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Promoting the surge immunity techniques of an uninterruptible hydro plant power system under the surge environment of high exposure

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ABSTRACT

Uninterruptible power systems in hydro plants under the surge environment of high exposure are susceptible to surge impact. In order to solve the problems of equipment malfunctions or failures caused by the surge, this paper applies the principle of surge energy transfer to design a low-voltage surge protection circuit, which prevents the surge from interfering with or damaging UPS devices. According to the IEEE and IEC standards test requirements, after the actual loads are connected to the load side of this circuit, surge generators are used to test the surge immunity of the surge protection circuit and actual load; test results confirm that the surge protection circuit proposed in this paper is effective for the protection of surge interference at low-voltage.

Introduction

The Feitsui plant in Taiwan is a hydro plant with very frequent start-stop operation. Its power system, shown in Fig. 1, contains a hydroelectric unit (77.7 MVA), two Taipower 69 kV loops, a diesel generator (500 kVA), the load groups of an auxiliary system and other related equipments (e.g. transformers, buses, switches and circuit breakers).

All auxiliary system loads in the plant support the generator operation, and must match the start–stop operating procedures of the plant; these loads are frequently operated and are vulnerable to the great damage caused by switching surges. There are two sets of lifting oil pumps in the auxiliary system; they mainly provide a layer of oil film on the top of the thrust bearings used to lift the generator rotor. The first set of lifting oil pumps immediately begins running when the start operating procedures are established. After the hydroelectric unit is connected in parallel with Taipower's system, the first set of lifting oil pumps is stopped, while the second set of lifting oil pumps starts and does not stop running until the stop operating procedures have been completed.

A vertical hydroelectric unit adopted by the Feitsui plant makes use of high-speed flow pushing a hydraulic turbine; it then drives a synchronous generator to produce electricity. The interface between the thrust bearing on the top of the hydraulic turbine and the upper generator rotor must be lubricated by a layer of oil film formed by the lifting oil pump. This pressurized oil film produces upward support force against the unit wear at high-speed operation. If an instantaneous power interruption in the plant will cause the lifting oil pump to fail, the situation will damage the thrust bearing and generator rotor; such a significant accident has occurred in the past. Even if the plant is equipped with a 500 kVA diesel generator, it cannot instantaneously supply power to these lifting oil pumps, so it is necessary to add uninterruptible power systems in the power source terminal of loads; the installed capacities of UPS are 2×50 kVA in total, and UPS devices adopt a parallel operation mode. Under the situation of a sudden power outage, this oil film will still lift the generator rotor at high-speed operation to maintain the generator's safety.

The Feitsui plant in Taiwan is located in a mountainous area containing a higher lightning density. Statistics on local lightning density report the number of cloud-to-ground flashes per square kilometer per year as above 9.36 [1]. Under such a high lightning density, some important facilities within this plant have frequently been damaged by lightning strikes over the years. In 2011, a lightning accident damaged the charging board of UPS; since the UPS device might supply power to the lifting oil pumps and the other important devices, this accident would affect the safety of the plant's operation. The sources of surge interference which UPS suffer from mainly include lightning flashover surge (LFS), switching surge and electromagnetic pulse (EMP). These interference sources

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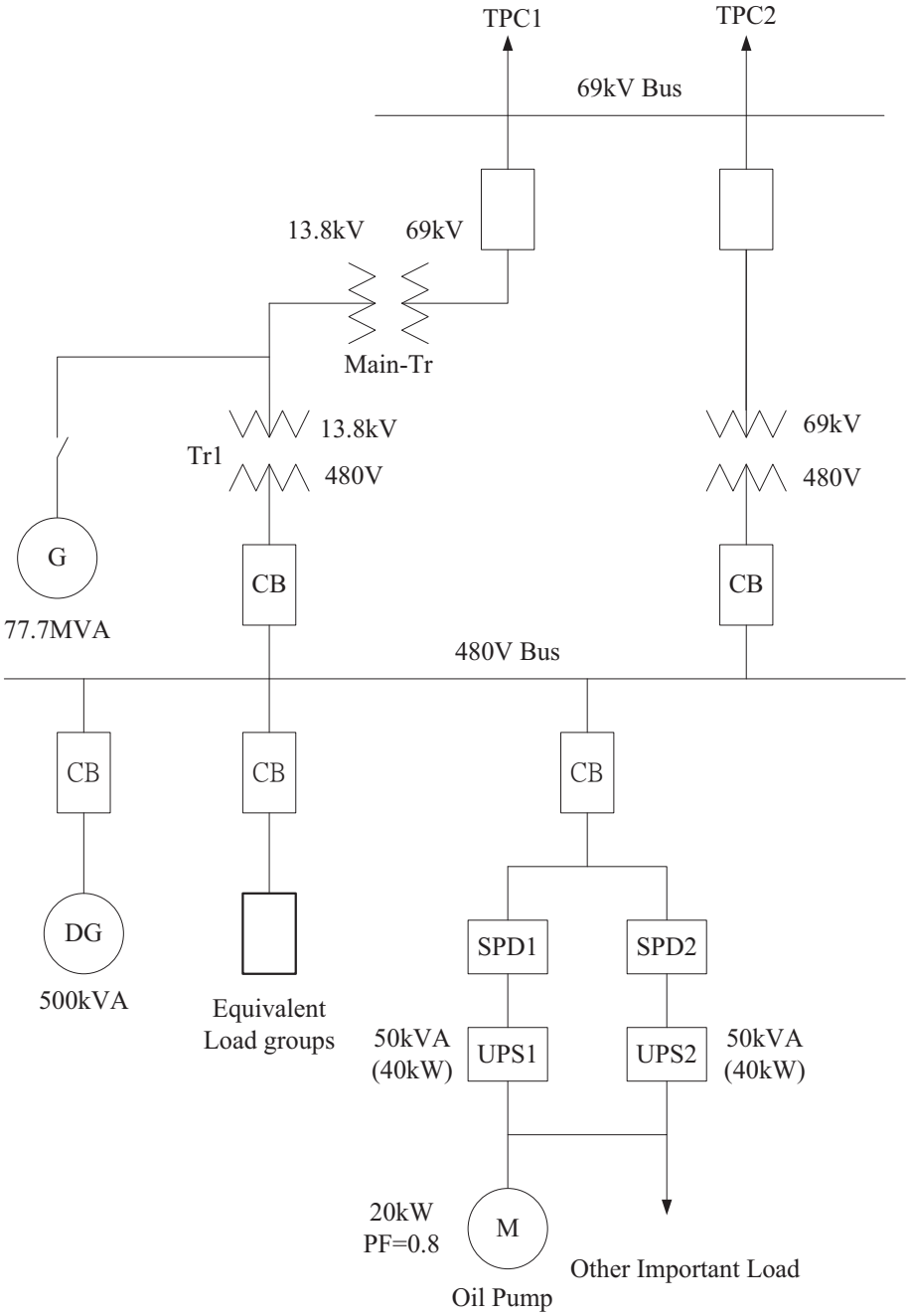

Fig. 1. The power system framework of the Feitsui hydro plant in Taiwan.

invade the equipments through the power lines, signal lines and ground lines.

For the surge protection study of UPS devices, the relevant papers published in recent years [2,3] have proposed that the supercapacitor based on energy circulation techniques as a surge protection is a good solution. If the supercapacitor has not been installed, entire UPS devices must be replaced, which is not cost-effective; the commercial supercapacitor has lower continuous DC voltage ratings, so the series of supercapacitors needs more than general batteries in its application. Therefore, this paper applies the principle of surge energy transfer to construct a low-voltage surge protection circuit; this circuit is mounted in front of UPS devices installed in the plant. The surge immunities of the surge protection circuit and actual load are tested according to IEEE and IEC relevant standards [4–8]; the test results confirm that the surge protection circuit may effectively provide protection from the effects of LFS and system surge.

Surge environment analysis

If the system lacks the abilities of surge protection and suppression, or if a method of treatment is inappropriate, the loads will be bound to fail. In order to get effective surge protection measures, it is necessary to first make the right surge analysis and hazard assessment for the surge environment. The researches concerning the surge environment indicate that the main surge sources of low-voltage system in this plant include: (1) lightning flashover surge, (2) switching surge and (3) electromagnetic pulse.