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Power Quality Improvement of Microgrid System using Control Strategies: A Survey

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ABSTRACT: A microgrid (MG) is a discrete energy system consisting of an interconnection of distributed energy sources and loads capable of operating in parallel with or independently from the main power grid. The microgrid concept integrated with renewable energy generation and energy storage systems has gained significant interest recently, triggered by increasing demand for clean, efficient, secure, reliable and sustainable heat and electricity. However, the concept of efficient integration of energy storage systems faces many challenges (e.g., charging, discharging, safety, size, cost, reliability and overall management). Additionally, proper implementation and justification of these technologies in MGs cannot be done without energy management systems, which control various aspects of power management and operation of energy storage systems in microgrids. This review discusses different energy storage technologies that can have high penetration and integration in microgrids. Moreover, their working operations and characteristics are discussed.

KEYWORDS: - Microgrid, Power Quality, Control Strategies

I. INTRODUCTION

With a growing share of renewable energy generation, distribution companies of power sector are facing some new challenges [1]. Despite the environment benefits and sustainability of renewable based energy resources, two main problem arises when it is integrated into distribution network. First, renewable energy production is well-known to be heavily dependent on weather conditions. The intermittent properties of non-dispatchable renewable based energy resources can lead to instability in power system [2]. To address this point, the system operator must provide sufficient reserve to ensure the system safe operation against uncertainty regarding renewable power. In this scenario, standard generation units must have a more regular start and stop, which has important wear and tear effects on these units and can possibly reduce the general system efficiency [3]. Secondly, as renewable energy penetration rises, it is more complicated to absorb the rise in renewable energy generation for conventional distribution network. In [4], it is discussed that over generation of photovoltaic resulted in very small net demand in California at midday, but net demand in another periods was still high when photovoltaics were unable to produce energy. Therefore, when additional photovoltaic is included, this net demand profile would see the net demand through deepen in the center of the day, leading to the so called "Duck-curve". As a result, with a restricted capacity to accommodate this enormous ramp, it is necessary to curtail solar energy, thus decreasing the financial and environment benefits of inclusion of renewable energy. One of the potential alternative to the above mentioned problems is to use hybrid renewable based energy systems and incorporating multiple renewables energy resources in an optimal manner [5]. In this respect, periods with low generation resource could obviously be offset by other high energy generation resource [6]. In [7], it is presented by the combination of complementary nature of wind and solar generation resources. Comprehensive literature on the optimal accommodation of distributed generation units [8], energy management and control [9] are available in such hybrid renewable integrations. There has been extensive study of the use of energy storage systems (ESS) to promote the growing penetration of renewable based energy source by absorbing and releasing power in distinct time horizons [10]. Battery energy storage system (BESS) has drawn significant attention from the multiple kinds of ESS technology available, with clear benefits such as rapid response, controllability and geographical autonomy [11]. However, negative effect of high penetration of renewable based distributed generation such as reverse power flow and energy loss can be mitigated through optimal accommodation and operation of BESS [12]. In addition to the above mentioned benefits, BESS also has a wide range of application such as power quality, energy management and voltage improvements etc. In [13], explores the optimal operating state schedule of wind turbine for reducing battery capacity and operational cost. In [14], proposed the solar generation and BESS hybrid energy management plan for achieving technical and economic benefits. In, the exchangeable battery system was suggested and renewable energy can be used effectively to charge that battery system. In [15], arises the issue of embedded generation in the

distribution system. In, investigate the impact of optimal sizing of BESS on operation cost of micro grid. It is clear from the literature that appropriate use of grid integrated BESS can mitigate the operational challenges of distribution system. Therefore, BESS has great potential for both power utility and consumers but it is done only by adopting optimal operation strategy.

II. LITERATURE REVIEW

Markus Ovaskainen et al. [1], a lattice associated battery energy stockpiling framework (BESS) has different applications as a matrix supporting unit. Most normal applications consider the capacity of a BESS to decouple electric power age and utilization in various settings which is generally attractive according to the matrix administrator perspective. A microgrid comprising of environmentally friendly power sources associated with power electronic converters can encounter hardships with symphonious voltages and receptive inrush flows. Receptive flows might cause a voltage drop in the line impedances. Voltage variances and sounds can cause issues, for example, hardware stumbling, overheating and failing. The strength of the microgrid is subject to the microgrid units' capacities to relieve and make up for these peculiarities. A BESS can be utilized to all the while trade dynamic power between the battery and the matrix and further develop the power nature of a microgrid. With autonomous fell control of flows and dynamic and receptive power, a BESS can handle the responsive power balance in a microgrid and subsequently guarantee voltage solidness. Furthermore, a BESS can fill in as a functioning symphonious channel. Because of the transient idea of the portrayed peculiarities, these control plans require control progressively. Every one of the applications referenced above can be acknowledged all the while with appropriate control plan where the distinctive controlled amounts are superposed. This paper audits the innovation of a BESS and the necessary control frameworks to understand the power quality highlights and presents reproduction results as confirmation of their practicality. The recreations exhibit how a BESS can significantly add to microgrid steadiness while likewise performing dynamic power trade.

S. Golshannavaz et al. [2], this paper proposes a home energy the board (HEM) procedure to decrease the client's charging cost as well as to remunerate the receptive power at the mark of lattice joining. The created HEM empowers the property holder to oversee various parts and machines including electric vehicle (EV), energy stockpiling framework (ESS), and shiftable burdens (SLs). Ideal booking of utilization seasons of SLs and charging/releasing patterns of EV and ESS closes in reasonable decrease in day by day activity cost. Then, at that point, fulfilling the got least activity cost inside the requirements, the excess limit of EV and ESS inverters is committed to receptive power pay of the home apparatuses. Likewise, the power factor (PF) of home-to-framework association is reasonably improved. The proposed HEM is demonstrated as a blended number straight programming (MILP) and is tackled with general logarithmic displaying framework (GAMS). The got results endorse both the financial and specialized victories.

S. Kirmani et al. [3], "Electric Power Quality (EPQ) is a term that alludes to keeping up with the close to sinusoidal waveform of force appropriation transport voltages and flows at appraised size and recurrence". Today clients are more mindful of the reality that the power quality has, this brief the utilities to guarantee great nature of capacity to their client. The power quality is essentially client driven. Expanded focal point of utilities toward keeping up with solid power supply by utilizing power quality improvement apparatuses has decreased the blackouts and shut down impressively. Great power quality is the attribute of solid power supply. Low power factor, symphonious contamination, load lopsidedness, quick voltage varieties are some normal boundaries which are utilized to characterize the power quality. On the off chance that the power quality issues are not checked for example the boundaries that characterize power quality doesn't fall inside the predefined principles than it will lead into high power charge, high running expense in enterprises, failing of types of gear, challenges in associating sustainable. Capacitor banks, FACTS gadgets, consonant channels, SVC's (static voltage compensators), STATCOM (Static-Compensator) are the answers for accomplish the power quality. The presentation of Wind turbine generators is impacted by low quality power, simultaneously these breeze power producing plant influences the power quality contrarily. This paper presents the STATCOM-BESS (battery energy stockpiling framework) framework and studies its effect on the power quality in a framework which comprises of wind turbine generator, non-direct burden, hysteresis regulator for controlling the activity of STATCOM and matrix. The model is reenacted in the MATLAB/Simulink. This plan mitigates the power quality issues, further develops voltage profile and furthermore diminishes consonant twisting of the waveforms. BESS level out the uneven characters made in genuine power due discontinuous nature of wind power accessible because of shifting breeze speeds.

M. I. H. Omer et al. [4], have a tunnel is one of the significant passages to the island of Montreal, and related to the scaffold, it is the longest submerged passage span in Canada. Ongoing reports gauge that around 130,000 vehicles drive

through the passage day by day. High functional principles are needed to guarantee the wellbeing of workers. Thus, high-feelings of anxiety are considered the electrical matrix. The high strain levels on electrical power matrices and the costly cost of pinnacle power request have incited both the purchaser and the utility to take on Energy Capacity Systems (ESS) for top burden shaving. In this proposal, a Battery Energy Storage System (BESS) is measured and controlled to decrease the imperatives forced on the electrical lattice by the Louis-Hippolyte-La Fontaine Tunnel by implies of pinnacle load shaving. The pinnacle load decrease is accomplished through top burden shaving by using a BESS, and furthermore through energy and pinnacle load shaving by involving BESS related to Photovoltaics sun based cells (PV). Likewise in this proposal, a control plot is produced for Voltage Source Inverters (VSI) utilized in top shaving applications. The created control initially permits the VSI to interact top shaving frameworks with the matrix decreasing feelings of anxiety forced on the network, what's more also, assume the part of force factor rectification for receptive power remuneration, and at last, to carry out the abilities of dynamic consonant channels and symphonious alleviation methods to stifle the consonant substance in the line current.

T. Suntio et al. [5], filling the requirement for a reference that clarifies the conduct of force electronic converters, this book gives data presently inaccessible in comparable messages on power hardware. Obviously coordinated into four sections, the initial segment treats the elements and control of ordinary converters, while the subsequent part covers the elements and control of DC-DC converters in environmentally friendly power applications, including a prologue to the sources just as the plan of current-took care of converters applying duality-change techniques. The third part treats the elements and control of three-deliberately ease rectifiers in voltage-obtained applications, and the last part takes a gander at the elements and control of three-work inverters in environmentally friendly power applications. With its future-arranged point of view and progressed, direct information, this is a superb asset for specialists and rehearsing engineers requiring a prepared reference on the plan and control of force electronic converters.

X. Luo et al. [6], electrical power age is changing significantly across the world as a result of the need to diminish ozone harming substance discharges and to present blended energy sources. The power network faces extraordinary moves in transmission and conveyance to satisfy need with erratic every day and occasional varieties. Electrical Energy Storage (EES) is perceived as supporting advances to have extraordinary potential in gathering these difficulties, by which energy is put away in a specific state, as per the innovation utilized, and is changed over to electrical energy when required. In any case, the wide assortment of choices and complex trademark frameworks make it hard to assess a particular EES innovation for a specific application. This paper expects to moderate this issue by giving an exhaustive and clear image of the best in class advancements accessible, and where they would be appropriate for coordination into a power age and dissemination framework. The paper begins with an outline of the activity standards, specialized and monetary execution highlights and the flow innovative work of significant EES advances, arranged into six principle classifications dependent on the sorts of energy put away. Following this, a thorough correlation and an application likely investigation of the surveyed advances are introduced.

L. Xu et al. [7], slight unbalance in voltage in a dissemination framework can bring about high unbalance in flows because of enlistment machine loads. Further, a wide range of consonant parts will be produced in flows because of uncontrolled power electronic burdens utilizing diode-span rectifiers. Power quality turns into a basic issue for a microgrid on the off chance that both enlistment machine burdens and rectifier loads exist. Relief of lopsided and consonant flows without extra ventures is of interest of service organizations. With energy stockpiling frameworks, for example, batteries introduced for top forming and valley filling, power quality improvement through voltage source converter (VSC) based battery inverters is proposed in this paper. This paper fosters an Unbalanced Current (UC) and Harmonic Current (HC) regulator for battery inverters dependent on the construction of Proportional-Resonance (PR) regulator. Constant reproductions did in RT-LAB show the matrix current can be effectively improved to fulfill the IEEE guideline when the negative succession part of network voltage is lower than 4% for the review framework in this paper.

M. T. Lawder et al. [8], the flow electric lattice is a wasteful framework that squanders huge measures of the power it produces in light of the fact that there is a distinction between how much energy buyers require and how much energy delivered from age sources. Power plants commonly produce more power than needed to guarantee satisfactory power quality. By exploiting energy stockpiling inside the lattice, large numbers of these failures can be eliminated. When utilizing battery energy stockpiling frameworks (BESS) for matrix stockpiling, progressed demonstrating is needed to precisely screen and control the capacity framework. A battery the executives framework (BMS) controls how the capacity framework will be utilized and a BMS that uses progressed material science based models will propose for substantially more powerful activity of the capacity framework. The paper diagrams the present status of the workmanship for displaying in BMS and the high level models needed to completely use BMS for both lithium-particle

batteries and vanadium redox-stream batteries. Also, framework engineering and how it tends to be valuable in observing and control is talked about. A pathway for propelling BMS to all the more likely use BESS for lattice scale applications is laid out.

III. MICROGRID STRUCTURE

Microgrid solar PV and wind generation system become very attractive solution in particular for stand-alone applications. Combining the two sources of solar and wind can provide better reliability and their hybrid system becomes more economical to run since the weakness of one system can be complemented by the strength of the other one. The integration of hybrid solar and wind power systems into the grid can further help in improving the overall economy and reliability of renewable power generation to supply its load. Similarly, the integration of hybrid solar and wind power in a stand-alone system can reduce the size of energy storage needed to supply continuous power. Solar electricity generation systems use either photovoltaics or concentrated solar power. The focus in this paper will be on the photovoltaics type. Detailed descriptions of the different technologies, physics and basics of PV can be found in many textbooks and papers such as [4-7]. Kurtz [8] pointed out that ten years ago the concentrator cell was only ~30% efficient compared with more than 40% today with the potential to approach 50% in the coming years. Si cells have efficiencies of 26% and multi-junction III-V-compound cells have efficiencies above 45% (48% in the laboratory) as pointed out in reference [9]. PV modules produce outputs that are determined mainly by the level of incident radiation. As the light intensity increases, photocurrent will be increased and the open-circuit voltage will be reduced [10]. The efficiency of any photovoltaic cell decreases with the increasing temperature which is non-uniformly distributed across the cell [11]. The solar output power can be smoothed by the distribution of solar power in different geographical areas [12]. Electricity from solar PV and concentrated solar power plants is significantly expensive and requires significant drop in cost or change in policies by either subsidizing or forcing the use of these technologies to be able to achieve significant market penetration [13]. Global wind report (2012) indicated that the annual market grew by around 10% to reach around 45 GW and the cumulative market growth was almost 19% [14]. Detailed descriptions of the wind energy can be found in references [4] and [15]. Wind turbines (WTs) are classified into two types: horizontal-axis WT (HAWT) and vertical-axis WT (VAWT). The highest achievable extraction of power by a WT is 59% of the total theoretical wind power. Hybrid solar-wind systems can be classified into two types: grid connected and stand-alone. Literature reviews for hybrid grid connected and stand-alone solar PV and wind energies were conducted worldwide by many researchers who have presented various challenges and proposed several possible solutions. Due to the nature of hybrid solar PV and wind energies, optimization techniques can play a good role in utilizing them efficiently. Graphic construction methods, linear programming, and probabilistic approach are few examples of optimization techniques that have been developed for techno-economically optimum hybrid renewable energy system for both types. It conducted a review of existing research of optimal sizing of renewable hybrids energy systems with energy storage components for both stand-alone and grid-connected systems. The authors gave brief descriptions about those indicators and the different sizing methods. A review of control strategies for a hybrid renewable energy system was carried out in and another review was done in for optimization of hybrid renewable energy system with more focus on wind and solar PV systems. The reviews in and are applicable for both types; grid-connected and stand-alone systems.

IV. CONTROL OF MICROGRID

The control strategies for microgrid depend on the mode of its operation. The aim of control technique should be to stabilize the operation of microgrid. When designing a controller, operation mode of MG plays a vital role. Therefore, after modelling the key aspect of the microgrid is control.

1. Control of Grid Connected

In grid connected mode, microgrid acts as a controllable load/source. It should not actively regulate the voltage at the point of common coupling (PCC). Its main function is to satisfy its load requirements with good citizen behavior towards main grid. The balance between generation and demand, control of the parameters of the system is taken care by the utility grid. The voltage and frequency reference of the microgrid is also set by the main grid. Therefore the main task of a DG unit is to control the output real power (P) and reactive power (Q).

2. Control Islanded Microgrid

In islanded mode, the reactive power sharing is highly dependent on impedance of power line. Due to the different distances among DERs interface converters (DICs), the equivalent transmission line impedance could be unequal [51]. P_f and Q_V droop characteristics are used in DER interface converters for power sharing operations. The P_f droop

control provides an accurate real power sharing among the DIC's but the problem arises in QV droop control. Because of this unequal impedance load sharing performance of QV control can be affected.

V. GRID CONNECTED SYSTEM

The integration of combined solar and wind power systems into the grid can help in reducing the overall cost and improving reliability of renewable power generation to supply its load. The grid takes excess renewable power from renewable energy site and supplies power to the site's loads when required. Fig. 1 and Fig. 2 show the common DC and common AC bus grid-connected to solar PV and wind hybrid system, respectively

Power electronics topologies and control

There are two topologies for grid-connected solar PV and wind hybrid system as can be seen from Fig. 1 and Fig. 2. Fig. 1 shows that the DC outputs' voltages from individual solar PV, wind and battery bank stream, through individual DC/DC and AC/DC units, are integrated on the DC side and go through one common DC/AC inverter which acts as an interface between the power sources and the grid to provide the desired power even with only one source available. Hence, the renewable energy sources act as current sources and can exchange power with the grid and the common DC/AC inverter controls the DC bus voltage. The individual units can be employed for maximum power point tracking (MPPT) systems to have the maximum power from the solar PV and wind systems and the common DC/AC inverter will control the DC bus voltage.

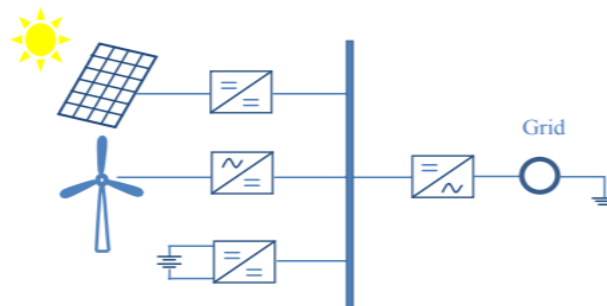


Figure 1: Grid-connected hybrid system at common DC bus

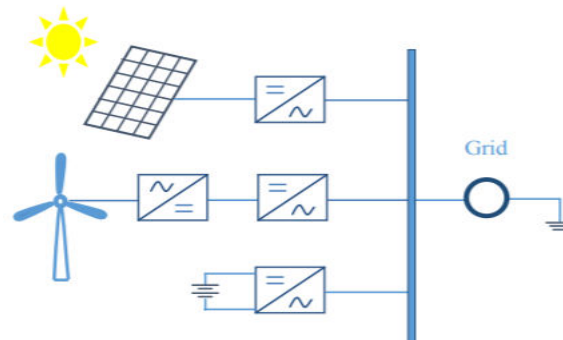


Figure 2: Grid-connected hybrid system at common AC bus

The battery bank is charged when there is an extra power and discharged (by supplying power) when there is shortage of power from the renewable energy sources. On the other hand, Fig. 2 shows that renewable energy sources are injecting power directly to the grid through individual DC/AC and AC/DC-DC/AC units.

Power quality

The increased penetration of grid-connected renewable energy sources has an impact on the grid power quality in particular weak grids. Voltage fluctuation, frequency fluctuation and harmonics are major power quality issues. Furthermore, intermittent energy from solar PV and wind has a huge impact on network reliability. However, accurate forecasting and scheduling systems can minimize the impacts. Various statistical forecasting and regression analysis approaches and algorithms are used to forecast weather pattern, solar radiation and wind speed [12-13]. System operator can adjust other dispatchable generation elsewhere in a system to deal with any deficit or surplus power from renewable power generation [14]. This will reduce the impact of the fluctuations from the generation of the renewable energy sources. In addition, the distribution of RES to larger geographical area in small units instead of large unit

concentrating in one area can control the intermittence effect of power generation from RES [15]. Energy storage devices like batteries or Uninterruptable Power Supply (UPS) can work as a balancing devices that provide power when there is an energy deficiency in renewable generation and store excess energy when there is surplus power from renewable generation [16-17]. Active power filters such as dynamic voltage regulators, static synchronous compensators and unified power quality conditioners can be used to resolve voltage fluctuation. Similarly, power compensators such as fixed or switched capacitor can be used to resolve reactive power issue [12]. They are the latest interfacing devices between grids and consumer appliances. Sudden changes in active power drawn by a load could cause system frequency fluctuation in AC grids. These changes represent unbalance situations between load and generation. In view of the above, it is important to design control loops for power and frequency control to mitigate quality issues [13]. Bae and Kwasinski highlighted that a primary goal of a pulse width modulation (PWM) inverter controller was to regulate three-phase local AC bus voltage and frequency in a microgrid. Harmonics are normally caused by power electronics devices and non-linear appliances. Appropriate filters and PWM switching converter can be used to mitigate harmonic's distortion.

Stand-alone (autonomous) system

The stand-alone or autonomous power system is an excellent solution for remote areas where utilities facilities, in particular transmission lines, are not economical to run or difficult to install due to their high cost and/or difficulties of terrain, etc. The stand-alone systems can be sub-classified into common DC bus or common AC bus. The strength of one source could overcome the weakness of the other during a certain period of time [11]. For stand-alone applications, storage cost still represents the major economic issue. Combining both PV solar and wind powers can minimize the storage requirements and ultimately the overall cost of the system [13]. Increasing PV panels and capacity of wind turbines could be a better choice compared to the increasing of batteries since batteries are much more expensive with a shorter lifespan compared to the life time of a PV or WT. However, for high reliability systems, too few batteries can't meet the reliability requirements, which will incur more cost since too many PV modules or too large WTs will be required. For a small islanded electricity system in New Zealand, with winter peaking demand, I. G. Mason found that the average storage ratio for solar PV to wind was 1.768:1 in comparison to 0.613:1 (residential) and 0.455:1 (farm dairy) with summer peaking demand. Integration of renewable energy generation with battery storage and diesel generator back-up systems is becoming cost-effective solution for resolving less usable renewable energy during the year. [15]. However, if storage runs out, there is no way of importing energy. Therefore, integrating PV and wind energy sources with fuel cells is a promising alternative back up energy source for hybrid generation systems. Distributed generators can help fluctuations in power supply since generations' units will be close to the loads. However, introducing distributed generators will require an up gradation in the existing protection schemes.

Optimization

As mentioned earlier, a combination of solar PV and wind sources improves overall energy output. However, energy storage system is required to have a continuous power supply and cover any deficiency in power generation from the renewable energy sources. The storage system can be battery banks, fuel cells, etc. with a more focus here on battery banks. Various optimization techniques have been reported which could be applied to reach a techno-economically optimum hybrid renewable energy system. A comparison was made for many optimization techniques of hybrid systems in [13]. For remote areas which represent most of the standalone application for hybrid solar PV and wind systems, it is not always easy to find long-term weather data, such as solar radiation and wind speed that are used for sizing purposes. Hence, more artificial intelligence techniques such as fuzzy logic, genetic algorithms and artificial neural network are used for sizing standalone systems in comparison with traditional sizing method based on long-term weather data.

VI. CONCLUSION

In this paper, three different operational strategies of BESS in presence of wind generation is proposed and compared. GA is used to solve the problem of network loss reduction of distribution system. The Strategy 3 model offers greater flexibility in terms of charging and discharging of BESS in active distribution system. It is concluded from the results that Strategy 3 gives the maximum network loss reduction as compared to other two operational strategies. A technical and economical investigation also highlights the applicability of the proposed organized dispatch of BESS. The simulation results shows that the optimum scheduling of BESS with a large wind power have positive impact on distribution system. Also, the results shows that the proposed strategy of BESS keeps the node voltage magnitude of all buses within the permitted range and absorbs the wind energy variations.

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