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PHOTO VOLTAIC SYSTEM GRID INTEGRATION USING HIGH-FREQUENCY LINK MULTILEVEL MEDIUM VOLTAGE CONVERTER

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Abstract— This paper presents a High-frequency link multilevel cascaded medium voltage converter. Medium-voltage converters eliminate the step-up transformer for direct grid integration of renewable power plants, but MMC converters require multiple DC supplies. The high frequency magnetic link is used to generate the multiple isolated DC sources for all H-bridge inverter cells of the MMC converters and it also minimizes the voltage imbalance, common mode issues. The proposed system performance is analyzed in the MATLAB/Simulink environment. It is expected that the proposed new technology will have great potential for future renewable power generation and smart grid application.

Keywords— Direct grid integration, high-frequency link, medium-voltage converters, modular multilevel cascaded converters, renewable energy systems.

I. INTRODUCTION

This document is a A high-frequency link multilevel cascaded medium voltage converter is proposed for direct grid integration of renewable sources. The common magnetic link generates multiple isolated and balanced dc supplies for all of the H-bridge inverter cells of the MMC converter from a single or multiple renewable sources. The grid electrical isolation and voltage imbalance problems are solved through the common high-frequency link.

II. BASIC BLOCK DIAGRAM OF THE PROPOSED SYSTEM

Fig 1 show the basic block diagram of the proposed system. In the proposed system, the available renewable power is converted to a medium/high frequency ac through the medium/high-frequency full-bridge inverter.

For high-power applications, a number of medium/high-frequency full-bridge inverters can be used in parallel. The parallel operation of multiple medium/high-frequency inverters enables the proposed topology to use mature low-rated power and low-cost semiconductor devices. To ensure a fixed grid voltage, a constant output voltage of the inverter is maintained. The inverter output is supplied to the primary windings depends of a common multi winding medium/high-frequency link. Each secondary winding is connected with the H-bridge inverter through a bridge rectifier.

The number of primary windings depends on the number of sources and the number of secondary windings depends on the number of levels of the MMC converter. The grid electrical isolation and voltage imbalance problems are solved inherently through the common medium/high-frequency link.

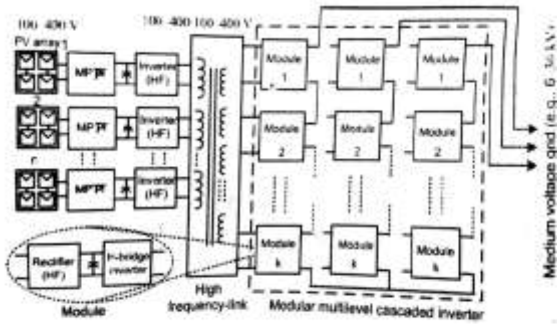

Figure 1 Basic block diagram of proposed PV inverter system for direct medium voltage grid integration

A field-programmable gate array (FPGA)-based control circuit is used to control the magnitude and phase angle, and to ensure the power quality and stability of the system. In this paper, the phase-shifted carrier and third harmonic injected sinusoidal reference-based pulse width modulation(PWM) scheme is used. Desired output voltage level can be generated by cascading more modules on each phase. A high-level converter results in the elimination of the step-up transformer and lower total harmonic distortion (THD) with lower switching frequency. It also leads to the elimination of the output filters and a reduction in running cost. A high-level number attainability also allows for a lower level dc-link voltage requirement for each H-bridge inverter that serves to eliminate the boosters.

III. DESIGN OF MEDIUM/HIGH-FREQUENCY LINK

At the beginning, according to the power converter rating, the transformer-link specifications, such as rated power, frequency, excitation current, and voltage, are calculated. The core materials selected according to the availability, system requirements, and cost. From the specifications of the transformer-link and data sheets of core materials, the transformer-link initial parameters are calculated. These parameters are used as initial values of the optimization process. The volume and weight of the transformer need to be optimized by selecting proper parameters. The winding dimensions depend on the diameter and number of the conductors, and winding structure. Single layer winding pro-vides low ac/dc resistance ratios, but it increases the winding and core dimension significantly. For simplicity of the winding process, a toroidal structure core is considered. Different factors are also considered during the selection of core dimensions, such as the winding dimensions, toroid hole reserve for natural cooling, maximum temperature limits, maximum power loss, availability of core material stripe dimensions, leakage inductance, and the possibility to induce an equal voltage in multiple secondary windings. Therefore, the design process involves multi physics problems with some critical decision-making tasks.

A. Core material selection
B. Calculation of number of turns
C. Winding wire selection
D. Core development

HIGH FREQUENCY AC LINK

High-frequency link power converters are receiving increasing attention as an alternative to more conventional dc link power conversion systems. Use of high-frequency ac voltage link in a power conversion systems permits adjustment of the link voltage to meet the individual needs of loads/sources in the system, allows stepping up of the voltages in sections, and realizes electrical isolation by using transformers on the link side of the interface converters. This flexibility can be very useful in system design, particularly in distributed power conversion systems where voltage levels can vary widely due to the need to integrate a wide variety of loads and sources into the

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system. By operating the link at a high frequency, the system can be made compact because of the large reduction in the size and the weight of the transformers and the passive components needed for filtering and temporary energy storage functions. High-frequency operation also speeds up the system response and, if the frequency is above the audible range, reduces acoustic noise,

High-frequency link power conversion has been employed very successfully in dc-to-dc converters. Their enormous success has demonstrated the benefits and, to some extent, the difficulties of working at high frequencies. In particular, problems arise from the limitations of both the components and the circuit topologies. As the demand has grown and the technology has matured, there has been a large improvement in the quality of components. High-quality capacitors, good magnetic materials for design of compact low-loss inductors and transformers, and the semiconductor devices designed especially for high speed power applications have become available. This trend can be expected to continue with further improvement in performance and even larger gains in the cost and availability of these components.

A number of high-frequency link systems have also been proposed foe dc-to-ac and ac-to-ac power conversion. Nearly all of these systems use the favorable switching characteristics of resonant converters to realize dedicated conversion systems. The majority of the configurations, however, are not suitable for power conversion systems having more than one type of load and sources.

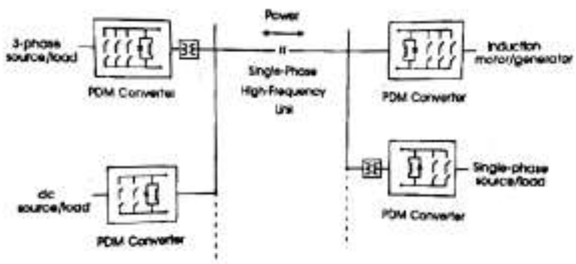

Figure. 2 High-frequency link based static power conversion system

Figure shows the proposed high-frequency link power conversion system in block schematic form. A single-phase ac voltage link operating at a fixed frequency of higher interconnects all sources and loads in the system through interface converters and link-side transformer as needed. The interface converters operate directly from the bidirectional high-frequency voltage of the link to synthesize low-frequency voltage are current source outputs as appropriate for the source/load being interfaced.

IV. DESIGN OF POWER CONVERSION CIRCUIT:

The comparator module compares the carrier signal with the respective reference signal and generates control pulses including reasonable dead time as required by the switching devices. An onboard crystal (e.g., 50 MHz) is used for a clock source and a clock divider reduces the clock frequency. The basic architecture of the detailed power conversion is
illustrated in Fig..3.
The magnetic link provides electrical isolation between the PV array and the grid, thus inherently overcomes the common mode and voltage imbalance problems.

Design and Analysis of the Proposed System

If *ml* is the number of levels of the converter, the number of cascaded modules on each phase can be calculated from $Mn= ml-12$ (1)
If Vll(rms) is the grid line to line voltage, the minimum dc-link voltage of each *H*-bridge inverter cell can be calculated from
$Vdc(min)= 2Vll\ rms\ ml-1$ (2)
To determine the nominal dc-link voltage of each *H*-bridge inverter cell, a voltage reserve of 4% is assumed, i. e.,

$Vdc\ nom = 1.04 Vdc(min)$ (3)

If Ip(rms) is the inverter phase current, the apparent output Power can be calculated from

$Sc = 3\ Vll\ rms\ Ip\ rms$ (4)

V. CONTROL STRATAGY

In these proposed system, the parameters of the system are given in the appendix. the control architecture
of the system is shown in fig 4, and the MPPT control strategy is shown in fig. 5

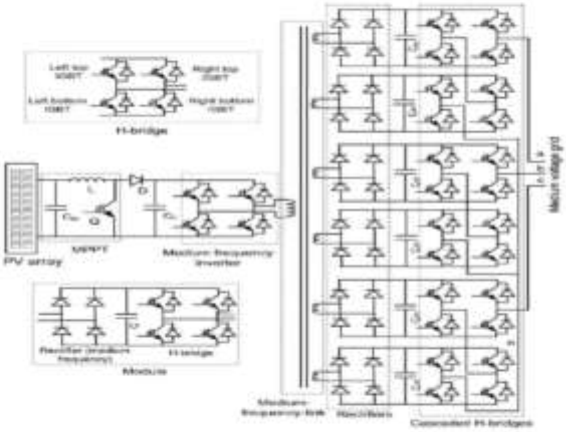

Figure. 3. Detailed power conversion circuit

CONTROLLER ARCHITECTURE:

A look-up table (LUT) is used to generate the reference signals, which makes the control circuit totally digital and integrated. In total, there are eight switching devices in a phase of a three-phase five-level MMC converter, requiring eight gate pulses to drive them. Including the inverted carrier signals, a total of four carriers are able to generate four gate pulses when comparing them with a reference signal. The other four gate pulses can be generated by just inverting these four gate pulses with a consideration of dead time.

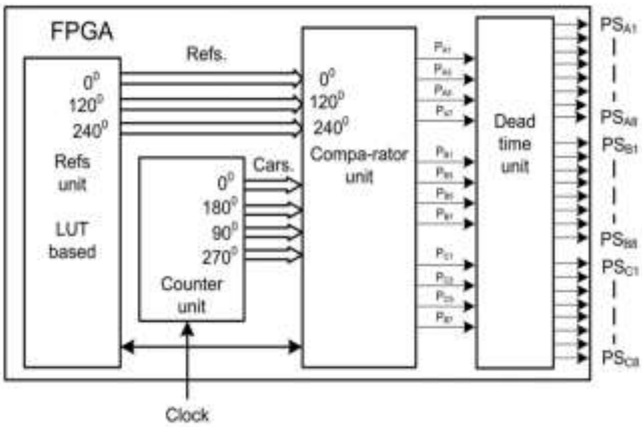

Figure 4 switching controller architecture

MPPT CONTROL:

Out of different MPPT methods reported in the literature, P&Oalgorith is used here due to its generic nature and simplicity. Fig 5 represents a step by step procedure of
the MPPT operation in these proposed system.

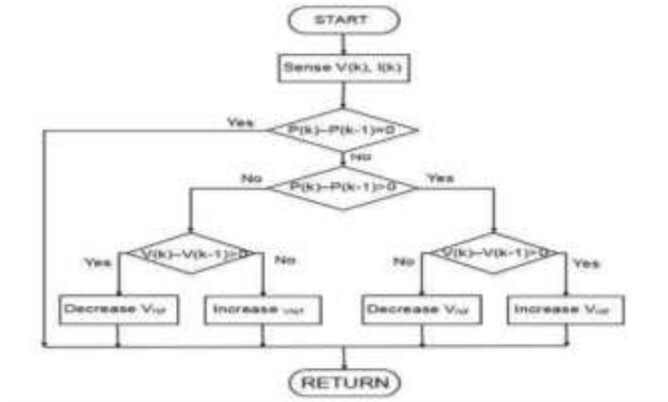

Figure 5 P&O Algorithm

VI. SIMULINK MODEL AND RESULT ANALYSIS

To verify the feasibility of the proposed system a simulink model is developed with modular five-level cascaded converter which gives three phase 1kV rms as output. Fig. 6. shows the PV sub system in the simulink model.

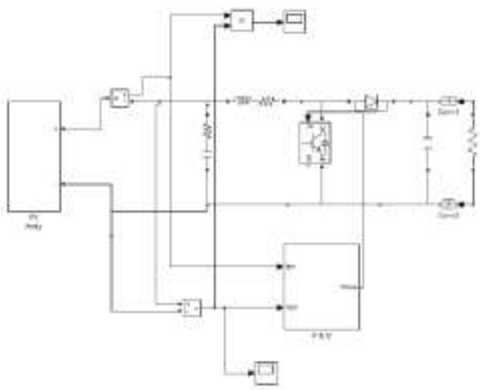

Figure 6 PV Sub System

Gate pulses are applied to the switching devices of the converter and the obtained output voltage and line currents are as shown in fig. 7, fig. 8. Each level of the output voltage contains a number of PWM pulses.

The frequency spectrum of line voltages is shown in fig. 9. The output voltage waveform contains about 4. 07% THD.

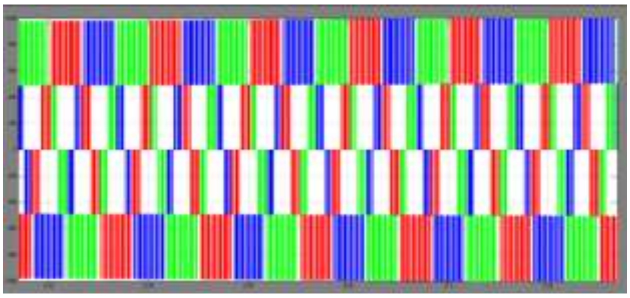

Figure. 7. Simulated three phase line voltages of 1-kV multilevel cascaded converter

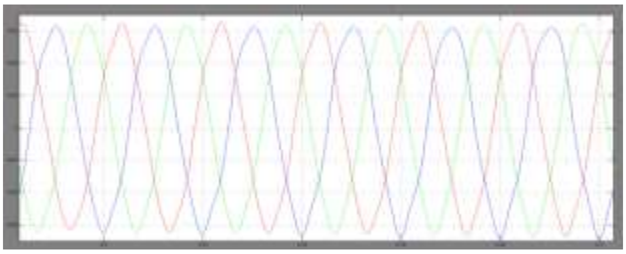

Figure. 8. Simulated line currents of the 1-kV multilevel cascaded converter

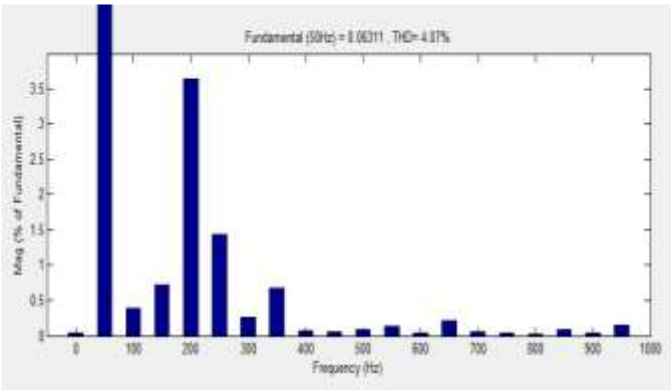

Figure. 9. Frequency spectrum of line voltages

VII. EXTENSION WORK

Renewable energy sources have daily and seasonal variable patterns. Due to these reasons, uninterrupted power supply to any load is not possible by a stand-alone renewable resource. For this problem, grid integration of renewable sources is the only practical solution. In extension work both PV and Wind power generation systems are connected to the grid. There are always periods without wind. Thus, WECS must be linked energy storage or parallel generating system if supplies are to be maintained. Fig. 10. shows the sub system of wind power generation along with PV sub system. The following are the simulation results when two renewable sources (PV, Wind power generation systems) are connected to the grid through medium/high frequency link.

The frequency spectrum of line voltages when two renewable sources (PV, Wind power generation systems) are connected to grid is shown in fig. 13. The Output voltage waveform contains about 2. 24% THD.

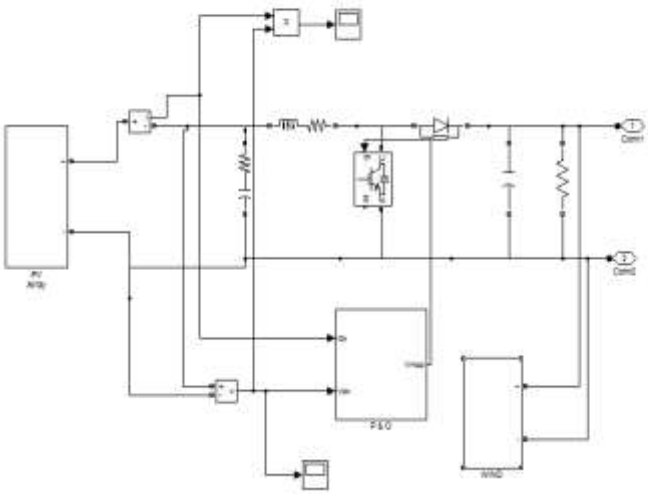

Figure. 10. Sub system of Wind power generation system along with PV system.

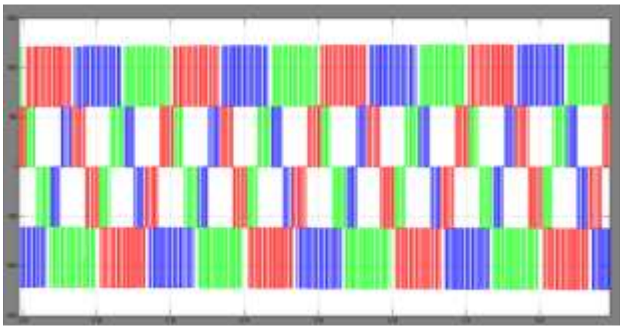

Figure. 11. simulated three phase line voltages of 1. 2 kV multilevel converter.

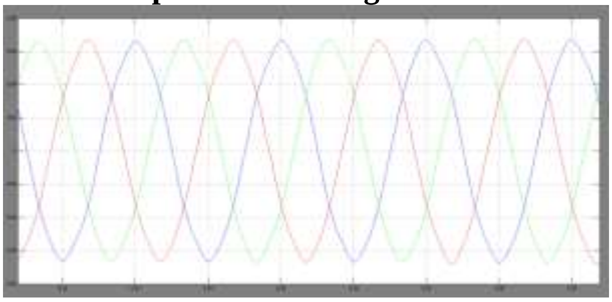

Figure. 12. Simulated three phase line currents of 1. 2 kV multilevel converter.

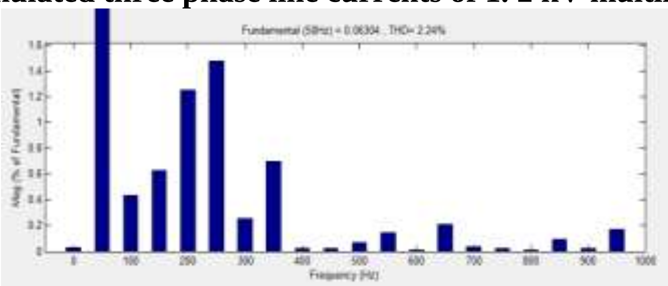

Figure. 13. Frequency spectrum of line voltages.

VIII. CONCLUSION

In this paper, a new-medium voltage PV inverter system is proposed for medium – or large-scale PV power plants. A common magnetic link is employed to interconnect PV arrays to form a single source. Multiple isolated and balanced dc supplies for the multilevel inverter have 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 High-frequency link. Although the additional windings and rectifiers may increase loss of the proposed system, the overall performance is still similar to the traditional system. The elimination of line filter and step-up transformer from traditional system will enable the large cost savings in terms of the installation, running and maintenance of the PV power plant.. In extension work both PV and Wind generation systems are connected to the grid to give uninterrupted power supply to the required areas. Here, the proposed medium-voltage system has been developed by MATLAB/Simulink model.

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