Pakistan Journal of Science, 71 (4 Suppl.): 2019, Page 150-153
ISSN: 2411-0930

CONTROL SYSTEM SELECTION FOR HELIOSTAT OF CONCENTRATED SOLAR THERMAL TOWER POWER PLANT

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ABSTRACT: The continuous increase in global energy demand and the impact of conventional energy sources on environment has pushed the world to adopt renewable energy technologies like solar, wind, hydral etc. Solar thermal tower power plant is an emerging technology and its feasibility depends upon its efficiency. In order to have an efficient plant, efficient solar tracking system for heliostat is needed. In this paper selection of control system for solar tracker of heliostat is carried out. Different type of control system available along with their advantages and disadvantages are included. Based on this study control system for heliostat is determined.

Keywords: Control systems, solar tower power plant, heliostat, solar energy

INTRODUCTION

Solar power Tower (SPT) is one of the most promising technologies due to its high availability and dispatchable options. Industrial and laboratory studies are currently aimed at improving SPT (Abdallah and Nijmeh, 2004; Elagib and Osman, 2013; Aksjonov *et al.*, 2016). Plants like CSIRO (Australia) PSA (Spain), NSTTF (New Mexico), THEMIS (France), and Julius Sun Tower (Germany) are dedicated to research studies. The basic concept is based on the area of individual mirrors to track the sun, which reflect the solar radiation falling on the mirrors to the receiver placed on top of tower. Thus, radiations coming from sun are concentrated on the receiver so that high concentration is achieved. As a result, the reflected energy transferred to the tower, 75-90% is absorbed by Heat transfer fluid (HTF) (Ashley *et al.*, 2019; Bingol *et al.*, 2006; López et al., 2018). In recent years, more and more attention is paid in using storage to enhance solar technology. SPT typically includes cold and hot storage placed at ground near the tower, which provides and collects the fluid flowing through receiver (Arbab *et al.*, 2009). HTF in the cold storage is pumped to the receiver. The hot HTF is then collected in a hot storage and sent to a steam generator, usually in a supercritical cycle. Solar thermal tower power plant efficiency and accuracy depends upon the amount of energy concentrated on the receiver(Bedaouche *et al.*, 2017; Luo *et al.*, 2018). Thus indirectly depends upon the energy reflected by heliostat. Accuracy of heliostat tracking is of great importance and a tracking system having actuators or drives along with a control system is used to track the sun all day long. Since in the SPT field thousand of heliostats are placed all around the tower, a calibration process is required for efficient functioning of the plant. Different types of sensors are also employed which can assist control system of heliostats.

Figure 1: Solar thermal tower power plant.

MATERIALS AND METHODS

Controller is a hardware or sometime combination of hardware and software that control the tracking system by sending motors or actuators right signals by tracking real-time or predefined calculated sun position. Controller is most important part of tracking system and also referred as brain of the system. There are three general types of control system design i.e. Open-loop, Closed Loop and Hybrid. In open loop controllers

there is no feedback mechanism (means Sensors) to remove errors. This type of controllers is inexpensive, simple and normally used in trackers that only use predefined calculations for sun position while the closed loop controllers use a sensor for feedback and continuously remove error from the output by comparing it with set point. These types of controllers are a little bit expensive and complex than open loop systems but have a good efficiency and accurate outputs.

Figure 2:Open loop System.

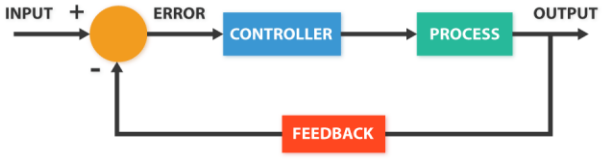

Figure 3: Close loop System.

The hybrid system is the combination of both open and closed loop system so less expensive, more accurate and efficient. From implementation point of view, the controllers are divided into three types: Passive, Microprocessor and Electro-Optical Controllers. Passive controller did not use any electronic circuitry and only used in passive trackers where tracking is performed using special type of fluid, Microprocessors are simply a small processing units so used in open loop systems to calculate sun position from formula and electro optical controller uses some kind of information from sensors, so used in closed loop system. For hybrid system a combination of microprocessor and electro optical controller is used.

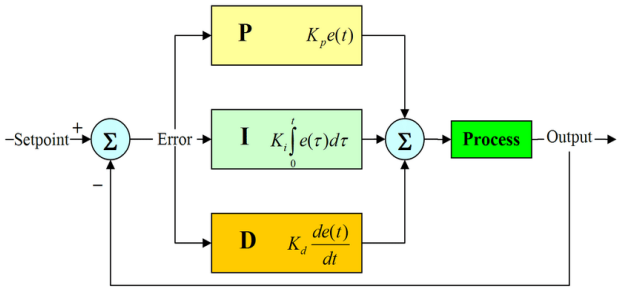

Figure 4: Block diagram of PID controller.

Fuzzy logic Controller: Fuzzy logic is a form of gradient logic in which there is a gradient of values between two bounds like all real number between 0 and 1 inclusive. In traditional Boolean logic there are only two states i.e. On/Off, True/False, 0/1 while in fuzzy logic you can assign every value in between 0 and 1 to signal partially true or partially false. For example, in case of traditional logic if we are going to check the temperature of water it will be 0 (Cold) or 1 (Hot), keeping in mind the assignment of these states is defined in rule base of fuzzy logic controller. In case of fuzzy logic, we have a gradient between 0 and 1 or Cold and Hot, so it totally depends upon the rule base of controller which value represents Hot and which one Cold. For Example, we declare 0.3 is Normal, 0.5 is Warm, 0.7 is Hot and 1 is steam (Carballo *et al.*, 2019; Chen *et al.*, 2016; Coquand *et al.*, 2017).

RESULTS AND DISCUSSION

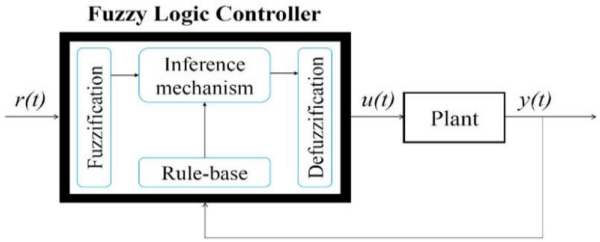

Figure 5: Fuzzy logic Controller.

Adaptive control system: Adaptive Control System can adapt its changing and unpredictable environment by updating parameters of the system which are totally uncertain or varying. It is a dynamic system that adapts to measurements of variations. For example, as an aircraft flies, during takeoff the wind speed and other aerodynamics cannot be accurately forecasted; a control algorithm is required that allows system to adjust itself to such dynamic conditions. The core of adaptive control systems is estimation of parameters, which is actually branch of system identification (Duarte *et al.*, 2011).

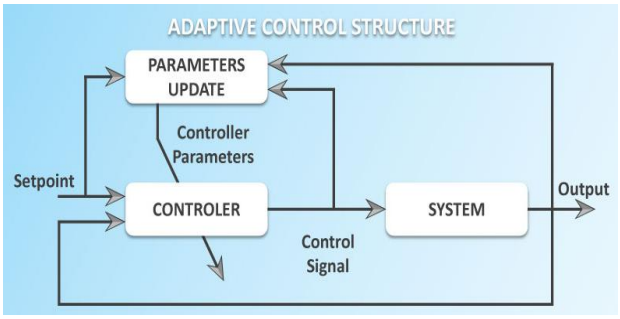

Figure 6: Adaptive control system.

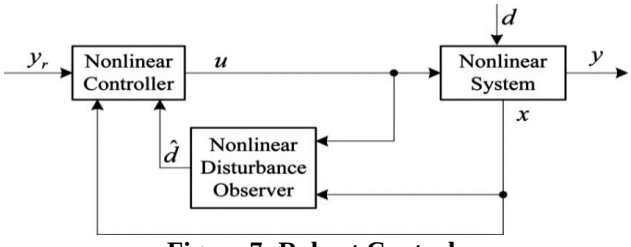

Figure 7: Robust Control.

Robust Control: Robust controllers are designed for estimation, unknown parameters or disturbances within some bounds or limits (normally small). The main objective of robust control system is robust stability and performance of the system by considering the bounded modelling errors of the system. The main difference between adaptive control algorithm and robust control algorithm is the robust system is static and does not adapt its environment, In Robust controllers it is assumed that the unknown variables will be bounded. Typically robust controllers tuned to worst case rather than the physical system, assuming future will be much like present ignoring environment changes (Younis *et al.*, 2011; Yang *et al.*, 2014).

Sliding mode: Sliding mode control or SMC is a nonlinear control algorithm that forces the system to slide along normal or reference behavior of the non-linear system within its specified limits by changing its dynamics using discontinuous control signal. Basis on its current position in state space, it can move from one continuous structure to another means its feedback control algorithm is not continuous with respect to time. Hence, they are variable structure control systems (Lou *et al.*, 2018; López *et al.*, 2018).

Advantages

- System bounds are required instead of exact value
- Reduce the order of the system

Neural network: Neural Networks or Neural Nets are used typically for problems which are non-linear in nature. For implementation of Neural Network Controller, one should understand the model of plant or transfer function. There are a lot of learning algorithms to train a neural network control system. The most common one referred to as the general learning scheme which is same as normal training process used for NN. The algorithm used offline mode to learn plant's inverse dynamics directly. A number of training patterns are selected and corresponding inputs are provided to system to obtain outputs. Once it is trained, it can provide the desired input as function of outputs of the plant. If we want to adjust the weight of net at each sample by using back propagation an online method is employed. The error is the difference between actual plant output and desired output. But it does not guarantee the initial stability of plant and it requires a knowledge of important plant parameters (i.e. Jacobean) (Elagib and Osman, 2013; Lee *et al.*, 2013).

Conventional Logics: An integrated circuit that performs a logical operation on one or more than one binary input and generates single binary output (Barsoum *et al.*, 2010). Soteris A. Kalogirou described a tracking system using combination of NAND gates and inverters with LDRs and relays. George C. Bakos used four relays and interfaced them to the computer that works under logic conditions 0 and 1. The solar energy collected from this measured mechanism on the mobile surface was much larger than the fixed surface (up to 46.46%) (Bakos, 2006).

Conclusion: Different control systems are discussed in detail. There advantages and disadvantages are enlisted. PLC system is robust and normally used in different control system of solar thermal power plant installed in harsh environment conditions.

It is concluded that Arduino Due is a cheap and updated replacement for the PLC. A control system based on this will give flexibility and more central control. Multiple heliostats placed in a stack can be controlled with a single control system.

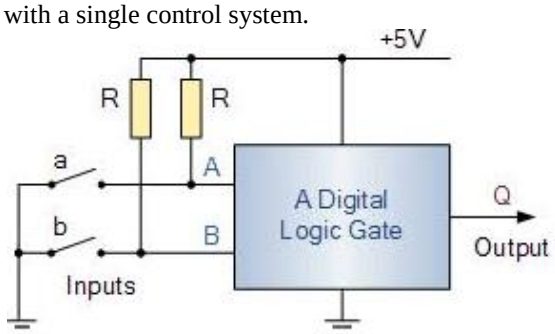

Figure 8: Digital Logics/Gates.

It is suggested that Arduino Due development board can be used for designing a Hybrid Active Controller for Heliostat's control system due to following reasons

1. Open source hardware
2. Low cost and easily available
3. Compact size with 54 I/O pins
4. 84MHz clock with 32-bit ARM cortex processor
5. RISC architecture
6. Support I2C, SPI, UART, Analog/Digital Interfacing, USB OTG Supported, PWM.

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