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INVESTIGATION OF POWER FACTOR BEHAVIOUR IN AC SYSTEMS BASED ON TRANSFORMERS LOADING CONDITIONS DUE TO INRUSH CURRENT IN POWER TRANSFORMERS

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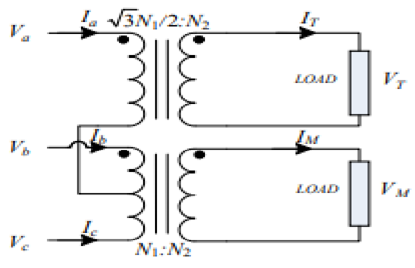
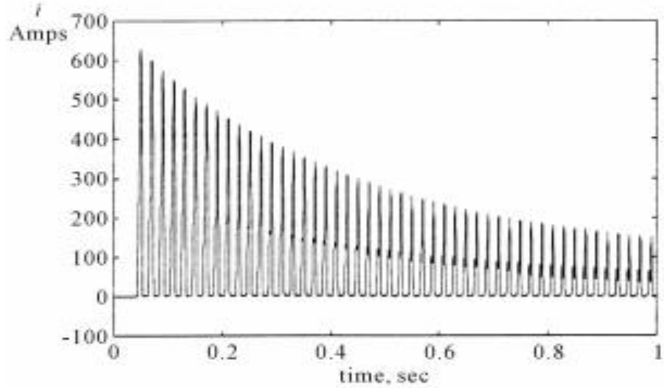
Abstract:* *Simulation study is made with MATLAB/SIMULINK program to represent the impacts of harmonic components and unbalance loading on the power factor behaviour in the Electrical AC systems The primary objective of the research is to investigate the possible extreme circumstances due to Inrush current. It is concluded that the power and distribution transformers should be progressively de-rated under such circumstances for their safe operations, which will not only prove cost-effective for utilities but also improve the reliability of the power supply to their valued customers in the challenging future smart grid environment.

I. INTRODUCTION

Power transformers are one of the most important elements in power systems. Therefore, the protection of power transformers and the prevention of tripping power transformer unnecessarily due to inrush current are crucial for the continuity of the power supply. Inrush current is drawn by the transformer when it is energized during commissioning, testing, or when it is connected to the network after maintenance. Inrush current is very high in magnitude compared to the normal magnetizing current and to the rated current of the power transformer which might reach hundred times the normal magnetizing current and few times the rated current. The impact of large power transformer failure on power systems is due to their high cost, the impact on system operation due to their location and role in the network, and the fact that they are encased in tanks of flammable and toxic fluid, which is a potential risk to people, property and the environment [1]. These factors surely present a strong motivation for utilities to monitor the health of their power transformers. In short, power transformers are likely to be the most expensive asset within electrical networks [2], and so their availability and reliability is of paramount importance. Their nominal life expectancy is expressed in years, corresponding to their nameplate rated load and ideal conditions [3]. Failure will eventually occur as the paper insulation on the windings erodes and passes the limit where the structural and electrical



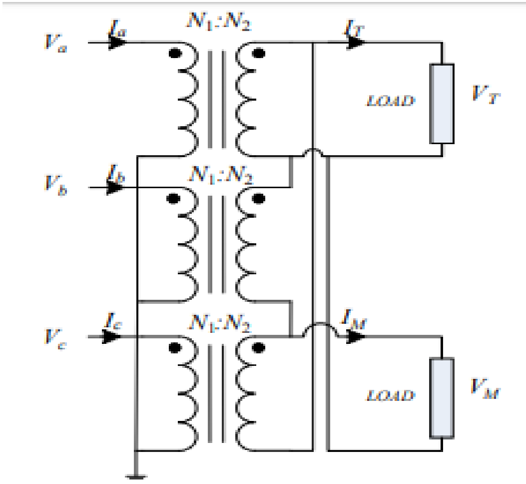
Scott connection in a transformer done



Inrush current in a transformer

Power transformer exciting current at steady state causes current to flow in protective relay but it is so small under normal load conditions that the protective relay has no tendency to operate. However, any condition that calls for an instantaneous change in flux linkages in a power transformer will cause abnormally large magnetizing currents to flow, and these will produce an operating tendency in protective relays. The largest inrush current and hence the greatest relay operating tendency occur when a power transformer has been completely de-energized and then a circuit breaker is closed, thereby applying voltage to the winding on one side (normally supply side) with the winding on the other side still disconnected (normally the load side). The inrush current might reach 50 times the normal exciting current and few times the rated current of the power transformer. The inrush current starts very large and it decays in mill seconds to its steady state value. The inrush current [4] is composed of harmonics of multiples of the fundamental frequency as shown in Table 1. The second harmonic is very significant where it represents 63% of the amplitude of the total inrush current. The fault current is composed of the fundamental frequency and it lasts until the fault is removed. The magnitude of the fault current depends on the type of the fault and location. Protective relays schemes used to prevent relays from tripping power transformers during inrush current based on the knowledge of the nature of the inrush current signal and its difference from the fault current where power transformer should be tripped.

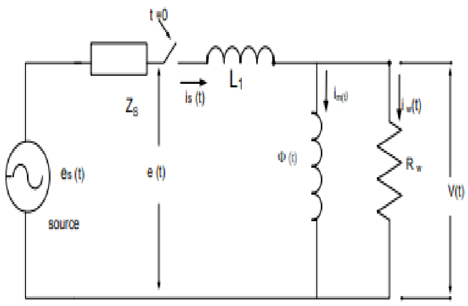
Wye-Delta Connection The Wye-Delta transformer, another specially connected transformer consisting of three two-winding transformers is used in electric railways. The current and voltage relationships obtained



Star delta Connections

Simulation work done

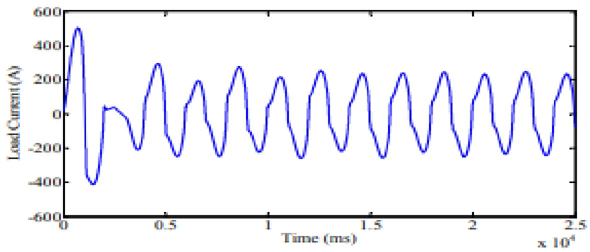
To consider the effects of the harmonics on the utility grid, a 2.5-MW thyristor rectifier locomotive (rated at 25 KV) are assumed [8]. It is modelled as two half-controlled thyristor bridge rectifiers in series as shown in Figure 7. Transformer ratio is 1:0.5:0.5. All locomotives parameters are converted to a 25 KV base. When two or more such locomotives are running together hauling a single train, they are assumed to have identical firing angles. This assumption allows two locomotives to be modeled as a single locomotive of double or manifold the real size, which is easily obtained for example by halving the inductances, and doubling the capacitance and also doubling the load current. Figure 8 shows the traction load current and its harmonics spectrum. This simulation results represent that the odd harmonic order of the traction load current compared to even one as an expected It is based on measurements of the magnetizing curve of the ferromagnetic material of the iron core of the power transformer. The analytical form of the saturation characteristic can be completely described by only three parameters. These three parameters are enough to take into account: the slope of the linear region of the saturation curve, the position of the knee, and the saturating slope. Modern power transformers have lower values of the second harmonic and also due to transient its value might become small enough to give wrong indication to the relay system. The minimum time to allow tripping is one cycle which is the time needed to estimate the system harmonics. One cycle (0.02 seconds for 50 Hz systems) is considered long time for severe short circuit and might put the power transformer in risk

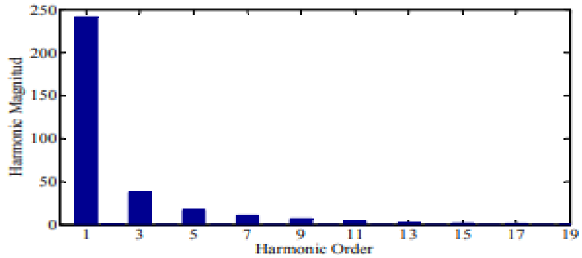


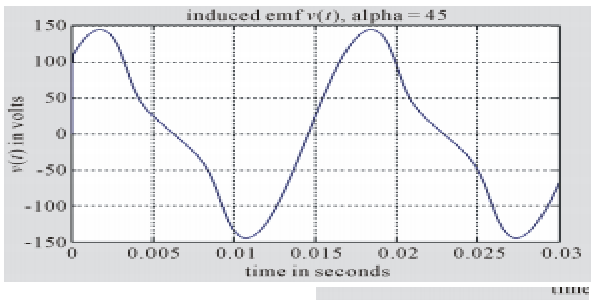
The sample model circuit considered for simulation

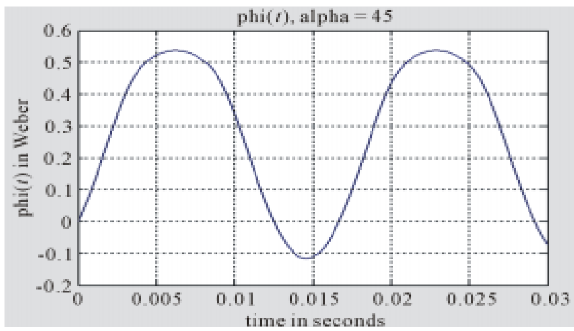
II. RESULTS

The results in Figures 7-9 are carried out for Rw = 400 Ω and time range 0 ≤ t ≤ 30 milliseconds. In Figure 7 for α = 0˚ the current is(t) is unidirectional and reaches a maximum value of 23 A which is almost 9 times the steady state value (2.5 A). The waveform shows a high harmonic content. Both the flux φ(t) and the induced voltage v(t) are distorted. In Figure 8 for α = 45˚ the three time waveforms of the current is(t), the flux φ(t) and the induced voltage v(t) shows almost the same level of harmonics content and distortion. But the current magnitude shows a lower value 15 A. In Figure 9 for α = 90˚ the time waveform of the current is(t) still reflects the harmonics content and distortion and its peak value almost equals the steady state value 2.5 A. The flux φ(t) time waveform is sinusoidal. Regarding the different functions of various transformers, this investigation is performed in four cases considering various connections. Furthermore, the power factor behavior is also taken in to account and simulated based on unbalance index from zero to 100 percent.









III. CONCLUSION & FUTURE WORK

To prevent transformers from early ageing, they should only be operated less than 3 hours per day in this worst environmental condition as stated above. This study will be useful for electric power utilities to revise the allowable loadings of their transformers to avoid damage, as well as for the safe and reliable distribution of power to their valued customers. Using the single-phase transformer culminates in the most trouble unbalance circumstances. Within the scope of three phase transformers, the V/V and Wye-Delta impose undesired imbalances on the utility grid compared to other connections. traction substation. Consequently, PFV power factor is the most efficient utility due to better stability and covering harmonic effects in comparison with other power factors as discussed in last section. It is worth nothing that, PF1 can be suitable substitutions for PFV, when its calculation is impossible or challenging.

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Bibliography

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