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An Analysis of Multilevel Medium-Voltage Inverter for Single Phase Grid Connected Photovoltaic Power System

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Abstract: A Multilevel Medium-Voltage Inverter for Grid Connected Photovoltaic System" is composed of this project is medium (0.1–5 MW) and large (>5 MW) scale Photovoltaic (PV) power system have attracted great attention, where Medium-Voltage grid connection (typically 6–36 kV) is essential for efficient power transmission and distribution. A power frequency transformer operated at 50 or 60 Hz is generally used to step up the traditional inverter's low output voltage (usually ≤400 V) to the Medium-Voltage level. As an alternative approach to achieve a compact and lightweight direct grid connection, this project proposes a single phase medium-voltage PV inverter system. And also achieve to reduce the THD

Keywords: multilevel medium-voltage inverter, photovoltaic power system, MPPT and THD.

I. Introduction

A Multilevel Medium-Voltage Inverter for Grid Connected Photovoltaic (PV) System uses special transformers were compact contrast with the conventional distribution transformers which were still large and heavy for remote area PV applications. The huge size and heavy weight step-up transformer may increase the system weight and volume, and can be pricey and complex for installation and maintenance. The medium-voltage inverter may be a possible solution to connect the PV power plant to the medium-voltage grid directly. Moreover, it can also be possible to ensure electrical isolation through the inverter, which is important for the connection of PV power plants with medium-voltage grids. Therefore, medium-voltage inverters for step-up-transformer direct grid connection of PV systems have attracted a high degree of attention Because of some special features, the Modular Multilevel Cascaded (MMC) inverter topology was considered as a possible candidate for medium-voltage applications. The component numbers of the MMC inverters scale linearly with the number of levels, and individual modules are identical and completely modular in constriction, thereby enabling high level number attainability.

The purpose of the project is where medium-voltage grid connection (typically 6–36 kV) is essential for efficient power transmission and distribution. A power frequency transformer operated at 50 or 60 Hz is generally used to step up the traditional inverter's low output voltage (usually ≤400 V) to the medium-voltage level. Because of the heavy weight and large size of the power frequency transformer, the PV inverter system can be expensive and complex for installation and maintenance. As an alternative approach to achieve a compact and lightweight direct grid connection, this paper proposes a single phase medium-voltage PV inverter system. The advantages of the proposed PV inverter are [1] step-up-transformer and line-filter-less medium-voltage grid connection, [2] an inherent minimization of the grid isolation problem through the magnetic link, [3] an inherent dc-link voltage balance due to the common magnetic link, [4] a wide range of MPPT operation, and [5] an overall compact and lightweight system. Single phase medium-voltage inverter is proposed for step-up-transformer direct grid connected of PV system. A medium-frequency link (common magnetic link) instead of the common dc link is used to generate all the isolated and balanced dc supplies of MMC inverter from a single or multiple PV arrays.

In 2011, different multilevel inverter topologies were compared for possible medium-voltage grid connection of PV power plants. Because of some special features, the modular multilevel cascaded (MMC) inverter topology was considered as a possible candidate for medium-voltage applications. The component numbers of the MMC inverters scale linearly with the number of levels, and individual modules are identical and completely modular in constriction, thereby enabling high level number attainability. However, the MMC inverter requires multiple-

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isolated Dc sources that must be balanced. In 2011, a high-frequency link was proposed to generate multiple-imbalanced sources for asymmetrical multilevel inverters. In the proposed system, only the auxiliary H-bridges are connected through high frequency link. The main H-bridges are supplied directly from the source, which means that there is no electrical isolation. Therefore, the use of this inverter is only for isolated winding motor applications. Compared with the power frequency transformers, the medium-frequency link has much smaller and lighter magnetic cores and windings, thus much lower costs.

In 2012, by combination of a quasi-Z source inverter into a MMC converter, a medium-voltage PV inverter was proposed. The proposed PV inverter does not have isolation between PV array and medium-voltage grid. Multiple-isolate DC/DC converter-based PV inverter topologies were proposed. In the proposed configuration, the voltage balancing is a challenging issue, since each H-bridge cell is connected to a PV array through a dc/dc converter

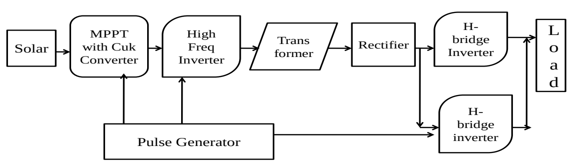

Fig.1. The basic block diagram of the proposed medium-voltage inverter.

A single phase multilevel medium-voltage inverter for grid connected photovoltaic system .Fig.1 shows the basic block diagram of the proposed medium-voltage inverter. The advantages of the proposed PV inverter are 1) step-up- transformer-less and line-filter-less medium-voltage grid connection, 2) an inherent minimization of the grid isolation problem through the magnetic link, 3) an inherent dc-link voltage balance due to the common magnetic link, 4) a wide range of MPPT operation, and 5) an overall compact and lightweight system.

II. Proposed Photovoltaic System

In this work, an alternative approach to minimize the voltage imbalance problem with a wide range of MPPT operation, an amorphous alloy 2605SA1-based common magnetic link is considered. The cuk converter is considered for the MPPT operation. The array DC power is converted to a medium frequency ac through a medium-frequency inverter. The inverter also ensures constant output voltage. The inverter is connected to a primary winding of a multi winding medium-frequency transformer. Each secondary winding works as an isolated source and is connected to an H-bridge cell through a bridge rectifier. The number of primary windings depends on the number of PV arrays and the number of secondary windings depends on number of levels of the inverter. The detailed power circuit of a single-phase five-level PV inverter system is shown in Fig.2, which is used to validate the proposed inverter in the laboratory. In large PV system, several PV arrays are operated in parallel. For this case, multi input and multi output magnetic link can be used, where each PV array is connected to a primary winding through a booster and medium-frequency inverter.

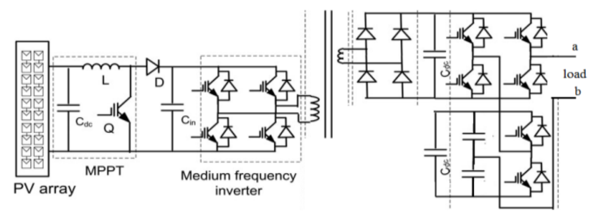

Fig.2. Detailed power conversion circuit with single-phase 5-level MMC inverter
(For simplicity single PV array is used).

III. Multilevel Inverter

Photovoltaic systems were probable to play an important role in future energy production. Such systems transform light energy into electrical energy. The input current of the converter is continuous, and they can draw a ripple free current from a PV array that is important for efficient MPPT. A rectifier is an electrical device that converts ac, which periodically reverses direction, to dc, which flows in only one direction. The process is known as rectification. An H-bridge is an electronic circuit that enables a voltage to be applied across a load in either direction. These circuits are often used in robotics and other applications to allow DC motors to run forwards and backwards.

Most dc-to-ac converters (power inverters), most ac to ac converter, the dc-to-dc push–pull converter, most motor controllers, and many other kinds of power electronics use H-bridges. In particular, a bipolar stepper motor is almost invariably driven by a motor controller containing two H-bridges. The term H-Bridge is derived

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from the typical graphical representation of such a circuit. An H-bridge is built with four switches (solid-state or mechanical). Switched dc-to-dc converters offer a method to increase voltage from a partially lowered battery voltage thereby saving space instead of using multiple batteries to accomplish the same thing. Most dc-to-dc converters also regulate the output voltage. Although these special transformers are compact compared with the conventional distribution transformers, they are still large and heavy for remote area PV applications. The Medium-Voltage inverter may be a possible solution to connect the PV system to the Medium-Voltage grid directly.

Therefore, the use of this inverter is only for isolated winding motor applications. In, a Medium-Frequency transformer operated at a few Kilo hertz to Mega hertz was proposed to generate multiple isolated and balanced dc sources for MMC inverters from a single source. In, by combination of a quasi-Z Source Inverter into a MMC converter, a Medium-Voltage PV inverter was proposed. The proposed PV inverter does not have isolation between PV array and Medium-Voltage grid. Multiple-isolated dc-to-dc converter based PV inverter topologies were proposed. In the proposed configuration, the voltage balancing is a challenging issue, since each H-Bridge cell is connected to a PV array through a dc-to-dc converter and accordingly limits the range of MPPT operation. Many years ago, Dr. Cuk invented the integrated magnetic concept called DC transformer, where the sum of DC fluxes created by currents in the winding of the input inductor (L_1) and transformer is equal to dc flux created by the current in the output inductor (L_2) winding. Hence the dc fluxes are opposing each other and thus result in a mutual cancellation of the dc fluxes. cuk converter has several advantages over the buck converter. One of them cuk converter provides capacitive isolation which protects against switch failure (unlike the Buck topology). Other advantage is, the input current of the cúk is continuous, and they can draw a ripple free current from a PV array that is important for efficient MPPT. When the input voltage turned on and MOSFET is switched off, diode (D) is forward biased and capacitor (C_1) is charged through L_1 –D.

A rectifier is an electrical device that converts AC, which periodically reverses direction to DC which flows in only one direction. The process is known as rectification. Physically, rectifiers take a number of forms, including vacuum tube diodes, mercury-arc valves, copper and selenium oxide rectifiers, semiconductor diodes, silicon-controlled rectifiers and other silicon-based semiconductor switches. Rectifiers have many uses, but are often found serving as components of DC power supplies and high-voltage direct current power transmission systems. In these applications the output of the rectifier is smoothed by an electronic filter (usually a capacitor) to produce a steady current.

(A) H-Bridge Inverter

An H-Bridge is an electronic circuit that enables a voltage to be applied across a load in either direction. These circuits are often used in robotics and other applications to allow DC motors to run forwards and backwards. Most DC-to-AC converters (power inverters), most AC/AC converters, the DC-to-DC push–pull converter, most motor controllers, and many other kinds of power electronics use H Bridges. In particular, a bipolar stepper motor is almost invariably driven by a motor controller containing two H Bridges. The term H-Bridge is derived from the typical graphical representation of such a circuit. An H-bridge is built with four switches (solid-state or mechanical). When the switches S_1 and S_4 are closed (and S_2 and S_3 are open) a positive voltage will be applied across the motor. By opening S_1 and S_4 switches and closing S_2 and S_3 switches, this voltage is reversed, allowing reverse operation of the motor. Using the nomenclature above, the switches S_1 and S_2 should never be closed at the same time, as this would cause a short circuit on the input voltage source. The same applies to the switches S_3 and S_4.

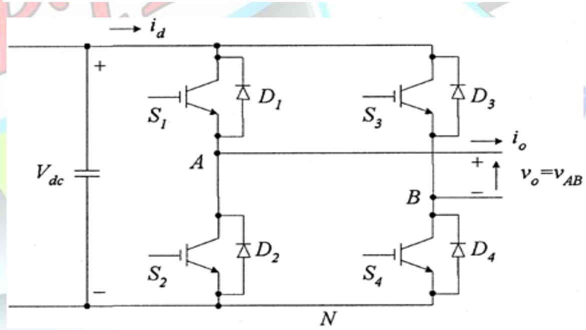

Fig.3.Schematic diagram of H-bridge Inverter

A Metal–Oxide–Semiconductor Field-Effect Transistor (MOSFET) is based on the modulation of charge concentration by a MOS capacitance between a body electrode and a gate electrode located above the body and insulated from all other device regions by a gate dielectric layer which in the case of a MOSFET is an oxide, such as silicon dioxide. If dielectrics other than an oxide such as silicon dioxide (often referred to as oxide) are employed the device may be referred to as a Metal–

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Insulator–Semiconductor FET (MISFET). Compared to the MOS capacitor, the MOSFET includes two additional terminals (source and drain), each connected to individual highly doped regions that are separated by the body region. These regions can be either p or n type, but they must both be of the same type, and of opposite type to the body region. The source and drain (unlike the body) are highly doped as signified by a "+" sign after the type of doping. If the MOSFET is an n-channel or n MOS FET, then the source and drain are "n+" regions and the body is a "p" region.

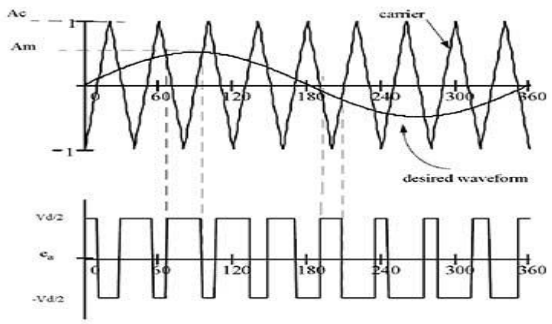

Fig.4. PWM signal waveform

When a negative gate-source voltage (positive source-gate) is applied, it creates a p-channel at the surface of the n region, analogous to the n-channel case, but with opposite polarities of charges and voltages. When a voltage less negative than the threshold value (a negative voltage for p-channel) is applied between gate and source, the channel disappears and only a very small sub threshold current can flow between the source and the drain. Pulse-Width Modulation (PWM), or Pulse-Duration Modulation (PDM), is a modulation technique that conforms the width of the pulse, formally the pulse duration, based on modulator signal information.

The total harmonic distortion, or THD, of a signal is a measurement of the harmonic distortion present and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. THD is used to characterize the linearity of audio systems and the power quality of electric power systems. Distortion factor is a closely related term, sometimes used as a synonym. In audio systems, lower THD means the components in a loudspeaker, amplifier or microphone or other equipment produce a more accurate reproduction by reducing harmonics added by electronics and audio media. In radio communications, lower THD means the pure signal emission without causing interferences to other electronic devices. THD is a measurement of the extent of that distortion.

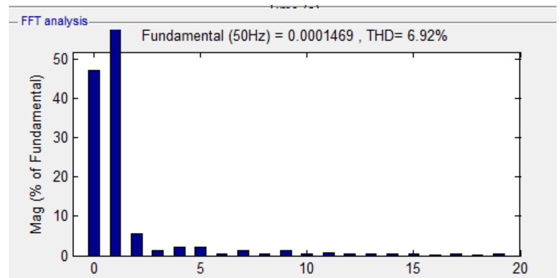

Fig.5. THD graph

The main concert criterion is the ″purity″ of the original sine wave (in other words, the contribution of the original frequency with respect to its harmonics), the measurement is most commonly defined as the ratio of the RMS amplitude of a set of higher harmonic frequencies to the RMS amplitude of the first harmonic, or fundamental, frequency

$$\mathrm{THD} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \cdots + V_n^2}}{V_1}$$

Where V_n is the RMS voltage of nth harmonic and $n = 1$ is the fundamental frequency.

IV. Simulation Results Analysis

A five-level single-phase MMC inverter requires six isolated and balanced dc sources. The output of each secondary winding is connected to a fast recovery diode-based rectifier with a low-pass RC filter circuit. Such similarity of characteristics is obligatory to generate balanced multiple sources for the MMC inverters. MATLAB is an ideal tool for simulating digital communication systems, thanks to its easy scripting language and excellent data visualization capabilities. Performing bit-error-rate testing with MATLAB is very simple, but does require some prerequisite knowledge in MATLAB.

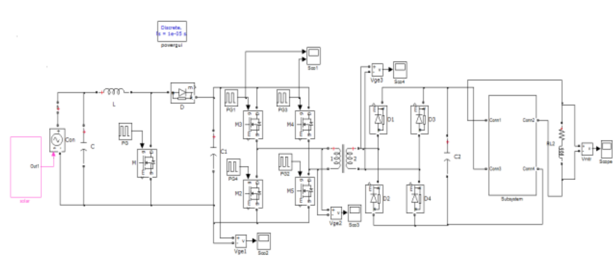

Fig.6. A Multilevel Medium-Voltage Inverter Simulation Circuit

Simulation software allows for modeling of circuit operation and is a precious analysis tool. A Multilevel Medium-Voltage Inverter for Grid Connected Photovoltaic System simulation circuit given below:

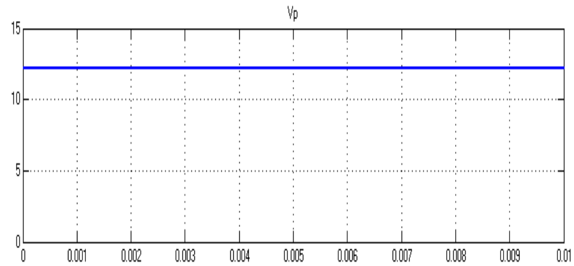

Fig.7. Photovoltaic voltage waveform

The photovoltaic voltage is 12V from get in solar panel. It is a constant DC voltage. In proposed system circuit of input voltage is constant DC 12V.

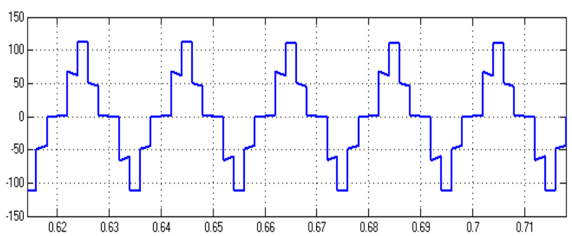

Fig.8. Final dc output voltage waveform

The dc output voltage is 100V with 5 levels in this proposed multilevel medium voltage for grid connected photovoltaic system.

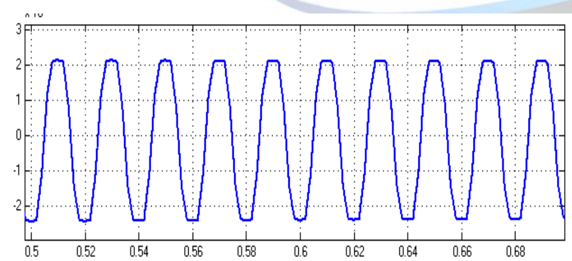

Fig.9. Final dc output current waveform

The dc output current is 2.1A at sine wave. This output current is smoothly and continuously.

V. CONCLUSION

A novel medium-voltage PV inverter system was proposed for Medium- or Large-Scale PV system. A universal magnetic link is employed to interconnect PV arrays to form a single source. Multiple isolated and balanced DC supplies for the multilevel inverter had been generated through the common magnetic link, which automatically minimizes the voltage imbalance problem. The grid isolation and safety problems have also been solved inherently due to electrical isolation provided by the Medium-Frequency link. Although the additional windings and rectifiers may add to the loss of the proposed inverter, the overall performance is still similar to the traditional system. The elimination of the line filter and step-up transformer from the traditional system will enable big cost savings in conditions of the installation, running and maintenance of the PV systems.

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