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A hybrid ac/dc microgrid manages power for its bidirectional interallied converters using a localized distributed fuzzy logic controller

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Abstract: The Bidirectional Inter-Allied Converter (BIAC) is a key component of hybrid AC/DC microgrids as a bridge unit that facilitates power transfer between AC and DC subgrids. Instead of using a single BIAC, a power management strategy for the BIAC community is suggested as an extension of the concept of power sharing. To create the proper power references, a well-designed localised distributed fuzzy logic controller (LDFLC) is assigned to each BIAC in this control method. Each subgrid's rated capacity determines how much electricity is allocated to it, which significantly enhances dependability and scalability. The Matlab/Simulink platform, which is used to test the stability analysis of the power management plan, also incorporates the concepts of balanced power sharing, bidirectional power flow, and communication time delay. A power management controller is recommended in this paper In order to increase efficiency in the hybrid distributed generating system, Bidirectional Inter-Allied Converter (BIAC) is constructed using LDFLC and compared to Proportional Integral based localised distributed controller (PILDC).

Keywords: hybrid AC/DC microgrid; bidirectional inter-allied converter; localised distributed fuzzy logic controller

1 Introduction

Development of hybrid AC-DC microgrids (HADMs) has been increased day-by-day, since they have the combined advantages of both the AC and DC microgrids [1]. To reduce the losses correlated with conversion stages and for economical operation of microgrid, AC, DC sources and loads are united to consequent buses. All around the world, many projects were demonstrated on HADM systems (Morozumi et al., 2008). In practical, to build any HADM, bridging unit called BIAC plays a major role which couples both the AC and DC buses[2]. In order to meet the consumer load, more number of distributed renewable energy sources were integrated into the microgrid leads to rise in capacity levels of individual subgrid present in the HADM (Pabbuleti and Somlal, 2020). Due to increase in capacity of the hybrid microgrid large power interactions occurs between the subgrids, this may lead to high

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power through BIAC [3]. To overcome the above aforementioned problem and to progress the grid performance with high scalability and redundancy is, use of multiple BIACs instead of frequent upgrade of single BIAC [4]. Using multiple BIACs the power can be shared based on their ratings to avoid stress with single BIAC.

Many power management strategies were implemented for single BIAC and are quite different for multiple BIACs and involve many challenges [5]. Most of the published work represents mitigation of circulating currents among BIACs, which cause high power losses and in result damages the power devices of the BIAC [6]. For successful suppression of circulating currents, researchers proposed many control strategies. Among them, few are, an inductor method is implemented in Asiminoaei et al. (2008), which creates zero sequence impedance to suppress circulating currents and a real-time control strategy was implemented in Chen (2011) to reduce the circulating currents produced in multi-paralleled converters connected between AC and DC buses using pulse width modulation technique [7]. A switching constraint strategy with simplified pulse-width modulation was proposed in Liao and Chen (2014) to decrement circulating currents using conventional control with low parallel converter system cost [8]. A strategy with zero sequence voltage modulation was proposed in Zhu et al. (2016), to effectively suppress the circulating currents by reducing the difference in zero sequence voltage for every switching cycle [9].

From the above discussions it is clear that the centralised method of control concentrates only on equal sharing of power among BIACs [10]. It does not consider the rating of BIACs and if a latest BIAC is installed in the community the central controller must be reprogrammed which affects the system efficiency and plug-and-play (pnp) property. In case of decentralised method of control [11], BIACs allow power to transfer in one direction i.e., either from DC to AC or AC to DC and it forms like a barrier for the expansion of HADM systems [12]. A distributed power management strategy for a two level BIAC community using conventional PI controller was proposed in Lin et al. (2019) overcoming the above aforementioned problems for global power sharing. But a communication delay was observed and the power through BIACs takes much time to reach steady state by affecting the system stability. So as to improve the system stability and pnp property by maintaining balanced and bidirectional power flow, a novel method of control is proposed using LDFLC. Moreover, when the controller of the newly installed BIAC tuned locally without reporting central controller [13], the BIAC joins directly to BIAC community and starts power transmission [14]. Section 1 presents introduction followed by configuration of HADM in Section 2. Section 3 realises the BIAC community and Section 4 presents implementation of proposed LDFLC followed by results and conclusion in Sections 5 and 6.

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1. Configuration of HADM with individual subgrid operation

HADM with renewables such as Photo-Voltaics and Wind Turbines, Energy Storages and Diesel Generators uses as backup, Resistive Loads and Motor Drives as constant power loads is shown in Figure 1. In the typical layout of HADM, AC sources were allied to AC bus[15], DC sources were united to DC bus and the BIAC community with multiple BIACs were united in parallel to form a bridging unit between AC and DC bus (Lin et al., 2019).

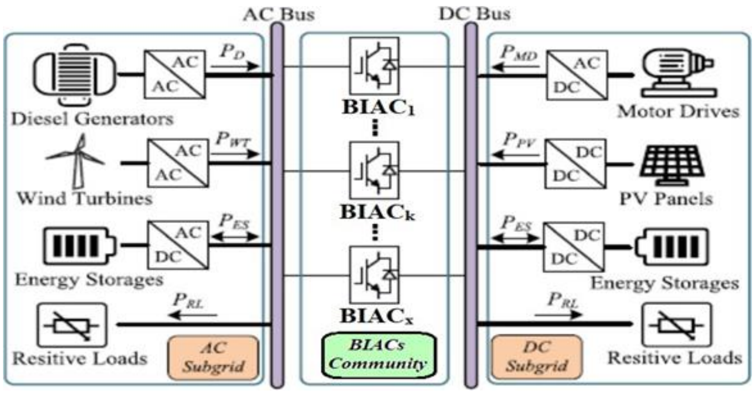
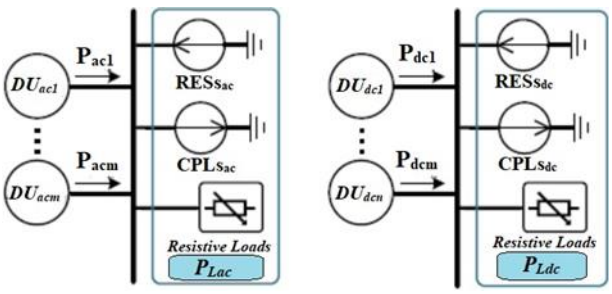


Figure 1 Configuration of autonomous HADM (see online version for colours)

To easily understand the operation of autonomous HADM, individual study of each subgrid is necessary. Figure 2 shows the simplified schematic of each subgrid individually. To analyse each subgrid independently, except renewables remaining all the energy sources exist in the hybrid AC/DC microgrid were considered as dispatched units operates under droop control methods whereas renewables, constant power loads and resistive loads were combined to form a lumped load.

Figure 2 Simplified representation of individual subgrids: (a) AC sub grid and (b) DC sub grid (see online version for colours)



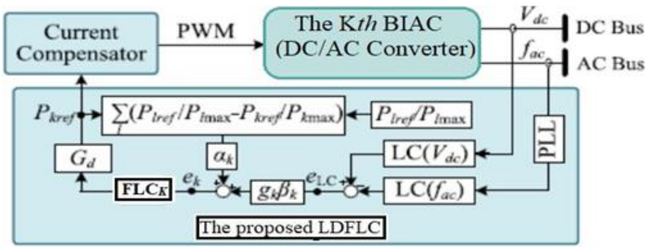


Figure 3 Proposed LDFLC control diagram (see online version for colours)

4 Implementation of proposed LDFLC

From Figure 4, the power references from LDFLC are sent to current compensator which generates PWM signals to drive corresponding BIAC switches. A BIAC with large capacity may have lower switching frequency, which results delay in control. Hence inductive filters with large value are required to suppress higher order harmonics.

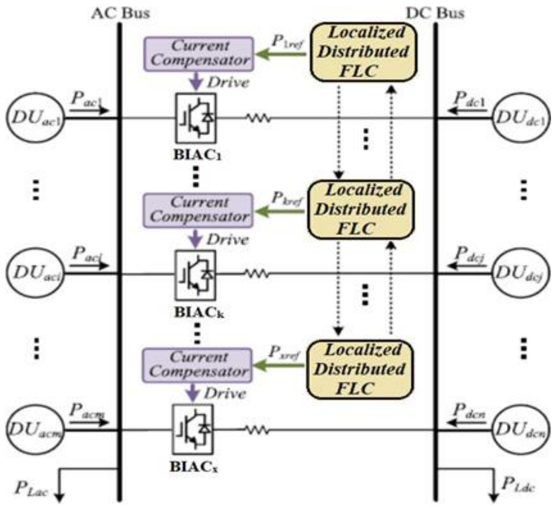


Figure 4 Power management strategy for BIAC community (see online version for colours)

So, to avoid discontinuity, the shape of membership function is restricted to triangular, trapezoidal, quantised, and sinusoidal or bell shaped etc. A trapezoidal membership function of one input variable i.e., error denoted as ‘e’ output variable denoted as ‘o’is shown in Figures 5 and 6 respectively.

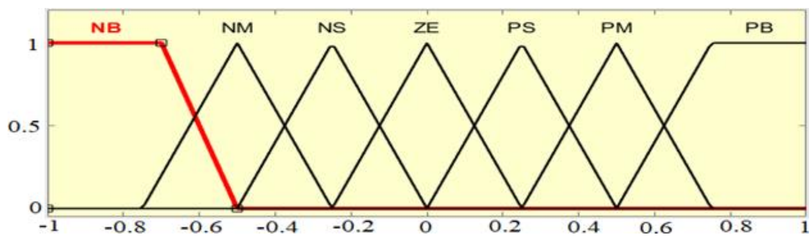


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Figure 5 Trapezoidal membership function of one input variable error (see online version for colours)

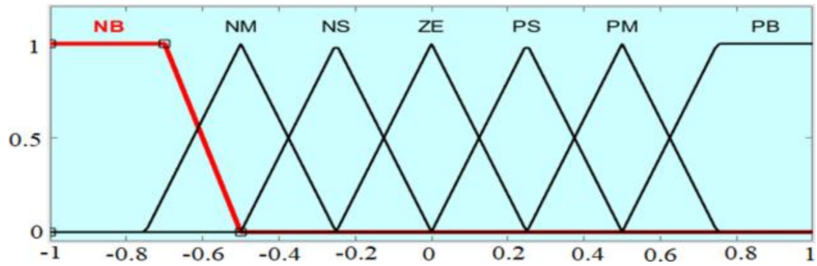

Figure 6 Output membership function of fuzzy logic controller (see online version for colours)

Generation of power reference by the fuzzy logic controller process two error inputs is independent of line impedance are enforced to zero to achieve global power sharing in the proposed power management strategy. Hence, no matter whether the impedance connected between BIAC community and buses. To generate proper power references, the two inputs error (*e*) and rate of change of error (Δ*e*) are arranged in a suitable way.

Table 1 Fuzzy logic rules for the proposed work

e Δ*e*	*NB*	*NM*	*NS*	*ZE*	*PS*	*PM*	*PB*
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

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The output of the inference process so far is a possibility distribution of control action. The control action generated by LDFLC gives power reference to the current compensator, which produces gate signals to drive BIAC. So that the power reference tracks the real power flow through BIAC.

5 Results

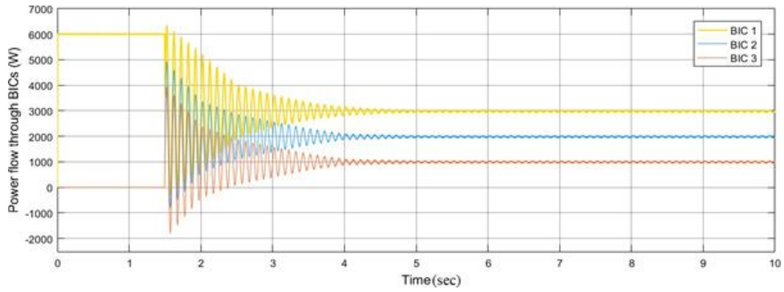
For affective validation of the proposed fuzzy logic controller based localised distributed control in HADM using MATLAB/Simulink platform, the following four cases are considered and are put side by side with conventional PI controller based localised distributed controller (LDC). Case 1 explains the pnp function of BIACs. Case 2 demonstrates the leading role of $BIAC_2$ due to the failure of $BIAC_1$. Case 3 explains the property of bidirectional power flow of BIACs and case 4 show the performance of system stability with the increased value of □*d* . Based on standard residential voltage in India i.e., rms 220/50 Hz, ac voltage amplitude is 220 □ 1.414 = 311 V. To bridge and for proper interaction of power between both the buses AC and DC, the DC bus voltage can be selected as more than that of ac voltage amplitude. In the proposed work DC bus voltage can be chosen as 710 V. For validating the results of the proposed work the system parameters to be considered is presented in Table 2.

Table 2 System parameters of the proposed work

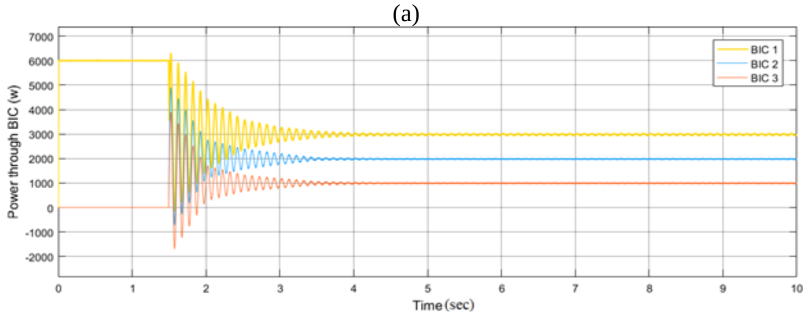
Parameter	*Description*	*Value*
vdc	DC Bus Voltage	700 V
fac	AC Bus Frequency	50 Hz
vdcmax	Maximum dc bus voltage	710 V
vdcmin	Minimum dc bus voltage	690 V
facmax	Maximum ac frequency	51 Hz
facmin	Minimum ac frequency	49 Hz
p1max	Power rating of BIAC1	6 KW
p2max	Power rating of BIAC2	4 KW
p3max	Power rating of BIAC3	**6** KW

Figure 11 Results with PILDC for different values of time delays: (a) τ_d = 0.5 s; (b) τ_d = 0.8 s and

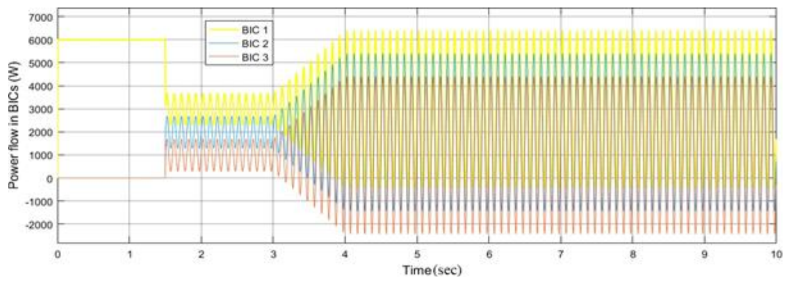
(c) τ_d = 1 s (see online version for colours)



(a)



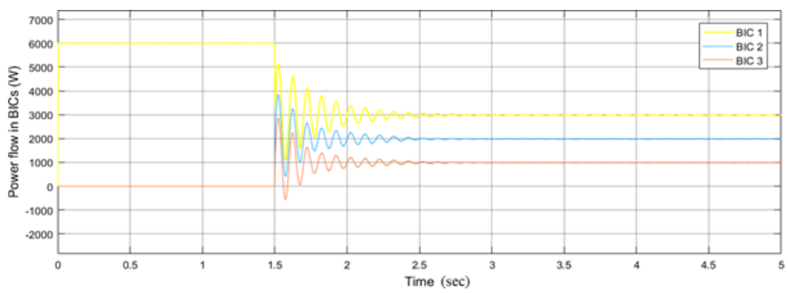
(b)



(c)

Figure 12 Results with LDFLC for different values of time delays: (a) τ_d = 0.5 s; (b) τ_d = 0.8 s and

(c) τ_d = 1 s (see online version for colours) (continued)



(b)

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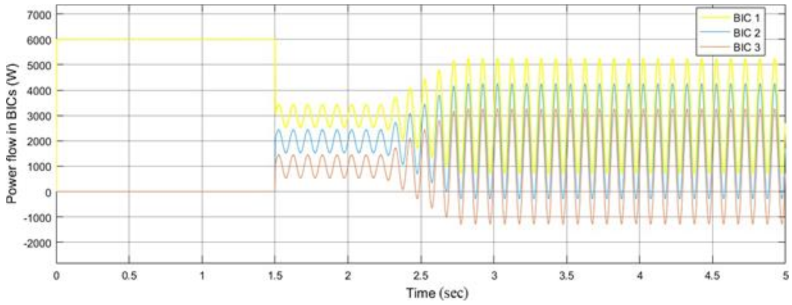

(c)

6 Conclusion

An islanded HADM microgrid's BIAC community's power management using a fuzzy logic controller has been proposed in this study. The suggested controller integrates bus-signaling and FLC technologies to regulate the flow of power between various energy sources. The multi-parallel BIAC community in the HADM is effectively added to by the suggested power management method. A brand-new LDFLC convokes each BIAC to create its own power reference. According to the BIACs' power ratings, the bidirectional power flowing between the two subgrids can be precisely allocated using FLLDC. such that GPS in HADM can also be accomplished and BIACs are protected from Using a linearized tiny signal model, the effects of time delay on HADM system stability are also examined. The results of the PILDC and LDFLC were validated and compared for the efficacy of the suggested power management method using MATLAB/Simulation overstress. A structured design for a current compensator is shown to improve system modularization and communication.

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