Contribution of Energy Storage Technologies in Load Frequency Control - A Review

Subhranshu Sekhar Pati*‡, and Saroj Kumar Mishra*

* Department of Electrical Engineering, International Institute of Information Technology (IIIT) Bhubaneswar, Odisha, India-751003.

(subhranshupati16@gmail.com, saroj@iiit-bh.ac.in)

‡ Corresponding Author; Subhranshu Sekhar Pati, Department of Electrical Engineering, International Institute of Information Technology (IIIT) Bhubaneswar, Odisha, India-751003, subhranshupati16@gmail.com

Received: 04.03.2020 Accepted:11.05.2020

Abstract- Due to increased population and the continuous efforts through the global residents to lessen the impact of environmental change have caused the prompt usage of renewable based energy plants such as wind power plant and solar centred power generation units. The usage of such power generating unit is purely dependent upon nature. Additionally, integration of renewable unit to power system causes instability. The frequency stability is one of the important aspects and depends on balance between generation and demand. To restore the frequency deviation back to its normal condition, an effective control strategy called Load Frequency Control is adopted. To improve the performance of the control scheme different energy storage technologies can be considered. The storage technology not only has distinctive features of fast response and high energy density but also helps in load levelling, peak shaving and black start support. In this paper, comprehensive survey of diverse energy storage technology, its current market scenario and utilization in frequency regulation services are presented by collecting, reviewing and interrupting numerous research articles. Furthermore, current scenario of energy storage management in different parts of the world is included. Application and control strategies of energy storage system in frequency regulation is also presented for research scholars. In the paper, all the control structures are discussed theatrically also the pros and cons of each is addressed from technical point of view.

Keywords: Energy Storage Technology, Load Frequency Control, Battery Storage, Load Scale System, Grid Scale System.

1. Introduction

In an interconnected power system, the equilibrium among the generation and load demand must be conserved for smooth and stable operation. The equilibrium is directly proportional to frequency deviation and change in inter area power called tie line power at scheduled level in respective control areas. On the other hand, if balance is not maintained, then there is a severe deviation of frequency as well as tie line power , which challenges the stability and sustainability of the overall power structure [1-2]. The balance of generation and load demand is not sustained due to either one or more numbers of generation units are tripped (known as generation side) or abruptly change of connecting loads (known as load side). Such type scenario may happen any time of the day and cannot be forecasted well before time by the method of short time load forecasting [3-5].

In recent years, the portion of power generation from the renewable based power plant is increasing and reaching at greater level, which in turn challenges the generation-demand balance [6]. Hence to maintain this equilibrium, three distinct control schemes (i.e. primary, secondary, and tertiary schemes) are applied in the power structure. According to North American Electric Reliability Corporation (NERC), the control vector is termed as 'balancing authority'. The control schemes which are applied to power system have a specific time frame as presented in the Fig.1 [7]. Among three control schemes, secondary control also termed as load frequency control (LFC) is the most effective one whose prime objective is to restrict the frequency fluctuation and tie line power in the respective control area under prescribed limit and maintains the steady power flow. Normally, LFC is symbolized as the "minute-to-minute" control that applied in the system to restrict the frequency under the nominal value followed by any disturbances [8]. In traditional LFC control, diverse power plant is controlled and coordinated which are operated with the grid synchronously that delivers the power to load fully or partially. In that process, a term is involved named as Area Control Error (ACE) which is the summation of frequency fluctuation and incremental change in tie line power [2, 9]. The ACE signal coming from automatic generation controller is fed to the power generation unit. The power plant will be operated in such a fashion that the control error will converge to zero. However, in that process LFC faces certain economical as well as practical challenges such as high operational and maintenance cost and the reduction of efficiency due to partial loading operation [10-

12]. Additionally, LFC takes 1-10 minutes to operate as various mechanical linkages are linked in the process, which is found to be not sufficient to counteract the challenges discussed above. Hence, researches suggested various control schemes to enhance the LFC, to effectively operate under the sudden mismatch of power generation and demand.

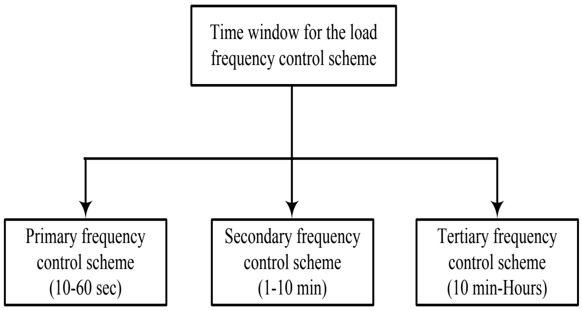

Fig. 1. Specified time window for LFC control scheme

One of the effective methods of overcoming such disturbances present in the power system is to use fast operative energy storage elements. There are several storage technologies such as pumped energy storage, fly wheel, thermal, battery energy storage that may be incorporated in LFC control. Detailed discussions regarding various energy storage units are presented in the subsequent section. Among these storage systems, Battery storage is one of the efficient energy storage options owing to competitive characteristics like faster operating time, support to the system stability and high energy density. Additionally, battery storage is well adaptable with advance power electronics equipment which makes it a noticeable player in frequency regulation applications. It is observed from the literature survey that, lots of work related to energy storage and flexible AC transmission (FACT) devices are done by many researchers.

Most of the review papers highlighted the different power system model, its control and other dynamic aspects of frequency regulation but a few number of papers highlighted the utilization of energy storage management in frequency regulation. Hence, in this paper, authors attempted to study various storage systems and their categories of the present strategies with advantages and disadvantages and detailed discussion regarding the technical aspects. Also, the current scenario of energy storage in various developed and underdeveloped countries like USA, Japan, China and India is discussed. Finally, the application of storage and associated control mechanisms in frequency regulation is included in the paper. However, the major findings of the paper are highlighted as:

- Study of several energy storage technologies and linking its technical features with each other.
- Present development of energy storage management in different parts of the world.
- Application and control approaches of energy storage system (primarily, battery storage system) in frequency regulation

2. Storage Technology

2.1. *Pumped hydroelectric storage System (PHSS)*

Pumped hydroelectric storage is one of the prominent technologies in the field of energy storage applications and has a characteristic of a massive storage of energy for prolong duration of time [13-15]. The presence of PHSS is found across the globe but mostly set up in the countries like Japan (24.6GW) followed by USA (21.8 GW), and least in European peninsula, particularly in Spain (5.3 GW). Generally, PHSS are installed either in over ground (known as conventional) and underground. Among them few are operated as pump back and rest are normal PHSS. In normal PHSS system, two reservoirs are created and head is maintained in between the two reservoirs so that the potential energy of the water gets converted to kinetic energy and turbine is rotated. But in case of the pump back system, the water which is used to run the turbine is pumped back again to main reservoirs in the off peak hours[16-18].

Generally, pump back system is the augmentation of the conventional hydro-electric station. Hence with the use of a pump back system with conventional hydro system, the efficiency of the overall unit gets improved [19]. PHSS has lots of advantages such as longer life span, quick starting time, highly reliable and efficient under up-down regulation of power and frequency operation. Unfortunately, PHSS involves high capital cost with longer construction time and prolonged payback period. However, with support from government as well as other organization, PHSS certainly become profitable and at the same time can be used for flood control and irrigation purpose [20].

2.2. *Compressed air energy storage (CAES)*

CAES is one of the mature technologies for large scale energy storage and can be used as either a short or long duration. It involves three stages named as compression, storage and expansion [22, 23]. Researchers are trying to improve the efficiency of the system by modifying only one stage or multiple stages. For small scale application (i.e. up to 100 kWkW), pressurized air is stored in closed container but for large scale applications air is kept in underground caverns like salt caves, abandoned natural gas wells, hard rock/limestone mines, surface/buried air tanks [24]. Hence, the geographical topology of the storage site plays a vital role in the quantity of storage.

In some cases, CAES is operated with gas power plant to maximize efficiency [25]. Even re-searchers are developing advance technology to use CAES in cryogenic mode so that more power can be derived without wasting energy. It has come with lots of ad-vantages similar to PHSS like high reliability, high efficiency and long life etc. Moreover, from Table 1, it can be inferred that CAES has high volumetric, mass energy and power delivered rate compared to PHSS [21]. Despite the various benefits of this storage, very few profitable executions have been appreciated in the recent scenario. Thus commercial feasibility remains a big question [26].

Table 1. General Specification of Pumped Hydro, Compressed Air and Flywheel storage System

Metric	Pumped Hydro	Compressed Air	Flywheel
Specific Energy[Wh/kg]	0.3-1.33	3.200-60	5-200
Energy Density[kWh/m^3]	0.5-1.33	0.4-20	0.25-424
Specific Power[W/kg]	0.01-0.12	2.2-24	400-30,000
Power Density[kW/m^3]	0.01-0.12	0.04-10	40-2,000
Efficiency[%]	65-87	57-89	70-96
Lifespan[yrs]	20-80	20-40	15-20
Self-Discharge Rate[%/day]	0	0	24-100
Scale[MW]	10-8,000	0.01-3,000	0.001-10
Energy Capital Cost[US$/kWh]	1-291.2	1-140	200-150,000
Power Capital Cost[US$/kW]	300-5,288	400-2,250	30.28-700
Application	Higher Scale Energy Management	Higher Scale Energy Management	Medium Scale Power Quality
Technical Maturity	Highly Mature/ Fully Commercialized	Proven/Commercializ-ing	Mature/Commercia-lizing
Environmental Impact	High/Medium	Medium/Low	Low

Table 2. General Specification of diverse thermal energy storages

Metric	Sensible Heat	Latent Heat	Reaction Heat
Specific Energy [Wh/kg]	10-120	150-250	250
Energy Density [kWh/m^3]	25-120	100.00-370	300
Specific Power [W/kg]	-	10-30	-
Efficiency [%]	7-90	75-90	75-100
Lifespan [yrs]	10-20	20-40	-
Self-Discharge Rate [%/day]	0.5	0.5-1	-
Scale [MW]	0.001-10	0.001-300	0.01-1
Energy Capital Cost [US$/kWh]	0.04-50	3-88.73	10.9-137
Power Capital Cost [US$/kW]	2,500-7,900	200.00-300.00	-
Application	Medium Scale, Bridging Power	Medium/Large Scale, Energy Management	Small/Medium Scale, Energy Management
Technical Maturity	Mature/Commercia-lized	Proven/Commercia-lizing	Proven/Develop-ing
Environmental Impact	Low	Low/Uncertain	Low/Uncertain

2.3. Flywheel energy storage unit (FESU)

FESU is one of the oldest technologies of energy storage which stores energy in the form of rotational motion. Generally, FESU is used for short duration energy storage and virtually independent of normal temperature at the time of discharging [27-28]. A recent study suggested that its efficiency can be improved by modernizing the sub system associated with FESU. A 2.2 MWh fly wheel coupled with a 400MW/1MWh generator is used in the study at Fusion

Institute of JAEA (Japan Atomic Energy Agency) [29]. Through modular design centred on 2 MW units, a low power and high energy (20MW/5MWh) commercial flywheel energy storage is achieved for grid connected application [30, 31]. However, for grid connected mode, the design of FESU is still under development. Hence its commercial feasibility remains in doubt. FESU is now used in regenerative breaking system of locomotive in which electricity is generated when brake is applied [32]. It can be observed from Table 1, FESU has large number of benefits such as high power and energy density, fast operating time, long life span, invariant to temperature and require less maintenance. There are certain constraints in FESU like contamination problem and gyroscopic effect due to earth rotational motion [33, 34].

2.4. Thermal energy storage

Its application can be found in solar power tower for time shifting in grid applications [35-37]. Time shifting refers to extending the energy conversion rate in thermal alternator and its associated energy conversion device [38]. It is highly effective in grid management system due to its efficient mechanism, high power/energy density and slow rate of discharge as shown in following Table 2 [21].

2.5. Battery Energy Storage Unit (BESU)

The most effective and widely used device in the field of energy storage is chemical battery. Table-3 as well as Table-4, demonstrates the diverse features and physical constraints with appropriate application of selective range of battery such as Zinc Silver Oxide, Alkaline, Lead Acid and Lithium Ion [21, 39-41]. Generally, battery is constituents of three main components namely the electrode at the positive and negative side, the electrolyte and separating medium as separator. In a conventional battery, the efficiency is strongly dependent upon the materials used in the electrodes. However, cycle life and lifespan of the battery is calculated based on the composition of used electrolyte and its stability. Hence most of the battery is affected by the temperature variation, environment condition and the charging-discharging regime. One of the batteries, known as Zink Silver Oxide (ZnAg), has characteristics of flat discharging rate, low temperature and climate effect and high durability [42]. Though its performance is superior over other batteries, the cost linked with electrode material (Zinc) is high. Thus it does not fit in large scale of storage applications, so presence of ZnAg battery is restricted to small storage application such as hearing aids devices and timepieces [43]. Alkaline zinc manganese dioxide (ZnMn) batteries are the most used storage technology across the globe [44]. Although it's operated under low/ high temperature condition, its internal resistance is low so that it provides low/high current drain performance, but increased demand creates the problem of soil contamination as low recovery rate of its materials (Zinc, Manganese, and Steel) from soil [45]. In a stationary energy storage application, the selection of an opposite energy storage unit is vital. Hence in these cases, redox flow battery (RFB) is one of the deserving storage devices [46]. RFB is electrochemical energy conversion devices that exhibit redox processes of types in mixed solution of liquid form, deposited in the external containers, and when needed, the solution is introduced in the process [47]. Moreover, its working mechanism is similar to that of polymer electrolyte membrane fuel cell (PEMFC) [48]. It has some remarkable characteristics such as stability, size is free from power and energy application, flexibility, reduced impact on environment, high depth of dis-charge, etc., making it ideal for supporting the electricity production from non-conventional power sources. In recent years, the use of lithium ion (Li-Ion) batteries is increased multiple times owing to advantages like low costs, excellent charge retention time, high cell voltages, superior performance under low temperature, long life cycle [49, 50]. Furthermore, researchers are shifting the focus toward the storage management in Plug in hybrid vehicle (PEV) by the help of (Li-Ion) battery [52]. But, in certain cases, nickel metal hydride (NiMH) batteries are used in PEV storage management system [51]. A comparative assessment of Diverse Flow batteries are presented in Table 4.

Table 3. General Specification of the diverse battery storage system

Metric	Zinc Silver Oxide	Alkaline	Lead Acid	Lithium Ion
Specific Energy [Wh/kg]	81-276	80-175	10-50	30–300
Energy Density [kWh/m^3]	4.2-957	360-400	25-90	94–500
Specific Power [W/kg]	0.09-330	4.35-35	25-415	8–2,000
Power Density [kW/m^3]	0.36-610	12.35-101.7	10-400	56.8–800
Efficiency [%]	20-100	36-94	63-90	70–100
Lifespan [yrs]	2-10	2.5-10	3-20	2–20
Cycle Life [cycles]	1-1,500	1-200	100-2,000	250–10,000
Self-Discharge Rate [%/day]	0.01-0.25	0.008-0.011	0.033-1.1	0.03–0.33
Scale [MW]	0-0.25	0-0.001	0-50	0–3
Energy Capital Cost [US$/kWh]]	3,167-20,000	100-1,000	50-1,100	200–4,000
Power Capital Cost [US$/kW]	7,140,620-741,935	1,000-11,900	175-900	175–4,000

Application	Small Scale Energy Management	Small Scale Energy Managemer	Small/Medium Scale Energy Management	Small/Medium Scal Energy Managemen
Technical Maturity	Highly Mature/Fully Commercialized	Highly Mature/Full Commercialized	Highly Mature/Fully Commercialized	Mature/ Commercialized
Environmental Impact	Low	Medium	High	High/Medium

Table 4. General Specification of flow battery storage system

Metric	Vanadium Redox	Zinc Bromine	Polysulphide Bromine
Specific Energy [Wh/kg]	10–50	11.1–90	10–50
Energy Density [kWh/m^3]	10–33	5.17–70	10.8–60
Specific Power [W/kg]	31.3–166	5.50–110	-
Power Density [kW/m^3]	2.50–33.42	2.58–8.5	1.35–4.16
Efficiency [%]	60–88	60–85	57–83
Lifespan[yrs]	2–20	5–20	10–15
Cycle Life [cycles]	800–16,000	800–5,000	800–4,000
Scale [MW]	0–20	0.001–20	0.001–100
Energy Capital Cost [US$/kWh]	100–2,000	110–2,000	110–2,000
Power Capital Cost [US$/kW]	175–9,444	175–4,500	330–4,500
Application	Medium/Large Scale Energy Management	Large Scale Energy Management	Large Scale Energy Management
Technical Maturity	Proven/Commercializin	Proven/Developing	Proven/Developing
Environmental Impact	Medium/Low	Medium	Medium

Table 5. General Specification of SMES and super capacitor storage system

Metric	SMES	Super capacitor
Specific Energy [Wh/Kg]	0.27–75	0.07–85.6
Energy Density [kWh/m3]	0.2–13.8	1–35
Specific Power [W/Kg]	500–15,000	5.44–100,000
Power Density [kW/m3]	300–4,000	15–4,500
Efficiency [%]	80–99	65–99
Lifespan [yrs]	20–30	5–20
Cycle Life [cycles]	10,000–100,000	10,000–1,000,000
Self-Discharge Rate [%/day]	1–15	0.46–40
Scale [MW]	0.01–200	0–5
Energy Capital Cost [US$/kWh]	500-1,080,000	100.00–94,000
Power Capital Cost [US$/kW]	196–10,000	100–800
Application	Medium/Large Scale Power Quality	Small/Medium Scale Power Quality
Technical Maturity	Proven/Commercializing	Proven/Commercializing
Environmental Impact	Low	Too Low

2.6. Super conducting magnetic energy storage and Super Capacitor

Superconductors are vastly used in generation and storage applications such as fly-wheel storage system and synchronous generator [53-54]. Moreover, using the property of superconductor, super conducting magnetic energy storage (SMES) is build-up. The main use of such a device is to deliver a relatively high quality of power for the shorter duration [55]. As it is observed that, maximum numbers of grid failure is due to sag and outages, which lasts for less than one second. In SMES unit, super conductors are achieved through cryogenic process and mainly used for producing high intensity magnetic fields in magnetic resonance imaging devices and laboratory re-search setup [56]. In view of grid application, SMES are much effective for faster operations and power quality issues. Additionally, SMES are aimed for managing the sag compensation and quality of power ranging from 10 to 1000 MW, expected to be seen by 2030-40 [57].

Super capacitor sometimes called as electric double layer capacitor, is generally used as a secondary system with a primary system usually in hybrid electric vehicles [58]. In recent years, Shanghai municipal corporation tested an electric bus (capa buses) operated by super capacitor. It has high rate efficiency, faster charging time and low internal losses [59]. As a result, it is used in grid operation mainly for sag compensation. Although SMES and super capacitor are much costly, but super capacitor is virtually maintenance free. The technical specification of both SMES and super capacitor is depicted in Table 5. With multiple manufactures entering in to market, it is expected that cost of super capacitor will gradually decrease [60].

3. Storage Scenario Across the World

3.1. United States of America

The United States of America is one of the most developed countries that have matured technology of energy storage technology [61-62]. The first battery was developed by Volta hence called as Volta's cell in 1800, and the first energy storage system located in Rocky River Pumped Storage plant in Housatonic River in Connecticut, which is founded in 1929. It is estimated that 25.2 GW rated power over 1082 GW total power is installed. It is calculated that 2.5 % power which is used comes from storage or recycled. As of 2018, 1361 numbers of projects are under operation [61]. In US, 41% of projects were functional, and 33% are under construction. California is the topmost state, which has 220 functional projects of total 4.2GW power followed by Virginia and South Carolina comes. Energy storage is growing at faster rate in USA at 174% from 2013 to 2018 due to various steps taken by government as well as local agency [63]. From the literatures, it is found that the maximum amount (94%) of energy storage is the PHES, which is of 23.68 GW followed by BES (0.75 GW), CAES (0.114 GW) and FESU (0.058 GW) as of June 2018 [61-62].

3.2. Japan

The battery storage system of Japan holds commanding lead with comparison of world stage largely [64]. Due to ongoing research, Japan provides an effective and efficient mechanism; hence it becomes the world leader in battery energy storing technology and applications. Japan has 277 MW of functional energy storage projects and 59 projects are under construction as per 2012 report. It is noteworthy that, the figure is not only the best but also surpasses the data of other developed countries like US and China [65]. Though the USA presently has the biggest supplementary battery storage system under construction, Japan is still the world leader in terms of battery storage capacity. Moreover, Japan's ambitious plan is to capture half of the world's battery storage market by end of 2020. From 1990 onwards, NaS battery installation increases at a faster rate as the data is revelling. In 1998, the rating was only 10 MW but in 2009 the rating becomes 300 MW/2000 MWh and in next year 350MW storage is achieved. The recent study suggests that, Japan dominates the manufacturing of NaS across worldwide. In 2012, NGK installed a sodium sulphur based energy system of 450 MW. In the meantime, Japan becomes second largest manufactures of lead-acid battery after the USA. In the future, the rating of storage system will rapidly reach at the ultimate level with support of new policy and incentive schemes introduced by the government [66].

3.3. China

Advancement of energy storage in China is growing at a faster rate due to continuous growth of ancillary services as well as sustainable investment towards the grid with realization of smart grid [67, 68]. China's current storage market size is $700 million and expected to be reached at a record of $6 billion by 2024. The decrease of technology costs and emerging of new technology in the existing system will further boost the storage market. In recent times, it is witnessed that the cost of lithium ion battery is reduced up to 50% as compared to past. The world's first and China's largest electromechanical energy storage station with virtual synchronous generator is started its operation in JinJiang, Fujian Province in 2019 [69]. This plant has 100 MWh battery energy storage with integrated 400 MW of wind energy, 200 MW of PV, and 50 MW of concentrated Photovoltaic plant. In subsequent stage the rating of system will increased up to 1000 MWh. Government reforms favour the development of storage system across the country, which will further enhance the system capacity [70].

3.4. India

The storage sector in India is just started blooming after much-awaited reforms and encouragement done by the government [71]. As per the study conducted by Indian Energy Storage Alliance (IESA), energy storage system alone for renewable energy will be 6000MW by 2020 [72, 73]. It is expected that the new range for energy storage will be much higher than the existing unit as the government targeted to increase the renewable power generation up to 175 GW by 2022. Apart from this, the Ministry of New and Renewable Energy (MNRE) has a plan to include 10,000 micro-grid/500 MW of micro and mini-grids in the existing system [74]. In 2019, Solar Energy Corporation of India (SECI) asked to install 3.6 GWh of storage that should make a couple to 1.2 GW of solar on India's interstate grid transmission, the largest battery realization in the country to come yet [75]. Hence it is suggested that lots of additional opportunities can be seen in storage system if it fulfils the above said target.

4. Overview and Application of Energy Storage in LFC

Energy storage battery technologies have been in operation in power system applications since the early 1900s. In reference [28], the authors discussed the use of batteries as an equalizer and carried out the tests on the distribution substations supplied by Indiana's Union Traction Company in 1902. BESU systems can be used in a wide range of grid support applications, including generation, transmission, distribution, and end-user services, due to their rapid response to sudden power fluctuations [77, 78]. For example, the use of energy storage could be 2-3 times more effective than the addition of a combustion generation unit to the system [79] for frequency regulations. For example, BESU is found in numerous applications such as peak shaving [80, 81], load levelling [82, 83], black start support [84, 85], frequency regulation [86, 87], and voltage support [88, 89]. Figure 2 provides a hierarchical summary of the use of energy storage in power systems. One of these applications is the load frequency control, and BESS has now been used for decades. The provision of BESU in LFC is being discussed by researchers since the mid-1980s after Kunisch et al. [90] proposed the first effective BESU demonstration facility as an approach to improve the performance of LFC control in Germany-1986 [90-92]. During periods, when the frequency goes above the scheduled value, the battery is charged known as charging mode. Similarly, when the frequency drops below the scheduled value under such circumstances, BESU provides energy to the grid called dis-charging mode. Until now, researchers have been considered as inspiring, particularly given the recent extension of the concept of intelligent grid systems [93, 94]. The strategy of controlling LFC using energy storage technology has been described in Fig. 3 [95]. Two types of strategies are introduced depending on the amount of energy storage, its location and possession in the power system, quality and its behaviour with independent dispatching centre [96]. The two different types are known as Load Scale System and Grid Scale System.

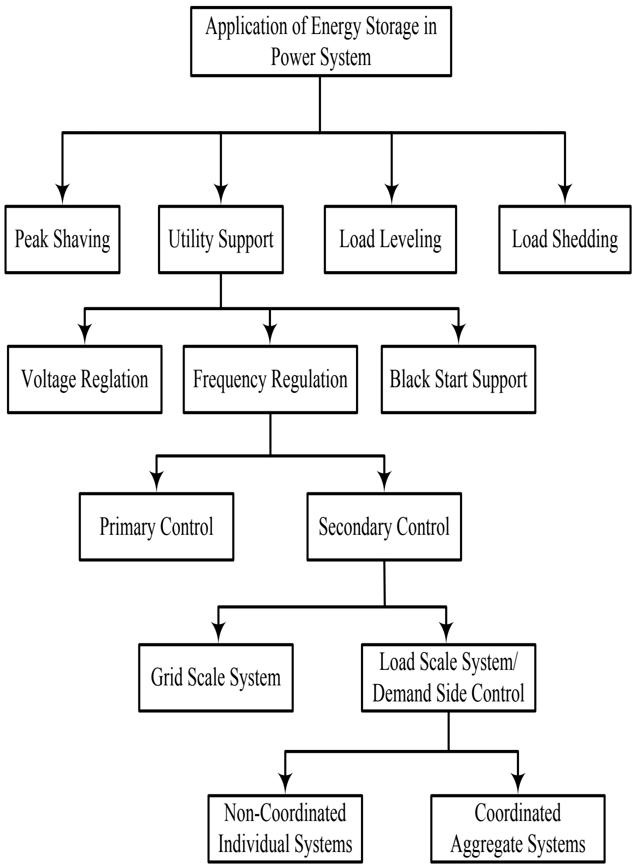

Fig. 2. Flow diagram showing the application of energy storage in power system

4.1. Grid Scale System

In this type, centralized battery systems are being controlled using LFC and modern reheat type was taken into consideration. In 2001, the authors Aditya and Das have observed the usage of BESU for LFC with reheat thermal plant in two interconnected power systems. As per the simulation result, enhancement in the system response has been noticed at a 1% step increase in demand. Moreover, the BESU performance for LFC in two area interconnected system has been simulated in MATLAB simulation environment by [96-97]. In case of isolated power grids, a small amount of spinning reserve problem arises. So, in this case, reliable system frequency regulation is necessary [92]. By the author's in reference [98], BESU is utilized to improve the LFC performance of the system. In an isolated power system, the impact of BESU on LFC was performed and optimal sizing of BES was taken into account by Mercier et al. [99]. Using MATLAB, the result of BESU was inspected for one month of operation. It is observed that 0.98% (scheduled 50Hz) frequency deviation occurs without BESU while this deviation was only 0.26% using BESU.

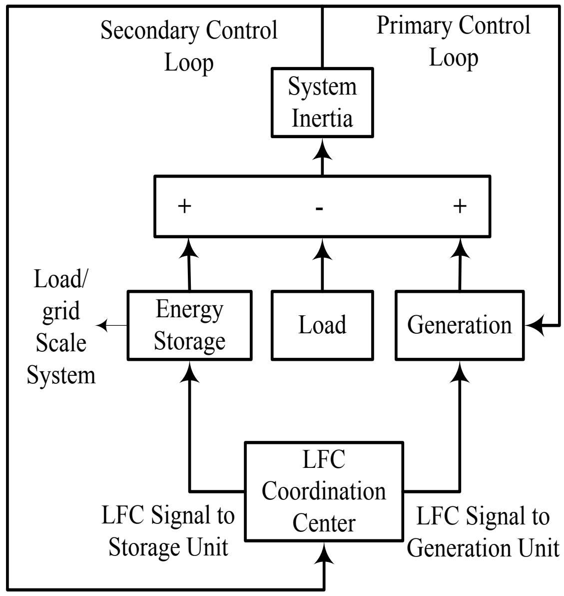

Fig. 3. Line diagram showing the LFC Coordination in single area system

The idea of integrating distributed BESU in microgrid system can be accepted in multi microgrid system [100]. It is observed a multi microgrid with two microgrids that are interconnected with each other. For frequency control of a multi microgrid two ACEs, the frequency control is used in this purpose. But in case of isolation systems, the control signal is the frequency response of the system [101]. The equipment of an isolated system are the wind turbine generator, battery backup and hydro plants. The chrematistics of LFC was tested by using and without using energy storage element. In system frequency variation a considerable amount of attenuation was achieved. Later Mohammadi et al. proposed an advanced LFC strategy having a synchronous generator, battery storage, PV units and loads [102]. The aim was splitting of microgrid into several virtual areas that are interconnected with virtual tie line. By this tie line LFC signal was obtained, which is used to control the frequency and power deviation. In the result section the characteristics of LFC was described. For controlling the frequency, how the energy capacity of BESU was affected by the power ramp rate of thermal units has been discussed by the authors [103]. It is observed that the power rate of the BESU reduces to 53%. The type of Grid Scale System is revised by deliberating the following characteristics.

4.1.1. LFC Control Techniques

The techniques of LFC are important in terms of future study. In Automatic Generation Control (AGC), LFC control techniques are used inevitably. We can use different types of control strategies to integrate the AGC controller. The function of a controller is to initiate the control signal to the units contributing to the LFC, depending on the requirement of the system. For more information regarding LFC control techniques, refer to [104]. Umrao et al. [105] has classified the LFC controllers into two types.

- Classic control technique: Proportional, integral derivative by linear quadratic regulators.
- Artificial intelligence (AI) control technique: It includes fuzzy, genetic, neural, hybrid optimization technique.

A battery energy system can be implemented in all types of control methods to offer an improved BESU in LFC technique. In this case, the function of the controller is to deliver signals to the aided BESU and LFC units. The authors Kalyani et al. and Sen et al. have described about Integral, Proportional Integral, Proportional Integral Derivative control techniques [96, 97]. From the literature survey, it is also found that multi stage controller, fractional order controller and cascaded controller are recently used in LFC study [188, 189]. The authors in reference [106-110] examined a robust control method namely H-infinity by replacing regular PI controller. The authors considered problems like uncertainty in parameters and propagation delay which are presented in control channels and treated them. The control system introduced by them was examined by New England 39-bus network on an LFC of two area. It infers from the result that the stability and robustness provided by H-infinity controller was better than PI controller. Though it is categorized into load scale system, the work done by the authors are Janfeshan et al. [111]. They have presented a control method based on decentralized fuzzy logic by considering BESU used in electric vehicles. The idea of manipulating electric vehicles by regulating the frequency has been described more briefly in the subsequent sections.

4.1.2. BESS Characteristics

Usually, three basic modules are present in a battery storage system [112]:

- Battery pack: A group of battery cells arranged in series or parallel configuration.
- Power conditioning module: For tie-up BES with the grid, power electronic converters are used.
- Control as well as protection: It keeps track of state of charge (SOC) and confirms that the capability of battery power for applications regulates the charging-discharging of battery with respect to the control variable of the system, used for safety and protection purposes.

In BES various types of batteries are used. The authors in reference [113] observed various kinds of batteries, their merits, and demerits in various applications. Battery characteristics like efficiency of the battery, discharge rate, rate of charging and discharging, life-time restriction, SOC limitation differ for different kinds of batteries and perform a vital role in the LFC performance [76, 114]. Generally, in power system two kinds of secondary batteries are used:

- Conventional battery: It comprises Sodium Sulphur, Lithium ion, Nickel Cadmium, Lead Acid.
- Flow battery: Characterized by vanadium redox.

The most efficient battery technology that is mostly adopted in the grid system is Sodium Sulphur [115]. Nevertheless, the production cost of Lithium batteries is high as compared to other types of batteries. The reason behind the high cost is that additional protection units are required as Lithium batteries are more vulnerable towards overheating and overcharging conditions. Using the protection system, the cost increases by 25% and weight up to 50% [116]. The most common NiMH battery technology is practiced in electric vehicle technologies. By considering safety, cost, life cycle and high energy density, this battery technology can play a vital role [117]. Currently, a new NiMH battery technology research is going on by the inventor of NiMH battery technology, the world leader of chemical industry [118] by which the energy capacity of the battery can be increased to eight times as well as the price of the kWh will be reduced to $146 [116]. Both the categories as described above are used in the LFC application. Shibasaki et al. presented the application of Sodium Sulphur battery system [119]. A controlling method has been developed, which uses H-infinity controller. Using two area system, it is observed that the fluctuations in generation greatly reduces by using Sodium Sulphur battery system. In utility systems Flow batteries are reliable among various rechargeable batteries. Flow batteries are used extensively in LFC applications because of durability, fast response, and high power capability and no self-discharge. But the disadvantages of redox batteries are complicacy, costly, low energy density as compared to conventional batteries [113, 120]. Sasaki et al. performed load frequency control using redox flow battery [120]. The authors examined performance of Redox Flow batteries; its advantages by doing simulation of two area inter connected systems. Both the interconnected systems have hydroelectric and thermal generation units with Redox

Flow batteries. In transmitting the LFC signal, the variation of the response speed between thermal units and RF units were taken into consideration. The results from the simulation shows in LFC application the RFB batteries are very effective as they have overload ability and fast response. The effectiveness of RFB batteries was discussed in [121] for LFC of the deregulated system. In the above-mentioned works, the authors have explained about LFC system using one kind of battery. But they have not discussed about the effects of various characteristics of different sets of BESU. In [122], the use of various sets of BESU has been discussed. Taking charge and discharge characteristics, the authors invented advanced SOC based control techniques. Two sets of Sodium Sulphur and Nickel Metal Hydride batteries with different capacities were taken into account and examined for this study. From the simulation results, it is obtained that the performance of the LFC system has been improved by the proposed control techniques in spite of the variation in the charging-discharging rate of the used battery.

4.1.3. Optimum Size of BESU

One of the main problem is the positioning of BESU in the utility system is the price of the BESU system. Cook et al. stated that “before discussing the price of BES, we have to consider the size of BESU system” [123]. Therefore, by optimizing the size of BESU, a great profitability can be achieved in the system [124]. Moreover, the size of batteries is primarily selected in such a way that it can meet the LFC power and energy requirement. Hence, the optimal sizing of BESU should be realized. Authors in reference [125-126] have worked in this field. Before deciding the size of the battery, the variations in speed of response among the batteries and LFC units have to be taken into account. In order to restrict the required size of BESU, Amano et al. invented a new technology for ACE to the LFC and BESU units [127]. This proposed method allocates low frequency ACE signal to LFC units and high frequencies are transmitted towards faster BESS. A similar strategy has been proposed by Leitermann et al. regarding the reduction of ramp rate of thermal units and the vital capacity of BESU [129]. A strategy of LFC by implementing BESU by considering reduced BES capacity has been discussed in [129]. By dividing the LFC duty, the authors observed a difference in response speed of thermal units and BESU. BESU units regulate the frequency of the system while thermal units take care of the load flow. Thus, fast BESU is associated with small charge and discharge and does not abolish thermal units. In this way, BESU energy capacity is reduced to a great extent [130-131]. The aim is to obtain LFC signals from tie line power deviation with battery storage output. This can be useful in the case where the output of the thermal unit does not rely on BESU. It is shown that BESU capacity has been reduced to 30%. The authors in reference [99] proposed a method using Net Present Value formula to optimize the BESU size for maximizing the operating revenue.

4.1.4. Grid Scale Systems in a Nutshell

All the work review in this category is based mainly on grid connected BESU in large scale systems and utilizing generation side control [132-134]. This method is most popular in the power system. The practical challenge encountered by it has been described below:

- The installation cost is high in large scale BESU systems.
- High efficiency is required in BESU systems.
- Between thermal units, system operators and BES units, correlative dispatch of LFC signal is required because of time scale variance between generation units and BESU units.

Now a day, more attention is given towards demand side control utilizing loads to take part in frequency regulation and distribute the hinder with generation side control. In reference [132], the authors stated that the loads having battery storage can effectively reduce the capacity of BESU to a greater extent. In the upcoming section, different methods of LFC using BESU and local loads as controlled reserve are described.

4.2. Load Scale System

If the frequency deviation occurs in the generation, transmission, or distribution system, it can be identified instantly and can be measured by effective mechanism, which in turn affects the load generation balance [135]. Thus, loads play a vital role in controlling the frequency of the system instead of sitting idly in the grid [136-137]. Before discussing various LFC control techniques in this section, first the role of loads in regulation of frequency is discussed. In this area many research papers have been issued [138-140]. Loads like heat pump water heaters, refrigerators, resistive heaters are appropriate for this type of application because they can store thermal energy [141-143]. In references [144-146], thermal energy storage with heat pump water heaters were used for LFC support. This type of loads can be governed via switching ON-OFF to track the deviation in frequency for a short period of time. Zhao et al. have discussed some researches that have been implemented in load control techniques based on frequency [147]. Grid Friendly Controller of Pacific Northwest National Laboratory (Grid Friendly TM Controller Helps Balance Energy Supply and Demand) is one of them. This controller measures the line frequencies to regulate the appliances. When the frequency goes below standard value (50 Hz in India), the appliances are switched off from few seconds to few minutes by the controller for reduction of load.

On the other hand, this technique has some downsides of customer side disutility because appliances go to off state during overload period. In order to reduce the burden of customers, the disutility period must be controlled, or else this method might not be helpful towards the users [132]. In reference [147], the authors presented a technique of distributed load control with monitoring the frequency of the system to reduce the disutility of load. In order to improve the accuracy in frequency measurement at different load periods, communication among loads is necessary. Thus, an adjustment must be made between modest communication and small disutility period. During over frequency period, this control method may not provide better regulation. To encounter this problem, a group of equipment should be arranged and dedicated to be turned ON when frequency goes beyond the standard value. Hence a controlling algorithm is required to develop for ON-OFF switching for appliances so that it does not interfere with the user's choice. In reference [136], the authors proposed an ON-OFF technique for the equipment to permit main reserve in both directions, and three kinds of users' choice were taken into account, namely conservative, optimistic, and probabilistic. The authors also developed a new theory stated as 'electric spring' [148-151]. These authors implemented a creative idea of 'smart loads' by using power electronic devices.

The above mentioned controlled techniques are outside of our scope of review as we discussed explicitly deployment of battery storage in frequency regulation. Hence demand side BESS is focused here. For the improvement of LFC control, customers load having battery storage can be used. According to our classification, it comes under load scale system category. In this type, distributed energy storages are in-stalled as secondary storages at the load side and also controlled in such a way that it is similar to the AGC of thermal generation depending on available data. Nowadays, electric vehicles are widely used and mostly discussed for this application purpose. There are different kinds of electrical vehicles categorized by U.S. DoE ('Hybrid and Plug-In Electric Vehicles'). With the advancement of technology, diverse researchers proposed that these electric vehicles can be implemented in LFC as a mobile BESU unit [152-155]. According to the way of communication between power system units and controlled loads, the load scale system technique can be divided into two types: Coordinated Aggregate System and Non-Coordinated Individual System.

4.2.1. Coordinated Aggregate System

The aggregate system plays a vital role among all other load scale systems. Electric vehicles are the revolutionary appliances that are being researched to be used in this technique. Authors in [157,159] stated that other techniques of distributed battery energy storage like domestic battery banks or battery installed appliances can be easily used. According to this technique, a number of electric vehicles are linked to a central charging station, having coordinated system operators and electric vehicles using V2G mode of operation [159,160]. Guille et al. implemented an administrator and intermediate controller (which is known as aggregator), collects information about battery SOC, switch on and off time [162]. They also calculated the arrival and subsequent time of charging from smart interfaces of electric vehicles and interconnected with dispatching centre. Then LFC signals were transmitted to the electric vehicles using the aggregator [163, 164]. The author Shimizu et al. proposed an LFC technique which reduces the necessity of BES using Battery of EVs [152]. A control technique was developed which gives priority to its users considering SOC of electric vehicles battery. This SOC technique regulates only the plugged and fully charged electric vehicles in which SOC level is 80%-90% in order to provide satisfaction to its users. This proposed model contains 50000 electric vehicles dispersed in 500 local control centres that are interconnected with central load dispatch centre. The system was inspected using two conditions that are considering users expediency and not considering users expediency. It is observed from the result that the frequency response is better in case of considering user expediency than in the case where user's expediency was not taken into account. In the second case the output of electric vehicles is controlled by using SOC limits. In [165], authors proposed a control method of LFC using the BESU of distributed plug in hybrid electric vehicles with thermostatically regulated loads. The authors invented an aggregation method by implementing in a management system which is known as aggregator based model predictive control method [166-168].

This aggregation method keeps a high level of management between the control loads, plug in hybrid electric vehicles, system operators and distribution through communication. The proposed model consists of a bunch of 40000 plug in hybrid electric vehicles, thermostatically regulated appliances, a CHP unit all linked to a network providing service to an urban community of 160000 populations. It is observed from the results that for the improvement of the system LFC such frequency control methods are effective. On the other hand, the author raises a question about the availability and sufficiency of the reserve quantity given by those loads for the practical application of the proposed system. Moreover, the performance of aggregation is discussed by considering fast communication condition and the consequence of delay in communication system was also not presented. In reference [169], authors discussed about the effects of data exchange and communication method between the grid and the loads controlled by LFC. With the help of numerical simulations, the authors examined the processing delay and network delay to transmit the LFC signal to the distributed battery storage system. In the end, the authors also neglected the network delay. The model was simulated under random variation of load 8000 MW and large influence of wind energy 1800 MW. They also proposed various processing delays and variation in the rate of installation of battery energy storage system. A control method known as cutoff control was also invented to keep coordination with the batteries having a slow response rate. A problem arises in this method which is the small use of BESU because in some operating situations, the slow batteries cannot be dispatched. Another problem is that to avoid over charging or over discharging of batteries SOC limits also considered [170, 171]. The authors have tackled the issues of SOC limits by building an energy control system utilizing Hierarchical Model Predictive Control to regulate the frequency of smart grid [172]. The proposed model consists of conventional generators, coordinated electric vehicles, and recurrent renewable energy sources. The proposed HiMPC method predicts and controls the SOC of electric vehicles and keeps away from over charging and discharging [173]. A noteworthy enhancement in the performance of LFC was seen utilizing electric vehicles in comparison to the case where electric vehicles are not accessible for control [174, 175]. The author, Vachirasricirikul et al. discovered a new control technique using V2G scheme for frequency support [176]. The main objective is to manage the problems associated with system uncertainties, disturbances and to develop a simple and robust controller. To regulate the parameters of the frequency of the controller, both classical as well as intelligent control techniques were used where a particle swarm optimization method using the H2/H infinity control technique was implemented [177]. The frequency controller was used with a PI controller. Using SOC optimization strategy, the power output of the battery was regulated to sustain battery SOC within a predefined limit. From the results of the simulation of the two-area wind firm sys-tem, the efficacy and heftiness of the control technique were obtained. The author Huang et al. also observed the usefulness of electric vehicles in LFC system [178]. The publication list about the role of electric vehicles in frequency control is very long, but here the value of LFC control technique was highlighted and the readers can find more material in the literature about the vehicle to grid strategy. As per our discussion the following problems must be solved:

- The charge-discharge control method must give priority to the customer's necessity and suitability.
- In order to achieve the above case, system operators should be able to control and keep track of a large number of loads. Therefore, intermediate control and aggregation units are required for dispatching LFC signals and in interconnection with the generation units.
- Without knowing the status of the entire system, the aggregator examines the required LFC services from the local operating systems. This is accomplished by metering, regulation and collection of real time statuses of the loads like battery SOC limit, frequency, electric vehicles plug in and out times as reported in [179].
- The interconnection between utility operators and aggregator requires seam-less two-way communication method with high-speed protocols [180].

By implementing the above techniques, the installation and maintenance cost of the system increases. Hence, it is important to obtain top-notch trade-offs between control complexity, cost, the amount of communication and usefulness of frequency regulation so that the utility operators can adopt this load control technique.

4.2.2. Non-Coordinated aggregate Systems

Nowadays, vigorous development can be seen in the field of power electronics control techniques. According to the authors Ribeiro et al., and Ota et al. appliances having battery storage system can be implemented in interface circuits having capability to measure system frequency accurately and respond to deviation in power [135, 181]. The theory of non-regulated control of individual loads having battery energy storage to obtain load side control of frequency is still not implemented by anyone. In the coordinated aggregate system, electric vehicles play a vital role where decentralized regulation is obtained at electric vehicles end via battery chargers. Hence, smart interface circuits which control the bidirectional flow of power between the power line and battery and measures frequency are required. Rei et al. invented an improved smart interface circuit for electric vehicles [182]. In this model, a three-phase multilevel diode is used as a bidirectional AC/DC converter. According to the droop control methodology, this circuit uses voltage control services and auxiliary frequency. Using this technique, Ota et al. developed a single-phase Grid economic interface system to understand the V2G and smart charging concept [183].

The main objective behind the non-regulated discrete system is to distribute the cyber security and communication requirement between system operators and regulated loads for getting a more supple system as stated by the authors in reference [184]. The authors in reference [185] stated that this technique is similar to the frequency controlled load regulation and grid responsive controller. The charging-discharging process of load battery energy storage is regulated with droop control technique corresponding to the generator droop control, so that turning off the equipment during under frequency period is not required. Hence this strategy does not fall under the category of secondary control strategy. On the other hand, it comprehends the primary frequency regulation because no interconnection signals between the generation side and the battery storage is directed. The line frequency signal only represents the communication signal between the generation side and the battery side.

The charge controller, by sensing the frequency for electric vehicles is invented by Argonne National Laboratory. They proposed that using droop control technique and without taking any signals from the dispatching centre, the PEV of battery loads can be regulated automatically [188]. When the variation in the range of the frequency is between the range of 0.1Hz $<\Delta f$ $<$0.5Hz, the controller decreases the charging rate to 50%. But when the frequency drops below the range of 59.5Hz, it finally stops charging. When it reaches 50%, the charging method is resumed where the power mismatch is recovered and the frequency range is 59.7%. Charging is continued at full rate when the frequency exceeds to 60Hz. This control method is known as V1G/smart charging. In this case, one-way power transfer is permitted from grid to vehicle and discharge of powers does not occur during under voltage period to maintain the utility grid as in the V2G technique. The authors in [135] presented a distributed and non-coordinated V2G control scheme by implementing a two-way power transfer technique between the grid and the electric vehicle. However, V1G control method is also used to control the SOC level of the battery of the vehicle within the limit as required by users. The proposed control technique states that the power of the battery storage is modulated in proportional to the variation in the frequency.

The safe charging and discharging of the battery is maintained by the SOC algorithm and keeps its SOC value in the range of 10%-90%. The maximum amount of charging and discharging power is obtained at frequency variation between +0.025 Hz/-0.025 Hz. By responding to the request of the driver, the control switches between V1G and V2G modes. The result of 250MW V2G power unit was examined under two-area of thermal system with the absence of coordination between the thermal generators, electric vehicles, system operators. A noticeable enhancement of frequency regulation of both the areas was realized by setting the SOC within its predefined limit of around 50%. To get another level of SOC, the parameters of SOC have to be modified in the algorithm. Liu et al. invented a SOC holding algorithm which controls the level of SOC according to the user's choice without making any changes in the boundary limits of SOC [180]. For this type of control method, electric vehicles are used widely as battery storage installed appliances. Now a day, more focus is given towards the domestic batteries for the load side control strategy of Behind-the-Meter Energy Storage matching with the discovery of modern domestic batteries by battery companies like Powerwall of Tesla, xStorage of Nissan. In Rocky Mountain Institute, Fitzgerald et al. studied that except the meter energy storage, there are many challenges that keeps away it from supplying frequency control services and to the customer-oriented services [189]. This study explains about these problems, the necessary actions to avoid them, and the appliances that should follow these steps to permit this model of battery energy storage to work in the frequency control. The proposed study by the research community shows that it is necessary to capitalize efforts to build technical as well as economic strategies. In the literature, it is found that many attempts were made in this regard. The authors in reference [156] analysed the performance of domestic lithium ion battery. From the results obtained from the simulation, the energy efficiency and cycling capacity of the battery were evaluated. Different authors discussed about the decentralized control algorithm of domestic batteries [190, 191]. The authors in references [192, 193] explained the advantages of PEV as behind the meter energy storage unit in an advanced control technique for primary and secondary frequency regulation]. The distributed individual entities aim to give prioritize the user's suitability considering the parameters of SOC and to safeguard their privacy by decreasing the rate of communication with the operator of the system.

5. Conclusion

Energy storage is found to be crucial for the enhancement of power quality also sag compensation, power smoothing, load levelling, and power balancing when multiple renewable energy sources are included in the power system. In addition to that, it also supports the stability of the system with significant technical and economic assistances. This Methodology can be realized with a large capacity of diverse storage units that should be operated by the utility in accord with LFC. Such type of scheme requires the highest level of accuracy and price control by the operator and utility. Much attention is needed by the demand side control as distributed energy storage can be connected to loads or placed in the customer's home so that the size of centralized storage unit can be reduced. EVs do not only help the frequency regulation but also act as excellent energy storage. The utilization of battery storage can be achieved through efficient and advance batteries like Tesla's Powerwall and Nissan's xStorage. For power, the EVs, high energy density storage technology will play a vital role in the near future. With the advancement of energy technology, frequency regulation could be reasonable and also the commercial services obtainable by these smart-grid-oriented applications. It is expected that, all of us will experience a modern and matured storage technology with their corresponding roles in near future.

References

[1] O. I. Elgerd, Electric energy systems theory: an Introduction, McGraw-Hill, 1971.

[2] P. Kundur, N. J. Balu, and M. G. Lauby, Power system stability and control. New York, McGraw-Hill, 1994.

[3] C. Zhao, U. Topcu, and S. H. Low, "Optimal Load Control via Frequency Measurement and Neighborhood Area Communication", IEEE Transaction on Power Systems, pp. 1–12, 2013.

[4] S. Saxena, and Y. V Hote, "Load Frequency Control in Power Systems via Internal Model Control Scheme". IEEE Transaction on Power Systems, vol. 28, no. 3, pp. 2749–57, 2013.

[5] Balancing and frequency control: A Technical Document Prepared by the NERC Resources Subcommittee. [Online]. Available: http://www.nerc.com/docs/oc/rs/NERC. [Accessed: 02-Aug-2019].

[6] Beiter, and Philipp, Renewable Energy Data Book, 2014.

[7] M. D. Galus, S. Koch, and G. Anderson, "Provision of Load Control by PHEVs, Controllable Loads, and a Cogeneration Unit", IEEE Transaction on Industrial Electronics, vol. 58, no. 10, pp. 4568–82, 2011.

[8] B. H. Bakken and O. S. Grande, "Automatic Generation Control in a Deregulated Power System", IEEE Transactions on Power Systems, vol. 13, no. 4, pp. 1401-1406, 1998.

[9] N. Jaleeli, L. S. Vanslyck, D. N. Ewart, L. H. Fink, and A. G. Hoffmann, "Understanding Automatic Generation Control", IEEE Transactions on Power Systems, vol. 7, no. 3, pp. 1106–22, 1992.

[10] O. Leitermann, and L.K. James, "Energy Storage for Use in Load Frequency Control" IEEE Conference on Innovative Technologies for an Efficient and Reliable Electricity Supply (CITRES), pp. 292–96, 2010.

[11] E. Kabalcı, E. Irmak, I. Colak., "Design of an AC-DC-AC converter for wind turbines", International Journal of Energy Research, Wiley Interscience, vol. 36, no. 2, pp. 169-175, 2011.

[12] K. Samarakoon, J. Ekanayake, and N. Jenkins, "Investigation of Domestic Load Control to Provide Primary Frequency Response Using Smart Meters", IEEE Transactions on Smart Grid, vol. 3, no. 1, pp. 282–92, 2012.

[13] N. Mousavi, G. Kothapalli, D. Habibi, M. Khiadani, and C.K. Das, "An improved mathematical model for a pumped hydro storage system considering electrical, mechanical, and hydraulic losses", Applied energy, vol. 247, pp. 228-236, 2019.

[14] E.L. Provis, "Pumped-hydro in Bendigo: Room for wider reform?" The Electricity Journal, vol. 32, no. 8, pp.106-134, 2019.

[15] Y. Wu, T. Zhang, C. Xu, X. Zhang, Y. Ke, H. Chu, and R. Xu, "Location selection of seawater pumped hydro storage station in China based on multi-attribute decision making", Renewable Energy, vol. 139, pp. 410-425, 2019.

[16] S. Rehman, L. M. A. Hadhrami, and M. M. Alam, "Pumped hydro energy storage system: A technological review", Renewable and Sustainable Energy Reviews, vol. 44, pp.586-598, 2015.

[17] E. Barbour, I. G. Wilson, J. Radcliffe, Y. Ding, and Y. Li, "A review of pumped hydro energy storage development in significant international electricity markets" Renewable and Sustainable Energy Reviews, vol. 61, pp. 421-432, 2016.

[18] G.D.O. E. Silva, and P. Hendrick, "Pumped hydro energy storage in buildings", Applied energy, vol. 179, pp. 1242-1250, 2016.

[19] C.J. Yang, "Pumped hydroelectric storage", Storing Energy, pp. 25-38, 2016.

[20] M. Stocks, B. Lu, K. Anderson, A. Nadolny and A. Blakers, "Western Australia pumped hydro energy storage (PHES) atlas", An atlas of pumped hydro energy storage, 2018.

[21] S. Sabihuddin, A. Kiprakis, and M. Mueller, "A numerical and graphical review of energy storage technologies", Energies, vol. 8, no. 1, pp.172-216, 2015.

[22] I. Calero, C.A. Canizares, and K. Bhattacharya, "Compressed Air Energy Storage System Modeling for Power System Studies", IEEE Transactions on Power Systems, 2019.

[23] H. Lund, and G. Salgi, "The role of compressed air energy storage (CAES) in future sustainable energy systems", Energy conversion and management, vol. 50, no. 5, pp.1172-1179, 2009.

[24] A. Cohn,, and D. J. Minderman, "Electric Power Research Institute", Power plant utilizing compressed air energy storage and saturation. U.S. Patent, 5, 491, 969, 1996.

[25] J. Zhan, O. A. Ansari, W. Liu, and C. Y. Chung, "An accurate bilinear cavern model for compressed air energy storage", Applied Energy, vol. 242, pp. 752-768, 2009.

[26] M. Cheayb, M. M. Gallego, M. Tazerout, and S. Poncet, "Modelling and experimental validation of a small-scale trigenerative compressed air energy storage system", Applied Energy, vol. 239, pp. 1371-1384, 2019.

[27] F. Faraji, A. Majazi, and K. Al-Haddad, "A comprehensive review of flywheel energy storage system technology", Renewable and Sustainable Energy Reviews, vol. 67, pp. 477-490, 2017.

[28] A. K. Arani, H. Karami, G.B. Gharehpetian, and M.S.A. Hejazi, "Review of flywheel energy storage systems structures and applications in power systems and microgrids". Renewable and Sustainable Energy Reviews, vol. 69, pp. 9-18, 2017.

[29] F. Zhang, Z. Hu, X. Xie, J. Zhang, and Y. Song, "Assessment of the effectiveness of energy storage resources in the frequency regulation of a single-area power system". IEEE Transactions on Power Systems, vol. 32, no. 5, pp. 3373-3380, 2017.

[30] Y.A.O. Liangzhong, Y.A.N.G. Bo, C.U.I. Hongfen, J. Zhuang, Y.E. Jilei, and Z.U.E Jinhua, "Challenges and progresses of energy storage technology and its application in power systems". Journal of Modern Power Systems and Clean Energy, vol. 4, no. 4, pp. 519-528, 2016.

[31] S. Adhikari, R. Karki, and P. Piya, "Recovery Risk Mitigation of Wind Integrated Bulk Power System with Flywheel Energy Storage" IEEE Transactions on Power Systems, 2019.

[32] F.W. Capp, M.L. Lazarewicz, A.J. Arseneaux, P. Dresens, and H.A. Rojas, Beacon Power LLC, Methods,

systems and apparatus for regulating frequency of generated power using flywheel energy storage systems with varying load and/or power generation, 2017.

[33] M. Amiryar, and K. Pullen, "A review of flywheel energy storage system technologies and their applications", Applied Sciences, vol. 7, no. 3, pp. 286, 2017.

[34] H. Silva-Saravia, H. Pulgar-Painemal, and J.M. Mauricio, "Flywheel energy storage model, control and location for improving stability: The Chilean case", IEEE Transactions on Power Systems, vol. 32, no. 4, pp. 3111-3119, 2016.

[35] M.T. Elsir, A.A. Mohammed, A.T. Al-Awami, and M. Khalid. "Sizing and Allocation for Solar Energy Storage System Considering the Cost Optimization." In 2019 8th International Conference on Renewable Energy Research and Applications, pp. 407-412. IEEE, 2019.

[36] I. Dincer, and M.A. Ezan, "Thermal Energy Storage Methods. In Heat Storage: A Unique Solution for Energy Systems", vol. 57-84, 2018.

[37] I Sarbu, and C. Sebarchievici, "A comprehensive review of thermal energy storage", Sustainability, vol. 10, no. 1, pp. 191, 2018.

[38] R. McKenna, D. Fehrenbach, and E. Merkel, "The role of seasonal thermal energy storage in increasing renewable heating shares: A techno-economic analysis for a typical residential district", Energy and Buildings, vol. 187, pp. 38-49, 2019.

[39] E. Reihani, S. Sepasi, L.R, Roose, and M. Matsuura,, "Energy management at the distribution grid using a Battery Energy Storage System (BESS)", International Journal of Electrical Power & Energy Systems, vol. 77, pp. 337-344, 2016.

[40] D.I. Stroe, V. Knap, M. Swierczynski, A.I, Stroe, and R. Teodorescu, "Operation of a grid-connected lithium-ion battery energy storage system for primary frequency regulation: A battery lifetime perspective", IEEE transactions on industry applications, vol. 53, no. 1, pp. 430-438, 2016.

[41] A. Zurfi, Zhang, and Jing, "Exploitation of Battery Energy Storage in Load Frequency Control - A Literature Survey", American Journal of Engineering and Applied Sciences, vol. 9, pp. 1173-1188, 2016.

[42] D. Linden, and T.B. Reddy, Handbook of Batteries, McGraw-Hill: New York, NY, USA, 2002.

[43] R. Dueber, "Strategic overview of silver-zinc rechargeable batteries", Battery Power Prod. Technology, vol.12, pp. 1–2, 2008.

[44] E. Olivetti, J. Gregory, and R. Kirchain, "Life Cycle Impacts of Alkaline Batteries with A Focus on End-of-Life", Massachusetts Institute of Technology: Cambridge, MA, USA, 2011.

[45] J.W. Evans, J. Keist, C. Ho, B. Quan., and P.K. Wright,"Printed Energy Storage" University of California Berkeley: Berkeley, CA, USA, 2014.

[46] K. Lin, Q. Chen, M.R. Gerhardt, L. Tong, S.B.Kim, L. Eisenach, A.W. Valle, D. Hardee, R.G. Gordon, M.J. Aziz, and M.P. Marshak, "Alkaline quinone flow battery", Science, vol. 349, no. 62, pp. 1529-1532, 2015.

[47] T. Janoschka, N. Martin, U. Martin, C. Friebe, S. Morgenstern, H. Hiller, M.D. Hager, and Schubert, "U.S.: An aqueous, polymer-based redox-flow battery using non-corrosive, safe, and low-cost materials" Nature, vol. 527, no. 7576, pp. 78, 2015.

[48] A. Rubio, and W. Agila. "Sustainable Energy: A Strategic Overview of Fuel Cells." In 2019 8th International Conference on Renewable Energy Research and Applications (ICRERA), pp. 239-243. IEEE, 2019.

[49] X.B. Cheng, R. Zhang, C.Z. Zhao, and Q. Zhang, "Toward safe lithium metal anode in rechargeable batteries: a review", Chemical reviews, vol. 117, no. 15, pp. 10403-10473, 2017.

[50] S. Abada, G. Marlair, A. Lecocq, M. Petit, V. Sauvant-Moynot, and F. Huet, "Safety focused modeling of lithium-ion batteries: A review". Journal of Power Sources, vol. 306, pp. 178-192, 2016.

[51] A. Fotouhi, D.J. Auger, K. Propp, S. Longo, and M. Wild, "A review on electric vehicle battery modelling: From Lithium-ion toward Lithium–Sulphur", Renewable and Sustainable Energy Reviews, vol. 56, pp. 1008-1021, 2016.

[52] J. Jaguemont, L. Boulon, and Y. Dubé, "A comprehensive review of lithium-ion batteries used in hybrid and electric vehicles at cold temperatures", Applied Energy, vol. 164, pp.99-114, 2016.

[53] M.R. Djalal, "Superconducting Magnetic Energy Storage Optimization for Load Frequency Control in Micro Hydro Power Plant using Imperialist Competitive Algorithm". International Journal of Engineering and Manufacturing, vol. 8, no. 5, 2018.

[54] W.J. Gil-González, A. Garcés, and A. Escobar, "A generalized model and control for supermagnetic and supercapacitor energy storage". Ingeniería y Ciencia, vol. 13, vol. 26, pp.147-171, 2017.

[55] A.N. Ghalelou, A.P. Fakhri, S. Nojavan, M. Majidi, and H. Hatami, "A stochastic self-scheduling program for compressed air energy storage (CAES) of renewable

energy sources (RESs) based on a demand response mechanism", Energy conversion and management, vol. 120, pp.388-396, 2016.

[56] W. Buckles, and W.V. Hassenzahl, "Superconducting magnetic energy storage". IEEE Power Engineering Review, vol. 20, no. 5, pp.16-20, 2000.

[57] H.J. Boenig, and J.F. Hauer, "Commissioning tests of the Bonneville Power Administration 30 MJ superconducting magnetic energy storage unit", IEEE Transactions on Power Apparatus and Systems, vol. 2, pp. 302-312, 1985.

[58] O. Veneri, C. Capasso, and S. Patalano, "Experimental investigation into the effectiveness of a super-capacitor based hybrid energy storage system for urban commercial vehicles", Applied Energy, vol. 227, pp. 312-323, 2018.

[59] H.Y. Tong, "Development of a Driving Cycle for a Supercapacitor Electric Bus Route in Hong Kong" Sustainable Cities and Society, 2019.

[60] D.N. Luta, and A.K. Raji, "Optimal sizing of hybrid fuel cell-supercapacitor storage system for off-grid renewable applications", Energy, vol. 166, pp. 530-540, 2019.

[61] U.S. Grid Energy Storage factsheet, center for sustainable systems, University of Michigan, 2019, [Accessed: 28- July-2019].

[62] K. Zhang, D. Zhao, X. Yin, R. Yang, and G. Tan, "Energy saving and economic analysis of a new hybrid radiative cooling system for single-family houses in the USA". Applied energy, vol. 224, pp. 371-381, 2018.

[63] D. Bresser, K. Hosoi, D. Howell, H. Li, H. Zeisel, K. Amine, and S. Passerini, "Perspectives of automotive battery R&D in China, Germany, Japan, and the USA", Journal of Power Sources, vol. 382, pp. 176-178, 2018.

[64] M. Esteban, J. Portugal-Pereira, B.C. Mclellan, J. Bricker, H. Farzaneh, N. Djalilova, K.N. Ishihara, H. Takagi, and V. Roeber, "100% renewable energy system in Japan: Smoothening and ancillary services" Applied energy, vol. 224, pp.698-707, 2018.

[65] C.T. Lee, N.E.M. Rozali, Y. Van Fan, J.J. Klemeš, and S. Towprayoon, "Low-carbon emission development in Asia: energy sector, waste management and environmental management system", Clean Technologies and Environmental Policy, vol. 20, no. 3, pp. 443-449, 2018.

[66] C. Zhang, Y.L. Wei, P.F. Cao, and M.C Lin, "Energy storage system: Current studies on batteries and power condition system", Renewable and Sustainable Energy Reviews, vol. 82, pp. 3091-3106, 2018.

[67] Y. Ding, C. Shao, J. Yan, Y. Song, C. Zhang, and C. Guo, "Economical flexibility options for integrating fluctuating wind energy in power systems: The case of China", Applied Energy, vol. 228, pp. 426-436, 2018.

[68] L. Ye, K. Wen, Z. Zhang, F. Yang, Y. Liang, W. Lv, Y. Lin, J. Gu, J.H. Dickerson, and W. He, "Energy Storage: Highly Efficient Materials Assembly Via Electrophoretic Deposition for Electrochemical Energy Conversion and Storage Devices", Advanced Energy Materials, vol. 6, no. 7, 2016.

[69] Energy storage for a brighter china, The China Energy Storage Alliance, Available: http://en.cnesa.org, [Accessed: 24- July-2019].

[70] Energy Storage in China, deployment and innovation, Georgetown University, Available: www2.itif.org/2018-lewis-energystorage.pdf, [Assessed: 11-Aug.-2018].

[71] B. Shyam, and P. Kanakasabapathy, "Large scale electrical energy storage systems in India-current status and future prospects". Journal of Energy Storage, vol. 18, pp. 112-120, 2018.

[72] S.K. Sahoo, "Renewable and sustainable energy reviews solar photovoltaic energy progress in India: A review", Renewable and Sustainable Energy Reviews, vol. 59, pp. 927-939, 2016.

[73] A. Chauhan, and R.P. Saini, "Techno-economic feasibility study on Integrated Renewable Energy System for an isolated community of India", Renewable and Sustainable Energy Reviews, vol. 59, pp. 388-405, 2016.

[74] A. Gulagi, D. Bogdanov, and C. Breyer, "The role of storage technologies in energy transition pathways towards achieving a fully sustainable energy system for India", Journal of Energy Storage, vol. 17, pp. 525-539, 2018.

[75] R.K. Vishnoi, and L.P. Joshi, "Challenges in Reliable Power System Planning and Management with Large Scale Infusion of Renewable Sources in India". In 2019 IEEE PES GTD Grand International Conference and Exposition Asia (GTD Asia), pp. 63-67, 2019.

[76] J. Alshehri, A. Alzahrani, and M. Khalid. "Voltage and Frequency Control of Microgrids with Distributed Generations and Battery Energy Storage." In 2019 8th International Conference on Renewable Energy Research and Applications (ICRERA), pp. 381-385. IEEE, 2019.

[77] Akhil, and Abbas, "Trends and Status of Battery Energy Storage for Utility Applications". In Proceedings of the Tenth Annual Battery Conference on Applications and Advances, pp. 273–77, 1995.

[78] S. Tae Cha, Z. Haoran, W. Qiuwei, A. Saleem, and J. Ostergaard, "Coordinated Control Scheme of Battery Energy Storage System (BESS) and Distributed Generations (DGs) for Electric Distribution Grid Operation." IECON 2012 - 38th Annual Conference on IEEE Industrial Electronics Society, pp. 4758–64, 2012.

[79] B. Lian, Y. Dongmin, C. Wang, S.L. Blond, and R. W. Dunn, "Investigation of Energy Storage and Open Cycle Gas Turbine for Load Frequency Regulation", In 49th International Universities Power Engineering Conference (UPEC), 2014.

[80] M. J. E. Alam, M. M. Kashem and D. Sutanto., "A Controllable Local Peak Shaving Strategy for Effective Utilization of PEV Battery Capacity for Distribution Network Support". IEEE Transactions on Industry Applications, 2013.

[81] I. Papi, "Simulation Model for Discharging a Lead-Acid Battery Energy Storage System for Load Leveling". IEEE Transaction on Energy Conversion, vol. 21, no. 2, pp. 608–15, 2006.

[82] K.H. Jung, H. Kim, and D. Rho, "Determination of the Instalation Site and Optimal Capacity of the Battery Energy Storage for Load Leveling", IEEE Transactions on Energy Conversion, vol. 11, no. 1, pp. 162–67, 1996.

[83] T.H. Mehr, M.A.S Masoum, and N. Jabalameli, "Grid-Connected Lithium- Ion Battery Energy Storage System for Load Leveling and Peak Shaving", In Australasian Universities Power Engineering Conference, 2013.

[84] C. Noce, S. Riva, G. Sapienza, and M. Brenna, "Electrical Energy Storage in Smart Grid: Black-Start Study Using a Real-Time Digital Simulator", In 2012 3rd IEEE International Symposium on Power Electronics for Distributed Generation Systems (PEDG), pp. 216–20, 2012.

[85] D. Dong, P. Wang, W. Qin, and X. Han, "Investigation of a Microgrid with Vanadium Redox Flow Battery Storages as a Black Start Source for Power System Restoration.", In Proceedings of the 2014 9th IEEE Conference on Industrial Electronics and Applications, pp. 140–45, 2014.

[86] I. Serban, and C. Marinescu, "Control Strategy of Three-Phase Battery Energy Storage Systems for Frequency Support in Microgrids and with Uninterrupted Supply of Local Loads.", IEEE Transaction on Power Electronics, vol. 29, no. 9, pp. 5010–5020, 2014.

[87] X. Li, Y. Huang, J. Huang, S. Tan, M. Wang, T. Xu, and X. Cheng, "Modeling and Control Strategy of Battery Energy Storage System for Primary Frequency Regulation", In 2014 International Conference on Power System Technology, pp. 543–459, 2014.

[88] A. Agrawal, M. Kumar, D.K Prajapati, M. Singh, and P. Kumar, "Smart Public Transit System Using an Energy Storage System and Its Coordination with a Distribution Grid", IEEE Transactions on Intelligent Transportation Systems, vol. 15, no.4, pp. 1622–32, 2014.

[89] R. Bhatt, and B. Chowdhury, "Grid Frequency and Voltage Support Using PV Systems with Energy Storage", In North American Power Symposium (NAPS), pp. 1–6, 2011.

[90] H.J. Kunisch, K.G. Kramer, and H. Dominik, "Battery Energy Storage Another Option for Load-Frequency-Control and Instantaneous Reserve". IEEE Transactions on Energy Conversion, vol. 1, no. 3, pp. 41–46, 1986.

[91] C. Lu, C. Liu, and C. Wu, "Effect of Battery Energy Storage System on Load Frequency Control Considering Governor Deadband and Generation Rate Constraint", IEEE Transactions on Energy Conversion, vol. 10, no. 3, pp. 555–61, 1995.

[92] D. Kottick, M. Blau, and D. Edelstein. "Battery Energy Storage for Frequency Regulation in an Island Power System", IEEE Transaction on Energy Conversion, vol. 8, no. 3, pp. 455–59, 1993.

[93] Y. Ghiassi-farrokhfal, K. Srinivasan, and C. Rosenberg, "Toward a Realistic Performance Analysis of Storage Systems in Smart Grids", IEEE Transaction on Smart Grid, vol. 6, no. 1, pp. 402–10, 2015.

[94] E.V. Martínez, and J.A.D.L.O. Serna, "Smart Grids Part 1: Instrumentation Challenges", IEEE Instrumentation & Measurement Magazine, 2015.

[95] K. Shimizu, T. Masuta,Y. Ota, and A. Yokoyama, "Load Frequency Control in power system using Vehicle-to-Grid system considering the customer convenience of Electric Vehicles" , International Conference on Power System Technology, 2010.

[96] S.S. Pati, T.K. Panigrahi, and A. Behera, Performance Analysis of Solar and Plug-in Electric Vehicle's Integration to the Power System with Automatic Generation Control. In Intelligent Computing Techniques for Smart Energy Systems, Springer, pp. 703-711, Singapore, 2020.

[97] U. Sen, and N. Kumar, "Load Frequency Control with Battery Energy Storage System". In International Conference on Power, Control and Embedded Systems (ICPCES), 2014.

[98] S.K. Aditya, and D. Das, "Battery Energy Storage for Load Frequency Control of an Interconnected Power System", Electric Power Systems Research, vol. 58, no. 3, pp. 179–85, 2001.

[99] P. Mercier, R. Cherkaoui, and A. Oudalov, "Optimizing a Battery Energy Storage System for Frequency Control Application in an Isolated Power System", IEEE Transaction on Power Systems, vol. 24, no. 3, pp. 1469–77, 2009.

[100] A.H. Chowdhury, and M.A. Zaman, "Load Frequency Control of Multi-Microgrid Using Energy Storage System", In 8th International Conference on Electrical and Computer Engineering, pp. 548–51, 2014.

[101] A. Harrouz, I. Colak, and K. Kayisli, ""Energy Modeling Output of Wind System based on Wind Speed." In 2019 8th International Conference on Renewable Energy Research and Applications (ICRERA), pp. 63-68. IEEE, 2019.

[102] F. D. Mohammadi, M. J. Ghorbani, A. Feliachi, and M.A. Choudhry, "Novel Load Frequency Control Approach Based on Virtual Area Error in a Microgrid Including PV and Battery", In PES General Meeting Conference & Exposition, pp. 1–5, 2014.

[103] K. Hongesombut, T. Piroon, and Y. Weerakamaeng, "Evaluation of Battery Energy Storage System for Frequency Control in Microgrid System", In 2013 10th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology, pp. 3–6, 2013.

[104] H. Shayeghi, H.A. Shayanfar, and A. Jalili, "Load Frequency Control Strategies: A State-of-the-Art Survey for the Researcher", Energy Conversion and Management, vol. 50, no. 2, pp. 344–53, 2009.

[105] R. Umrao, S. Kumar, M. Mohan, and D.K. Chaturvedi, "Load Frequency Control Methodologies for Power System". In 2012 2nd international Conference on Power, Control and Embedded Systems, 2012.

[106] A.D. Rosaline, and U. Somarajan, "Structured H-Infinity Controller for an Uncertain Deregulated Power System", IEEE Transactions on Industry Applications, vol. 55, no. 1, pp. 892-906, 2019.

[107] V.P. Singh, N. Kishor, P. Samuel, and S.R. Mohanty, "Impact of communication delay on frequency regulation in hybrid power system using optimized H-infinity controller", IETE Journal of research, vol. 62, no. 3, pp.356-367, 2016.

[108] W. Yan, L. Sheng, D. Xu, W. Yang, and Q. Liu, "H∞ Robust Load Frequency Control for Multi-Area Interconnected Power System with Hybrid Energy Storage System". Applied Sciences, vol. 8, no. 10, pp. 1748, 2018.

[109] A. Davidson, and S. Ushakumari, "Robust H-infinity loopshaping controller for load frequency control of an uncertain deregulated power system", AMSE J. C: Autom. Control (Theory Appl.), vol. 71, no. 1, pp. 39-59, 2016.

[110] P. Apkarian, and D. Noll, "Nonsmooth H-infinity synthesis", IEEE Trans. Autom. Control, vol. 71, no 1, pp. 71-86, 2006.

[111] K. Janfeshan, A.S. Masoum Mohammad, and Sara Deilami, "V2G Application to Frequency Regulation in a Microgrid Using Decentralized Fuzzy Controller", In Proceedings of 2014 International Conference on Modelling, Identification & Control, pp. 361–64, 2014.

[112] M.A.X.D Anderson, and D.S. Carr, "Battery Energy Storage Technologies". Proceedings of the IEEE, vol. 81, no. 3, pp. 475–79, 1993.

[113] K.C. Divya, and J. Østergaard, "Battery Energy Storage Technology for Power systems—An Overview", Electric Power Systems Research, vol. 79, no. 4, pp. 511–520, 2009.

[114] A. S. Subburaj, and S.B. Bayne, "Analysis of Dual Polarization Battery Model for Grid Applications", In 2014 IEEE International Telecommunications Energy Conference (INTELEC), pp.1–6, 2014.

[115] A. Stock, S. Petra, and V. Sahajwalla, "Powerful Potential: Battery Storage for Renewable Energy and Electric Cars", climatecouncil.org.au,[Accessed: 26- Jan.-2018].

[116] Bullis, and Kevin, "Old Battery Type Gets a Energy Boost, MIT Energy Review, [Online]. Available: https://www.technologyreview.com/s/535251/oldbattery-type-gets-an-energy-boost/. [Accessed: 08-Jun-2018].

[117] R. Ruegg, and P. Thomas, "Linkages of DOE's Energy Storage R&D to Batteries and Ultracapacitors for Hybrid, Plug-In Hybrid, and Electric Vehicles". U.S. Department of Energy, 2008.

[118] Tullo, and Alexander H, "Global Top 50 Chemical Companies", Chemical & Engineering News, Available: http://cen.acs.org/articles/93/i30/Global-Top-50.html/ [Accessed: 03-Jun-2018].

[119] S. Shibasaki, M. Toge, and S. Iwamoto, "Load Frequency Control Using a NaS Battery System Controlled by a Kalman Filter". In 10th International Power & Energy Conference (IPEC), pp. 236–41, 2012.

[120] T. Sasaki, T. Kadoya, and K. Enomoto. "Study on Load Frequency Control Using Redox Flow Batteries", IEEE Transactions on Power Systems, vol. 19, no. 1, pp. 660–67, 2004.

[121] R. Shankar, K. Chatterjee, and R. Bhushan, "Impact of Energy Storage System on Load Frequency Control for Diverse Sources of Interconnected Power System in

Deregulated Power Environment", International Journal of Electrical Power & Energy Systems, vol. 79, pp. 11–26, 2016.

[122] S.S. Pati, and S.K. Mishra, Automatic Generation Control of a Wind Turbine Integrated Hydro-thermal Plant with Redox Flow Batteries for 2-Area Interconnected Power System. In Smart Intelligent Computing and Applications, Springer, pp. 411-418, Singapore, 2020.

[123] G.M. Cook, W.C. Spindler, and C. Grefe, "Overview of Battery Power Regulation and Storage", IEEE Transaction on Energy Conversion, vol.6, vol. 1, pp. 204–11, 1991.

[124] Y. Yang, S. Bremner, C. Menictas, and M. Kay, "Battery energy storage system size determination in renewable energy systems: A review", Renewable and Sustainable Energy Reviews, vol. 91, pp. 109-125, 2018.

[125] E. Barbour, D. Parra, Z. Awwad, and M.C. González, "Community energy storage: A smart choice for the smart grid?", Applied energy, vol. 212, pp. 489-497, 2018.

[126] B. Cárdenas, T.R. Davenne, J. Wang, Y. Ding, Y. Jin, H. Chen, Y. Wu, and S.D. Garvey, "Techno-economic optimization of a packed-bed for utility-scale energy storage", Applied Thermal Engineering, 2019.

[127] H. Amano, Y. Ohshiro, T. Kawakami, and T. Inoue, "Utilization of Battery Energy Storage System for Load Frequency Control toward Large-Scale Renewable Energy Penetration", In 3rd IEEE PES International Conference and Exhibition on Innovative Smart Grid Technologies (ISGT Europe), pp. 1–7, 2012.

[128] O. Leitermann, and J.L. Kirtley, "Energy Storage for Use in Load Frequency Control", In Innovative Technologies for an Efficient and Reliable Electricity Supply (CITRES), IEEE Conference on, pp. 292–96, 2010.

[129] H. Nagoya, S. Komami, and K. Ogimoto, "A Method for Load Frequency Control Using Battery in Power System with Highly Penetrated Photovoltaic Generation", Electrical Engineering in Japan, vol. 184, no. 4, pp. 22–31, 2013.

[130] L. Al-Ghussain, O. Taylan, and D.K. Baker, "An investigation of optimum PV and wind energy system capacities for alternate short and long-term energy storage sizing methodologies", International Journal of Energy Research, vol. 43, no. 1, pp.204-218, 2019.

[131] H. Aoyagi, R. Isomura, P. Mandal, N. Krishna, T. Senjyu, and H. Takahashi, "Optimum Capacity and Placement of Storage Batteries Considering Photovoltaics", Sustainability, vol. 11, no. 9, pp. 2556, 2019.

[132] C. Zhao, U. Topcu, and S.H. Low, "Frequency-Based Load Control in Power Systems", In American Control Conference, pp. 4423–30, 2012.

[133] J. Abushnaf, and A. Rassau, "An efficient scheme for residential load scheduling integrated with demand side programs and small-scale distributed renewable energy generation and storage". International Transactions on Electrical Energy Systems, vol. 29, no. 2, pp. 2720, 2019.

[134] X. Zhang, D.J. Hill, and C. Lu, "Identification of Composite Demand Side Model with Distributed Photovoltaic Generation and Energy Storage". IEEE Transactions on Sustainable Energy, 2019.

[135] Y. Ota, H. Taniguchi, T. Nakajima, K.M. Liyanage, J. Baba, and A. Yokoyama, "Autonomous Distributed V2G (Vehicle-to-Grid) Considering Charging Request and Battery Condition", In Innovative Smart Grid Technologies Conference Europe (ISGT Europe), pp. 1–6, 2010.

[136] R. Iacobucci, B. McLellan, and T. Tezuka, "Optimization of shared autonomous electric vehicles operations with charge scheduling and vehicle-to-grid", Transportation Research Part C: Emerging Technologies, vol. 100, pp. 34-52, 2019.

[137] Z. Yi, J. Smart, and M. Shirk, "Energy impact evaluation for eco-routing and charging of autonomous electric vehicle fleet: Ambient temperature consideration", Transportation Research Part C: Emerging Technologies, vol. 89, pp. 344-363, 2018.

[138] B. Biegel, L.H. Hansen, P. Andersen, and J. Stoustrup, "Primary Control by ON/OFF Demand-Side Devices", IEEE Transactions on Smart Grid, vol. 4, no. 4, pp. 2061–71, 2013.

[139] X. Zhao, J. Ostergaard, and M. Togeby, "Demand as Frequency Controlled Reserve", IEEE Transaction on Power Systems, vol. 26, no. 3, pp. 1062–71, 2011.

[140] Q. Shi, F. Li, Q. Hu, and Z. Wang, "Dynamic demand control for system frequency regulation: Concept review, algorithm comparison, and future vision", Electric Power Systems Research, vol. 154, pp. 75-87, 2018.

[141] P.J. Douglass, R. Garcia-valle, P. Nyeng, J. Østergaard, and M. Togeby, "Smart Demand for Frequency Regulation: Experimental Results", IEEE Transaction on Smart Grid, vol. 4, no. 3, pp. 1713–20, 2013.

[142] R. Khezri, A. Oshnoei, M. Tarafdar Hagh, and S.M. Muyeen, "Coordination of heat pumps, electric vehicles

and AGC for efficient LFC in a smart hybrid power system via SCA-based optimized FOPID controllers", Energies, vol. 11, no. 2, pp. 420, 2018|.

[143] R. Zhao, W. Yan, J. Zhang, J. Lu, B. Li, H. Wang, And W. Guo, "Dynamic Coordination Optimization Model of Regional and Provincial AGC Unit Control for Ultra-high Voltage Line Interconnected Power System", In International Conference on Power System Technology (POWERCON), pp. 3497-3506, 2018.

[144] T. Masuta, A. Yokoyama, and Y. Tada, "Modeling of a Number of Heat Pump Water Heaters as Control Equipment for Load Frequency Control in Power Systems", In IEEE Trondheim Power Tech, pp. 1–7, 2011.

[145] T. Masuta, A. Yokoyama, and Y. Tada, "System Frequency Control by Heat Pump Water Heaters (HPWHs) on Customer Side Based on Statistical HPWH Model in Power System with a Large Penetration of Renewable Energy Sources", In International Conference on Power System Technology, pp. 1–7, 2010.

[146] X. Shi, J. Yu, J. Cao, and T. Yong, "Decentralised frequency-based control of a population of heterogeneous ACs without power oscillations", IET Generation, Transmission & Distribution, vol. 12, no. 10, pp. 2471-2479, 2018.

[147] C. Zhao, U. Topcu, and S.H. Low, "Optimal Load Control via Frequency Measurement and Neighborhood Area Communication", IEEE Transaction on Power Systems, pp. 1–12, 2013.

[148] S.Y. Hui, C.K. Lee, and F.F. Wu, "Electric Springs—a New Smart Grid Technology" IEEE Transactions on Smart Grid, vol. 3, no. 3, pp. 1552–61, 2012.

[149] C.K. Lee, L.C. Kai, and M.N Wai, "Load Characterisation of Electric Spring". In IEEE Energy Conversion Congress and Exposition, pp. 4665–70, 2013.

[150] S.C. Tan, C.K. Lee, and S.Y. Hui, "General Steady-State Analysis and Control Principle of Electric Springs with Active and Reactive Power Compensations", IEEE Transactions on Power Electronics, vol. 28, no. 8, pp. 3958–3969, 2013.

[151] J.M.G. López, E. Pouresmaeil, C.A. Canizares, K. Bhattacharya, A. Mosaddegh, and B.V. Solanki, "Smart residential load simulator for energy management in smart grids", IEEE Transactions on Industrial Electronics, vol. 66, no. 2, pp.1443-1452, 2019.

[152] K. Shimizu, T. Masuta, Y. Ota, and A. Yokoyama, "Load Frequency Control in Power System Using Vehicle-to-Grid System Considering the Customer Convenience of Electric Vehicles", In International Conference on Power System Technology, pp. 1–8, 2010.

[153] M. Ehsani, Y. Gao, S. Longo, and K. Ebrahimi, Modern electric, hybrid electric, and fuel cell vehicles, CRC press, 2018.

[154] H. Liu, K. Huang, Y. Yang, H. Wei, and S. Ma, "real-time vehicle-to-grid control for frequency regulation with high frequency regulating signal", Protection and Control of Modern Power Systems, vol. 3, no. 1, pp.13, 2018.

[155] S. Debbarma, and A. Dutta, "Utilizing electric vehicles for LFC in restructured power systems using fractional order controller", IEEE transactions on smart grid, vol. 8, no. 6, pp.2554-2564, 2016.

[156] M. Bila, C. Opathella, and B. Venkatesh, "Grid Connected Performance of a Household Lithium-Ion Battery Energy Storage System" Journal of Energy Storage, pp. 178–85, 2016.

[157] M. Sun, X. Yang, D. Huisingh, R. Wang, and Y. Wang, "Consumer behavior and perspectives concerning spent household battery collection and recycling in China: a case study", Journal of Cleaner Production, vol. 107, pp. 775-785, 2015.

[158] S., Hattori, H. Eto, F. Kurokawa, and K. Kajiwara, "An evaluation of charging power balance of EV battery for household distributed power system", International Journal of Renewable Energy Research, vol. 8, no. 1, pp. 1-6, 2018.

[159] P. Lazzeroni, S. Olivero, M. Repetto, F. Stirano, and M. Vallet, "Optimal battery management for vehicle-to-home and vehicle-to-grid operations in a residential case study", Energy, 2019.

[160] V. Monteiro, J.G. Pinto, and J.L. Afonso, "Improved vehicle-for-grid (iV4G) mode: Novel operation mode for EVs battery chargers in smart grids", International Journal of Electrical Power & Energy Systems, vol. 110, pp. 579-587, 2019.

[161] U. Datta, N. Saiprasad, A. Kalam, J. Shi, and A. Zayegh, "A price-regulated electric vehicle charge-discharge strategy for G2V, V2H, and V2G". International Journal of Energy Research, vol. 43, no. 2, pp. 1032-1042, 2019.

[162] C. Guille, and G. Gross, "2A Conceptual Framework for the Vehicle-to-Grid (V2G) Implementation". Energy Policy, vol. 37, no. 11, pp. 4379–4390, 2009.

[163] F. Kennel, D. Görges, and S. Liu, "Energy Management for Smart Grids with Electric Vehicles Based on Hierarchical MPC", IEEE Transactions on Industrial Informatics, vol. 9, no. 3, pp. 1528–37, 2013.

[164] X. Zhang, M.R. Nakhai, G. Zheng, S. Lambotharan, and J. Chambers, "Distributed Foresighted Energy Management in Smart-Grid-Powered Cellular Networks" IEEE Transactions on Vehicular Technology, 2019.

[165] M.D. Galus, S. Koch, and G. Anderson, "Provision of Load Frequency Control by PHEVs, Controllable Loads, and a Cogeneration Unit" IEEE Transaction on Industrial Electronics, vol. 58, no. 10, pp. 4568–82, 2011.

[166] G. Jinquan, H. Hongwen, P. Jiankun, and Z. Nana, "A novel MPC-based adaptive energy management strategy in plug-in hybrid electric vehicles", Energy, vol. 175, pp. 378-392, 2019.

[167] Y. Zheng, Y. Song, D.J. Hill, and K. Meng," Online Distributed MPC-based Optimal Scheduling for EV Charging Stations in Distribution Systems", IEEE Transactions on Industrial Informatics, vol. 15, no. 2, pp. 638-649, 2019.

[168] S. Xie, X. Hu, S. Qi, X. Tang, K. Lang, Z. Xin, and J. Brighton, "Model predictive energy management for plug-in hybrid electric vehicles considering optimal battery depth of discharge", Energy, vol. 173, pp. 667-678, 2019.

[169] K. Wada, and A. Yokoyama, "Load Frequency Control Using Distributed Batteries on the Demand Side with Communication Characteristics", In 3rd IEEE PES Innovative Smart Grid Technologies Europe (ISGT Europe), pp. 1– 8, 2012.

[170] L. Fang, J. Li, and B. Peng, "Online Estimation and Error Analysis of both SOC and SOH of Lithium-ion Battery based on DEKF Method", Energy Procedia, vol. 158, pp. 3008-3013, 2019.

[171] M. Jinhao, D.I. Stroe, M. Ricco, L. Guangzhao, and R. Teodorescu, "A Simplified Model based State-of-Charge Estimation Approach for Lithium-ion Battery with Dynamic Linear Model", IEEE Transactions on Industrial Electronics, vol. 66, no. 10, 2019.

[172] C.A. Hans, P. Braun, J. Raisch, L. Grüne, and C. Reincke-Collon, "Hierarchical distributed model predictive control of interconnected microgrids", IEEE Transactions on Sustainable Energy, vol. 10, no. 1, pp. 407-416, 2019.

[173] X. Kong, X. Liu, L. Ma, and K.Y. Lee, "Hierarchical Distributed Model Predictive Control of Standalone Wind/Solar/Battery Power System". IEEE Transactions on Systems, Man, and Cybernetics: Systems, vol. 49, no 8, 2019.

[174] S. N. Saxena. "Smart Distribution Grid – and How to Reach the Goal" Internatıonal Journal of Smart Gri\d, vol.3, no.4, pp. 188-200, 2019.

[175] Y. Huang, H. Wang, A. Khajepour, H. He, and J. Ji, "Model predictive control power management strategies for HEVs: A review", Journal of Power Sources, vol. 341, pp. 91-106, 2017.

[176] S. Vachirasricirikul, and I. Ngamroo, "Robust LFC in a Smart Grid with Wind Power Penetration by Coordinated V2G Control". IEEE Transactions on Smart Grid, vol. 5, no. 1, pp. 371–80, 2014.

[177] X. Gong, J. Suh, and C. Lin, "A novel method for identifying inertial parameters of electric vehicles based on the dual H infinity filter", Vehicle System Dynamics, pp. 1-21, 2019.

[178] Y. Huang, J. Liu, C. Li, and W. Gong, "Considering the Electric Vehicles in the Load Frequency Control", In Asia-Pacific Power and Energy Engineering Conference, pp. 1–3, 2012.

[179] S.S. Pati, A. Behera, and T.K. Panigrahi, Plug in electric vehicle-wind integrated multi-area automatic generation control tuned by intelligent water drops algorithm." In International Conference on Intelligent Systems Design and Applications, Springer, Cham, pp. 240-250, 2018.

[180] S. Liu, Xi. Wang, and P.X. Liu, "Impact of Communication Delays on Secondary Frequency Control in an Islanded Microgrid", IEEE Transactions on Industrial Electronics, vol. 62, no. 4, pp. 2021–31, 2015.

[181] P.F. Ribeiro, B.K. Johnson, M.L. Crow, A. Arsoy, and Y. Liu, "Energy Storage Systems for Advanced Power Applications". Proceedings of the IEEE, vol. 89, no. 12, pp. 1744–56, 2001.

[182] R.J. Rei, F.J. Soares, P.M. Rocha Almeida, and J.A. Peças Lopes, "Grid Interactive Charging Control for Plug-in Electric Vehicles", In 13th International IEEE Annual Conference on Intelligent Transportation Systems Madeira Island, Portugal, pp. 386–91, 2010.

[183] Y. Ota, H. Taniguchi, H. Suzuki, T. Nakajima, J. Baba, and A. Yokoyama, "Implementation of Grid-Friendly Charging Scheme to Electric Vehicle off- Board Charger for V2G",3rd IEEE PES Innovative Smart Grid Technologies Europe, pp. 1–6, 2012.

[184] A. Molina-Garcia, F. Bouffard, and D.S. Kirschen, "Decentralized Demand-Side Contribution to Primary Frequency Control", IEEE Transactions on Power Systems, vol. 26, no. 1, pp. 411–19, 2011.

[185] I. Colak, S. Sagiroglu, G. Fulli, M. Yesilbudak, and C.F. Covrig. "A survey on the critical issues in smart grid technologies." Renewable and Sustainable Energy Reviews, vol. 54, pp. 396-405, 2016.

[186] A. Panda, A. Das, S. S. Pati, and S. K. Mishra. "A PSO Based PIDF Controller for Multiarea Multisource System Incorporating Dish Stirling Solar System." In 2019 International Conference on Intelligent Computing and Control Systems (ICCS), pp. 1458-1462. IEEE, 2019.

[187] S.S. Pati, and S.K. Mishra, "A PSO based modified multi stage controller for Automatic Generation Control with integration of Renewable Sources and FACT device", International Journal of Renewable Energy Research, vol. 9, no. 2, pp. 673-683, 2019.

[188] G. Saldaña, J.I.S. Martin, I. Zamora, F.J. Asensio, and O. Oñederra, "Electric Vehicle into the Grid: Charging Methodologies Aimed at Providing Ancillary Services Considering Battery Degradation", Energies, vol. 12, pp. 2443, 2019.

[189] G. Fitzgerald, J. Mandel, J. Morris, and H. Touati, the Economics of Battery Energy Storage, 2015.

[190] B. Celik, R. Roche, D. Bouquain, and A. Miraoui, "Decentralized neighborhood energy management with coordinated smart home energy sharing", IEEE Transactions on Smart Grid, vol. 9, no. 6, pp. 6387-6397, 2018.

[191] L. Wang, S. Sharkh, and A. Chipperfield, "Optimal decentralized coordination of electric vehicles and renewable generators in a distribution network using A∗ search", International Journal of Electrical Power & Energy Systems, vol. 98, pp. 474-487, 2018.

[192] O. Borne, K. Korte, Y. Perez, M. Petit, and A, Purkus, "Barriers to entry in frequency-regulation services markets: Review of the status quo and options for improvements", Renewable and Sustainable Energy Reviews, vol. 81, pp. 605-614, 2018.

[193] D.M. Greenwood, K.Y. Lim, C. Patsios, P.F. Lyons, Y.S. Lim, and P.C. Taylor, "Frequency response services designed for energy storage". Applied Energy, vol. 203, pp. 115-127, 2017.