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Novel Topology of Multilevel Inverter with Less Harmonic Content Applied for Renewable Energy

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Abstract-— **Multilevel inverter research has been carried out with 7 levels. The development of renewable energy that is increasingly widespread, such as the use of photovoltaic in distribution generation which requires inverter with more efficient. Multilevel inverter H-Bridge is an inverter that is commonly used with the aim of reducing the content of Total Harmonic Distortion that affects the voltage and current waveform in the load. Achieving a 7-level system needs a series arrangement of three H-Bridge cells. This is a consideration for developing a new design by considering that the H-Bridge series arrangement is a bulky system and uses many switches and resulting in a large switch loss. This paper proposes a new design called the T-H inverter topology which is a combination of the H-Bridge and T-type inverters. The advantage of the T-H inverter is that for one cell it is able to produce 7 voltage levels and the number of switches used is less than the bulky H-Bridge. The T-H inverter topology is built with a Phase Shift Sinusoidal Pulse Width Modulation control scheme. The switching frequency used is 5 kHz. The simulation is built with simulink Matlab 2018a. The simulation results show that current THD content of the three H-Bridge cells and the T-H inverter are 2.33% and 2.31%, respectively, at a fundamental frequency of 50 Hz.**

Index Terms - Multilevel inverter, renewable energy, topology, total harmonic distortion.

I. INTRODUCTION

Over the last few decades, depletion of fossil fuels and climate change global has encouraged researchers and industry to find other alternatives to produce clean, efficient electricity. Despite the potential for fossil fuels regularly discovered, oil and natural gas are depleted during the 21st century. On the contrary, coal provide abundant and cheap prospect compared to fossil resources other. On the other hand, coal accounts for most of the energy source emitted combustion of CO_2. To overcome the depletion of fossil resources and global warming, it is necessary use of renewable energy resources such as wind turbines, photovoltaics, biomass, fuel cell, and geothermal energy.

Photovoltaics (PV) are increasingly becoming the most appropriate source for generating electricity among all other sustainable energy sources because of its advantages such as abundance, pollution free (known as green energy), no rotating parts, more less maintenance, less noise, lower national operating costs, and high modularity. PV system has great flexibility for distributed power generation. By generating power from the solar panels near the point the load reduces lost transmission. To improve system efficiency, with track maximum power points at all times, by incorporating a point tracking algorithm maximum power (MPPT) in the Power Conditioning System (PCS). Then the PV module typically have low voltages, ranging from 30 to 60 V DC. To meet demand voltage (peak voltage 325 V for 1-phase and peak 565 V in case 3-phase) of the AC load, the need for inversion as well as increasing the voltage, meanwhile the increasing voltage depends on parameters such as module voltage, quantity modules, and their connections.

Photovoltaic power plants must meet the requirements of the grid in which they are connected, especially when it comes to power quality issues. Harmonics are a cause for concern harmonic currents increase power losses, neutral conductors and transformers overheat and may cause equipment damage. Harmonic quantities and order of harmonics depending on the inverter technology design used. H-Bridge topology with 7 levels is configuration arranged of single H-Bridge in three series to produce 7 different voltage levels. With a seven level of multilevel inverter, it is able to reduce the current THD content which is smaller than the three levels inverter. At this paper a new inverter is designed with 7 inverter levels but the number of switches is less than the H bridge topology. With a reduced number of switches, it is expected to reduce switch losses, bulky inverter and costs. For the structure of this paper, section I is an introduction, section II is the proposed topology, then section III is about the control scheme of the new topology. The results of the simulation using simulink are shown in section IV and followed by the conclusion in last section.

Proposed topology

Multilevel inverters commonly used in commercial is an H-Bridge topology to convert a DC waveform to an AC sinusoidal waveform. In the H-Bride topology, which consists of 4 switches, it produces three voltage levels, namely +V, 0, -V. In this topology the content of Total Harmonic Distortion is quite large so that it will affect the power quality of the system. A more sinusoidal waveform will lower the current THD content of the inverter. Therefore, an inverter system with a higher voltage level was built. The H-Bridge configuration is the basic cell topology. When made in series two of the H-Bridge produces five output voltage levels namely, +2V, +V, 0, -V, -2V. This configuration requires a total of 8 switches. In Figure (1) is a topological configuration with a series of 3 H-Bridge cells with 12 switches. The resulting AC output voltage is 7 levels so that it is able to produce a more sinusoidal waveform and as a result the THD content of the current decreases.

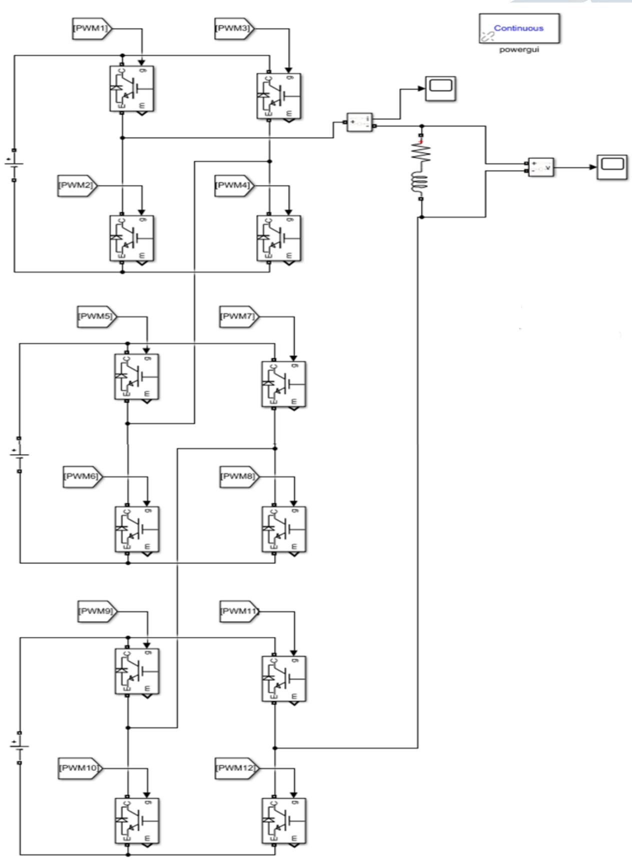

Figure 1 Topology of 3 Cell H-Bridge 7 Level Inverter

The drawbacks of the 7-level multilevel inverter in the H-Bridge topology are the large number of switches that result in higher switch losses, bulky systems, and more expensive design costs. Therefore, a new design is needed for a 7-level multilevel inverter with a small number of switches and is able to reduce the current THD content. In this paper, we propose a topology called hybrid T-H inverter in Figure (2). In this new topology, it is a combination of a single-cell H-Bridge inverter and a T-type inverter which is capable of producing 7 levels of voltage with only 10 switches. This topology is able to reduce the number of switches by two to the 3 cell H-Bridge topology.

To obtain a 7-level multilevel, three dc sources are required. The nominal voltage of each source does not have to be the same. One of the advantages of multilevel voltage is being able to support non-equal DC sources in which the voltage output will be in sync. In the three cells topology of the H-Bridge series a switch arrangement is required to produce seven different voltages. At a voltage of +3V, the switch (S) that turns on is only S1, S4, S5, S8, S9, S12. Next is a switch that turns on to produce a voltage level while the others must be off including: +2V voltage output: S2, S4, S5, S8, S9, S12. Then output +V voltage: S2, S4, S6, S8, S9, S12. 0V output voltage: S2, S4, S6, S8, S10, S12. Furthermore, it is necessary to set a switch for a negative voltage level. At -V voltage, only S2, S4, S6, S8, S10, S11 switches are on. Output voltage -2V: S2, S4, S6, S7, S10, S11. And for the output voltage of -3V, the switches that turn on S2, S3, S6, S7, S10, S11 and the others go out. The seven voltage levels +3V, +2V, +V, 0V, -V, -2V, -3V then form a sinusoidal wave on the output side and the results will be analyzed for the current THD content.

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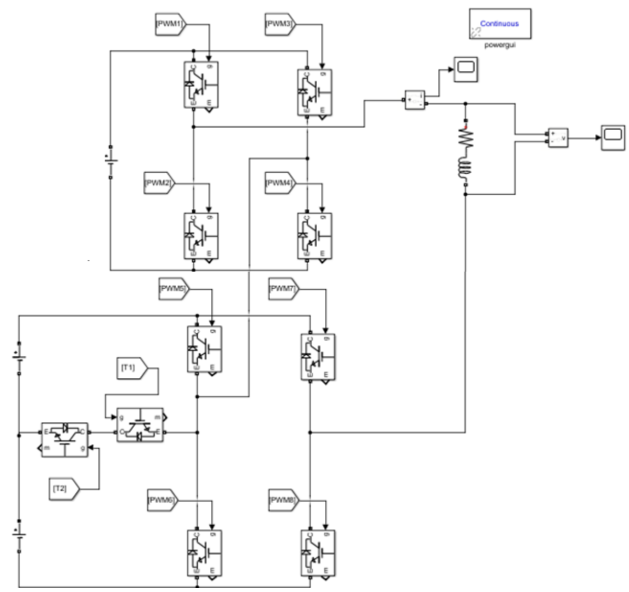

Figure 2 Proposed Topology of T-H Inverter

In this paper, a new topology is proposed which is called the T-H topology. This topology is conceptually a single cell capable of housing 3 dc sources. With one cell capable of producing a voltage output of 7 levels. Another advantage of this topology is that there are 10 switches, when compared to the 3 cell H-Bridge topology which requires 12 switches, the T-H topology has fewer switch losses and the resulting THD content is also low. This topology is expected to be able to meet the challenges of renewable energy which requires low-cost and high-efficiency inverter technology, seen from the low current THD content. The following is a configuration of switches that are on while others are off for each voltage level. To build voltage level –(V1+V2+V3): S2, S3, S7, S6 while for voltage level –(V1+V2): S3, S2, T2, S7. Voltage level -V1 is combination switch as: S2, S3, S5, S7. Meanwhile, for zero voltage: all switches are off and voltage level +(V1+V2+V3) is S1, S4, S5, S8. For voltage level +(V1+V3) is S1, S4, T1, S8 and voltage level +V1 is S1, S4, S6, S8.

CONTROL SCHEME

The topology in Figure (1) shows that the voltage level in the 3 series H-Bridge arrangement is 7 voltage levels. The switching combination setting produces different voltage levels including +3V, +2V, +V, 0, -V, -2V, -3V. Switching settings through the gate current control scheme on the power transistor. There are two signals used in controlling the gate current on the switch, namely the carrier signal and the reference signal. The simulation system in this paper uses Simulink Matlab R2018a. Setting the reference signal is a sinusoidal signal with a fundamental frequency, the simulation system used a frequency of 50 Hertz. As for the selection of a reference signal in the form of a sinusoidal wave with the aim of replicating an AC wave such as a sinusoidal wave. The carrier signal uses a triangular waveform.

The switching frequency on the selected triangular wave is 5 kHz. The 7-level system requires the number of signal carriers as much as 3 triangular waves. The control scheme uses a phase shifted sinusoidal pulse modulation with an ignition angle of 300. The phase shift switching frequencies used include 0, 1/6, and 1/3. The reference signal and carrier signal are then masked to the comparator to form pulse width modulation. In Figure (3) shows the logic gate current control scheme on a 3 cell H-Bridge topology with 7 voltage levels.

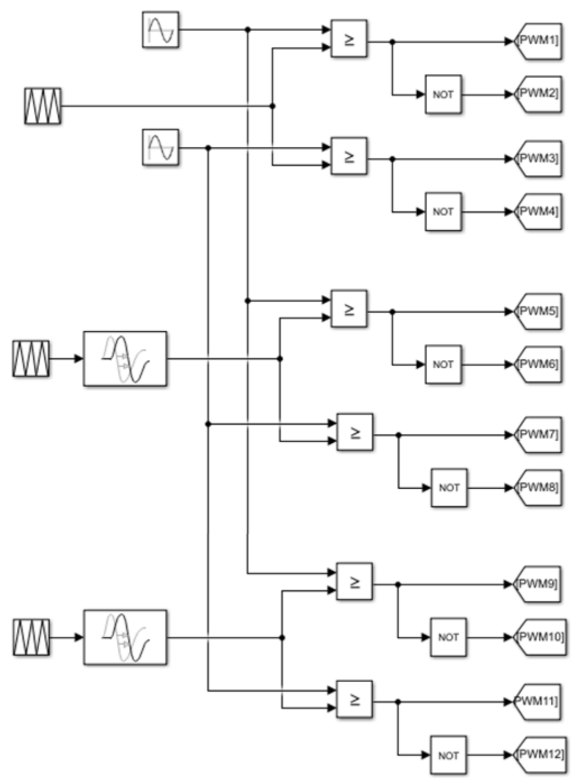

Figure 3 Control Scheme for 3 Cell H-Bridge Inverter

For gate current control on the T-H switch topology is shown in Figure (4) which uses the Phase Shifted Sinusoidal Pulse Modulation scheme. The switching frequency used is 5 kHz.

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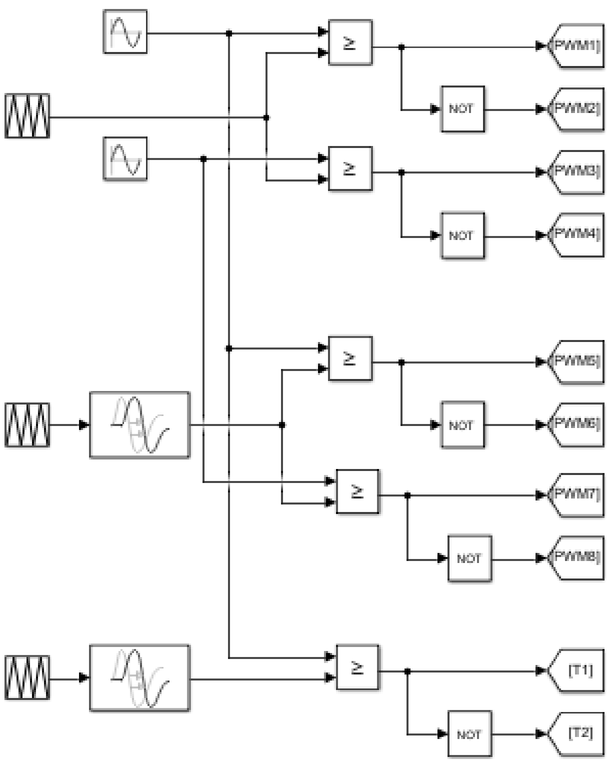

Figure 4 Control Scheme for T-H Inverter

RESULTS

The results of the simulation of the two topologies get the output voltage waveform, current waveform, voltage THD content and current THD content. It should be noted that the load used is the RL series circuit, with a value of R = 10 ohms and a value of L = 3 mH and the input voltage of the three is the same, each of which is 100 volts.

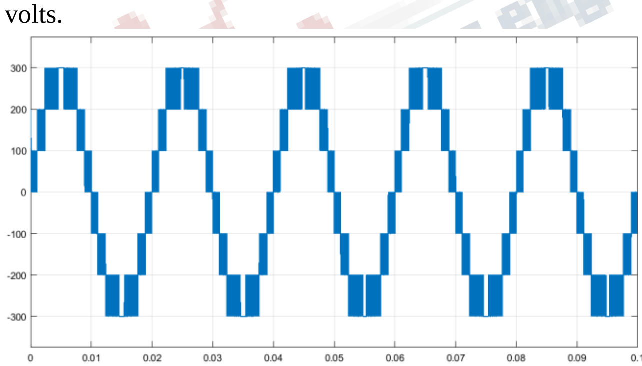

Figure 5 Voltage Waveform of 7 level H-Bridge Inverter

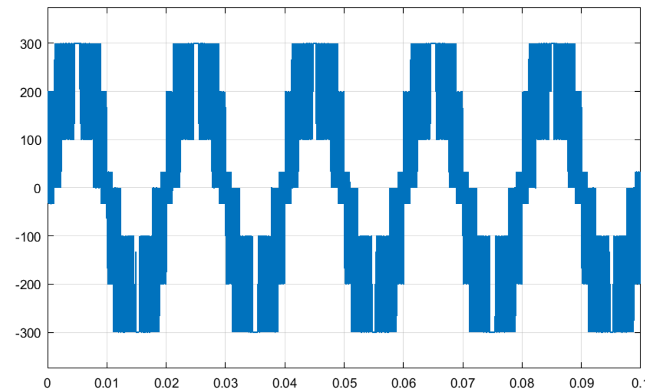

Figure 6 Voltage Waveform of T-H Inverter

The output voltage waveform is shown in Figure (5) and Figure (6). Figure (5) is a simulation result of a 3 cell H-Bridge inverter topology with 7 voltage levels. The output voltage waveform is sinusoidal and has voltage levels of +300V, +200V, +100V, 0V, -100V, -200V, -300V with a period of 20 ms or an output waveform frequency of 50 Hz. The simulation results for the T-H inverter topology are shown in Figure (6) with a sinusoidal waveform with 7 voltage levels. However, the T-H inverter output voltage is different in the multilevel waveform of the 3-cell H-Bridge. This is because the T-H topology is not symmetrical so that the gate current control scheme overlaps its pulse modulation at positive V and negative V voltage levels.

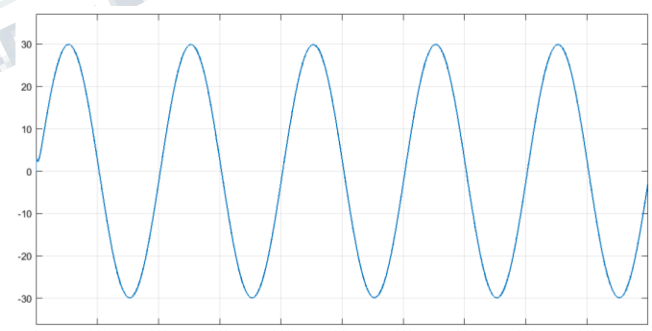

Figure 7 Current Waveform of 7 level H-Bridge Inverter

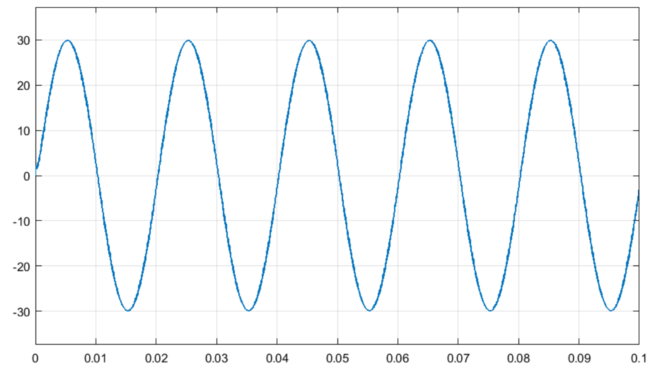

Figure 8 Current Waveform of T-H Inverter

The next simulation result is in the form of a current waveform with the RL load section. In Figure (7) the current waveform of the H-Bridge 3 cell inverter topology while Figure (8) is for the T-H inverter topology. Both of them appear on the oscilloscope simulation showing a sinusoidal wave with a period of 20 ms or a frequency of 50 Hz so that it can be concluded that both topologies are successful as inverters that convert dc voltage into ac voltage.

The purpose of designing this new topology is to reduce the number of switches and reduce the content of harmonics. The harmonic content of inverter technology plays an important role in renewable energy to increase the efficiency of distribution generators. Next is the analysis of the harmonics generated from the topological design. The harmonic contents that will be discussed in both H-Bridge and T-H inverter topologies are related to the THD voltage and THD current contents.

The analysis of THD_v and THD_i is calculated for one cycle with a frequency range of up to 2500 Hz or up to the 50th order harmonics. This is intended to obtain a wider view of the contribution of harmonics to high frequencies. For THD voltage analysis, it is shown in Figure (9) for THD_v 3 cell H-Bridge topology. The THD_v content is 18.64% while the T-H inverter topology THD_v content is 30.47% in Figure (10). The THD_v T-H inverter is greater due to the overlapping voltage waveforms as a result of an asymmetrical topology that affects the gate current control scheme on the switch.

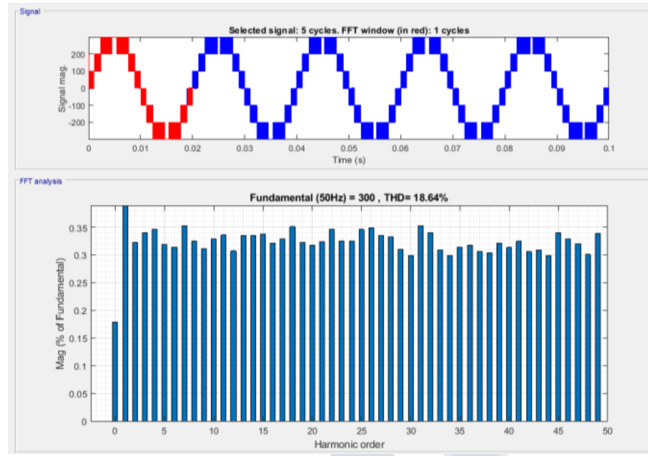

Figure 9 Voltage THD of H-Bridge Inverter

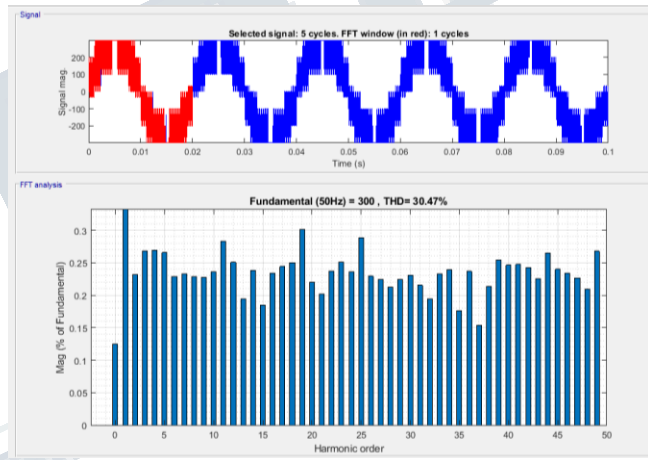

Figure 10 Voltage THD of T-H Inverter

Analysis of the current THD for the 3 cell H-Bridge topology in Figure (11) is THD_i = 2.33% and for the T-H inverter topology the THD_i content is = 2.31%. Here it shows that the current THD content of the proposed topology has a small value below the standard threshold current THD of 5%. The T-H inverter topology has the advantage of having fewer switches than the 3 cell H-Bridge topology, but both have low THD currents.

CONCLUSION

In this paper, a new inverter topology is proposed to address the challenges in renewable energy sources that require inverters with low current THD contents followed by non-bulky and low-cost. The topology of the T-H inverter is a multilevel type with seven voltage levels and as a comparison to the 3 cell H-Bridge type inverter. The simulation results show that the current THD contents for each 3 cell H-Bridge topology and T-H inverter topology are 2.33% and 2.31%.

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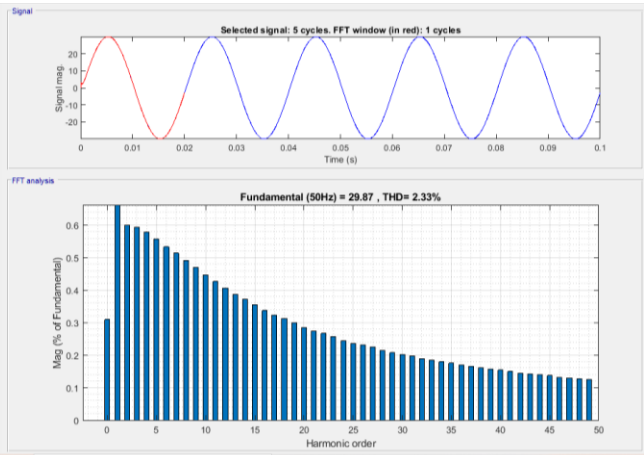

Figure 11 Current THD of H-Bridge Inverter

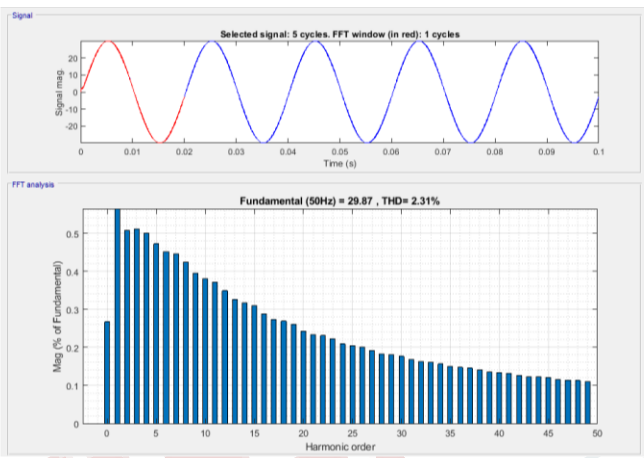

Figure 12 Current THD of T-H Inverter

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