**SCHEDULE P: SPECIFICATIONS FOR MEASUREMENT SYSTEMS OF CENTRAL CHILLED-WATER PLANT**

The measurement system specified below shall be used to calculate and track the Average Annual Chilled-water Plant Specific Consumption and to carry out consistency checks on measured data. For energy conservation measures related to the optimisation or retrofit of central chilled-water plant, the following requirements shall be adhered to:

1. The overall measurement system for the central chilled-water plant shall be capable of calculating a resultant chilled-water plant efficiency within 5% of the true value. The overall uncertainty of the measurement system shall be the arithmetic sum of the individual error of each measurement system. The ESCO shall state clearly how the overall uncertainty is derived in the report.
2. The system heat balance shall be computed for the central chilled-water plant, with at least 80% of the measured points within a system heat balance of 5%.
3. Measuring instruments shall be supplied and installed to monitor the following variables at 1-minute intervals, all parameters being automatically trended without any need for menu setup:
4. Chilled-water return temperature in °C, for chilled-water headerand individual chillers\*;
5. Chilled-water supply temperature in °C, for chilled-water headerand individual chillers\*;
6. Entering condenser water temperature in °C, for condenser water headerand individual chillers\*;
7. Leaving condenser water temperature in °C, for condenser water headerand individual chillers\*;
8. Chilled-water flow rate in L/s, for chilled-water header and individual chillers\*;
9. Condenser water flow rate in L/s, for condenser water header and individual chillers\*;
10. Electrical power inputs in kW from external power meters, for each chiller;
11. Electrical power inputs and frequencies in kW and Hz respectively from variable speed drives, for individual pumps and cooling tower fans;
12. Outdoor ambient dry-bulb air temperature in °C and outdoor ambient relative humidity in % (converted, displayed and trended), for 2 separate locations, both being spaced along the length of the cooling towers to indicate the wet bulb temperature in the vicinity of the cooling towers; and
13. Any other instruments required for optimisation of central chilled-water plant.

 \* For replaced chillers.

1. The required accuracies of the measuring systems are listed in the table below:

|  |  |
| --- | --- |
| **Measurement System****(includes sensor and data acquisition system)** | **Required Accuracy** |
| Temperature | ±0.03°C |
| Flow | ±1% |
| Power | ±1% |

1. In general, resistance thermometers shall be used for temperature measurement. All thermometers shall be fitted in thermowells. An additional thermowell shall be installed for each thermometer so that the chilled water / condenser water supply and return sensors can be installed in series to verify that the readings are within allowable tolerance. Screw-on protection covers shall be provided for all unoccupied thermowells. The chilled water / condenser water supply and return sensors shall be interchangeable to verify accuracy. Sufficient length of cable and conduits shall be provided so that such checking and interchange can be done easily.
2. For the flow measurement in common headers, magnetic full bore (in-line) measuring method shall be used, if it is possible to shutdown the central chilled-water plant. Turbine-type meters shall not be used for flow measurement.
3. The memory space of the data acquisition system shall be sized for at least 36 months of storage capacity.
4. All measuring and control cables shall have a common screen (aluminum or copper-foil) to eliminate any extraneous influences and to prevent faulty signals.
5. Instrumentation specified in this Schedule, except those measuring the pumps’ and fans’ electrical power inputs and frequencies, shall be calibrated with procedures developed by the National Institute of Standards and Technology (NIST) or equivalent. Primary standards and no less than third-order NIST or equivalent traceable calibration equipment shall be utilized wherever possible. A certificate of calibration shall be provided with each piece of measuring equipment used in the measurement and monitoring of the efficiency of the central chilled-water plant.
6. Before the installation of the measurement system, a detailed report on the proposed measurement systems to be installed for the purpose of measuring, monitoring and optimizing the operation of the central chilled-water plant shall be submitted to the agency/company for approval.
7. All quantifiable sources of measurement errors shall be stated clearly and listed in an instrumentation table and included in the report submitted to the agency/company.
8. All non-quantifiable measurement errors shall be stated clearly in the report and the ESCO shall state clearly what measures are taken to minimise such errors.
9. The ESCO shall provide extensive photographs and AutoCAD drawings to show the locations of all sensors on-site; and
10. The requirements on man-machine interface to be developed and deployed in the Building Management System (BMS) by the ESCO shall include, but not limited to, the following:

Overview Display

i. A graphic showing the overall operating status of the chilled-water plant, including but not limited to the following information:

* All sensors’ locations, in accordance to the list of instruments specified in this Schedule, and their dynamic values;
* Operating status of key components (i.e. chillers, chilled-water pumps, condenser water pumps and cooling towers) of the central chilled-water plant;
* Overall system efficiency (kW/RT) of the chilled-water plant and the overall efficiency (kW/RT) of each of its key components (i.e. chillers, chilled-water pumps, condenser water pumps and cooling towers);
* Outdoor ambient wet-bulb air temperatures (determined based on the readings from the outdoor ambient dry-bulb air-temperature and relative humidity sensors);
* Total chilled-water tonnage and total condenser water tonnage; and
* Power consumed by the chillers, chilled-water pumps, condenser water pumps, cooling towers and total power consumed by the chilled-water plant.

Other Displays

1. A graphic showing the system heat balance of the central chilled-water plant;
2. A graphic showing the electrical parameters of each chiller, including each phase’s voltage (V), current (A), power factor, kilowatt and kilo-VA;

Trend Display

1. Trend displays showing the readings of the sensors supplied and values computed under this contract. It should be possible to display the real time and historical trend data available in the data acquisition system by scrolling or expanding the time base. Multi-trend feature that allows display of combination of variables on the same trend display shall also be possible; and

Tools

1. Tools to access and export any measured or computed value for analysis in MS Excel format for any chosen arbitrary period of time.

The sampling, trending and storage intervals shall be 1 minute per sample and the resolution of the graphics shall be at least 1280 x 1024 pixels.