PERFORMANCE ENHANCEMENT OF ELECTRICAL POWER SYSTEM AT NSRRC

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Abstract

A lot of efforts have been devoted to improve the reliability and the quality of NSRRC electrical power system in recent years. The improvements include the power factor correction, solving nuisance tripping of air circuit breakers, replacing old-type capacitor banks, installing automatic voltage regulators and designing multi-source backup system with automatic transfer switches. All these improvement works are to ensure the reliable operation of NSRRC power system and to reduce the electrical power accidents during the normal operation. Further, it can also provide the convenience for the electrical power dispatching during the regular maintenance of power system.

INTRODUCTION

Since Taiwan Light Source started to provide synchrotron radiation for the research 20 years ago, many ingenious works have been performed. For attaining remarkable scientific achievements, the accelerator facility has made many improvements ever since. During this period the electric utility system which provided the power to the accelerator facility has also been upgraded gradually for a better power quality. The upgrades which gave the power system obvious improvements were the installation of power factor correction capacitor banks and the automatic voltage regulators, the backup systems for the power and the modification for the air circuit breakers.

IMPROVEMENT OF POWER FACTOR

In the electric utility system at NSRRC, the vast majority of loads, such as cooling system, pumps, air conditioners etc., are inductive. All these equipments cause the power system a lagging power factor, which results in an inefficient use of electrical energy. In order to improve the power factor of electric utility system, the power factor correction capacitor banks have been installed in many of the low-voltage feeders. Before the installation the requirement at each feeder was analyzed and the appropriate parameters were set through the automatic power factor regulator to carry out power factor correction. The installation works have been done gradually since year 2004. From year 2009, the power factor at NSRRC has always maintained at above 0.999. Figure 1 shows the historical trend of power factor at NSRRC since year 2004. Due to this improvement, the electric utility bill of NSRRC has got a discount from Taipower (Taiwan Power Company). The saving on electric utility bill due to the improved power factor since year 2004 is shown in Fig. 2. The one-day trend of power factor of one of the high-voltage feeder which provides the electrical power to the accelerator facility is also shown in Fig. 3. In this figure the estimated real power is about 1700 kW and the reactive power is 35 kVar. Thus, the power factor after the installation of power factor correction capacitor bank is about 0.999.

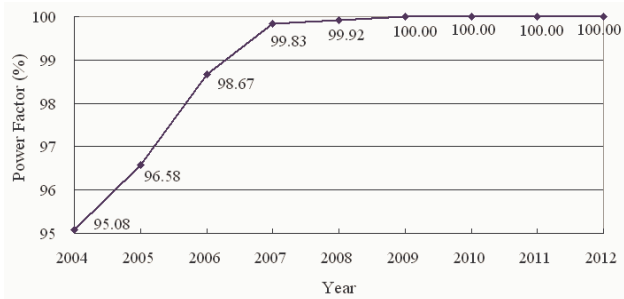

Figure 1: The improvement of power factor during the last 9 years.

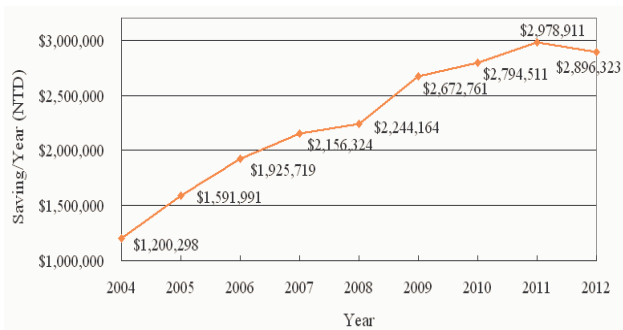

Figure 2: The saving on electric utility bill during the last 9 years (USD $1 ~ NTD $30).

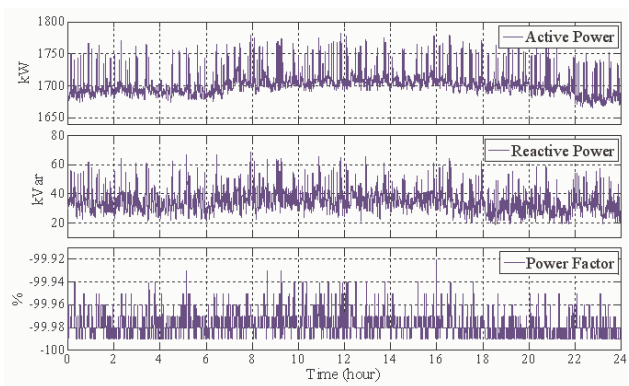

Figure 3: The one-day trend of power factor.

IMPROVEMENT ON POWER FACTOR CORRECTION CAPACITOR BANK

In a power system capacitors are relatively fragile. When the capacitors operate in coordinate with the reactive power compensator, the inrush current/voltage during the on/off can damage the insulation of capacitors. Also, the harmonic currents can degrade the capacitors and result in a premature failure. In order to improve its performance, a serial reactor can be added in front of the power factor correction capacitor bank to reduce the damage from the inrush current/voltage [1], Fig. 4. During the installation of serial reactor, besides selecting one with an appropriate voltage rating, the characteristics of harmonics should be analyzed for mitigating the harmonic distortion and reducing the inrush current/voltage.

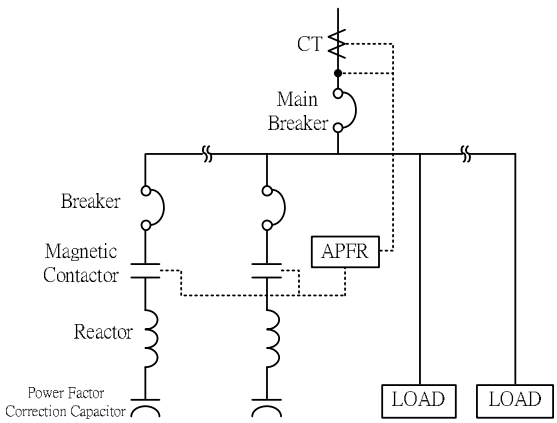

Figure 4: The power factor correction capacitor banks installed in the power system.

The capacitors used initially in the power system of NSRRC have self-healing dielectric made of metallized polypropylene film. This type of capacitor winding was housed and fixed in an insulating enclosure with double casing insulation. It is also non-flammable. During the service period, it was found during the fault it could produce smoke and give off peculiar smell. In some occasion, the fire alarms were triggered. Since year 2008, a better improved type of capacitor was selected to replace the original one. Besides the original functions, the new type of capacitor has a better fire protection mechanism. The capacitor elements are placed in a plastic case and encapsulated in thermal-setting resin surrounded by vermiculite which is an inorganic, inert, fire proof and non-toxic granular material. All these elements are all placed inside a sheet steel box. This new type of capacitor has proven having a better performance since the installation.

AUTOMATIC VOLTAGE REGULATOR

If the variation of voltage is larger than the tolerance of device during the power disturbance, the device will behave abnormally or even be damaged. For this sake, the on-line UPS (uninterruptible power supply) was installed for the device which needed precise control in order to minimize the effects from poor power quality or from the switching of large inductive loads. For magnet power supplies and the radio frequency plant the automatic voltage regulators (AVR) were installed to maintain a constant voltage. The one-day trend of input voltage and output voltage of AVR for the power supply of magnet system is shown in Fig. 5. In the figure the voltage of electric power from Taipower has variation of ± 1.5%, but that after regulated by AVR has variance lower than ± 0.15%. The stable output of voltage minimizes the probability of mis-operation and also improves the precision of control.

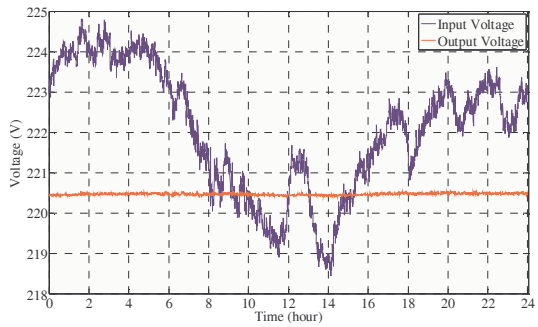

Figure 5: The one-day trend of input voltage and output voltage of automatic voltage regulator.

MUTUAL BACKUP SYSTEM OF EMERGENCY POWER

In order to increase the reliability of present emergency power system and to connect the different type of electric generators used, automatic transfer switch (ATS) was used, Fig 6. The generator in Utility Building I and that in Utility Building II were connected with ATS for mutual backup in order to achieve the purpose of reliable power dispatch.

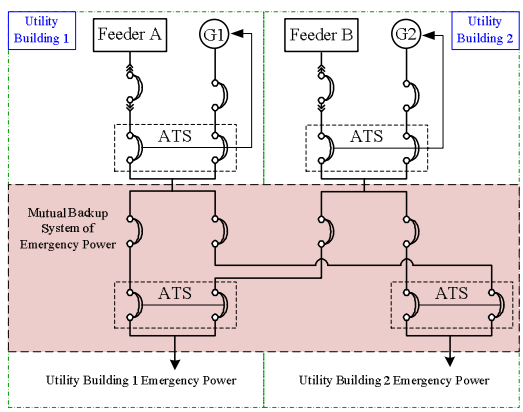

Figure 6: The mutual backup system of emergency power.

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MULTI-SOURCE AUTOMATIC SWITCH POWER BACKUP SYSTEM

There are some devices which require operating continuously in the accelerator facility for a long period of time. It is hard to arrange a shutdown of power which supports these facilities for the maintenance of power utility. A multi-source automatic switch power backup system was installed for the maintenance of power system or for the fault recovery of power. This multi-source automatic switch power backup system has been connected to the critical devices of vacuum system, radio frequency system, cryogenic system and control system, Fig. 7. During the maintenance period, the personnel can switch the power in the primary feeder to another feeder for carrying out the maintenance of original circuit. Also, during the breakout of one of the feeders, the ATS can switch the power to another feeder automatically. When the UPS is used with this arrangement, a very good power quality can be achieved. Owing to this arrangement, the electronic control system for our radio frequency system has been continuously operating for 10 years since its inception.

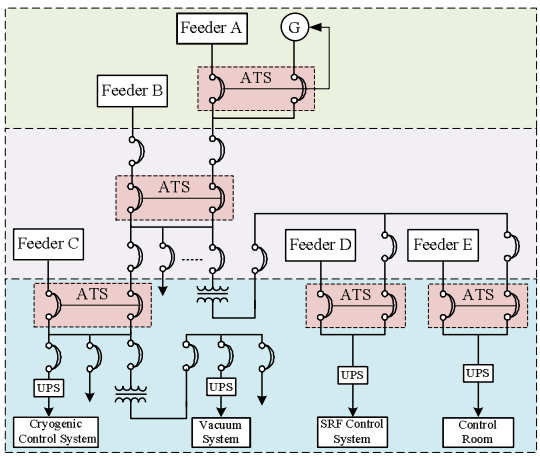

Figure 7: The multi-source automatic switch power backup system.

AIR CIRCUIT BREAKER PROTECTION RELAY

The original air circuit breakers (ACB) used for several years have built-in electronic tripping devices to handle some critical conditions such as overload, fault current. When a critical condition is detected, the breaker will be turned off to isolate the fault and protect the load. After using for several years, these electronic tripping devices became aging and interfered easily by noise or pulse signals, thus, a modification of this type of devices became necessary. After studying the cost of upgrade and the installation method, an external protection relay was adopted, Fig. 8. The tripping unit in the original module was disabled. The original current transformer was used for detecting the current and an external protection relay was installed to replace the original one. It is proven to be cost effective, thus, the same type of ACBs have been modified the same way. Since the upgrade there was no malfunction occurred at the ACBs.

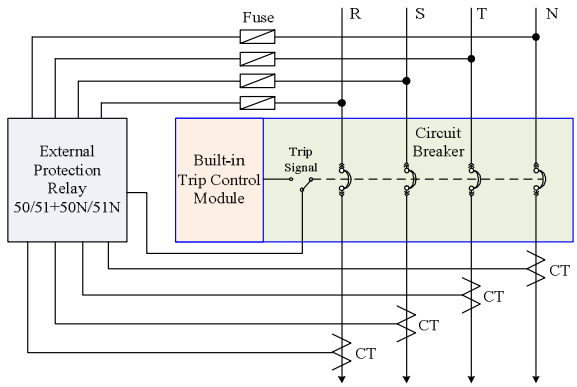

Figure 8: The installation of external protection relay for air circuit breaker.

CONCLUSION

The power system of NSRRC has always kept power factor above 0.999 since the installation of power factor correction capacitor banks. The benefits obtained are the reducing of power loss in the circuit and in the transformer, increasing the power transmission efficiency and the reserved margin of transformer. Further, it gains discount in the electric utility bill. When the power factor correction capacitor banks are used, the inrush current /voltage and the harmonic distortions needed to be handled carefully to minimize the damages to capacitors. The installation of AVR improves the quality and the stability of power. The ATS provides the function of continuing support of power from the emergency power generators or from another power feeder when it is necessary. These can easy the maintenance schedule. For providing an excellent quality of electric power for the operation of accelerator facility the personnel at NSRRC will continuously improve the power system in order to make the synchrotron research fruitful.

REFERENCES

[1] IEEE Std C37.99-2000, *IEEE Guide for the Protection of Shunt Capacitor Banks*, IEEE, New York, (2000).