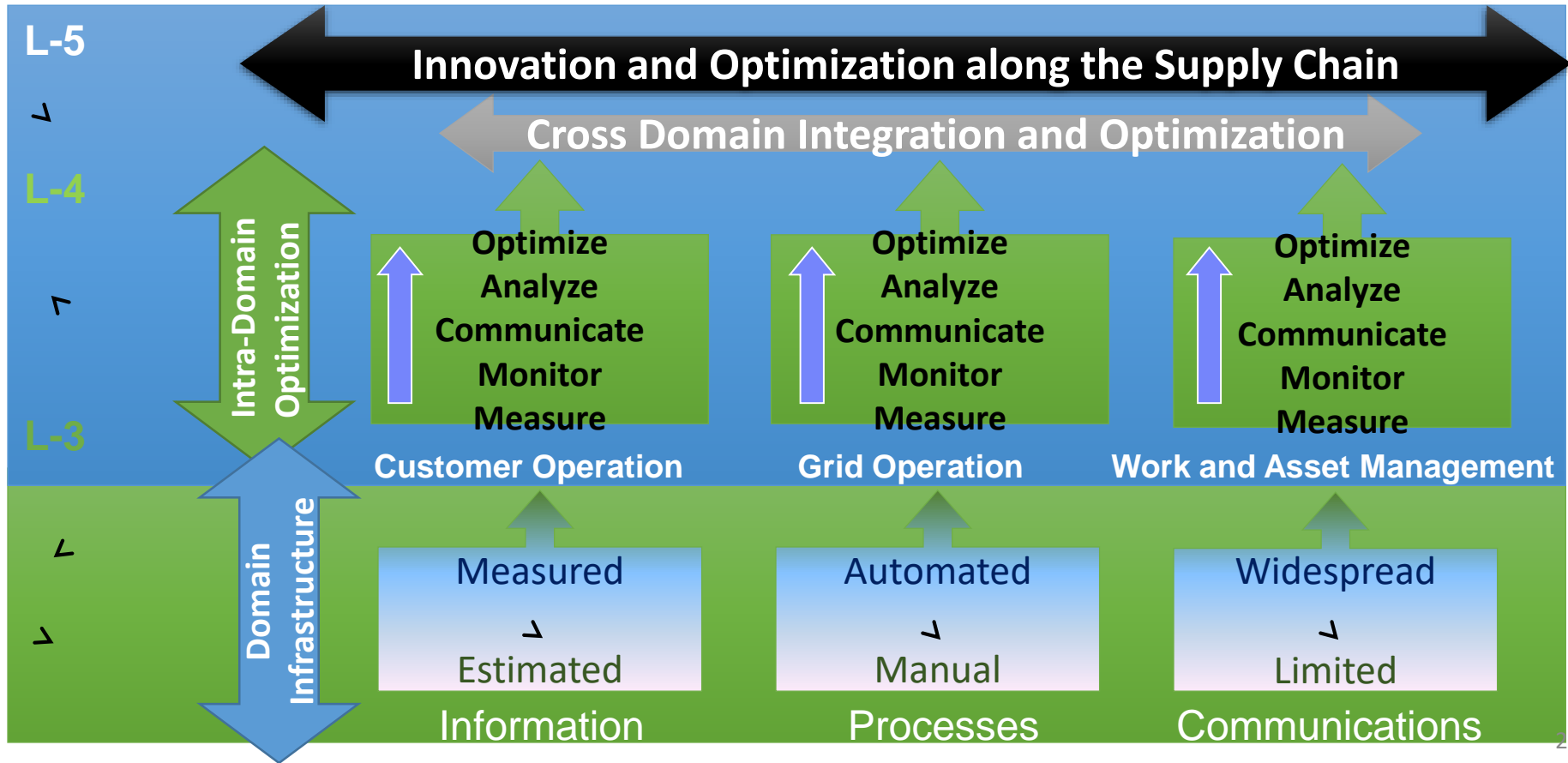


GLOBAL TECHNOLOGY TRENDS

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Smart Grid Maturity Model



Flexibility Needs for System

Flexibility for Power

Flexibility for Energy

Flexibility for Transfer Capacity

Flexibility for Voltage

SMART GRID by adopting Information and Communications Technology to facilitate bidirectional flow of Energy and Information for flexibility needs.

New Entrants in Power Sector



Green Energy Challenges

Purpose:

- At COP 21 in Paris in 2015, India's commitment of meeting 40% of its electricity generation from non-fossil fuels by 2030.
- The integration of DERs on the LV grid require the support of active DR and ESS to maintain grid stability.
- Grid stability is a growing concern for DISCOMs and the DISCOMs are seeking technical and policy measures to sustain the uptake of VRE resources.
- ESS coupled with Demand Response (DR) and Vehicle Grid Integration (VGI) will add flexibility to the grid

175 GW RE Program:

- Solar : 100 GW (40GW from RTPV)
- Wind : 60 GW
- Small Hydro : 5 GW
- Bioenergy : 10 GW

Key areas for Energy Storage Applications:

- Integrating RE with transmission grids and distribution Grids
- Setting up rural micro grids with diversified loads or stand-alone systems
- Developing storage component for electric mobility plans

MV/LV Stabilization and Optimization for 40 GW RTPV: Technical Issues and Challenges

Issues at MV and LT level:

1. **Voltage rise:** If the generation from PV resources are high enough to offset the loads on the feeder, the surplus power will create voltage rise. With cluster-based installation of PV, the voltage rise impact may propagate to upstream MV network.
2. **Effect of clouds:** PV output ramps up and down at high rates as per the irradiation level. At certain locations, voltage at inverter end may exceed beyond a certain limit, which may cause undesirable tripping
3. **High neutral current:** Unbalanced allocation of PV units can create a high neutral current, particularly in the mid-day, when reverse power flow is at the peak level.
4. **Lower power Factor:** Along with PV generation, reactive power compensation or power factor improvement is needed.
5. **Variation of feeder power loss:** Power loss may vary due to the variation of PV output throughout the day.
6. **Voltage Unbalance:** As the allocation of inverters of a feeder are varied by the category of customers, the distribution of PV generation may not be equal at all the phases.
7. **Change in tap operations:** Voltage rise caused by PV clusters may require the regulators to operate during midday to keep the voltage profile below the upper limit

Challenges of EV Proliferation

Increase in Harmonics

Managing Mobile Load

Managing Charging Infrastructure

Controlled charging requirements to manage peak load

Performance Expectations

- Utility to Consumer
- Consumer to Utility
- 3rd Parties to Utility
- Utility to 3rd Parties

Prosumer Enablement

Public Charging Stations

MoP Guidelines for Charging Station

- Transformer with all related equipment including safety
- 33/11 kV cables with metering
- Civil works and adequate space for parking, entry and exits
- Adoption of international standards as well as Indian standards (published by BIS)
- Tie up with online network service providers (NSP) to enable advanced/remote booking with geo tagging, types and availability information
- Minimum charging points shall be installed as per below table

Type	Connectors	Rated Voltage (V)	No. of points/connector Guns (CG)
Fast	CCS (min. 50 kW)	200-1000	1/1
	CHAdeMO (min. 50 kW)	200-1000	1/1
	Type-2 AC (min. 22 kW)	380-480	1/1
Moderate / Slow	Bharat DC-001 (15 kW)	72-200	1/1
	Bharat AC-001 (10 kW)	230	3/3 of 3.3 kW each

Each Charging station need to provide connected load of minimum 150 Kw and a charging station may be required after every 2-3 kms.

Smart Grid Solutions

System Balancing

Better forecasting

- Widespread instrumentation and advanced computer models allow system operators to better predict and manage RE variability and uncertainty.

Smart inverters

- Inverters and other power electronics can provide control to system operators, as well as to automatically provide some level of grid support.

Demand response

- Smart meters, coupled with intelligent appliances and even industrial scale loads, can allow demand-side contributions to balancing.

Integrated storage

- Storage can help to smooth short-term variations in RE output, as well as to manage mismatches in supply and demand.

Real-time system awareness

- Sensors across networks allows system operators to have real-time awareness of system conditions, and the ability to actively manage grid behavior.

Smart Inverter

- “Smart Inverter” is a inverter that can contribute to grid support during excursions from normal operating voltage and frequency conditions by providing:
 - Dynamic reactive and real power support
 - Voltage and frequency ride-through
 - Ramp rate controls
 - Communication systems with the ability to accept external commands from the electric utility.
- California and Hawaii have already begun deployment of smart inverter functionality
- IEEE 1547, IEEE1547.1, IEC 62109, IEC 62116 and IEEE 2030.5 are the standards for Smart inverters.

Regulatory Sandbox: DR Case Study

BSES Yamuna

- BSES Yamuna implemented DR program to manage its peak load and maintaining tie- line schedule.
- Overall, 9-15 consumers participated in each event,
- Resulted in demand savings of 0.89 to 3.45 MW per event.
- Maximum reduction provided by manufacturing units, followed by hotels, malls, hospitals, and others

Tata Power, Delhi

- Participation - 161 customers > 100 kW (cold storage, commercial, education, flour mill, hospital, industrial, pumping, retail,
- 17 DR events for 30 to 60 minutes each in the summer of 2014
- Achieved max shed potential of 7.2 MVA with a cumulative saving of 0.063 MUs.
- Max demand reduction ranged from 2% (for Education) to 28% (for Packaging).

Tata Power, Mumbai

- Tata power, Mumbai implemented both aggregator based and auto DR projects in Mumbai at Malls, Hospitals, IT parks and Municipal sewage treatment plants etc.
- Aggregator level DR was triggered 21 times each for duration of 2 hours.
- 15 MW curtailment achieved.

Battery Storage for Flexibility

High share of renewable energy sources leads to a massive fluctuating power injection, which can be balanced by battery energy storage.

Grid stabilization and increased power quality by four-Quadrant Operation (Active and Reactive Power Control), Peak Shaving and Load Balancing, day to night shifting of renewable PV Energy

Ability to control harmonic emissions of power electronic equipment connected to the same busbar, by the use of active damping or active filtering functionality

Variants of Battery :-

- Ni-Cd
- Lead Acid
- Lithium-Ion
- Advanced Lead Acid
- NaS
- Flow Type

Types of Energy Storage Technologies

- **Mechanical**

- Pumped Hydro Energy Storage (PHES)
- Compressed Air Energy Storage
- Flywheel Energy Storage

- **Electrochemical**

- Lead Acid Batteries, Advanced Lead Acid (Lead Carbon, Bipolar Lead Acid)
- Lithium Batteries (LCO, LMO, LFP, NMC, LTO, NCA)
- Flow Batteries (ZnBr, Vn Redox)
- Sodium Batteries (NaS, NaNiCl₂)
- Zinc Batteries Zn Air, ZnMnO₂

- **Thermal**

- Sensible-Molten Salt, Chilled Water
- Latent- ice Storage, Phase Change materials
- Thermochemical Storage

- **Electrical**

- Super Capacitors
- Superconducting Magnetic Energy Storage (SMES)

- **Chemical (Hydrogen) electrochemical**

- Power-to –Power (Fuel Cells, etc)
- Power-to-Gas

Mission Innovation

- India is leading partner in ISGAN and Mission Innovation, R&D Collaboration Smart Grid Agenda.
- Six Smart Grids R&D Tasks (POWs) are established collaboration with MI IC1 member countries.



MI Goal

1. Double clean energy RD&D investments over 5 years
2. Work closely with the private sector to increase investment
3. Build and improve technology innovation roadmaps and other tools
4. Transparent, easily-accessible information on their respective clean energy RD&D efforts

**A GLOBAL INITIATIVE OF
23 COUNTRIES & THE EU
WORKING TO ACCELERATE
CLEAN ENERGY
INNOVATION**

Mission Innovation Challenges



IC1: Smart Grids



IC2: Off-Grid Access to Electricity



IC3: Carbon Capture



IC4: Sustainable Biofuels



IC5: Converting Sunlight



IC6: Clean Energy Materials



IC7: Affordable Heating and Cooling of Buildings



IC8: Renewable and Clean Hydrogen

R&D Tasks identified under IC1: Smart Grid

R&D TASK	Smart Grid Task Topic
TASK 1	Improve STORAGE INTEGRATION at all time scales (in operation for system services but also when performing planning studies as an additional degree of freedom) as a source of flexibility
TASK 2	Use of DEMAND RESPONSE for system services with well-defined interactions between the market players and the network operators (and TSO-DSO exchange of information)
TASK 3	Developing regional ELECTRICITY HIGHWAYS with both AC and DC technologies
TASK 4	Identify and support improvements of suitable FLEXIBILITY OPTIONS (RES generation, flexible thermal power generation, load, network, storage) to ensure adequacy and security
TASK 5	Study and demonstrate NEW GRID CONTROL ARCHITECTURES both at transmission and distribution level
TASK 6	POWER ELECTRONIC technologies, to improve development of advanced components and optimal control scenarios, and to further accelerate adoption and insertion of power electronics into the electric grid in order to improve qualities of the system

Current Funded Projects

1. Demonstration of MW scale Solar energy Integration in weak grid using Distributed Energy Storage architecture (D-SIDES)
2. Design and Development of Hybrid Renewable Energy Microgrid with Value Chain Applications for Agriculture & Dairy Farm
3. AlGaIn/GaN Power Transistor Based Platform Technology and Modules for Smart Grid Applications
4. SMART Planning and Operations of Grids with Renewables and Storage (SPORes)
5. Demonstration of grid supportive EV charger and charging infrastructure at LT level (D-EVCI)
6. Stability analysis, protection, and coordinated control of networked Microgrids
7. Development of a Prosumer Driven Integrated SMART grid
8. Mix-Energy-Source Electric Vehicle Charging Systems Design and its Impact on Indian Smart-distribution-
9. Research and development of smart, secure, scalable, resilient and adaptive cyber-physical power system (S3RA-CPPS)
10. Advanced Communication and Control for the Prevention of Blackouts
11. Reliable and Efficient System for Community Energy Solutions (RESCUES)
12. High Energy And Power Density (HEAPD)
13. Intelligent Microgrids with Appropriate Storage for Energy (IMASE)
14. Reconfigurable Distribution Networks
15. UK India Clean Energy Research Institute (UKICERI)
16. US – India Collaborative For Smart Distribution System With Storage
17. India-UK Center for Education and Research in Clean Energy (IUCERCE)

Opportunities for R&D in SmartGrid

Technology
Development

Low cost Smart
Inverter
Development

Market
Integration

Technology
Integration

Hardware-in-
Loop Testing

R&D synergy
with Standards

Interoperability

System
Integration

System Level
Testing

Demand Response
Pilots

System level Testing

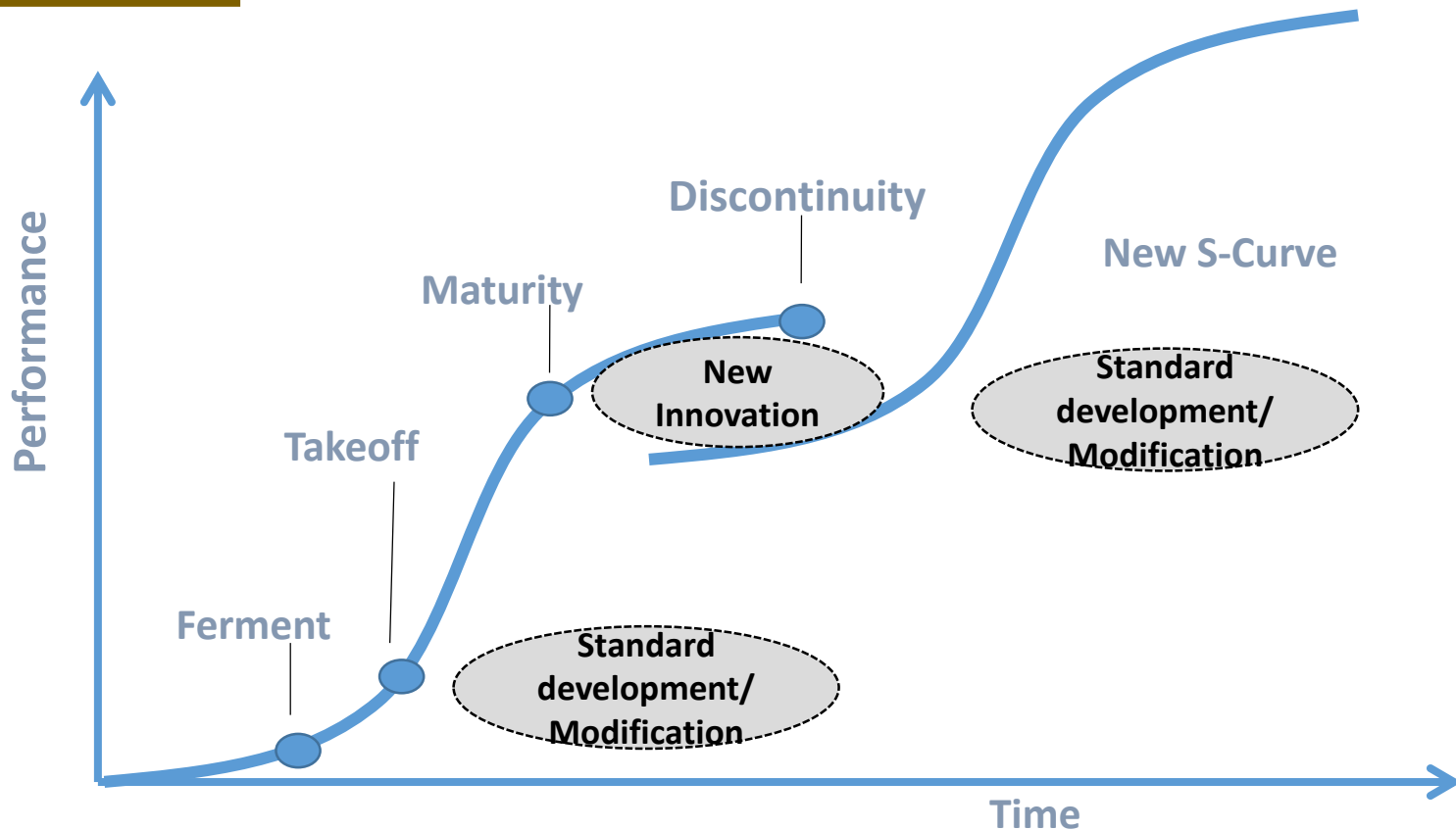


National Solar Mission
Ministry of Power
Government of India



- System level testing is taking over device level testing to ensure interworking of different domains and grid stability.
- Performance Testing of solutions for RE integration is complex due to multi domain nature-
 - ✓ IT, communications, controls, power devices, protection schemes etc
- ISGAN Annex-5, SIRFN , is working to develop test procedures for system testing including-
 - ✓ Advanced interoperability functions of DER
 - ✓ Smart Grid modeling and simulation
 - ✓ Advanced laboratory testing methods like HIL
- NPMU has suggested to include HIL testing in the MNRE guidelines for proposed test bed for DER

Innovation & Standard



EU-India DST Joint programme

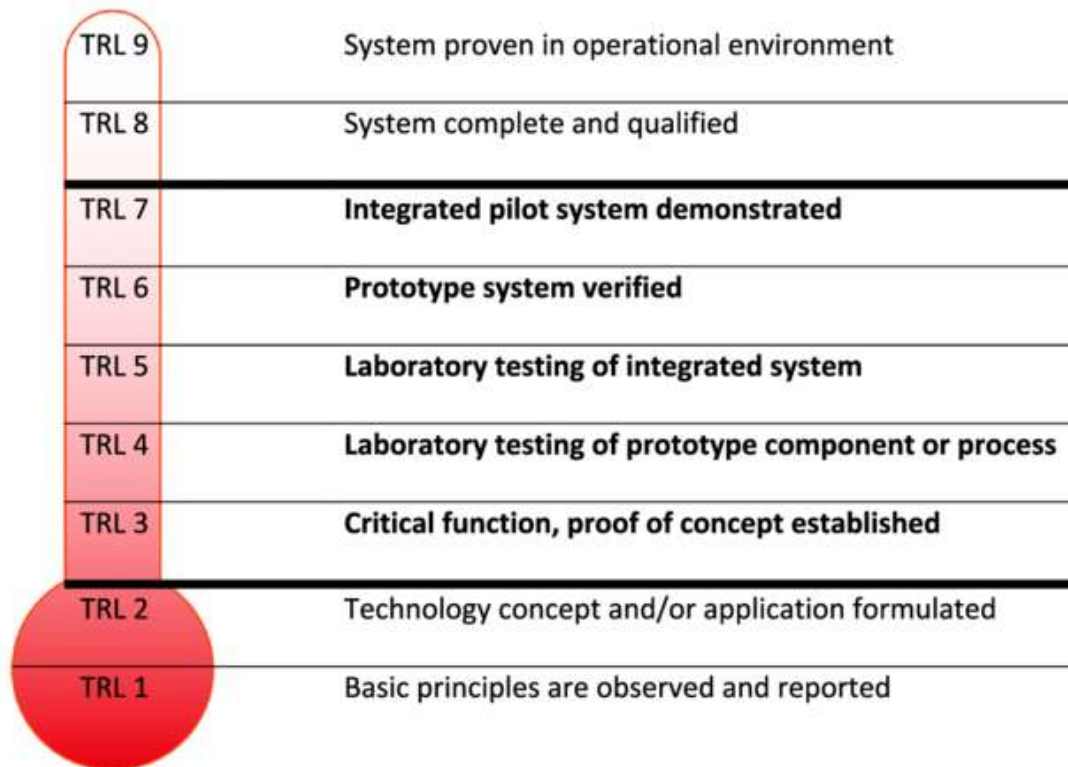
- Move towards **tangible cooperation projects in the field** : first demonstration projects in which EU and India utilities work together in the field have started in March 2019, supported by EU funding (Horizon 2020)
- EU and India also founding partners of Mission Innovation (MI) initiative taken during COP21 in Paris in 2015 committed to concentrate research and innovation efforts to make clean energy widely affordable
- New deliverable: **Joint Call on Smart & Integrated local energy systems** ('energy islands' ; opening deadline 3 September 2019 and closing on 29 January 2020)
- In total €18 million Euro: **€9 million from EU R&I programme Horizon 2020 matched by DST**

Scope: India EU joint call

Main Focus: Integrated local energy systems (Energy islands): International cooperation with India

- Develop and demonstrate novel solutions which analyse and combine, in a well delimited system, all the energy vectors that are present and interconnect them, where appropriate, to optimise their joint operation that is demonstrated by an increased share of renewables in and higher energy efficiency of the local energy system.
- Proposals should present a preliminary analysis of the local case as part of the content of the proposal and propose to develop solutions and tools for the optimisation of the local energy network, that also have a high replication potential across Europe and India.
- It should bring together all vital stakeholders: local consumers, small to medium industrial production facilities and/or commercial buildings should be involved in the projects from the start, preferably by creating energy renewable energy communities.
- Proposals should propose to develop solutions and tools for the optimisation of the local energy network, that also have a high replication potential across Europe and India.

Technology Readiness Level (TRL)



Thank You



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