CHAPTER 3

RESPONSE OF WINDINGS TO CHOPPED LIGHTNING IMPULSE

3.1 INTRODUCTION

In the previous chapter it was shown that a lumped parameter model shows a response that is adequate for frequencies arising from a 1.2/50µs lightning impulse waveform. In this chapter we extend the study to the case of the chopped LI and also the transferred surge to the secondary winding.

3.2 RESULTS ON LIGHTNING IMPULSE WAVEFORMS

Having considered the case of the secondary winding being open, experiments were continued for all connections described in section 2.5 i.e, with one end of the secondary earthed to the shield. The current response for this case is shown in Fig. 3.1. Fig. 3.2 shows the Fourier transform of the current waveform. The first six resonant frequencies are 36 kHz, 100 kHz, 210 kHz, 320 kHz, 425 kHz and 510 kHz respectively.

In the final configuration, the secondary winding is short circuited and connected to earth. Fig. 3.3 shows the response for this arrangement. The resonant frequencies as determined from Fig. 3.4 are 36 kHz, 50 kHz, 80 kHz, 122.5 kHz, 162.5 kHz, 225 kHz and 250 kHz respectively. Fig. 3.5 shows the response of the primary winding and the transferred voltage across the secondary. Fig. 3.6 shows the FFT of current waveform shown in Fig. 3.5.
Fig. 3.1 Waveforms across transformer when secondary is open and one end of secondary is grounded
1. Input lightning impulse
2. Primary winding current
Fig. 3.2 Fourier transform of current waveform of Fig. 3.1
Fig. 3.3 Waveforms of Lightning Impulse and primary winding current when secondary is shorted and grounded
Fig. 3.4 Fourier transform of current waveform of Fig.3.3
Fig. 3.5 Waveforms obtained when transformer windings are connected for transfer of surge
1. Input lightning impulse
2. Primary winding current
3. Voltage waveform across secondary
Fig. 3.6  Fourier transform of current waveform of Fig.3.5
3.3 RESPONSE OF WINDINGS TO A CHOPPED LIGHTNING IMPULSE

In the methodology adopted in this work, it is considered necessary to increase the confidence levels with models in a step by step manner in the frequency domain. The chopped LI has a higher frequency content than a 1.2/50µs LI and further by its nature creates regions in the frequency domain that are close to zero. To elaborate this further, a pulse with a 2 µs width has a frequency response in the form of the sinc function. Fig. 3.7 shows the frequency content of chopped waves having 2µs and 6 µs widths.

This characteristic of the chopped waveform has been known to create problems in the computation of the transfer function in transformers. Several studies by Hanique (Hanique 1994) have shown that the division operation between the winding current I(f) and the voltage V(f) which yields the transfer function, T(f) = I(f) / V(f) results in noise in the computation. As a result, it is not always easy to determine the poles of the transfer function.

Experimental investigations are performed on section of the winding as shown in Fig. 3.8. Experimental investigation across voltage transfer from sections of its primary winding is carried out. The procedure adopted is as follows:

Initially a chopped voltage is applied across the entire primary winding. The winding current in the primary and the voltage transferred to the secondary are monitored. In terms of additional information vis-à-vis the standard 1.2/50µs LI wave, higher frequencies exist in the input waveform and should evoke an appropriate response. This is indeed true, as seen from the
Fig. 3.7 Frequency spectrum of 6 μs and 2 μs pulses
Fig. 3.8 Arrangement showing tappings across primary of two winding transformer.
higher frequencies in the current response. Fig. 3.9 shows the time domain response of the secondary winding to a chopped impulse. Fig. 3.10 is the frequency response of the winding current.

Figures 3.11a, 3.12a and 3.13a show the response of the winding current when the chopped voltage is applied across 50%, 25% and 10% of the winding respectively. Fig. 3.11b, 3.12b and 3.13b give the respective FFT of current responses of voltage applied across 50%, 25% and 10%.

The experimental results obtained in chapter 2 and 3 serve as the basis for proposing newer methods of fault analysis during impulse tests. In particular it will be shown that the results of chapter 3 serve a useful role in establishing the location of faults. In effect, the lumped parameter model can be used to represent the winding response to both lightning impulse and chopped lightning impulse. Of these the chopped lightning impulse has indicated greater problem in identification especially when the time to chopping are not identical. In the next chapter the requirement of an impulse analysis system are reviewed and objective definition for faults are proposed.
Fig. 3.9 Waveforms of chopped impulse applied at 100% of primary winding
1. Input waveform
2. Primary winding current
3. Voltage waveform across secondary
Fig. 3.10 Fourier transform of current waveform of Fig. 3.9
Fig. 3.11a. Waveforms of chopped impulse applied at 50% of primary winding
1. Input waveform
2. Primary winding current
3. Voltage waveform across secondary
Fig. 3.11b  Fourier transform of current waveform of Fig. 3.11a
Fig. 3.12a. Waveforms of chopped impulse applied at 25% of primary winding
1. Input waveform
2. Primary winding current
3. Voltage waveform across secondary
Fig. 3.12b  Fourier transform of current waveform of Fig. 3.12a
Fig. 3.13a. Waveforms of chopped impulse applied at 10% of primary winding
1. Input waveform
2. Primary winding current
3. Voltage waveform across secondary
Fig. 3.13b  Fourier transform of current waveform of Fig. 3.13a