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An Efficient Rule-Based Control Algorithm for Frequency Response Ancillary Service with BESS for UK and Turkish Grid Scenarios

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Abstract- In this study, a rule-based algorithm has been developed to optimally balance the grid frequency for the battery energy storage system (BESS), which is one of the most important sources of flexibility for electricity transmission and distribution networks and microgrids and is currently used to support the grid in many methods in developed countries. It is important to be able to control the net load since it is ensured that the net load is constant in the electrical grids and the grid frequency is constant. For this purpose, grid reliability is ensured by grid frequency support by making use of ancillary services of electricity system operators. A rule-based algorithm of a BESS system used to provide flexibility in ancillary services over the electricity grids of the UK and Turkey, and an algorithm that will provide ancillary service criteria by using real frequency data for both countries, by considering battery health in an optimum method, has been designed with MATLAB platform and the results of the simulation study have been interpreted. The difference between this study from the studies in the literature is that the optimum maximum and optimum minimum limits are determined in addition to the highest and lowest operating limits of the battery. The frequency support ancillary service between the limits defined in the grid codes and the results obtained are analyzed have been graphically demonstrated in both countries to be provided in the most appropriate manner and the results obtained are evaluated.

Keywords Ancillary services, battery state of charge, BESS, energy management, frequency support.

1. Introduction

The unpredictable generation of renewable energy introduces several grid management variables as their integration into traditional systems (such as diesel power plants) rises [1]. Providing optimum control from a technological and financial perspective is very important for the stability, reliability, and security of the network. While studies continue in the literature on the estimation of generation from renewable energies, the controllability of the net load in terms of the grid is also studied [2]. The concept of the net load is the amount of power that must be met between production and consumption from revolving reserves or by grid operators through ancillary services [3]. In conventionally operated power plants, this flexibility is met by load shedding and load reduction commands. However, the ongoing climate crisis all over the world and the necessity of the use of renewable energies in terms of sustainability, the widespread use of electric vehicles with increasing popularity, the unbalanced loading of charging stations into the grid, the desire of electricity transmission and distribution companies to provide high quality and continuous service to consumers demonstrates that flexibility in the electricity grid is an important research area that needs to be studied.

Excessive renewable energy generation in the system will cause a 'duck curve' (or net load curve) effect on the system as shown in “Fig. 1”, battery energy storage system (BESS) can be requested at this point as it offers a softer slope effect [4].

The integration of renewable resources significantly affects the rate of change of frequency (RoCoF) index [5]. The provision of ancillary services is critical to maintaining grid stability when faced with power system disturbances [6]. In general, these services can be classified into three main groups. Active power ancillary services that keep the grid frequency within the rated frequency, and reactive power services focus on grid voltage regulation and black start. Within the first group, there is a regrouping that differs between regions: primary, secondary, and tertiary services. The key difference here is the time required to provide grid support after any disturbance [7].

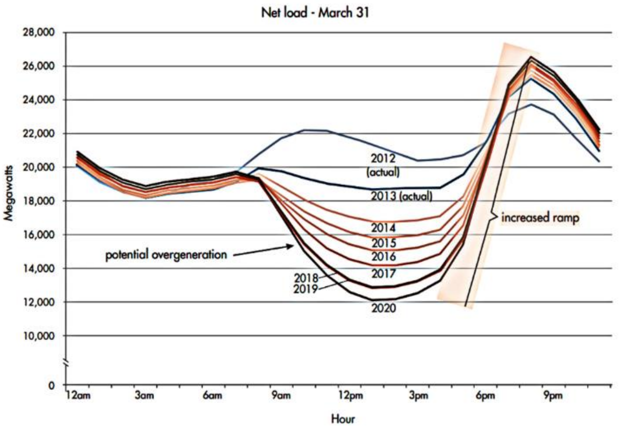

Fig. 1. Net-load difference in a daytime [8]

The increasing demand for electricity quality in many countries, especially in developed countries, has led to the regulation of electricity market ancillary services and the implementation of new technologies and solutions in the grid. To provide flexibility in electrical networks, methods such as network integration of large-powered batteries and demand-side management are being studied with today's developing technology.

BESS is an electrochemical device that is charged (or harvested) from the grid or from a power plant and then discharged that energy to provide electricity or other grid services as needed. [9]. A battery energy storage system includes the battery, monitoring and control systems, and a power conversion system that connects the BESS to the grid [10]. BESS has several advantages and applications nowadays rapid response than conventional power plants, is used for spinning reserve and supporting the black start, and can be used for peak shaving and valley filling or energy arbitrage opportunity [11-15].

As the contribution of renewable sources (e.g., wind and solar) to grid power generation continues to increase, energy storage is needed to replace and optimize the energy output from renewable sources. Storage time and efficiency are among the essential features [16].

Voltage support and frequency regulation are essential ancillary services for power systems. Numerous types of research have been done on the use of BESS for frequency response ancillary service. To support frequencies quickly, effectively, and consistently, researchers model control algorithms in the literature.

Using the UK National Grid's Future Energy Scenarios, Homan et al. discovered that by boosting dynamic regulation's capacity by 50 MW, inertia reduction may successfully implement new ancillary services. [17].

The 720 kVA/560 kWh battery energy storage system on the campus of the Ecole Polytechnique Federale de Lausanne has been used to test the method in real-time by Yuan et al. The algorithm was designed and experimentally validated to provide frequency and voltage support to the electricity network with the help of BESS. [18] The DC-AC converter's voltage-dependent capacitance curve serves as the operating limitation for this control technique.

By making the premise that the UK will use more renewable energy, Baig et al. [19] claim that frequency distortions with low inertia levels will rise. This is accomplished by employing the inertial Stochastic Unit Commitment (SUC) model to relate inertia and frequency response.

Dynamic Frequency Regulation (DFR), an algorithm created by Mahesh et al. [20], analyzes previous and forecasted data to increase battery life and offer ancillary services. MATLAB was used to simulate the method and the outcomes are contrasted with the power of the lithium-ion battery incorporated into the 22 kV system in real-time conventional frequency control. It has been noted that the battery's lifespan is extended by 80%.

A PI control and ramp rate function-based battery SoC controller model was designed for vanadium redox flow battery by Bahloul et al. [21]. Real grid frequency and battery SoC value used as input data and calculated power for EFR and SoC have managed EFR dynamic performance successfully.

In the literature, the maximum and minimum values of the battery SOC value are handled differently in the rule-based algorithms created for BESSs participating in frequency support ancillary services [18,20-23]. There is no exact value for the highest and lowest levels of the battery SOC value. Since values such as temperature and c-rate change according to the application area of the battery, additional levels are created for the control of the battery SOC value by adding the optimum highest and lowest values in addition to the highest and lowest charge value levels. This study is the first to use 4-SOC level battery control. Compared to other rule-based algorithms, it provides frequency support by staying within the active power-frequency envelope without the need for additional control. In addition, the optimum operating range of the battery was used as an alternative to the 50% SOC value, which is accepted as the optimum SOC value of the battery in the literature, based on the study published by NREL [24].

Four different SOC levels have been used in the construction of a control algorithm for the effective frequency response provided by BESS in this study. The algorithm's goal is to support the electricity grid's required frequency while also protecting the battery from overheating and extending battery life by reducing the battery's cycle range. To achieve this, the battery power output-frequency droop control is not used to confine the frequency and SOC minimum and maximum constraints; instead, optimum values are given to the control to enhance it and provide consumers to charge or discharge batteries for a profit with an optimized timescale. Control methods have been simulated in two different scenarios, Turkiye and UK, and it has been shown that a BESS with 2MW/1MWh capacity provides this control in accordance with the frequency regulation ancillary service criteria of these countries.

2. Frequency Response Specifications with BESS

2.1. UK Frequency Response Services

Any change in supply and demand causes changes in the frequency level. For example, if the generation level is lower than the consumption, the frequency level is expected to decrease, or vice versa, if the electricity supply is higher than the demand, the frequency level is expected to increase.

At this point, National Grid (NG) has a license responsibility to control the system frequency at 50 Hz ±1% (The SCADA center normally balances the frequency within a narrow operating point of 49.8 to 50.2 Hz). The NG is responsible for ensuring that there is sufficient production and demand kept ready to manage any conditions that may cause frequency changes. Required reserves are calculated and maintained to assist in setting legal limits for frequency. These reserves are called frequency response services.

A frequency response service named Enhanced Frequency Response (EFR) was launched by National Grid Electricity Transmission (NGET), which includes higher technical requirements and specialized items for energy storage assets [25].

The EFR sets a dead band where active power output is allowed to vary within the range of ±9% to manage the responsiveness of the assets and allow the system to recover. The EFR has also established stricter technical standards for reaction time (within 1 second), accuracy, and ramp rate [26].

Service providers should provide active power to the grid proportionally to changes in system frequency outside the dead band. Here, proportionality means that the active power increase or decrease is related to how much the frequency deviates from 50 Hz. The frequency response delay is the interval of time between a frequency variation and an MW response to the grid. Upon detection of a frequency variation by the frequency monitoring device, the time it takes to give an instruction, and the time it takes for the entities to supply the MW change in output are all included in this delay. For EFR, the delay in time should be no more than 500 ms for detecting and instruction response, but not more than 1 second in total.

The distribution envelope defines the region in which the responses of the EFR entities should be located, as shown in "Fig. 2" One of the two service envelopes must be followed by assets in order to deliver continuous active electricity. For every frequency that is expected to be post-fault, these envelopes are created to be in their smallest range. Service-1 and Service-2 include a reference line between the upper and lower profiles as seen in "Table 1". For EFR, assets must ensure that their power outputs are always within the upper and lower profile. The reference profile serves as a target profile for assets without a finite energy capacity (such as batteries), which do not require the management of a SOC value.

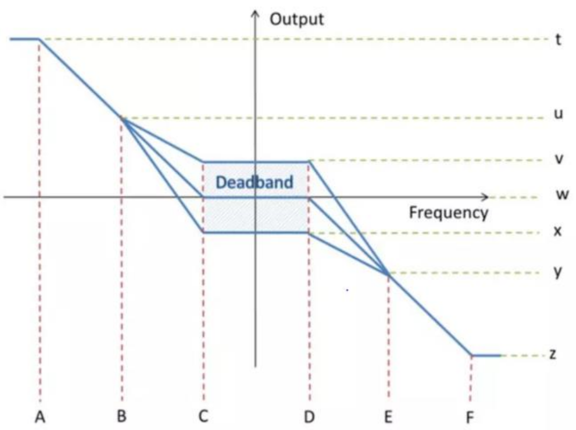

Fig. 2. EFR Distribution Envelope (Blue lines indicate upper, lower, and reference limits) [25]

"Table 1" shows the upper, lower and reference limits of the response at different frequencies. The frequency area between points C and D, or the frequency area when the reference profile is at 0 MW output, is known as the dead band. It appears that there is a dead band (light blue zone) where the frequency support is allowed to vary over a wide range, designed to restore the response capabilities of facilities providing EFR service. Within this range, the assets' active power need not respond proportionally to the system frequency. This is a serious advantage for energy storage systems, they do not need to adhere to SOC adjustment periods. EFR assets' power input or output should not exceed ±9% of their maximum input or output power while operating inside the dead band. For instance, the maximum I/O in the dead band for a 2MW EFR service will be about ±180 kW.

Outside the dead band, the allowable band gap, determined by the maximum and minimum limits, gradually becomes smaller and becomes narrower and ended when the frequency fluctuation is large (both in the over-frequency and under-frequency directions) [25].

Table 1. Maximum, Minimum, and Reference Limits of Frequency Responses [25]

Reference Point	Service-1(Hz)	Service-2(Hz)
A	49.5	49.5
B	49.75	49.75
C	49.95	49.985
D	50.05	50.015
E	50.25	50.25
F	50.5	50.5

As seen in "Table 2", at points u and y (critical points) of the distribution envelope, the EFR might provide two different services. It should be noted as a proportion of contractual capacity, the response is normalized. The two services' primary distinction is that the Service-2 type EFR has a much narrower dead band area and as a result requires higher technical specifications on EFR assets.

Table 2. Maximum, Minimum, and Reference Power Limits to Provide for Frequency Responses [25]

Reference Point	Service-1(Hz)	Service-2(Hz)
t	%100	%100
u	%44.44444	%48.45361
v	%9	%9
w	%0	%0
x	−%9	−%9
y	−%44.44444	−%48.45361
z	−%100	−%100

EFR is much quicker than traditional frequency response, hence, EFR entities also need to meet constraints on the rate of change of response to avoid potential short-term stability problems.

Assets can move within the upper and lower envelopes (for example, by managing the state of charge for a battery) to assure that they are ready to continually render a service in the future. The ramp rates are subject to the limitations shown in the chart. Ramp rate limits change depending on the frequency and response of the energy system at a particular moment. “Fig.3” demonstrates that the status of EFR assets is divided into A, B, C and D regions.

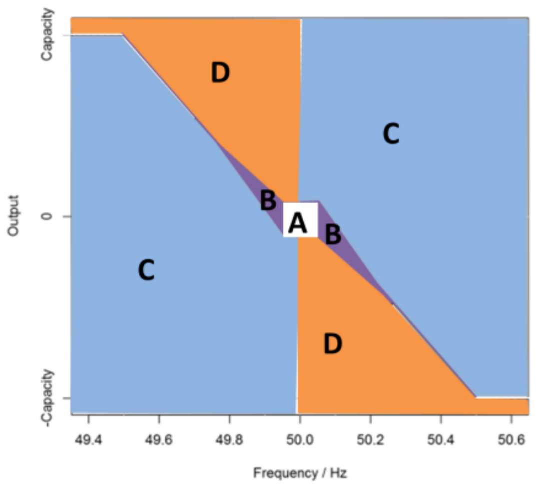

Fig. 3. Ramp Rate Zones to be provided According to Frequency Value [25]

The ramp speed for shaded regions A, C, and D should adhere to the values shown below unless doing so would exceed the service envelope.

Table 3. Highest and Lowest Ramp Rates to be provided by Ramp Rate Regions [25]

Region	Highest ramp rate as a percent of operating capacity (MW/s)	Lowest ramp rate as a percent of operating capacity (MW/s)
A	%1	%0
C	%200	%0
D	%10	%0

Even though the C and D ramp rates are included, the use of EFR assets outside of support restrictions is still not justified. Penalties will apply if you work in these regions for an availability fee through Service Performance Measurement (SPM). Nevertheless, when this occurs, providers are allowed to return to the B or preferably area A as fast as the power grid allows. These rates are shown in “Table 3”.

The frequency change ratio determines the proper ramp rates in the zones marked B. The ramp rate is constrained for all frequencies in area B, as shown in "Table 4". These ramp speed limitations will never take priority over the service envelope. The ramp rate zone B is defined as the area between the upper and lower envelopes, excluding the dead band, and therefore continues up to ±100 percent capacity.

Table 4. Ramp Rate Limits for Zone B [25]

Ramp Rate for Zone B	**Highest ramp rate as percent of operating capacity (MW/s)**	**Lowest ramp rate as percent of operating capacity (MW/s)**
Service-1 (wide)	$\left(-\frac{1}{0.45}{df}/{dt} + 0.01\right) * 100$	$\left(-\frac{1}{0.45}{df}/{dt} - 0.01\right) * 100$
Service-2 (narrow)	$\left(-\frac{1}{0.485}{df}/{dt} + 0.01\right) * 100$	$\left(-\frac{1}{0.485}{df}/{dt} - 0.01\right) * 100$

2.2. Turkish Frequency Response Services

Turkish Electricity Transmission Corporation (TEIAS) published "Technical Criteria for Connecting Electricity Storage Facilities to the Grid and Using Them in Ancillary Services" at the end of 2021 in Turkiye. This regulation specifies the ancillary services that energy storage systems may provide, including reactive power support, primary frequency control and secondary frequency control, and black start. In accordance with the rule,

- The Primary Frequency Control (PFC) reserve capacity must be able to be triggered by the grid-connected BESS, from the electricity transmission, in less than one second.
- In addition, energy storage facilities must have a minimum installed capacity of 10 MW to attend to PFC supplementary service. A ±10 mHz frequency limit will be in use when BESSs are providing frequency support under the PFC service.
- The SoC level of the aforementioned BESS should be restored to 50% in the event that the stored energy level changes as a result of the PFC reserve it provides, in the context of ESS engagement in PFC. One can choose from one of the four Methods to regulate the energy storage boundary. [27].

The initial approach is comparable to the EFR service envelope of the UK National Grid, the other three ways are not discussed here. In this article, Method-1 is used to supply the ancillary service for frequency response.

NG has two distinct services, as was already noted, in contrast to Turkey's participation in BESS for technical grid frequency support rules (EFR Services 1 and 2 are Wide and Narrow, respectively). Turkish legislation will permit the electricity storage facility to export no more than 10% of its installed power and import no more than 10% of its installed power within a specific dead band range (10 mHz).

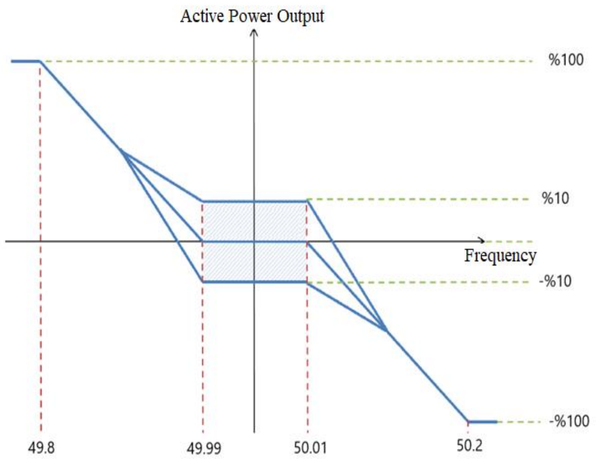

Fig. 4. PFC Limits from Turkish BESS Technical Regulation Method-1 [27].

The envelopes for minimum and maximum power support may be seen in "Fig. 4," in addition to the primary frequency droop management method. Using the BESS nominal power in "Table 5", it is possible to compute the system's output power (P_n).

Table 5. Frequency and Power Limits [27].

f (Hz)	Power Limits (*%Pn*)
49.8	100%
49.99	10%
50.1	-10%
50.2	-100%

BESS facilities are required to import energy into the grid when the frequency increases over the determined level in the dead band and to export energy to the grid in the form of active power output when the frequency decreases below a certain threshold. Additionally, BESS systems are attended to the frequency response ancillary service, charge level of the battery is very important element to consider. The battery could keep its SOC level in optimum and protect itself against any damage while providing the grid frequency. Since an explosion of the battery due to an extremely high SOC level might be an example of battery damage, battery management should be considered.

3. Historical Grid Frequency for Input Data

3.1. National Grid (NG) Frequency Data

To make the simulation of the designed algorithm more similar to reality, the frequency data, which is one of the input data of the model, was taken from the official web pages of the network operators. Frequency data with the 1-second resolution for the UK were obtained from the archive on its website by National Grid [28]. The decision to utilize the data from 21st November 2015 was made because of a statistical analysis of historical frequency data since there is an excess of data on an annual basis. The database criterion examined is the number of deviations and the amount of deviation from the fundamental value of the frequency data, 50 Hz, according to the limit maximum and minimum values, which are the grid criteria. It can be said that the data whose histogram is examined is the worst value by the network operator and that even within these value ranges, the designed algorithm should apply the optimum control by considering the battery health.

In "Fig. 5", a 24-hour period of frequency data with one-second resolution (86400 data points) was examined and it can be seen that the distribution of the data in all values of x-axis.

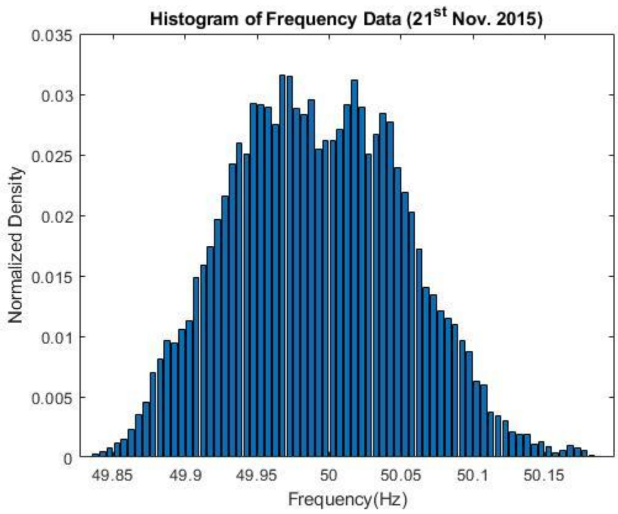

Fig. 5. Histogram graph of the frequency data for November 2015

3.2. Turkish Electricity Transmission Corporation (TEIAS) Frequency Data

Daily frequency statistics with a one-second precision are published on the system operator TEIAS' website [29]. The technical feasibility of their energy system outputs is assessed by these data frequency support facilities. A detailed analysis of the statistics for February may be found in this section. The main aim is to identify how drastically the frequency value fluctuates from the values in Method-1 and to develop a control algorithm that uses the largest standard deviation value of real frequency data and operates at its optimum under the most challenging circumstances.

Given the weather, it is a good idea to investigate the frequency statistics for February 2022. "Fig. 6" and "Fig. 7" provide the standard deviation and histogram for one day and one-month period total data. The standard deviation for the 2nd of February was preferred as the input data for the frequency control algorithm since it is the highest.

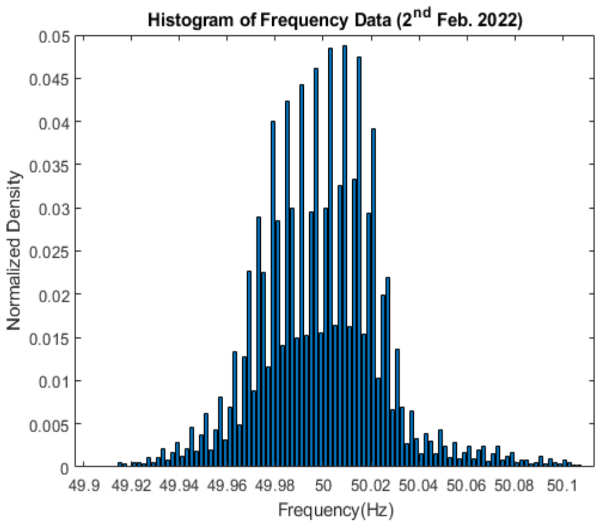

Fig. 6. Histogram graph of the real grid frequency data for one month period - February 2022

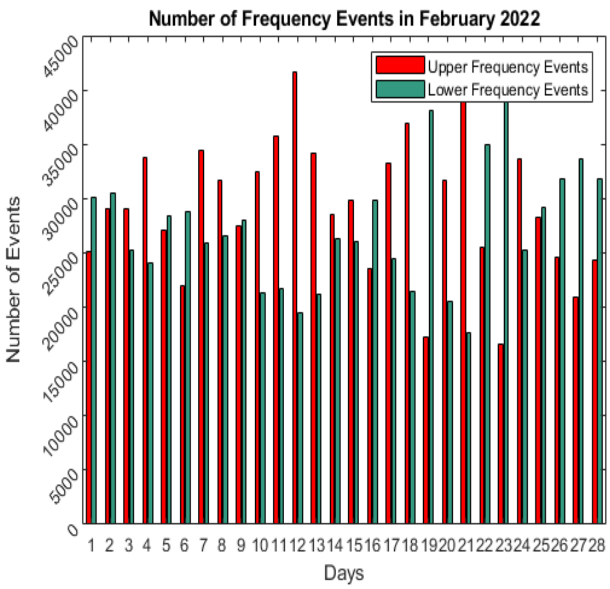

Fig. 7. Probability distributions of frequency events per day for Method-1.

4. BESS Control Strategy

4.1. Frequency Droop Control

The slope of a curve is the droop mean. The general droop formula, which employs the space between two points on a curve, is used to manage frequency droop.

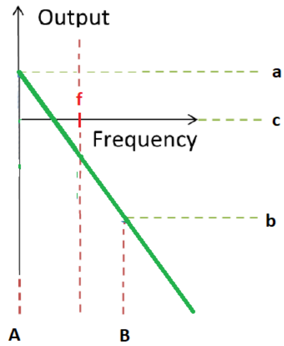

Fig. 8. Droop Graph

The value of the f point in "Fig. 8" can be found by using the formula of the line equation whose two points are known. In this study, Formula (1) is used to determine all power outputs.

$$Output = \left(\frac{f-A}{B-A}\right)(b-a)+b \quad (1)$$

4.2. State of Charge Control

In the literature there are various state of charge estimation methods have been utilized. Coulomb counting is the most popular and preferred calculation. In this study, removing the complexity and processing time besides data-driven estimations, Coulomb counting is preferred. The formula below will be used to estimate SOC in this study.

$$SOC_{out}(t) = SOC_{init}(t_0) + \frac{\int_0^t P_{batt}dt}{3600\ x\ Q} \quad (2)$$

Formula (2), $SOC_{init}(t_0)$, Q and $P_{batt,}$ indicate the battery's initial SOC value, Watt-hour capacity of the battery and instantaneous battery power [30].

The operating restrictions for battery charge levels may be changed in accordance with the urgency of the system operator's request and the different grid frequency boundaries stated in the ancillary service regulation. For instance, Oudalov et al. [31] frequency response control method employed a set SOC level. They shield the battery from overcharging and discharging situations and give the power market a little amount of energy for adjusting the charge level between SOC limitations.

To extend battery life, there are four SOC values in this study, which are depicted in "Table 6" and "Fig. 9".

Table 6. Limitations for battery SOC operation during frequency support

SOC Minimum (%)	SOC Optimum Minimum (%)	SOC Optimum Maximum (%)	SOC Maximum (%)
30	45	55	70

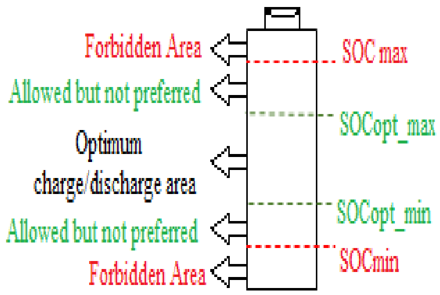

Fig. 9. Purposed Battery SOC limits in the algorithm

Numerous types of research have found that the minimum and maximum operating points for battery SOC levels are merely 2 levels. According to frequency response urgency, this control algorithm switches the SOC operating levels between 4 levels. These additional levels are referred to as ideal minimum and optimal maximum in the code. In this case, decreasing the battery's cycle count is the aim when the range between the maximum and minimum is small. The ideal SOC values are sufficient to supply active power if the frequency value is outside of the dead band. As opposed to that, Method-1 suggests using the highest and lowest SOC values according to the frequency.

4.3. Rule-Based Control Algorithm

The dead band (blue area), A, and B (red areas)—the three states of the power output—are shown in "Fig. 10".

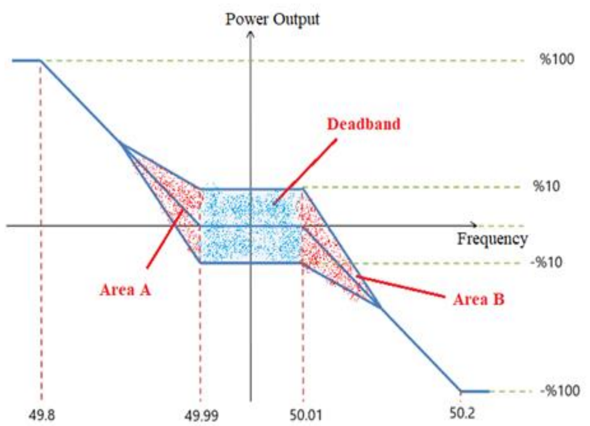

Fig. 10. Frequency response levels and areas between the limits

In "Fig. 11" and "Fig. 12" the algorithm's flowchart is displayed in detail. Eq. (2) is used at the beginning of the procedure to estimate battery SOC level by measuring grid frequency. As stated by the grid regulation for frequency ancillary service, power set limitations are established depending on the zone, which might be in the dead band, A, B, or outside of the envelope. There are some possibilities in the dead band area for a frequency value. Since the power set constraints in the dead band are the same, it is possible to distinguish between charging and discharging depending on the position of 50 Hz, either to the right or left (P_{max} and P_{min} are mirrored). For Areas A and B, there are three states present: minimum, maximum, and linear line output real power calculation. The SOC restrictions and SOC modifications depending on the time step during the power output determination stage are advantageous to the technique. Outside of each of these zones, there is only one power output option that may be selected and calculated with the help of Eq (1). According to the control algorithm, if the charge level of the battery, *SOC(t)*, is outside of the SOC limits, the BESS must not import or export energy to the grid to manage safety itself.

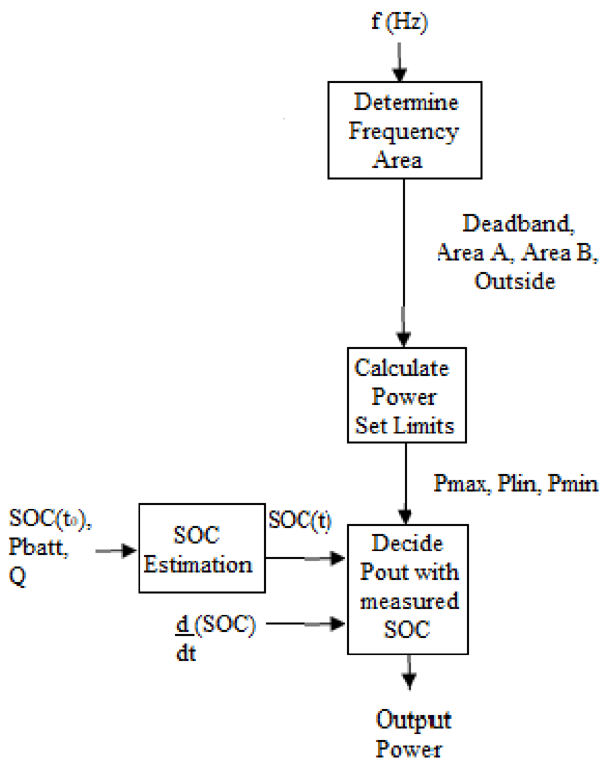

Fig. 11. Block Structure of Frequency Response Control Algorithm

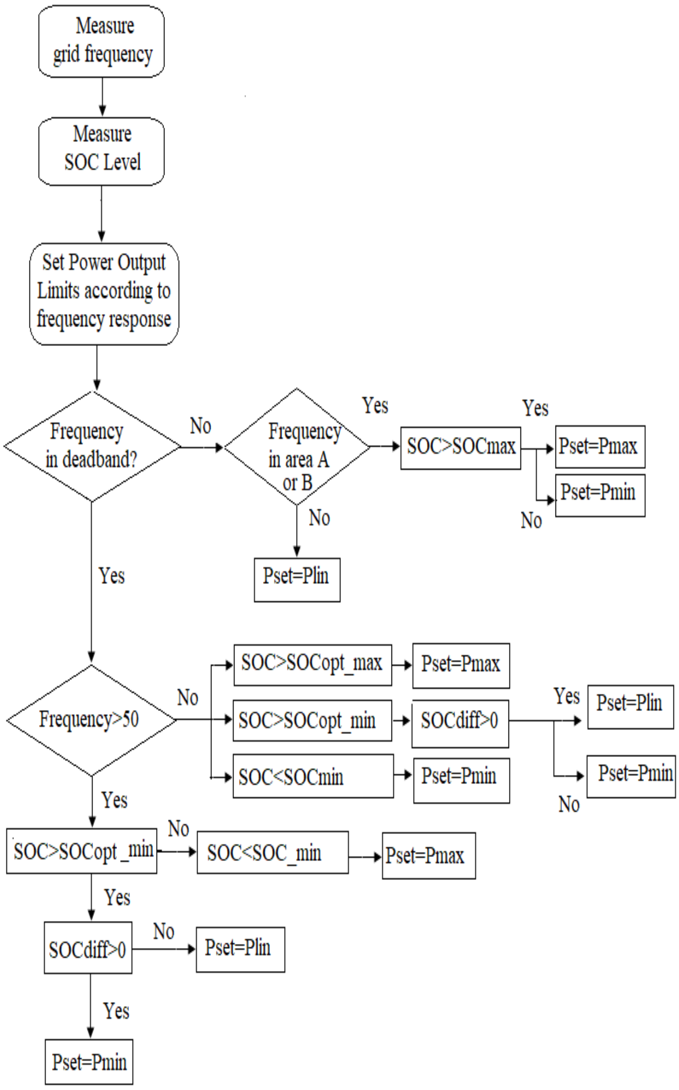

Fig. 12. The frequency support control method with SOC level manipulation

5. Simulation Results

5.1. UK Frequency Control Case

The data of the frequency with 1-second resolution published on the NG official website, dated 21 November 2015, was decided to be used for simulation as a result of statistical analysis. The variation of this frequency data with time and the frequency band determined according to ERF Service-2 are shown in “Fig. 13”.

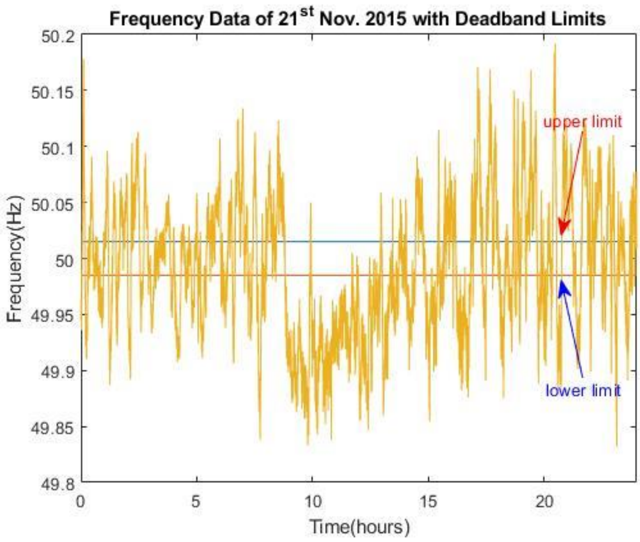

Fig 13. Frequency Data distribution for UK Electricity Grid (21st of November 2022)

According to the scenario where the initial SOC value is accepted as 50% using this frequency data, the graph of the active power value to be provided by BESS over time is also shown in “Fig. 14”, and it is seen that this active power value is exactly the opposite according to the frequency graph. The variation of the SOC value of the battery, which is the most important parameter, according to time is also shown in “Fig. 15”. Accordingly, it is seen that after the 10th hour, when the frequency drops a lot compared to the limit values, the battery must be discharged too much to support the network and the SOC value decreases depending on the amount of discharge. The SOC value fell below the limit values because the grid frequency dropped excessively, but as shown in “Fig. 16”, it provided successfully support between the limits of the EFR graph required in the grid criteria.

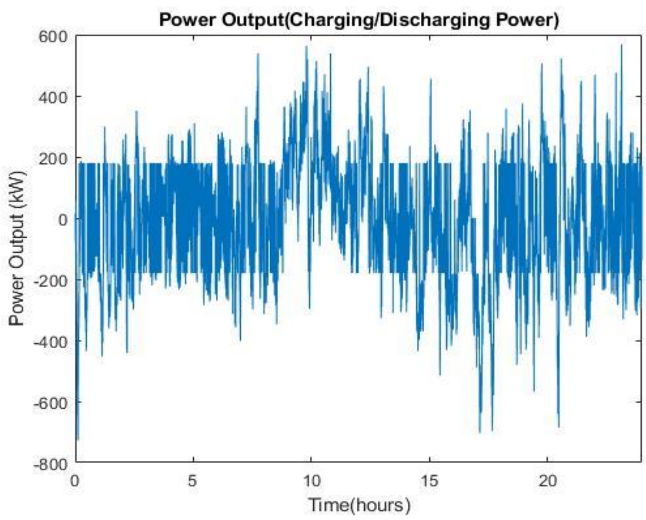

Fig. 14. Power output (kW) of the battery energy storage system for UK Grid Code

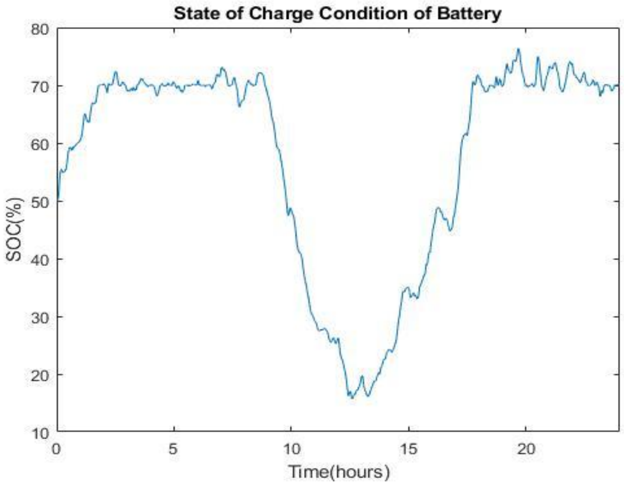

Fig. 15. Battery SOC level fluctuates based on charge/discharge for UK Electricity Grid Scenario

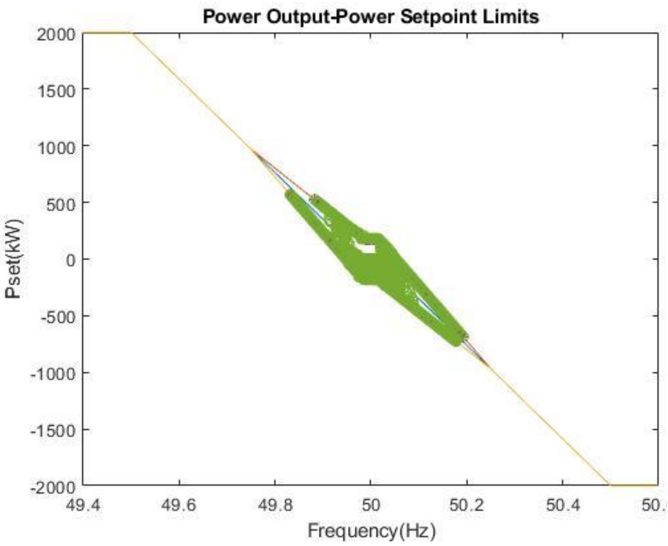

Fig. 16. Limits on power and frequency dead band in the UK EFR Service with power outputs.

5.2. Turkish Frequency Control Case

The real grid frequency data taken from the TEIAS website and utilized as input data for the frequency control algorithm is shown over time in "Fig. 17," with the regions where it outside of the frequency dead band zone defined in the frequency support ancillary service highlighted.

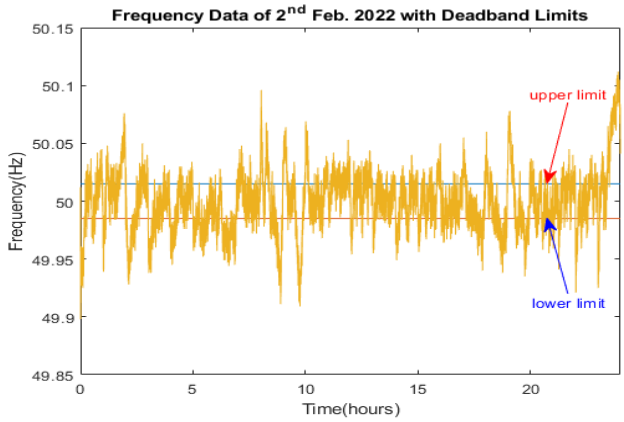

Fig. 17. Frequency Data distribution for Turkish Electricity Grid (2nd of February 2022)

According to the first scenario where a BESS with 2 MW/1MWh installed power maintains the real grid frequency, the algorithm determines the real power (kW) requirement that must be charged or discharged when there is a variation, and "Fig. 18" illustrates its graph over time. It is obvious that the BESS is self-charging when the frequency surpasses the upper limit and real power output has a value negative to the frequency value. The algorithm controls the battery SOC level when BESS charges or discharges itself to protect the battery and prolong its life cycle with the appropriate SOC values. The SOC vs. time graph in "Fig. 19" shows that the BESS charges and discharges between 50% and 70% and maintains a level that is close to 70% while it is operating; this level may be changed. The designed control algorithm successfully provides frequency ancillary service support between EFR service-2 areas, as seen in “Fig. 20”.

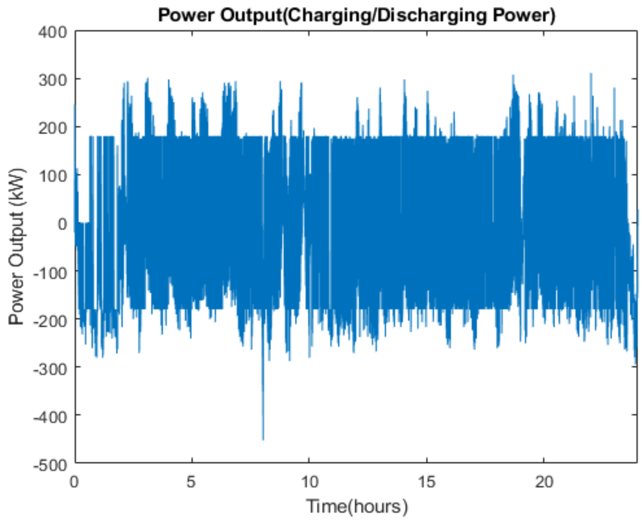

Fig. 18. Power output (kW) of the battery energy storage system for Turkish Grid Criteria

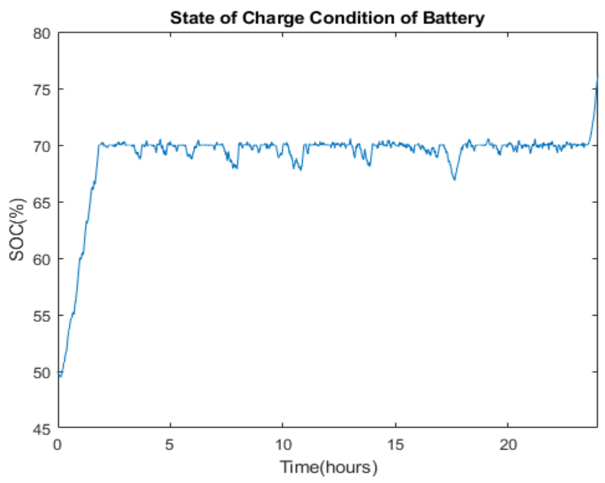

Fig. 19. Battery SOC level fluctuates based on charge/discharge for the Turkish Electricity Grid Scenario

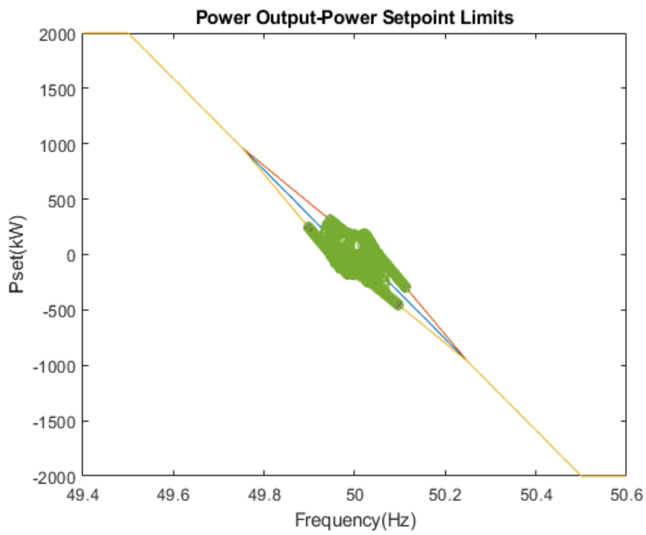

Fig. 20. Limits on power and frequency dead band in the TEIAS Grid Regulation, Method-1 with power outputs.

6. Conclusion

In this study, a battery energy management control algorithm is developed to ensure the optimal value of battery SOC level in the case of rapid frequency support ancillary services. Unlike previous studies in the literature, the algorithm for operation includes optimal maximum and optimal minimum SOC intervals for this purpose in addition to the maximum and minimum SOC limit specified to protect the battery itself. This control algorithm's goal is to utilize the battery life as effectively as possible while also foremost achieving the grid criteria. For the simulation of the designed algorithm, two different scenarios were considered for the UK and Turkey, and a simulation study was performed for 50% of the initial SOC value by using real frequency data. The changes in the distribution envelope published in BESS active output power, SOC value and most importantly network criteria are shown graphically. All the results prove that the rule-based control algorithm for 4 SOC levels meets the grid code criterion for both UK and Turkish Electricity Grid Regulation.

As a consequence, it has been demonstrated that rapid frequency support is offered in accordance with the grid code standards and that the battery performs at its best at the same time.

In future studies, energy arbitrage can be added to the algorithm for determining the profit of the BESS. Arbitrage is a highly significant subject for the investment clearness of BESS projects. Another important subject is AI-based control algorithms for controlling and predicting the frequency and BESS action.

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