ANALYSIS OF OVERCURRENTS OCCURRED DURING THE SYNCHRONOUS STARTUP OF SMPSs

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ABSTRACT

In this paper, reasons of overcurrents occurred during the parallel connection of SMPSs (Switch – Mode Power Supplies) to AC line and synchronous startup of these circuits are explained. It is shown that the amplitude and pulse width of overcurrent depend on the filter capacitor of the circuit. Moreover, reasons of short-duration overcurrents occurred in case of parallel connection of SMPS and plate transformer power supplies to AC line are also described. It is shown that overcurrent is caused by current resonances due to the filter capacitor of SMPS and inductance of the transformer primer.

1. INTRODUCTION

Currently, SMPS circuits are widely used[1-28], e.g. in computers, televisions, charge devices, etc. There are various papers in the literature for the parallel operation of SMPS in DC region [6-11,14], however there is no work about the parallel connection of SMPS to AC line.

Overcurrent is pulled from AC line when several SMPS circuits are connected to the AC line at the same time. This overcurrent causes noises to occur in the AC line. Moreover, arcs can occur because of these currents when power ON/OFF switches are closed. This phenomenon may result in the break down of switches.

In industrial electronics, plate transformer power supplies are also used as well as SMPS power supplies. When plate transformer power supply and SMPS circuits are connected to the AC line at the same time, they cause current resonances.

In this paper, reasons of overcurrents occurred in cases of parallel operation of SMPSs and plate transformer power supplies and parallel connection of these devices to AC line are analyzed.

2. OVERCURRENTS OCCURED DURING THE PARALLEL OPERATION OF SMPS CIRCUITS AND PARALLEL CONNECTION OF THESE CIRCUITS TO AC LINES

Generally, AC voltage is directly applied to a bridge rectifier and filtered by a capacitor in SMPSs. Parallel connection of SMPS circuits is shown in Fig. 1, where R_M is the measurement resistor, C_1, C_2, ..., C_n are filter capacitors.

When SW switch is closed, C_1, C_2, ..., C_n capacitors begin to be charged.

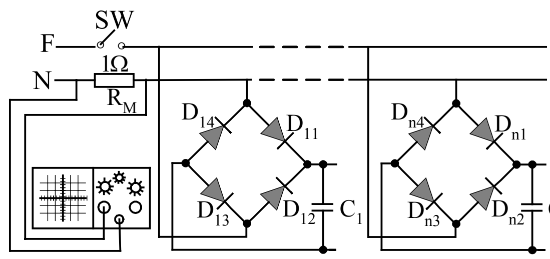

Fig. 1. Simplified diagram of SMPS circuits in parallel operation

The equivalent diagram representing the charge of capacitors is shown in Fig. 2, where D1-D3 are diodes of the bridge circuits that operate at the same time.

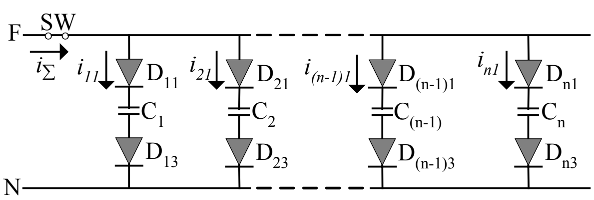

Fig. 2. Equivalent diagram representing the charge of capacitors

Assuming that electrical properties of SMPSs in Fig. 2 are similar and same types of diodes and capacitors are used in the circuit, amplitude of the total short-duration current pulled from the AC line can be expressed as

$$i_{\Sigma} = i_{11} + i_{21} + ... + i_{(n-1)1} + i_{n1} = n.i_{11}$$

where $i_{11}, i_{21}, ..., i_{n1}$ are short-duration currents that flow through branches connected in parallel.
Maximum value of each short-duration current will be

$$i_{11} = i_{21} = ... = i_{(n-1)1} = i_{n1} = \frac{U_m - (U_{D11} + U_{D13})}{X_C}$$
$$= (U_m - 2U_D) 2\pi f C_{n1}$$

where U_D is the threshold voltage of rectifying diodes, U_m is the maximum value of sinusoidal voltage, C_{n1} is the capacity of filter capacitor and f is the frequency of supply voltage.

The capacity of filter capacitors increases with the increasing power of SMPSs. Typical values of filter capacitors used in SMPSs are between 10μF and 120μF. Assuming the filter capacitor value as 100μF, RMS value of supply voltage as 220V and supply voltage frequency as 50Hz and omitting the dynamical resistors of rectifying diodes, amplitude of the total short-duration current pulled from the supply until the full charge of filter capacitors can be computed as

$$i_{\Sigma} = n \frac{U_m}{\sqrt{2}} 2\pi f C = n220.2.3,14.50.100\mu F \cong n.6,9A$$

Current value increases with the increasing numbers of SMPS circuits. Overcurrent causes a noise in the AC line and this may result in the break down of electronic circuits. To prevent electronic devices from these overcurrents, SMPS circuits must be connected to the AC line one by one.

3. PARALLEL OPERATION OF SMPSs WITH PLATE TRANSFORMER SUPPLY CIRCUITS

More dangerous cases can occur with respect to the previous one during the parallel operation of SMPSs with plate transformer supply circuits and connection of these devices to the AC line. Simplified diagram of such a connection is shown in Fig. 3, where R_M is the measurement resistor.

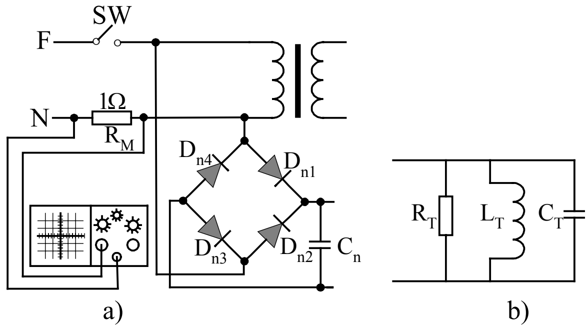

Fig. 3. a) Parallel operation of supply circuits containing SMPS and plate transformer b) equivalent diagram

Equivalent diagram of the connection is shown in Fig. 3. Threshold voltages of diodes are not considered in the development of this equivalent diagram. Inductance of the plate transformer primer (L_T) and filter capacitor of SMPS (C_n) form a circuit connected in parallel to the supply voltage. Current resonances take place when inductive resistor of L_T and capacitive resistor of C_n are equal (X_L=X_C) and therefore total impedance of the circuit (Z) equals to the active resistor of the primer (R_T).

$$Z = \sqrt{R_T^2 + (X_T - X_C)^2} = R_T$$

The value of R_T decreases and the current pulled from the AC line increases with the increasing power of plate transformers. This causes overcurrents to occur. For example, primer resistor of a 100 W transformer is about 10Ω. In this case, the amplitude of the maximum current pulled from 220V supply voltage will be 22A.

4. EXPERIMENTS

Two Escort computers containing SMPSs and a plate transformer oscilloscope are used in experiments. Signals obtained on a 1Ω measurement resistor in cases of startup of only one computer, parallel startup of two computers and parallel startup of a computer and an oscilloscope are shown in Fig. 4, respectively. As shown in Fig. 4a, a current of about 15A occurs during the startup of one computer. A current which is over 20A occurs during the parallel startup of two computers (Fig. 4b). Current fluctuations can be observed during the parallel startup of a computer and a plate trasformer oscilloscope (Fig. 4c). This is a case that resembles current resonances. The amplitude of the current is about 18A.

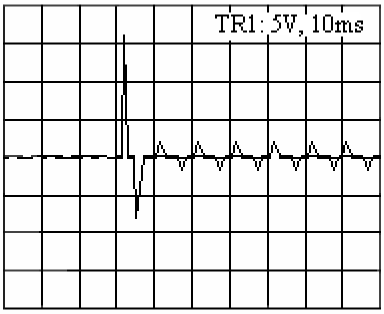

Fig. 4a. One computer

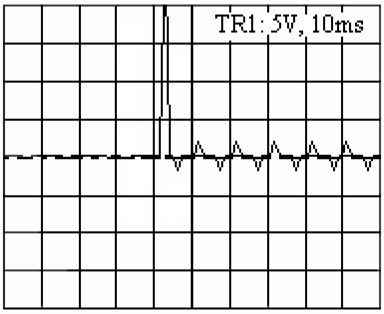

Fig. 4b. Two computers

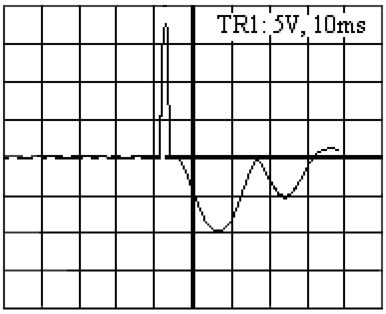

Fig. 4c. One computer and an oscilloscope

5. APPLICATION

Analyses show that the duration of overcurrents occured during the startup of SMPS devices is between 1ms and 10ms. Therefore, a minimum delay of 10 ms is required between startups of two subsequent devices for a reliable parallel operation of SMPS devices.

To achieve this process, a microprocessor based circuit has been designed. Circuit diagram is shown in Fig. 5. SMPSs, which are connected in parallel to the supply voltage, are also connected to power triacs (T_1, T_2, ..., T_n) from one end. When SW switch is closed, the microprocessor triggers power triacs T_1, T_2, ..., T_n via optocouplers OPK1, OPK2, ..., OPKn, respectively. Thus subsequent startups of parallel connected SMPS devices are achieved. Numbers of optocouplers and triacs are selected according to the numbers of SMPS devices. MOC3021 phototriac optocoupler has been used as optocoupler[29]. The gate current of the triac used in the circuit should be between 25mA and 50mA.

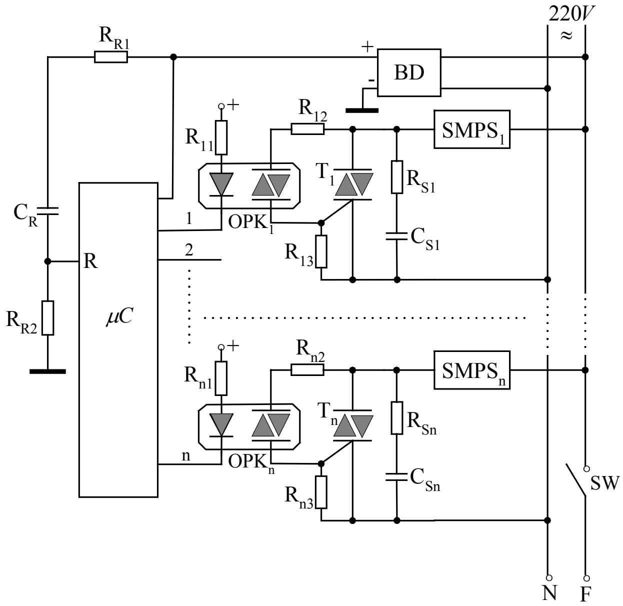

Fig. 5. The circuit designed for the subsequent startups of SMPS devices

6. CONCLUSION

Reasons of overcurrents occured during the synchronous startup of SMPSs connected in parallel to the supply voltage have been explained. Overcurrents are pulled from the AC line until the full charge of SMPS filter capacitors. Amplitudes and durations of these currents depend on the capacities of SMPS capacitors.

Current resonances occur during the parallel operation of SMPSs with plate transformer supply circuits and the current is determined by the active resistor of plate transformer.

As explained in this study, subsequent startups of SMPSs are required for a reliable parallel operation.

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