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ANALYSIS OF THE UNINTERRUPTIBLE POWER SUPPLY SYSTEM IN ELECTRIC POWER SUBSTATION

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Abstract: *Inverters, or devices for converting DC to AC voltage, are today an integral part of most 220 V DC uninterruptible power supply systems in transmission substations 110 / X kV.*

Given the extreme importance and the role of DC power supply in electric power facilities on the one hand, and an increasing number of requests for incorporation of inverter modules on the other, it is necessary to examine the impact and to determine the effects and consequences which installed inverters have on proper functioning of uninterruptible DC power supply system. This paper deals with analysis of actual measurements and tests carried out on the field and proposes solutions for encountered problems.

Keywords*: Inverter, power UPS, selectivity, circuit breaker, substation*

1. INTRODUCTION

Nowadays the electrical power substations have an increasing number of telecommunication facilities and equipment for monitoring and control which are using AC voltage as its auxiliary power supply. In order to operate properly these devices also need an uninterruptible and safe power supply (BC hydro, 2005). However, the realization of this condition is possible only by installing an inverter.

Given the fact that the DC distribution should and must be one of the most reliable part of every electric power facility, it is necessary to carefully analyze whether and what kind of effect has the connection of each new consumer, including inverters i.e., devices designed to convert DC voltage into AC voltage.

This paper will analyze the impact of the inverters which are connected to the 220 V DC power supply system, as one among other consumers in the substations which are powered by the DC voltage. These are usually single-phase small power inverters of up to 3 kVA which convert 220 V DC voltage to 220 or 230 V AC voltage, 50 Hz (Skok, 2002).

2. SELECTIVITY TESTING OF THE 220 V DC DISTRIBUTION

Selectivity between circuit breakers in the DC distribution is one of the basic criteria of reliability of the DC power supply system.

Selectivity testing of the protective circuit breakers is achieved by deliberately provoking a short-circuit in the DC distribution.

In order to check selective interruption between two circuit breakers, where one is at higher and other at lower level in the DC distribution structure, a short-circuit must be made behind the lower level circuit breaker.

Therefore, higher level circuit breaker is also a circuit breaker with a higher rated current and lower level circuit breaker is a circuit breaker with a lower rated current. With the occurrence of a short-circuit, current passes through both circuit breakers and they have the same current load. When the different level circuit breakers are equally loaded, lower rated circuit breaker should interrupt short-circuit current before the higher rated circuit breaker.

This interruption can be considered as ***selective***. All the other cases of interruption can be described and considered as ***nonselective***.

2.1 Selectivity testing of the 220 V DC distribution in the SS 400/220/110/35/10 kV MELINA

Figure 1. demonstrates one part of the configuration of the 220 V DC distribution system in the SS Melina (Dobrec et al.,2007). Only circuits that are most important for a better understanding of the conducted test are shown. It is important to emphasize that in this case there are three inverters of different power and different manufacturers which are connected in identical manner to the 220 V DC distribution system. Tests conducted on different types of inverters will lead us to better problem analysis and conclusions.

A short-circuit was initiated with a special testing device just behind the II. level circuit breaker -Q118 (type NS100N/TM 40D, 2P, Ir = 40 A, Merlin Gerin). Inverter modules are connected to the system over the III. level circuit breakers -Q115, -Q116 and -Q145 (type C32H-DC 2P, Ir = 6 A, Merlin Gerin).

By initiating a short-circuit in the above-mentioned point of the DC distribution, the circuit breaker -Q118 made correct interruption and immediately discontinued current flow. At the same time, all the circuit breakers that are supplying inverters also made an interruption. Those interruptions were unwanted and incorrect. In that moment all inverters were cut off from the DC power supply. This phenomenon encouraged the authors to investigate and find the cause of these nonselective interruptions, and to give an answer to the question whether such behavior endanger safe and reliable operation of the 220 V DC power supply.

The value and waveform of the input current of the Inverter 3 at the moment of short-circuit was measured.

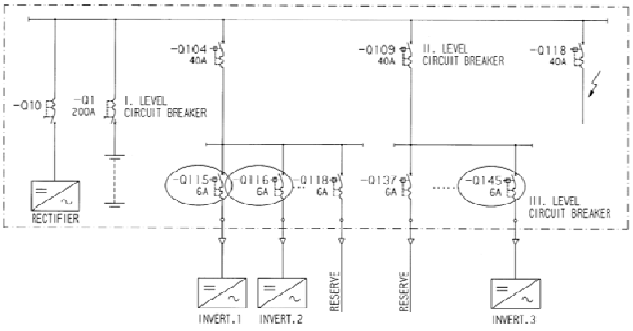

Fig. 1.Part of the configuration of the 220 V DC distribution system in the SS Melina

At the moment of the short-circuit current in the amount of 144.9 A flowed, from the Inverter 3 to the DC power supply

system, i.e. the point of short-circuit. That caused activation and interruption of the circuit breaker.

3. COMMENTS AND ANALYSIS OF PROJECT RESULTS

Performed analysis demonstrated nonselective interruption of III. level circuit breakers of 220 V DC power supply system, which supply DC input circuits of inverters. Namely, the circuit breakers properly detected a fault and made an interruption, what was caused by the fact that at the moment of short-circuit, current that flew through them, was greater than 8-10 I_r (rated current). It has been shown and proved that inverters along with station battery and rectifiers make the total short-circuit current. Multiple repetition of the test has also shown that the occurrence of faults on the DC input circuit of inverter, in any case does not affect on its AC output circuit.

The main cause of this behavior of inverters and described interruptions of circuit breakers is the inverters input filter. As demonstrated, at a simplified schematic overview of inverter (Figure 2.), it consists of an input filter (C1) and circuit for its slowly charging (D1, R1, K1). The input filter is needed for proper functioning of the inverter bridge (V1-V4) and for filtering current towards the DC power supply (EL-UR, 2009). While operating the inverter bridge creates a number of transcendent harmonics that could create interferences in the work of other devices supplied from the same source. Because of the large capacity of capacitor used in the input filter, it is necessary to install the circuit for its slowly charging, which prevents inrush current shocks at the time of connecting devices to the DC power supply.

At the moment of connecting the inverter to the DC power supply, capacitor in the input circuit, charges through diode D1 and resistor R1. Once the capacitor is charged, contact of contactor K1 closes, which makes a capacitor directly connected to inverters input terminals.

The occurrence of short-circuit at some point of the DC distribution system, leads to capacitor discharging, and it becomes just another source in the circuit which supplies the place of a short-circuit (fault). The value of discharging current depends, of course, on its capacity and the distance between the inverter and the point of short-circuit. Besides causing nonselective interruptions of circuit breakers, discharging current is also a cause of another, perhaps even larger problem. At the moment of the short-circuit, current no longer flows out of the DC power supply to the inverter, but vice versa, from the inverter to the DC power supply. During the installation of DC circuit breakers it is extremely important to pay attention to the connection polarity, which is strictly defined by the manufacturer (ABB, 2007).

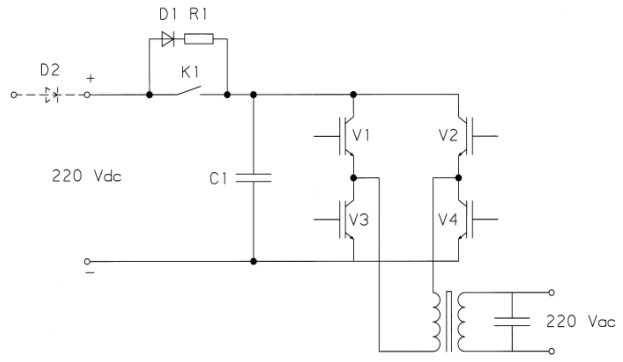

Fig. 2. Simplified schematic overview of the inverter

Interruption of reverse current due to its construction is a huge problem for DC circuit breaker.Namely, interrupting the short-circuit currents under these conditions lead very quickly to destruction of the circuit breaker, which then loses its protective characteristics, and in worse-case scenario could even lead to its explosion.

For all these reasons, it is very important to find a way to prevent the discharge of capacitor in the input circuit of the inverter and flow of discharge current from the inverter to the DC power supply system. A simple solution to this problem is installation of the diode (D2) into the input DC circuit, which would prevent the return of discharge current to the DC power supply system. In normal operation, the diode will not affect the proper functioning of inverter.

4. CONCLUSION

Actual measurements and tests showed that the inverter, along with station battery and rectifiers, is just another source that affects the total amount of short-circuit current, which flows into the system at the moment when a fault occurs. Inverter contributes to total short-circuit current of the system with a current that is a consequence of discharging of the capacitor in its input circuit. This discharge current is causing nonselective interruption of protective DC circuit breakers in the inverters DC input circuit. In addition, the interruption of current, which changed direction, represents a huge problem for the analyzed circuit breaker that can ultimately cause great damage. Installation of a diode is a possible solution to this problem. Installed diode prevents capacitor discharge and flow of discharge current from the inverter to the DC power supply system. Consequently, it fully ensures safe and reliable operation of the DC power supply and of all its components in both normal mode and the moment of failure, i.e. short-circuit in the system.

However, observations during this study, led the authors to consider and analyze the optimal how-to mode for provideing 220 V AC uninterruptible power supply for all important consumers in transmission substations. Is it better to use inverters in the manner described in this paper, where they are part of existing DC power supply system, or use standalone, distributed low power UPS's, or maybe use central high-power UPS? These are questions that the authors seek to answer in their future research.

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