

Article

Dispatchable Substation for Operation and Control of Renewable Energy Resources

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Abstract: Renewable generation in power systems has proved to be challenging for system operators owing to the increasing levels of penetration. The operation of power systems currently requires additional flexibility and reserves due to the intermittency and unpredictability of renewable generators. However, it is difficult to precisely predict and control the stochastic nature of renewable sources; nevertheless, its capacity continues to increase. To monitor and control renewable generators efficiently, the entire system needs to be established in a hierarchical order. This study proposed the concept of a substation that is uniquely designed for renewable interconnection. The purpose of this substation is simple: to make the renewable generators dispatchable to operators such that each group of renewable generators is sufficiently stable to be considered as conventional generators. For this purpose, methods for sizing and controlling energy storage system are proposed based on forecasts and error distributions.

Keywords: DIR; ESS; forecast error; renewable generator; substation

1. Introduction

Transmission system operators (TSOs) face several problems owing to the increased penetration of renewable generation in existing power systems. Photovoltaic (PV) and wind power generation depend completely on natural phenomena. These sources differ significantly from conventional synchronous generators in terms of intermittency and unpredictability. Despite these drawbacks, the proportion of renewable energy production continues to increase globally. In 2019, the net capacity of newly installed renewable generation exceeded the net installation of fossil fuel and nuclear power combined [1]. In most countries that lead in terms of renewable generation, the levelized cost of energy (LCOE) of PV and wind generation is less than that of newly built fossil fuel generators. Furthermore, renewable generation is expected to increase in capacity owing to economic and political factors.

Operating a power system with a high level of renewable energy penetration requires auxiliary devices for grid balancing. Previously, the power generated from renewable generators was absorbed into a network without any constraints. The balancing and stabilization of a network depend entirely on the synchronous generators in a system. Several problems arise with the increase in penetration level, such as frequency stability and lack of inertia in the power system [2,3]. The primary cause of such problems is the displacement of the synchronous generators by renewable generators that cannot

inherently contribute to the stability of the network. Numerous studies have been conducted and countermeasures have been adopted for the stable operation of a power system with high levels of renewable energy penetration.

The most reliable and fundamental solution for this problem is to increase the proportion of synchronous generators or other devices that can suitably replace synchronous generators. Energy storage systems (ESSs), or synchronous condensers, are considered to be good alternatives for synchronous generators. Pumped storage hydroelectricity generators or batteries can absorb or supply active power to the network, while synchronous condensers can increase the overall inertia of the network and enhance the voltage stability. The response of a battery energy storage system is sufficiently fast to support the frequency response of a network with properly designed controllers. However, the capital costs of these devices hinder the realization of the required capacity for a power system. In a case where countermeasures are insufficient, a grid operator needs to limit or curtail generation from renewable generators directly. As the cost of renewable generation continues to decrease and with the increase in penetration, several TSOs have started adopting constraints or curtailment of renewable generation at a daily or hourly basis. In previous research, ref [4] proved that forecast information can be utilized to make renewable generators dispatchable, similar to conventional generators. The Midcontinent Independent System Operator (MISO) uses an interconnection tool to operate PV and wind turbines as dispatchable intermittent resources (DIRs) based on the forecast information obtained every 5 min. It is expected that more TSOs or power systems will consider renewable sources as DIRs, as their penetration into their network continues to increase.

To realize the dispatchability of intermittent resources, the forecast information must be accurate. Depending on the reliability of the forecast information, the addition of ESSs is feasible if the amount of erroneous forecast becomes significant. Typically, TSOs design an appropriate range of do-not-exceed (DNE) limits of DIR to improve the accuracy of the forecast information. The DNE limits and dispatch signal can be applied to individual renewable energy source (RES) units or managed centrally at the plant level in case of large wind farms. Hierarchically managing the unpredictability of RES can be beneficial for both TSOs and renewable generators, because fluctuations caused by a large group of renewable generators would be more stable than a single unit's output [5]. Dispatching of DIRs can, therefore, be more efficient if multiple wind or PV farms are clustered together and made to work as a single generator unit. This can be accomplished at the substation level by adding ESSs and other auxiliary devices for more grid-supporting features.

In the cases of small distributed renewable sources, such as rooftop solar panels, these requirements such as DNE or curtailment order by TSOs are difficult to realize and may not be obligated in order to promote installation of distributed renewable sources by government policies. With the increasing deployment of renewable sources, the operation of transmission systems becomes increasingly complex. Therefore, to minimize uncertainty and complexity of generation from distributed renewable sources, hierarchical control can be implemented. In [6], the author proposed a hierarchical control algorithm for distribution systems with renewable resources. A substation is an ideal unit as a mid-level management center in hierarchical control. Furthermore, ESSs can be added to make groups of distributed renewable sources dispatchable, which can be performed at the substation level [7]. There are several studies and field demonstrations in developing ESS technologies to integrate variable renewable sources. Most representative use cases of ESS are for wind farm applications, such as Duke Energy BESS project in Notrees, Texas, or SCE wind energy storage project in Tehachapi, California [8]. In South Korea, more than 1.8 GWh of BESS are installed voluntarily by renewable generator owners to receive government incentives for shifting generation output [9]. Most of the ESS projects for renewable integration were designed to provide reserve capacity or shifting generation output. No project or demonstration is found for use of ESS for forecast error reduction.

Optimal usage of ESSs at substation may result in an increased use of renewable energy and reduced intermittency. However, the high capital cost and uncertain economic returns make the deployment of ESSs unattractive. Thus, many researchers have worked on optimization problems to

find the proper size and operation of ESSs. Mathematical programming and heuristic methods are popular for optimal sizing and siting of ESSs [10]. In case of utilizing ESSs for renewable energy in a predefined location, an analytical method can be applied by making use of statistical data analysis, such as historic wind or solar data [11,12]. Since wind and solar generation are highly stochastic, probabilistic method for ESSs sizing is suggested in many literatures. In [13], statistical behavior of the forecast error and ESSs sizing are analyzed for several forecast methods. In [14], the author suggested an optimal sizing method of ESS that operated under a model predictive control (MPC) scheme. The MPC is designed to consider forecast uncertainties within one-hour prediction horizon. When considering the ESSs in the substation for reduction of uncertainty by interconnected PV or wind, the relationship between forecast error and size of ESS needs to be analyzed under various combinations of renewable generator. Very few research studies are focused on defining these relationships. In [15,16], they suggested a method to build a spatial correlation of forecast errors in wind and load forecast using copula theory. In [17], the authors proposed a joint probability distribution model to define temporal correlation of hourly day-ahead short-term wind power forecast error for optimal ESS sizing, and yet the direct relationship between forecast error and ESSs capacity for uncertainty reduction is not defined.

This study proposes the concept of “Dispatchable Substation” (DSS) and describes its operation for interconnection of renewable energy sources. The relation between renewable forecast data and error is analyzed to find the optimal size of ESSs in the proposed substation. The key role of the proposed substation is to minimize uncertainties from interconnected renewable generators, to receive dispatch orders from TSOs. The entire substation and the interconnected RES are considered as a single generator unit with controllability. Additionally, the DSS provides emergency responses, such as inertia response, governor response, and reactive power support, similar to those of a synchronous generator.

2. Requirement for Dispatch-Able Substation

Numerous factors must be considered for the configuration and operation of DSSs. The overall operation of a DSS is depicted in Figure 1.

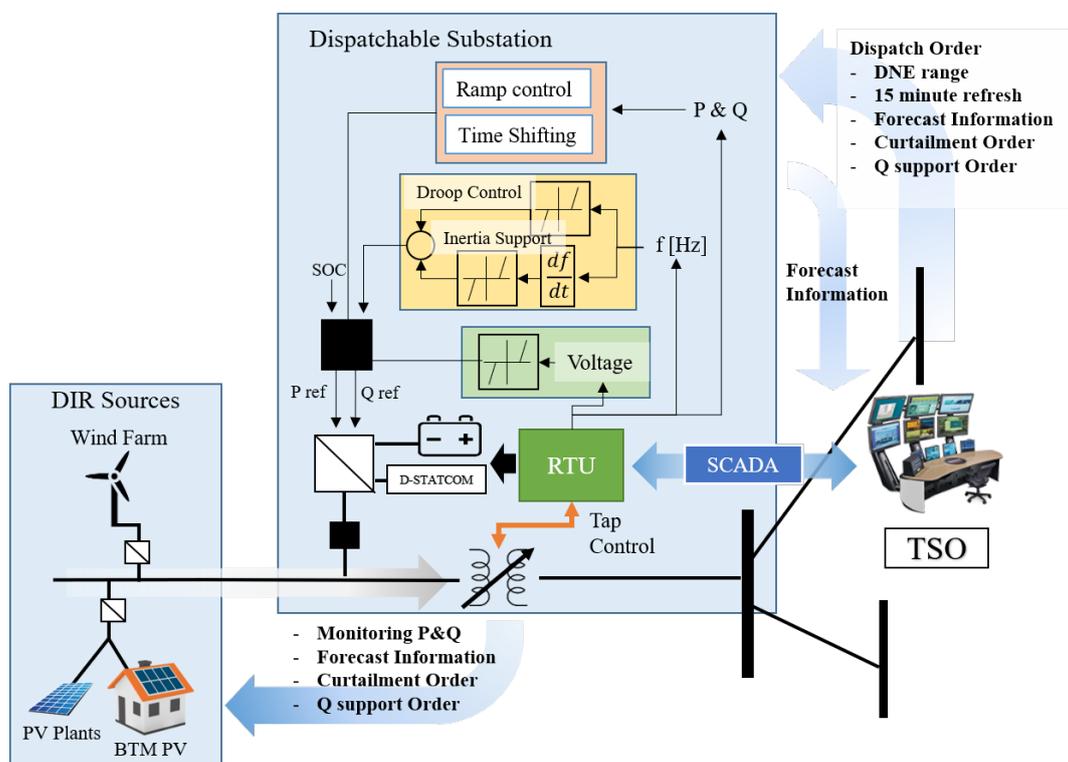


Figure 1. Operation of dispatchable substation.

2.1. Forecast Accuracy

The TSOs can predict the expected generation from renewable sources in specific areas using the weather forecast data. Wind velocity and solar irradiance are the key factors for determining the generation from wind turbines and PV generators, respectively. The accuracy of the forecast information declines with long-term prediction. Therefore, a DIR operator needs to combine multi-scale forecast data and predict the uncertainties in generation until the next dispatch signal is determined. When multiple RESs are combined, the accuracy of forecasting of the overall generation varies depending on the type and combination of the renewable generators. With combined forecast information, the DIR calculates an affordable range of generation within a certain period and reports it to the TSO. Then, the TSO calculates the optimal power flow (OPF) and dispatch signal for each generator without violating the security constraints. In case the security constraints are violated due to surplus generation of RES, the TSO may decide to limit or curtail their output.

Note that the OPF and security constraints should be managed by the TSO. A DSS is required only to provide accurate forecast information and firmly follow the dispatch order from the TSO. Therefore, a DIR or DSS requires only guaranteed output prediction with fewer errors. An ESS is an efficient solution for decreasing uncertainty from RES, because it can supply or absorb active power to compensate forecast errors [7]. For this purpose, an ESS can be assessed based on the manner a violation penalty is calculated and also based on the capital cost of these facilities. In terms of reliability, the capacity of the required ESS can be assessed based on the uncertainty of the interconnected RES. Because the stochastic nature of the RESs differs depending on the generator type, the configuration of an ESS should be assessed differently depending on the type and combination of the RESs.

Several differences exist between PV and wind generation in terms of their pattern and forecasting method. For periods of less than 30 min, the persistence forecast method works fairly accurately for wind turbines [4]. This is a prediction method based on the most recent output values from wind turbines; because wind plants usually have large mass and inertia, their output does not change instantly. However, for extended forecast periods, e.g., beyond an hour or day, this method becomes inaccurate quickly. The state-of-the-art forecasting method for wind turbines combines the results from several prediction models and data, and develops a complex dynamic space model to increase the forecast accuracy [18]. Doppler radars or wind speed sensors can provide information regarding the wind field around an area and increase the forecast accuracy when they are installed in sufficient numbers.

Changes in solar irradiance could be more drastic and noisier, compared with the variability of wind. For instance, a small group of clouds passing over a solar panel can cause variations in the irradiance level on the PV generator, thereby rapidly reducing the overall generation. Therefore, the formation of clouds and the movement of clouds and the sun are important factors in the forecasting of solar energy. Similar to wind forecasts, meteorological data and prediction can provide long-term forecast information, such as day-ahead prediction or much longer. For short-term forecasts, satellite images of clouds can provide accurate information about the time and location a shadow would cover an area. For a more accurate forecast, a high-resolution wind-angle camera can be installed in PV plants to find and track nearby clouds [19]. The system operator can put together multiple pieces of forecast information for an accurate prediction and report it to the TSO for dispatch.

The forecast accuracy of PV and wind power generation plays an important role in determining the range of dispatch for the next few minutes (before receiving the next dispatch order). Generally, the forecast errors for PV power plants are brief but drastic, because the prediction of solar irradiance is fairly accurate when no interference is caused by clouds. On the other hand, although wind power plants have less variability in the short term, long-term consistent errors could exist [20]. For reducing the uncertainties of PV sources, the ESS of a DSS requires the power conversion system (PCS) to have a large power capability; contrarily, connection to wind sources requires a larger battery capacity. Figure 2 shows the operation of a DSS when the predictions for solar energy forecast are beyond the limit of the TSO, represented by $DNE \pm 10\%$.

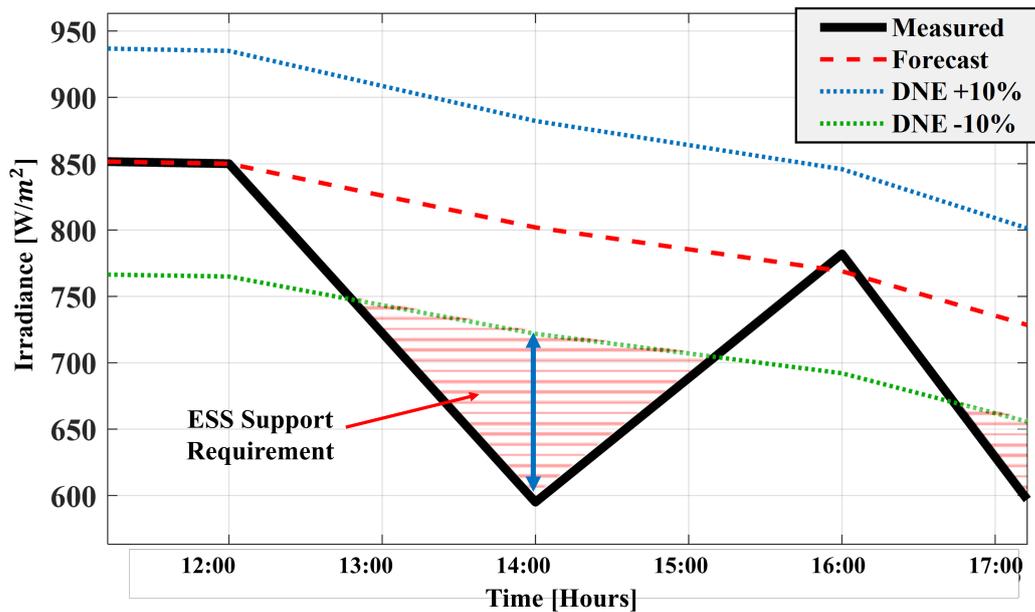


Figure 2. Operation of an energy storage system (ESS) in a dispatchable substation.

2.2. Mitigate Fluctuations and Voltage Stability

The interconnection of renewable generation can cause voltage fluctuations due to its variable output. It is the obligation of the renewable generator to maintain the power factor within a stable range, and in some countries, they are required to sustain the voltage level more actively. In the distribution system, a transformer usually controls the overall voltage level; if the fluctuations are very rapid, the distribution network fails to maintain the voltage within the range defined by the grid code. Developing a grid code for limiting the output fluctuations of renewable generation can improve the voltage stability of the network. Combining ESS with RES can efficiently smooth out fluctuations with low energy loss. Additionally, it can operate as a reactive power source for additional grid support. In the proposed DSS system, ESS can function as a reactive source; however, it is recommended to include additional reactive power sources. The frequent use of ESS for reactive support can reduce the overall life cycle of the devices, consequently increasing the operation cost of the entire system. Thus, the voltage support devices must be selected based on a detailed analysis of the neighboring network.

2.3. Emergency Grid Support and AGC

To operate a power system without adequate support from synchronous generators, a TSO needs to prepare sufficient number of frequency support devices to withstand contingency situations such as an “N-1 scenario”. A sudden drop in the number of power supply devices leads to imbalance and frequency deviation. Failure to balance out immediately after an event can trigger other generators to trip out for de-synchronization protection. In a power system with high renewable energy penetration, the frequency stability of the system can be severely exacerbated. A spinning reserve or hydro-pumped generation can be a direct solution for such situations, but they are not cost-effective and flexible. Recent studies have focused on the role of the ESS and renewable generators in the frequency support action. Because of its fast response, an ESS can act as a synchronous generator by creating a synthetic frequency response for grid support in the case of a contingency situation. The same control strategy can be adopted for converter-based generators, such as PV and a special type of wind turbine [21] (Types 3 and 4). The difference between ESS and renewable generators lies in the amount of time the

frequency response can be supplied. For prolonged frequency support from renewable generators, their operating efficiency can be intentionally curtailed from the maximum power harnessing status.

The DSS can be a suitable control center for interconnected renewable sources to arbitrate frequency support requirements for grid interconnection. Based on the forecast information and capacity received from the dispatchable substation, the TSO can calculate the operation reserve for the DSS. Then, the DSS manages reserve assets behind substations, such as the ESS and headroom of curtailed RES generation.

2.4. Frequency and Voltage Support Operation

For the interconnection of DIRs to a bulk power system (BPS), technical regulations or requests should be satisfied. The IEEE 1547 standard (revised in 2018) describes the requirements for the interconnection of distributed energy resources (DERs), including power quality, reactive power capability, and response to abnormal conditions. In [22], the allowable voltage variation induced by a DER was limited to 3–5% per second of its nominal voltage. Furthermore, the reactive power control capability of DERs, which is not included in most of the existing DERs, may become mandatory for voltage control by utilizing volt-VAr curves. In terms of response to abnormal conditions in a BPS, allowable operating modes, including mandatory operation and momentary cessation modes, are defined according to the voltage and frequency. Ref [23] introduced regulations not only for the disturbance withstand capability on abnormal voltage, frequency, and rate-of-change-of-frequency (RoCoF), but also for grid support functions, such as reactive power support and frequency response.

The regulations applicable for interconnection consistently demand DIRs to act as conventional generators with various support functions. However, considering the unique characteristics, including intermittency and variability, it is difficult for RESs to solely act as conventional synchronous generators. Specifically, satisfying these regulations could be challenging for DIRs that have already been installed based on the assumption of no further modifications.

In a contingency situation, a DSS is required to support frequency mitigation by supplying or absorbing active power. The droop response of synchronous generators can be easily replaced by the fast response of the ESS in a DSS. Figure 3 shows the frequency support response of a DSS. R_{ESS} refers to the droop response of a DSS that makes the active power response of the ESS proportional to the frequency deviation. The coefficient K_{IR} is related to the inertia response by creating a response that is proportional to the derivative value of the frequency. Theoretically, this response can create synthetic inertia for the power system and mitigate the rate of change of frequency [24].

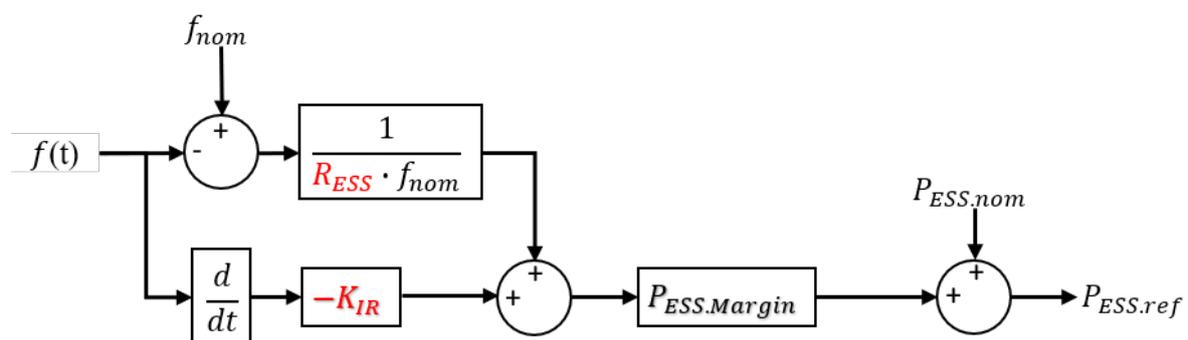


Figure 3. Operation of ESS in a dispatchable substation.

3. Operation of Dispatchable Substation with Renewable Generator Mix

The primary operation objective of a DSS is to reduce uncertainties from renewable generators for TSOs. Depending on the range of accuracy that the TSO is obligated to the DSS between each dispatch period, the size and operation of the required ESS can be determined. For instance, the New York ISO requires wind turbines to follow dispatch orders within 10% of their forecast, which is 8% for MISO [4]. By smoothing out the generation from renewable generators, the DSS can

regulate the voltage fluctuation of interconnected buses and the neighboring transmission lines. It is also the responsibility of the DSS to calculate accurate forecast information and report it to the TSO every few minutes. As mentioned above, the accuracy of the forecast information can be increased with the support of metering and monitoring devices; these can be installed within a substation, thereby minimizing the size of the ESS required for smoothing out the generation.

The operation and configuration of the DSS can be varied depending on the type of interconnected renewable generators and the quality of the given forecast information. The overall operation and sizing method of the ESS for DSSs are followed for a given set of meteorological data. The solar forecast information and actual measurement data for a year were obtained from Solcast (<https://solcast.com>), which is a global solar forecasting and historical solar irradiance data company. Solcast’s database has been recommended for use in solar research applications [25].

3.1. Operation of a Dispatchable Substation

Lithium-ion or lead-acid type batteries are the most commonly used batteries in ESSs; the expected battery life is directly related to the number of charge and discharge cycles that a battery can endure [26]. It is recommended to continuously operate under the charge mode or discharge mode until the state of charge (SOC) of an ESS reaches the upper or lower limit of its hardware specification. Accordingly, the operation mode of the DSS is bimodal for the charge and discharge of the ESS, (Figure 4). The forecast information reported to the TSO every 15 min is compared with the real-time measurement data to determine whether it stays within the DNE limit. In this case, 10% of the DNE boundary was adopted for both charge and discharge modes. The measured data is compared with upper bound (depicted as U.B) and lower bound (L.B) that calculated from DNE boundary ($\pm 10\%$ of forecast value) and decide the charge or discharge operation of ESSs.

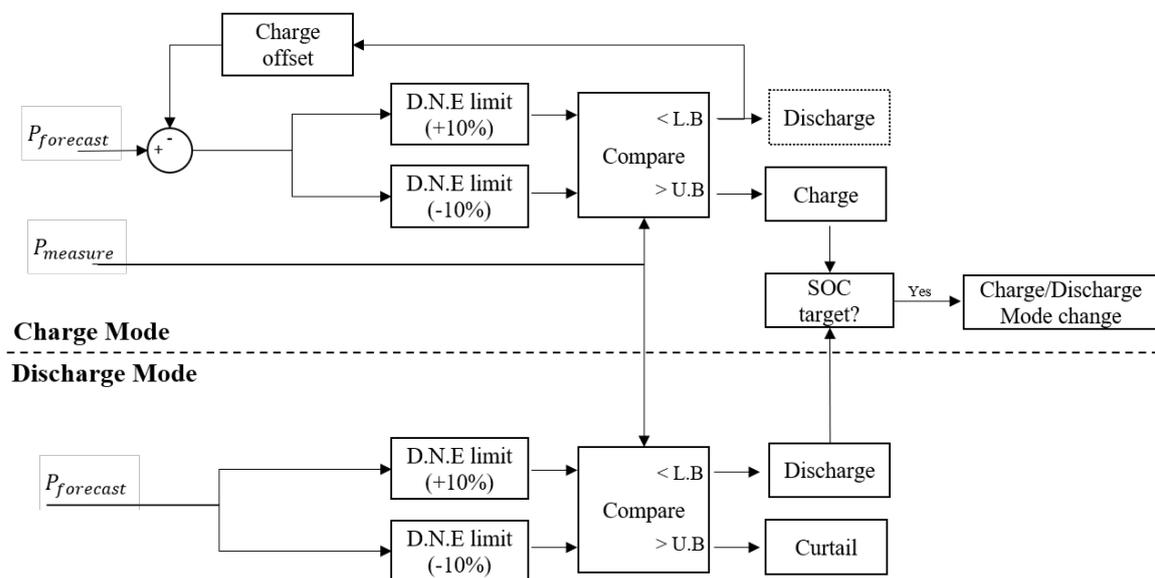


Figure 4. Operation of ESS in a dispatchable substation.

In the discharge mode, the ESS attempts to discharge as much as possible, while the charge operation is replaced by the curtailment of renewable generation under its interconnection. On the other hand, for the charge mode, the forecast information reported to the TSO is slightly decreased to make the charge operation occur more frequently. The charge offset for the charge operation should be properly assessed to avoid a situation that would require discharging of the ESS. Depending on the violation penalty by TSO for exceeding the DNE limit, the discharge operation can be neglected or conducted inevitably. Figure 5 shows the operation of the ESS under the charge mode with charge offset. The charge offset prevents the operation of the ESS from the mode changing at

around 11:40 in the simulation time. The charge offset should be adjusted in real time if mode change occurs frequently, because of the small offset value.

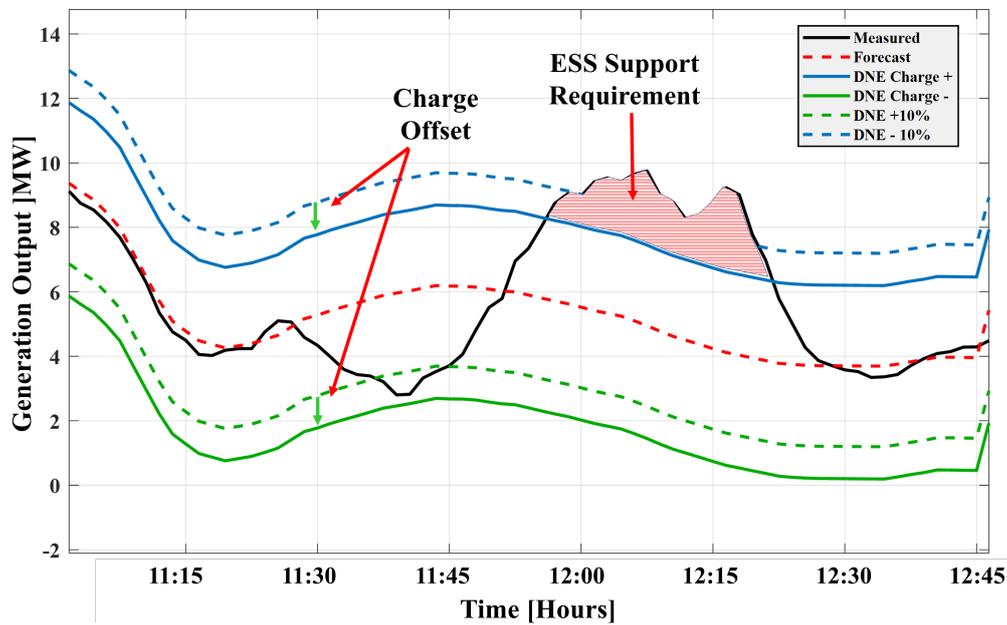


Figure 5. Operation of a dispatchable substation in the charge mode.

3.2. ESS Configuration Considering RES Type and Forecast Accuracy

A difference exists in the forecast accuracy and generation pattern between the wind and PV generators. It is important for the DSS to analyze the characteristics of interconnected renewable generators with a variable combination of PV and wind capacity. The combination of the generation mix is listed in Table 1 for a 30-MW substation connection. The forecast and measured data were obtained from a weather station near Rotterdam, Netherlands. For each case, solar irradiance and wind speed are adopted for the given capacity value to calculate the difference between the generation output of the forecast and the measured data. Figure 6 shows the deviation of the measured value from the forecast value for a given data of one year. The graph shows that case 1 (wind plants only) recorded the most frequent deviation from the forecast value. Except for the record of the 1-MW forecast error, the most stable generation mix with the least forecast error is seen for case 3, which has an equal proportion of PV and wind generator capacity. This is because the correlation between wind forecast error and the PV forecast error is insignificant.

Table 1. Generation mix for forecast error analysis.

	Wind [MW]	PV [MW]	Total Generation Per Year [GWh]
Case 1	30	0	255.9
Case 2	22.5	7.5	228.6
Case 3	15	15	201.3
Case 4	7.5	22.5	174.0
Case 5	0	30	146.7

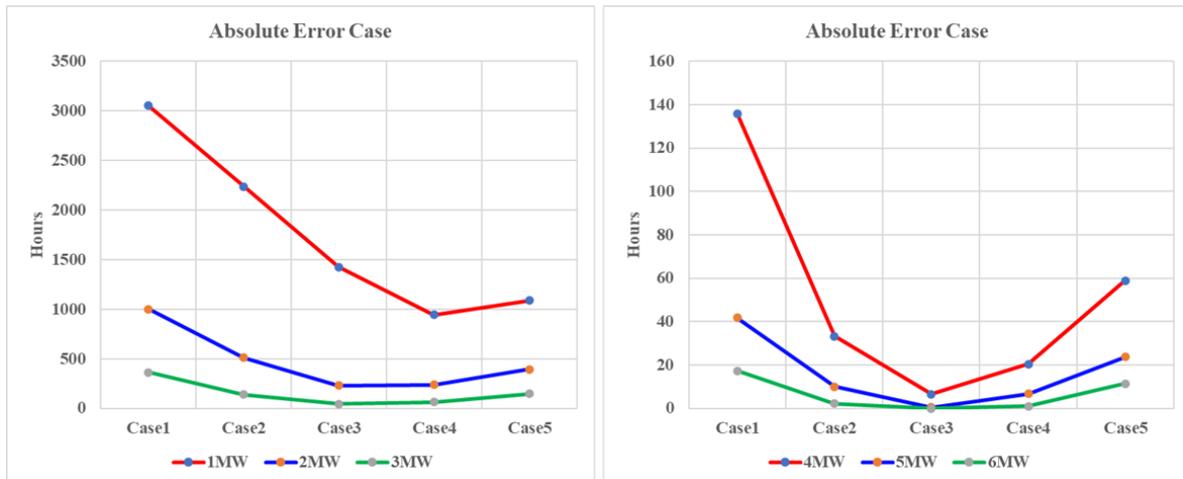


Figure 6. Cumulative hours of forecast error for each case in Table 1.

When the DNE limit set by the TSO is assumed to be 10% for the rated capacity of the renewable generators, the ESS in the DSS must actively compensate for the generation that deviates from the forecast values by more than 3 MW. For an operation data of one year, more than 365 h of violation occur for case 1, whereas only 45 h of predictions are missed for case 3. With a DSS, it is expected that the forecast error beyond the DNE limit can be significantly reduced. With the 0.5-MW ESS in the substation, the number of violations can be reduced by up to 50%. Although forecast errors for wind turbines are recorded more frequently than those for PV systems (compare case 1 and case 5), the total yearly generation of wind turbines is greater. Thus, a large wind-farm with DSS requires more ESS’s capacity than DSS with PV generators only. A precise assessment of the ESS’s capacity should be performed by comparing the capital cost of facilities and the economic benefits with ESS installation.

The joint distribution of the measured and forecasted generation output is shown in Figure 7. The correlation distribution within the DNE limit is depicted by a blue circle, and the mis-predicted data are depicted by an orange cross. The kernel distribution of the histogram of each data point can be found on each axis.

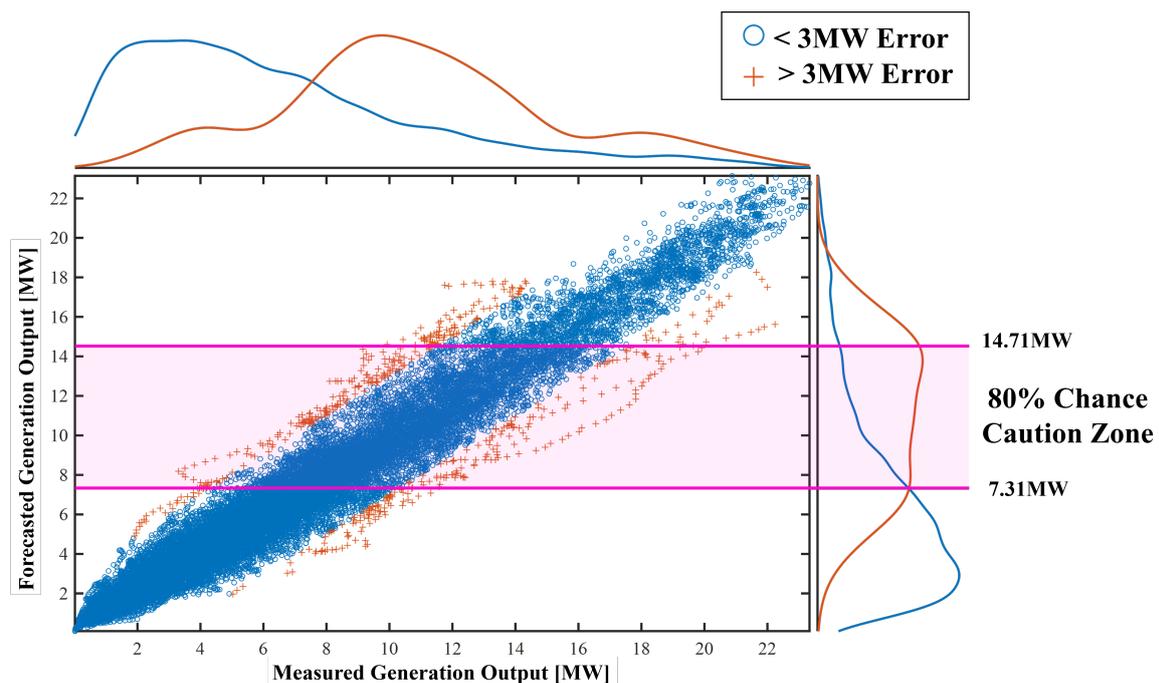


Figure 7. Joint distribution of measured and forecast generation output for case 2 in Table 1.

The blue line represents the kernel distribution of cases that less than 3 MW forecast error occurred while the orange line is the kernel distribution of cases with more than 3 MW forecast error. The distribution on x-axis is corresponding to the kernel distribution that is sorted by measured values. Likewise, the distribution on y axis is sorted by forecast values.

Normally, the distribution of wind generation can be described by a “Weibull distribution”. The data with more than 3 MW prediction errors have different distributions compared with normal cases that have a Weibull distribution. Furthermore, 80% of error cases are concentrated between 7.31 MW and 14.71 MW. It can be concluded from the joint distribution that the operation of the ESS in the DSS must be more active when the forecasted generation is expected to exist within the 80% area. In this case, the ESS can operate under the discharge mode because it can provide a wider range of active power support.

The joint distribution of the remaining cases is shown in Figure 8. The 80% zone was placed differently for each generation mix case, as shown in the graph. Therefore, the DSS control should be adjusted depending on the type and capacity of the interconnected generators. The capacity requirement of the ESS for each case is determined to reduce the forecast error to less than 0.01% of the total operation hours. The forecast and error data of solar irradiance and wind speed have a time step of 15 min. Thus, several assumptions are applied in the simulation. Assuming that the TSO performs dispatch in a period of 15 min, the battery capacity (MWh) can be calculated for a 15-min operation. Since the dispatch and forecast information is updated every 15 min, battery capacity for a 15-min operation is sufficient. This is a valid assumption, as the forecast error cannot be accumulated for more than 15 min period. One-year of wind speed and solar irradiance data are used for simulation, and the operation of ESS follows the scheme that depicted in Figure 4. The switch between charge and discharge mode of ESS in the substation is determined whether the forecast value lies in-between 80% chance zone or not. Using the given data, the required capacity(MW) of ESS is found via iterative simulation. Battery capacity(MWh) of ESS is calculated assuming 4-crate specification. The parameters for the DSS and ESS facilities are shown in Table 2.

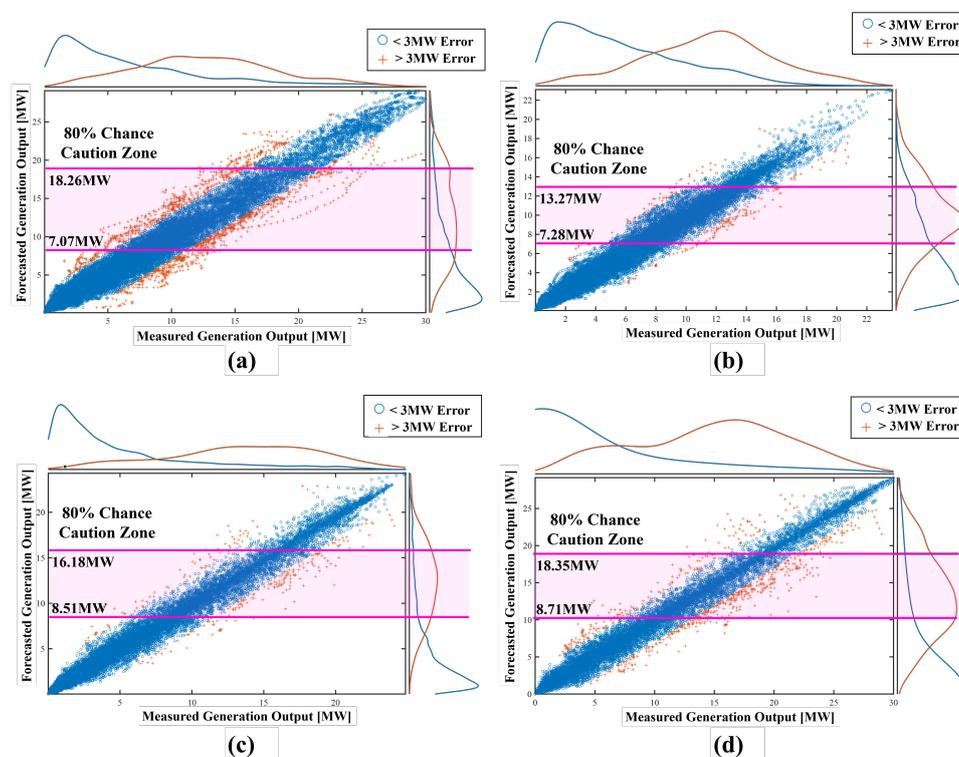


Figure 8. Joint distribution of measured and forecast generation output for (a) case 1, (b) case 3, (c) case 4, and (d) case 5.

From Table 2, it can be noted that case 3 requires the smallest amount of ESS for forecast error reduction. Since the correlation between wind speed and solar irradiance is unnoticeable, uncertainty from forecast of each sources is mitigated when the capacity of each device became even. Furthermore, the lower range of 80% zone elevates as the portion of the PV generator increases. The PV forecast error tends to be focused at high irradiance level, while wind speed forecast error is distributed evenly.

Table 2. ESS capacity and operation parameters for dispatchable substation for each case in Table 1.

	ESS Capacity		80% Chance Zone	
	MW	MWh	Upper Range [MW]	Lower Range [MW]
Case 1	5.5	1.38	18.26	7.07
Case 2	4.3	1.08	14.71	7.31
Case 3	3.5	0.88	13.27	7.28
Case 4	4.1	1.03	16.18	8.51
Case 5	5.5	1.38	18.35	8.71

4. Conclusions

A sizing method and control of the ESS in the substation were proposed in this study based on forecast errors. The substation proposed herein is a conceptual facility for the hierarchical control of renewable resources. Furthermore, the concept and operation of a dispatchable substation were proposed for renewable interconnection. In a hierarchical control structure, a TSO can expect a dispatchable substation to stabilize the local network's voltage and support the frequency response of the network, similar to a synchronous generator. As the dispatchable substation reports the renewable generation status and forecast values, the TSO calculates and orders the dispatch signal and reserve requirement back to each substation. The possible forecast mismatch or fluctuation that exceeds the DNE limit will be handled within the substation. To increase the utilization ratio of the transmission line, a medium voltage DC connection can be considered between each hub station. DC-based grid expansion planning would resolve line congestion for a future power system with collaborative operation with an ESS in the substation. To realize the concept of the proposed substation, mutual interference among mid-level substations should be investigated during active power control. Since the proposed concept requires ESS as a solution for renewable interconnection, it also should be economically attractive to both TSO and renewable generators. It also should be noted that the development of the weather forecast technology influence directly on assessment of facilities in dispatch-able substation. Thus, state-of-the-art forecast technology should be considered for validation of the proposed concept. When deployed in the network sufficiently, the proposed dispatchable substation can manage problems via the renewable integration of the power system in the future.

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Abbreviations

The following abbreviations are used in this manuscript:

TSO	Transmission system operator
LCOE	Levelized cost of energy
ESS	Energy storage system
MISO	Midcontinent independent system operator
DIR	Dispatch-able intermittent resources
DNE	Do-not-exceed
BPS	Bulk power system
ROCOF	Rate of change of frequency
PV	Photo voltaic
RES	Renewable energy system
R_{ESS}	Droop coefficient of ESS
K_{IR}	Inertia response coefficient of ESS
SOC	State of charge
MW	Mega watt
MWh	Mega watt hours
LB	Lower bound
UP	Upper bound

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