International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in; editorijoer@gmail.com

Vol.6., Issue.3, 2018
May-June

RESEARCH ARTICLE

ISSN: 2321-7758

HYBRID ENERGY STORAGE SYSTEM MICRO GRIDS INTEGRATION FOR POWER QUALITY IMPROVEMENT USING NPC INVERTER

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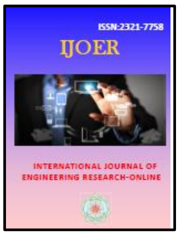

ABSTRACT

Rising demand for distributed generation based on Renewable Energy Sources (RES) has led to several issues in the operation of utility grids. The micro grid is a promising solution to solve these problems. A dedicated energy storage system could contribute to a better integration of RES into the micro grid by smoothing the renewable resource's intermittency, improving the quality of the injected power and enabling additional services like voltage and frequency regulation. However, due to energy power technological limitations, it is often necessary to use Hybrid Energy Storage Systems (HESS). In this paper, a second order sliding mode controller is proposed for the power flow control of a HESS, using a Four Leg Three Level Neutral Point Clamped (4-Leg 3L - NPC) inverter as the only interface between the RES/HESS and the micro grid. A three dimensional space vector modulation and a sequence decomposition based AC side control allows the inverter to work in unbalanced load conditions while maintaining a balanced AC voltage at the point of common coupling. DC current harmonics caused by unbalanced load and the NPC floating middle point voltage, together with the power division limits are carefully addressed in this paper. The effectiveness of the propose d technique for the HESS power flow control is compared to a classical PI control scheme and is proven through simulations and experimentally using a 4 Leg 3L - NPC prototype on a test bench.

Keywords: AC voltage controller, Grounding fault, Hybrid energy storage system, Micro grid, Reactive power controller.

I. INTRODUCTION

The increasing penetration of DG is changing management of the grid from centralized to decentralized schemes, creating several challenges that must be carefully addressed in order to keep the electrical grid's proper operation. High penetration of renewable energy can lead to Stability and power quality issues due to the stochastic nature of RES, such as wind and solar energy. The micro grid concept, which can be defined as a small scale weak electrical grid that is able to operate both in connected and islanded mode, has been extensively studied as a solution for RES integration. The weak nature of a micro grid implies the use of an Energy Storage System (ESS) to increase RES penetration and insure its stability .The use of an ESS integrates constraints such as admissible bandwidth, maximum ratings, current/power maximum gradient and the number of cycles. If these constraints are not respected it can lead to a dramatic lifetime reduction of the ESS, or in certain cases, to its destruction. The use of a Hybrid Energy Storage System (HESS) offers the necessary trade -off for increasing the lifetime of each ESS while also increasing the global specific energy and power of the whole system The main

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structures currently found in the literature to integrate a HESS into a grid. The passive topology, shows a lack of control of the power flow as well as the ESSs State of Charge (SOC) .The floating b) and parallel c) topologies are active topologies that use DC/DC converters to manage energy flows directly. They are already being used within the industry and fulfill a high standard (stress reduction and specific power/energy enhancement Parallel topology offers the best flexibility but the use of several DC/DC converters affects the global efficiency. Finally, despite a lower flexibility when compared to the parallel topology, the 3L -NPC topology d) can be used as a single power converter able to manage the power flow of a HESS, acting as an interface between the RES and the grid. increased number of voltage levels, the 3L-NPC topology becomes more efficient while showing a lower current Total Harmonic Distortion (THD) than an equivalent two level inverter.

II. SYSTEM ANALYSIS

The use of a 4-Leg 3L-NPC power converter topology to interface a RES with a HESS (formed by a VRB and a Li-Ion battery) in a microgrid context has been investigated. A new model of the structural limits is presented and implemented to exploit the entire capability of the 4-Leg 3L-NPC converter to insure a maximum power division between the two ESS. The power flow management of a HESS Composed of a Li-Ion battery and a Vanadium Redox Battery (VRB) is investigated in a microgrid context. The 4 Leg 3LNPC inverter has been chosen to interface the HESS with the microgrid due to its low THD, high efficiency and its ability to manage unbalanced AC loads through the 4th leg. The objective is to prove that by adding the fourth leg to a 3L-NPC converter and using a new DC side control strategy it is possible to reach both fast and efficient DC power sharing between the two aces and the RES, and at the same time improves the AC side power quality.

The main contribution lays in the DC power flow controller which allows HESS power flow control and DC current harmonics suppression. The new model for 4-Leg 3L-NPC structural limits proposed is assessed. A non-linear 2-SMC scheme has been designed and tuned to control the zero sequence injection in the modulating signals in order to control the power flow of the HESS. The proposed DC side control strategy is based on the Second Order Sliding Mode Control for its accuracy and robustness regarding some particular uncertainties. It aims to control the power flow of the HESS according to grid needs.

III. THEORETICAL ANALYSIS OF REACTIVE POWER CONTROLLABILITY

This section is to examine the reactive power controllability by capacitor insertion and firing angle control. The capacitor insertion strategy and capacitor voltage balancing actions affect the system from three different aspects. Firstly the overlap angle is smaller due to additional commutation voltage from capacitors. Secondly the average voltage across the 6-pulse bridge is increased due to the difference of capacitor voltage change during commutation.

Thirdly the pre-insertion of capacitors for charging purpose also increases the average bridge voltage. In the following, analytical derivations will be presented for all three aspects and then variation of power factor (interchangeably variation of reactive power) as a function of firing angle and extinction angle will be shown. In addition, selection of capacitor voltage level for the desired operating range is also presented. The commutation period from TY1 to TY3 as shown in Fig. 4 is considered in this section where is the transformer leakage inductance, is the capacitor value, is the instantaneous voltage for the capacitor inserted in negative direction and is the instantaneous voltage for the capacitor inserted in in positive direction, and are instantaneous currents flowing through TY1 and TY3, respectively. The instantaneous line-to-neutral source voltages are c L C n v p v 1 i 3 iusing the parameters from Benchmark model and of , overlap angle can be calculated as a function of capacitor voltage levels for different firing angles by solving (17). The capacitor value of 585 unfits the same as that calculated in [22] so that the level of capacitor voltage change is not significant after each commutation.

It can be seen from Fig. 5 that as capacitor voltage increases, overlap angle reduces to about and does not vary significantly for different firing angles C 585F 0 10Fig. 6 shows the variation of power factor as a function of firing angle and extinction angle, and this means that reactive power at the inverter AC side can be controlled via the firing angle. In particular by controlling the firing angle to be close to , power factor can be favorably controlled to be about unity. At the same time as shown in Fig. 6(b), the extinction angle is negative which means that commutation completes after the AC commutation voltage becomes negative. The success of commutation in this case is guaranteed by the commutation voltage from the capacitors.

A. CAPACITOR VOLTAGE LEVEL

The required capacitor voltage level is determined by the desired operating range. In this design, the nominal operating condition of inverter side is at unity power factor which means a firing angle close to, so a maximum firing angle of is chosen for the selection of capacitor voltage level. The required voltage level with firing angle ranges from to . It should be noted that in this case the normal operating point is at unity power factor which means a higher AC voltage, hence the transformer turns ratio is modified to achieve the same power transfer level at similar DC and AC voltages as the original benchmark system. Traditionally, extinction angle for a specific thyristor valve is obtained by measuring the time between the completion of commutation and the point when valve voltage becomes positive. However with the proposed system, inverter side can have the ability to export reactive power which means the extinction angle can sometimes be negative.

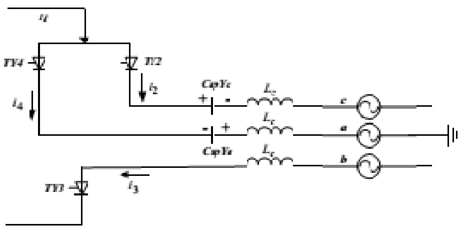


Fig 1 Commutation fromTY2 to TY4

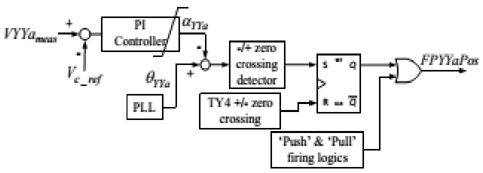


Fig 2 Capacitor voltage balancing logics

Consequently new method of extinction angle measurement with the ability to accommodate negative values is needed. A pulse Q is generated when commutation voltage becomes positive and is reset when TY2 current reaches zero. Then by subtracting the phase angle represented by the length of Q from , extinction angle for TY2 can be calculated. The final measured extinction angle for the control system is obtained by taking the minimum of all the calculated ca e 0 180.

B. SYSTEM CONTROL

The main requirements of the control system are to control the frequency and voltage on the oil platforms. A simplified control block diagram for the offshore station of the proposed hybrid system. The receiving HVDC converter (inverter) is in DC current control, whilst the sending HVDC converter (rectifier) is in DC voltage control. This avoids the need to send the current order, which is generated by the STATCOM DC voltage controller, to the rectifier controller by fast telecommunication.

C. AC VOLTAGE CONTROLLER

To control the AC voltage at the inverter AC bus, an AC voltage controller can be designed utilizing the reactive power controllability of the proposed system. In this case, the AC voltage is controlled by controlling the reactive power import/export of the inverter station. Therefore the inverter AC voltage stability can be improved. The proposed inverter controller and inverter AC voltage reference and measured values, respectively. A PI controller is used to generate inverter firing angle by minimizing AC voltage error.

D. RECTIFIER ACTIVE POWER CONTROL

As discussed before that it is important to ensure that active power transfer of the DC system is kept at desired values when inverter is controlling reactive power/AC voltage. Such operational behavior is achieved by utilizing rectifier side controller to control active power transfer. The active power reference is divided by DC voltage measurement to get the desired current, and the DC current order signal is obtained by taking the minimum value of desired current and current order from VDCOL- . Finally PI controller is used to generate the control input of firing angle. The parameters for the above PI controllers are selected by trial and error through simulation studies.

IV. STATCOM RATING AND ENERGY STORAGE

The system can be designed to allow for greater load variation on the offshore platform and provide for less AC voltage disturbance if the rating of the STATCOM is increased. Since the energy storage on the DC side of the STATCOM is used to balance the active power during transient system conditions the capacity of this energy storage may also be increased to provide more stable operation and less voltage variation. These options should be taken into account during the feasibility stage since they will impact on the both the capital cost and the physical size of the offshore equipment.

A. COMPARISON WITH VSC TRANSMISSION SOLUTION

An equivalent VSC Transmission solution can also provide excellent performance during load switching. However, like the proposed hybrid system, the overload capability is limited. Under fault conditions, the performance of these two schemes is also similar. The capital cost of the VSC Transmission solution is likely to be higher than the proposed hybrid system particularly for relatively high power ratings. The power loss of a VSC Transmission solution is also likely to be much higher than the hybrid scheme. The exact breakeven point for the two schemes depends on the power rating, load conditions and loss capitalization.

V. THREE PHASE GROUNDING FAULT

The three phase grounding belongs to a typical symmetric fault. The fault occurred at 1 s and disappeared at 1.05 s. The fault point was set in the ac system side of inverter. The blue represents FC; The red stands for SVC and the green represents SC (the following figures are the same to this). **Figures 6** and **7** show the dynamic recovery characteristics of DC power and DC voltage under the three phase grounding fault. It can be seen that the recovery of the DC power and DC voltage is the slowest when SVC is used for compensation. Because the TSC repeatedly switch during and after the fault, the system will appear the oscillation during the recovery.

The recovery of the system is the fastest when SC is used. That is because SC emits and absorbs reactive power by changing the volt- age and current waveform of VSC besides it don't need the capacitor group and shunt reactor, and there is no shortcoming of the SVC compensation runtime. The main advantage is that SC not relies on the system volt- age when it emits the capacitive reactive current, and the ability is suitable for the occasion that the system needs to support voltage during and after the fault especially [19].

VI. SINGLE PHASE GROUNDING FAULT

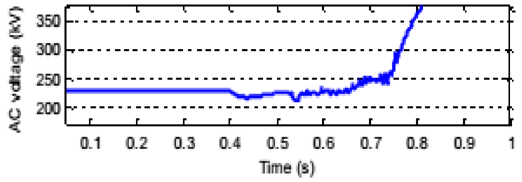
The single phase grounding fault is a common fault in the ac system, and also is a kind of typical asymmetric fault. The fault occurred at 1 s and disappeared at 1.05 s. The fault point was set in the ac system side of inverter. Figures 8 and 9 show the dynamic recovery characteristics of DC power and DC voltage under the single phase grounding fault. They are similar with Figures 6 and 7. Among the different var compensating devices, the recovery of the system is the fastest when SC is used, while the recovery of the dc power and dc voltage is the slowest when SVC is used for compensation, but the overall the rate of recovery increases.

VII. SIMULATION RESULT

The hybrid system was studied using EMTDC/PSCAD. The HVDC system is a mono-polar scheme rated at 300MW/300kV modified from the benchmark model proposed in [9]. The rectifier is a conventional 12-pulse converter connected to an AC source with a Short Circuit Ratio of 5. For the purpose of this study, the STATCOM is modelled as a 2-level VSC switched at 1350Hz and rated at +/-100MVar. Its DC capacitor has a total energy storage of 4MJ when charged at its rated voltage. Two passive harmonic filters are used. One is rated at 60Mvar, tuned at 12th/24th and the other is a 12MVar high pass filter.

Six loads are considered in the study and are listed in Table I. Large induction machines are included as this is usually the load condition on oil platforms. Loads 1, 2, 4 and 6 are connected to the system via a250MVA transformer while Loads 3 and 5 are connected via their separate transformers rated at50MVA, respectively. The mechanical loads of the induction machines are assumed to be proportional to the cube of machine shaft speeds. Table II shows the operational sequence of the studied system, where it is assumed that the DC capacitor is fully charged before the sequence begins.The HVDC rectifier controls the DC voltage, and hence its value stays almost constant throughout the operating conditions shown in the case study. Fig. 3 clearly shows that the proposed hybrid system gives stable operation and is well controlled over the whole operating range simulated.

(a)



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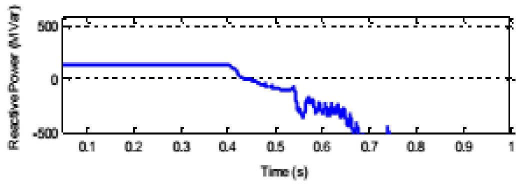

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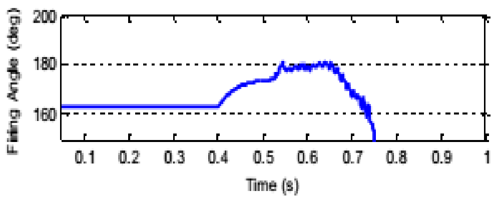

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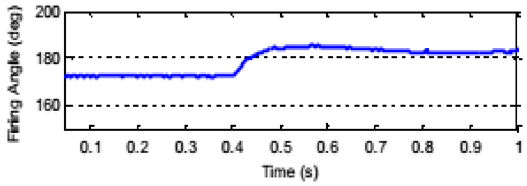

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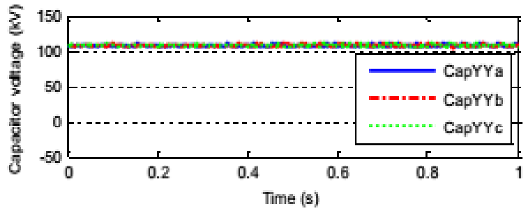

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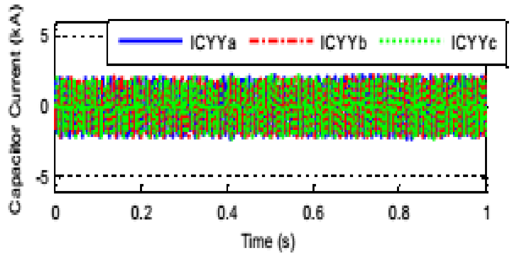
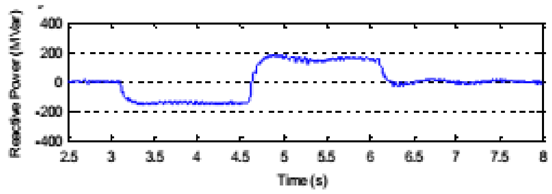


Fig 3: System responses with inductive load switching, (a) Inverter bus voltage; (b) Inverter reactive power consumption; (c) Inverter firing anglr; (d) DC current; (e) Capacitor voltages(CapYYA, CapYYb, CapYYc); (f) Capacitor currents (CapYYA, CapYYb, CapYYc)

VIII. FAULT RECOVERY

The time taken by the HVDC system to recover the 80% of the pre-fault power after the fault clearance is known as the DC power recovery time. The DC power recovery time is often desired the recovery ability of a DC system PI controller and the capability of reactive power compensators during system disturbances. From the inverter DC power recovery simulation results (fig 6 and table 3), it is observed that the during rectifier side AC system faults, the system recovery with the firefly slightly faster than the conventional PI controller. On the other hand, for the faults in the rectifier DC side, the inverter AC and DC sides, the firefly algorithm based optimal PI controller makes the system recovery much faster than the conventional PI controller.



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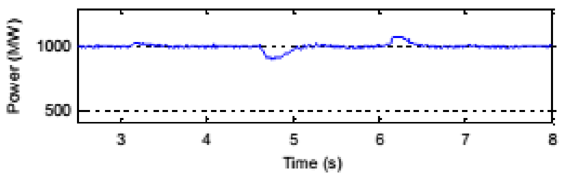

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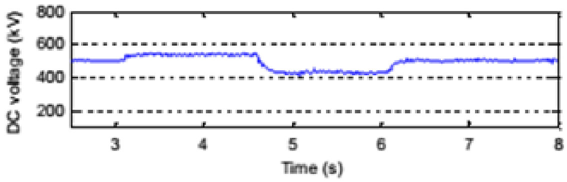

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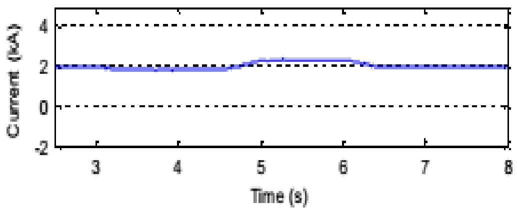

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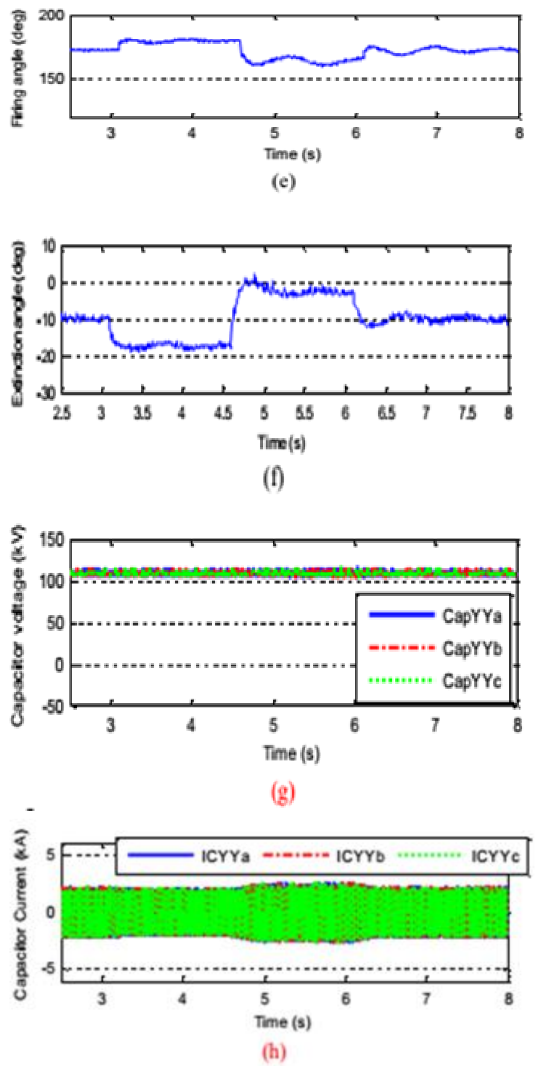

Fig 4: System responses with reactive power reference step changes; (a) Reactive power consumption at inverter; (b) Active power transfer; (c) Dc voltage; (d) Dc current; (e) Inverter firing angle; (f) Excitation firing angle; (g) Capacitors voltages(CapYYa, Cap YYb, CapYYc); (h) Capacitors currents(CapYYa, Cap YYb, CapYYc)

IX. CONCLUSION

In this Project the use of a 4-Leg 3L-NPC power converter topology to interface a RES with a HESS (formed by a VRB and a Li -Ion battery) in a micro grid context has been investigated. A new model of the structural limits is presented and implemented to exploit the entire capability of the 4-Leg 3L -NPC converter to insure a maximum power division between the two ESS. A non-linear 2 -SMC scheme has been designed and tuned to control the zero sequence injection in the modulating signals in order to control the power flow of the HESS. Furthermore, the fourth leg of the converter allows the unbalanced load issue to be addressed, and thus enable active power filter capabilities. The investigation of the limits of the topology showed a power exchange capability among the HESS. Simulation and experimental results proved the capacity of the proposed control strategy to manage a HESS in order to improve the power quality and stability as well as to control the renewable energy injected in to a micro grid.

X. REFERENCES

[1] M. YekiniSuberu, M. Wazir Mustafa, and N. Bashir, "Energy storage systems for renewable energy power sector integration and mitigation of intermittency," Renew. Sustain. Energy Rev., vol. 35, pp. 499–514, Jul. 2014.

[2] S. Vazquez, S. M. Lukic, E. Galvan, L. G. Franquelo, and J. M. Carrasco, "Energy Storage Systems for Transport and Grid Applications," IEEE Trans. Ind. Electron., vol. 57, no. 12, pp. 3881– 3895, Dec. 2010.

[3] M. G. Molina and P. E. Mercado, "Power Flow Stabilization and Control of Microgrid with Wind Generation by Superconducting Magnetic Energy Storage," IEEE Trans. Power Electron., vol. 26, no. 3, pp. 910 –922, Mar. 2011.

[4] M.-E. Choi, S.-W. Kim, and S.-W. Seo, "Energy Management Optimization in a Battery/Supercapacitor Hybrid Energy Storage System," IEEE Trans. Smart Grid, vol. 3, no. 1, pp. 463–472, Mar. 2012.

[5] G. Qiu, C. R. Dennison, K. W. Knehr, E. C. Kumbur, and Y. Sun, "Pore scale analysis ofeffects of electrode morphology and electrolyte flow conditions on performance of vanadium redox flow batteries," J. Power Sources, vol. 219, pp. 223–234, Dec. 2012.

[6] X. Tan, Q. Li, and H. Wang, "Advances and trends of energy storage technology in Micro grid," Int. J. Electr. Power Energy Syst., vol. 44, no. 1, pp. 179–191, Jan. 2013.

[7] N. R. Tummuru, M. K. Mishra, and S. Srinivas, "Dynamic Energy Management of Renewable Grid Integrated Hybrid Energy Storage System," IEEE Trans. Ind. Electron., vol. 62, no. 12, pp. 7728–7737, Dec. 2015.

[8] T. A. Smith, J. P. Mars, and G. A. Turner, "Using supercapacitors to improve battery performance," in 2002 IEEE 33rd Annual IEEE

Power Electronics Specialists Conference. Proceedings, 2002, vol. 1, pp. 124 –128.

[9] R. A. Dougal, S. Liu, and R. E. White, "Power and life extension of battery- ultracapacitor hybrids," IEEE Trans. Components Packag. Technol., vol. 25, no. 1, pp. 120 –131, Mar. 2002.

[10] T. Zhou and B. François, "Energy management and power control of a hybrid active wind generator for distributed power generation and grid integration," IEEE Trans. Ind. Electron., vol. 58, no. 1, pp. 95–104, Jan. 2011