CIRCULATING CURRENT MINIMIZATION IN LOW-VOLTAGE DC MICROGRID BASED ON DROOP CONTROL STRATEGY

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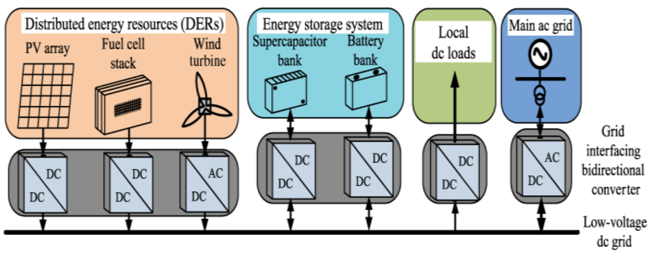
ABSTRACT *This paper addresses load current sharing and circulating current issues of parallel-connected dc–dc converters in low-voltage dc microgrid .microgrids can help overcome power system limitations, improve efficiency, reduce emissions and manage the variability of renewable sources.Droop index (DI) is introduced in order to improve the performance of DC micro grid, which is a function of normalized current sharing difference and losses in the output side of the converters.The proposed fuzzy based droop control method minimizes the circulating current and current sharing difference between the converters based on instantaneous virtual resistance .This results shows difference between pi and fuzzy and it is implemented using MATLAB/SIMULINK*

Keywords:

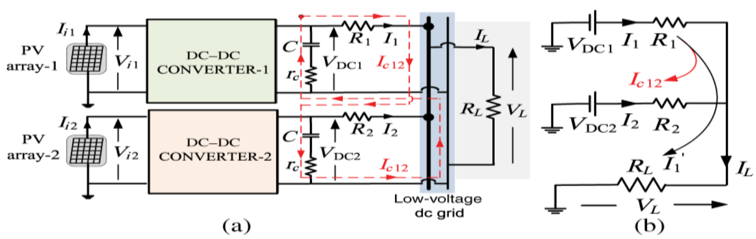
INTRODUCTION

The concept of Microgrid has been introduced for sustainable energy generation and proper utilization of small-scale distributed energy resources (DERs). When DERs such as solar, wind, and fuel cell are connected together, its energy management becomes important [1]. It is not necessary that these energy sources exist in the same site but can be scattered depending upon the ease of energy harness. Integrating DERs to a common ac or dc grid through power electronic interfaces gives flexibility in conversion and power level. One of the main advantages of microgrid is that, it can be operated in islanded or grid-connected mode [2]. Several effective control strategies have been developed and implemented to integrate DERs to existing power grid [3]–[5]. The control of ac microgrid deals with the power flow, load sharing, voltage regulation and mitigation of various kinds of power quality issues [6]; whereas, in dc microgrid, power quality issues such as reactive power and skin effect are not present. There are several control issues related to the microgrid, including interconnection schemes between DERs and common dc grid, voltage control among parallel converters, load sharing, maximum power point tracking, and energy storage [9], [10]. Among these, this paper focuses on the voltage control and load sharing between different DERs connected through dc–dc converters to a common dc microgrid. The problems associated with voltage control are poor load sharing and circulating current between converters [12]. The reasons for variations from the constant output voltage power,load,parametricvariations,and error in voltage and current feedback. The circulating current issue will arise if there is a mismatch in the converters output voltages. Several load sharing methods have been proposed in literature in which, most popular schemes are active current sharing [13], [14] and droop control methods. Droop control method is a decentralized voltage control method in which each converter output voltage reference is controlled based on its output current [15]. A droop current sharing method without any communication link between converters is explained in . In this paper, the calculation of maximum droop range for parallel-connected converters is explained. A novel droop method for converters parallel operation is reported in [18], in which peak output current is compared with current set value to control the reference voltage of each converter. This algorithm gives better performance only when the source supplies rated power because the droop gain values are calculated based on rated power. A dc bus signaling method (DBS) [19] can also be used for parallel operation of converters). This algorithm minimizes the mismatch in the converters output voltages due to droop method; however, the effect of cable resistance was not considered. A decentralized circulating current control method is proposed in [21], which is based on no-load circulating current values. This algorithm is inefficient for parallel operation of conventional boost converter in microgrid because no load operation is not possible. In order to improve voltage regulation, droop control with voltage shifting is reported in . The advantage of this method is that the magnitude of droop does not affect the output voltage of the converters.Animproveddroopcontrolmethodisalsodiscussed in [. In this method, conventional droop control with LBC and local controllers are used to achieve load current sharing and dc bus voltage restoration. An adaptive droop resistance (ADR) technique is proposed in for adaptive voltage positioning (AVP) control in dc–dc converters. The proposed ADR technique can vary the droop resistance to track the variation of the load current. Load sharing issues of an autonomous hybrid microgrid is explained based on ac and dc subgrids in [In this method, the active power flows within subgrids is brought to a common per-unit range for power sharing. A co-operative algorithm with a voltage regulator and current regulator is presented in . In this algorithm, the current regulator compares local per-unit current with the neighbours per-unit currents and, accordingly, adjusts the droop virtual impedance to balance the per-unit supplied currents. In literature, there are methods based on gain scheduling and fuzzy logic microgrid are poor voltage regulation, use of To overcome these limitations, an instantaneous droop calculation method is proposed in this paper. The calculation of droop values are based on a figure of merit called droop index (DI). This method gives better control over circulating current and proper load sharing in both transient and steady-state conditions.



II. LOAD SHARING AND CIRCULATING CURRENT ISSUES:

In this section, load current sharing and circulating current issues for parallel dc–dc converters connected to a low-voltage dc microgrid are discussed. Two parallelconnected dc–dc converters, which interface PV arrays and dc grid. In this figure, VDC1, VDC2, I1, I2, and R1, R2 represent output voltages, output currents, and cable resistances of converter-1 (Conv-1) and converter-2 (Conv-2), respectively. The output side of the converter can be represented as a voltage source in series with the cable resistance and its equivalent circuit is shown. If VDC1 >VDC2, IC12 is the circulating current component from Conv-1 to Conv-2 and I⍰ 1 is the load component from Conv-1. Case studies for current sharing and circulating current based on the converters output voltages and cable resistances are listed below.



a)DC–DC converters with different output voltages.
(b) Steady state equivalent circuit for the DC output side.

III. VOLTAGE CONTROL BY ADDING R_{droop}:

This section explains the sharing of converter currents by addingaseriesresistor Rdroop toeachconverter. Illustrates n numbers of dc–dc boost converters in parallel with first and jth converters, which interface different DERs and low-voltage dc microgrid with Rdroop. In this figure, S1 and Sj are the main switches, rDS is the main switch ON-state resistance, Vf is the cut-in voltage of diode, rf is the ON-state resistance of diode, L is the input inductor, rL is the ESR of inductor, C is the output capacitor, and rC is the ESR of filter capacitor. The voltages Vi1 and Vij are PV array output R_{droop} is implemented using virtual impedance method. By adding R_{droop1} and R_{droop2} the current sharing can be controlled and thus circulating currents can be minimized to some extent. Then the resultant signal is subtracted from the reference voltage of each corresponding converter give new voltage reference signal.

$$V_{DC\ new} = V_{DC} - I R_{droop}$$

But this method has still got drawbacks as it's a fixed value and therefore the voltage regulation will be poor.

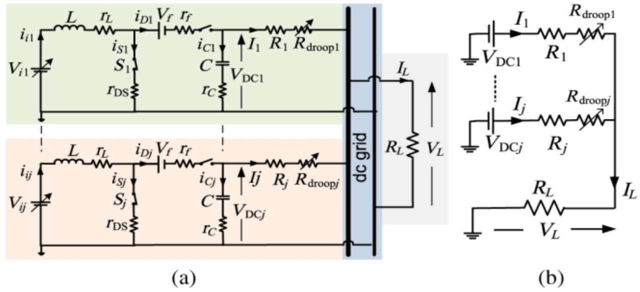


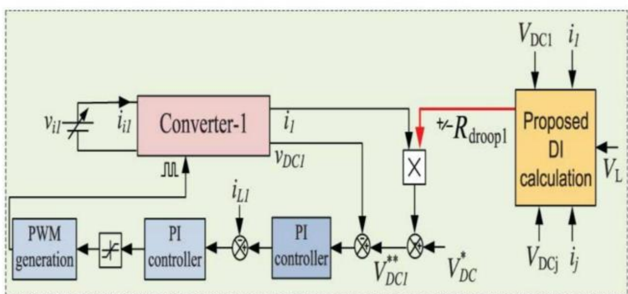
Fig3.1: Equivalent circuit for DC output side with R_{droop}

CONTROL DIAGRAM OF PARALLEL CONVERTERS WITH $\boldsymbol{R_{droop}}$ calculation

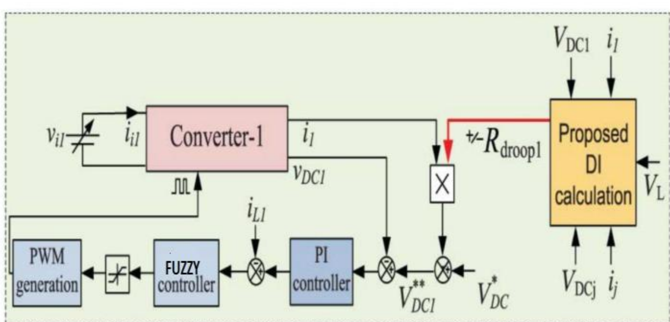
IV. PI CONTROL METHOD BY DI CALCILATION:

DI CALCILATION:In parallel-connected system, as given in (5), the circulating current becomes zero if the current sharing is proper. Simultaneously, insertion of the series resistor will cause the drop in the converter output voltage. Therefore, the proposed DI is taken as function of normalized current sharing difference and output power loss and is given as

$$\mathrm{DI} = \min\left[\frac{1}{2}\left[|I_1 - I_2|_{\mathrm{N}_i} + (P_{\mathrm{loss}})_{N_p}\right]\right]$$



Proposed system



Reference speed / Error	VVL	VL	L	LL	ML	N	H
NB	Z	Z	Z	Z	S	N	ML
NM	Z	Z	Z	S	N	ML	LL
NS	Z	Z	S	N	ML	LL	L
Z	Z	S	N	ML	LL	L	VL
PS	S	N	ML	LL	L	VL	VVL
PM	N	ML	LL	L	VL	VVL	VVL
PB	ML	LL	L	VL	VVL	VVL	VVL

RESULTS;

Consider two converters as two voltage sources which give different output voltages which are taken as V_{DC1}, V_{DC2}. The output currents are taken as I_1, I_2 .The circulating currents which is the difference between the two currents are take as I_C. In this unit we are comparing the results between PI controller and fuzzy controller.

CASE 1: WITHOUT ANY DROOP CONTROL :

SIMULATION RESULTS WITHOUT ANY DROOP METHOD

Time(s)	V_{DC1},V_{DC2},V_L (V)	$I_L(I_1, I_2)$ (A)	ΔI_{err} (%)	I_C (A)
0-0.1	48,48,47.75	4(2,2)	0	0
0.1-0.3	48,48.48,47.95	4(0.1,3.9)	95(3.8A)	1.9
0.3-0.5	48,48,47.75	4(2,2)	0	0
0.5-0.7	48,47.52,47.6	4(3.9,0.1)	95(3.8A)	1.9

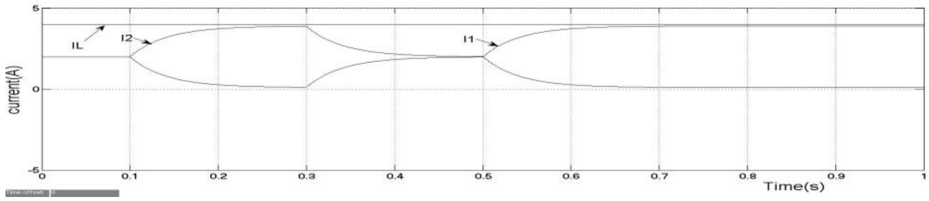


Fig.5.3 Output currents with pi controller

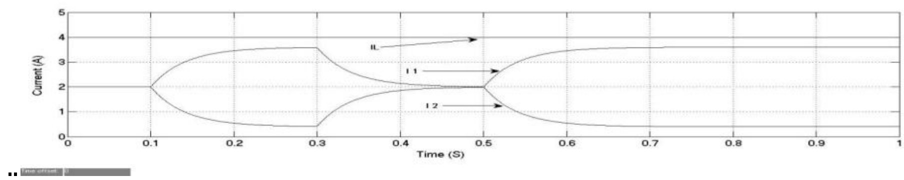


Fig.5.4 Output currents with fuzzy controller

In this case, the load current remains same. The currents I_1 reduces from 3.9A to 3.6A and the current I_2 reduces from 0.9A to 0.6A.

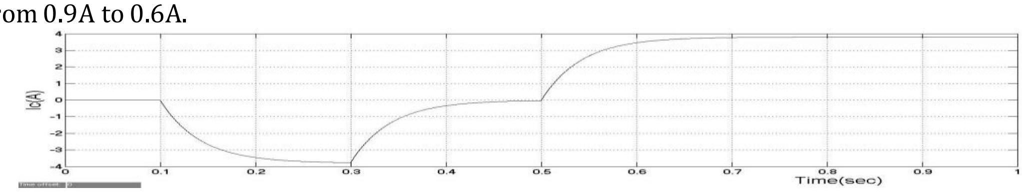


FIG 5.5 Circulating current of PI controller.

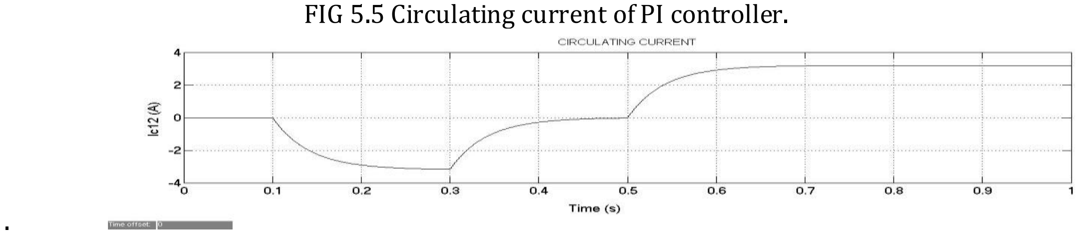


FIG 5.6 Circulating current of Fuzzy controller.

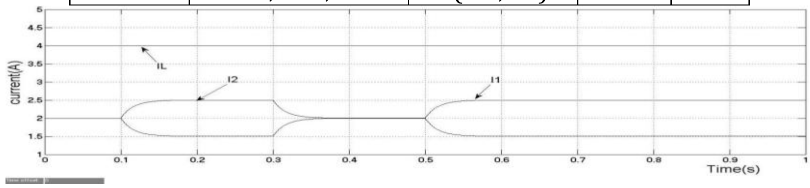
The circulating current I_{c12} reduces from 3.9A to 3.6A from PI controller to Fuzzy controller.

Case-2: FOR SAME CABLE RESISTANCE:

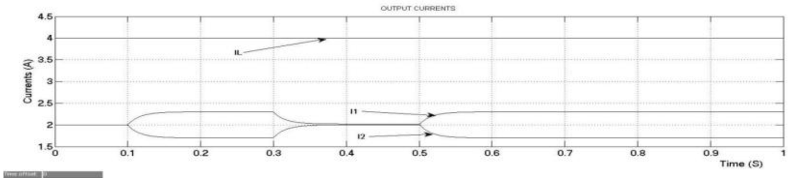
SIMULATION RESULTS WITH $R_{droopnew}$ FOR SAME CABLE RESISTANCE

Time(s)	V_{DC1},V_{DC2},V_L (V)	$I_L(I_1, I_2)$ (A)	ΔI_{err} (%)	I_C (A)
0-0.1	48,48,47.75	4(2,2)	0	0
0.1-0.3	47.5,47.65,47.35	4(1.5,2.5)	25	0.12

0.3-0.5	48,48,47.75	4(1.95,2.05)	1.25	0.02
0.5-0.7	47.25,47.1,46.95	4(2.5,1.5)	25	0.12



5.9 output currents of PI controller



output currents of Fuzzy controller.

In this case, the load current remains same. The currents I_1 reduces from 2.5A to 2.3A and the current I_2 reduces from 1.9A to 1.5A.

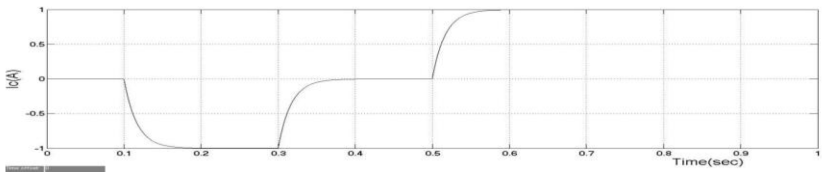


FIG 5.11 Circulating current of PI controller.

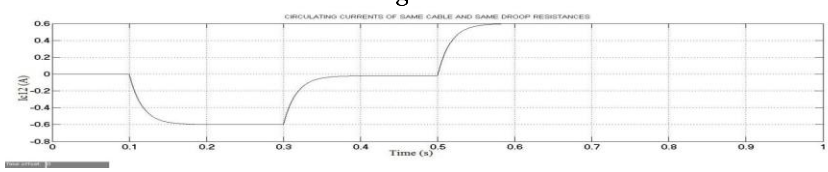


FIG 5.12 Circulating current of Fuzzy controller

The circulating current I_{c12} reduces from 1A to 0.6A from PI controller to Fuzzy controller.

Case 3: FOR DIFFERENT CABLE RESISTANCE:

SIMULATION RESULTS WITH $R_{droopnew}$ FOR DIFFERENT CABLE RESISTANCES

Time(s)	V_{DC1},$V_{DC2,}$$V_L$ (V)	$I_L(I_1,I_2)$ (A)	ΔI_{err} (%)	I_C (A)
0-0.1	48.3,48.3,48.1	4(2.2,1.8)	0.1	0.03
0.1-0.3	48.4,48.4,48.2	4(2.2,1.8)	0.1	0.03
0.3-0.5	48.3,48.3,48.1	4(2.2,1.8)	0.1	0.03
0.5-0.7	48.2,48.2,48	5(2.2,1.8)	0.1	0.03

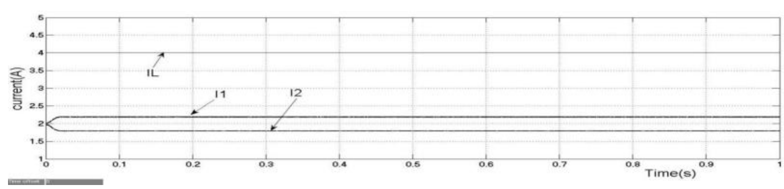


FIG 5.15 output currents of PI controller

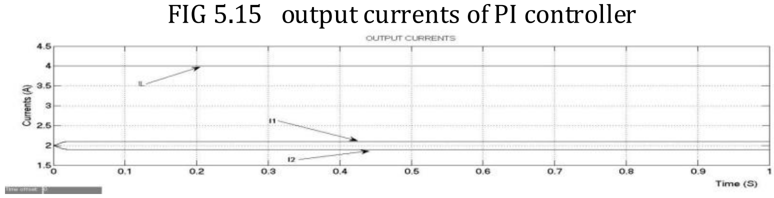


FIG 5.16 output currents of Fuzzy controller.

In this case, the load current remains same. The currents I_1 reduces from 2.4A to 2.1A and the current I_2 reduces from 1.9A to 1.7A.

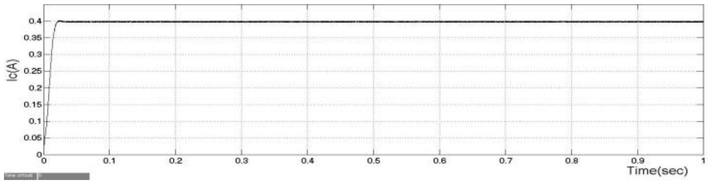


FIG 5.9 Circulating current of PI controller.

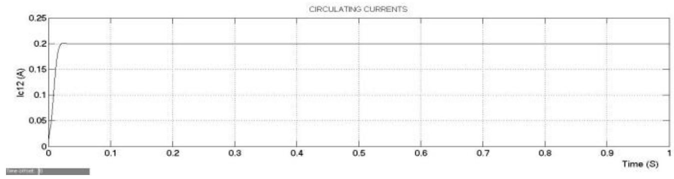


FIG 5.9 Circulating current of Fuzzy controller.

The circulating current I_{c12} reduces from 0.4A to 0.2A from PI controller to Fuzzy controller.

Conclusion :

In this project, the DI method for parallel dc–dc converter operation in low-voltage dc micro grid is proposed. This method calculates the virtual resistance R_{droop} positive or negative values instantaneously based on the converter output voltage deviation. This fuzzy gives proper load current sharing, decreases circulating current between the converters, and improves the load voltage. The effects of converter cable resistances are also taken into account to verify the viability of the fuzzy based DI method.

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