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Optimal Hybrid AC/DC Microgrid Operation with Multi-Bus DC Sub-Grid

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Abstract: In this study, identical distributed generation has been used to preserve the power system's economic operation and incremental cost management. In order to equalise incremental cost, a droop control mechanism based on incremental cost is adopted for synchronising the sub-grid's DC bus voltage & AC bus frequency. This configuration of a hybrid (alternating current/direct current) AC/DC Micro grid (MG)DC sub-grid (SG) is initially designed. Droop technique, however, results in variations in AC bus fervency and dc bus voltages. Second, a suggested and realised distributed fuzzy logic control architecture with incremental cost-based droops allows uncertainly dispersed generations to interact with their neighbour ones, therefore lowering communication weights and improving the performance of the uncertain system. Because the suggested architecture includes a fuzzy logic controller, the transient behaviour of architecture, the system's voltage and frequency exhibit less transient behaviour and quickly achieve steady state. Additionally, all distributed generations' additional costs are equalised. MATLAB/Simulink is a platform that is used to demonstrate the effectiveness of planned control strategies and to validate outcomes.

Keywords: Economic operation, DG (Distributed Generation), Incremental Cost (IC)based droop, Multi-Bus System (MBS).

1. Introduction:

The latest report of Indian government on climate change has painted a dire picture of earth and mankind's future global warming. It will be impossible to keep it minimal unless greenhouse gas emissions are quickly and drastically reduced. The solution to the problem is large scale usage of renewables for electricity generation to meet the world's largest energy crisis. To integrate huge renewables into system, the only way is distribution generation (DG). The affective way to take advantage of a greater number of DGs is microgrids [1]. Configurations such as DC micro grids and AC networks have been created in the last several years. Hybrid AC/DC MGs are developed to combine

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the advantages of both (Alternate current & distribute current) AC& DC MG's and also to avoid the multiple conversions [2]. Power converters play a major role and forms as a bridging unit in distribution generation for power exchange [3]. Hybrid ac/dc MGs functioned as in grid linked mode and also in autonomous or islanded mode [4]. Much research has done in the area of operating challenges i.e power management strategies among power converters and DGs [5]. At present, more attention on economic operation of microgrid is also required.

Generally, for working of Hybrid AC/DC MG's autonomously, the general two control methods considered are master/slave method [6] and peer to peer control method [7]. In case of

master/slave method, a reference DG acts as master and coordinates all the remaining DGs for balanced power flow. Whereas peer to peer control method also adopts same strategy for power balance but uses droop method for frequency and voltage restoration i.e control of real and reactive power. In past, many researchers worked on economic operation strategies and proposed different iterative methods such as a Linear programming based method [8] to linearized the non-linear cost equation which is computationally expensive as well as unreliable, a Lagrangian Relaxation method [9] by decomposing large problem to few sub problems for easy solving and to obtain optimal solution, (Fast Newton Raphson Method)FNRM [10] using a Quadratic Programming approach to incorporate flow constraints and emissions costs by changing the Jacobian matrix at each step [11] formulated Objective operation based on unit expenditure curve for optimal solution, a genetic algorithm equipped with multiplier updating for efficient searching and explored the solutions actively, and new self-organizing particle swarm optimization method to handle premature convergence problems assuming no convexity for optimal solution. All these optimization methods are accurate and controllable but suffer from single point failure issues with high communication and computational burdens.

2. Configuration of Hybrid AC/DC MG's with Multi-DC Bus Sub Grid (SG):

An AC/DC hybrid motor generator with numerous DC motors is seen in Figure 1. One Alternating Current(AC) subgrid and one Direct Current(DC) subgrid with three DC buses make up this system. The bus voltages for three DC buses are 700V, 380V and 1000V respectively. To interlink all the subgrids Bidirectional Inter-Allied Converter (BIAC) plays a major role for power interaction and acts as bridging unit. Three BIACS are required for the proposed configuration and are named as BIAC1, BIAC2 and BIAC3 respectively which were operated in power control mode. BIAC1 acts as a bridging unit for DC subgrid 1 AC subgrid, BIAC2 and BIAC3 connect DC subgrids 2 and 3 to DC subgrid 1, respectively, so that they may communicate with one another. The local loads of individual subgrids are represented as PLDC1, PLDC2, PLDC3, and PLAC.

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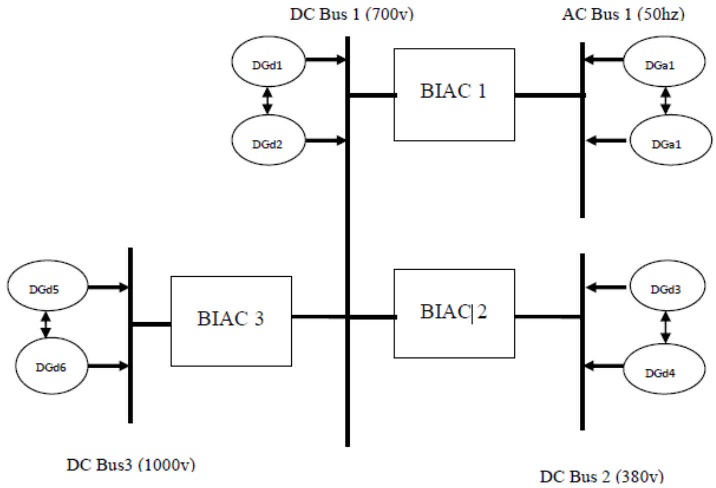

Figure.1 Proposed system (Hybrid AC/DC MG's with multi-Dc buses)

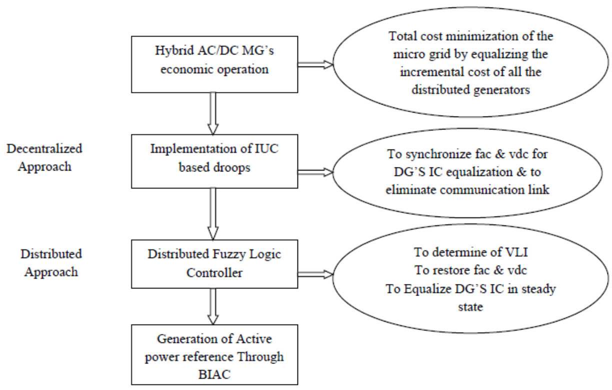

Figure 2: Representation of Hybrid AC/DC MG's control architecture

3. Proposed Uncertain Distributed Fuzzy Logic Control Architecture

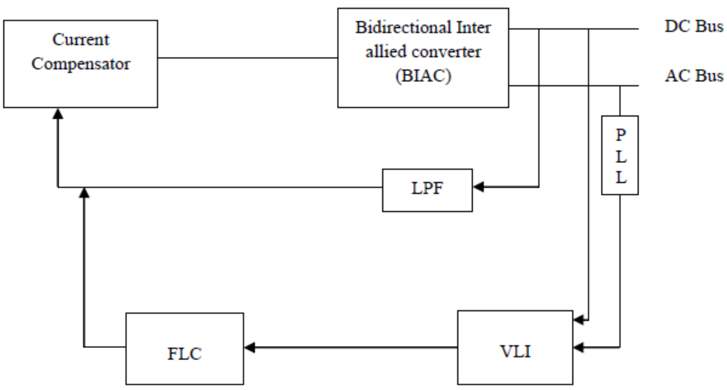

Figure. 3 Proposed distributed architecture for BIAC using fuzzy logic controller

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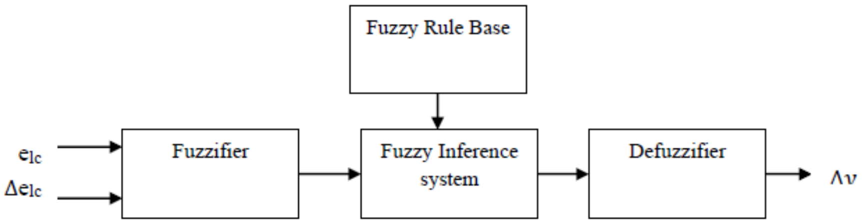

Figure. 4 FLC Block diagram

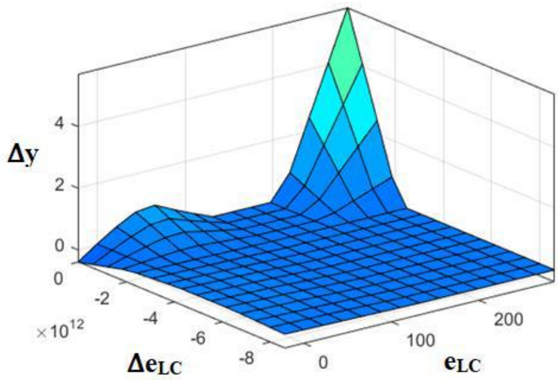

Figure 6 surface view fuzzy logic controllers with input and output

In the proposed work 25 if-then fuzzy rules are formed by relating input variables to output variable presented in Table 1 and There are four types of parameters: Negative Large (NL), Negative Small (NS), a value of Zero (ZR), & a value of positive small (PS) (PL). These are arranged based on their triangular membership functions using AND operator. Hence the fuzzy outputs of the inference system are de-fuzzified by using the most commonly used Centroid method.

Table 1 Fuzzy logic with input & output parameters

eL ΔeL	@NL	@NS	@ZR	@PS	@PL
@NL	@PS	@PS	@ZR	@ZR	@ZR
@NS	@PS	@PS	@ZR	@ZR	@ZR
@ZR	@PS	@PS	@ZR	@ZR	@ZR
@PS	@PS	@PS	@ZR	@ZR	@PL
@PL	@NL	@PS	@ZR	@ZR	@PL

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The output of fuzzy logic controller generates power reference which helps to drive the converter circuit for proper power interchange through BIAC. The process continues until the existence of difference in VLI values of both the subgrids for IC value equalization.

1. Results

Matlab/Simulation is used to test the commercial functioning of a hybrid ac/dc microgrid with multi-bus DC subgrid, and the findings of recommended control architecture are validated. The system requirements for the proposed task are shown in Table 2.

Table 2 System specifications

Parameter	Description	Value
# Vdc1	DC Bus 1 Voltage	700V
#Vdc2	DC Bus 2 Voltage	380V
#Vdc3	DC Bus 3 Voltage	1000V
#fac	Frequency of AC bus	50Hz

For normal operation of the microgrid system the AC bus frequency should be maintained as 50Hz is plotted in Figure 7. Figure 8 depicts the voltage level on DC bus 1 being maintained at 700V despite rapid load fluctuations at various instants of time. Figure 9 and Figure 10 illustrate the voltage level on DC bus 2 and DC & 3 respectively, with 380V and 1000V, respectively.

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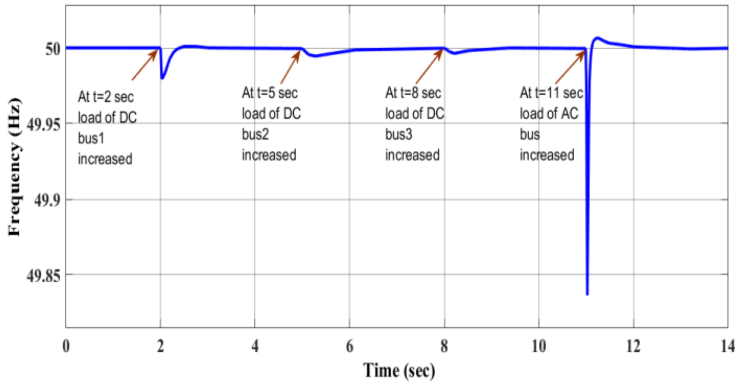

Figure.7 AC bus frequency of microgrid system

Figure 7 shows that the AC bus frequency has to be kept at 50 hertz in order to ensure that the microgrid system operates properly.

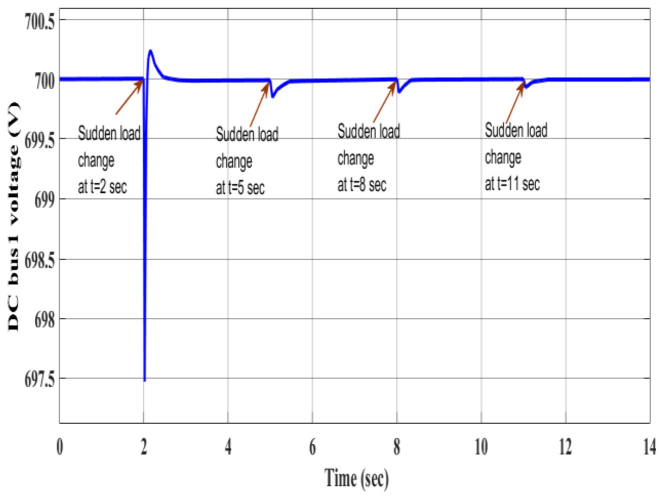

Figure. 8 Voltage level of DC bus 1

Figure 8 shows that the voltage level on DC bus 1 is maintained at 700V despite rapid fluctuations in the load at various points in time.

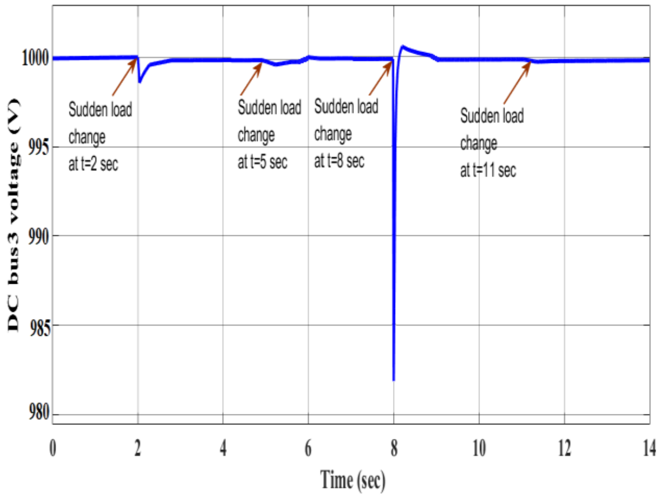

Figure.10 DC Bus 3 Voltage level

Figure.10 shows the voltage level on DC bus 3 is maintained at 1000V despite rapid fluctuations in the load at various points in time.

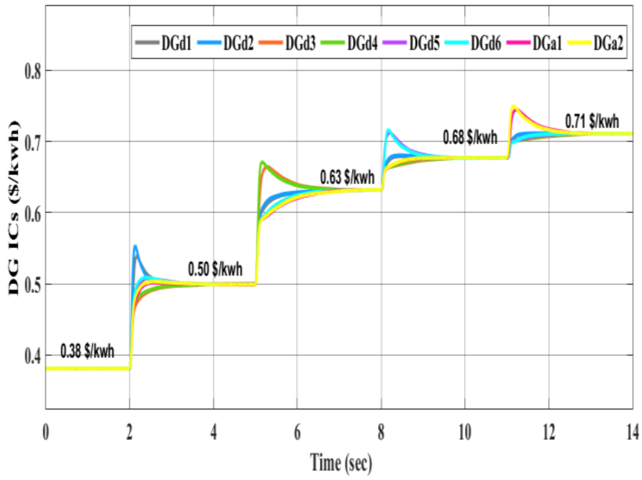

Figure.11 IC values of all DG's in Hybrid ac/dc microgrid configured with uncertain multiple DC bus

Figure.11 shows the IC values of all DG's. From t=0 to 2sec IC values of all DG's present in the hybrid microgrid read as0.38 $/kwh. As the load increases gradually at different instants of time i.e at t=5sec, 8sec, and 11sec the DG's IC values read as 00.50 $/kwh, 00.64$/kwh, 00.68$/kwh and 00.71$/kwh by maintaining IC value equalization.

5. Conclusions

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In order to efficiently operate hybrid AC/DC MGs with multiple DC bus systems, this research provides an uncertain IC droop-based distributed control framework using fuzzy logic controllers. For all DC buses and AC bus systems, the distributed control structure uses IC droops to ensure steady state voltage. It is common knowledge that droop schemes cause voltage and frequency swings in response to rapid changes in load. In order to ascertain the unobserved loading condition as well as to equalise the IC values of all the DGs, even those present in hybrid c/dc MG, a distributed control structure with fuzzy logic controller incorporating the value of VLI is presented. Power reference can be produced by comparing the VLI values of the two subgrids using fuzzy logic BIAC controller to power it. Equivalent IC values for all of the DGs are produced by properly scheduling the BIAC, which demonstrates the practical operation of hybrid AC/DC MGs. Impact of communication time delay is also taken into account in the control structure of the MG's to enhance overall system stability. Lastly, the outcomes of the MATLAB/Simulation demonstrate the practicality and effectiveness of the proposed uncertain system.

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