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DESIGN AND CONSTRUCTION OF UNINTERRUPTIBLE PARALLELING TRANSFER SWITCHES FOR AN EMERGENCY POWER SYSTEM IN TAIWAN LIGHT SOURCE

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Abstract

The ATS of an emergency power system in Utility Building II has operated over 18 years; in recent years the failure rate is gradually increasing because of aged components. To improve old switches, schemes of upgrading and developing new and efficient transfer switches have been conducted cautiously. A new device named an Uninterruptible Paralleling Transfer Switch (UPTS) is designed and implemented to replace an existing ATS to enhance the performance to meet the requirements of uninterrupted power transfer. The UPTS can uninterruptedly switch the grid power to emergency power of a backup generator during a planned utility power outage, and also exactly switch emergency power to the grid power uninterruptedly when the utility power is restored. If grid power is unexpectedly lost, UPTS acts like a typical ATS, automatically transferring power from a primary source to a backup source with switching duration a few seconds. A practical UPTS has been assembled and installed in Utility Building II and has performed well effectively to eliminate power-switching transients.

INTRODUCTION

When an unexpected outage occurs in the power grid of Utility Building II at NSRRC, the emergency power system can automatically transfer power from grid power as a source to generator power within a few seconds through an automatic transfer switch (ATS); this mechanism has been in operation for many years. Recently, as the ATS equipment is ageing and has part failures (e.g., trip unit failure, status judgment error), we plan to replace it and to upgrade its functions; the main considerations for the update project follow.

1. The main load of the emergency power system of utility building II is the cryogenic system and the RF system of Taiwan Light Source (TLS), To avoid causing a quenching of the RF system, this ATS update project limits the duration of power outage not to exceed 6 h.
2. Mothballing and disabling the original ATS control system preserves the possibility of resuming operation in an emergency (replacing the faulty old equipment before decommissioning).
3. A UPTS switching system is added in the existing limited space. the power feeder is reconnected to realize an uninterrupted power-switching function.
4. The downstream feeder ATS is combined with a third backup power from Utility Building III to construct a completely redundant backup power system.

The above items are integrated into a design for a new emergency power-distribution system as Fig. 1 shows. The actual equipment completed is shown in Fig. 2. The left side of the single line diagram is the original emergency power-system architecture of Utility Building II; the right side is the newly added UPTS control system combining an ATS backup-system architecture.

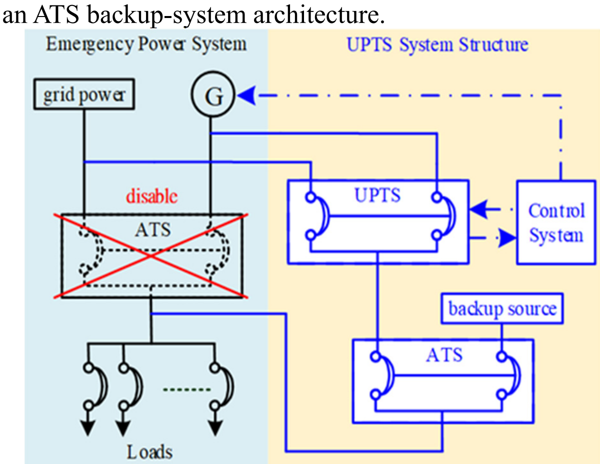

Figure 1: System architecture of UPTS update project.

Figure 2: Photograph of actual equipment after completion.

DESCRIPTION OF OPERATING MODE

Planned Power Outage

As Fig. 3 shows, to illustrate the electricity supply and switching mechanism of this system, the load power is supplied mainly by grid power (path 1) under normal conditions; the generator can be pre-started before paralleling or a planned power outage is required. A UPTS has the characteristics of a parallel electric supply; first, it detects the phase, voltage and frequency of the grid power, and orders the generator's governor to perform synchronous matching [1]. After the synchronization is successful, the breaker on

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the generator side is closed in parallel for the electricity supply (the load is supplied by paths 1 & 2 at the same time). There are then two modes to choose: in mode 1, a parallel electricity supply for a long time is suitable for special conditions in which the grid power capacity is limited; in mode 2, the load from the grid power to the generator is transferred in a short period of time, and the grid power is disconnected after completion; it will be powered only by the generator (path 2). During power transfer, because the power from various sources is connected in parallel, switching does not cause power interruption.

The program to match synchronization is repeated when we want to switch the power source back to the grid power; after powers on both sides are synchronized, the grid-side breaker is closed in parallel, and the load is gradually transferred back to the grid electricity supply. The circuit breaker of the generator side is finally opened and separated from the generator.

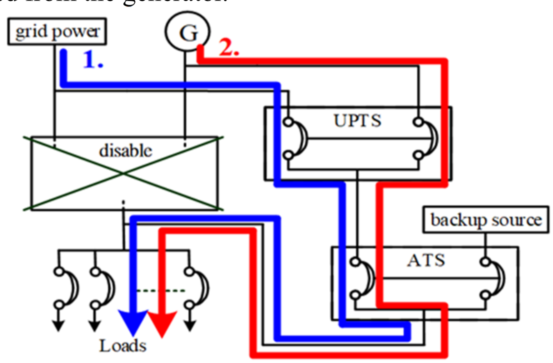

Figure 3: Diagram of uninterruptible electricity supply path in parallel.

Sudden Power Outage

The grid power of power companies is much more stable than self-built generators or micro-grids, but power transmission equipment is occasionally interrupted by a natural disaster such as a typhoon, earthquake or lightning strike. As Fig. 4 shows, in the event of an unexpected sudden power outage [2], an emergency generator begins automatically to run when the UPTS detects that the electricity supply is interrupted; the breakers are switched to path 2, to assume the electricity supply task.

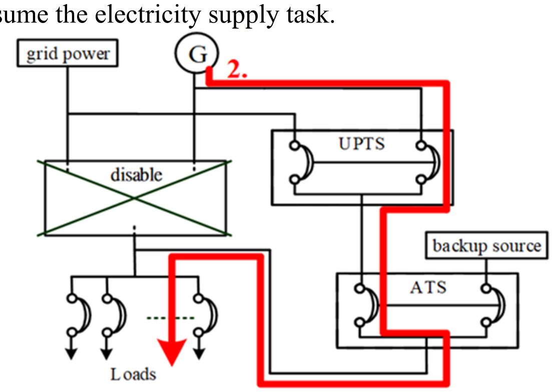

Figure 4: Electricity supply path for sudden power outage.

Completely Redundant Backup Architecture

As the emergency power system of utility building II has been in operation for more than 18 years, although appropriate maintenance and part updates have continued, to improve the stability of the overall emergency power system and to prevent a generator shutdown from a sudden failure condition, as Fig. 5 shows, the other emergency power of utility building III serves as a completely redundant backup source (path 3).

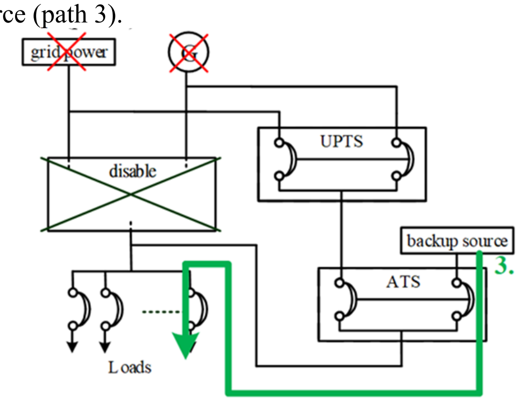

Figure 5: Diagram of electricity supply path of the redundant backup source.

MEASURED WAVEFORM

The construction of this project is divided into two stages; the first stage must be finalized within 6 h and maintains the minimum power to supply some units of the cryogenic system. It must be completed within the time limit to ensure that the liquid helium for the RF system can be restored; in the second stage, the switchboard and cable lines are completely refitted within 32 h.

During the running test, to verify the stability of the switching transient and whether the power quality is satisfactory, the power quality is measured with a power analyser with five voltage channels and five current channels simultaneously sampling and recording; the following analysis illustrates the measurement data in various scenarios.

Uninterruptible Paralleling Transfer by Generator Electricity Supply

This feeder of the power distribution system is 3-phase 4-wire 380 V-220 V used mainly to supply the loads of the cryogenic system; the power consumption is about 230 kW. After the generator receives the parallel start command of the UPTS system, it completes the synchronization of voltage, frequency and phase within about 26 s; then the power generated by the generator is formally converted to parallel. As Fig. 6 shows, when the generator-side circuit breaker is closed, the initial circulating current of the generator is about 350 A; the parallel load adjustment is completed after about 0.55 s. The circuit breaker is then opened on the grid side and supplies power independently by the generator; the voltage drops slightly, by about 4 %, but does not reach the voltage-sag limit range of SEMI F47-0200.

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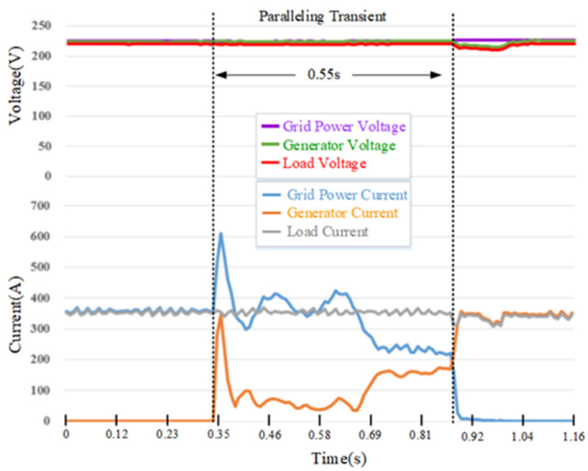

Figure 6: Voltage and current trends of the uninterruptible paralleling transfer.

The instantaneous waveforms of voltage and current during the parallel connection of generators are shown in Fig. 7. When the parallel connection begins, the generator receives a reverse circulating current from the grid; it can be seen that a peak reverse current about 620 A is generated. After about eight cycles of oscillation, it gradually stabilizes and tends to be in phase. It can be seen from Fig. 6 that in the parallel transient process, although the generator and grid have circulating currents, they have no significant impact on the voltage and current on the load side.

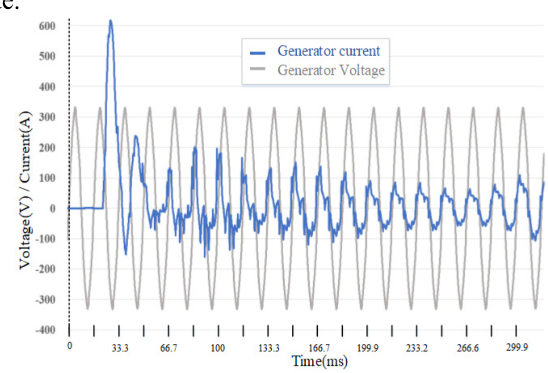

Figure 7: Transient voltage and current waveforms of generators connected in parallel.

Uninterruptible Paralleling Transfer by Grid Electricity Supply

When the voltage of the grid power returns to a stable and normal state, the Uninterruptible Paralleling Transfer System is used to order the generator to unload by the electrical operator. First, the generator becomes synchronized with the grid power, and the grid-side circuit breaker is put into parallel with the grid power after completion. As shown in Fig. 8, the generator gradually decreases the output current after the circuit breaker on the grid side is closed, and transfers the electricity supply responsibility to the grid side. The load transfer is completed in about 13.6 s; finally, the load voltage and current switch smoothly during the opening of the generator-side circuit breaker.

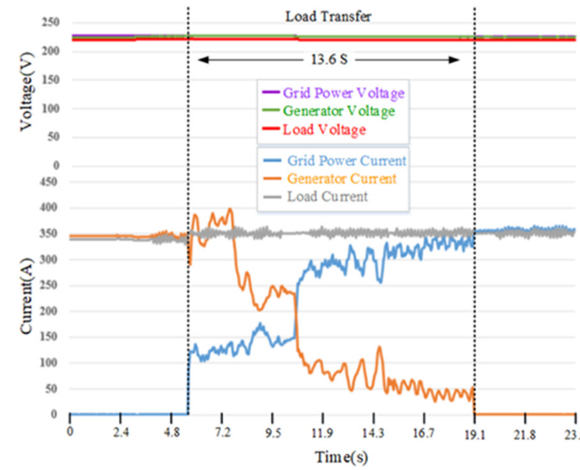

Figure 8: Voltage and current trends of parallel unloading of the generator.

Automatic Switching at a Sudden Power Outage

If the utility power is suddenly interrupted under unexpected circumstances, the system switches automatically to the ATS mode. First the grid-side circuit breaker is cut off to avoid the reverse transmission of power back to the grid; then the generator is commanded to begin, as shown in Fig. 9. It can be seen that the generator began after 7.2 s of power failure, and 5.3 s later a complete voltage is established. The generator-side breaker is then closed; the voltage has transient oscillations at the moment of loading.

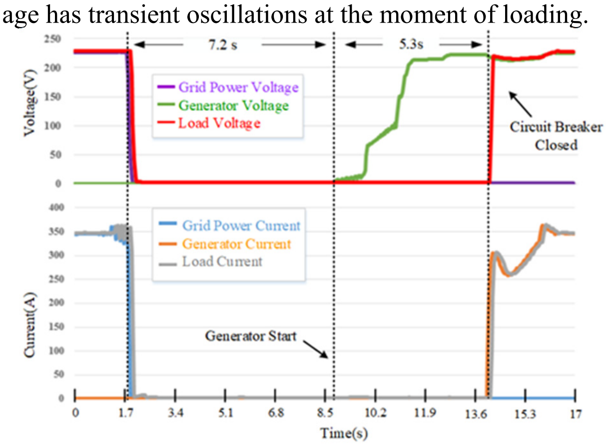

Figure 9: Voltage and current trends in a sudden power outage.

CONCLUSION

The improvement project of the structure of this article has twice experienced verification of long-time planned power outages after completion. The power source is converted through the operating mechanism of the Uninterruptible Paralleling Transfer System before power outage and after restoration. During the power conversion, the power is supplied steadily and the load operates without interruption. In the future, this architecture will be promoted to other utility buildings, and newer parallel controllers will be introduced to eliminate transient disturbances of power quality during switching.

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