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HARMONIC ANALYSIS OF POWER ELECTRONIC TRANSFORMER

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ABSTRACT

Transformer size can be reduced significantly by increasing the frequency of the transformer, which can be achieved by using several power electronic converters on both sides of the transformer. This high frequency transformer is called power electronic transformer, but high frequency increases iron loss significantly. Square wave also has high value of DC component, which has undesirable effects on transformer, large values of DC voltages can shift the operation in to regions past the knee region of the saturation curve. This would result into excessive temperature rise. This paper analyzes high frequency square wave input's adverse effects on transformer.

KEYWORDS: Power electronic transformer, DC component, Square wave, Iron loss ,Knee region.

I. INTRODUCTION

Transformers are universally used for voltage conversion worldwide, but there are some issues with conventional transformer, they are bulky, massive and expensive. Another way which can be used for voltage conversion is power electronic transformers. In power electronic transformers, frequency is increased so significantly that size is reduced by a considerable margin. There are many topologies available within power electronic transformers. One topology has three stages, namely input, output and isolation. This topology uses DC link with several power electronic converters[1]. Another topology makes use of matrix converters for AC-AC conversion and it basically avoids need of the DC link capacitors[2]. There are various combinations of these two topologies is also possible as used in [3].All of these topologies provide square wave input to transformer, square wave has high value of DC component.

II. ADVERSE EFFECTS OF HIGH FREQUENCY SQUARE WAVE ON TRANSFORMER

The DC component of a waveform has undesirable effects on transformer, due to the phenomenon of core saturation. Saturation of the core is caused by operating the core at magnetic field above the knee of the magnetization curve. Transformers are designed to operate below the knee portion of the curve. When DC voltages or currents applied to the transformer winding, large DC magnetic fields are set up in the transformer core. The sum of the AC and the DC magnetic fields can shift the transformer operation into regions past the knee of the saturation curve. Operation in the saturation region places large excitation power requirements on the power system. The transformer losses are substantially increased, causing excessive temperature rise. Iron loss of transformer is directly proportional to frequency, so high frequency would increase iron loss specially eddy current loss, which is directly proportional to the square of the frequency. Such kind of increase in eddy current loss is very harmful, to say the least.

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The selected topology for analysis

This paper analyzes topology given in [1], which contains three stages namely the input stage, the isolation stage and the output stage.

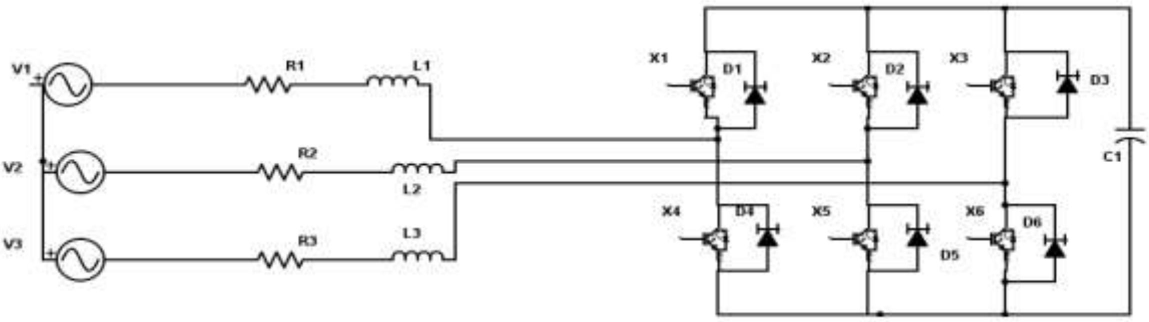
1. Input stage- There is a three phase supply, which is converted into a DC voltage by using a three phase pulse width modulation converter working as rectifier.

2. Isolation stage- The DC voltage provided by converter is converted into a high frequency square wave, coupled to the secondary with a suitable turn ratio. This square wave voltage is again converted into DC voltage by using a full wave converter.

3. Output stage- The DC voltage supplied by the isolation stage is converted into a three phase ac voltage by using a three phase inverter, which is finally supplied to the load/generation. A low pass filter is used to eliminate the high order harmonics.

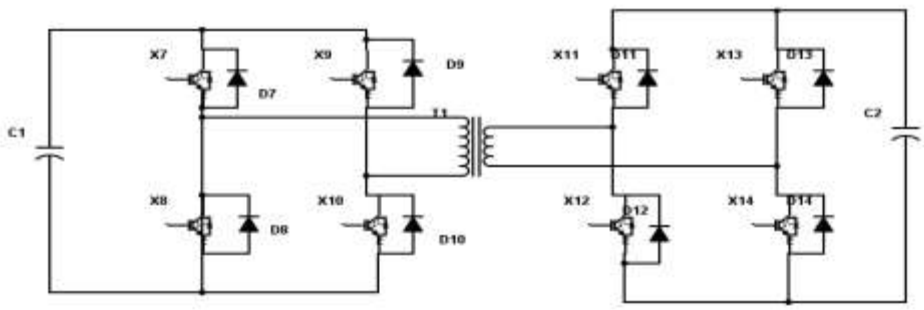
This paper deals with the input supplied to the transformer in the isolation stage because this waveform is solely responsible for iron losses in transformer, though this waveform may vary with change in configuration but it will be a square wave in all the configurations.

Figure:1



The input stage

Figure:2



Isolation stage

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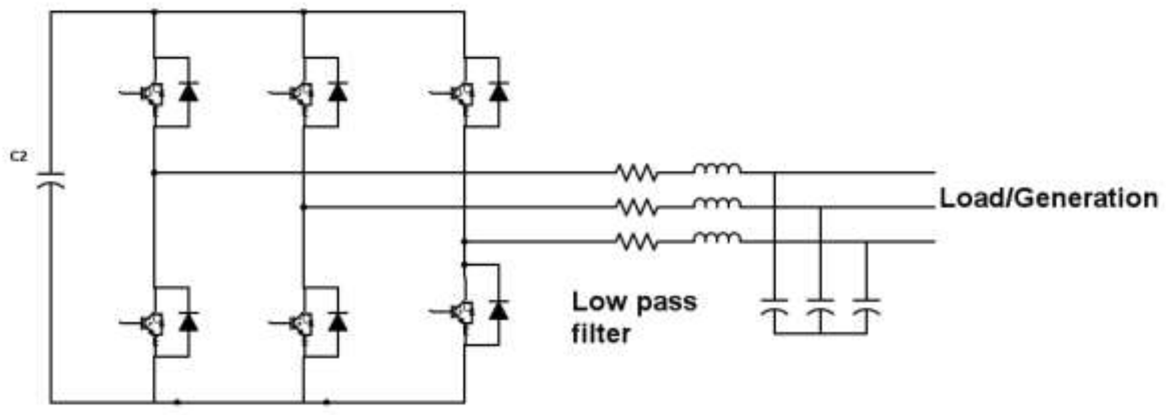
Figure:3



The Output stage

III. RESULTS AND DISCUSSION

Exact replica of the figures given in 1, 2 and 3 is used for simulation, they are interconnected MATLAB-simulink software is our tool for simulation. The supply voltage is 10KV and other parameters are given in the table. Our aim is to study harmonics of the system, total harmonic distortion of the input waveform to the transformer is 80.30%. Such high level of THD suggests it would have undesirable effects on transformer and might result into transformer operating into region past the knee region.

Table 1. Various parameters and their values

Parameters	Values
Input resistance(R_1)	0.8929 ohms
Input inductance(L_1)	16.58 mH
DC link capacitor(C_1)	100 micro farads
DC link capacitor(c_2)	100 micro Farads
Output filter resistance	0.5 ohms
Output filter inductance	1 mH
Output filter capacitance	470 micro Farads
Transformer operating frequency	1000 Hz
Supply voltage frequency	50 Hz

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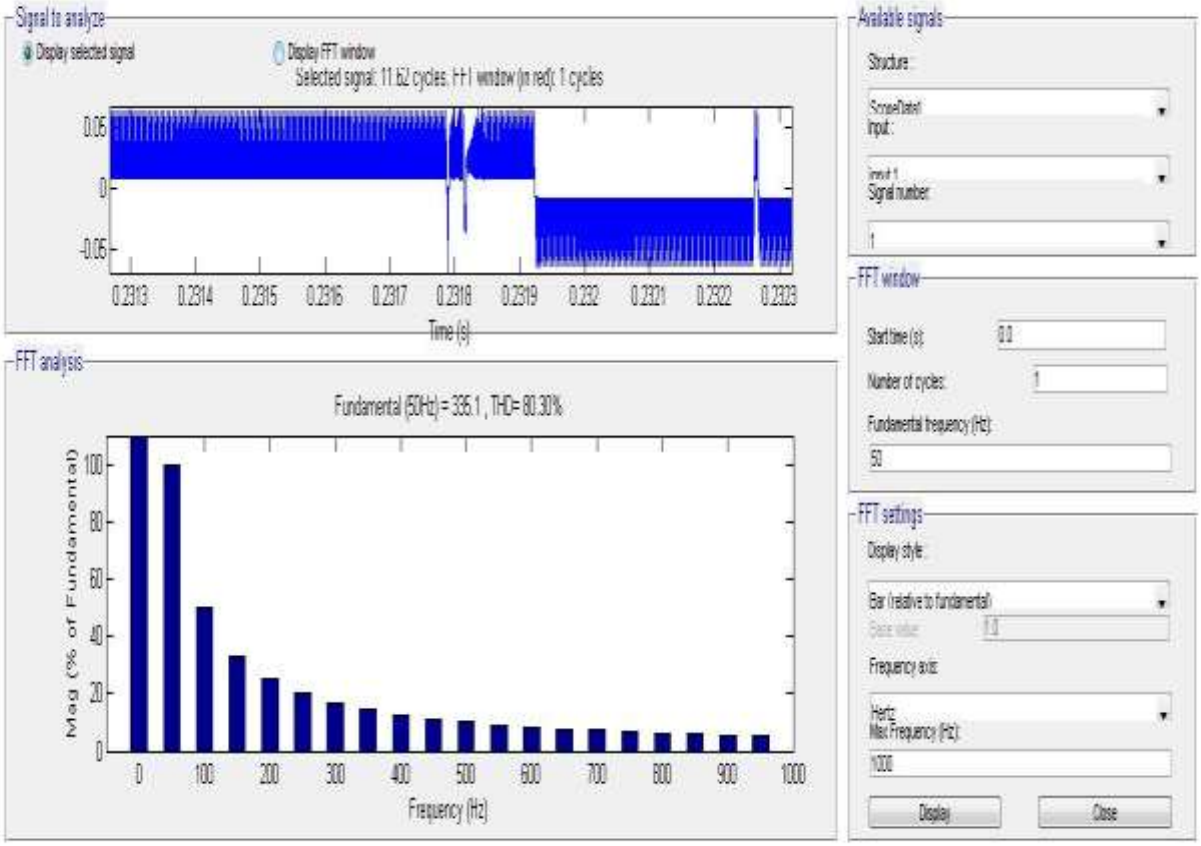
Figure:4



Simulation result of PET

IV. CONCLUSION

Power electronic transformers might have the potential to replace conventional transformers in the future but they still have problems to overcome. High eddy current loss will result into excessive temperature rise making current state of power electronic transformer close to unsafe to operate but there is a massive scope to improve.

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