How Wind, Solar, Storage as an Integrated Renewable Hybrid Solution Can Reliably Match Load Requirements

Amelie Wulff
GE Renewable Energy
Renewable Hybrids
Paris, France
amelie.wulff@ge.com

I. RENEWABLES AS MAIN SOURCE OF ENERGY

The cost of electricity is a key factor in the competitiveness of companies across different industrial sectors. Because of this, industrial companies should seek access to the most cost-effective sources of energy, while maintaining the highest level of reliability for their operations.

Large electricity consumers are mandated to comply with Renewable Purchase Obligations (RPOs) or Renewable Energy Certificates (REC) as set by as put in place by various global regulators and agencies. In addition to this, many companies have set objectives to go green or carbon neutral, motivated by their commitment with the environment and their stakeholders, as well as by an effort to stay relevant in the future.

Continuous decline in costs of wind and solar in many regions of the world made them competitive with conventional fossil power plants. Retiring of coal plants in developed countries and shifting of growth from coal to renewables in developing countries, puts pressure on renewables in a short term to provide more predictable power (power firming) and in a long term to be able to increase or decrease level of power production on command (dispatchable power).

II. DISPATCHABLLE RENEWABLES

In order for a renewable hybrid solution such as a combination of Wind and Storage, Solar and Storage or Wind, Solar and Storage to be able to match conventional generation sources they need to be able to follow load requirements / demand curves at any given point. Load following is the ability of a plant to match the load pattern over the course of an operating day. The key requirement being able to provide the power when and as needed by the system load. In this sense, the power plant 'follows' the load. The benefits to the system operator stem from the fact that electricity prices are directly correlated to system demand. Hence being able to procure renewable power that has been shifted to peak periods helps offset power procurement that must be made during peak periods from other expensive generation sources.

As such a load following hybrid renewable plant, is a combination of complimentary Wind, Solar resources which are collocated and supported by rightly sized battery and electrical balance of plant that can deliver reliable power to appropriately meet the daily load profile. Such hybrid renewable plant needs to be supported by an appropriate digital infrastructure (controls, dispatch analytics and optimizers, forecasting, asset performance management analytics). The recommendations for the storage sizing for the Load following renewable application is very site specific and has to performed to optimize electrical balance of plant, interconnect capacity and battery size.

III. CONCEPT OF LOAD FOLLOWING

A Load following wind / solar and battery renewable hybrid solution with controls brings in numerous advantages of:

- Reduced Plant CAPEX and OPEX
- Better utilization of land and the eBoP Equipment
- Improved capacity factor
- Reduced evacuation capacity and congestion
- Predictable/Dispatchable renewables
- Support in maintaining tie line flows and frequency
- Assist the system in managing net load ramps and shift energy to peak load hours

In ***Figure I*** below the battery storage controller along with forecasting capabilities also take into account expected peak demand upcoming in the next hours. Battery storage in this case works as a balancing device that delivers electricity in case of deficiency in renewable generation and stores excess energy when there is surplus power from generation and when future demand is projected to not be able to met with forecasted generation from both Wind and Solar.

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Figure I - Source: GE Research

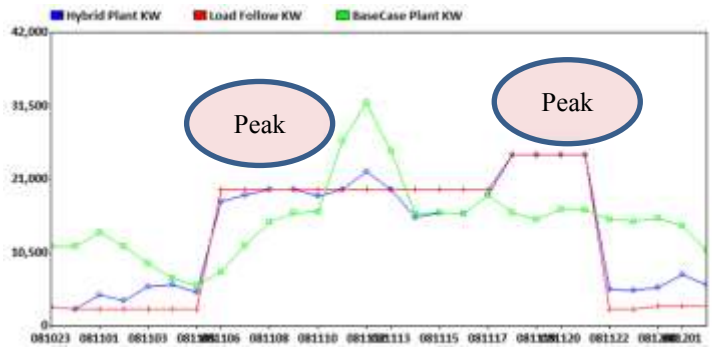

Figure II - Source: GE Research

Critical for the adherence of the load curve is the appropriate sizing of the storage solution; be it battery storage, thermal storage or pumped storage. Whilst one wants to size the storage solution for the highest percentage of load curve adherence, one has to balance the incremental cost of increasing the storage size. There may be occasions where one decides to carry the risk of non-compliance with the load curve for sake of a smaller storage solution investment and better project returns. These could be situations where customers have access to back-up power cheaper than incremental storage costs, or where penalties for non-adherence are lower than associated storage investments.

IV. Load Following renewables in Operation

A load following renewable hybrid plant consists both of hardware (wind, solar and storage technology along with electrical balance of plant and other hardware etc.) as well as software which operates and controls the individual assets to run and operate as one system rather than individual technologies. Such supervisory hybrid controls architecture provides various functionalities including but not exclusive to forecasting, scheduling and dispatch optimization. It further ensures grid compliance.

A supervisory hybrid control system is core particularly for load following where the system operator or other grid authority shall define the plant's generation profile or generation requirements for specific hours of the day, often corresponding to peak hours. Load following is unique from the firming use case in that the grid authority defines a set of generation requirements or a profile to follow; in contrast, the firming use case requires the plant to forecast its power output and minimize its forecast deviation

The optimization system for the load following plant takes day ahead forecast and load profiles for the day ahead market and develops an hourly commitment pattern (MW vs. time). Further on, the optimizer prioritizes different times of day based on peak load and/or price. Highest priority is given to meeting the load variability and the lowest priority to meet baseload. All the energy that is available from the wind and solar daily, needs to be allocated from highest priority to lowest priority as contracted. In ***Figure II***, the red curve indicates the desired load following KW setpoint. The green trend indicates the total wind and solar power that would have been produced without battery operation. The blue curve indicates the aggregate hybrid plant response given the operation of the storage system. Compliance during peaks is specifically marked in the above response with a more relaxed farm output during other intervals.

V. End User of Load Following Hybrid Solutions

The $3+ trillion energy industry is undergoing a major transition towards decentralization, decarbonization, and digitization. In the future global energy systems will experience a shift from conventional generation such as coal and nuclear to an energy system that will increasingly consist variable renewables energy sources (VRE).

Meanwhile and according to IRENA [1], commercial and industrial energy consumers account for about two thirds of the world total energy consumption. Switching their needs to variable renewable energy sources is core to achieving global climate goals and a carbon free environment.

In 2014, the Climate Group and CDP have partnered to form the "RE100" initiative which unites more than 120 companies in their ambition to use 100% renewable energy for their self-consumption purposes [2]. Members of the RE100 initiative included reputed companies such as Nike, Apple, Google, IKEA and many more. These companies are in need for renewable solutions that enable them to be 100% self-sufficient with green energy.

Figure III - Source: RE100 PROGRESS AND INSIGHTS. ANNUAL REPORT, NOVEMBER 2018

Whilst the approach to procure energy directly from onsite or offsite green generation assets is still fairly small compared to contracting with suppliers of green energy products or purchasing renewable energy certificates (REC), it is an approach that is growing globally. If and when commercial and industrial energy consumers consumer energy directly from renewable generation assets; ideally, they want to do

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that in accordance with their daily load and demand requirements. India stands out in terms of direct procurement of energy from green generation assets. The Electricity Act of 2003, introduced open access, giving large consumers with more than 1 MW of load need, access to the transmission and distribution network to source electricity directly from Generators. Using the open access facility, industrial companies can therefore choose to consume electricity from a source that allows them to be competitive. Open access transactions can be non-captive (electricity purchased under a third party PPA) or captive (generators owned for self-consumption purposes).

The decision to procure energy directly from green generation sources is not however just driven by sustainability targets but more so driven by the need for reliable energy supply at a lower cost of energy. The cost of electricity is a key factor in the competitiveness of companies across different industrial sectors. Because of this, industrial companies should seek access to the most cost-effective sources of energy, while maintaining the highest level of reliability for their operations.

One particular industrial segment with a need to replace more expensive conventional generation as energy source is the Mining segment. For Mines on average, electricity costs represent on average 15-40% of operating expenses. Further on securing a reliable grid connection to remote mines can be expensive [3]. Recent examples of renewable hybrid solutions to provide dispatchable energy include:

- DeGrussa, Sandfire Resources (Australia) - 10.6MWp Solar PV + 4MW/6MWp Battery storage integrated to existing 19MW diesel plant
- Granny Smith, Goldfields (Australia) - initially, existing diesel generators were replaced by gas generation, now 3 MW Solar PV + 2MW/1MWh battery storage will be added
- Diavik, Canada – 9.8MW Wind added to existing diesel on-site generation, replaced 10% of existing diesel fuel consumption

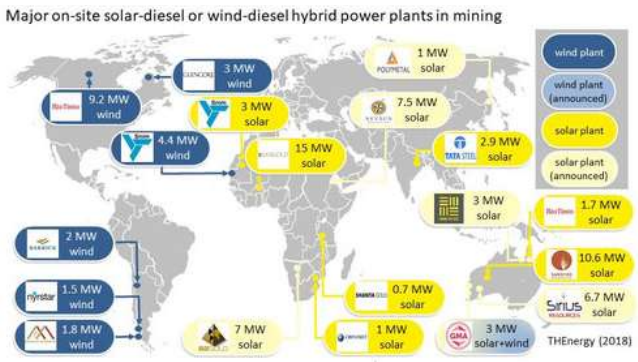

Figure IV - Source: THEnergy

VI. DISPATCHABLE RENEWABLES – KEY THINGS TO SOLVE FOR

Matching Demand with Supply – design for load following

- Fully understand load / demand profile, peaks and grid compliance requirements
- Design the plant to match the load pattern over the course of an operating day / week /year
- Focus on compliance to pre-designated "peak" periods

Designing the optimal digital infrastructure (controls, dispatch analytics and optimizer)

- Management of Day Ahead scheduling & Forecast Deviations
- Integration of system level demand forecast vs. forecasts for wind and solar power generation
- Dispatch optimizer to drive optimal dispatch pattern for storage to derive best possible value

VII. CONCLUSIONS

In a world that is in transition to a 100% renewable energy powered grid infrastructure, it is essential to show pathways that can help accelerate that transition. As much as renewable energy is variable it is nowadays possible to think that a hybrid renewable generator could be made to work as a dispatchable generator.

A load following hybrid renewable plant can follow a predetermined load profile. A combination of renewable generators like wind and solar in a right proportion, when combined with batteries can be dispatched in baseload or load following modes using smart controls, optimization and communication architecture; the latter is crucial to leverage the synergies of all connected devices and to ensure optimal operation of a hybrid renewable plant. The level of adherence to the load profile demanded will drive the size of batteries; the higher the adherence level desired the higher the battery size needs to be. Storage in this case work as a balancing device that delivers electricity in case of deficiency in renewable generation and stores excess energy when there is surplus power from generation. Alternatively oversizing on the generation side may also be an approach to increase the % adherence level to the load whilst also being mindful to not do that at the expense of spillage / curtailment.

REFERENCES

[1] IRENA, "http://www.irena.org/publications/2018/May/Corporate-Sourcing-of-Renewable-Energy"

[2] RE100, Progress and Insights. Annual Report, November 2018

[3] Thomas Hillig, THEnergy, https://www.th-energy.net/english/media

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