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Conference Paper

Modern Day Automation for Heat Exchanger Monitoring

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Abstract: Heat exchanger monitoring for efficiency & fouling is a considerable economic & technical concern for any process plant/industry, be it chemical, oil & gas or power. Heat Exchangers cleaning/repair forms the major part of the maintenance budget & its availability continues to be a major concern for operations. Non-availability of a Critical exchanger directly affects the production of the refinery unit. BUT traditionally it's still ignored during engineering & draws little attention from process engineers. The purpose of this paper is to highlight heat exchanger performance related issues in brief & will detail the instrumentation / automation options to address these issues. The article will also include the various options available for each method of monitoring depending upon the site conditions, criticality & will also include the cost element. The paper will be focused on the different types of instrumentation schemes for effective monitoring including achieving these solutions through HART, FF, Modbus or Wireless sensors & multiplexers. Technological developments in this field will also be discussed in brief. Typical case implementation will also be discussed from the various solutions implemented during the vast experience gained working on various solutions provided in Fluor for different brown field & green field Refineries / Petrochemical units. Fluor's Subject Matter Experts can develop algorithm for effective monitoring of various types of exchangers using the existing PCS or new PCS systems by utilizing their experience & customize it for specific units based on the discussions with the end user's process/maintenance engineers & offline data available from past records. Economic model & its necessity for the ultimate result of reaping benefits by implementing effective maintenance schedule with correct timing & cleaning methodology.

Keywords: Industrial Automation, Engineering, Maintenance, Heat Exchanger

1. Introduction

Heat exchangers can have a range of problems which can cause them to perform poorly or stop working all together. The most common heat exchanger problem for many chemical engineers is fouling which can occur within the inside of a tube wall and decrease performance and even damage the heat exchanger in the long run. Heat exchanger degradation and failure decrease system reliability while increasing plant operation and maintenance costs. Heat exchanger monitoring for efficiency & fouling continues to be a considerable economic & technical concern for any process plant/industry, be it chemical, oil & gas or power. Heat Exchangers cleaning/repair forms the major part of the maintenance budget & its availability continues to be a major concern for operations. Non-availability of a Critical exchanger directly affects the production of the refinery unit. Section-1 will describe these issues. Traditionally Heat Exchanger Monitoring addressed during maintenance & it's still ignored during engineering & draws little attention from process engineers at the time of engineering. Section-2 will detail the instrumentation / automation options to address the issues discussed in Section-1. This section will include the various options available for each method of monitoring depending upon the site conditions, criticality & will also talk about cost optimizations possible for each solution. Section-2 will be mainly be focused on the different types of instrumentation schemes for effective monitoring including achieving these solutions through HART, FF, Modbus or wireless sensors & multiplexers. Technological developments in this field will also be discussed in brief.

2. Heat Exchanger & Its Performance/Problems

This section describes the Heat exchanger, its key performance indicators & general concerns which process/maintenance engineers face while monitoring. Heat exchanger monitoring for efficiency & fouling is a considerable economic & technical concern for any process plant/industry, be it chemical, oil & gas or power. Heat Exchangers cleaning/repair forms the major part of the maintenance budget & its availability continues to be a major concern for operations. Even though most process heat exchangers are installed with a margin of design heat exchange capacity, gradual fouling of the exchanger surfaces reduce the effectiveness of heat transfer, requiring more fuel to be burned in the process heaters and more heat rejected to the environment.

Fouling is the buildup of debris and dirt on the surface area of a heat exchanger and is the most common problem encountered with heat exchangers. Fouling prevents heat from transferring, increases the pressure drop and can obstruct fluid flow. This problem can be closely linked to another problems on the list; acting as a chain reaction. A lot of exchanger leakage can be found to come from flow distribution issues. If the flow through the exchanger is not uniform, then high flow velocities can cause an additional problem, vibration. This vibration can increase the effect of erosion in exchangers which then leads to frequent leakage of exchangers creating problematic maintenance and associated costs.

Finally the problem of fouling can come in many forms listed below but it is essential to determine the type of fouling and it's mechanism to offer a solution. Different types of fouling can be described as Crystallization, Decomposition, Polymerization and / or oxidation, Settlement of sludge, rust or dust particles, Biological deposits, Corrosion etc.

Above problems guide towards the Key Performance indicators of a Heat exchanger, which are:

- Heat Exchanger Duty
- Process/Utility Side Pressure Drop: Determine pressure drop across tubes and indicate fouling.
- Tube side fouling coefficient: Based on pressure drop, with correction for flow rate, to quantify actual surface fouling.
- Inlet & Outlet Conditions: Effects of inlet/outlet conditions on performance.
- Heat Transfer Degradation: Determine the effect of degradation on the heat transfer achieved within the exchanger.

3. Heat Exchanger Monitoring

This section describes the various how the key performance parameters can be monitored for a Heat exchanger & which automation / instrumentation techniques shall be used for monitoring of a Heat Exchanger. It all depends how critical is the exchanger to the process, can it be bypassed, how does it affect the production, time to repair/maintenance etc. Apart from criticality, we also need to consider if the upgrade is for brown field or green field project, location of the exchange, type of system being used to connect the field instrumentation etc also defines the type of automation.

Heat exchanger monitoring is designed to monitor the performance of heat exchangers with the primary goal of developing an optimum exchanger cleaning strategy. Monitoring can be used to determine the effects of base case fouling as well as to indicate the relative effectiveness of various potential solutions to fouling problems.

The heat exchanger monitoring generally consists of data collection & exchanger performance calculations, this shall be followed by an economic analysis to help decide on the appropriate time & duration of maintenance. The data collection mainly consists of collecting operating data like pressure, temperature, flow etc., estimation &/or assumption of the incomplete/missing data, identifying & editing of inaccuracies in the data collection to eliminate inconsistencies. The heat exchanger performance can then be determined by compiling these parameters to calculate heat duties, pressure drop and flow corrected heat transfer coefficients. These parameters can be trended for overall heat transfer coefficients versus time which indicates the rate of fouling in the heat exchanger. Based on the maintenance costs, loss of energy, cost of production loss an economic model can be developed. The economic model can be used to develop & optimize the maintenance and/or cleaning schedule with respect to the timing, duration, exchanger maintenance philosophy & cleaning technique to optimize the overall cost of maintenance to help reduce the production loss. This analysis can also be helpful in evaluation of possible fouling patterns & defining the prevention measures.

Moving forward, we need to ascertain the optimum use of field instrumentation with appropriate technology & system. In old days, heat exchanger used to have test thermowell for periodic temperature survey & pressure gauges for manual checking of pressure drop. This checking used to be by field operators based on the schedule. Now the technology has improved drastically resulting in better affordability of the automation in monitoring of such maintenance prone equipments. Field instrumentation has wide variety to suit the requirement. We have temperature, pressure & flow monitoring. We can use switches and/or transmitters for field instrumentation. Signal transfer from these instruments can be either by digital transfer, 4-20 mA, HART, foundation field bus, mod-bus, wireless which can be further optimized by using multiplexers (HART, FF or Wireless) as these signals are for long term monitoring & analysis. The overall solution can be optimized as per the criticality & the budget available. If you consider the complete life cycle cost the cost of any solution which can predict fouling can be paid back pretty quickly.

The sample model we implemented for this study was an existing exchanger in a refinery. Being a brown field upgrade, multiple options were explored as key performance parameter of the upgrade was not just Safety & cost but the minimal changes & minimal work in the running plant. We actually have to study the complete instrumentation in the existing unit including the system & possible protocols which can be used. Our final solution came out to be quite cheap while the implementation also was very easy & fast due the existing facilities available.

We used the FF multiplexer for temperature & the existing non-critical segment for pressure transmitters. This enables the solution implementation by just laying the secondary cables to the existing multiplexer JBs & field barrier segment JB. Online configuration was done in the DCS for defining the instruments in the system to display on the existing system & HMI. A graphics page was developed & the calculation blocks were used in the DCS system. Calculation blocks were customized & added to the block library, similarly Heat exchanger figure was also added to the object library. These were used as standard later for the whole plant. Field instrumentation & signal processing from field to DCS was done differently as per the suitability to that location & the available spares/infrastructure in that location. In some cases we used the existing mod-bus multiplexer for temperature & the readings were taken directly to the HMI so no IO usage as well as no loading to controller in the DCS & we found that this solution has just marginal added cost against using temperature gauges. We also used the existing flow meters in the common inlet & outlet line of the exchangers by developing a correlation model in the system which helped us to develop a more robust system for monitoring the fouling pattern. We developed the Algorithm in DCS in consultation with process / maintenance engineers and experience data of last few years was used to fine tune the algorithm. Reports were generated for continues monitoring and trends configured for online prediction of fouling pattern. This actually indicates the changes in exchanger performance but it doesn't help us to determine the maintenance schedule directly. An arbitrary schedule considering the fouling pattern alone will reduce the real optimization opportunities. Hence we developed an economy model which gave the correlation with the production loss cost, maintenance costs, loss of energy etc. which gave various options to evaluate the maintenance / cleaning strategy to be developed.

Adequate engineering care shall be taken while engineering the green field projects for the thermowell heat exchanger nozzle. The caution to be considered here is, nozzle size on which TW shall be installed, since Temperature instruments including TWs where these are installed are required to be blown to the size of 3" or 4" or 6".

Technology has not just changed the online monitoring but offline monitoring has can provide semi automatic type of offline models due to easy availability & cost affordability of the hand held systems, wireless monitors, and infrared tools. These tools have capability to store the data from field & download to the system in control rooms or asset management systems which gives the similar trends and algorithms works similarly for these in the same fashion, the results are slower but are more accurate over a period of time, if take out the human error factor.

Following are some of the points which are quite simple but gives you great returns.

Effects of heat exchanger operating temperature: The heat exchanger operating temperature affects heat exchange. In refineries, stream temperatures can vary due to changes in the operating procedures. Any alterations in the stream temperature will create a variation in the approaches; the exchanger duty and log mean temperature difference. A low approach difference will give a corresponding log mean temperature difference, and high load vice versa. When the operating temperature limits are exceeded, the material condenses as a result of deposits and coats the internals of heat exchangers, which produces a wall temperature that is lower than the bulk limit temperature. Since operating temperature needs to be maintained so the inlet and outlet temperature are generally monitored by Operators & hence becomes the first Alert point.

Effects of heat exchanger operating pressure: The pressure differential between the suction and discharge of each fluid stream is the main driving force of that stream. The pressure differential is affected by fluid flow rates, pipe surface friction, and number of heat exchanger passes, bulk density and viscosity. Deposits, if present, reduce the available surface area and increase the pressure differential, thus resulting in inadequate flow. So if a pressure difference is noticed, the model starts giving you a trend which directly relates to the efficiency.

Effects of nature and properties of heat exchanger are equally important & this plays a very important role in developing the algorithm. Algorithm must take care of the chemical relationship between the heat exchanger materials of construction and the chemical nature of the fluid stream in transit.

With the above understanding & actually doing many such studies & implementing the findings/results on actual projects, we found that just inlet & outlet temperatures of hot & cold streams alone can give you a great piece of information when it comes to monitoring of heat exchangers. In fact there are companies which have developed commercial models for Heat Exchanger Monitoring on this basis itself.

As you can see that small changes in the field instrumentation optimizing the IO/technology available & possible with the existing infrastructure at minimal cost were implemented. This is what we actually discussed above in the paper. Calculations were developed based on the past historical data and the past operational/maintenance experience. These calculations were also supplemented by the Company database & Experts inputs resulting in a simple but very useful model for generating various kinds of alerts as discussed in the paper above. Reports were be generated for continues monitoring and trends were configured to predict fouling pattern. Simple changes & calculations resulted in highly efficient monitoring & in turn better plant performance was achieved by altering the process controls according.

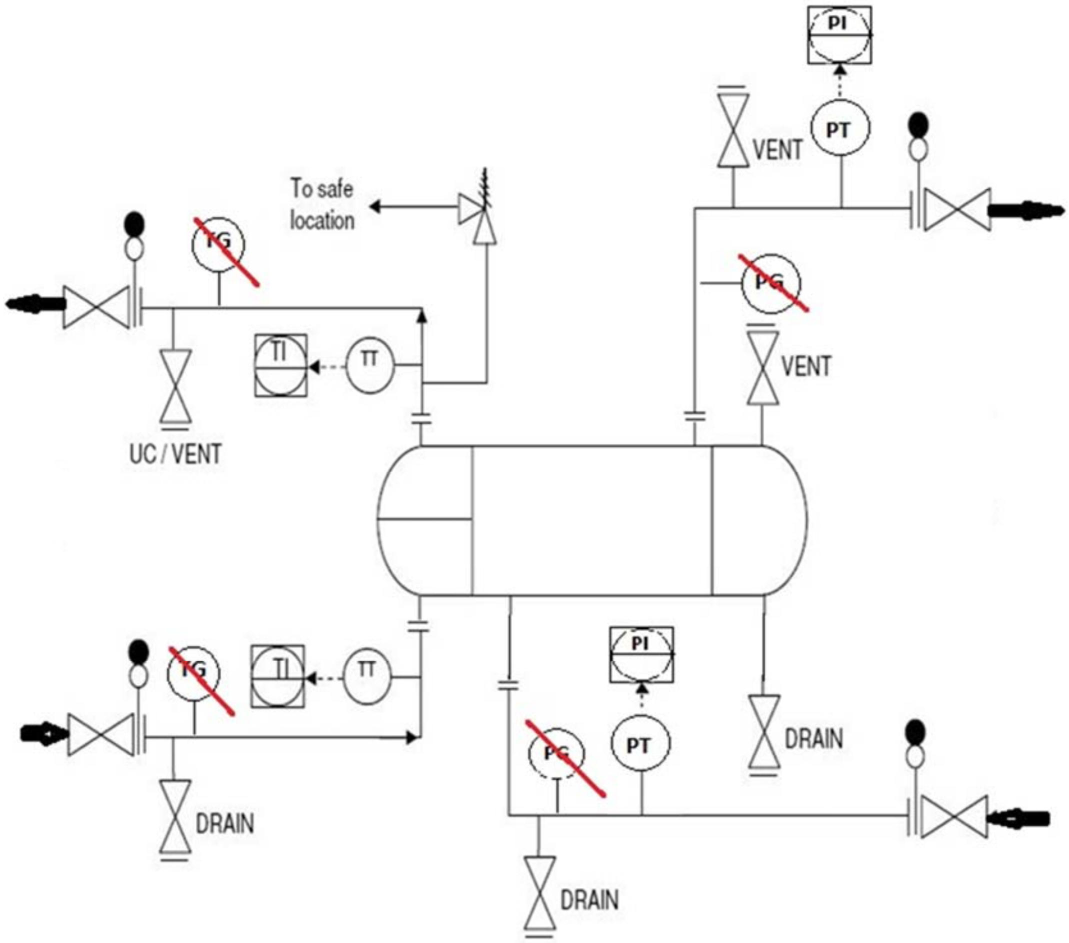

Figure 1. S*ample Model used for Study on Brown Field Engineering*

4. Conclusion

Automated analysis and automated alerts help reduce the risks associated with manual monitoring and provide earlier identification of abnormal situations. A good Heat Exchanger model can result in potential savings provided we attach an economic model combined with the fouling pattern analysis & define the maintenance / cleaning strategy. Continuation in the monitoring & the maintenance/cleaning activities is essential to achieve the goal of overall cost reduction & stabilized refinery operations.

Automated Monitoring & Alerts will result in:

- Very effective monitoring of exchanger fouling pattern.
- Heat transfer efficiency improvement & reduced operating cost
- Increased Exchanger availability by monitoring fouling pattern & predictive/proactive planned maintenance.
- More effective temperature/process control
- Significant reduction in Downtime due to planned maintenance.

Adequate importance shall be given at the time of engineering to ensure availability of adequate the field instrumentation with proper operation/maintenance risk assessment as per the criticality & availability requirements of each heat exchanger. We shall consider the optimum use of the technology by utilizing the signal multiplexing for this monitoring unless we are using some of these parameters for the control.

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