Cloudbusting

Forecasting | Short-term PV forecasting offers a multitude of benefits, from trading on wholesale power markets to improved plant operation. Sara Verbruggen reports on some of new the technologies driving forward improvements in the accuracy of forecasting techniques

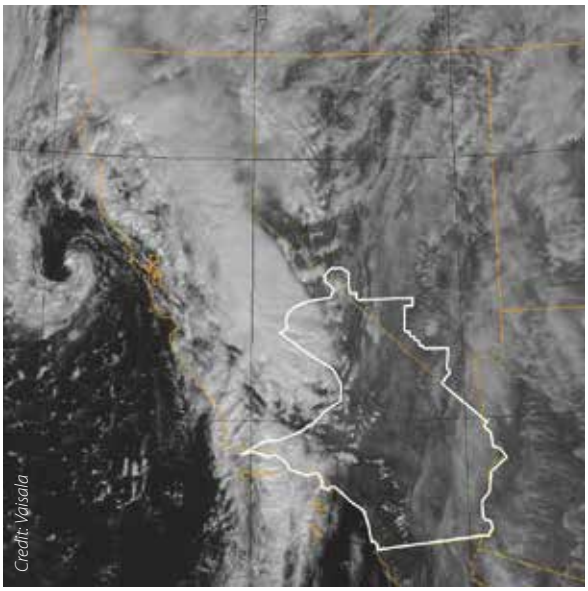
Short-term forecasting bridges the gap between the inherently intermittent nature of renewables such as solar and wind, and power systems and markets, designed around fossil fuel power generation output, which is controlled to match demand. Before the advent of wind and solar PV generation, consumption was the only variable component in the power system balance and forecasting techniques have been used for many decades to predict changes in power demand.

Though there are many emerging use cases for short-term solar PV forecasting, in a nutshell the more accurate this type of forecast, the better the planning of the energy mix, which usually results in the use of lower-cost energy generation. Short-term forecasting spans predictions in weather activity, ranging from one week ahead, to one day ahead, down to intraday, which can be hourly, or sub-hourly, such as every 15 minutes.

Advances over the past two years in several areas, including data analysis, satellite imaging, simulation modelling and sky imaging using ground cameras, have underpinned improvements in the accuracy of short-term PV forecasting. But, according to proponents of short-term PV forecasting tools and services, there still remains untapped opportunity for the technology's use across the global PV market.

Numerical weather prediction (NWP) models are the main tool for making forecasts with horizons of six hours to one week ahead. Key sources of NWP models include the European Centre for Medium-Range Weather Forecasts (ECMWF), which has developed the Integrated Forecasting System. The other is the US-based National Oceanic and Atmospheric Administration's Global Forecast System, a vast dataset, comprising measurements of temperatures, winds and precipitation to soil moisture and atmospheric ozone concentration, all over the world.

Several independent providers of short-term PV forecasts take NWP models and splice these with statistical methods, known as Model Output Statistics, to produce a more accurate forecast. These post-processing algorithms can use historical ground measurements. For instance, Solargis, a Slovakia-based provider of solar forecasting tools, has a database of historical solar irradiation data from different global regions, and can use this to improve the accuracy of its day-ahead or several-days-ahead forecasts.



Satellite image of cloud cover over the southern portion of the CAISO service area, California. Improvements in short-term forecasting capabilities are bringing benefits to energy traders, grid operators and PV plant owners

To make intraday solar PV forecasts providers such as Solargis and Reuniwatt will buy images taken regularly, every 15 minutes or less, from five geostationary satellites, which cover the world's surface. The images are fed into companies' own datasets to calculate regional or global irradiance.

Solargis is one of a few companies that can provide this type of short-term forecasting for most global regions, as opposed to a specific region, such as Europe or North America. The company provides intraday forecasts and day-ahead forecasts in Europe, Africa, Japan and North America and plans to expand these to Southeast Asia in the next few months.

Integration of solar PV

Regulators across Europe, including Germany and Italy, are changing regulations in order to make renewable energy plants part of balancing operations. Forming a balancing group is a requirement of taking part in wholesale power markets. Transmission system operators (TSOs) ensure trades are balanced and balancing group managers are penalised if contracted generation fails to match demand. Short-term forecasting can provide TSOs with data on PV capacity on the grid, so that operation reserves can be more accurately determined.

Improvements to integration of renewable energy is needed as feed-in tariff (FiT) incentives give way to market-based systems, such as auctions for new renewable energy capacity, and direct marketing of output into wholesale markets, which is how conventional forms of energy are traded.

In a growing number of countries in Europe, including Germany, Spain and most recently France, owners of PV plants must also trade output via the wholesale market. These trading block horizons vary, from every 15 minutes in Germany to every 30 minutes in France and every 60 minutes in Spain as well as day ahead markets on the European Power Exchange Market (Epex).

Like energy traders, TSOs, which operate wholesale power markets, benefit from more accurate forecasting because they know how much power from renewable energy sources is required to meet demand.

"More accurate forecasting ultimately allows TSOs the scope to have more energy from renewables traded in the market, as opposed to underestimating the amount in the likelihood that renewable output falls short. This leads to better integration as more renewables that might otherwise be curtailed are actually injected into the grid," says Marion Lafuma, marketing manager, at Reuniwatt.

For TSOs, Reuniwatt's forecasting can provide a global forecast, which requires aggregating satellite images, various regional forecasts and for energy traders and PV

Reuniwatt has helped manage the production profile of a rooftop solar-plus-storage facility owned by Albioma in Saint-Leu using short-term forecasting tools including sky imaging. Such technologies have helped Réunion Island exceed 30% renewables penetration

Credit: Reuniwatt

plant operators, it uses regional forecasts, including satellite images.

In markets where solar PV makes up a big proportion of the energy mix, which is the case in several European markets, including Romania and Bulgaria, owners of PV plants have to provide a schedule of production to the grid operator. Mismatch in demand and output, as a result of inaccurate forecasting, can lead to financial penalties in some of these markets. Penalties usually consist of a fixed euro amount per megawatt of output over- or under-produced.

Harsh Goenka, business development manager at Solargis, says: "We also see opportunities emerging in India, where central and state-level regulatory commissions have produced draft guidelines, which when implemented could lead to penalties if output and demand from PV plants fail to correspond."

Karnataka has published final regulations, while several states including Odisha, Madhya Pradesh, Tamil Nadu and Rajasthan have produced draft regulations, according to Goenka

"Similarly, in emerging PV markets, in several developing economies, where relatively small amounts of installed capacity can account for a comparatively large share of the overall energy mix, in places such as Kenya and Panama, grid operators could also impose fines if output does not match demand, in order to avoid imbalances in the system. Accurate short-term forecasting may be required," he says.

Solargis has also been operating some demonstrations and pilots for grid operators around the world, which need aggregated forecasts for a region or area in order to get a precise understanding of how much PV output there is in relation to actual demand. Meanwhile, Vaisala, which has started offering short-term PV forecasting tools and services, in addition to wind forecasting, has created a short-term solar PV forecast for the California Independent System Operator (CAISO) market, which it introduced in April 2016.

"This type of forecast contributes to making energy markets more liquid and efficient. The more market participants there are and resultant trading that occurs, the more efficiently the market operates. If the market rules are designed well, price volatility and the day-ahead real-time price spread will be reduced. We do not have much diversity in the ways markets handle solar energy to date but from looking at how wind energy is traded in different markets there is a range of possibilities," says Gwen Bender, product manager for solar assessment services at Vaisala.

Tesolva was set up a year and a half ago to provide custom-made software for companies in various sectors. Its customers for short-term PV forecasting include an energy trader in Europe.

"After a test phase, we were able to convince the client of our service, because he was able to compare us to similarly priced options. Through improved quality the trader was able to make better trading decisions and increase profits," says Joachim Falk, Tesolva's managing director.

While there have been improvements across short-term PV forecasting, the accuracy of intraday forecasting has improved the most. "The inclusion of live data, such as measurements from the PV site and live satellite images, allow for additional improvements that just weren't widely available a few years ago," says Falk.

Goenka says: "In case of intraday forecasting, we are starting to process satellite imagery from newly launched satellites that provide higher resolution imagery and more frequent updates. The newly launched HIMAWARI satellite, for example, provides satellite imagery every 10 minutes. Previously it was every 30 minutes. We also try to reduce the delay with which we are

receiving satellite imagery – this helps us improve forecast in time horizon of next one to two hours."

New developments – sky imaging and simulations

To provide forecasts in time horizons of several minutes, a few providers have also developed tools that use ground cameras installed at PV installations. Sky imaging from ground cameras can take images every few seconds, which in combination with other datasets can predict when and how long clouds will move in front of the sun, which causes a drop in PV output.

Vaisala is prototyping a ground camera for sky imaging because it is looking at the ability to combine images taken of the sky from individual solar PV plants in combination with its own intraday forecasting methods. According to Bender, initial tests indicate sky imaging can significantly improve the short-term forecasting.

She says: "We see this demand for very precise site-level forecasting, for up to 15 minutes, for grid integration of PV plants where PV ramps on and off very rapidly, which can include locations where one or two very large PV plants can account for a very large proportion of the local grid, in emerging US state-level PV markets, where penetration is currently low, such as in south-east US and parts of north-east US."

Tesolva's tool uses PV plant simulation modelling as well as statistical methods to create its intraday forecasts. The simulation modelling, a relatively new approach, can be used in areas where the density of PV plants is relatively low, where there is a lack of available data that can be fed into calculations.

The PV plant is simulated on a cloud server, as a virtual reconstruction with inputs from key components such as modules and inverters and details on array configuration. The advantage of this approach is that not only weather but other site-specific factors that can impact output can be taken into consideration to produce the forecast.

Reuniwatt, which was established on the French island of Reunion in 2010, has developed its own sky camera technology based on infrared imaging that is able to produce images without blurring round the sun, and which can also provide an accurate estimate of cloud height and cloud density.

Images taken at dawn and dusk using the technology are also more accurate, compared with other ground cameras. Overall Reuniwatt claims its Sky Insight technology is able to produce forecasts that are 30% more accurate than other ground cameras.

Sky imaging deployments

Sky Insight is useful for owners of on- and off-grid PV and hybrid plants, which combine PV and diesel or PV and storage. A remote farm in Australia, which generates its own electricity from two 300kW diesel generator sets and a 250kW solar PV farm, has had the camera installed for two years and has been able to achieve savings of AUS$20,000 (US$15,300) a year, because the camera has enabled it to optimise its use of solar PV electricity, while only relying on diesel at night time or when there is a drop in output from the solar plant.

On Réunion Island, Reuniwatt has installed its infrared camera with a 1MW rooftop solar PV installation which is coupled to a 1MW battery storage system. Using the camera, satellite images and NWP to provide forecasts a day in advance, the owner of the installation is able to see how much energy can be injected into the grid, or how much needs to be stored in the batteries, and when to release the energy.

The solar and storage installation owner is obliged to send the TSO a day-ahead forecast, which is fed into the battery storage facility's energy management system, in order to avoid incurring fines for over- or under-production. "The producer used to inject 87% of total electricity output into the grid. With the Sky Insight camera and our forecasting services, the producer is now able to inject 95% of output into the grid," says Lafuma.

A more recent customer for the Sky Insight technology is French oil company Total, which along with utilities and partners, including EDF, is setting up a smart grid test bed just outside of Paris, called IssyGrid. Forecasting starts

How Vaisala's intraday forecasting is giving traders the edge over the CAISO public forecast

The California Independent System Operator (CAISO) market solar 'zone' forecast developed by Vaisala is similar to what has been done for wind energy TSO/ISO-level forecasting.

"This is an hour-ahead forecast that gets updated every five to 15 minutes. To do this we use historical observation and metadata, then train our statistical models on the historical observations and changes in the installed capacity," says Gwen Bender, product manager for solar assessment services at Vaisala.

Energy traders that want another opinion on the forecasted grid-connected solar energy output are using the forecast for an information advantage. CAISO publishes its own grid-connected solar energy forecast. "Everybody can see this, but customers want to know when our forecast is different than the CAISO public forecast because this gives them a competitive advantage and added insight about how solar capacity on the grid may influence energy prices. We show both forecasts in our tools to help clients make decisions quickly," Bender says.

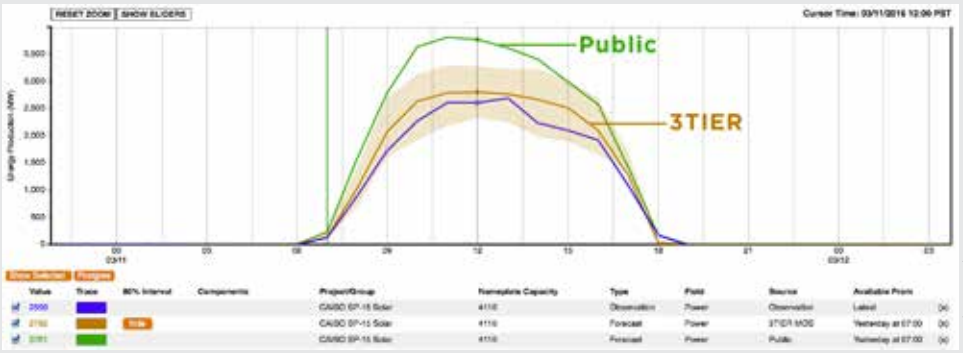
For the time being the forecast is inclusive of utility-scale solar in the region but does not include distributed solar sites, though the plan is to include these resources in the future.

"In California, the Renewable Portfolio Standard (RPS) for utilities is a big driver and that's why we see large-scale solar plants. In other US states, we may see more distributed small solar PV systems due to incentives in place. ISO/TSOs will be much more keen on both grid-connected and behind-the-meter short-term solar forecasts as penetration levels increase. We're only seeing this today primarily in California, but hopefully that will change as RPS target deadlines approach," says Bender.

To validate the tool ahead of launch, Vaisala used over six months of data from CAISO's public forecast, to compare the performance of its forecast.

"Ours was consistently more accurate than the day-ahead public forecast. For example, in CAISO SP-15 [which accounts for a majority of the California's utility-scale solar capacity] Vaisala successfully predicted reduced solar production days 60% more often than the public forecast," says Bender.

Vaisala is also looking at other regions in the US where solar PV capacity is increasing, such as Texas, where there is potential for a short-term – several-minute horizon – forecasting tool. "PJM is also seeing more solar penetration in parts of the grid it operates, which is the biggest in North America with high solar resource variability much of the year unlike CAISO," Bender says.



Credit: Vaisala

CAISO's public PV generation forecast plotted against the more accurate forecast from Vaisala/3TIER

in the first quarter of 2017.

The camera is installed at a building housing a law school, which has a rooftop PV system and also a battery system. The camera will help the school to optimise self-consumption, so that most of the electricity is used on site, during the week. "In smart grids, or solar-plus-storage projects, solar forecasting represents the low-hanging fruit," Lafuma says.

Historical weather and irradiation data is of importance when it comes to the system's design because it helps to determine how productive the PV installation is going to be. From that, it can be calculated how much energy storage may be required, based also on other parameters such as the energy consumption of different loads. The storage component can be more accurately sized, reducing capital expenditure.

"However, when the smart grid is operational, short-term forecasts can be fed into the energy management system to enable more efficient operation of the whole system, so if there is a drop in PV output loads can be powered by the battery. Another, better option might be to turn down or switch off a load, or use electricity from the grid," Lafuma says.

More accurate predictions also mean the battery is only likely to be charged up when necessary, so preserving the performance of the battery cells.

Further opportunities for short-term PV forecasting

Despite progress made in improvements to short-term PV forecasting, the technology is underused and there may be several reasons for this. One is that until comparatively recently forecasting technology has been expensive.

However, along with falling costs of solar PV modules, balance of system components and other costs, providers of forecasting software tools have also been forced to look at ways to reduce their costs, according to Falk. "When we set up our simulation model two years ago it took a while, now we can do it very quickly and it is self-learning."

Typically contracts are for a year or two and the client will pay a monthly subscription, which can range from a thousand to tens of thousands of euros, dependent on whether the forecasting package is for one, a few or a fleet of PV plants, which can be equivalent to hundreds of megawatts of capacity.

But there is also the other challenge of clients' abilities to process and act on the data that short-term forecasting provides.

Falk says: "For the direct marketing of electricity most energy traders work with data based on day-ahead forecast. If one wants to use the intraday data effectively, then who is going to be tasked with dealing with all that data? When we've spoken to energy traders and they see the amount of data that is generated at 15 minute intervals over a 72-hour period, across many PV plants; that's a huge amount of information and they don't have the resources to use it and act upon it."

And although intraday forecasting potential offers higher profits, it also requires increased spending on internal resources. "While some market participants are already taking the opportunity to include intra-day forecasts, others are having problems expanding their structures to accommodate a cost-effective intraday trade. But as the forecasting costs come down then it will make this market segment accessible to traders," says Falk.

However, over the next two to three years market pull for short-term PV forecasting is likely to continue to come from energy traders. "Probably traders are the only group that can afford short-term forecasting. But with costs coming down, it opens up more applications. Two years ago this technology would be too expensive for an O&M service provider, but it is changing," says Falk.

In Bender's opinion the jury is still out on the demand for short-term forecasting in the future. "As technological advancement continues to occur, the processing, distillation and delivery of short-term solar forecasts may change dramatically and it is not clear yet if this will be done by EPCs, solar module companies, ISOs, or independent forecast providers." ■