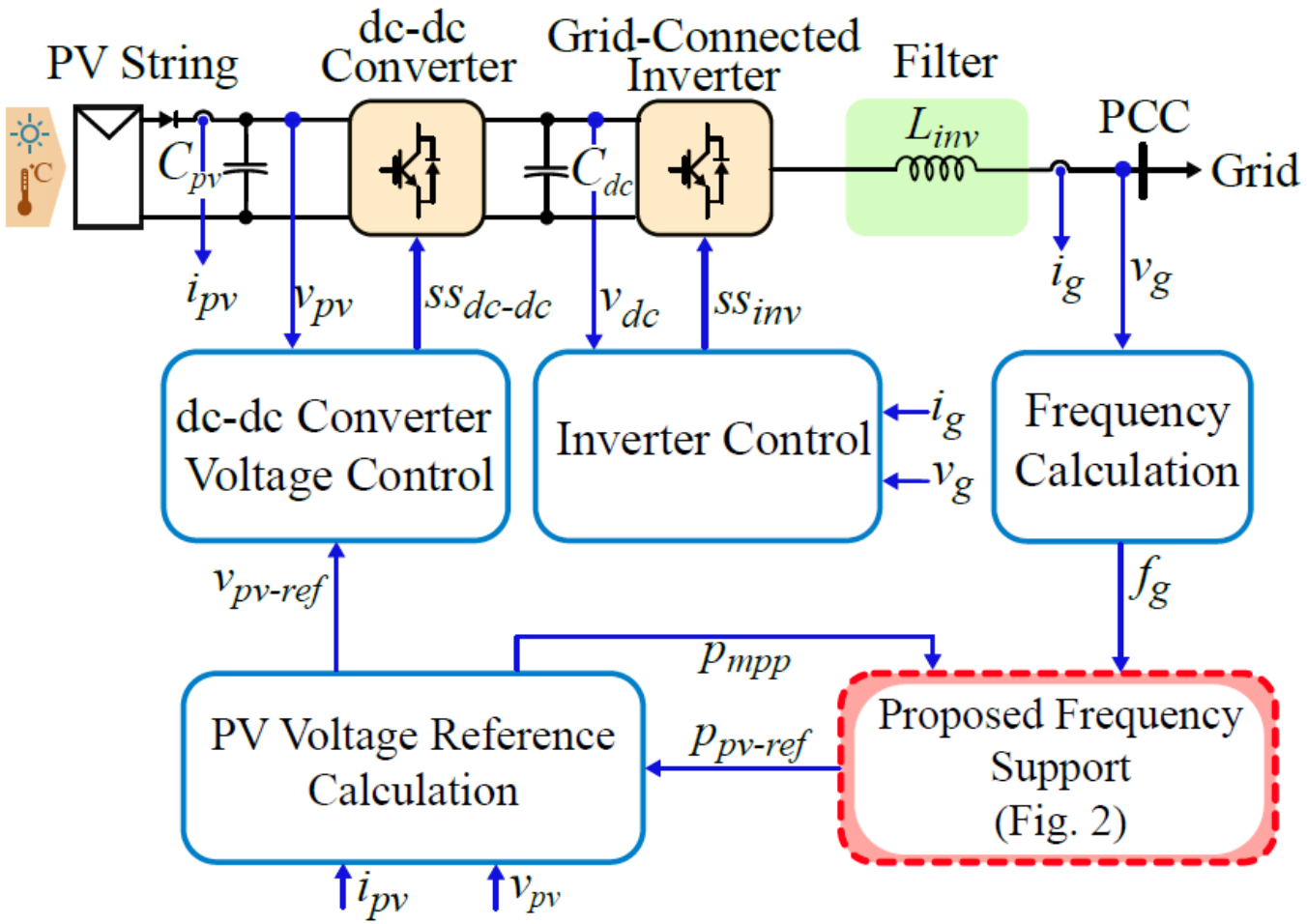
Frequency Support with PV Systems



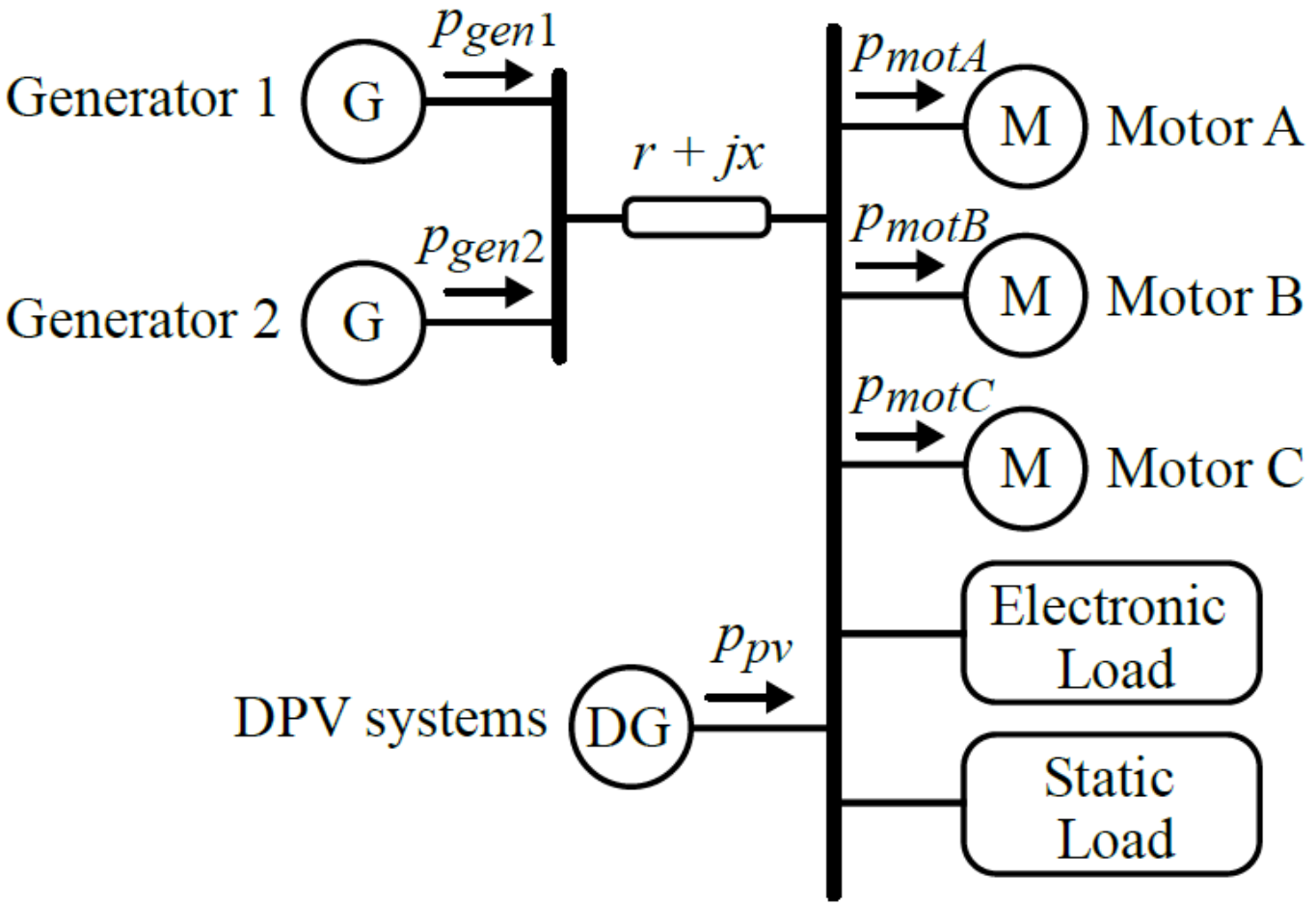
Frequency Support with PV Systems



Frequency Support with PV Systems



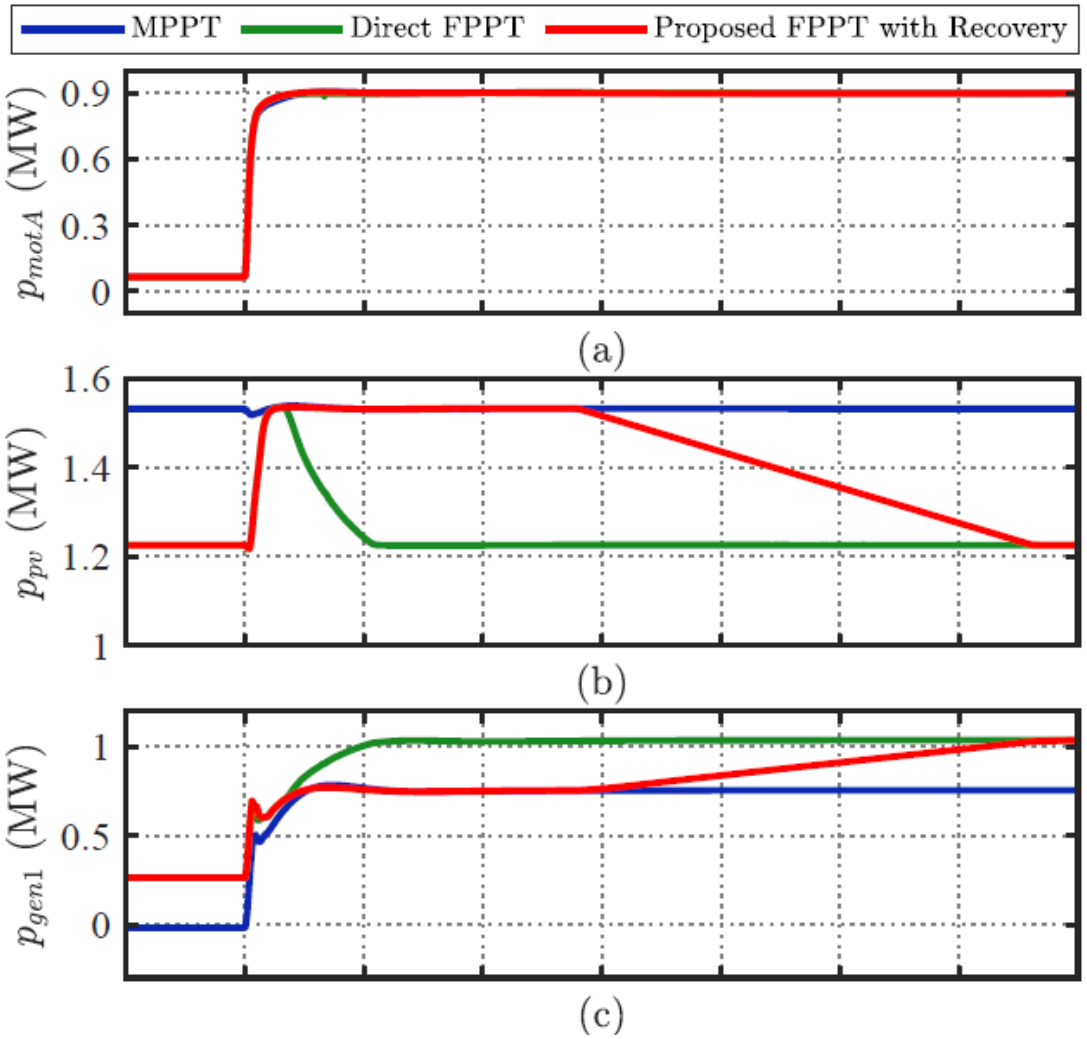
Composite Load Model

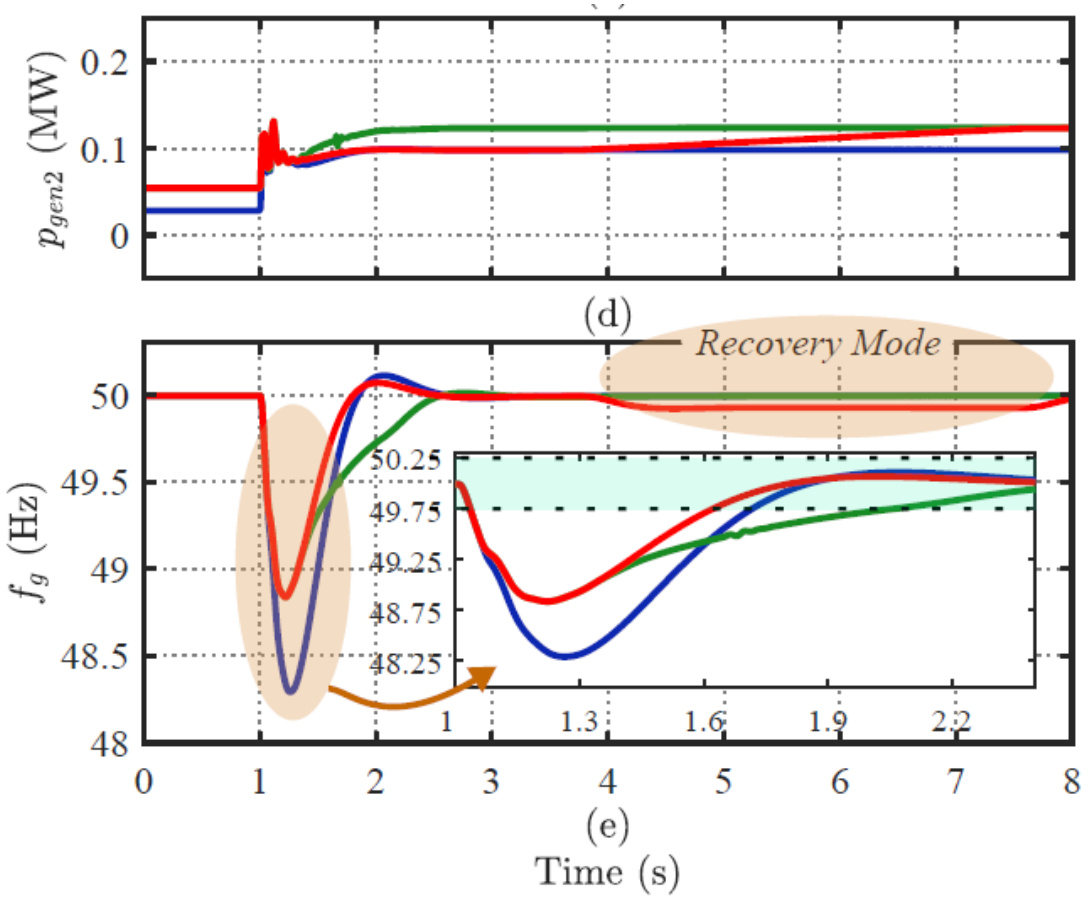


Composite Load Model

- *Motor A:* This motor represents an aggregation of three phase induction motors with low inertia (H = 0.1 s) that are usually installed in industrial premises to drive constant torque loads.
- *Motor B:* This motor is a representation of aggregated three phase induction motors with high inertia (H = 0.25-1 s). This motor represents the motors found in commercial ventilation fans and air handling systems.
- *Motor C:* The aggregation of commonly found commercial water circulation pumps is represented with this motor with low inertia (H = 0.1-0.2 s).
- *Electronic Load:* This type of load represents electronic based loads with constant active and reactive power for a range of grid voltage values.
- *Static loads:* This component is modeled using polynomial equations, which relate the load to the voltage and frequency. This load represents other available types of loads in the distribution system, which are not mentioned above.

Simulation Results





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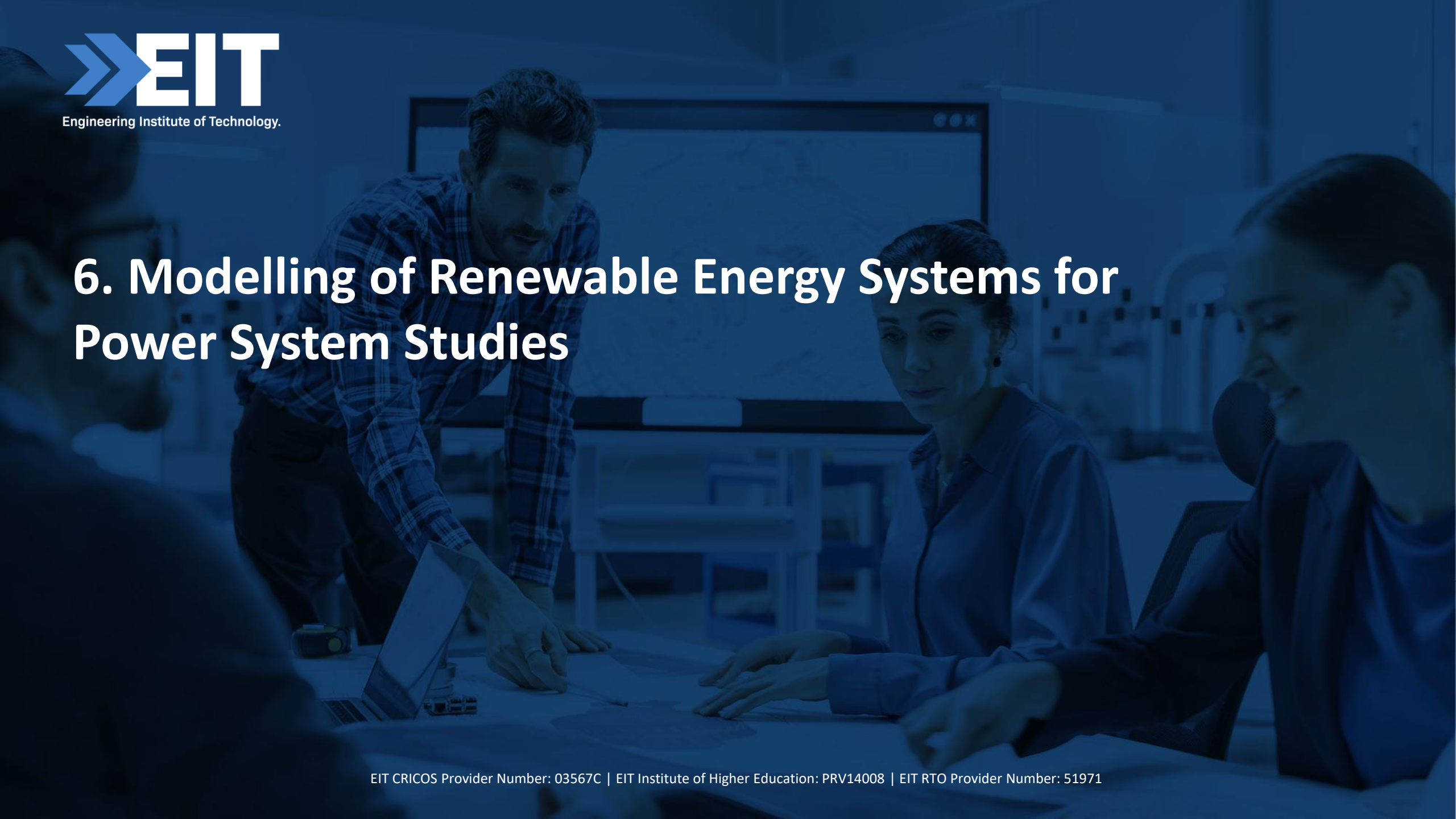
6. Modelling of Renewable Energy Systems for Power System Studies



QLD – SA Separation Event
NEM Frequency

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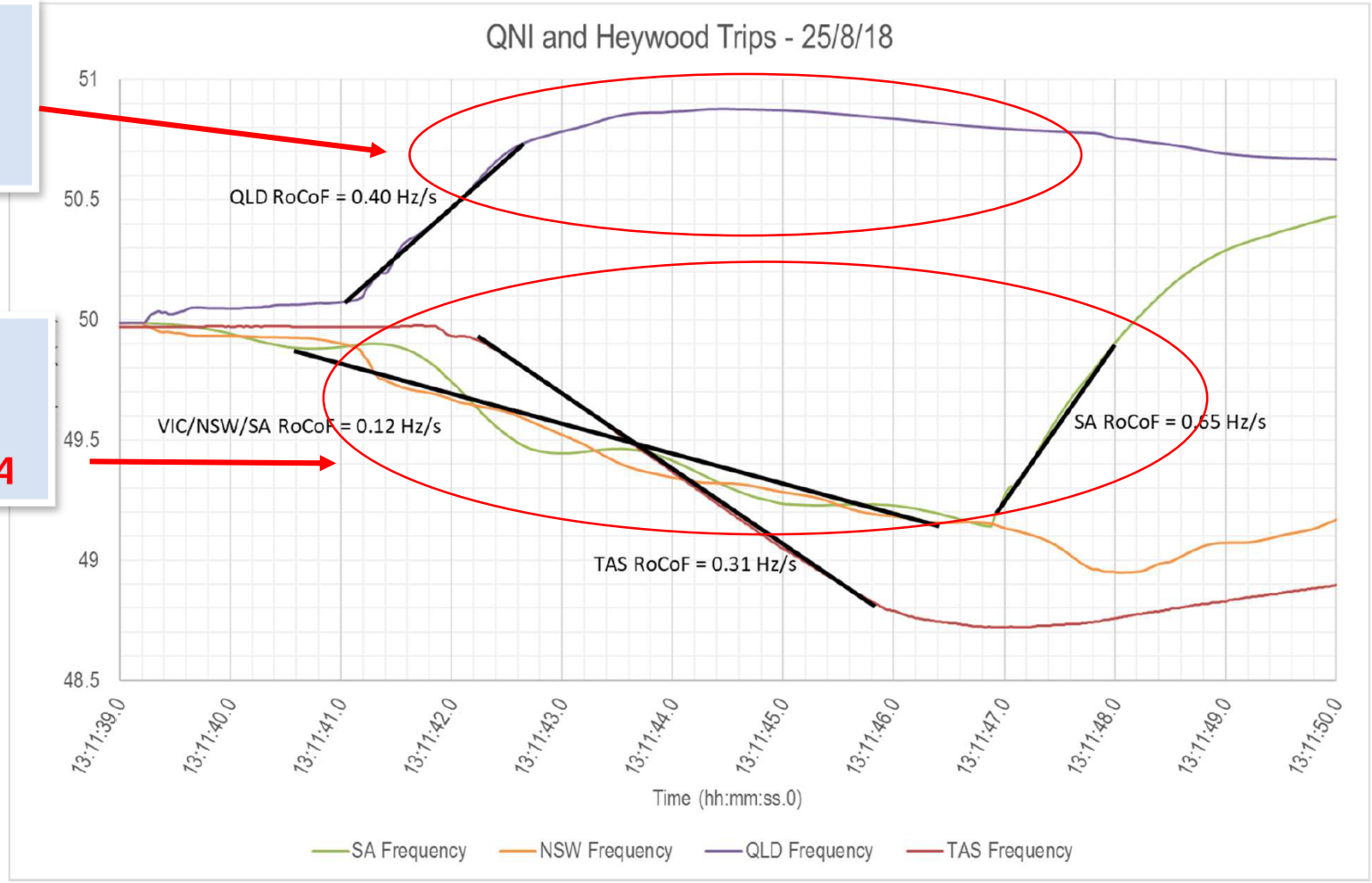
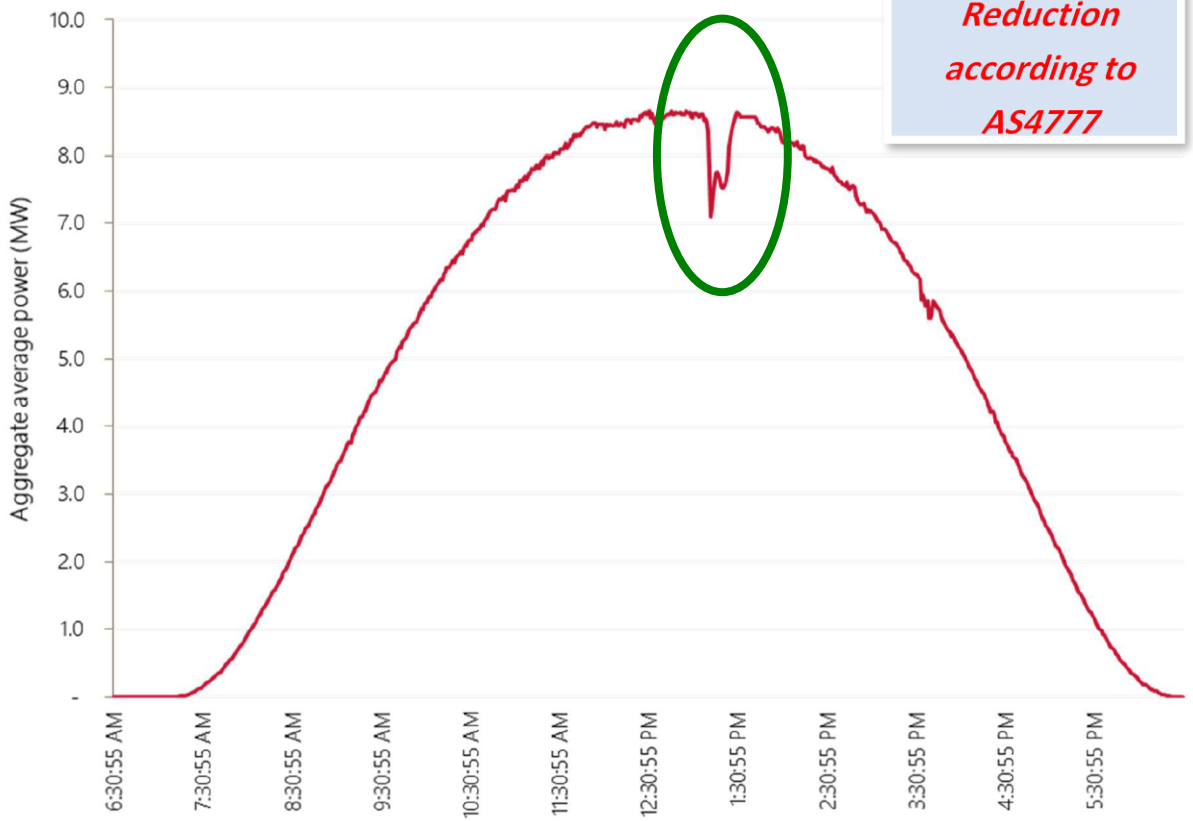
Over Frequency For LD

Under Frequency For VIC/NSW/SA

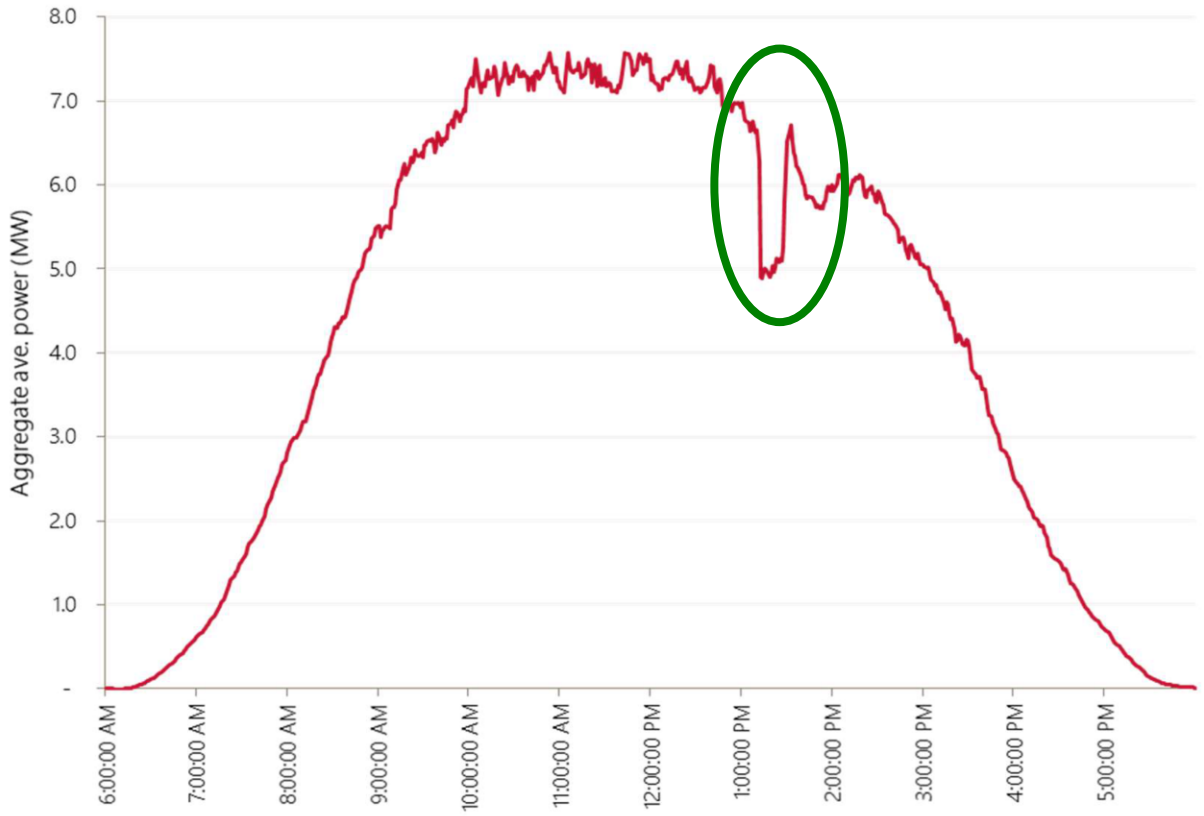


QLD – SA Separation Event

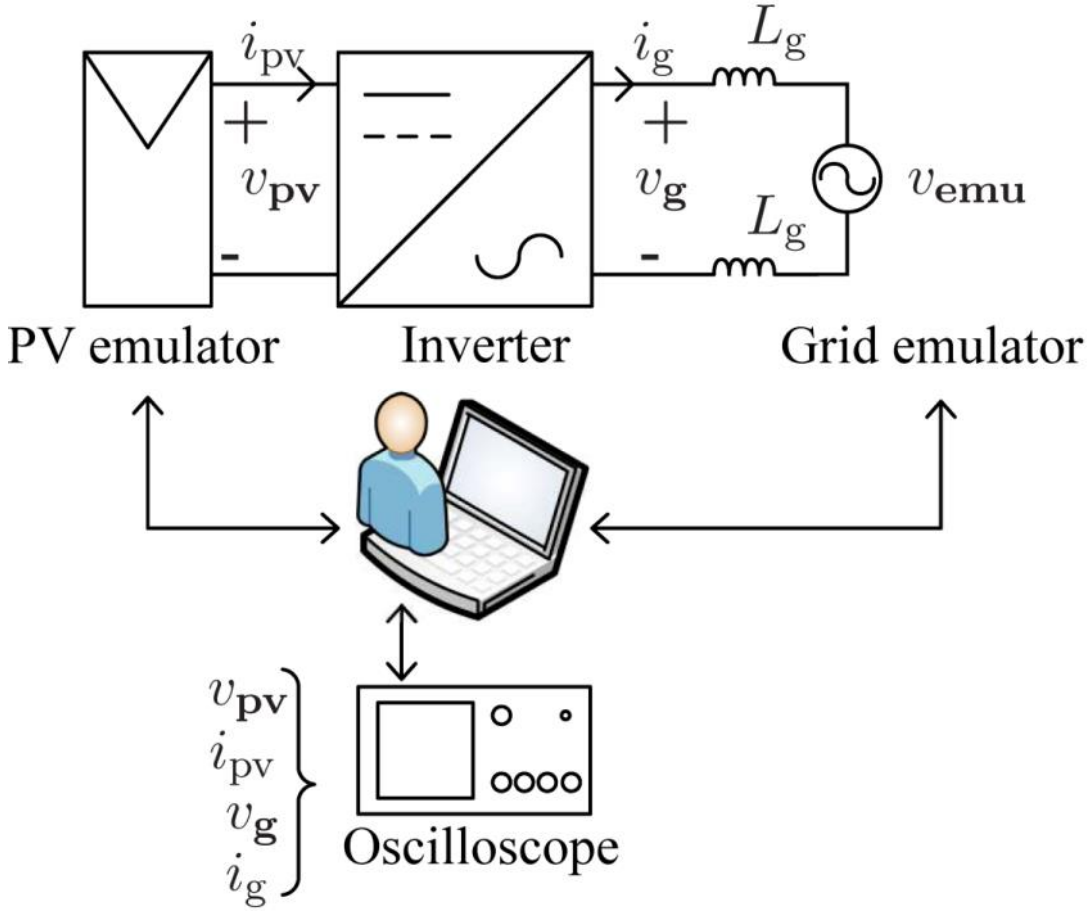
QLD response (Sampled)

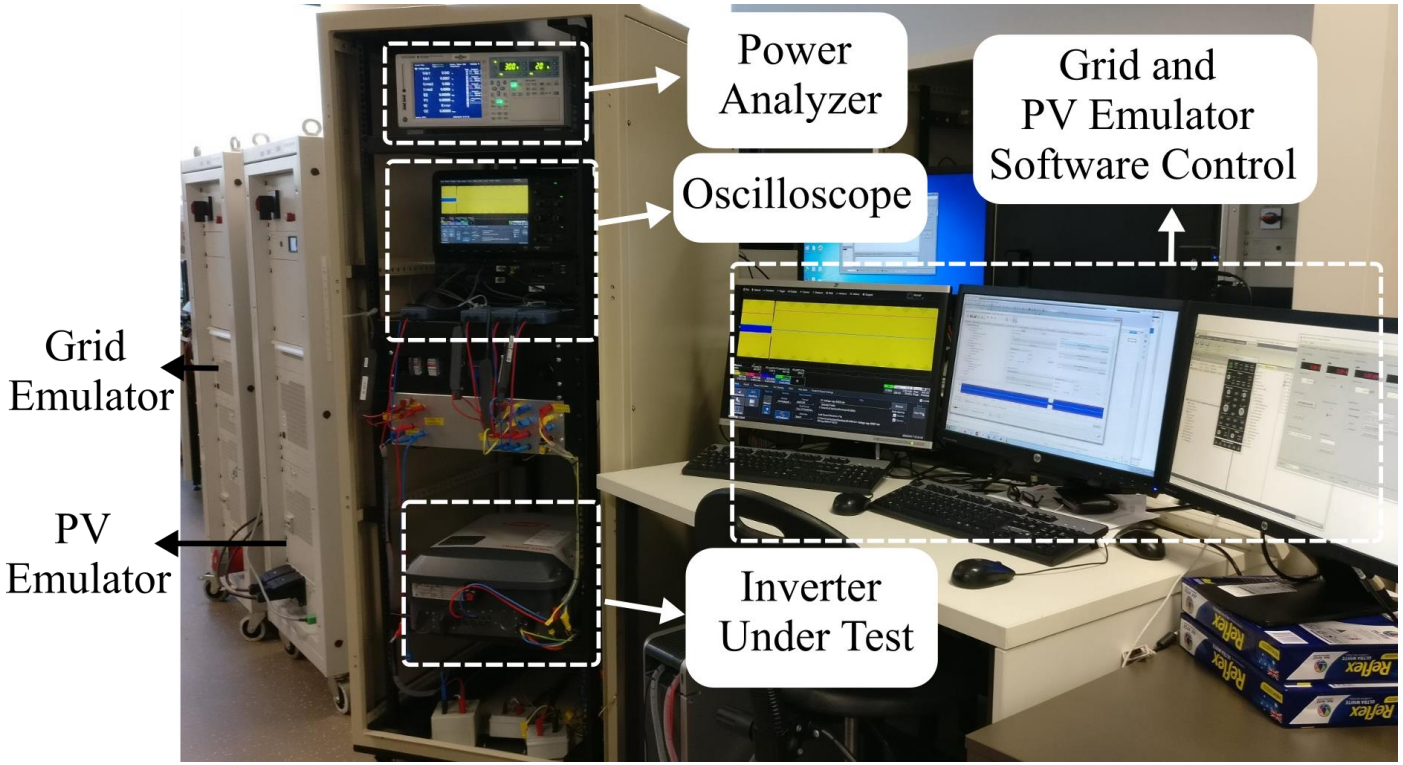


SA response (Sampled)



Benchmarking Setup

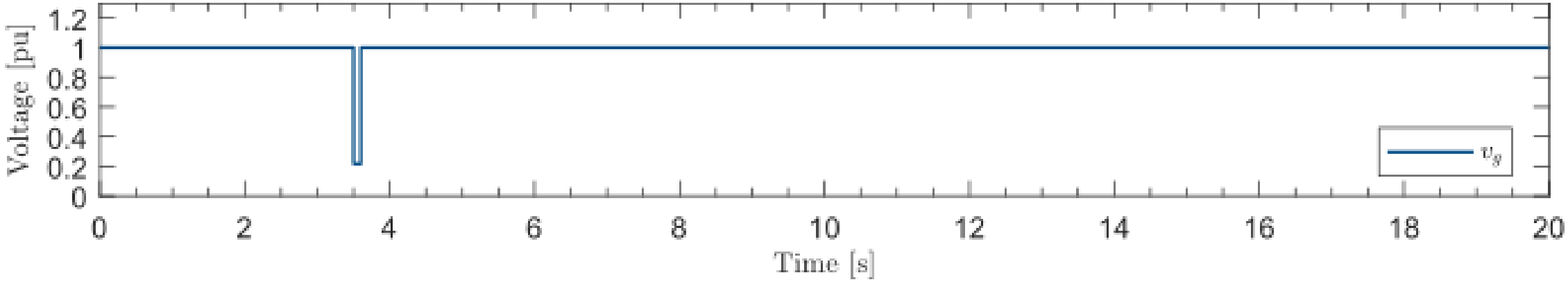




Voltage Sag – Standard Requirements

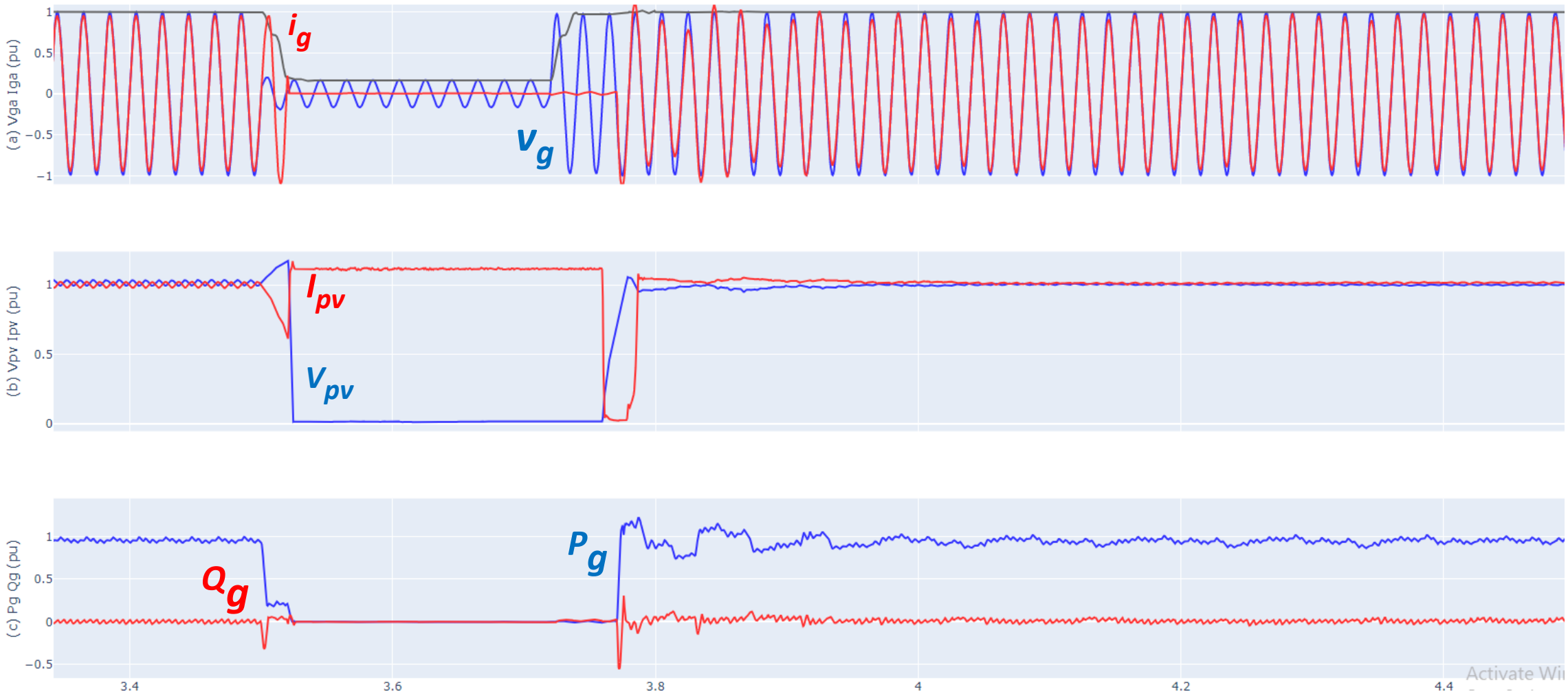
Protective function	Protective function limit	Trip delay time	Maximum disconnection time
Undervoltage (V<)	180 V	1 s	2 s
Overvoltage 1 (V>)	260 V	1 s	2 s
Overvoltage 2 (V>>)	265 V	—	0.2 s
Under-frequency (F<)	47 Hz (Australia) 45 Hz (New Zealand)	1 s	2 s
Over-frequency (F>)	52 Hz	—	0.2 s

However! There is no guideline in the appendix of AS 4777.2:2015 specifying test procedures for an under-voltage that is cleared before the trip delay time is elapsed.



Voltage Sag Response:

Inverter 1 - Ride-through with momentary cessation behaviour, sag with voltage of 0.2 p.u. for 220ms



Voltage Sag Response:

Inverter 2 - Ride-through without momentary cessation behaviour, sag with voltage of 0.4 p.u. for 220ms

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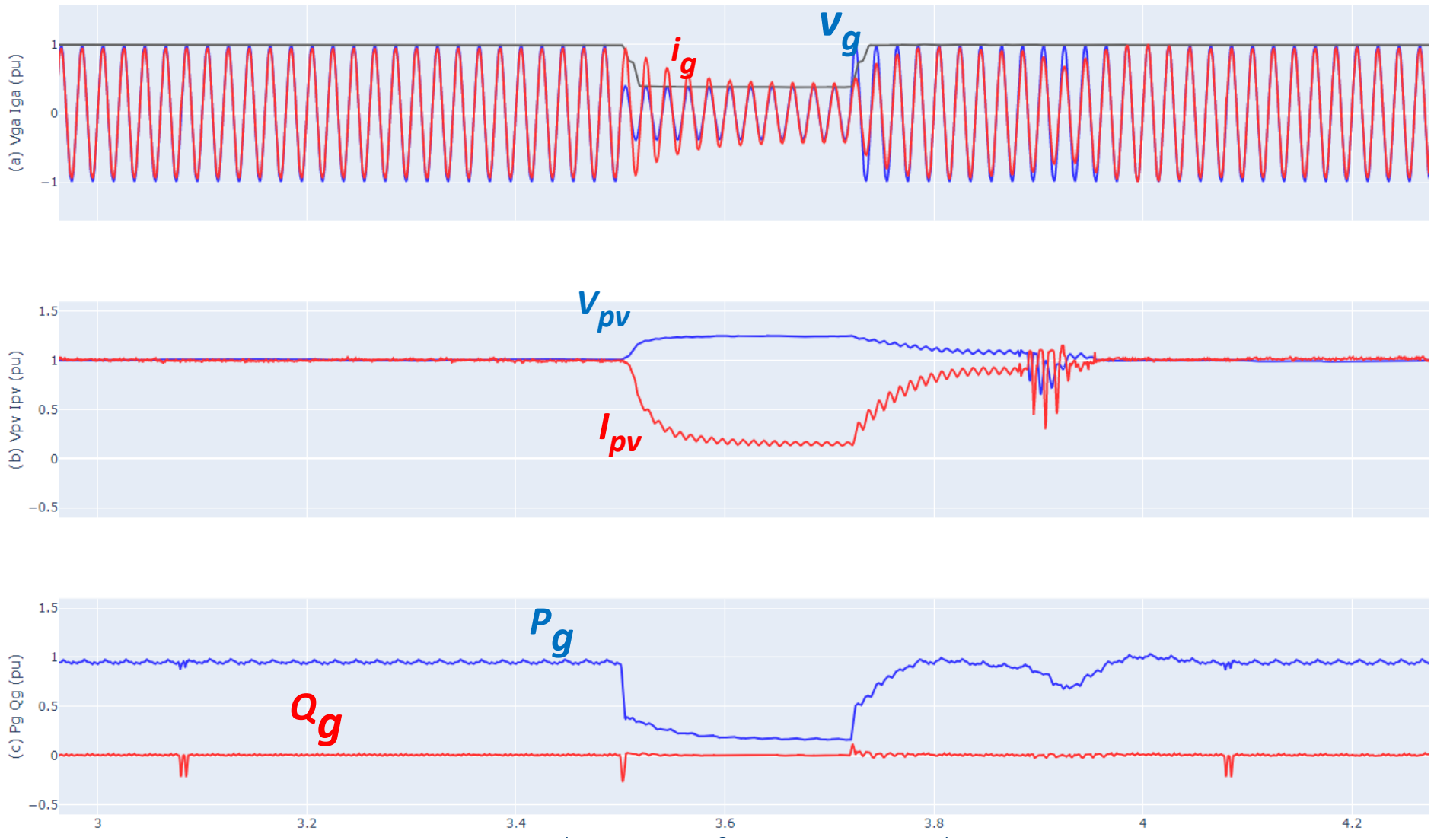

Voltage Sag Response

Inverter 3 - power curtailment to zero, sag with voltage of 0.2 p.u. for 220ms

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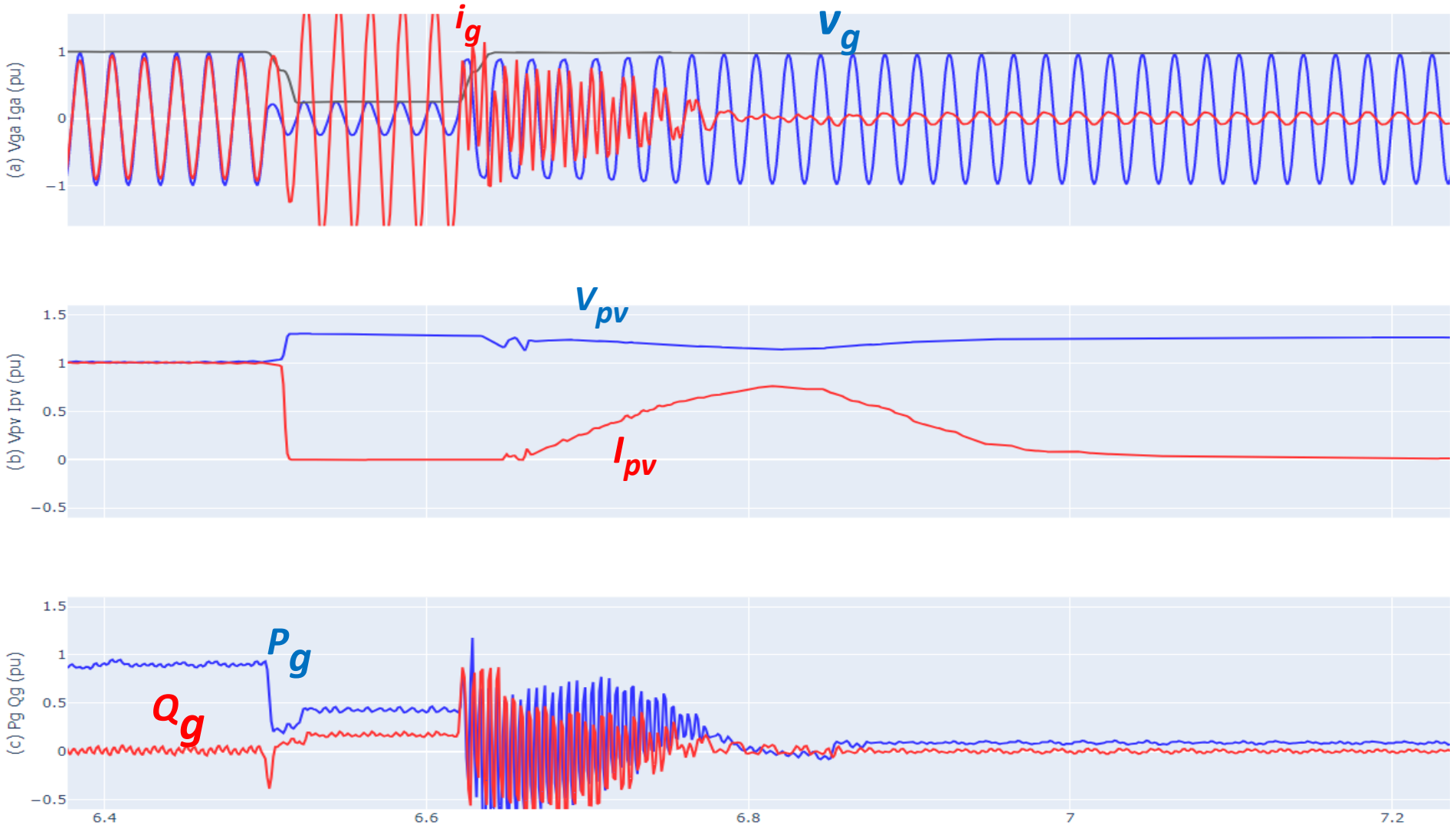
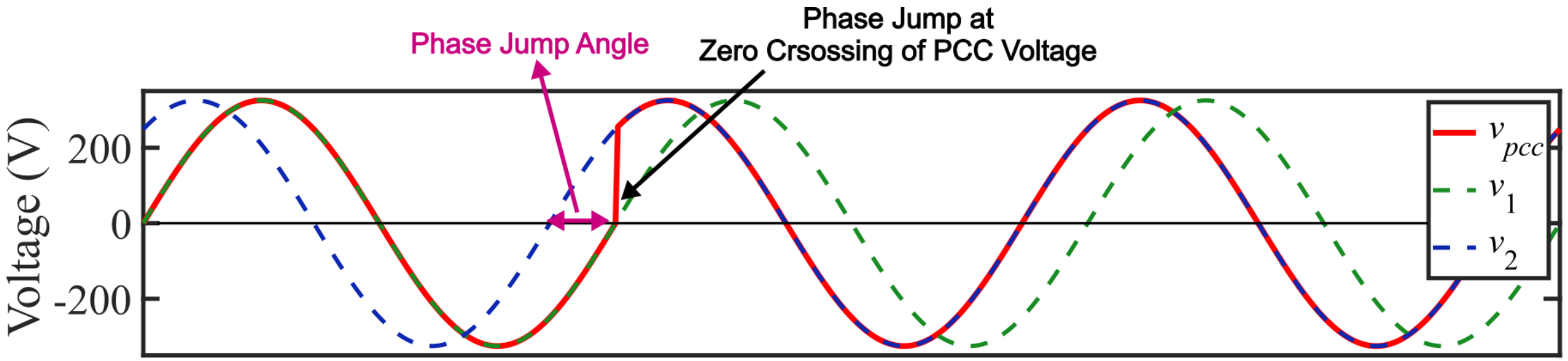
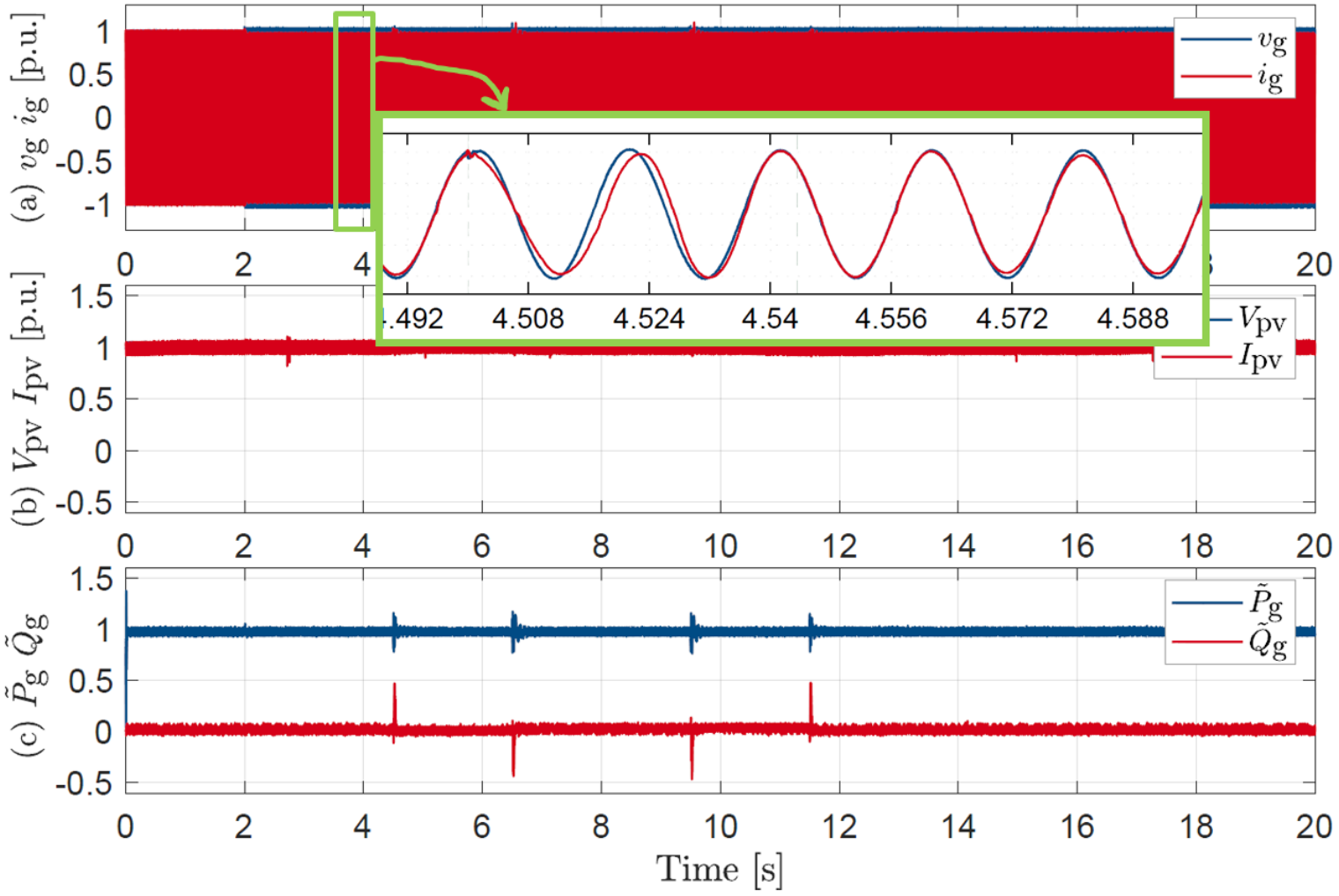


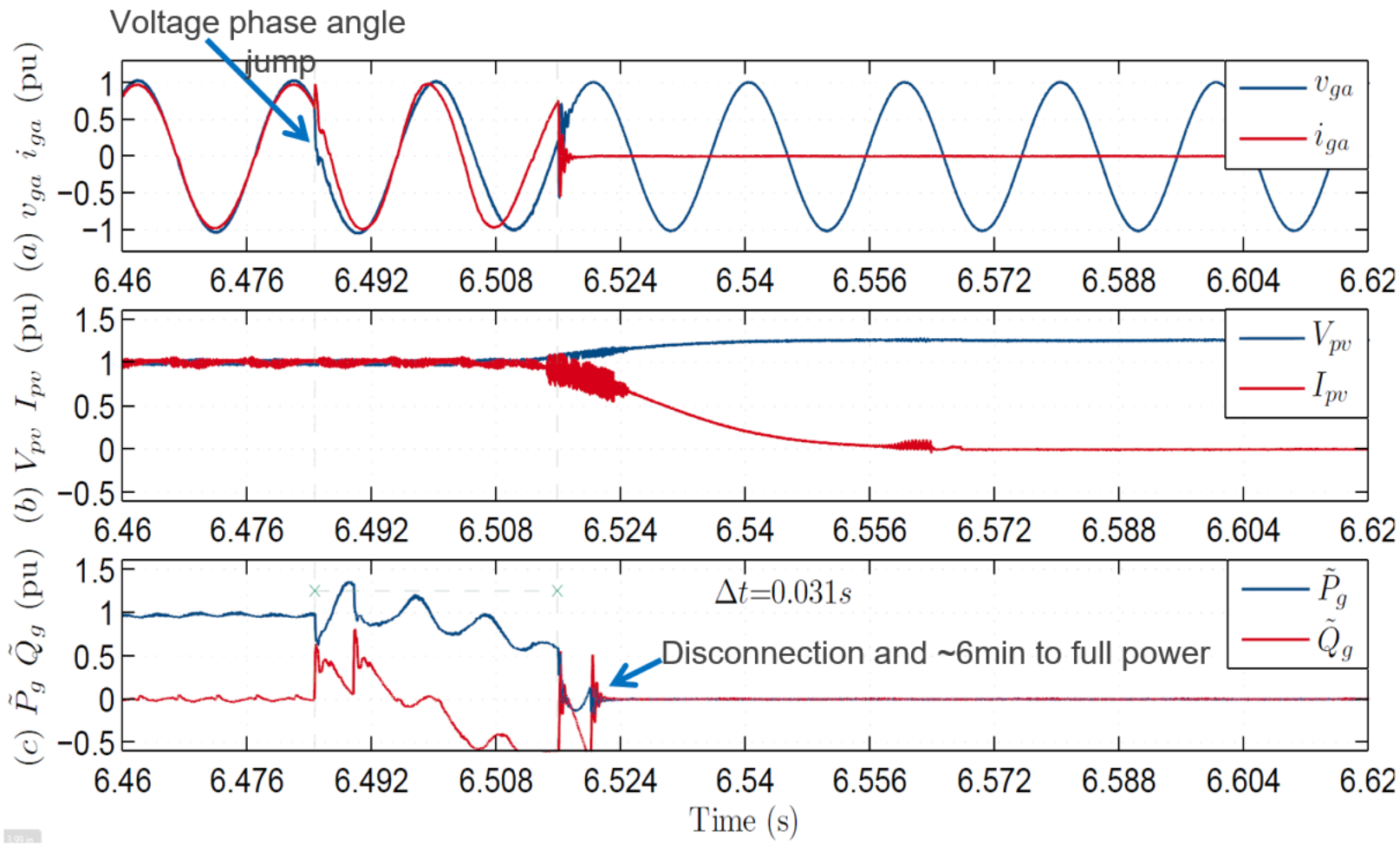
Grid Voltage Phase Angle Jump



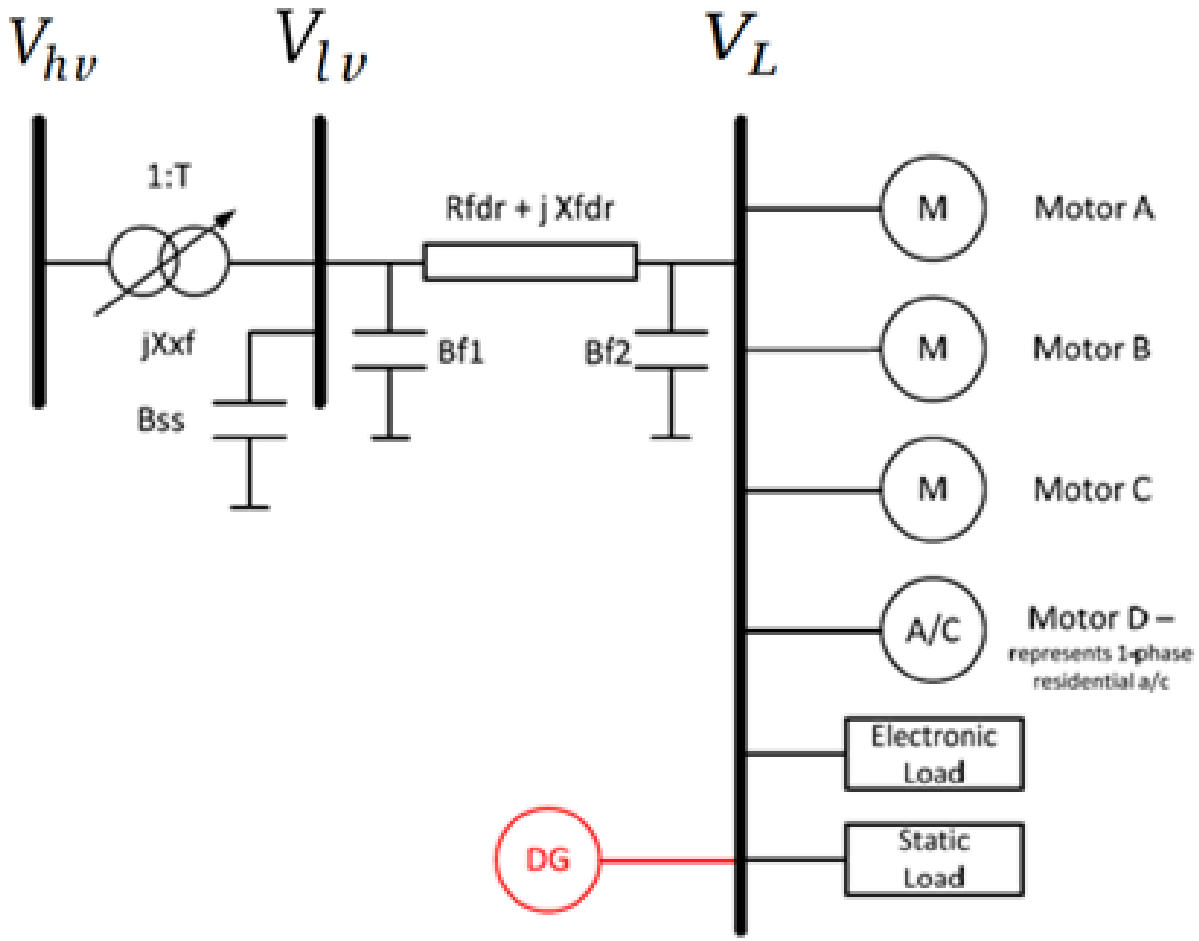
15˚ Grid Voltage Phase Angle Jump : Ride-through



30˚ Grid Voltage Phase Angle Jump: Disconnect

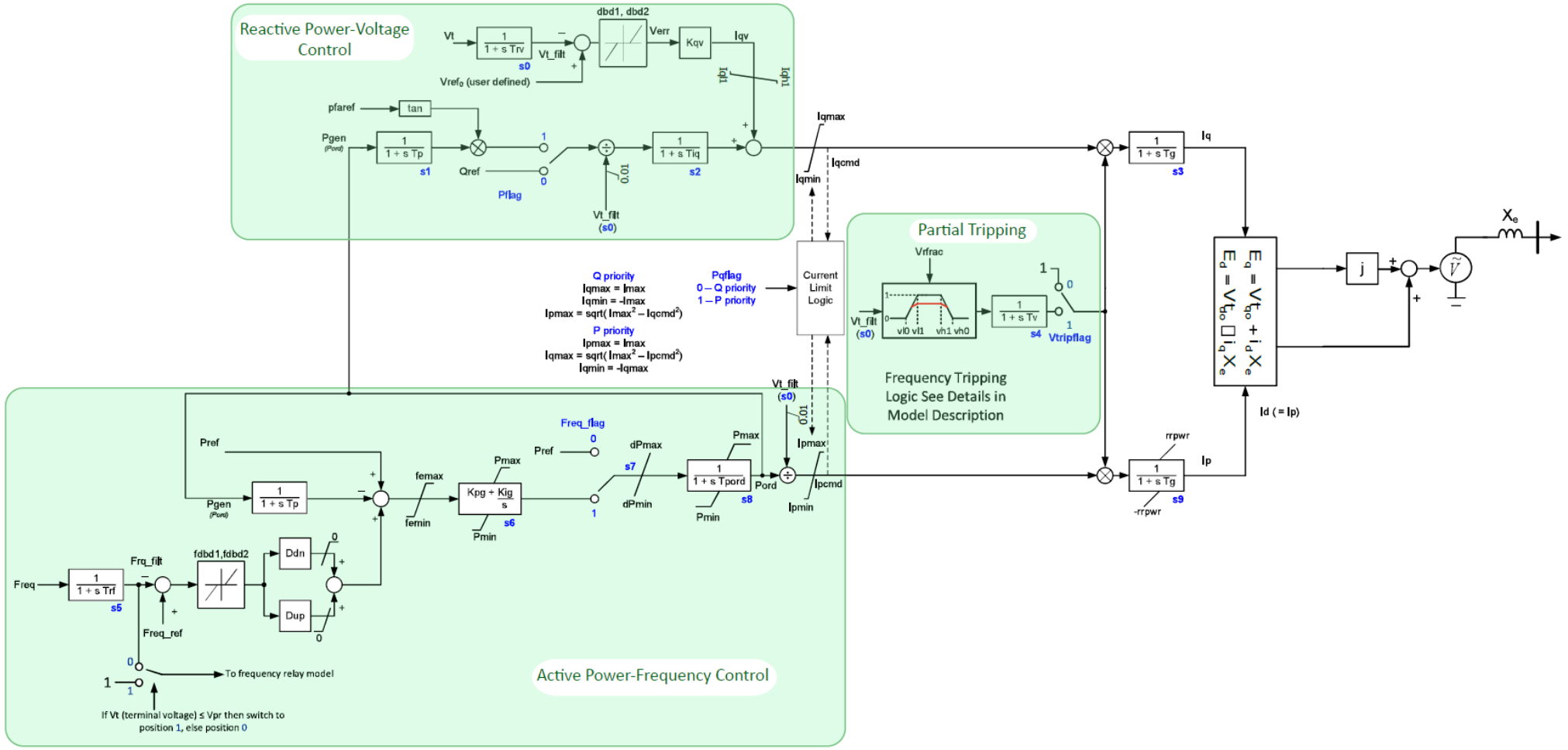


Western Electricity Coordinating Council Composite Load Model



PV inverter test results are essential for developing an accurate DG model in the WECC-CMDL.

Western Electricity Coordinating Council Composite Load Model



Summary

- New challenges for power system operator under high penetration of PV systems
- Principles of flexible power point tracking
- Grid frequency support using flexible power point tracking
- Unusual behavior of installed PV inverters under grid transients and importance of accurate modelling of inverters for system studies

Thank you!

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