INDIA-UK CENTRE FOR EDUCATION AND RESEARCH IN CLEAN ENERGY (IUCERCE)

A Joint Virtual Clean Energy Centre

IIT Kanpur IIT Hyderabad IIT Bombay CDAC Tezpur University

PI (India): Prof. B. G. Fernandes (IIT Bombay)

Budget: INR 21.83 Crores| Start date: August 2017

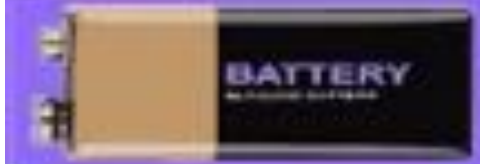
PI (UK): Dr. Murray Thomson (Loughborough University)

Loughborough University	Swansea University Prifysgol Abertawe	MANCHESTER 1824 The University of Manchester	UNIVERSITY OF BIRMINGHAM	UNIVERSITY OF OXFORD
CARDIFF UNIVERSITY PRIFYSGOL CAERDYD	Imperial College London	UNIVERSITY OF Southampton	UNIVERSITY OF EXETER	WARWICK THE UNIVERSITY OF WARWICK

Thematic Areas

μ-grid (MGD)

Development of AC/DC hybrid micro-grid capable of operating in grid connected and isolated mode with seamless mode transition



Energy Storage System (ESS)

Development of hybrid energy storage systems to improve the power quality, diurnal mismatch and seasonal mismatch in the microgrid.

Photovoltaic System (PVS)

Diagnosis and modelling of reliability of solar modules associated with deployment in different climatic zones across India

System integration & demonstration (SID)

System integration and demonstration of hybrid microgrids (30-50 kW) in different Indian scenario (climatic and current grid isolated community).

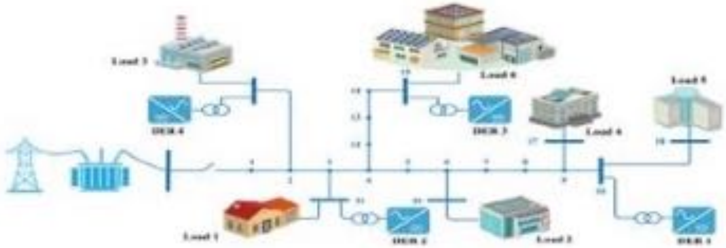
Capacity building (CPB)

Capacity building through student exchanges, training programmes and dissemination of knowledge through workshops.

Overreaching Tangible Outputs

- **System integration and demonstration of 3 hybrid microgrids (10-20 kWp) in different Indian scenario (climatic and grid isolated community)**
- **Lakshadweep**
- **Mount Abu**
- **Shillong**

India – UK Centre for Education and Research in Clean Energy (IUCERCE)

Site 1 – **LEDA housing complex, Kavarati - Lakshadweep** Number of consumers – 20 (residential complex) Focus of technology – Reliable off-grid operation with on grid support in hot, humid environment End user: Lakshadweep Energy Development Agency(LEDA)	 
Site 2 – **Brahmakumari's Ashram, Mount Abu** Number of consumers – Ashram building(Annex) Focus of technology – Reliable off-grid operation/on grid support with focus on energy storage aspects and climate control in dry/hot environment End user: Brahmakumari's Ashram	 
Site 3 – **North Eastern Hill University(NEHU) Campus, Shillong** Number of consumers – Administrative building and street lighting Focus of technology – Reliable RE power conditioning systems in humid and rainy climate End user: NEHU-Shillong	 
Site 4 – **IIT-B Laboratory** Laboratory test bed Focus of technology – Test platform for ON grid and OFF grid operation, development test-bed for futuristic control and protection methods End user: IITB	

Overreaching Tangible Outputs

- **Development of 12.5 kW, 3 Phase, 4-wire modular DC/AC converter with high frequency transformer isolation capable of operating in grid connected and isolated mode with seamless mode transition**

- **Development of smart converter for microgrid**

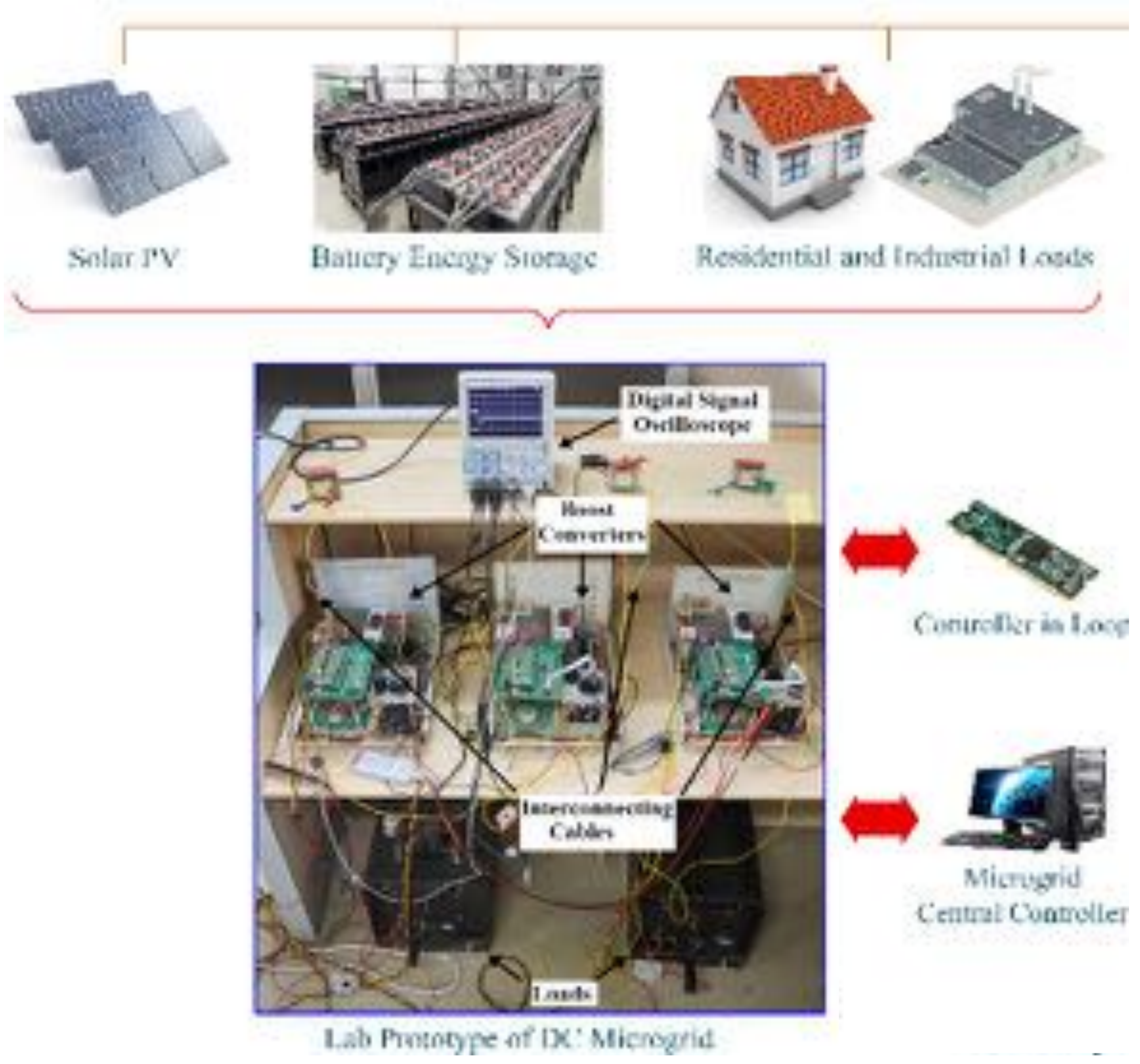
Overreaching Tangible Outputs

Problem:

- Communication is one of the most important requirement in Micro Grid
- Remote areas may not have access to fast communication
- Dedicated fast communication require high investment and longer return-on-investment (ROI) period
- Possibility of sharing communication to provide additional services

Contribution / Proposed Solution:

- Utilize low BW communication – quality index based
- Require less interconnects – consensus control
- Shared communication link – delay analysis



Technology Readiness levels

Work Package	TRL now	TRL expected
MGD 1	6	7
MGD 2	6	7
MGD 3	7	8
MGD 4	8	8
ESS 1	5	6
ESS 2	5	5
PVS 1	3	5
PVS 2	4	6
SID 1	7	8
SID 2	7	9

Work Package wise Presentations

Broad framework

MGD

i. **MGD1**: Seamless Integration of Hybrid AC/DC microgrids with the main grid (IITB)

ii. **MGD2**: Control of power electronic converters for operation and management of power in microgrid (IITK, IITH, IITB)
   i. **MGD2.1**: Autonomous re-synchronisable micro-grids. - CDAC
   ii. **MGD 2.2**: Data Analytics for Demand Characterisation / Forecasting - IITH
   iii. **MGD 2.3**: Development of next generation "smart power converters". - IITK
   iv. **MGD 2.4**: Development of optimal topology for power electronic transformer for microgrids. - IITB

iii. **MGD3**: Control and Protection in AC/DC microgrids and issues with large scale integration (IITK, IITK)
   i. **MGD 3.1**: Design and development of 10 kVA laboratory scale microgrid. - IITK
   ii. **MGD 3.2**: Protection in DC Microgrid: Define a generic DC microgrid architecture and investigate for fault currents through simulation. - IITB
   iii. **MGD 3.3**: Investigating the effects of renewable sources on electromechanical dynamics of a system. - IITB

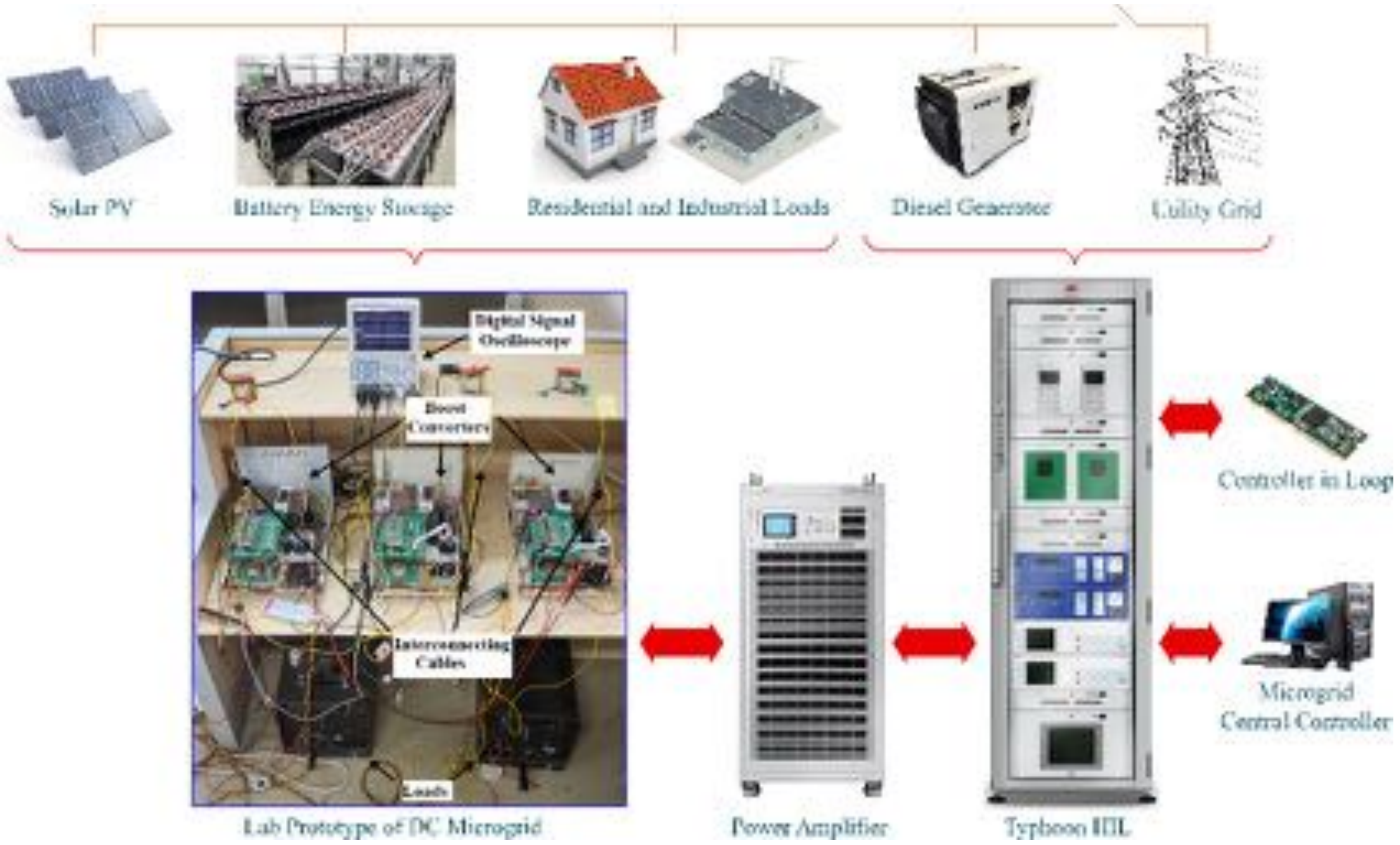
iv. **MGD4**: Microgrid Emulation (30-50 kW) using multilevel modular converters (CDAC, IITB)
   i. **MGD 4.1**: Design and development of MMC (simulation) for microgrids. – IITB/CDAC
   ii. **MGD 4.2**: System level emulation and testing of microgrids using MMC. - IITB

Objectives

Development of Microgrid Prototype

Secondary Control for Power Management in the Microgrid

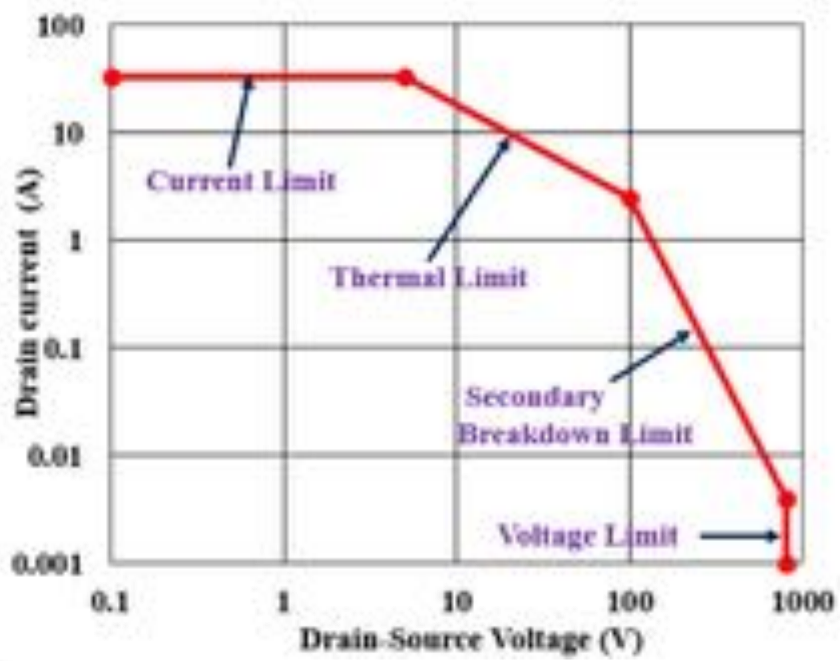
Integration of Solar PV



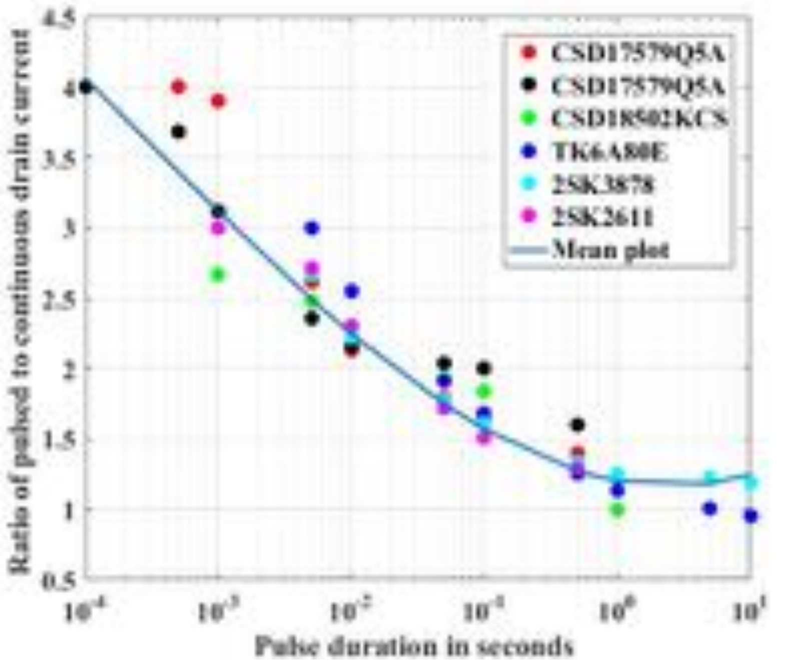
Developed Microgrid Prototype

Dynamic Overcurrent Saturation of Distributed Sources in DC Microgrid

- Overloading of a source converter during load transient.
- Source near to load provides large transient current.
- Significant disturbances when converter recovers from saturation.
- Dynamic overcurrent saturation to address these issues.



MOSFET SOA Plot With Different Limit

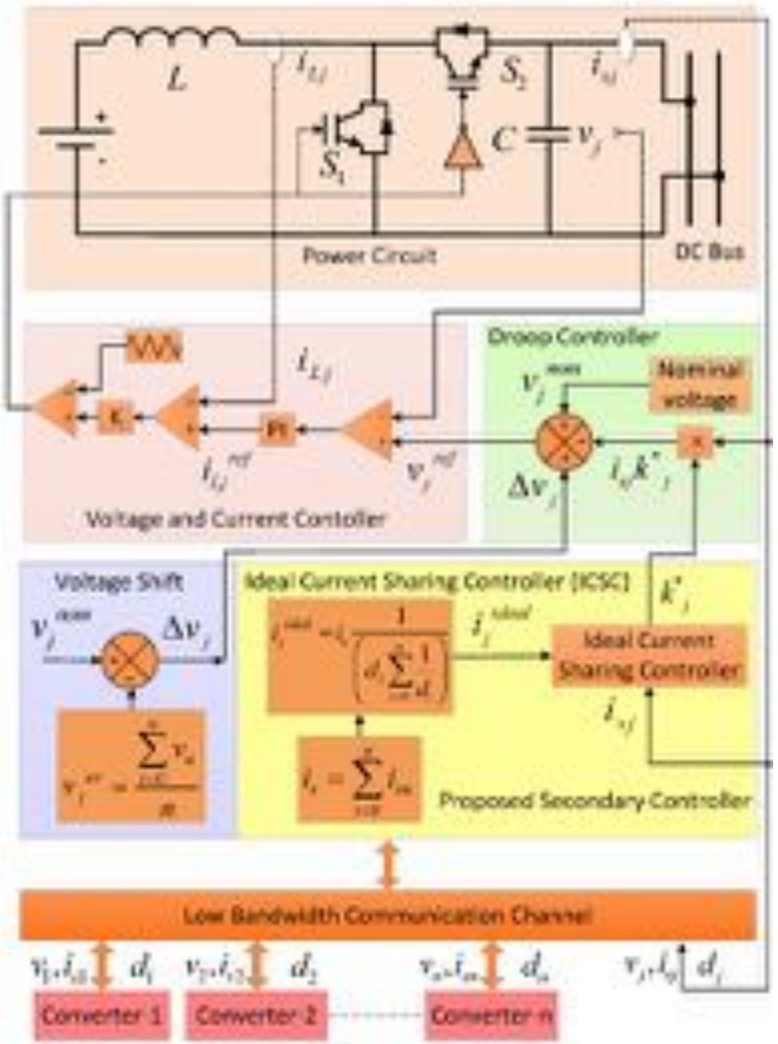


Normalized and Mean Plot for Different MOSFET

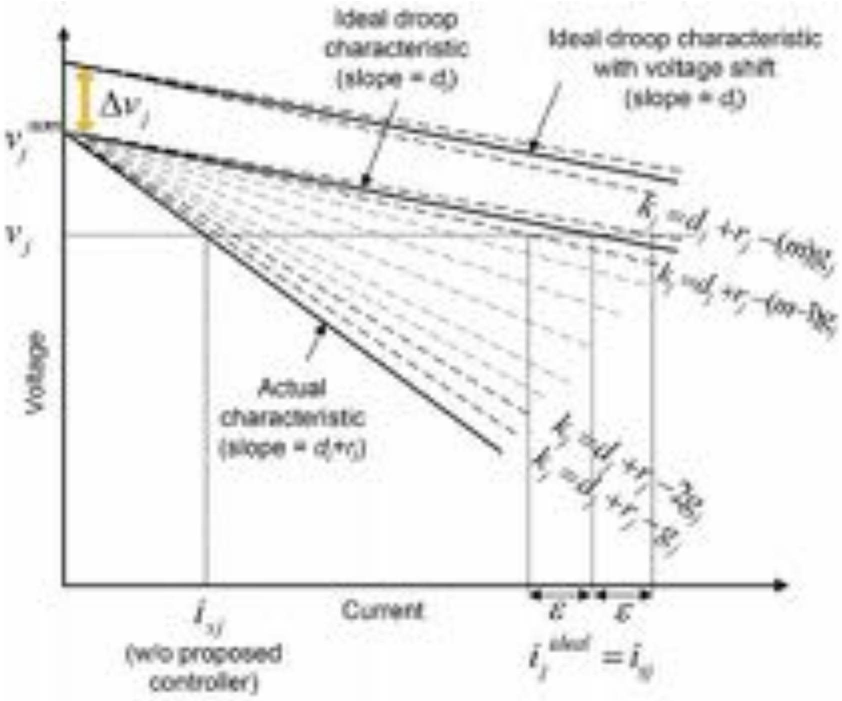
D. Dhua, A. B. Shyam, S. Anand, and S. R. Sahoo, "Dynamic Overcurrent Saturation of Distributed Sources in a DC Microgrid System", 20th National Power Systems Conference, NPSC'18, Tiruchirappalli, India, Dec 2018.

Ideal Current Based Distributed Control

- Dynamic droop gain dictated by ideal current based controller.
- Shift in nominal voltage to ensure average microgrid voltage within limits.
- Communication for exchange of voltage and current information.



Proposed Controller with DC-DC Converter

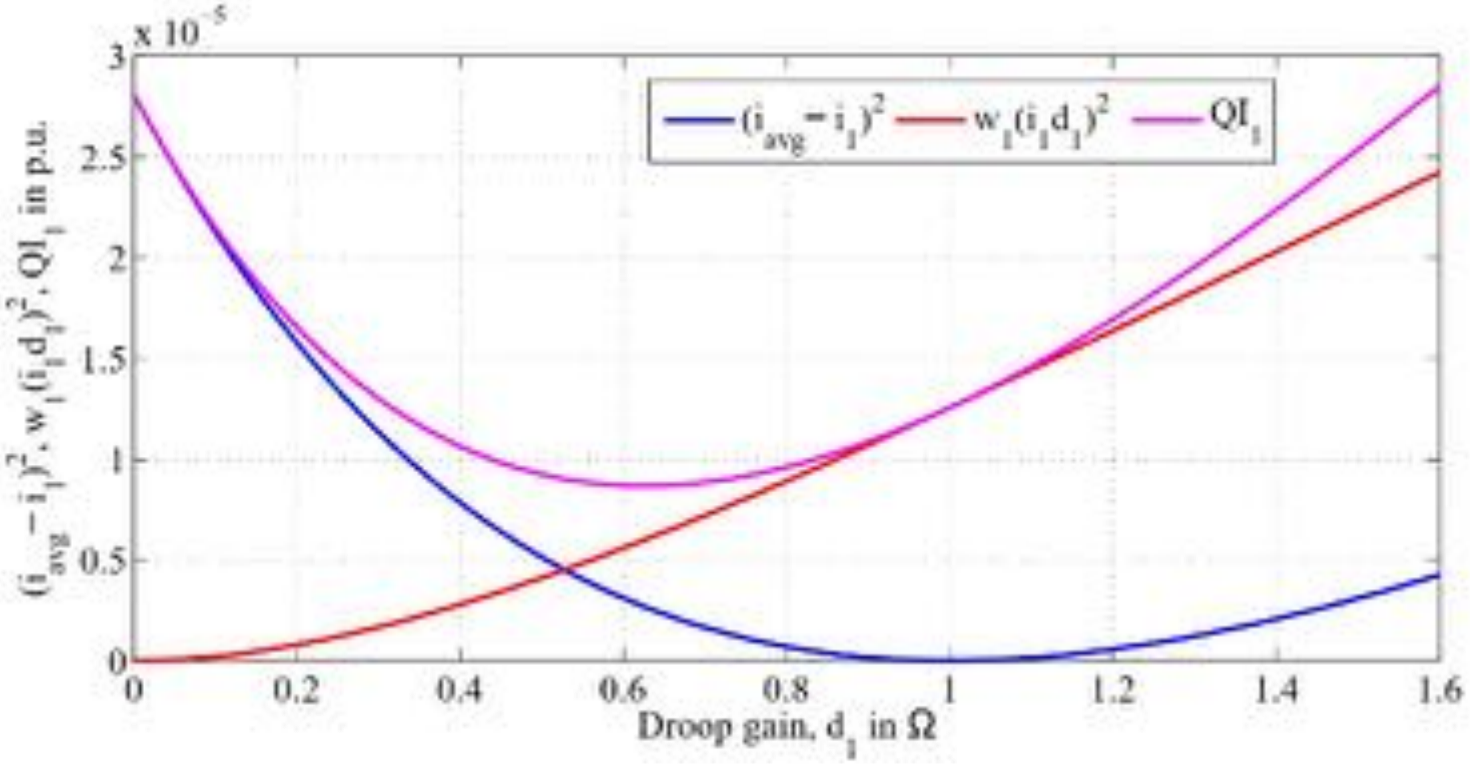


Effect of Proposed Distributed Controller on droop Characteristics

S. Islam, S. Agarwal, A. B. Shyam, A. Ingle, S. Anand, and S. R. Sahoo, "Ideal current-based distributed control to compensate line impedance in DC microgrid," in IET Power Electronics, vol. 11, no. 7, pp. 1178-1186, Jun. 2018.

Quality Index Based Distributed Secondary Controller

- **Communication of only source current**
- **Proportional current sharing and improved voltage regulation**
- **Dynamic droop gain depending on “Quality-index”**
- **Works for full and reduced communication**

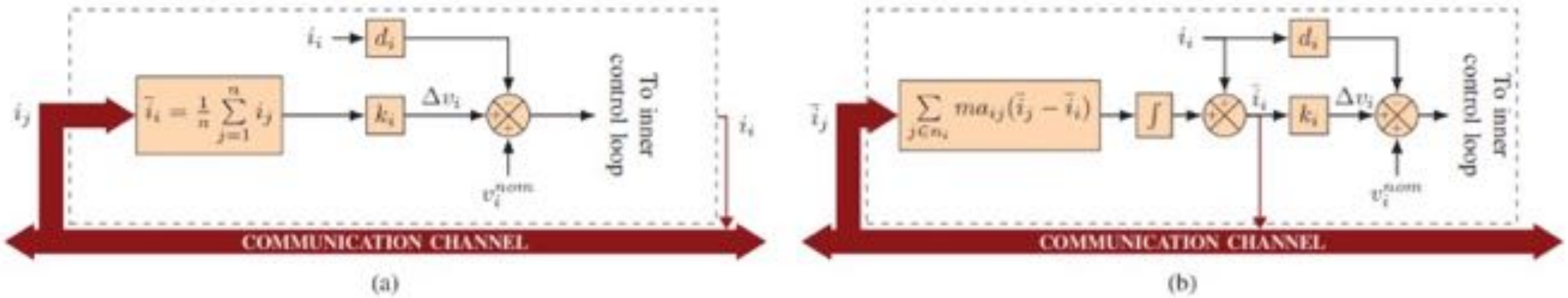


Trend of Quality Index vs Droop Gain

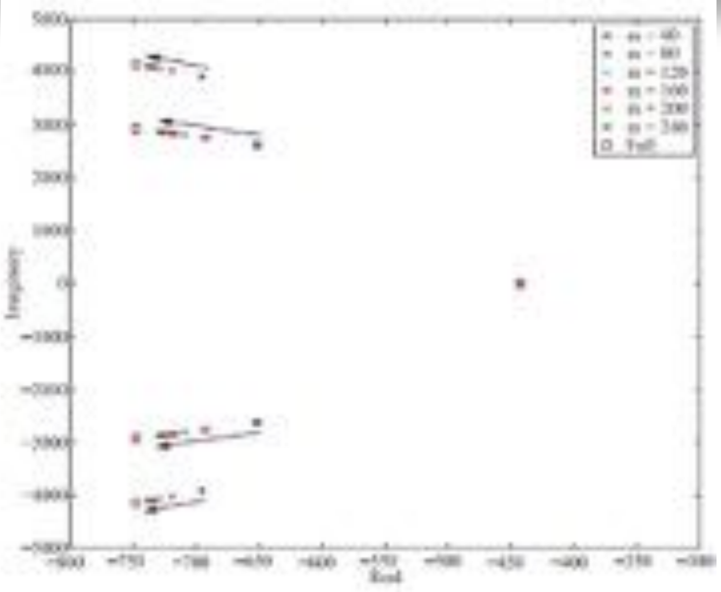
A. Ingle, A. B. Shyam, S. R. Sahoo and S. Anand, "Quality-Index Based Distributed Secondary Controller for a Low-Voltage DC Microgrid," in IEEE Transactions on Industrial Electronics, vol. 65, no. 9, pp. 7004-7014, Sept. 2018.

Performance Analysis of Reduced Communication Network

- Compares the performance of secondary controller with reduced and full communication topologies
- For large value of m, reduced communication scheme shows similar response as that of full communication



Secondary Controller with (a) Full Controller, (b) Reduced Controller

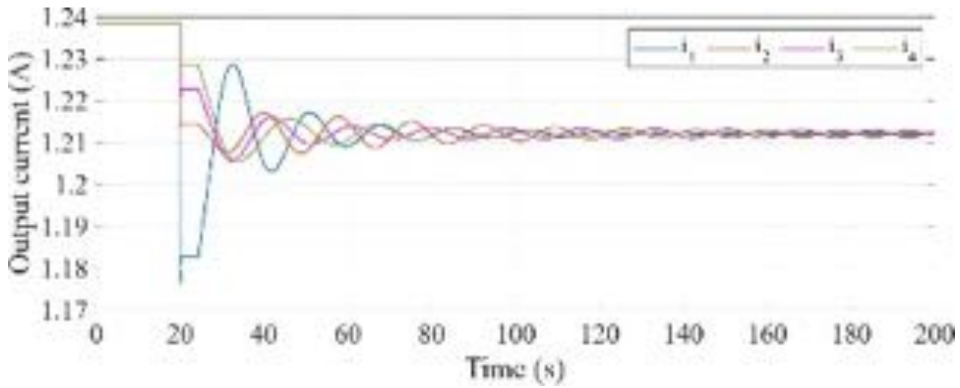


Locus of Dominant Poles of the System With Reduced Communication

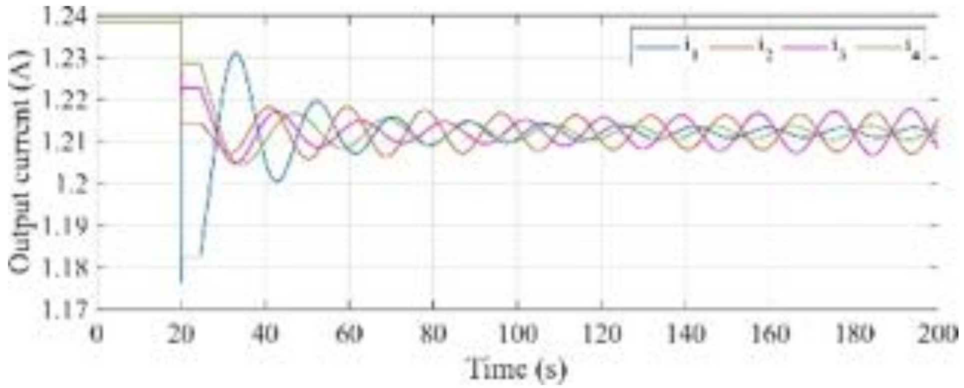
A. B. Shyam, A. Ingle, S. R. Sahoo and S. Anand, "Performance Analysis of Reduced Communication Network in DC Microgrid," 2018 IEEE Innovative Smart Grid Technologies - Asia (ISGT Asia), Singapore, 2018, pp. 976-981.

Effect of Communication Delay on Consensus Control

- **Delay Margin: value of delay above which system becomes unstable**
- **Analytical determination of delay margin – validated through simulation and experiment**
- **Delay margin mostly affected by changes in branch resistance, droop gain and integral controller gain**



Delay<Delay Margin

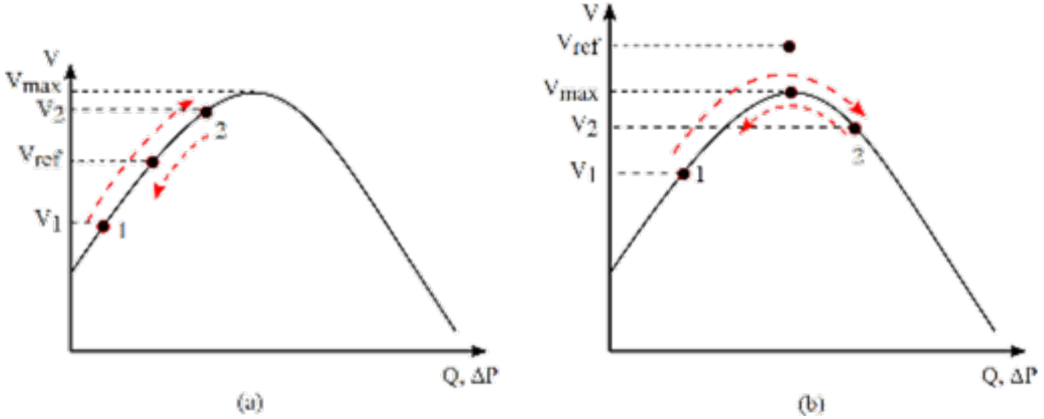


Delay>Delay Margin

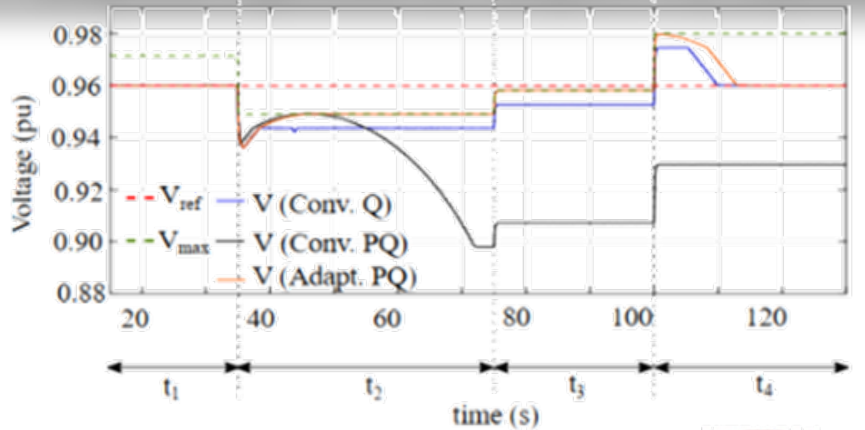
A. B. Shyam, S. Anand and S. R. Sahoo, "Effect of Communication Delay on Consensus-Based Secondary Controllers in DC Microgrid," in IEEE Transactions on Industrial Electronics, vol. 68, no. 4, pp. 3202-3212, April 2021

A Modified SMS Islanding Detection Technique for Reduced NDZ

- Collaboration between IIT Kanpur, and Imperial College, London
- Investigation of PV node voltage-P/Q relation
- Adaptive PQ adjustment to identify the optimal operating point
- Validation of the proposed scheme through simulation



Proposed Algorithm for Adaptive PQ Adjustment



Voltage Regulation Performance

A. Das, E. Batzelis, S. Anand, and S. R. Sahoo, “Adaptive PQ Management Technique for Grid Voltage Regulation in PV system," in 21st National Power System Conference (NPEC 2020), Gandhinagar, Dec 2020.

Objectives

Development, System integration and demonstration of hybrid microgrids (10-20 kW) in different Indian climatic condition and grid isolated scenario

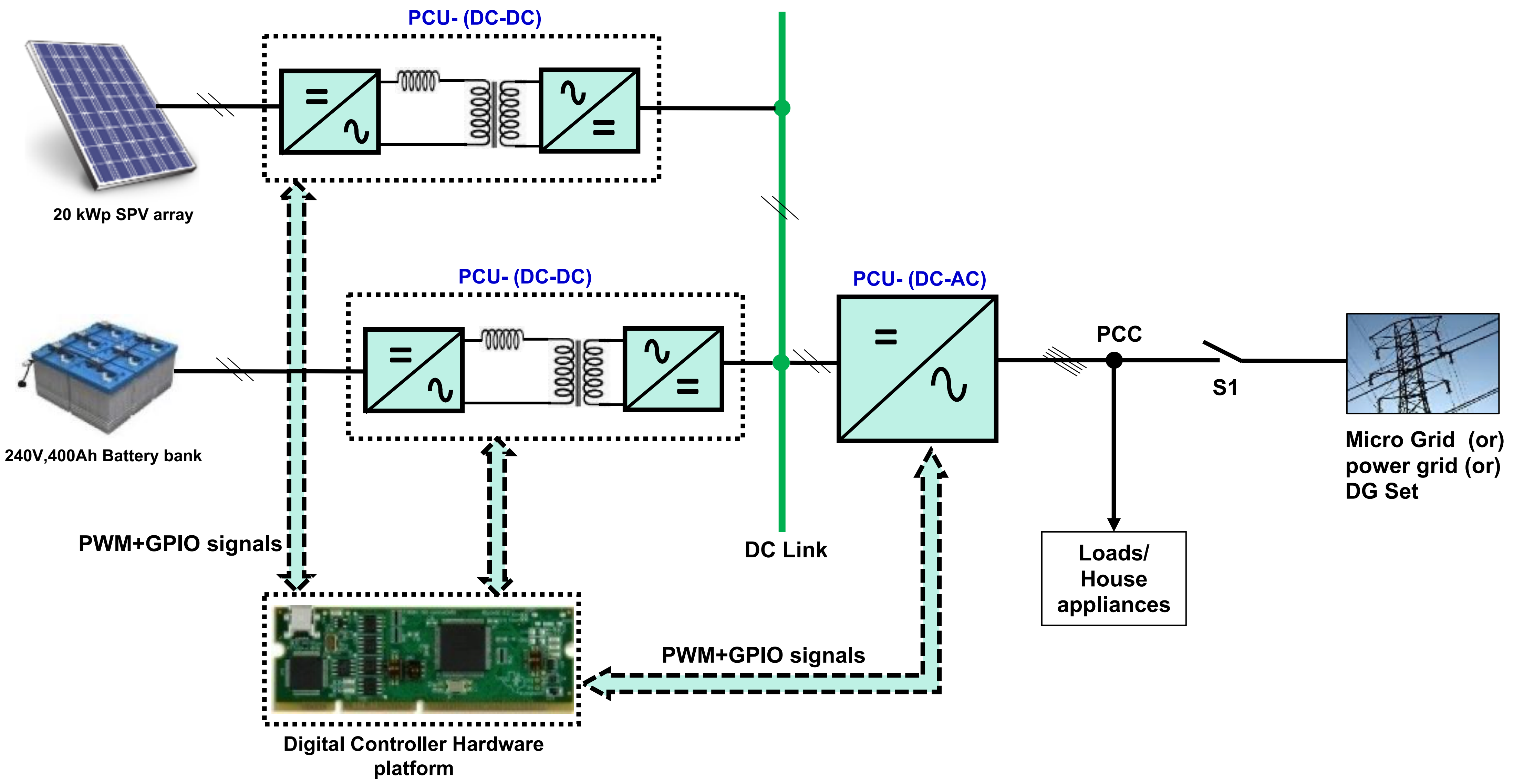
Field deployment by CDAC

- LEDA housing complex , Kavaratti Island, Lakshadweep
- Brahma Kumari's Ashram, Mount Abu, Rajasthan

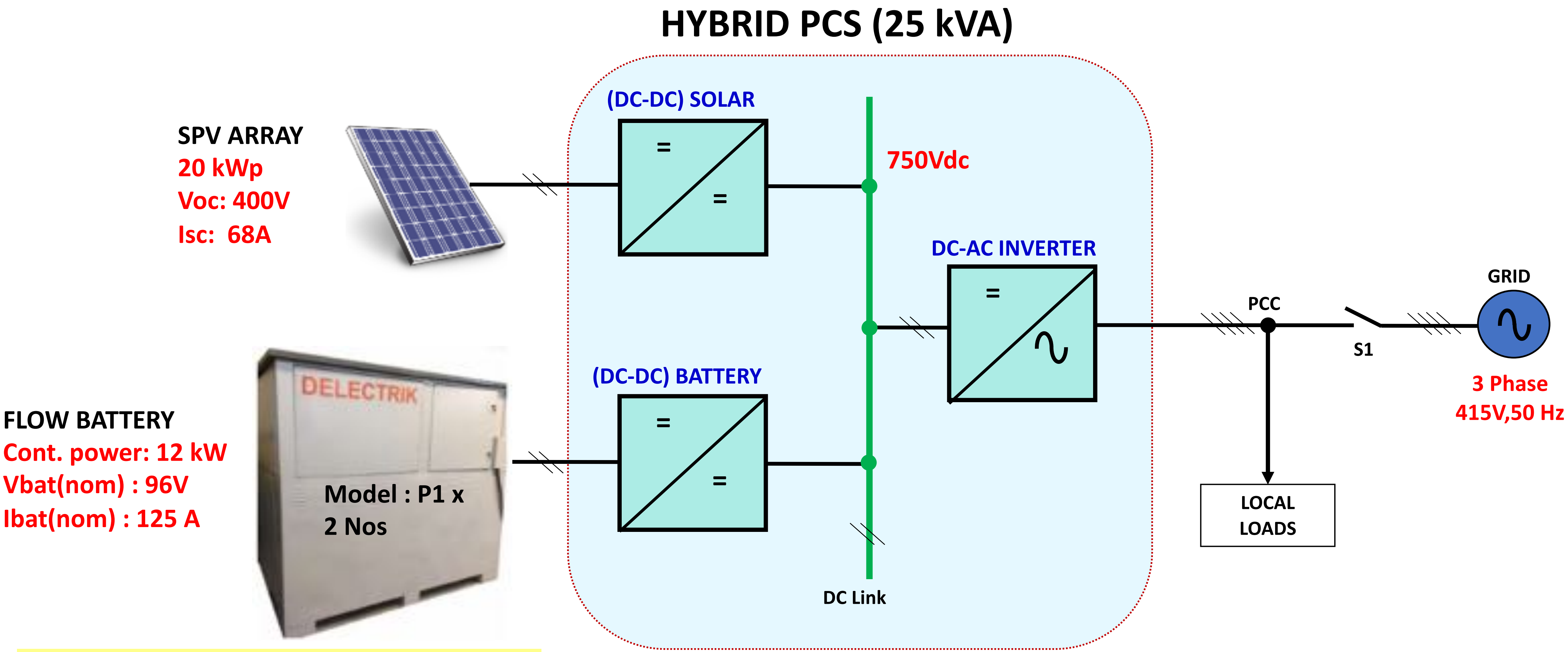
Support to IITB for Field deployment

- North-Eastern Hill University, Meghalaya
- IIT Bombay Campus

Microgrid deployment at Lakshadweep



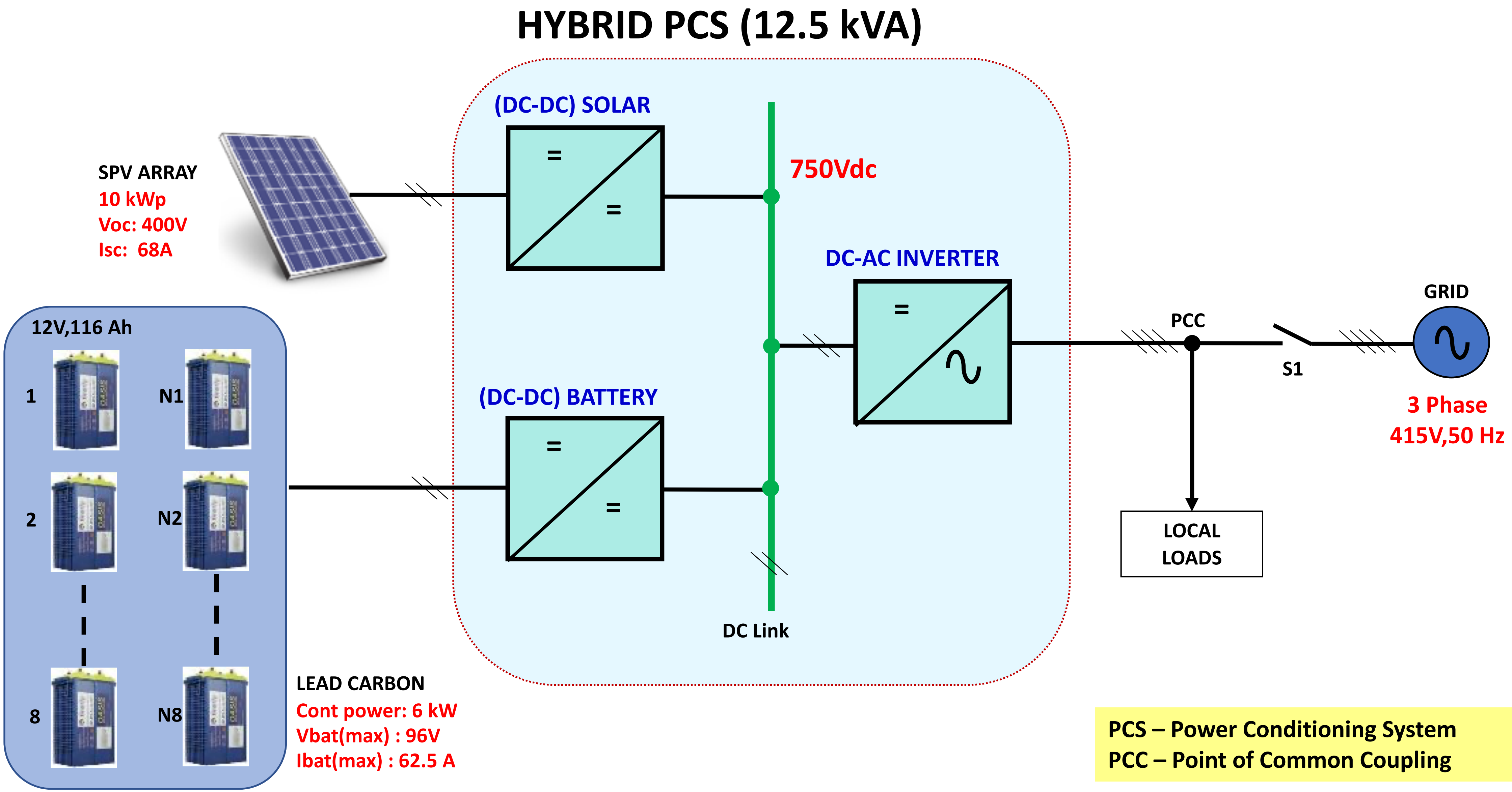
Micro grid deployment at Mount Abu



Pls note that 2 Nos of Model P1 will be connected in SERIES to get 96V output

PCS – Power Conditioning System
PCC – Point of Common Coupling

Micro grid deployment at NEHU, Shillong



PCS – Power Conditioning System
PCC – Point of Common Coupling

Thank You!