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Effective Grid Connected Power Injection Scheme Using Multilevel Inverter Based Hybrid Wind Solar Energy Conversion System

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Abstract
An improved cascaded H-Bridge multilevel inverter (CHBMLI)-based, grid-connected hybrid wind-solar energy conversion system (HWSECS) with a focus on power quality is presented in this paper. Through their respective DC/DC converters-based maximum power point tracking (MPPT) systems, the wind energy conversion system (WECS) and solar energy conversion system (SECS) are connected separately to isolated dc-links of the CHBMLI. When used as a PWM rectifier, the CHB topology causes capacitor unbalancing issues between the dc-links that feed different dc loads. The same problem occurs when the rectifier is operated in regenerative mode, with different sources injecting different amounts of power into each cell. When two distinct sources—WECS and SECS—are added to isolated dc-links, the proposed HWSECS system experiences the same unbalance voltages. The author tried to take advantage of topology's advantages while also writing the solution to problems with system control and operation. In addition to providing additional benefits, the proposed system's features and control scheme maximize power injection into the grid from renewable energy sources (RES). MATLAB/Simulink was used to conduct the simulation studies, which were then validated experimentally on a prototype with the help of dSPACE-1104. Additionally, a mathematical model of the HWSECS based on CHB-MLI has been developed for analysis

1. Introduction

Fossil fuels are running out and current centralized power generation plants are inefficient with a significant amount of energy lost as heat to the environment, in addition to producing harmful emissions and greenhouse gases. Furthermore current power systems, especially in developing countries suffer from several limitations such as high cost of expansion and efficiency improvement limits within existing grid infrastructure. Renewable energy sources can help address these issues, but it can be a challenge to get stable power from these sources as they are variable in nature. Distributed generators, including renewable sources, within micro grids can help overcome power system limitations, improve efficiency, reduce emissions and manage the variability of renewable sources.

Applications with photovoltaic (PV) energy and wind energy have been increased significantly due to the rapid growth of power electronics techniques. Generally, PV power and wind power are complementary since sunny days are usually calm and strong winds are often occurred at cloudy days or at night time. Hence, the hybrid PV/wind power system therefore has higher reliability to deliver continuous power than either individual source. Traditionally, a substantial energy storage battery bank is used to deliver the reliable power and to draw the maximum power from the PV arrays or the wind turbine for either one of them has an intermittent nature. However, the battery is not an environmental friendly product because of its heavy weights, bulky size, high costs, limited life cycles, and chemical pollution. Therefore, it is very common to utilize the solar or wind energy by connecting them to the ac mains directly.

Usually, two separated inverters for the PV array and the wind turbine are used for the hybrid PV/wind power system. An alternative approach is to use the multi-input inverter for combining these renewable energy sources in the dc end instead of the ac end. It can simplify the hybrid PV/wind power system and reduce the costs.

The objective of this paper is to propose a novel multi-input inverter for grid-connected hybrid PV/wind power system. The proposed multi-input inverter has the following advantages: 1) power from the PV array or the wind turbine can be delivered to the utility grid individually or simultaneously, 2) maximum power point tracking (MPPT) feature can berealized for both solar and wind energy, and 3) a large range of input voltage variation caused by different insulation and wind speed is acceptable.

Stability Improvement of a Multimachine Power System Connected With a Large-Scale Hybrid Wind-Photovoltaic Farm Using a Supercapacitor

The above paper presents the stability improvement of a multimachine power system connected with a large-scale hybrid wind-photovoltaic (PV) farm using an energy-storage unit based on supercapacitor (SC). The operating characteristics of the hybrid wind-PV farm are simulated by an equivalent aggregated 300-MW wind-turbine generator (WTG) based on permanent- magnet synchronous generator and an equivalent aggregated 75-MW PV array. The WTG and the PV array are connected to a common dc link through a voltage-source converter and a dc/dc boost converter, respectively. The power of the common dc link is transferred to the multimachine power system through a voltage-source inverter, step-up transformers, and a connection line. The SC-based energy-storage unit, which is integrated into the common dc link through a bidirectional dc/dc converter, is employed for smoothing out the power fluctuations due to variations of wind speed and/or solar irradiance. A proportional-integral- derivative (PID)-supplementary damping controller (PID-SDC) is designed for the bidirectional dc/dc converter of the SC to enhance the damping characteristics of the low- frequency oscillations associated with the studied multimachine power system. The root loci of the studied system are examined under wide ranges of wind speed and solar irradiance. The effectiveness of the proposed SC joined with the PID-SDC on improving the performance of the studied system under different disturbance conditions is also demonstrated using time- domain simulations

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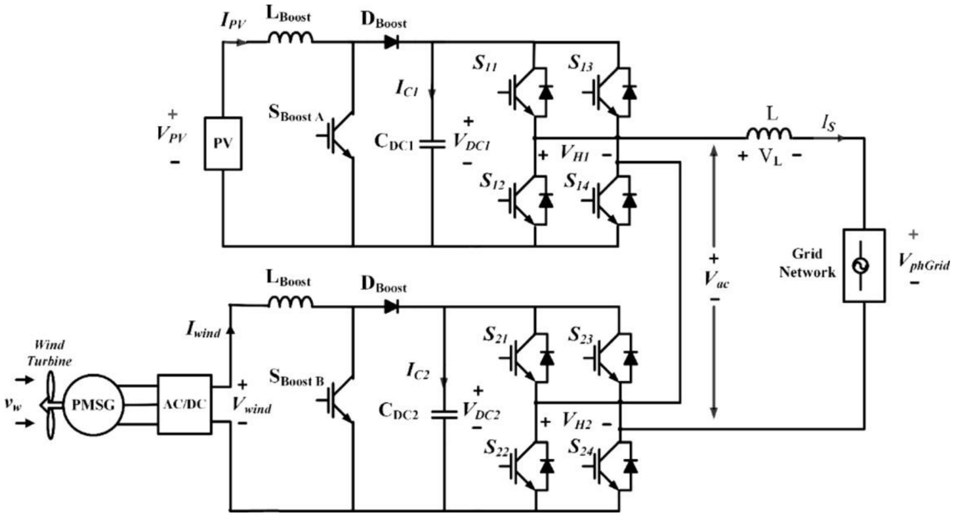

Fig.1 Schematic diagram of the proposed multi-input inverter

2. Literature Review

Stability Improvement of a Multimachine Power System Connected With a Large-Scale Hybrid Wind-Photovoltaic Farm Using a Supercapacitor The above paper presents the stability improvement of a multimachine power system connected with a large-scale hybrid wind-photovoltaic (PV) farm using an energy-storage unit based on supercapacitor (SC). The operating characteristics of the hybrid wind-PV farm are simulated by an equivalent aggregated 300-MW wind-turbine generator (WTG) based on permanent- magnet synchronous generator and an equivalent aggregated 75-MW PV array. The WTG and the PV array are connected to a common dc link through a voltage-source converter and a dc/dc boost converter, respectively. The power of the common dc link is transferred to the multimachine power system through a voltage-source inverter, step-up transformers, and a connection line. The SC-based energy-storage unit, which is integrated into the common dc link through a bidirectional dc/dc converter, is employed for smoothing out the power fluctuations due to variations of wind speed and/or solar irradiance. A proportional-integral-derivative (PID)-supplementary damping controller (PID-SDC) is designed for the bidirectional dc/dc converter of the SC to enhance the damping characteristics of the low-frequency oscillations associated with the studied multimachine power system. The root loci of the studied system are examined under wide ranges of wind speed and solar irradiance. The effectiveness of the proposed SC joined with the PID-SDC on improving the performance of the studied system under different disturbance conditions is also demonstrated using time- domain simulations.

Review of solar photovoltaic and wind hybrid energy systems for sizing strategies optimization techniques and cost analysis methodologies

Electrical energy becomes necessary for human being. Generation of electrical energy mostly depends on fossils fuel, they are limited in nature and also responsible for environmental pollution. Renewable energy resources provides a better alternative for future, In comparison to conventional energy resources economical aspect is a major issue of renewable energy

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sources with the feasibility and efficiency. These limitations are tried to overcome by deployment hybrid renewable energy resources. There are certain criteria to analyze and implement the sized, optimized and cost efficient system. The above paper focuses on hybrid energy systems based on solar photovoltaic (PV) and wind resources. This paper shed lights on various parameters of economic feasibility, sizing strategies with logical advancements to enhance their utilization, future prospects, and their arrangement. Strategies to develop an effective storage system are also presented. A brief review on developments in optimization techniques, reliability index and cost analyzing techniques for hybrid renewable energy systems are also presented.

MPPT with Single DC–DC Converter and Inverter for Grid-Connected Hybrid Wind- Driven PMSG–PV System

In the above paper a new topology of a hybrid distributed generator based on photovoltaic and wind-driven permanent magnet synchronous generator is proposed. In this generator, the sources are connected together to the grid with the help of only a single boost converter followed by an inverter. Thus, compared to earlier schemes, the proposed scheme has fewer power converters. A model of the proposed scheme in the d-q-axis reference frame is developed. Two low-cost controllers are also proposed for the new hybrid scheme to separately trigger the dc-dc converter and the inverter for tracking the maximum power from both sources. The integrated operations of both proposed controllers for different conditions are demonstrated through simulation and experimentation. The steady-state performance of the system and the transient response of the controllers are also presented to demonstrate the successful operation of the new hybrid system. Comparisons of experimental and simulation results are given to validate the simulation model.

Grid-Connected PV-Wind-Battery-Based Multi-Input Transformer-Coupled Bidirectional DC-DC Converter for Household Applications

In the above paper, a control strategy for power flow management of a grid-connected hybrid photovoltaic (PV)-wind-battery-based system with an efficient multi-input transformer-coupled bidirectional dc-dc converter is presented. The proposed system aims to satisfy the load demand, manage the power flow from different sources, inject the surplus power into the grid, and charge the battery from the grid as and when required. A transformer-coupled boost half-bridge converter is used to harness power from wind, while a bidirectional buck-boost converter is used to harness power from PV along with battery charging/discharging control. A single-phase full-bridge bidirectional converter is used for feeding ac loads and interaction with the grid. The proposed converter architecture has reduced number of power conversion stages with less component count and reduced losses compared with existing grid-connected hybrid systems. This improves the efficiency and the reliability of the system. Simulation results obtained using MATLAB/Simulink show the performance of the proposed control strategy for power flow management under various modes of operation. The effectiveness of the topology and the efficacy of the proposed control strategy are validated through detailed experimental studies to demonstrate the capability of the system operation in different modes.

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Effective power transfer scheme for a grid connected hybrid wind/photovoltaic system In the above paper a new topology and effective power transfer scheme with minimum number of converters is proposed for a grid connected wind/photovoltaic (PV) system. Distributed generation sources considered are permanent magnet synchronous generator (PMSG)-based wind energy conversion system and PV array system. Two voltage source converters with a common DC-link serve as wind side converter (WSC) and grid side converter (GSC), respectively. The PV array is directly tied to the DC link without any power converter providing variable DC-link voltage. The Perturb and Observe technique extracts the maximum power from PV.

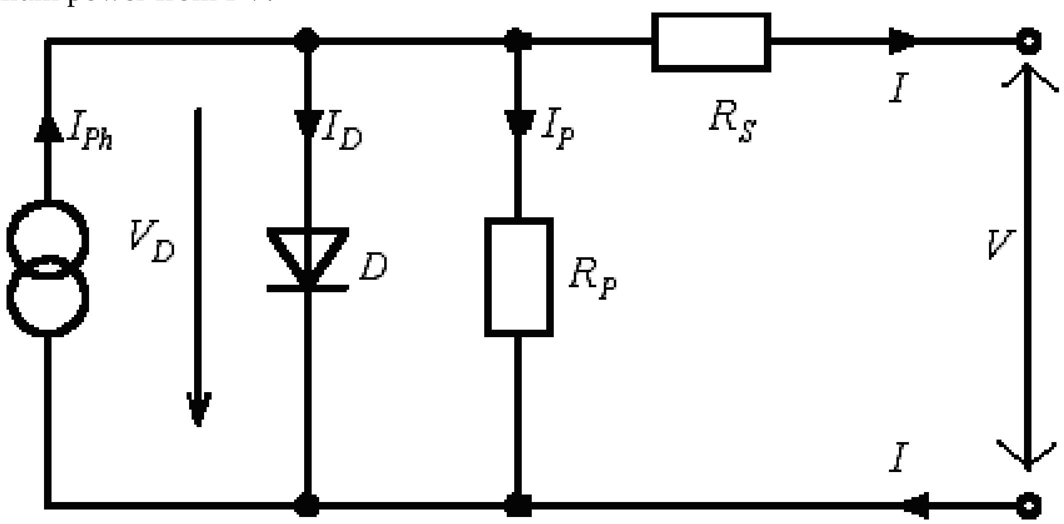

Fig.2 Equivalent Circuit for One Diode Model Of A Solar Cell

3. Proposed System

Over the past three decades, inverters have been developed to meet the drive high voltage rating and low dv/dt value requirements that the traditional two-level inverter could not. Power transistors were slow in the past, and their lengthy turn-on and off times caused significant switching losses that limited the switching frequency to a few kHz range. Power transistors also had a voltage blocking capability below a kilovolt, which meant that they couldn't be used in two-level inverters at high voltage levels or at switching frequencies in the tens of kilohertz range.

The three-level NPC inverter was able to offer high inverter voltage ratings (twice that of the two-level inverter) and effectively quadrupled switching frequency in the early 1980s by utilizing darling ton power transistors and Gate Turn Off Thyristors (GTOs). Because of this, the three-level NPC inverter can produce power and voltage levels that are higher than those of a two-level inverter, and it is already being used in traction drives and industrial drives.

The IGBT was introduced in the 1990s as a fast-on, fast-off device that had no secondary breakdown of the Bipolar Junction Transistor (BJT) and significantly reduced switching loss. The two-level inverter ratings have been extended to the kilovolt level by IGBTs with higher switching frequencies and blocking voltages; consequently, the three-level NPC inverter could be substituted for some applications. However, the two-level inverter proved to be

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problematic due to the dv/dt stresses created by the rapid switching of IGBTs, particularly at voltages above 400 V. Since the NPC inverter has a lower dv/dt rating than the two-level inverter, it has been favored once more. Therefore, when fast IGBTs are used at voltages above 400 V, the three-level NPC inverter is currently advantageous.

The current practical power converter topology is a multilevel inverter topology as the power converter rating rises above a megawatt, which also implies a voltage rating above 400 V. The three-level NPC inverter and the cascaded H-bridge topology have been in use in industry for more than a decade in the lower megawatt range.

Higher level inverters like four, five, or higher level NPC inverters are used in utility power electronics applications like Static Compensator (STATCOM), Unified Power Flow Controller (UPFC), and Flexible AC Transmission System (FACTS), and the flying capacitor topology has recently also been considered.

Multilevel inverters are required for utility power electronics applications due to the extremely high voltage levels (kV range) and the fact that the required level can only be achieved through either series connection of a large number of power semiconductors or multilevel inverter topologies involving a large number of levels. The three-level inverter topology typically suffices at the 400 V distribution system level.

With low dv/dt, reduced common mode voltage, and low harmonics, multilevel inverter topologies typically produce a nearly sinusoidal output waveform with variable frequency and variable voltage, resulting in motor-friendly performance. Even though there are many different types of topologies, the basic idea behind all multilevel inverter topologies is to use low voltage rating power transistors in series with multistage DC capacitor voltage levels to get higher output voltage levels in small steps.

The multilevel inverters reduce the impact of winding insulation breakdown in motor drives and result in negligible bearing current due to their high voltage waveform quality. When used as PWM rectifiers and power conditioners, they provide a better interface between DC voltage sources and loads and the AC utility grid due to reduced stresses and EMI

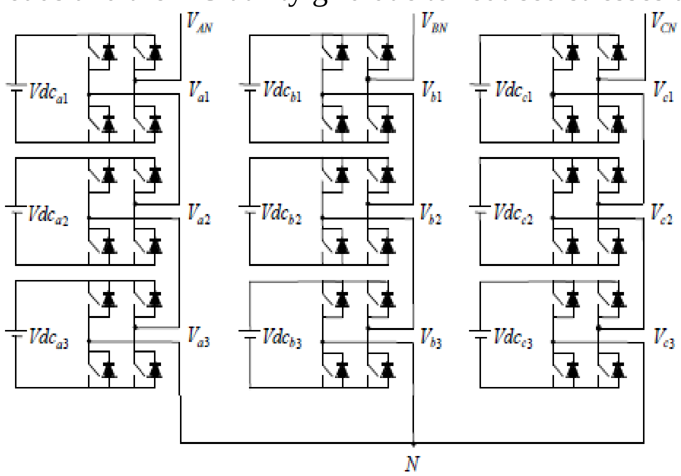

Fig.3 Proposed Method

4. Conclusion

In this paper, proposed grid-connected five-level CHBMLI converts the power obtained from HWSECS to ac power and feeds into the grid system. This topology will help to improve the utilisation of connected wind power sources and PV array, which are connected individually to each dc-link, with the independent MPPT algorithm. It is clear from the above discussed simulation and experimental studies that along with the input and output performance parameters of the proposed control scheme and system model extracts the maximum power that can be enabled from each RES. The mathematical modelling of single-phase grid connected CHBMLI has been derived to find out the relation of dclink capacitor voltages (VDC1 and VDC2), CHBMLI output voltage (Vac), dc-link currents (IDC1 and IDC2) and grid current (Is) in terms of switching functions. Simulations are carried on to justify that, in varying dc-link currents in integrated wind and solar system the DC capacitor balancing is achieved, and a grid current is injected into the grid network which is sinusoidal in shape having minimum THD and UPF. The experimental results clearly support the simulation results obtained, and thus the motive of this control technique is accomplished. This developed grid connected HWSECS converter topology with the applied control technique thus helping to acquire the DC capacitor balancing and high power quality.

References

1. L. Wang, A.V. Prokhorov, Q. Son Vo, Stability Improvement of a Multimachine Power System Connected with a Large- Scale Hybrid Wind-Photovoltaic Farm Using a Supercapacitor Quang-Son Vo, IEEE Trans. Ind. Electron. 54 (2017) 1–9, https:// doi.org/10.1109/TIA.2017.2751004.
2. F.A. Khan, N. Pal, S.H. Saeed, Review of solar photovoltaic and wind hybrid energy systems for sizing strategies optimization techniques and cost analysis methodologies, Renew. Sustain. Energy Rev. 92 (2018) 937–947, https://doi.org/10.1016/j. rser.2018.04.107.
3. Y. Sawle, S.C. Gupta, A.K. Bohre, Socio- techno-economic design of hybrid renewable energy system using optimization techniques, Renew. Energy. 119 (2018) 459–472, https://doi.org/10.1016/j.renene.2017.11.058.
4. M.M.R. Singaravel, S.A. Daniel, MPPT with Single DC-DC Converter and Inverter for Grid- Connected Hybrid Wind-Driven PMSG-PV System, IEEE Trans. Ind. Electron. 62 (2015) 4849–4857, https://doi.org/10.1109/TIE.2015.2399277.
5. B. Mangu, S. Akshatha, D.Suryanarayana, B.G. Fernandes, Grid-Connected PVWind-Battery-Based Bidirectional DC- DC Converter for Household Applications, IEEE J. Emerg. Sel. Top. Power Electron. 4 (2016) 1086–1095, https://doi.org/10. 1109/JESTPE.2016.2544789. [6] P. Shanthi, G. Uma, M.S.
6. Keerthana, Effective power transfer scheme for a grid connected hybrid wind/photovoltaic system, IET Renew. Power Gener.
7. Weitemeyer S, Kleinhans D, Vogt T, Agert C. Integration of renewable energy sources in future power systems: the role of storage. Renew Energy 2015;75:14–20.

The Ciência & Engenharia - Science & Engineering Journal
ISSN: 0103-944X
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pp: 94 - 101

8. Kouro S, Leon JI, Vinnikov D, Franquelo LG. Grid-connected photovoltaic systems: an overview of recent research and emerging pv converter technology. IEEE Ind Electron Mag 2015;9(1):47–61.
9. Li Q, Wolfs P. A review of the single phase photovoltaic module integrated converter topologies with three different dc link configurations. IEEE Trans Power Electron 2008;23(3):1320–33.
10. El Khateb AH, Rahim NA, Selvaraj J, Williams BW. Dc-to-dc converter with low input current ripple for maximum photovoltaic power extraction. IEEE Trans Industr Electron 2015;62(4):2246–56.