National Electric Power Regulatory Authority
Islamic Republic of Pakistan

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No. NEPRA/M&E/LAT-01/ 1451-235 August 18, 2017

Managing Director,
National Transmission & Despatch Company,
414-WAPDA House,
Lahore.

Subject: **Approval of Grid Code Addendum No. 1 (Revision-1) for Grid Integration of Wind Power Plants.**

Reference: *(i) No. GMT/NTDCL/TD-187/2542-50 dated 29.03.2017*
(ii) No. MD/NTDC/GMT/C&M/TD/187/2813-17 dated 07.07.2017

Enclosed please find Grid Code Addendum No.1 (Revision-1) approved by the National Electric Power Regulatory Authority for Grid Integration of Wind Power Plants as an applicable document of NEPRA.

DA/Addendum No. 1 (Revision-1) (15x Pages)

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(Syed Safeer Hussain)

CC: (along with copy of approved Addendum No. 1 (Revision-1) to the Grid Code)

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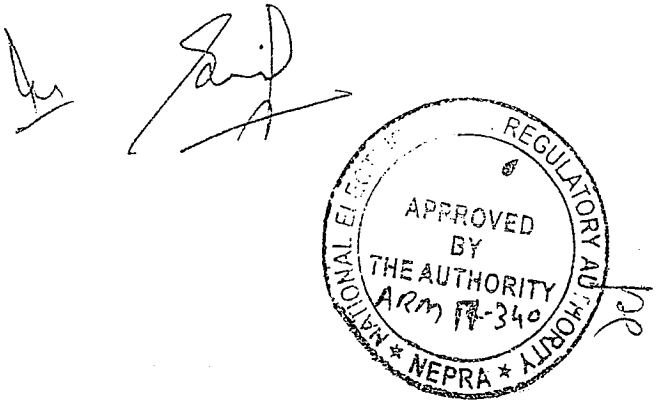
National Transmission and Despatch Company Limited (NTDC)

Grid Code Addendum No.1 (Revision-1)

Grid Integration of Wind Power Plants

AUGUST 2017



NTDC Grid Code Addendum No. 1 (Revision-1) for Grid Integration of Wind Power Plants

1. General

(i) This addendum is applicable only to grid-connected wind power plants.

(ii) This addendum becomes part of the Grid Code with immediate effect.

(iii) All other clauses of Grid Code, which are not covered by this addendum, if otherwise applicable as such, shall be applicable to Grid-connected Wind Power Plants.

(iv) All relevant clauses of Grid Code, which are covered through this addendum, shall be treated as amended as per this addendum.

(v) Any provisions of this addendum which have not been previously provided in the Grid Code, shall now form part of the Grid Code, applicable to Wind Power Plants including already Grid-connected wind power plants.

(vi) NEPRA may approve any subsequent modification to this addendum proposed by NTDC through the Grid Code Review Panel (GCRP). However, a Grid-connected Wind Power Plant may operate, for its full EPA term, in compliance to the Grid Code prevailing at the time of its financial closing.

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(vii) Notwithstanding anything contained in this Grid Code Addendum No. 1 (Revision-1) for Wind Power Plants, the Regulator may review, amend, modify or change the Addendum from time to time.

2. Definitions

2.1 Black Start
As defined in the Grid Code.

2.2 Fixed Speed WTG
A WTG, whose rotor speed depends on wind speed with no arrangements to vary thus determined speed.

2.3 Energy Purchase Agreement
The agreement, along with all schedules and annexures attached therewith, by and between the seller and the purchaser, for the purposes of sale and purchase of electrical energy from a power project.

2.4 Financial Closing
As defined in the relevant Energy Purchase Agreement (EPA).

2.5 Forecasting Error Rebate
This is the rebate that Seller would pay to purchaser against the error of forecasted Net Delivered Energy for a specified period as percentage of the Energy Payment invoiced by the Seller for the same period.

2.6 Grid Connected Power Plant
A power plant which can deliver electrical energy to the National Grid System /DISCO Systems.

2.7 High Voltage Ride Through (HVRT)
The capability of a generator to withstand the impact of high voltage swell, for a certain transient time, to remain connected to grid without being damaged, in case of external fault conditions.

2.8 Hybrid Generating System
A generating system in which the power plant utilizes more than one input power resources in order to overcome deficiencies in one or all resources.

2.9 Islanded Operation
Operational mode of a power plant in which it stands alone in generating electrical power and feeding a particular load with no other generator running in parallel.

2.10 Low Voltage Ride Through (LVRT)
The capability of a generator to withstand the impact of low voltage dip, for a certain transient time, to remain connected to grid without being damaged, in case of external fault conditions.

2.11 Net Delivered Energy
This is the net energy delivered to the grid at the Point of Common Coupling.

2.12 Pitch Control
The control which is capable of varying angle of blades of WTG thus changing energy perceived by WTG resulting in change of rotor speed.

2.13 Point of Common Coupling(PCC)
The point of connection for off-take of power from a Wind Power Plant to the network of Transmission /Distribution Company. It may also be termed as Point of Connection (POC).

2.14 Purchaser
As defined in Energy Purchase Agreement (EPA).

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2.15 Ramp Rate
Upper limit of a generator in terms of rate of increase of real power (MW/min).

2.16 Regulator
National Electric Power Regulatory Authority (NEPRA) established under Section 3 of NEPRA Act.

2.17 Retained Voltage
The value of voltage, normally in percentage of normal rated voltage, which persists at a particular point of a grid system in case of fault conditions.

2.18 Seller
As defined in Energy Purchase Agreement (EPA).

2.19 Strategic Generation Expansion Plan
Strategic Generation Expansion Plan covering all types and technologies of generation including all renewable resources and considering overall energy policies/priorities of Government.

2.20 Stuck Breaker Case
A case of fault condition at a grid system, in which the fault is not cleared by operation of the concerned breaker, being stuck, and is therefore cleared by the breaker(s) at zones other than faulty zone.

2.21 Term
The total period of Energy Purchase Agreement for sale and purchase of electrical energy.

2.22 Variable Speed WTG
A WTG having arrangements to vary its rotor speed.

2.23 Wind Farm Controller
Master controller of entire Wind Farm having supervisory control on all WTGs' local controllers and also controls all outputs/inputs to/from the Grid at Point of Common Coupling as shown in Figure-1

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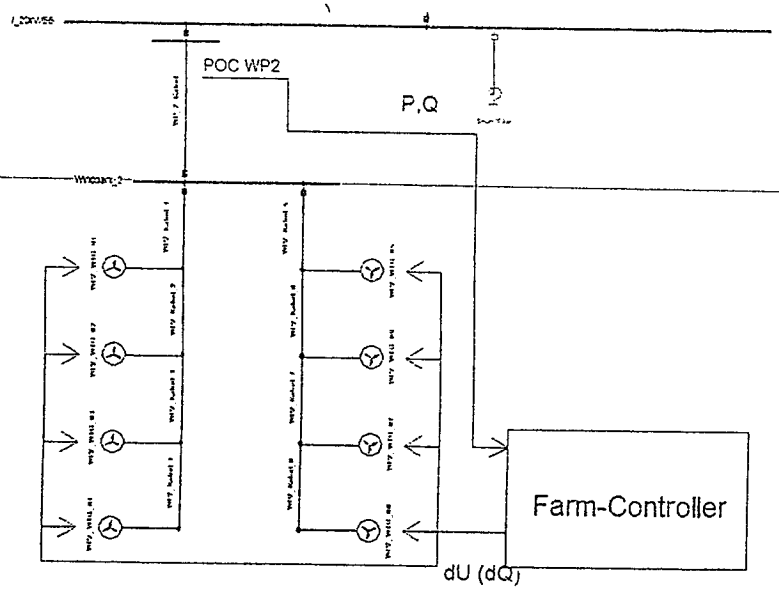

Figure-1

2.24 Wind Power Plant (WPP)
An installation including equipment and devices attached therewith, with the capability of converting kinetic energy of wind into electrical energy.

2.25 Wind Turbine Generator (WTG)
A set of turbine, generator and other devices, capable of converting kinetic energy of wind into electrical energy.

3. Wind Turbine Generator Technology Requirements

The criteria of Wind Turbine Generator (WTG) selection shall be based on compatibility with the National Grid System/DISCO Systems, improved operating performance, and optimal efficiency.

4. Generator Data Requirements

A grid-connected Wind Power Plant shall be required to provide "Generator Data" applicable to the type of the Wind Turbine Generator (WTG) being installed. In addition, the Wind Power Plant shall provide Standard Planning Data as outlined in the Grid Code to the extent applicable.

5. Black Start and Islanded Operation Requirements

A Wind Power Plant is exempted from Black Start and Islanded Operation for full term of Energy Purchase Agreement.

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6. Synchronization / De-Synchronization

(i) A Wind Power Plant shall, through appropriate necessary equipment be capable of managing, without feeling jerk(s) on the National Grid System / DISCO Systems, the following:

(a) Smooth synchronization
(b) Smooth de-Synchronization

7. Active Power and Frequency Control

(i) Grid-connected Wind Power Plants shall be exempted from the responsibility of frequency regulation and controlfor the "Frequency Sensitive Mode" which is defined by the range between 49.8Hz and 50.2Hz according to OC 4.8.1 (c, ii) of the Grid Code.

(ii) Above 50.2Hz, when frequency enters "Tolerance Frequency Band", with upper range defined as 50.5Hz according to OC 4.8.1 (c, iii), of the Grid Code, all the Grid-connected Wind Power Plants should contribute to a frequency stabilization by reducing active power as described in Figure-2 below:

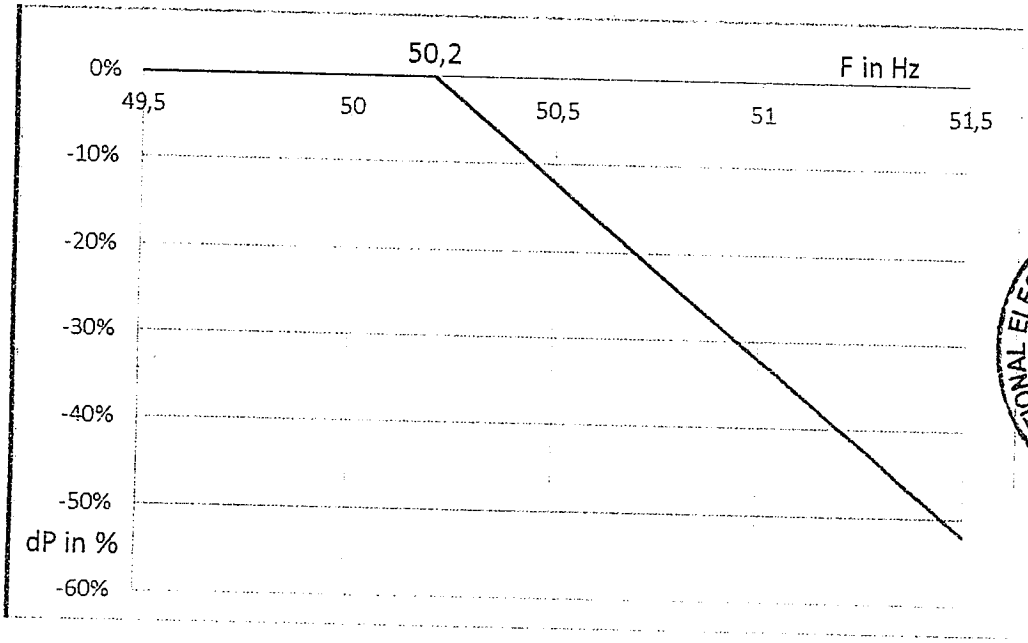


Figure-2

(iii) For under-frequency dips when frequency enters "Tolerance Frequency Band", with lower range defined as 49.5Hz according to OC 4.8.1 (c, iii), of the Grid Code, the Grid-connected Wind Power Plants of sizes of 49 MW and aboveshould have the technical capability for primary and secondary controland contribute to frequency stabilisation by maintaining appropriate active spinning reserve in proportion to available power of Plant dependant on availability of wind speed

(iv) For steady state frequency regulation,all Gird connected Wind Power Plants, shall be capable of managing the following, through Pitch Control, disconnection/connection operations of the WTG or any other control, as per dispatch instructions by System Operator (NPCC/RCC/or Any Licensed Dispatcher) :-

(a) Load adjustments in the range of zero to 100%of available power subject to availability of wind speed.

(b) A minimum Ramp Rate of 10 % of plant available power per minute subject to availability of wind speed.

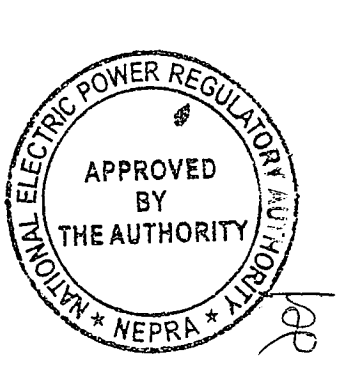
8. Reactive Power and Voltage Control

A Wind Farm Controller must be able to operate in power factor, reactive power or voltage control as follows:

(i) Power Factor:
A Wind Power Plant shall manage at the Point of interconnection the reactive power control to maintain the power factor within the range of 0.95 lagging to 0.95 leading, over the full range of plant operation, as per dispatch instructions and/or voltage adjustments/requirements within the above range of power factor.

(ii) Reactive Power
A Wind Power Plant shall manage at the Point of interconnection the reactive power control within the setpoints of Qmin and Qmax as Per Unit of full output of Plant as shown in Figure-3. The setpoints of Qmin and Qmax would be as follows:

Qmin = -0.33 P.U. of Full Output
Qmax = + 0.33 P.U. of Full Output



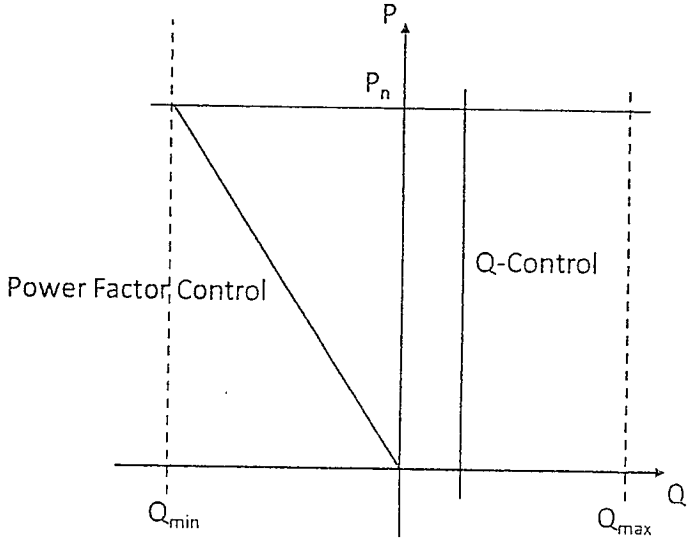


Figure-3

(iii) Voltage Control

A Wind Power Plant must control voltage at POC along a voltage vs. reactive power characteristic as shown in Figure 4. The following parameters are set as

- Voltage offset: ± 5 % under normal operating conditions and ± 10 % during contingency conditions.
- Reactive power offset: ± 0.33 PU of Full Output of Plant
- Droop (5 % of nominal voltage at max. reactive power)

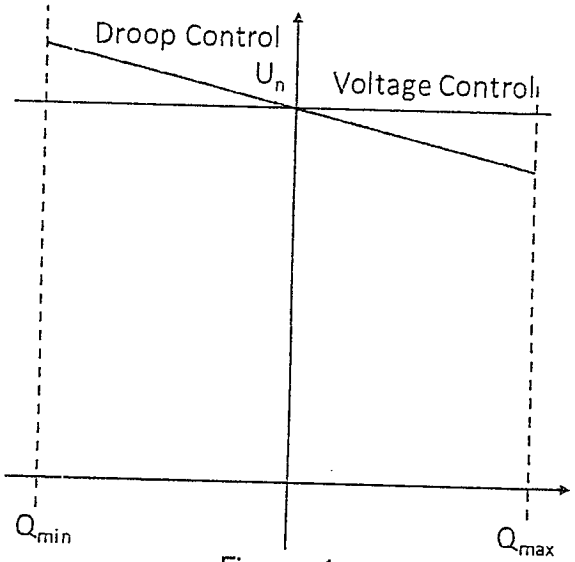


Figure-4

9. Power Quality Requirements

(i) Power quality parameters, of power output of a Wind Power Plant shall be governed, for full Term of Energy Purchase Agreement, by latest relevant IEC Standards (IEC61400-21 amended time to time) prevailing at the time of Financial Closing.

(ii) Power Quality parameters, for implementation of clause 9(i) shall be observed at the Point of Interconnection of the grid connected Wind Power Plant with the National Grid System/DISCO Systems.

(iii) For continuous monitoring of power quality parameters, a Wind Power Plant shall install and maintain necessary monitoring equipment, at its site.

10. LVRT/HVRT Requirements

(i) A Wind Power Plant must stay connected for transient short duration low voltage dips with slow recovery i.e. called Low Voltage Ride Through (LVRT), and short duration high voltage swells i.e. called High Voltage Ride Through (HVRT).

(ii) A Wind Power Plant must have the LVRT/HVRT capability as indicated in Figure-5. The WTGs are required to stay connected in the voltage envelope below the HVRT curve and above the LVRT curve.

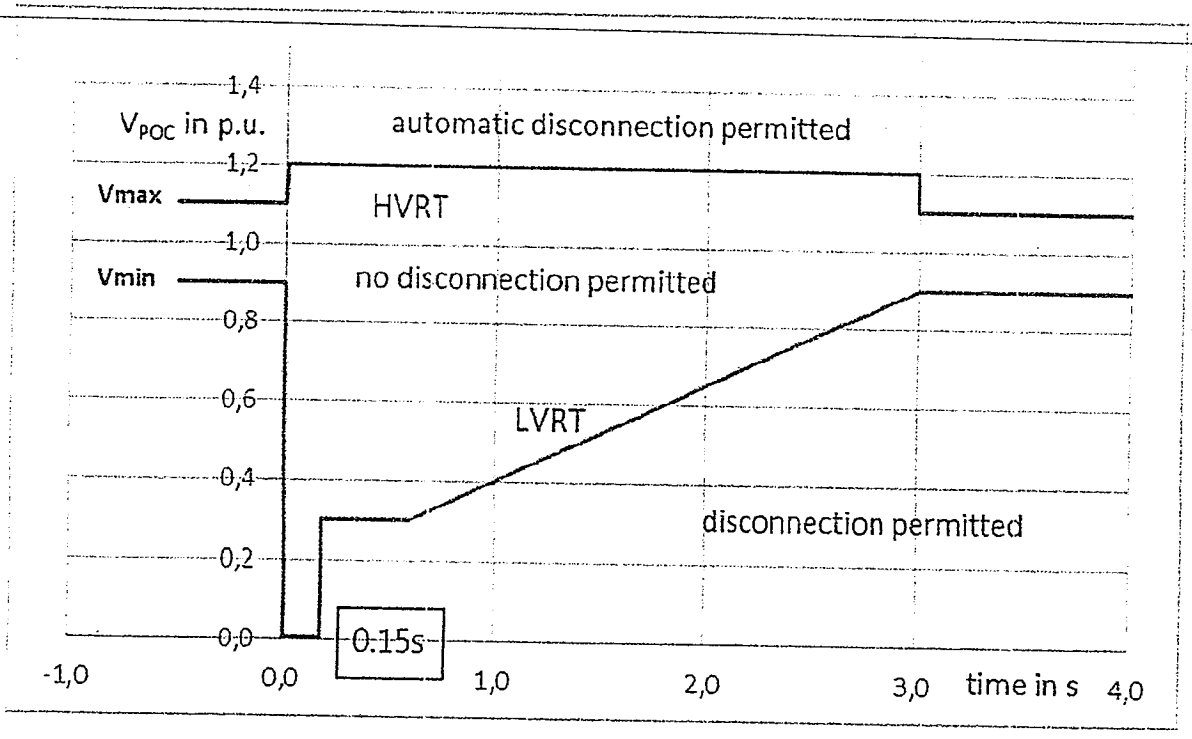


Figure-5

(iii) LVRT Requirements:
WTG must stay connected for

a. Zero Voltage i.e. Zero Voltage Ride Through (ZVRT) for the initial duration of 150 ms.
b. Recovered/Retained Voltage of 30 % for the next duration of 0.5s
c. Slow voltage recovery upto 0.9 PU in 3 seconds after occurrence of fault.
d. WTG may disconnect if the voltage dips below these limits for longer durations as specified in the envelope

(iv) HVRT Requirements:

a. Voltage swell upto 1.2 PU for the duration of 3 s.
b. Voltage recovers to 1.1 PU in 3 seconds after occurrence of fault
c. WTGs may disconnect if the voltage swells higher than this limit or for longer duration as specified in the envelope.

(v) Reactive current support during LVRT/HVRT situations:
In order to actively support voltage during low voltage situations (LVRT-situations), a Wind Power Plant must inject additional reactive current into the grid.
Likewise, in order to actively reduce the voltage and help keep the voltage within reasonable limits during high voltage conditions, a Wind Power Plant must absorb reactive current
The characteristics of reactive current support are indicated in Figure-6.

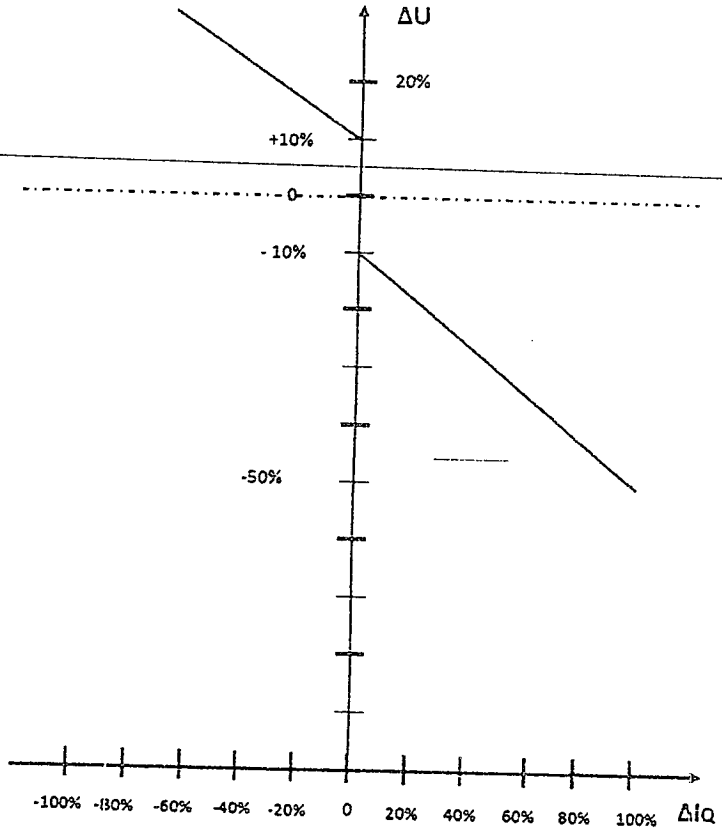


Figure-6

According to this diagram, a WTG will inject an additional reactive current (DIq in addition to the pre-fault reactive current) into the grid if the difference between post-disturbance and pre-disturbance voltage (DU) goes below -10%.

In the case that DU goes above 10%, a high voltage condition is identified and a DI will be absorbed in order to stabilize the voltage.

It is further recommended that DI is defined as being in proportion to DU (the factor of proportionality is then named "K").

Besides this, the definition of reactive current support shall include the following:

a) It applies to both, symmetrical and asymmetrical
b) Voltage and Current means, deviation of positive sequence voltage and currents post-fault from pre-fault values
c) The support is required at the generator terminals and not at POC because POC is almost impossible to implement
d) The value of is settable, 0<=K<=10 -> reactive current support can be disabled)
e) Dynamic performance requirement for this support is 60ms, well below minimum fault clearing times
f) The accuracy of reactive current injection within the tolerance band of +/-20% of the given value

g) The limitation of this current would be absolute current value to rated current

h) The minimum voltage threshold for the applicability of the reactive current support would be 10%, meaning that below a retained voltage of 10%, reactive current injection is not required.

(vi) The Wind Power Plant shall manage active power restoration, after the voltage recovery, at a rate of at least 20% of nominal output power per second, subject to availability of adequate wind speed at site. However active power recovery must not be faster than a rate of 50% of nominal power per second. The active power has to be ramped up to pre-fault level (or maximum available power), or at least to 90% of pre-fault level.

(vii) The Wind Power Plant must manage reactive power restoration, after voltage recovery, such that post-fault reactive power must not be below pre-fault reactive power with a minimum tolerance of 10 % and maximum delay time of 200 ms after fault clearance.

11. Signalling and Control

A Wind Power Plant shall establish bi-directional communication link with NPCC which would be interfaced with NPCC SCADA system
In order to allow the System Operator to monitor actual and forecasted power outputs of wind power plants and for ensuring that active power can be curtailed for congestion management and plants can be tripped in emergency situations, bi-directional communication links between the NPCC and the plant operator must be put in place and interfaced with the NPCC SCADA System.
In addition to active power control signals, voltage/reactive power control modes and setpoints have to be exchanged. For this purpose clear standards with regard to communication technology, interfaces with the System Operator's system etc. have to be specified in the EPA.
A signalling List is attached as Appendix-1

12. Power Generation Capability Forecasting Requirements

Forecasting of Net Delivered Energy from the Wind Power Plant would be carried out as follows:

(a) For and following the Commercial Operations Date, the Seller shall provide the forecasts of Net Delivered Energy to the Control Centre and to the Purchaser through the Forecasting Arrangement using state-of-the-art methodology as follows:

(i) **Hourly Forecast:** Not later than four (4) hours before the start of each hour, a forecast of Net Delivered Energy for the said hour, provided, the Seller may revise once, and only once, the forecast for the said hour no later than three (3) hours prior to the commencement of the hour for which the forecast is revised;

(ii) **Four Hourly Forecast:** Not later than eight (8) hours before the start of each four (4) hour period, a forecast of Net Delivered Energy for such four (4) hour period, provided, the Seller may revise once, and only once, the forecast for any four (4) hour period no later than six (6) hours prior to the commencement of the four (4) hour period for which the forecast is revised;

(iii) **Day Ahead Forecast:** Not later than twelve (12) hours prior to the beginning of each Day, the Seller shall notify the Purchaser (or revise any such information previously given) of the estimated net output of the Wind Power Plant in MWh which is likely to be generated for each hour of such Day;

(iv) **Month Ahead Forecast:** Not later than one (1) Week before the beginning of each Month, the Seller shall notify the Purchaser (or revise any such information previously given) of the Month ahead forecast of estimated net output of the Wind Power Plant in MWh which it is likely to generate for each Week of such Month; and

(v) **Year Ahead Forecast:** Not later than thirty (30) Days before the beginning of each Agreement Year, the Seller shall notify the Purchaser (or revise any such information previously given) of the year ahead forecast of estimated net output of the Wind Power Plant in MWh which it is likely to generate for each Month of such Agreement Year.

(b) The Hourly Forecasts (as may be revised in accordance with Section 12(a)(i)) shall be binding on the Seller.

(c) The Hourly Forecast Error shall be determined using the following formula:

$$(Hourly\ Forecast\ Error_h) = \left(\frac{((NDE_h + X) - (Forecast\ Energy_h))}{Contract\ Capacity \times 0.98}\right) \times 100$$

where;

$Hourly\ Forecast\ Error_h$	=	Hourly Forecast Error for the hour "h"
NDE_h	=	Net Delivered Energy for the hour "h"
$Forecast\ Energy_h$	=	forecast energy for the hour "h"
X	=	forecast energy not generated due to Non Project Events in the hour "h"

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(d) The Monthly Mean Absolute Error shall be determined using the following formula:

$$(Monthly\ Mean\ Absolute\ Error_m) = \frac{\sum_1^n (Hourly\ Forecast\ Error_h)}{n}$$

where;

$(Monthly\ Mean\ Absolute\ Error_m)$	=	Monthly Mean Absolute Error for the Month "m"
$(Hourly\ Forecast\ Error_h)$	=	Hourly Forecast Error for the hour "h" during the relevant Month "m"
n	=	*Number of Hourly Forecast Error$_h$ values during the relevant month "m"*

(e) The Annual Mean Absolute Error shall be determined using the following formula:

$$(Annual\ Mean\ Absolute\ Error_y) = \frac{\sum_1^n (Monthly\ Mean\ Absolute\ Error_m)}{n}$$

where;

$(Annual\ Mean\ Absolute\ Error_y)$	=	Annual Mean Absolute Error for the relevant Year "y"
$(Monthly\ Mean\ Absolute\ Error_m)$	=	Monthly Mean Absolute Error for the Month "m" during the relevant Year "y"
n	=	*Number of Monthly Mean Absolute Error$_m$ values during the relevant Year "y"*

(f) Should the Annual Mean Absolute Error exceed fifteen percent (15%) in the first year or the second year, and thereafter ten percent (10%) in any year in the Term, the Seller shall give a rebate ("**Forecasting Error Rebate**") to the Purchaser in the Seller's first invoice delivered to the Purchaser in the year next after the year for which the Forecasting Error Rebate is calculated, according to the following table:

Annual Mean Absolute Error Range	*Forecasting Error Rebate as percentage of the Energy Payment invoiced by the Seller*
15% to 25%	Ten percent (10%)
25% to 35%	10%, plus 1% for each 1% variation in excess of 25% upto 35%
Above 35%	Thirty percent (30%)

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However, Forecasting Error Rebate has to be capped at some level which would be agreed in the EPA.

13. Limitation on Total Grid Connected Wind Power Capacity

(i) This addendum allows integration of Wind Power Plants to National Grid /DISCO Systems upto a maximum total power limited to a value that does not deteriorate the overall quality of power of Grid Systems beyond international IEC Standards.

(ii) Initially, this upper limit is set to be equal to 5% of the total installed grid-connected installed power (MW) capacity. The process of future projects integration will be carried out as per planned capacity of respective future years.

(iii) A modification to above-mentioned allowable limit of total grid-connected wind power capacity shall be made in Strategic Generation Expansion Plan to be prepared by NTDC. Until then the limit as defined in Section 13 (ii) shall prevail.

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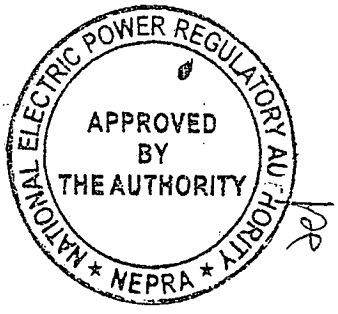
Signal List 1 – General

(1). The wind power plant operator shall make the following signals available at a System Operator designated communication gateway equipment located at the wind site:

(a). Actual sent-out (MW) at the POC
(b). Active Power Ramp rate of the entire wind power plant
(c). Reactive Power Import/Export (+/-Mvar) at the POC
(d). Reactive power range upper and lower limits
(e). Power Factor
(f). Voltage output
(g). Echo MW set point
(h). Echo Mvar set point
(i). Echo Voltage set point
(j). Protection relay operations
(k). Alarms, indicators and event updates



Signal List 2 – WPGF Availability Estimates

(1). Wind power plant operator shall make available the following signals at System Operator designated communication gateway equipment located at the wind power plant site:

(a). Available MW and forecast MW for the next 24 hours updated hourly on the hour (alternatively: 15min).
(b). Available range of Mvar capability for the next 24 hours updated hourly on the hour (alternatively: 15min)

Signal List 3 – WPGF MW Curtailment Data

(1).The wind power plant operator shall make the following signals available at a System Operator designated communication gateway equipment located at the wind power plant site:

(a). MW Curtailment facility status indication (ON/OFF) as a double bit point. This is a controllable point which is set on or off by the SO. When set "On" the power plant shall then clarify and initiate the curtailment based on the curtailment set point value below.
(b). Curtailment in progress - digital feedback. This single bit point will be set high by the power plant while the facility is in the process of curtailing its output.
(c). MW Curtailment set point value (MW- feedback).

(2). In the event of a curtailment, the SO will pulse the curtailment set point value down. The power plant response to the changed curtailment value will be echoed by changing the corresponding echo MW value. This will provide feedback that the power plant is responding to the curtailment request.

Signal List 4 – Frequency and Voltage response system settings

(1).The power plant operator shall make the following signals available at a SO designated communication gateway equipment located at the power plant site:

(a). Frequency Response System mode status indication (ON/OFF) as a double bit point.

(b). Voltage control system mode status indication (ON/OFF) as a double bit point.

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