

VOLTAGE SPIKES MINIMALIZATION IN VOLTAGE FREQUENCY CONVERTER DRIVES SUPPLIED FROM IT MAINS

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Abstract. Voltage Frequency Converters for ac drives supplied from IT mains can produce voltage spikes on the mains. The spikes are minimalized by earthed RFI filter which is built in intermediate circuit of VFC. In high power drives the voltage spikes cause damages of VFCs. Description, conclusion, experimental and simulation results of VFC drives with earthed and non earthed intermediate circuit RFI filter are presented in this paper.

1. INTRODUCTION

EMC regulations concern TN-S mains. In IT mains methods which reduce electromagnetic distortion and provide proper electric shock safety should be applied. These methods should take into consideration lack of galvanic connection between the earthing of load and power supplying transformer [1]. IT mains are commonly used in mining where frequency converters are utilized for control of induction motor drives – fig. 1. Usually induction motor drives are replacing the old DC motor drives [2]. High power frequency converters are sources of voltage spikes in supplying mains. These spikes can lead to the destruction of frequency converter.

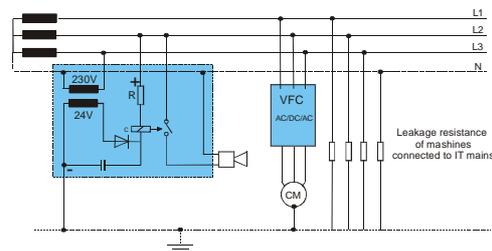


Fig.1. IT main with drive VFC and isolation monitoring circuit.

The aim of this article is to present the influence of the RFI filter located in the intermediate circuit of frequency converter on the minimalization of voltage spikes in the

supplying voltage. Simulation and experimental test were made in order to verify effectiveness of filtering of the voltage spikes in IT mains by RFI filter.

2. VOLTAGE FREQUENCY CONVERTER WITH SEPARATED FROM THE GROUND THE INTERMEDIATE CIRCUIT RFI FILTER

Installation of power supply of frequency converters in IT mains can be performed in two basic configurations, fig. 2 – the earthing of RFI filter can be either switched on or switched off.

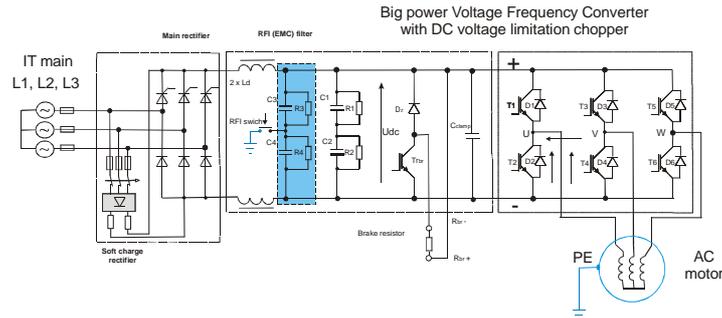


Fig.2. Supplied from IT main power section of VFC without earthed RFI filter.

Interferences which occur in IT mains in the situation when the earthing of RFI filter of frequency converter is switched off lead to the damages of frequency converters. Furthermore these interferences cause malfunction of other electrical equipment installed nearby. In fig. 3 voltage waveforms of frequency converter from IT mains power station investigated by author are presented. The voltage spikes in fig. 3B and fig. 3C are the result of capacitance leakage currents in the case when the earthing of the RFI switch is off. Measured voltage spikes on the mains of frequency converter reached 1.2 kV. Voltage spikes in the intermediate circuit reached 1.1 kV.

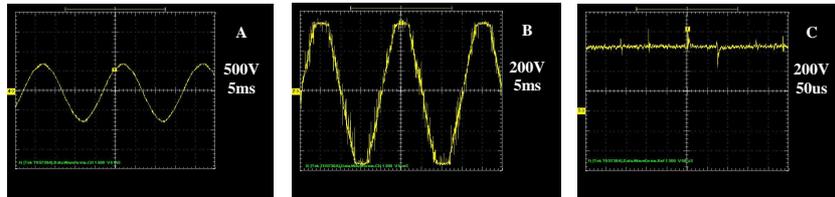


Fig.3. Measured voltage spikes on mains of VFC without earthed intermediate circuit RFI filter. The supply transformer 3x6kV/3x540V/1.6kVA, IT main. VFCs(FOC)-4x350kW/500V. Cage motors 4x315kW/500V/1000rev./min. Supply cables 5-10m, motor cables 2 in parallel (screened) length is approx. 50 - 80m. AC coils in front of each VFD – $L=0.05\text{mH}/I_n=500\text{A}/U_{\text{max}}=3\times 750\text{V}$.

- A. The main ph-ph voltage of VFC in standby mode (motor stopped) $I_m=0\text{A}$
- B. The main ph-ph voltage of VFC in the working state, motor current $I_m=180\text{A}$
- C. The DC voltage of VFC in the working state, motor current $I_m=244\text{A}$

Simulation results made by author confirm the relationship between the value of leakage capacitance and the amplitude of voltage spikes in IT mains supply – fig. 4.

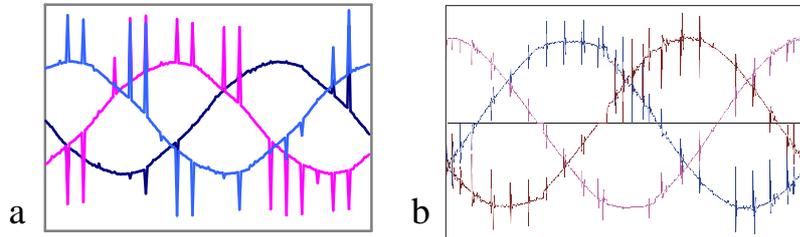


Fig.4. *a. Measured voltage spikes on IT mains on the input of VFC without earthed intermediate circuit RFI filter, $I_m=260A$.
 b. Simulation results of voltage spikes on IT mains of voltage frequency converter without earthed RFI filter. Line-line voltage $3 \times 500V$. With the assumption that the capacitance between VFC voltage output and line voltage input $10nF$.*

If voltage is supplied to the frequency converter when the RFI switch is off (RFI filter is not earthed) it doesn't mean that the voltage supply of the frequency converter is separated from the ground. Earthing of the one of the output phases of the frequency converter will cause the flow of increased capacitance leakage currents from the earthing point through the transformer to the voltage supply of the frequency converter. Such earthing is not registered by the insulation monitoring device of the IT mains. Values of these currents won't cause the reaction of internal protection of frequency converter against earthings.

Motor's cables in high power electrical drives are usually screened and earthed for improvement of electromagnetic capability (EMC). Screen of the cable is typically double side earthed. However, for the longer cables i.e. higher than 50m, one side earthing at the frequency converter should be taken into consideration. Screened motor cables characterize increased, in comparison the non-screened cables, earth leakage currents. With higher length and diameter of the screened cables, interferences causing voltage spikes in the supply voltage are increasing. Because of this reason in the frequency converters of high power there is a need of switching on the RFI filter in the intermediate circuit. Frequency of the voltage spikes of the supply voltage is the effect of the switching frequency of the IGBT transistors in the inverter part of voltage frequency converter. In drive applications the switching frequency is usually equal to 3 - 4.5 kHz.

3. VOLTAGE FREQUENCY CONVERTER WITH EARTHED INTERMEDIATE CIRCUIT RFI FILTER

Measured phase to phase voltage of mains supply and the voltage in the intermediate circuit of loaded frequency converter with switched-on RFI filter in the DC circuit are presented in the fig. 6.

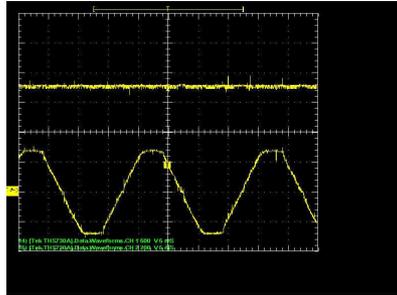


Fig.6. Measured main ph-ph voltage U_{L1-L2} and DC voltage - Loaded VFC with earthed RFI filter. Motor current $I_s=180A$.

When the RFI filter in the intermediate circuit is switched on (earthed) potential of the connection point of the cage motor stator windings (star winding configuration) has the mean value equal to the potential of the earth. Nevertheless, temporary voltage between earthing and the point of common connection windings has the shape of rectangular wave and the amplitude equal to the half of the U_{DC} voltage.

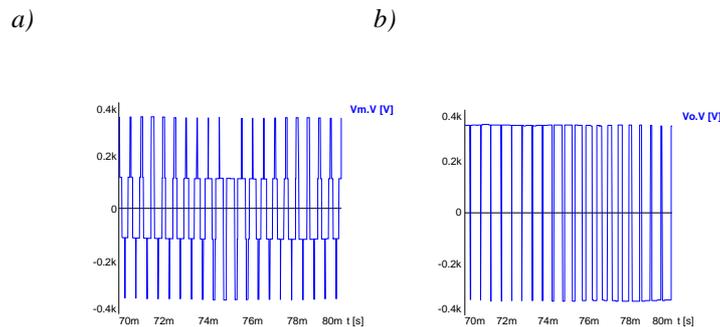


Fig.7. a) Shape of voltage between the earth and common connection of the stator coils of cage motor- $V_m[V]$ b) Shape of the output voltage of VFC- $V_o[V]$. Simulation data for both figures: basic harmonic of output voltage - 50Hz, modulation type - PWM, mains ph-ph voltage of VFD - $3 \times 500V$.

Recently, it was determined that PWM inverter drives with fast switching IGBT devices are known to cause machine bearing leakage current problem. Insulation of the bearing oils of an ac motor decreases leakage currents what in turn contributes to the improvement of the usage time of the bearing [5].

When the earthing of one of the output phases of the frequency converter occurs the short circuit current starts to flow. The RMS value of this current depends on the capacitance of the capacitor of the RFI filter in the intermediate circuit, value of the mains voltage supply and the switching frequency of inverter IGBTs. Short circuit path and the short circuit current are presented in the fig. 8.

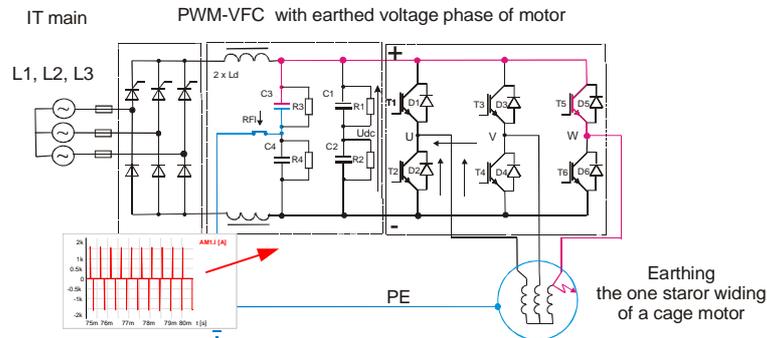


Fig.8 Short circuit path and the short circuit current – earthing of one of the stator windings of the motor.

Typical values of the capacitance of the capacitors of the RFI filter in the intermediate circuit are: $C_3 = C_4 = 0.15 \mu\text{F}$. With these values of capacitances the short circuit currents can have the RMS value up to few amps. The protection circuit of the frequency converter should detect the short current and cause the turn off of the IGBTs of the inverter. However, higher power frequency converters could not recognize this kind of earthing because of the reason that the value of the short circuit current is much smaller in comparison to the nominal current of the frequency converter [3,4].

4. CONCLUSION

In the lower power frequency converters the RFI filter can be switched off (not earthed). Leakage currents in the case of short motor cables are small and aren't causing voltage spikes in voltage supply.

Such kind of assumption can be made: In IT mains for the frequency converters with power higher than 100 kW the intermediate circuit RFI filter should be earthed (switched on). In lower power frequency converters with short motor cables the RFI filter in the intermediate circuit can be not earthed (switched off).

In spite of the fact that EMC regulations concern TN-S mains, the analysis which was carried out and experiences of the author confirm that intermediate circuit RFI filter is equally effective in TN-S mains and IT mains.

When the RFI filter is earthed one another, not discussed in this paper, danger can occur. It's possible that the earthing of phase voltage supply can occur on the input of VFC. Earthing of the RFI filter in the intermediate circuit can lead to the increase of the voltage in the DC circuit of the frequency converter above allowed values (up to $2xU_{DC}$) [1]. Raise of the voltage in the intermediate circuit can cause the destruction of the frequency converter.

In order to avoid the destruction of the frequency converter additional safety precautions should be applied. These safety precaution cause the limitation of the voltage in the intermediate circuit [1]. Because of this reason usage of VFC without earthed RFI filter in the same kind of installation need to be seriously considered.

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