MERC

MAHARASHTRA ELECTRICITY REGULATORY COMMISSION

DRAFT REGULATIONS FOR FORECASTING, SCHEDULING AND DEVIATION SETTLEMENT FRAMEWORK FOR SOLAR AND WIND GENERATION IN MAHARASHTRA

APPROACH PAPER

February, 2018

1. INTRODUCTION

1.1 Context

1.1.1 Maharashtra has a diversity of Renewable Energy (RE) sources, including Wind energy, Solar power, Small Hydro power, biomass and bagasse. The State has been at the forefront of harnessing different types of RE sources. The installed capacity of RE power exceeded 7.3 gigawatt (GW) by January, 2017.

1.1.2 As per the provisions of the State Grid Code, Solar and Wind generation is treated as 'Must Run' by the system operator. However, considering the likely capacity addition, there is an urgent need to formulate a framework for forecasting and scheduling (F&S) to facilitate grid integration of the increasing Solar and Wind generation in the State, and for the settlement of deviations.

1.1.3 Considering the variable and intermittent nature of Solar and Wind generation, F&S of these RE sources is necessary to ensure load generation balance at each point of time in the synchronized grid, and to prevent line overloading and grid instability. Forecasting refers to the prediction of generation available in the near future, while scheduling relates to the planned operation of the power system, on day-ahead basis, through estimation of generation availability and anticipated demand.

1.1.4 When load and generation in the grid are exactly balanced, the operating frequency of the grid is 50 Hertz (Hz). If the total generation in the grid is more than the total demand, the operating frequency goes above 50 Hz. The higher the excess generation, the higher is the frequency above 50 Hz, and vice versa. At present, the generation mix in the State is dominated by conventional sources, which are scheduled with a high degree of accuracy. This enables the Maharashtra State Load Despatch Centre (MSLDC) to plan for the load generation balance in advance and achieve real-time balance of the grid.

1.1.5 However, with an increasing quantum and proportion of variable RE sources in the generation portfolio of the State, maintaining the grid balance is becoming increasingly challenging. Besides, the seasonal variation and diurnal variation of variable RE sources poses a challenge in terms of need to maintain flexible thermal/hydel generation or generation with quick ramp up/ramp down capabilities. This would lead to part load/backing down of thermal generation and also require investment in storage facilities, which has significant cost implications. In addition, managing the voltage profile and congestion with increasing variable RE at remote links to the transmission network is crucial for ensuring secure and reliable grid operations.

Box: 1–RE Potential and Installed Capacity in Maharashtra

The installed RE capacity of Maharashtra is 7,348.74 megawatt (MW) (as on December, 2016), which includes 4,662 MW from Wind and 366 MW from Solar. Maharashtra has set an ambitious target in line with the national level RE capacity addition target of 14.4 GW by 2020. A robust F&S Framework would provide a mechanism for integrating the RE capacity addition into the electricity grid and to meet the future grid operation requirements.

Table 1: RE capacity in Maharashtra

RE Source	Potential	Installed capacity (MW) as on 30-11-2016	Target up to 2020 (MW)
Solar	64.32 GWp	365.75	7500
Wind	45,394 MW	4,661.91	5,000
SHP	732 MW	292.91	400
Biomass + Bagasse	2,981 MW	1,990.85	1,300
Other RE	635 MW	37.71	200
Total	**-**	**7,349.13**	**14,400**

1.1.6 F&S is necessary to facilitate the integration of higher share of RE in the grid to assist intra-State and inter-State wheeling of RE power and to ensure scheduling and energy accounting for such transactions. Solar and Wind Energy are the main variable RE generation sources in the State. The fact that most such Generators are connected to the State network calls for a holistic mechanism for F&S and stability of the grid. A robust F&S mechanism at the State level has to be coupled with 100% metering (with Availability Based Tariff (ABT) compliant meters) and setting up an efficient and scalable telemetry system. This will enhance the visibility of the RE Generators at the MSLDC, enable a commercial settlement mechanism based on actual/scheduled generation and establish an institutional framework to facilitate this process.

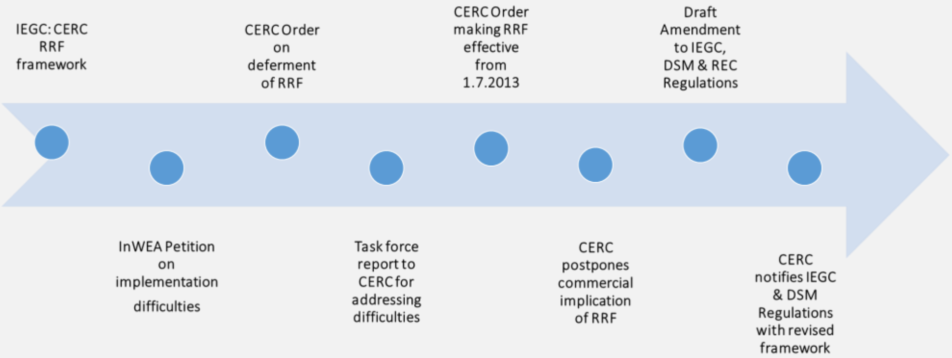
1.1.7 The Commission proposes to establish such a Framework for Solar and Wind generation through Regulations. This Approach Paper, prepared by the Commission with contributions from its consultants, Idam Infrastructure Advisory Pvt. Ltd., is to be read with the Proposed Regulations on which public comments are invited.

1.2 Approach and Regulatory process

1.2.1 For formulating a F&S Framework for Maharashtra, it is useful to consider the developments at the national level and initiatives taken in other RE rich States.

Box 2: Status of F&S at Centre and in other States

The Renewable Regulatory Fund (RRF) Mechanism was initiated in 2010 by the Central Electricity Regulatory Commission (CERC). It could not be implemented because of various difficulties concerning metering and scheduling and ambiguity in settlement leading, and was deferred. In early 2013, the CERC directed that the RRF Mechanism be implemented from the second half of the year. This led to amendments to the Indian Electricity Grid Code (IEGC), and the commercial implications were postponed.



In August 2014, the CERC notified amendments to the IEGC, 2010, the Deviation Settlement Mechanism (DSM) Regulations and formulated the Ancillary Services Regulations. However, these are only applicable at the inter-State level. Since most of the Solar and Wind Generators are intra-State entities, a robust F&S mechanism, DSM, imbalance handling and settlement mechanism and metering and Generator payment mechanism needs to be formulated at the State level. This will entail 100% metering, an institutional framework and a suitable telemetry system to increase the visibility of Solar and Wind generation at the MSLDC.

The Forum of Regulators (FOR) circulated Model Regulations on forecasting, scheduling and deviation settlement for Solar and Wind Generating Stations at the State level to the State Electricity Regulatory Commissions (SERCs) in November, 2015. Thereafter, the SERCs of Andhra Pradesh, Karnataka, Rajasthan, Tamil Nadu, Gujarat and some other SERCs have published their drafts or final Regulations. The FOR Technical Committee (of which Shri Deepak Lad, Member of the Maharashtra ERC is a Member) has also recommended that the RE rich States should come up with a F&S Framework.

2 F&S FRAMEWORK AT NATIONAL LEVEL

2.1 CERC F&S Framework

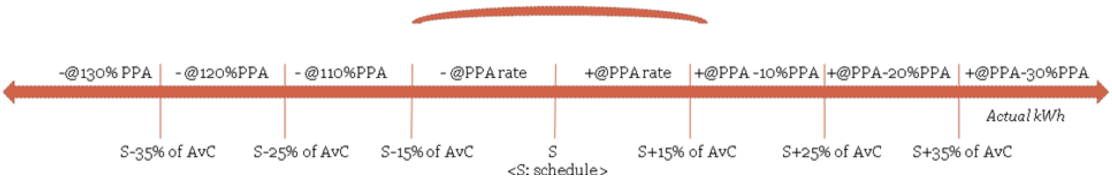
The CERC specified its F&S Framework for Solar and Wind energy at the national level through the CERC (Indian Electricity Grid Code) (Third Amendment) Regulations, 2015 and CERC (Deviation Settlement Mechanism and related matters) (Second Amendment) Regulations, 2015. Table 2 summarises the salient features of F&S Framework of the CERC.

Table 2: CERC F&S Framework for Solar and Wind Energy

Parameter	Description
Objective	To maintain grid discipline and grid security as envisaged under Grid Code through commercial mechanism for deviation settlement through drawal and injection of electricity by users of the grid.
Applicability	Applicable to Solar and Wind Generators which are Regional entities, whether supplying power to the distribution licensees under PPAs, or through open-access to third party consumers or for captive consumption.
Forecasting	Multiple forecasting by both the RLDC/REMC and Solar and Wind Generators for better confidence level/lower Forecast Errors. RE Generator will have an option to choose between its own forecast or site level forecasting done by the RLDC to provide its schedule. However, commercial impact of deviation from forecast would be borne by the RE Generator.
Frequency of revision of schedule per day	One revision for each time slot of one and half hours starting from 00:00 hours of a particular day subject to a maximum of 16 revisions during the day.
Definition of Forecasting Error	Error (%) = (Actual Generation – Scheduled Generation) / (Available Capacity) x100 Where Available Capacity is the cumulative capacity rating of the Wind turbines/Solar inverters that are capable of generating power in a given time block.
Tolerance limits	Within +/-15% band.
Data telemetry	Required at the Wind turbine/Solar inverter level. Parameters such as turbine availability, power output and real-time weather measurements (Wind speed, temperature, pressure etc.) must be provided by the Generator.

2.1.1 The pricing vector for deviation settlement for Solar and Wind Generators which are Regional entities is represented in Figure 1.

Figure 1: Price Vector for Deviation Settlement (CERC Regulations)



1. Absolute Error =100 X [(Actual generation – Scheduled generation)/Available Capacity]
2. Payment as per schedule at the Power Purchase Agreement (PPA) rate
3. Deviation settlement within tolerance band (+/- 15%):
    a. Receipt from/payment to Pool at the PPA rate (i.e., in effect, payment as per actuals)
    b. Beyond 15%, 3 Bands for Deviation Charges are specified as below:

Absolute Error (% of AvC)	Deviation Charge related to PPA	Per Unit Deviation Charge (Rs./unit)
15%-25%	110% (for under-injection) or 90% (for over-injection) of PPA rate	0.50/unit
25%-35%	120% or 80% of PPA rate	1.00/unit
>35%	130% or 70% of PPA rate	1.50/unit

2.1.2 For Regional entities, CERC has specified that a Qualified Coordinating Agency (QCA) would act on behalf of Solar and Wind Generators connected to a Pooling Sub-Station, and that the 'lead' Generator may be the QCA. The QCA would be responsible for operational and commercial activities such as providing data on day-ahead schedules, Available Capacity (AvC), forecasting, and actual generation to the Regional Load Despatch Centre (RLDC), allocation of the Deviation Charges among the Generators connected to a Pooling Sub-Station, technical coordination with these Generators, etc., on behalf of the Generators connected to each Pooling Sub-Station.

2.1.3 The CERC has amended its IEGC and DSM Regulations to incorporate this F&S Framework. The National Load Despatch Centre (NLDC) has formulated a detailed F&S procedure defining the roles and responsibilities of the entities involved and the procedures to be followed by them in pursuance of the CERC Framework.

2.2 FOR Model Regulations for State level

2.2.1 The salient features of the FOR Model Regulations are summarised in Table 3.

Table 3: FOR Model F**&S Framework for Solar and Wind Generators**

Parameter	Description
Objective	Facilitate large-scale grid integration of Solar and Wind Generating Stations while maintaining grid stability and security.

Parameter	Description
Applicability	All Solar and Wind Generators connected to the State grid, including those connected via Pooling Sub-Stations, and selling power within or outside the State.
Forecasting responsibility	Solar and Wind Generator or QCA, or forecast by the MSLDC to be accepted.
Computation of Error formula	The formula for computation of the Error is: 100x {(Actual Generation- Scheduled Generation)/ Available Capacity}
Scheduling requirement	Weekly and day-ahead, with maximum 16 revisions during a day.
Tolerance band for demand side management (DSM)	1. 10% for new Solar and Wind Generator. 2. < = 15% for existing Solar and Wind Generator.
Reference point for DSM	Pooling Sub-Station
Apportionment of energy deviations and DSM charges among RE Generators at a Pooling Sub-Station	In proportion to actual generated units or available capacity
Telemetry and communication requirement	Data relating to power system output and weather
Responsibility of providing telemetry and communication	Solar and Wind Generator
Procedure for data telemetry and communication	Detailed procedure to be evolved by the SLDC
DSM For sale outside State specified	Yes
Meeting shortfall of DSM Pool	From Power System Development Fund (PSDF) and National Clean Energy Fund (NCEF)

2.2.2 Several SERCs have considered the Model FOR Regulations for designing the F&S Frameworks for their States. However, various issues were raised by stake-holders regarding such Frameworks at the Regional and State levels. In order to address these issues, a Technical Committee was constituted on 18 November, 2015 by the FOR.

2.3 FOR Technical Committee

2.3.1 The FOR Technical Committee was to evolve a roadmap for action on the following:

1. Deployment and implementation of framework on F&S and deviation settlement of Solar and Wind Generating Stations at the State level.
2. Introduction/implementation of ABT framework at the State level as mandated in the National Electricity Policy and Tariff Policy.
3. Introduction of ancillary services and reserves at the State level.

4 Implementation of automatic generation and primary control within States.

5 Provide periodic reports to the FOR.

The Technical Committee has made certain recommendations on a F&S Framework and on the development of a favourable ecosystem at the State level.

2.3.2 The Technical Committee has accepted a report on 'Scheduling, Accounting, Metering and Settlement of Transactions in Electricity' (SAMAST) prepared by a sub-Committee in July, 2016, and made the following recommendations for implementing SAMAST at the State level:

- Elaborate the roles and responsibilities of the governance structures (involving entities such as NLDC, the Central and State Transmission Utilities (CTU and STUs), site owners, MSLDC/RLDC, and the Regional and State Power Committees (RPCs and SPCs).

- Enable a comprehensive information technology (IT) for market operation functions other than only SCADA/EMS.

- Demarcate the interface boundary and identify the Pool members.

- Develop a uniform energy accounting system.

- Implement F&S in a systematic manner considering the following categorisation of SLDCs:

  Group A-States where SLDCs have first-hand experience of all the aspects of intra-State accounting and settlement system. Maharashtra is in this group.

  Group B-States where deviation settlement system has been introduced for a few intra-State entities or mock exercises have been undertaken by the SLDC.

  Group C-States where draft Regulations have been notified and preparatory exercises have commenced.

  Group D-States where deviation settlement is yet to commence.

2.3.3 For formulating the State level framework for F&S, the following guiding principles were suggested:

- Encouraging scheduling discipline
- Ease of implementation (simplicity)
- Compatible with State/Regional/national framework
- Scalable and flexible

- Minimal commercial implications for participants
- Enforceable
- Continuation of existing transactions without significant modifications.

2.3.4 The Technical Committee considered clarity on the following issues relating to the FOR Model Framework to be critical for implementation at the State Level:

Figure 2: Key issues in F&S Framework

Operationalisation of Virtual Pool within the State Imbalance Pool	• Mechanism to operate the Virtual pool • Entity responsible to operate the Virtual Pool
Mechanism of deviation settlement at pooling S/S level	• Principles of de-pooling of Deviation Charges • Between the RE Generators at the pooling S/S
Role of QCA and it's eligibility criteria	• Regulatory oversight of the QCA in appropriate regulations • Technical and financial criteria of the QCA • Governance mechanism of the QCA • Model term sheet
Funding deficit of the State Imbalance Pool	• Dependence on national level funds for long-term and its sustainability • Need to create state level funds for funding deficit
Diverse sets of metering practises being followed across states	• Need to create standardised metering points in all states • Devise uniform metering and energy accounting policy
DSM mechanism for RE Generators connected to STU with inter-state transactions	• Treatment for the RE Generators with multiple transactions at pooling S/S level

The Technical Committee has proposed revisions to the FOR Model Regulations to facilitate implementation at the State level.

3. PREPAREDNESS IN MAHARASHTRA

3.1 Overview of RE Development

3.1.1 RE Potential

India has a very large RE potential (245 GW). The National Institute of Wind Energy (NIWE) has estimated a Wind energy potential of 103GW at 80 metre hub height.

More than 55 GW of RE was added during the 12th 5-Year Plan period (upto 2017). An addition of more than 72.4 GW is envisaged by 2022, in which Solar energy is expected to contribute 28%. Thus, Wind and Solar energy will be the predominant RE sources in the near future.

3.1.2 Legal and Policy Framework

The Electricity Act (EA), 2003, provides for policy formulation by the Government of India (GoI) and mandates the ERCs to promote RE. GoI has revised the targets under the Jawaharlal Nehru National Solar Mission (JNNSM) from 20 GW to 100 GW by 2022. The revised target of RE capacity addition by FY 2021-22 is 175 GW, which includes100 GW of Solar and 60 GW of Wind energy.

India has confirmed its Intended Nationally Determined Contribution (INDC) in response to the Conference of Parties (COP) decisions 1/CP.19 and 1/CP.20 to achieve low carbon growth and sustainable development. India's anticipated contribution of RE is 40% in the total generation capacity by 2030.

In line with GoI's RE target of 175 GW, the Government of Maharashtra (GoM) has also set an ambitious target of 14.40 GW for RE by 2020, which includes7.5 GW of Solar and 5.0 GW of Wind power.

The Commission has taken pro-active measures for promoting RE-based generation in Maharashtra, including through its RE Tariff Regulations and the annual determination of Preferential RE Tariff, setting and monitoring Renewable Purchase Obligation (RPO) targets, Net Metering for RE generation, Grid Connectivity Framework, etc. From as early as between 2002 to 2004, before the relevant Regulations were framed, the Commission issued Orders setting out the tariff and other dispensations for bagasse-based co-generation and generation from Wind energy and biomass.

3.1.3 RE Capacity Addition

RE contributes 17% of the total installed generation capacity in the country (CEA,May,2017). Wind energy continues to be the mainstay of grid connected renewable power in India. The rate of growth of Solar has been particularly significant over the last 5 years (2012-2017). The installed capacity of RE in India is 57.0 GW, which includes32GW of Wind and 12.00GW of Solar.

The installed capacity of Maharashtra is 42,327 MW (CEA, May, 2017), which includes 4,700 MW of Wind and 440 MW of Solar power. Thus, Wind and Solar generation is 12% of the total installed generation capacity and amounts to 25% of the peak demand met in the State. If the variable RE generation of 5 GW Wind and 7.5 GW Solar, as envisaged by the State Policy, is achieved, the variable RE will constitute over 30% of the installed capacity and over 50% of the system peak demand to be met in the next five years.

3.1.4 Grid Connectivity of Wind and Solar Power Projects

Wind and Solar Generators are either connected to the Intra-State Transmission Grid directly or through Pooling Sub-Stations at voltage levels of 132 kilovolt (kV) and above. According to MSLDC, there are 60 existing and under-construction Pooling Sub-Stations.The number of remote terminal units (RTU) connected to the SCADA system are 236, and all are at 132 kV and above voltage level.

Figure 3: Connectivity at Pooling Sub-Station

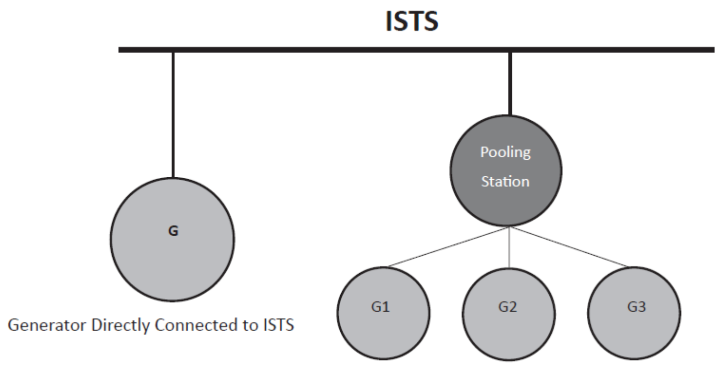


Table 4: Pooling Sub-Stations and Metering Points

Particulars	No. of Pooling Sub-Stations	No. of interface points/ metering points
Wind power	47	151
Solar power	15	23
Total (Wind and Solar)	**62**	**174**

3.1.5 Visibility of Solar and Wind Generators at MSLDC

Under Section 32 (1) of the EA, 2003, the MSLDC is responsible for ensuring the integrated operation of the power system in Maharashtra. For monitoring grid operations, visibility of the load and generation at the MSLDC level is necessary. At present, real-time data from Solar and Wind Generators is not available in the existing SCADA systems at the MSLDC, and they are not communicating forecasting and real-time data to the MSLDC. In view of large variations in Solar and Wind generation due to seasonal factors, monitoring and control over the Intra-State Transmission System (InSTS) is difficult in the absence of real-time data.

The features of the existing SCADA/EMS system at MSLDC (Siemens – Sinaut Spectrum version 4.5.1) are as shown below.

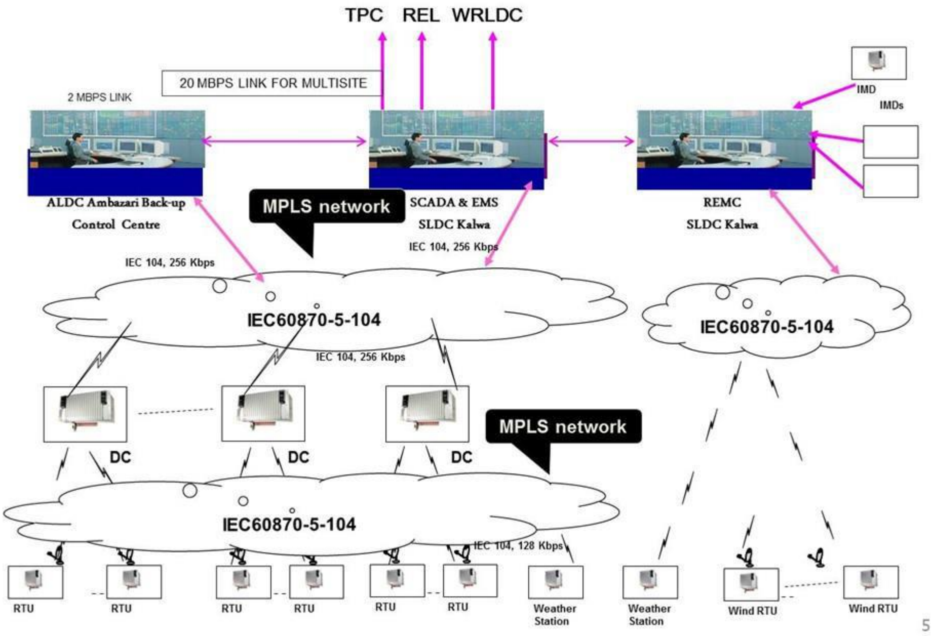
Table 5: SCADA/EMS system of MSLDC

Parameters	Details
Brand of SCADA system	Siemens
Type of SCADA system	Sinaut Spectrum version 4.5.1
Extension capability	Upto 500 RTUs
System architecture scheme available	SLDC(Main)- ALDC (Backup) Main to back up on Siemens Multisite proprietary protocol ICCP Link with TPCL, R-Infra, and WRLDC
Service/Maintenance Contract in force	AMC WITH M/S Siemens
No of RTUs connected	236 RTU
No of elements	17,500 Analog and 15,550 Digital
RTU protocols	IEC 6087-5-104
Actualization for measurements	2-10 second update for measurements
RTU communication media	MPLS communication network by RTU to DC - 512 kilobits per second (Kbps) RF, DC to MSLDC 1 megabits per second (Mbps) RF, DC to ALDC 1 Mbps RF
Operation and maintenance (O&M)	M/s Tata Teleservices Ltd. , 1 SE+1EE+ 2 Sr.Engineers+4 Engineers for SCADA System Maintenance communication is looked after by MSETCL
Capability of CIM	No
XLDC communication with stakeholders	Communication with TPC, REL and WRLDC. TPC and WRLDC is through ICCP (OFN owned) REL external leased line (MTNL)
XLDC users: Operations manpower	3 person x3 shift x 5 team

The present real-time data received at the control centre are (a) analog measurements of active power MW, reactive power MVAR, current amps, bus voltages, frequency, transformer tap positions (b) status indications of circuit breakers, isolator and (c) alarms – CB trip, bus protection, station battery failure and communication failure. Source: REMC Report of MSLDC.)

The network architecture diagram of the existing SCADA Systems is shown below.

Figure 4: Network architecture diagram of existing SCADA Systems



3.1.6 Off-take arrangements of Solar and Wind Generation

Many Solar and Wind Generators in Maharashtra have Energy Purchase Agreements (EPAs) with Distribution Licensees at the Preferential Tariff determined by the Commission for fulfilling their RPO targets. Some are operating as Captive Power Plants (CPPs) or selling power to third parties at mutually agreed tariff through Open Access. Most of these Generators are located in the Licence area of the Maharashtra State Electricity Distribution Co. Ltd. (MSEDCL) and connected to the intra-State grid through Pooling Sub-Stations. The Pooling Sub-Stations of over 50 MW have ABT metering arrangements. However, some Solar and Wind Generators are connected to the distribution network of MSEDCL. The Generators operating as CPPs or with third party sale arrangements are availing banking and wheeling facilities as per the relevant Regulations and Orders of the Commission.

3.2 Assessment of State Preparedness

3.2.1 Existing infrastructure of the MSLDC for RE generation

Table 6 below sets out the existing MSLDC infrastructure for connectivity and monitoring of RE generation.

Table 6: MSLDC Infrastructure for RE connectivity

Sr.	Parameters	Specifications
1	No. of Pooling Sub-Stations	60 Nos.
2	No. of Remote Terminal Units (RTU) connected to SCADA system	236 Nos.
3	Voltage level at which	132 kV

Sr.	Parameters	Specifications
	RTU are connected	
4	RTU protocols	IEC 6087-5-104
5	No. of elements	17,500 analog and 15,550 Digital
6	Real-time data received at control room	Analog measurements: Active power MW, reactive power MVAR, current amps, Bus voltages, frequency, transformer tap positions Status Indications**:** Circuit breakers and isolators Alarms indications: CB trip, bus protection, station battery failure, communication failure

The 236 RTUs are connected to the SCADA/EMS system for data acquisition to and from the concerned Sub-Station, and are mostly installed at Sub-Stations of 132 kV and above. The MSLDC is planning installation of RTUs at other RE Pooling Sub-Stations also. Communication system upgradation and the installation of equipment for communicating the real-time RE generation to the REMC are underway. The present SCADA at the MSLDC has been sized for 17,500 analog points and 15,550 digital points.

Scheduling Tools

Scheduling software is in operation for generation control. This software package is based on Internet technology and enables nation-wide control of Power Plants from all SLDCs up to 6/15 minutes in advance. No RE generation is connected to the InSTS network presently and all schedules relate only to conventional Generators.

3.2.2 Existing Metering Infrastructure

The SAMAST report discusses the metering infrastructure in various States. The sub-Committee of the FOR Technical Committee conducted a survey of SLDC activities in energy metering, scheduling, accounting and settlement at the intra-State and inter-State levels. The Interface Energy Meters (IEM) measure and record the exchange of energy at the interface point. The interface boundaries are defined by placement of meters. Tables7and 8 set out the number of interface points of Intra-State Entities with the Intra-State Grid of Maharashtra.

Table 7: Interface points of Intra-State Entities with Intra-State Grid of Maharashtra

SLDC	G-T	RES-T	ISTS-InSTS	D-T	HT-T	OA-T	Total
Maharashtra	160	416	63	1,776	271	NA	2,686
D-T: Tie lines between Distribution and Transmission Grid H-T: Tie lines between HT consumer and Transmission Grid OA – T: Tie lines between Short-Term Open Access User and Transmission Grid							

Table 8: Interface Energy Metering at Intra-State level in Maharashtra (MSLDC)

SLDC	Main meters	Check meters	Standby meters	Total interface energy meters	AMR
Maharashtra	2,513	1,575	0	4,088	No

3.2.3 Energy Accounting practices

In Maharashtra, most of the RE Generators are located in the MSEDCL area. MSEDCL takes joint meter readings (JMR) in respect of RE Generators with which it has EPAs and pays them according to the Preferential Tariff (FiT) determined by the Commission. MSEDCL also takes the JMRs of the RE Generators which are operating as CPPs or selling power to third parties. After taking the JMR, the monthly Generation Credit Notes (GCNs) are issued by MSEDCL. The GCNs contain Time of Day (ToD) time slot-wise RE generation details for the respective months for giving credit adjustment. The field offices of MSEDCL gives the corresponding ToD time slot-wise credit adjustment in the monthly energy bills of the OA consumer.

Banking Facility: Banking facility has been provided to OA consumers sourcing Solar and Wind power through various Orders of the Commission and its Open Access Regulations. The current Regulations of 2016 provide for carrying forward unadjusted units during a month till the end of the financial year and purchase of surplus units (upto 10% of the total generation) by MSEDCL at the lowest ToD slab Tariff.

Wheeling Charges: An Open Access consumer must pay Wheeling Charges for the use of the Transmission and Distribution Network of the Licensees as determined by the Commission from time to time.

3.3 Overview of REMC

3.3.1 The system operator needs a RE-dedicated SCADA/EMS system for better integration of RE in the grid. Under the Green Corridor Project, REMCs are proposed to be established at each SLDC, RLDC and at the NLDC. The REMC at the SLDC level is expected to deal with the F&S of RE generation in the State. The proposed functionalities of the REMCs are as follows:

i) Real-time monitoring of all RE generation at the Pooling Sub-Station level

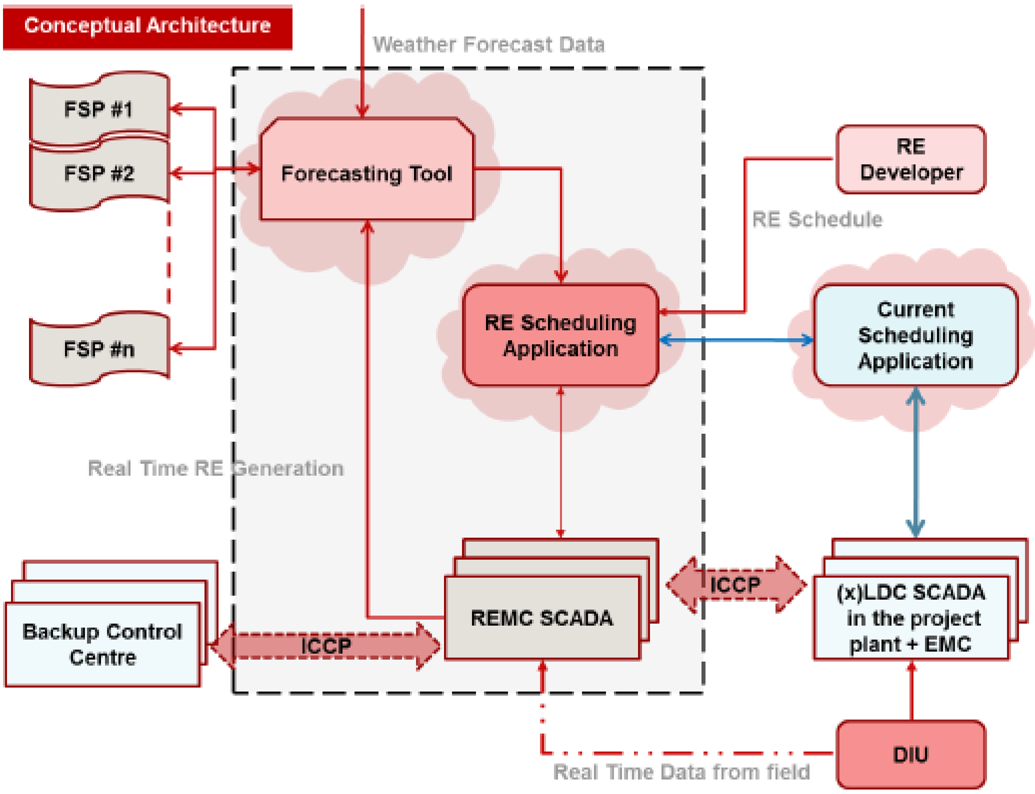
ii) Intra-day and day-ahead forecasting of RE generation

iii) Coordinating with the corresponding SLDC for scheduling and dispatch of RE generation

iv) Coordination between the SLDC and RE developers.

v) The REMCs at the State level will also monitor the operating reserves in the State.

Figure 5: Conceptual architecture of REMC



Source: REMC DPR prepared by GIZ for MSLDC

3.3.2 Conceptual Architecture of REMC

The Detailed Project Report (DPR) prepared for the SLDCs of the RE-rich States by Germany's Gesellschaft für Internationale Zusammenarbeit *(*GIZ*)* proposes architecture of REMC comprising the following modules:

1. REMC SCADA monitoring tool for real-time monitoring of RE generation by collection of data from RTUs.

2. Forecasting tools for

   i) Collection of data from Forecast Service Providers and exchange of weather data with them

   ii) Collection of site-level actual RE generation data from REMC SCADA tools

   iii) Collection of weather forecasts, analysis and validation of accuracy of the forecast provided by individual RE developers.

   iv) Providing forecasts to RE developers not having forecasting tools.

3.3.3 Roles and responsibilities in implementation of REMC

A. Power Grid Corporation of India Limited (PGCIL)

A roadmap for integrating the envisaged RE production capacity into the electricity grid and its adaptation to future requirements was prepared in July, 2012 by PGCIL on behalf of the Ministry of New and Renewable Energy (MNRE). PGCIL has initiated a Green Corridor Project for evacuation of RE which envisages REMCs for RE-rich States.

B. STU/SLDC

The STU/SLDC shall make ready the space required for the REMC and the civil, architectural works, UPS/auxiliary power supply and air conditioning. The historical RE generation and other static information will be provided by the STU/SLDC to the implementing agency before the contract award for the REMC. The STU shall install RTUs at new locations if any additional data is required for the REMC. The STU/SLDC shall identify dedicated personnel for the REMC, to be trained by the Implementing Agency.

C. Implementing Agency

The Implementing Agency will be responsible for tender development, selection and awards of contracts for establishment of the necessary hardware, software and tools for the REMC along with project management, commissioning and handing over of the operational REMC.

D. RE Developers/Utility

The RE Developer/Utility will coordinate with the STU to ensure that the voice communication between the control centre and the RE Generating Units are available at the REMC, and to ensure the data communication facilities for sending the RE generation data to the REMC SCADA.

E. Current Status of REMC Implementation

The MSETCL Board has accorded in-principle approval to the DPR for implementation of the REMC for Maharashtra in August, 2016. A Working Group has been constituted to monitor and facilitate the implementation aspects of the REMC.

3.4 STU/MSLDC Perspective

3.4.1 Interactions with MSLDC indicate that it is facing challenges in handling increasing variable RE generation because of the following:

i) Wind and Solar Generators connected to the distribution network do not have visibility at the MSLDC level.

ii) Absence of any scientific method for scheduling Wind or Solar generation in day-ahead schedule of the State as a whole.

iii) The schedule for the next day is prepared on the basis of actual generation of Wind and Solar of the previous day . No forecasting of RE generation is done considering meteorological data.

iv) Very high ramp up/ and ramp down rates of Wind and Solar generation.

3.4.2 MSLDC has highlighted the following requirements for a F&S Framework for Wind and Solar generation:

i) Visibility of all RE generation, mainly variable RE, at MSLDC is required

ii) Need for reliable communication links, including RTUs, between all the RE Pooling Sub-Stations and MSLDC

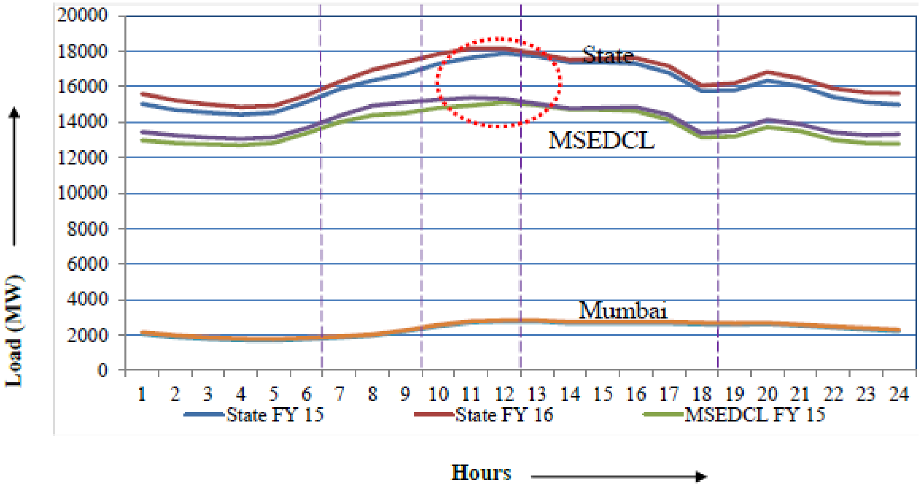
iii) Need to install Special Energy Meters (SEMs) at all Pooling Sub-Stations

iv) Need for visibility at the MSLDC level of the Open Access RE Generators connected to the Distribution Network.

3.4.3 As per the IEGC, variable RE Generators (such as Wind and Solar) are considered as 'must run' and are not covered by the Merit Order Despatch (MoD). All such variable RE generation coming into the grid needs to be despatched irrespective of demand in the grid, which results in the curtailment of conventional generation based on the MOD. This arises mainly due to non-visibility of day-ahead RE generation. Forecasting of variable RE generation can provide more realistic scheduling of RE and conventional generation considering the expected generation of variable RE for the next day. Conventional Generators can be more flexible in their operation and respond to load variations by minimising their generation upto the technical minimum instead of backing down entirely.

3.4.4 There are also demand variations during the day of about 2500 to 3000 MW, as shown in Figure 6 below. This load variation is difficult to predict and adds to complexities in management of load-generation balancing on day-ahead as well as real-time basis. Thus, apart from challenges in forecasting the variable RE generation and the management of such variation, the variation in the load or demand also needs to be considered while developing a F&S framework and designing a suitable deviation settlement mechanism (DSM).

Figure 6: Load Variation during the day for Maharashtra, MSEDCL and Mumbai Area.



Source: MSLDC

3.4.5 During discussions, MSLDC also emphasised the need for flexible generation such as Hydro power to be available as a balancing tool. Presently, MSLDC is operating Hydro generation as a peaking generation source considering its flexible operation. Additionally, the pumped Hydro Power Plant, viz., the Ghatghar Pumped Storage Scheme (2 X 250 MW) is operated by MSLDC as an energy storage option for balancing the grid to some extent. MSLDC also highlighted the need for more such pumped storage schemes for grid balancing in the future.

3.5 Regulatory intervention for addressing Variable RE Generation

3.5.1 Change in Deviation limit in Unscheduled Interchange (UI) Mechanism:

At present, the volume limit of deviations in UI mechanism is 150 MW for all States. However, many States approached the CERC to relax this limit. Until States build up the ecosystem of demand forecasting, reserves, ancillary services and RE F&S, the CERC in 2016 had raised the limit for RE-rich States to 200 MW if the installed capacity of Wind and Solar power is between 1,000 to 3,000 MW and 250 MW where the installed capacity is greater than 3,000 MW. These higher limits will reduce the financial burden on the States arising from the UI charges due to deviations. The deviation limit of 250 MW is presently applicable to Maharashtra. However, Maharashtra is expected to come up with its F&S Framework for variable RE generation to reduce the deviations at the inter-State level.

3.5.2 The Proposed Regulations will require strengthening of MSLDC in terms of skilled manpower and appropriate tools. To the extent that funds are not provided by other sources, the Commission will take into account the requirements while approving the Budget for MSLDC's operations and its fees and charges.

4 DESIGN ISSUES IN PROPOSED REGULATIONS

4.1 Objective, Scope and Applicability

4.1.1 Objective

The objective of the Proposed Regulations is to facilitate large-scale grid integration of Solar and Wind generation in Maharashtra while maintaining grid stability and security, through forecasting, scheduling and a commercial mechanism for deviation settlement of such Generators.

In order to maintain system security, stability and reliability, MSLDC will have to consider Solar and Wind power generation forecasts for the mid-term to long-term, day-ahead and intra-day for planning and scheduling. MSLDC would make full use of the flexibility available from conventional Power Plants as well as the capacity of the inter-grid tie lines to accommodate the maximum Wind and Solar power generation.

4.1.2 Scope and Applicability

1. Existing vs. New Solar and Wind Projects

The existing Solar and Wind generating projects were developed at a time when there was no F&S requirement. Bringing them under the new F&S regime may entail some additional costs to them, although they may also be better placed than new projects since they have the advantage of operational experience. In any case, such variable generation is already posing a challenge to grid operation, and excluding >4 GW of existing RE capacity would not be tenable for large-scale integration.

The FOR Model Regulations and the Regulations (proposed or notified) of several SERCs envisage differential treatment for existing and new Solar and Wind projects, with more liberal deviation allowances for the latter. However, while new projects can be planned from the outset with F&S capability, the existing projects have the advantage of historical data of actual generation, wind speed, seasonal variations and experience of site operations.

Besides, there are already Pooling Sub-Stations where Solar and Wind generation capacity is operational. Hence, any distinction in the treatment of new and existing Projects would complicate the operationalisation of the F&S Framework. With reasonable Error/Deviation Bands, the Commission is of the view that no distinction needs to be made between existing and new Solar and Wind Projects**.**

Considering the rapid pace of RE development in recent years and the projected future trajectory, the proposed Regulations expressly provide for a review within two years (though they do not debar the Regulations from being revisited before that if necessary).

2. Solar vs. Wind Generation Plants

The FOR Model Regulations do not treat Solar and Wind generation differently. However, some SERCs envisage such a distinction. For example, the Karnataka ERC (KERC) has applied its Regulations to Wind Generators with an installed capacity of 10 MW and above, and of 5 MW and above in the case of Solar. The Gujarat ERC (GERC) has proposed different Error/ Deviation Band and Price Vectors for Wind and Solar Generating Stations, and proposes to allow 16 and 8 revisions in schedule, respectively.

In the initial stage of the F&S Framework, the mechanism should be simple, flexible and easy to operate. Similar statistical tools and numerical weather prediction models are used for forecasting of both Wind and Solar energy generation, though the algorithm and rationale would vary. The Commission is of the view that differentiating between Solar and Wind Energy at this inception stage is unlikely to yield any significant benefits. Besides, within the Virtual Pool and State Imbalance Pool, it is proposed to treat all such variable RE as a common pool.

Besides, with the advent of Hybrid (Solar and Wind) RE generation, several Pooling Sub-Stations would have both Solar as well as Wind generation capacity with common evacuation infrastructure. That being the case, treating Wind and Solar generation differently would further complicate the F&S Framework.

Hence, the proposed Regulations do not make any distinction between Solar and Wind energy generation**.**

3. Minimum Installed Capacity

The FOR Model Regulations do not stipulate any minimum capacity for application of the F&S regime. However, KERC has specified a minimum capacity of 10 MW for Wind and 5 MW for Solar projects connected to the State grid, whereas the Rajasthan ERC (RERC) has specified a minimum capacity of 5 MW for Solar projects.

However, if the pooling sub-station is considered as the basic unit for F&S (as is now proposed), the installed capacity of individual Generators should not matter. Moreover, decentralised or distributed generating sources such as small Wind or Solar roof-top installations are not being included in the F&S regime. According to MSLDC, Maharashtra has 47 Wind and 15 Solar Pooling Sub-Stations. All of them are connected at voltage levels of 110 kV and above (except for the Solar Plant of Videocon at Chandrapur connected at 33 kV voltage level).

Hence, the Proposed Regulations apply the F&S Framework to an aggregate capacity of 5 MW and above at the Pooling Sub-Station level (or a capacity of 5 MW and above in case of a stand-alone Solar or Wind Generator not connected through a Pooling Sub-Station) connected to the InSTS Network, i.e. at a voltage level above 33 kV. The relevant parameters for Stand-alone Generators not connected to the InSTS (being at the 33 kV level, such as the Videocon Solar Project) are subsumed in the demand of the Distribution Licensee (MSEDCL in this case).

4.2 Absolute Error and Deviation

4.2.1 Deviation between Scheduled Generation and Actual Generation

As discussed, Wind and Solar generation is nature dependent, and actual generation is likely to deviate frequently from scheduled generation. Such deviations can be minimised by more accurate forecasting.

Earlier, under the IEGC, 2010, while introducing a scheduling and deviation accounting framework for variable Solar and Wind generation by way of a Renewable Regulatory Fund (RRF) Mechanism, the CERC defined the Error formula (deviation from schedule) as a percentage of the scheduled generation, i.e. (Scheduled Generation – Actual Generation)/Scheduled Generation).

However, subsequently, through the 3rd amendment of the IEGC in 2015, the framework for scheduling and deviation accounting for Wind and Solar generation was modified and CERC has defined the Error formula (deviation from schedule) in terms of percentage of the AvC, i.e. (Actual Generation –Scheduled Generation)/Available Capacity).

The CERC's Statement of Reasons explains that, in order to remove the dependency of the denominator on weather, scheduled generation term has been replaced by AvC in the denominator. Thus, the CERC decided to define the Error percentage normalized to AvC, instead of against the schedule. This was to ensure that the Error quantum corresponds to the physical impact in MW on the grid, that the forecasting models are aligned to minimize the actual MW deviations, and that the Error definition is valid in all seasons.

The concept of Mean Absolute Error (MAE) with linkage to Available Peak Capacity is also aligned with norms adopted globally for denomination of the accuracy of forecasts. The AvC would be equal to the Installed Capacity, unless one or more turbines/inverters are under maintenance or shutdown. Any mis-declaration of capacity when it is actually not available due to maintenance or shutdown would amount to gaming and would be liable to action under the relevant provisions of the EA, 2003 and the proposed Regulations.

4.2.2 Alternative Error definitions

Two alternative formulations can be considered for deriving the Absolute Error percentage:

Option 1: Absolute Error = (Actual Generation – Scheduled Generation)/AvC.

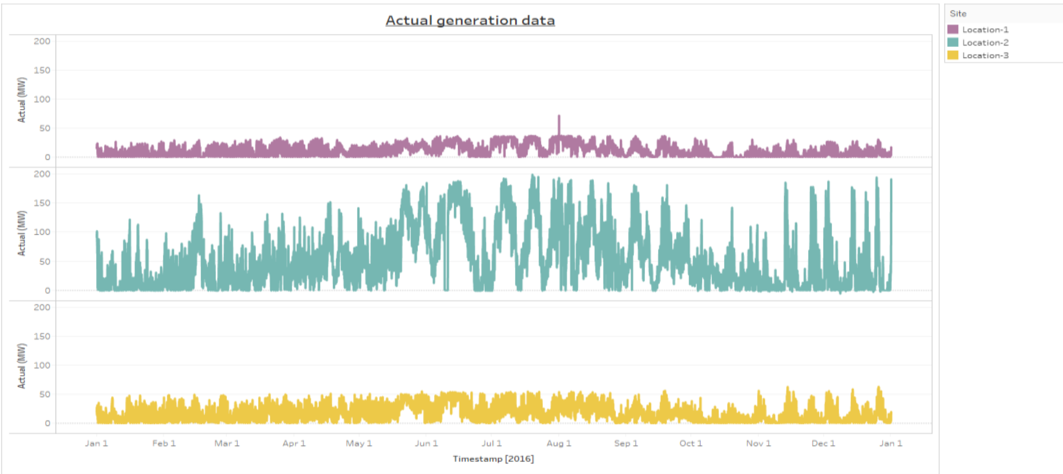
Option 2: Absolute Error = (Actual Generation - Scheduled Generation)/Scheduled Generation.

For assessing the merits and demerits of these options, simulation of actual data at 15-minute time block for one year from three different Wind generation sites (Pooling Sub-Stations) was undertaken:

Table 9: Pooling Sub-Stations for simulation

Wind Pooling Sub-Station	Installed capacity
Site No. 1	38 MW
Site No. 2	200 MW
Site No. 3	65MW

Figure 7: Generation data for 3 locations



The above Figure shows the annual generation variations during the year. The Error Equations (Options 1 and 2) above are applied on the actual generation data for the three locations and the results are plotted below in the form of a line chart to show their variation over time. Figures 8 and 9 indicate very large differences between the two Options.

<u>Option 1</u> uses AvC to calculate the Absolute Error percentage. The AvC is expected to be relatively constant for a generation site, thereby introducing some predictability. The Absolute Error percentage values recorded in the plots are also within an expected range.

<u>Option 2</u> uses the scheduled generation obtained from the Generator or the QCA in advance for every15-minute time block. Although it seems more logical to link the forecasting output to the penalty charged through the DSM, it also introduces uncertainties. The minimum and maximum Absolute Error percentage values for all the 3 locations for 2016 is high due to the poor scheduling processes at present. This is the case in respect of low resource periods where schedules are very low and unpredictable.

4.2.3 Determination of Error Bands:

Figure 8 represents a predictable distribution plot for the Error formula. The three locations exhibit the highest concentration of Error values in ±15% Error Band when it is based on the AvC formula. Each vertical bar, which is equivalent to a 5% Error Band, represents the total number of 15-minute time blocks in a year with Error values falling in the respective Error Bands.

Figure 9 represents a highly unpredictable distribution of Error based on the Scheduled Generation formula and there is no clear distribution pattern.

Figure 8: Histogram for Error computation

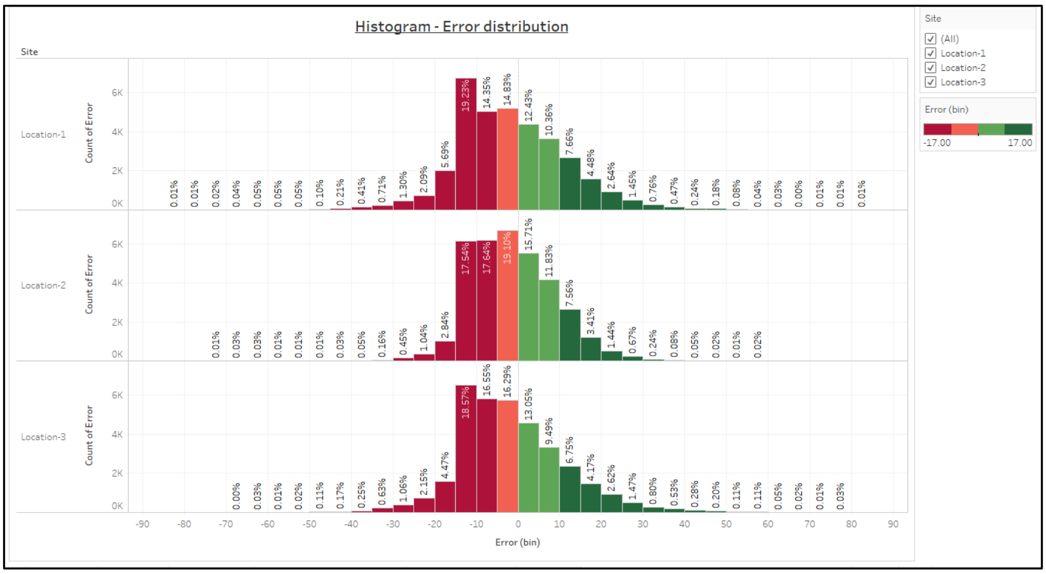
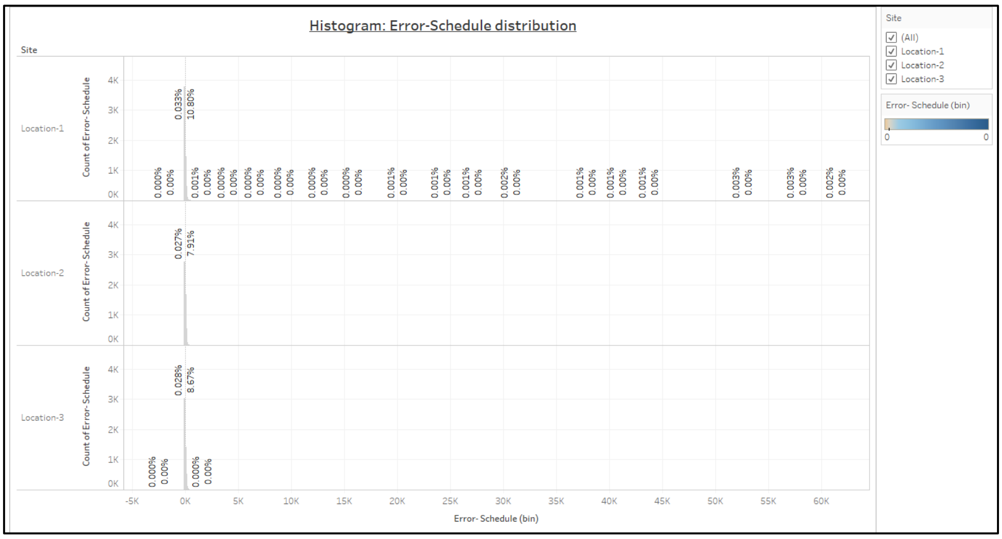


Figure 9: Histogram for Error-Schedule computation



4.2.4 Analysis of Error Formulae

Tables 10 and 11 show the distribution of Absolute Error percentage values and their corresponding actual generation values within the specified bands identified for analysis of the two alternative Options.

The Error Formula-2 based on scheduled generation as the denominator has the largest number of values (more than 31%) in the 50-100% Band, while the >100% band comprises more than 11% of the total instances of deviation. These two bands together cover 18% of the total actual generation in 2016. As the Absolute Error values >100% can lie anywhere between 101% to infinity, higher Deviation Bands will have to be defined in case the Error formula is linked to Scheduled Generation as the denominator. The wide distribution of values within the 0-100% Bands makes it difficult to determine the appropriate Deviation Charges and Deviation Bands.

In the Error Formula 1 linked to AvC and Accuracy Band upto 15%, over 90% of the actual generation is covered. In contrast, in Error Formula-2 based on scheduled generation and Accuracy Band upto 15%, only 42% of the actual generation is covered.

Table 10: Actual energy generation distribution - Available Capacity as denominator

Error (bin) (group)	% of total count of Error along Error (bin) (group)	% of total Actual generation	Actual generation(MWh)
<5%	30.47%	33.44%	2,32,875
5% - 10%	26.74%	27.85%	1,93,970
10% - 15%	25.77%	19.06%	1,32,767
15% - 20%	8.35%	9.39%	65,395
20% - 25%	3.99%	4.93%	34,370
25% - 30%	2.13%	2.54%	17,688
30% - 35%	1.10%	1.18%	8,185
35% - 40%	0.59%	0.64%	4,485
40% - 45%	0.33%	0.37%	2,584
45% - 50%	0.21%	0.23%	1,625
50% - 100%	0.31%	0.36%	2,540
>100%	0.00%	0.00%	--
		100%	**696,485**

Table 11: Actual energy generation distribution – Scheduled Generation as denominator

Error (bin) (group)	% of Total count of Error along Error (bin) (group)	% of Total actual generation	Actual generation(MWh)
<5%	8.45%	14.98%	1,04,348
5% - 10%	7.95%	14.02%	97,660
10% - 15%	7.63%	12.98%	90,404
15% - 20%	6.66%	10.72%	74,694
20% - 25%	5.70%	7.47%	52,056

25% - 30%	5.05%	6.02%	41,924
30% - 35%	4.59%	4.90%	34,139
35% - 40%	4.20%	4.51%	31,394
40% - 45%	3.82%	3.60%	25,063
45% - 50%	3.37%	2.84%	19,783
50% - 100%	31.25%	11.88%	82,720
>100%	11.32%	5.95%	41,457
		100%	**696,485**

While the Error formula based on scheduled generation may be conceptually logical, it does not cover significant data-points within a reasonable Accuracy Band level. In other words, if the Error formula is based on scheduled generation as the denominator, much wider accuracy bands will have to be stipulated. Moreover, during non-peak seasons, the degree of error in absolute terms would be insignificant but the percentage error value would be significantly higher since forecasts and schedules are much lower.

On the other hand, the Error formula based on AvC is not saddled with such large differences and a smaller range of accuracy bands can be followed uniformly despite seasonal variations.

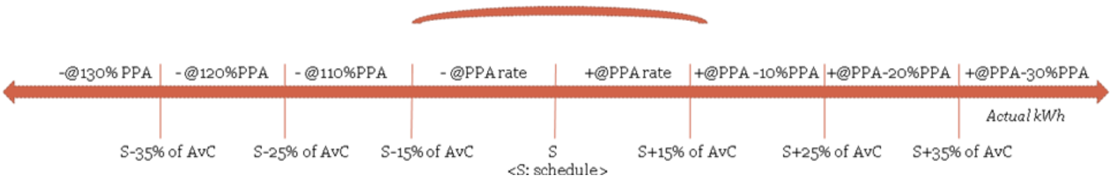
In the light of this discussion, the Commission's Proposed Regulations set out both Options for definition of Absolute Error formulation, i.e. an Error formula based on Available Capacity (AvC) and the alternative formula based on Scheduled Generation, for the purpose of public consultation. The Commission will incorporate one of these two Options in its final Regulations after considering the comments received.

4.2.5 Deviation Charge:

The Deviation Charge should reflect the system cost of balancing deviations. Under the Regional framework, the Deviation Charge is guided by the DSM price vector notified by CERC from time to time. However, under the FBSM mechanism currently operational in Maharashtra, deviations are priced as a combination of the system marginal variable cost along with part allocation of Regional DSM to Pool Participants (Net UI). The effective cost of imbalance settlement for host Distribution Licensees has been below Rs.2 per unit considering the effect of increments/decrements over various time-blocks spread over the annual period. At this inception stage of Deviation Charges for variable Solar and Wind generation at the State level, it is proposed to price the deviations conservatively and with incremental increases over the accuracy bands, particularly since the intra-State conventional power generation is not yet subject to such deviation pricing mechanism in Maharashtra.

In its F&S Framework for Solar and Wind Generators which are Regional entities, the CERC has specified Deviation Charges based on the following methodology:

Figure 10: Price Vector for Deviation Settlement (CERC Regulations)



1. Absolute Error =100 X [(Actual generation – Scheduled generation)/AvC]
2. Payment as per schedule @PPA rate
3. Deviation settlement within tolerance band (+/- 15%):
   a. Receipt from/payment to pool @PPA rate (i.e., in effect, payment as per actuals)
   b. Beyond 15%, there are 3 graded bands for Deviation Charges, as below:

Absolute Error (% of AvC)	Deviation Charge related to PPA
15%-25%	110% of the PPA rate for under-injection, 90% for over-injection
25%-35%	120%, or 80% ofPPA rate
>35%	130%, or 70% ofPPA rate

CERC has linked the Deviation Charge to a reference rate such as the PPA rate, as determined by the Appropriate Commission under Section 62 of the EA, 2003 Act or as adopted by it under Section 63. Further, for Open Access participants selling power which is not accounted for the RPO compliance of the buyer and for Wind or Solar CPPs, the rate is the Average Power Purchase Cost (APPC) rate at the national level as determined by the CERC from time to time.

Similarly, the FOR Model Regulations for the State level propose deviation settlement with the State DSM pool at the PPA rate/APPC rate as the reference rates. For Generators selling both intra-State and inter-State at different PPA rates, a weighted average PPA rate is suggested.

There are essentially two categories of Wind and Solar Generators:

i. Generators who have PPAs with Distribution Licensees

ii. Generators providing power to third parties through Open Access; or using it for self-consumption, usually also requiring Open Access.

The average rate of variable RE power procurement of MSEDCL in FY 2016-17 was expected to be between Rs. 5.00/kWh to 6.00/kWh. The APPC of MSEDCL for FY 2017-18 has been projected to be Rs. 4.01/kWh and additionally Rs.1.00/kWh for Renewable Energy Certificate (REC) procurement, i.e. the total equivalent expenses would be Rs. 5.01/kWh.

Considering the above, it is proposed that the Deviation Charge for deviation >10% can be fixed at around 10% of the PPA rate, which works out to Rs. 0.50/kWh. Rs. 0.50/kWh is also suggested in the FOR Model Regulations and is in line with the CERC F&S Framework. Hence, the Commission's Proposed Regulations envisage a Deviation Charge of Rs. 0.50 per unit for Error percentage between 10% to 20%, Rs.1.00 per unit between 20% to30% and Rs.1.50 per unit beyond 30% (in case the Error percentage is based on AvC as the denominator).

4.2.6 Analysis of Deviation Charges

For the Deviation Bands and Charges shown in the Table below, the financial impact of changing the Absolute Error computation formula in terms of Per Unit Deviation Charges (PPU) computed using Equation 1 is presented in Figure 11 and 12.

$$\textbf{Deviation Charge per unit} = \frac{\textbf{Deviation Charge computed for the year}}{\textbf{Annual actual generation}} - \qquad \textbf{Equation 1}$$

Case1	
%age Absolute Error in 15-minute time block	**Deviation Charges payable to the State Deviation Pool Account**
<= 10%	None
>10% but <=20%	(At Rs. 0.50 per unit for shortfall or excess energy for Absolute Error beyond 10% and upto 20%)
>20% but <=30%	(At Rs. 0.50 per unit for shortfall or excess energy for Absolute Error beyond 10% and upto 20%) + (At Rs. 1.00 per unit for balance energy beyond 20% and upto 30%)
>30%	(At Rs. 0.50 per unit for shortfall or excess energy for Absolute Error beyond 10% and upto 20%) + (At Rs 1.00 per unit for shortfall or excess energy beyond 20% and upto 30%)+ (At Rs. 1.50 per unit for balance energy beyond 30%)
Case2	
%age Absolute Error in 15-minute time block	**Deviation Charges payable to State Deviation Pool Account**
<= 15%	None
>15% but <=25%	(At Rs. 0.50 per unit for shortfall or excess energy for Absolute Error beyond 15% and upto 25%)
>25% but <=35%	(At Rs. 0.50 per unit for shortfall or excess energy for Absolute Error beyond 15% and upto 25%)+ (At Rs. 1.00 per unit for balance energy beyond 25% and upto 35%)
>35%	(At Rs. 0.50 per unit for shortfall or excess energy for Absolute Error beyond 15% and upto 25%)+ (At Rs. 1.00 per unit for shortfall or excess energy beyond 25% and upto 35%)+ (At Rs. 1.50 per unit for balance energy beyond 35%)

Figure 11: Comparison of Per Unit Penalty- Case 1

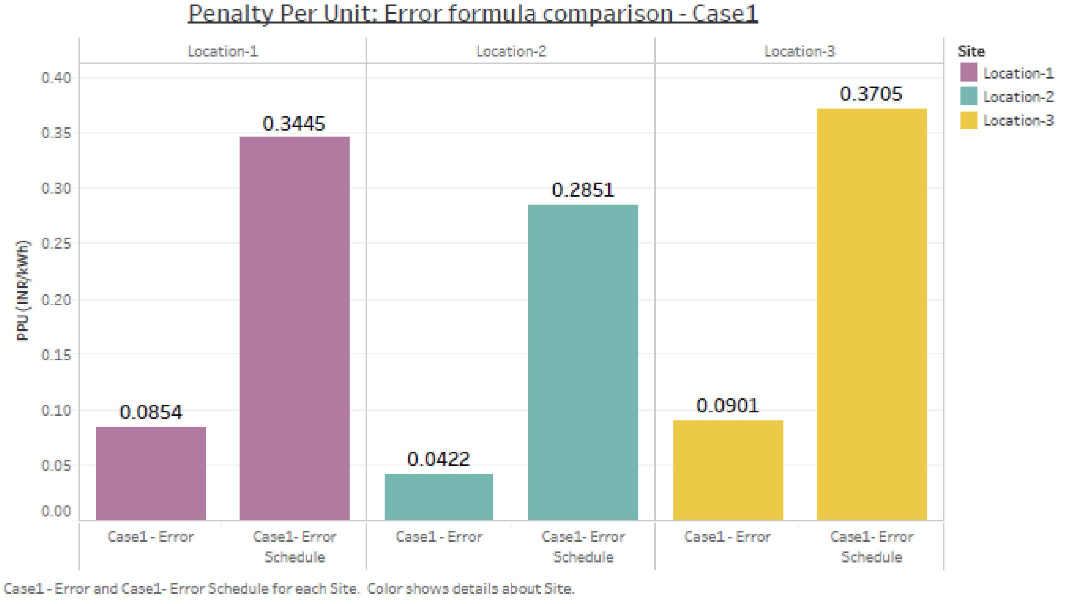
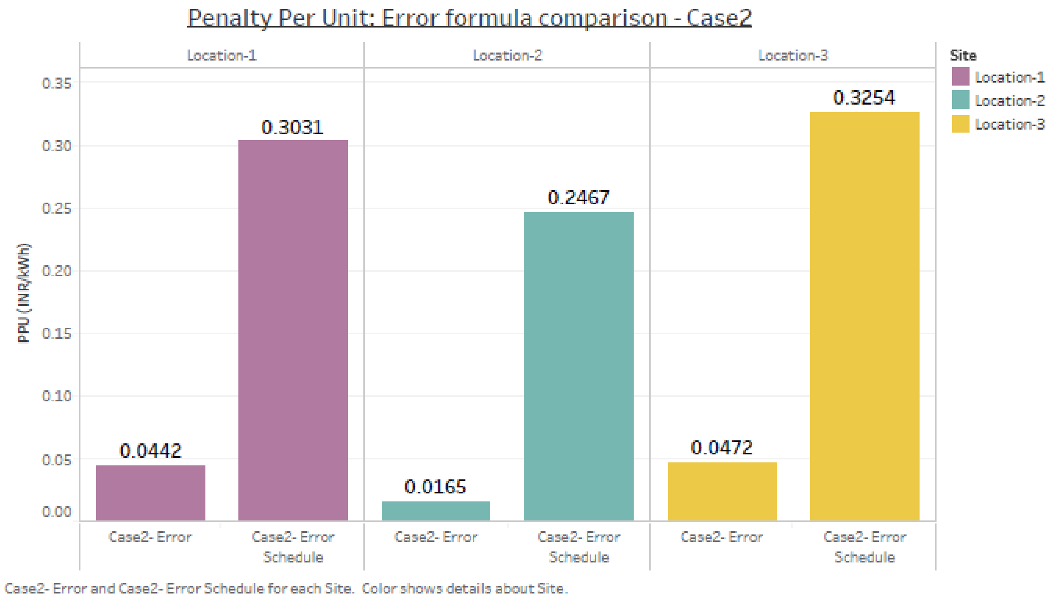


Figure 12: Comparison of per unit Penalty - Case2



The Deviation Charge computed in Equation 1 is the sum of Deviation Charges payable to the State Deviation Pool Account computed for each 15-minute time block in the entire year, i.e. 4 x24 x8760 time blocks. Similarly, the annual actual generation is the sum of the actual generation recorded for each 15-minute time block in the year. By evaluating the Deviation Charges per unit or penalty per unit (PPU), the expected financial impact on per unit RE generation can be analysed for different error formulae and price vectors.

There is a substantial increase in the PPU for the assessed year for all the three locations if the Error Formula based on scheduled generation is applied. Hence, the

Deviation Bands and corresponding Charges will have to be redefined in case the Error formula based on Scheduled Generation is applied, and each Band will have to be much broader than would be the case with the AvC as the denominator.

4.2.7 Conclusion

The Absolute Error percentage can be calculated based on the AvC or the Scheduled Generation as the denominator. As Wind and Solar generation can vary widely, the error distribution is very wide with respect to the scheduled generation. Hence, CERC and some SERCs have computed the error with respect to the AvC.

Moreover, the error as against the installed capacity enables the Generator to understand the deviation better and correct it in future to within the permissible limits.

Except in case of Plants under maintenance, the AvC is equal to the installed capacity. Computing the Error against the AvC also incentivises the Generator to keep its total AvC at the maximum in order to reduce the Absolute Error and, consequently, to minimise the Deviation Charge payable.

Table 10 shows that, if the Error is based on the AvC, 61% of the Wind generation lies in the Absolute Error Band of 0 to 10%. On the other hand, Table 11 shows that, if it is based on scheduled generation, only 29% of the Wind generation lies in the Absolute Error Band of 0% to 10%.Thus, the minimum allowable Error percentage and Error Bands need to be redefined if the error formula is based on Scheduled generation.

Hence, if no Deviation Charges are attracted for deviations below 10% of the AvC (as suggested for one alternative in the Proposed Regulations), the Wind and Solar Generators would be encouraged to schedule their generation better by improved forecasting methods. However, if the error is to be computed as against the scheduled generation, the first Deviation Band for which no Deviation Charge would be payable would have to be expanded to upto 30% (instead of 10%), followed by subsequent wider slabs as compared to the AvC-based Error Formula.

Computation of Error based on Scheduled Generation	
%age Absolute Error based on Scheduled Generation	**Deviation Charges payable**
<= 30%	None
>30% and<=40%	Rs. 0.50 per unit for shortfall or excess
>40% and<=50%	Rs. 0.50 per unit for shortfall or excess for Absolute Error beyond 30% and upto 40% + Re. 1.00 per unit for the balance beyond 40% and upto 50%
>50%	Rs. 0.50 per unit for shortfall or excess for Absolute Error beyond 30% and upto 40% + Re. 1.00 per unit for shortfall or excess beyond 40% and upto 50% + Rs. 1.50 per unit for balance beyond 50%

Considering the purpose of the Proposed Regulations, the Absolute Error should be defined and Deviation Charges set so as to encourage better forecasting and greater scheduling discipline, while at the same time not penalising Generators for deviations that may occur on account of the nature of Solar and Wind generation inspite of their due diligence. After gaining some experience of the functioning of this system, the Error Bands and Deviation Charges can be revisited.

Figure 13: Price Vector Comparison for Case 1 & Case 2

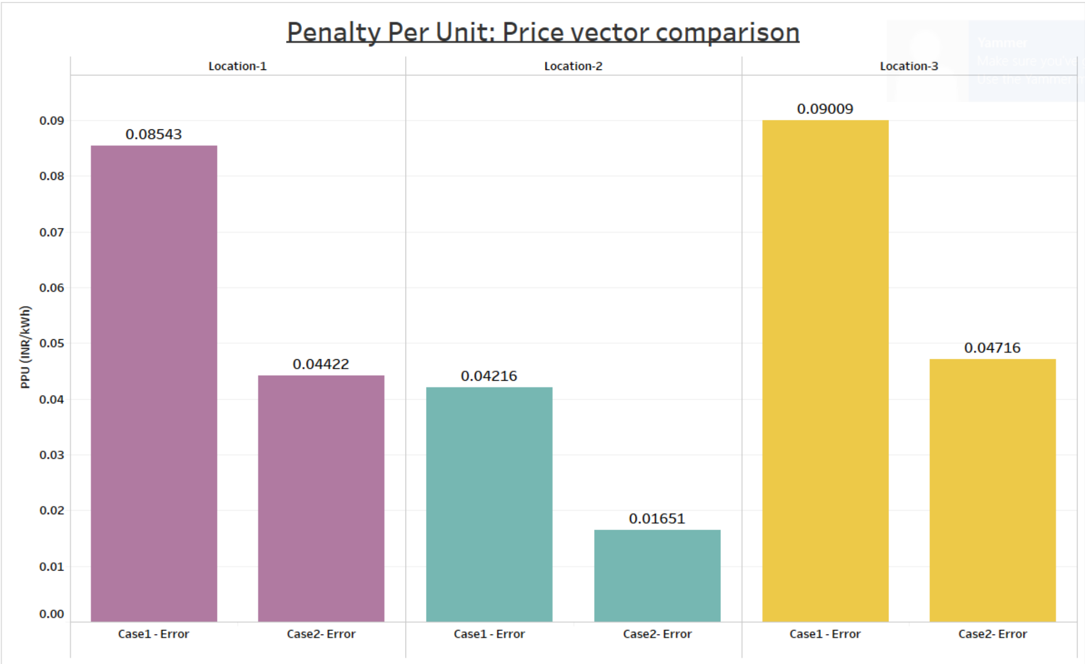


Figure 13 compares the outcomes with Deviation Bands with error percentage of 0-10%, 10-20%, 20-30%and above 30% (if the Error is computed against the AvC, i.e. Case 1 above) with the Deviation Bands with Error percentage of 0-15%, 15-25%, 25-35% and above 35% (i.e. Case 2) and the corresponding Deviation Charges. The Error definition need to be designed and the corresponding Deviation Charges specified in a manner that would best encourage forecasting and scheduling discipline. Limiting deviation tolerance to 10% instead of 15% (particularly when the Error formula is linked to AvC) will not only encourage greater discipline but is also feasible and realistic at this introduction stage. It is likely that, with experience of the working of this Framework, it would be possible to progressively tighten the Error Bands.

4.3 Institutional Structure – QCA

Considering the rationale of the CERC and Model FOR Regulations, the draft and final Regulations of some other SERCs in this regard, and the fact that most Solar and Wind Generators connected through Pooling Sub-Stations and have different off-take arrangements, the Proposed Regulations envisage an institutional structure in the form of a QCA to coordinate or undertake forecasting, scheduling and commercial settlement of deviations between the Generators and the MSLDC.

4.3.1 The FOR Model Regulations define the QCA as the agency coordinating on behalf of Wind/Solar Generators connected to a Pooling Sub-Station. The QCA may be one of the Generators or any other mutually agreed agency for the following purposes:

- To provide schedules with periodic revisions on behalf of the Wind/Solar Generators connected to the Pooling Sub-Station.
- Be responsible for metering, data collection/transmission, communication, coordination with Distribution Licensees, SLDC and other agencies.
- To undertake commercial settlement of all charges on behalf of the Generators, including payments to the State UI Pool accounts through the SLDC.
- To undertake de-pooling of payments received from the State UI Pool account and settle them with the individual Generators.
- To undertake commercial settlement of any other charges on behalf of the Generators as may be mandated from time to time.

The QCA shall be treated as a State Entity.

However, the State-level Regulations in this regard would also need to address the following issues:

1. Number of QCAs at a pooling sub-station.
2. Whether the QCA shall undertake the commercial settlement of all charges or only Deviation Charges?
3. Technical and financial competence and eligibility criteria for appointment of QCA.
4. Modalities for engagement of QCA.
5. Terms of engagement of QCA.
6. Modalities and procedures for operationalising the QCA mechanism.

1. <u>Number of QCAs at Pooling Sub-Station</u>

In Maharashtra, each Pooling Sub-Station has several Generating Units owned by different entities with different off-take arrangements (sale to Distribution Licensees, captive or group captive sales/consumption and third party sales through Open Access).

In order to best operationalise the F&S and the settlement of deviations of a large number of Solar and Wind Generators, and taking advantage of the fact that most of them are connected through a much smaller and more manageable number of pooling sub-stations, the Commission is of the view that the most appropriate model is for a single QCA to provide the interface between all the Generators at a Pooling Sub-Station and the MSLDC for the communication of aggregate schedules and for the associated commercial settlements. The QCA would aggregate the schedules provided by the individual Generators at the Pooling Sub-Station level for submission to MSLDC. This is reflected in the Proposed Regulations.

Since the Generators attached to a Pooling Sub-Station are located in the same compact area, the responsibility for forecasting (including through out-sourcing) and it's sharing with the constituent Generators can also be cast on the QCA. Alternatively, some or all of the individual Generators at a Pooling Sub-Station may prefer to base their schedules on their own forecasting arrangements. The Proposed Regulations leave the preferred modality in this regard to the inter-se arrangement agreed between the individual Generators and their QCA. The QCA and/or Generators could also avail of the forecasts available with the MSLDC instead.

Stand-alone Generators not connected to a Pooling Sub-Station may act as their own QCA or appoint some other entity for the purpose.

A particular entity may happen to be the QCA for several Pooling Sub-Stations or stand-alone Generators, but shall deal with them separately and independently in its interface with MSLDC and other agencies.

2. Whether the QCA should be responsible for commercial settlement of all charges or only Deviation Charges?

Payments relating to the energy supplied are made to the Solar and Wind Generators RE Generators directly by the off-takers. However, the FOR Model Regulations envisage that the QCA would undertake all such commercial settlements also on behalf of the Generators. The Commission is of the view, however, that the objective and scope of its Proposed Regulations is to provide a framework for scheduling based on forecasting and the commercial consequences of deviations.

Considering the substantial and increasing number of Solar and Wind installations at a large number of locations and taking advantage of the fact that most of these are connected through Pooling Sub-Stations, a single QCA at each Pooling Sub-Station would make the system of forecasting, scheduling, deviation settlement, visibility and interaction with MSLDC operationally manageable. Thus, considering the ambit of the Proposed Regulations, the concept of QCA has no relation to other commercial settlements on behalf of Generators. It is always open to a Generator to separately authorise any entity to undertake such other commercial settlements on its behalf as its representative or agent. Such representative or agent may happen to be the same entity which is, in a separate capacity, the QCA under the Proposed Regulations. However, the Commission finds no reason to compel Generators through these Regulations to undertake other settlements also through the QCA and to share the related details with it.

3. Technical and Financial Competence and Eligibility Criteria for QCA

Presently, with around 60 Pooling Sub-Stations dedicated for Wind and Solar Energy Generators with an installed variable RE capacity of 5.0 GW, it is expected that QCA would undertake forecasting, scheduling, energy accounting and deviation settlement of variable generation of around 10 BU per annum. At the level of the Pooling Sub-Stations, the QCAs would be required to undertake the F&S for 50 MW to 200 MW+ of variable RE capacity. This translates to handling deviation settlement account of around Rs. 5 Crore to Rs. 25 Crore per annum at the level of each pooling sub-station (considering the FOR Model Regulation parameters, for instance).

The FOR Model Regulations have not stipulated any eligibility criteria for the entities to be engaged by the Generators as QCAs.

The Commission is of the view that it should be entirely upto the Generators at a Pooling Sub-Station (or a stand-alone Generator) to determine, before its selection, whether an entity is equipped to discharge the functions of a QCA. Hence, the Proposed Regulations do not specify any qualification criteria. However, the Proposed Regulations suggest that the Generators satisfy themselves, in their own interest, that their QCA is technically and financially competent to undertake on their behalf the functions and discharge the obligations specified in the Regulations. While the inter-se terms of engagement would also be up to the Generators, the proposed Regulations also suggest that they include provisions on the following aspects:

a) The respective roles and responsibilities of the Generators and their QCA considering (but not limited to) the provisions of the Regulations and other relevant requirements;

b) The metering, billing and energy accounting arrangements;

c) The modalities for recovery of Deviation Charges from the Generators and their settlement, including the principles for de-pooling;

d) The payment security mechanism and related provisions;

e) The events of default and their mitigation. .

4. Modalities for Engagement of QCA

There are several options with regard to the modalities for engagement of a QCA. One option could be to give MSLDC the responsibility of selecting and assigning a QCA for a particular Pooling Sub-Station or stand-alone Generator; or for MSLDC to empanel certain entities for selection by such Generators as their QCA; or for MSLDC to identify a ‘lead’ Generator to be the QCA for its Pooling Sub-Station.

However, for the same reason that the Commission has not felt it necessary or appropriate to specify in the Proposed Regulations any minimum eligibility criteria for appointment as QCA, the Commission is of the view that the choice of QCA should be left entirely to the concerned Generators since it will be acting on their behalf, rather than being imposed on them by the MSLDC or other agency.

The Generators can select one among themselves or any other entity as their QCA. The Commission expects that the Generators at a Pooling Sub-Station would select their QCA by consensus. However, if a consensus cannot be reached, the Proposed Regulations provide that the entity which has the largest support among the constituent Generators, in terms of the total installed capacity at the Pooling Sub-Station, shall be appointed as their QCA.

5. Functions of QCA and Detailed Procedure

As discussed earlier, the Proposed Regulations provide that the QCA shall be the single point of contact between the concerned Generators and the MSLDC for energy accounting, deviation settlement and instructions for despatch or curtailment. The specific functions and activities of the QCA arising from this role and from the F&S and DSM Framework proposed by the Commission is elaborated in the Proposed Regulations. These would include:

- undertaking commercial settlement of deviations on behalf of the Generator
- providing energy account statements considering the following:

- energy accounting and DSM computation for each 15 minute time block
- weekly settlement period of energy accounts and DSM accounts
- quarterly adjustment/ truing-up of DSM accounts, if necessary.

The Proposed Regulations require the MSLDC to formulate the Detailed Procedure for registration of the selected QCAs and for the various functional modalities in pursuance of the specified F&S and DSM Framework, and to submit it within 2 months to the Commission for approval. In the context of the Regulations and the functions of the QCA, the Detailed Procedure would cover the following aspects:

- The procedure and requirements, including the payment of fees and penalties, for the registration and de-registration of QCAs by the MSLDC.

- The information and data, and the formats, required by the MSLDC from the QCAs and to be provided by the MSLDC to them.

- The mode and protocol of communication for exchange of information and data between the QCAs and the MSLDC.

- The plan for data telemetry, formats of forecast submission and other modalities and requirements.

- The guidelines for energy and deviation accounting of Solar and Wind energy transactions under the State energy accounting framework, with illustrative examples, in accordance with the principles specified in the Regulations.

- The mechanism for monitoring compliance of the Forecasting and Scheduling Code by the QCAs.

- The default conditions in the State Pool Settlement by QCAs and their treatment.

4.4 Deviation Accounting at State-Level

Solar and Wind generation is variable in nature as Forecasting and Scheduling from these sources pose a great challenge. Operationalising Virtual Pool of all the RE Generators at the State level is a novel mechanism to minimise the adverse commercial effects of these variations by enlarging the balancing area.

The FOR Model Regulations require the submission of schedules of each pooling sub-station to SLDC. The energy charges are to be paid to the RE Generators or through the concerned QCAs by the off-takers. Deviation Charges are to be shared between the RE Generators through the Virtual Pool. In order to take advantage of the diversity of Pooling Sub-Stations, the Deviation Charges can be settled by considering different Pools in a State Control Area as one “Virtual Pool”.

In such a Virtual Pool mechanism, the deviations of all the different Pooling Sub-Stations (Virtual Pool) can be combined, and the resulting net deviation can be worked out. Since it is likely the deviations in some Pooling Sub-Stations may be negative and may be positive in others, it is likely that the net deviation across them would be much lower than the absolute sum of individual deviations. This net deviation needs to be de-pooled (apportioned) among the different Pooling Sub-Stations.

The main objective of the Virtual Pool suggested in the FOR Model Regulations is to aggregate the diversity of Solar and Wind Generators at the State level and minimise the net commercial impact. As far as Maharashtra is concerned, MSLDC would be the appropriate entity to maintain the Virtual Pool.

Thus, the Proposed Regulations envisage that

- The Deviation Charge payable or receivable for the State as a whole at the State periphery shall be computed by the MSLDC.

- MSLDC shall compute the impact of the deviation of the Solar and Wind Energy Generation and its contribution to the Deviation Charge at the State periphery

- MSLDC shall compute the Absolute Error, i.e. the difference between the scheduled and the actual energy injected, in respect of each Pooling Sub-Station, and shall accordingly determine the amounts payable by each set of Pooling Sub-Station Solar and Wind Generators (or by Stand-Alone Generators) on account of the Deviation Charge.

- Any shortfall in the aggregate amount of Deviation Charge payable by Generators at the State periphery and the amount receivable from them by the Pool Account shall be paid by the respective QCAs in proportion to their deviation as reflected at the State periphery.

4.5 De-Pooling Principles

The FOR Model Regulations suggest that the QCA shall de-pool the Deviation Charges (a) in proportion to the actual unit generated in each time block by each Generator, or (b) in proportion to the AvC of each Generator.

There are several options for apportioning the Deviation Charges between the RE Generators at a Pooling Sub-Station, i.e. based on:

- Available capacity (MW)
- Scheduled generation (MWh)
- Actual generation (MWh)
- Deviation in energy (MWh)
- Deviation in value (Rs.)

While de-pooling/allocation amongst the RE Generators can be easily undertaken on the basis of AvC or Actual Generation, doing so on the basis of other three parameters would require information regarding the schedule for each Generator (turbine or feeder level) to be maintained and be available with the QCA. While forecasts at the turbine level could be available, the schedule at each turbine level or reconciliation of schedule at the turbine or Generator level vis-à-vis the aggregate schedule at the pooling sub-station level would be difficult. Hence, the Proposed Regulations envisage de-pooling on the basis of Actual Generation (MWh) among the constituent Generators at each Pooling Sub-Station.

4.6 Funding Deficits in the State Imbalance Pool

Many times, the renewable rich States show reluctance toward addition of more and more RE in their control areas, due to the reasons of commercial loss they experience due to creation of ever increasing deficit in view of the difference in the Deviation Charges applicable for RE Generation vis-à-vis Deviation Charges applicable for the conventional Generators/load serving entities etc.

The FOR Model Regulations propose that the deficit, if any, in the State Imbalance Pool arising from the difference between the DSM of the Solar and Wind Generators and the State grid on the one hand, and the State and Regional grid on the other, be funded through the PSDF or NCEF.

However, there is no assurance that such external funding would be available. In any case, this issue does not arise in the Framework envisaged in the Proposed Regulations since the shortfall, if any, would be recovered from Solar and Wind Generators through their QCAs at the Pooling Sub-Station level in proportion to their contribution to deviations at the State periphery.

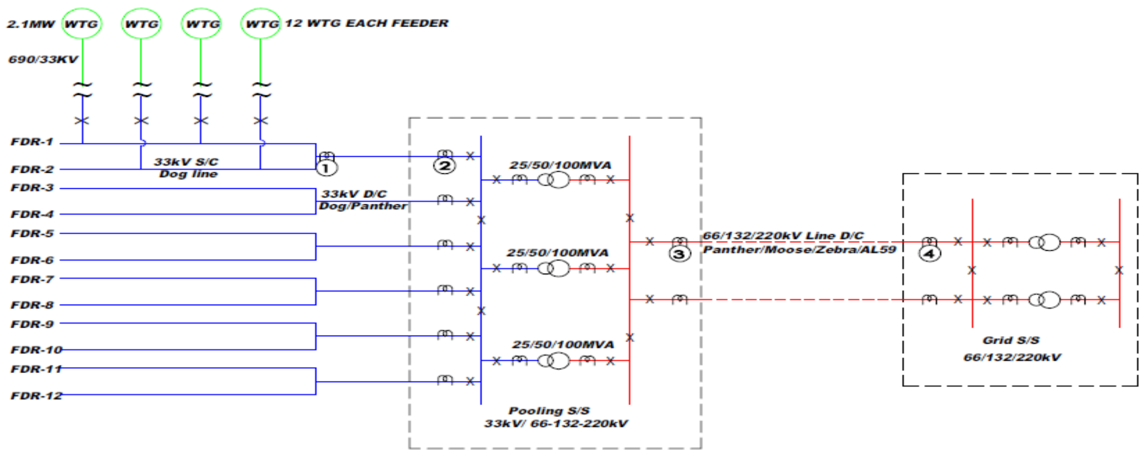
4.7 Metering and Communication Arrangements

Apart from Stand-Alone Generators, the Proposed Regulations envisage the Pooling Sub-Station as the basic unit for the F&S and DSM mechanism. All the relevant parameters, namely, Scheduled Generation, Actual Injection, Deviations (Absolute Error) and Deviation Charges, would be monitored and accounted for within the State Imbalance Pool with reference to the Pooling Sub-Station. Hence, the metering arrangements, communication infrastructure and protocol at each such Sub-Station are critical.

Metering Arrangement

In the illustration at Figure 14 below, the reference point for the purpose of energy and deviation accounting for a Wind Energy Plant within the State Imbalance Pool is the Interconnection Point (No. 3), i.e., the line isolator on the outgoing feeder at the HV side of the Pooling Sub-Station. Similarly, in case of a Solar Power Plant, the reference point shall be the Interconnection Point (No. 3).

Figure 14: Schematic of Solar and Wind Power Plants at Pooling Sub-Station



The QCA shall be responsible for coordinating the schedules, actual meter readings, real-time data/information exchange, settlement of energy account and deviation account with the State Imbalance Pool and de-pooling of Deviation Charges vis-à-vis Interconnection Point No. 3.

The QCA may have internal arrangements for sub-metering at the feeder level (at Point No. 2) or at the turbine/inverter level (at Point No1). All meters and metering arrangements shall be in accordance with the CEA Metering Regulations.

The QCA (or Stand-Alone Generator) shall establish communication infrastructure and online real-time data/information sharing facility for exchange with MSLDC in accordance with the Detailed Procedure to be formulated by MSLDC.

Since the Proposed Regulations do not distinguish between Solar and Wind Generators for forecasting, scheduling and deviation accounting, there would also be no difficulty in this regard for Hybrid (Solar and Wind) Plants at the Pooling Sub-either. However, energy accounts may require to be maintained separately for the purpose of Solar and Non-Solar RPO assessments.

Solar and Wind Generators (which are State Entities) undertaking inter-State wheeling transactions should be connected to separate feeders for ease of energy and deviation accounting, since there is a different treatment for their settlement of energy transactions on ‘schedule’ basis and their deviation settlement within the State Imbalance Pool is undertaken on different principles than for intra-State transactions whose energy settlement is done on ‘actual’ basis.

Thus, in the case of inter-State transactions of Solar and Wind Generators, energy and deviation accounting shall be accounted separately at Point No. 2 in Figure 13, and grossed up for normative losses of the Pooling Sub-Station so that schedules, deviations and energy accounting for such Generators is undertaken with reference to Interconnection Connection Point No. 1 within the State Imbalance Pool.

Communication Arrangements

The QCA shall install Telemetry/Communication and Data Acquisition Systems for transfer of data/information to MSLDC in line with the Detailed Procedure.

The Detailed Procedure stipulated by the MSLDC would set out the protocol for communication and exchange of information between the QCA and the MSLDC, including the following aspects:

a) Communicating day-ahead, intra-day and week-ahead schedule along with revisions to the MSLDC.

b) Communication of real-time generation at the Pooling Sub-Station.

c) Communication of grid constraints and curtailments by MSLDC to the QCA.

SLDC shall develop the necessary software and IT enabled communication platform for communication between it and the QCAs.

The QCA shall provide the IT-enabled communication software login details to the MSLDC to enable it to access live data of all schedules and deviations and facilitate timely billing and payment of Deviation Charges. The software should enable MSLDC and QCA to exchange information on the following:

i. information on Generator outages and their reasons.

ii. intimation of the Deviation Charges at the Pooling Sub-Station or Stand-Alone Generator level to the QCA.

iii. basic information of the site and Wind Turbines, Solar Inverters, etc.

iv. viewing of the schedules and the generation being handled by the QCA.

4.8 Treatment of Inter-State Transactions of State Entities

As discussed earlier, the mechanisms for the energy settlement of intra-State wheeling transactions (on 'actual generation' basis) and inter-State wheeling transaction (on 'schedule generation' basis) of Solar and Wind Generators is different. Thus, their deviation accounting and settlement within the State Imbalance Pool will also be different. The main differences between intra-State (as per the Proposed Regulations) and inter-State wheeling (as per CERC) are as shown in Table 12 below.

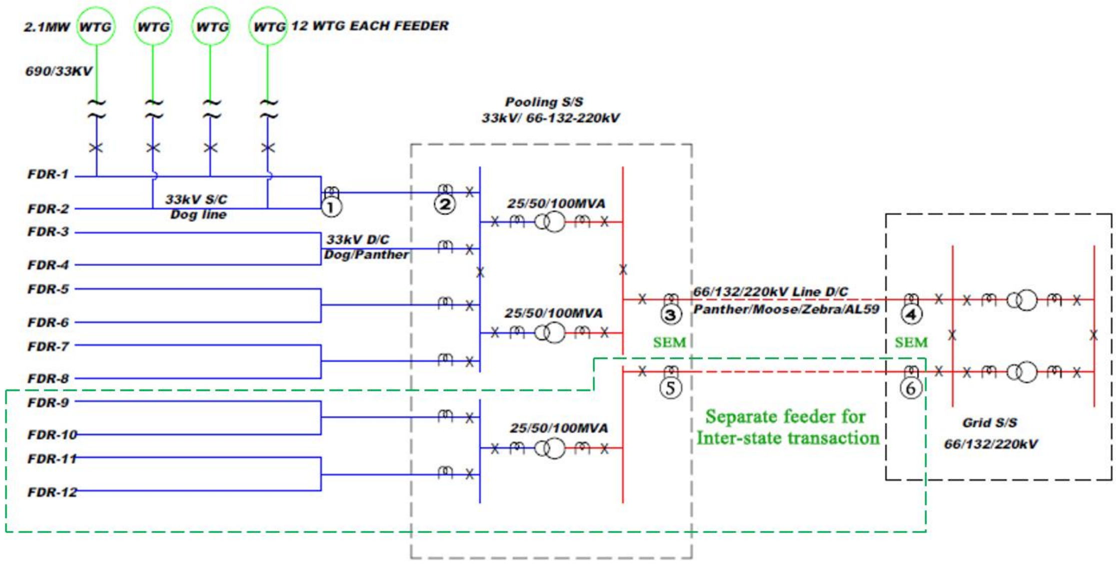
Table 12: Differences between intra-State inter-State Wheeling

Parameter	Intra-State Wheeling (Solar/Wind) (in Proposed Regulations)	Inter-State Wheeling (Solar/Wind) (as per CERC)
Payment to RE Generators	Actual generation basis	Scheduled generation basis
Rates for Deviation Settlement	Fixed rate in Bands, (i.e., Rs/per unit of 0.50, 1.00, 1.50)	Linked to the percentage of PPA rate or APPC, in Bands (i.e., 110%, 120%, 130% for under-injection and 90%, 80%, 70% for over-injection)
Deviation Charge Settlement with the State Imbalance Pool	• For over-injection: Pay into DSM Pool • For under-injection: Pay into DSM Pool	• For over-injection: Receive from DSM Pool • For under-injection : Pay into DSM Pool

Some Generators connected to a pooling sub-station may undertake intra-State wheeling transactions while others may undertake inter-State wheeling transactions. As schedules are prepared at the pooling sub-station level, carrying out deviation settlement in such a case poses challenges considering the differential treatment of intra-State and inter-State transactions.

Following Figure 15 illustrates a schematic of separate Bay for Wind Energy Plants undertaking inter-State transactions at a Pooling Sub-Station.

Figure15: Schematic of Wind Power Plant



Consequently, the Proposed Regulations provide a framework for treatment of inter-State wheeling transactions of Solar and Wind Generators, keeping in view that it should be easy to operationalise and be scalable considering future developments. All inter-State wheeling transactions at a pooling sub-station would be allowed if connected through a separate feeder.

If intra-State wheeling transactions move to a ‘schedule’ based compensation regime in future, no such distinction in the treatment for intra-State and inter-State transactions would be necessary.