Annexure-V

Grid Controller of India Limited

(formerly Power System Operation Corporation Limited)

National Load Despatch Centre (NLDC)

Methodology for Computation of Primary Frequency Response Obligation and Performance

Prepared in Compliance

to

IEGC Regulation 30 of clause (10)

of Central Electricity Regulatory Commission
Indian Electricity Grid Code

Regulations, 2023

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Definitions provided in IEGC-2023 required for this section

Control Area- means an electrical system bounded by interconnections (tie lines), metering and telemetry which controls its generation and/or load to maintain its interchange schedule with other control areas and contributes to regulation of frequency as specified in these regulations;

Connectivity- means the state of getting connected to the inter-State transmission system by a generating station including a captive generating plant, a bulk consumer or an Inter-State Transmission licensee, in terms of the GNA Regulations;

'Reference contingency' - means the maximum positive power deviation occurring instantaneously between generation and demand and considered for dimensioning of reserves.

Free Governor Mode of Operation - Means the mode of operation of governor where machines are loaded or unloaded directly in response to grid frequency i.e machine unloads when grid frequency is more than 50 Hz and loads when grid frequency is less than 50 Hz. The amount of loading or unloading is proportional to the governor droop.

'Frequency Response Characteristics' or 'FRC' - means automatic, sustained change in the power consumption by load or output of the generators that occurs immediately after a change in the load-generation balance of a control area and which is in a direction to oppose any change in frequency.
Mathematically it is equivalent to
FRC = Change in Power (ΔP) **/** Change in Frequency (Δf);

Frequency Response Obligation' or 'FRO' - means the minimum frequency response a control area has to provide in the event of any frequency deviation;

'Frequency Response Performance' or 'FRP'- means the ratio of actual frequency response with frequency response obligation;

Methodology for Computation of Primary Frequency Response Obligation and Performance

1. Introduction-

As per clause (1) & (2) of IEGC Regulation 30, the NLDC, RLDC and SLDC shall endeavor that Indian grid frequency remains close to 50.000 Hz and in case frequency goes outside the allowable band, ensure that the frequency is restored within the allowable band of 49.900-50.050 Hz at the earliest. The frequency shall be maintained within operational band through primary secondary and tertiary control. The National Reference Frequency shall be 50.000 Hz.
This document lays down the methodology for estimation of minimum All India target for frequency response characteristics, computation of Primary Frequency Response Obligation of each control area based on target FRC and assessment of Frequency Response Performance of each control area in line with the IEGC 2023.

the sub-clause (f) of clause (10) of IEGC Regulation 30, as quoted below:
''The minimum All India target frequency response characteristics (FRC) shall be estimated and based on such target FRC, the frequency response obligation of each control area shall be assessed by NLDC as per Annexure-2, giving due consideration to generation and load within each control area and details as given in Table 1 under sub-clause(g) of this clause. The same shall be informed to all control areas by 15th of March every year for the next financial year''

2. Provisions of IEGC 2023 for Primary Frequency Response

i. All SLDCs, RLDCs shall identify the Control areas for minimum frequency response obligation and each RLDC shall notify the list of control areas on their respective website. *(Referred from clause (1) & (3) of IEGC Regulation 45)*

ii. All the generating units shall have their governors or frequency controllers in operation all the time with droop settings of 3 to 6 % (for thermal generating units and WS Seller) or 0-10% (for hydro generating units) as specified in the CEA Technical Standards for Connectivity. *(sub-clause (g) of clause (10) of IEGC Regulation 30)*

iii. Table - I PRIMARY RESPONSE OF VARIOUS TYPES OF GENERATING UNITS

Fuel/ Source	Minimum unit size/Capacity	Up to
Coal/Lignite Based	200 MW and above	±5% of MCR

Hydro	25 MW and above	±10% of MCR
Gas based	Gas Turbine above 50 MW	±5**%** of MCR (corrected for ambience temperature)
WS Seller (commissioned after the date as specified in the CEA Technical Standards for Connectivity)	Capacity of Generating station more than 10 MW and connected at 33 kV and above	As per CEA Technical Standards for Connectivity

Provided that:

WS Sellers commissioned after the date as specified in CEA Technical Standards for Connectivity shall have the option to provide primary response individually through ESS or through a common ESS installed at its pooling station.

Nuclear generating stations and hydro generating stations (with pondage up to 3 hours or Run of the river projects) shall be exempt from mandatory primary response. They may provide the primary response to the extent possible, considering the safety and security of machines and humans.
(sub-clause (h) of clause (10) of IEGC Regulation 30)

iv. a) All generating stations mentioned in Table-1 shall have the capability of instantaneously picking up to a *minimum of 105% of their operating level and up to 105% or 110% of their MCR*, as the case may be, when the frequency falls suddenly and thus providing primary response whenever conditions arise. *(Referred from sub-clause (i) of clause (10) of IEGC Regulation 30)*

b) All generating stations, including the WS seller mentioned in above table-I shall have the capability of reducing output at least by 5% or 10%, as applicable, of their operating level and up to 5% or 10% of their MCR, as applicable, limited to the minimum turndown level when the frequency rises above the reference frequency and thus providing primary response, whenever condition arise.

Any generating station not complying with the above iv (a) and iv (b) requirements shall be kept in operation (synchronized with the regional grid) only after obtaining permission from the concerned RLDC. *(sub-clause (j) of clause (10) of IEGC Regulation 30)*

v. a) All SLDC, RLDC and the generating stations shall ensure that all units shall have electronically controlled governing systems or frequency controllers in accordance with the CEA Technical Standards for Connectivity. The generating stations and units with governors shall be under Free Governor Mode of Operation. *(sub-clause (d) of clause (10) of IEGC Regulation 30)*

b) The thermal and hydro generating units shall not resort to Valve Wide Open (VWO) operation to make available margin for providing governor action. *(sub-clause (I)&(J) of clause (10) of IEGC Regulation 30)*

c) The normal governor action shall not be suppressed in any manner through load limiter, Automatic Turbine Run-up System (ATRS), turbine supervisory control or coordinated control system and no time delays shall be deliberately introduced. In the case of a renewable energy generating unit, a reactive power limiter or power factor controller or voltage limiter shall not suppress the primary frequency response within its capabilities. The inherent dead band of a generating unit or frequency controller shall not exceed +/- 0.03 Hz.
The governor shall be set with respect to a reference frequency of 50.000 Hz and response outside the dead band shall be with respect to a total change in frequency. *(sub-clause (k) of clause (10) of IEGC Regulation 30)*

vi. a) The primary frequency response shall start immediately when the frequency deviates beyond the dead band as specified in above sub-clause (viii) of this clause and shall be capable of providing its full primary frequency response obligation within 45 seconds and sustaining at least for the next five (5) minutes. *(referred from sub-clause (m) of clause (10) of IEGC Regulation 30)*

b) After notification of Primary Reserves Ancillary Service (PRAS), Primary control shall be governed by the mechanism defined under Primary Reserves Ancillary Service (PRAS).

The methodology for Computation of *Primary Frequency Response Obligation and Performance* in line with the sub-clause (f) of clause (10) of Regulation 30 of these regulations comprises of following points:

a) Assessment of reference contingency,
b) All India minimum target frequency response characteristics,
c) Calculation of frequency response obligation of each control area,
d) Methodology of Frequency Response Characteristics (FRC) computation
   i. Criteria for reportable event.
   ii. Notification of reportable event for FRC computation:
   iii. Input data for FRC computation and compliance
   iv. FRC computation and reporting
   v. Steps for computation of FRC
   vi. Frequency Response Performance Evaluation

a) Assessment of reference contingency-

i. The reference contingency is the quantum of sudden generation or demand outage in an event. The reference contingency considers quantum of generation outage based on outage of largest power plant, group of power plants, a generation complex, or a generation pooling station, or the actual generation outage occurred in an event during last two years, or a credible outage scenario. Similarly reference contingency also considers outage of single largest load center or actual outage of load occurred in an event during last two years. *(Referred from clause (05) IEGC Regulation Annexure-2).*

ii. As per regulation 5 of IEGC 2023, the reference contingency shall be 4500 MW. NLDC shall keep track of the reportable grid events and revise the reference contingency if required. The reference contingency shall be published on NLDC website under given link https://posoco.in/reference-contingency/ .

b) All India minimum target frequency response characteristics

i. The all India minimum target frequency response characteristic (MW/Hz) shall be reference contingency quantum (MW) divided by maximum steady frequency deviation (Hz) allowable for the reference contingency event. *(sub-clause (a) of clause (06) of IEGC Regulation Annexure-2)*

ii. The primary reserves shall be activated immediately (within few seconds) when the frequency deviates from 50 Hz. The safe, secure and reliable operation of grid requires that the nadir frequency should be at least 0.1 Hz above the first stage of under frequency load shedding scheme. This implies that the nadir frequency shall be above or 49.5 Hz (considering first stage of under frequency loading shedding setting as 49.4 Hz) for the reference contingency event and the maximum steady state frequency deviation should not cross 0.30 Hz for the reference contingency event. *(sub-clause (b) of clause (06) of IEGC Regulation Annexure-2)*

iii. Therefore, the minimum All India target Frequency Response Characteristic currently shall be quantum of load or generation loss in reference contingency (as defined in Section a(iii) above) divided by frequency deviation value of 0.3 Hz i.e. **15000 MW/Hz (4500 MW/0.3 Hz).** *(sub-clause (c) of clause (06) of IEGC Regulation Annexure-2)*

iv. **The minimum target FRC shall be revised by NLDC from 15th of March every year**. *(Referred from sub-clause (f) of clause (10) IEGC Regulation 30)*

c) Calculation of Frequency Response Obligation (FRO) of Each Control Area

The minimum Frequency Response Obligation (FRO) of each control area in MW/Hz shall be calculated as:

FRO = (Control Area average Demand + Control Area average Generation) * minimum all India Target Frequency Response Characteristic / (Sum of peak or average demand of all control areas + Sum of average generation of all control areas)

Provided FRO shall be nil in case of a control area not having any generation resources, such as Goa, DD, DNH etc.
(clause (07) of IEGC Regulation Annexure-2)

Control Area average Demand shall be taken from SCADA of control area for a time period of one year with data resolution of 5-minute.

Control Area average Generation shall be taken from SCADA of control area for a time period of one year with data resolution of 5-minute.

Average demand of all control areas shall be sum of average demand of all control areas.

Average Generation of all control areas shall be sum of average generation of all control areas.

FRO shall be informed by NLDC to all control areas by 15th of March every year for the next financial year.
(Referred from sub-clause (f) of clause (10) IEGC Regulation 30)

d) Methodology of Frequency Response Characteristics (FRC) computation

All generating stations/control area shall provide primary frequency response during event of generation/load loss. The NLDC/RLDC/SLDC/control areas shall calculate actual frequency response characteristics of their respective control area/generating stations and the performance of each control area/generating stations in providing frequency response characteristics shall be calculated for each reportable event.

I. **Criteria for reportable event:** The frequency response characteristic (FRC) calculation shall be carried out by each control area for any load or generation loss incident involving net change of **more than 1000 MW** of load or generation or a

frequency change involving **0.1 Hz or more**. The event shall be notified by NLDC *(clause (8) IEGC Annexure-2)*

II. Notification of reportable event for FRC computation:

- After each reportable event, NLDC would also get the exact quantum of load/generation lost from the RLDC of the affected region. (referred *sub-clause (a(i)) of clause (9) of IEGC Regulation Annexure-2).* RLDC of the affected region *(Region where the reportable event has taken place)* shall report the brief detail of the event along with generation & load loss quantum within *one working day* after the event to NLDC/RLDCs in the format as specified in *Annexure-I* of this document. RLDC of the affected region may coordinate with SLDC/affected control area for collecting inputs/details of the reportable event.

- NLDC would get the PMUs frequency and shall plot the frequency graph (at least with total 03 minutes time window consisting of 01 minute before the event and 02 minute after the event data with the resolution of 40 milli second or better available resolution).

- NLDC shall determine the initial frequency, minimum/maximum frequency, settling frequency and time points (points A, C and B of the Figure-A). Accordingly, frequency difference points & corresponding time to be used for FRC calculations would be informed to all RLDCs. *(referred from sub-clause (a(ii)) of clause (9) of IEGC Regulation Annexure-2)*

- RLDCs shall forward the data shared by NLDC to SLDCs/ISGS Generators for computation of FRC at their end.

III. Input data for FRC computation and compliance:

- The data for frequency response characteristic Calculations may be taken from the real time telemetered data recorded by the SCADA or PMU systems (as per the availability) installed at Control Areas / Regional Load Despatch Centres / National Load Despatch Centre. *(sub-clause (b(i)) of clause (9) of IEGC Regulation Annexure-2)*

- FRC computation shall be done based on 10 second or better resolution Historical Data Recording (HDR) data available at Control Areas / State Load Despatch Centres / Regional Load Despatch Centres National Load Despatch Centre and 1 (one) second (or better resolution) data for regional entity generating stations, intra state generating station and energy storage systems. *(referred from sub-clause (n) of clause (10) of IEGC Regulation 30)*

- All generating stations shall furnish the requisite data to the RLDC/SLDC within two working days from notification of reportable event by the NLDC. *(referred from clause (08) of IEGC Regulation 30).* Total time window of requisite data for FRC computation shall be at least 10 min. (03 min. pre-event & 07 min. post event). Event time to be considered as notified by NLDC on event basis.

- Bad quality of data could be flagged / mentioned by the control centre(s) and Reasonable assumptions made for FRC computation. Details of these may be mentioned. *(sub-clause (b(ii)) of clause (9) of IEGC Regulation Annexure-2)*

- All Control Areas / State Load Despatch Centres /Regional Load Despatch Centres / National Load Despatch Centre shall ensure the data availability and healthiness of telemetry system.

IV. FRC computation and reporting:

- The FRC shall be worked out by NLDC, RLDCs and SLDCs to for each interconnection/region/control area (including for each generating station). Each generating station shall also compute it's FRC. *(referred from sub-clause (a) of clause (9) of IEGC Regulation Annexure-2)*

- NLDC shall also work out region wise and neighboring countries (Bhutan and Nepal) FRC (Format as per Table-III) based on 10 second or better resolution Historical Data Recording (HDR) data available at NLDC and inform all RLDCs within three (3) working days. RLDCs shall inform the SLDCs/regional entities in their region. *(sub-clause (a(iii)) of clause (9) of IEGC Regulation Annexure-2)*

- Each control area shall assess its frequency response characteristics and share the assessment with the concerned RLDC along with high resolution data of at least 1 (one) second (or better resolution) for regional entity generating stations and energy storage systems and 10 (ten) seconds for the state control area. *(sub-clause (n) of clause (10) of IEGC Regulation 30)*

- RLDCs shall also work out each control area wise FRC (Format as per Table-III) based on HDR data available at RLDCs within six (6) working days after the event. *(sub-clause (a(iv)) of clause (9) of IEGC Regulation Annexure-2)*

- All regional entity generating stations shall also assess the FRC for their respective stations and submit the same to respective RLDC within six (6) working days. (Format as per Table-III). The high-resolution data (1 second or better resolution) of active power generation and frequency shall also be shared with RLDC. *(sub-clause (a(vi)) of clause (9) of IEGC Regulation Annexure-2)*

- All the SLDCs shall work out FRC for all the intra-state entities (for events indicated by the Regional Load Despatch Centres) based on the HDR available at their respective SLDCs and submit the same to respective RLDC within six (6) working days after the event. (Format as per Table-III). *(sub-clause (a(v)) of clause (9) of IEGC Regulation Annexure-2)*

- All the intra state generating station shall also assess the FRC for their respective stations and submit the same to respective SLDC. (Format as per Table-III). The high-resolution data (1 second or better resolution) of active power generation and frequency shall also be shared with SLDC.

Table-II: Timeline for FRC computation during events

Entity	Timeline for FRC reporting
NLDC	Within 3 working days after the event
RLDC	Within 6 working days after the event
SLDC	Within 6 working days after the event
ISGS	Within 6 working days after the event

*Timeline for FRC computation mentioned above is excluding the day of event.
(referred from clause (9) of IEGC Regulation Annexure-2)

V. Steps for computation of FRC:

- A sample frequency chart given at Figure-A with points A, B, and C labeled, depicts a typical frequency excursion caused by a loss of a large generator in Indian power system.

  Point A denotes the interconnection frequency immediately before the disturbance.

  Point B represents the Interconnection frequency at the point immediately after the frequency stabilizes due to governor action but before the contingent area takes any corrective actions, automatic or manual.

  Point C (Nadir point) represents the interconnection frequency at its maximum deviation due to the loss of generation/Load.

  (sub-clause (c) of clause (9) of IEGC Regulation Annexure-2)

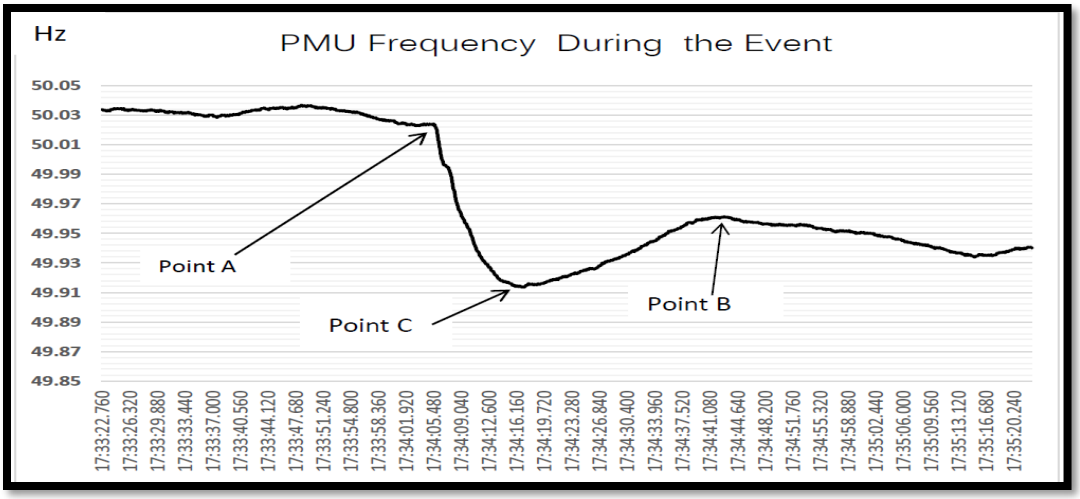


Figure A: sample PMU frequency plot showing relevant points for FRC calculation

Steps to work out frequency response characteristics of control area are as follows: -

Step-1: Actual net interchange of the control area immediately before the disturbance (Point‐ A in the figure-A), say PA. Sign convention for net power imported into a Control Area is positive (+) and net power exported out of a control area is negative (-).

Step-2: Actual net interchange of the control area immediately after the disturbance (Point‐ B in the figure-A), say PB. Use the same sign convention as Step-1.

Step-3: The change in net interchange of the Control Area = (PB -PA). [For a disturbance that causes the frequency to decrease, this value should ideally be negative. The net interchange of a control area may be positive, if the drop-in generation has occurred in that control area. Similarly, for load throw off or frequency rise cases in a control area, the net interchange shall normally be positive except for the Control Area, where the load throw off has taken place.]

Step-4: If the control area has suffered the loss, then Load or generation lost by the control area = PL. Otherwise, the loss (PL) is zero. Sign convention for Load Loss is negative (-) and Generation Loss positive (+).

Step-5: The Control Area Response Δ P = (PB-PA) - PL

Step-6: The Frequency immediately before the disturbance = fA.

Step-7: The Frequency immediately after the disturbance = fB.

Step-8: Change in Interconnection Frequency from Point A to Point B = Δf = (fB - fA)

Step-9: Frequency Response Characteristic (FRC) of the Control Area = Δ P/ Δf

Step-10: Frequency Response Obligation (FRO) of each control area calculated in advance as per clause (C) of this Annexure

Step 11: Frequency Response Performance (FRP) = Actual Frequency Response Characteristic (AFRC)/ Frequency Response Obligation (FRO)

Table-III: FRC calculation sheet to be used by all SLDC/RLDC/NLDC/Control Area

S. No	Particulars	Dimension	Control area/Region
1	Actual Net Interchange of the control area before the Event $\mathbf{P_A}$ (Import +ve / Export -ve)	MW	
2	Actual Net Interchange of the control area before the Event $\mathbf{P_B}$ (Import +ve / Export -ve)	MW	
3	The change in net interchange of the Control Area $\mathbf{P_B-P_A}$ (2 - 1)	MW	
4	Generation Loss (+) / Load Throw off (-) during the Event in the control area $\mathbf{P_L}$	MW	
5	Control Area Response $\mathbf{\Delta P=(P_B-P_A) – P_L}$ (3-4)	MW	
6	Frequency before the Event $\mathbf{f_A}$	HZ	
7	Frequency after the Event $\mathbf{f_B}$	HZ	
8	Change in Frequency from Point A to Point B $\mathbf{\Delta f=(f_B-f_A)}$ (7-6)	HZ	
9	Frequency Response Characteristic $\mathbf{\Delta P/ \Delta f}$ (5 / 8)	MW/HZ	
10	Frequency Response Obligation (FRO) of each control area	MW/HZ	
11	Frequency Response Performance (FRP) = Actual Frequency Response Characteristic (AFRC) / Frequency Response Obligation (FRO) (9/10)	Numeric value (up to two decimal places) -	
Remarks			

VI. Frequency Response Performance Evaluation

- The performance of each control area in providing frequency response characteristic shall be calculated for each reportable event. Each control area shall separately assess their frequency response characteristic and share with RLDC along with high resolution data of at least one (1) second for regional entity generating stations and ten (10) second for state control area.

Frequency Response Performance (FRP) = Actual Frequency Response Characteristic (AFRC)/ Frequency Response Obligation (FRO)

- Each control area shall be graded based on median Frequency Response Performance annually (at least 10 events) as per following criteria:

Table-IV: Frequency Response Criteria

S. No	Performance*	Grading
1	FRP$\geq$ 1	Excellent
2	0.85 $\leq$ FRP < 1	Good
3	0.75 $\leq$ FRP <0.85	Average
4	0.5$\leq$ FRP < 0.75	Below Average
5	FRP <0.5	Poor

**Provided that for wind/solar generating stations and state control areas with internal generation less than 100 MW or annual peak demand less than 1000 MW, the FRP grading shall be indicative only.*

(sub-clause (a) of clause (10) of IEGC Regulation Annexure-2)

- NLDC, RLDCs and SLDCs shall grade the median Frequency Response Performance annually, considering at least 10 reportable events. In case the median Frequency Response Performance is less than 0.75, NLDC, RLDCs, SLDCs, as the case may be, after analyzing the FRP shall direct the concerned entities to take corrective action. All such cases shall be reported to the concerned RPC for its review.

Annexure-I

Reporting format for reporting of reportable event for FRC/FRP computation

1. **Date and Time of the Grid Event (ग्रिड घटना की तिथि और समय):** hh:mm:ss / dd-mm-yyyy

2. **Name of the Control area/Substation/Generating Station/Pooling Station Affected (सब-स्टेशन का नाम):**

3. **Brief Details of the Grid Event (ग्रिड घटना का संक्षिप्त विवरण)**:
   - **Description of the event in brief:**
   - **SPS operation details if any:** details of operation along with generation/load relief quantum during the event
   - **df/dt operation details if any:** details of operation along with load relief quantum during the event
   - **UFR operation details if any:** details of operation along with load relief quantum during the event

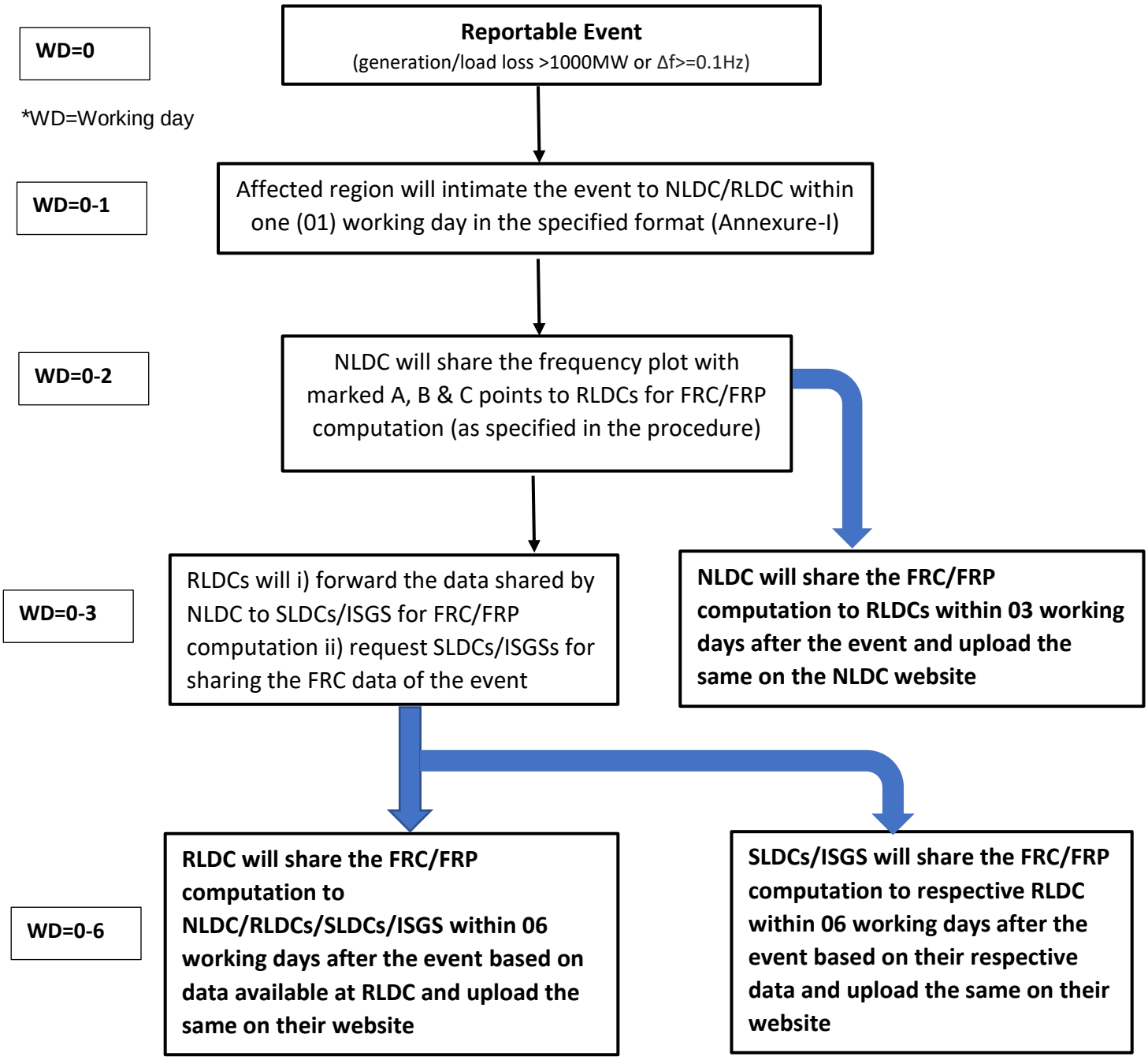
4. **Generation Loss/Load loss (MW) (उत्पादन/भार क्षति):**

   - RLDC of the affected region will share the Quantum of generation/load loss (MW) in Control area (as per SCADA/PMU) along with Time series data of affected control area/station.
   - In case of event of RE generation loss, quantum of recovery of RE generation during the PFR time period shall be shared. (MW vs frequency PMU plot)

5. **PMU/SCADA plots:**
   - PMU plot of frequency
   - SCADA/PMU plot of generation/load loss of affected control area/station
   - PMU data resolution- 40 milli second or better resolution, SCADA data resolution- 10 second or better resolution.

Annexure-II

Flow Chart for FRC Computation



The minimum all India Target FRC & FRO for all control areas shall be declared by NLDC by 15th of March of every year for the next financial year.