TRANSIENTS DUE TO LOAD ENERGIZING IN LOW VOLTAGE SYSTEMS

Anna TJÄDER, Jaap DAALDER
Chalmers University of Technology, Department of Electric Power Engineering, Gothenburg, Sweden
anna.tjader@elteknik.chalmers.se

INTRODUCTION

Transients are an important but little investigated power quality phenomenon. Switching transients, lightning overvoltages and capacitor energizing are known for their adverse effect on equipment [1]. This paper investigates switching transients in low voltage systems. Large voltage and current transients can occur when common load objects with switched mode power supply such as personal computers are energized. Measurements and corresponding simulations have been performed with computers as load objects.

BACKGROUND

The measurements were performed by energizing one or two personal computers in two different networks. One network was an office network mainly loaded with desktop computers, and the other network was a laboratory network which was almost unloaded except for the testing equipment. The differences in the networks are the source capacitance and the source inductance representing the power transformer and the cables. The two networks are totally separated.

The measurements were performed with a Dranetz 658 Power Quality Monitor with an impulse sampling rate of 1.84 MHz. The energizing actions cause the transient disturbances while the de-energizing actions takes place at current zero crossing and therefore do not cause any transients. The difference in the transient characteristics for the two networks is visible mainly in the frequency. The transients have only short propagation through the networks [2], and therefore the different networks have limited influence on the transient characteristics. Parallel load objects have to be connected to the same feeder, as the load object causing the measured transient, to have any influence on the transient behaviour.

The simulations were performed with PSpice network simulation program. The power supply circuit studied was of the switched mode type, used in common personal computers. The component values were taken from the data sheet of the equipment tested. As only a short period of a few milliseconds was studied, only the power supply of the computer was represented in the simulation.

VOLTAGE TRANSIENTS FOR ONE COMPUTER

Measurements

The measurements were performed in the laboratory network with no other load present except for the desktop computer causing the transient. As the propagation of switching transients is limited to a short distance, the energy-absorbing load has to be located very close to where the energizing action is taking place if damping of the transient will occur. In this case the measurements have shown that load has to be present at the same feeder to influence the transient behaviour. Fig. 1 shows the scheme of the power network and the first part of the power supply for the computer. Some of the small capacitors with values of some nanofarads are oscillating with the inductances in the circuit at a very high frequency. Fig. 2 shows a voltage transient caused by a computer energizing action.

Fig. 1. Network and computer power supply

Fig. 2. Voltage transient due to computer switching, measurement, high resolution.
Analyzing the voltage transient in the figure results in the following values:

- Minimum value in the oscillation 110 V, maximum value 410 V
- Maximum oscillation amplitude p-p 300 V
- Main oscillation frequency approximately 110 kHz

Repeated measurements show that the transient observed is typical for the tested equipment [3].

**Simulations**

The first part of the circuit shown in Fig. 3 represents the transformer and the cables of the laboratory network. The second part represents the switched mode power supply of the computer.

The simulation result is shown in Fig. 4. Simulating the circuit gives the following results:

- Minimum value in the oscillation is 10V, maximum value 430 V
- Maximum oscillation amplitude p-p 420 V
- Oscillation frequency 80 kHz

The oscillation frequency, in a first approach, is mainly the frequency created by the network impedance, the network capacitor and the first capacitance in the switched mode power supply in Eq. (1) [4].

\[ f = \frac{1}{2\pi\sqrt{LC}} \]  

(1)

The frequency calculated from Eq. (1) for the laboratory network is 58.5 kHz and the frequency derived form the simulation, is 80 kHz. The difference between the calculated value from Eq. (1) and the estimated value from Fig. 4 indicates the influence from other components in the circuit. A simulation with a circuit shown in Fig. 5, where only the first capacitor in the switched mode power supply is present, results in a frequency of 50 kHz, which well corresponds to the frequency calculated from Eq. (1).

**CURRENT TRANSIENTS FOR ONE COMPUTER**

The measurements show that other components in the computer also affect the frequency behaviour. The simulation shows that the frequency is increasing when the whole circuit is present.

**Measurements**

The current measurements were performed with a 200 MHz oscilloscope. A current measurement is shown in Fig. 7.
The initial current transient reaches a value of 20 A, and has a duration of 0.5 ms. The measurement shows a current transient not far from the voltage zero crossing. An attempt was made to measure the maximum inrush current, with an energizing action at voltage maximum. Close to voltage maximum an initial current transient of almost 40 A was detected, see Fig. 8.

**Simulations**

The simulation circuit is shown in Fig. 5. The initial current transient reaches a value of 16 A, and has a duration of 0.8 ms, Fig. 9.

**Comparison between measurements and simulations**

The characteristics for the measurements and simulations correspond well for the amplitudes. After some oscillations the current reaches its operating level which is approximately 0.4 A for one computer. The maximum inrush current is reached when the energizing of the computer takes place at voltage maximum.

**VOLTAGE TRANSIENTS FOR TWO COMPUTERS**

**Measurements**

In the measurements one computer was energized and after a short period a second computer was energized. The transient from the second computer energizing is shown in Fig. 10.

The characteristics for the transient are depending on the load located on the same feeder. The existing load absorbs a part of the transient energy. The amplitude is smaller than
the voltage transient for the case with one computer.

Simulations

![Simulations](image)

The simulation circuit for two computers is shown in Fig. 11. The second computer is installed on the same feeder. An inductance is representing the distance between the two computers. The result from the second computer energizing is shown in Fig. 12. The difference in the results can be explained by the fact that the complete load is not present in the simulation circuit and therefore the damping is not as distinct as in the measurements. The high frequency components are not visible in the measurements.

![Fig. 12. Voltage transient for second computer energizing action, simulation.](image)

CURRENT TRANSIENTS FOR TWO COMPUTERS

The results from the current measurements and simulations for two computers are similar to the result for one computer as the second computer is energized a short period after the first one. The current transient can reach very high values if many computers are energized simultaneously. This was the situation when power returned after a blackout at an office at Chalmers. Many computers were in stand by mode when the black out occurred and when power returned the low-voltage circuit breaker tripped due to the total inrush currents of all computers.

CONCLUSIONS

The most important conclusion is that ordinary computer load may generate severe voltage and current transients when energized. For the voltage transients the measurements and simulations show a difference in frequency up to a factor of 1.4. There are no indications that the existing load in the office supply network is absorbing energy from transients. The maximum inrush current for one computer reaches a high value, and there are reasons to believe that energizing of many computers at the same time is hazardous. The simulation circuit is a switched mode power supply used in normal electronic equipment such as desktop computers and TV receivers. This means that the simulation method can be used for transient behaviour for other circuits besides computers.

DISCUSSION

The frequency range detected in the measurements is the same range as remote electricity meters is working in [REF]. This may cause disturbance problems in the future when the system with these meters will be used in many countries.

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