New Advancements in Solar Grid Controllers

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***Abstract*—The quantity of solar photovoltaic (PV) generation sites has increased exponentially over the last decade. In the United States, most new power plants commissioned by 2050 are expected to be either natural gas combined cycle or PV. PV sites range in nameplate rating from kilowatts to hundreds of megawatts, are often categorized as distributed energy resources (DERs), and may be owned by many various entities. These characteristics set them apart from more traditional power generation sites.**

As PV becomes a bigger part of the overall generation resource mix, it is important that the industry provide both plant operators and electric utilities with the tools necessary to efficiently and safely maintain interconnection of these sites to the grid, while still allowing the site owners to meet operational objectives. These objectives vary from site to site. Some want to reduce their facility's total purchased power, and some want to sell power to their utility. Some sites wish to retain reserve capacity for use as support during a frequency or voltage event, and some need to react to such events at a high speed using co-located battery storage. All these sites, however, must operate within a structured agreement with the utility they are interconnected to, and these agreements can contain requirements regarding net-zero export, reverse current flow monitoring, down-ramp control, frequency control or support, battery integration, and other power resource integration.

This paper examines these items from a technical perspective, as features that are being integrated into solar grid management controllers. It also examines how current and emerging standards impact energy management of distributed energy resources. The impact that interconnection and power purchasing agreements have on PV generation inverter management and the technical challenges presented by implementing these features all must be balanced by careful design and application, with a focus on simplicity and reduction of complexity. Successful implementations of these next generation solutions must allow PV generation site operators to meet emerging expectations for interconnection performance and capability. Implementations must also make the presence of ever-expanding DERs a successful venture for all parties involved.

I. Introduction

It is difficult to exaggerate the growth of solar energy in the past decade. Photovoltaic (PV) energy has many attributes that make it unique compared to other generation types. But one of the biggest differences is the ability for PV panels to scale from small rooftop systems at 1 kW up to large PV farms at 100+ MW. No other generation type sees such a variety of installation locations from residential homes, commercial facilities, farms, small generation sites, and large utility power plants. Panels in each of these applications affect the power grid in different ways. In addition, the motivation for owners in each of these different applications is unique. Smaller systems, 1 MW and under, are typically owned by residential and commercial sites that are looking to offset their power bills from the utility. Some of these sites may integrate with batteries and be able to operate on their own, but that is not the primary purpose. Some of these systems may feed back into the grid and generate revenue for their owners, which is often a bonus for them. These owners are typically very cost sensitive and are looking to generate as much power from the panels as possible. There are some exceptions, but most are not concerned about the power factor of their PV system, VAR control, or the ability to curtail inverters at certain times. Their goal is to offset their power bill and sell extra energy to their utility, if possible. These site owners are looking to spend very little to no money on engineering and a PV controller separate from the inverters.

There is another tier of solar power systems that is typically in the 1 to 20 MW range that is a small dedicated power plant not looking to offset power bills or provide greater reliability to existing infrastructure. The owners of these systems generate revenue by selling energy into the power grid. Depending on the market requirements for where these solar farms exist, they have varying needs for a power plant control system. Some solar plants are able to sell as much power as they can generate and are compensated for curtailment, so the only PV controller functionality they need is curtailment functionality, whereas other solar farms participate in unbalance markets and need to bid into the market at an economical price and provide energy accurately in their assigned five-minute windows. They can also sell ancillary services. This requires additional PV controller capabilities. These sites may or may not plan to have engineering costs for a power plant controller.

The largest solar power system tiers is are large power plants that can exceed 100 MW of capability. Typically, these sites are utility-owned and are dedicated solely to generating large amounts of power. These sites are expected to operate at specific voltage ranges, provide VAR support, and take power output set points, among other services. These systems require a power plant controller, and the engineering work to design and build these sites is planned into the system.

This paper examines new features of PV energy and the benefits they can provide. Over the next decade, these features will likely become standard options in power plant controllers as PV energy continues to become a larger portion of the generation mix and the power system continues to integrate with these systems in new ways.

II. Modern Plant Controller Features

The primary objective for any PV plant is to generate usable power (watts). However, the reality is that more than just watts or kilowatts (kW) must be considered when exporting power to the grid; voltage and reactive power must be considered as well. The purpose of a PV plant controller is to operate all plant assets in concert in order to meet a set of objectives defined at the point of common coupling (PCC)—the bus that acts as the boundary between the plant and the utility. Referencing the PCC in terms of both generation quantities and control values serves multiple purposes: it allows the utility and the power producer to better communicate on the same terms, and it allows plant measurement and control to be simplified. The following sections provide additional explanations.

A. Plant Control Fundamentals

Consider a plant with 24 1 megawatt peak (MWp) PV inverters. The owners of this fictional facility want to generate 19.2 MWp. If the facility does not have a plant controller, each inverter must be provided with a set point of 800 kW and each inverter output must be monitored (see Fig. 1). As solar irradiance varies over the PV panels, one or more inverters may be unable to produce 800 kW for periods of time. This results in less than 19.2 MWp being produced because since the inverters are not coordinated, each inverter is not aware of the outputs of the other inverters.

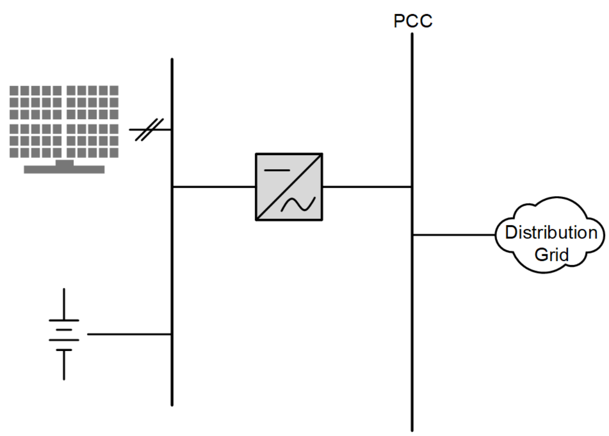

Fig. 1. Uncoordinated Inverter Operation

1) Plant Controller Without PCC Data

The plant described above could coordinate its inverters by using a plant controller (see Fig. 2). A plant controller receives the 19.2 MW set point from the operator and, using that along with its knowledge of the size and quantity of PV inverters within the plant, calculates and sends a set point to each inverter.

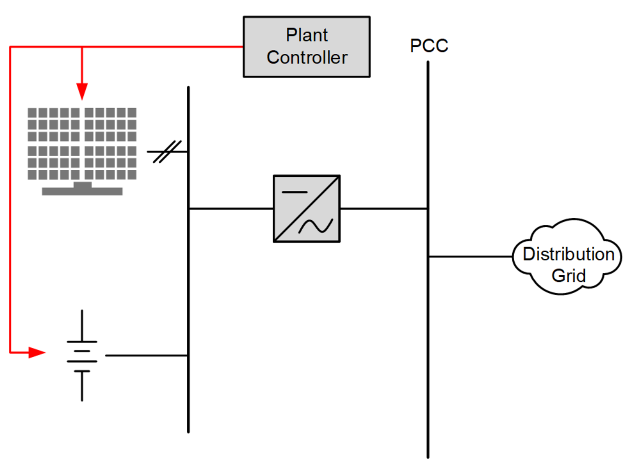

Fig. 2. Plant Controller Without PCC Measurement

The plant controller can then communicate with each inverter to determine its present output, sum the outputs together, and make set point adjustments as necessary instead of using a meter at the PCC for the summation of inverter output. This can greatly stabilize the plant output at the PCC, but this solution comes with several problems.

a) Misoperation Risk Increases With Inverter Count

A plant controller designed in this manner depends on its ability to accurately sum the power exported from each inverter and make control decisions based on that calculation. It must also rely on the ability of the inverter to reliably accept and apply a provided set point. The risk of an inverter failure, instrumentation problem, or inadvertent inverter mode change increases as the device count increases, and a single failure will result in inaccurate power export control.

b) Inverter Communications Are Not Always Fast Enough

Most PV inverters communicate using the Modbus protocol. The round-trip time between sending a set point and receiving an updated quantity for exported power can be seconds. For control schemes that require speed, such as frequency control, voltage control, or high-speed smoothing or down ramp control (discussed in future sections), this is unacceptably slow. A faster method of measuring total plant export power is needed.

c) It Is Not the Simplest Solution

The plant controller described thus far requires 100 percent reliable communication with every inverter. Losing control of an inverter because of a network problem or equipment fault will result in a loss of accurate control of export power; the plant controller cannot be certain whether the missing inverter is exporting any power or not and it must make an assumption (usually the last-sent set point or zero power output). This solution is most reliable when only one inverter exists and becomes less robust as the inverter count increases. Ideally, a plant control design would have the reliability of a single inverter plant but be able to control virtually any number of inverters.

2) Plant Controller With PCC Data

Fig. 3 shows a plant controller that is collecting data from a revenue meter monitoring the PCC. The addition of a meter eliminates the need for the plant controller to monitor and of all the output quantities reported by each inverter.

A direct measurement of all relevant quantities (kW, PF, VAR, V, and F) can be provided to the plant controller at high speed (as fast as 60 times per second) via a protocol such as IEEE C37.118 Synchrophasors. This makes it possible for precise plant control by directly comparing a user-provided set point (19.2 MW) to an actual PCC MW output. This controller design can now assume that the value it is measuring (kW in this example PCC) may not correlate accurately with the quantities it is controlling (inverter kW set points). This is true in the event of a faulted inverter, a communications issue, or a load present behind the PCC bus that is not modeled in the plant controller. Failure of any plant asset, besides the high-availability meter, no longer negatively impacts the ability of the plant controller to precisely control output. The controller usually accomplishes this by using a proportional integral (PI) controller.

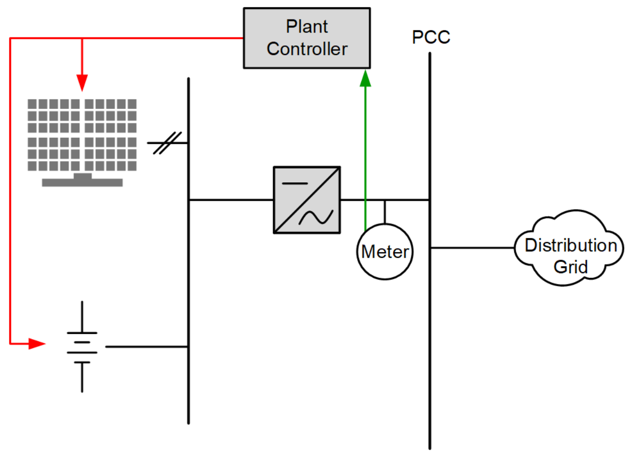

Fig. 3. Plant Controller With PCC Measurement

B. PI Controllers for Solar Plant Control

A PI controller is a feedback control algorithm commonly found in industrial applications. This algorithm is most often referred to as a proportional integral derivative (PID) controller, but the derivative term is often unused in solar applications because the rate-of-change of measured error is often not as much of a concern because both the measured and controlled values are closely coupled in normal operating conditions.

A PI controller measures one analog value, compares it against a user-provided set point, and adjusts a control analog value until the measured value and set point are the same (see Fig. 4). The beauty of this algorithm is that the measured value is not required to be the same as the controlled value. An example of this is solar plant voltage control: PCC voltage is the measured value, and inverter VARs is the controlled value.

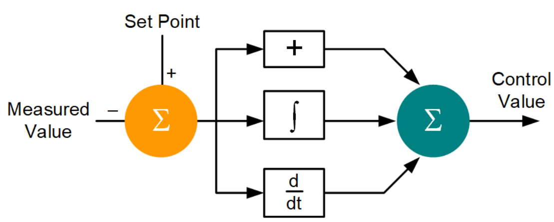

Fig. 4. PI Controller Operation

The advantage of a PI controller in solar plant control applications is it allows the plant controller to remain effective even if one or more inverters become unavailable. It also allows the control algorithm to continue to operate when the measured value and the controlled value are very different. For example, a measured power factor at the PCC may differ from the power factor set point sent to the inverters because of an unmodeled capacitor on the PCC bus or unmodeled transformer reactance. Technically, these items do not need to be modeled in the plant controller. The use of PI controllers makes the control algorithm forgiving to a plant model implementation that is incomplete.

III. Solar and Storage

As PV continues to become a larger portion of the worldwide generation mix, it is increasingly apparent that some technical challenges need to be addressed. The largest of these is that PV is an intermittent resource (dependent on the weather and geographical insolation). The reality is that renewable resources that are dependent on day-to-day weather are not reliable in the same way as more traditional generation resources. This is true whether the forecast horizon is considered in terms of days, hours, or minutes (the wind may suddenly start or stop, cloud cover may be highly variable, etc.). This complicates the abilities of PV resources to participate in energy markets and, without technical solutions, may lead to grid reliability issues in the future as these resources continue to be commissioned.

Another challenge for PV generation is that generation peak (usually in early afternoon) generally occurs prior to load peak (usually late afternoon to evening). Resolution of this misalignment of supply and demand requires a mechanism by which energy can be shifted in time (i.e., captured at peak generation and distributed at peak load). PV co-located with storage presents a possible solution.

A. Using Storage for Time-Shifting Generation

Storage comes in many forms; pumped hydro, thermal, or batteries and fuel cells. All of these solutions have different economic, technical, and environmental impacts, but all serve the same end: store energy for use at a later time. As PV gains additional presence on the grid, its contribution at peak output begins to create a “duck curve” (a sharp reduction in net load mid-day, followed by a steep ramp in demand as solar irradiance decreases in late afternoon). Storage solutions can flatten this curve by more evenly distributing PV generation later into the day. Storage may charge off-grid during periods of decreased demand in order to maintain an appropriate state of charge (SoC). The economic impact of SoC is something system operators are only now beginning to take into account [1].

B. Using Storage for Output Smoothing

PV and storage are both low-inertia resources—they can ramp up and down extremely quickly if needed. Because of this, they may be able to take advantage of the marginal cost of under- or over-supply in energy markets [1], but they can also create problems of their own. Sudden decreases in renewable generation because of intermittent cloud cover and other weather results in sharp variations in output capacity. These variations cause increased stress and wear and tear on rotating generator components that must adjust in real time. Storage can be used to smooth the output of PV sites by enforcing down-ramp control. While storage solutions are often referred to in terms of “four-hour supply,” meaning they are designed to provide a specific number of MWh for a four-hour period, this particular use case is a much shorter period. When PV output drops dramatically because of variations in weather or some other on-site event, storage can discharge to smooth the output. Plant controllers monitoring the PCC meter at high speed can use onsite storage to account for seconds-long variations in PV output. If PV output lags for a sufficiently long period of time (many seconds or minutes), the plant controller can begin to decrease the storage resource to slowly ramp total plant output down to the new PV output value. Using storage for smoothing and ramp control results in more predictable output behavior from PV resources.

C. Using Storage for Localized Peak Shaving

Large commercial and industrial facilities are often charged a peak demand surcharge on top of their use-base cost. In other words, they are charged not only on what they use, but on the maximum amount they require at any given time. In this way, these larger customers pay a share of the infrastructure and peaking capacity that the utility must maintain in order to provide enough energy to meet that peak demand. This peak demand is often calculated once per billing period (for instance, every month). Because of this surcharge, commercial and industrial customers are turning to plant controllers capable of using storage solutions to reduce this peak demand by discharging when load is high and charging when load is low. This not only reduces the demand surcharge they receive from the utility but decreases the amount of costly peaking power that the utility must provide.

IV. Ancillary Services

A majority of PV generation sites have one primary objective: export as many watts as possible. These sites may vary in size from 1 MWp to hundreds of MWp. They tend to be small in comparison to traditional generation sites and are more numerous—interconnecting to the distribution and transmission system at many different points. This injection of power at many distributed locations creates a few technical challenges. For instance, voltage and frequency become more difficult to regulate. Fortunately, although PV sites are one cause of the problem, they can also be the solution.

A. Using PV Plants for Frequency Regulation

When frequency deviates from its nominal value (e.g., 60 Hz) grid-connected generation resources and the grid as a whole respond with two different actions: primary and secondary frequency control. Primary control is generally a response to a change in turbine speed or grid frequency by a turbine governor or electronics controlling an electronically coupled generation resource [2]. These actions are taken to stabilize grid interconnections. Secondary response is then taken to return frequency to its nominal value and may incorporate a combination of local generation control and grid-level balancing control. System operators compute an area control error (ACE) that indicates the amount of real power that should be injected into the system to return frequency to its nominal value. They then draw on available generation resources to reduce ACE [3]. A centralized plant controller can adjust real power output in response to set point changes received from a system operator or in response to a change in frequency measured at the PCC. For PV plants with storage capability, a decision could be made to charge or discharge in order to assist in stabilizing the grid until frequency returns to nominal.

B. Using PV Plants for Voltage and Reactive Power Support

Most modern PV inverters are capable of generating power at a specific power factor (PF). Some are also now capable of processing VAR set points, which makes PV sites capable of providing voltage and reactive power support without a change in real power output. Plant controllers can coordinate PV inverters to supply or consume a set quantity of VARs based on a manual set point received by an operator, by a deviation in voltage observed on the PCC, or by following a multisegment curve relating volts to VARs. A proliferation of distributed energy resources (DERs) increases the possibility for voltage deviations (especially high voltages at the distribution bus inside the substation). PV generation sites must be able to adjust VAR output to compensate for this occurrence.

V. Forecasting Power Production

Forecasting power production from PV and wind generators seems like a feature that should be in high demand from power plant controllers. However, forecasting power production in combination with meteorology data is not a feature available in most power plant controllers. The sites that have the greatest need for forecasting information are solar and wind sites that connect to independent system operators (ISOs) who need to know how much energy they can get from these sites in order to participate in the energy market. These sites do not handle the forecasting of their own power production. In order for each of these sites to connect and participate in a market that is run by an ISO, they must send weather data via the telemetry system, and they are typically charged a few cents per MWh to have forecasting information performed for them. Sites are able to provide their own forecasting information through another interface to the ISO; however, the site is still typically charged a forecasting fee. In addition, the site owners must demonstrate how they are going to perform the forecasting methods and gain approval [4], because generating forecasting data is a nontrivial activity. It is for this primary reason that power plant controllers do not provide forecasting power production. The primary reason that power plant controllers do not provide forecasting power production is that there is no market drive for this functionality.

An interesting market drive in this area is the desire for generation owners to integrate storage with their solar and wind generation capabilities. This has potential to significantly alter the capability of the generation site. ISOs recognize this challenge today, and as a result, they require that the generation owner provide forecasting data if a site integrates storage and generation behind the same meter [5]. This is a significant challenge that most generation site owners do not want to own. As a result, most hybrid generation systems have a separate generator ID and meters for integration with their ISO. This certainly simplifies the approach for ISOs who are able to easily identify generation capabilities of both the PV and wind site and the battery. However, this introduces additional complexities and cost for the generation owners who would like to remove or simplify these barriers. California Independent System Operator (CAISO), a leader in integrating solar and wind into the energy market, is currently in the process of revising their technical report for integrating hybrid systems into the energy market. This initiative discusses a couple of methods for submitting generation capability. Part of the proposal discusses the idea that resources will reflect their generation capability through their bid capacities by using their existing mechanisms. If the generation resource experiences intra-hour variability the generation resource will be required to submit forecasting capability in real time to CAISO on its own. This new proposal will require generation owners to own the forecasting process rather than CAISO [1]. Scheduling coordinators who would be responsible for these data may drive this calculation to be done in power plant controllers or identify another mechanism for forecasting, because currently, CAISO does not accept forecasting data through their telemetry system. It seems clear that the ISOs will not take the additional complexities of attempting to calculate hybrid system power production capabilities. As such, it will drive this functionality into either the PV controller or another system that requires significant data from the PV controller.

When examining the required forecasts for ISOs, a few different kinds are required. But for the discussion of this paper, these forecasts can be broken into two categories: next-hour forecasts (5 minutes to 6 hours) and next-day forecasts (6+ hours). The next-day forecast requires a significant amount of information that power plant controllers simply do not have access to. Often, this weather analysis is generated using satellite data and sensors over a wide geographical area to predict weather movement over the generation site several hours/days ahead. This type of forecast also benefits from averaging forecast data over large geographical regions to create a more accurate model for overall production capabilities of solar/wind generation [6]. This type of forecast does not make much sense for a power plant controller to calculate. Nor is it very beneficial to system operators who interact with the power plant controllers who are focused on real-time operation and future short-term production. Power plant controllers will primarily need to focus on the next-hour forecast, which benefits significantly from the local weather station at the site. There is some disconnect between the forecasting goals of day-ahead information, which looks for general approximations to see the need of generation capabilities from solar and wind, and the need to coordinate with other resource types. However, bidding into the energy market requires great accuracy in the amount bid, accepted, and produced. Therefore, it makes the most sense for a power plant controller to calculate a short forecast and coordinate it with a long-term forecast. The long-term forecast is used to create the day-ahead market bid and identify any potential differences in order to avoid fines or pick up additional power production bids and increase revenue that a power plant controller could have potentially missed out on.

There is a large amount of actively ongoing research regarding mechanisms for developing next-hour forecasting data. Many mathematical models and methods are being explored to create a more accurate prediction. This paper briefly covers a summary of the most significant factors in calculating the forecast and the general methods that can be applied. The primary factors that determine how much power a PV panel will produce are the irradiance in the plane of the PV array and the temperature at the back of the PV modules [6]. There are two general approaches when taking this information and creating a forecast of power production. The first is a physical approach where the irradiance and ambient temperature are measured and then combined with system location (geography and time of year have a large impact on PV performance), orientation, and manufacturer specifications about the PV panels. These are then processed to create the forecast. The second approach can be categorized as statistical and relies on past data of irradiance, temperature, and PV panel power output to train a model of what power output will look like based on the current value of measured irradiance and temperature [6]. An advantage of this method is that it does not require any information about the specific inverter, making it universally applicable to systems, regardless of manufacturer. The trade-off is that a certain amount of time and data are needed before forecasting can begin. Both of these methods have some accuracy error for calculating the power output of the system but errors for both methods are in the low single-digit percentage range [6]. The next important part in creating a forecast for a local system is to identify what the irradiance measurements and temperature will be in the next 10 minutes to couple of hours. For irradiance and temperature, the primary source is the sun, which has a very predictable behavior and can be extrapolated to the near future. A major factor that affects irradiance is interference of the sun from cloud cover. If the sky is clear, these values can be calculated with a relatively high degree of accuracy; however, these values significantly fluctuate with varying degrees of cloud cover. The next natural step becomes identifying incoming cloud cover over the PV site. For immediate measurements, sky imagery is measured onsite by taking pictures of the sky and using image processing to track cloud movement and calculate irradiance based on the cloud shadow that is created by the opacity of the cloud. By measuring the direction and speed of the cloud, the approximate time when the cloud cover will affect PV power production can be identified [7]. This provides intra-hour forecasting information that, with a small amount of advance notice, gives power system operators knowledge of potential ramping that will occur and can be used to account for upcoming changes in power production. To account for forecasting data that are approximately 1 to 5 hours ahead, a data source other than sky imaging directly at the PV site is needed. Satellite imagery is starting to become a more accurate source of data for determining incoming cloud movement [7]. This adds another level of complication to the forecasting calculation because the PV controller needs to communicate with an outside source to obtain these data. This forecasting information, while useful to understand expected PV panel output for energy production and usage purposes, becomes significantly more valuable with integrated storage systems that can begin to make economical choices about when to charge and discharge storage systems based on weather, time of day, and energy market price. Current challenges today include getting this information to the PV plant controller to run these forecasting calculations and integrating it into the traditional power system communications systems.

VI. Data, Analytics, and Visibility

Traditionally, power plant controllers have been implemented in PLC platforms, which historically have been excellent platforms for hardware reliability and cyclical data processing—two important factors for a power plant controller integrating with the power system. Reliable and hardened electronics, which could pass a wide variety of type tests and operating temperatures, historically limited CPU, memory, and storage capacity. These are three important factors in storing data and performing analytics. Most operational data for power plant controllers today are either consumed in real time and then lost or a small subset of them is passed into a historical database where more processing power is available for analytics.

However, modern technology is starting to change the computational resources available in substation-hardened equipment with multiple cores, substantial memory, and expandable storage solutions that meet the operational requirements of a power plant controller. The power plant controller is the center of information for a wide variety of PV systems. Only a small subset of the data goes on to supervisory control and data acquisition (SCADA) or ISOs for operational information. Not all of this information about each individual inverter needs to leave the power plant controller, but it can be analyzed and monitored in a manner that is beneficial to the site power system operators.

A. *Inverter Maintenance*

Power system owners are becoming very serious about condition-based monitoring and preventive maintenance for many power system assets including current transformers (CTs), potential transformers (PTs), circuit breakers, transformers, capacitor banks, power lines, and other equipment. The same needs to become true for PV panel inverters. The large expansion of PV inverters has mostly occurred in the past decade and most of these systems are being put in service with little maintenance or performance data being passed through. Power plant controllers should be doing more than simply passing along power output, fault status, and communications status. Power plant controllers see the power output across multiple inverters and should be comparing the power output from each inverter against each other. Cloud cover and other small factors may account for power production differences for a 12-hour period, but over the course of a week, a month, or a year, inverters of the same model and capacity should have very similar production values. Just like CTs and PTs are monitored to determine if they are out of spec with each other, inverter power production should be compared against other inverters in the same site to identify inverters that do not perform as well as other inverters. A 10 or 20 percent decrease in one or more inverters is unlikely to be recognized at the PCC since many power plant controllers use closed-loop PI controllers to meet set point requirements. Power system operators will not know that the PCC is simply requesting more power from inverters that are able to produce the requested set point to account for a reduced output from inverters with a degraded performance. By recognizing power production inverters, maintenance personnel can be alerted to investigate individual inverter problems before the inverter goes into a faulted state or offline completely.

B. *PV Plant Utilization*

Earlier in this paper, the topic of PV plant forecasting is discussed and why it is so challenging to predict future performance based on weather patterns. However, an easy calculation and measurements for the PCC is to determine what the maximum power production is in real time. This should be correlated with actual power plant production and recorded over periods of time. Generation owners can easily see their return on investment of the plant by comparing their revenue to cost of operation and construction costs. But they do not often see their potential missed revenue based on the capacity to generate and the actual amount produced. Sometimes when market prices are high, it is easy to ask or review how much more the system could have produced in that small window. But, if the PCC were to keep track of this information all the time, generation operators and scheduling coordinators would have significant information on the utilization of the generation site and could potentially affect how they bid that site into the energy market.

VII. Conclusion

This paper has discussed a variety of power plant control features targeted toward PV generation that are not standard or even options on most PV plant controllers in the market. But even if these PV plant controller features were standard to system operators, these features are not being driven by owners of these generation devices. Functionality of power systems is typically driven by economic benefits or regulation requirements. The features discussed in this paper all offer greater utilization of PV generation sites that would increase the economic benefits to the PV generation owner. However, because of the wide use cases of PV generation panels, the entirety of the market does not drive the same requirements for controllers. PV generation has a wide variety of power purchase agreements. Some sites are allowed to produce as much or as little as they are able to and are compensated for it. Other sites participate in energy markets that are run by ISOs, which have strict regulations and financial penalties for not meeting production targets from accepted bids. However, even where economics would normally drive advanced functionality of PV controllers, there are regulations that make it difficult for generation owners to incorporate PV and storage at the same site. This reduces the drive for more sophisticated control capabilities that could produce greater economic benefits.

Regulatory hurdles reduce the drive for more sophisticated control capabilities that could produce greater economic benefits. As most papers and articles about PV indicate, the generation capacity keeps increasing to make up larger double-digit percentages of the generation mix and the price of solar energy continues to drop. Technology of power plant controllers is not the limiting factor in increasing PV panel integration into the bulk electric system, but rather policy and regulation of PV generation are preventing further advancements in its capabilities.

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IX. Biographies

Brian Waldron is a development lead automation engineer with Schweitzer Engineering Laboratories, Inc. He has several years of experience in designing and troubleshooting automation systems and communications networks. He has authored several technical papers, application guides, and teaching presentations focusing on integrating automation products. Brian graduated from Gonzaga University with a B.S. degree in electrical engineering.

Bryan Fazzari is a development lead engineer in the research and development division of Schweitzer Engineering Laboratories, Inc. (SEL). His primary focus is on the current and future application of automation products, protocols, and technology in the industrial and electric power sectors. He has extensive experience with the design, configuration, testing, and commissioning of a wide array of automation systems. These systems include distribution automation control solutions, industrial high-speed load shedding applications, data collection and concentration systems, HMIs, and custom simulations and training programs. Bryan joined SEL in 2007, and since that time he has worked in both research and development and engineering services in both technical and management roles.

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