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Power Sharing Using Droop Control for Distributed Generators in DC Micro grid

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Abstract: The power sharing control method is a preferred way for integrating many renewable energy sources into the grid and maintaining their synchronized functioning. Power sharing control between dispersed generators are essential for the reliable operation of thepower grid network. In theproposed approach,aDCmicrogrid'spowerfromeachindividualgeneratorissharedusingadroopcontroltechnique.TheprimaryproblemswithPoorcurrentsharinganddropcharacterize the traditional droop approach. Circulatingcurrentissuewillalsoariseduetomismatchintheconvertersoutput voltages.Thedroopindex(DI),ameasure of merit, is introduced in this study, in order toenhance the efficiency of a DC microgrid. The proposedpower sharing control approach can be broadly used togrid-connected networks and island power grid networksinordertoachievehighdistributionefficiencyandstability. The suggested approach also guarantees voltagestability in a DC microgrid. In a MATLAB/Simulink, thepower sharing control mechanism is created, modelled,and confirmed.

Key Word: Power sharing; Droopcontrol;Microgrid

1. Introduction

In the modern age, renewable energy use has increased due to growing environmental concerns and rising fossil fuel prices.The need for integrated grid systems powered by renewableresourceshasincreasedasaresultoftheburdenthatcontinuousgrowthintheindustrialandcommercialsectorshasplacedonthetraditionalelectricitygrid.Historically,alternatingcurrenthasbeenusedbecauseitcanchangevoltagetomatchneedsattheloadend.Inthesectorsofelectric power generation, transmission, and distribution, theuseofDCpowerhasconsiderablyexpandedrecently.Dependingontheavailabilityofpowersupply,microgridscanoperatein grid-connectedoroff-grid linkedmodes.

Significant developments in the field of DC energy haveled to the adoption of DC microgrids into the electrical grid.Forelectronics-basedappliances,theDCmicrogridissuitableandeffective[1],[2].Theideaofmicrogridsispresentedinorder tointegraterenewable energysources,such as solar, wind, and other sources, with energy storagedevicesandACutility lines[3]-[6].

The outputpowerofrenewableenergysources(RESs)isvariable, unpredictable, and sporadic. Energy storage devicesareconsequentlyviewedasacrucialcomponentofDCmicrogridsinordertoovercometheseproblems.Powerconvertersthat actinaccordancewithparticularcontrolapproaches are used to link the majority of the microgrid'scomponents to the bus, 1ensuring the microgrid's steady andefficientoperation[7]–[10].For microgrids,energyfromrenewable sources isoftenthemainenergysource. Droopcontrolisusedtoregulateandcontrolthevoltagebytheconverters and generators connected to the microgrid. Energymay be transferred more reliably and effectively thanks to DCmicrogrids,asevidencedbytheiruse[11]– [15].Dependingonthetype, micro gridscanrunindependentlyorbe connected to the grid. whether it be AC or DC, of power.DC energy has made tremendous progress, which has resultedin theDC microgrids are beingintroducedintothepowernetwork. The efficiency of the DC microgrids is higher.as wellasadherencetothecustomer'selectronicloads[1].Themicrogridsoftenutilizeas theirprimarysourceofenergy,renewable energy. Voltage is controlled using droop control And controlinthemicrogrid-connected convertersandgenerators. AC microgrids are used has demonstrated to offer improved efficiency and trustworthy energy transfer [3].

DCdistributionisusedsystem'sharmonicmanagementandsynchronization have contributed to its widespread adoption[2]. The Integrating the network with the primary power gridensures its dependability. Given that there itpossible for theintegration of the electronic AC-DC and DC-AC converters. microgridalongsidetheconventionalACgrid.Thedataand telecomindustrieshaveseenextensiveuse of theDCmicrogrid.Industry,whoseindependentworknaturenecessitatesanislandedorindividualgridsystem[4,5].Installation of microgrids can be relied on by regions that are disconnectedfromthemaingridtoprovideaccesstotheprimary grid would be careless. Microgrids on islands can beconstructed using their own power. Resource and does notrequire grid integration. Microgrids generate their own power.This guarantees constant power reliability by using a backupstoragesystem.

TosolvethisweaknessoftheACmicrogrid,theDCmicrogridwascreated.Inaddition,itoffersadvantagesintermsof issueswithpowerquality,reactivepowercontrol,skineffect,andfrequencysynchronization.ThekeyissuesintheDCmicrogridare minimizing voltageregulationacrosslinked loads withreferenceto busvoltageandequalizingper-unitcurrentsharingamongconverters.Droopcontrolisapopularmethodforbalancingcurrentsharingamongconverters,similartohowreactivepowersharingisdoneintheACmicrogrid[16]-[19].Conventionaldroopcontrolfunctionsbycreatingavirtualresistanceinlines[20]and[21]toequalize currentsharing. However, a furthervoltage drop lowers the reference bus voltage, which leads to poor voltageregulation.Whendecidingonthevalueofvirtualresistance,therearetradeoffsbetweenvoltageregulationandcurrentsharing.PoorLowvirtualresistanceresultsincurrentsharing,butbettervoltageregulation.However,thelargevalueofvirtualresistanceresultsinhighercurrentsharingandpoorvoltagemanagement.Avoltage-shiftingtermandamoderateamountofvirtualresistanceareaddedtothereferencebusvoltage in order to maintain equalcurrentsharingand retainlow-voltage regulation. Unevenlineresistancesare anotherproblemthatimpairsbothcurrentsharingandvoltageregulation.Theseissuesareaddressedbytheadaptivevirtualresistance idea. The fixed virtual resistance is subtracted fromtheoutputcurrentafterithasbeenmultipliedbythecurrenterror term. This adaptive resistance drop fluctuates dependingon howmuchthe outputcurrentdeviatesfromthe averageoutputcurrentofallconverters.Asaresult,thepresentsharing is more precise. Voltage control is still a big problem.Thisissueisresolvedbysubtractingtheadaptivevirtualresistancedropfromthebusreferencevoltageinordertoproduceavoltage-shiftingterm.Todistributeelectricityandreducecirculatingcurrent,thisarticlesuggestsanadaptivedroopcontrolapproach.Asaresult,thearticle'smaincontributionistoreducetheamountofcirculatingcurrentintheparallel-connectedDCboostconverter.Additionally,regulatevoltageandsharepowerintheDCmicrogrid.Thethen-currentpower-sharingmethodsusedinDCdistributionsystemswerediscussed.Thischapterintroducesthebuildingofanewdroop controllernetwork,as wellas theirroleincontrolandpowersharing,withafocusonDCsystems.ACnetworks werethecontextfortheinvention ofdroop. The system's voltage is maintained atitsratedlevelusingcontrol[29].Thesystem'soperationissustainedbykeepingthevoltageconstantforcontrolandpowerdistribution.Powersharingbetweenthegeneratorsisefficientlymanagedbythecontrollerforeachgenerator.Converter.TheDCDCconverters serveaseachgenerator'spowersharinginterface.Theloadhasagridconnection.Powersharinghasamoresignificantimpactonsystemstability.Thecriticalimpactsof instability occurring at each point in this model are intended to bewithstood. Generator-conversion apparatus.

The rest of the paper is arranged as follows: Section II briefsabout the structure of a DC microgrid system with differentsource of power. In Section III, the control methodology of theproposed system is discussed. The simulation implementationpartandanalysisofresultsiscarriedoutisdiscussedinSection

2. Structure of DC Micro Grid

The architecture of load sharingbetweendifferentrenew-ableenergysourceshasshowninFig.1.Intheproposed methodmore than one distributed generators (DGs) areconnectedtoa singlemicrogridtomeetthedemandat theloadendofthemicrogrid.The traditional grid network canalso be linked with the microgrid. It blends the grid resilienceandenergymanagementtoincreaseconversionefficiency.When there is greater availability to power, transmission gridefficiencyinthecaseofDCdistributedgenerators,whichrequire a DC-DC or DC-AC converter system to be integratedwith the DC or AC grid is found to be more balanced. DCmicrogrid systems powered by photovoltaic and wind energyhave experienced significant progress in recent years electricalengineering.Itintroducedpowerconvertersthatcanrunexclusivelyon DC power. Theloadpowerdemand isalsoexceedinglyincreasingforDCsource.ADC-DCForDCsources, the load power demand is also extremely high. A DC-DC, As depicted in Fig. 2, a converter has been used as aninterface between the solar source and the load or grid system.Toensurethesystemisproperlystable,theconverterisconnected to the external grid or the output load via a couplingresistor. Based on the power demand at the end of the loadsystem, the designed system can be run at any load percentage.Thevoltagedroopshouldbelessthan4%,whichisthebasisonwhichtheaforementioned modelwascreated.

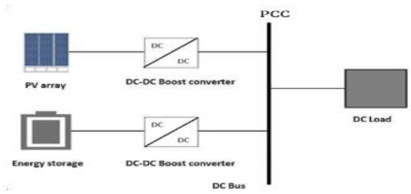


Fig.1 Structure of DC Micro grid

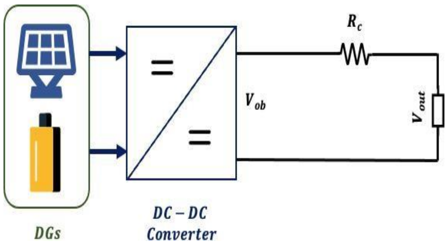


Fig.2:Circuit Model of DC Microgrid

3.Control methodology

This section goes into more detail about the suggestedcontrolmethods.ADC-DCconverterlinksthesolarsourceandtheload,orgridsystem.Theconverteriscoupled with either the output load or the external gridvia a resistor to guarantee that the system is adequatelystable. The planned system can be operated at any loadpercentage depending on the power need at the system'sloadend.Sincethevoltageisconstantlymaintainedconstant, this is accomplished by managing the currentnecessary to satisfy the given power demand. In the Thissection goes into more detail about the suggested controlmethods. A DC-DC converter links the solar source andthe load, or grid system. The converter is coupled witheithertheoutputloadortheexternalgridviaaresistorto guarantee that the system is adequately stable. Theplanned system can be operated at any load percentagedepending on the power need at the system's load end.Since the voltage is constantly maintained constant, thisis achieved by controlling the current necessary to satisfythegivenpower demand.

A. **Droop Control In Dc Networks**

InaDCsystem,adroopcontrollerisemployedastheguiding principle to parallel theconverters. keep the rightbalance of power between them. The error that occurs isremoved by the droop controller, in preserving the system'sratedconstantvoltage. Droopmanagement ispossible.

In many ways. Droop is typically regarded asa delay orreduction in the necessary voltage.at a specific point in time.Typically,thedelayorlossfromtheratedvoltageisconsidered the error signal that is sent in order to create thefeedback signal and the duty cycle signal for the converter'sswitch. When the external voltage is lower, the errorsignalisproduced.beyondwhatisnecessarytosatisfytheconverters'standards,suchastheoutputvoltageortherated voltage.In a different approach, the feedback signal isproducedbyavoltagedroopcontroller,whichemploysseveral converter signals as a source and a reference.Droopcontroltechniquesarefrequentlyemployedinmicrogridnetworks to preserve the rated voltage throughout the grid.Droopcontrolisusedtoregulatethepowerdistributionbetweenthegridsystemandtheconverters.Thepowerprovidedtocontrol voltagedroopttheerrorbetweentheconverters is tracked and the feedback signal is producedtaking place in the system. Generating units, energy storageunits,andinterfacecomponentsmakeupmicrogrids betweenthegridandtheconverters.Maintaininganequitableandeffectivepowersplitisnecessary.betweenthem for the microgrid system's effective stability. The powerexchanged is analysed, calculated, and a function of converterconstants and variables is produced. sent to the controller fordroop. To generate the error or to generate the mistake orfeedback,areferencevoltagesignalisusedsignalforthecontrollerofdroop.Typically,thesystem'sratedvoltageservesas the reference.

B. Droop Control For Dc Distribution Systems

ThestyleoftheDCmicrogridsflourishedastheuseofrenewableenergyincreasedsourcesusingphotovoltaicgenerationmethods,windenergygenerationtechnologies,improved integrated power systems and DCmicrogridinstallationinislandnetworksnetworks.DCmicrogrids can often function in both islanded and grid-connectedmodes.Themicrogrid'sgridconnectedoperatingmodeaidsinincreasingthereliabilityofthepowersupplyincreasestheefficiencyofdistributedgenerators,lessenstheeffectsoferraticpowersupply,and also raises the qualityof the power. To restorethestability of the energy storage units when the microgrid isin islanded mode, the system. Controlling voltage droop isused to the integrated systems connectedto the network can be more effectively shared power by microgridsystem.Alongwiththedroopcontrol,virtualimpedance control is also employed, although the outputcurrentmustbemeasuredandanalyzedbythecontrolmethod.aconvertercontrolfeatureTheoutputcurrentsensingiseliminatedusinganoutputvariable.Theredesigned droop controller includes the output variablesof the converter, which are related to the system's outputpower.

C. Droop characteristics of DC micro grid

In a DC network, the droop controller is used to keep thevoltageconstantandregulatethepoweraccordingtodemand.Thebasicprincipleistocontroltheconverter’soutput voltage in order to maintain the desired load power.The output current to the load and to the coupling resistorcan be changed, allowing the output power to the grid to beadjusted based on the required load percentage by adjustingthe output voltage of the converter. The entire model is builtaround the idea of keeping the voltage droop to a minimum.The proposed model’s droop curve is shown in Fig. 3. Thecurrent of the system is shown on theX-axis. The Y-axisrepresents theoutputvoltageof the converterviz.V_{DC1}andV_{DC2}.

The parallel voltage regulated module (VRM) application was the first to use the droop control mechanism [22]. The secondary controller contrasts the average detected outputcurrent (i0) with the actual sensed output current (ī0) of each VRM. When i0 is greater than i0, the comparator simplyoutputs a voltage correction term; otherwise, it outputs zero. The reference voltage for the primary controller is then created by subtracting the product of the fixed virtual resistance (R) and output current I from the δ0 reference voltage (Vo∗) and adding the result to the comparator output (V0), we get:

$$v^*_{ref} = v^*_o - \delta v_o$$
$$\delta v_o \quad = k_p + \frac{k_i}{s}(v^*_{ref} - v^*_o)$$

where,$K_p$isproportionalcontrollerand$K_i$isintegralcontroller.

Higher output current reduces the effectiveness of thisapproach,anditisunabletoproduceexcellentvoltageregulation acrosseachconverter'sload.

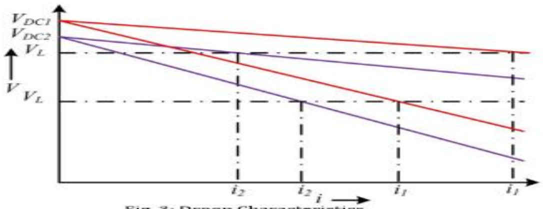


Fig. 3: Droop Characteristics

4.Load Sharing nd Circulating Currents Issue

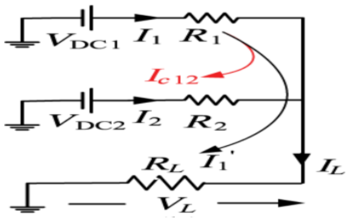


Fig.4 Parallel Equivalent Circuit For The Dc Output Side

Discussions are held regarding problems with parallel dc-dc converters linked to low-voltage dc microgrids. In Fig. 4,two parallel linked dc-dc converters that connect DC gridand PV arrays The output voltages, output currents, andcableresistancesofthedevicearerepresentedinthisfigure as V_{DC1}, V_{DC2}, I_1, I_2, and R_1, R_2. converters 1 and 2 aredesignated as Conv-1 and Conv-2, respectively. A voltagesourceinseries with thecableresistanceand itsequivalent might be used to represent the converter's output side. Itdisplays the circuit [12]. If I_{C12} is the case, $V_{DC1} > V_{DC2}$ Conv-1to Conv-2's circulating current component, and Case studiesforcurrentsharingandcirculatingcurrentbasedontheconverters outputvoltages and cable resistances are listed inTableI.

Table1 Circulating current, output voltages & resistance

Case	V_{DC1},V_{DC2}	R_1,R_2	I_1,I_2	I_{C12},I_{C21}
1	Equal	Equal	Equal	Zero
2	Equal	Different	Different	Zero
3	Different	Equal	Different	NotZero
4	Different	Different	Different	NotZero

A. Parallel Units Distributed Generators

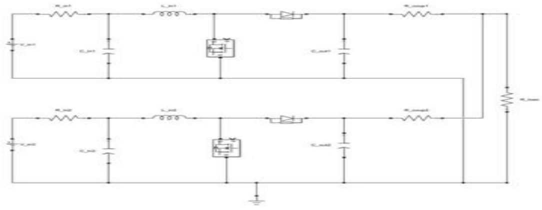


Fig. 5: Equivalent Circuit Diagram of Parallel Units

connections between the load and the output gridare made by two distributed generators. Using the system'sdroopcontrol,thepowersharingbetweenthetwogenerators is managed. In this case, converters 1, 2, and thegridallprovideelectricitytotheload.Evenifneitherconverteroperatesatfullcapacity,theoverallpowerdemand is distributed between the converters and the gridinanefficientmanner.Thesingleunitdistributedgenerator's construction is identical to that of the duty cycleand droop controllers.The functioning of the parallel unit iscomparable to that of the single unit. The power source forboth units is a photovoltaic generating system. To improvepowersharingamongsttheconverters,thedistributedgenerators are connected in parallel.The converter is usedto boost the voltage to the rated value. The controller ofboth units is set up in such a manner that it can produce therequired output power even if one of the units connected inparalleldoesnotoperateat full loadcapacity.

5.Results And Discussions

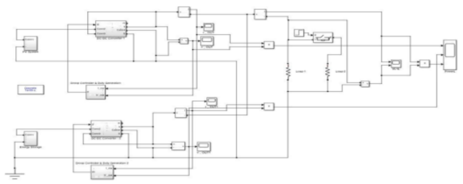


Fig.6:Simulink model of DC Microgrid with droop controller

The droop controller block is built using the derived droop equation as a basis. It generates the signal required for duty cycle generation based on the load demand. The value varies according to changes in output load power. A PWM generator in the duty cycle generator block produces the switching signal for the MOSFET switch. The duty cycle generator block is built using the standard duty cycle equation to avoid system instability issues. The duty cycle is given to the switch in order to facilitate the conversion activity of the boost converter.

A.Droop Controller Block

The fig.7 below shows the droop controller block,The output voltage and current are monitored in the droop controller block. The voltage and current across the load are given as the input to the droop controller. The droop controller is designed based on full load rating and hence the required output current. This block generates the required output voltage for the converter to maintain the rated voltage across the system. The calculated signal is given to a PWM. generator for the generation of the duty cycle to be given to the switch connected to the DC-DC converter. The components are made to produce output voltage and power at their rated levels. The proposed system is simulated using MATLAB/Simulink environment.Fig.6 shows the Simulink model.

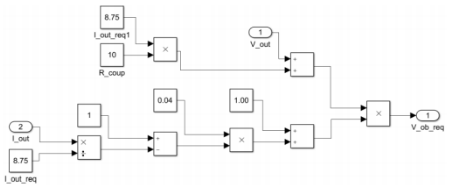


Fig..7. Droop Controller Block

B.Duty Cycle Generator Block

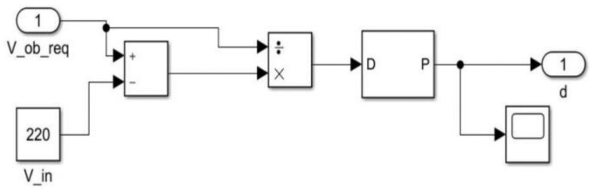


Fig 7. SIMULINK Model of the Duty Cycle Generator Block

In the duty cycle generator block, a PWM generator is used to generate the switching signal for the MOSFET switch. The standard duty cycle equation is used to build the duty cycle generator block to avoid instability issues in the system. The duty cycle is given to the switch to enable the conversion operation of the boost converter. The components are designed to obtain rated values of output voltage and power

The load and the output grid are both connected in parallel by two distributed generators. The system's droop control is used to regulate how much power is shared between the two generators. The way a parallel unit operates is comparable to how a single unit operates. Here, converters 1, 2, and the grid all share the electricity going to the load. Even if neither converter operates at full capacity, the overall power demand is efficiently split between the converters and the grid. The duty cycle generators and droop controllers are constructed similarly to single unit distributed generators. For the simulation parameters used are depicted in Table II.

Regardless of whether one of the parallel-connected units is not operating at full load capacity, the controller of both units is configured so that it can still generate the appropriate output power. The entire grid system is improved as a result, resulting in constant power delivery to the load. As a result, the system becomes less unstable and there is a lower chance of a blackout since the load power may be efficiently distributed among the converters.

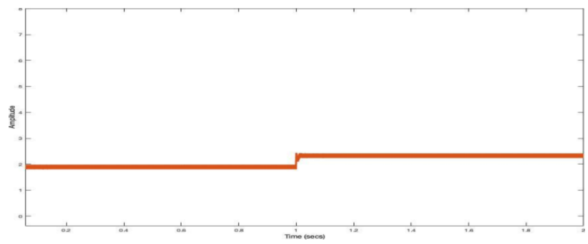
TABLE2: Table totest captionsandlabels

Sr.No.	Parameter	Rating
1	Source-1&Source-2	$V_{DC1}=V_{DC2}=110V$
2	GridBusvoltage	220V
3	Inductor(L)	$1mH$
4	Capacitor(C)	$1\mu F$
5	InternalResistances	$R_1=R_2=0.001$
6	Powers	$P_{L1}=800W$&$P_{L2}=200W$
7	PIController	$K_P=0.025$&$K_I=1.25$

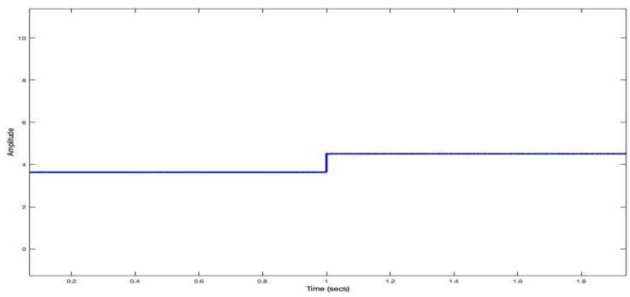
C. Power Sharing

In order to improve the power sharing across the converters, the distributed generators are linked in parallel.

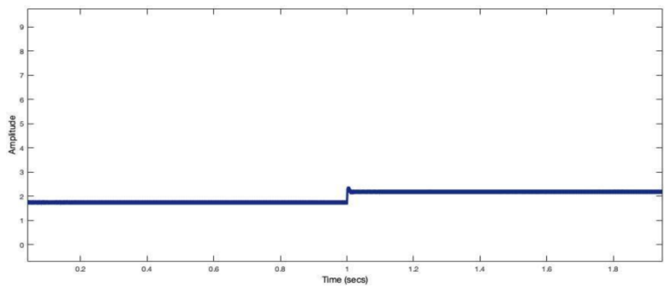
The converter raises the voltage to the specified level. The system's droop control is used to regulate how much power is shared between the two generators. The way a parallel unit operates is comparable to how a single unit operates. Here, converters 1, 2, and the grid all share the electricity going to the load. Even if neither converter operates at full capacity, the overall power demand is efficiently split between the converters and the grid. The duty cycle generators and droop controllers are constructed similarly to single unit distributed generators. Here, to demonstrate equal power sharing two cases are considered. Case 1 is considered to have a power of 800W; whereas case 2 is of 1000W (200W increased). The simulation results show that current is equally shared without burdening the converter or source, as shown in Fig. 8. From Fig. 9, it is seen that both converters will share equally, and during this time the bus voltage will be maintained at rated values. The output power of both converters and load power is also verified using the simulation with the help of aforementioned two cases and the results are shown in Fig. 1



(a)I_{DC1}



(b)I_{DC2}



(c) IDC

Fig. 8: Current waveform for converter 1 & converter-2 and load

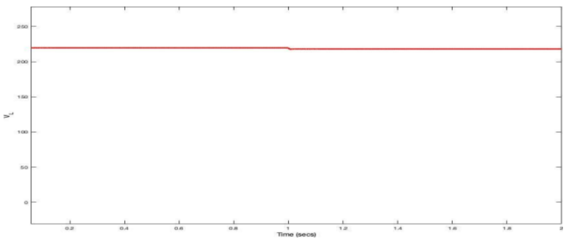


Fig. 9 : Load voltage during case-1 (PL1 = 800W) and case-2 (PL2 = 1000W)

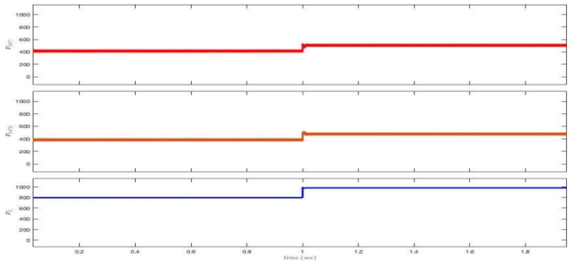


Fig.10 : Output power for case-1 (PL1 = 800W), case-2 (PL2 = 1000W) and load power

6.Conclusion

The proposed system uses droop control to regulate how much power is shared between the two generators. The way a parallel unit operates is comparable to how a single unit operates. Here, converters 1, 2, and the grid all share the electricity going to the load. Even if neither converter operates at full capacity, the overall power demand is efficiently split between the converters and the grid. The duty cycle generators and droop controllers are constructed similarly to single unit distributed generators. The simulation results demonstrate that the power is shared equally. Furthermore, it is seen that there is no burden on either of the converters, and equal sharing is done by both converters even after there is a change in load. This proposed system can be further designed and developed using advanced controllers to improve transient stability. Future work will concentrate on increasing the number of converters in the system, examining how well it performs when power is shared, and using alternative renewable energy sources as the main energy source for various distributed generator systems. To evaluate the system's effectiveness and efficiency,the proposed model's hardware implementation must also be used..

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