International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 4 Issue 1, December 2019 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Qualitative Design of Supervisory Control and Data Acquisition System for a Regenerative Type Heat Exchanger

Gourav Vivek Kulkarni[1], Divya Rajendra Lagmavar[2]

[1]B. E., Mechanical, KLS Gogte Institute of Technology, Belagavi, India
[2]B. E., Electronics and Communication, PES Institute of Technology South Campus, Bengaluru, India

ABSTRACT

The growing demand for energy calls for better and efficient systems that can work in tandem to generate the same. Control of multiple systems can prove to be an uphill task if the same needs to be done in a customized manner. In order to ease and secure the control of multiple elements in a system, a Supervisory Control and Data Acquisition system is employed. These systems facilitate complete supervisory control from remote locations with effective Human Machine Interface supported by state of the art graphics to help the control room operator vary the parameters thereby controlling the output. This paper shall consider qualitative design of such a system for an application that may employ a Regenerative type Heat Exchanger. A literature review shall be put forward to understand the research in the associated areas. Thereafter the design parameters to be considered for two types of Regenerative Heat Exchangers namely Static and Dynamic will be put forward. Certain security aspects specific to this application shall be highlighted towards the end. A conclusion shall be drawn thereafter stating the importance of employing these systems for ease of operational control and improved system efficiency so as to contribute towards technological advancement in future.

KEYWORDS: *SCADA, Regenerative, Heat Exchangers, Design, Supervisory, Control, Data, Acquisition*

How to cite this paper: Gourav Vivek Kulkarni | Divya Rajendra Lagmavar "Qualitative Design of Supervisory Control and Data Acquisition System for a Regenerative Type Heat Exchanger" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-4 | Issue-1, December 2019, pp.884-886, URL: www.ijtsrd.com/papers/ijtsrd29750.pdf

IJTSRD29750

A. INRODUCTION

Control Systems Engineering is an emerging field of Engineering wherein any system, be it simple or complex is designed to be controlled for improved performance. Thermal Engineering systems extensively employ various control systems to utilize the energy of the working fluids with optimized effectiveness to convert the same into other forms as designed. While doing so, continuous monitoring and supervision are required to ensure all the process parameters are within the designed control and the output is as planned. This itself has led to the development of a Supervisory Control and Data Acquisition system which is widely known as SCADA. These systems carry out two functions. Firstly they allow the control room operator to supervise the entire process that is taking place in real time and secondly they carry out data acquisition which allows control of the process. Thus SCADA in general refers to a system that can be used to control a large thermal system with a remote control using various devices supported by a Human Machine Interface (HMI). The control thus facilitates the output as desired by carrying out minor variations as and when required. These systems can be of utmost help in applications like Thermal Power plants, Diesel Engine Power Plants, Construction materials manufacturing plants and so on. In subsequent sections the concepts have been further elaborated.

A.A. Introduction to SCADA

SCADA stands for Supervisory Control and Data Acquisition. The acronym has become popular in the context of various applications in the recent past. In the near future there are huge prospects of these systems taking over the cumbersome human task of supervision thereby consolidating the same by bringing the control in the hands of fewer controllers with the aid of Human Machine Interface. Supervision refers to monitoring of various processes simultaneously to ensure that the variables are maintained within the prescribed limits to achieve the desired outputs. This requires extensive human intervention whenever there is a requirement of continuous monitoring and control in case of critical processes. Thus in order to make supervisory control more effective, certain standard operating procedures have been set at various plants. But there is always a need for complete control in event of hazards. This has paved way towards the development of a system that can carry out online Supervision. SCADA systems have another function which is that of data acquisition. This is facilitated by various types of sensors which include thermal sensors to detect temperature variations, pressure sensors for pressure, proximity sensors to check extents and many more. The data generated from these devices is collected and presented in real time to the control room operator. Thus SCADA facilitates remote access and can be employed in Industrial Control systems.

There are five levels of SCADA which are as follows.
Level 0 refers to the Floor level where various sensors carry out their task of data acquisition and various other actuators that are controlled by remote carry out the task of actuation.
Level 1 comprises of the input output modules and electronic circuitry for the control of the system.

Level 2 refers to the control system at the other end of the Human Machine Interface which facilitates the control from a designated control room.

Level 3 and 4 are mainly concerned with the planning and scheduling of the activities of the process flow. Thus it is quite evident that a SCADA system can be employed for efficient control of systems using displays that indicate the process in real time. For example boilers, heat exchangers, valves etc can be represented pictorially on a screen and the controller can input certain parameters which would then be converted to signals and the actuation can take place in the machinery with the help of various actuators by using Programmable Logic Controllers (PLC) or Remote Terminal Units (RTU).

A.B. Regenerative Heat Exchangers
A heat Exchanger by definition is a device used to transfer heat between two or more fluids. There are various configurations in which heat exchangers are designed to carry out heat transfer. This paper shall consider Regenerative type Heat Exchanger. As the name itself indicates, a regenerative heat exchanger initially stores heat in a certain system and utilizes it at a later stage by withdrawing the same. It is quite interesting to know how this is facilitated. In order to know the same, an important point regarding heat exchangers that needs to be kept in mind is that there is no mixing of fluids that takes place. The fluids are maintained in separate tubes and the process of heat transfer takes place thereby.

In a Regenerative Heat Exchanger, heat from the hot fluid is intermittently stored in a thermal storage before it is transferred to the cold fluid. This means that whenever the hot fluid is in action, the heat is trapped in certain material and the same is withdrawn at a later stage. While doing so, the Zeroth Law of Thermodynamics forms the basis for Heat Transfer. Depending on the method by which heat from hot fluid is stored, Regenerative Heat Exchangers are of two types i.e. Static Regenerative Heat Exchangers and Dynamic Regenerative Heat Exchangers. These shall be discussed in subsequent sections.

B. Literature Review
In the paper titled SCADA applications in thermal power plants by M. N. Lakhoua [1], the author has described the application of SCADA on a larger scale in a Thermal Power Plant. Various examples like counting system of natural gas, supervision of pumps vibrations and supervision of heavy fuel oil have been considered to elaborate the system requirements.

In the paper titled "Fault Detection of an Industrial Heat-Exchanger: A Model-Based Approach" by Dejan Dragan [2], the author has explained a model based approach towards detection of faults in industrial heat exchangers. The model considers effect of various input parameters on the working of the industrial heat exchanger and problems caused due to faults. It comments on the method of detection of faults in heat exchangers.

The paper titled "Application of Predictive Control to a Heat Exchanger" by Laszczyk P. et al [3], describes technical considerations to be taken into account while designing a Heat Exchanger system with predictive control. The predictive control involves consideration of variables like flow and temperature to extrapolate the effectiveness of the heat exchanger.

C. Types of regenerative Heat Exchangers
As discussed earlier, there are two types of Regenerative Heat Exchangers. The division has been done on the basis of overall system requirements. Applications where moving parts can be accommodated employ dynamic type while those which cannot go for the static type.

C.A. Static Regenerative Heat Exchangers
In a Static type Regenerative Heat exchanger, the heat of the hot fluid is stored in certain porous material like steel wool or rock. Once the hot fluid is passed through the porous material, the heat transferred from the hot fluid to the porous material is stored for the required time duration. When the need for passing the cold fluid arises, the same is made to pass through the porous material which makes the heat to be transferred from the porous material to the cold fluid thereby increasing its temperature and effectively using the heat which was about to be lost if not utilized. It may be noted that both the fluids never flow through the porous material at the same time thereby avoiding mixing with each other. One of the major applications of this type include utilization of concentrated solar energy for power generation at night.

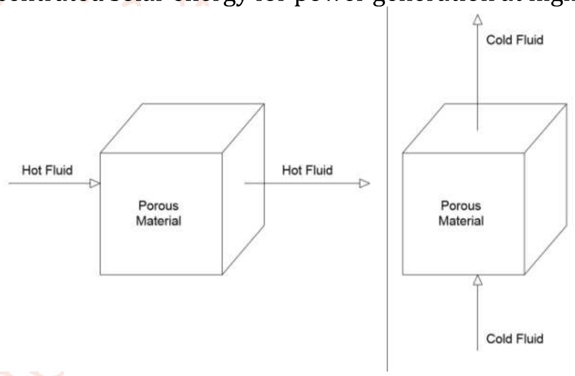

Fig.1. Static Regenerative Heat Exchanger

C.B. Dynamic Regenerative Heat Exchangers
In this type of Heat Exchanger, instead of a static pile of porous material, a wheel made up of porous material is used. A baffle plate is used to avoid mixing of the fluids. During first half of the rotation, the hot fluid flows over a part of the porous wheel, While rotating in this manner, the wheel picks up the heat from the hot fluid. During the next half of the rotation, the picked up heat is transferred to the cold fluid. Thus due to the continuous movement of the porous wheel, the type of heat exchanger has been named as dynamic type heat exchanger as depicted in Fig 2.

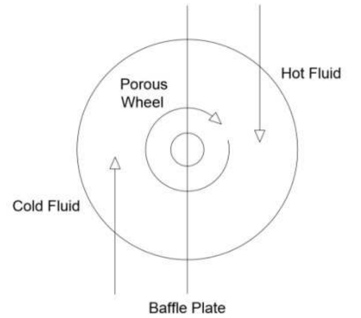

Fig2. Dynamic Regenerative Heat Exchanger

D. Qualitative design of SCADA for Regenerative Heat Exchangers in Industrial Applications

The key applications include small scale power generation units. In these units, it is required that a finite number of process parameters are controlled by supervisory control. The same shall be discussed in subsequent sections. Emphasis shall be laid on the system requirements and qualitative effect of certain key process variables on the effectiveness of the heat exchanger.

D.A. Qualitative Design of SCADA for Static type Regenerative Heat Exchangers

The control parameters in this type of Heat Exchanger include mass of the porous material, maximum temperature that can be withstood by the porous material, mass flow rate of the hot fluid, mass flow rate of the cold fluid, duration of contact flow of the hot fluid and time of flow of the cold fluid. A SCADA system would comprise of a pictorial representation of the system along with graphics to enable system control from the Human Machine Interface. Each of the mentioned parameter shall be considered and executive control shall now be discussed.

While calculating the heat retention capacity of the Heat exchanger, a certain minimum mass of the porous material needs to be maintained. This is because reduction in it would lead to lesser heat retention thereby reducing the effectiveness of the heat exchanger. Loss of mass may take place due to aggravation in flow parameters. Thus load sensors located at the core of the heat exchanger ensure constant mass. There is a certain threshold to the maximum temperature that can be attained by the porous material. Suitable warning signals need to be generated when the temperature would cross safe working limits. Mass flow rate of the hot and cold fluid can be controlled by using flow control valves. This is a critical performance variable as it contributes to effective heat transfer between the hot and the cold fluid. Actuators can be used to control these valves and appropriate employment of sensors facilitates data acquisition. The flow duration is critical because if not controlled, it can lead to mixing of the fluids which would be undesirable. Thus the SCADA system should have control over the mentioned parameters improve the effectiveness of the heat exchanger.

D.B. Qualitative Design of SCADA for Dynamic type Regenerative Heat Exchangers

The control parameters in this type of Heat Exchanger include angular velocity of the porous wheel, mass of the wheel, maximum temperature that could be withstood by the porous wheel, mass flow rates of hot and cold fluids and duration of contact flow of hot and cold fluid. Similar to the Static type the SCADA system would comprise of a pictorial representation of the system along with graphics to enable system control from the Human Machine Interface. Each of the mentioned parameter shall be considered and executive control shall now be discussed.

Rotational or angular velocity of wheel needs to be controlled using motor control. This is an essential performance parameter because for effective heat transfer, the fluid needs to be in contact with the wheel for a certain duration. This duration is governed by the angular velocity of the wheel. Accelerometers can be employed to regulate the angular velocity and suitable alarm systems can be employed to warn in event the velocity crosses the working limits. The mass of the wheel governs the specific heat capacity of the material and should ideally be constant to maintain the effectiveness of the system. Load sensors can facilitate the required service in this regard. The maximum temperature limit needs to be checked from time to time because in case of dynamic systems, due to rotation, there is certain additional heat that needs to be accounted for which may be generated due to the incoming energy to rotate the wheel. The mass flow rates of hot and cold fluids can be controlled by flow controlled valves and actuators similar to that in static type. The contact duration in this case plays an important role because due to rotation, there is continuous motion and the effective time is less. This can be countered by designing for optimized wheel diameter and angular velocity.

E. Security concerns and their effects in the context of SCADA for Regenerative Heat Exchangers

A major security concern in the field of Thermal Engineering is system failure due to malware attack or arbitrary efforts by individuals to cause damage. In the case of Regenerative heat exchangers, the system needs to made fool proof by providing adequate standard operating procedures and checking the adherence to the same by periodic assessments.

Malware attacks can cause serious deviations in the performance of the system thereby leading to wastage of energy that could have been harnessed. Such events should be avoided to the best possible extent by effective and secure design of systems.

Conclusion

Thus it can be concluded that in order to establish control over a wider range of systems, SCADA systems can be employed. These systems can facilitate accurate supervision and allow the control room operator to control the entire plant from a single remote location. Use of Human Machine Interface and graphics can make the system more user friendly and employable thereby leading to technological advancement by a single point control. The qualitative design concepts pave way towards a new area of research wherein SCADA can be effectively employed to facilitate the working of Static as well as Dynamic type Regenerative Heat Exchangers.

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