FÓRUM LATINO-AMERICANO DE SMART GRID

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CENTRO DE CONVENÇÕES FREICANECA | 11 E 12 DE SETEMBRO DE 2023
SÃO PAULO - SP

Advanced Technologies for Energy Integrtaion and Management – Case Study of Indian Power System

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India's Tryst with Electrification

1898: 130 kW Sidrapong hydroelectric power station in Darjeeling

CESC LIMITED

1899: 1 MW thermal plant in Kolkata

1902: Electric Trams in Kolkata

India's Tryst with Electrification

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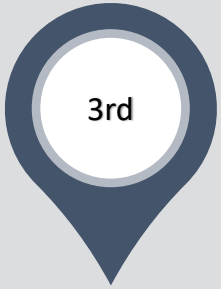
Generation Capacity
1947: 1.36 GW
2023: **423 GW** (>300X in 75 Yrs!)

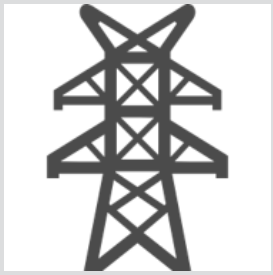
Per Capita Consumption
1947: 16.3 kWh
2022: 1400 kWh

Installed Power Generation Capacity (Source-wise) in GW							
Thermal (Coal, Gas and Diesel)	Hydro	Solar	Wind	Nuclear	Other	Total Non-Fossil	Grand Total
238.14	**46.85**	**71.15**	**43.94**	**7.48**	**15.80**	**185.22**	**423.36**
56.3%	11.1%	16.8%	10.4%	1.8%	3.7%	**43.7%**	100%

One Nation – One Grid



India has the 3rd largest power system in the world



Modern Transmission System

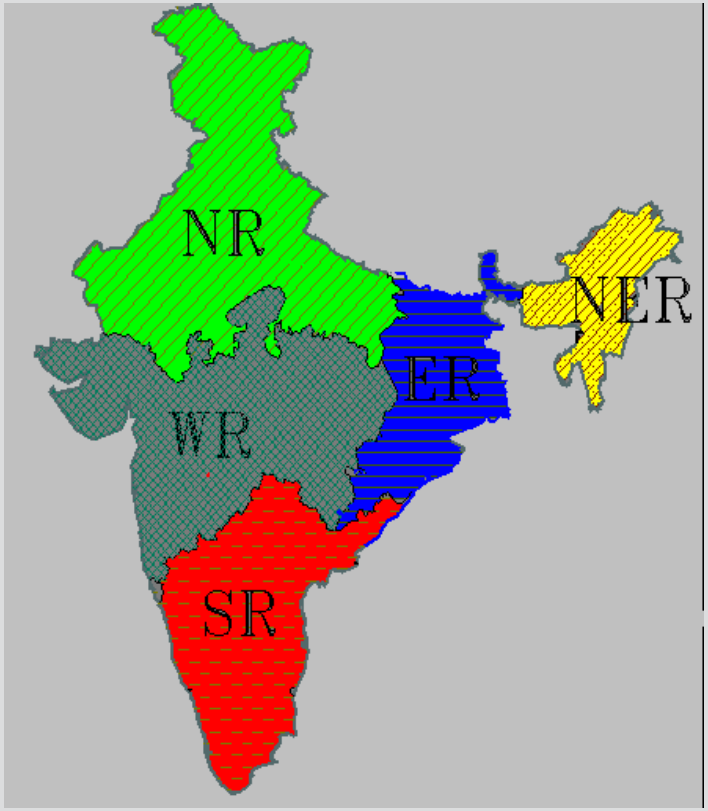
- 800 kV & 500 kV HVDC lines
- 765 kV & 400 kV AC lines
- Modern Control Centers

423 GW, 300 million customers
One Grid covering >3 million Sqkm operating in one frequency

Electrification

- 619000 villages and 99.9% households electrified
- 27 million households electrified in 18 months (Nov 2017 to March 2019) through a focused mission

One Nation – One Grid



- Indian Power System is operated as 5 regional grids with separate control centers – Regional Load Dispatch Centers (RLDCs)
- National Control Centre (NLDC) integrates all 5 Regions (RLDC)
- Independent System Operator (GRID CONTROLLER OF INDIA LTD) manages the RLDCs and NLDCs
- All states have State Load Dispatch Centers (SLDCs) managed by respective state transmission companies
- All regions are interconnected and operates in ONE FREQUENCY
- 18 Renewable Energy Management Centers (REMCs) with Advanced Tools for Weather and Generation Forecasting
- Matured power markets with 3 functional power exchanges
- Renewable Purchase Obligations (RPO) for Utilities
- Real-Time Market operational since June 2020
- Green Term Ahead Market (GTAM) launched in 2021
- Green Energy Open Access Rules in 2022 (open access for customers with >100kW demand)
- Carbon Market will be launched by end of 2023

India – New Initiatives

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- **India is the only country amongst major economies that achieved the target under Paris Climate Agreement of 40% power generation capacity from non-fossil fuels by 2030 in 2022 – 8 years ahead!**
- **New Target: 500 GW Renewable Energy (RE) capacity by 2030**
- **Smart Grid Initiatives in India**
  - ***Smart Grid Vision and Roadmap in 2013*** *(formulated by ISGF, adopted by Ministry of Power)*
  - ***14 Smart Grid Pilot Projects*** *allotted in 2013 – 50% project cost by Govt of India*
  - *National Standards for Smart Meters (IS:16444/IS:15959) in 2015/2017*
  - *EVSE Standards: IS 17017 series; 12 standards issued, rest under progress*
- **Net Metering:** All States and Union Territories issued net metering policies between 2013 and 2016
- **Energy Storage Systems Roadmap for India prepared by ISGF in 2019 -** cumulative capacity estimated by **2032 is 2416 GWh of which 209 GWh is for grid support**
- **250 Million Smart Meters presently under rollout on fast track on innovative business model – 15% capex by Govt of India as grant; rest as monthly fee (Opex): $xx per meter per month for 93 months**
- **Time of Day or variable tariff for all customers from April 2025 – upto 20% rebate during high solar hours; and up to 20% surcharge during peak hours**

Major Success Stories

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Solar and Wind

- Projects allotted through transparent auctions brought prices to **3 US Cents per kWh** which is cheaper than power from new coal plants
- Last 4 years added more RE capacity than coal and gas

Unnat Jyoti by Affordable LEDs for All (UJALA)

- LED Bulbs: 368 Million (Till Feb 2023)
- Savings: 47.8 Billion kWh (BU) (>US $ 2.5 billion) per year
- Carbon Reduction: 3.85 MTOE CO_2 per year

Other Energy Efficiency Programs

- Star labelling - 10 mandatory and 13 voluntary labeled appliances
- Total electricity savings in 2017-18: 86 BU (7.14% of total consumption)-US$ 7.5 bn/year
- Total reduction in CO_2 emissions of around 108 MTOE annually

APDRP, R-APDRP, IPDS and UDAY

- T&D loss reduction by over 50% in last 15 years (>36% to below 18%)

SAUBHAGYA

- 27 million households in the remotest parts electrified in 17 months – a World Record!

KUSUM (Under progress now)

- 10,000 megawatts (MW) of decentralized ground mounted grid-connected RE units
- 1.75 million standalone solar powered agriculture pumps
- 1 million grid-connected solar powered agriculture pumps

Projected Growth of Indian Power System

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IEA Projections of Indian Power System (Capacities in GW)		
	2030	**2040**
Solar	207	622
Wind	119	219
Other RE	19	28
Other Sources	444	597
Battery Storage	34	118
Total	823	1584
Flexibility Requirement	-	**±85% (50% ramp-up and 35% backdown**

Need to build demand-side flexibility, power plant flexibility, energy storage systems, grid flexibility; policy, market and regulatory solutions for short-term to medium-term

India's Approach on RE Integration

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A. What we have done/are doing

- Green Corridors
- Renewable Energy Monitoring Centers (REMC)
- Round The Clock (RTC) RE Power - Energy Storage Systems (ESS) with Solar and Wind Farms to supply 24x7 RE
- Smart Grids
- Solarization of Irrigation Pump (IP) sets with BESS

B. What ISGF is advocating - Flexibility in Demand and Generation

- Distributed ESS - Replacement of Diesel Generating Sets with Battery Energy Storage Systems (BESS), District Cooling Systems etc
- Demand Response and Ancillary Services
- Time of Use (TOU) or Real-time Tariffs
- National Solar Rooftop Registry
- Smart Inverters – IEEE 1547: 2018
- Electric Vehicles (EV) - Grid Integration
- Grid Interactive Buildings and Campuses – Smart Microgrids
- Peer to Peer (P2P) Transactions of Green Energy
- Redesign of the Grid

Green Energy Corridors

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- Green Energy Corridor is a comprehensive scheme for evacuation and integration of RE from large wind and solar farms in 8 RE rich states - Tamil Nadu, Rajasthan, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Himachal Pradesh and Madhya Pradesh

- The first phase of the project includes about approx. 9400 ckm transmission lines and substations of total capacity of approx. 19000 MVA (32.5 GW of RE Plants)

- The funding mechanism consists of Viability Gap Funding (VGF) of 40% of the project cost from Government of India

- Second Phase is presently under implementation

Green Energy Corridors

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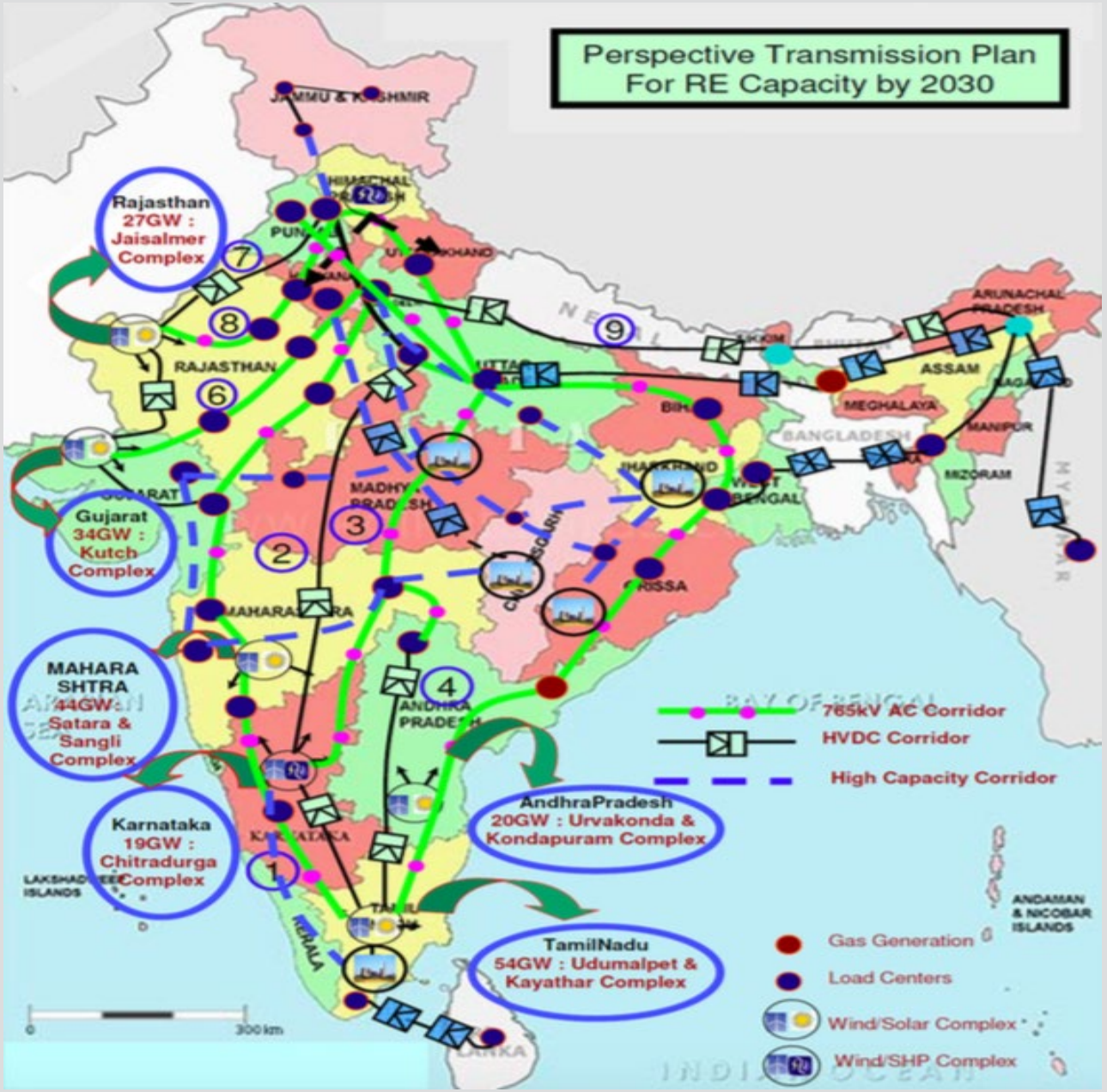


Renewable Energy Management Centers (REMC)

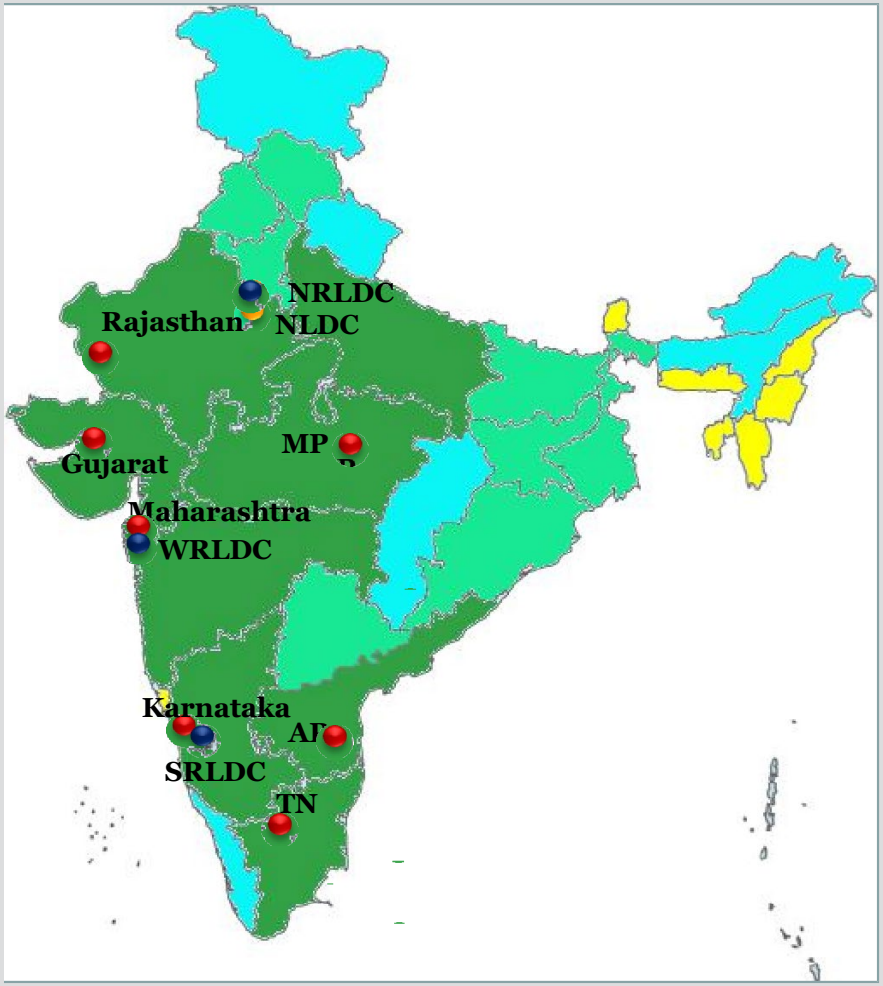
Objectives and Benefits

- State of the Art modelling tools for accurate RE generation forecasts integrated with weather forecasting inputs
- RE scheduling with secure interfaces for Grid Operators, Regulators and RE Generators; maximize RE utilization and help utilities meet Renewable energy Purchase Obligations (RPO)
- System-wide visibility and improved operational coordination; visualization and evaluation of RE forecast performance

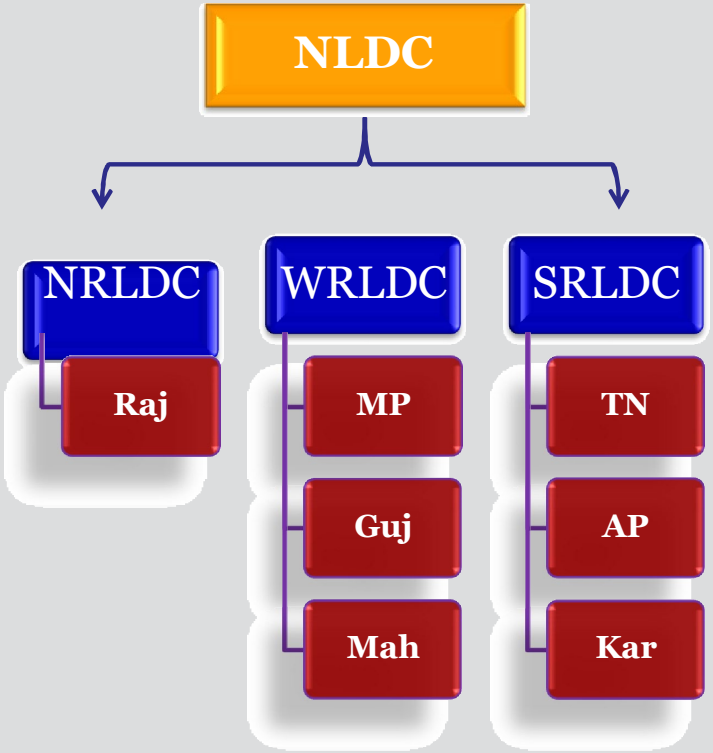
Architecture

- 4 Regional REMCs (Northern, Southern, Western and Eastern) and a National REMC – these are integrated with the Regional Load Dispatch Centers (RLDCs) and the National Load Dispatch Centre (NLDC)
- Supports Grid Operators to ensure coordination with conventional resources to achieve lower operational costs
- Manage reliability challenges through curtailment and modification of RE schedules during constrained conditions

REMC – Phase 1



Phase 2: REMCs in 6 States and one Region under implementation



Phase 1: REMCs in 7 States, 3 Regions and National Level (11 REMCs) for US$ 62 Million – completed

REMC Scope

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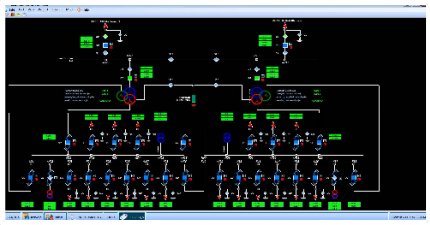
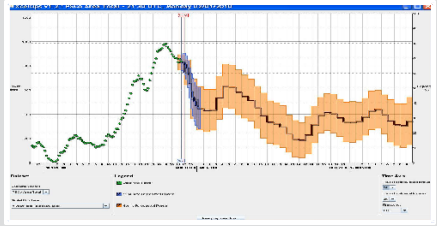
- Forecasting of RE generation on very short term (15 mins), day-ahead, intra-day and week-ahead basis
- Real time tracking of generation from RE sources and its geo-spatial visualization
- Scheduling solutions for private RE project developers
- Close coordination with respective SLDCs for RE generation and control for smooth grid operation
- Single source information repository and coordination point for RE penetration (static /dynamic data)

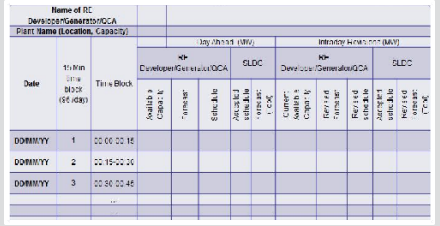
REMC Main Modules



SCADA

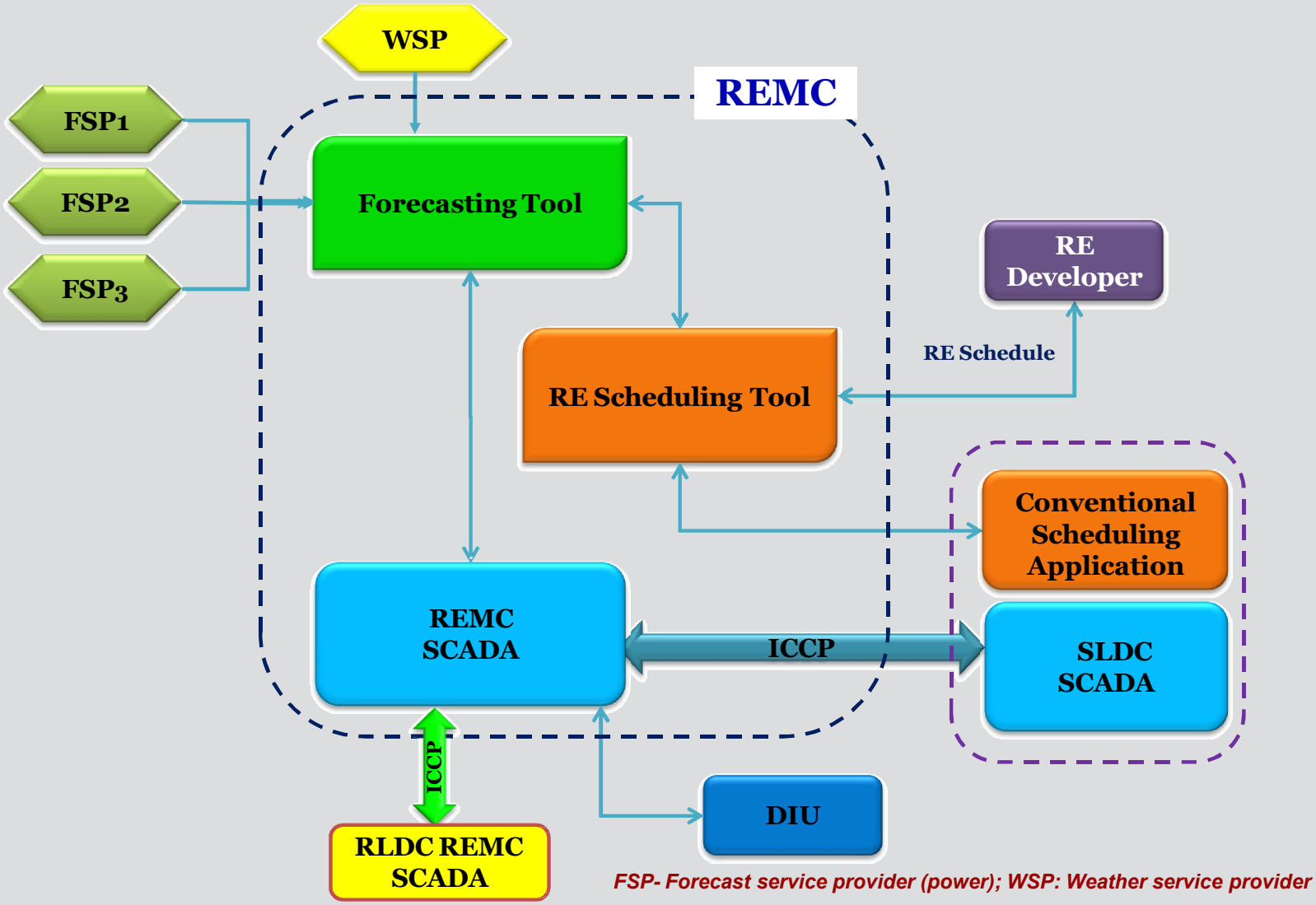


Forecasting Tool



Scheduling Tool

REMC Architecture



FSP- Forecast service provider (power); WSP: Weather service provider

Features of RE Forecasting Tool

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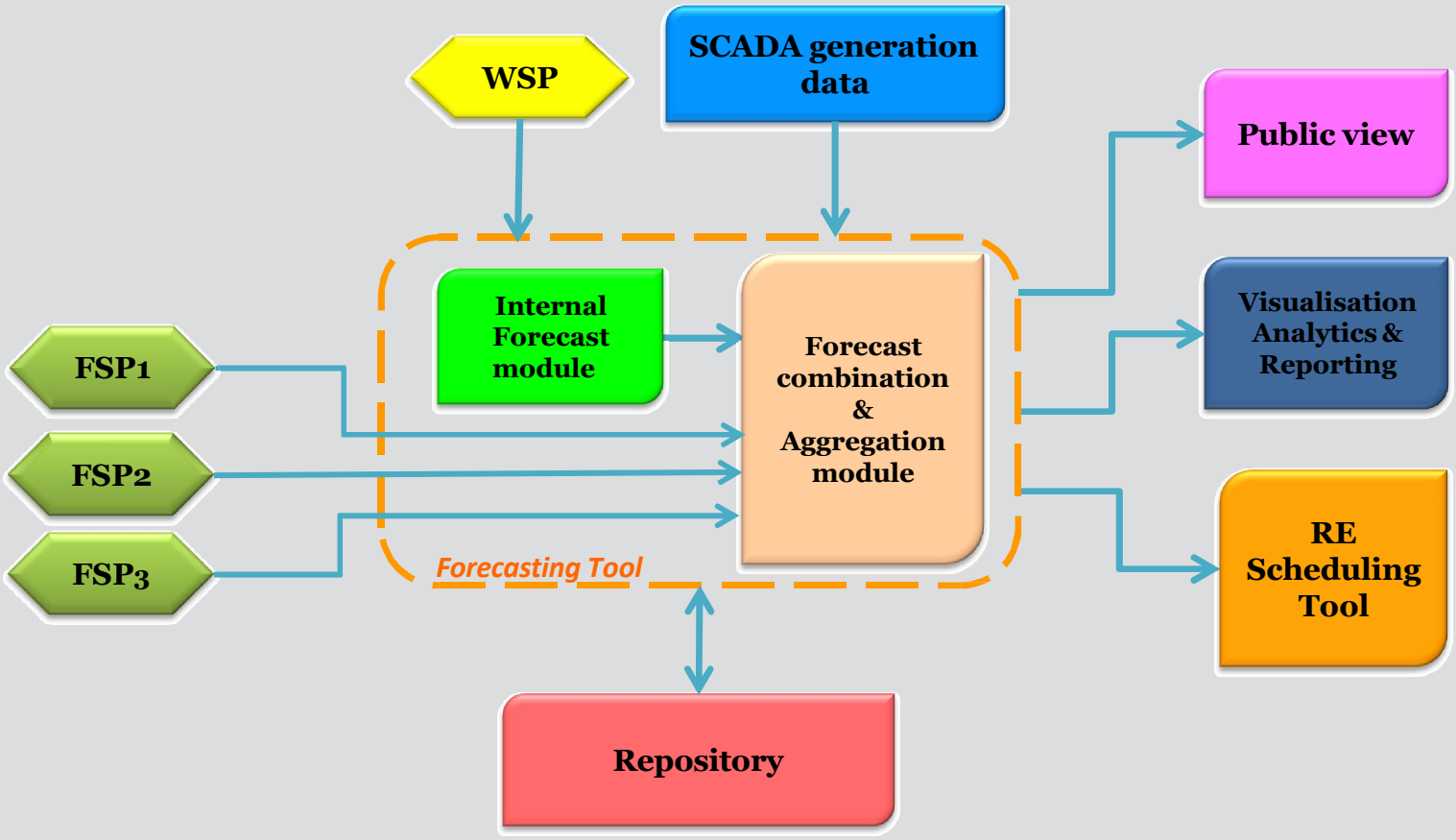
Data Exchange

- Share Static, Historical and Real Time SCADA data with Forecast Service Providers (FSPs)
- Collect Power forecast from different FSPs as well as Internal Fx tool
- Transfer of power forecasts to scheduling Tool
- Historical data from repository

Analytics Module

- Accuracy Analysis of power forecasts which has implication on payments terms – performance based payments
- Performance based retentions terms for FSPs (after two years)

RE Forecasting Tool



Round The Clock RE Power

- **Round The Clock (RTC) RE Plants**

RE Developers to Setup ESS to Supply 24x7 RE Power to Buyers

Solar Energy Corporation of India awarded several such projects in last 2 years

Project Developers are setting up pumped-hydro storage or BESS

First project expected to be completed in 2024

Distributed Energy Storage Systems

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- **Distributed Energy Storage Systems (ESS)**
  1. **Diesel Generator (DG) set replacement with BESS**
  2. **District Cooling Systems (DCS) with Thermal Energy Storage**

- **Replacement of DG sets with BESS** is the fastest and cheapest route to build flexibility for the Indian grid
  - Over 80 GW of large-size DG sets in India
  - Diesel at INR 95/liter, DG set will cost >INR 30/kWh
  - Power from BESS will be INR 15.40/kWh
  - Ban DG sets for standby power in new buildings
- More than half the electricity consumption in a building is for space cooling
  - Instead of each building having their centralized air-conditioning plant (or room-ACs)
  - **District Cooling Systems (DCS)** are successfully implemented around the world (including GIFT City in Gujarat, India)
- *ISGF White Paper on DG Replacement with Lithium-Ion Batteries in Commercial Buildings – www.indiasmartgrid.org*
- *ISGF White Paper on Sustainable Air Conditioning with District Cooling Systems -– www.indiasmartgrid.org*

Ancillary Services and Demand Response

Demand Response and Ancillary Services

Ancillary Services Regulations at transmission levels is in place – need to bring it to distribution grid

Business models for Demand Response need to be worked out

Time of Use (TOU) Tariff

- **Time of Use (TOU) Tariff for Electricity**

Time of Use (ToU) Tariffs are real-time pricing for electricity based on supply-demand scenario in real-time

- Price signals are communicated to the participating customers in advance about the Rebate or Surcharge in different time-blocks on the following day so that customers can adjust their interruptible loads accordingly
- *ISGF prepared TOU Tariff Framework for Gujarat in 2020 – www.indiasmartgrid.org*
- *ISGF conducted a Pilot Demonstration Project in Lucknow with 50 customers (22 MW load) during 2022 - 2023*

Rooftop Solar Registry

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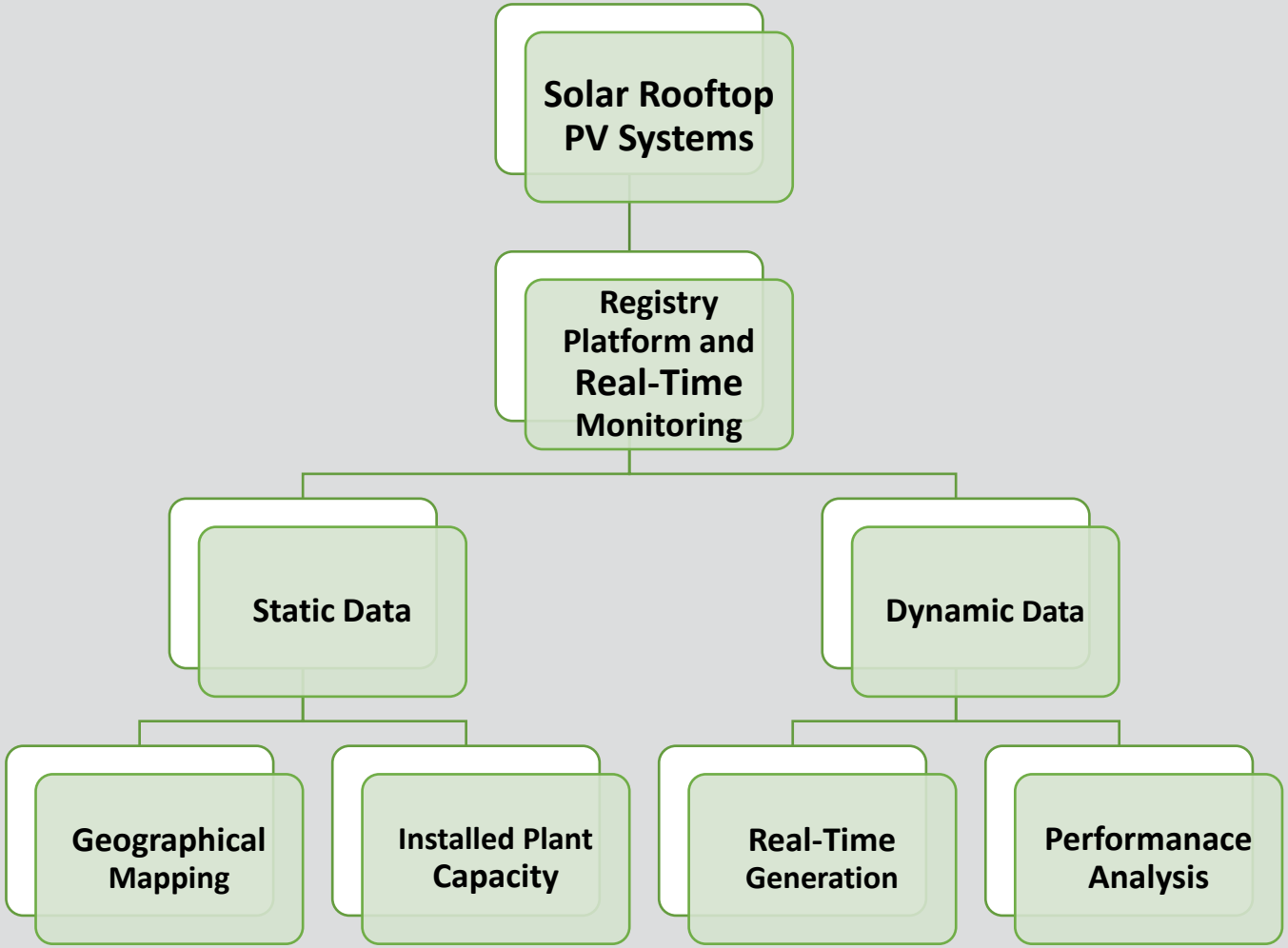
- National Rooftop Solar Registry – required for forecasting, scheduling and dispatch of Rooftop Solar Generation



Smart Inverters

Smart Inverters – IEEE 1547:2018 compliant

- Mandating Smart Inverters for all DERs
- IEEE 1547:2018 standard compliant smart inverters have following functionalities:
  - Remote Monitoring and Control
  - Voltage Ride-Through and Dynamic Voltage Support
  - Frequency Ride-Through and Frequency Support
  - Start-Up Ramp Rate

Bureau of Indian Standards to adapt IEEE 1547-2018 soon

EV- Grid Integration

- **EV-Grid integration - Vehicle-to-Grid (V2G) technologies**
- **Virtual Power Plants (VPPs)**
- **Promotion of RE for EV charging**

EV-Grid Integration

- Both EVs and Rooftop PV (RTPV) are connected to the low-voltage (LV) grid
- **V2G:** Grid connected EVs can mitigate the variability of RTPV generation during the day as well as store surplus generation in the EV batteries and pump back to the grid during peak hours
- **VPP:** Large number of EVs connected to the grid can be aggregated as virtual power plants (VPP)
- **Promotion of RE for EV charging** through innovative business models to decarbonize the transport sector

Grid Interactive Buildings/ Campuses and Smart Appliances

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Grid Interactive Buildings and Campuses - Smart Microgrids

Smart Appliances

Smart "grid-connected" microgrids: Large building and campuses to be made **Grid-interactive** with islanding features to provide flexibility to the main grid

- Buildings and Campuses with RTPV, BESS (instead of DG sets for standby power), and EVs with V2G capability
- Microgrids can buy (green) electricity from the grid at the cheapest rates and store it in the BESS and EVs and use it during peak hours or even sell it back to the grid at higher prices

Smart Appliances: All electrical equipment and appliances should be made smart and grid interactive; Ban production and sale of inefficient equipment and appliances in a phased manner

Dynamic RE Markets and P2P Transaction of Green Energy

- **Peer-to-Peer (P2P) Trading on Blockchain Platforms**
- **Dynamic RE Markets**

- **Peer-to-Peer (P2P) Trading:** Prosumers with RTPV systems can sell their surplus electricity to others who wish to buy GREEN ELECTRICITY – this can be done efficiently on blockchain platforms
- Promotion of Dynamic RE Markets - where those obligated to offset Scope 2 Emissions can buy green energy
  - *ISGF implemented 3 pilot projects (Lucknow, Delhi and Kolkata) on P2P trading of solar energy on blockchain*

Redesign of the Grid

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Comprehensive planning and re-design of the electrical network for the evolving "green grid of the 21st century"

Comprehensive planning and re-design of the electrical network – both transmission and distribution grids

- Present architecture of transmission and distribution grids is based on the concepts of: ***"one-way flow of electricity***" and "***electricity cannot be stored"***

Why planning and re-design?

- Distributed Energy Resources (DER) that are intermittent and connected to the low-voltage grid
- Bi-directional energy flows - Prosumers
- Transfer of RE power to major load centers
- Energy storage systems (ESS)
- EV-Grid Integration

India Brings Volumes to the Benefit of Whole World!

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- **Mobile Phone:** in 1995 – US$ 1000; today smart phones available at <US$50
- **Solar PV:** In 2011 – US$ 0.40/kWh; today it is US$0.03/kWh
- **LED Lamps:** 2014 – US$5 for a 7W lamp; today <US$1 for a 9W lamp
- **Smart Meters:** 2015 - >US$100/meter; today US$ 50/meter – we are yet to start roll outs!

Volumes offered by a market of >1.4 billion people brings benefits to rest of the 7 billion in the world!

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Stakeholder Map of Indian Power Sector

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