To analyse technical challenges for in integrating solar photovoltaic (PV) systems (with and without energy storage) and developing a smart architecture as well as road map to accelerate the solar PV based microgrid development in India.

This study investigates key challenges associated with the renewable energy integration in the distributed network, and will attempt to find solutions considering technical challenges, efficiency, reliability as well as financial viability with large scale deployment of solar PV systems based micro-grids in India.

Key Objectives:

- To analyse technical challenges for integrating solar PV systems (with and without energy storage) into distribution network.
- To design and develop micro-grid architecture for integrating solar PV to dispatch controlled power considering power system operation as well as demand side management.
- To develop smart micro-grid architecture based on field results through the TERI's micro-grid system and prepare a road map to accelerate the solar PV based micro-grid development in India.

Main Activities

- **Technical review on different micro-grid architectures for integrating Solar PV systems with and without energy storage in the distributed network.**

The comparison of different micro-grid models will be done for numerous factors including controllable dispatching of active and reactive power for maintaining the power system stability and quality, techno-economics of the distributed generators, electricity tariff mechanisms, types of load and their reliability levels, geographic location based constraints and operations and maintenance.

- **Modelling and analysis of solar PV based micro-grid for grid connected and off-grid systems**

Technical analysis of the real time operational results, of PV system grid interaction with load for tuning the power conditioning devices, will be conducted. The University of Agder (UiA) expertise on modelling and analysis of off-grid as well as on-grid system based on solar PV will be utilized.

- **Develop smart micro-grid architecture to scale up solar PV based micro-grid projects in India**

A detailed methodology will be developed for smart micro-grid architecture considering the power quality and effective power flow management with innovative power droop characteristics and power network security. The UiA expertise will be used for developing smart micro-grid architecture model in coordination with the TERI.

- **Knowledge sharing, dialogue and collaborations**

This activity would focus on dissemination of the knowledge and build up capacity of various stakeholders on micro-grid technologies and its applications.

Norwegian Partner:

University of Agder,

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UNIVERSITETET I AGDER

Principal Investigator from UiA

Professor (Dr) Mohan Kolhe, University of Agder (Norway)

Prof. Kolhe is full professor in electrical power engineering with focus in smart grid and renewable energy. He has more than twenty-five years' academic experience at international level on electrical and renewable energy systems. He has previously held academic positions at the world's prestigious universities e.g. University College London (UK / Australia), University of Dundee (UK); University of Jyvaskyla (Finland); and Hydrogen Research Institute, QC (Canada). He was a member of the Government of South Australia's Renewable Energy Board (2009-2011) and worked on developing renewable energy policies.

Co- Principal Investigator from UiA

Dr Nils Ulltveit-Moe, University of Agder (Norway)

Dr Ulltveit-Moe is associate professor in information and communication technology, specialising in security and privacy of critical infrastructures, including smart grid. He has interest in developing usable solutions for privacy and security, including policy-based privacy and security enforcement and anonymisation. He has experience as work package leader on methodology in the EU-FP7 security project PRECYSE as well as work package leader on security and privacy in EU-FP7 SEMIAH, and currently works on a national innovation project on security in SCADA systems.

PhD student at UiA

Mr. Arvind Sharma, Fellow at TERI is pursuing PhD at the University of Agder (Norway) on smart micro-grid architecture under this project.

The Energy and Resources Institute

Principal Investigator from TERI

Mr. Shirish Garud, Senior Fellow and Director at TERI

Mr. Garud has more than 30 years of experience in renewable energy, energy planning and policy development. He has excellent understanding of the Indian renewable energy sector and technologies, especially the solar energy sector. He has in depth understanding of renewable energy sector business environment and financial viability aspects.

Co- Principal Investigator from TERI

Mr. Arvind Sharma, Fellow at TERI

Mr. Sharma has been associated with the field of Solar Photovoltaic Systems more than 10 years. His area of expertise is Testing & Certification, Design, Development and Customization of the Solar PV based micro grid systems and components i.e. battery storage, inverter, controller and charge controller. He has been implemented many projects in India and African countries related to Solar PV systems and focussing on Solar Lightning applications.

Ms. Ashwini Mudgal, Associate Fellow, TERI

Ms. Mudgal has completed her Masters in Electrical and Computer Engineering from Oakland University, MI, US. Her experience includes development of hybrid energy systems having Fuel cell and Solar PV modules. She has about 5 years of experience in micro-grid system development. She is also a member of BIS, ETD – 52 committee (Electrical Energy Storage).

Mr. Kapil Muddineni, Research Associate, TERI

Mr. Muddineni has received his Master degree in Energy Systems and Engineering with silver medal from the Indian Institute of Technology (IIT), Mumbai, India. His research interest is control of power electronic interfaces for distributed generation and control architecture for smart micro-grids.

Publication(s):

"Battery Capacity Estimation for Building Integrated Photovoltaic System: Design Study for Different Geographical Location(s)", by Mohammed A.M. Yassin, Mohan Kolhe, Arvind Sharma, Shirish Garud, 9th International Conference on Applied Energy, ICAE2017, 21-24 August 2017, Cardiff, UK. (in press, Energy Procedia of Elsevier).

Event(s)

Workshop on 'Micro-grid's Interconnection Issues and Recycling of Solar PV Modules and Batteries' was organized on 30th May, 2017 at Indian Habitat Centre(IHC), Lodhi Road New Delhi.

The objective of the workshop was to bring together key stakeholders like industry partners, research and academic institutes to discuss latest technological development, key technical issues, and best practices and suggest solutions to address the challenges associated micro-grid deployment and recycling of PV module and batteries.

The first half (WP1) of the workshop was focused on Micro-grid's integration and interconnection issues and the second half (WP2) of the workshop was focused on recycling of Solar PV modules and batteries.

Dr. Ajay Mathur, Director General, TERI, welcomed the conglomerate and shared his insights and guidance for the issues as well as the project. **Dr. P. C. Maithani**, Scientist- G and Advisor, MNRE, shared his experience from MNRE and delivered the keynote address.

Mr. Arild Oksnevad, Counsellor, Head of Cooperation, the Royal Norwegian Embassy, delivered special address and informed the forum about the newly built Green Building of Norwegian embassy.

Dr Nils Ulltveit-Moe, University of Agder (Norway) has highlighted the importance of cyber security for a secure micro-grid network. **Prof. Mohan Kolhe** from UiA (Norway) has provided overview of different micro-grid architecture and proposed smart micro-grid architecture.

The workshop sessions were moderated by eminent experts like Mr. Shirish Garud, Director, TERI, Mr. K. Ramanathan, Distinguished Fellow, TERI, Mr. Suneel Pandey, Director, Centre for Waste Management, Mr. Debajit Palit, Associate Director, TERI and Mr. Pugazhenthy, Executive Director, India Lead Zinc Development Association.

There were 21 speakers representing various organizations i.e Central Electricity Authority (CEA), Ministry of New and Renewable Energy (MNRE), India Smart Grid Forum (ISGF),India Energy Storage Alliance (IESA), Sakti Sustainable Energy Foundation, Poseidon Solar Services Pvt. Ltd., Namo eWaste Management Ltd, Shanghai Jiao Tong University China, India Lead Zinc Development Association, Regnant Energy Solutions, Gravita India Ltd. Ministry of Environment and Forests (MoEF), International Finance corporation(IFC), Sigma Institute of Energy and Environment etc. The workshop has more than 60 participants from Solar PV manufacturers, Battery manufactures, System Integrators, Micro-grid operators, financial institutions, Electronics waste recycling Industries, batteries recycling industries etc.

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