THE REAL-TIME REMOTE MONITORING OF ELECTRIC POWER SYSTEM CONDITION AT NSRRC

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Abstract

For monitoring effectively the real time status of NSRRC's electric power system, an electric power quality monitoring system has been set up to measure the power quality of high voltage feeders, which includes the voltage/current phase, the variation of frequency, voltage sags and swells. The measured result will be analysed and used to further improve the performance of power system. Furthermore, a partial discharge monitoring system was also installed to monitor the phenomena of electric discharges. Using the ultra-high frequency discharge sensor, the magnitude and the pulse-per-second of discharge are measured and analysed. It allows the electrical engineers to diagnose the degradation of insulation of the electric equipment beforehand to reduce the power failure.

INTRODUCTION

A high grade and stable electric power distribution system is crucial to today's high-tech industry. It is also very important to the operation of an accelerator. When the power company delivers the electricity to the users, its distribution system will convert the high voltage to the lower voltage which is suit to the users. If an event occurs, a proper protection coordination mechanism can isolate the fault to minimize the damage. It is to guarantee the safe operation of user loads. In TPS the electrical power is delivered from Taipower (Taiwan Power Company) through two main distribution feeders. The rated voltage of the main feeder is 22.8 kV. The power demand is 7.5 MW for TPS at present. For the power distribution system of TPS, power SCADA systems [1] were set up to monitor the steady state status, such as voltage, current, load, temperature, humidity, status of alerts, etc. For further monitoring the transient behavior, power quality monitoring systems and partial discharge monitoring systems were installed to acquire detailed information for diagnosing the faults.

POWER QUALITY MONITORING

Besides using the Power SCADA to monitor and control the electric power, the power quality monitoring system uses a power quality recorder (ADX 3010) [2] and many auxiliary devices to monitor and record the data related to the steady state and the transient behavior of electric power. This setup has 10 kHz data acquisition rate and 12 bit A/D conversion resolution. The GPS is also used to guarantee the data been acquired simultaneously. The acquired data are also backed up with RAID. Many more parameters concerning the power flow such as frequency, phase, voltage, current, real power, reactive power, sag, swell, etc. are recorded.

Real Time Status of Electric Power

The real time data of power shown in the phasor meter are recorded accompanied by the measured values of voltages, currents and phase angles, Fig. 1. From the value of voltage one can determine if it meets the rated voltage at PCC (Point of Common Coupling). In Fig. 1(a), the magnitudes and phases of 3 phases are 23.13 kV (0^o), 23.21 kV (-120.1^o) and 23.03 kV (-240.2^o). According to IEEE Std. 141 [3], the unbalance rate of voltage is calculated as

$$V_{UR}=\{Max(|V_a-V_{avg}|,|V_b-V_{avg}|,|V_c-V_{avg}|)\}/V_{avg} \times 100\%,$$

$$V_{avg} =(V_a + V_b + V_c) / 3,$$

where V_{UR} is the voltage unbalance ratio, V_a, V_b, V_c are the 3-phase voltages. V_{UR} is about 0.3% at TPS. For the 3-phase currents, their magnitudes and phases are 93.5 A (-0.5^o), 96.3 A (-123.0^o) and 91.8 A (-243.5^o). Fig. 1(b) shows the real/reactive power and the power factor. In the figure, the real power is 3759 kW, the reactive power is 146.9 kVAR and the apparent power is 3762 kVA. Also, the power factor is 99.9%, which indicates it is an inductive load. The frequency variation of power provided by Taipower is shown in Fig. 2.

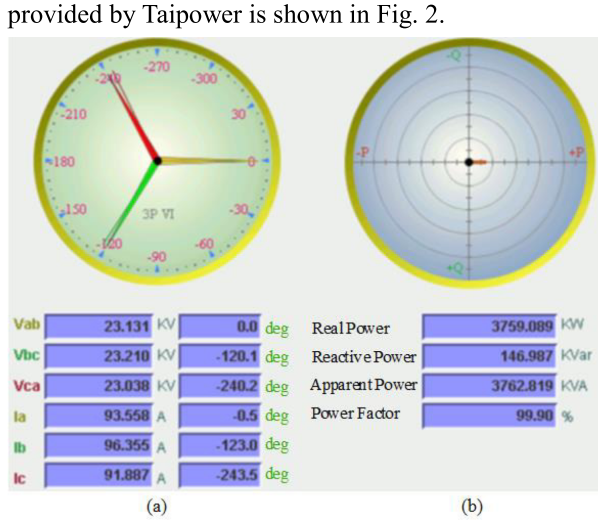

Figure 1: The real time phasor diagram and power parameters at TPS.

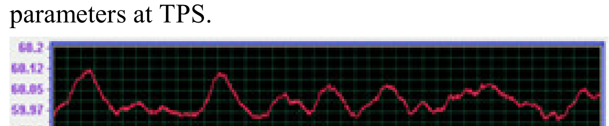

Figure 2: The frequency of power provided by Taipower.

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In general, a balanced 3-phase load has only positive-sequence component after decomposing its phase sequence. But, if the 3-phase load is unbalanced, the negative-sequence current will appear. This can cause transformers or motors overheated or damaged. If there is a leakage ground current exists, a current of zero-sequence component will appear. Thus, when a fault is detected in the power system, the type of failure can be identified according to whether it is a component of zero-sequence or a negative-sequence. At NSRRC, the negative-sequence current unbalance rate (I_{U2}) is about 2.76% and the zero-sequence current unbalance rate (I_{U0}) is about 0.13%.

Detection and Recording of Voltage Sags

Voltage sags are caused by lightning strikes, termite damage, salt corrosion, destructive weather or equipment failure. When the voltage sag occurs at Taipower's feeder, it will cause the accelerator losing beam partially or even having a beam trip. If the power quality monitoring system can record the voltage drop information in more detail during the voltage sag, the cause of improper behavior of electron beam in the accelerator could be identified by the operators. The voltage sags always occur unexpectedly in general. In order to capture the detailed information before and after the occurrence of voltage sag, the power quality recorder was installed. It can capture the information with 10 kHz sampling rate and save the variation of voltage, ΔV, such as (Fig. 3):

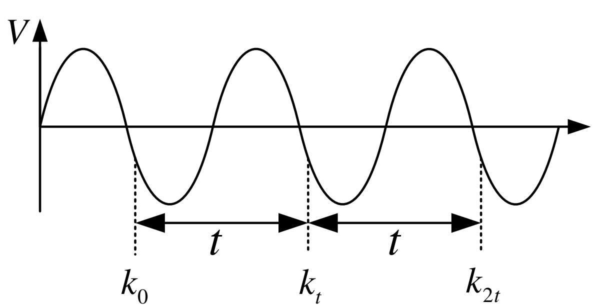

Figure 3: Voltages at the points of data sampling.

$$\Delta V = ||k_o - k_t| - |k_t - k_{2t}||$$

t : the period of data sampling
k_o, k_t, k_{2t} : the voltages at points of data sampling

A voltage sag occurs at TPS was recorded by the power quality recorder, Fig. 4. It contains the information of event type, feeder, time, period, amplitude and waveform. When the voltage sag/swell or frequency variation occurs, the monitor will trigger and save the information containing 10 periods before and 15 periods after the event occurs. In Fig. 4, the voltage drops to 76.1% and lasting for 72.4 ms (about 4.3 cycles). It is a B type voltage sag as shown in SEMI F47-0200 diagram [4]. The variation of waveform after the voltage sag is also shown in the figure. It can also be used to judge if a phase jump occurs.

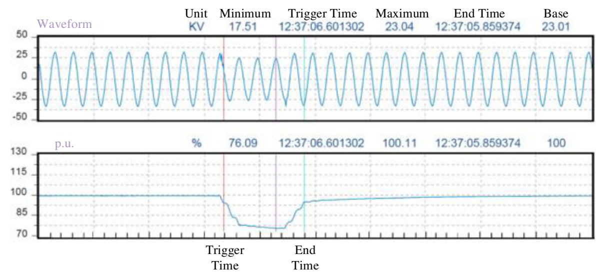

Figure 4: The voltage sag occurred at TPS was recorded by the power quality monitoring system.

The depth and the time duration of voltage sags of TLS electric power system from 2011/01/01 to 2015/12/31 are shown in Fig. 5. Their severity is defined as A, B, C, and D as shown in the diagram. In Fig. 5, there were 27 sags total during this 5-year period. Among them 7 sags belonged to type A, 17 sags belonged to type B and 3 sags belonged to type C. All these sags resulted in 13 beam trips and 2 partial beam losses in TLS accelerator. There were 8 times having no influence on the accelerator, and another 4 times occurred when the accelerator was not in operation.

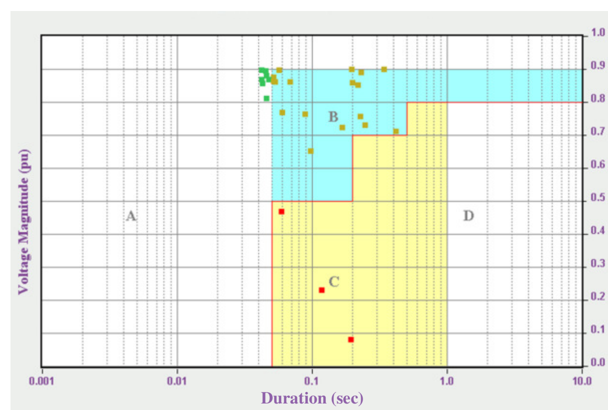

Figure 5: The voltage sags occurred in TLS from 2011/01/01 to 2015/12/31.

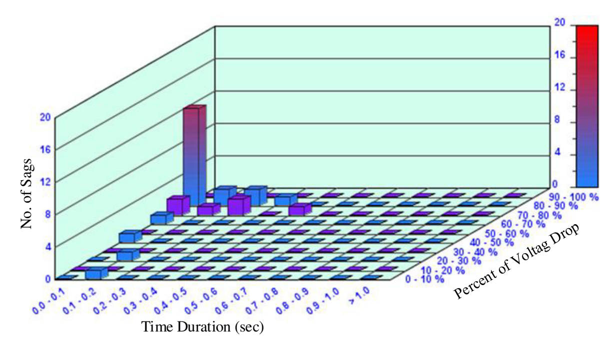

Figure 6: The voltage sags occurred from 2011/01/01 to 2015/12/31 in TLS are plotted as 3D bar chart.

The same data are also plotted as 3D bar chart, Fig. 6. In the figure, there are 12 times the voltages drop to between 80% and 90% in magnitude and the duration lasting for 0.1 sec. It is about 44% in this period. Also, in the figure it shows that no matter how deep the voltage drops, it will not exceed 0.5 sec. Thus, if a device with tolerance better than type B is used, it should be able to withstand 88% of the voltage sag effect.

MONITORING OF PARTIAL DISCHARGE

Partial discharge is a localized electrical discharge of a small portion of solid or fluid electrical insulation system under high voltage stress, which does not completely bridge the space between two conductors. It causes generally the long term degradation and eventually failure of the electrical insulation. In order to monitoring the occurrence of partial discharge effects at the high voltage equipment, partial discharge monitoring systems were installed. With a UHF (Ultra High Frequency) sensor which has range of frequency from 30 MHz to 1.2 GHz the change of transient magnetic field caused by partial discharge activities can be detected easily. One of UHF sensors installed at the cable termination of 22.8 kV transformer is shown in Fig. 7. A one-day trend of partial discharge monitored by the installed system at this position is shown in Fig. 8. The monitored information includes the magnitude of discharge and PPS (Pulses Per Second) as defined by IEEE Std 1434-2014 [5]. In the figure, the magnitudes of pulses of discharges are lower than 0.5 mV and PPS are lower than 30. If the magnitude of discharge is over 5 mV and the PPS is more than hundreds, more attention should be paid to the related equipment in order to keep it from malfunction.

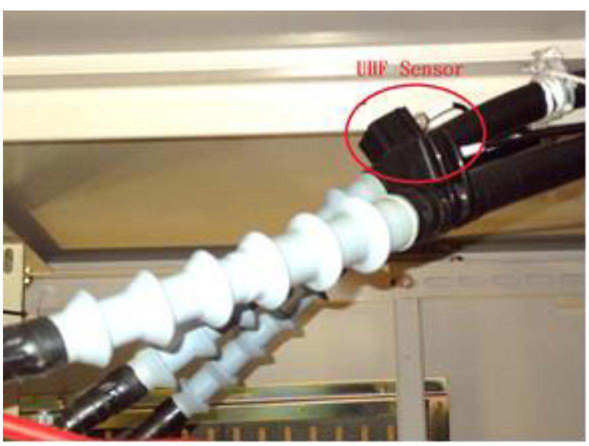

Figure 7: One of UHF sensors installed at the cable termination of 22.8 kV transformer.

Figure 8: A one-day trend of partial discharge monitored by the installed system at the position shown in figure 7.

CONCLUSION

The power quality monitoring system can monitor various kinds of electric events and help the electrical engineers to discover the abnormal power behavior. The partial discharge monitoring system helps to monitor the partial discharge events at selected location remotely to uncover the degradation of insulation of the electric equipment beforehand to reduce the power system faults. At NSRRC, power quality monitoring systems and partial discharge monitoring systems have been installed at both the power systems of TLS and TPS. Since the installation of power quality monitoring systems at TLS they have helped to detect many voltage sags. Any improper behavior of accelerator related to these sages allows us to study the tolerance of accelerator devices to the voltage sags. It provides many useful information to improve these devices. There are 4 partial discharge monitoring systems installed in the power systems of TLS and TPS at present. More partial discharge monitoring systems are planned to be installed on the major high voltage equipment of NSRRC's power system in order to diagnose the degradation of insulation of the electric equipment.

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