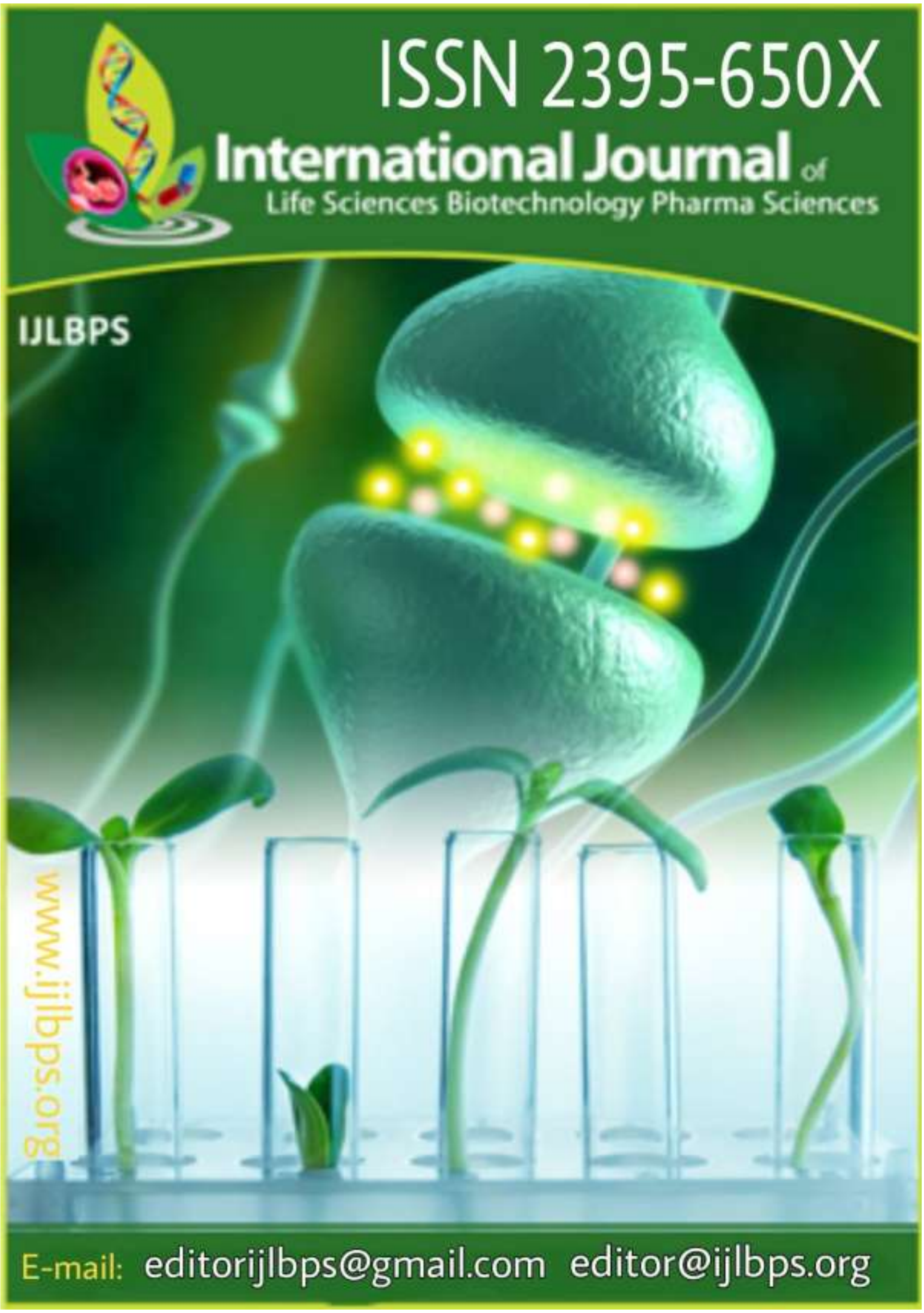
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Enhanced Power Control Approach for Tie Converter Based AC-DC Micro grids

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Abstract

Current AC-DC microgrid power management solutions have a number of technical shortcomings. When it comes to controlling the voltage of interconnected microgrids, certain current control methods are established with the primary purpose of distributing electricity among interconnected microgrids based on their loading circumstances, whereas others do not take this into account. The current systems, on the other hand, are unable to successfully pursue these objectives. In order to tackle these issues, an autonomous power management strategy is proposed, which takes into account the DC microgrid's individual loading condition before importing power from the associated AC microgrid. Controlling DC microgrid voltage with fewer converters is possible with this method. Generators and tie-converters can be used with the proposed system because it is plug-and-play compatible. A variety of operating scenarios have been used to evaluate the effectiveness of the proposed control scheme. Researchers found that the proposed strategy successfully and independently controls the DC microgrid's power shortfall while maintaining increased voltage resiliency.

Keywords: Autonomous control, distributed control, droopcontrol,hybridmicrogrids ,interlinkedmicrogrids, power management.

1. Introduction

Since renewable and alternative energy sources [1] have been widely implemented in various network topologies and configurations, the improvement of power electronics technology is critical [2]. In the same way, they have been regulated and managed utilizing a variety of control systems and designs. Most of their network configurations and control tactics are based on optimizing performance while also keeping up with the expected amount of network traffic. Microgrids are increasingly incorporating renewable and alternative energy technology. Numerous benefits, such as better resource utilization, superior power quality and increased supply reliability [4], make microgrid deployment of these novel technologies preferable. The zone-based grid architectures [5], multi-microgrids, interrelated AC-AC microgrids [6], and interlinked AC-DC microgrids [7] have recently developed as more advanced grid systems. Renewable and alternative energy resources are a major focus of these cutting-edge network systems. Interconnecting two or more microgrids, for example, will allow reserve sharing, voltage and frequency support, and ultimately improve the overall dependability and resilience of linked microgrids. A microgrid's interconnection with other microgrids or utility grids is largely determined by the overall goals of each microgrid and the control and management methods employed within each microgrid. It is possible to connect the microgrids directly or via tie-converters. Harmonizing tieconverters are generally employed when the operational voltage and/or frequency of two or more microgrids diverge. If the microgrids to be interconnected have tieconverters, they are also necessary.different control strategies and the power flow among them needs to be regulated [8].Similarly,theinterlinkingoftheDCmicrogridwiththeutilitygridoranotherACmicrogridalsorequirestie-converterstoregulatethepowerflowamongotherfunctionalities, and that has been investigated under various scenarios in the publishedliterature [9]. In [10], the demand droop control has been proposed for the interlinking ortie-convertersoftheAC-DCmicrogrids.Thepowerflowactionisdeterminedbasedonthe normalized terminal voltage and frequency of the droop controlled interlinked AC-DCmicrogrids. This scheme enables autonomous power transfer between two interlinkedMicrogrids are classified according to how much power they are putting out. Power flow decisions based on relative loading may result in excessive operational losses if the interlinking converter operates continuously. Interconnected microgrids with a storage system use the same power sharing scheme [11]. The progressive auto-tuning of interlinking converters reduces the energy flow even further in this design. Only when one microgrid is significantly loaded and the other is lightly loaded may electricity be transferred using the suggested auto tuning. Different operating situations of interconnected AC and DC microgrids have been studied using the droop-based power sharing concept [12]. The power management method for a three-port system including AC, DC, and a storage network is shown in [12]. The interconnected networks' loading diction is used to make the power sharing choice, which is largely the same as that described in [20]. To cut down on the number of interlinking converters, a multilayer supervisory control system based on communication is also being considered. For the interconnected AC-DC microgrid, another power management method has been proposed that aims to maintain a constant voltage in the DC microgrid regardless of the specific loading level of the generators. A single tie-converter is all that is needed to achieve this plug-and-play approach. For interconnected AC-DC microgrids, a number centralized power management techniques have been tested.

The reliability of the rapid communication links is a major concern with centralized methods. As a result, decentralized systems tend to be more popular. Decentralized power sharing solutions for interconnected AC-DC microgrids based on the droop principle or voltage regulation have thus far been published. There are power sharing techniques that use droop to transfer power between interconnected microgrids. Interconnected microgrids' voltage and frequency are not regulated by the power transfer during contingencies or uneven loading conditions. However, the interconnecting converters are able to plug and play with these schemes. If more than one interlinking converter is present, this feature ensures that all converters will function regardless of the total amount of power transferred. This could result in unnecessarily high converter losses. On the contrary, DC microgrid voltage control schemes govern the DC microgrid's voltage without taking into account the generators' individual loading conditions and without the plug-n'play option for tie converters.

This paper's proposed control method expressly addresses these flaws. The suggested autonomous power management method for interconnected AC-DC microgrids takes into account the individual loading situation of the generators, and transfers power from AC to DC microgrid during its peak-load demand, and also adjusts the voltage of the DC microgrid. " In order to eliminate excessive losses, a plug-and-play function for tie converters has been provided in the proposed scheme. There is insufficient generation capacity for the DC microgrid, due to the significant fluctuation of loads and renewable generation. At times of peak demand or contingency, the AC microgrid can transmit surplus power to the DC microgrid because of its regulated voltage and frequency. For interconnected AC-DC microgrids, a hybrid droop and voltage regulation mode control has been developed for the tie-converters to achieve the desired qualities. The droop-controlled DC microgrid's overall loading state is determined by the tie-converter terminal voltage information. The automatic initiation of the tie converter occurs when the set loading threshold is met.transferspowertotheDCmicrogridduringthepeak-loaddemandorcontingencycondition in the DC microgrid. With the proposed hybrid control mode, the voltage of theDC microgrid is regulated at a defined nominal level. In addition, the proposed schemeallows interfacing more than one tie-converters, but as opposed to the existing schemewhere all tie-converters operate simultaneously regardless of the power transfer demand,the subsequent tie-converter only activates once the first converter power capacity hasbeensaturated.Theproposed schemeisfullyautonomouswith enhancedfeatures.

2

. PhotovoltaicInverter

A PV cell is a simple p-n junction diode that converts the irradiation into electricity. Fig.1Illustrates a simple equivalent circuit diagram of a PV cell. This model consists of acurrent source which represents the generated current from PV cell, a diode in parallelwiththe currentsource,a shuntresistance, anda seriesresistance.

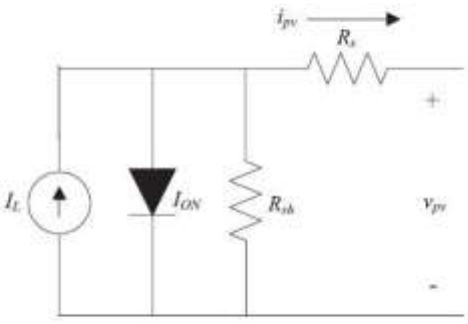

Figure1.Equivalentcircuitdiagramofthe PVcell

3. DC-DCConverters

ABattery backup systems for uninterruptible power supplies and DC-DC converters with high step-up voltage can all benefit from this technology. It is theoretically possible to get a high step up voltage with a high effective duty ratio using a DC-DC boost converter. Power switches and inductors/capacitors' equivalent series resistance (ESR) limit the step-up voltage gain in practice.

4. When a high voltage gain and a big duty ratio are required, traditional boost converters are typically used. However, the losses of power switches and diodes, the equivalent series resistance of inductors and capacitors, and the reverse recovery difficulty of diodes limit the efficiency and voltage gain. In these converters, considerable voltage stress and power dissipation are caused by the active switch because of the transformer's leakage inductance. Resistance capacitor diodes can be used to lessen the voltage stress on the active switch to reduce the voltage spike. However, this results in a decrease in productivity. Converters with low input ripple current have been designed using the coupled inductor as a basis. An extra LC circuit with a connected inductor is used to achieve these converters' minimal input current ripple.

5. Inverter

Direct current (DC) can be converted to alternating current (AC) using proper transformers, switching, and control circuits, and the AC can be at any desired voltage and frequency. There are no moving parts in a static inverter and they can be utilized in a wide range of applications, from small computer power supplies to huge electric utility high voltage direct

Bulk power transportation applications in use today. Solar panels and batteries can be powered by inverters, which convert DC power into AC power. High-power electronic oscillators are used in the inverter. "Inverted" is a term that refers to a mechanical AC to DC converter that was designed to work in reverse, converting DC to AC.

5.1 CascadedH-BridgesInverter

5.2 An m-level cascaded inverter's single phase structure is depicted in Figure 2. Full bridge or H-bridge inverters are used for each distinct DC source (SDCS). The DC source can be connected to the ac output through various combinations of the four switches S1, S2, S3, and S4 at each inverter level to provide three different voltage outputs, +Vdc, 0, and –Vdc. Switches S1 and S4 are switched on to gain +Vdc, while switches S1 and S3 are turned on to obtain –Vdc. 0 volts of output voltage is obtained by turning on S1, 2, 3, or 4. All of the full bridge inverter outputs are connected in series, resulting in a voltage waveform that is equal to the sum of all of the inverter outputs. Cascading inverters can have up to 2s+1 output phase voltage levels m, which is dictated by the number of independent DC sources. It's illustrated in Figure3 is an 11-level cascaded H-bridge inverter with five SDCSs and five full-bridges. The voltage across each phase + …

(4.1)

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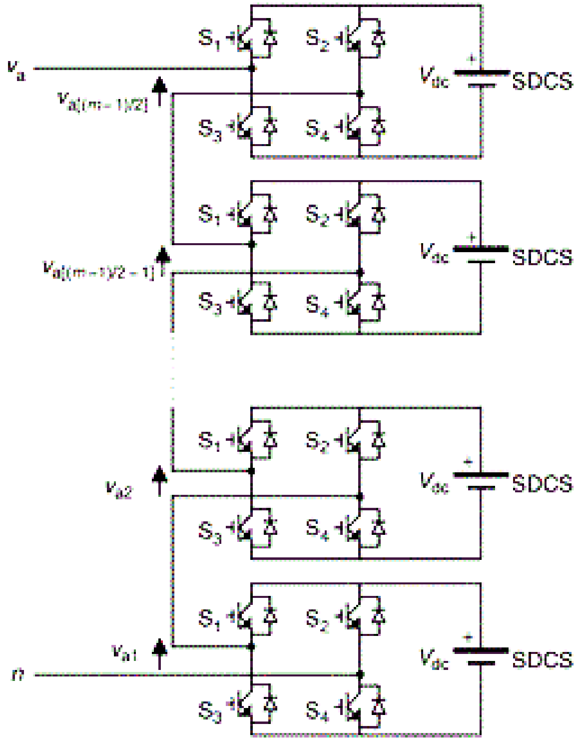


Figure2.Single-phasestructureofamultilevelcascadedH-bridgesinverter

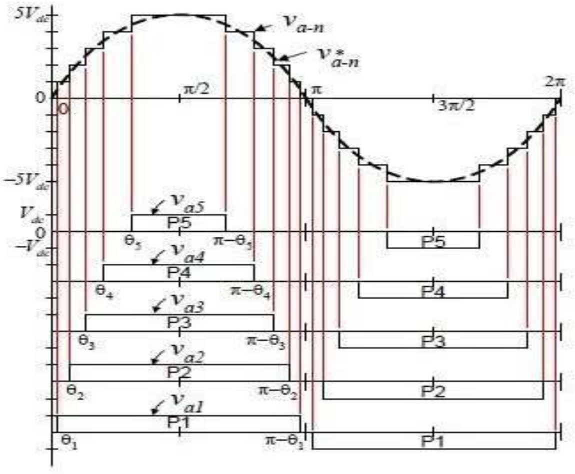
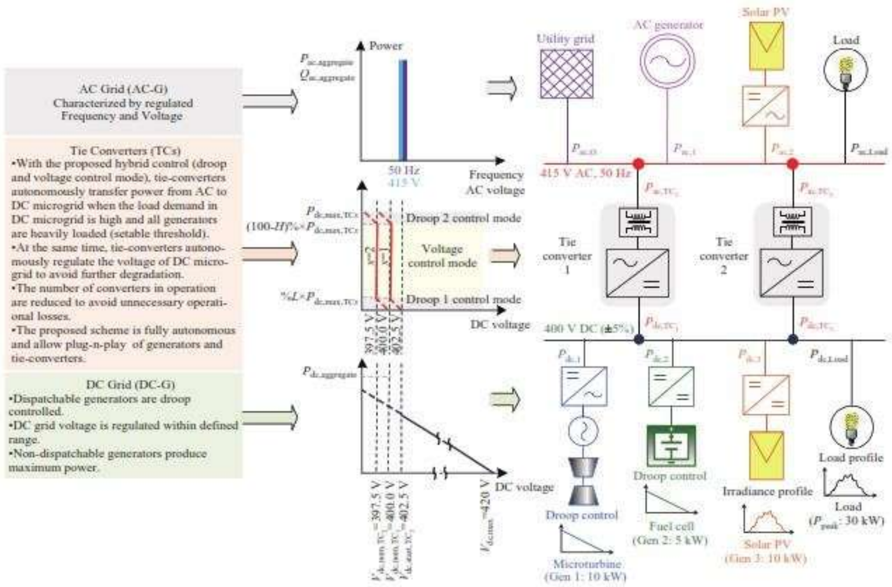


Figure3.Outputphasevoltagewaveformofan11levelcascadeinverterwith5separatedcsources

6.Control of A Cand DC Microgrids

As depicted in Fig. 4, the proposed DC micro grid contains a nondispatchable generator (solar-PV) as well as dispatchable generators (micro turbine, fuel cell). Using a current control mode, the nondispatchable solar PV system gets the most electricity possible at all times. Decentralized or centralized control schemes can be used to manage the dispatchable generators, which are often employed to stabilize renewable capacity. As a result of its simplicity and dependability, the decentralized droop system is the most commonly employed and preferred. As a result, the DC micro grid's dispatchable generators use the standard droop (P-V) method.

The power sharing accuracy is impacted by a voltage mismatch at the generator terminals, which must be corrected using one of several compensation methods. Vdc,ref,i = Vdc,maxdc,iPdc,i + idc,iXi may be used to rewrite the droop equation with compensation for the feeder voltage drop. (5) The droop-controlled DC microgrid's voltage will fluctuate as the load changes, but will remain within the acceptable range. Figure 4 depicts the voltage range for the DC microgrid under consideration as the aggregated load increases (bottomleft). At 395 V, the droop-controlled generators will supply no power, while at 395 V, the generators will deliver 100% of their rated power. To satisfy peak demand and regulate the DC microgrid voltage, tie-converters import electricity from the AC microgrid after the DC generators are severely loaded (e.g., 402.5 V at 80% generator loading). The voltage and frequency of the AC microgrid are considered stiff in the example of interconnected microgrids in Fig. 4. It is possible to regulate droop in the AC microgrid by using secondary voltage and frequency regulation, or by connecting it to the grid. According to the AC microgrid's Fig. 4 characteristics, the voltage and frequency remain constant (e.g., 50 Hz and 415 V). Using proposed autonomous tie-converter control, it has been shown that the AC microgrid has sufficient generation capacity to meet local demand and export surpluspowertotheDCmicrogrid.



AC Grid (AC-G)
Characterized by regulated Frequency and Voltage

Tie Converters (TCs)
- With the proposed hybrid control (droop and voltage control mode), tie-converters autonomously transfer power from AC to DC microgrid when the load demand in DC microgrid is high and all generators are heavily loaded (setable threshold).
- At the same time, tie-converters autonomously regulate the voltage of DC microgrid to avoid further degradation.
- The number of converters in operation are reduced to avoid unnecessary operational losses.
- The proposed scheme is fully autonomous and allow plug-n-play of generators and tie-converters.

DC Grid (DC-G)
- Dispatchable generators are droop controlled.
- DC grid voltage is regulated within defined range.
- Non-dispatchable generators produce maximum power.

Figure4.InterlinkedAC-DCmicrogridsandtheircontrolstrategy

7. Proposed Hybrid Control of Tie-Converters

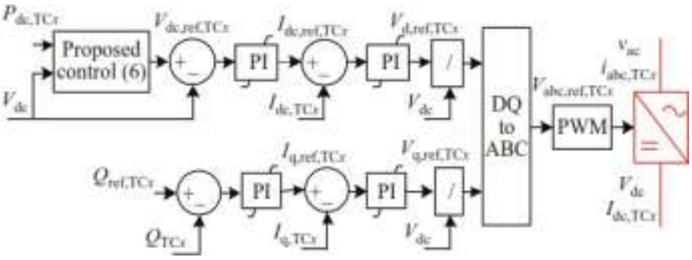
For stabilizing renewable capacity, the power rating of dispatchable generators or storage systems varies according to how much variability in the renewable source and loads in the microgrid have. Since renewables and loads are so variable, high-power dispatchable generators or storage devices may or may not be a feasible alternative. Microgrids can be connected to each other directly or via harmonizing converters if one lacks sufficient generation capacity. Only tie-converters, as depicted in Figure 4, can connect a DC microgrid to an AC utility grid. The AC microgrid in the proposed interconnected system has a regulated voltage and current. frequencysystemwithadequategenerationcapacity,whereastheDCmicrogridischaracterizedasadroop controlledsystemwithinadequategenerationcapacity duetothehighvariabilityoftherenewableandloads.

The DC microgrid imports power from the AC microgrid at times of high demand or low renewable power output. Ideally, the suggested control of the tie-converters can perform this efficiently and autonomously. In essence, the tie-converter control strategy is designed with the following goals in mind: In order to minimize power transfer losses, e.g., the number of tie-converters in operation should be based on power transfer demand, the AC to DC microgrid should only be used during peak demand or generation contingency in the DC microgrid; For the droop-controlled DC microgrid, 3) to manage the voltage; 4) to accomplish autonomous control without relying on the communication network; and 5) to enable the plug-and-play feature for connecting converters and generators. Instead of existing AC-DC microgrid control techniques [18–22], a hybrid droop-voltage regulation mode control is proposed for tie-converters, with the mathematical form provided by:

Thedroop2gain(athighpower)ofxthtieconverter.AsshowninFig.4,tie-converter1 starts in droop 1controlmodewhen the voltage in theDC microgriddropstothesetthresholdofVdc,start,TCx.ThisvoltagethresholdimpliesthatallthegeneratorsintheDCmicrogridareheavilyloaded(e.g.over80%loaded).The

The droop control mode of the tieconverter allows for a smooth transition to the voltage regulation mode at the given condition i.e., Pdc,TCx> L percent Pdc,max,TCx. For peak power supply and voltage management, the tie-converter imports electricity from the AC microgrid and regulates its voltage to meet the DC microgrid's normal values.

Furthermore, unlike the parallel operation of all tieconverters in the existingschemes,theconvertersoperationhasbeenprioritized.Thefirsttie -converteronlystarts when all the generators in the DC microgrid are heavily-loaded. Once the firsttie-converterpowercapacityisneartosaturationatPdc,TCx=(100−H)%×Pdc,max,TCx,itscontrolmodeischangedfromthevoltageregulationtodroop2controlmodetoallowminorvoltagedrop.Thisminorvoltagedropcausedbyt hedroop2controlmodewillenablethenexttie-convertertostartitsoperation.Incaseoffailureofthefirsttie-converter,thesecondtie-converterwillautomaticallystartits operation followed by the voltage drop due to high load demand. Therefore, theproposedcontrolstrategyensuresefficientoperationduring alloperatingconditionswithoutcompromisingtheinheritedflexibilityofthedroopbasedscheme.



Droop 1 and droop 2 control mode allocation depends on the user-defined values of L percent and H percent, and should be tuned to allow smooth transitions between modes while taking into account the voltage and power measurement tolerance/errors in the considered microgrid's voltage and power measurement tolerances. The overall voltage regulation performance of the DC microgrid can be improved using the proposed voltage regulation mode. In particular, the DC microgrid's voltage is regulated at the nominal value during peak demand, which is not the case with current power management techniques for interconnected microgrids.

Figure5.Controlblockdiagramoftie-converter

8. SimulationResults

From 5 kW to 20 kW, the DC microgrid's load can be adjusted in 10-watt stages. The DC microgrid's voltage is below the predetermined threshold of Vdc,start,TC1 = 402.5 V at the 15 kW load demand since the projected loadings of generators 1 and 2 are more than 80%. It is only when this requirement is met that the DC microgrid's nominal voltage of Vdc,nom,TC1 = 400.0 V may be maintained by using power imported from the AC microgrid and controlled by the tieconverter 1 (TC1). The outcomes confirm this projected level of performance. To get to the first highlight point, the DC microgrid voltage drops to below 400 V for 8 seconds, followed by a step load increase from 10 to 15 megawatts. Tie-converter 1 enters droop 1 control mode at point 2 as a result of this voltage drop. Droop 1 is the beginning point.

if the preset threshold is met (Pdc,TC1 > 10% Pdc,max, TC1), the tie-converter control mode automatically switches to voltage regulation mode at point three. DC microgrid demand is increased to 20 kW at 12 seconds, and the AC microgrid's output is correspondingly increased. DC microgrid's tie-converter 1 remains operational during peak demand from 8s to 12s, keeping the DC microgrid voltage stable. The tie-converter at point 5 automatically shuts off after a brief delay after the load demand in the DC microgrid is reduced at the highlighted point 4. As can be seen, tie-converter 1 only comes on when the DC generators are all running at full capacity. The DC microgrid maintains a constant voltage of 400 volts throughout its operation. This strategy's improved voltage regulation performance and efficient operation make it more appealing..

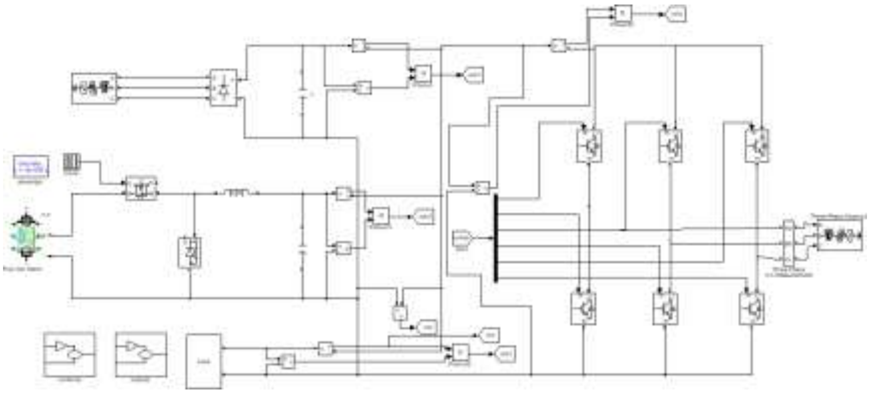


Figure6.Simulinkcircuitofproposedsystem

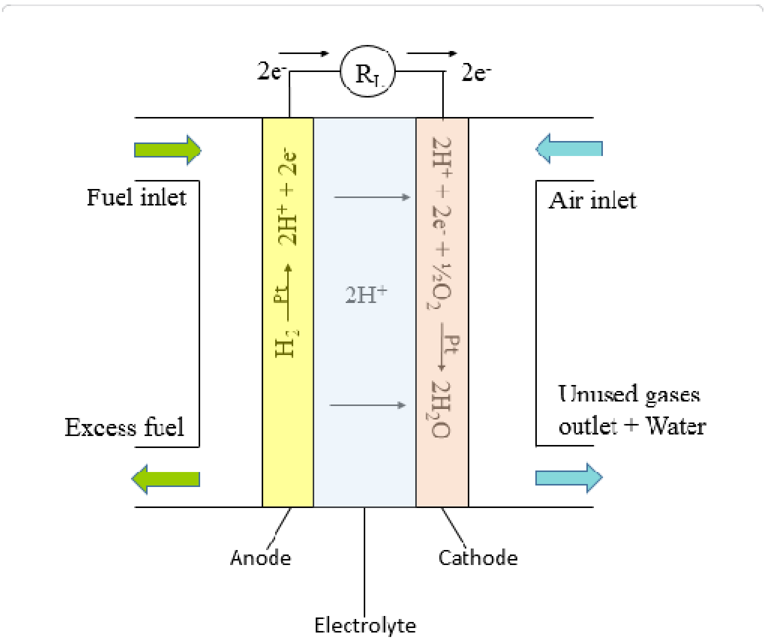


Figure7.Circuitdiagramoffuelcell

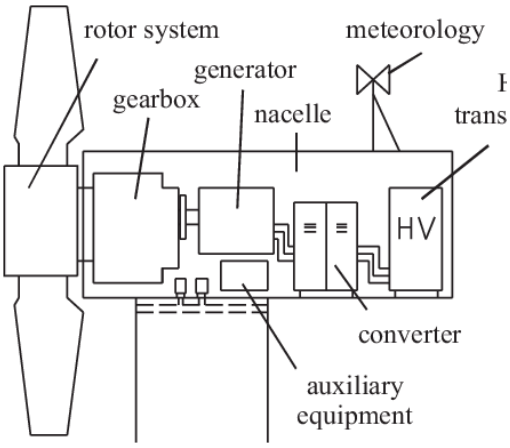


Figure8. CircuitdiagramofWindturbine

Figure9.Generatorsandtie-converterpower

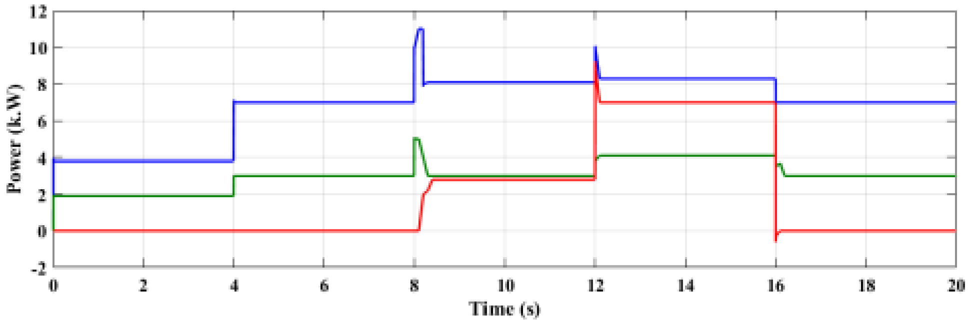
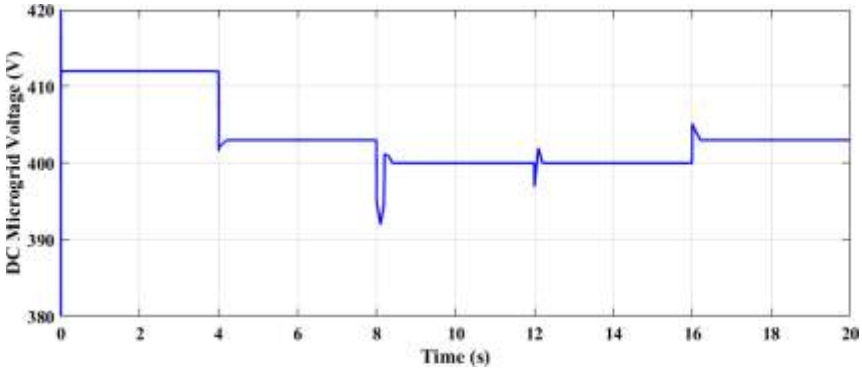


Figure10.DCmicrogridvoltage



After reaching a peak of 24.5 kW, the DC microgrid's load progressively drops. As the demand for power grows, so does the burden on the DC generators. A high-demand load combined with a low solar PV output results in a decline in DC microgrid voltage below the 402.5 V threshold established for Vdc,start,TC1, which is reached at highlight point 1. Tie-converter 1 starts at the highlighted point 1 and imports power from the AC microgrid to solve the power imbalance in the DC microgrid while managing its voltage in accordance with the intended control. Tie-converter 1 regulates the voltage from point 2 to point 3 in 8.5 s and 14.2 s, respectively. DC microgrid load dwindles from point 3 onward, requiring the tie-converter to work in the droop 1 control mode before it can turn the switch to the droop 2 control mode.

cut off at 16.4 s at the marked point number four. The load demand in the DC microgrid may be fulfilled by the local generators from point 4 onward, since the generation is less than the demand. In line with expectations, the tie-converter has only been shown to work when the DC microgrid is experiencing a power shortfall. In addition, power imported from the AC grid regulates the DC microgrid's voltage. AC microgrids are connected to the grid via a tie-converter in this manner.

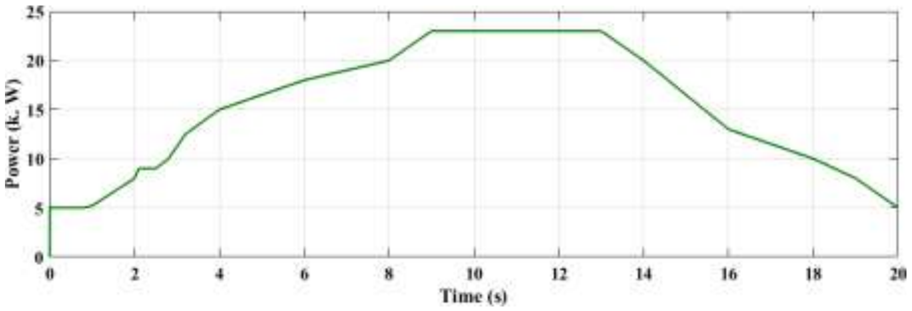


Figure11. DCmicrogridload demand,

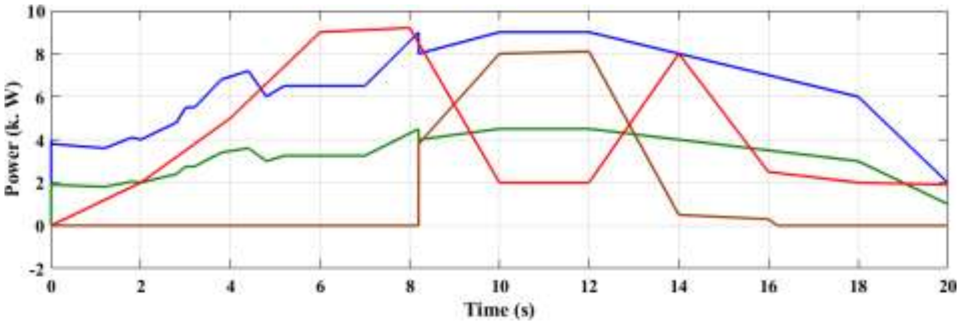


Figure12.Generatorsandtie-converter power

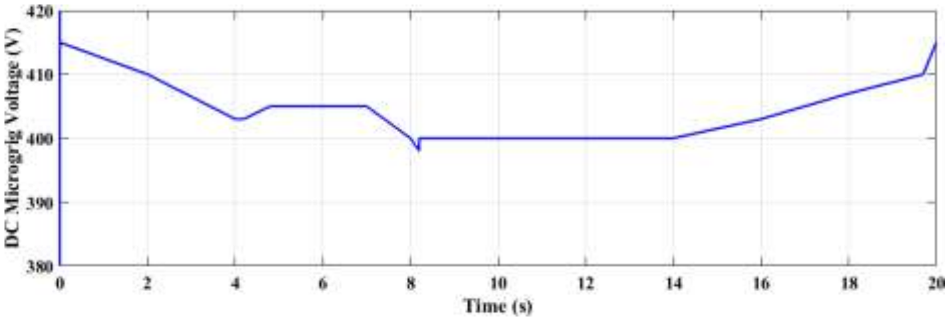


Figure13. DCmicrogridvoltage

9. Conclusion

An autonomous power management system has been developed for AC-DC microgrids with a variety of topologies. DC microgrid's power deficit will be successfully and autonomously addressed by the proposed strategy. The intended prioritizing has restricted the number of tie-converters in service in order to save unnecessary running expenditures. The method has been proved to improve voltage regulation in a DC microgrid. Two different DC microgrid scenarios with varying load conditions were used to test the proposed scheme's efficiency and durability.

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When it comes to evaluating the availability of DC microgrids, it is important to take into account the system architecture and converter topology design choices.

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