THREE-LEVEL INVERTER BASED AUTONOMOUS POWER MANAGEMENT SCHEME FOR INTERLINKING AC-DC MICRO-GRIDS

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Abstract: The main theme of this scheme is to regulate the power among the interlinked microgrids by considering a specific loading condition. This autonomous power management scheme for interlinking microgrids considers a specific loading condition of dc micro grid before importing power from Ac micro grid by using a interlinking through a medium called three-level inverter. The use three-phase three level inverters can reduce the harmonic distortion in the output waveform without any filter circuit and also operates for higher and lower switching frequencies.

IndexTerms **- Autonomous control, Distributed control, Droop control, Hybrid microgrids, Interlinked micro grids, Three level inverter (TLI), power management.**

I. INTRODUCTION

The technical advancement in power electronics is playing an important role in the deployment of renewables and alternative energy technologies which have so far been widely realized in different forms of network topologies and configurations. Similarly, they have been controlled and managed using various control strategies and architectures. Their network topologies and control strategies are mainly determined to maximize the benefits while meeting the load requirements. At present, renewable and alternative energy technologies are widely deployed in microgrids. The deployment of these new technologies in the form of a microgrid is preferred due to several advantages, such as optimal utilization of resources, improved power quality and enhanced supply reliability. Recently, more advanced grid architectures have emerged including the zone- based grid architectures, multi-microgrids, interlinked AC-AC microgrids and interlinked AC-DC microgrids. The main objective of these advanced network architectures is to exploit maximum benefits from renewables and alternative energy resources. For example, by interconnecting two or more microgrids, it will enable reserve sharing, support voltage and frequency, and ultimately enhance the overall reliability and resilience of interlinked microgrids.

The interlinking arrangement between two or more micro- grids or with utility grids primarily depends on the overall objectives, as well as the control and management scheme used in individual microgrids. The microgrids can be interlinked directly or through multilevel inverters. Multi level diode inverters are primarily used when two or more microgrids have different operating voltages and/or frequencies. The multi level inverters are also essential if the microgrids to be interlinked have different control strategies and the power flow among them needs to be regulated. Similarly, the interlinking of the DC microgrid with the utility grid or another AC microgrid also requires multi level inverters to regulate the power flow among other functionalities, and that has been investigated under various scenarios in the published literature. In the demand-droop control has been proposed for the interlinking or tie-converters of the AC-DC microgrids. The power flow action is determined based on the normalized terminal voltage and frequency of the droop controlled interlinked AC-DC microgrids.This scheme enables autonomous power transfer between two interlinked microgrids based on their relative loading condition. The power flow decision based on the relative loading may cause the interlinking converter to operate continuously, and thus it may result in unnecessary operational losses. The same power sharing scheme has been extended to interlinked microgrids with a storage system.

This scheme is further improved with the progressive auto-tuning to minimize the energy flow through interlinking converters. The proposed auto-tuning enables the power transfer only when one micro grid is heavily-loaded, and another microgrid is lightly-loaded. The droop based power sharing concept has been further investigated for different operating conditions of the interlinked AC and DC microgrids. The power management strategy is presented for a three- port system comprising AC, DC and a storage network. The decision about the power sharing is based on the loading condition of the interlinked networks which is principally the same as presented. In addition, a communication based multilevel supervisory control is proposed to reduce the operation of interlinking converters. Another power management scheme presented for the interlinked AC-DC microgrid has an objective to regulate the voltage of the DC microgrid without taking into consideration the specific loading level of the generators. This scheme can be implemented only at a single three phase three level inverter, hence limits the plug-n-play feature. In addition, a few centralized power management schemes have been investigated for interlinked AC-DC microgrids. The key concern with the centralized schemes is the reliability associated with the fast communication links. Therefore, the decentralized schemes are usually preferred.

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 lack the plug-n-play feature for tie plug-n-play feature for three level inverters. These shortcomings can be specifically addressed using the proposed control scheme in this paper.

The proposed autonomous power management scheme for interlinked AC-DC microgrids takes into consideration the specific loading condition of the generators, and transfers power from AC to DC microgrid during its peak-load demand, and also regulates the voltage of the DC microgrid. The proposed scheme enables the plug-n-play feature for tie converters and reduces the number of converters in operation to avoid unnecessary losses. In the considered scenario, the DC microgrid has inadequate generation capacity due to the high variability of the loads and renewable generation.

The AC microgrid is considered to have regulated voltage and frequency as well as the surplus power to transfer to the DC microgrid during its peak demand or contingency condition. To achieve the features discussed above, a hybrid droop and voltage regulation mode control has been proposed for the tie-converters in interlinked AC-DC microgrids. The proposed control scheme relies on the tie-converter terminal voltage information to determine the overall loading condition of the droop-controlled DC microgrid. Based on the set loading threshold, the tie-converter starts automatically and transfers power to the DC microgrid during the peak-load demand or contingency condition in the DC microgrid. With the proposed hybrid control mode, the voltage of the DC microgrid is regulated at a defined nominal level. In addition, the proposed scheme allows interfacing more than one three level inverter, but as opposed to the existing scheme where all three level inverters operate simultaneously regardless of the power transfer demand, the subsequent three level inverters activates once the first converter power capacity has been saturated. The proposed scheme is fully autonomous with enhanced features.

II . CONTROL OF AC AND DC MICROGRIDS

The considered DC microgrid includes a non-dispatchable generator (solar-PV) and dispatchable generators (microturbine, fuel-cell) and loads, as shown in Fig. 1. The nondispatchable-solar PV system is set to operate in current control mode and thus extracts maximum power at all the times. The dispatchable generators are typically used for firming the renewable capacity and can be controlled either through a centralized or decentralized control scheme. The decentralized droop scheme is the most widely used and preferred, as it is simple and reliable. Therefore, the traditional droop (P-V) scheme has been used for the dispatchable generators of the DC microgrid (see Fig. 1), which is given by

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

$$\partial_{dc,i} = V_{dc,max} - V_{dc,min}{}^{i} / P_{dc,max,i} = \Delta V_{dc} / P_{dc,max,i} \qquad (1)$$

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; Pdc,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., Vdc,ref,1 = Vdc,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

$$V_{dc,ref,1} = V_{dc,max} - \partial_{dc,1} P_{dc,1} \qquad 2)$$

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

$$\partial_{dc,1} P_{dc,1} = \partial_{dc,2} P_{dc,2} \rightarrow P_{dc,1} / P_{dc,max,1} = P_{dc,2} / P_{dc,max,2} = P_{dc,i} / P_{dc,max,i} \qquad (4)$$

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. The droop equation with compensation of the feeder voltage drop can be rewritten by

$$V_{dc,ref,i} = V_{dc,max} - \partial_{dc,i} P_{dc,i} + I_{dc,i} X_{i}. \qquad (5)$$

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 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 three level inverters 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 mode based three level inverters control are given in Section III.

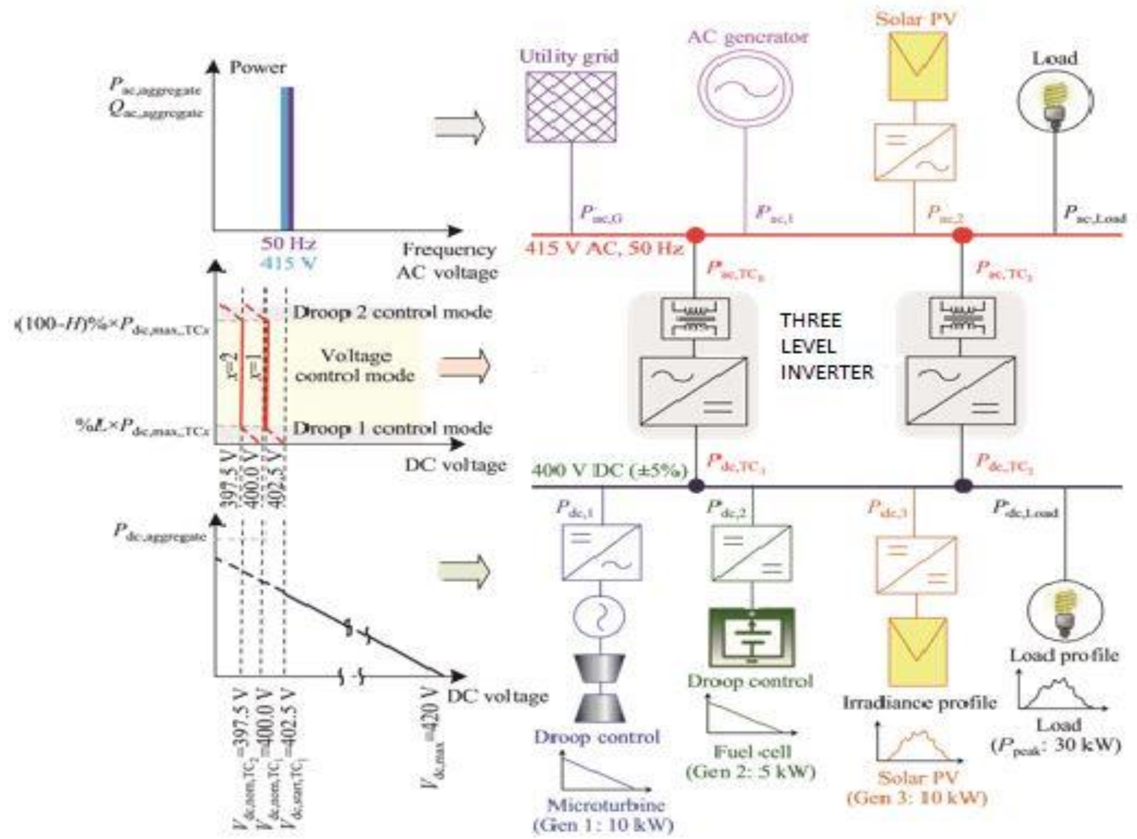


Figure 1.Interlinked ac-dc micro grids with their control strategy

III. PROPOSED HYBRID CONTROL OF THREE LEVEL INVERTERS

The power rating of dispatchable generators or storage systems for firming the renewable capacity depends on the variability of the renewable source and loads in the microgrid. The high variability of renewable and loads requires dispatch able generators or storage systems with a high power rating, which may or may not be a viable solution. Alternatively, the microgrid with inadequate generation capacity could be interconnected with another microgrid or utility grid, directly or through tie mode three level inverter scheme. The tying of a DC microgrid with a AC microgrid or utility grid is only possible through three level inverters in tie converters, as shown in Fig. 1. In the proposed interlinked system, the AC microgrid is characterized as a regulated voltage and frequency system with adequate generation capacity, whereas the DC micro grid is characterized as a droop controlled system with inadequate generation capacity due to the high variability of the renewable and loads. During the peak demand or the low renewable power output, the power deficit in the DC micro grid is managed by importing power from the AC micro grid. Ideally, it can be achieved efficiently and autonomously with the proposed control of the three level inverters. In summary, the control scheme of three level inverters in tie converters is developed based on the following objectives: 1) To transfer power from the AC to DC micro grid during the peak load demand or generation contingency in the DC micro grid; 2) To minimize the power transfer losses, e , e.g., three level inverter should operate only during the peak-load demand in the DC micro grid,; 3) The total harmonic distortion becomes low in the output waveform without using any filter circuit in the DC micro grid; 4) To achieve fully autonomous control without depending on the communication networks ,a hybrid droop and voltage regulation mode control is proposed for the three level inverters and the mathematical form of the proposed control scheme is given by:

$$V_{dc,ref,TCx} =$$

$$\begin{cases} \text{Off;} & V_{dc} > V_{dc,start,TCx} \\ V_{dc,start,TCx} - \delta_{L,TCx} \times P_{dc,TCx}; & 0 \le P_{dc,TCx} \le L\% \times P_{dc,max,TCx} \\ V_{dc,nom,TCx}; & L\% \times P_{dc,max,TCx} < (100-H)\% \times P_{dc,max,TCx} \\ V_{dc,nom,TCx} - \delta_{H,TCx}[P_{dc,TCx} - (100-H)\% \times P_{dc,max,TCx}]; & (100-H)\% \times P_{dc,max,TCx} \le P_{dc,TCx} \le P_{dc,max,TCx} \end{cases} \quad (6)$$

where TCx 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 x^{th} 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 x^{th} tie-converter; L% and H% are the percentage of tie-converer rated power allocated for droop1 and 2 mode, respectively; $V_{dc,nom,TCx+1}$ is the DC microgrid voltage when x^{th} tie-converter transfers maximum power; $\delta_{L,TCx} = (V_{dc,start,TCx} V_{dc,nom,TCx})/(L\% \, P_{dc,max,TCx})$ is the droop 1 gain (at low power)of x^{th} tie- converter; $\delta_{H,TCx} = (V_{dc,nom,TCx} x V_{dc,nom,TCx+1})/(H\% \, P_{dc,max,TCx})$ 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 thethree level inverter 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 mode based three level inverters in the existing schemes, the converters operation has been prioritized. The first Three level inverter only starts when all the generators in the DC microgrid are heavily-loaded. Once the first Three level inverter 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 three level inverter, 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-mode operated three level inverter'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 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.

By using three level inverter scheme the number switches in the control scheme, reduces stress at the switches thereby decreasing the temperature and also the leakage currents at the switches, So by that we can get distortion free output.

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-II.

TABLE I CONTROL MODE OF DC AND AC MICROGRIDS

Entity	Control mode	
AC microgrid	Islanded-microgrid with regulated voltage and frequency Grid-connected mode	-
Three level inverter	Hybrid droop and voltage control mode	-
DC mirogrid	Dispatchable generators - droop controlled	
	Non-dispatchable generators - current control mode of MPPT	

TABLE II DC MICROGRID PARAMETERS

Description	Parameter	value
Voltage	V_{dc}(V)	400(+5%,-1.25:%)
Micro-turbine	$P_{dc,max,1}$ (kw) $\partial_{dc,1}$ (V/kw)	10 2.5
Fuel cell	$P_{dc,max,2}$ (kw) $\partial_{dc,2}$ (V/kw)	5 5
Solar PV	$P_{dc,max,3}$ (kw)	10
Load	$P_{Load,peak}$ (kw)	25

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, the three level inverter scheme is shown in fig. 4, in Both scenarios have been tested at different load operating conditions to demonstrate the robustness and effectiveness of the proposed scheme.

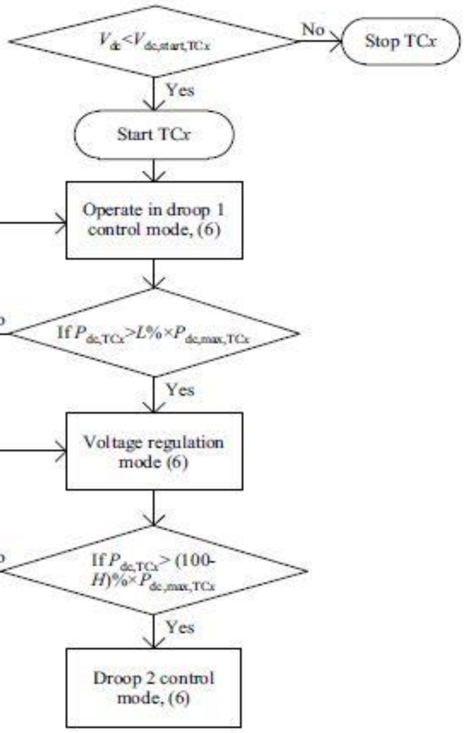


Fig. 2. Logic flow diagram showing mode transitions of tie converter

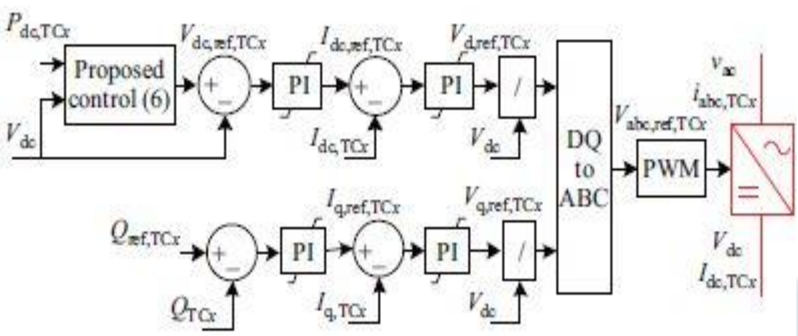


Fig. 3. Control block diagram of tie converter

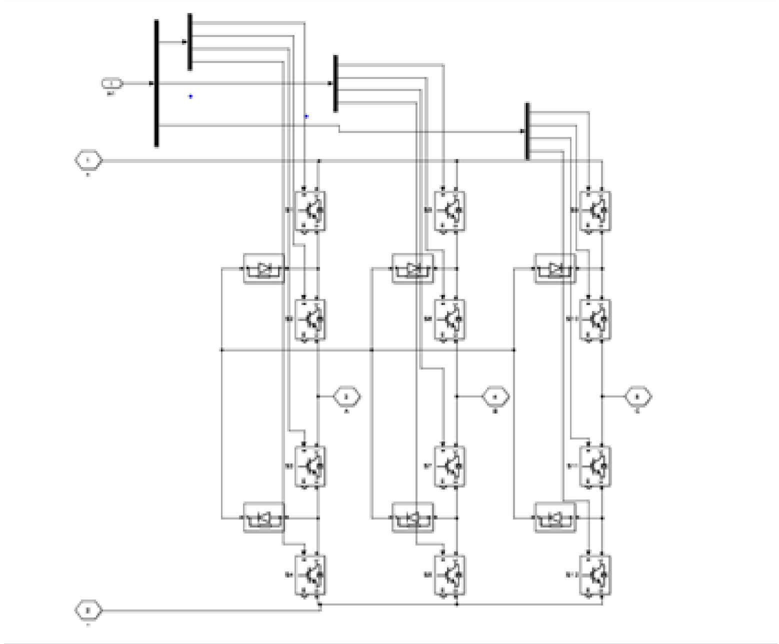


Fig.4. Three level inverter scheme

A. 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 three level inverter ($P_{dc,max,TC1}$ = 10 kW), as shown in Fig. 5.

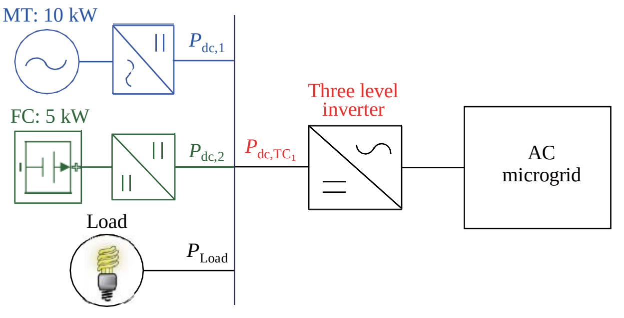
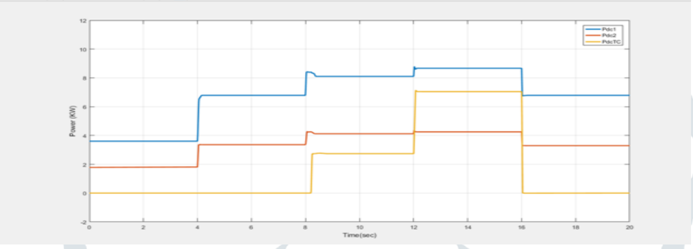
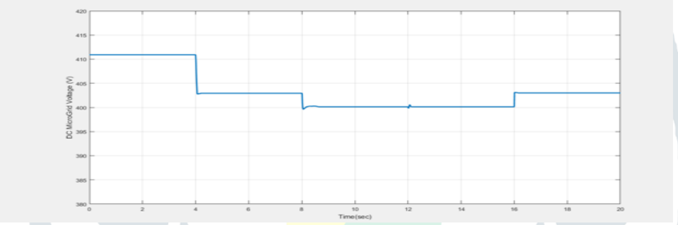


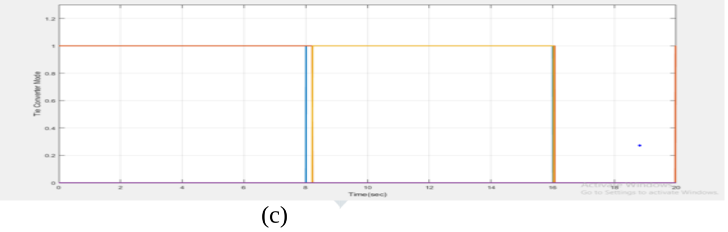
Fig.5.senario1: DC microgrid with micro turbine,fuel cell and load



(a)



(b)



(c)

Fig.6. senario1: Results showing (a) generators and three level inverter power, (b) DC microgrid voltage and (c) tie converter mode based three level inverter control signals for four different load operating conditions.

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 $V_{dc,start,TC1}$ = 402.5 V. This condition will enable the Three Level Inverter 1 to import power from the AC 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.3. 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 10 kW to 15 kW. This voltage drop triggers Three Level Inverter 1 to start in droop 1 control mode at point 2. After starting in droop 1 control mode, the Three Level Inverter control mode is immediately transitioned to the voltage regulation mode at point 3, since the set threshold (Pdc,TC1 > 10%×Pdc,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, Three Level Inverter 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 Three Level Inverter turns off automatically after a short delay at point 5, as shown in Fig.6. 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-dispatch able Generator and Load Profile.

A non-dispatch able generator–solar PV system is added to scenario 1, as shown in Fig.7. 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.

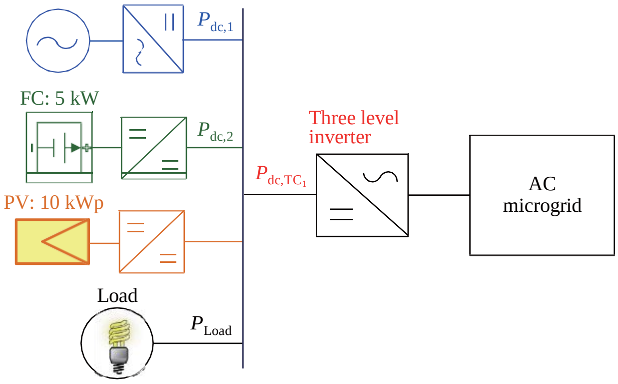


Fig.7.scenario2: DC micro grid with micro turbine, fuel cell, solar PV and load

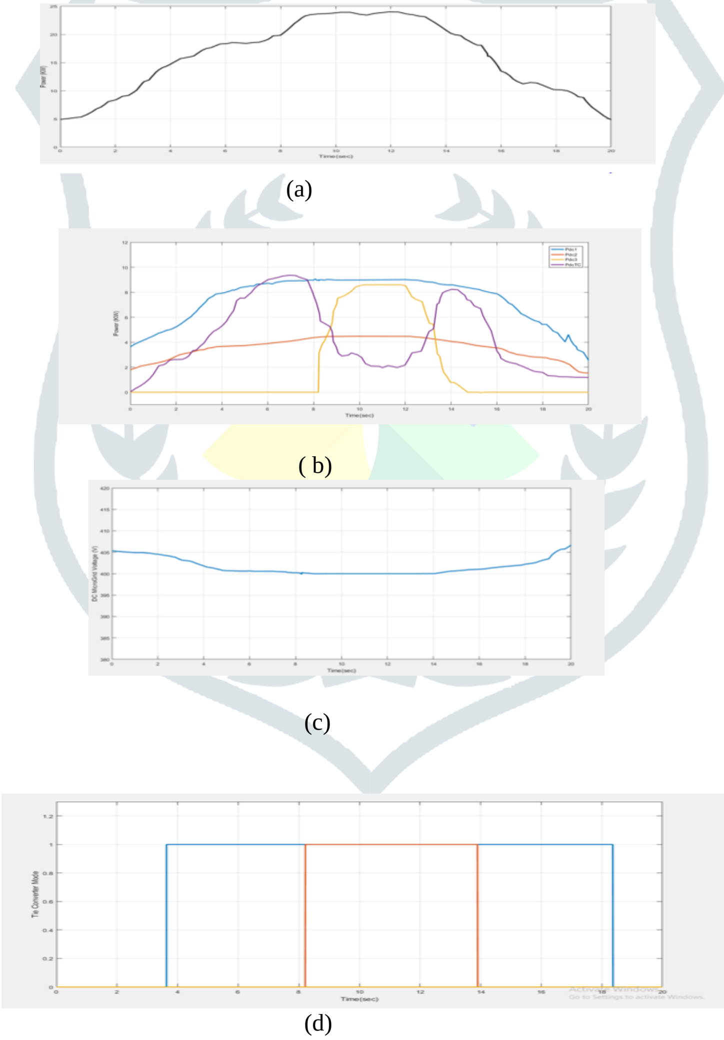


Fig.8. scenario 2: Results showing (a) DC microgrid load demand, (b) generators and tie-converter power, (c) DC micro grid voltage and (d) tie converter mode three level inverter control signals at varying solar PV and load operating conditions

The load in the DC microgrid increases gradually to the peak value 24.5 kW, and then decreases, as shown in Fig. 8(a).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 V $_{dc,start,Tcx1}$ = 402.5 V when the load demand is very high and the solar PV output is less. In agreement with the proposed control, Three Level Inverter 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. Three Level Inverter 1 operates in the voltage regulating mode from point 2 at 8.5 s to point 3 and onward, the load in the DC microgrid deceases such that the tie-converter power output is below 10% $\times P_{dc,max,TC_1}$ 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 at 14.2 s. Three Level Inverter 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 Three Level Inverter 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 Three Level Inverter.

V. CONCLUSION

The proposed scheme for interlinking AC-DC micro grids have various configurations which we have discussed. The suggested three level Inverter reduces the total harmonic distortions in the output without any filter circuit, operates at very low switching frequency and generates low switching frequency losses and maintains better voltage regulation in the DC microgrids .while, managing the power deflect in the dc micro grid. The proposed two scenarios give the better view on DC micro grid at variable load conditions.

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 ˜ ˇr´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 micro grids 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 multimicrogrids,” IEEE Transactions on Smart Grid, vol. 7, no. 6, pp. 2869– 2879, Nov. 2016