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Connection Of Converters To A Low And Medium Power Dc Network Using An Inductor Circuit

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ABSTRACT

The generator voltage of a cutting-edge wind turbine generation system (WTGS) is expected to increase from the conventional low-voltage level of 690 V to a medium-voltage level of 6.6 kV with a power level up to 10 MW without the application of a parallel connection of multiple power units. On the other hand, it is difficult to see a conventional two-level or three-level converter in a WTGS with a dc-link voltage of 10– 13 kV owing to the limitations on the voltage ratings of power devices.

This paper presents a 10-MW WTGS consisting of a three-phase open winding synchronous generator equipped with six lead terminals and a modular multilevel cascade converter (MMCC) formed by three identical sub-converters. The MMCC carries out direct ac/ac power conversion from three single-phase voltages with a time-varying frequency (from the generator) to a three-phase voltage with a line frequency of 50 Hz. This paper discusses the operating principles and control methods for the WTGS, followed by simulations using **the software package "PSCAD/EMTDC."**

INTRODUCTION

A wind turbine generation system (WTGS) is a renewable energy source, which has recently become a rapidly growing technology. Among several configurations, a WTGS consisting of a multi-pole permanent-magnet synchronous generator (PMSG) and back-to-back (BTB) converter(s) is considered to be the most prominent technology for a multi- MMW WTGS. The reason is that it can remove gearboxes and slip rings from the system, leading to maintenance-free operation and lifetime extension. Moreover, this configuration has better grid-support capabilities than a WTGS based on a doubly-fed induction generator. The power rating of the WTGS is increasing year by year to reduce electric-power generation cost, and it is expected to be as high as 10 MW in the near future.

Nowadays, some manufacturers are developing 10-MW WTGSs. A circuit configuration of a WTGS based on a PMSG and BTB units, which is suitable for multi-MW power conversion. Each BTB unit consists of a two-level pulse-width modulated (PWM) rectifier that converts the time varying voltage of the generator to a regulated dc-link voltage and a two-level PWM inverter for grid connection. Because the generator line-to-line rms voltage in a conventional system is as low as 690 V, the converter is subjected to a large generator current amounting to several kilo-amperes. As a consequence, multiple BTB units should be connected in parallel via ac link inductors, to increase the current rating. However, the use of multiple ac-link inductors makes the system heavy, bulky, and lossy. The generator voltage of a cutting-edge WTGS is expected to increase from 690 V to a medium-voltage level of 6.6 kV.

However, the conventional two-level or three-level converter is not applicable to a BTB unit with a dc-link voltage as high as 10–13 kV if no series connection of power devices is considered. Recently, modular multilevel cascade converters (MMCCs), which are suitable for medium- or high-voltage applications, have attracted considerable attention. MMCCs are formed by a cascade connection of multiple identical converter cells, producing lower harmonic voltages and lower electromagnetic interference (EMI) emissions. Another attractive feature of an MMCC is its fault-ride-through capability due to the modular structure. For example, when a fault occurs at one cell, this faulty cell can be bypassed, and the remaining cells can continue operation seamlessly without reducing the power rating.

Some MMCCs can achieve direct ac/ac power conversion, which is an attractive solution for WTGSs with different frequencies between the generator and grid sides. There are two methods to achieve direct ac/ac power conversion by using MMCCs. One is the conversion of a three-phase generator voltage with a time-varying frequency to a three-phase grid voltage with a line frequency of 50 Hz, which is accomplished by using an MMCC based on triple star bridge-cells (TSBC). The other relies on a three-phase open-winding generator equipped with six lead terminals and an MMCC that converts a three single-phase voltage set with a time-varying frequency to a three-phase grid voltage with a line frequency of 50 Hz.

In this study, the latter is chosen because the number of converter cells required for power conversion is lower, and the control method is simpler. This paper presents a 6.6-kV 10-MW WTGS based on a three-phase open-winding PMSG and an MMCC capable of direct power conversion from a three single-phase voltage set to a three-phase voltage.

The proposed system has the following advantages over the WTGS.

1) It produces fewer harmonic voltages and less EMI emissions.

2) The ac-link inductors can be eliminated from the system. This paper devotes itself to establishing the operating principles and control methods for the WTGS, including how to regulate all floating dc-capacitor voltages in the MMCC and how to suppress the zero-sequence current flowing in the stator windings. Computer simulations using the PSCAD/EMTDC software package are carried out to verify the validity and effectiveness of the system. The experimental result obtained from a 200-V 6-kW downscaled system confirms the reliability of simulation results of the complete three-phase system.

Electricity production from wind turbines has been the focus of considerable attention when it comes to the fulfillment of renewable-energy targets set by governments worldwide. Multi-mega-watt (multi-MW) wind turbines, often organized in wind parks, are the main solution to achieve these goals. In the last years, the focus has been shifted toward offshore resources not only due to the higher wind-energy potential but also because of the limitations and the polemic issues raised around environmental impacts of land-based wind turbines. The generators conventionally used in large WECSs are the doubly fed induction generator (DFIG), the cage induction generator (IG), and the synchronous generator (SG).

EXISTING SYSTEM:

This paper describes a circuit design based on an inductor to connect the converters to the DC-Link that has no need for the use of a capacitor.

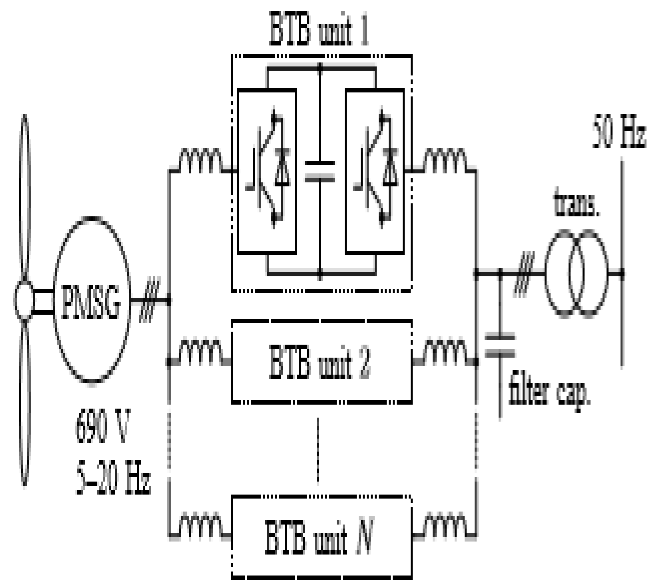
The circuit allows the connection of converters through a coil and avoids short-circuit currents with different instantaneous values of voltage output .

The inductor is calculated for each power converter connected to the Dc-Link. The connection in this scheme may produce a short circuit if there is no capacitor in the DC-Link. This can be resolved by connecting the converters using an inductor for each of the converters.

This solution is more flexible because it allows easy expansion and is also more economical because the sizing is carried out for each of the converters. There will be a current-limiting circuit of the inductor by means of two diodes, one of them a zener diode.

PROPOSED SYSTEM

A 10-MW WTGS consisting of a three-phase open-winding synchronous generator equipped with six lead terminals and a modular multilevel cascade converter (MMCC) formed by three identical sub-converters. The MMCC carries out direct ac/ac power conversion from three single-phase voltages with a time-varying frequency (from the generator) to a three-phase voltage with a line frequency of 50 Hz.



System configuration of a multi-MW WTGS based on a 690-V multi-pole PMSG and multiple BTB converters connected in parallel.

OVERALL CONFIGURATION:

It consists of a three-phase open-winding PMSG with six lead terminals, an MMCC that performs ac/ac direct power conversion, and a step-up line frequency transformer for grid connection. This means that the line-to-line rms voltage of the generator would be 6.6 Kv if the three windings were connected to the common neutral point, similar to a general generator with three lead terminals.

The only difference between the conventional star-connected generator and the open-winding generator is that each of the three windings is not connected at the neutral points.

This means that the same design procedure can be applied when designing an open-winding generator. The MMCC consists of three identical sub-converters, which have a function to convert a three single-phase voltage set from the generator to a three-phase voltage for grid connection.

Here, va, vb, and vc are the generator-side voltages of the MMCC, and ia, ib, and ic are the generator currents. The three generator-side voltages should be galvanically isolated each other to avoid undesirable short circuits formed between the sub-converters. The relationship of ia + ib + ic$\neq$ 0 exists in the generator currents owing to the open windings. This implies that the generator suffers from an additional loss and current distortion caused by a zero-sequence current. The grid-side terminals of the MMCC are connected in a star connection, producing the grid-side voltages vu, vv, and vw and the grid-side currents iu, iv, and iw. The MMCC has the following three functions: generator control for extracting the maximum power from the wind, regulation of the dc-capacitor voltages in each sub-converter, and decoupled current control on the grid side.

CONCLUSION

The validity and effectiveness of the control methods and the complete three-phase system presented in this paper were verified by computer simulation using the PSCAD/EMTDC software package, the reliability of which has been guaranteed by experimental results obtained from a 200-V 6-kW down scaled system designed and developed in the authors' lab.

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