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Design and Simulation of DC Microgrid for Utility

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Abstract*:* *Due to the widespread use of direct current (DC) power sources, including fuel cells, solar photovoltaic (PV), and other DC loads, high-level integration of various energy storage systems, including batteries, supercapacitors, and DC microgrids, has become more significant in recent years. Additionally, DC microgrids do not experience problems with synchronization, harmonics, reactive power regulation, or frequency control like traditional AC systems do. The control of DC bus voltage as well as power sharing is complicated by the inclusion of various distributed generators, such as PV, wind, fuel cells, loads, and energy storage devices, in the same DC bus. Several control strategies, including centralized, decentralized, distributed, multilevel, and hierarchical control, are described to assure the secure and safe functioning of DC microgrids.*

Keywords: MPPT- Maximum Power Point Tracking, IREA- International Renewable Energy Agency, RES- Renewable Energy Sources, SVC- static variable-frequency, PV- Photo Voltaic

I. INTRODUCTION

Use of RESs has grown in prominence recently as a result of the continuing depletion of fossil fuels. High-level integration of RESs raises a number of technical issues, including inadequate fault ride-through capacity, excessive fault current, inadequate system inertia, and insufficient generation reserve. IREA predicts that by 2050, RESs will meet 66 percent of world electricity demand. Solar and wind power are the most promising renewable energy sources (RESs)because of their cheap production costs and the ability to monitor their maximum power point (MPPT). Yet, direct integration into the electrical grid might be challenging because to the intermittent nature of RESs. Solar and PV power producer integration with the DC grid might be a workable solution.

Controlling DC link voltage and managing power between sources and loads are major areas of interest in DC microgrid research. Traditional droop control in DC microgrids is simple to implement due to the absence of a communication connection. Parameter choices for the droop controller might cause DC bus voltage oscillations and inefficient current sharing. These droop control challenges may be overcome by using a hierarchical control scheme with a low-bandwidth communication link. A DC microgrid's controller needs to account for the batteries' and supercapacitors' varying levels of charge (SOC) in order to function properly. This calls for a fresh approach to droop controller design, one in which droop parameters play a central role. Nonetheless, the DC bus voltage is kept within specified limits by the use of a number of different control mechanisms implemented at the device level. Based on the availability of producing units, load demand, and generation cost, operational decisions are made using unit commitment (UC) and economic dispatch (ED) to minimise overall cost and maximise profit.

II. POWER ELECTRONICS

2.1 Introduction to Power Electronics

In power electronics, electrical power (power) is integrated with electronics and control systems. Electric power requires both stationary and mobile machinery for generation, transmission, and distribution. Technology researchers in electronics study solid-state semiconductor power devices and circuits with the goal of achieving the required control goals (to control the output voltage and output power). Power electronics refers to the use of power semiconductor devices (Thyristors) for controlling and transforming electrical current.

Thyristors power controllers are the main area of study in power electronics. These controllers are used in a wide variety of contexts, such as the control of heat, light, and illumination, motor control for AC/DC motor drives in

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industrial settings, high voltage power supply, and vehicle propulsion systems. Commercial Power Electronics, Elevators, Emergency Lighting, Uninterruptible Power Supply (UPS), Computers, Office Equipment, Heating and Ventilation Systems, and Central Air Conditioning and Refrigeration. Household Uses like Appliances for the Kitchen, Lighting, Heating, Air Conditioning, Refrigerators and Freezers, Computers and Electronics, Home-Theaters, and Uninterruptible Power Supplies. Pumps, compressors, blowers, and fans are all examples of mechanical devices that have several uses in industry. Fabrication equipment such as machine tools, arc furnaces, induction furnaces, lighting control circuits, industrial lasers, induction heating, and welding machines. Space shuttle power systems, satellite power systems, and aircraft power systems are all examples of aerospace applications. Mobile phone chargers, DC power supply, and UPS systems all fall within the category of telecommunications. Transportation-related topics include engine controls, traction controls, electric battery chargers, electric locomotives, streetcars, and trolley buses. High-voltage direct current (HVDC) transmission, static variable-frequency (SVC) correction, alternative energy (wind, PV), fuel cells, energy storage systems, induced draught fans, and boiler feed water pumps are all examples of utility systems. It's possible to answer this question in a number of different ways. Power electronics, in a nutshell, refer to any and all electrical gadgets that deal with power. General-purpose electronics make use of a wide variety of components, such as diodes, bipolar junction transistors (BJTs), and metal oxide semiconductor field effect transistors (MOSFETs). You Can Find These Devices in Both Power Electronics and Traditional Electronics. Power electronics devices may differ in construction and operation from standard electronic components. In contrast to other forms of electricity generation, Pe uses certain devices uniquely developed for it.A power converter is any electrical or electromechanical device used to change the form or quantity of electrical energy. Altering the power's polarity from alternating current (AC) to direct current (DC) or vice versa is one possibility.Many instruments are used for this purpose, including rectifier. Among these devices are the inverter, DC-DC converter, and AC-AC converter.By use of a rectifier, alternating current (ac) is converted to direct current (dc), which always travels in the same direction. An electrical component called a rectifier makes this transformation possible.Rectifiers find usage in many devices, from radio signal detectors to components of electrical generators. Rectifiers may be made using a variety of components, including mercury arc valves, vacuum tube diodes, solid-state diodes, and more.DC-to-AC inverter/converter

An inverter may convert DC to AC with the right transformers, switching, and control circuits, allowing for the generation of AC at any voltage and frequency.

2.2 Three-Level Inverter Analysis

A three-stage inverter to compare and contrast with a standard two-stage inverter. An inverter with three independent phases and three output levels requires a layout very similar to that used with 12 electronic devices (IGBT). The three voltage levels (+V dc/2, 0 and -Vdc/2) will cycle through on each phase. The maximum voltage across the IGBT in this configuration is bounded by the value of the DC link voltage divided by two (Vdc/2). This is because two fast diodes, known as neutral clamp diodes, link the MP of the IGBTs to the neutral point.

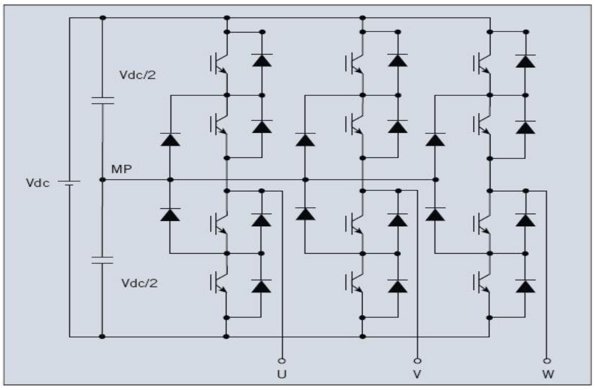


Fig:2.1 Three-phase three-level inverter topology, in which each phase switches across three voltage levels.

Three-phase two-level (PWM) inverter design algorithms may be used to multilayer inverters as well. As a carrier and a reference are needed for a three-level inverter, it follows that methods using a triangular carrier waveform will provide the greatest benefits for lowering harmonic distortion. The number of triangular carriers is equal to L-1, where L is the total number of voltage levels. Hence, a three-phase, three-level inverter necessitates two triangular carriers and one sinusoidal reference. Depending on the inverter's design, three distinct PWM approaches with distinct phase relationships are available. Carrier phase changes of 180 degrees between adjacent bands characterise APOD, or alternate phase-opposition disposition.

2.3 Three-Level Inverter Benefits

When the carriers above and below the reference zero point are 180 degrees out of phase, we say that the carriers are in a phase-opposition disposition (POD). When there is phase disposition, all carriers are in phase on all frequencies (PD). The PD technique is often used because it produces low levels of harmonic distortion in the final line-to-line voltage. Current waveforms of an IGBT and an NCD, together with a triangular carrier waveform and a sinusoidal reference waveform.

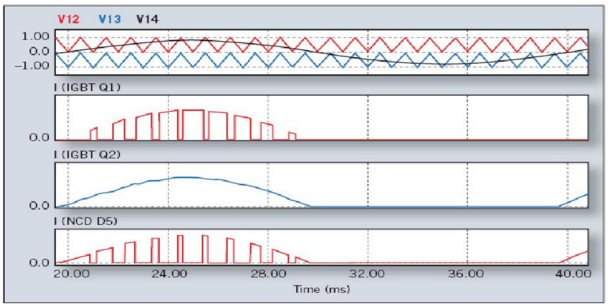


Fig:2.2 Phase disposition (PD) three-level inverter, where all carriers are in phase across all bands and currents profiles.

It would seem that a three-level inverter has far more complex circuitry than a two-level inverter. Nonetheless, three-level inverters are recommended owing to the technical and economical gains they provide.

The reverse-blocking voltage of an IGBT in a three-level inverter is 600 V, rather to the higher value of 1,200 V required by single-level inverters. 600-V chips, in comparison to 1,200-V circuits, are often more compact and faster. For this reason, a three-level inverter's silicon has lower switching losses and a smaller forward voltage drop, and its total losses are 60% lower per single arm than those of a two-level inverter. In Q2 and Q3, switching losses are negligible. As Q1 commutes to D5 and Q4 travels to D1, the current via diodes D1 and D4 is quite low.

III. CONTROLLERS IN ELECTRICAL ENGINEERING

Autonomous Open-Loop Management

An open-loop action (controlled chain) is shown; only the kind of disturbances for which the system was intended may be mitigated; the controlled item cannot itself become unstable so long as it remains stable.

3.1 The P.I. Controller Idea

Integral and Proportional Regulators Systems with open loop transfer functions of type 1 or above are ideal candidates for PI controllers due to their zero steady state error with respect to a step input.

Which of the following is the PI regulator?

But, this is simply accomplished in the following form:

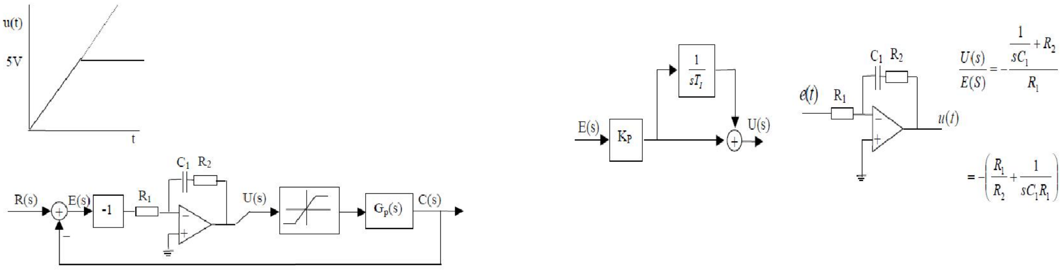


Fig:3.1 Discrete PI controller to regulate the DC-link average voltage

You Will Not Realize Any Integral Gain in the Beginning (TI large)
You should keep raising K_P until you reach an optimal result.
Then, lower the time integrator (T_I) by adding in integrals until the steady-state error is gone (may need to reduce K_P if the combination becomes oscillatory).

Circuit Controllers: PID (THREE-TERM)

Taking quick action in proportion to shifts in error deviation. Action that takes into account the whole system is more time-consuming but results in output that is consistent with the standard.

The derivative action accelerates the response time of the system by introducing a control action that is proportional to the square of the rate of change of the feedback error. As the error signal contains noise, it limits the derivative gain. Using this, it's possible to utilise larger KP and KI (and hence lower TI) values than are possible with pure PI regulators, albeit doing so would cause instability at high levels of derivative gain (KD).

IV. DC MICROGRIDS PLANING

Many considerations, like as reliability, cost, and environmental impact, must be considered in the building and operation of DC microgrids. On the one hand, operations are significantly impacted by how well a DC microgrid is planned. Nonetheless, the implementation strategy plays a significant role in ensuring microgrids continue to be stable and reliable. DC microgrids are capable of functioning in either an independent, "islanding," or "grid-connected" configuration. It is essential to carefully prepare for the available producing units and load in order to optimize system dependability when DC micro grids are disconnected from the main grids due to failures, voltage fluctuations, or other interruptions. There are three types of microgrid planning expenses: dependable, operational, and investment. An estimate of the total cost of the investment throughout its expected lifetime is made.

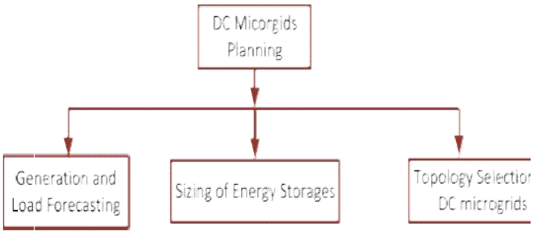


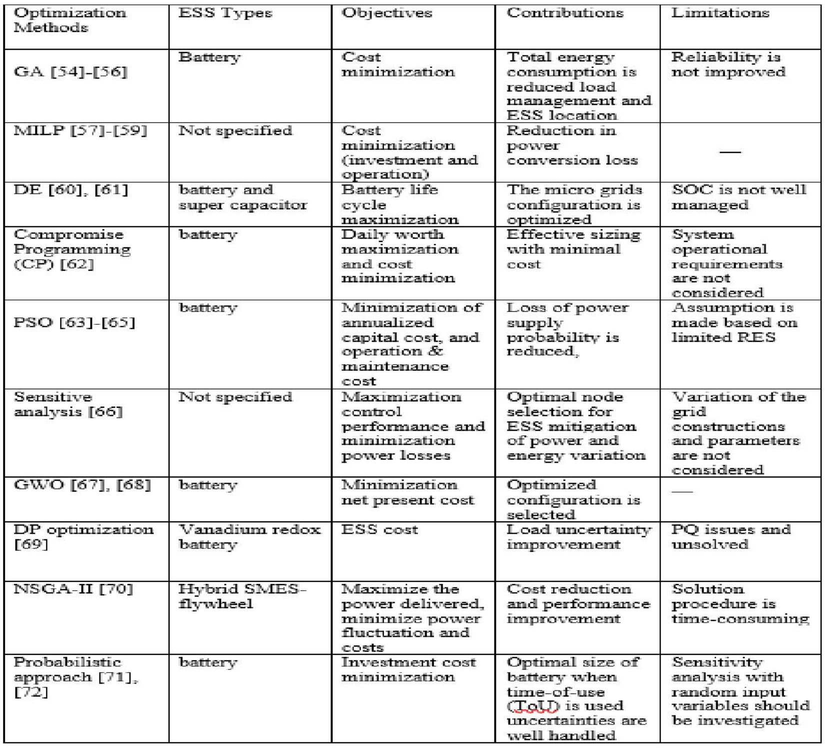
Fig 4.1: Planning method sinDC microgrids.

Encompasses many different cases, such as the base case micro grid design, critical load sensitivity analysis, market price sensitivity analysis, and DC load sensitivity analysis. DERs are optimised for their specific applications in terms of size and location. The heuristic approach is used to solve the first stage of the algorithm, which entails determining the microgrid topology, the optimal location of equipment, and the optimal size of equipment. Microgrid network reliability is addressed in the second stage of the algorithm.

4.1 Generation and Load Forecasting

As renewable energy sources are inherently unreliable, effective energy management in DC microgrids is essential. Power from renewable sources might be a little erratic, but that's important for the smooth operation of DC microgrids. So, when substantial levels of penetration are expected, projecting renewable energy for DC microgrids is performed. A back propagation neural network built on top of a modified particle swarm optimization was described with the intention of forecasting renewable energy in a way that minimises both total cost and power loss. DC microgrids models are constructed using optimization results, with many different kinds of hybrid distributed generators (DG) taken into account.

Table:4.2 Different ESS sizing strategies



Optimization Methods	ESS Types	Objectives	Contributions	Limitations
GA [54]-[56]	Battery	Cost minimization	Total energy consumption is reduced load management and ESS location	Reliability is not improved
MILP [57]-[59]	Not specified	Cost minimization (investment and operation)	Reduction in power conversion loss	—
DE [60], [61]	battery and super capacitor	Battery life cycle maximization	The micro grids configuration is optimized	SOC is not well managed
Compromise Programming (CP) [62]	battery	Daily worth maximization and cost minimization	Effective sizing with minimal cost	System operational requirements are not considered
PSO [63]-[65]	battery	Minimization of annualized capital cost, and operation & maintenance cost	Loss of power supply probability is reduced,	Assumption is made based on limited RES
Sensitive analysis [66]	Not specified	Maximization control performance and minimization power losses	Optimal node selection for ESS mitigation of power and energy variation	Variation of the grid constructions and parameters are not considered
GWO [67], [68]	battery	Minimization net present cost	Optimized configuration is selected	—
DP optimization [69]	Vanadium redox battery	ESS cost	Load uncertainty improvement	PQ issues and unsolved
NSGA-II [70]	Hybrid SMES-flywheel	Maximize the power delivered, minimize power fluctuation and costs	Cost reduction and performance improvement	Solution procedure is time-consuming
Probabilistic approach [71], [72]	battery	Investment cost minimization	Optimal size of battery when time-of-use (ToU) is used uncertainties are well handled	Sensitivity analysis with random input variables should be investigated

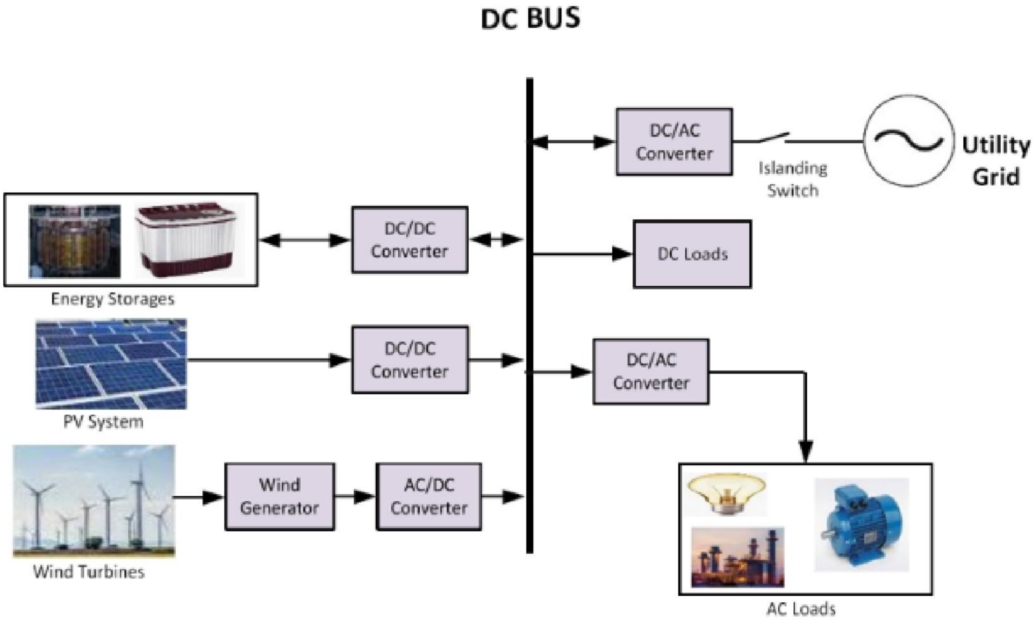


Fig:4.3 Basic components of DC microgrids

The forecasting algorithm considers the previous day's hourly load data, the day type of the week, and the month. For the most part, meteorological data, which is also derived using a forecasting approach, is used as the basis for renewable energy forecasting in microgrids. When one method of predicting relies on another, it introduces an additional source of error. As a consequence, we provide a persistent strategy for load forecasting and renewable energy that relies on previous power data rather than meteorological data. Fuzzy logic, statistical approaches, intelligent algorithms, and an adaptive neuro-fuzzy inference system are some of the other methods that have been addressed in

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the literature for predicting load and generation (ANFIS). Yet, more accurate demand and generation estimates for DC microgrids may arise from future research strategies that integrate those methodologies or models together with others.

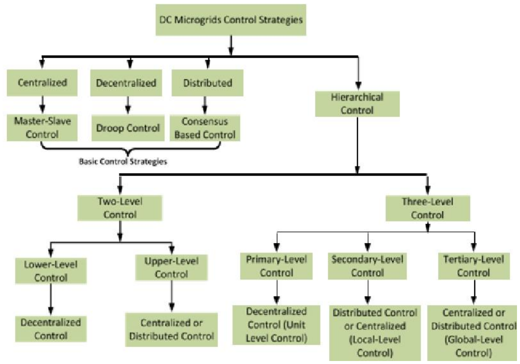


Fig:4.4 Control for DC micro grids

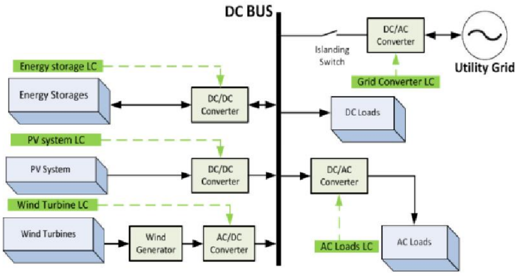


Fig 4.5: Decentralized controller for DC micro

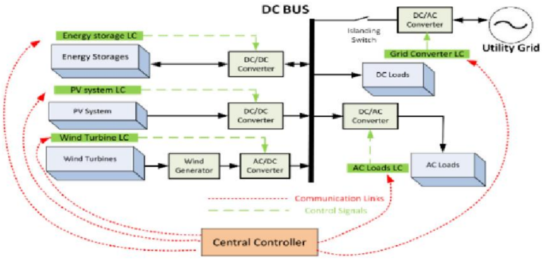


Fig 4.6: Decentralized controller for DC micro

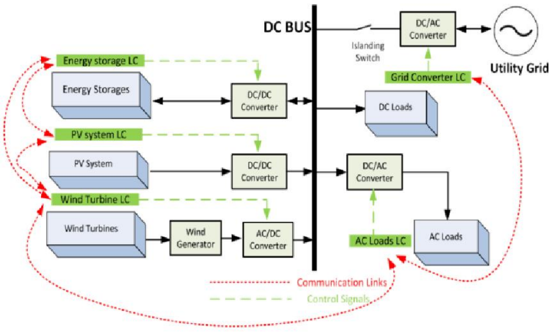


Fig:4.7 Distributed controller for DC micro grids.

The droop controller is composed of a virtual resistance droop (VRD) for the battery and a virtual capacitance droop (VCD) for the supercapacitor. Normal droop controls suffer from a lack of DC link voltage as the output current rises. In order to solve this issue and get rid of the necessity for a secondary central controller, a decentralised control system is offered that is based on low bandwidth communication (LBC). In order to establish a decentralised controller, each controller is constructed locally, and the LBC system-based controller is activated to regulate the DC current and voltage. An autonomous droop-based controller for a DC island grid is presented, which allows for more effective power management, bus voltage restoration, and state-of-charge (SOC) recovery for energy storage. The battery converter is under the control of a high pass filter droop.

Hierarchical Control

Hierarchical control of DC microgrids aims to coordinate control of various energy storagedevices, differently distributed generations, loads, and renewable energy sources through a functionality-based generic structure with primarily three control levels, such as primary, secondary, and tertiary control. The main controller of a microgrid, the quickest of the three controllers since it just has to rely on local measurements to fix the DC link voltage and ensure concurrent power-sharing in both static and dynamic conditions, does just that. The main controller's effect on voltage is counteracted by the secondary controller's quicker response time. Equalizing power amongst all parties is another goal of this approach.

Primary Control

As was said before, the primary control's main responsibilities in DC microgrids are to regulate DC link voltage and to maintain equitable power distribution. Droop control, master-slave control, fuzzy logic control, and DC-bus signalling are some of the most common main controllers. By employing the DC bus voltage as an information carrier, DC-bus signaling was created to enable DC microgrids to regulate DC link voltage and control active power without the need for a communication connection. In this method, the threshold voltage of each converter is used to switch between power-sucking and power-sending modes. A DC-bus signaling system is presented, where the DC-link voltage is used as the information carrier, to indicate the different working modes of micro sources. The controller is similarly sensitive to load.

Secondary Control

The primary controller is insufficient for DC microgrids due to poor voltage management and unequal power distribution. Mostly when there is excessive line resistance in long feeds, the controller's performance suffers. The hierarchical method thus employs not one but two controllers: a main and a secondary controller. All common controller types, including centralized, decentralized, and distributed, may be implemented in the secondary controller with the goal of supplying voltage and current reference signals to the main controller. Overall power quality, proportional power sharing, and reliability in DC microgrids are enhanced by the secondary controller's reference signals to the main controller. Hence, the secondary controller is where all the loads converge.

V. SIMULINK/MATLAB MODEL

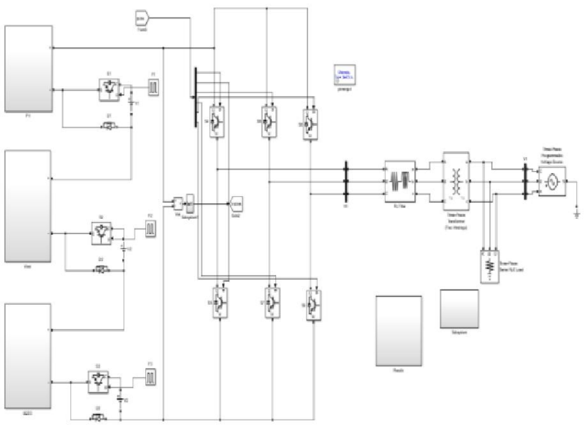


Fig:5.1 over all Simulink/MATLAB circuit

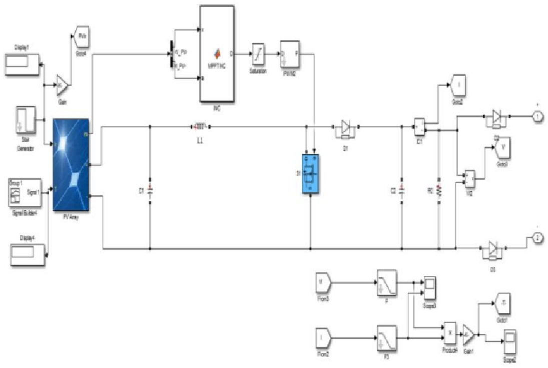


Fig:5.2 Simulink/MATLAB model of solar PV system

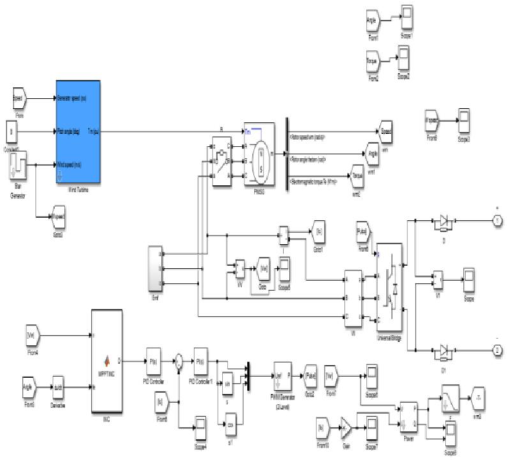


Fig:5.3 Simulink/MATLAB model of wind generator

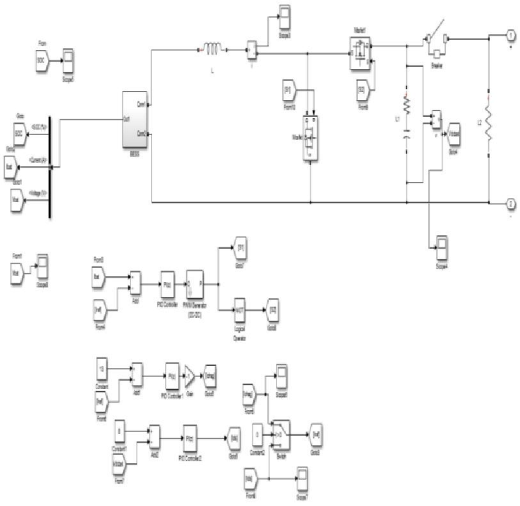
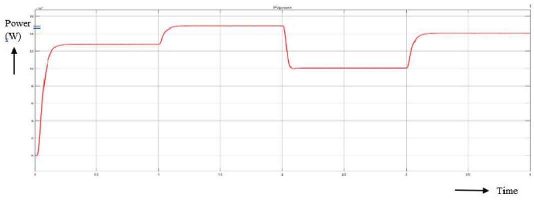


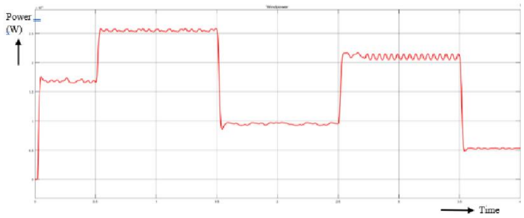
Fig:5.4 Simulink /MATLAB model of battery energy storage system

VI. SIMULINK/MATLAB RESULTS



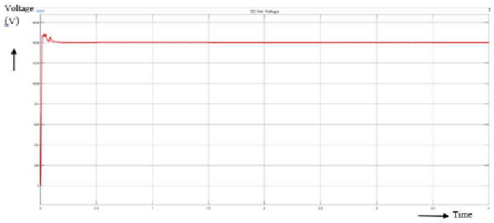
Power in Watts
$15x10^4$

Fig: 6.1 Wave form of PV Power



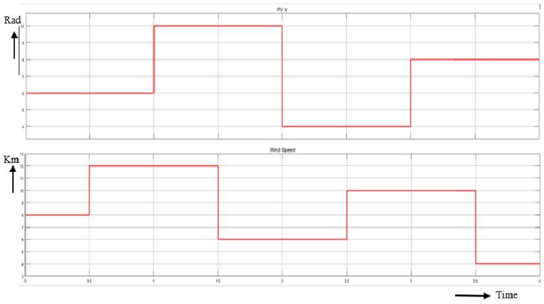
Power in Watts
$2.5x10^4$

Fig:6.2 Wave form of Wind Power



DC Link Voltage in V
1400

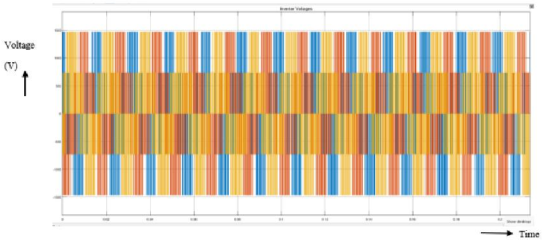
Fig: 6.3 Wave form of DC Link Voltage



Irradiance in Rad
10

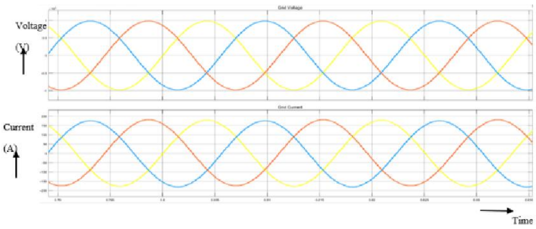
Wind Speed
12

Fig:6.4 Wave form of PV Irradiance and Wind Speed



Inverter Voltage in V
1400

Fig:6.5 Wave form of inverter voltage



Three Phase Voltage in V
1x10⁴

Current in A
175

Fig:6.6 Wave form of Three-Phase Voltage(V) and Current(Amp)

VII. CONCLUSION

More and more people are starting to pay attention to DC microgrids because of the advantages they may provide, but it is still a difficult challenge to create effective planning, operation, and control algorithms for such systems. The complexity arisesfrom having to plan for, operate, and regulate largescale implementations of RES, power balancing, energy management, and DC link voltage regulation. This article provides a critical analysis of the design, operation, and management of DC microgrids from a holistic perspective that might aid in the field's future growth. New research has been used to analyse the pros and cons of both standalone DC micro-grids and those linked to the larger grid. Planning and operating DC microgrids, as well as the basics of control schemes including centralization, decentralization, distribution, and sophisticated higher-level controllers, have all been covered in detail. This paper concludes that further study is needed into real-time planning, enhanced higher-level controller for concurrent power sharing and voltage regulation, coordination between capacitor and inductor storage capacity, and life-cycle enhancement of ESS. Cutting-edge technology and fresh research may help close the gaps in DC micro-grids' design, operation, and control. Read this article for a summary of the key concepts behind DC microgrid design, operation, and control. Finally, some suggestions for the future of DC microgrid design, operation, and control have been presented.

REFERENCES

[1]. M.Taylor,‘‘Energysubsidies:Evolutionintheglobalenergytransformationto2050,’’AbuDhabiInt.Renew.Energy Agency,AbuDhabi,UnitedArab Emirates, 2020.

[2]. S. Ullah, A. M. A. Haidar, P. Hoole, H. Zen, and T. Ahfock, ‘‘Thecurrent state of distributed renewable generation, challenges of interconnectionandopportunitiesforenergyconversion basedDCmicrogrids,’’ J. Cleaner Prod.,vol. 273,Nov. 2020,Art. no.122777.

[3]. J.Kumar,A.Agarwal,andN.Singh,‘‘Design,operationandcontrolofavast DC microgrid for integration of renewable energy sources,’’ Renew.Energy Focus, vol. 34, pp. 17–36, Sep. 2020.

[4]. W.Gil-González,O.D.Montoya,L.F.Grisales-Noreña,F.Cruz Peragón,andG. Alcalá,‘‘Economic dispatch of renewable generators and BESS in DC microgrids using second order cone optimization,’’Energies,vol.13,no. 7, p. 1703, Apr. 2020.

[5]. H.Armghan,M.Yang,A.Armghan,N.Ali,M.Q.Wang,andAhmad,‘‘Design of integral terminal sliding mode controller for the hybrid AC/DC micro grids involving renewable and energy storage systems,’’Int.J.Electr.PowerEnergySyst.,vol.119,Jul.2020,Art. no. 105857.

[6]. Y.ZhangandW.Wei,‘‘DecentralizedcoordinationcontrolofPVgener-ators, storage battery, hydrogen production unit and fuel cell in islanded DC microgrid, ’’Int.J. Hydrogen Energy, vol.45, no.15, pp.8243–8256,Mar.2020.

[7]. I. Zafeiratou, I. Prodan, L. Lefèvre, and L. Piétrac, ‘‘Meshed DC micro-gridhierarchicalcontrol:Adifferentialflatnessapproach,’’Electr.PowerSyst. Res., vol. 180,Mar. 2020, Art.no. 106133.

[8]. A. Naderipour, H. Saboori, H. Mehrjerdi, S. Jadid, and Z. Abdul-Malek,‘‘Sustainable and reliable hybrid AC/DC microgrid planning consideringtechnology choice of equipment,’’ Sustain. Energy, Grids Netw., vol. 23,Sep. 2020, Art. no. 100386.

[9]. A. M. Sallam, H. M. A. Ahmed, and M. M. A. Salama, ‘‘A planningframework for AC-DC bilayer microgrids,’’ Electric Power Syst. Res.,vol. 188, Nov. 2020, Art. no. 106524.

[10]. M. Shafiee-Rad, M. S. Sadabadi, Q. Shafiee, and M. R. Jahed-Motlagh,‘‘Robust decentralized voltage control for uncertain DC microgrids,’’Int. J.Electr.PowerEnergy Syst., vol.125, Feb.2021, Art.no.106468.

[11]. Q.Xu,T.Zhao,Y.Xu,Z.Xu,P.Wang,andF.Blaabjerg,‘‘Adistributed and robust energy management system for networked hybrid AC/DCmicrogrids,’’IEEETrans.SmartGrid,vol.11,no.4,pp. 3496–3508,Jul. 2020.

[12]. F.Li,J.Qin,andY.Kang,‘‘Closed-loop hierarchical operation for optimal unit commitment and dispatch in microgrids: Ahybrid system approach,’’IEEE Trans. PowerSyst., vol. 35,no. 1, pp.516–526, Jan. 2020.

[13]. A.Moradzadeh,S.Zakeri,M.Shoaran,B.Mohammadi-Ivatloo,and F. Mohammadi, ‘‘Short-term load forecasting of microgrid via hybrid support vector regression and long short-term memory algorithms,’’ Sustainability, vol. 12,no. 17,p. 7076,Aug. 2020.

[14]. I.P.Panapakidis,N.Skiadopoulos,andG.C.Christoforidis,‘‘Combinedforecastingsystemforshort-termbusloadforecastingbasedonclusteringand neural networks,’’ IET Gener., Transmiss. Distrib., vol. 14, no. 18,pp. 3652–3664, Sep. 2020.

[15]. W. M. Hamanah, M. A. Abido, and L. M. Alhems, ‘‘Optimum sizing ofhybrid PV, wind, battery and diesel system using lightning search algo-rithm,’’Arabian J. Sci.Eng., vol.45, no. 3,pp. 1871–1883, Mar.2020.

[16]. S. Mohamed, M. F. Shaaban, M. Ismail, E. Serpedin, and K. A. Qaraqe,‘‘An efficient planning algorithm for hybrid remote microgrids,’’ IEEETrans. Sustain.Energy, vol.10, no.1, pp.257–267, Jan.2019.

[17]. M. Alam, M. Abido, and A. Hussein, ‘‘Non-linear control for variableresistive bridge type fault current limiter in AC-DC systems,’’ Energies,vol. 12, no. 4, p. 713, Feb. 2019.

[18]. W. M. Hamanah, M. A. Abido, and L. M. Alhems, ‘‘Optimum sizing ofhybrid PV, wind, battery and diesel system using lightning search algo-rithm,’’Arabian J. Sci.Eng., vol.45, no. 3,pp. 1871–1883, Mar.2020.

[19]. A. Sujil, R. Kumar, and R. C. Bansal, ‘‘FCM Clustering-ANFIS-basedPV and wind generationforecasting agent for energy management in asmart microgrid,’’J. Eng.,vol.2019, no.18, pp.4852–4857,Jul. 2019.