

# Wireless Instrument and Wireless Control Network for Multi-tower CSP Power Plant

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**Abstract**—In this paper, one type of multi-tower CSP power plant's instrument configuration and function for heliostats, solar thermal receivers, steam and water pipes is presented. Wireless instrument and wireless network configuration are developed based on the character of the instrument configuration. Each type of wireless instrument and its detail application in multi-tower CSP power plant is described. Function and configuration of each type of wireless network equipment, such as wireless multi-function node, every type of wireless adaptor, handheld, wireless device manager is also presented.

**Keywords**—multi-tower, CSP power plant, industrial wireless network, wireless instrument

## I. INTRODUCTION

The areas covered by a tower type CSP power plant is very large (about 1~10 square kilometers). There is no large object that may stop wireless communication or electric magnetic interference source such as big power motors in the heliostats field. Wireless instrument and wireless network [1] are suitable for the heliostats field which can save large amount of control cable, signal cable and communication cable (thousands kilometers of cable can be saved for one CSP power plant). And cable related work such as erection, commissioning will be saved too. The total erection period of CSP power plant will be reduced dramatically. The faults caused by cable mechanical damage or rodent biting can be reduced to minimum.

One type of multi-tower CSP power plant process configuration is presented in this paper as following: heat receiver filled with high purity of graphite located on the top of each tower, and there are some heliostats arranged under the tower. The heliostats reflect and concentrate the sunrays to the cavity at the bottom of the heat receiver on the top of tower. The graphite in the heat receiver will be heated by the sunrays to very high temperature up to 800 °C. The graphite then can heat the feed water and steam pipes buried in the graphite to generate high temperature steam to drive the steam turbine generator to send out electric power.

This type of multi-tower CSP power plant heliostats field's instrument and control equipment can be realized by wireless instrument or wireless adaptors to connect with

central control server of heliostats field. The main equipment connect with the wireless network are heat receiver systems, heliostats and meteorological station etc.

## II. HEAT RECEIVER MEDIUM TEMPERATURE MONITORING

Heat receiver medium (graphite) in multi-tower CSP power plant must operate in proper temperature range. Too low temperature will result in no proper temperature steam available for steam turbine generator running. Too high temperature will endanger the safety operation of the system such as heat receiver medium destroy, heat exchange pipe destroy or instrument & control equipment destroy etc. Heat receiver medium temperature monitoring shall also provide input for heat storage calculation. The heat storage calculation result can be used for selection of operation mode of CSP power plant. The followings are the main temperature monitoring items:

- 1) Heat receiver cavity temperature monitoring;
- 2) Heat receiver medium temperature (temperature gradient) monitoring;
- 3) Heat receiver output steam temperature monitoring and control.

The above temperature monitoring shall all be done by wireless temperature transmitters.

Heat receiver cavity temperature monitoring is of most important. It has the following main function:

- 1) Measure the solar energy input;
- 2) Control heliostats operation.

When heat receiver cavity temperature reach its high limit (heat receiver's energy storage reach its high limit), all or part of the heliostats shall be defocused (direct some of the heliostats skywards) to avoid heat receiver medium overheated. If the heat receiver is producing steam, part of heliostats shall be defocused to make the energy input and output of the heat receiver equal. If the heat receiver is not producing steam, all of heliostats shall be defocused.

## III. METEOROLOGICAL STATION OF CSP POWER PLANT

The meteorological station of CSP power plant mainly measures the meteorological parameter near the ground:

- Direct Normal solar Irradiance (DNI)
- Wind speed

- Wind direction
- Air temperature
- Air humidity
- Cloud amount
- Amount of precipitation

The above parameter shall be sampled every minute at least.

According to the interface configuration of the meteorological station, wireless Modbus TCP / RTU adaptor or wireless HART adaptor may be used to transfer the meteorological parameter wirelessly to central control server of heliostats field. City or national meteorological stations' data may also send to central control server wirelessly to obtain upper air meteorological parameter for CSP power plant control purpose.

#### IV. HEAT RECEIVER STEAM TEMPERATURE CONTROL AND INSTRUMENT CONFIGURATION

Heat receiver internal medium temperature will drop during steam generation process without enough solar energy input (the heat energy in heat receiver medium transfer to steam). The temperature difference between heat receiver medium and feed water decreases in this process. To maintain constant steam temperature required by the steam turbine generator, the feed water flow rate must be reduced too. The heat receiver steam temperature shall be controlled by modulating the feed water flow rate through the heat receiver. The relation of feed water flow rate and heat receiver medium temperature is approximately linear relation.

The following instrument configured for this system:

- Feed water temperature (Resistant temperature detector), wireless temperature transmitters adopted;
- Steam temperature (Thermocouple), wireless temperature transmitters adopted;
- Feed water flow rate modulating valve, wireless multi-function combined adaptor adopted;
- Feed water pressure, wireless pressure transmitters adopted;
- Steam pressure, wireless pressure transmitters adopted.

#### V. HELIOSTAT CONTROL AND INSTRUMENT CONFIGURATION

Each heliostat is equipped one field controller and two high precision driving motors and their control module [2]. Driving motors usually powered by 48VDC with solid limit switches. The function of field controller can also be carried by central control server of heliostats field and heliostat equipped with driving motors and their control module. These two configurations have different network communication load and control logic calculation load distribution and should be selected based on cost and technical analysis.

Heliostat can equipped with wireless multi-function combined adaptor for heliostat without field controller or wireless Modbus TCP / RTU adaptor (or wireless HART adaptor) for heliostat with field controller. The field

controller of heliostat carries out task such as driving motor position command calculation, state monitoring etc. These functions can be carried out by central control server of heliostats field for heliostat without field controller. Heliostat can equipped with wireless mirror position transmitters based on actual control need to monitor mirror position in a real time manner.

#### VI. WIRELESS CONTROL NETWORK STRUCTURE AND CONFIGURATION

Wireless multi-function node is arranged on top of each heat receiver tower and the node communicates with heliostats, transmitters etc. belong to this heat receiver tower. Wireless multi-function node on steam turbine generator house communicates with the central control server of heliostats field. All of the wireless multi-function nodes form the backbone of the wireless control network. Wireless multi-function nodes and other wireless equipment can be powered locally by heliostat driving motor power supply. Wireless instrument and wireless equipment can set some parameters according to control requirement such as resolution rate, gain of antenna etc. Wireless instrument and wireless equipment can communicate with wireless multi-function nodes directly or communicate with wireless multi-function nodes through other wireless instrument or wireless equipment.

#### VII. WIRELESS DEVICE MANAGERS

Wireless device manager is a platform based on web pages that manage the wireless network, wireless instrument and wireless equipment in the CSP power plant. Wireless device manager has internal fire wall and all necessary security and management software.

Wireless device manager's main functions list below:

- 1) Diagnose wireless network communication: diagnose and manage the wireless communication of the equipment within the wireless network; display wireless communication state and network topological structure; detect the location and tag of the faulty wireless instrument and equipment for maintaining.
- 2) Support remote configures, calibration and maintenance.
- 3) Manage wireless network security.
- 4) Remote access through PC or handheld equipment with correct authorization and proper security measures.

Wireless device manager can be arranged in central control server of heliostats field in the CSP power plant or in special security server.

#### VIII. WIRELESS INSTRUMENT AND EQUIPMENT CONFIGURATION

Wireless instrument and equipment usually support 1 second resolution uttermost. The resolution rate can also set to 5 second, 10 second, 1 minute or longer. Wireless transmitters' and wireless adaptors' for heliostats and resolution can set to 1 second, and 1 minute for meteorological station. Heat receiver medium wireless temperature transmitters' resolution can set to 1 minute or

longer for medium temperature changes very slowly with large heat capacity of medium. But wireless transmitters on feed water and steam pipes shall set to the highest resolution that the equipment support.

The outdoor wireless instrument and wireless equipment shall have a shell protection rate of IP66 for high pressure water cleaning of the mirrors. Wireless instrument and wireless equipment in hazardous areas shall have a certification suitable to relative hazardous area.

Heat protection for wireless transmitters and wireless multi-function node shall be done to prevent concentrated sunray spot irradiation on them. The erection location of them should be free of concentrated sunray spot irradiation for the best. The outdoor wireless equipment shall be equipped with surge protectors. And the surge protectors' grounding terminal shall be grounded safely. Other necessary lightning protection measures shall be taken to consideration to protect outdoor wireless equipment from lightning.

#### IX. MAIN CATEGORIES OF WIRELESS INSTRUMENT AND WIRELESS EQUIPMENT IN CSP POWER PLANT

1) Wireless pressure transmitters: including gauge pressure and absolute pressure, accuracy:  $\pm 0.075\%$ . Wireless pressure transmitters are suitable for various pipes pressure measurement and data acquisition. Wireless pressure transmitters are mainly used for heat receiver feed water and steam pressure measurement in CSP power plant.

2) Wireless temperature transmitters: measure and transmit the various temperature measurement points in power plant. Wireless temperature transmitters are suitable for various pipes temperature, tanks temperature and metal temperature measurement and data acquisition. Wireless temperature transmitters are mainly used for heat receiver feed water and steam temperature, heat receiver medium & cavity temperature measurement in CSP power plant.

3) Wireless difference pressure / flow transmitters: measure and transmit the various difference pressure / flow measurement points in power plant with accuracy:  $\pm 0.075\%$ . Wireless flow transmitters are mainly used for heat receiver feed water flow and plant makeup water flow measurement in CSP power plant.

4) Wireless multi-function combined adaptor: sample the wired signals and transmit them wirelessly in real time manner. The wired signals can be sampled by adaptors include analog input (4-20mA, 1-5V, 0-5V) signals, thermal couple signals, digital input signals, digital output signals etc. The signals type can be combined flexibly. Wireless multi-function combined adaptors are mainly

used for valve position, temperature, mirror position measurement as well as non-critical motor driven valves, pneumatic valves, solenoid valves and heliostat driving motors control in CSP power plant.

5) Wireless HART adaptor: sample the wired HART signals and transmit them wirelessly in real time manner. Wireless HART adaptors are used for transmitters, valve actuators and heliostats controllers with HART interface in CSP power plant.

6) Wireless Modbus TCP/RTU adaptor: sample the wired Modbus TCP/RTU signals and transmit them wirelessly in real time manner. Wireless Modbus TCP/RTU adaptors are used for heliostats controllers and meteorological station with Modbus TCP/RTU interface in CSP power plant.

7) Wireless valve position transmitters: Wireless valve position transmitters are mainly used for valve position sample of manual valves, motor driven valves, pneumatic valves, safety valves in CSP power plant.

8) Wireless multi-function node: support construction of wireless backbone network, and support Wi-Fi equipment, wireless Ethernet equipment, and ISA-100.11a wireless transmitters' connection. Wireless multi-function node can serve as wireless gateway. Wireless multi-function nodes are used for wireless control network and connection with wired control system of steam turbine generators in CSP power plant.

9) Wireless handheld equipment: carry out wireless and wired field equipment software update, authorization, diagnosis and configuration through Wi-Fi, Bluetooth or other wireless technique.

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