The Ciência & Engenharia - Science & Engineering Journal
ISSN: 0103-944X
Volume 11 Issue 1, 2023
pp: 2488 - 2498

Optimal Design and Performance Analysis of a Hybrid off Grid Renewable Power System Considering Different Component Scheduling, PV Modules and Solar Tracking System

Dr. P. Ranjith Kumar [1], Dr. M. Sangeetha [2], Dr. K. Vijayan [3], Dr. P. Lilly Florence [4], Dr. Kannan[5], Dr. C. Senthamarai [6]

Professor [1], Mechanical [1], Professor [2], EEE [2], Associate Professor [3], Mechanical [3], Professor [4], Chemistry [4], Associate Professor [5], Mechanical [5] Associate Professor [6], CSE [6]

M. A. M. School of Engineering, Siruganur, Trichy-621105

Abstract: As electric distribution technology steps into the next century, many trends are becoming noticeable that will change the requirements of energy delivery. These modifications are being driven from both the demand side where higher energy availability and efficiency are desired and from the supply side where the integration of distributed generation and peaks having technologies must be accommodated. Power systems currently undergo considerable change in operating requirements mainly as a result of deregulation and due to an increasing amount of distributed energy resources (DER). In many cases DERs include different technologies that allow generation in small scale (micro sources) and some of them take advantage of renewable energy resources (RES) such as solar, wind or hydro energy. Having micro sources close to the load has the advantage of reducing transmission losses as well as preventing network congestions. Moreover, the possibility of having a power supply interruption of end-customers connected to a low voltage (LV) distribution grid (in Europe 230 V and in the USA 110 V) is diminished since adjacent micro sources, controllable loads and energy storage systems can operate in the islanded mode in case of severe system disturbances. This is identified nowadays as a micro grid. Figure 1.1 depicts a typical micro grid. The distinctive micro grid has the similar size as a low voltage distribution feeder and will rare exceed a capacity of 1 MVA and a geographic span of 1 km. Generally more than 90% of low voltage domestic customers are supplied by underground cable when the rest is supplied by overhead lines. The micro grid often supplies both electricity and heat to the customers by means of combined heat and power plants (CHP), gas turbines, fuel cells, photovoltaic (PV) systems, wind turbines, etc. The energy storage systems usually include batteries and flywheels. The storing device in the micro grid is equivalent to the rotating reserve of large generators in the conventional grid which ensures the balance between energy generation and consumption especially during rapid changes in load or generation .

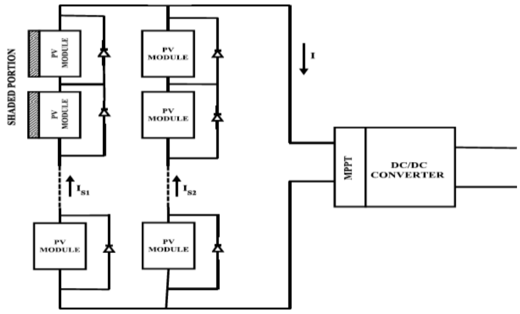
Objective

- To implement hybrid energy system based three phase micro grid.
- To maintain constant voltage to the AC grid using H bridge inverterwith pi controller.

To achieve AC synchronization using pi controller.

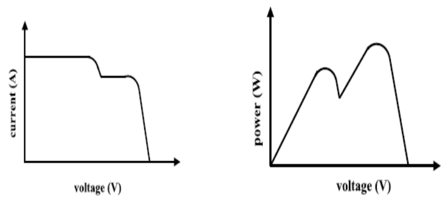
Shading Effect

When a module or a part of it is shaded it starts generating less voltage or current as compared to unshaded one. When modules are connected in series, same current will flow in entire circuit but shaded portion cannot able to generate same current but have to allow the same current to flow, so shadedportion starts behaving like load and starts consuming power. When shaded portion starts to act as load this condition is known as hot-spot problem. Without appropriate protection, problem of hot-spot may arise and, in severe cases, the system may get damaged. To reduce the damage in this condition we generally use a bypass diode . Block diagram of PV array in shaded condition is shown below.



PV Array in Shaded condition

Due to partial shading or total shading PV characteristic become more non-linear, having more than one maximum power point. So for this condition tracking of the maximum power point become very tedious. We can easily seethe effect of shading on PV characteristics in the fig shown below. Effect of partial shading on I-V & P-V characteristics There is wastage of power due to the loss contributed by reverse current which results in overheating of shaded cell.



Maximum Power Point Tracking

Maximum power point tracing (MPPT) system is an electronic control system that can be able to coerce the maximum power from a PV system. It does not involve a single mechanical component that results in the movement of the modules changing their direction and make them face straight towards the sun. MPPT control system is a completely electronic system which can deliver maximum allowable power by varying the operating point of the modules electrically.

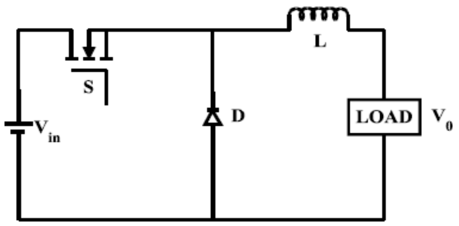
Necessity Of Maximum Power Point Tracking

In the Power Vs Voltage characteristic of a PV module shown in fig
we can observe that there exist single maxima i.e. a maximum power point associated with a specific voltage and current that are supplied. The overall efficiency of a module is very low around 13%. So it is necessary to operate it at the crest power point so that the maximum power can be provided to the load irrespective of continuously changing environmental conditions. This increased power makes it better for the use of the solar PV module. A DC/DC converter which is placed next to the PV module extracts maximum power by

matching the impedance of the circuit to the impedance of the PV module andtransfers it to the load. Impedance matching can be done by varying the duty cycle of the switching elements.

MPPT algorithm

There are many algorithms which help in tracing the maximum power point of the PV module. They are following:



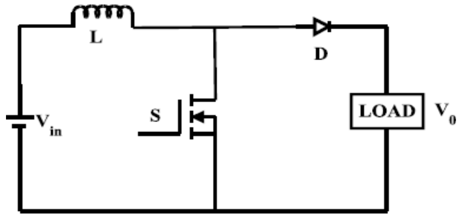
a. P&O algorithm
b. IC algorithm
Parasitic capacitance
Voltage based peak power tracking
Current Based peak power tracking

Types Of Dc-Dc Converter

DC-DC converter is an electrical circuit whose main application is to transform a dc voltage from one level to another level. It is similar to a
transformer in AC source, it can able to step the voltage level up or down. Thevariable dc voltage level can be regulated by controlling the duty ratio (on-off time of a switch) of the converter. There are various types of dc-dc converters that can be used to transform the level of the voltage as per the supply availability and load requirement. Some of them are discussed below.

1. Buck converter
3. Boost converter
3. Buck-Boost converter

Each of them is explained below.



Buck Converter

The functionality of a buck converter is to reduce the voltage level. Thecircuit diagram of the buck converter is manifested in figure 3.10.

Circuit diagram of buck converter

When the switching element is in state of conduction the voltage appearing across the load is

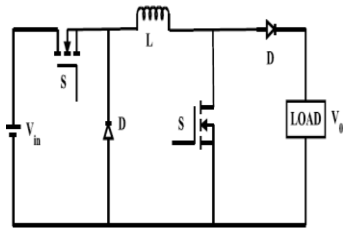
Vin and the current is supplied from source to load. When the switch is off the load voltage is zero and the direction of current remains the same. As the power flows from source side to load side, the load side voltage remains less than the source side voltage. The output voltage is determined as a function of source voltage using the duty ratio ofthe gate pulse given to the switch. It is the product of the duty ratio and the input voltage

Boost Converter

The functionality of boost converter is to increase the voltage level.
The circuit configuration of the boost converter is manifested in figure
Circuit diagram of boost converter

The current carried by the inductor starts rising and it stores energy during ON time of the switching element. The circuit is said to be in charging state. During OFF condition, the reserve energy of the inductor starts dissipating into the load along with the supply. The output voltage level exceeds that of the input voltage and is dependent on the inductor time constant. The load side voltage is the ratio of source side voltage and the duty ratio of the switching device.

Buck Boost Converter

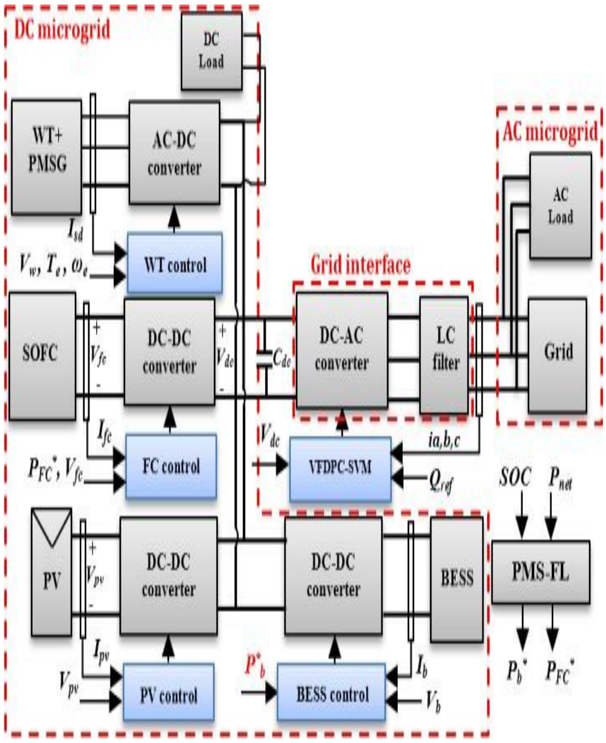


The functionality of a buck-boost converter is to set the level of load side voltage to either greater than or less than that of the source side voltage. The circuit configuration of the buck-boost converter is manifested in figure Circuit diagram of buck-boost converter
When the switches are in the state of conduction, the current carried by the inductor starts rising and it stores energy. The circuit is said to be in charging state. While the switches are in the OFF state, this stored energy of the inductor is dissipated to the load through the diodes. The output voltage can be varied based on the On-time of the switches. The buck-boost converter acts as both buck and boost converters depending on the duty cycle of the switches. For the duty ratio less than 50%it acts as a buck converter and for the duty ratio exceeds than 50% it acts as boost converter.

$$P_{air} = \frac{1}{2}(\text{air mass per unit time})(V_\infty)^2$$
$$= \frac{1}{2}(\rho A V_\infty)(V_\infty)^2$$
$$= \frac{1}{2}\rho A {V_\infty}^3$$

The Ciência & Engenharia - Science & Engineering
Journa
ISSN: 0103-944X
Volume 11 Issue 1, 2023

Wind Turbines



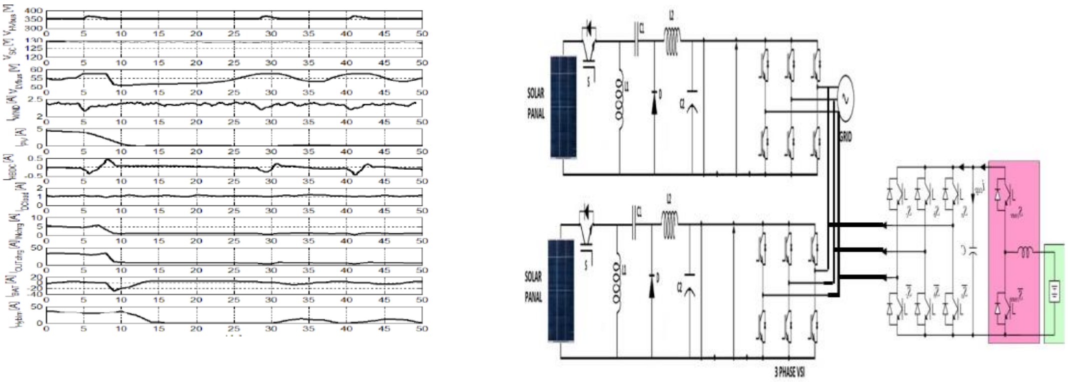
With the use of power of the wind, wind turbines produce electricity to drive an electrical generator. Usually wind passes over the blades, generating lift and exerting a turning force. Inside the nacelle the rotating blades turn a shaft then goes into a gearbox. The gearbox helps in increasing the rotational speed for the operation of the generator and utilizes magnetic fields to convert the rotational energy into electrical energy. Then the output electrical power goes to a transformer, which converts the electricity to the appropriate voltage for the power collection system. A wind turbine extracts kinetic energy from the swept area of the blades. The power contained in the wind is given by the kinetic energy of the flowing air mass per unit time.

Existing System

This paper proposes a hybrid ac/dc micro grid to reduce the processes of multiple dc–ac–dc or ac–dc–ac conversions in an individual ac or dc grid. The hybrid grid consists of both ac and dc networks connected together by multi-bidirectional converters. AC sources and loads are connected to the ac network whereas dc sources and loads are tied to the dc network. Energy storage systems can be connected to dc or ac links. The proposed hybrid grid can operate in a grid-tied or autonomous mode. The coordination control algorithms are proposed for smooth power transfer between ac and dc links and for stable system operation under various generation and load conditions. Uncertainty and intermittent characteristics of wind speed, solar irradiation level, ambient temperature, and load are also considered in system control andoperation. A small hybrid grid has been modeled and simulated using the Simulink in the MATLAB. The simulation results show that the system can maintain stable operation under the proposed coordination control schemes when the grid is switched from one operating condition to another.

Circuit Diagram

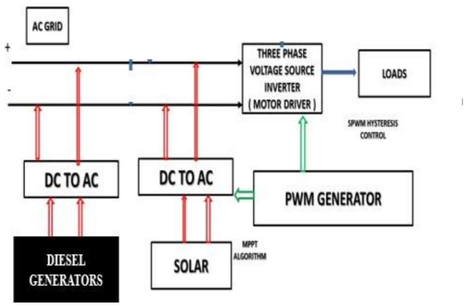
A hybrid ac/dc microgrid system.



A hybrid ac/dc microgrid system outputs

Results

The concept of microgrid is considered as a collection of loads and micro sources which functions as a single controllable system that provides both power and heat to its local area. This idea offers a new paradigm for the definition of the distributed generation operation. To the utility the microgrid can be thought of as a controlled cell of the power system. For example this cell could be measured as a single dispatch able load, which can reply in seconds to meet the requirements of the transmission system. To the customer the microgrid can be planned to meet their special requirements; such as, enhancement of local reliability, reduction of feeder losses, local voltages support, increased efficiency through use waste heat, voltage sag correction . The main purpose of this concept is to accelerate the recognition of theadvantage offered by small scale distributed generators like ability to supply waste heat during the time of need. The microgrid or distribution network subsystem will create less trouble to the utility network than the conventional micro generation if there is proper and intelligent coordination of micro generation and loads. Microgrid considered as a 'grid friendly entity" and does not give undesirable influences to the connecting distribution network i.e. operation policy of distribution grid does not have to be modified.



A hybrid DC/AC micro grid system

Circuit Diagram

A hybrid AC/DC microgrid system Circuit diagram

The configuration of the hybrid system is shown in Figure 4.1 where various DC and AC sources and loads are connected to the corresponding DC and AC networks. The DC and AC

ISSN: 0103-944X
Volume 11 Issue 1, 2023

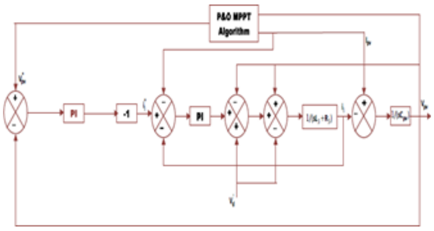
links are linked together through two transformers and two four quadrant operating three phase converters. The AC bus of the hybrid grid is tied to the utility grid. Figure 4.2 describes the hybrid system configuration which consists of DC and AC grid. The DC and AC grids have their corresponding sources, loads and energy storage elements, and are interconnected by a three phase converter. The AC bus is connected to the utility grid through a transformer and circuit breaker. In the proposed system, PV arrays are connected to the DC bus through boost converter to simulate DC sources. A other solar system is connected to DC bus to simulate AC sources. A battery with bidirectional AC/DC converter is connected to DCbus as energy storage. A variable DC and AC load are connected to their DC and AC buses to simulate various loads. PV modules are connected in series and parallel. As solar radiation level and ambient temperature changes the output power of the solar panel alters. A capacitor C is added to the PV terminal in order to suppress high frequency ripples of the PV output voltage. The bidirectional DC/DC converter is designed to maintain the stable DC bus voltage through charging or discharging the battery when the system operates in the autonomous operation mode. The three converters (boost converter, main converter, and bidirectional converter) share a common DC bus. A wind generation system consists of doubly fed induction generator (PMSG) with back to back AC/DC/AC PWM converter connected between the rotor through slip rings and AC bus. The AC and DC buses are coupled through a three phase transformer and a main bidirectional power flow converter to exchange power between DC and AC sides. The transformer helps to step up the AC voltage of the main converter to utility voltage level and to isolate AC and DC grids.

Operation Of Grid

The hybrid grid performs its operation in two modes.

Grid Tied Mode

In this mode the main converter is to provide stable DC bus voltage, and required reactive power to exchange power between AC and DC buses. Maximum power can be obtained by controlling the boost converter and wind turbine generators. When output power of DC sources is greater than DC loads the converter acts as inverter and in this situation power flows from DC to AC side. When generation of total power is less than the total load at DC side, the converter injects power from AC to DCside. The converter helps to inject power to the utility grid in case the total power generation is greater than the total load in the hybrid grid,. Otherwise hybrid receives power from the utility grid. The role of battery converter is not important in system operation as power is balanced by utility grid.



Autonomous Mode

The battery plays very important role for both power balance and voltage stability. DC bus voltage is maintained stable by battery converter or boost converter. The main converter is

The Ciência & Engenharia - Science & Engineering
Journa
ISSN: 0103-944X
Volume 11 Issue 1, 2023

controlled to provide stable and high quality AC bus voltage.

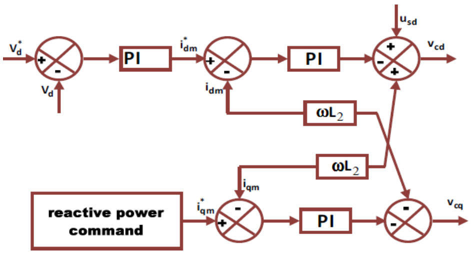
Modelling Of Boost Converter

Control block diagram of SEPIC converter

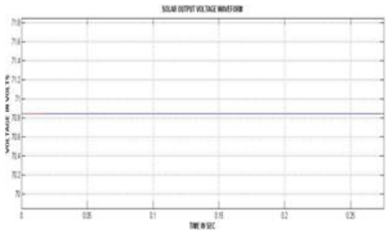
With the implementation of Fuzzy logic algorithm a reference value is calculated which mainly depends upon solar irradiation and temperature of PV array. Here for the boost converter dual loop control is proposed. Here the control objective is to provide a high quality DC voltage with good dynamic response. The outer voltage loop helps in tracking of reference voltage with zero steady state error and inner current loop help in improvisation of dynamic response.

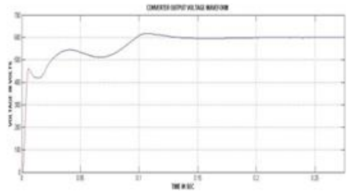
Modelling Of Main Converter

The role of the main converter is to exchange power between AC and DC bus. The key purpose of main converter is to maintain a stable DC-link voltage in grid tied mode. When the converter operates in grid tied mode, it has to supply a given active and reactive power. Here PQ control scheme is used for the control of main converter. The PQ control is achieved using a current controlled voltage source. Two PI controllers are used for real and reactive power control. When resource conditions or load capacities change, the DC bus voltage is settled to constant through PI regulation. The PI controller is set as the instantaneous active current iT- reference and the instantaneous reactive current in- reference is determined by reactive power compensation command. Control block diagram of main converter



In case of sudden DC load drop, there is power surplus at DC side and the main converter is controlled to transfer power from DC to AC side. The active power absorbed by the capacitor CT leads to rising of DC-link voltage VT. The negative error caused by the increase of VT produces a higher active current reference iT through PI control. A higher positive reference iT will force active current reference iT- to increase through the inner current control loop. Therefore the power surplus of the DC grid can be transferred to the AC side. Also a sudden increase of DC load causes the power shortage and VT drop at the DC grid. The main converter is controlled to supply power fromthe AC to DC side. The positive voltage error caused by VT drop makes the magnitude of iT- increase through the PI control. Since iT- and iT are both negative, the magnitude of iT- is increased through the inner current control loop. Hence power is transferred from AC grid to the DC side.





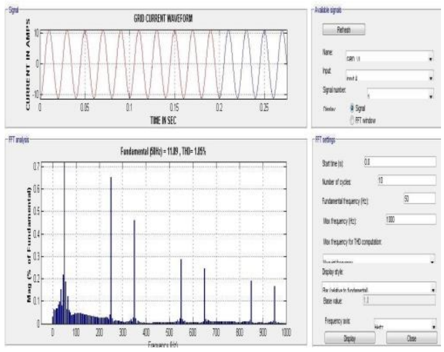
Simulation Results

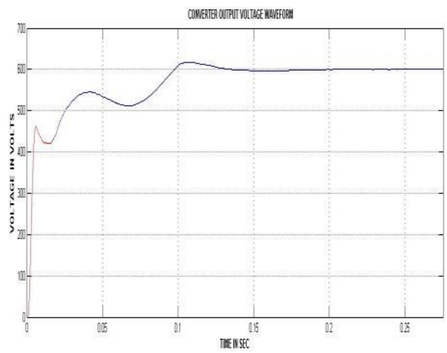
A hybrid microgrid is simulated using MATLAB/SIMULINK environment. The operation is carried out for the grid connected mode. Along with the hybrid microgrid, the performance of the doubly fed induction generator, photovoltaic system is analyzed. The solar irradiation, cell temperature and wind speed are also taken into consideration for the study of hybrid microgrid. The performance analysis is done using simulated results which are found using MATLAB.

Matlab Simulink

Proposed system simulation diagram

Solar Panel Output Wave Form





Converter Input & Output

Conclusion

The modeling of hybrid micro grid for power system configuration is done in MATLAB/SIMULINK environment. The present work mainly includes the grid tied mode of operation of hybrid grid. The models are developed for all the converters to maintain stable system under various loads and resource conditions and also the control mechanism are studied. Maximum power from DC sources and to coordinate the power exchange between DC and AC grid. Although the hybrid grid can diminish the processes of DC/AC and AC/DC conversions in an individual AC or DC grid,there are many practical problems for the implementation of the hybrid grid based on the current AC dominated infrastructure. The efficiency of the total system depends on the diminution of conversion losses and the increase for anextra AC link. The hybrid grid can provide a reliable, high quality and more efficient power to consumer. The hybrid grid may be feasible for small isolated industrial plants with both PV systems and SOLAR as the major power supply

.

References

[1] S. Bose, Y. Liu, K. Bahei-Eldin, J.de Bedout, and M. Adamiak, “Tie line Controls in Microgrid Applications,” in *iREP Symposium Bulk Power System Dynamics and Control VII, Revitalizing Operational Reliability,* pp. 1-9, Aug.2007.

[2] R. H. Lasseter, “MicroGrids,” in *Proc. IEEE-PES’02,* pp. 305-308, 2002.

[3] Michael Angelo Pedrasa and Ted Spooner, “A Survey of Techniques Used to Control Microgrid Generation and Storage during Island Operation,” in *AUPEC,* 2006.

[4] F. D. Kanellos, A. I. Tsouchnikas, and N. D. Hatziargyriou, “Microgrid Simulation during Grid-Connected and Islanded Mode of Operation,” in *Int. Conf. Power Systems Transients (IPST’05),* June. 2005.

[5] Kshirsagar, P. R., Reddy, D. H., Dhingra, M., Dhabliya, D., & Gupta, A. (2023). A Scalable Platform to Collect, Store, Visualize and Analyze Big Data in Real-Time. 2023 3rd International Conference on Innovative Practices in Technology and Management (ICIPTM), 1–6. IEEE.

[6] Y. W. Li, D. M. Vilathgamuwa, and P. C. Loh, Design, analysis, and real- time testing of a controller for multi bus microgrid system, *IEEE Trans. Power Electron.*, vol. 19, pp. 1195-1204, Sep. 2004.

[7] R. H. Lasseter and P. Paigi, “Microgrid: A conceptual solution,” in *Proc. IEEEPESC’ 04*, pp. 4285-4290, 2004.

[8] F. Katiraei and M. R. Iravani, “Power Management Strategies for a Microgrid with Multiple Distributed Generation Units,” *IEEE trans. Power System*, vol. 21, no. 4, Nov. 2006.

[9] P. Piagi and R. H. Lasseter, “Autonomous control of microgrids,” in *Proc. IEEE-PES’06,* 2006, *IEEE*, 2006.

[10] Pareek, M., Gupta, S., Lanke, G. R., & Dhabliya, D. (2023). Anamoly Detection in Very Large Scale System using Big Data. SK Gupta, GR Lanke, M Pareek, M Mittal, D Dhabliya, T Venkatesh,.." Anamoly Detection in Very Large Scale System Using Big Data. 2022 International Conference on Knowledge Engineering and Communication Systems (ICKES).

[11] M. Barnes, J. Kondoh, H. Asano, and J. Oyarzabal, “Real-World MicroGrids- an Overview,” in *IEEE Int. Conf. Systems of Systems Engineering,* pp.1-8, 2007.

[12] Chi Jin, Poh Chiang Loh, Peng Wang, Yang Mi, and Frede Blaabjerg, “Autonomous Operation of Hybrid AC-DC Microgrids,” in *IEEE Int. Conf. Sustainable Energy Technologies,* pp. 1-7, 2010.

[11]Y. Zoka, H. Sasaki, N.Yomo, K. Kawahara, C. C. Liu, “An Interaction Problem of Distributed Generators Installed in a MicroGrid,” in *Proc. IEEE Elect. Utility Deregulation,*

Restructuring and Power Technologies, pp. 795- 799, Apr. 2004.

[12]H. Nikkhajoei, R. H. Lasseter, "Microgrid Protection," in *IEEE Power Engineering Society General Meeting,* pp. 1-6, 2007.

[13] Zhenhua Jiang, and Xunwei Yu, "Hybrid DC- and AC-Linked Microgrids: Towards Integration of Distributed Energy Resources," in *IEEE Energy2030 Conf., pp.1*-8, 2008.

[14] Bo Dong, Yongdong Li, ZhixueZheng, Lie Xu "Control Strategies of Microgrid with Hybrid DC and AC Buses," in *Power Electronics and Applications, EPE'11, 14thEuropean Conf.,* pp. 1-8, 2011.

[15] Kumbhkar, M., Shukla, P., Singh, Y., Sangia, R. A., & Dhabliya, D. (2023). Dimensional Reduction Method based on Big Data Techniques for Large Scale Data. 2023 IEEE International Conference on Integrated Circuits and Communication Systems (ICICACS), 1–7. IEEE.

[16] Dong Bo, Yongdong Li , and Zedong Zheng, "Energy Management of Hybrid DC and AC Bus Linked Microgrid," in *IEEE Int. Symposium Power Electronics for Distributed Generation System,* pp. 713-716, 2010.

[17] Kawale, S., Dhabliya, D., & Yenurkar, G. (2022). Analysis and Simulation of Sound Classification System Using Machine Learning Techniques. 2022 International Conference on Emerging Trends in Engineering and Medical Sciences (ICETEMS), 407–412. IEEE.