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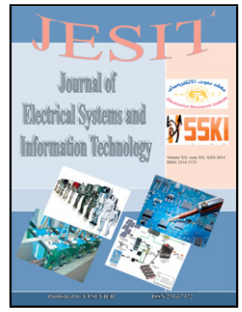

Title: Simulation and Analysis of a Grid Connected Multi-Level Converter Topologies and Their Comparison

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Simulation and Analysis of a Grid Connected Multi-Level Converter Topologies and Their Comparison

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Abstract: **This paper presents simulation and analysis of a grid connected multi-level converter topologies. In this paper, converter circuit works as an inverter by controlling the switching angle (α). This paper, presents a MATLAB/SIMULINK model of multi-level converter topologies (topology1 & topology2). Topology1, is without transformer while topology2 with transformer. Both the topologies are simulated and analysed for three level converters in order to reduce the total harmonic distortion (THD). A comparative study of topology1 and topology2 is also presented in this paper for different switching angles (α) and battery voltages. The results has been tabulated and discussed.**

Keywords-* *Total Harmonic Distortion (THD), Multi-level converter, Grid connected inverter.

1.1 INTRODUCTION

Inverters can be used to feed the dc power to ac grid. DC power can be obtained from solar panel, wind farms, fuel cells etc. Multilevel line commutated inverters for renewable energy systems have gained popularity in recent times. In this paper, thyristor is used as a commutating device because of the high value of power handling capability and reliability as compared to gate commutated devices (IGBT, MOSFET, GTO etc.). Multilevel inverters have a lower switching frequency than standard PWM inverters and thus have reduced switching losses [Adil Sarwar]. Multi-level converter technology is based on number of voltage levels on dc side. As the number of levels on dc side increases, the inverter output waveform adds more steps, producing a staircase waveform which approaches the sinusoidal wave with low total harmonic distortion (THD).

A line commutated controlled rectifier can be made to operate in inversion mode by connecting a dc voltage source at the load end and controlling the switching angle (α). It is basically a phase-controlled converter with an RLE load. Normally, the switching angle is varied up to 165^0 for inversion operation to facilitate the commutation voltage for SCR [M.S.Jamil Asghar].

In this paper, 3-level, line commutated inverter topologies (1 & 2) has been developed with reduced THD. A comparative study of topology1 and topology2 is also presented in this paper for different switching angles (α) and battery voltages. The results has been tabulated and discussed.

1.2 DEVELOPED SCHEME OF TOPOLOGY1 AND TOPOLOGY2

In this section, circuits for topology1 & topology2 are shown in figure 1 & figure 2 respectively. In topology1 dc load side has not been isolated from the grid while in topology2 dc load side, isolated from the grid via multi-winding transformer.

The circuits has been analyzed and implemented for three level of line current and can be extended to higher levels for better performance but the increase of level adds to the cost of converter. THD has been calculated for both the topologies.

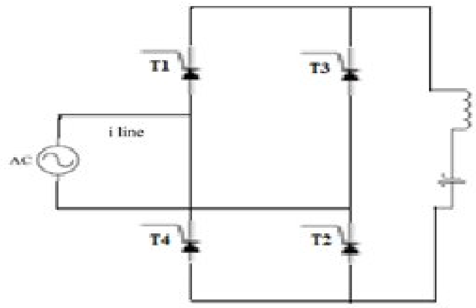

Figure 1 Circuit for topology1

For topology1, four thyristors (T_1-T_4) are required. Thyristors T_1 and T_2 are fired together while T_3 and T_4 are fired 180º after T_1 and T_2.

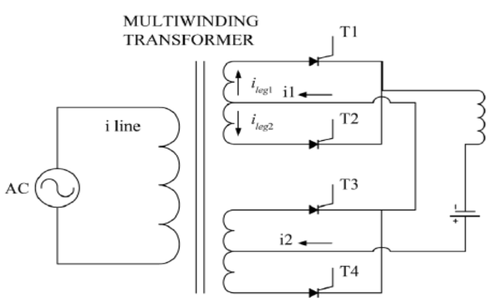

Figure 2 Circuit for topology2

For topology 2, a set of secondary winding with centre tap arrangement is required. Each pair of thyristor in a centre tap secondary is fired at a switching delay of 180°. The upper leg thyristor is fired at angle greater than 90° for inversion operation. Simultaneously lower leg thyristor is fired at a delay of 180° with respect to the upper leg thyristors. Each converter contributes to the line current and the net line current, i_{line}, is equal to the sum of all $(i_{leg1} + i_{leg2})_n$. n = 1, 2. [Adil Sarwar].

1.3 SIMULINK MODEL FOR TOPOLOGY1 AND TOPOLOGY2

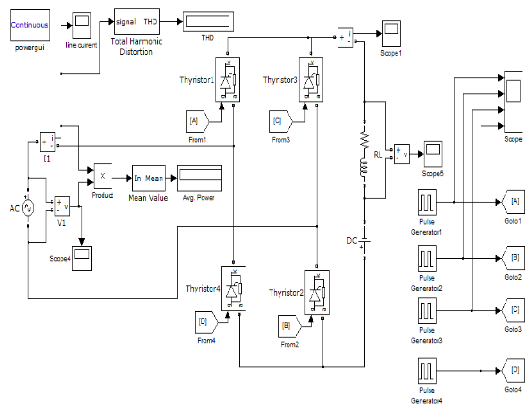

Figure 3 Simulink model for topology1

Simulink model of three level converter for topology1 is shown in figure3. Load R-L has a value of R=0.5Ω and L=20mH. Resistance is included to simulate the real inductor.

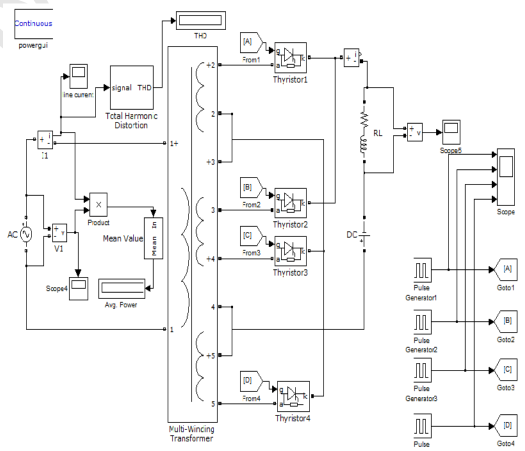

Figure 4 Simulink model for topology2

Simulink model of three level converter for topology2 is shown in figure4. The transformer ratio is 230V:: 50V:50V:50V:50V for each secondary winding. Load R-L has a value of R=0.5Ω and L=20mH. Resistance is included to simulate the real inductor. A high value of inductance ensures continuous conduction. Figure 5 and Figure 6 shows the triggering pulses, given from the pulse generator of the simulink blockset for topology1 and topology2 respectively.

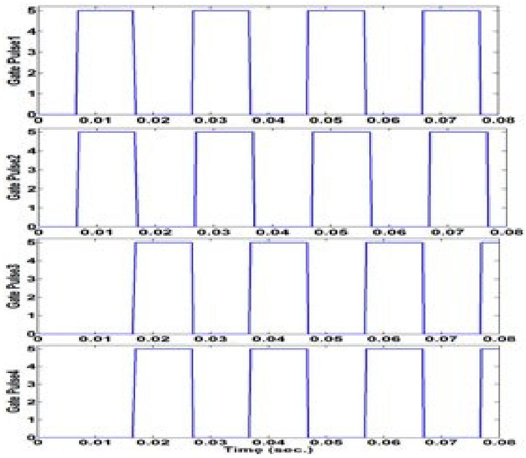

Figure 5 Triggering pulses from pulse generator for topology1

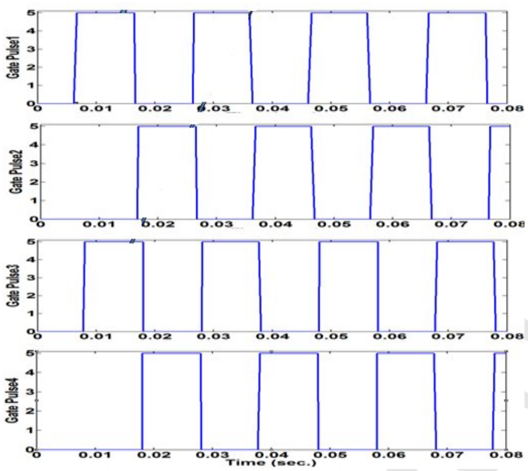

Figure 6 Triggering pulses from pulse generator for topology2

1.4 ANALYSIS AND SIMULATION RESULTS

The THD and power transfer analysis is done for different switching angle and battery voltage combinations. For topology1 THD minima has been achieved for switching angle $\alpha=110^0$ i.e. 4.44% as shown in figure10 but the fundamental component is very high. Figure 7 shows the line current with THD and harmonics for topology1 at switching angle $\alpha=130^0$. Figure 9 & figure 10 shows the variation of power and THD with different switching angles for topology1.

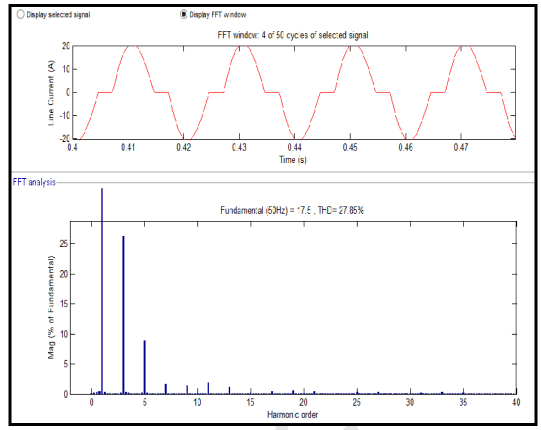

Figure 7 Line current with THD and harmonics for topology1 at switching angle $\alpha=130^0$

For topology2 THD minima has been achieved for triggering configuration such as ($\alpha_1=105^0$, $\alpha_2=145^0$), ($\alpha_1=110^0$, $\alpha_2=150^0$), ($\alpha_1=115^0$, $\alpha_2=150^0$), ($\alpha_1=120^0$, $\alpha_2=155^0$), ($\alpha_1=125^0$, $\alpha_2=155^0$), ($\alpha_1=130^0$, $\alpha_2=160^0$), ($\alpha_1=135^0$, $\alpha_2=155^0$). Global lowest being for ($\alpha_1=135^0$, $\alpha_2=155^0$) i.e. 18.98%. Figure 8 shows the line current with THD and harmonics for topology2 at switching angle combinations ($\alpha_1=115^0$, $\alpha_2=150^0$). Figure 11 & figure 12 shows the variation of power & THD with different switching angle combinations for topology2.

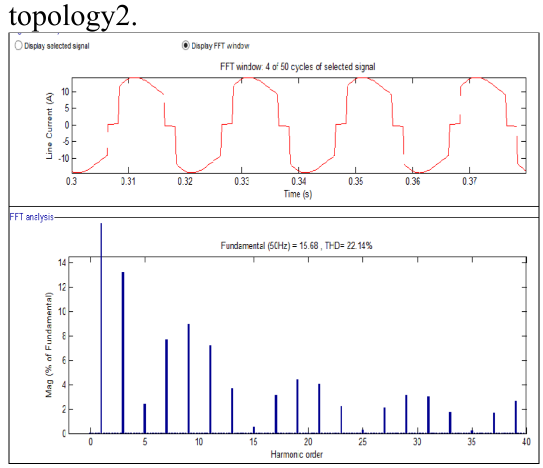

Figure 8 Line current with THD and harmonics for topology2 at switching angle $\alpha_1=115^0$, $\alpha_2=150^0$

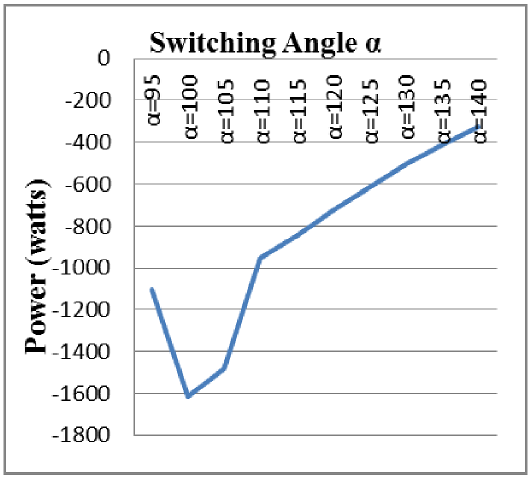

Figure 9 Variation of power with different switching angles for topology1

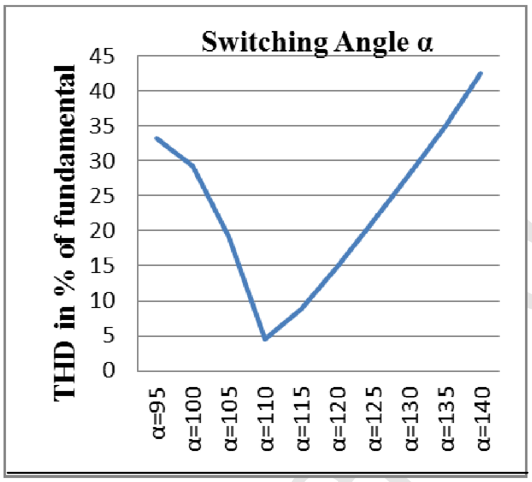

Figure 10 Variation of THD with different switching angles for topology1

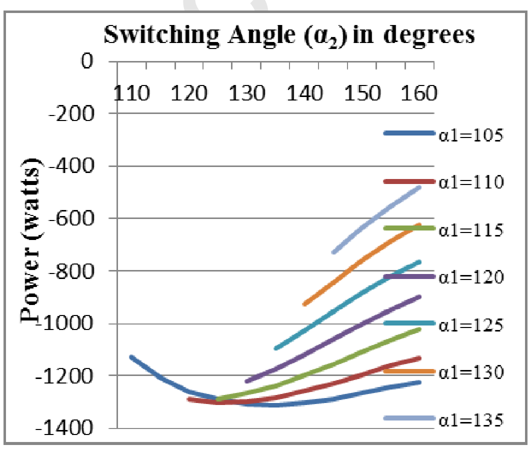

Figure 11 Variation of power with different switching angle combinations for topology2

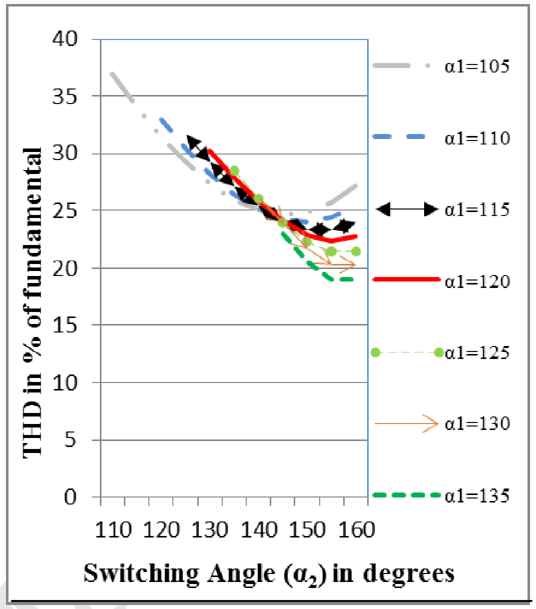

Figure 12 Variation of THD with different switching angle combinations for topology2

1.5 COMPARISON OF TOPOLOGY1 AND TOPOLOGY2

Comparison of topology1 and topology2 for power and THD at different battery voltage combinations is tabulated in Table1. From table1 it is clear that, as the battery voltage decreases, power transferred from load side to grid side decreases more for topology1 in comparison with topology2. Similarly, at different battery voltages, THD for topology2 is very much lesser as compared to topology1. Therefore, a suitable compromise has to be made between power and THD.

Figure13 and figure14, shows the variation of power and THD with different battery voltages for topology1 and topology2

Table 1 Variation of power transferred to grid and THD of line current with the following battery voltage combination for topology1 and topology2

S.No.	Battery Voltage	Topology1 at switching angle $\alpha=130^0$		Topology2 at switching angles $\alpha_1=115^0$, $\alpha_2=150^0$	
		Power (watts)	THD (%)	Power (watts)	THD (%)
1	50	-363.6	33.36	-462.1	17.35
2	52	-390	32.44	-590.9	18.71
3	54	-417.8	31.57	-721.2	20.09
4	56	-446.6	30.69	-851.3	21.29
5	58	-476.6	29.81	-979.3	22.54
6	60	-507.8	28.92	-1108	23.4
7	62	-540.2	28.03	-1237	24.11
8	64	-573.9	27.14	-1366	24.73
9	66	-608.9	26.23	-1495	25.23
10	68	-645.2	25.33	-1624	25.69
11	70	-682.9	24.41	-1752	26.08

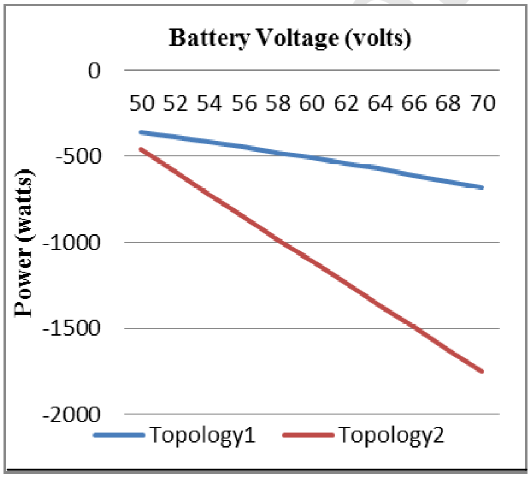

Figure 13 Variation of power with different battery voltages for topology1 and topology2

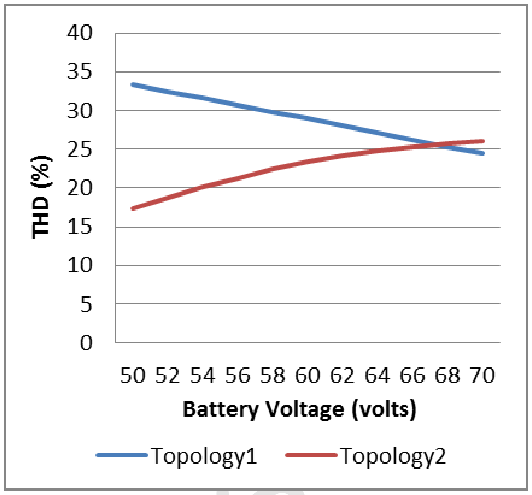

Figure 14 Variation of THD with different battery voltages for topology1 and topology2

1.6 CONCLUSION

In this paper, simulink model of three level grid connected multi-level inverter for topology1 (without transformer) and topology2 (with transformer) is successfully implemented. From the results, shown in this paper, it is clear that, the THD of line current for topology2 is much lesser as compared to topology1 (for topology1 27.85% and for topology2 22.14%). Therefore, topology2 is better than the topology1 with respect to THD and for providing isolation between load side and grid side but the use of multi-winding transformer in topology2 increases its cost.

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