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STUDY OF LOAD CURVES AND PEAK SHAVING BY SOLAR PV INTEGRATION

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Abstract

This paper presents a practical and efficient method for reducing the peak load of a state discom integrated microgrid. The proposed microgrid consists of Solar Panels, Battery Energy storage system, loads and measuring devices. The main aim is to reduce the peak load at the time of occurrence and rest of the time the microgrid will charge the energy storage system and supply the connected defined load. The main objective is to develop a framework to control the operation of microgrid and manage the power flow exchanges ensuring high quality services to the clients and grid system. The implementation of various peak shaving strategies represents a significant step towards a more sustainable, reliable and efficient power system. In future the grid loads will increase continuously and also the peak load will increase so various modern sustainable solutions to incorporate in the grid system.

KEYWORDS: Battery Energy Storage System, Solar PV, Peak load Shaving, Distribution company discom, Microgrid.

I.INTRODUCTION

In today's global context, the advantages of utilizing renewable energy sources (RESs) are widely acknowledged. These benefits encompass cost reduction in power generation and minimizing losses in distribution networks through efficient resource management [1]. Dispatch strategy based microgrid design has been popular among researchers as they offer regulated costs and component size requirement [2]. The research paper in [3] highlights the importance of developing sophisticated dispatch strategies for hybrid energy systems to achieve continuous operation at minimal cost. By integrating renewable energy sources such as PV and wind with conventional sources like diesel generators and batteries, it becomes possible to create more sustainable and cost-effective energy solutions for residential areas and potentially other applications as well.

The paper [4] discusses the impact of the battery energy storage system (BESS) on the operating/fuel cost of the microgrid for the economic dispatch problem. Additionally, it mentions the changing illustration of demand response in microgrids, and a demand flexibility (DF) model has been established to optimize the process with variations in consumers' demands. The results indicate a reduction in cost and better management from the demand side using the demand flexibility model.

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In recent years, there has been significant research and development in the area of peak shaving strategies for smart grids, with a range of innovative technologies and techniques emerging [5]. In the review paper, we explore 10 different peak shaving strategies that have demonstrated some potential to reduce peak demand, including the use of battery energy storage systems (BESSs), nuclear and battery storage power plants, hybrid energy storage systems, photovoltaic (PV) system installations, real-time scheduling of household appliances, repurposed electric vehicle (EV) batteries, uni- and bidirectional EV charging, a demand response, time-of-use pricing, load shedding, distributed generation and energy-efficient management [6]. Through a comprehensive analysis of the latest research and case studies, we aim to provide a comprehensive overview of the strengths and limitations of each peak shaving strategy and identify areas for further research and development. By understanding the potential of these strategies, we can better equip utilities and power system operators to meet the challenges of the modern energy landscape and create a more sustainable, resilient and efficient power system.

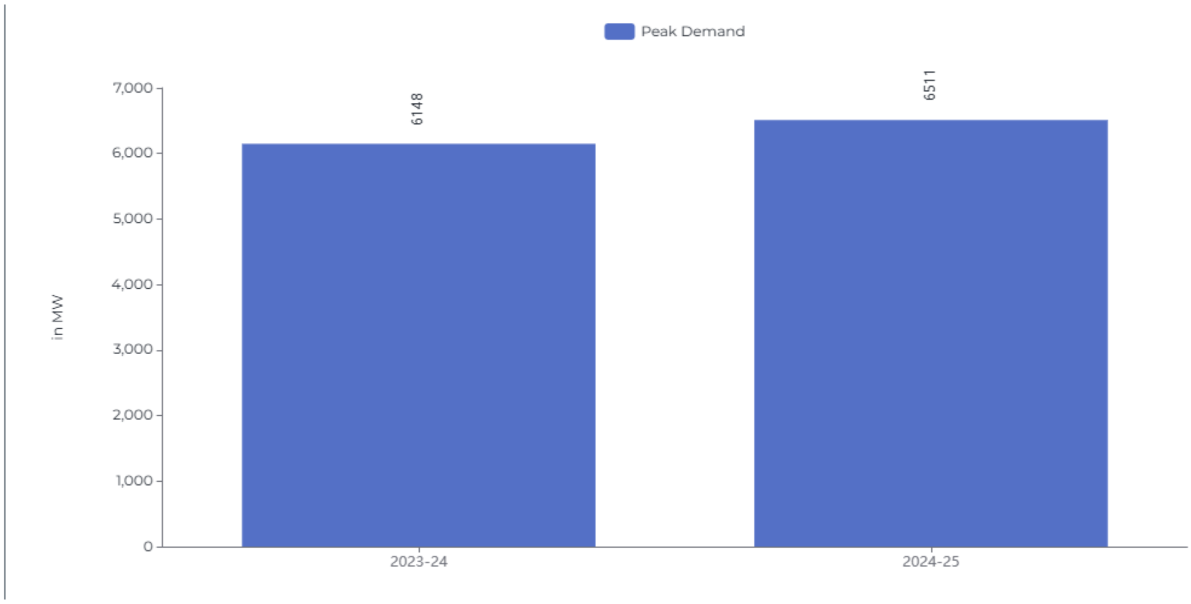

Fig. 1 National Level Consumption *source- iced.niti.gov.in*

II .Load Profile

A load profile is a visual representation of your energy consumption that shows daily or seasonal variations as energy use varies throughout the year. By looking at this graph, you can see trends in your electricity use, including peak and off-peak hours, such as higher use at night when you are at home and lower usage during the day when you are at work. You can find possibilities to lower your use of electricity by analysing the load profile, which could enable you to reduce the amount you pay for electricity. The cyclical nature of load or demand over time is described by a load profile. It can be seen as a graph that depicts the peaks and valleys of demand over the course of a day, a week, or a year. Load profiles come in a variety of forms. Consumption, or the overall amount of electricity utilized, is represented by the area under the demand line. Demand varies within each day of the daily load profiles; however, daily load

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profiles for most days are the same. Demand changes from season to season dominate any daily or weekly variations in a seasonal load profile. Demand varies more from one day to the next than it does from week to week in a weekly load profile [7].

Load profiles serve as crucial blueprints for effective peak shaving strategies, aiding in pinpointing peak demand periods, optimizing energy consumption schedules, and facilitating demand response actions. By analysing these profiles, organizations can strategically implement load shifting, energy storage sizing, and renewable energy integration to curtail peak demand during critical periods. Moreover, load profiles enable data-driven decision-making, guiding the development of optimal control algorithms and facilitating the evaluation of strategy effectiveness over time, ultimately contributing to more efficient energy usage and grid stability.

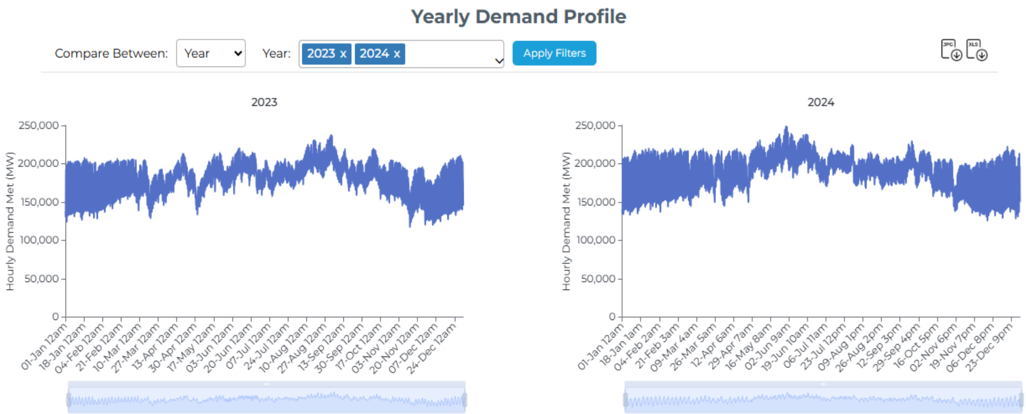

Fig. 2 Yearly Demand Profile of India *source- iced.niti.gov.in*

III .Peak Load Curve of GSS 220KV

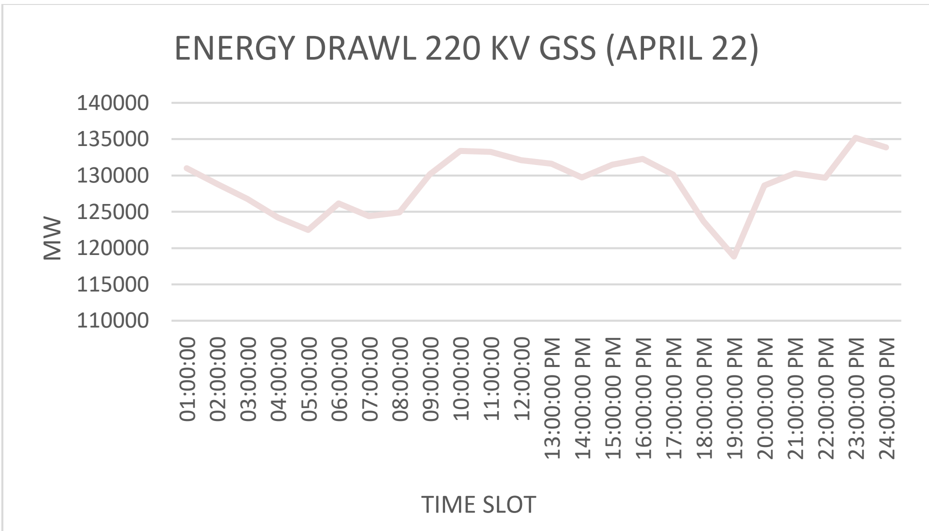

Fig. 3 Summer Season load curve

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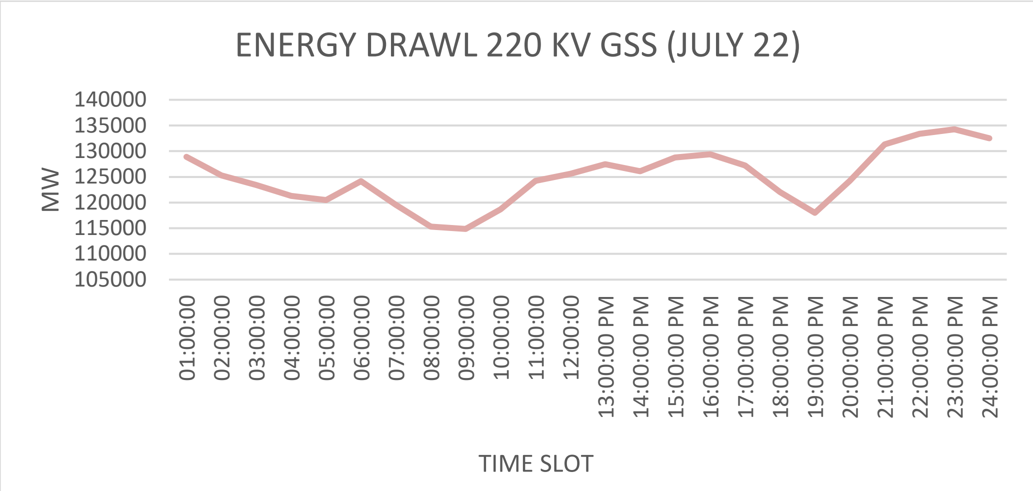

Fig. 4 Rainy Season load curve

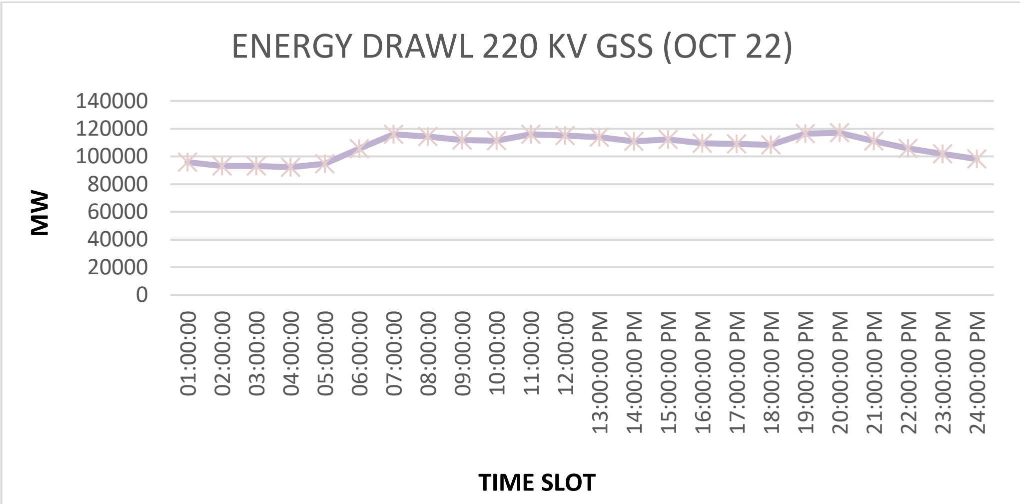

Fig. 5 Autumn Season load curve

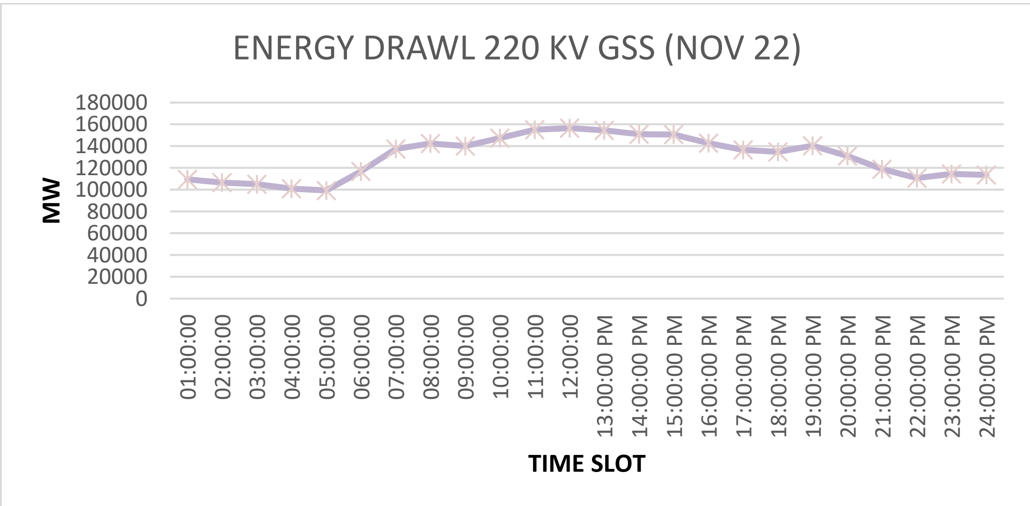

Fig. 6 Winter Season load curve

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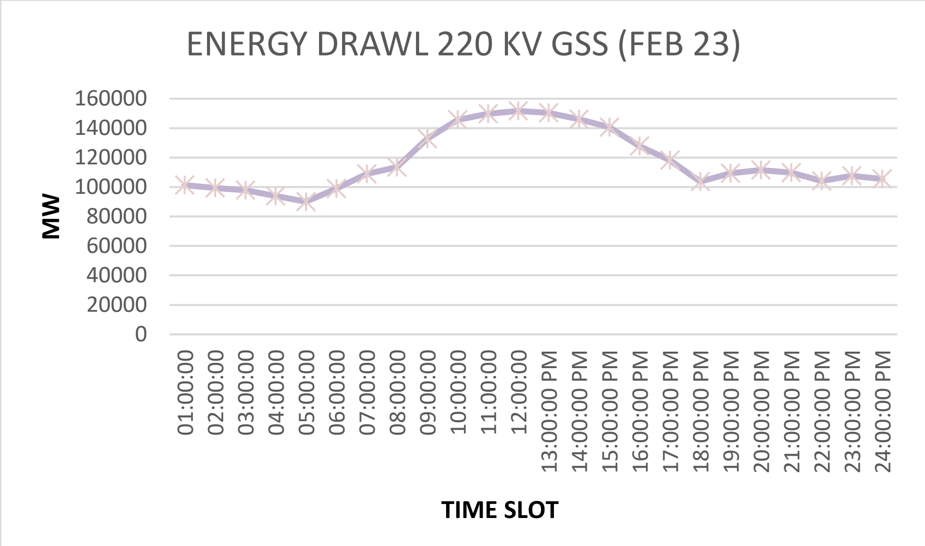

Fig. 7 Spring Season load curve

For analysis we have selected a northern region state and find out the load curve. There are number of 220KV substation we have taken one grid substation and find out the load curves of power drawn from that grid substation. From the above graphs we can easily identify the peak load hours and at different climatic conditions. Mostly the starting of office hours till noon the peak load occurs at every season. In northern region of India the summer season is very hot and in winter season the temperature is very low so extreme cold. This will make the heating and cooling load at both the season.

This will make the renewable energy integration necessary in such regions where the heating and cooling load is very high to reduce the peak load. In this case a solar PV of 100 KW or 1MW installation has been assumed and calculations done accordingly.

IV .Solar PV Installation

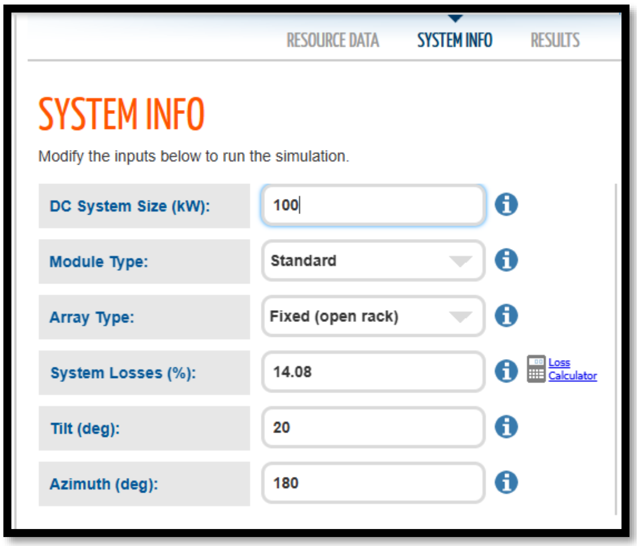

Fig. 8 Solar PV system Information

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RESULTS

Print Results

157,007 kWh/Year*

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	5.23	12,316
February	6.20	12,758
March	6.94	15,262
April	7.04	14,521
May	6.81	14,389
June	6.15	12,961
July	5.15	11,646
August	5.21	11,805
September	6.12	13,322
October	6.01	13,526
November	5.62	12,524
December	5.09	11,977
Annual	5.96	157,007

Fig. 9 Annual generation form Solar PV

100KW Solar PV

When a 100KW Solar PV has been installed in the state selected in northern region of India. A solar PV calculator helps to calculate the annual generation of the Solar PV installed and we can see in the above figures that approximate 153 MWH can be generated in a year. The generation can be directly connected to the grid as always. In the next phase we can also connected the battery energy storage system in this installation. The major aim is to charge the batteries and we can modify the system with various algorithms. The BESS system will help out the grid at the time of peak load. As we can see that the peak load time will be dynamic and we can only expect the duration of hours when the peak load will occur. The time slot can be defined by the previous experience like the in summers the afternoon time from 1.00 PM to 4.00 PM will be the peak load in the northern region as this area will experience extreme hot in summers. Due to this reason cooling load will increase rapidly. This increase in cooling load will make extreme stress in the grid.

V. RESULT AND DISCUSSION

A simple Matlab model has been designed to justify the design of a solar PV connected with the battery to look upon the simulation results if we will do this in a large scale with megawatts capacity of solar plant and battery storage system. The Solar PV will charge the battery storage system and can connect to the grid at the time of peak load. This type of system can be installed near grid substations to perform the peak load time service by the battery storage system to the loads and peak shaving of load can be achieved. Below show the simulation results of the Matlab model output waveform to the battery from solar PV and state of charge waveforms of the battery.

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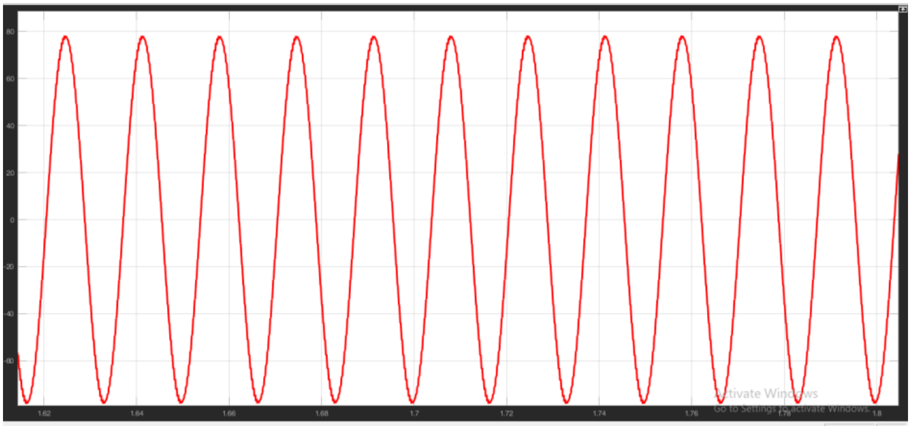

Fig. 10 Single phase voltage at the output

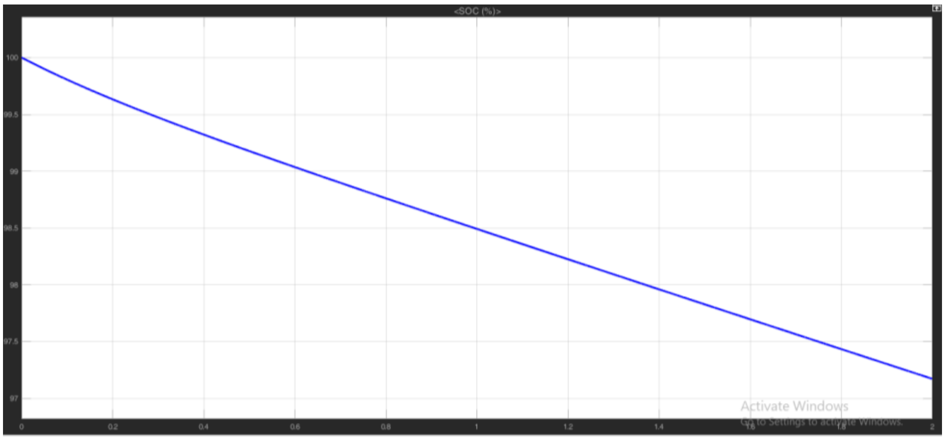

Fig. 11 SOC of battery

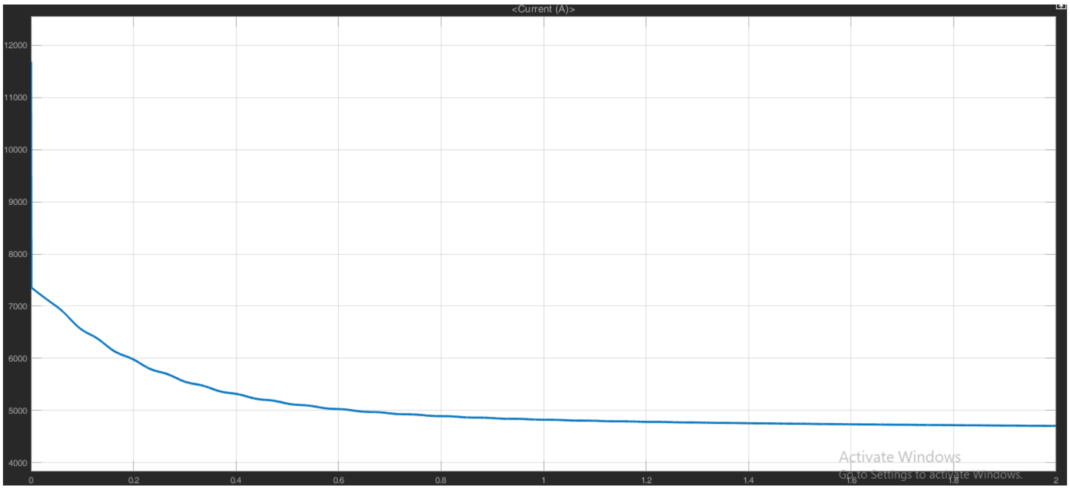

Fig. 12 Current in battery

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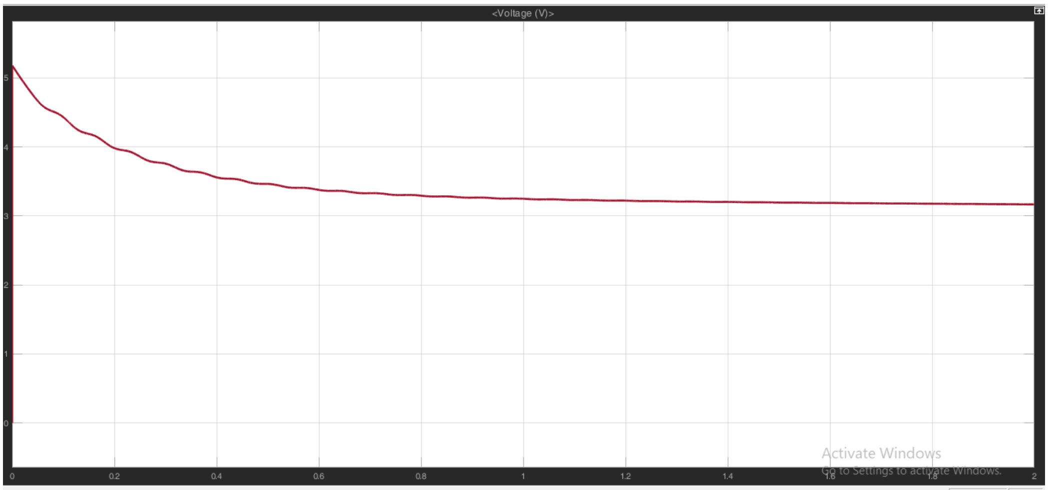

Fig. 13 Voltage in battery

VI.CONCLUSION

In this work first we identify the load curves of northern state where the heating and cooling load both assumed to be very high. The seasonal load curve shows that the load where the peak occurs this will give extreme load to the grid. The first idea is to install the renewable source of energy like solar PV and the battery to be connected with the plant. This plant will generate power and charge the battery and we can also switch towards the load side. During the peak time several megawatts of power can be provide by the battery energy storage system. This idea will reduce the peak load and peak shaving is possible. In this case just from the 100KW solar plant we can see that annual generation is in megawatt hours. This can be used to charge the batteries and switching of load will be feasible for the grid,

REFERENCES

1. B. Jin, X. Xu, Forecasts of thermal coal prices through Gaussian process regressions, Ironmak. Steelmak. 51 (8) (2024) 819--834.
2. M.F. Ishraque, S.A. Shezan, M. Ali, M. Rashid, Optimization of load dispatch strategies for an islanded microgrid connected with renewable energy sources, Appl. Energy 292 (2021) 116879.
3. A. Toopshekan, H. Yousefi, F.R. Astaraei, Technical, economic, and performance analysis of a hybrid energy system using a novel dispatch strategy, Energy 213 (2020) 118850.
4. N. Kumar, S. Dahiya, K. Singh Parmar, Multi-objective economic emission dispatch optimization strategy considering battery energy storage system in islanded microgrid, J. Oper. Autom. Power Eng. 12 (4) (2024) 296--311.
5. Borlase S (2018) Smart grids: Advanced technologies and solutions, second edition (2nd Ed.). *CRC Press, Taylor & Francis Group*.
6. Uddin M, Romlie MF, Abdullah MF, et al. (2017) A review on peak load shaving strategies. *Renewable Sustainable Energy Rev* 82: 3323–3332.

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7. Zhang TS, Sheng WX, Song XH, et al. (2013) Probabilistic modelling and simulation of stochastic load for power system studies. UKSim 15th International Conference on Computer Modelling and Simulation, Cambridge, UK, 519–524.

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