OVERVIEW OF INDIAN WIND GRID CODE AND ITS COMPARISON WITH IRISH AND GERMAN GRID CODE

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Abstract—Electricity utilities across the world are launching newer wind power projects so as to meet environmental protection goal. Therefore as the penetration level increases, countries have formulated and implement new grid code meeting the challenging factors of wind power generation. In this paper Indian Wind Grid Code and practices are analyzed and comparison with Irish Grid and German Code is presented. Also, certain technical advancement is suggested in Indian Code.

Keywords—Indian Wind Grid Code; Irish Wind Code System (WECS), Low Voltage Ride Through (LVRT), Indian Electricity Grid Code (IEGC), Point of Common Coupling (PCC).

Introduction
India is having good potential of wind power as accessed by Centre for Wind Energy Technology (CWET). Wind power has been estimated on –shore potential of 102788MW at 80metre level [Source-National Institute of Wind Energy India]. In past decades, there is no any off-shore wind power plant envisaged in India. But with the passage of time, the manufacturing cost of wind turbines has been considerably reduced and Government of India is also promoted wind energy generation by offering various incentives. Detailed surveys have been conducted to access the wind power potential both at off-shore and on-shore. Now, a separate Off-shore policy has been framed by Govt. of India.

Earlier, the penetration level of wind power in Indian Power Grid is insignificant and is below 15%. Their scheduling was done as per Indian Electricity Grid Code, but didn’t participate in grid security. Therefore seeking the vide requirements of Wind Power, a grid code namely Indian Wind Grid Code was framed in 2009 and same is analyzed in this paper. Denmark is one of the pioneer country framed and incorporated Wind Code in year 2004.

Different countries frame wind code as per their requirement, some of them are having more penetration level like Denmark. Countries like Denmark, Germany, Spain, UK, Ireland, US & China are some of the pioneering countries which made significant progress in wind sector. Conventionally, wind power plants are of smaller rating and hence they didn’t participate in voltage or frequency stability control. But with the advancement of technology countries like spain have developed WPP to actively participate in voltage and frequency control for better grid operation under contingency conditions.
In response to latest grid codes, wind plant manufacturers are being modifying their design so as to meet the requirement of utility. Earlier Fixed speed WTG are manufactured which have no inherited facility to control reactive power but with the development of better control techniques, DFIG based WTG are manufactured which emulated inertia and injecting reactive power at the time of fault conditions. Thus aided Grid during pre-fault and post-fault conditions for maintaining stability at PCC. Common technical parameters for integration of WPP into grid are described briefly in respect of India, Ireland and Germany.

**TECHNICAL REQUIREMENTS IN GRID CODE**

The common objective of any wind code is to integrate wind power to grid with security and stability of supply. The common grid requirements of Indian Wind Grid Code are:-

**During Normal Operating Conditions [1]:**
- Frequency Band.
- Voltage Range
- Active Power Control
- Reactive Power Control.

**During Contingencies:**
- Low Voltage Ride Through
- Reactive power injection.

**Voltage Range:**

In Indian scenario, WPP should be able to inject power at PCC at one of the standard voltage level. The variations of voltage on negative and positive side are given in table 1 for different voltage levels.

<table>
<thead>
<tr>
<th>Nomin al(KV )</th>
<th>% of variation</th>
<th>Maximum m(KV)</th>
<th>Minimum m(KV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>+5% to -10%</td>
<td>420</td>
<td>360</td>
</tr>
<tr>
<td>220</td>
<td>+11% to -9%</td>
<td>245</td>
<td>220</td>
</tr>
<tr>
<td>132</td>
<td>+10% to -9%</td>
<td>145</td>
<td>120</td>
</tr>
</tbody>
</table>

| 110          | +10% to -12.5% | 121        | 96.25       |
| 66           | +10% to -9%    | 72.5       | 60          |
| 33           | +5 to -10%     | 34.65      | 29.7        |

**Table-1**

**Frequency Range:**

IWGC specifies the WTG to operate in frequency band between 47.5 Hz to 51.5 Hz. But within this range the active power deliver as per frequency response curve. Above 50.3 Hz the active power is limited to 50% of its rated capacity beyond that frequency sensing relays must shut down WTG. Figure-1 shows the graphical representation of active power curtailment with the variation of frequency within the permitted band.

<table>
<thead>
<tr>
<th>Percentage of Available Power</th>
<th>0%</th>
<th>50%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>47.5</td>
<td>50.3</td>
<td>51.5</td>
</tr>
</tbody>
</table>

Figure-2 represents the frequency requirements of Irish Grid code [2]. It indicates that WTG can operate continuously within frequency range of 49.5 to 50.5 Hz as represented by dark black area. Whereas WTG are allowed to operate only for one hour for frequency upto 47.5 to 52Hz, this is represented by Grey area. For frequency below 47.5 Hz to 47Hz they are permitted to operate only for 20sec.
Figure-3 presents the frequency requirement for German Code wherein which WTG are permitted to continuously operate in frequency band 49 to 51.5Hz. As compared to Irish code, this band is wider for operation. German Code give more flexibility for WTG to operate for frequency 48.5Hz to 51.5 at higher voltage, but machine can operate in this band only for 30minutes. Moreover for more frequency deviations till 46.5Hz operation time are reduced.

Active Power Control:
Active power control is a facility retained with WPP to adjust its active power output with respect to frequency deviation in grid and also as per instruction received from Transmission System Operator. With the help of Active power control, WPP can participate in primary and secondary frequency control. Although primary control in conventional thermal plants is supported by inertial of synchronous generator. In case of WPP they are having negligible mechanical inertia, but by virtue of control technique aided with Type-3 or 4 converters, inertia can be emulated [7].

Indian Code
Normally wind farms are scheduled on must run criteria and are not subjected to priority scheduling process. However, Grid Operator (TSO) may limit its generation under contingencies. Indian Grid code specifies wind farms to deliver 50% of their rated capacity at frequency 51.5Hz. IWGC requires that supplied active power must lie in range 0.95 lagging power factor to 0.95 leading power factor [3].
Indian Code also regulates ramping facility for wind farm with installed capacity greater than 50MW. Ramp control facility minimizes the deviation of active power injected at particular bus. Two types of ramp rates are applicable for maximum 10minute and 1 minute block. Table-2 shows the ramp rate limits for WPPs of different categories.

<table>
<thead>
<tr>
<th>Wind Farm Installed Capacity(MW)</th>
<th>10min Maximum Ramp(MW)</th>
<th>1min Maximum Ramp(MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50-150</td>
<td>Installed Capacity/ 1.5</td>
<td>Installed Capacity/5</td>
</tr>
<tr>
<td>150</td>
<td>100</td>
<td>30</td>
</tr>
</tbody>
</table>

Irish Code
The Transmission System Operator of Irish Grid keep track on power and frequency as in ABCDE points and do needful correction as per prevailing scenario. In order to participate WPP in frequency control, TSO are required to take control of ramp rate of active power in coordination with other stake holders.
Irish Grid Code signifies the ramp rate for one minute block should not exceed three times the average ramp rate for ten minute time block. Figure-4 shows the frequency power dependence for various conditions in Ireland Grid and directs WTG to shut-down in case frequency exceeds 52Hz.
German Code

This code states that, when prevailing system frequency exceeds 50.2%, WPP are required to curtail their active power injection with a rate of 0.4pu/Hz [4].

Reactive Power Control:

The prime requirement of any grid code is that WTG should support Voltage control in event of any disturbance at PCC. Type-1 WTG consumes reactive power during fault conditions and severely affected the Voltage stability of Grid. Hence Type-1 & 2 Wind turbine generator doesn’t participate in Voltage Stability. WTG equipped with Induction Generator consume near 35% of rated reactive power which is the major cause of voltage instability. This reactive power consumption can be countered by running capacitor banks or controlled SVC or STATCOM for better regulation of reactive power. Certain WTG are having self commutated drives which can maintain voltage and power factor by regulating Reactive power[5].

Indian Code

Since India is having large Power Grid but renewable are connected through weak links. Moreover, new transmission lines are being constructed to make it more stable and strong. India had made certain measure to support reactive power at WPP. Some of them are:-

- WPP requires to pay TSO for VAr drawl from grid when voltage is below 97%. At PCC
- WPP will get payment for supplying VAr to grid when the prevailing voltage is below 97%.
- WPP will get payment for draw VAr from grid when PCC voltage is above 103%.
- WPP need to pay for injecting VAr into the grid when PCC voltage is above 103%.

WPP are required not to inject grid VAr when the voltage is above 105% conversely they can’t draw VAr from grid when PCC voltage is below 95%. WPPs can provide VAr compensation facility by installing switchable capacitor banks. Indian code permitted 0.95 leading to 0.95 lagging operation of WTG [3].

German Grid Control

German Grid Code indicate reactive power control in form of area as function of voltage at One per unit and as a function of active power for the scenario when Wind Power Plant is producing power below 1PU. The dependency of voltage versus active power signifies behavior of reactive power [4].

Figure-5
Irish Grid Code

Irish Grid Code for reactive power control requires the WPP to be operated in the range 0.95 lagging to 0.95 leading for rated active power generation [2]. This requirement is equivalent to 0.33 pu reactive power on both lagging and leading side. Moreover, when active power is reduced below 0.5pu, reactive power requirements also decrease linearly till zero. The characteristics are drawn in figure 7.

Behavior under Grid Disturbance:

Indian Prospective

V/f relays installed at wind farms trigger the trip signal to isolate all WTG under grid disturbance conditions violating voltage and frequency limits. In Indian prospectus, Wind farms upto 66KV level get disconnected because LVRT facility is not mandatory upto 66KV.

All newly commissioned wind farms in India are equipped with Type-3 or 4 Generator having capacity of emulating inertia for enhancing stability [10].

Low Voltage Ride Through:

This feature is available with Wind Turbine Generator to remain synchronized with grid during disturbance. During Grid disturbance there will be experienced a voltage drop at point of common coupling (PCC) and wind farm connected to it may isolated resulting in further loss of generation. Conventional Wind Farms consume reactive power in event of fault, therefore causes furthermore voltage drop at PCC [6]. Indian Wind Code mandated the Wind farm to provide LVRT for 15% of nominal voltage for the minimum period of 300ms (66KV level).
German Grid Code
Within the black area no interruption is allowed. The wind power plant must remain connected even when the voltage at Point of Common Coupling is zero. The maximum time delay of 150ms is allowed for advanced numerical relay to operate.
If the voltage drop at PCC causes stability problem, a facility of short term interrupt in with resynchronization in maximum time of 2sec is permitted. This zone is represented by Dark grey area [4].
During contingency conditions, to support the reactive power requirements the current injected to grid is considerable reduced. For asymmetrical faults, the injected current can be reduced to 40% of rated [11].
Favorable Post faults conditions directs WPP to increase reactive power stepwise with the increase of active power with gradient of 20%/s. In case of short disconnection, active power injection is limited to 10%/s.
Figure-8 represents typical VRT characteristics of WTG under German Grid Code.

III. CONCLUSION
In this paper, the specific features of Indian Wind Grid Code were discussed for wind power integration. A comparative survey is done with other utilities already implemented and having good experience of large scale wind power penetration.
Indian Wind Grid mandates the Low Voltage ride through facility to be mandated for WPP of capacity above 30MW. As the penetration level of wind power in power sector is being increasing with fast rate, addition of resynchronization mechanism may further strengthen VRT mechanism and WPP can more or less participate in frequency control. Several parameters of Indian Wind Grid have been extracted from Irish Code. Since Irish Grid code is also a matured version of experiences and practices of wind integration in Ireland, several other features of VRT from German Code are also useful from Indian scenario.

VII. REFERENCES
1858-1872.
[10]Jacob Aho et al,” A Tutorial of Wind Turbine Control for Supporting Grid Frequency through Active power Control” IEEE.