# Parameters Calculations of Transformer and its Performance Analysis under Transients

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## Abstract

*During this study, a high frequency model of transformer is proposed which is capable of eliminating the effects of transients applied on transformer. The conventional transformers use surge arrestors to remove these kind of effects, but they also transfers the effects of transients on secondary side which are hazardous for electrical equipment's. Our proposed model is capable of eliminating the effects of transients without any major change in secondary voltage. This method is based on two-port network (T model) theory. The results of our method are examined and evaluated by computer simulations based on MATLAB.*

**Key words:** High Frequency; Transients; Surge Arrestors; Two Port Network (T model); MATLAB

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## INTRODUCTION

Transient over voltage's induced in distribution transformers due to lightning strokes and they cause disturbances through the transformer as well as at consumer side system. In order to remove the effect of these transient voltages a design is required for protection of system (McNutt et al., 1973), so we require an accurate high-frequency transformer model which should be capable to survive under heavy lightning strokes.

An accurate model of transient surges studies was introduced. The model parameters were determined by measurements using an impedance analyzer (Okabe et al., 2001).

In (Shibuya et al., 2004), a simplified lumped parameter model for the transformer and associated distribution system has been described depending on the stroke current. In (Smith et al., 1989), a technique of an indirect measurement of linear and nonlinear elements of a wideband transformer using scattering matrix theory has been presented. However, this technique was used to directly calculate the total power loss in the transformer, and the model was not tested for transferred voltage to the secondary side. In (Biernacki et al., 2001), modeling the transformer from the frequency response has been presented where the transformer parameters were calculated by using the mathematical procedure which needs the module of the impedance with certain behavior. However, this behavior is not available for all transformers. In (Pleite et al., 2002), a simpler transformer model was introduced. So an accurate R-L-C model of transformer has been presented in which R-L-C

parameters are calculated with analytical and numerical methods (finite elements) by using MATLAB (Simulink). However, these models need sophistications to find their parameters (Shibuya et al., 2002).

Many researchers worked on finding the parameters of distribution transformer under lightning surge or transients. They studied the behavior of highs transferred to the secondary side voltage of transformer. The base of their study is to find a proper technical solution to avoid from interruption in the power supply. We study these methods which are following.

Some researchers Vaessen, Morched and Bachega design some models for study parameters of transformer on high frequency in 1988, 1993 and 2003 respectively. But they do not give authentic results because they do not study all variables for design the model of transformer which are necessary to consider the effects of load on the analysis of the stresses transferred to the secondary side of transformer (Vaessen et al., 1998; Morched et al., 1993; Bachega et al., 2003).

In 1991 Piantini presented a theoretical model to study the behavior of distribution transformer and analysis of the stresses produced in the primary network due to the lightning. He had performed tests on a large range of frequencies to know the parameters and behavior of the transformer with respect to the transferred transients. He was determined to find frequency response and input impedance. His work was based on the simulation consists of a simple RLC circuit. But his main concern was to study the behavior of induced

voltage due to lightening on distribution lines (Piantini et al., 1991).

In 1999 Piantini and some other researcher's analysis the transformer model under the on load conditions. They analyze the effect of surge that transferred on the secondary side of distribution transformer. They used the frequency and impedance analysis of transformer model. The objective of this analysis was to develop a model of distribution transformer for the study of voltage spikes when transferred to the secondary side due to direct or indirect lightning considering the effect of load (Piantini et al., 1999).

In 2009 N.A. Sabiha and M. Lehtonen did experiment of distribution transformer model under lightning strokes. They took the model of distribution transformer under lightning impulses introduced by Piantini under no load condition. They modified the model. They took more than one resonance frequency into consideration during the calculation of parameters of model. Therefore, the frequency response of the simulated transient voltage was improved as compare to previous models. They compared the experimental and simulation results. Experiments had been conducted to calculate the high frequency response of the distribution transformer under lightning surges. These calculations helped to find the parameters of the simple equivalent circuit of the transformer. As lightning induced voltages on overhead lines were practically the same in all phases, all tests were made with the HV terminals interconnected. These experiments were carried out at the Power System and High Voltage Laboratory, Helsinki University of Technology, Finland (Sabiha et al., 2009).

In 2010 N.A. Sabiha and M. Lehtonen studied the voltage transferred to the secondary terminal of the transformer due to lightning strokes hitting the primary terminals. They studied the high frequency model of the distribution transformer. The proposed model introduced was based on two port network theory where its parameters were calculated at two resonance frequencies experimentally measured. The model was suitable for unloaded and loaded conditions and it was experimentally verified under different balanced loads considering two different practical distribution transformers (Nehmdoh et al., 2010).

Transients come across in electrical system which cause the changing effects in impedance behaviour leading to changing voltage. This may cause a disturbance in distribution system and may harm electrical devices. Our research question is how to design a model which should be capable to supress the transient's effect of high resonance frequency.

We hypothesized that two port (T equivalent) model can be design to supress the transient's effect of high resonance frequency.

The main contribution of this paper is to find parameters by open circuit test and validate these by using MATLAB Simulink.

## MATERIALS AND METHODS

In two port systems there was change the parameter of transformer into RLC circuit. We find impedance and frequency response and see the behavior under surge by applying surge generator on simulation. Impulse voltage source 450V, 1.2/50 μs.
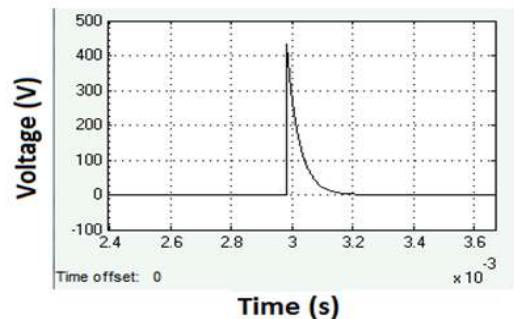


**Figure 1:** Surge generator output voltage

The proposed model is based on two-port network theory. The port-type networks are classified to impedance parameters, admittance parameters and transmission parameters networks. The simplest one is the impedance parameters network as the open-circuit tests are needed to compute the network parameters. Therefore, the impedance parameters of two-port network are considered. These impedance parameters (magnitude and angle) of T-equivalent circuit of transformer can be converted to R-L-C parameters.
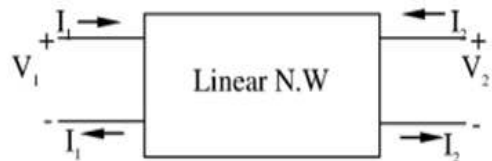


**Figure 2:** Two port network

Using the two port network model:

$$V_1 = Z_{11}I_1 + Z_{12}I_2 \quad (1)$$
$$V_2 = Z_{21}I_1 + Z_{22}I_2 \quad (2)$$

The impedance parameters ($Z_{11}$, $Z_{12}$, $Z_{21}$ and $Z_{22}$) can be evaluated by setting $I_1=0$ (input port open circuited) or $I_2=0$ (output port open circuited). So, the impedance parameters are obtained as:

$$(I_2=0)\frac{V_1}{I_1}=Z_{11} \quad (3)$$
$$(I_1=0)\frac{V_1}{I_2}=Z_{12} \quad (4)$$
$$(I_1=0)\frac{V_2}{I_2}=Z_{22} \quad (5)$$
$$(I_2=0)\frac{V_2}{I_1}=Z_{21} \quad (6)$$

Where $Z_{11}$ is the open-circuit input impedance, $Z_{12}$ is the open circuit transfer impedance from port 1 to port 2. $Z_{21}$ is the open circuit transfer impedance from port 2 to port 1, and $Z_{22}$ is the open-circuit output impedance. In order to describe the high-frequency distribution transformer model by these impedance parameters, the impulse voltage was applied on the primary side when the secondary was opened ($I_2=0$), then the impulse voltage was applied on the secondary side when the primary was opened ($I_1=0$).
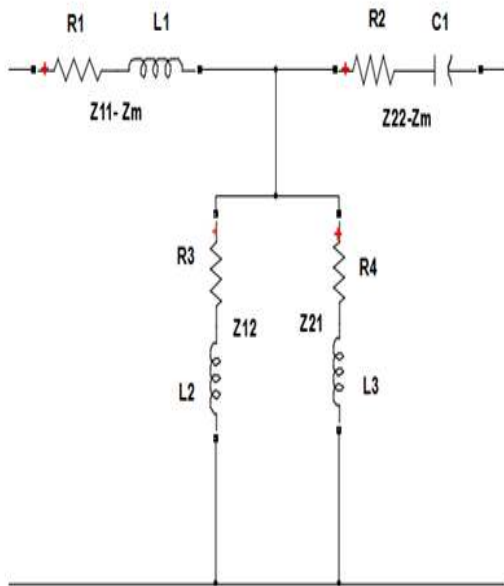
## RESULTS



**Figure 3:** Transformer transient protection model

**Table 1: Transformer transient protection model values**

| Components | Values |
|---|---|
| R1 | 1026305.496 Ω |
| R2 | 4206.78241 Ω |
| R3 | 14030.88185 Ω |
| R4 | 14317.37 Ω |
| L1 | 0.0896980 H |
| L2 | 0.00122627 H |
| L3 | 0.001251316 H |
| C1 | 0.00689e-06 F |

## DISCUSSION

Test simulations were done on 100KVA transformer DYn5 (Delta/Star neutral earthed, with phase displacement (-150º). With rated voltage 21 KV/420 V and rated current 2.75 A/137.5A.
By applying open circuit tests on rated transformer we find its T-equivalent model. This model is design with the help of input impedance ($Z_{11}$), output impedance ($Z_{22}$) and transfer impedance ($Z_m$). From this we find the values of R, L and C which are given in table 1.

## CONCLUSION

With help of table 1 transformer equivalent model is designed. After applying the transient voltage on transformer equivalent model we find out the results of transformer which suppresses the transients as shown in figure 4
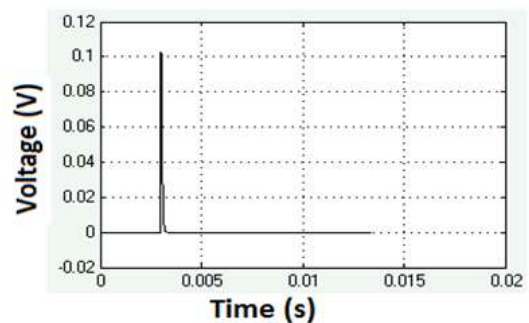


**Figure 4:** Suppressed output voltage

Validation of our proposed model have been done on one frequency. In future we suggest to enhance this model for a specified range of frequency.

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