Design and Optimization of Renewable Hybrid Plants

Rahul Khandelwal (Author)
Renewable Hybrids
GE Renewable Energy
Berlin, Germany
rahul.khandelwal@ge.com

***Abstract*— Renewable Hybrid Plants which consist of more than one power source i.e. solar, wind, hydro power and battery or hydro storage, not only provide green electrons but also reliable energy generation.**

Renewable Hybrid Plants in addition to reducing the intermittent nature of generation, bring a unique capability when integrating energy storage, which provides applications ranging from energy arbitrage to power firming, enhancing compliance and curtailment capture during congestion. Renewable Hybrid Plants leverage multiple revenue streams by offering different services, but also provide greater grid reliability.

Each hybrid application is unique and requires in-depth techno-economic modelling to determine the right sizing and configuration. Such modeling considers several parameters and constraints including NPV, IRR, LCOE, cost benefit analysis, capacity factor, load factor and site resourcefulness. In the case of a Wind+Solar Hybrid Plant for example, cost competitiveness comes from value synergies through shared infrastructure (Capex synergy), operation & maintenance (Opex synergy), reduced uncertainty (around AEP), and resource correlation. This paper will address the main design and optimization levers driving viability of hybrid plants including technical & commercial synergies.

I. Introduction

As per IRENA's "Global Renewables Outlook 2020" report [1], CO2 emissions related to energy have risen by 1% per year over the past decade. According to their "baseline energy scenario" energy related emissions may increase by a compounded annual rate of 0.7% per year to 43 gigatons (Gt) by 2050, resulting in a likely temperature rise of 3°c or more in the second half of this century. As per the conditions of the Paris Agreement, we need to keep temperature increase below 2°C to maintain a sustainable environment. To do that, energy related emissions need to fall at compound rate of 3.8% per year to some 10Gt (70% less than today's level), by 2050. To reach those levels, renewable energy will need to be deployed at a massive scale. According to IRENA, the share of renewable energy needs to be around 28% of total energy generation by 2030 and 66% by 2050 to meet the before-mentioned CO2 targets. This increase in renewable energy penetration will challenge grid stability, due to renewable's intermittent nature. One of the ways to improve stability is Renewable Hybrid Plants, which will help create stable renewable energy production at a plant level.

II. Techno-Economic Analysis Process

A. *Use cases:*

In the past decade, renewable energy specifically Wind & Solar energy have been looked at from the perspective of pure energy production, with the objective being to produce energy at the lowest possible LCOE (levelized cost of energy). However, as the penetration of renewables increases with solar & wind reaching 9% of total generation [2], this objective is evolving from producing cheap energy compared to conventional energy sources, to also being "dispatchable ", and producing cheap energy when needed.

Recent tenders, such as SECI's (Solar energy corporation of India) tender for setting 1.2GW renewable projects with assured peak power, SECI's tender for 5GW of Round-the-Clock (RTC) Power from Grid-Connected Renewable Energy (RE) Power Projects [3] and South Africa ESKOM's Risk Mitigation Independent Power Produced Program (RMIPP) are aligned with the concept of giving value to dispatchability of renewable energy. Hybrids can be the way forward to achieving these requirements, as indicated by these tenders, where multiple sources or renewables are combined with energy storage and/or thermal generation. GE Renewable Energy has had the opportunity to support multiple companies in these tenders through the unique capability of sizing and designing technical solutions, in addition to the supply of plant controls, dispatch optimization software and original equipment.

B. *Solution Design*

Providing renewable energy reliably and on demand typically requires storage, making it a critical piece of hybrids design. The addition of battery storage adds complications to the sizing of a hybrid power plant. Determining the right sizing mixture of wind, solar and storage holds the key to economic feasibility of the plant and requires advanced modeling.

Over the past few years, GE has developed a digital tool called Hybrid Architect (Figure 1) which is used to evaluate the various aspects of hybrid power plants. The tool evaluates the techno-economic performance of hybrid power plants (generation system) by simulating the system hourly operation throughout the project's life. For each hour during the proposed project life, the Hybrid Architect first evaluates the power available from solar and wind taking into account electric losses and nameplate sizing of each system component. Depending on the desired operation of the plant as a power plant (output no larger than the point of interconnection capacity) or as an island model microgrid (out-put equals to onsite load demand), Hybrid Architect will use an energy arbitrage based dispatch algorithm or a load following dispatch algorithm to decide the flow of power and then calculate the economic performance of the plant.

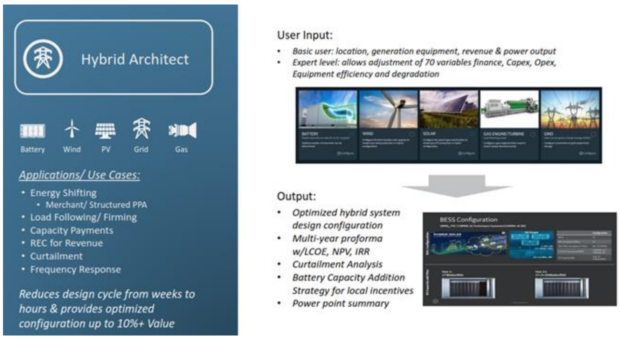

Figure 3GE Hybrid Architect that is capable of evaluate techno-economic performance of a hybrid power generation system and is capable of optimizing hybrid system configuration to achieve optimal NPV/IRR/LCOE

C. *Value levers*

When designing a hybrid solution, value levers such as proximity of wind and solar to the sub-station, complementarity of renewable resources, auxiliary load supply, available additional revenue streams (like ancillary services), CAPEX & OPEX synergies, portfolio benefits (portfolio benefit in hybrids not only reduce uncertainties but amplify the P75/P90 hybrid energy numbers that creates marginal value and improves the overall LCOE of the project) are determined and integrated into the hybrids modelling process.

For the purpose of validation of the before mentioned value levers a theoretical case study was carried out for a site in the Middle East with wind (38MWac) and solar (23MWac) and an interconnection capacity of 50MWac. Based on this case study the following observations were made:

- Portfolio benefits due to uncertainty reduction provided a benefit of approx. $1/MWh @P90 level.
- Aux loads were reduced by close to 45%, by supplying them through the project vs. buying them from the grid.
- ~$2.3M Capex synergies due to single sub-station sharing between wind & solar followed by additional saving on land capex due to sharing of land between wind & solar.
- Elimination of cost duplication for project management, site mobilization etc. reduced DC sub-system cost by approx. ~$200K.
- Opex synergies between wind and solar of close to ~$110k.

Considering the above-mentioned value levers & other project parameter assumptions, a reduction of about 9.5% in LCOE is foreseen as against the baseline scenario.

III. CASE STUDY FOR DISPATCHABLITY

This section is focused on India's RTC Auction Use Case. The aforementioned use case is chosen to verify the "dispatchability" and validate the "design" of the Hybrid Power Plant. The analysis is based on a hypothetical Wind + Solar + BESS Renewable Hybrid Plant for round-the-clock power output with a required annual CUF (capacity utilization factor) of 80% through the 20-year project life. Sizing of Wind, Solar and BESS subsystems was fine-tuned to achieve minimum LCOE while meeting required minimum annual CUF. A flat rate PPA (power purchase agreement) from the offtaker without annual PPA rate escalation was used as the revenue stream.

GE's Hybrid Architect was used as the modeling tool. For the case study project, financial parameters such as project duration, financial leverage and hurdle rate were assumed along with capital and operational expenditures. A suitable location was chosen with complementary wind and solar resources meaning the time period when solar increased then wind decreased & vice-versa. Based on the aforementioned assumptions, simulations were carried out to enhance the sizing of wind, solar and battery based on the LCOE parameter leading to below mentioned energy profile (figure 2) and sizing of renewable hybrid power plant (figure 3).

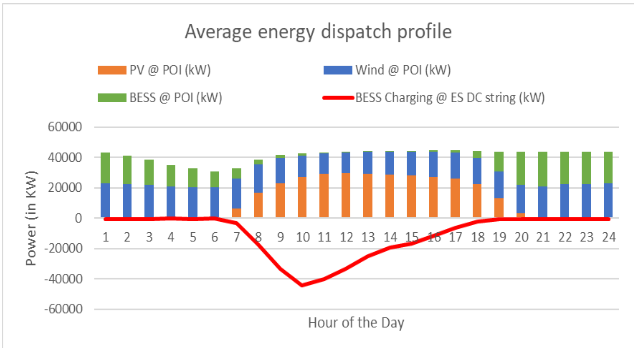

Figure 1 Energy Dispatch Profile of designed renewable hybrid power plant

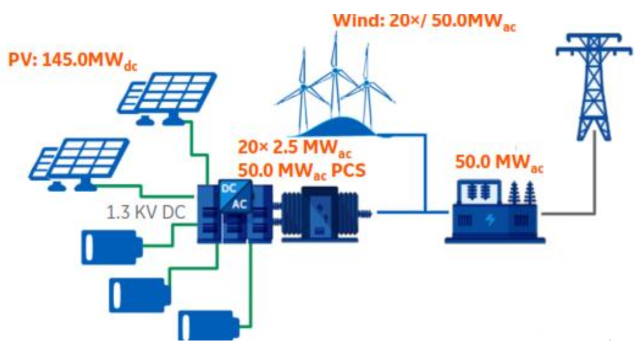

Figure 2 Renewable hybrid power plant design

Table 1 lists the project specific KPI for the round-the-clock use case while table 2 lists the project parameters.

Table 1 Project parameter specification

Project Parameters	Specifications
Plant location	India
POI	50 MWac
Annual CUF required	>80% through project life.
Max # of wind turbine	20 (plant allows up to 20× GE2.5-116)
Solar & BESS Size (Range explored)	22.5 - 50MWac (Solar); 200-600MWh (Battery)
PV DC/AC Ration (Range explored)	1.5 - 3
Optimization criteria	Minimum LCOE
Plant availability	100%
Losses (from generation to injection @grid)	Standard
Revenue stream	Flat rate PPA without annual escalation.
BESS coupling to PV	DC Coupled
BESS augmentation	Add addition battery (and container if necessary) when capacity degrades to performance guarantee.

Table 2Project KPI Values

KPI	Value
BESS/PV Inverter Nameplate (MWac)	50
PV Nameplate (MWdc)	145
Wind Turbine Nameplate (MWac)	50
BESS Energy Nameplate (MWh)	335.47
Total AEP (GWh/Yr)	362.63
Capacity Factor	82.79%
LCOE ($/Mwh)	50.53

IV. Hybrids Flex Portfolio

GE's FLEXIQ portfolio is a digital platform that provides design, operations, and fleet management solutions to enable grid compliance and maximize project lifetime value. The core of FLEXIQ portfolio is composed of the following:

- Hybrid Architect:
- Dispatcher
- Plant Control
- Monitoring & Diagnostics (MD)

The FLEXIQ's portfolio capability starts in the origination stage with Hybrid Architect which is used to provide the techno-economic modeling of the project, In the operation stage Plant Control provides multi-asset coordination, Dispatcher develops a revenue optimized generation schedule based on resource forecasts, and MD provides advanced monitoring of asset performance. Combined together the FLEXIQ portfolio offerings help customers achieve maximum value for their Hybrid projects.

V. Conclusion

Hybrids is an evolving field which promises to be one of the solutions to required renewables dispatchability. Renewable Hybrid Plants don't just provide dispatchable energy but also provide economic benefits based on the value synergies discussed in the paper. And decreasing battery prices [4] combined with further development of wind & solar technology and volatility in energy prices, renewable hybrids will only add more value to the process of transitioning to renewable energy.

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References

[1] IRENA Global Renewables Outlook. Edition 2020.

[2] Agency, I. E. (April 2020). Von https://www.iea.org/reports/global-energy-review-2020/renewables abgerufen

[3] SECI https://www.seci.co.in/view/publish/tender?tender=all abgerufen

[4] BNEF BESS pricing forecast report