Journal of Engineering Sciences

Vol 10, Issue 11, NOV/2019

ISSN NO:0377-9254

FUZZY BASED AUTONOMOUS POWER MANAGEMENT FOR AC-DC MICROGRIDS

[1]**B.SIDDESWARA**, P.V.K.K INSTITUTE OF TECHNOLOGY, ANANTAPURAMU.
[2]**S.V.SIVANAGARAJU,** ASSOCIATE PROFESSOR, P.V.K.K INSTITUTE OF TECHNOLOGY, ANANTAPURAMU.

ABSTRACT: Several control schemes are designed with the intension of sharing power among the interlinked microgrids based on their loading conditions, while other schemes regulate the voltage of the interlinked microgrids without considering the specific loading conditions. However, the existing schemes cannot achieve both objectives efficiently. For this, an autonomous power management scheme is proposed, which explicitly considers the specific loading condition of the DC microgrid before importing power from the interlinked AC microgrid. This facilitates voltage regulation in the DC microgrid, and also reduces the number of converters in operation and is fully autonomous while it retains the plug-n play features for generators and tie-converters. The fuzzy logic controller is used in the control scheme to regulate the errors and oscillations. The performance of the proposed control scheme has been validated under different operating scenarios. The results demonstrate the effectiveness of the proposed scheme with fuzzy controlling in regulating the power deficit in the DC microgrid efficiently and autonomously while maintaining the better voltage regulation in the DC microgrid.

I. INTRODUCTION

The interlinking course of action between at least two microgrids or with utility matrices principally relies upon the general targets, just as the control and the board plan utilized in individual microgrids. The microgrids can be interlinked straightforwardly or through blending tie-converters. The blending tie-converters are principally utilized when at least two microgrids have distinctive working voltages and additionally frequencies. The tie converters are likewise basic if the microgrids to be interlinked have diverse control procedures and the power stream among them should be directed [16]. Additionally, the interlinking of the DC microgrid with the utility network or another AC microgrid likewise requires attach converters to direct the power stream among different functionalities, and that has been explored under different situations in the distributed writing [18]–[22]. In [18], the interest hang control has been proposed for the interlinking or tie-converters of the AC-DC microgrids. The power stream activity is resolved dependent on the standardized terminal voltage and recurrence of the hang controlled interlinked AC-DC microgrids. This plan empowers independent power move between two interlinked microgrids dependent on their relative stacking condition. The power stream choice dependent on the relative stacking may make the interlinking converter work consistently, and in this manner it might bring about pointless operational misfortunes. A similar power sharing plan has been reached out to interlinked microgrids with a capacity framework [19]. This plan is additionally improved with the dynamic auto-tuning to limit the vitality move through interlinking converters [20]. The proposed auto-tuning empowers the power move just when one microgrid is vigorously stacked, and another microgrid is delicately stacked. The hang based power sharing idea has been additionally researched for various working states of the interlinked AC and DC microgrids in [21].

So far the published decentralized power sharing schemes for interlinked AC-DC microgrids are either entirely based on droop principle or voltage regulation. The droop based power sharing schemes transfer power based on relative loading of the interlinked microgrids. The power transfer during a contingency or uneven loading condition supports the voltage and frequency but does not regulate the voltage and/or frequency of the interconnected microgrids. However, these schemes enable plug-n-play feature for the interlinking converters. With this feature, in case there is more than one interlinking converter, all converters will operate regardless of the overall power transfer requirement. This may incur unnecessary converter operational losses. Contrarily, the voltage regulation schemes regulate the voltage of the DC microgrid without considering specific loading conditions of the generators, and lacks the plug-n-play feature for tie-converters. These shortcomings can be specifically addressed using the proposed control scheme in this paper.

The proposed independent power the executives plot for interlinked AC-DC microgrids mulls over the particular stacking state of the generators, and moves control from AC to DC microgrid during its pinnacle burden request, and furthermore directs the voltage of the DC microgrid. The proposed plan empowers the attachment n-play include for tie converters and decreases the quantity of converters in activity to evade pointless misfortunes. In the thought about situation, the DC microgrid has deficient age limit because of the high changeability of the heaps and sustainable age. The AC microgrid is considered to have managed voltage and recurrence just as the surplus capacity to move to the DC microgrid during its pinnacle request or possibility condition. To accomplish the highlights talked about over, a half and half hang and voltage guideline mode control has been proposed for the tie-converters in interlinked AC-DC microgrids. The proposed control plan depends on the tie-converter terminal voltage data to decide the general stacking state of the hang controlled DC microgrid. In light of the set stacking limit, the tie-converter begins consequently and moves capacity to the DC microgrid during the pinnacle burden request or possibility condition in the DC microgrid. With the proposed crossover control mode, the voltage of the DC microgrid is controlled at a characterized ostensible level.

Moreover, the proposed plan permits interfacing more than one tie-converters, yet instead of the current plan where all tie-converters work at the same time paying little heed to the power move request, the consequent tie-converter just initiates once the main converter control limit has been immersed. The proposed plan is completely self-governing with improved highlights. It utilizes the fluffy rationale controlling for the controlling of the tie converter beats.

II. CONTROL OF AC AND DC MICROGRIDS

The considered DC microgrid incorporates a non-dispatchable generator (sun based PV) and dispatchable generators (smaller scale turbine, energy unit) and burdens, as appeared in Fig. 1. The non-dispatchable-sun based PV framework is set to work in current control mode and accordingly removes most extreme power at all the occasions. The dispatchable generators are ordinarily utilized for firming the sustainable limit and can be controlled either through a brought together or decentralized control plot. The decentralized hang plan is the most generally utilized and liked, as it is straightforward and dependable. In this way, the customary hang (P-V) conspire has been utilized for the dispatchable generators of the DC microgrid (see Fig. 1), which is given by

$$V_{dc,ref,i} = V_{dc,max} - \eth_{dc,i} P_{dc,i}$$

$$\eth_{dc,i} = (V_{dc,max} - \eth_{dc,i} P_{dc,i}) / (P_{dc,max,i}) = \Delta V_{dc} / P_{dc,max,i} \quad (1)$$

where, i is the DC generator number (i = 1, 2, 3. . .); $V_{dc,ref},i$ is the reference voltage of i_{th} generator; $P_{dc,i}$ is the output power of i_{th} generator; $V_{dc,max}$ and ($V_{dc,min}$ = $V_{dc,nom,TC1}$) are the defined maximum and minimum voltage; $P_{dc,max,i}$ is the maximum or rated power of i_{th} generator; and $\partial_{dc,i}$ is the droop gain of i_{th} generator.

Based on (1), the voltage reference for the droop controlled generators 1 and 2 can be calculated by (2) and (3). As generators 1 and 2 share common DC bus voltage (i.e., $V_{dc,ref,1}$ = $V_{dc,ref,2}$), (2) and (3) can be equated and rewritten by (4), which demonstrates that the droop controlled generator will share proportional power according to their rated power capacity.

$$V_{dc,ref,1} = V_{dc,max} - \eth_{dc,1} P_{dc,1} \quad (2)$$

$$V_{dc,ref,2} = V_{dc,max} - \eth_{dc,2} P_{dc,2} \quad (3)$$

$$\eth_{dc,1} P_{dc,1} = \eth_{dc,2} P_{dc,2} \rightarrow \frac{P_{dc,1}}{P_{dc,max,1}} = \frac{P_{dc,2}}{P_{dc,max,2}} = \frac{P_{dc,i}}{P_{dc,max,i}} \quad (4)$$

Journal of Engineering Sciences

Vol 10, Issue 11, NOV/2019

ISSN NO:0377-9254

The equality in (4) is based on the fact that the voltage at the generator terminals is the same. Practically, the voltage at all the generator terminals is not the same due to the fact that they are connected through feeders/cables of different lengths. This voltage mismatch at the generator terminals affects the power sharing accuracy, which needs to be compensated by using any of the appropriate compensation methods [26], [27]. The droop equation with compensation of the feeder voltage drop can be rewritten by

$$V_{dc,ref,i} = V_{dc,max} - \eth_{dc,i} P_{dc,i} + i_{dc,i} X_i \quad (5)$$

The voltage of the droop controlled DC microgrid will vary with the changing load, but within the defined permissible range. For the considered DC microgrid, the voltage range with increased aggregated loading is shown in Fig. 1 (bottom left). For the droop controlled generators, the voltage range is

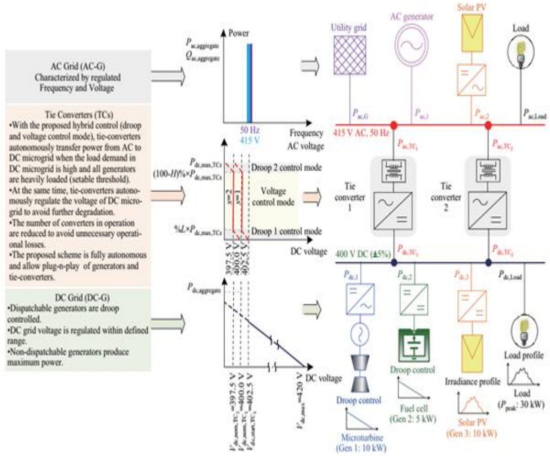


Fig. 1. Interlinked AC-DC microgrids and their control strategy.

set between 395 V and 420 V, indicating that the generators will deliver no-power at 420 V and 100% power at 395 V. Once the DC generators are heavily loaded (e.g., ≤ 402.5 V at 80% generators loading), the tie-converters will start to import power from the AC microgrid to meet the peak load demand, and also regulate the voltage of the DC microgrid.

For the example of interlinked microgrids in Fig. 1, the voltage and frequency of the AC microgrid is considered stiff. The AC microgrid can be droop controlled with secondary voltage and frequency regulation, or operating in grid-connected mode. The characteristics of the AC microgrid are shown in Fig. 1, where the voltage and frequency are constant at nominal value (e.g., 50 Hz and 415 V). In addition, the AC microgrid has sufficient generation capacity to meet its local demand and export surplus power to the DC microgrid which has been demonstrated through the proposed autonomous control of the tie-converters. The details of the tie-converters control are given in Section III.

III. PROPOSED HYBRID CONTROL OF TIE-CONVERTERS

The strength score of dispatchable mills or garage systems for firming the renewable ability relies upon on the range of the renewable supply and masses in the microgrid. The excessive variability of renewable and hundreds requires dispatchable turbines or storage structures with a excessive electricity rating, which may or may not be a viable solution. Alternatively, the microgrid with inadequate era capability may be interconnected with every other microgrid or application grid, without delay or thru harmonizing converters. The tying of a DC microgrid with a AC microgrid or utility grid is handiest possible through tie-converters, as proven in Fig. 1. In the proposed interlinked device, the AC microgrid is characterized as a regulated voltage and frequency gadget with ok era ability, while the DC microgrid is characterized as a hunch managed system with inadequate technology capacity due to the excessive variability of the renewable and loads. During the height call for or the low renewable energy output, the electricity deficit inside the DC microgrid is controlled through importing energy from the AC microgrid. Ideally, it is able to be accomplished efficaciously and autonomously with the proposed manage of the tie-converters.

In summary, the control scheme of the tie-converters is developed based on the following objectives: 1) To transfer power from the AC to DC microgrid during the peak load demand or generation contingency in the DC microgrid; 2) To minimize the power transfer losses, e.g., tie-converter should operate only during the peak-load demand in the DC microgrid, and the number of tie-converters in operation should be based on power transfer demand; 3) To regulate the voltage of the droop controlled DC microgrid; 4) To achieve fully autonomous control without depending on the communication network; 5) To enable the plug-n-play feature for tie-converters and generators.

Unlike the existing schemes for the interlinked AC-DC microgrids [18]–[22], a hybrid droop and voltage regulation mode control is proposed for the tie-converters and the mathematical form of the proposed control scheme is given by:

$$V_{dc,ref,TCx} = \begin{cases} off; \\ V_{dc,start,TCx} - \delta_{L,TCx} * P_{dc,TCx}; \\ V_{dc,nom,TCx}; \\ V_{dc,nom,TCx} - \delta_{H,TCx} \left[P_{dc,TCx} - (100-H)\% * P_{dc,max,TCx} \right]; \end{cases} \quad (6)$$

where T_{Cx} represents the tie-converter number (x = 1, 2, 3..); V_{dc} is the DC microgrid voltage; $V_{dc,ref,TCx}$ is the reference voltage of x_{th} tie-converter; $V_{dc,start,TCx}$ is the threshold voltage to start of x_{th} tie-converter; $V_{dc,nom,TCx}$ is the nominal voltage to be regulated by xth tie-converter; $P_{dc,TCx}$ is the DC power output of x_{th} tie-converter; $P_{dc,max,TCx}$ is the maximum power limit of xth tie-converter; L% and H% are the percentage of tie-converter rated power allocated for droop1 and 2 mode, respectively; Vdc,nom,TCx+1 is the DC microgrid voltage when xth tie-converter transfers maximum power; $\delta_{L,TCx} = (V_{dc,start,TCx} - V_{dc,nom,TCx})/(L\% \times P_{dc,max,TCx})$ is the droop 1 gain (at low power) of xth tie-converter; $\delta_{H,TCx} = (V_{dc,nom,TCx} - V_{dc,nom,TCx}+1)/(H\% \times P_{dc,max,TCx})$ is the droop 2 gain (at high power) of x_{th} tie-converter.

As shown in Fig. 1, tie-converter 1 starts in droop 1 control mode when the voltage in the DC microgrid drops to the set threshold of $V_{dc,start,TCx}$. This voltage threshold implies that all the generators in the DC microgrid are heavily-loaded (e.g. over 80% loaded). The start of the tie-converter in the droop control mode enables a smooth transition to the voltage regulation mode at the set condition i.e., $P_{dc,TCx} > L\% \times P_{dc,max,TCx}$. During the voltage regulation mode, the tie-converter imports power from the AC microgrid to meet the DC microgrid peak power demand as well as regulate its voltage to be set to the nominal value of $V_{dc,nom,TCx}$.

Furthermore, unlike the parallel operation of all tie-converters in the existing schemes, the converters operation has been prioritized. The first tie-converter only starts when all the generators in the DC microgrid are heavily-loaded. Once the first tie-converter power capacity is near to saturation at $P_{dc,TCx} = (100 - H)\% \times P_{dc,max,TCx}$, its control mode is changed from the voltage regulation to droop 2 control mode to allow minor voltage drop. This minor voltage drop caused by the droop 2 control mode will enable the next tie-converter to start its operation. In case of failure of the first tie-converter, the second tie-converter will automatically start its operation followed by the voltage drop due to high load demand. Therefore, the proposed control strategy ensures efficient operation during all operating conditions without compromising the inherited flexibility of the droop based scheme. The allocation of the tie-converter's power for droop 1 and droop 2 control mode depends on the chosen value of L% and H% which are user definable, and should be tuned to allow smooth transition between different modes while considering the voltage and power measurement tolerance/errors in the considered microgrid.

With the proposed voltage regulation mode, the overall voltage regulation performance of the DC microgrid can be improved. In particular during the peak load demand, the

$$V_{dc} > V_{dc,start,TCx}$$

$$0 \le P_{dc,TCx} \le L\% * P_{dc,max,TCx}$$

$$L\% * P_{dc,maxTCx} < P_{dc,TCx} < (100-H)\% * P_{dc,max,TCx}$$

$$(100-H)\% * P_{dc,max,TCx} \le P_{dc,TCx} \le P_{dc,max,TCx} \quad (7)$$

voltage of the DC microgrid is regulated at the nominal value, which is not the case with the existing power management schemes for interlinked microgrids. The performance of the proposed scheme has been validated for different load operating scenarios, as described in Section IV.

Journal of Engineering Sciences
Vol 10, Issue 11, NOV/2019
ISSN NO:0377-9254

IV. PERFORMANCE VALIDATION

The performance of the proposed scheme has been validated for two different scenarios of the DC microgrid. In the first scenario, the microgrid comprises a dispatchable micro-turbine (Gen 1), fuel cell (Gen 2) and variable load. In the second scenario, a non-dispatchable solar PV generator (Gen 3) is added to scenario 1. The system parameters are summarized in Tables I–III.

TABLE 1-CONTROL MODE OF DC AND AC MICROGRID

Entity	Control Mode	
AC Microgrid	Islanded-microgrid with regulated voltage and frequency Grid-connected mode	
Tie-converter	Hybrid droop and voltage control mode	
DC microgrid	Dispatchable generators	Droop controlled
	Non-dispatchable generators	Current control mode with MPPT

TABLE-2 :DC MICROGRID PARAMETERS

Description	Parameters	Value
Voltage	V_{dc}(V)	400(+5%, -1.25%)
Micro-turbine	$P_{dc,max,1}$(kW) $ð_{dc,1}$(V/kW)	10 2.5
Fuel cell	$P_{dc,max,2}$(kW) $ð_{dc,2}$(V/kW)	5 5
Solar PV	$P_{dc,max,3}$(kW)	10
Load	$P_{Load,peak}$(kW)	25

TABLE 3: AC MICROGRID AND TIE CONVERTER PARAMETERS

Description	Parameter	Value
AC Microgrid	V_{ac}(V) f(HZ)	415(l-l) 50
Tie-Converter	$P_{dc,max,TC1}$ (kW) $V_{dc,start,TC1}$ (V) $V_{dc,nom,TC1}$ (V) Vdc,nom,TC2 (V) L% = H%	10 402.5 400.0 397.5 10%

The mode transition logic of the tie-converter is given in the logic flow diagram shown in Fig. 2, and the detailed control block diagram of the tie-converter is shown in Fig. 3. Both scenarios have been tested at different load operating conditions to demonstrate the robustness and effectiveness of the proposed scheme.

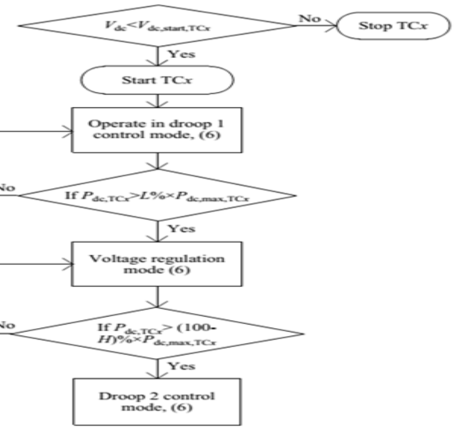


Fig. 2. Logic flow diagram showing mode transitions of tie-converter.

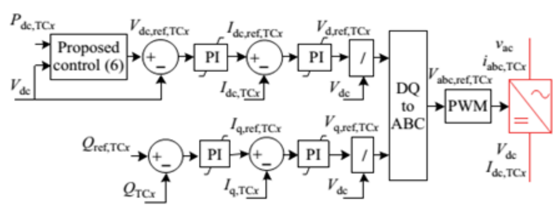


Fig. 3. Control block diagram of tie-converter

V.FUZZY CONTROLLER

There are specific components characteristic of a fuzzy controller to support a design procedure. In the block diagram in Fig. , the controller is between a preprocessing block and a post-processing block.

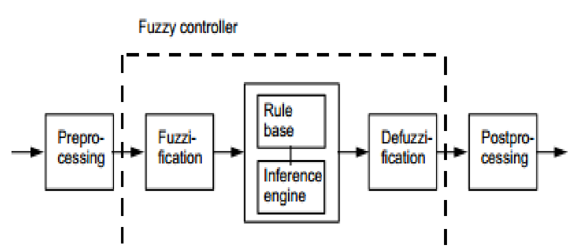


Fig.4. Blocks of fuzzy logic controllers

Preprocessing: A preprocessor conditions the measurements before they enter the controller. Examples of preprocessing are:

- Quantization in connection with sampling or rounding to integers;
- normalization or scaling onto a particular, standard range;
- filtering in order to remove noise;
- averaging to obtain long term or short term tendencies;
- a combination of several measurements to obtain key indicators; and
- differentiation and integration or their discrete equivalences.

Fuzzification: The fuzzification block matches the input data with the conditions of the rules to determine how well the condition of each rule matches that particular input instance. There is a degree of membership for each linguistic term that applies to that input variable.

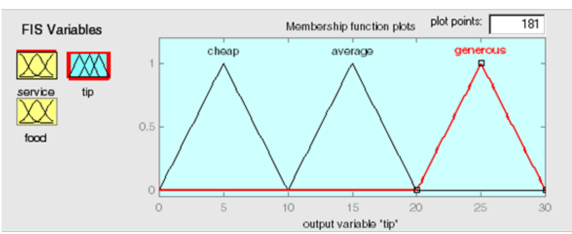


Fig.5. Membership function of inputs and output

Rule base: Basically a linguistic controller contains rules in the if-then format, but they can be presented in different formats. In many systems, the rules are presented to the end-user in a format similar to the one below,

- If error is Neg and change in error is Neg then output is NB
- If error is Neg and change in error is Zero then output is NM
- If error is Neg and change in error is Pos then output is Zero
- If error is Zero and change in error is Neg then output is NM
- If error is Zero and change in error is Zero then output is Zero (2)
- If error is Zero and change in error is Pos then output is PM
- If error is Pos and change in error is Neg then output is Zero
- If error is Pos and change in error is Zero then output is PM
- If error is Pos and change in error is Pos then output is PB

Defuzzification: The resulting fuzzy set must be converted to a number that can be sent to the process as a control signal. This operation is called Defuzzification.

Post processing: Output scaling is also relevant. In case the output is defined on a standard universe this must be scaled to engineering units, for instance, volts, meters, or tons per hour. The post processing block often contains an output gain that can be tuned, and sometimes also an integrator.

SCENARIO 1: DC MICROGRID WITH VARIABLE LOAD

The DC microgrid comprises micro turbine ($P_{dc,max,1}$ = 10 kW), fuel cell ($P_{dc,max,2}$ = 5 kW) and variable DC load (P_{Load}, peak = 20 kW) and it is interlinked with the AC microgrid through a tie-converter ($P_{dc,max,TC1}$ = 10 kW), as shown in Fig. 4.

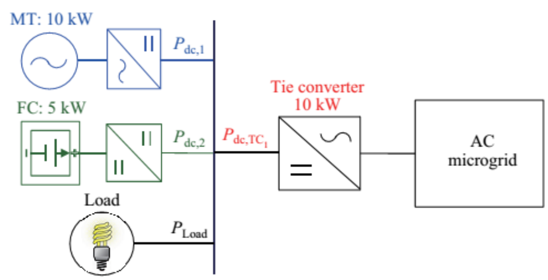


Fig. 6. Scenario 1: DC microgrid with micro turbine, fuel cell and load.

The load in the DC microgrid is varied in steps from 5 kW to 20 kW (i.e. 5 kW → 10 kW → 15 kW → 20 kW → 10 kW). At the 15 kW load demand, the expected loadings of generator 1 and generator 2 are more than 80%, and the voltage of the DC microgrid is below the set threshold of Vdc,start,TC1 = 402.5 V. This condition will enable the tie converter 1 to import power from the AC

Vol 10, Issue 11, NOV/2019
ISSN NO:0377-9254

microgrid and regulate the voltage of the DC microgrid at the defined nominal value of Vdc,nom,TC1 = 400.0 V. This expected performance can be witnessed from the results shown in Fig. 5. At the highlight point 1, at 8 s, the voltage of the DC microgrid decreases below 400 V followed by the step load change from

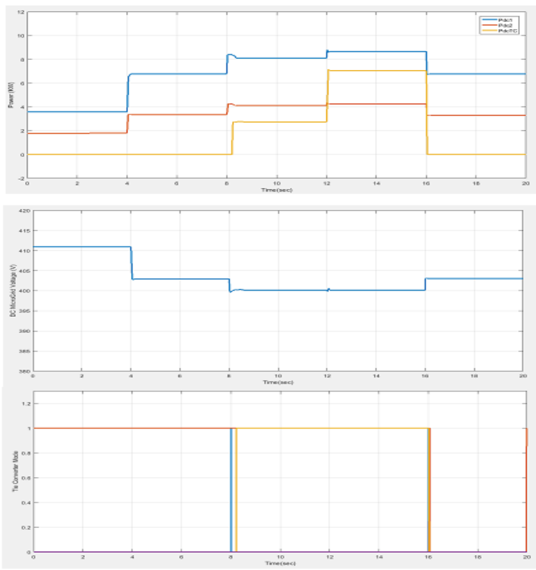


Fig. 7. Scenario 1: Results showing (a) generators and tie-converter power, (b) DC microgrid voltage and (c) tie-converter control signals for four different load operating conditions.

10 kW to 15 kW. This voltage drop triggers tie-converter 1 to start in droop 1 control mode at point 2. After starting in droop 1 control mode, the tie-converter control mode is immediately transitioned to the voltage regulation mode at point 3, since the set threshold ($P_{dc,TC1}$>10%×$P_{dc,max,TC1}$) is satisfied. At 12 s, the load in the DC microgrid is further increased from 15 kW to 20 kW, and the power transferred from the AC microgrid is increased accordingly. Throughout the peak-load demand in the DC microgrid from 8 s to 12 s, tie-converter 1 remains operational and regulates the voltage of the DC microgrid. Once the load demand in the DC microgrid is decreased at the highlighted point 4, at 16 s, the tie-converter turns off automatically after a short delay at point 5, as shown in Fig.5. As demonstrated, tie-converter 1 only operates once all the DC generators are heavily loaded. During its operation, the voltage in the DC microgrid is regulated to the defined nominal value of 400 V. Therefore the proposed strategy has better voltage regulation performance and ensures efficient operation.

B. SCENARIO 2: DC MICROGRID WITH NON-DISPATCHABLE GENERATOR AND LOAD PROFILE

A non-dispatchable generator–solar PV system is added to scenario 1, as shown in Fig. 6. The power output of the solar PV system is based on a continuously varying irradiance profile. The load in scenario 2 also has a varying profile with a peak demand of 25 kW. This test scenario is developed to further demonstrate the effectiveness of the proposed strategy for various practical operating conditions of renewable generation and load demand.

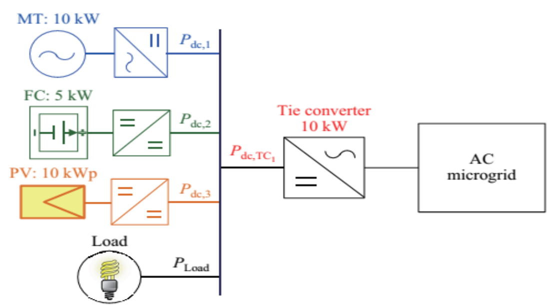
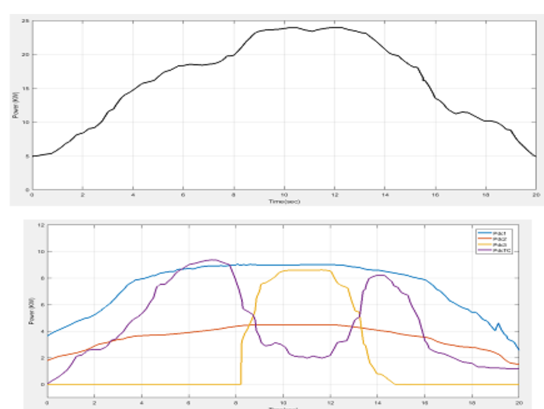


Fig. 8. Scenario 2: DC microgrid with micro turbine, fuel cell, solar PV and load.

The load in the DC microgrid increases gradually to the peak value 24.5 kW, and then decreases, as shown in Fig. 7(a)



Vol 10, Issue 11, NOV/2019
ISSN NO:0377-9254

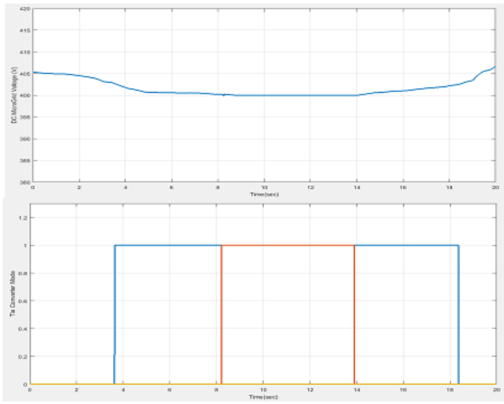


Fig. 9. Scenario 2: Results showing (a) DC microgrid load demand, (b) generators and tie-converter power, (c) DC microgrid voltage and (d) tie-converter control signals at varying solar PV and load operating conditions

The loading on the DC generators increases with the increasing load demand. At the highlight point 1, the loading on generator 1 and generator 2 exceeds 80% and the voltage of the DC microgrid drops below the set threshold of Vdc,start,TC1 = 402.5 V when the load demand is very high and the solar PV output is less. In agreement with the proposed control, tie-converter 1 starts at highlighted point 1 and imports power from the AC microgrid to overcome the power deficit in the DC microgrid while regulating its voltage. Tie-converter 1 operates in the voltage regulating mode from point 2 at 8.5 s to point 3 at 14.2 s. From point 3 and onward, the load in the DC microgrid deceases such that the tie-converter power output is below 10%×Pdc,max,TC1 and this condition requires the tie-converter to operate in the droop 1 control mode before it turns off at highlighted point 4 at 16.4 s. From point 4 and onward, the load demand in the DC microgrid is less than the generation, hence it can be met by the local generators. As expected, it has been demonstrated that the tie-converter only operates during the power deficit in the DC microgrid. In addition, the voltage of the DC microgrid is also regulated by importing power from the AC grid. This behavior depicts the grid-connected mode of the AC microgrid but through a tie-converter.

VI.CONCLUSION

This paper shows An independent power the board plan exhibited for interlinked AC-DC microgrids having various setups. The proposed plan deals with the power in the DC microgrid proficiently and independently. The quantity of tie-converters in activity has been diminished with the proposed prioritization to stay away from pointless operational misfortunes. The plan has shown better voltage guideline in the DC microgrid. The fuzzy logic controller is utilized in the controlling circuit to moderate the motions through the tie converter beats. The exhibition and strength of the proposed plan have been approved for two unique situations of the DC microgrid at variable burden conditions. The proposed situations gives better outcomes with the fuzzy controlling and appears to have preferred execution over the past strategy.

REFERENCES

[1] J. Rocabert, A. Luna, F. Blaabjerg, and P. Rodr´ıguez, "Control of power converters in AC microgrids," IEEE Transactions on Power Electronics, vol. 27, no. 11, pp. 4734–4749, Nov. 2012.

[2] M. Liserre, T. Sauter, and J. Y. Hung, "Future energy systems: integrating renewable energy sources into the smart power grid through industrial electronics," IEEE Industrial Electronics Magazine, vol.4. no. 1, pp. 18–37, Mar. 2010.

[3] M. Tsili and S. Papathanassiou, "A review of grid code technical requirements for wind farms," IET Renewable Power Generation, vol. 3, no. 3, pp. 308–332, Sep. 2009.

[4] T. Strasser, F. Andren, J. Kathan, C. Cecati, C. Buccella, P. Siano, P. ´ Leitao, G. Zhabelova, V. Vyatkin, P. Vrba, and V. Ma ˜ ˇ r´ık, "A review of architectures and concepts for intelligence in future electric energy systems," IEEE Transactions on Industrial Electronics, vol. 62, no. 4, pp. 2424–2438, Apr. 2015.

[5] A. Kwasinski, "Quantitative evaluation of dc microgrids availability: Effects of system architecture and converter topology design choices," IEEE

Transactions on Power Electronics, vol. 26, no. 3, pp. 835–851, Mar. 2011.

[6] P. Basak, S. Chowdhury, S. H. N. Dey, S. P. Chowdhury, "A literature review on integration of distributed energy resources in the perspective of control, protection and stability of microgrid," Renewable and Sustainable Energy Reviews, vol. 16, no. 8, pp. 5545–5556, Oct. 2012.

[7] D. E. Olivares, A. Mehrizi-Sani, A. H. Etemadi, C. A. Canizares, R. Iravani, M. Kazerani, A. H. Hajimiragha, O. Gomis-Bellmunt, M. Saeedifard, R. alma-Behnke, G. A. Jimenez-Estevez, and N. D. Hatziargyriou, "Trends in microgrid control," IEEE Transactions on Smart Grid, vol. 5, no. 4, pp. 1905–1919, Jul. 2014.

[8] N. Hatziargyriou, H. Asano, R. Iravani, and C. Marnay, "Microgrids," IEEE Power and Energy Magazine, vol. 5, no. 4, pp. 78–94, Jul. /Aug. 2007.

[9] L. E. Zubieta, "Are microgrids the future of energy?: DC microgrids from concept to demonstration to deployment," IEEE Electrification Magazine, vol. 4, no. 2, pp. 37–44, Jun. 2016.

[10] G. Venkataramanan and C. Marnay, "A larger role for microgrids," IEEE Power and Energy Magazine, vol. 6, no. 3, pp. 78–82, May-Jun. 2008.

[11] W. Yuan, J. H. Wang, F. Qiu, C. Chen, C. Q. Kang, and B. Zeng, "Robust optimization-based resilient distribution network planning against natural disasters," IEEE Transactions on Smart Grid, vol. 7, no. 6, pp. 2817–2826, Nov. 2016.

[12] N. Nikmehr, S. N. Ravadanegh, "Optimal power dispatch of multi-microgrids at future smart distribution grids," IEEE Transactions on Smart Grid, vol. 6, no. 4, pp. 1648–1657, Jul. 2015.

[13] H. Farzin, M. Fotuhi-Firuzabad, M. Moeini-Aghtaie, "Enhancing power system resilience through hierarchical outage management in multi microgrids," IEEE Transactions on Smart Grid, vol. 7, no. 6, pp. 2869– 2879, Nov. 2016.

[14] J. Wu, X. H. Guan, "Coordinated multi-microgrids optimal control algorithm for smart distribution management system," IEEE Transactions on Smart Grid, vol. 4, no. 4, pp. 2174–2181, Dec. 2013.

[15] N. Hatziargyriou, "Operation of multi-microgrids," in Microgrids: Architectures and Control, Wiley-IEEE Press, 2014.

[16] I. U. Nutkani, P. C. Loh, and F. Blaabjerg, "Distributed operation of interlinked AC microgrids with dynamic active and reactive power tuning," IEEE Transactions on Industry Applications, vol. 49, no. 5, pp. 2188–2196, Sep. /Oct. 2013.

[17] I. U. Nutkani, P. C. Loh, and F. Blaabjerg, "Power flow control of intertied AC microgrids," IET Power Electronics, vol. 6, no. 7, pp. 1329– 1338, Aug. 2013.

[18] P. C. Loh, D. Li, Y. K. Chai, and F. Blaabjerg, "Autonomous operation of hybrid microgrid with AC and DC subgrids," IEEE Transactions on Power Electronics, vol. 28, no. 5, pp. 2214–2223, May 2013.

[19] P. C. Loh, D. Li, Y. K. Chai, and F. Blaabjerg, "Autonomous control of interlinking converter with energy storage in hybrid AC–DC microgrid," IEEE Transactions on Industry Applications, vol. 49, no. 3, pp. 1374– 1382, May-Jun. 2013.

[20] P. C. Loh, D. Li, Y. K. Chai, and F. Blaabjerg, "Autonomous operation of ac-dc microgrids with minimized interlinking energy flow," IET Power Electronics, vol. 6, no. 8, pp. 1650–1657, Sep. 2013.

AUTHOR'S PROFILE;

B.SIDDESWARA
Pursuing Master of Technology (M.Tech.) on branch of Power system Engineering within p.v.k.k institute of technology ,anantapuramu.
E-mail: siddureddybathedar@gmail.com

S.V.SIVANAGARAJU ,M.TECH
Working as associate Professor, department of Electrical & Electronic Engineering within p.v.k.k institute of technology ,anantapuramu.
E-mail: venkat.snraju@gmail.com