Large Scale Battery Storage for Grid Stability / Backup

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***Abstract*— Large scale battery storage systems (LSBS) are becoming essential because of the increasing share of Renewable energy. The system can be connected `Behind the Meter' or to the grid independently or along with a Renewable energy source. The `Behind the meter' / Captive storage reduces the diesel consumption in DG sets and the grid connected systems are meant for frequency control. Steag recently installed one of the largest LSBS, (90 MW size) that has around 120 MWh Li-ion Batteries for primary frequency control of the grid in Germany. Earlier, Steag installed a, One MW storage in 2009 as an R&D and pilot project. The systems are grid connected. When the grid frequency is going down, the battery supplies to the grid and when the frequency is going up, the battery starts storing. The batteries are kept at half charge status to accommodate both plus and minus frequency variation. Steag invested around 100 Million Euros in this project. The authorities invite weekly bids for hiring such LSBSs. The payment is for making the system available for the period and has no relation with the amount of energy flowing in / out of the battery. The projects are economically viable without any subsidies. Since the renewable share is increasing very fast in India, such systems can to be deployed for primary frequency control as well as other applications. Although, the grid conditions and requirements are different but the solution can be adopted. The applications for India could be:1) Primary frequency control, 2) Behind the Meter / captive, 3) With Renewable generation sources (wind and solar)**

There is scope for technical learning and regulatory and policy learning from this German project for application in India.

Keywords-Battery Storage; Grid Stability; Power Backup;

I. Introduction

The Battery systems are becoming essential to stabilize the grids in view of the increasing share of Renewable energy worldwide. The batteries can be connected `Behind the Meter' or to the grid independently or along with a Renewable energy source. The `Behind the meter' / Captive storage reduces the diesel consumption in DG sets while the grid connected systems are meant for frequency control.

STEAG GmbH recently installed a Large Scale Battery Storage (LSBS) system of 90 MW size for primary frequency control of the grid in Germany. The system has around 120 MWh Li-ion Batteries. The systems are grid connected. STEAG invested around 100 Million Euros in this project. Such projects are economically viable without any subsidies. Earlier STEAG had developed a large-scale battery (1 MW capacity) in the R&D-Project, LESSY (Lithium-Ion Electricity Storage System). LESSY had been installed at the Völklingen-Fenne power plant and has been operated for primary control power since February 2014.

Since the renewable share is increasing very fast in India, the need for quick and automatic frequency control could be felt very soon. Such LSBS can then be deployed for primary frequency control as well as other applications. Although, the grid conditions and requirements are different, the solution can be adopted. This paper shares STEAG's experience from this important project.

II. Need for the system

Currently, the share of energy from renewable sources in Germany is about 30%. With further aggressive approach, this percentage is likely to increase to 55 - 60 percent by the year 2035. In India this percentage is rather small currently with an installed capacity of 37 GW (solar plus wind) in a total grid size of 315 GW as of Feb 2017. However, with a target of 175 GW by 2021-22, the infirm power percentage could become a significant proportion of the overall grid size. At that stage, it would result in fluctuations in the grid – since the production of solar or wind power is uneven and cannot be precisely forecast. Such fluctuations and grid disturbances must be compensated for immediately, so a system is required which automatically responds to the frequency change. Such a system is often referred to as Primary Frequency Control.

Outside of India, traditionally, the Primary frequency control power had been predominantly supplied by conventional power plants because photovoltaic systems and wind turbines were unable to do so owing to no spare capacity and no rotating inertia. Also, since the share of conventional energy shall be reducing in the long run, the ability of conventional power plants to keep supplying the frequency control power will keep diminishing. Therefore, there is a need to look for alternate systems to provide choice for Primary Frequency Control power.

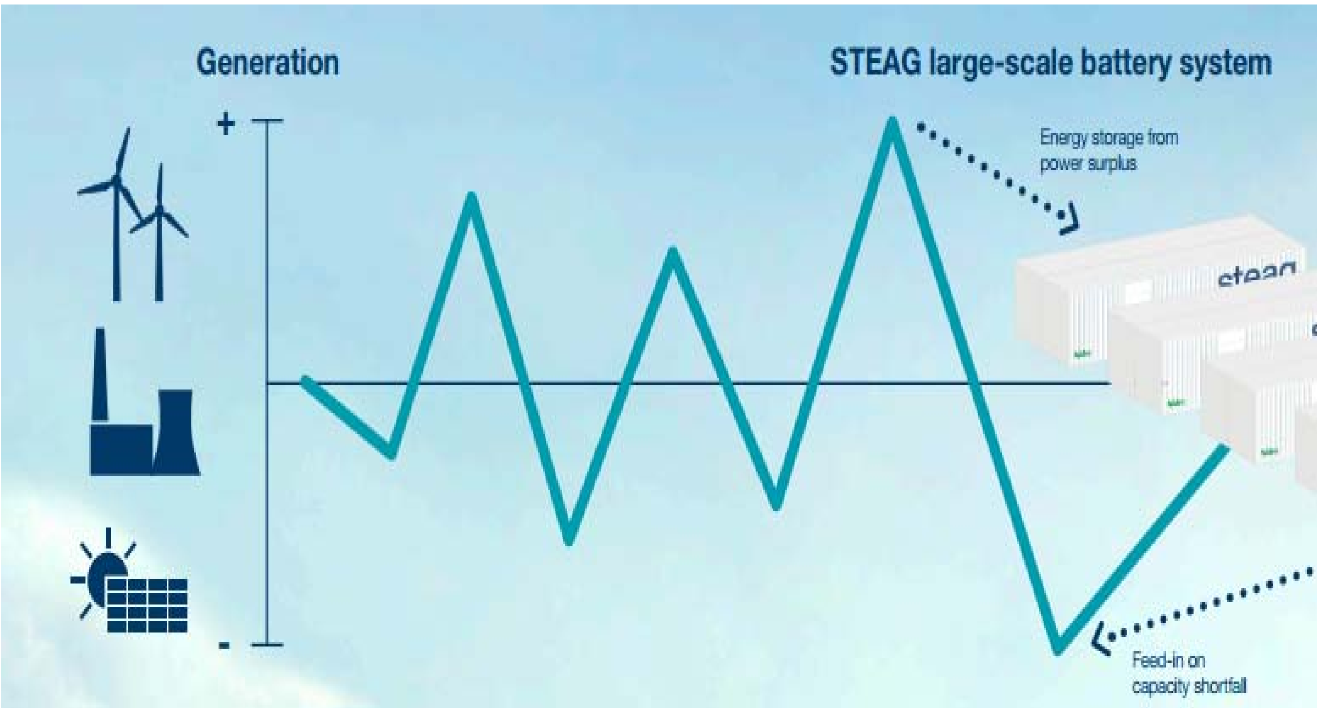

Figure 1. Battery storage for primary frequency control

III. Battery storage for Primary Frequency Control

When primary control power is supplied by conventional power plants, those plants have to generate a certain minimum load at all times and burn coal, oil or gas. In the case of large-scale batteries, this is not necessary. Consequently, valuable resources are conserved, CO2 emissions are reduced and costs are lowered. Also, the frequency response of the battery based system is much faster. The batteries are able to store electricity from the grid or feed electricity into the grid in a matter of seconds, compensating for the fluctuations, therefore battery becomes a natural choice for primary frequency control power.

The basic principle of frequency control using batteries as shown in “Fig. 1” is as follows:

When the grid frequency is going down, the battery supplies to the grid and when the frequency is going up, the battery starts storing. The batteries are, to the extent possible, kept at half charge status to accommodate both plus and minus frequency variation.

IV. Key facts regarding STEAG LSBS Project

The STEAG 90 MW LSBS project is in the form of six installations of 15 MW each providing a capacity of plus or minus 30 minutes. These are located at six conventional power plant locations belonging to STEAG GmbH across Germany. The co-location with conventional power plants does not mean that they are anyway connected to the plant. In fact, they are connected to the grid directly. Each 15 MW system (as it is referred to) actually has a battery bank of around 20 MWh. Latest generation, high efficiency lithium-ion batteries supplied by L.G. have been used. They are optimally suitable for operation at medium charge, which is necessary for the provision of primary control power.

The salient features of each installation are as follows:

- 10 battery storage units each in a container including:
- Auxiliary units such as heating, air conditioning, on-site power and 400V AC auxiliary supply
- 4-Quadrant-Power Converters with network filter (Bi-directional AC/DC power converting system)

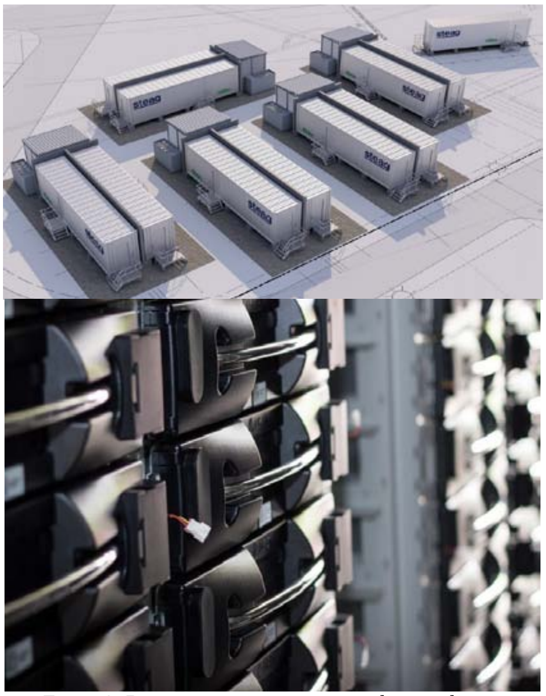
Figure 2. Battery storage containers and internal view

- 1 container housing as shown in “Fig. 2”, the electronic control unit with superior control & communication technology for
- Operation and monitoring
- Protection and control
- Hierarchic protection and surveillance system
- Connection to grid at 10kV
- Capacity to provide primary frequency control reserve for 30 minutes according to the requirements of the TSO

V. Large Scale Battery contribution in Ancillary services

In Germany, the so-called “ancillary services” include maintenance of frequency stability, maintenance of voltage stability, restoration of supply after failures and operational management. Battery systems are a fundamental element of the energy transition, in particular as a safeguard for system stability and system security, as they are able to contribute to the various ancillary services like -

- Maintenance of frequency stability ensures the balance between generation and consumption. Initially, this task is performed by the instantaneous reserve which is currently provided by the inertia of the rotating masses of the generators in large conventional power plants; this ensures that frequency variations are damped before control power is deployed.
- Maintenance of voltage ensures that the stability and the nominal system voltage do not exceed defined limit values. For this purpose, reactive power and short-circuit power are supplied as necessary.
- In the event of a large-scale power failure, the ability to restore supply is a crucial property of the electricity system. With the assistance of power plants with black start capability, the responsible system operator must be able to supply its system area with electricity in a controlled manner.
- Operational management mainly includes the monitoring of all generators and consumers connected to the electricity system as a whole; this task is performed by the TSOs, which detect any faults and initiate appropriate countermeasures. This also includes congestion management and feed-in management.

In Germany, at present, only the supply of control power for frequency stability is put out to tender. All other ancillary services, such as the provision of reactive power or maintenance of voltage stability are solely requested by the responsible TSO from conventional power plants. To ensure that such ancillary services can likewise be offered by all players participating in the ever more distributed generating environment of the liberalized electricity market, it is necessary for new markets to be established on which the individual ancillary services are put out to tender, similarly to the control energy market. This will enable facilities such as battery systems to be developed for the specific application case and operated profitably. For India also, the first step in the ancillary services could be the Primary frequency control. The market for other services could be seen later but can be kept in the overall master plan.

VI. Frequency control mechanism in German Grid

When the actual system frequency deviates from the nominal frequency of 50 Hz, primary control power, secondary control power and tertiary control power (minute reserve) are deployed one after the other in order to stabilize the system.

Primary control power is activated fully automatically, triggered by the deviation of the actual frequency from the nominal frequency of the system. In order not to utilize the primary control power capacity fully, secondary control power comes in and replaces primary control power supply after 5 minutes. Thus the primary control capacity is available for new frequency upsets. The higher-level controller of secondary control power supply control zone ensures that the planned exchange of electricity with other control zones is restored and the frequency deviation is compensated for. In this context, the frequency deviation is mathematically converted into an adjustment set point, which is then systematically and jointly met by the generator sets deployed for secondary control power supply in the integrated grid control system. The sources of secondary control power could be Pumped storage units, Large gas and coal plants, Biogas, Biomass etc. In order to ensure that the secondary control range is kept available, secondary control power is replaced by minute reserve power (tertiary control) if the frequency deviation persists. Minute reserve power is a scheduled product that is manually or automatically requested by the respective connecting TSO and is fully activated within 15 minutes from the moment the request was issued.

A. *Primary Frequency Control market*

As of March 2017, a primary control power volume of ±1300 MW is put out to tender in weekly auctions via an internet platform (www.regelleistung.net) for the combined markets of Germany, France, Austria, Switzerland, Belgium and the Netherlands. The minimum lot size is currently ±1 MW, and a technical availability of 100% must be ensured for the performance period from Monday 0:00 hrs to Sunday 23:59 hrs, if necessary by keeping available sufficient back-up capacity.

The provision of primary control reserve is remunerated by payment of a capacity price. After expiry of the deadlines for the submission of bids, the TSOs sort the bids received by capacity price offered and award contracts, starting with the bid with the lowest price, in ascending order until the demand for primary control power to be provided is covered. Unlike in the case of secondary control power and minute reserve power, the energy actually supplied is not paid for separately.

VII. Battery backup duration for Primary frequency control

The duration for which the Primary control frequency is required depends upon a number of factors. A thorough analysis and simulations for the past disturbances with battery support must be done to arrive at this duration. It will be different for different grid systems. In case of European grid, such simulations showed that the supply of primary control power for at least 30 minutes would have been necessary in order to contribute to system stability during the past major disturbances. The “Fig. 3 & Fig. 4” show the frequency curves during real faults that occurred in September 2003 in Italy and in November 2006 in the overhead line crossing over the river Ems in Germany; the data were recorded at the Duisburg-Walsum power plant site.

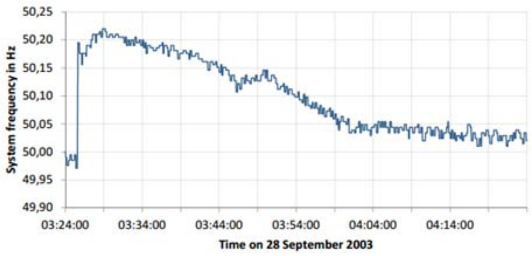

Figure 3. System frequency during the incident in Italy

Both situations make clear that the provision of primary control power for a period of 15 minutes would not have been sufficient to compensate for the faults and continue providing primary control power until the normal condition of the system was restored.

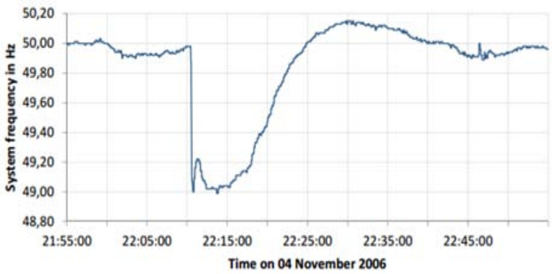

Figure 4. System frequency during the incident at the Ems overhead line crossing

For India also, similar simulations would be required to discover the size and duration of battery backup required for stabilizing the grid.

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BIOGRAPHICAL INFORMATION

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He is currently working as General Manager – Renewable Energy in Steag, where he is involved Designing, Erection & Commissioning, Consultancy, Technical due diligence studies, owners’ engineering assignments and hybridization studies of Renewable projects including Solar and storage. He has earlier worked in the field of process optimization software for various types of power plants.

[2] Arun Kumar V has Six years experience in industry during which he has been working in Renewable energy especially in Solar Energy and Thermal power generation. He is a Electrical engineer with Masters in Energy from Anna University in India and his area of Research is hybrid Renewables with storage.

He is currently working as Assistant Manager – Renewable Energy in Steag, where he is involved Consultancy, Detail Designing, Erection & Commissioning, Technical due diligence studies, owners’ engineering assignments,Electrical studies in DigSilent and hybridization studies of Renewable projects including Solar, biomass and storage.