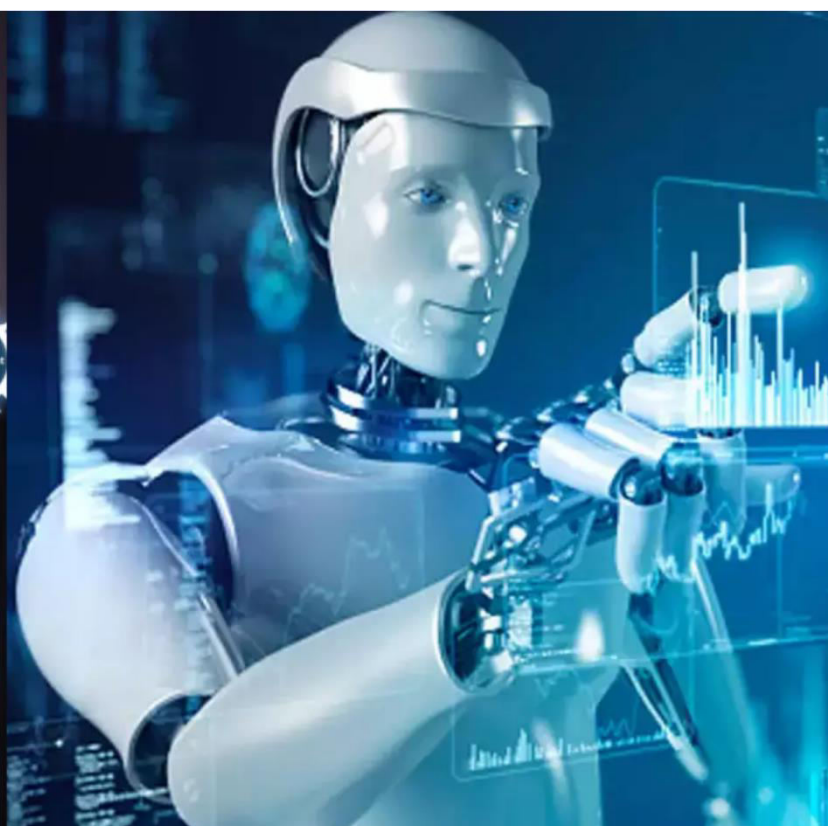




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Analysis of Battery Energy Storage System to Stabilize Transient Response of System

Hemant Kumar Barley¹, Dr. S.P Makhija², Deepshikha Soni³

M.Tech Scholar, Department of EE, RCET, CSVTU Bhilai, C.G, India¹

Associate Professor, Department of EE, CCET, CSVTU Bhilai, C.G, India²

M.Tech Scholar, Department of EE, RCET, CSVTU Bhilai, C.G, India³

ABSTRACT: In this study, a state from northern India has been selected for analysis based on its energy consumption patterns. The research begins with the development of load curves to capture seasonal variations, followed by a peak demand analysis derived from these curves. Data for the study was obtained from the relevant department, and a comprehensive analysis was conducted. Based on the findings, solutions involving renewable energy sources and Battery Energy Storage Systems (BESS) have been proposed. A simplified analysis of the transient response and its impact on the grid has also been carried out. The BESS can be effectively utilized for frequency regulation, thereby enhancing system stability. Additionally, BESS can serve as a tool for energy arbitrage, contributing to the reduction of generation costs.

KEYWORDS: Battery Energy Storage System BESS, Solar Photovoltaic PV Wind speed, Total Harmonic Distortion THD, Renewable Energy Services RES.

I. INTRODUCTION

India is facing challenges to sustain its speedy economic growth and on the same front, dealing with global threat of climate change. Keeping in mind its development agenda and commitment to low carbon growth, India has communicated its Intended Nationally Determined Contribution (INDC) in response to COP (Conference of Parties) decisions 1/CP.19 and 1/CP.20 for the period 2021 to 2030, which will directly or indirectly lead to reduced GHG emissions². The key points are: During COP 2009 at Copenhagen, Denmark, voluntary commitment is made to reduce emission by 20 to 25% by 2020 from 2005 levels, Launched Jawaharlal Nehru National Solar Mission (JNNSM) with a target of 20 GW of grid connected solar power by 2020 which has been enhanced in 2015 to 100 GW by 2022. At COP21 at Paris, India INDC commitments are: To adopt a climate friendly and a cleaner path than the one followed hitherto by others at corresponding level of economic development. To reduce the emissions intensity 33 to 35% by 2030 from 2005 level. To achieve about 40% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030 with the help of transfer of technology and low-cost finance from international institutions including Green Climate Fund (GCF). [1]

Storage energy is very important in an AC-Mini-Grid system. The excess power generated (over the demand power) can be stored in a battery storage system; and when the loads need additional power; the battery storage compensates the shortage. The battery storage need to work in parallel with solar system in off-grid system to generate that availability of power even with the variable power demand of the load. More importantly, it is required to response smoothly to the charge and discharge powers. In addition, in stand-alone systems, Maximum Power Point Tracking (MPPT) is possible only if battery backup is present for the reliability of the system [1-3].

Many research works have been done on controlling voltage and frequency to improve the damping capacity of the power system. Prior studies have demonstrated that the combination of a BESS with a STATCOM can improve power, frequency, or voltage damping. Nevertheless, the state of charge (SOC) of the battery was either ignored in these studies or was taken to be a constant value, which is not the case in a real power system. Furthermore, the BESS is solely controlled by the conventional Proportional-Integral (PI) controller, and because deadband is not included in the design, the suggested BESS control is vulnerable to rapid charging and discharging. Studies have been done on a BESS for controlling voltage or frequency, but not both at the same time, in an isolated power system that is prioritized by

active or reactive power. In order to reduce inter-area oscillations, a STATCOM with a BESS has been proposed for a large-scale power system. The BESS would be utilized as an active or reactive power stabilizer.

(A. Chakraborty, S. K. Musunuri, A. K. Srivastava, and A. K. Kondabathini). The literature analysis pointed up a number of advantages of including BESS for transient voltage and frequency stabilization as well as enhancing power export capabilities. Enhanced grid resilience, decreased curtailment, greater grid stability, and better utilization of renewable energy are some of these advantages. For BESS integration to be successful, a number of obstacles must be overcome, including high upfront expenditures, a small amount of energy storage capacity, and technical problems with battery degradation and system control. Benefits from integrating, BESS include better usage of renewable energy, lower curtailment, more grid resilience, and greater grid stability. For implementation to be successful, though, obstacles including high upfront prices, a small amount of energy storage capacity, and technical problems with battery deterioration and system control must be resolved.

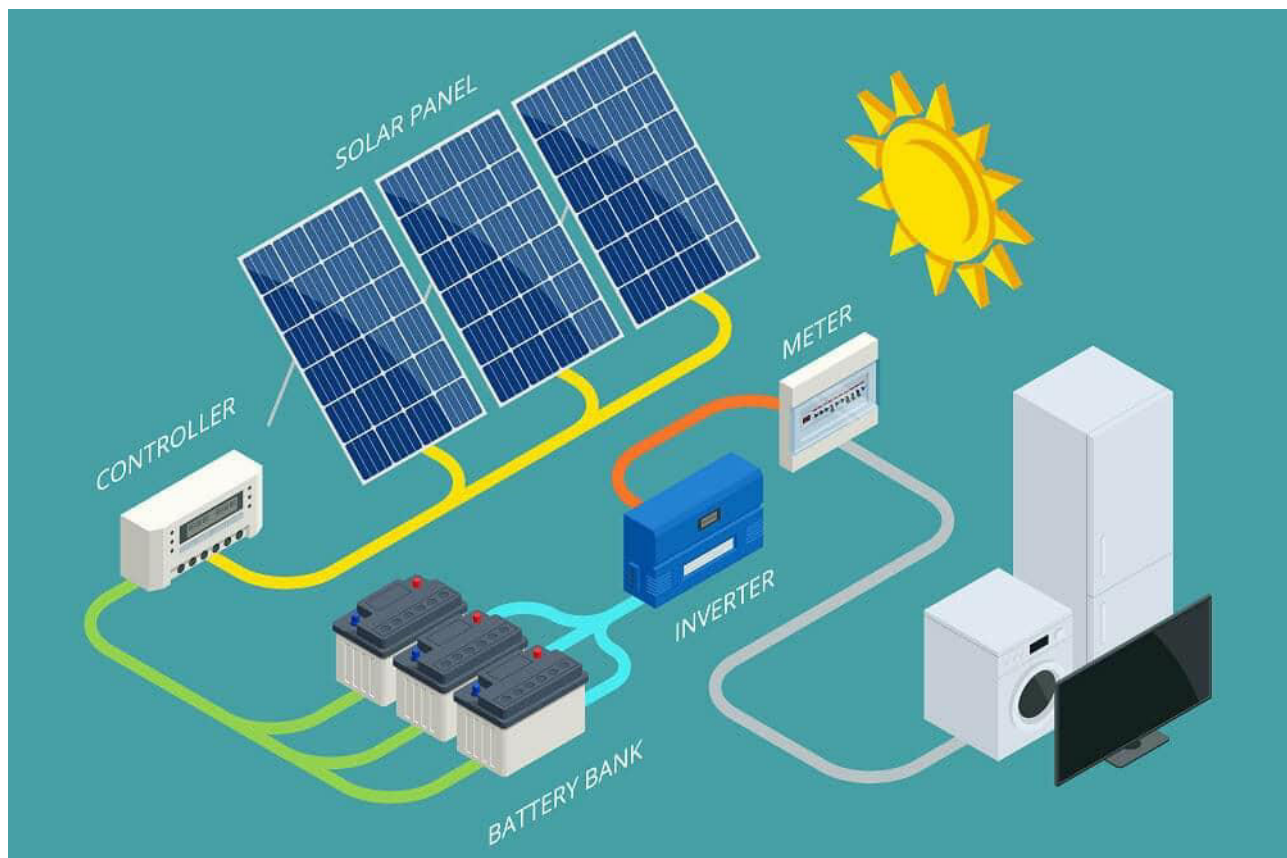


Fig. 1 BESS for sustainable power management

The next step to achieve the set targets for the energy storage systems in India. The analysis has been done in a particular site by the consumption pattern of the consumers. We have taken a state of northern India where the load are very high at summers. Since the climate zone is hot and dry. The peak load goes high at the time of summers due to cooling load mainly due to air conditioning system and chillers.

The seasons are divided for a year and every season has approximately 3 months. So we have taken data of one month of each season and try to find out the consumption pattern by drawing the load curve as per data.

As the data of 220 KV GSS Energy Drawl has been given in 15 min slot, the energy drawl of every 15 mins has been compiled and converted into Hourly blocks & take average of hourly blocks into consideration. (ex, 00:15+00:30+00:45+00:60/)

Throughout the whole month timestamp has been added on daily basis according to hour slab (which has been shown in table and chart as well).

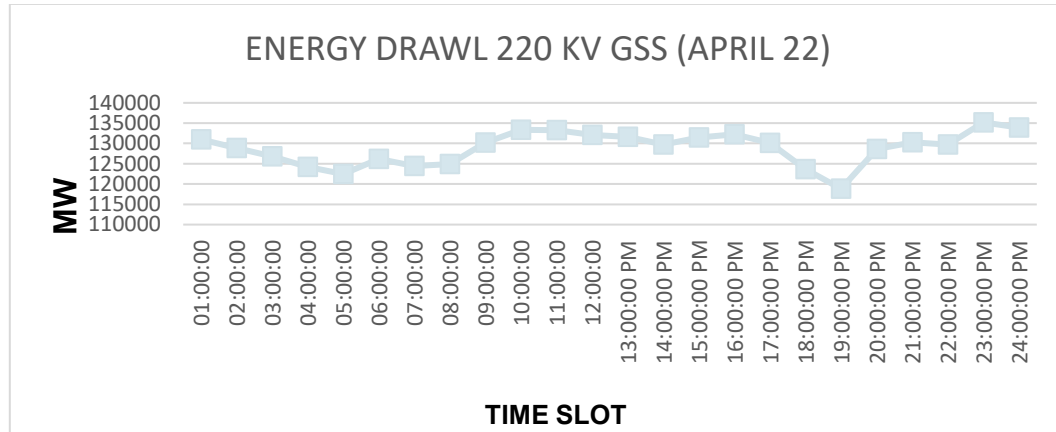


Fig. 2 Peak load curve of Summer season

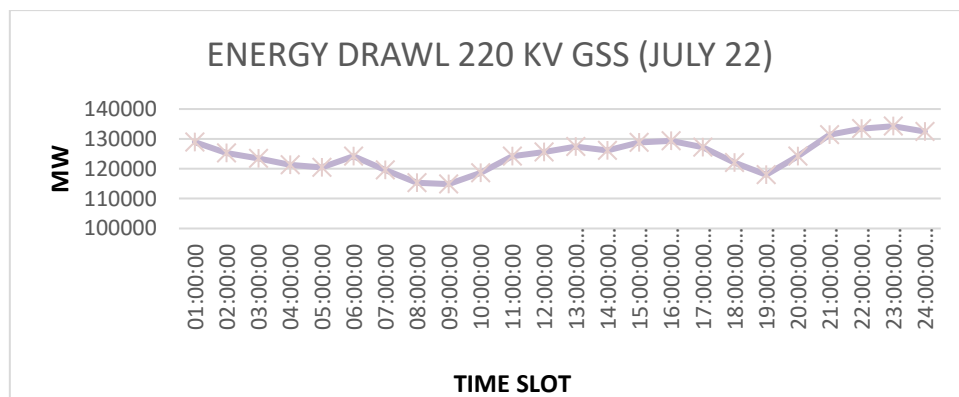


Fig. 3 Peak load curve of Rainy season

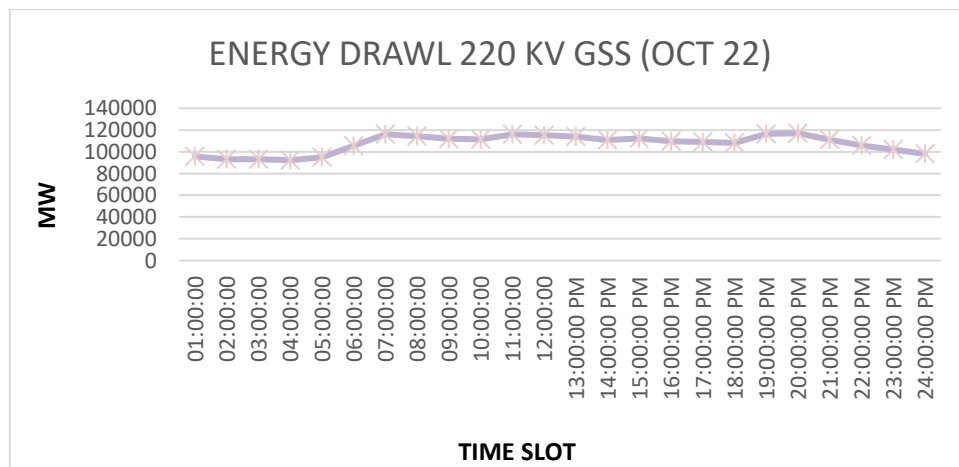


Fig. 4 Peak load curve of Autumn season

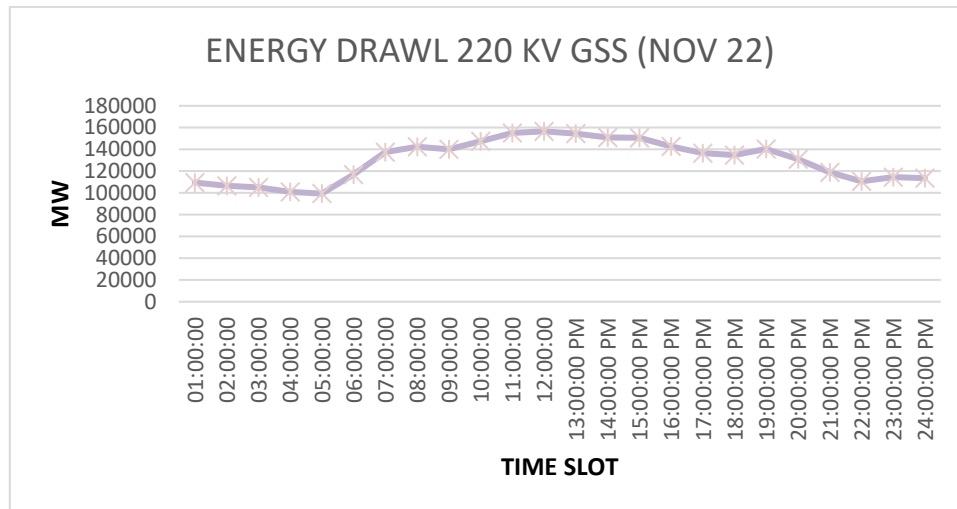


Fig. 5 Peak load curve of Rainy season

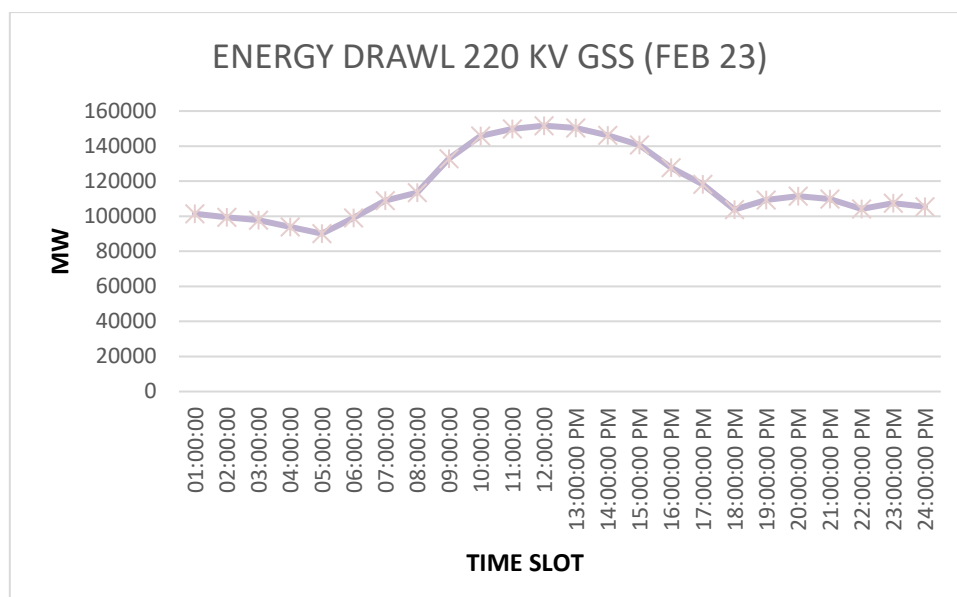


Fig. 6 Peak load curve of spring season

As observed from the load curves, a 220 kV Grid Substation (GSS) catering primarily to residential consumers has been selected for analysis. During the summer season, peak load occurs between 10:00 AM and 12:00 PM, and again at night between 11:00 PM and 12:00 AM. In the rainy season, the peak load is recorded in the afternoon around 1:00 PM, as well as during the late night hours (11:00 PM to 12:00 AM). The spring season exhibits peak demand typically between 11:00 AM and 1:00 PM. In several states, power availability is dependent on external sources, as local generation facilities are either limited or non-existent. Consequently, power procurement from other regions becomes essential to meet the demands of various consumer categories, including residential, agricultural, and commercial sectors.

During peak demand periods, Time-of-Day (ToD) tariffs are often applied, particularly for industrial and commercial consumers. Under this tariff structure, electricity costs are higher during peak hours compared to off-peak periods. The

primary objective is to flatten the peak demand curve by integrating alternative energy sources and optimizing power supply to consumers during high-demand intervals.

Battery Energy Storage Systems (BESS) present an effective solution for mitigating peak demand. By deploying BESS strategically, electricity demand during peak hours can be significantly reduced. In addition to BESS, various other initiatives are being implemented across the country under Demand Side Management (DSM) programs to enhance grid efficiency and ensure reliable power distribution.

In February 2018, an expert committee under the chairmanship of Secretary, Ministry of New and Renewable Energy (MNRE), with representatives from relevant ministries, industry associations, research institutions and subject matter experts was constituted by the MNRE to prepare draft proposal for setting up National Energy Storage Mission (NESM) for India. This expert committee has prepared the draft NESM with objective to strive for leadership in energy storage domain by creating an enabling policy and regulatory framework that encourages manufacturing, deployment, innovation and further cost reduction. NITI Aayog and Rocky Mountain Institute's (RMI) joint report on India's energy storage mission has proposed three stage solution approach i.e. creating an environment for battery manufacturing, growth and scaling up supply chain strategies and scaling of battery cell manufacturing. Energy Storage is one of the most crucial and critical components of India's energy infrastructure strategy and also for supporting India's sustained thrust to renewables.

In this work a small battery energy storage system club with the solar PV connected to the grid will be analysed by the use of Matlab software and we can also approach the same idea in the large scale to reduce the peak demand and peak clipping to reduce the power purchase at the time of peak at higher cost can be reduced.

II. RESULT AND DISCUSSION

The output waveform of the designed model has been recorded for voltages, currents and other parameters in the output ports of the System.

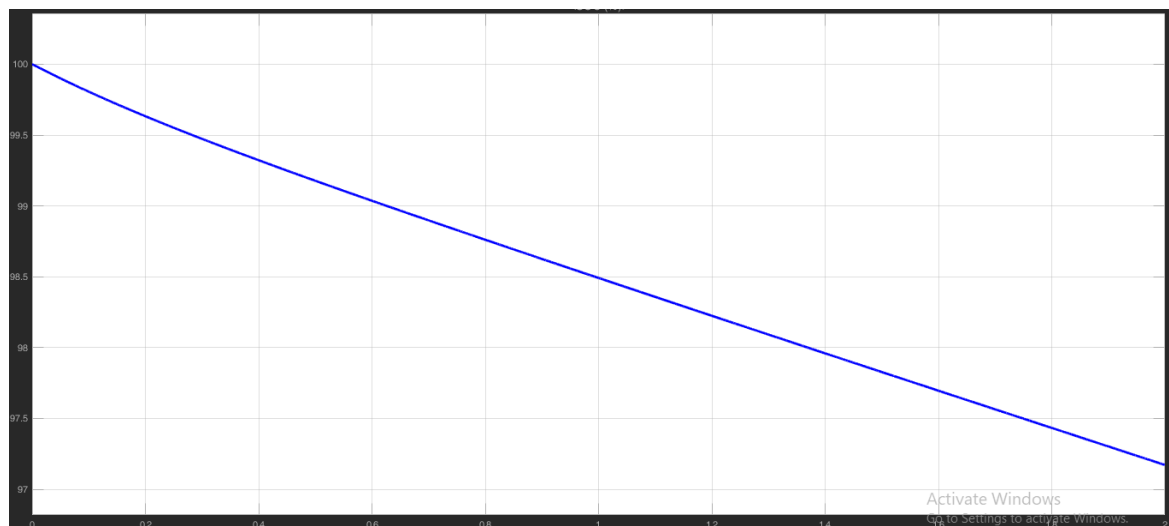


Fig. 7 State of Charge

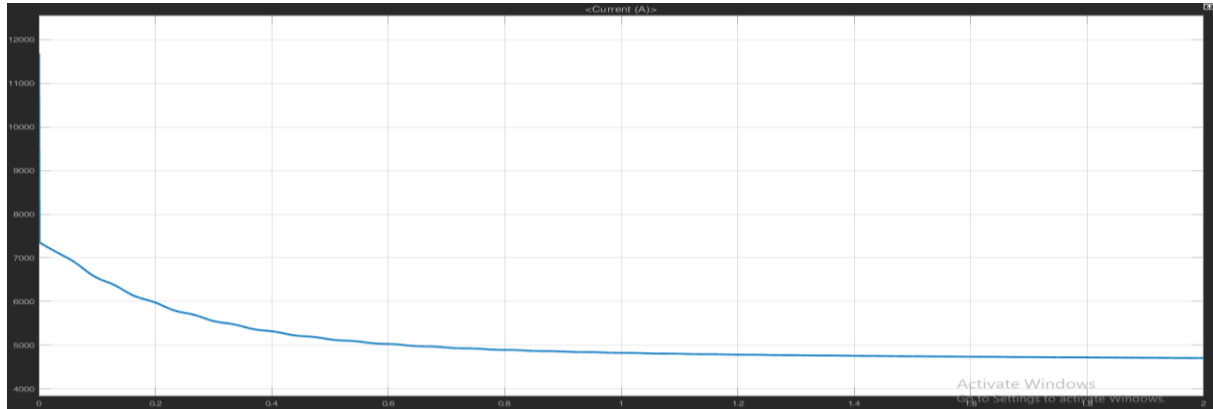


Fig. 8 Current from battery

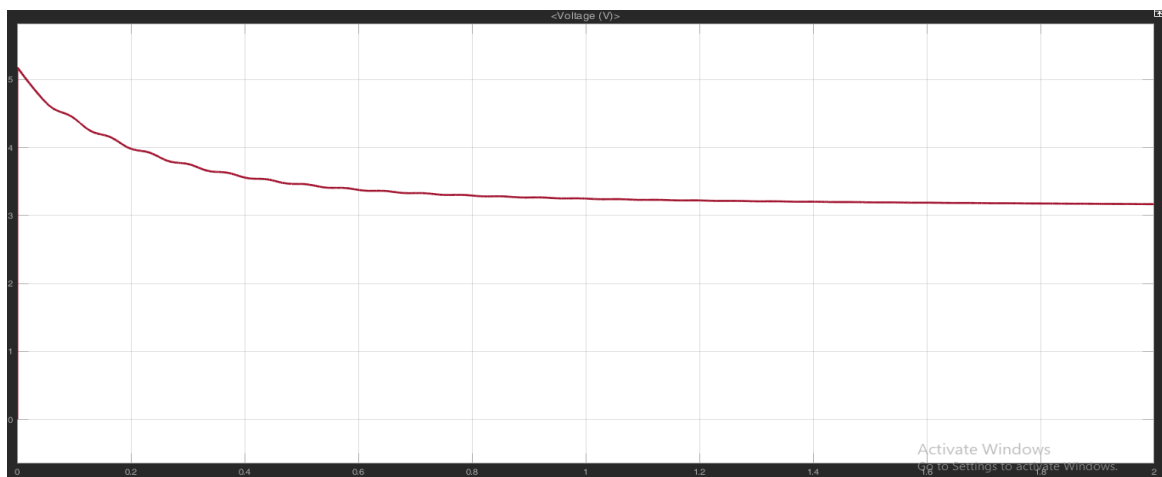


Fig. 9 Voltage from battery

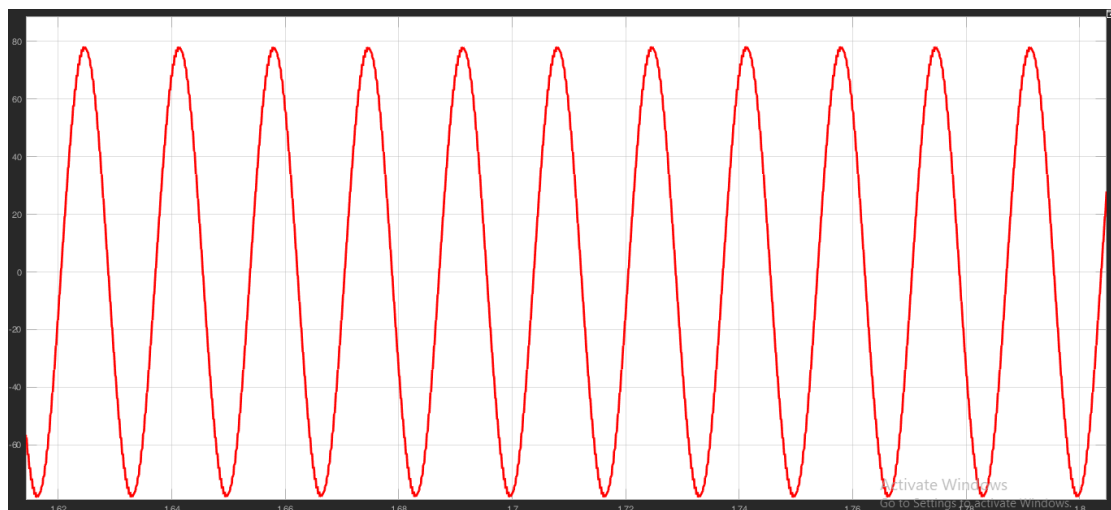


Fig. 10 Single phase voltage at output

III. CONCLUSION

In this model, a 10 kW battery has been integrated into the system. The battery energy storage system (BESS) is capable of storing and discharging 10 kilowatt-hours (kWh) of electricity. Such batteries are commonly employed in residential and commercial applications, particularly for storing energy generated from renewable sources such as solar photovoltaic (PV) panels and wind turbines. They enable the storage of excess energy produced during the day—especially from solar PV—and facilitate its use during nighttime or peak demand hours, based on predefined energy management strategies.

To analyze system performance, a simple solar PV system coupled with a battery energy storage unit has been designed and simulated using MATLAB software, with the system connected to the utility grid. This model serves as a foundation for planning larger-scale implementations, potentially involving systems with capacities in the range of several megawatts. Such large-scale energy storage deployments can significantly reduce nighttime peak demand by allowing a complete or partial shift of energy usage to stored renewable energy, thereby enhancing grid reliability and reducing dependence on conventional power sources.

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