CHAPTER 5

CONCLUSION AND DISCUSSION

5.1 CONCLUSION

Partial discharge testing has been used for long time to measure the quality of electrical insulation and to detect if insulation deterioration has occurred in high voltage apparatus. On line partial discharge measurement has been applied in recent years and is one of the appropriate methods to detect and to monitor partial discharge activities in the actual condition of hydroelectric generators during their normal operation. The effective measurement is when the electrical noise can be eliminated and information is clearly interpreted and in this case the generator may not need to shutdown. Winding degradation can be successfully identified by on-line measurement to guide confirmation by visual inspection, and thus can be repaired in early stage. The on-line partial discharge measurement implemented on Sirikit hydroelectric generator yielded positive results in all aspects such as appropriate method of measurement selection, electrical noise elimination, data interpretation and its benefit as follow:

5.1.1 Appropriate method of measurement

There are several on line measurement, which depend on type of sensor used. The 80 pF capacitor coupler was selected to use to be special sensor by connecting within stator winding. The electrical noise elimination by comparison method has been successful and suitable for hydroelectric generator at Sirikit Power Station.

5.1.2 Coupler fabrication and installation

The 80 pF capacitor has been made from high voltage cable. It is highly efficient and lowest cost coupler. The area nearest the lead of each parallel path of each phase of generator winding is a suitable location to install each coupler and the coupler can be made in loop or open loop – type depend on space available. The important point is the quality

connection to ensure that can withstand high voltage during operation, which was proven by applying high potential test as recommendation of ANSI. C50 –1977.

5.1.3 Measurement procedure

To determine condition of winding, four conditions of generator operation are set up for testing. No load cold, Full load cold, Full load hot and No load hot are the condition of each testing in order to determine partial discharge activities as temperature and vibration changing. The first measurement is used to be database for comparison with next measurement. Quantity and magnitude of partial discharge are not important than the trend of them.

5.1.4 Interpretation and implementation in maintenance program

Four conditions of measurement give some specific pattern of partial discharge graphs. A change in positive pulse, negative pulse and both +ve NQN and –ve NQN show the condition of specific parts in winding. The important conditions of winding represented by a change of partial discharge pulse are following:

a). Slot discharges determine coil surface damage due to improper semi-conducting coating.

b). Internal discharges determine delamination occurred within main ground wall insulation.

c). Copper interface discharges determine copper conductor delaminated from main ground wall insulation.

d). Loose winding or tight winding determines loose or tight wedging, more looses of winding will effect to increase surface deterrioration.

Criteria value of data measurement There were a lot of data measurement, which signed some insulation deterioration, but it was very difficult to indicate that which value of measurement was criteria point to define the generator could be still operated or must be shutdown for correction. Many experience paper as defined in Chapter 2 were used to guide

to interpret the data and prepare to approve or correct some parts that signed deterioration when value of measurement exceed experience data. The values of data measurement were compiled for analysis and interpretation for maintenance purposes. The value of data measurement should be recorded in order to compare with the next measurement for indicating significant of deterioration. For long term measurement at the same generator when compared with test data and actual results from inspection, it could be created the criteria value of test data for each type of machine. However, the on-line measurement method is the suitable method as the special maintenance tool for generator.

The benefit of this measurement is using interpretation result in maintenance program of that generator. The greatest use of information is to prepare method of repairs and materials required, if the measurement is taken several times then condition prediction can be made and used to adjust plan of maintenance. The interpretation result of Sirikit unit 2 showed high partial discharge activities. There were a lot of internal discharges, copper interface discharges and slot discharges occurring, winding parallel path 2 phase A and C had more partial discharge activities than the other path. These results were used to prepare repair procedure including materials and special tools in the early stage, resulting in keeping schedule on time and economic.

5.2 DISCUSSION

The coupler fabrication and installation on Sirikit hydroelectric generator unit 2 are successful together with noise elimination. The first measurement was taken on 4 conditions in order to receive partial discharge pulses on each condition changed. However, depending on demand of system and status of Head of water in reservoir the generator could not be operated at maximum load. The difficulty is in coupler installation is the generator must be shutdown and disassembled for several days. The installation could be done on period of overhaul generator only and to ensure in installation that did not affect to decrease quality of winding, the appropriate proof test must be applied. Another difficult is electrical noise elimination method, generator with multi-paths of winding is easy to eliminate noise but

some generators with single path of winding, then the location for installation must be considered. The other procedure of on line partial discharge test have been discussed below:

5.2.1 Measurement procedure

To confirm effective vibration and temperature, four conditions of generator operation were set up to be standard of measurement procedure. In actually, the power demand and quantity of water will be greatly affected to do the measurement. No load cold and Full or normal load hot should be enough for measurement procedure.

The test data can be interpreted to sign some deterioration for overall stator winding at that time but could not indicate pinpoint to specific part of deterioration. The special electrical test such as dielectric test should be applied at off-line to indicate where the weak point is.

For the best benefit for maintenance program, the schedule of on-line measurement should be set up in order to compile test data and interpretation for tracking of insulation deterioration. Usually 2 or 3 months a time is set up for on-line measurement of each machine.

5.2.2 Interpretation

It is difficult to define how much partial discharge is too much partial discharge. From experience data of Ontario Hydro described in chapter 2 shown more than 450 NQN of polyester insulation type must be more serious deterioration occurring. The means value of NQN in Sirikit unit2 was about over 1000 NQN and the generator still be operated at nowadays. However, from visual inspection in minor inspection period indicated that a lot of discharges had occurred within anywhere of winding and from experience maintenance of EGAT these were the main cause of insulation breakdown while operating. The slot discharge activities were important significant sign of winding deterioration, winding was closely to ground and easy to breakdown when the deterioration progressed too fast. Sirikit unit 2 informed high slot discharges but could not be inspected and repaired due to did not

withdraw the generator rotor. Result in the whole picture of winding was not in so good condition.

Success in minor inspection period by keeping on time and save cost of operation by apply test results to prepare anything at early stage, but some parts of winding did not inspect and repaired due to short time planning. The more information with technical supported should be done to plan to sufficient period of minor inspection

5.3 RECOMMENDATION

Partial discharge is not the direct cause of deterioration, but it is a symptom of thermal or mechanical deterioration. Mechanisms create air pockets or voids and generate partial discharge pulses, the large void the large magnitude of pulse. An increase in partial discharge indicates that more thermal deterioration has occurred.

The measurement procedure should be frequency done to receive more data to monitor real condition of winding. The first test can not define how serious the insulation deterioration was. Comparison method can indicate the sign of deterioration occurred. From literature survey described in chapter 2, indicated different type of insulation will give different values of partial discharge. The comparison test from different generator with different type of insulation can not be compared with each other.

The changes of data of each measurement are very useful to indicate trend of deterioration mechanism. The suitable planning for measurement schedule could be done on intend to observe trend of deterioration based on type of generator insulation, generator age and history of operation.

The results of on line measurement are very useful for maintenance program, but are not sufficient to make decision to renovate the machine or repairing of some winding parts. Some specific electrical test such as insulation power factor measurement, insulation resistance measurement and acceptance test of high potential test must be applied at generator standstill for final evaluation of winding.