# Impact of Secondary Burden and X/R Ratio on CT Saturation

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***Abstract* – Proper selection of a CT (Current Transducer) is required for a good protection scheme operation. Among many other factors which can affect the current measurements accuracy this paper only investigates two of them i.e.: X/R ratio of the primary fault path and secondary burden of a CT. The importance of taking this two parameters under consideration is shown.**

## I. INTRODUCTION

Current measurements are most often conducted with the use of iron-core CTs which are relatively cheap and reliable devices. Their major disadvantage is that ferromagnetic core saturates and this affects the secondary current of a CT. The CT saturation occurs when the magnetic flux exceeds the linear region on the CT magnetizing characteristic. This effect strongly depends on a fault current and the CT secondary burden. The bigger the difference between the primary and secondary current the less information is given to a protective relay and this can lead to a relay malfunction.

One possible solution of this problem is increasing the core size which would allow measurements of a higher current. This is yet unacceptable from an economical point of view. That is why it is desired to choose a CT suitable for specified conditions such as X/R ratio and CT secondary burden. The first can be estimated since the parameters of a power line are known. The latter is the impedance not only of a relay itself but also CT wire impedance and wire connecting relay with a CT (pilots) [1].

Simulations were conducted with use of electro-magnetic transient program (EMTP). Fig. 1 presents test circuit used for simulations. The primary impedance of the CT was neglected as also was the resistance in the magnetizing branch. Nonlinearity of the core was simulated using nonlinear inductor (Type 98) and Fig. 2 shows its excitation curve. CT ratio is 1000:5.

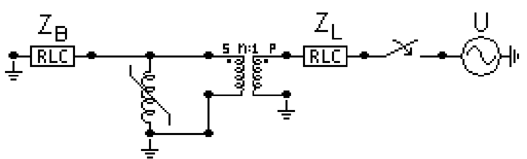


Fig. 1. Simulation model [2].

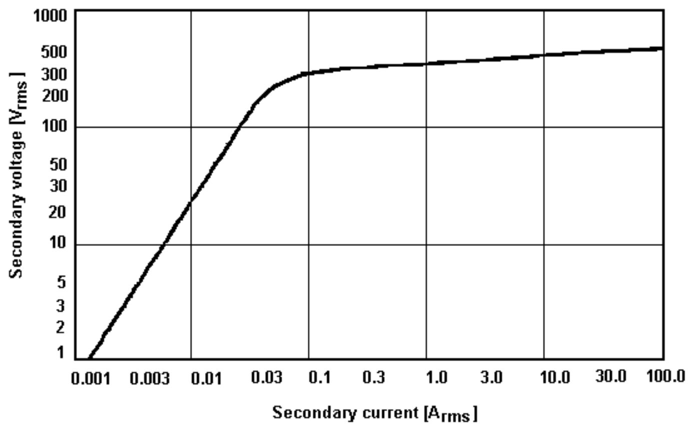


Fig. 2. Excitation curve of the inductor used in simulation.

For the sake of simplicity residual magnetization was neglected in the simulation.

## II. SIMULATIONS

### *A. Impact of secondary burden*

Relay impedance (especially if it is a modern one) is relatively small. The most important part of the burden of a relay is the impedance of pilots and it is almost only resistance. Table 1 shows values used for this simulation.

TABLE 1
VALUES OF PARAMETERS USED IN THE SIMULATION

| | |
|---|---|
| $R_B$ | 0.3 ; 3.0 ; 5.0; 10 Ω |
| $X_B$ | 0.01 Ω |
| $X_L/R_L$ | 8 |
| U | 110 $kV_{RMS}$ |
| $I_f$ | Approx. 13.6 kA |
| f | 60 Hz |

Fig. 3 presents the secondary current versus time and in this case no saturation can be observed. As the burden was increased the waveform distortions were more visible (Fig. 4). This proves that even relative small burden can influence CT accuracy if the fault current is not correctly anticipated.

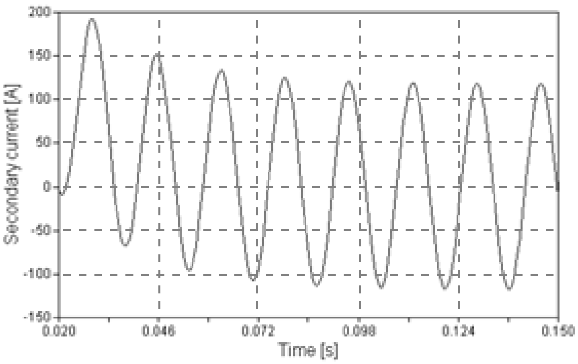


Fig. 3. Undistorted secondary current ($R_B$ = 0.3 Ω).

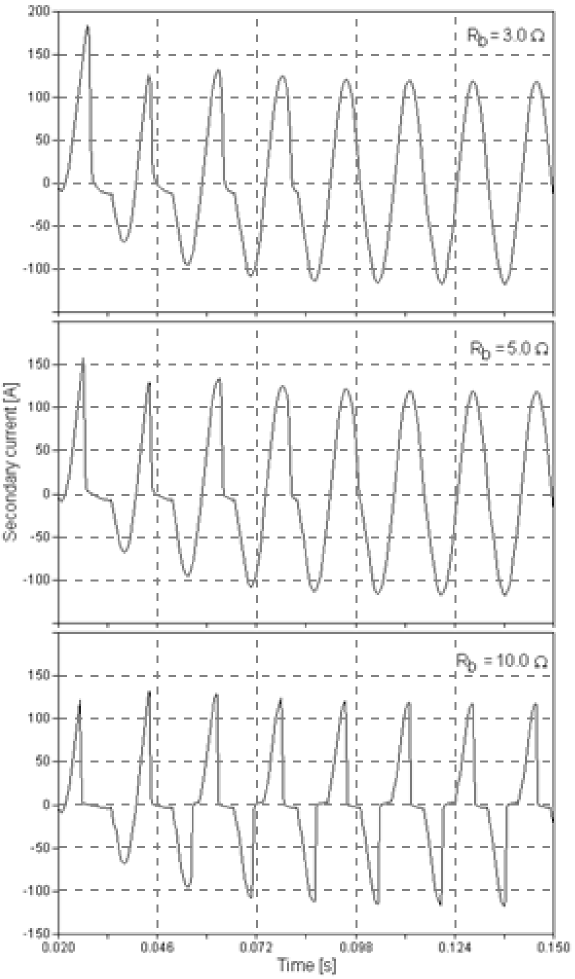


Fig. 4. Distortions in secondary current dependent on the CT burden.

*B. Impact of X/R ratio*

X/R ratio is an important parameter when considering CT saturation because it is responsible for the decaying DC component in fault current. Since this DC component produces an almost constant magnetic flux (in comparison with magnetic flux produced by a 50 Hz sine wave) it significantly contributes to CT saturation [4].

Table 2 shows values used for this simulation. Since it was desired to show only the influence of the X/R ratio the steady-state fault current value had to be the same for every simulation. This can be achieved only when both (1) and (2) are satisfied at the same time. Table 2 shows values obtained after solving this set of equations.

$$|Z_L| = \sqrt{R_L^2 + X_L^2} = const \quad (1)$$

$$\frac{X_L}{R_L} = 8\,;10\,;15\,;20 \quad (2)$$

TABLE 2

VALUES OF R AND X FOR DIFFERENT X/R RATIOS

| $X_L/R_L$ | $R_L$ [Ω] | $X_L$ [Ω] |
|---|---|---|
| 8 | 1.000 | 8.000 |
| 10 | 0.802 | 8.022 |
| 15 | 0.536 | 8.044 |
| 20 | 0.403 | 8.052 |

In the following simulations burden was held constant at $Z_B$ = 3+j0.1 Ω. Fig. 5 presents secondary current waveform for X/R=8 which is only slightly distorted. As the reactive part of the fault path impedance increased distortions were more visible (Fig. 6). In opposition to distortions caused by the CT burden, in this case not only the shape of the waveform was distorted but also was the amplitude of the fault current. When simulating X/R = 20 approximately 20 ms after the fault amplitude of the current was 90 A, where the amplitude of the steady-state fault current was 120 A. This difference increases with the increase of X/R ratio as also does the time required for the fault current to reach its steady-state value. Two types of distortions: in shape and in amplitude can make the current measured in the first few cycles to be extremely inaccurate.

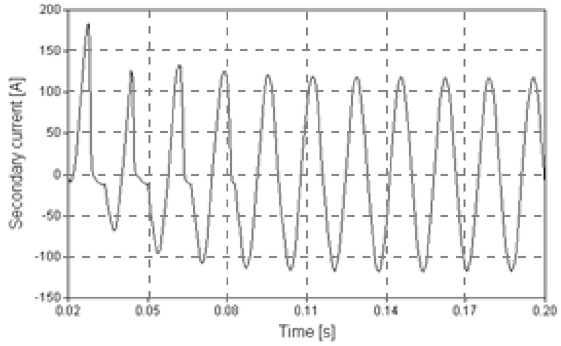


Fig.5. Secondary current for X/R = 8.

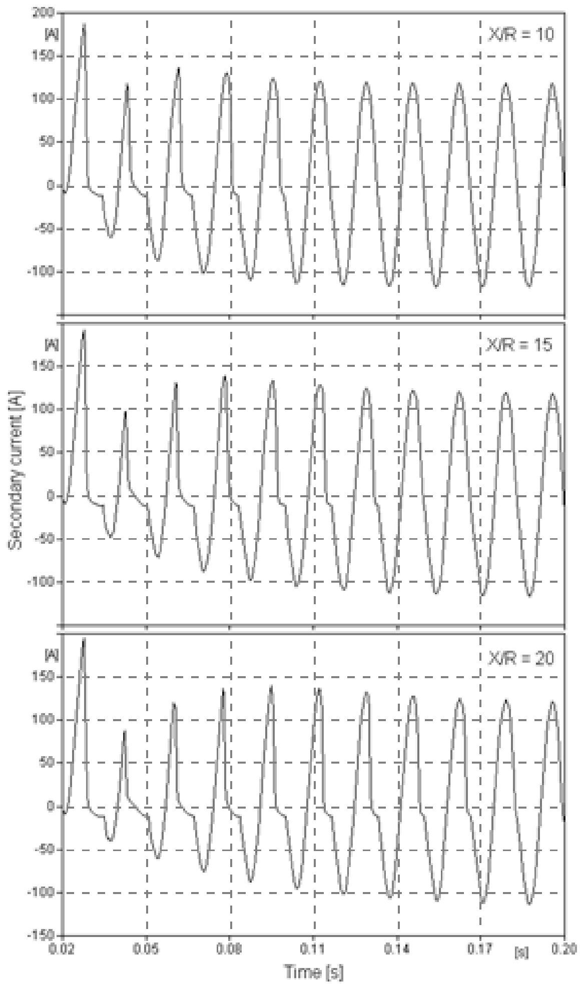


Fig. 6. Distortions in secondary current dependent on the X/R ratio.

## III. Conclusions

Conducted simulations show the importance of a proper choice of a CT. Influence of both secondary burden and X/R ratio was investigated and it proved that not taking even one of those factors into account can cause a CT to produce a highly distorted secondary current.

After changing the burden from 0.3 Ω to 3.0 Ω a small indication of core saturation was observed for at least 4 cycles after the fault. After setting burden to 10.0 Ω distortions were present during the whole simulation and they caused RMS current to be smaller than in fact it was. This is extremely important since one of the fundamental protection criteria is based on that value. Since it is often the case that the connecting wire resistance plays the most important part in CT burden it is required to place relays as close to a CT as it is possible. If from some reasons this is difficult to achieve a different CT should be chosen. In case of replacing a relay with a new one it is also advisable to investigate the influence of this change on the CT burden.

In the simulation X/R ratio had a smaller impact on secondary current distortion nevertheless this influence cannot be underestimated. For example when X/R ratio was set to 20 first few cycles were significantly distorted. With further increase of X/R this impact is even more severe. It was also observed that with the increase of X/R ratio the difference between the minimum fault current and the steady-state fault current increases. This means that for a highly reactive fault path the current measured by a CT in the first few cycles is significantly smaller than the actual fault current. This can cause the relay to trip after a longer period of time than it was originally anticipated. Since X/R ratio cannot be altered for the power protection purpose it can only be suggested that the described phenomenon should be carefully taken under consideration when choosing a CT.

## References


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