International Journal of Engineering Works
ISSN-p: 2521-2419
ISSN-e: 2409-2770
Vol. 5, Issue 12, PP. 252-259, December 2018
https://www.ijew.io/

Intelligent Control Algorithm for Distributed Battery Energy Storage Systems

Asfand Yar Ali[1], Juveria Anwar[1], Rabia bibi[1], Muhammad Raheel Khattak[1], Abdul Basit[1]
[1]US Pakistan center for Advance Studies in energy, University of Engineering and Technology Peshawar
Received: 01 December, Revised: 08 December, Accepted: 15 December

***Abstract*—** Recent trends towards bulk renewable energy penetration in the power grid have made it essential to have reserve power in the system to overcome variability and intermittent nature of renewable energy sources. Battery energy storage systems (BESS) are vastly utilized for this purpose but the cost and limited life of batteries limits its use. In this paper a control strategy for battery energy storage systems is proposed in which batteries are discharged based on state of charge and state of health. Simulations are performed in MATLAB. By implementing this algorithm load can be shifted small batteries to batteries with better health and capacity. The results show the working of algorithm and the selection of batteries based on set input variable. In this way battery energy storage systems will have longer lifetime, better efficiency and economical operation.

***Keywords*—** Battery energy storage systems, State of charge, Control algorithm, Renewable energy

I. Introduction

21st century along with its technological advancement also brought some challenges and climate change is one of those critical challenges which is drawing a lot of concern for a sustainable future [1]. Average temperature of earth is increasing gradually due to increased carbon emissions from burning of fossil fuels [2]. Also, natural resources of fossil fuels are depleting with time. To mitigate this problem, efforts at global level were needed and so an agreement was signed between 195 United Nations Framework Convention in Climate Change (UNFCC) members. According to this agreement the parties will play active role to minimize usage of fossil fuels to keep the rise of earth temperature within 2℃ [3]. This made it essential to seek other energy sources such as wind and solar energy. Current share of Renewable energy is less than 20% and to achieve this target of reducing global warming this has to increase to 65%[4].

Wind and solar energy sources provide a reliable non exhaustive substitute for fossil fuels. But there some challenges associated with it. These energy sources are variable and do not have constant energy output [5]. Wind energy is intermittent by nature while solar energy is available for a limited number of hours per day [6]. Also, these sources are immediately available and have to be utilized instantly otherwise the power will waste. To overcome this challenge reserve power is required and battery energy storage systems are vastly used for this purpose [7]. Excess power is storage in the batteries when the generation is greater than load and is used during peak load hours.

Although, batteries are very reliable way to store excess energy but the cost of battery and limited life makes it difficult to use on large scale [8]. In recent years cost of batteries is reduced drastically due to research and development in this sector because of electric vehicles [9]. Large scale implementation of battery energy storage systems is vastly adapted to increase penetration of renewable energy is the electric grid [10].

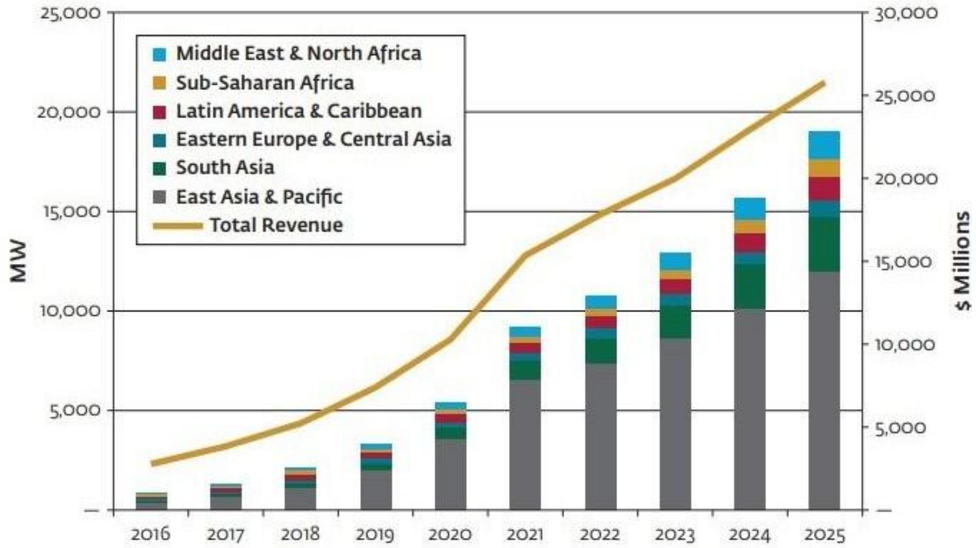

Figure 1: Trends in utilization of Stationary storage systems and future forecast by region

Figure 1 shows the trends in use of battery storage systems. It also forecasts that the utilization of battery technologies may exceed 25000 MW by 2025.

Batteries have limited life cycles and calendar life. Battery capacity fades with each cycle depending on the depth of discharge [11]. For same operation DOD for smaller batteries will be higher than DOD for batteries with higher capacity. Coordinated control systems can be used to control this function which transfers the load to BESS with higher capacity and BESS with lower capacity has lower priority of operation.

II. CONTROL VARIABLES

A. Power Generation and Load

For stable operation of system a balance between power generated by power plants and the power utilized by the load should be equal. BESS are added in the system to mitigate variable output of solar. The sum of power produced by PV, power utilized by load and power provided or absorbed by batteries should be equal to zero.

$$Pgen+Pbat+Pload=0 \tag{1}$$

B. Stored Energy

Stroed energy (SE) is the total energy that is available in battery. It is the product of battery state of charge (SOC), voltage (Vbat) and the maximum charge storage capacity of the battery (MC).

$$SE = Vbat * SOC * MC \tag{2}$$

Where: SE is the stored energy in the battery at any instance. MC is the maximum capacity of the battery.

III. CONTROL ALGORITHM

Two sets of algorithm are running for coordinated control of BESS.

A. BESS Operation Mode Control:

BESS operation mode is decided in the central control.

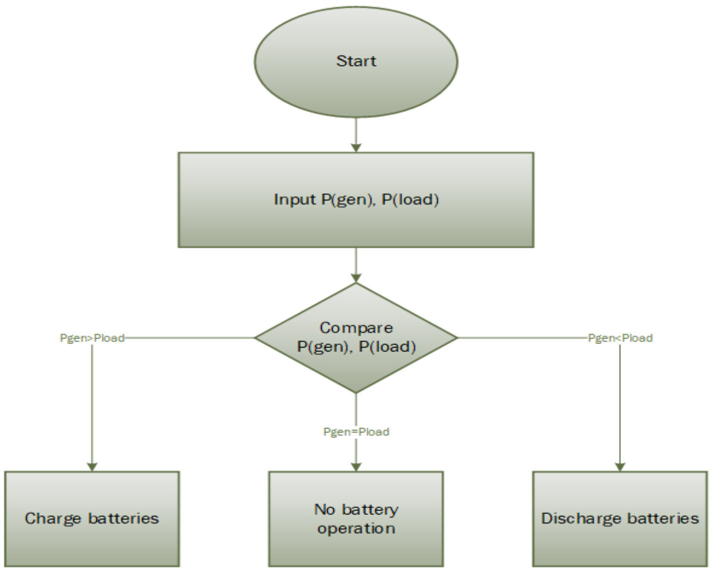

Figure 2: Operation mode control algorithm

The system takes the generation and load demand in real time. This algorithm has three cases given below:

1- If the real time generation is higher than load demand then a signal to turn on charging of BESS is generated.
2- If the real time generation is equal to load demand then BESS are not operational.
3- If the real time generation is less than load demand then a signal to turn on discharging mode of BESS is generated.

B. Discharge Control:

Discharge function in the algorithm is called when the central control detects that power deficit between generation and load.

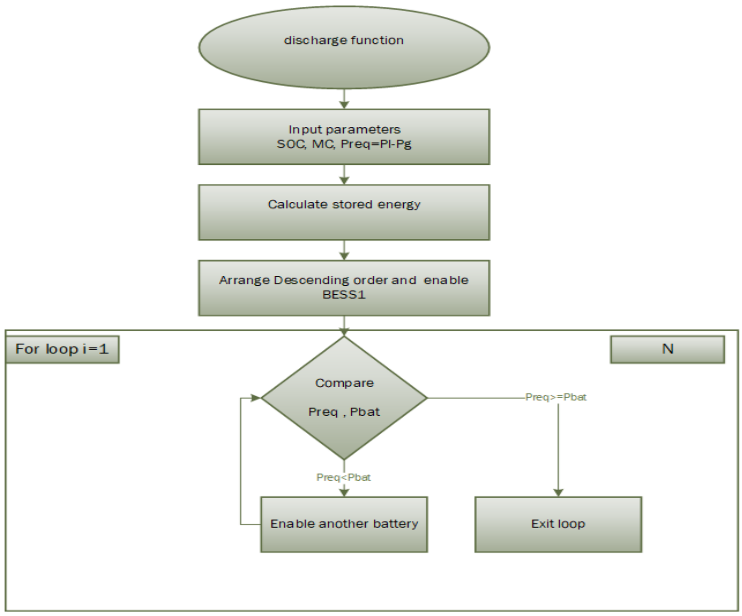

Figure 3: Discharge function flow diagram

Discharge function takes the battery parameters as input, calculates the energy stored in each battery and turns on BESS one by one based on priority of their stored energy.

IV. System Design for Simulation

A test system is designed in SIMULINK to implement the proposed algorithm. Fig. 4 shows the Simulink model of test system and Fig. 6 shows the block diagram of test system. It consists of a solar power plant, three battery energy storage systems, dynamic load and a control center to monitor and control the system.

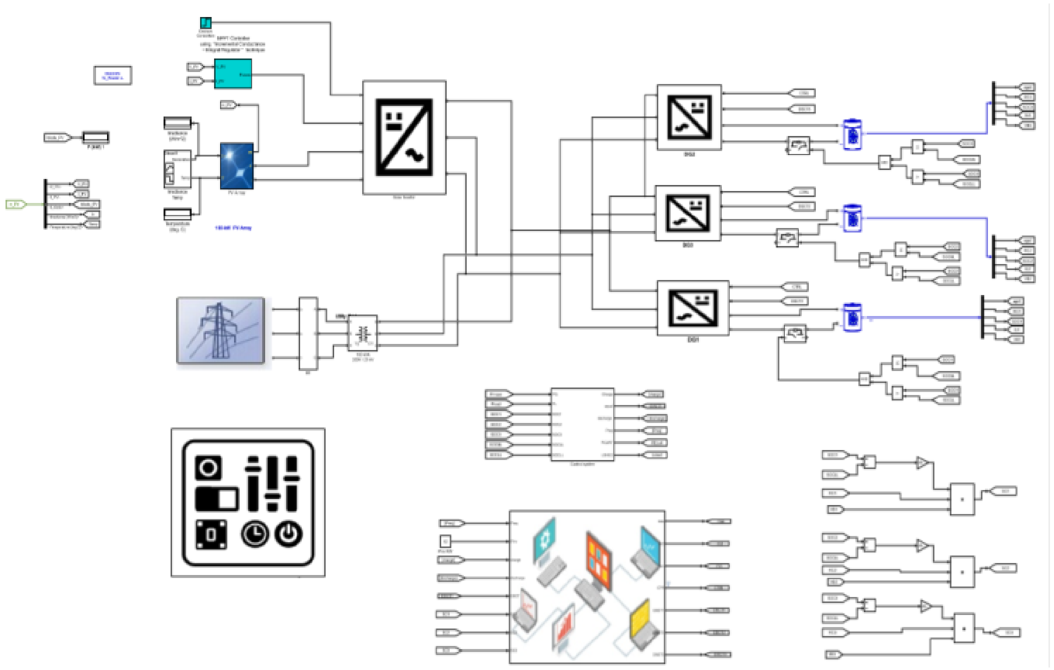

Figure 4: Simulink model of test system

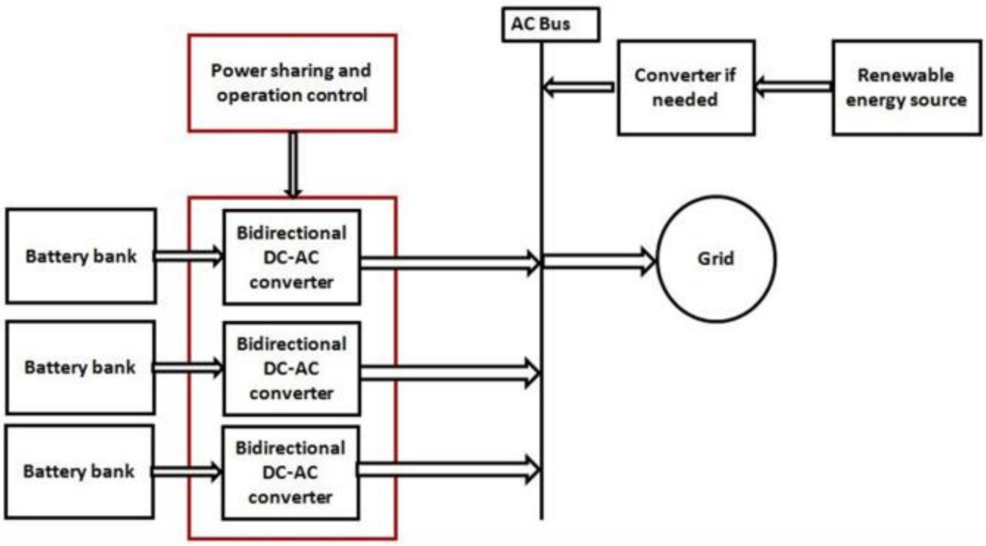

Figure 5: Block diagram of test system

A. *Solar Power Plant*

Solar power plant modeled in the test system is 100 KW. Input temperature and irradiance can be controlled by using sample data curves. Incremental conductance MPPT technique is used with integral regulator for reliable operation. A solar inverter is connected to the output to PV panels which converts the DC voltage to three phase AC voltage.

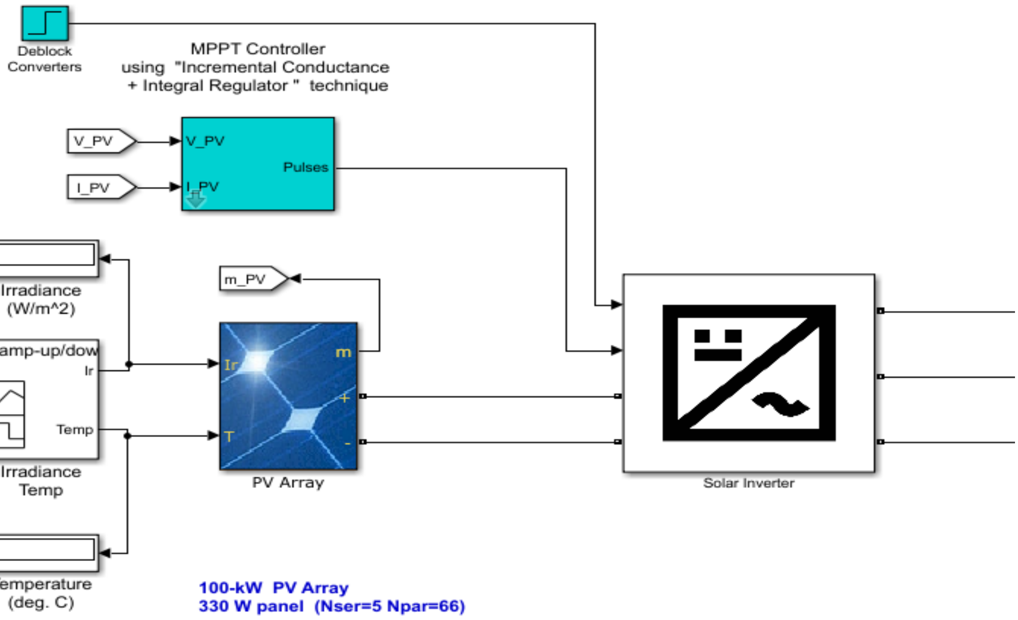

Figure 6: 100KW PV plant simulink model

Fig. 6 shows the simulink model of PV plant developed in the test system. MPPT controller controls the pulses for boost controller at the output of solar panel to regulate DC voltage.

B. *Battery Energy Storage System*

Battery energy storage system as shown in Fig. 7 a battery is connected to an ideal switch which controls the SOC limits of the battery. It is then connected to a bidirectional controller which is controlled centrally by coordinated control.

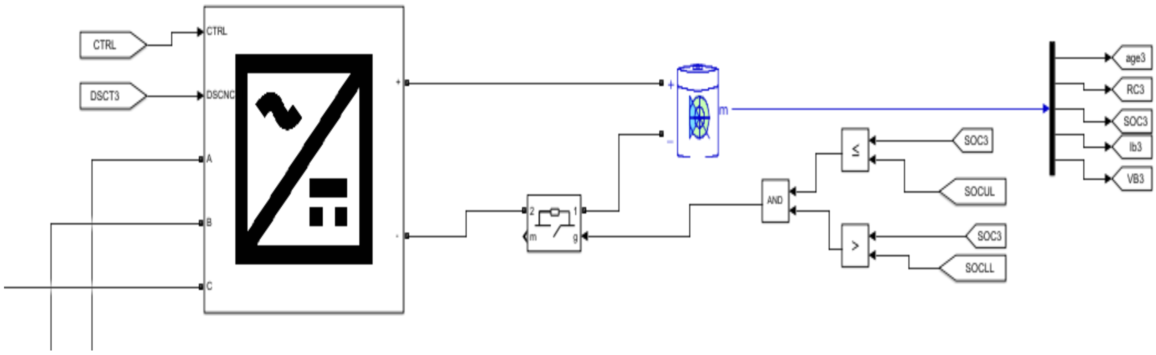

Figure 7: Battery energy storage system Simulink model

C. Dynamic Load Module

Fig. 8 represents the simulink model of dynamic load in the test system. Active and reactive power of load can be controlled by input load curves.

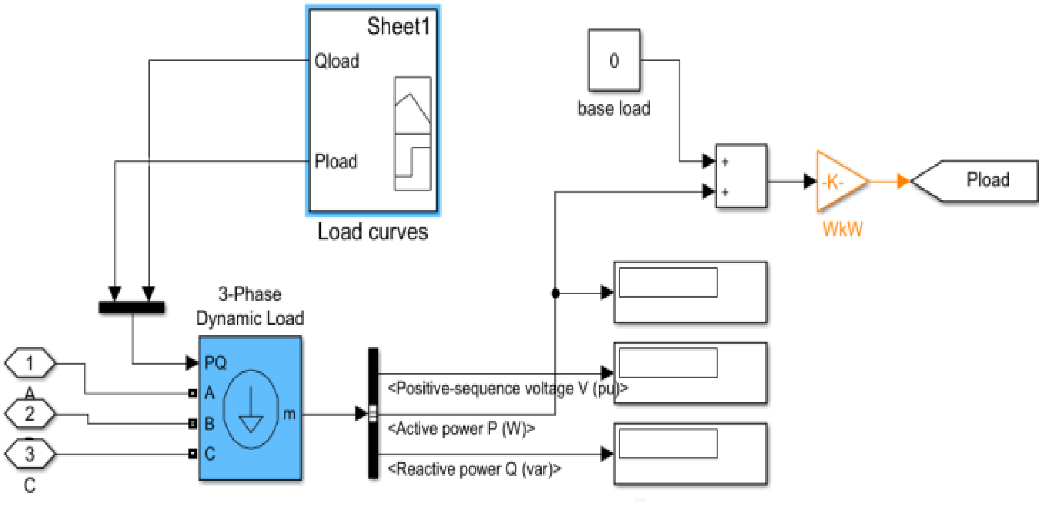

Figure 8: Load representation in Simulink

V. RESULTS:

Simulations are performed for different cases with initial parameters such as SOC and battery capacity in AH are given below:

- SOC 1 =SOC 2 = SOC 3= 80%
- BESS 1= 10 AH BESS 2= 20 AH BESS 3= 8 AH
- Inverter rating: 15 KVA

Under different load and generation conditions different results are obtained. Output consists of 4 curves. Operation mode is “1” when discharge operation is required and is “0” when charging operation is required. BESS 1 to BESS 3 represent if that specific BESS is operation or not. “1” represents it is operational and “0” represents it is idle.

A. Case 1: Charging

In this case PV generation is 50KW and load is 20KW, thus there is excess power in the system. Fig. 9 shows the the output of the system. Here operation mode is “0” indicating charging mode of bidirectional converters. All three of BESS are at level “1” indicating that these are operational and absorbing excess power from the system.

Figure 9: Simulation output for case 1

B. Case 2: No BESS operation

In this case PV generation is 20KW and load is 20KW thus no battery operation is required. Fig. 10 shows the output of the system. Here operation mode is “0” indicating charging mode of bidirectional converters. All three of BESS are at level “0” indicating that these are disconnected from the system.

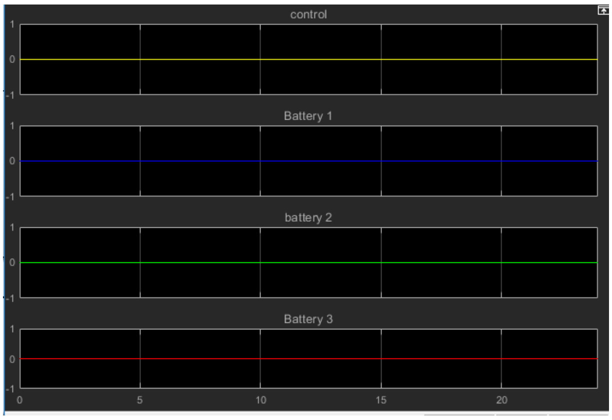

Figure 10: Simulation output for case 2

C. Case 3: Discharging operation

In this case PV generation is 20KW and load is 30KW, thus power is required from BESS. Fig. 11 shows the output of the system. Here operation mode is “1” indicating discharging mode of bidirectional converters. Only BESS 1 is operational because it has more stored charge due to higher capacity and same SOC level as other BESS. In this case only one inverter is enough to supply power to the load i.e. 10 KW.

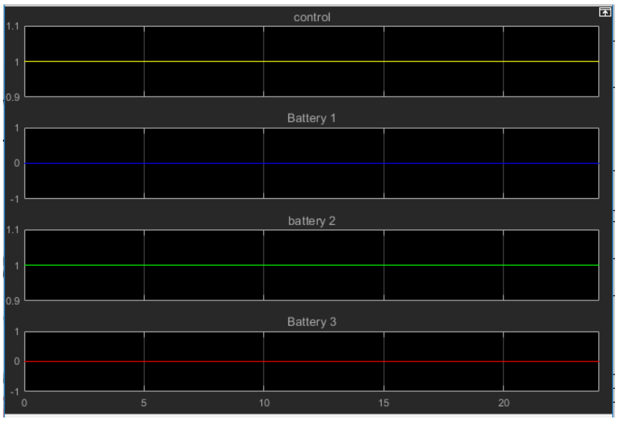

Figure 11: Simulation output for discharging one BESS

Similarly, when the generation is set to 10KW and load is 30 KW. Two inverters will be operational to supply power to load. BESS 1 and 2 have higher capacity then BESS 3 so they are turned on in discharging mode as shown in Fig. 12.

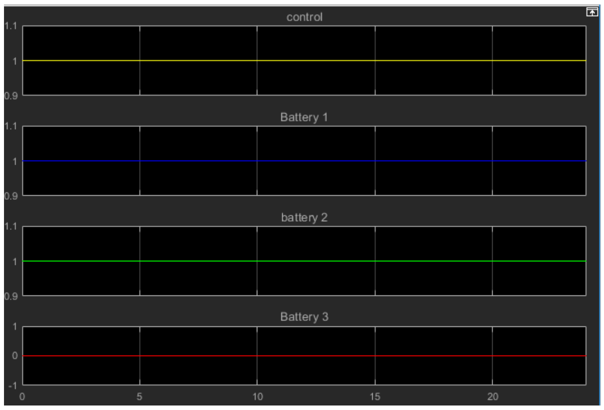

Figure 12: Simulation output for discharging two BESS

When load is further increased to 40KW and generation is kept at 10KW then all three inverters will turn on in discharging mode as shown in Fig 13.

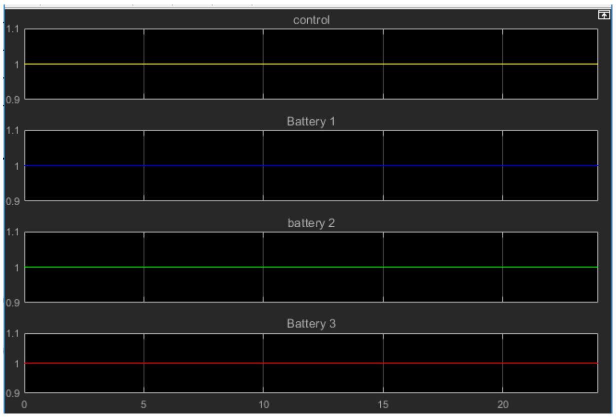

Figure 13: Simulation output for discharging three BESS

CONCUSLION

Battery energy storage systems provide an effective way to mitigate the variability of renewable energy. By using intelligent control algorithms battery lifetime and efficiency of the system can be achieved. In this paper the proposed algorithm for the selection of battery operation based on stored energy and maximum capacity. This algorithm can be implemented in systems with distributed battery energy storage systems. It has been shown that the proposed algorithm is effectively selecting the batteries operation mode based on system parameters and discharging batteries with higher stored energy on priority. By doing so depth of discharge for batteries can be controlled thus utilizes the limited lifecycles more efficiently.

REFERENCES

[1] Trenberth, K., et al., Observations: surface and atmospheric climate change. Chapter 3. Climate change, 2007: p. 235-336.

[2] Cline, W.R., The economics of global warming. 1992: Institute for International Economics.

[3] Rogelj, J., et al., Paris Agreement climate proposals need a boost to keep warming well below 2 C. Nature, 2016. 534(7609): p. 631.

[4] Pittock, A.B., Climate change: turning up the heat. 2017: Routledge.

[5] Painuly, J.P., Barriers to renewable energy penetration; a framework for analysis. Renewable energy, 2001. 24(1): p. 73-89.

[6] Singh, M., et al., Grid interconnection of renewable energy sources at the distribution level with power-quality improvement features. IEEE transactions on power delivery, 2011. 26(1): p. 307-315.

[7] Divya, K. and J. Østergaard, Battery energy storage technology for power systems—An overview. Electric power systems research, 2009. 79(4): p. 511-520.

[8] Oudalov, A., R. Cherkaoui, and A. Beguin. Sizing and optimal operation of battery energy storage system for peak shaving application. in Power Tech, 2007 IEEE Lausanne. 2007. IEEE.

[9] Nykvist, B. and M. Nilsson, Rapidly falling costs of battery packs for electric vehicles. nature climate change, 2015. 5(4): p. 329.

[10] Vrettos, E.I. and S.A. Papathanassiou, Operating policy and optimal sizing of a high penetration RES-BESS system for small isolated grids. IEEE Transactions on Energy Conversion, 2011. 26(3): p. 744-756.

[11] Ning, G., B. Haran, and B.N. Popov, Capacity fade study of lithium-ion batteries cycled at high discharge rates. Journal of Power Sources, 2003. 117(1-2): p. 160-169.