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Research Paper

Using the CPISMC Approach, HESS-Based DC Micro Grids can Regulate Power Sharing Voltage and Control Their State of Charge Actively

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Abstract— One reason DC microgrids are becoming more popular is the use of photovoltaic (PV) systems. The use of battery storage improves the stability of PV-based DCMG. Improving the DC microgrid's dynamic stability and the battery's lifespan is possible with the addition of a second energy storage device, the supercapacitor (SC). "Hybrid energy storage system" refers to a setup that combines SC with batteries. The HESS relies heavily on the control and sharing of power between the battery and the SC. Power may be dynamically shared between the battery and the SC in conventional HESS control systems that use frequency constant low pass filters. However, DC bus regulation yet battery state-of-charge (SoC) are impacted by the continual and sluggish dynamics of HESS management. An energy administration strategy (EMS) based on a system-on-chip (SoC) variable frequency creative low-pass filter is proposed in this work to enhance the dynamic performance of HESS. Under specific circumstances, the proposed EMS improves the battery's performance by controlling the power split between the battery and the SC. Our proposed approach improves the stability of dynamic DC buses, extends the life of batteries, and makes efficient use of SC. The suggested EMS has been thoroughly tested using both digital simulation in real-time and Matlab simulation.

Keywords: DC microgrid, stability, PV system, energy management, hybrid storage.

INTRODUCTION

One possible answer to the world's acute energy crisis, rising power demand, and environmental difficulties is the use of renewable energy resources (RER), which are now being considered as a potential replacement for traditional sources. Since renewable energy sources may provide higher benefits, reducing financial and technological obstacles may be possible with insufficient collaboration of dispersed generation. In the face of economic and political constraints at the regional level, the establishment of new transmission routes is sluggish and often postponed. Microgrids, with their distributed generating features, are superior in terms of overall economic efficiency and operational viability, and they remain a viable alternative to the electrical current system of long-distance energy transmission via distant generations. Renewable energy sources that are gentler on the planet are ideal for use in microgrids, which run on distributed energy resources (DER). There are two main types of microgrids, those that use alternating current (ACMG) and those that use direct current (DCMG), and each one consists of two or more RER, such as PV, turbines for wind power, energy storage, and loads. As the usage of DC RER, load, and storage devices grows at an exponential rate, DC small grids (DCMG) have gained popularity and compliance in the last decade due to their remarkable simplicity, stability, and efficiency. On the other hand, DCMG is unaffected by a number of ACMG-popular power quality concerns, including reactive power, dependability, and cost-effective solutions for certain uses.

Energy storage devices are essential for standalone DCMG to compensate for the generating gap between demand and supply and improve power efficiency due to the intermittent & variable nature of RER. In microgrids that generate wind electricity, energy storage systems for batteries (BESS) have been used to keep demand constant even when there are intermittent occurrences. for a DC micro grid that is solely powered by PV and equipped with BESS, a cooperative control-based energy management approach is being explored. Furthermore, methods for extending the battery's life were covered, including controlling the voltage of the DC bus and keeping the state of charge, or SOC within predetermined limits. Power management and control for photovoltaic (PV) systems and battery-based microgrids in both grid-connected and island modes are shown. Battery life is lowered and total system expenses are raised since it maintains the DC & AC bus power distributions in all conditions.

REATED WORK :

"Regulation of voltage, current sharing, and state of charge in a HESS-based DC microgrid using the CPISMC method,"

Solar panels and wind turbines are illustrations of energy from renewable resources (RER) that need storage systems for energy with more dependable and strong control methods to handle the unpredictability and periodic nature of these resources. The unpredictable nature of RER makes it difficult to stabilise voltages, keep power demand and production constant, and extend the life of energy storage systems. This study proposes a CPISMC method, which combines PI or sliding mode control, to manage the dc bus voltage, keep the state of charge (SOC) within bounds, and enhance present-day sharing between the battery or supercapacitor to meet the demand-generation disparity. Key advantages include an increase in battery life due to the redistribution of unwaged currents from the battery to the supercapacitor in conjunction with high-frequency current components. A number of simulations, including comparisons with more traditional control strategies, have been run to see how well the suggested control approach works. The suggested control technique has enhanced current-sharing among HESS, longer battery life, and better regulation of the dc bus voltage compared to the present conventional control strategy. By using hardware-in-loop (HIL) on a real-time simulator based on field-programmable gate arrays (FPGAs), the outcomes have been experimentally verified.

"The Control and Management of Voltage in DC Microgrids: A Critical Review,"

The lack of problems with controlling frequency and reactive power, the incorporation of solar photovoltaics (PV) and devices that store energy (ESDs), and the extensive usage of direct current loads are all contributing factors. Important aspects of a DC microgrid include voltage regulation on the DC bus, management of power, efficient power distribution among the ESDs, and restoration of the state of charge (SoC). Because microgrids use power electronic converters to link a number of distributed generator (DGs), loads, utilities grids, & ESDs to the DC bus, controlling the bus voltage and managing the power supply posed challenges. When it comes to DC microgrids, controlling the bus voltage and managing power among sources and loads is crucial for stability and dependability. A variety of control systems, including hierarchical, multi-level, distributed, centralized, and decentralized ones, may be used to safely and securely operate DC microgrids. On top of that, state-of-the-art control methods including AI, model predictive, nonlinear, and robust control are used. The two primary facets of direct current microgrids that are examined in this article are power management and voltage control. The article delves into the difficulties and potential solutions around DC microgrid voltage authority and control management. Thanks to the extensive documentation of the pros and cons of different voltage control as well as power management approaches, this resource is invaluable for both academics and professionals in the field. We address technical concerns of DC microgrids that are either island-connected or grid-connected, specifically with voltage regulation and power management. We find important gaps in the research that new technology may fill. Insights into the present and future of DC microgrids power management and voltage control, as well as the need for more study, are provided to readers by means of this article.

"Microgrid Energy Distribution Regulation and Performance Evaluation with Hybrid Energy Storage and Wind Power Integration,"

An innovative and practical way to create a sustainable energy environment that incorporates sources of renewable energy (RES) with energy storage technologies (ESS) is the direct current microgrid. In this piece, we take a look at a new PDCS that was developed for microgrids that use small-scale wind energy to generate low-voltage direct current (LVDC). Because wind energy is intermittent and stochastically volatile, and because load demand might vary unexpectedly, microgrids that use wind power must also have storage devices with high power densities. For this purpose, the 48 V LVDC bus is connected to a system for storing hybrid energy (HESS) that uses batteries and supercapacitors (SCs). In order to increase the battery's cycle life, hybridization primarily aims to reduce the need for immediate surge current and to lessen the strain on the battery from rapid charge and discharge. This improves the dependability and efficiency of the integrated wind system. Faster control of the 48 V DC bus voltage and improved power-sharing between the battery and SC are two benefits of the suggested PDCS that help to close the gap between demand and generation. The proposed system also keeps the state-of-charge (SOC) within the operational limitations. Experiments with several case studies test the constructed autonomous LVDC system using the proposed PDCS. Evaluation of the PDCS's effectiveness and its ability to switch between modes with ease is supported by comparative testing results. Speedier SOC recovery is another benefit of the innovative approach, which takes care of SC charge/discharge regulation.

"Designing and analyzing the stability of a home grid-dependent PV system with battery-supercapacitor storage,"

Energy storage is crucial for resolving various stability concerns that develop in the power network due to the expansion of renewable energy sources and the unpredictable nature of solar irradiation. In this study, we take a look at a home PV system that uses a hybrid energy storage system that combines batteries and supercapacitors. We analyze its design and stability. In a fully operational parallel design, the 400 V DC-bus supplies power to both the battery & supercapacitor packs independently; as a result, the voltage levels of these components are distinct and their power flows are regulated independently. In order to develop current controllers to the bidirectional converters for the battery and supercapacitor, a thorough small-signal stability investigation is taken into account. The authors provide a significant improvement over previous works by conducting thorough stability analyses of the battery & supercapacitor converters in both boost and buck modes of operation. This enhanced accuracy allows for more precise controller tuning. The DC-bus voltages controller is designed with the microscopic stability investigation of VSI, or voltage source inverter, in mind. A benchmark output current is created using phase-locked loop, also known as PLL, for grid synchronization. Through the use of mathematical analysis & average modeling, the suggested model is created and tested inside the MATLAB/Simulink suite of software. This model's dynamic performance is confirmed by the simulation results, which show that it can handle several fast changes in PV production and load demand. Not only that, the model is accurate and responsive during mode changes, displaying lightning-fast regulation of the DC-bus voltage with a negligible ripple voltage of no more than 0.625%. Last but not least, the supercapacitor manages the rapid changes happening within 0.2 s, which reduces stress on the battery and increases its lifespan.

"Dynamic power-sharing and voltage regulation in a DC microgrid using a hybrid energy storage system via variable-structure control"

To solve the problem of demand-generation disparity and regulate the voltage on the DC bus, this research suggested a new approach that relies on variable structure management to share power between batteries and energy storage devices called supercapacitors (SC). Hybrid energy storage systems, such as batteries and fast SCs managed through current error signals, may be used for both moderate and quick compensations. With decreased battery stress, the suggested solution improves DC bus regulation by using hybrid storage of energy devices managed by proportionate integral (PI) and variable-structured controllers. Redirecting unwaged battery flows to SCs for quick compensation also increases battery longevity. By comparing the approach's efficacy with a traditional control method regarding of maximum DC bus voltage variations, simulations were used to examine the method's effectiveness. The outcomes were confirmed through experimental means by means of a field-programmable gate array-based real-time hardware-in-loop (HIL) simulator.

Methodology:

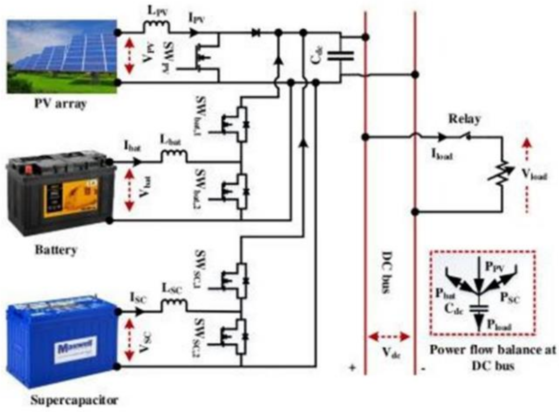


Fig. 3. Equivalent system configuration of PV based DC microgrid.

Figure 1: Comparative setup of a DC microgrid powered by photovoltaics

The performance of HESS-based DCMG is dependent on the maximum allowable charge/discharge rate of the batteries. Hence, this paper proposes a CPISMC technique to regulate the voltage regulation, state-of-charge regulation, and dynamic current sharing. The apparent electrical inertia means that the battery converter may not promptly monitor the reference currents. The supercapacitor would be charged with the reference currents from the undetectable battery converter using this suggested approach. Since the supercapacitor does in fact possess a high power density in comparison to the battery. This method improves the HESS performance as seen in figure 1 without requiring any changes to the converter components.

1.1 Developing a DC microgrid system and its modeling:

The HESS, PV panels, and loads make up a DC microgrid that can operate independently. Because of the uncertainty in solar power output, the HESS elements use high specific power densities and energy densities. Supercapacitors and battery modules are connected to the DC bus by bidirectional DC/DC converters (BDDC), while PV panels are connected to the DC bus using boost converters.

To choose the system's operating mode, the power management algorithm uses CPISMC, which stands for combined PI plus sliding mode control. Controlling the DC bus voltage in response to changes in the load and the source, as well as generating a reference current for use in controlling the PV converter, supercapacitor, and batteries, are all tasks of power management algorithm. The state-of-charge (SOC) limitations for the battery and supercapacitor are set to 20% ≤ SOCbat ≤ 90% and 100%, respectively, in the power management algorithm.

1.2 EPM: Excess Power Mode

Whereas, during this mode, iavg ought to be negative. Therefore, either the excess power has to be used by HESS or the PV power needs to be controlled in a way that it meets the load requirement.

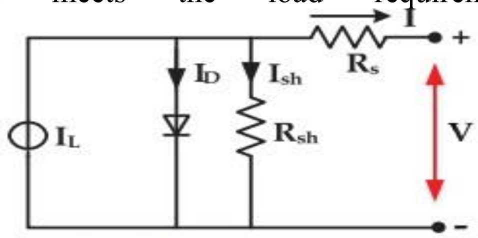


Fig. 5. Single diode equivalent circuit of PV cell.

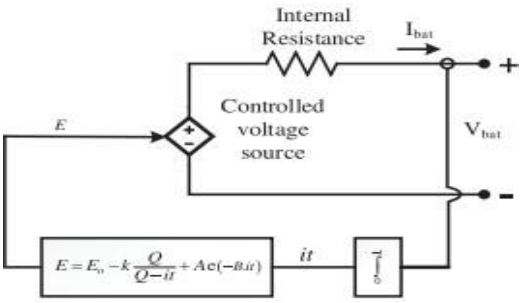


Fig. 6. Equivalent circuit of battery non-linear model.

Figure 1.1 **circuit that uses a single diode**

The power management algorithm, which is based on CPISMC, chooses the system's operating mode according to (iavg), as seen in Figure 8.4. Controlling the voltage at the DC bus in response to changes in the load and the source, as well as generating a reference current for use in controlling the PV converter, supercapacitor, and batteries, are all tasks of the power control algorithm.

The state-of-charge (SOC) limitations for the battery and supercapacitor are set to 20% ≤ SOCbat ≤ 90% and 100%, respectively, in the power management algorithm.

The state-of-charge (SOC) limitations for the battery and supercapacitor are set to 20% ≤ SOCbat ≤ 90% and 100%, respectively, in the power management algorithm. The following functional goals are shown in figure and informed the design of the power management algorithm.

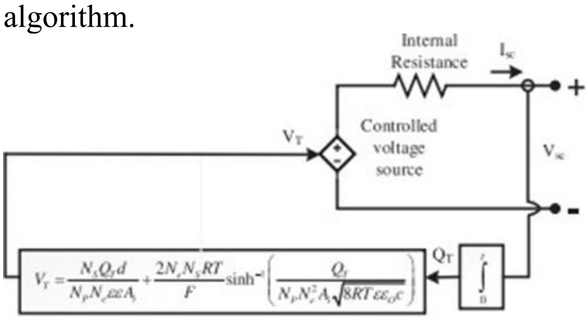


Fig. 7. Equivalent circuit of SC.

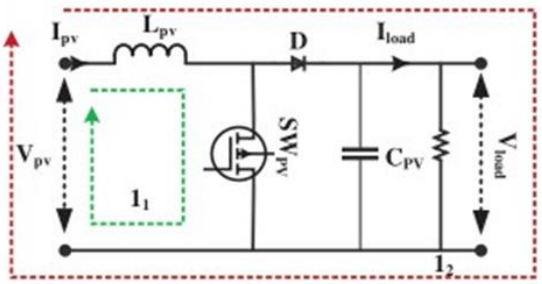


Fig. 8. Circuit diagram of PV DC/DC converter with its operating modes.

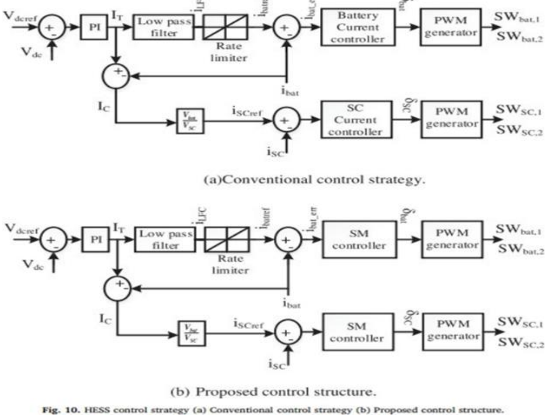
Figure 1.2: corresponding ckt of PV and SC

State of charge for the battery (BCM):

In this configuration, PV production significantly exceeds load demand, while the battery state of charge remains below the restrictions. So, as seen in figure 8.6, the battery controls the DC voltage of the bus by filling with the available extra power.

Battery state-of-charge is higher than 50% in

this form (condition 1-2), for example, when SOCbat > 50%. Photovoltaic (PV) units provide DC loads. Power excess allows for charging of the battery and supercapacitor.
The state-of-charge (SOC) limitations for the battery and supercapacitor are set to 20% ≤ SOCbat ≤ 90% and 100%, respectively, in the power management algorithm. A few practical goals were considered when developing the algorithm for power management.



(a)Conventional control strategy.

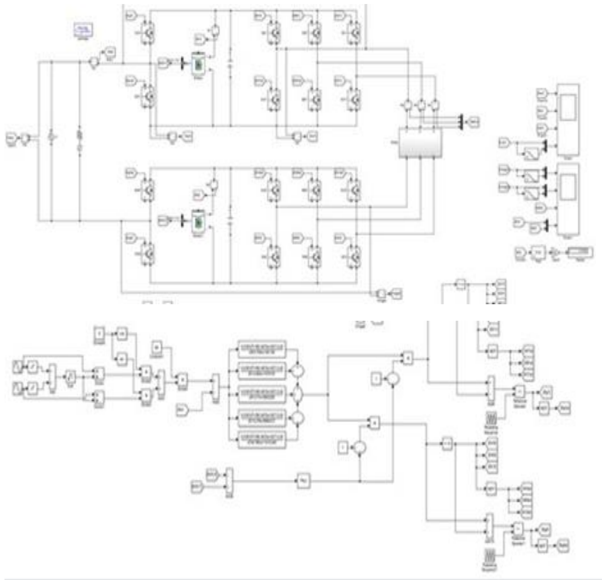
(b) Proposed control structure.

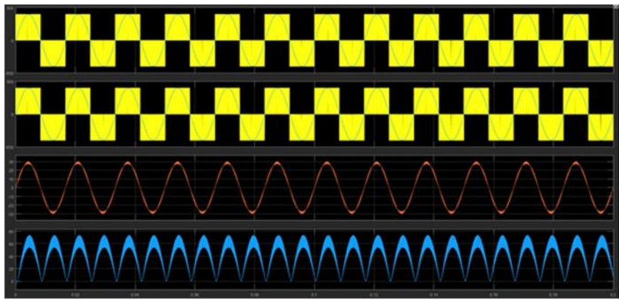
Fig. 10. HESS control strategy (a) Conventional control strategy (b) Proposed control structure.

Figure 1.2: **Current and Future Control Approaches**

Typical and suggested control block diagrams, respectively, for the two control strategies under consideration. In order to meet demand for load during low irradiances and transients, the suggested control method suggests a DC microgrid that uses standalone PV and HESS. In a HESS system like this, the battery takes care of the constant energy supply, while the SC gives the load immediate power, according to the energy concentration/power density relations between the two. An algorithm for energy management has been suggested, which would use a sliding mode control method to guarantee supply using hybrid energy storage. Sliding mode controllers are basically switching controllers that may be used with the planned DC microgrid. They transition between two configurations based on the system condition.

RESULT S :





Results of a steady-state simulation when linked to a 480Vrms grids are shown in Figure 3. Keep in mind that there is full overlap between the phase electrical currents (Isa, Isb, Isc) & the battery currents (Ib1, Ib2).

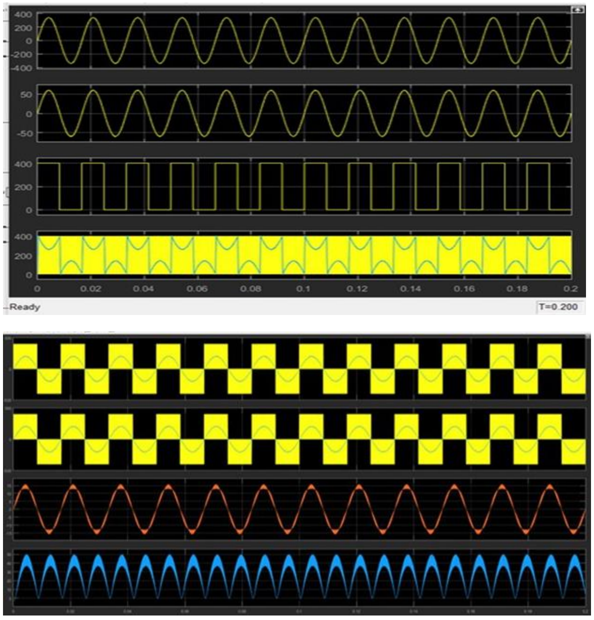


Fig. 3.1: Results of the steady-state simulation when linked to a 240Vrms matrix. You should know that the currents flowing through the phases (Isa, Isb, Isc) plus the batteries (Ib1, Ib2) are totally overlapping since they are the same.

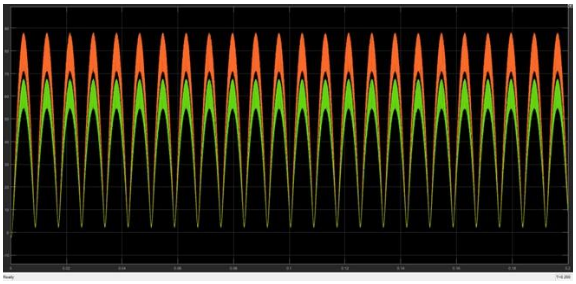


Fig.5.4: Computing outcomes using energy balance in the simulation.

CONCLUSION

In this research, we provide a control method that regulates the voltage of the DC bus and improves current-sharing among HESS using a combination of PI and the CPISMC techniques. Improved current splitting among HESS, quicker regulation of the dc bus voltage, lowering of battery stress levels with longer lifespan, and maintenance of energy storage Cos limits within the normal operating region are the essential aspects of the suggested control technique. Faster & better dc bus voltage management in accordance with IEEE standard 519-1992 is shown by the simulations and validation based on HIL real-time environment. The study also compares the suggested control method to the standard one and finds that it is more successful.

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REFERENCES

[1] A. Ehsan, Q. Yang, Optimal integration and planning of renewable distributed generation in the power distribution networks: a review of analytical techniques, Appl. Energy 210 (2018) 44–59 https://doi.org/10.1016/j.apenergy.2017.10.106.

[2] R.H. Lasseter, MicroGrids, 2002 IEEE Power Eng. Soc. Winter Meet. Conf. Proc. (Cat. No.02CH37309) (2007) 305–308 https://doi.org/10.1109/PESW.2002.985003.

[3] D. Kumar, F. Zare, A. Ghosh, DC Microgrid Technology, System architectures, AC grid interfaces, grounding schemes, power quality, communication networks, applications, and standardizations aspects, IEEE Access 5 (2017) 12230–12256 https://doi.org/10.1109/ACCESS.2017.2705914.

[4] L.-L. Fan, V. Nasirian, H. Modares, F.L. Lewis, Y.-D. Song, A. Davoudi, Game- theoretic control of active loads in DC microgrids, IEEE Trans. Energy Convers. 31 (2016) 882–895 https://doi.org/10.1109/TEC.2016.2543229.

[5] A.M. Gee, F.V.P. Robinson, R.W. Dunn, Analysis of battery lifetime

extension in a small-scale wind-energy system using supercapacitors, IEEE Trans. Energy Convers. 28 (2013) 24–33 https://doi.org/10.1109/TEC.2012.2228195.

[6] I. Serban, C. Marinescu, Battery energy storage system for frequency support in microgrids and with enhanced control features for uninterruptible supply of local loads, Int. J. Electr. Power Energy Syst. 54 (2014) 432–441 https://doi.org/10.1016/j.ijepes.2013.07.004.

[7] S. Sahoo, S. Mishra, S. Jha, B. Singh, A cooperative adaptive droop based energy management and optimal voltage regulation scheme for DC microgrids, IEEE Trans. Ind. Electron. 67 (2020) 2894–2904 https://doi.org/10.1109/TIE.2019.2910037.

[8] Z. Yi, W. Dong, A.H. Etemadi, A unified control and power management scheme for PV-battery-based hybrid microgrids for both grid-connected and islanded modes, IEEE Trans. Smart Grid. (2018) 5975–5985 https://doi.org/10.1109/TSG.2017.2700332.

[9] J. Hong, H. Lee, and K. Nam, “Charging Method for the Secondary Battery in Dual-Inverter Drive Systems for Electric Vehicles,” IEEE Transactions on Power Electronics, vol. 30, no. 2, pp. 909–921, feb 2015.

[11] S. Serna-Garcés, D. Gonzalez Montoya, C. Ramos-Paja, Sliding-mode control of a charger/discharger DC/DC converter for DC-bus regulation in renewable power systems, Energies 9 (2016) 245 https://doi.org/10.3390/en9040245.

[12] M. Mokhtar, M.I. Marei, A.A. El-Sattar, An adaptive droop control scheme for DC microgrids integrating sliding mode voltage and current controlled boost converters, IEEE Trans. Smart Grid. 10 (2019) 1685–1693 https://doi.org/10.1109/TSG.2017.2776281.