An Extensive Survey on Converters with Improved Common Current Sharing and Voltage Quality Enhancement for Microgrids

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Abstract - Microgrids are little scale, low voltage combined heat and power supply system intended to supply electrical furthermore, warmth loads for a little group, for example, a lodging home or a rural territory, or open group, for example, a college or school, a business territory, a mechanical site, an exchanging home or a civil locale. Microgrid is basically a distributed system on the ground that it is the combination of distributed generation frameworks and diverse burdens at circulation voltage levels. Power generated from renewable resources is either connected to the grid or to the local loads through inverters. A three-phase four-leg voltage source inverter can guarantee a balanced three-phase output even when the load is unbalanced and nonlinear. The simplification of the available switching scheme and common-mode voltage reduction switching scheme are also considered. The significant power quality problems at the AC utility grid, there has been a growing demand for clean, reliable AC power supplies and power conditioning equipment to keep electrical and electronic equipment operating under all circumstances. Critical loads such as computer systems, security systems, communication systems, hospital equipment, critical process control equipment and on-line management systems require clean and reliable AC electric power. In these work different various strategies are used in micro-grid power mitigation.

Keywords- Four-leg converter, microgrid, virtual impedance, voltage quality, unbalance islanded microgrid.

I. INTRODUCTION

Microgrids are little scale, low voltage combined heat and power supply system intended to supply electrical furthermore, warmth loads for a little group, for example, a lodging home or a rural territory, or open group, for example, a college or school, a business territory, a mechanical site, an exchanging home or a civil locale. Microgrid is basically a distributed system on the ground that it is the combination of distributed generation frameworks and diverse burdens at circulation voltage levels. The generators or micro sources utilized in a microgrid are typically renewable or non-routine distributed energy resources incorporated together to produce power at conveyance voltage. From operational perspective, the micro sources must be outfitted with force electronic interfaces and controls to give the obliged adaptability to guarantee operation as a solitary amassed framework and to keep up the predefined forced quality and vitality yield. This control adaptability would permit the microgrid to present itself to the primary utility force framework as a solitary controlled unit that meets neighbourhood vitality requirements for unwavering quality and security.

The key contrast between a microgrid and traditional force plant are as take after:

(1) Micro sources are of much littler limit regarding the expansive generators in routine force plants.

(2) Power produced at conveyance voltage can be straight forwardly encouraged to the utility of appropriation system.

(3) Micro sources are ordinarily introduced near to the clients premises so that the electrical burdens can be productively supplied with palatable voltage what's more, recurrence profile and irrelevant line misfortunes.

The specialized highlights of a microgrid make it suitable for supplying energy to remote regions of a nation where supply from the national network framework is either hard to benefit because of the topology oftentimes upset because of serious climatic conditions or manmade aggravations. From matrix perspective, the principle favourable position of a microgrid is that it is dealt with as a controlled element inside of the force framework. It can be worked as a solitary accumulated load. This finds its simple controllability and consistence with matrix principles and regulations without hampering the unwavering quality and security of the force utility. From clients prospective, microgrids are advantageous for generally meeting their electrical or heat prerequisites. They can supply uninterruptible force, enhance neighbourhood dependability, lessen feeder misfortunes and give nearby voltage support. From ecological perspective, microgrids lessen natural contamination and a worldwide temperature alteration through usage of low carbon innovation. MGs can be used for supporting the main grid during peak period time. On the contrary during off-peak time the main grid is utilized for charging the ESBs of the MGs or supplying it's local loads in case of power generation shortage or with batteries minimum state of charge. In MGs single-phase generation like PV rooftop can be utilized and different loads can be used by the end-users which can cause the grid currents to be unbalanced with poor power factor as shown in Figure 1.1.

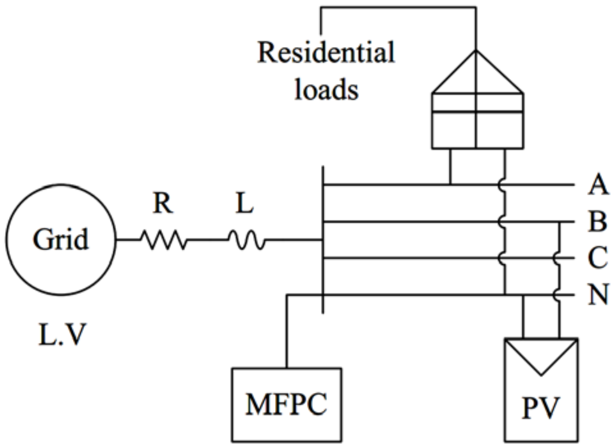

Figure 1.1 MG with unbalanced operation.

Today most of the electrical energy is processed through power electronics equipment while it travels from the AC grid to the final load. Thus, the power electronics device based AC utility line power quality problems have become challenging for electrical engineers. Considering the significant amount of power electronics related, natural phenomena related, and power system infrastructure related power quality problems, some critical loads requiring continuous and clean power cannot be directly fed from the AC power line.

II. SYSTEM MODEL CONVERTERS

A. Power Electronics Devices

The development of power electronic devices contributes substantially in developing of the technology of DG, whereas each DG unit needs to be interconnected with the main grid through power electronic converters to control and improve the output power. In MGs power electronic converters represent the key elements for operation and functionality improvements, the main purposes of using power converters in MGs, are power control, power sharing, RESs interfacing, power quality improvement and energy management.

- Power Electronics Devices

Semiconductor switches represent the main part, "the heart" of power electronic converters. These power devices have distinct characteristics, like switching frequency, Safe Operating Area (SOA), thermal performance and other characteristics. Figure 2.1 shows different power levels and switching frequencies of power devices. Silicon Controlled Rectifier (SCR) and Gate Turn Off Thyristor (GTO) operate up to near 1 kHz. It can be employed in high power converters where the switching frequency is not important. As a result such power converters are bulky with low power density.

Insulated Gate Bipolar Transistor (IGBT) and power Metal Oxide Semiconductor Field-Effect Transistor (MOSFET), has higher switching frequency ratings. They are used in the lower power applications hence high speed power devices are preferable with high switching frequency to reduce the size of passive components. IGBT has lower switching frequency in comparison with MOSFET. It has very low on-state losses "conduction losses". However IGBT suffers from a phenomena that called "tailing" which causes extra high turn-off losses and leads to relatively high switching losses.

- Power Modules

A power semiconductor module may be defined as a device which contains more than one semiconductor chip and provides electric and a heat flux paths. Power electronic systems have become much more compact, cost efficient and reliable, which require advanced device packaging and integration technology.

- Power Conversion Efficiency and Power Density

The main concerns in modern power electronic systems are delivering the power with maximum efficiency, minimum cost and high power density (weight reduction).

Power conversion efficiency is a crucial challenge for DG technology. Thus using high efficient power converters for interfacing renewable power sources like (photovoltaic, wind, fuel cells) with the utility grid is strongly recommended to enhance the utilization of these sources. Passive elements (inductors and capacitors) are used in power converters for filtering out harmonics thereby the Total Harmonic Distortion (THD) of current and voltage is reduced within the standard limits. The size of passive elements is proportional to the switching frequency. Therefore, using high switching frequency devices leads to decrease the size of these elements, reduce the losses, increase the efficiency; as a result the power density of these converters will also increase.

B. Power Conversion Technology

Power conversion process consists of two stages, power and control stages. As shown in Figure 2.1, 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.

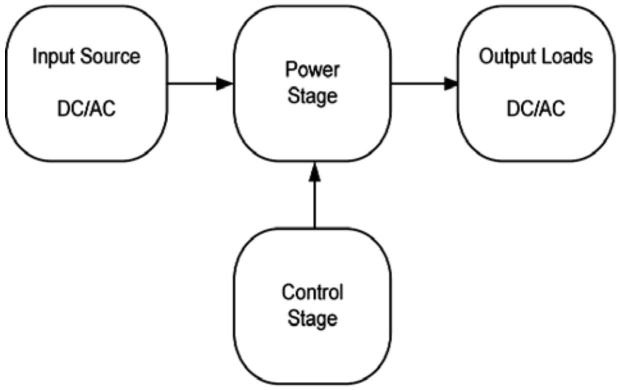

Figure 2.1 power electronic conversion.

Power conversion can be divided into four different categories according to the input and output power forms. In Figure 2.2, 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.

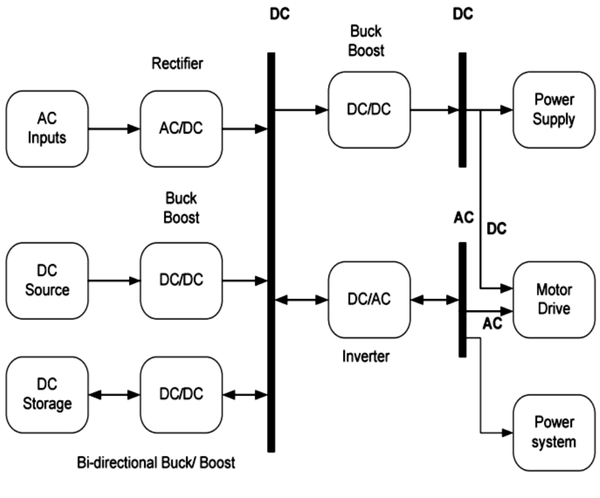

Figure 2.2 Energy conversion technologies based power converters.

III. RELATED WORK

X. Zhou, F. Tang, P. C. Loh, X. Jin and W. Cao,[1] Four-leg dc-ac power converters are widely used for the power grids to manage grid voltage unbalance caused by the interconnection of single-phase or three-phase unbalanced loads. These converters can further be connected in parallel to increase the overall power rating. The control of these converters poses a particular challenge if they are placed far apart with no links between them (e.g., in islanded microgrids). This challenge is studied in this work with each four-leg converter designed to have improved common current sharing and selective voltage-quality enhancement. The common current sharing, including zero sequence component, is necessary since loads are spread over the microgrid and they are hence the common responsibility of all converters. The voltage-quality enhancement consideration should however be more selective since different loads have different sensitivity levels towards voltage disturbances. Converters connected to the more sensitive load buses should therefore be selectively triggered for compensation when voltage unbalances at their protected buses exceed the predefined thresholds. The proposed scheme is therefore different from conventional centralized schemes protecting only a common bus. Simulation and experimental results obtained have verified the effectiveness of the proposed scheme when applied to a four-wire islanded microgrid.

Gong Hong, Wang Yuhong and Li Yuan,[2] An improved dual-loop control strategy is proposed in this work to improve the static synchronous compensator (STATCOM) operation performance under grid voltage unbalance conditions. In the proposed method, the second order harmonic resonant control blocks are added on the positive sequence control blocks to form the outer controller, and the negative sequence current references can be generated for STATCOM to eliminate voltage unbalance at point of common coupling(PCC). In order to accurately track the current reference values, the resonant control blocks are paralleled with PI controllers in inner controller in which the PI controllers are mainly designed for dc component error free control, and the resonant blocks are mainly designed for the second order harmonic component tracking. Simulation results verify the correctness and effectiveness of the improved control strategy.

A. Mahmoudi and H. R. Karshenas,[3] This work presents a decentralized voltage imbalance reduction approach in the islanded micro-grid under unbalanced condition of the nonlocal busbar. Control structure is implemented in the Positive and negative sequence synchronous reference frame. Then the proposed method of voltage imbalance compensation will be described. Under unbalanced condition, based on proposed negative sequence current-negative sequence impedance droop characteristic, the nonlocal busbar voltage compensation is done without any local bus voltage limit violation. The main target is to introduce a certain amount of imbalance in the local bus without exceeding the standard level, with the aim of improving voltage imbalance in the remote busbar. Finally, proper performance of the structure has been presented using PSIM simulation software.

G. C. Konstantopoulos, Q. C. Zhong, B. Ren and M. Krstic,[4] When paralleled inverters feed a common load, it is required that the load is shared according to their power ratings. In this work, the robust droop controller (RDC) proposed in the literature for achieving accurate proportional power sharing for paralleled inverters is implemented in a way to ensure a bounded closed-loop performance. Using non-linear Lyapunov methods, it is shown that the controller structure permits the control input to stay within a predefined range. While maintaining the main theory of the RDC, the proposed bounded droop controller (BDC) is proven to guarantee the stability of the closed-loop system in the sense of boundedness for the general load case given in the generalized dissipative Hamiltonian form, which can describe both linear and non-linear load dynamics. Extended simulation results for two single-phase inverters operated in parallel are presented to verify the effectiveness of the BDC for both a linear and a non-linear load case scenario.

Q. C. Zhong,[5] In this work, the inherent limitations of the conventional droop control scheme are revealed. It has been proven that parallel-operated inverters should have the same per-unit impedance in order for them to share the load accurately in proportion to their power ratings when the conventional droop control scheme is adopted. The droop controllers should also generate the same voltage set-point for the inverters. Both conditions are difficult to meet in practice, which results in errors in proportional load sharing. An improved droop controller is then proposed to achieve accurate proportional load sharing without meeting these two requirements and to reduce the load voltage drop due to the load effect and the droop effect. The load voltage can be maintained within the desired range around the rated value. The strategy is robust against numerical errors, disturbances, noises, feeder impedance, parameter drifts and component mismatches. The only sharing error, which is quantified in this work, comes from the error in measuring the load voltage. When there are errors in the voltage measured, a fundamental tradeoff between the voltage drop and the sharing accuracy appears. It has also been explained that, in order to avoid errors in power sharing, the global settings of the rated voltage and frequency should be accurate. Experimental results are provided to verify the analysis and design.

M. Savaghebi, A. Jalilian, J. C. Vasquez and J. M. Guerrero,[6] Recently, there has been an increasing interest in using distributed generators (DGs) not only to inject power into the grid but also to enhance the power quality. In this work, a stationary-frame control method for voltage unbalance compensation in an islanded microgrid is proposed. This method is based on the proper control of DGs interface converters. The DGs are properly controlled to autonomously compensate for voltage unbalance while sharing the compensation effort and also active and reactive powers. The control system of the DGs mainly consists of active and reactive power droop controllers, a virtual impedance loop, voltage and current controllers, and an unbalance compensator. The design approach of the control system is discussed in detail, and simulation and experimental results are presented. The results demonstrate the effectiveness of the proposed method in the compensation of voltage unbalance.

X. Wang, F. Blaabjerg and Z. Chen,[7] he virtual output impedance loop is known as an effective way to enhance the load sharing stability and quality of droop-controlled parallel inverters. This work proposes an improved design of virtual output impedance loop for parallel three-phase voltage source inverters. In the approach, a virtual output impedance loop based on the decomposition of inverter output current is developed, where the positive- and negative-sequence virtual impedances are synthesized separately. Thus, the negative-sequence circulating current among the parallel inverters can be minimized by using a large negative-sequence virtual resistance even in the case of feeding a balanced three-phase load. Furthermore, to adapt to the variety of unbalanced loads, a dynamically-tuned negative-sequence resistance loop is designed, such that a good compromise between the quality of inverter output voltage and the performance of load sharing can be obtained. Finally, laboratory test results of two parallel three-phase voltage source inverters are shown to confirm the validity of the proposed method.

IV. PROBLEM STATEMENT

In recent years, RESs interconnection with the main grid has become more common due to increased importance of environmental issues and economical benefits for electricity market. as a consequence more distributed power sources based on photovoltaic and wind power generation, in addition to other resources, are installed. Increasing the penetration level of these sources requires more integration of DG units. As a result, problem of system complexity leads to introduce new configurations and schemes of power system networks. MGs are a new paradigm of power system networks and have been extensively studied by researchers to investigate different issues in MGs. Unbalanced operation of MGs may lead to serious problems such as unbalanced faults, asymmetrical voltage drops, more losses, loads failure. Thus it is essential, to make MGs friendly with the main grid, improving the quality of power exchange in both power flow directions which allows to improve the overall efficiency and increase the penetration level of DG.

V. CONCLUSION

In these research different strategies of Power converters with ESSs can be adopted to mitigate the negative effects of unbalanced grid connected MGs, however, they require suitable control strategies. In this work a control strategy and converter technologies for MGs, based on vector control and symmetrical components is discussed to obtain grid friendly MGs under unbalanced operating conditions. A brief introduction could help to understand different issues related to this kind of systems, , discussing in general the EPSs, DG, MGs, SG and the imbalance with symmetrical components. Different algorithms and techniques can be used to mitigate power control are discussed and previous works in the field of microgrid are review and discussed.

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