STEADYSUN
THEnergy
white paper

Energy Generation Forecasting in Solar-Diesel-Hybrid Applications

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1 Introduction

In recent years, solar-diesel hybrid applications have become more and more interesting as the technology allowing for integrating photovoltaic (PV) energy into diesel power plants has improved considerably and PV investment costs have decreased to a great extent. While the first big wave of solar power plants occurred in a subsidized environment, these incentives are now running out or have been cut largely. Solar power has to compete with conventional forms of energy, while existing energy costs are a natural benchmark for renewable energy investments. Traditional power from diesel generations is expensive as the fuel has to be transported to remote locations, while diesel generators are relatively small and thus less efficient than large-scale conventional coal, gas or nuclear power plants. In this regard, we can observe that solar and wind energy are highly competitive in comparison to power from diesel.

Many companies that traditionally built or financed large-scale grid-connected solar power plants have identified the integration of solar power solutions into remote diesel power plants as a “sweet-spot” for the near future. More and more hybrid projects are being built or are under development. Typical applications are rural electrification, the telecommunication sector, the mining industry and remote hotels and resorts.

Solar-diesel hybrid systems are, by nature, often rather small, while the intermittency of the solar component often poses a considerable challenge for the system. This white paper examines how the forecasting of these intermittencies can optimize the system. It discusses forecasting in simple and more sophisticated solar-diesel hybrid systems with energy storage. Our paper thus takes into consideration the consequences for investment costs on the one hand side and for operating and maintenance costs on the other side.

2 Weather forecasting for solar-diesel hybrid systems

2.1 The basic concept

Hybrid energy systems generally combine two different energy sources. In the case of PV-diesel (often the broader expression “solar-diesel hybrid” is applied), PV and diesel energy are combined. The business case here consists in partially replacing rather expensive diesel energy by rather inexpensive solar energy.

Technically, the main challenges have arisen from the unstable energy generation of PV power plants and the fact that traditional diesel gensets are not very flexible and can hardly deal with loads of less than 30%-40%. In many PV-diesel hybrid systems, the diesel gensets are constantly run near their minimum load in order to provide so-called spinning reserve. for situations in which the power from the solar system drops, due to shading of the PV array. As a consequence, the renewable energy penetration, which is typically defined as the share of renewable capacity in respect to total peak capacity of the system, is not very high.

2.2 Storage in PV-diesel hybrid systems

Battery storage systems can be used to provide spinning reserve in solar-diesel hybrid systems. This application is also called “bridge to back-up”. If the PV array is shaded and power from the solar power plant drops, then a battery storage system forms the grid and provides electricity until one or more diesel generators are fully ramped-up and generate electricity. Normally this process just takes a few minutes and the battery storage systems used are rather small. Nevertheless, this advanced concept allows for switching the gensets-off during peak-irradiation and thus increases renewable energy penetration in the hybrid system. In this system, the PV array is dimensioned accordingly to be larger in order to fulfil electricity needs during peak generation and to charge the battery.

Depending on the cloud patterns in the specific region, there might be several charging/discharging cycles per day, which creates rather significant challenges for the battery.

Beyond “bridge to back-up”, batteries can be used for additional applications in solar-diesel hybrid systems. In larger battery solutions, solar energy can be generated during daytime and used during night-time. Ideally, diesel gensets will only be used as back-ups when energy from renewable resources is not available over a longer period, e.g. if there is low solar irradiation due to a bad period of weather.

Finally, energy storage can be used to improve power quality in the system.

So far we have had many hybrid systems without any storage. However, even if the integration of storage makes absolute sense from a technical point of view, storage systems are still rather expensive and sometimes have quite negative consequences on the competitivity of the hybrid system.

2.3 Value added of weather forecasting

Besides storage, a second solution for dealing with intermittencies in a Solar-Diesel Hybrid project is prediction. If sudden output changes in the solar power plant can be forecasted, then additional spinning reserve can be provided for certain time periods although not constantly. Solar power forecasting provides the ability to adjust the spinning reserve dynamically. In addition, knowledge about the duration of power output changes allows the optimization of the operation of the assets, both for the diesel gensets and the storage system. In the end, solar power forecasting can significantly reduce the Levelized Cost of Energy (LCOE) of solar-diesel hybrid systems.

Image 1: STEADYSUN's SteadyEye sky imager

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Sky imagers allow for extremely site-specific forecasts as they are deployed onsite. A PV production forecast is then made using the local data from a camera that is pointed toward the sky. Used in conjunction with image processing algorithms, a cloud mass movement forecast and physical models, the state of the cloud cover is then forecasted. The forecasting of the irradiation and the production of the PV plant is extremely reliable in the short-term. STEADYSUN's SteadyEye solution takes hemispherical photos every minute, while a forecasting algorithm provides power production forecasts for periods from 1 minute to 1 hour.

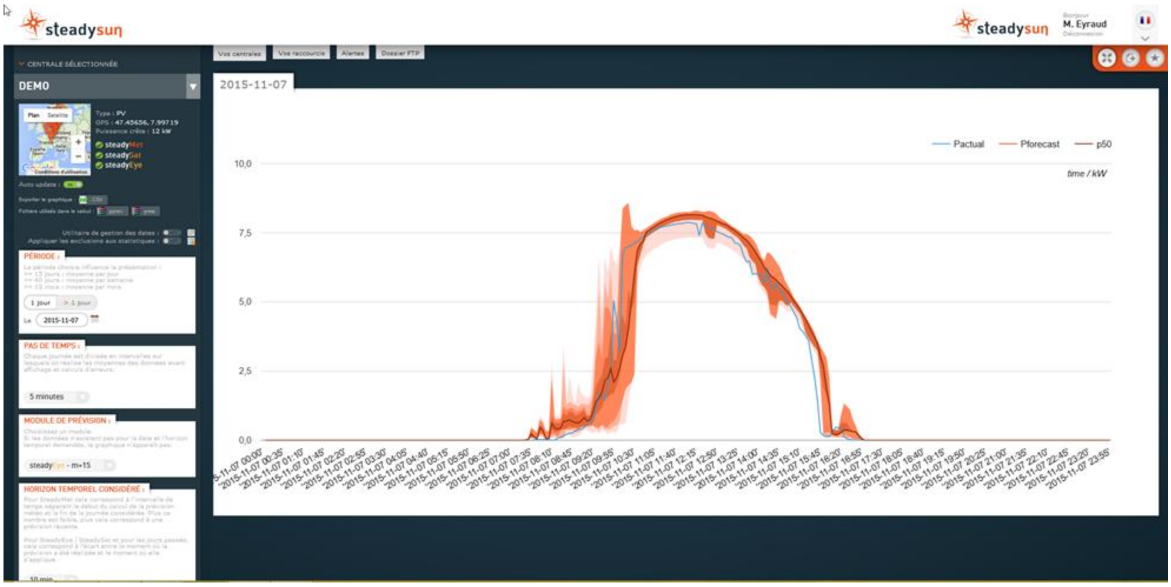

Image 2: STEADYSUN's forecasting software

The LCOE concept includes the investment side as well as operations of the system. Power production forecasting can improve both.

PV production forecasting for optimizing system investments

The forecasting devices are relatively inexpensive, particularly in comparison to storage solutions. The storage solution works as a bridge to back-up, i.e. it is optimized in a way to ensure that the power plant can avoid power drops stemming from shading or partial shading of the PV array. As traditional gensets need a certain time for ramp-up, the main function of the storage system in this regard is to provide power until the diesel gensets are available. Forecasting can overcome this gap by starting the diesel engines before the actual shading occurs. Therefore, production forecasting allows for optimized system designs and can considerably decrease investment costs. The system can be designed with the same renewable penetration rate in regard to the peak capacity of solar and diesel power. Differences with respect to energy contribution[1] are then marginal, especially in regions with high constant solar irradiation.

In addition, solar production forecasting can increase the lifetime of batteries. Batteries have advantages that go well beyond bridging the ramp-up time of generators. If solar-diesel hybrid systems are designed with batteries, then PV production forecasting can improve the lifetime of batteries. The number of charging/discharging cycles can be reduced as, for example, the forecasting shows that the shading lasts over a longer period of time. Hence, it can make sense not to use the battery and manage the situation solely with diesel gensets. Optimized charging/discharging behavior can actually increase the lifetime of batteries and avoid future

[1] Energy contribution in this context is defined as the actually energy produced by renewable vs. total energy produced (sum of renewables and conventional energy).

replacement investments. An optimized battery management system needs to be fitted to the respective battery technology and other framework conditions. In some cases, the usage of PV production forecasting favors a different and more cost efficient battery technology.

PV production forecast solutions can also increase the lifetime of gensets. In cases when the shading only lasts for very short time periods, it can make sense to completely rely on the storage system and avoid unnecessary wear to the gensets. This approach can also reduce the cost of replacement; here, regarding investments in gensets.

PV production forecasting for improving operation and maintenance costs of solar-diesel hybrid systems

The last two points managed to show how PV forecasting can improve investment costs throughout the lifetime of the hybrid power plant. In addition, O&M costs can be decreased by operating the gensets at more efficient generator load levels. Less spinning reserve needs to be provided by the diesel gensets which, in many settings, allow a fewer number of generators to be run at a higher load. As traditional generators are optimized for these higher loads, they run more efficiently and consume less diesel while achieving the same output.

In addition, the optimized start/stop cycles of generators reduces the maintenance requirements. At the same time, less maintenance means lower LCOE.

Both camera technology and the integration of the control system have considerably improved over recent years. Camera prices have fallen, prediction accuracy has improved and integration has become much easier. Furthermore, thanks to its cost efficiency, we can be expected that, in the near future, PV production forecasting will become a standard solution for PV-diesel hybrid systems.

3 Summary and outlook

PV production forecasting can improve LCOE through an optimized system design with lower investment costs. In basic PV-diesel hybrid systems, forecasting has the potential to crowd out battery storage system by predicting sudden shadings of the PV array which allows for the ramping up of gensets before potential power losses occur.

In more sophisticated systems, PV production forecasting can improve LCOE by optimizing the storage size and the diesel genset configuration. Investment costs can be reduced by using smaller storage systems and avoiding and postponing replacement investments in the battery system and the diesel gensets. In addition, the operation and maintenance costs of the gensets can be improved by running them at more efficient loading levels and avoiding unnecessary start/stop cycles.

Sky imagers are already proven in real applications and appear to be very reliable if configured correctly according to the specific framework conditions. Taking into account the relatively low costs of PV prediction solutions, it is obvious that considerable value is created in almost any kind of PV-diesel hybrid system. For solar-diesel hybrid systems, this means that they are becoming more competitive because overall LCOE are reduced and the investment case for solar-diesel hybrid solutions turns out to be more favorable.

Software simulation tools that include sky imagers are also being developed. They support functions for dimensioning and designing the optimal mode of operation of a hybrid system based on various framework conditions, such as different needs in regard to a secure supply of energy, electricity costs and various load and irradiation patterns.

Beyond their application in off-grid solar-diesel hybrid systems, similar advantages are inherent to small insular microgrids with solar power, rural electrification in weak grid areas and smart grids in an urban environment where a network of sky imagers can be deployed.

About STEADYSUN

STEADYSUN SAS, founded in 2013, is a spin-off of CEA (www.cea.fr). After more than five year of R&D at INES (www.ines-solaire.org), the company is now offering a comprehensive range of professional solar production forecasting services to contribute to a better integration of the solar energy in the power grids. STEADYSUN makes the management of power grids and photovoltaic power plants easier, enabling its customers to reduce their costs (CAPEX / OPEX) by using its solar forecasting solutions.

Combined with meteorological models, satellite imaging and sky imagers on site, STEADYSUN technology generates forecasts ranging from a few minutes to a few days at local, regional, and national level. Photovoltaic power plants operators, power grid managers and, energy traders can therefore better predict the power generated and reduce financial or technical risks related to variable weather conditions. The forecast solutions of STEADYSUN are currently implemented on more than 1400 PV plants in a dozen of countries worldwide. http://steady-sun.com/

About Dr. Thomas Hillig Energy Consulting ("THEnergy")

THEnergy assists companies in dealing with energy-related challenges. Renewable energy companies are offered strategy, marketing and sales consulting services. For industrial companies THEnergy develops energy concepts and shows how they can become more sustainable. It combines experience from conventional and renewable energy with industry knowledge in consulting. In addition to business consulting, THEnergy advises investors regarding renewable energy investments in changing markets. It is also active in marketing intelligence and as an information provider in select fields, such as renewables and mining, through the platform th-energy.net/mining or renewables on islands through the new platform th-energy.net/islands.

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