# SEC Webinar on “Assessment of wind and solar power forecasting techniques in SAARC countries”

***SAARC Energy Centre***

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# Module 1: Introduction to Wind and Solar Forecasting

# Framework adopted for the assignment

**Step 1**: Understanding of the readiness of each SAARC country in establishing state-of-the-art wind and solar forecasting systems

| | |
|---|---|
| Review of power sector structure | To frame contextual understanding |
| Review of publicly available information on met department and power utilities | To establish current status/scenario |
| Primary research surveys | To fill information gaps on current status |
| Review of grid operation procedures | To bring understanding of grid operation utility readiness |
| Gap analysis | To estimate overall readiness under a standardised structure |

**Step 2:** Assessment of challenges and recommendations

- Challenges in setting up of forecasting systems
- Standard guideline for setting up a solar and wind forecasting system in a nation
- Country specific recommendations for setting up of forecasting systems
- Role of the public and private sector in setting up of forecasting systems
- Impact of different stakeholders on development of forecasting systems

# Wind and solar power forecasting

## Need for forecasting

**I Issues in ensuring stability and security of grid**

- Intermittency of renewables
- Dispatch rules giving precedence to RE
- Challenges in managing grids with high RE penetration
- Deviations between schedule and dispatch

**II Evolution of deregulated electricity markets**

- Importance of short term load forecasting
- Price determination of short term power

**III Reduction in dependency on non-market mechanisms for short term power**

- Requirement of ancillary services based on potential grid intermittency
- Deviation settlement mechanisms put in place by regulators to ensure grid discipline among RE generators

**Stakeholder perspectives**

A. Utility: Grid Management activities and unit commitment through economic dispatch

B. Generator:

- Compliance with regulatory requirements
- Operational planning

C. Power markets: Efficient price discovery

# Wind and solar power forecasting

## Forecasting fundamentals

**Attributes of forecasts:**

- Temporal horizon e.g. 7 days ahead, 3 hours ahead, etc.
- Temporal resolution e.g. 5 mins, 1 hour, 24 hours, etc.
- Spatial Resolution e.g. 25 km x 25 km, etc.
- Frequency of forecasts e.g. 4/day, 16/day, etc.

**Types of forecasts:**

- Categorical forecasts
- Deterministic time-series forecasts
- Probabilistic time-series forecasts

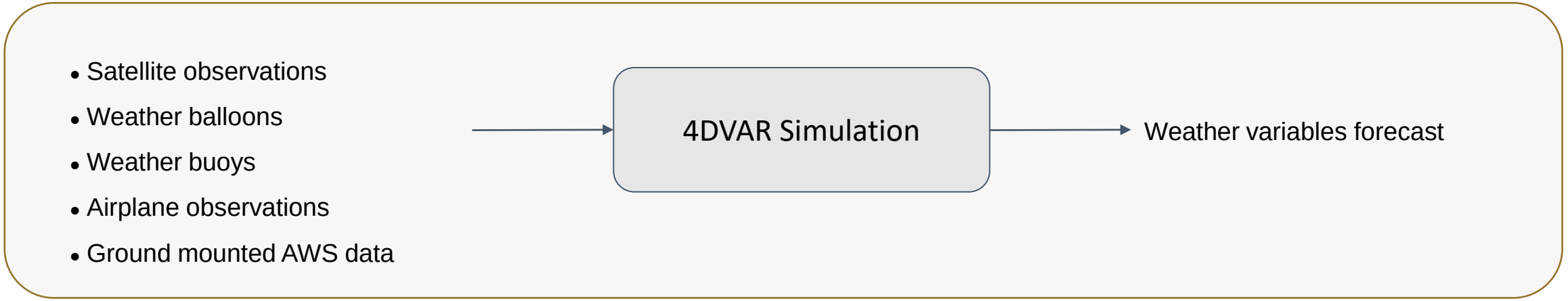
**Aggregation of forecasts**:

- Summation of forecasts of multiple generation units over a geographical area
- Larger the area, higher the forecast accuracy (assuming, larger area = larger capacity)

# Wind and solar power forecasting

## Weather forecasting

- Foundational layer and basis of wind and solar forecasting
- Well established science developed collaboratively by several nation states over centuries
- Numerical Weather Prediction (NWP) is the application most relevant to our study
  - NWP works by performing a time constrained simulation of the atmosphere and hydrosphere
  - NWP is performed at a global scale mostly by government backed meteorological agencies
  - Regional scale NWP simulations may be performed by smaller entities as well



# Wind and solar power forecasting

## Forecasting techniques

- **Physical Models** - Model the conversion of wind fields to power outputs of WTGs by mathematically representing the WTGs characteristics in relation to wind flows.
- **Statistical Models** - Based on data of weather patterns and power outputs used to establish relationships between the weather and power outputs
    - Time-series models - process forecasting models that rely on processes having seasonality and persistence of trend in addition to non-changing statistical properties
- **Artificial Intelligence Models** - Models that use process and associated variables data to learn general patterns from a large dataset and use an iterative function fitting approach to arrive at a predictor function which can be used to regress over future timesteps.
- **Hybrid Models** - Models that use a combination of multiple other model types for better performance.

| | Physical Models | Statistical Models | AI Models | Hybrid Models |
|---|---|---|---|---|
| ***Advantages*** | NWP Horizon applicable | Ease of implementation | Ease of implementation | Superior performance |
| ***Limitations*** | All NWP errors propagated | Limited to short-term horizons | Data dependence | Data and Expertise dependence |

# Wind and solar power forecasting

## Wind and Solar Forecasting Differences

Variables of interest vary:

- **Wind -** Wind-speeds, wind-direction, pressure, air density, etc.
- **Solar -** GHI, DNI, DHI, surface temperature, cloud cover, etc.

Solar Forecasting may involve specialized models for cloud cover predictions:

- Sky Imaging Systems - Require hardware installation at site to capture cloud patterns directly above
- Cloud Motion Vector Models - Capture cloud movements through remote sensing satellites for nowcasting

# Wind and solar power forecasting

## Global systems for wind and solar forecasting

AWEFS (Australian Wind Energy Forecasting System):

- Utilizes static data collected through a standardized format
- Horizons from 5 mins to 2 years ahead covered at varying resolutions
- Very high update frequencies for forecasts matching resolutions i.e. Forecasts updated every 5 minutes for a forecast resolution of 5 minutes.
- Real-time inputs from SCADA collected by utility from all sites covering weather and power parameters.
- NWP and climatological data is utilized as base data
- Operational inputs on generation availability also collected in real-time from all sites

ASEFS (Australian Solar Energy Forecasting System):

- Developed in two phases for 5 mins ahead to 7 days ahead horizons
- Phase 1 - Targeted at utility scale (>30 MW) plants and utilizes standard static data, NWP and SCADA data. Cloud movement monitoring using Himawari-8 satellite also incorporated.
- Phase 2 - Targeted at distributed solar (<100 kW). Reliance on observational data is much lower as most systems are rooftop mounted.

# Module 2: Assessment of SAARC Member States

# Assessment of SAARC Member States

| Part 1: RE capacities in SAARC Member States | | | | | | |
|---|---|---|---|---|---|---|
| Country | Present (CY2019/ FY2020) (in MW) | | CY2024/ FY2025 (in MW) | | CY2030/ FY2031 (in MW) | |
| | Solar | Wind | Solar | Wind | Solar | Wind |
| Afghanistan | 20 | 0.4 | 200 | 40 | 500 | 100 |
| Bangladesh | 39 | 0.9 | 250 | 50 | 1,000 | 100 |
| Bhutan | 0 | 0.6 | 2 | 2 | 10 | 5 |
| India | 34,627 | 37,694 | 90,000 | 53,000 | 190,000 | 80,000 |
| Maldives | 5 | 0 | 15 | 0 | 50 | 0 |
| Nepal | 1.78 | 0 | 35 | 5 | 80 | 20 |
| Pakistan | 2,000 | 1,500 | 3,000 | 2,500 | 4,000 | 4,500 |
| Sri Lanka | 160 | 129 | 900 | 250 | 1,900 | 800 |

- India is the most mature among SMS, when it comes to RE adoption and integration
- Pakistan has developed policy targets to improve RE uptake, however, implementation will be key
- Sri Lanka has abundant solar and wind potential. However, large scale wind power development is constrained owing to geographical dispersion of wind sites.
- Other SMS continue to lag in RE penetration.

# Assessment of SAARC Member States

## Part 2: Present Status of forecasting - Afghanistan

### I Introduction

- Power system covering 34 provinces is split across 4 networks and operated by Da Afghanistan Breshna Sherkat (DABS): North East Power System, South East Power System, Herat System and Turkmenistan System
- Several network islands exist within the system due to varying sources of power
- Resultant asynchronous system makes VRE integration more challenging than usual
- Wind capacity at 0.4 MW and Solar at 20 MW represent a small portion of 340 MW total.

### II Meteorology

- Afghanistan Meteorology Department (AMD) established in 1955 under Afghanistan Civil Aviation Authority
- Currently issuing 3 days ahead weather forecasts using METCAP+ software developed by Turkish State Meteorological Services
- Upgradation of observational network is needed as current system is outdated
- Upgradation of communication infrastructure is also underway which would allow better access to global datasets

### III Wind and Solar Forecasting

- Currently not a major area of focus as the need is for a stable and secure source of power which cannot be met by VRE
- Future projections of 100 MW wind and 500 MW solar power by 2031 if met could lead to an indispensable need for forecasting
- Asynchronous nature of grid makes forecasting an even greater requirement to enable smooth operations

# Assessment of SAARC Member States

## Part 2: Present Status of forecasting - Bangladesh

### I Introduction

- Wind capacity at 0.9 MW and Solar at 39 MW.
- Limited short term expansion plans owing to land-use constraints
- Projections for 2030 indicate 100 MW wind and 1000 MW solar capacities
- The power sector consists of a regulatory commission (BERC), GENCOs, TSO (Power Grid Company of Bangladesh) and distribution companies. However, promotion and facilitation of RE falls under SREDA

### II Meteorology

- Relatively advanced Bangladesh Meteorological Department (BMD) which maintains a network of observatories, radar/satellite stations and telecommunications infrastructure
- Weather forecasts upto 5 days ahead including nowcasting is disseminated by BMD
- Several global weather products are utilized by the BMD to issue forecasts twice a day

### III Wind and Solar Forecasting

- Given the land use constraints, the total potential for wind and solar power stands at ~3.4 GW
- This represents a small fraction of the country's total power requirements
- For wind and solar capacities that are less than 10% of the total power managed in the grid, the variability associated with them is inconsequential in terms of grid management
- Need for forecasting is as a result, very limited and focus remains on increasing RE capacities

# Assessment of SAARC Member States

## Part 2: Present Status of forecasting - Bhutan

### I Introduction

- Wind capacity at 0.6 MW expected to grow to 5 MW and solar capacity expected to grow to 10 MW by 2030.
- Represents a small fraction of the ~1600 MW of hydro generation in the country which also qualifies as a renewable energy source
- Power sector in the nation is governed by Druk Green Power Corporation Ltd. responsible for generation and Bhutan Power Corporation responsible for transmission and distribution.

### II Meteorology

- Meteorology in the country falls under the ambit of the National Center for Hydrology and Meteorology.
- The department maintains networks of atmospheric and hydrology observational stations
- Capacity to generate forecasts upto 3 days ahead and upto 4 times per day
- Focus of department is on extreme weather events affecting the country's hydrological resources

### III Wind and Solar Forecasting

- Need for forecasting is negligible to non existent due to highly limited share of wind and solar power
- Primary research shows that existing wind and solar resources are managed and evacuated by the BPC

# Assessment of SAARC Member States

## Part 2: Present Status of forecasting - India

### I Introduction

- The most advanced of SAARC nations in terms of wind and solar forecasting owing to a combined installed capacity of ~65 GW
- Grid management activities are carried out by the Power System Operation Corporation Ltd. (POSOCO) which acts as the operator while grid assets are owned by the Power Grid Corporation of India Ltd. (PGCIL)

### II Meteorology

- The Indian Meteorological Department (IMD) established in 1875 acts as the nodal meteorological agency
- Forecasts are issued by the IMD as well as the National Center for Medium Range Weather Forecasting (NCMRWF)
- Forecasts with horizons ranging from short-term (1-3 days ahead) to extended range (15 days ahead) are issued using multiple NWP models

### III Wind and Solar Forecasting

- Forecasting of wind and solar power is mandated for generators by state wise regulations that have led to private forecasting agencies finding markets
- Utility level forecasting is carried out through Renewable Energy Management Centers (REMCs) which serve as control centers for RE integration at every RE rich state and consist of forecasting tools as well as inputs fro private forecasting agencies
- Independent utility projects for RE and load forecasting also exist to meet custom requirements

# Assessment of SAARC Member States

## Part 2: Present Status of forecasting - Maldives

### I Introduction

- Current solar capacity stands at 5 MW expected to grow to 50 MW by 2030 and no wind capacity planned
- The island nations grid is governed by a single fully integrated utility - The State Electricity Company Ltd.

### II Meteorology

- The Maldives Meteorological Service (MMS) is the nodal meteorological agency established in 1942
- The MMS maintains a small network of observational systems and relies on foreign agencies such as IMD, ECMWF, etc. for weather forecasting products
- Limited capacity to generate and disseminate forecasts on its own

### III Wind and Solar Forecasting

- The solar capacity in the country is expected to grow in the form of direct use technologies such as rooftop solar and solar based water heating which do not require forecasting for operational use
- Grid connected capacity is and is expected to be highly limited and need for forecasting is also consequently highly limited
- Variability can be easily managed through fuel based generators and battery storage

# Assessment of SAARC Member States

## Part 2: Present Status of forecasting - Nepal

### I Introduction

- Current solar capacity stands at 1.78 MW expected to grow to 80 MW by 2030 and wind to grow to 20 MW from no current installations.
- Similar to Maldives, the power grid is governed by a single vertically integrated utility - Nepal Electricity Authority

### II Meteorology

- The Meteorological Forecasting Division (MFD) of the Department of Hydrology and Meteorology serves as the nodal agency for dissemination of forecasts in the country
- The agency maintains a small network of observational stations
- Supported by the Finnish Meteorological Institute (FMI), the MFD generates regional forecasts spanning up to 3.5 days ahead revised up to 4 times a day

### III Wind and Solar Forecasting

- Solar installations in the country comprise of several off-grid systems which do not require forecasting
- Utility scale solar plants are very limited and forecasting in the nation is of limited use as a result

# Assessment of SAARC Member States

## Part 2: Present Status of forecasting - Pakistan

### I Introduction

- Current installations totalling 2 and 1.5 GW respectively for solar and wind power represent a less than 3% share of the total power generation in Pakistan
- Primary consultations indicate forecasting being carried out by generators and shared with relevant authorities
- Estimated projections of net installed capacity rising up to 8-9 GW indicate a growth in need for forecasting

### II Meteorology

- The Pakistan Meteorological Department (PMD) established in 1947 has 5 regional centres serving the different regions in the country
- The PMD has an advanced forecast generation process that utilizes multiple NWP models and data from several foreign agencies including the German, UK and Italian meteorological agencies
- Forecasts up to 7 days ahead are disseminated by the PMD which stands in a good position to cater to the needs of wind and solar forecasting in the country

### III Wind and Solar Forecasting

- Lack of current regulations around forecasting allow for a situation where wind and solar generators are at risk of curtailment in spite of must-run status
- The country is in a good position to implement forecasting as part of its operational grid management processes

# Assessment of SAARC Member States

## Part 2: Present Status of forecasting – Sri Lanka

### I Introduction

- Current capacities of wind and solar stand at 129 MW and 160 MW with expansion projected to 800 MW and 1900 MW respectively by 2030
- Sri Lankan power sector is also governed by a vertically integrated utility - Ceylon Electricity Board
- RE in the country is promoted by Sri Lanka Sustainable Energy Authority acting as a separate entity

### II Meteorology

- The National Early Warning Meteorological Center of the Department of Meteorology (DOM) is the nodal agency for generation and dissemination of weather forecasts in the nation
- The center relies on forecasts from IMD and ECMWF to provide weather forecasts upto 5 days ahead
- The development of in-house forecasting is still at a nascent stage in the country

### III Wind and Solar Forecasting

- 2014 marked the nation achieving 10% of its power supply from wind and solar power
- Increasing capacities and a pledge to achieve 100% renewable energy consumption at a UN Climate conference indicates a growing need for wind and solar forecasting
- Private generators are expected to carry out forecasts for horizons of 2-6 hours ahead which are utilized by the utility for grid management. The utility does not carry out any forecasting of its own

# Assessment of SAARC Member States

## Part 3: GAP Analysis – Methodology (1/2)

An assessment tool has been prepared for evaluation and scoring of each nation's current status of wind and solar forecasting with the major criteria for assessment as defined

| Criteria | Area of assessment | Score |
|---|---|---|
| **Static data collection framework** | Collection and record-keeping of all the static information of wind and solar plants such as plant characteristics, location coordinates and manufacturer-provided generation characteristics | 0 - No static data collected<br>0.5 - Static data collected<br>1 - Static data collected via standardised framework |
| **Dynamic data collection** | Monitoring the generation, availability data of the solar and wind plants through the establishment of data acquisition and monitoring systems. | 0 - No dynamic data collected<br>0.5 - Dynamic data collected in real-time as part of existing system integration<br>1 - Dynamic data collected in real-time via renewable energy-specific framework |
| **Independent NWP** | Capability of the nation to carry out numerical weather predictions of weather parameters relevant to wind and solar power forecasting | 0 - No data available<br>0.5 - Data available<br>1 - Models operational and data available |
| **Short-term wind power forecasting** | Wind power forecasting on short range time horizon i.e. 0-23 hours ahead | 0 - Not operational<br>0.5 - Operational and not mandated<br>1 - Operational and mandated by regulation |
| **Medium-term wind power forecasting** | Wind power forecasting on medium range time horizon i.e. 24-360 hours ahead | 0 - Not operational<br>0.5 - Operational and not mandated<br>1 - Operational and mandated by regulation |

# Assessment of SAARC Member States

| Part 3: GAP Analysis – Methodology (2/2) | | |
|---|---|---|
| **Criteria** | **Area of assessment** | **Score** |
| **Long-term wind power forecasting** | Wind power forecasting on long range time horizon i.e. 16-90 days ahead | 0 - Not operational<br>0.5 - Operational and not mandated<br>1 - Operational and mandated by regulation |
| **Short-term solar power forecasting** | Status of solar power forecasting on short range time horizon i.e. 0-23 hours ahead | 0 - Not operational<br>0.5 - Operational and not mandated<br>1 - Operational and mandated by regulation |
| **Medium-term solar power forecasting** | Status of solar power forecasting on medium range time horizon i.e. 24-360 hours ahead | 0 - Not operational<br>0.5 - Operational and not mandated<br>1 - Operational and mandated by regulation |
| **Long-term solar power forecasting** | Status of solar power forecasting on long range time horizon i.e. 16-90 days ahead | 0 - Not operational<br>0.5 - Operational and not mandated<br>1 - Operational and mandated by regulation |
| **Dispatch of wind and solar power** | Wind and solar power generation management by the grid operators for unit commitment and dispatch | 0 - Not managed<br>0.5 - Dispatch managed through operator expertise<br>1 - Dispatch managed through forecast-driven plans |

The status of each assessment criterion may fall under:

- **Operational** - Already established and operational (Score = 1)
- **In progress** - In the process of development (Score = 0.5)
- **Lacking** - Not available and no work in progress (Score = 0)
- **No information** - Indicates a lack of information to assess the state (Score = 0)

# Assessment of SAARC Member States

## Part 3: GAP Analysis – Outcome

| | Afghanistan | Bangladesh | Bhutan | India | Maldives | Pakistan | Nepal | Sri Lanka |
|---|---|---|---|---|---|---|---|---|
| Static Data Collection Framework | 0 | 0.5 | 1 | 1 | 0.5 | 1 | 1 | 0.5 |
| Dynamic Data Collection | 0 | 0.5 | 0.5 | 1 | 0 | 0.5 | 0 | 0.5 |
| Independent NWP | 0.5 | 1 | 0.5 | 1 | 0.5 | 1 | 0.5 | 0.5 |
| Short-term wind forecasting | 0 | 0.5 | 0.5 | 1 | 0 | 0.5 | 0 | 0.5 |
| Medium-term wind forecasting | 0 | 0 | 0 | 1 | 0 | 0.5 | 0 | 0.5 |
| Long-term wind forecasting | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 |
| Short-term solar forecasting | 0 | 0.5 | 0.5 | 1 | 0 | 0.5 | 0 | 0.5 |
| Medium-term solar forecasting | 0 | 0 | 0 | 1 | 0 | 0.5 | 0 | 0.5 |
| Long-term solar forecasting | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 |
| Dispatch of wind and solar power | 0.5 | 0.5 | 0.5 | 1 | 0 | 0 | 0 | 0.5 |
| **Total** | **1** | **3.5** | **3.5** | **8** | **1** | **4.5** | **2.5** | **4** |

# Module 3: Implementation of forecasting techniques in SAARC Member States

# Implementation of forecasting techniques in SMS

**Challenges in setting up of RE forecasting systems**

**FACTOR 1: Policy and Regulatory**

| Country | Availability of latest RE policy | Strength in policy implementation | Overall |
|---|---|---|---|
| **Afghanistan** | Low | Low | Low |
| **Bangladesh** | Low | Medium | Low |
| **Bhutan** | Medium | Medium | Medium |
| **India** | High | Medium | High |
| **Maldives** | Low | Low | Low |
| **Nepal** | Low | Low | Low |
| **Pakistan** | High | Low | Medium |
| **Sri Lanka** | High | Medium | Medium |

- India has the most detailed and comprehensive policies for forecasting of wind and solar energy
- Bangladesh, Sri Lanka and Pakistan have policies in place, but are in nascent stages
- In Afghanistan, the Maldives, Bhutan and Nepal, there are no solar and wind forecasting policies as of now

# Implementation of forecasting techniques in SMS

## Challenges in setting up of RE forecasting systems

**FACTOR 2: Lack of market design and institutional framework**

1. **Afghanistan**: The prevailing power system in the country is weak and fragmented
2. **Bangladesh**: The country is yet to set up strong RE policies
3. **Bhutan:** State-owned entities, lack of private investments in solar and wind space, limited RE potential
4. **India**: Most DISCOs in India are government-owned and vertically integrated. This leads to system inefficiencies and sub-par performance. In the short-term market, liquidity constraints remain and a large proportion of transactions continue to occur outside the exchanges
5. **Maldives**: Due to the dispersed geographical position of the islands in the archipelago, transmission and distribution infrastructure is scattered and islanded, which restricts smooth operation of the power market
6. **Nepal**: The power sector is highly regulated and vertically integrated. The country is a single-buyer market, where bulk purchases are made without competition. The sector structure impedes development and trade
7. **Pakistan**: Pakistan's transmission and distribution losses are high and infrastructure is not ready to accommodate high in-firm RE generation. Furthermore, the country does not have an electricity market for power trading
8. **Sri Lanka**: Although the country has prepared a RE policy to foster such projects, the electricity market has not yet evolved to complement RE injection. Transmission and distribution infrastructure weak and energy access is constrained

# Implementation of forecasting techniques in SMS

## Challenges in setting up RE forecasting systems

### FACTOR 3: Implementation issues

- **Dispersed Connectivity** - Wind and solar plant locations are distributed across many remote locations within a country where telecommunications infrastructure may be lacking
- **Data Disruptions** - Breaks in dynamic data and misreporting of static information are a major pain point in developing a standardized forecasting framework for a country
- **Stakeholder Participation** - As RE capacity increases, so does the number of stakeholders involved in the sector leading to difficulties in aligning the objectives of all towards a common forecasting framework. Incentives may not be conducive without dedicated efforts towards aligning them

### FACTOR 4: Technical Challenges

- **Infrastructure**- - IT and SCADA infrastructure needs to be set-up in order to systematically collect and store static and dynamic data in a standardized format. This infrastructure aside from routine installations requires dedicated RE specific design incorporation to ensure prerequisites for forecasting are covered
- **Meteorology** - National scale efforts are needed to establish meteorological expertise and RE specific products in every country.
- **Information Technology** - Once, the infrastructure and meteorological requirements have been covered, the final layer in forecasting systems implementation requires software and technical expertise to utilize the datasets and information in order to develop forecasting models specific to each nation’s requirements. Expertise may be outsourced or developed in-house at power departments which will require resource allocation and effective cyber-security planning.

# Implementation of forecasting techniques in SMS

## Recommendations in setting up RE forecasting systems - Generic

### I Planning and Policy:

- Mapping of all current and in-pipeline wind and solar assets and collection of static details
- Benchmarking study to understand feasibility and accuracy expectations; Sample set may be selected to maintain cost effectiveness
- Compliance requirements to be created for data sharing standards, communications protocols and cyber-security; Care must be taken to ensure requirements allow for easy switching between vendors;
- Consultations with all stakeholders by an independent entity to ensure bias free cooperation and participation
- Distribution of forecasting responsibilities between multiple stakeholders such that financial burdens are not concentrated

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### II Meteorology

- Development of RE and power sector focussed NWP products through the use of regional forecasting models
- Greater collaborations between the meteorological departments and the power departments and expansion of levels of data and knowledge sharing between departments

# Implementation of forecasting techniques in SMS

**Recommendations in setting up RE forecasting systems - Generic**

## III Wind and Solar Forecasting

- Grid operation and market requirements based decision making on forecasting attributes such as required horizons, resolutions, update frequencies
- Decision on requirements for deterministic or probabilistic forecasting or both factoring in cost considerations and expected errors based on benchmarking study
- Decisions on reporting, support and training requirements for grid management staff
- Recommended to run a pilot project with more than one forecast provider after documentation of all requirements.
- Recommended to create a mandate for weather data collection hardware to be installed at all wind and solar sites in addition to the SCADA data requirements and also mandate sharing of such data with utilities.
- Depending on the share of solar power in the energy mix, an additional mandate for cloud movement capturing technology may be created on need basis.

# Implementation of forecasting techniques in SMS

**Recommendations in setting up RE forecasting systems – Country Specific**

**Afghanistan:**

- Zonal Renewable Energy Centers under the National Renewable Energy Policy can act as nodal agencies for RE forecasting and integration activities
- Capacity development activities at AMD may be taken up with a view to serving the power sector along with other use-cases
- Given low RE penetration levels and lack of sufficient infrastructure, data intensive methods of forecasting are unlikely to be feasible; Physical models based on NWP products may be the best approach in current scenario

**Bangladesh:**

- A benchmarking study may be carried out in the country with a view to understanding the benefits of implementing forecasting systems; SREDA may serve as an ideal entity to frame and carry out the benchmarking activity
- BMD has sufficient prowess to cater to the needs of wind and solar forecasting; Collaboration between the power departments and BMD may be formalized in order to utilize BMD's resources in the power sector.
- Given the negligible need for forecasting, centralized forecasting and model development may be carried out by the utilities to meet the basic planning and dispatch requirements if any

# Implementation of forecasting techniques in SMS

**Recommendations in setting up RE forecasting systems – Country Specific**

**Bhutan:**

- Given high levels of hydro generation which offers a dispatchable energy source, the need for forecasting is highly limited.
- Off-grid RE systems may be the most viable option for increasing wind and solar capacities. Forecasting of long-term trends of wind and solar generation may be useful in understanding potential for RE to offset periods of low hydro flows due to climatic changes

**India:**

- Most fundamental requirements of infrastructure, etc. are already in place in India; Focus may be placed on improving forecast accuracies and utilization
- Better utilization of IMD's existing capabilities may be achieved by creating a formal mechanism and framework for data and knowledge sharing from IMD to external governmental and private organizations in the power sector
- Current forecasting processes in the country are focussed at deterministic forecasts for grid management and accounting purposes; Probabilistic forecasting may be introduced for better understanding the uncertainties associated with the large wind and solar capacities and help in better grid operations and power purchase planning.

# Implementation of forecasting techniques in SMS

**Recommendations in setting up RE forecasting systems – Country Specific**

**Maldives:**

- The major growth in RE penetration is expected to in rooftop solar installations. Hence, the State Electricity Company may implement an easy to use framework for self registration of solar rooftop installations by the participants.
- Increased collaboration between the Met department and the electricity utility may prove beneficial to both parties as observational data from solar installation sites can be shared with the met department and forecast data can be shared with STELCO for grid management.
- Medium to long term forecasting of aggregated rooftop installations by STELCO is advisable as it will help plan for changes in electricity demand due to increasing rooftop solar penetration.

**Nepal:**

- No immediate recommendations for wind and solar forecasting are offered as the need for forecasting is non existent in the current scenario and not expected to change significantly over the medium term.
- It is advisable for the Nepal Electricity Authority to create a framework for registration of off-grid systems as their penetration is expected to increase. A repository of such systems maintained centrally will help in planning and policy activities.

# Implementation of forecasting techniques in SMS

## Recommendations in setting up RE forecasting systems – Country Specific

**Pakistan:**

- Alternative Energy Development Board (AEDB) may serve an ideal entity to initiate consultation processes in Pakistan as it is in the early stages of RE capacity development.
- It is advisable to initiate a benchmarking study in the country to understand current standing and potentials benefits and pitfalls of implementing a forecasting system.
- High collaboration between the PMD and power sector entities such as the AEDB is highly recommended as the PMD is well suited to serve the needs of the power sector in the country and it's forecasting requirements
- Risk of curtailment of wind and solar power due to a lack of regulatory process may be reduced by performing day-ahead and hours-ahead forecasting using statistical and physical models by the grid operator and generators.

**Sri Lanka:**

- With rapid expansion expected in wind and solar power, it is highly recommended to initiate the process of setting-up a state of the art forecasting system in the country
- It is advisable to focus initial efforts towards setting up the frameworks and infrastructure for data telemetry and storage for all the existing and upcoming wind and solar assets in the country
- Smaller capacity plants which are currently outside the scope of SCADA systems must be brought within the purview of SCADA provisioning as the aggregate impact of the smaller plants may eventually impact grid operations
- As the targets are for 100% RE generation in the country, variability will have a large impact on grid stability and operation; Consequentially deterministic forecasts will not suffice and plans for probabilistic forecasting should be incorporated at the earliest to ensure a smooth transition.

# Implementation of forecasting techniques in SMS

## Guidelines for setting up of RE forecasting systems (1/2)

| Aspect | Guidelines |
|---|---|
| Planning | • Technical decisions on horizons of forecasting, temporal resolutions and frequency of forecast updates<br>• Technical decisions on requirement for deterministic or probabilistic forecasts<br>• Technical decision on number of forecast service providers (FSP) to be engaged in system<br>• Decision on new installations or upgradation of SCADA systems connected to wind and solar generators<br>• Decision on sizing of IT infrastructure based on the technical parameters considered in previous points<br>• Decision on technical support expectations/requirements<br>• Framing of contract or tendering terms for required infrastructure, IT hardware and software |
| Infrastructure | • Vendor selection for installation/ upgradation of SCADA system if deemed necessary<br>• Vendor selection for IT infrastructure purchase and commissioning<br>• Vendor selection for system software development and installation<br>• Decision on requirement for installation of meteorological observation systems at generator sites<br>• Decision on installation of sky-imaging systems at solar generation sites |

# Implementation of forecasting techniques in SMS

**Guidelines for setting up of RE forecasting systems (2/2)**

| Aspect | Guidelines |
|---|---|
| Implementation | • Benchmarking studies on forecasting of wind and solar power<br>• Decision on standard error metrics for assessment of forecasts<br>• Decision on assigning responsibility of forecasting on generators or grid operator or other utility/national institution or all<br>• Pilot project with FSPs<br>• Decision on selection of FSPs<br>• Trial runs of forecast system with all stakeholder participation |
| Operation | • Decisions on assigning responsibility of managing forecasting system with existing or new team structures at the grid operation utilities<br>• Inclusion of generator downtime disclosure into forecasting system on a real-time basis<br>• Utilisation of forecasts at all time horizons into dispatch schedules planning and management<br>• Monitoring and reporting of the imbalance impacts before and after implementation of forecasting system<br>• Review of forecast performance regularly |

# Impact of proposed forecasting techniques on stakeholders

- **RE generators**: In countries like India, forecasting of energy generation falls on generators. Therefore, RE generators have to forecast power output to avoid payment of charges.
- **Ancillary service providers**: The forecast data for wind and solar generation as well as the uncertainties regarding the forecasts are important to assess the requirement of “closer to real-time” ancillary services.
- **System operators**: Strong forecasting systems help system operators evaluate the supply side of load balancing The relative cost of producing electricity from the available pool of power generators (including conventional and non-conventional) can help in evaluating dispatch economics and optimum cost of power generation.
- **Transmission and distribution companies**: Forecasting allows the T&D companies to undertake system planning and augment existing infrastructure to accommodate RE energy. This will lead to improved RE integration with the grid while reducing curtailments.
- **Power market participants**: A prior knowledge of power market price fluctuations helps suppliers to set up rational offers in the short term as well as design bilateral contract pricing in the medium term. This will allow for improved price discovery and power market liquidity.
- **Policy makers:** Policy makers would be required to come up with regulations that improve the overall power markets, including fostering competition, development of power trading exchanges, transmission planning, ancillary services planning and increasing overall RE penetration.

# Key Takeaways

- While all SAARC member states, apart from India, are at an initial market development stage in terms of RE adoption, there is scope for accelerated development going forward
- Countries like Sri Lanka and Pakistan, along with India, have been betting big on renewables
- Despite strong headwinds in the wind and solar sectors globally, most of the SAARC member states continue to remain underpenetrated in terms of actual installations
- Strong policy planning, implementation frameworks and public and private partnerships can help foster growth of RE in the SAARC member states
- Policy-level pushes like making RE must-run will reduce curtailments, while planned network strengthening projects to improve RE integration can improve business sentiment in a nation
- With rise in RE generation, countries will be required to set up strong forecasting systems
- Day-ahead and intra-day wind and solar forecasts needs to be undertaken to assess prospective generation
- This can lead to base-load power supply planning, overall power dispatch and overall power market improvement

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