A study on transmission level voltage profile of NER Grid & practices of controlling it with existing resources

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SYNOPSIS

One of the key concerns of the system operators is to maintain the system voltage within safe limit as the transmission network security is closely associated with the system voltage profile as well as it ensures the proper voltages at the distribution levels. As the voltage is a local phenomenon, it is prudent to control the bus voltages by providing reactive power resources locally, rather than making it to flow through the Grid. Various options like reactive power control by Generators, Reactor/Capacitor switching, EHV Line switching, HVDC power order adjustment, etc. are being explored by the system operator to control the grid voltage within the band stipulated by regulations.

This paper gives a brief overview of the transmission level voltage profile of North-Eastern Regional Grid and analysis is done on the characteristics of the voltage profile including graphical representation of voltage data throughout the year. The present processes and practices adopted by the operators to control the transmission level voltage and the effect of those methods on other aspects of the system are discussed. Other practices that may be adopted for voltage control by doing possible improvement in existing resources in the region is suggested.

KEYWORDS:

IEGC, HVDC, Power order, Low fault level, AVR, RPC, Synchronous Condenser, FACTS, SVC, STATCOM

1. INTRODUCTION

North-Eastern Region is the smallest among all the five Regional Grid of India with high Hydro potential in the region.Fig.1 shows the total installed capacity in the region as on 31st March, 2018. The share of hydro in the portfolio of North-Eastern Region is around 38%. Unlike the Thermal units whose generation

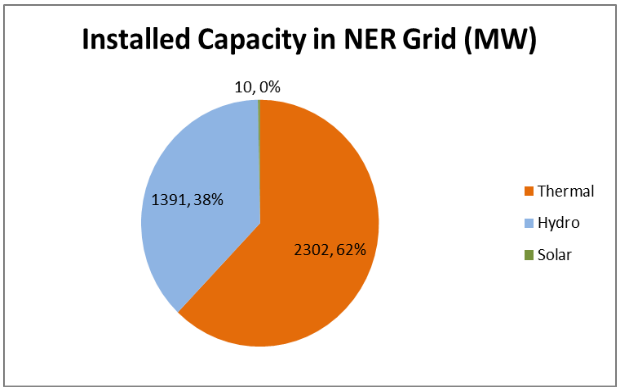

Fig. 1: Installed Capacity of NER

remains more or less consistent throughout the year, generation from Hydro units depend mostly on the rainfall, which varies from season to season throughout the year.

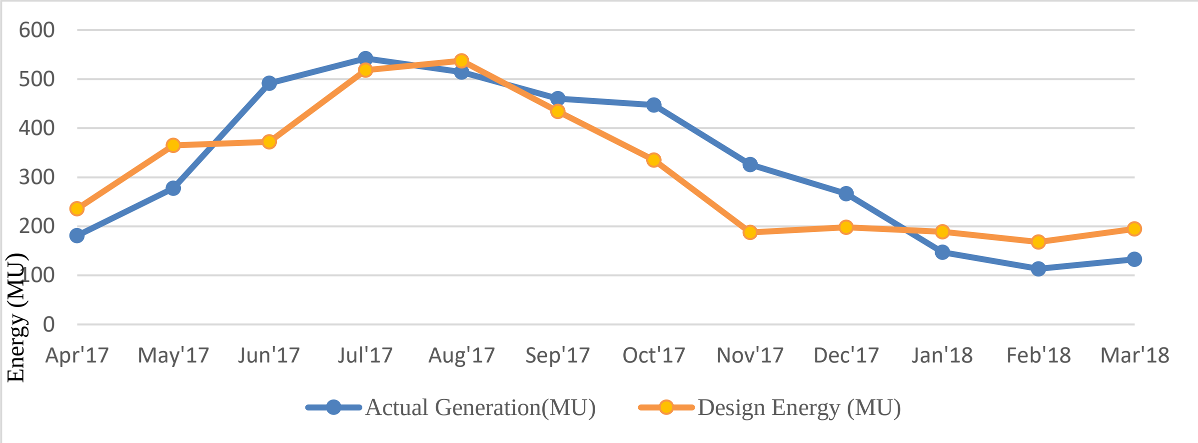

Fig. 2: Actual Generation v/s Design Energy of NER ISGS Hydro Units for FY2017-18

Fig. 2 shows the Actual energy (MU) vs Design energy (MU) of NER ISGS Hydro units for FY2017-18. From the plot, a substantial variation in monthly energy generation (MU) and design energy (MU) of NER ISGS Hydro stations at Peak (May-October) and Lean (November-April) rainfall period of the year may be observed. Among all the Hydro stations, Ranganadi Hydro Electric Project (RHEP) is the largest Hydro generating station in the North-Eastern Region with an Installed Capacity of 405 MW (3*135 MW) out of total 860MW ISGS Hydro installed capacity of NER as on 31st March'2018. Since RHEP happens to be a run-off the river type Hydro Station, so its water level and hence generation primarily depends on the seasonal rainfall. All other Hydro generating stations have storage capacity, which reduces the impact of seasonal rainfall variation to some extent. Other state sector Hydro Stations in the NER also dictate more or less similar patterns.

2. VOLTAGE PROFILE OVERVIEW AND ANALYSIS.

400kV Bongaigaon Substation is one of the most important Station of the region as it is the

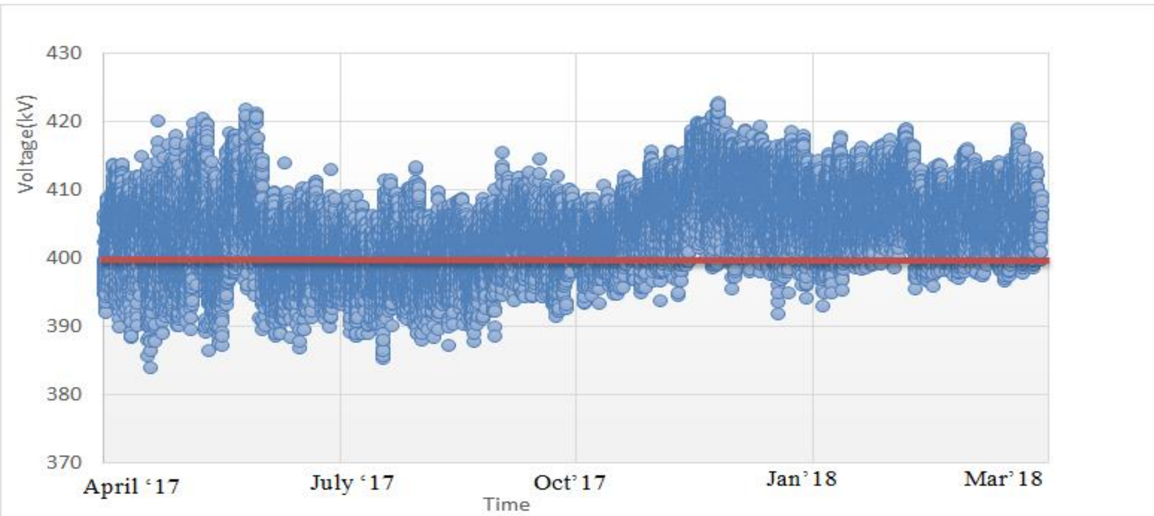

Fig. 3: Voltage profile of 400kV Bongaigaon Bus for FY17-18

gateway to the all India Grid. Bus voltage plot of the Bongaigaon substation is shown in Fig.3 for the FY 2017-18. The interpretation that may be derived from the plot of 400kV Bongaigaon Bus voltage plot is that average voltage during lean hydro season remains on the higher side as compared to the same in peak hydro season. In other words, voltage profile of NER is considerably influenced by seasonal variations of hydro generation.

Daily demand pattern of the Region during off-peak hours is generally around 40-60% of the peak demand of NER grid and also the fault level at the most of the 400kV Buses of the region are relatively low. These factors lead to a wide variation of voltage profile throughout the NER Grid in a day. Fig .4 shows the geographical locations of the NER Grid where over voltage during the off-peak hour is more prominent and this is that part of the NER Grid where conventional voltage control practices are carried out more often to contain the voltage within permissible limit. So, voltage profile analysis in this paper is done focussing on this part of the region.

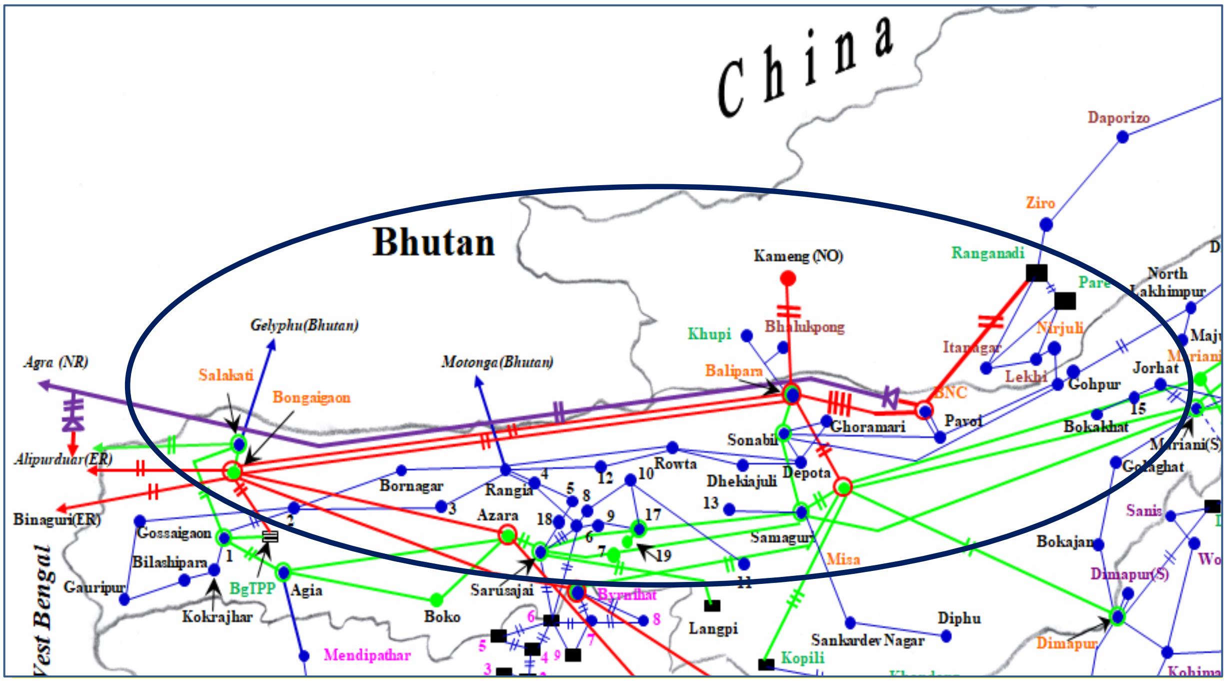

Fig. 4: Geographical map of NER Grid showing overvoltage prone area

3. MEASURES OF VOLTAGE CONTROL AND THEIR EFFECT

The modus operandi to control the transmission level voltage in the region within the band stipulated in IEGC [1] is as follows.

3.1. Reactive Power Support by Generators

Generating units can absorb or inject reactive power within respective capability limits without sacrificing active power and thus can help in regulating the voltage locally in the Grid. Automatic Voltage Regulator (AVR) present in the Generating unit helps in regulating the local bus voltage as per its settings. As quoted in the IEGC, all generating units shall normally have their automatic voltage regulators (AVR) in operation [1]. In NER Grid, during peak hydro season when more generating units remain on bar as compared to lean hydro season, the requirement of other voltage control measures to regulate Grid voltage gets reduced.

3.2. Power Order change of +/-800kV BNC-APD-AGRA HVDC link

The AC filters of +/-800kV BNC-APD-AGRA HVDC link at 400kV Bus of BNC Substation serve the dual purpose of filtering out AC harmonics and provide reactive power support to the converter. As the number of filter present in service depends on the power order of the HVDC link and number of pole in service, so by controlling the power order or the number of pole in service, AC voltage of BNC Bus and other nearby Bus can be controlled.

The Reactive Power Control (RPC) for the HVDC Poles at BNC substation is kept in manual mode most of the time and so the removal of filter during power order reduction is done manually. Table 1 shows the impact of switching a filter on voltage at 400kV BNC Bus.

Table 1: Impact of Filter switching on voltage

Filter Type	Filter Size(MVAR)	Fault Level of BNC Bus*(400kV)	Voltage Change(kV) at 400kV BNC Bus
HP12	125	5723	7.92
HP12B	160	5723	10.14
HP24/36	125	5723	7.92
HP3	159	5723	10.07

*Based on PSSE study of POSOCO all India Base Case as on December,2018

3.3. Switching of Reactors

Line Reactor and Bus Reactor are placed strategically at EHV line and EHV substation respectively. During high voltage condition in the Grid which generally occurs at off-peak hour, Reactors are kept in service so as to consume the excess reactive power generated by lightly loaded lines and to reduce the voltage of the line or bus. The change in voltage at a bus due to switching of a reactor is given by

$$\Delta V/V = \Delta Q / \text{Fault Level of the Bus}$$

Units: Δ V & V (kV), Δ Q (MVAR of Reactor), Fault Level (MVA)
Table 2 shows the impact of reactor switching on voltage change of the corresponding bus at 400kV Bus of Bongaigaon, Balipara and Misa Substation.

Table 2: Impact of reactor switching on voltage

Rector Size (MVAR)	Bongaigaon Bus(400kV)		Balipara Bus(400kV)		BNC Bus(400kV)	
	Fault Level* (MVA)	Change in Voltage(kV)	Fault Level* (MVA)	Change in Voltage(kV)	Fault Level* (MVA)	Change in Voltage(kV)
50	11802	1.53	6356	2.84	5723	3.16
63	11802	1.93	6356	3.59	5723	3.99
80	11802	2.45	6356	4.57	5723	5.07
125	11802	3.84	6356	7.13	5723	7.92

*Based on PSSE study of POSOCO all India Base Case as on December,2018

Since the Fault Level of most of the EHV Bus in NER Grid is on the lower side so impact on voltage due to reactor switching is considerably high. During low voltage condition, opening of a Line or Bus Reactor help in improving the voltage profile. As most of the 400kV substations in the region are configured as one and half breaker scheme, so opening a Bus Reactor renders loss of a diameter which impacts system reliability. Similarly, Line Reactor, which has Neutral Grounding Reactor (NGR), in opened condition affects the secondary arc extinction process in case of ground fault in the line and thus impacts on the probability of successful auto-reclosing. [2]

3.4. Switching of Lightly loaded Lines

Opening of lightly loaded EHV line in case of very high voltage situation is the last resort adopted by the grid operators to control the voltage as lightly loaded lines contribute towards the high voltage build-up due to reactive power generated by line shunt capacitance. Table 3 indicates the reactive power generated by shunt capacitance of 400kV lines of NER Grid, which are switched frequently for controlling grid voltage.

Table 3: Reactive power generation by the shunt capacitance of 400kV lines

Line	Type of conductor	Length (km)	Reactive Power generated by the line(MVAR)
400kV Bongaigaon-Balipara I or II	ACSR Twin Moose	289.7	160.78
400kV Bongaigaon-Balipara III or IV	ACSR Quad Moose	304.6	225.4
400kV BNC-Balipara I or II	ACSR Twin Moose	60	33.3
400kV BNC-Balipara III or IV	ACSR Twin Moose	57.1	31.7
400kV Ranganadi-BNC I or II	ACSR Twin Moose	131	72.7

Similarly, closing of these lines (if opened during high voltage situation) during low voltage condition is the first resort adopted to improve the system voltage.

Opening of lines results in decrease of system reliability. But, due to lack of sufficient reactive power resource or due to outage of other existing resource, lightly loaded EHV lines are opened to reduce voltage during high voltage situation.

400kV transmission line backbone in NER Grid consists of following four major corridors.

1. 400kV Bongaigaon – New Siliguri D/C & 400kV Bongaigaon - Alipurduar D/C
2. Two no. of 400kV Bongaigaon - Balipara D/C
3. Two no. of 400kV BNC - Balipara D/C

4. 400kV BNC - Ranganadi D/C

Lightly loaded 400kV lines are opened on daily basis to regulate the voltage in the system within the band stipulated in IEGC.

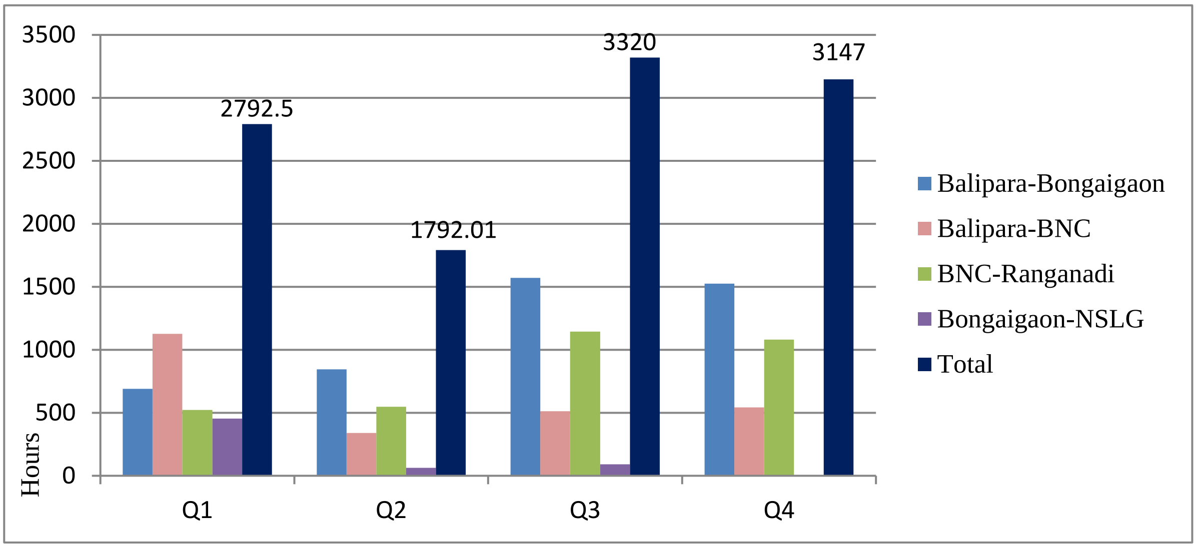

Fig. 5: Quarterly Outage hour of 400kV lines for voltage control during FY2017-18

Fig.5 depicts total quarterly outage hour of lines from four significant 400kV corridor of NER Grid during the FY17-18. It may be observed from Fig.5 that outage hour of 400kV lines for voltage control in NER Grid is comparatively more during lean hydro season as compared to peak hydro season.

4. LONG TERM MEASURES OF VOLTAGE CONTROL : HYDRO GENERATOR AS SYNCHRONOUS CONDENSER

High Voltage situation in NER Grid generally arises during off peak season due to non-availability of Hydro generation resources. In such situation, operating Hydro generators in synchronous condenser mode may be a possible way for voltage control with the existing resources, which may be explored to regulate voltage in Grid locally and thus preventing the switching of other elements for voltage control purpose, which in turn help in keeping the system reliability intact. The clause 9 of subsection A1 of Part II of Central Electricity Authority (Technical Standard for Connectivity to the Grid) (Amendment) Regulations, 2012 states that Hydro generating units having rated capacity of 50 MW and above shall be capable of operation in synchronous condenser mode, wherever feasible; provided that hydro generating units commissioned on or after 01.01.2014 and having rated capacity of 50 MW and above shall be equipped with facility to operate in synchronous condenser mode, if necessity for the same is established by the interconnection studies[3].

A synchronous condenser is a synchronous machine running without a prime mover or a mechanical load. By controlling the field excitation, it can be made to either generate or absorb reactive power. Synchronous condensers have several advantages over static compensators. Synchronous condensers contribute to system short-circuit capacity. Their reactive power production is not affected by the system voltage. [4]

Among the Hydro generating units in NER system, the feasibility of Ranganadi Hydroelectric Plant (RHEP) (3*135 MW) for using as synchronous condenser can be studied considering its location in the high voltage zone of NER Grid. Nameplate details of turbine and generator of RHEP are mentioned in the Table 4.

Table 4: Nameplate details of RHEP turbine and generators

Turbine		Generator	
Type	Vertical Francis	Type	Semi Umbrella
Rated Output(kW)	14540	Rated Output(MW)	135
Design Head(m)	304	Voltage(kV)	11
Net max/min head(m)	322/290	Current(A)	7800
Efficiency at full load	93.11%	Power factor	0.9 lag
Make	BHEL	Efficiency at full load	98%
Specific speed(rpm)	44.75		
Rated Speed(rpm)	300		
Runway speed(rpm)	490		

To use a Hydro Generator in Synchronous Condenser mode, all that is required is a means of accelerating the generator to synchronous speed and a means of detaching the prime mover from the generator after electrical synchronization has been achieved. The hydro unit can be started and accelerated up to synchronous speed either by using the prime mover or using a prony motor with necessary control circuit. This leaves the generator being driven (motored) by the electrical system and running at synchronous speed.
According to data of the All-Union Planning, Surveying, and Scientific-Research Institute (Gidroproekt), difficulties can occur in the effective expulsion of water from mixed-flow turbines at high-head hydro stations (heads of more than 200 m), in which case it may be required to close the gate ahead of the turbine during the entire time of the synchronous condenser regime [5]. So, the hydro generating units like that of RHEP which has Francis (mixed flow) turbine and design head of 304 meter are required to be equipped with devices for closing the gate along with the modification in control and protection system for switching to a synchronous condenser mode.

5. CONCLUSION

This paper presents a review on the practices followed for controlling voltage profile in NER Grid within the band stipulated by the Regulator during the lean and peak hydro season. Pros and cons of each of the voltage controlling measures have also been presented. On the other hand, additional measures that can be adopted with the existing asset like using hydro generating units as synchronous condenser etc. are discussed. With increasing complexity of the Grid as well as increasing energy consumption, reactive power resource planning is becoming more prominent. Proper study may be carried out to install FACTS devices like Static VAR Compensator (SVC), Static Synchronous Compensator (STATCOM) etc. for better or smooth control of voltage profile throughout the Grid.

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