Single phase to three phase converter engineering essay

Several solutions have been proposed where the objective is to reduce harmonic distortions in a generating system. It is now the renewable power utilization that is growing more, thus a small scale Wind Energy Conversion System is concentrated which needs harmonic reduction. The wind energy unit that we are planning to install is single phase so we go for a single phase to three phase ac-dc-ac converter designing to reduce harmonics. Parallel converters have been used to improve the power capability, reliability, efficiency, and redundancy. Usually the operation of converters in parallel requires a transformer for isolation. Here a single-phase to three-phase drive system composed of two parallel single-phase rectifiers and a three-phase inverter is proposed. Compared to the conventional topology, the proposed system permits: to reduce the rectifier switch currents; the total harmonic distortion (THD) of the grid current with same switching frequency or the switching frequency with same THD of the grid current; and to increase the fault tolerance characteristics. Also the loss of the proposed system is lower. The aforementioned benefits justify the initial investment of the proposed system, due to the increase of number of switches.

Index Terms- Converters, IGBT, MOSFET, Renewable Energy, Single Phase to Three Phase, Wind Energy.

Introduction

The paper deals with the enhancement of the usage of renewable energy and improvement of its utility. Wind energy is one of the most promising alternative energy technologies of the future. Throughout recent years, the amount of energy produced by wind-driven turbines has increased

exponentially due to significant breakthroughs in turbine technologies, making wind power economically compatible with conventional sources of energy.

One of the limitations of wind energy is Harmonic distortion that hinders the utility of the wind generation. Harmonics is referred as the disturbance or the deterioration of the purity of current or voltage after undergoing several changes or transformations. Since power quality is very important it is mandatory to discover methods to reduce harmonics and retain purity. As corrective action is always expensive and unpopular solution more thought and investment are devoted at the design stage on the basis that prevention is better than cure.

The sources of harmonics can be divided into 3 categories:

Large numbers of distributed non-linear components of small rating.

Large and continuously randomly varying non-linear loads.

Large static power converters and transmission system level power electronics devices.

Harmonics Reduction Technique

In general there are many techniques to reduce harmonics like

usage of harmonic filters [13]

PWM technique [4], [5], [13]

Filter is a device that is designed to suppress harmonic current and voltages from being injected into the power system since these causes damaging effects to the devices being used in the system. The harmful and damaging effects of harmonic distortion can be avoided by the usage of filters. There can be two types of filters that are used in order to reduce the harmonics distortion i. e. the active filters and the passive filters. Active harmonic filters are electronic devices that eliminate the undesirable harmonics on the network by inserting negative harmonics into the network. The active filters are normally available for low voltage networks.

In order to control power and reactive power, it is essential to control the magnitude and phase angle of the injected voltage by the converter [1], [4], [5], [7]. At the same time, it is desirable to regulate the DC bus voltage. Another requirement is to minimize the injection of the lower order harmonics by the converter. The pulse width modulation (PWM) is utilized to achieve the following objectives:

To control the output AC voltage for a constant DC voltage.

To minimize the harmonics subject to the constraints on the switching losses, generation of noise etc.

Circuit Design

The project deals with a converter design as an attempt to reduce harmonic distortions in wind energy conversion system. We design a converter circuit for a single phase –

three phase conversion with two single phase rectifiers connected in parallel and a three phase inverter. The experiment is simulated using MATLAB Simulink software and the results are compared for the effectiveness of the converter circuit [9]. Also the selection of switch for the converter is very essential thus we compare two different switches- MOSFET and IGBT and analyze its characteristics for the suitability and effectiveness.

Process of Switch Selection

The below table shows the comparison of different parameters considered in the course of selection of switch for the converter thereby helping us to justify our selection.

The Table below shows the comparison between different possible switches that are used in converters. We can see the characteristics and parameters based on which the switches are selected.

TABLE I. SELECTION OF SWITCH FOR THE CONVERTER CIRCUIT

Device

Comparison area

diode rectifier

Thyristor [SCR]

GTO

IGBT

MOSFET

Inverter switch

X

X

AC-DC conversion

X

X

X

X

X

Inverter types

Current source

X

X

Voltage source

X

X

X

Efficiency

High

High

Low

High

High

Gate control signal

NA

current

current

voltage

voltage

Gate current

NA

< 2 Amps

400-1000 Amps

0. 1 Amps

< 0. 01 Amp

Voltage rating

High

High

High

To 1200 Volts

4000 volts

Current rating

6000 Amps

5500 Amps

1000 Amps

1000 Amps

600 Amps

Switching losses

NA

Medium

High

Low

Low

Switching speed

NA

Low

Low

Very high

Very High

From the comparison it is evident that MOSFET, IGBT are the two most suitable switches for the Inverter section of converter as MOSFET and IGBT showed good efficiency, voltage and current ratings. Also the switching speed and switching losses are satisfactory. And it doesn’t need a special switching angle control mechanism. Thus the MOSFET, IGBT rectifier/inverter system is the proposed converter for the small scale wind energy conversion system. Also comparison between MSOFET and IGBT operation in Single phase – Three phase conversion as well as Three phase – Three phase conversion is done.

Technology used for switching

The maximum achievable efficiency of any practical system is 0. 93. However due to design considerations and operational constraints, the percentage drastically reduces to a maximum of 0. 5, in the case of a wind energy system. The aim of this project is to improve the normal operating mean efficiency of 0. 29. Various techniques have been instrumental in reducing the overall losses in the system, and also particular interest is streamlined in the domain of reduction of harmonics in the system. A lot of techniques by which, losses, and particularly, harmonics can be reduced have been figured out by analyzing various IEEE projects. Apart from circuit element modifications, design modifications have also been analyzed.

The Circuit Design

Here as per the circuit diagram we can see 14 switches totally i. e. 4 for each single phase rectifiers and 6 for the three phase inverter. Now when the single phase supply is given to the system the rectifiers convert the AC single phase supply to DC supply then it is fed to the inverter for further conversion into a three phase AC supply. Here as we can see the rectifiers are connected in parallel to each other, as we know the working of the rectifier. The converter can either use MOSFET as a switch or IGBT as a switch.

FIGURE 1. CIRCUIT DESING FOR SINGLE PHASE_ THREE PHSE CONVERTER

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Rectifier is a device that converts AC to DC signal. In a single phase controlled rectifier there are 4 switching devices two in each leg. Two switches at a time namely alternate switches of the legs are on at a time. Thereby converting the AC signal into DC signal. Then it is fed to the inverter which has 6 switching devices two per leg, thus a 3 phase inverter has 3 legs with 2 switches per leg. The working mechanism is almost similar to the rectifiers.

Simulation using MATLAB/Simulink

MOSFET Based Converter Simulation

The MATLAB simulation model clearly depicts the no of switches used, also the parameters involved in the analysis of the circuit. Simulation results help us clearly conclude the difference in the performance based analysis of MOSFET and IGBT converters.

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FIGURE. 2 MOSFET based Single phase – three phase converter using MATLAB Simulation

MATLAB is a high-level language and interactive environment for numerical computation, visualization, and programming. Using MATLAB, you can analyze data, develop algorithms, and create models and applications. The language, tools, and built-in math functions enable you to explore multiple approaches and reach a solution faster than with spreadsheets or traditional programming languages, such as C/C++ or Java.

Here we simulated converter circuit with MOSFET switches and IGBT switches and compared the difference in the capacity of reducing harmonics.

FIGURE. 3 RECTIFIER OUTPUT FOR MOSFET BASED SINGLE PHASE – THREE PHASE CONVERTER USING MATLAB SIMULATION.

This graph represents the rectifier output. The voltage amplitude is 310V i. e. the harmonics in the voltage causes spikes which reaches this value, where as the original voltage is around 230V. The graph is plotted for a time period of 20 milliseconds. The positive half wave is rectified better than the negative half wave. We can clearly see the spike occurrence in the positive half wave due to harmonics.

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FIGURE. 4 FINAL OUTPUT OF THE MOSFET BASED CONVERTER SYSTEM USING MATLAB SIMULATION

The output is around 220V with reduced harmonics. The inverter output by itself has reduced harmonics distortion found in the rectifier output. The spikes that were found in the rectifier are not present in the inverter output

waveform. From this it’s evident that the single phase to three phase voltage converter design helps in reducing the harmonics.

The MOSFET switch used is a voltage controlled device and has a high switching frequency that enhances the rectification as well as inversion of the generated voltage. The single phase to three phase configuration is helpful in reducing the harmonics is hence proved from the graphs above.

IGBT Based Converter Simulation

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FIGURE 5: MATLAB SIMULATION DIAGRAM FOR IGBT BASED SINGLE PHASE-THREE PHASE CONVERTER

The simulation model diagram for the IGBT single phase to three phase converter is given above. We can see that the topology is similar to that of the MOSFET based converter except for that the IGBT block contains a diode connected parallel to it.

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FIGURE. 6 RECTIFIER OUTPUT WAVEFORM OF IGBT BASED SINGLE PHASE – THREE PHASE CONVERTER WITH 220V SUPPLY

This graph is the rectifier output for a 220V input supply. In this graph the magnitude of output is around 220V which means the input is completely rectified. The occurrence of spike is at the junction of two half waves. Thus

the completeness of the half waves is affected by the harmonic distortions in the case of IGBT based converter.

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FIGURE. VII FINAL OUTPUT WAVEFORM OF THE SYSTEM WITH 220V SUPPLY

The output graph shows the reduction in harmonics to some extent the magnitude of harmonics is reduced and is evident in the output graph.

ANALYSIS OF HAMONIC REDUCTION WITH VARIATION OF INPUT INDUCTANCE

Initially we analyzed the system effectiveness for various input voltages like 230V, 220V, 200V etc., where we found a prominent result only for 220V input supply. Now that changing in voltage is not producing enough difference thus we try to change the input inductance and realize the effectiveness of the MOSFET and IGBT based conversion systems.

FIGURE. 8 GRAPHICAL REPRESENTATION OF VARIATION OF HARMONICS WITH VARIATION OF INDUCTANCE IN A MOSFET BASED SINGLE PHASE – THREE PHASE CONVERTER

In the single phase to three phase conversion topology of converter using MOSFET, the inductors L2 and L4 (corresponding to the negative cycle of supply) are varied from 0. 1 mH to 0. 4 mH under a varying operating voltages between 220 V and 230 V. The results that are thus obtained are represented in the graph. For operating voltage 220 V, the output voltage peak varies between 214. 4 V and 206. 1 V corresponding to the change in

input inductance values between 0. 1 mH and 0. 4 mH. Similarly, for operating voltage 230 V, the variation in peak voltage is between 224. 2 V and 215. 4 V for the same change in input inductance.

FIGURE. 9 GRAPHICAL REPRESENTATION OF VARIATION OF HARMONICS WITH INDUCTANCE IN AN IGBT BASED SINGLE PHASE – THREE PHASE CONVERTER.

In the single phase to three phase conversion topology of converter using IGBT, the inductors L2 and L4 (corresponding to the negative cycle of supply) are varied from 0. 1 mH to 0. 2 mH under a varying operating voltages between 220 V and 230 V. The results that are thus obtained are represented in the graph. For operating voltage 220 V, the output voltage peak varies between 219. 4 V and 216. 5 V corresponding to the change in input inductance values between 0. 1 mH and 0. 2 mH. Similarly, for operating voltage 230 V, the variation in peak voltage is between 229. 8 V and 226. 3 V for the same change in input inductance.

In the above graphs we see the variation of harmonics with the variation of input inductance thus choosing the input inductance wisely can affect the harmonics reduction process.

CONCLUSION

As per the above result and discussion we saw the variation of harmonics with variation of voltage magnitude and input inductance accordingly, with the result we observe that single phase – three phase MOSFET based converter reduces spikes to a great extent without any loss in the voltage magnitude when the input inductance is of 0. 1mH each. But when the

inductance is changed to L1, L3= 0. 1mH and L2, L4= 0. 4mH the output consists of negative peaks without loss in voltage magnitude.

Coming to IGBT based converter, the single phase – three phase converter has low harmonics in the rectifier as well as the inverter outputs when the inductance in L1, L3= 0. 1mH and L2, L4= 0. 2mH. when the inductance is changed to 0. 1mH all the rectifier output has little heavy spike at the junction of the half waves which are reduced without voltage loss.