National Centre for Photovoltaic Research and Education (NCPRE)

Indian Institute of Technology Bombay

Executive Summary

Presented By

B. G. Fernandes

National Centre for Photovoltaic Research and Education (NCPRE) – 1

- **NCPRE was established at IIT Bombay in September 2010** by Ministry of New and Renewable Energy (MNRE)
- **Phase I** of NCPRE: 2010-2016; **Phase II** of NCPRE: 2016-2021; **Phase III**: proposal under preparation
- NCPRE has **R&D** activities in areas related to solar PV, and also on **education** and training
- Total **direct funding** for Phases I and II: approximately **Rs 110 crore**, plus **indirect funding and support from IITB** in terms of faculty, student support, space and infrastructure facilities, access to IITB administrative systems, etc.
- International **collaborative projects with universities and R&D centers** in USA (NREL), Germany (Fraunhofer), UK (Cambridge, Oxford), Norway, Sweden, Netherlands

National Centre for Photovoltaic Research and Education (NCPRE) – 2

- NCPRE was created with a **highly multidisciplinary** vision – involving faculty and students from **9 Departments at IITB**, including Electrical Engineering, Energy Science & Engineering, Materials Science, Physics, chemistry and Mechanical
- **29 faculty** members and about **170 post-graduate students** contribute to various activities of NCPRE
- **Excellent research facilities** have been set up at NCPRE
- NCPRE has **published** over
  - 245 journal papers
  - 325 conference presentations
  - 22 patents
- NCPRE has an **International Advisory Committee,** which has met in Mumbai every year since 2011

NCPRE Faculty Investigators

S.No	Name	Department	S.No	Name	Department
1	**B. G. Fernandes***	**EE (PI)**	15	M. Aslam	Physics
2	**Surya Doolla***	**ESE (PI)**	16	S. Mallick	MEMS
3	**S. Mitra***	**ESE (Co-PI)**	17	P. Nair	EE
4	**A. Kottantharayil***	**EE (Co-PI)**	18	K. L. Narasimhan	EE
5	B. Kavaipatti*	ESE	19	D. Marla	ME
6	K. Chatterjee*	EE	20	A. Alam	Physics
7	N. Shiradkar*	EE	21	A. Sarkar	Chem. Engg
8	P. Sharma*	ESE	22	A. Yella	MEMS
9	D. Kabra*	Physics	23	M. Neergat	ESE
10	B. M. Arora	EE	24	V. Ramadesigan	ESE
11	P. Bhargava	MEMS	25	Z. Rather	ESE
12	A. Kumar	Chemistry	26	A. Singh	MEMS
13	A. Mukhopadhyay	MEMS	27	S. Agnihotri	CTARA, CPS
14	D. Gupta	MEMS	28	J. Vasi	EE
* *Members of the NCPRE Executive Committee, which meets twice monthly*			29	*C. S. Solanki (on leave)*	*ESE*

ESE: Energy Science & Engineering; MEMS: Metallurgical Engineering & Materials Science; EE: Electrical Engineering; ME: Mechanical Engineering; CTARA: Centre for Technology Alternatives for Rural Areas; CPS: Centre for Policy Studies

NCPRE Students and Staff

Designation	Numbers
Senior Scientific and Managerial Staff	7
Research Staff	10
M. Tech and Ph.D. Students	31
Project Engineers	4
Jr. and Sr. Technical Assistant	12
Administrative Staff	6
Total	70

Research Activities at NCPRE

NCPRE Labs at a Glance

No	Name of the Lab	Area (m^2)	Class
1	Battery Prototyping Lab	168.14	10% Rh controlled room
2	Silicon Fabrication Lab	210.24	1000 Class Clean Room
3	Characterization Lab	57.66	Semi Clean
4	FESEM Lab	26.11	Semi Clean
5	Hybrid Solar Cells Lab	79.12	Semi Clean
6	Silicon Metallization Lab	84.15	Semi Clean
7	Power Electronics Lab	135.59	General
8	Solar Module Lab – 1	120.85	Semi clean
9	Solar Module Lab – 2	23.5	Semi clean
10	Solar Module Lab – 3	120.17	Semi clean
11	Students’ Fabrication Lab	78	Semi clean
	Total	**1103.53**	

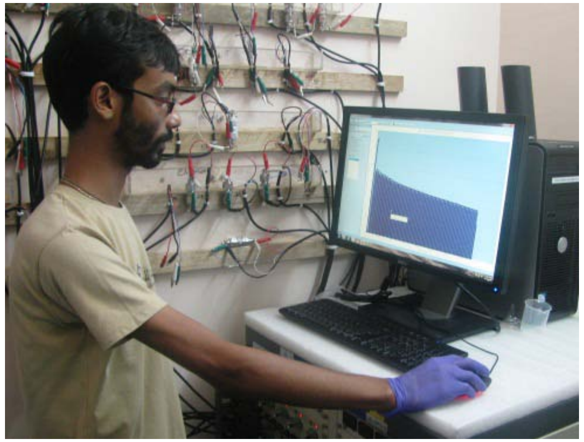
Facilities at NCPRE

Electron Beam Evaporator System

Electrochemical Capacitance Voltage (ECV) Dopant Profiler

LED Solar Simulator

Belt Furnace



Battery Testing Unit

Automated Screen Printer

Facilities at NCPRE

Glove Box integrated with Evaporator and Probe Station

Coating Machine

Needle Testing Machine

Field Emission Scanning Electron Microscope

Solar Simulator

Module Tester

Environmental Chamber

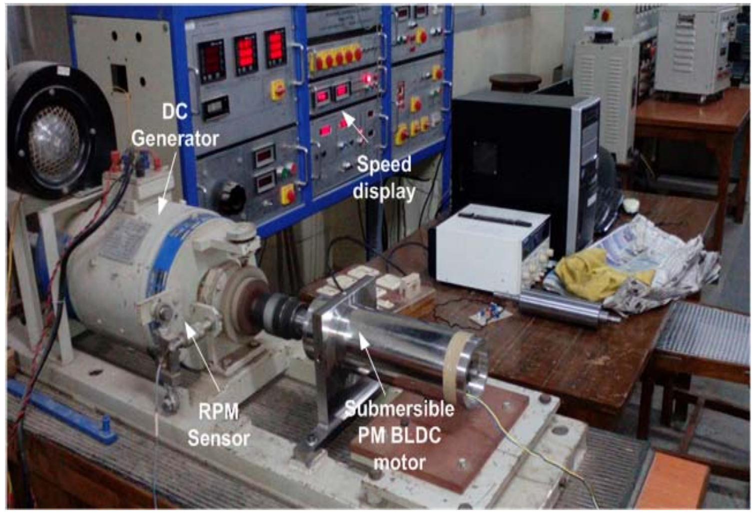
Dynamic Mechanical Loading System

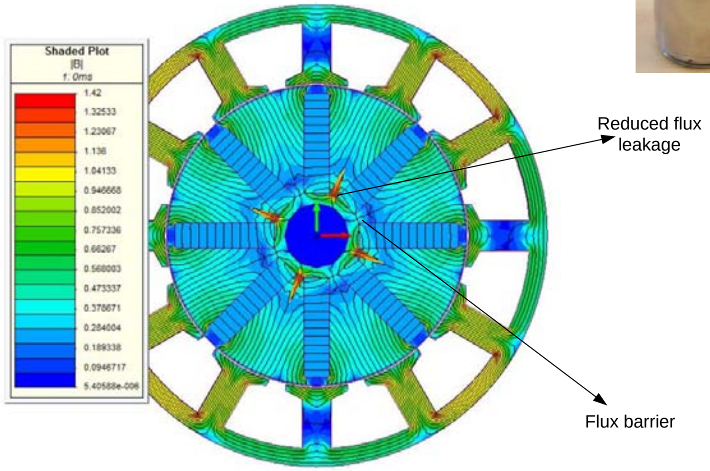
Facilities, Prototypes and Products Developed at NCPRE

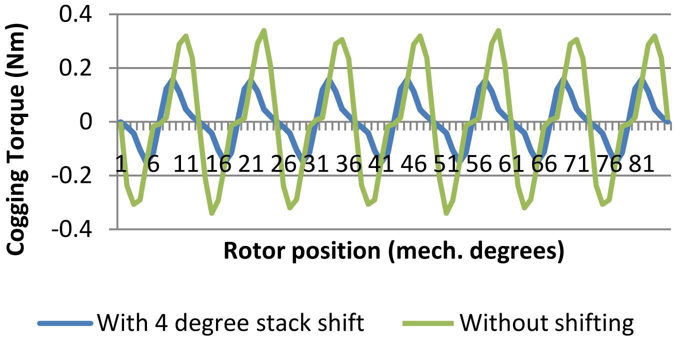
LOW-COST HIGH-SPEED BLDC MOTOR FOR A PV BASED DEEP-WELL SUBMERSIBLE PUMP

BLDC motor

- 12 slots, 8 poles (ceramic ferrite magnets)
- 2HP, Higher Efficiency 88%



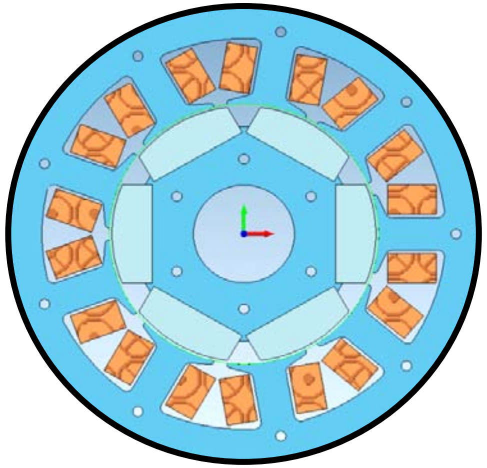




Features:

- Ferrite magnets – for low cost design.
- Radial flux BLDC topology and inner rotor type motor – 4 inch bore-well.
- Semi-Modular Dual-Stack Spoke type rotor – higher air-gap flux density.

BLDC Motor and Controller for a 3HP solar water (surface) pump



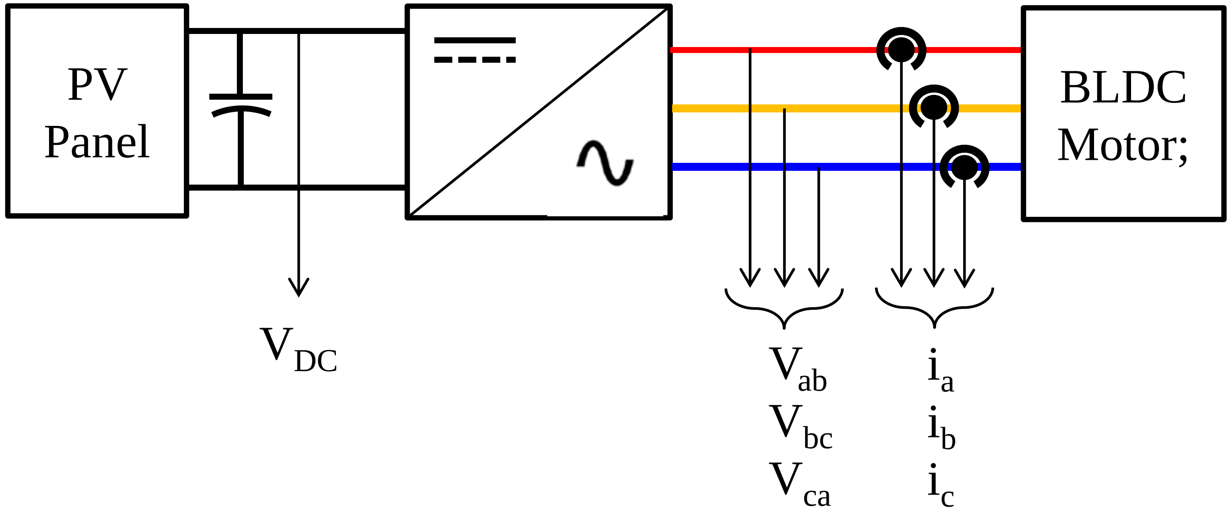
BLDC motor
- 9 slots, 6 poles (ferrite magnets)
- 3hp at 3000RPM
- Estimated efficiency ≈ 92%

➢ 3HP, 3000RPM Surface Pump – made equivalent to an industrial standard product (KDS335)

➢ Sensor less control algorithm for driving the BLDC motor

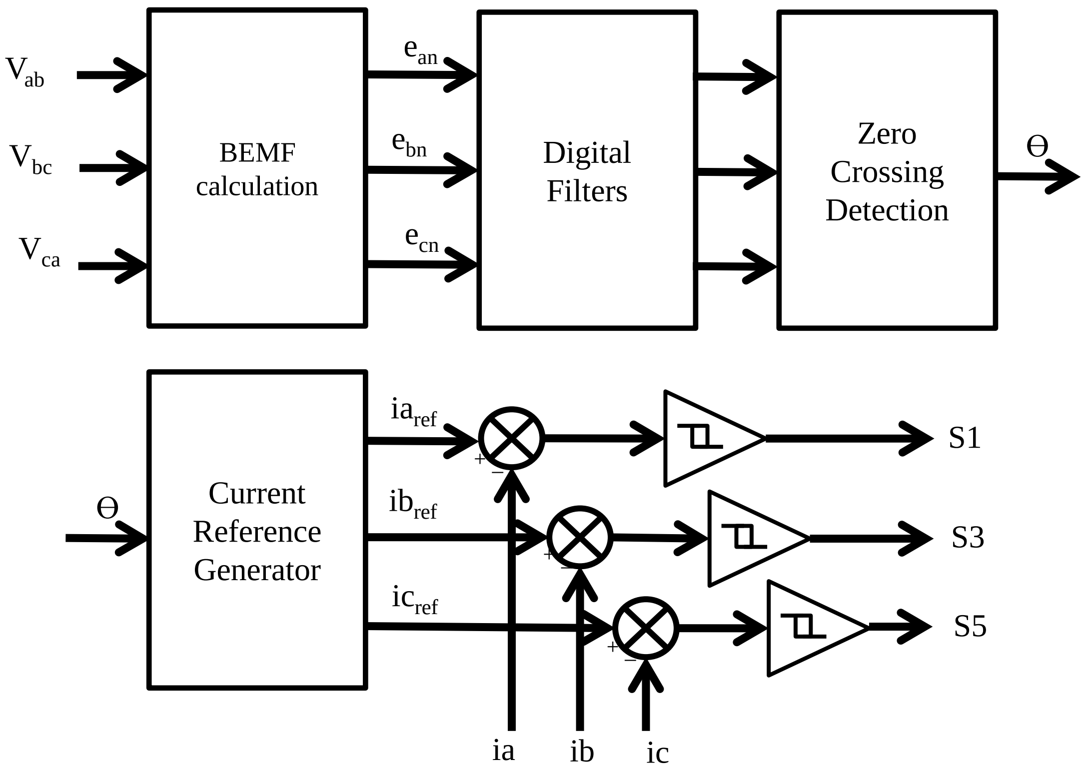
➢ PV interface with maximum power point tracking

Fabricated BLDC motor integrated with the surface pump

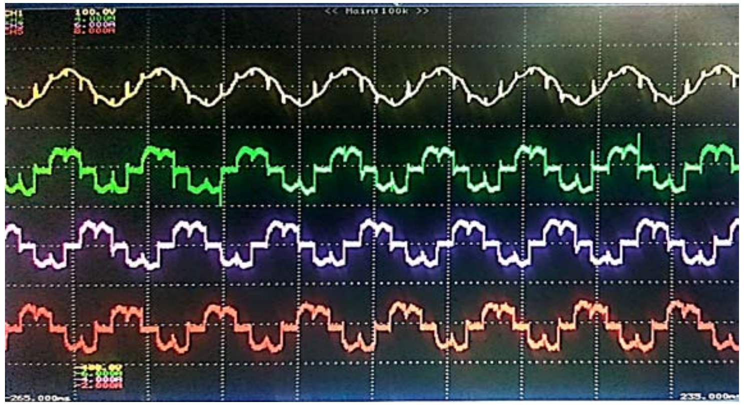


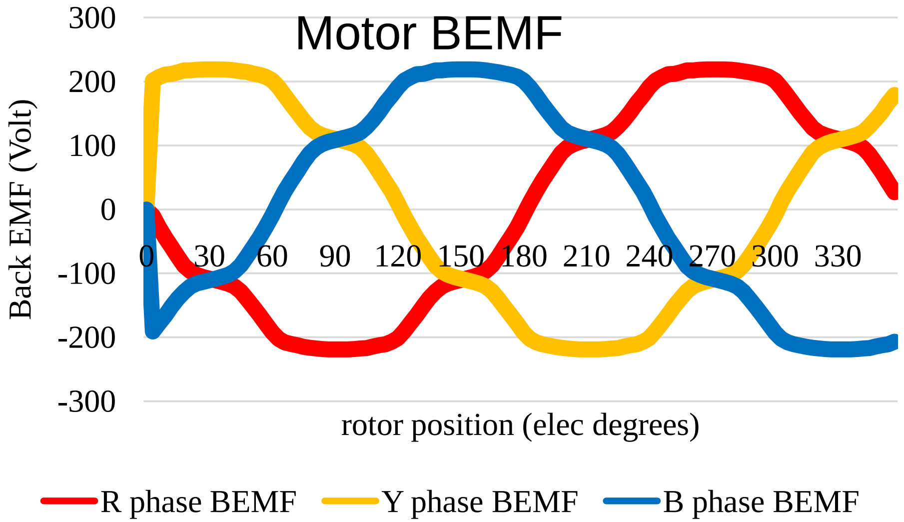
BLDC Motor and Controller for a 3HP solar water (surface) pump

Sensorless algorithm



Motor Voltage and Current Waveforms at no load





Field Testing of the Pump

SPECIFICATIONS OF THE PROPOSED SMDS BLDC MOTOR

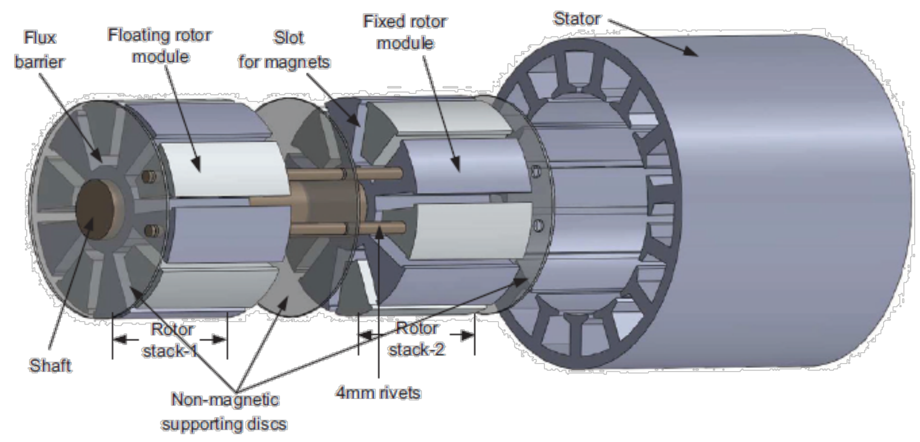


Figure. Semi-modular dual stack design for reducing flux leakage and maintaining rotor integrity

Air-gap flux density	0.44 T
Turns/Slot	17
Winding Type	concentrated
RMS slot current density	6.5 A / mm^2
Average Torque	4 N-m
Core loss	44 W
Ohmic loss	85 W
Bearing, friction and windage loss	40 W
Estimated full load efficiency (%)	**88**

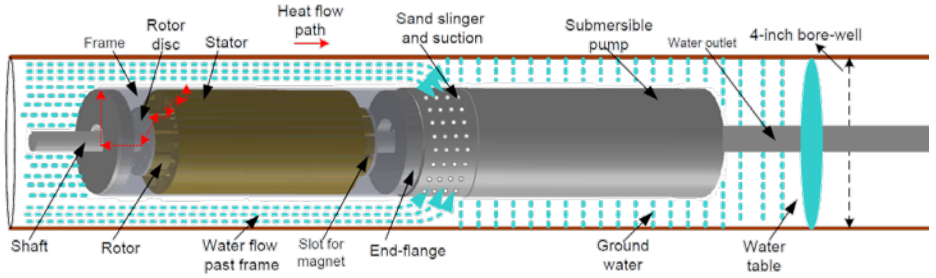
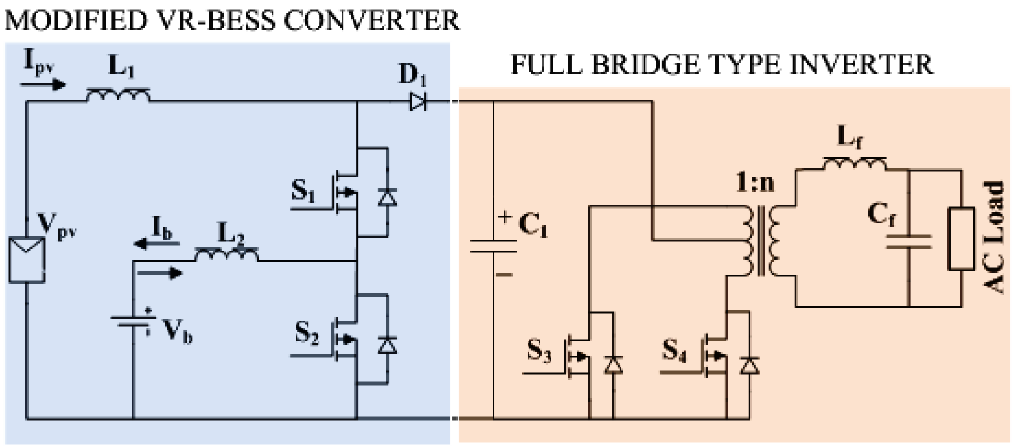
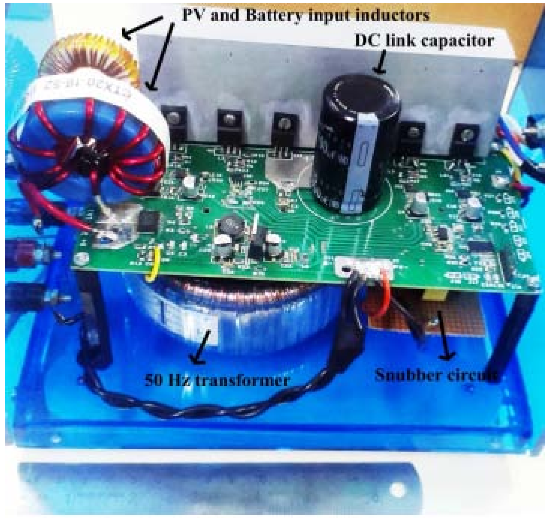


Figure. Horizontal view of the PV Deep Well Submersible Pump

Design Parameter	Value
D. C. Link Voltage	230 V
Average output power	1.21 kW
Base speed	2880 rpm
Stator outer diameter	88 mm
Total stack length	170 mm
Magnet dimensions	4 x 16 x 100 mm
Shaft diameter	17 mm
Stator and rotor laminations	M 43 29
Slots and poles	15, 10

Low Cost Reliable Battery Integrated Stand-Alone Photo-Voltaic System



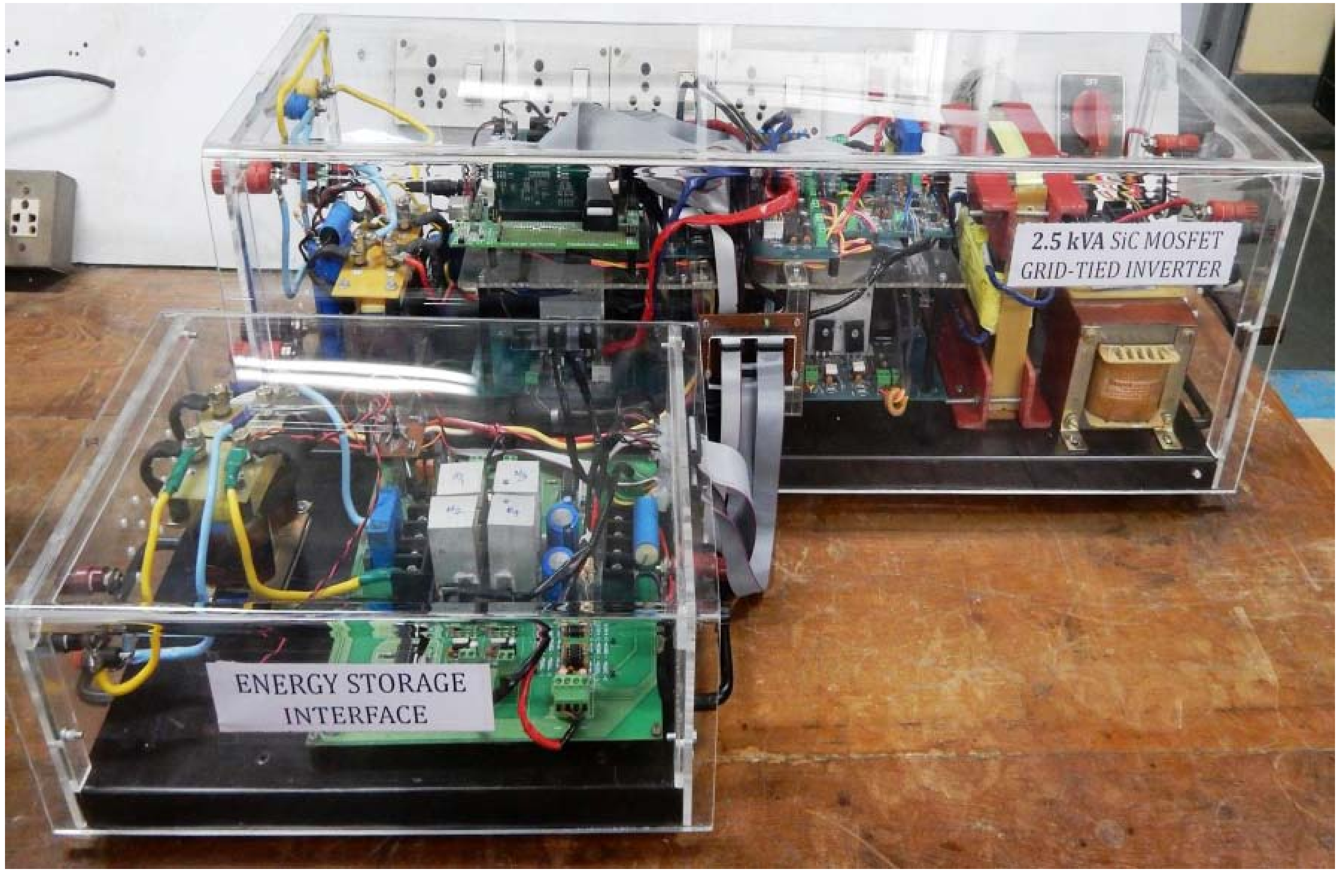


<u>Features :</u>

- Single phase 250VA Battery Integrated standalone inverter.
- Low cost and high reliability.
- Modified Voltage regulator Battery energy storage system.
- DC link capacitor selection for longer life time.
- Reduce number of power electronics switching devices.
- Low cost micro-controller, OPAMP less sensing circuits.
- Inverter stage is modified for a low frequency Push-Pull type DC to AC inverter.

High Performance 2.5 kVA On-Grid Grid Hybrid Solar Inverter

Can operate in on-grid and off-grid mode, with or without battery storage.



Features

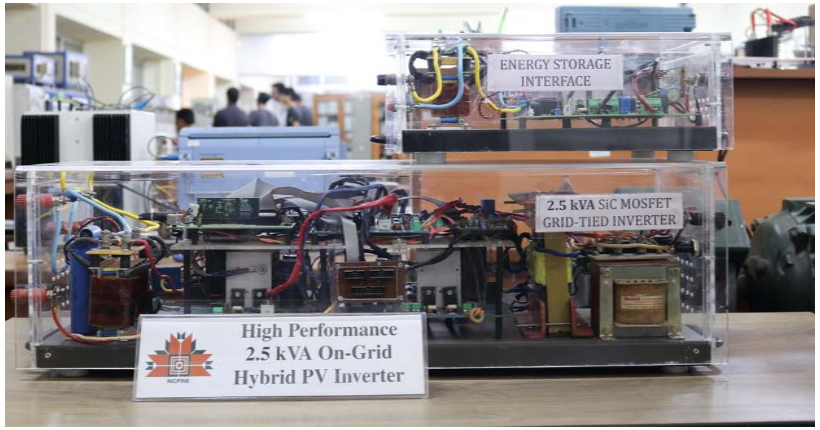
- SiC devices are used to decrease losses and increase performance.
- Completely Transformerless system with low PV leakage current .
- Low PV MPPT voltage at 90V to reduce shading loss and PID.
- Multilevel input and output operation to reduce magnetics size.
- Maximum efficiency greater than 95%

Power Electronics Products Developed

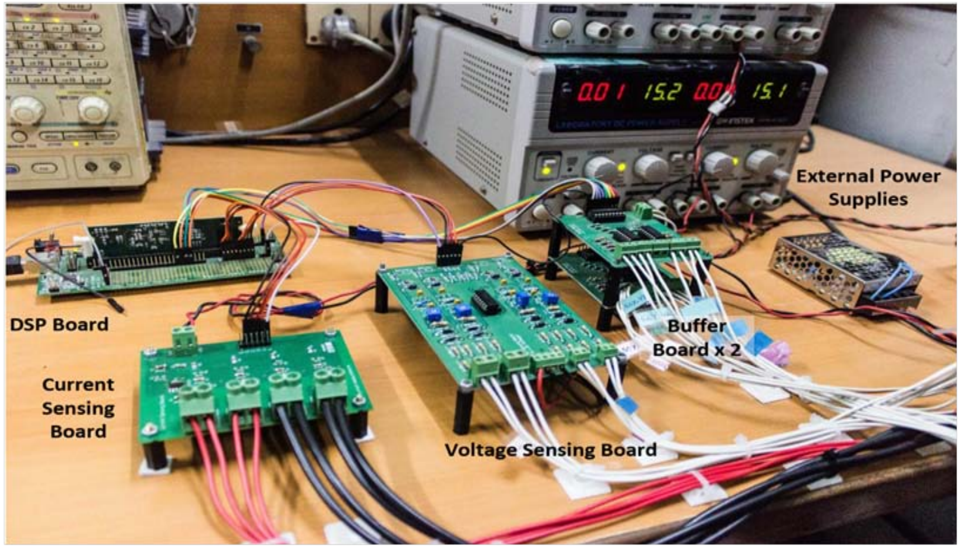
NCPRE

Prototypes

- Inverter topologies for VAr compensation.
- Power Electronic interfaces for non-conventional energy sources.
- SiC and GaN-Based Converters for EVs

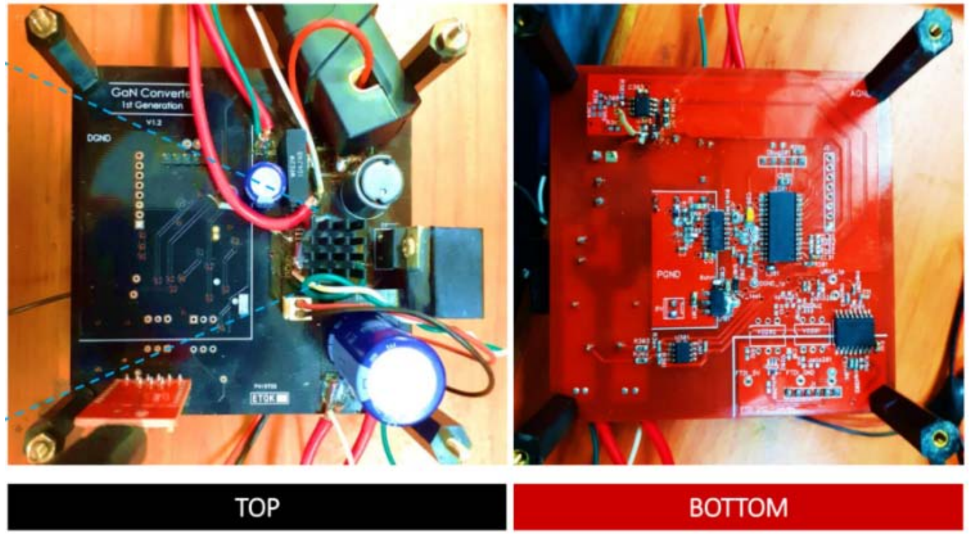


High Performance 2.5 kVA On-Grid Hybrid PV Inverter

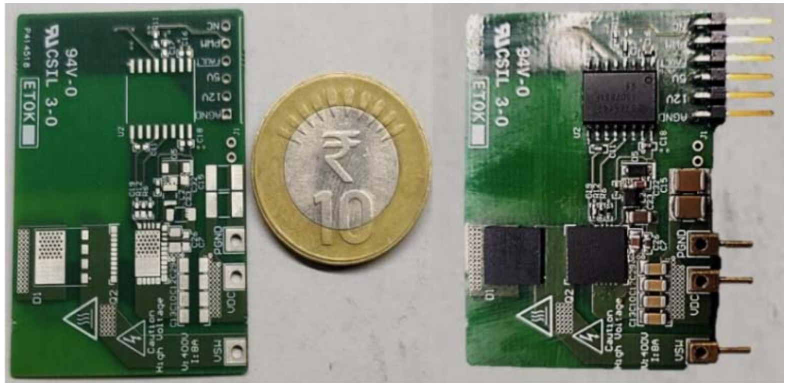


A Quad Active Bridge (QAB) Power Electronic Interface for an Electric Vehicle

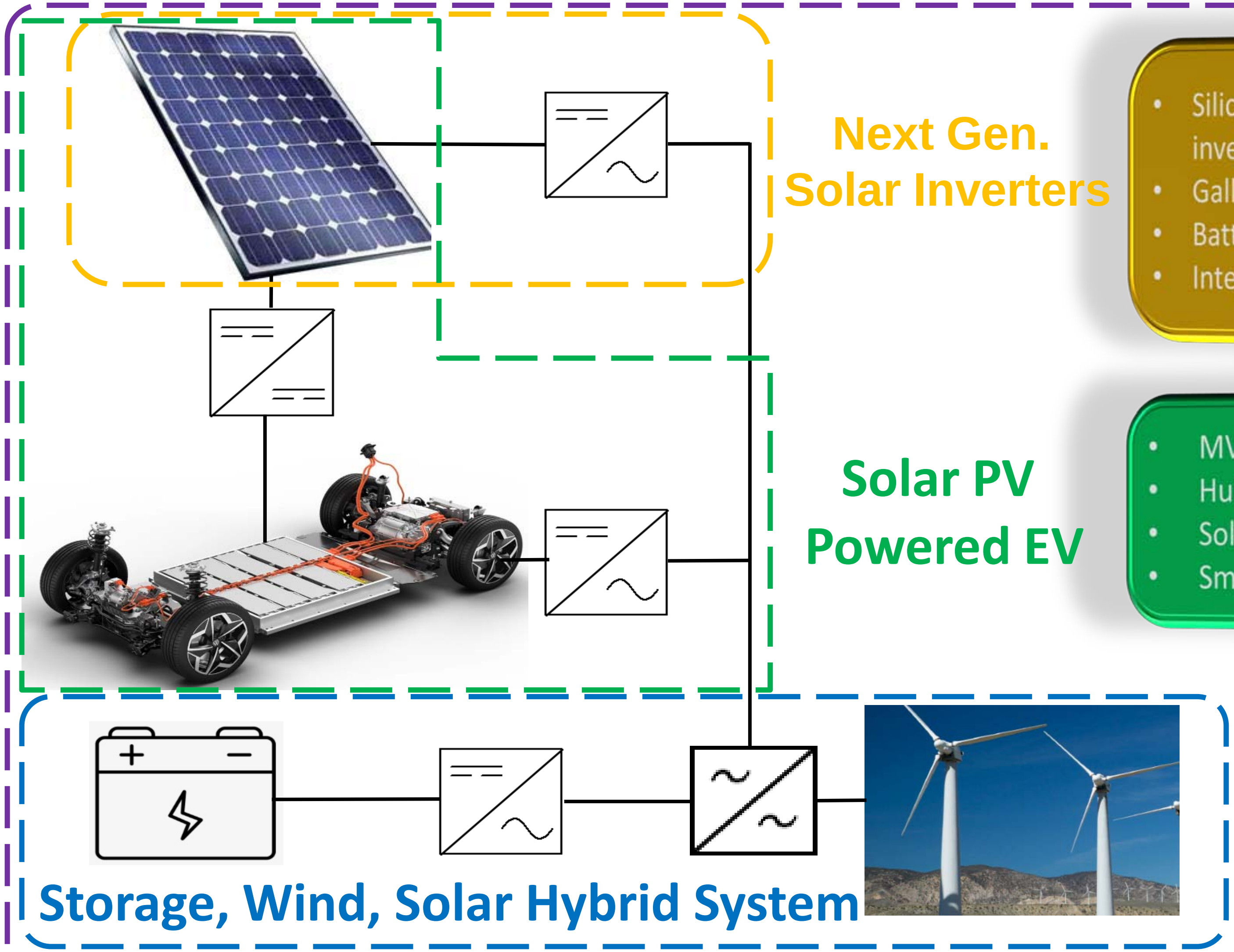
GaN Based Isolated Interleaved-Boost Converter



1MHz GaN Based Half Bridge Converter for Ultracapacitor and Battery for Electric Vehicles



GaN Based Half Bridge Leg for 1kW Totem pole PFC



- Silicon Carbide (SiC) based Medium Voltage (MV) connected PV inverters for mega plants.
- Gallium Nitride (GaN) based compact string inverters for roof-top.
- Battery-less inverter for remote electrification.
- Integration of upcoming PV technologies.

- MV interconnect of Hybrid EV charging system for 4-wheelers.
- Hub charging for 2/3-wheelers based on PV.
- Solar + EV hybrid system for residential power backup.
- Smart charger allocation system for commercial EVs.

- Impact of high renewable penetration on Grid operation and stability.
- Sizing and control of hybrid systems for reduced LCOE.
- Design of Active PV plants with multifunctional inverters.

Reliability of Inverters

- Reliability evaluation, test-bed for solar inverters.
- Online health monitoring and prognosis .

Support Industrial Manufacturers

- Evaluation boards and design to support manufacturers.

Man Power Development

- Training of manpower at the scientific and engineer level.

NCPRE – A Magnet for International Projects Requiring Interdisciplinary Expertise

NCPRE Groups	Indo – UK (Microgrids)	Indo - UK (SUNRISE)	Indo-Norwegian (New Wafers)	Indo – US (SERIIUS)	Indo-Swedish (Halide Perovskites)	Indo-Dutch (Power Electronics)	Indo-US (Waterless cleaning of panels)
Silicon Cell		✓	✓	✓			
PV Module Reliability	✓	✓	✓	✓			✓
Thin Films & New Materials		✓		✓	✓		
Power Electronics	✓			✓		✓	
Battery				✓			

- Close interaction between different groups at NCPRE has enabled us to get several international projects of interdisciplinary nature.
- Moreover, several projects from Indian Industry and PSUs have come to IIT Bombay due to NCPRE

NCPRE – Leading India on a Global Stage

International Solar Energy Alliance (ISA)

- Co-ordinated a special session on ISA at IEEE PVSC 2019
- Partnering with IEEE, ISA and WCPEC for 'inter-nationalizing of solar PV'
- Involved with ISA on technical and policy issues

(ISA aims to spread solar energy to 'solar-rich' countries. NCPRE is engaged with ISA to achieve this goal)

Standardization

- Leading the new standards development process for PV for Indian conditions through representation in IEC TC 82 and BIS ETD 28
- Research & Data driven standards development by sensitizing Indian stakeholders and soliciting feedback from them

(New standards are needed for PV in India due to some unique issues faced in Indian conditions)

Field Data for India

- Largest collection of field data of performance of PV modules, systems and also BoS components in Indian conditions.
- Understanding of unique Techno-Social-Commercial issues faced by new technologies during field deployment in India

(India is a growing economy and a testbed for several new technologies)

Next Decade of Solar PV for India: 2020 - 2030

- India has plans to install 300 GW of solar PV by 2030. Currently, only about 35.7 GW has been installed (December 2019).
- Approximately 10 times the current installed capacity would be installed in next 10 years!
- At the same time, we need to ensure that the installed modules have desired quality and reliability to last for 25 years in hot climates.
- There is a strong push to have a considerable fraction of these upcoming installations from domestically manufactured PV cells and modules.
- Most the upcoming PV installations would be coupled with some form of storage (battery / hydro).
- NCPRE has a major role to play in driving the solar future of India.

Thank You