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A Review of Three Level Inverters for Renewable Energy Resources System

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ABSTRACT: The use of distributed energy resources is increasingly being pursued as a supplement and an alternative to large conventional central power stations. The specification of a power-electronic interface is subject to requirements related not only to the renewable energy source itself but also to its effects on the power-system operation, especially where the intermittent energy source constitutes a significant part of the total system capacity. In this paper, new trends in power electronics for the integration of wind and photovoltaic (PV) power generators are presented. A review of the appropriate storage-system technology used for the integration of intermittent renewable energy sources is also introduced. Discussions about common and future trends in renewable energy systems based on reliability and maturity of each technology are presented.

Keywords*:* Distributed power generation, fuel cells, photovoltaic (PV), power electronics, renewable energy, wind energy

I. INTRODUCTION

power systems, large power generation plants located at adequate geographical places produce most of the power, which is then transferred toward large consumption centers over long distance transmission lines. The system control centers monitor and control the system continuously to ensure the quality of the power, namely the frequency and the voltage. However, the power system is changing, a large number of dispersed generation (DG) units, including both renewable and nonrenewable sources such as wind turbines, wave generators, photovoltaic (PV) generators, small hydro, fuel cells and gas/steam powered combined heat and power (CHP) stations, are being developed [1]–[3]. A wide spread use of renewable energy sources in distribution networks and a high penetration level will be seen in the near future. E.g., Denmark has a high penetration (20%) of wind energy in major areas of the country and today 14% of the whole electrical energy consumption is covered by wind energy. The main advantages of using renewable sources are the elimination of harmful emissions and the inexhaustible resources of the primary energy. However, the main disadvantage, apart from the higher costs, e.g., photovoltaic, is the uncontrollability. The availability of renewable energy sources has strong daily and seasonal patterns. But the power demand by the consumers could have a very different characteristic. Therefore, it would be difficult to operate a power system installed with only renewable generation units due to the characteristic differences and the high uncertainty of the availability of the renewable sources. The way of fully exploiting the renewable energy is the grid connection, normally at distribution level. In conventional generation stations, the generators operate at a fixed speed and thereby with a fixed grid-frequency, however, the dispersed generation presents a quite different and challenging picture. For example, the voltage generated by variable speed wind power generators, PV generators and fuel cells cannot be directly connected to the grid. The power electronic technology plays a vital role to match the characteristics of the dispersed generation units and the requirements of the grid connections,
including frequency, voltage, control of active and reactive power, harmonic minimization etc. Power electronic, being the technology of efficiently converting electric power, plays an important role in the field of modern electrical engineering [4], [5], it is an essential part for the integration of dispersed generation unit to achieve high efficiency and performance in power systems.

This paper will show how the present development of modern power electronic technology has enabled a successful integration. In the paper, the characteristics of some dispersed generation units and the general structures of the systems interfacing the power generation units will be presented, in particularly, wind power, fuel cells, and PV generators The wind and solar energy are omnipresent, freely available, and environmental friendly. The wind energy systems may not be technically viable at all sites because of low wind speeds and being more unpredictable than solar energy. The combined utilization of these renewable energy sources are therefore becoming increasingly attractive and are being widely used as alternative of oil-produced energy. Economic aspects of these renewable energy technologies are sufficiently promising to include them for rising power generation capability in developing countries. A renewable hybrid energy system consists of two or more energy sources, a power conditioning equipment, a controller and an optional energy storage system. These hybrid energy systems are becoming popular in remote area power generation applications due to advancements in renewable energy technologies and substantial rise in prices of petroleum products. Research and development efforts in solar, wind, and other renewable energy technologies are required to continue for, improving their performance, establishing techniques for accurately predicting their output and reliably integrating them with other conventional generating sources. The aim of this paper is to review the current state of the design, operation and control requirement of the stand-alone PV solar–wind hybrid energy systems with conventional backup source i.e. diesel or grid. This Paper also highlights the future developments, which have the potential to increase the economic attractiveness of such systems and their acceptance by the user.

II. HYBRID SYSTEM

Climatic conditions determine the availability and magnitude of wind and solar energy at particular site. Pre-feasibility studies are based on weather data [3] (wind speed, solar insulation) and load requirements for specific site. In order to calculate the performance of an existing system, or to predict energy consumption or energy generated from a system in the design stage, appropriate weather data is required. The global whether data could be obtained from internet and other sources like local metrological station. The global weather pattern is taken from NASA surface metrological station and the red and yellow indicate high wind energy is available while the blue colors reflect lower wind energy potential zone. the solar insulation level at different areas of the world. Wind and solar hybrid system can be designed with the help of these global weather patterns, for any location all over the world. Deciding on the best feasible solution will need to be done, on a site-to-site basis. Some sites can be best serviced by mains or grid power, others by generators, and some by Various hybrid energy systems have been installed in many countries over the last decade, resulting in the development of systems that can compete with conventional, fuel based remote area power supplies [2] in many applications. Research has focused on the performance analysis [of demonstration systems and the development of efficient power converters, such as bi-directional inverters, battery management units. Maximum power point trackers Various simulation programs are available, which allow the optimum sizing of hybrid energy systems. The recent state of art hybrid energy system technological development is the result of activities in a number of research areas, such as Advances in electrical power conversion through the availability of new power electronic semiconductor devices, have led to improved efficiency, system quality and reliability. Development of versatile hybrid energy system simulation software; continuing advances in the manufacturing process and improve efficiency of photovoltaic modules. The development of customized, automatic controllers, which improve the operation of hybrid energy systems and reduce maintenance requirements. Development of improved, deep-cycle, lead-acid batteries for renewable energy systems. Availability of more efficient and reliable AC and DC appliances which can recover their additional cost over their extended.

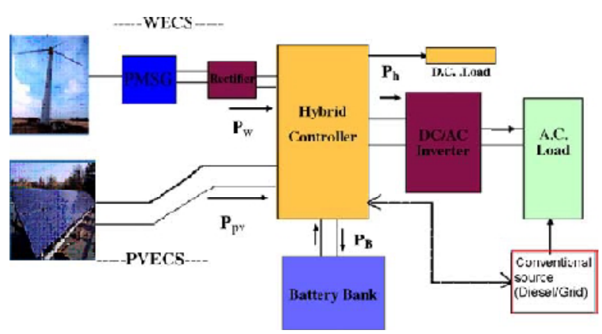

Fig. 1. Hybrid energy systems.

The task for the hybrid energy system controller is to control the interaction of various system components and control power flow within the system to provide a stable and reliable source of energy. With the wide spread introduction of net-metering, the use of small isolated or grid connected hybrid energy systems is expected to grow tremendously in the near future. The aim of this paper is to review the current state of the design and operation of hybrid energy systems, and to present future developments, which will allow a further expansion of markets, both in industrialized and developing countries.

III. THREE LEVEL VSI BASED SHUNT ACTIVE POWER FILTER

the configuration of the standard neutral point-clamped three-level VSI for the SAPF application. shows Basic block diagram of shunt active filter illustrating the hardware modules required. It can be implemented using DSP TMS320F28335 as a controller. Size of ripple filter can be decreased Using three level inverter based shunt active power filter.

Classification based on Power Topologies,

- Two Level VSI
- Three Level VSI
- Multilevel VSI

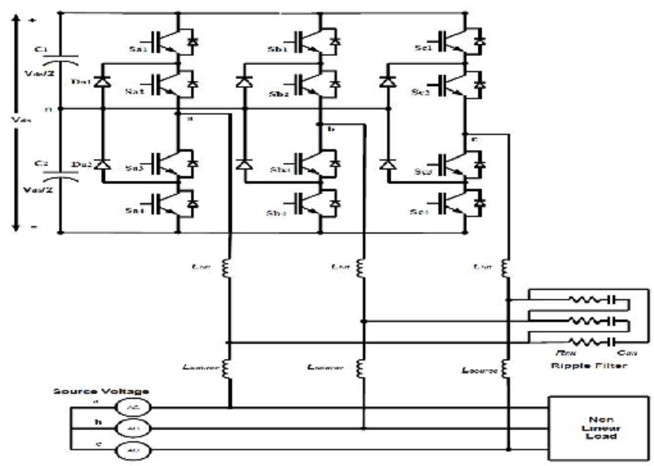

Fig. 2. Two and three-level VSI Block.

A review of shunt active power filter is discussed to understand various topologies, reference current prediction methods, current control methods and dead time compensation methods. All control methods for shunt active power filters have been compared from the research papers. It is concluded that three level inverter based shunt active power filter with FFT algorithm for reference current prediction will give better performance. PI based current control method can limit switching frequency but degrade transient performance. SVHCC method is robust to grid parameter variations and load changes. It is considered that this review will be useful to researcher and professionals working in this area.

IV. HIGH-VOLTAGE DC CABLES

The PV modules and the inverter, power losses due to a centralized MPPT, mismatch losses between the PV modules, losses in the string diodes, and a nonflexible design where the benefits of mass production could not be reached. The grid-con The present technology consists of the string inverters and the ac module . The string inverter, version of the centralized inverter, where a single string of PV modules is connected to the inverter [7]. The input voltage may be high enough to avoid voltage amplification. This requires roughly 16 PV modules in series for European systems. The total open-circuit voltage for 16 PV modules may reach as much as 720 V, which calls for a 1000-V MOSFET/IGBT in order to allow for a 75% voltage de-rating of the semiconductors. The normal operation voltage is, however, as low as 450 510 V.

The possibility of using fewer PV modules in series also exists, if a dc–dc converter or line-frequency transformer is used for voltage amplification.

There are no losses associated with string diodes and separate MPPTs can be applied to each string. This increases the overall efficiency compared to the centralized inverter, and reduces the price, due to mass production. The ac module depicted in Fig. 3(d) is the integration of the inverter and PV module into one electrical device [7]. It removes the mismatch losses between PV modules since there is only one PV module, as well as supports optimal adjustment between the PV module and the inverter and, hence, the individual MPPT. It includes the possibility of an easy enlarging of the system, due to the modular structure. The opportunity to become a "plugand- play" device, which can be used by persons without any knowledge of electrical installations, is also an inherent feature. On the other hand, the necessary high voltage-amplification may reduce the overall efficiency and increase the price per watt, because of more complex circuit topologies. On the other hand, the ac module is intended to be mass produced, which leads to low manufacturing cost and low retail prices. The present solutions use self-commutated dc–ac inverters, by means of IGBTs or MOSFETs, involving high power quality in compliance with the standards.

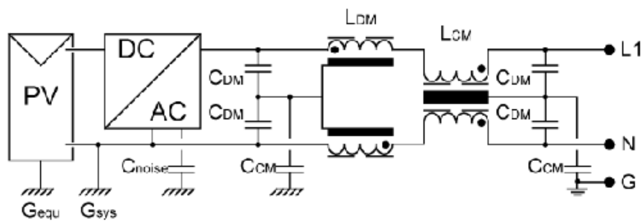

Fig. 3. Transformer less high-input-voltage PV inverter with single-phase common-mode.

Recent developments in power electronics technology have spurred interest in the use of renewable energy sources as distributed generation (DG) generators. The key component in DG generators is a grid-connected inverter that serves as an effective interface between the renewable energy source and the utility grid. The multifunctional inverter (MFI) is special type of grid-connected inverter that has elicited much attention in recent years. MFIs not only generate power for DGs but also provide increased functionality through improved power quality and voltage and reactive power support; thus, the capability of the auxiliary service for the utility grid is improved. This paper presents a comprehensive review of the various MFI system configurations for single-phase (two-wire) and three-phase (three- or four-wire) systems and control strategies for the compensation of different power quality problems In recent years, the installation of more distributed enerators (DG) in power distribution networks has elicited increased attention. A number of reasons can explain this trend. Such reasons include environmental concerns, electricity business restructuring, and the rapid development of small-scale power generation technologies and other micro-grid related devices and systems. In practice, DG units can be constructed with various renewable energy sources However, the real power output from these energy resources is essentially unstable. Given the increasing number of RESs and DG installations, new control strategies must be developed for the proper operation and management of new power grids embedded with DG units to maintain or improve system quality and reliability. Power electronics and smart technologies play an important role in DG operations, in which the effective integration of RES into the power grid is the major objective [1]-[6]. A comprehensive review of AC and DC micro-grid systems with RES-based DG units, energy storage devices, and loads available in recent literature was presented in [2]. Afuel cell system-based power generation system was presented in [7]-[9]. Several typical PV-based DG systems were designed in [10] and [11], and a DG system based on a wind power generator was presented in [12]. Utility is of concern because of the high penetration level of intermittent RES in distribution systems. This situation may cause a hazard to the network in terms of power quality (PQ), voltage regulation, and stability. The electric PQ guidelines and standard limits can be found in The negative effects of poor PQ were well investigated in and the relation between DG and PQ is ambiguous. Many authors have stressed the positive effects of DG on PQ problems. In the sources of PQ problems in DG systems were analyzed; this study has contributed significantly to this new research field.

In the resonance phenomenon in a PV plant was discussed to define the unwanted trip off of grid-tied inverters, a phenomenon that shows the significance and necessity significance of PQ enhancement in DG systems. In the field of exhaustive PQ evaluation, presented several useful suggestions to form a quantitative exhaustive indicator, including various PQ indicators. Exhaustive evaluation can provide a decision on the existing PQ, which A new type of multilevel inverter is introduced which is created by cascading two three-phase three-level inverters using the load connection, but requires only one dc voltage source. This new inverter can operate as a seven-level inverter and naturally splits the power conversion into a higher-voltage lower-frequency inverter and a lower-voltage higher-frequency inverter. This type of system presents particular advantages to Naval ship propulsion systems which rely on high power quality, survivable drives. New control methods are described involving both joint and separate control of the individual three-level inverters. Simulation results demonstrate the effectiveness of both controls. A laboratory set-up at the Naval Surface Warfare Center power electronics laboratory was used to validate the proposed joint-inverter control. Due to the effect of compounding levels in the cascaded inverter, a high number of levels are available resulting in a voltage.

V. MULTILEVEL INVERTERS

Power conversion in multiple voltage steps to obtain improved power quality, lower switching losses, better electromagnetic compatibility, and higher voltage capability. Considering these advantages, multilevel converters have been gaining considerable popularity in recent years The benefits are especially clear for medium-voltage drives in industrial applications [7], [9] and are being considered for future Naval ship propulsion systems. In fact, several IEEE conferences now hold entire sessions on multilevel power conversion. Several topologies for multilevel inverters have been proposed over the years; the most popular being the diode-clamped flying capacitor and cascaded H-bridge structures. One aspect which sets the cascaded H-bridge apart from other multilevel inverters is the capability of utilizing different dc voltages on the individual H-bridge cells which results in splitting the power conversion amongst higher-voltage lower-frequency and lower-voltage higher-frequency inverters An alternate method of cascading inverters involves series connection of two three-phase inverters through the neutral point of the load. Past research has shown this concept for cascading two-level inverters [and multilevel inverters. An advantage of this approach is that isolated sources are not required for each phase. It should be noted that cascaded inverter systems can be considered from a number of different viewpoints. Considering the cascaded inverter to be one unit, it can be seen that a higher number of voltage levels are available for a given number of semiconductor devices. Considering the system as separate inverters, the cascaded design can be regarded as a combination of a bulk power (higher-voltage) inverter and a conditioning (lower-power) inverter. An alternate viewpoint is to consider the conditioning inverter as an active filter and the bulk inverter as the drive inverter. In any case, the cascaded multilevel inverter has several advantages for Naval ship propulsion systems. One advantage is that cascaded inverters provide a compounding of voltage levels leading to extremely low harmonics. Another advantage is that the bulk inverter may be commercial-off-the-shelf; requiring that only the lower-power condition inverter to be custom made. Yet another advantage is that the cascaded design avoids a large number of isolated voltage sources which would be cumbersome in shipboard power systems. An additional advantage is that the dual inverter structure may be useful for redundancy providing remedial operation for survivability. Furthermore, in Naval applications, the propulsion motor is typically custom built and can be readily made to have access to both ends of each winding. This paper reports the development of new control methods for cascaded multilevel inverters. In particular, capacitor voltage regulation methods are introduced resulting in a cascaded inverter which only requires one dc source. The new control methods are applied to a topology where two three-level inverters are cascaded. Simulation and laboratory measurements are presented which demonstrate the effectiveness of the proposed control the passive components will change their effect on the system harmonics as the drive operating point is varied. Another aspect of eliminating the voltage source for the conditioning inverter is that it is no longer available for driving the motor in situations where there is a fault in the bulk inverter. In those cases, a dc source would need to be switched in to the conditioning inverter. One good feature about fault operation of ship propulsion loads is that a relatively low amount of power is needed to operate in a survivable situation.

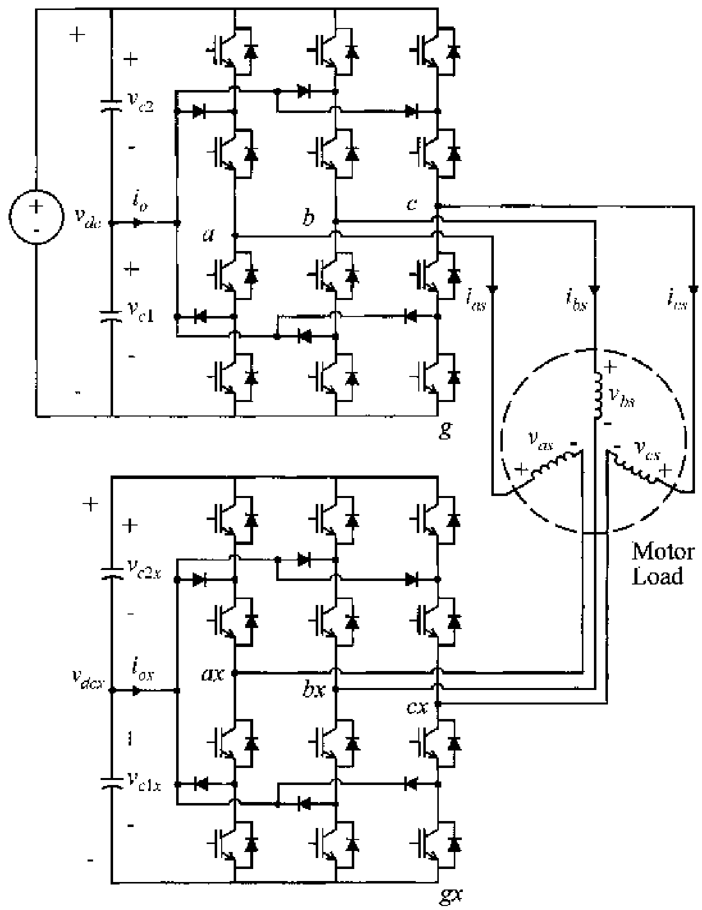

Fig. 4 . Cascade-3/3 multilevel inverter.

VI. CASCADE-3/3 INVERTER CONTROL

Before considering specific modulation and capacitor voltage regulation strategies, it is instructive to examine Therein, the vectors produced by the upper inverter are denoted as being slightly larger than the other vectors. The small three-level vector plots produced by the lower inverter are indicated by the dashed hexagons. One of the significant features of the controls developed herein is the ability to regulate the dc voltage so that only one dc source is required. This can be accomplished through redundant selection of inverter switching states. Overlap amongst the smaller hexagons and where this overlap occurs there is a choice as to the realization of the voltage vectors. This choice can be made with regard to the power flow in the lower inverter [14] so that the dc voltage remains at one-third of total. As can be seen form, a considerable amount of overlap occurs for vectors toward the inside of the vector plot and the full dc voltage may be utilized while regulating the lower inverter capacitor voltage. Toward the outside of the vector plot, the overlap is not present for many vectors and in this case, the power flow can not be used to maintain [35]. a limitation of operating region within the upper inverter considering the number of lower inverter vectors in-between the upper inverter vectors, it can be seen that this limitation will result in seven-level operation. However, only one dc source is required and that dc voltage can be fully utilized.

VII. CONCLUSIONS

This paper has studied a Renewable Energy Resources of multilevel inverter which consists of two three-phase three-level inverters cascaded through the load connections. Two types of control were developed for this inverter.

One relies on controlling the two three-level inverters jointly and the other uses separate controls. Both controls included capacitor voltage balancing so that a dc source was needed for only one three-level inverter new topology of the three-phase multilevel inverter was introduced. The suggested configuration was obtained from reduced number of power electronic components. Therefore, the proposed topology results in reduction of installation area and cost. The fundamental frequency staircase modulation technique was comfortably employed and showed high flexibility and simplicity in control. Moreover, the proposed configuration was extended to *N*-level with different methods. Furthermore, the method employed to determine the magnitudes of the dc voltage supplies was well executed. In order to verify the performance of the proposed multilevel inverter, the proposed configuration was simulated and its prototype was manufactured. The obtained simulation and hardware results met the desired output. Hence, subsequent work in the future may include an extension to higher level with other suggested methods. For purpose of minimizing THD%, a selective harmonic elimination pulse width modulation technique can be also implemented.

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