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Design and Analysis of Hybrid Microgrid with AC/DC Connection under Unbalanced Voltage Conditions

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Abstract: Nowadays, Renewable Energy Sources (RESs) have become more attractive and affordable due to recent advances in power electronic devices and control systems. Micro-Grids (MGs) represent a new paradigm of electrical grids with Distributed Generation(DG) units: they are generally composed of power converters, RESs, Energy Storage Systems (ESSs), local loads with measurement and control systems. Power converters with ESSs can be adopted to mitigate the negative effects of unbalanced grid connected MGs. However, suitable control strategies are required. In the hybrid ac/dc microgrid, the parallel-operated ac/dc bidirectional interfacing converters (IFCs) are increasingly used for large capacity renewable energy sources or as the interlinking converters between the ac and dc subsystems. When unbalanced grid faults occur, the active power transferred by the parallel-operated IFCs must be kept constant and oscillation-free to stabilize the dc bus voltage. Moreover, unbalanced voltage adverse effects on IFCs (such as output power oscillations, dc-link ripples, and output current enhancement) could be amplified by the number of parallel converters. Therefore, this paper investigates parallel operation of IFCs in hybrid ac/dc microgrids under unbalanced ac grid conditions and proposes a novel control strategy to enhance the active power transfer capability with zero active power oscillation. In the proposed control strategy, only one IFC, named as redundant IFC, needs to be designed and installed with higher current rating to ensure the constant and oscillation-free output active power of parallel IFCs. MATLAB/SIMULINK Simulation results verify the feasibility and effectiveness of the proposed control strategy.

Keywords: Renewable Energy Sources (RESs), Micro-Grids (MGs), Distributed Generation,Energy Storage Systems(ESSs).

I. INTRODUCTION

Clean Energy (CE) is generated by RESs like solar energy, wind energy, geothermal and other forms like biomass. These kinds of sources have been used in the past just for special purposes; for supplying rural areas with electricity, wherein supplying these areas from utility grids requires more infrastructures; transmission lines and transformers with more losses and huge investment costs. Nowadays renewable energy is commonly used in different applications mainly in grid connected systems. From the customer point of view, microgrids deliver both thermal and electricity requirements and in addition improve local reliability, reduce emissions, improve power excellence by supportive voltage and reducing voltage dips and potentially lower costs of energy supply. From the utility viewpoint, application of distributed energy sources can potentially reduce the demand for distribution and transmission facilities. Clearly, distributed generation located close to loads will reduce flows in transmission and distribution circuits with two important effects: loss reduction and ability to potentially substitute for network assets. In addition, the presence of generation close to demand could increase service quality seen by end customers. Microgrids can offer network support during the time of stress by relieving congestions and aiding restoration after faults. The development of microgrids can contribute to the reduction of emissions and the mitigation of climate changes. This is due to the availability and developing technologies for distributed generation units are based on renewable sources and micro sources that are characterized by very low emissions.

However, studies on the control of parallel IFCs under unbalanced grid voltage conditions are quite limited. During the parallel operation of IFCs, the active power oscillation under unbalanced grid voltage could be amplified by the number of parallel converters and is one of the main concerns due to its impact on dc-link voltage. For this reason, the active power oscillation of parallel IFCs should be controlled during grid fault events. For single IFC, if the oscillation-free and constant output power under unbalanced grid faults is desired, the three-phase currents of the IFC would be unbalanced and the peak current would increase to ensure the constant active power. In this case, the peak current may exceed the converter current rating limit. To avoid this problem, the reference power of converter should be reduced. As a result, in a single IFC, the oscillation-free output power may cause the reduction of active power transfer capability. For parallel IFCs, this would significantly reduce the power transfer capability between ac and dc buses under grid faults. One solution is to use converters with higher current ratings, which is not cost effective. Thus, it is desirable to propose a new control scheme to keep the power transfer capability constant without increasing the current rating of all IFCs.

II. POWER CONVERSION TECHNOLOGY

Power conversion process consists of two stages, power and control stages. As shown in Fig.1, the power stage is to convert the input power (AC or DC) and deliver it to the output side (AC or DC). The control stage is used for controlling the power converter to synthesis reference output power, by measuring input and output currents and voltages.

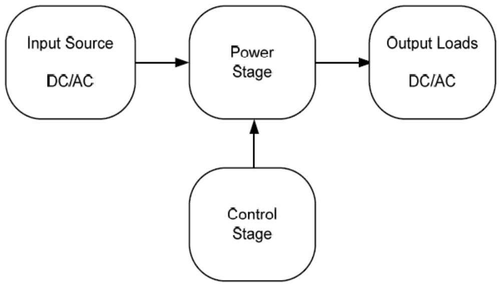


Fig.1. Power electronic conversion.

Power conversion can be divided into four different categories according to the input and output power forms. In Fig.2, four different combinations of power converters can be used for power conversion of renewable energy sources.

- DC-DC converter.
- AC-DC converter (rectifier).
- DC-AC converter (inverter).
- AC-AC converter.

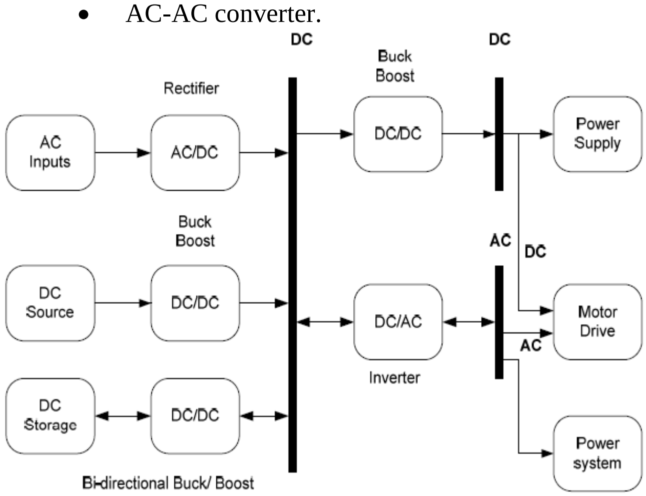


Fig.2. Energy conversion technologies based power converters.

The arising concerns on environment and sustainable energy issues have promoted the development of distributed renewable power generation and the emerging of microgrid. Since renewable power sources are naturally dispersed, it is very difficult for the power system to manage a countless, yet still growing, intermittent distributed power generation in a traditional way. In order to effectively manage distributed generation sources, load, and possibly energy storages, a systematic view has to be taken. By integrating all these distributed units together, a micro power system is formed from the distribution side, hence the nomination of microgrid. Given that distribution power system is formerly considered as load only, the inclusion of generation and storage units in microgrids is fundamentally changing the control and operational structure of traditional power system.

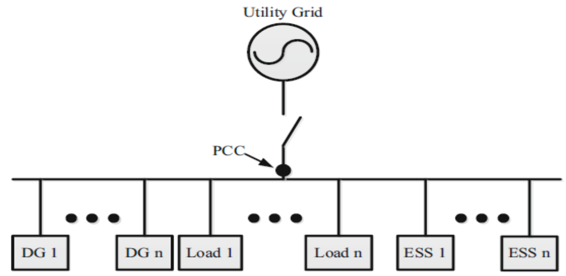


Fig.3. AC microgrid.

As traditional power system is based on AC, microgrids are considered to be naturally AC based at early stage. A three-phase AC bus is commonly employed as the point of common coupling (PCC). PCC is normally set as the only power interface between a utility grid and the microgrid. The schematic structure is shown in Fig. 3. A microgrid can be either operated in grid-connected condition or in some situations, switched to the stage of isolation, i.e., islanding operation. A fast switch can be placed in between PCC and utility grid as the cutoff point between the microgrid and utility grid. Comparing with traditional power grid, the emergence of DGs and ESSs is the major difference. In a microgrid, renewable DGs and ESSs are interfaced with power electronics converters with distributed control. Renewable DGs extract power from natural environment, blowing wind, or sunshine for instance, and try to maximize the power extraction and integration to the grid. In this sense, the actual power generated mainly depends on instant natural conditions. Therefore, the renewable DGs are generally considered to be nondeterministic from the grid operator’s view. The only exception occurs when renewable power must be curtailed or switched off, however, at a certain cost. ESSs are considered to be a controllable bidirectional source in a microgrid. A high-performance power electronics interface enables an ESS to provide instant support to power grid in addition to storage energy management.

This special feature can be employed to cope with the problem caused by intermittent renewable DGs. For example, the EV charging station can use its battery as an energy buffer to absorb intermittent power to avoid voltage instability and discharge it in peak hours to reduce the demand on spinning reverse. It has to be pointed out that a vehicle battery with a one-direction charger is not necessarily an ESS system. The comparison of AC and DC microgrid is generalized in Table1. A charging-only battery system, though controllable, behaves more like a controllable load in distribution power system due to its lack of discharging capability. However, a vehicle battery, or more likely a group of vehicle batteries in a charging station, with bidirectional “chargers” under certain control can play the role of ESS in a microgrid. A coordinating scheme, either distributed or centralized, is usually designed to combine all the above-mentioned DGs, loads, ESSs, and relays together to form a subsystem. This feature also defers from a passive distribution power system with isolated DGs and ESSs. A digital secondary control system is commonly used to supervise, manage, and monitor the whole system. Additional communications and energy management schemes might be applied with relevant supervisory control and data acquisition (SCADA) system of higher power system hierarchy.

TABLE I: DC Microgrid

Microgrid type	AC	DC
Conversion efficiency	Low: Multiple AC/DC and AC/DC conversions have to be used when interconnecting renewable sources and storages	High: AC/DC and DC/AC conversions between renewable sources and storages are reduced
Cost on converters	High: DC/AC converter has to be invested for each of the renewable sources and storages	Low: Reduced conversion stage means less converters are required
Transmission efficiency	Low: Additional loss due to reactive current	High: Loss associated with reactive current eliminated
Power supply reliability	Difficult-to-guarantee seamless transition after a utility fault	A guaranteed smooth transient DC power supply with limited voltage variation
Controllability	Difficult: Both voltage and frequency regulation needed; unbalance compensation needed in a three-phase system	Simple: No frequency, reactive power, or phase unbalance concern
Load availability	High: Available loads are dominantly designed with AC power supply	Low but with great potential: Digital and converter-based loads are highly compatible to DC
Protection	Mature arcing technique with cost-effective circuit breaker and well-developed protection system	High-cost circuit breaker with protection theory and equipment under development

III. SYSTEM MODELING

The proposed control strategy introduces adjustable current reference coefficients for parallel IFCs in order to enhance the active power transfer capability with zero active power oscillation. In the proposed control strategy, only one IFC, called as redundant IFC, needs to have higher current rating in comparison to other IFCs. Fig. 4(a) shows a typical hybrid ac/dc microgrid with parallel IFCs between ac and dc subsystem. The ac subsystem is connected to the utility grid through transformers at PCC. In this microgrid, energy storage system, PV system, wind power system, and different ac/dc loads are connected to ac or dc buses directly or through corresponding IFCs. In most cases, energy management system (EMS) is necessary to realize control of the whole system. Active power reference value is sent from EMS to each IFC through data bus. In this system, digital signal processors (DSPs) are needed for each IFC. For parallel IFCs, a master–slave communication structure is utilized. One IFC is configured as master converter and others are slave converters. Some critical control parameters could be sent from master to slave through data bus. A typical connection between parallel IFCs and the utility grid is presented in Fig. 4(b), where a grid fault is considered as a source of unbalance. In this project, IFCs under unity power factor operation are considered. That is to say, average reactive power of IFCs is zero and only active power transfer is considered. Actually, in some situations, it is also desired to transfer average reactive power between ac and dc buses. Reactive power transfer is not involved in this project. The grid fault is a two-phase to ground fault, as shown in Fig. 4(b), and it is assumed that $Z\ s^* = Z\ f^*$. If the transformer in Fig4(b) is a $\Delta - Y$ transformer, the voltage fault will change to type F fault at PCC after propagation. Positive- and negative-sequence components of fault voltage are 2/3 and 1/6 of the nominal value. Phase angle difference of positive- and negative-sequence components is 180°.

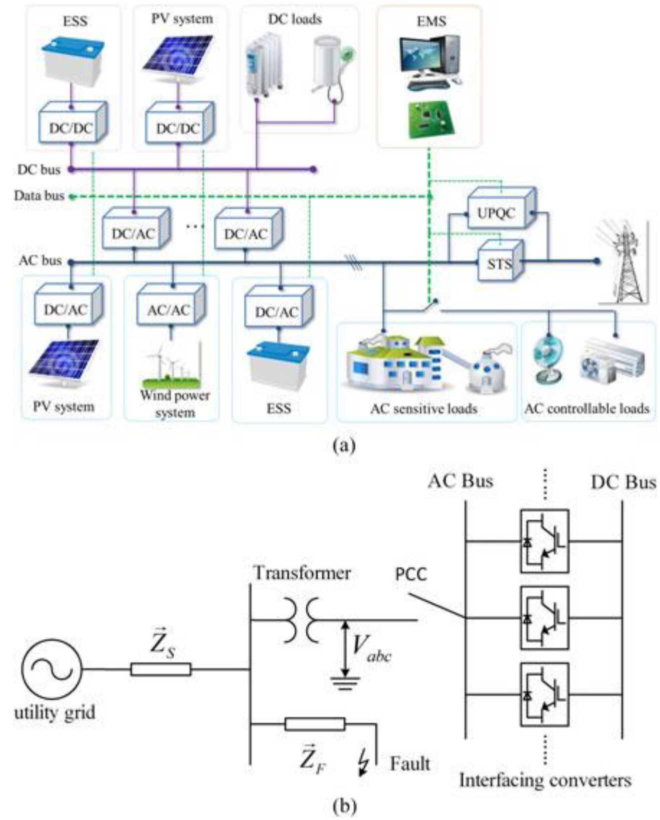


Fig. 4. (a) Hybrid ac/dc microgrid with parallel IFCs. (b) Parallel IFCs connection to the utility grid.

The utility grid is three-phase 110 Vrms/ 50 Hz. Active power reference is 3000 W and reactive power reference is zero. Here, current reference of is taken as an example to verify the proposed control strategy in our paper. Indeed, other current reference algorithm could also be used for IFCs under unbalanced grid faults. For example, Castilla *et al.* have proposed another control scheme with adjustable power quality characteristics using coefficients α and β. Using this algorithm, we could also get the proposed control strategy to enhance active power transfer capability of IFCs under grid faults. In order to reduce the peak currents of IFCs not to exceed their current rating limits, kp of common converters should be moved towards zero (peak current reaches its minimum value when $kp = 0$). However, since the value of peak current varies with the grid fault condition, it is possible that peak currents are still higher than current rating limits when $kp = 0$. If so, active power references should be reduced for further reduction of common converters' peak currents. In this way, a two-level regulation scheme is desired to restrict peak currents of common converters under all grid fault conditions.

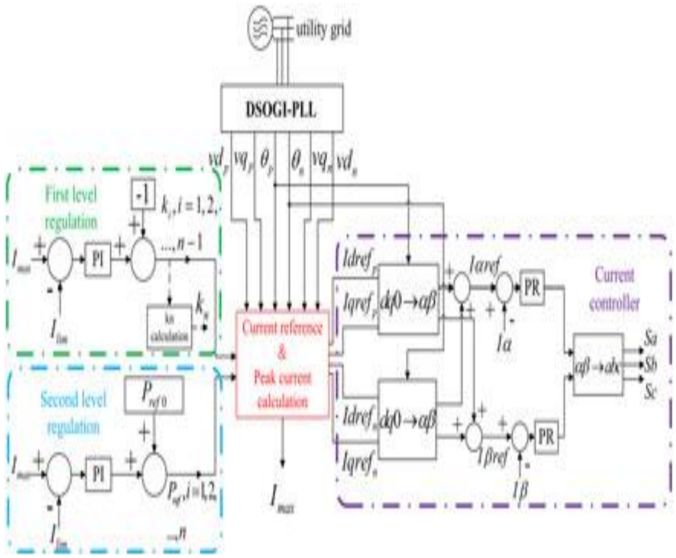


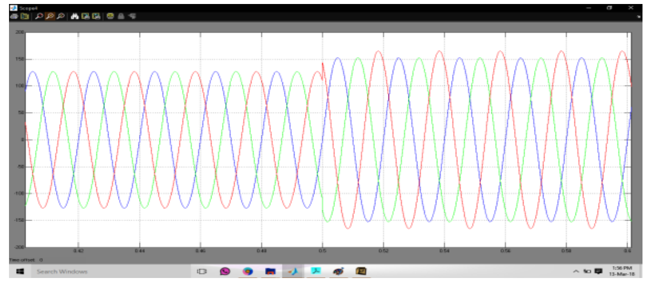
Fig.5. Block diagram of the proposed two-level control scheme.

Based on the aforementioned discussion, a two-level regulation scheme for IFCs is proposed. The control scheme block diagram is shown in Fig. 5. As shown in Fig. 5, the first-level regulation determines *kp* for each converter and the second-level regulation controls the active power reference *P*ref. It should be noted that *kn* of redundant IFC is determined using. In the control scheme, *I*lim and *I*max represent the current limit and peak current of each IFC, respectively. The detection and sequence separation of utility grid voltage is the key step in the control scheme. Different methods have been investigated up to now, which are mainly using filters and decoupling network. Recently, a dual second-order generalized integrator (DSOGI-PLL) has been introduced to not only decouple positive- and negative-sequence components but also harmonics in grid voltages. DSOGI-PLL is based on $\alpha\beta$ coordinates, and park transformation is not necessary. As shown in the upper part of Fig. 5, DSOGI-PLL is adopted due to its high accuracy and fast speed response. With the values of *kp, P*ref and outputs of DSOGI-PLL, the current reference and the value of peak current can be calculated using as shown in red block. In the inner current controllers, two PR regulators are used under $\alpha\beta$ coordinates to avoid complex coordination transformation.

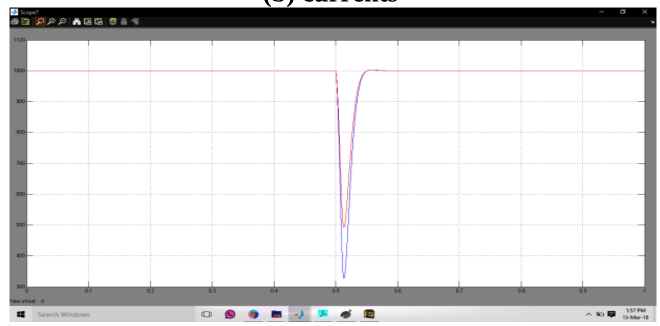
IV. SIMULATION RESULTS

Case-1: Power Complementary Strategy On Two Parallel IFCS

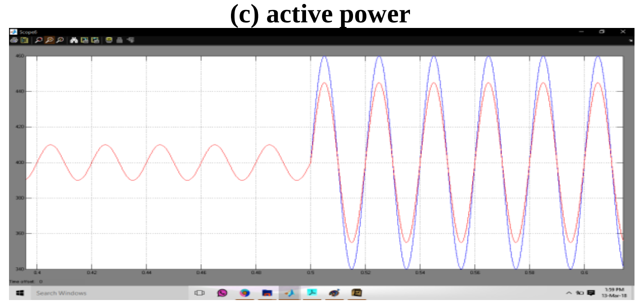
(a) grid voltages



(b) currents



(c) active power

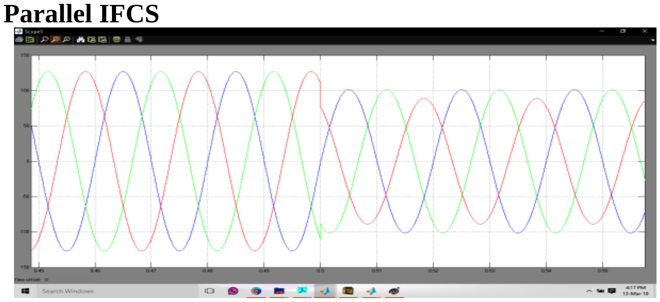


(d) reactive power

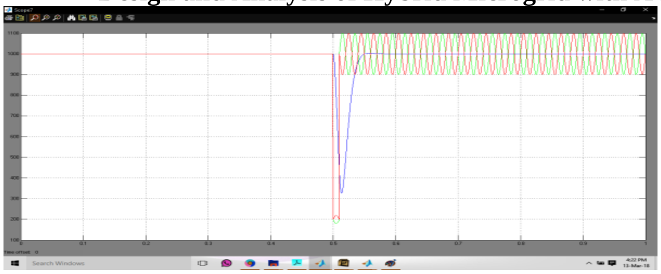
Fig.6.

The active and reactive power of each IFC and parallel IFCs together with output currents of converter A are shown in Fig. 6. It can be seen that active power of two IFCs oscillates in the same amplitude but 180° out of phase. As a result, the output active power of parallel IFCs is constant and free of oscillations. In the cases, the average reactive power of two IFCs is set on zero. As shown in Fig. 6, the larger *kP* results in smaller reactive power oscillation. However, the total reactive power oscillation of parallel IFCs is constant in cases, which coincides with the theoretical analysis. From the current waveforms, it is clear that the peak current decreases as *kA* moves toward zero.

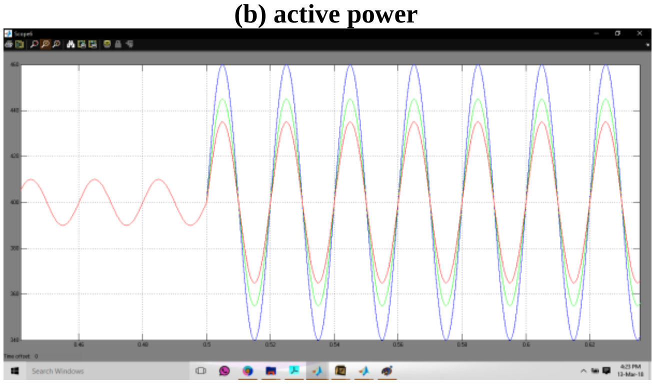
CASE-2: Power Complementary Strategy On Three Parallel IFCS



(a) grid voltages



(b) active power



(c) reactive power

Fig.7.

Simulations on the parallel operation of three IFCs are given in Fig7. However, total active power is oscillation-free in the cases. In cases, the amplitude of parallel IFCs reactive power oscillation is constant although it is different for each converter.

V. CONCLUSION

A novel control strategy for parallel operation of IFCs in hybrid ac/dc microgrid under unbalance grid condition is proposed in this project. By introducing adjustable current references for parallel IFCs, the proposed control strategy enhances the active power transfer capability with zero active power oscillation. In the proposed control strategy, only one IFC serves as a redundant converter with higher current rating to ensure the oscillation-free output active power of parallel IFCs. Simulation results confirmed the effectiveness of the proposed mechanism and corresponding control scheme. The work in this project focuses on unity power factor operation of IFCs. Future work will consider reactive power injection from IFCs, and the scenario of all IFCs participated in the active power oscillation cancellation in an optimized manner.

VII. REFERENCES

[1] J.He,Y.W. Li, J.M.Guerrero, F. Blaabjerg, and J. C. Vasquez, “An islanding microgrid power sharing approach using enhanced virtual impedance control scheme,” IEEE Trans. Power Electron., vol. 28, no. 11, pp. 5272–5282, Nov. 2013.

[2] T. Ma, B. Serrano, and O. Mohamme, “Distributed control of hybrid AC-DC microgrid with solar energy, energy storage and critical load,” in Proc. Power Syst. Conf., Mar. 11–14, 2014, pp. 1–6.

[3] N. Eghtedarpour and E. Farjah, “Power control and management in a hybrid AC/DC microgrid,” IEEE Trans. Smart Grid, vol. 5, no. 3, pp. 1494–1505, May 2014.

[4] A. P.Martins, A. S. Carvalho, and A. S. Araujo, “Design and implementation of a current controller for the parallel operation of standard UPSs,” in Proc. IEEE Int. Conf. Ind. Electron. Control Instrum., Orlando, FL, USA, 1995, pp. 584–589.

[5] J. Rajagopalan, K. Xing, Y. Guo, F. C. Lee, and B. Manners, “Modeling and dynamic analysis of paralleled DC/DC converters with master-slave current sharing control,” in Proc. IEEE Appl. Power Electron. Conf., 1996, pp. 678–684.

[6] J. M. Guerrero, J. C. Vasquez, J. Matas, M. Castilla, and L. G. de Vicuna, “Control strategy for flexible microgrid based on parallel line-interactive UPS systems,” IEEE Trans. Ind. Electron., vol. 56, no. 3, pp. 726–735, Aug. 2009.

[7] X. Lu, J. M. Guerrero,K. Sun, and J.C.Vasquez, “An improved droop control method for DC microgrids based on low bandwidth communication with DC bus voltage restoration and enhanced current sharing accuracy,” IEEE Trans. Power Electron., vol. 29, no. 4, pp. 1800–1812, Apr. 2014.

[8] Y. Li and Y.W. Li, “Powermanagement of inverter interfaced autonomous microgrid based on virtual frequency-voltage frame,” IEEE Trans. Smart Grid, vol. 2, no. 1, pp. 30–40, Mar. 2011.

[9] X. Liu, P. Wang, and P. C. Loh, “A hybrid AC/DC microgrid and its coordination control,” IEEE Trans. Smart Grid, vol. 2, no. 2, pp. 278–286, Jun. 2011.

[10] Z. Jiang and X. Yu, “Hybrid DC- and AC-linked microgrids: Towards integration of distributed energy resources,” in Proc. IEEE Energy 2030 Conf., 2008, pp. 1–8.