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Optimal design and development of heat tracing systems for enhancement of energy saving

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Abstract:

Because rapid rise in the consumption of energy due to growing demand, there requires a need for the effective use of energy resources as the cost of energy has been rising due to growing demand. In addition to industries are being strictly regulated by the government in terms of the reduction of the carbon dioxide emissions ,so all the industries are striving towards the most energy efficient solutions. In this report, the trace heating system of the petrochemical industry has been discussed which explains about the optimal design and the usage of the technologies of trace heaters towards an energy efficient solution. Here the proper selection of insulation system and the trace heater technology and its electrical distribution resulted in an energy saving of 37% where the control and monitoring strategies resulted in 91% savings. Here the evaluated results can be applied to the new installations in the trace heating so that the installation cost will be saved.

1 Introduction

To meet the required energy conservation goals there are many resources available in petrochemical industry. The United Nations industrial has given a benchmark for energy consumption for many processes by publishing a paper which estimates that the 26% energy saving be there if all are operated according to the given benchmark. The tern heat tracing refers to the applications of heat continuously or intermittently to pipes, vessel or a tank in order to replace the heat lost to the surroundings. Heat tracing is very much useful in cases of protection from being frozen, thawing, in maintaining the temperature of fluids at required point, prevention of condensation of gas and prevention of components separation in fluids[1].

There are two types of heat tracing systems which are electric and fluid. In fluid heat tracing systems, the fluids flowing the small pipeline or tube are used to transfer the heat the process materials at a very high temperatures. These fluid tubes are generally attached to the tubes which transport the process materials. We use either steam or organic heat transfer for the tracing of heat through fluids. Waste from the process steam, fossil fuel burning or steam or electricity can be used to provide these fluids for heat tracing.

Now, the other type of heat tracing other than fluid is the electric heat tracing where the heat transfer is done through the conversion of electric power into heat using the dissipated energy from the resistances. Most of the electric heat tracing systems employs the resistances which are run through the cables and are placed on the surface of the pipe for the heat transfer. These cables are connected to the voltage source and the current starts flowing through these cables where the resistances present in the cables dissipate the heat proportional to the square of the current and the resistance of the elements where the current flows [1]-[5]. Other than this type of electric heat tracing, there is skin conduction effect and impedance induction is also used to produce the heat to transfer to the process materials of the pipelines.

Now the energy saving of the trace heating systems can be done by using many tools of which the fluid or the steam trace heating system has the energy conservation opportunities by improving the insulation of the pipes to reduce the heat loss to the ambient and by improving the steam traps and its monitoring and maintenance, repair of leakage, recovery of flash steam and return of the condensate. Now in this paper, the major focus is on the application of heat tracing systems optimally to conserve energy so the reduction in the consumption of energy or saving of energy can be done by improving the heat tracing technologies used by the systems and by proper controlling and monitoring the trace systems and by proper selection of insulation and cladding and by proper placement and rating of the power distribution systems [5].

The different areas of engineering includes the what is required to be heated to what amount of temperature which gives the process involved and the type of insulation to be used to hold the cable as well as pipe which gives the mechanical construction of the system, proper placement of the circuit breakers and proper ranges of voltages and junction boxes and termination ends which involves in electrical configuration of electric heat trace system. Other field of engineering includes are instrumentation and piping engineering [2]-[4]. Among all these different areas of engineering disciplines, there are lot of opportunities involved which provides a tool for the proper management and saving of energy throughout the whole process.

Through different examples, the energy saving can be observed in the heat tracing system by the usage of improved technology which involves in proper selection of the insulator by improving the insulator technology, proper control of the system and the better strategy for monitoring the different aspects of the system, optimized distribution of power alternatives, good selection of trace heaters which can have a performance which is optimized.

2 Methodologies

The optimal placement and application of trace heating system using resistance has led to the efficiency of the system through energy savings and the conservation of energy is also done. In addition to these above methods used there are other factors involved in leading the trace heating design to become optimal. These factors can be proper man force to correct the deficiencies occurred, acceptable span of temperature, proper maintenance and improving the flexibility of operation and recovering the cost involved the production which lost due to the faults or losses. All these requirements of the user who uses in the end can be met for this principle design with the lowest operating, running and installation cost. Here we will observe the impact of different parameters which are associated with the design of the system on the usage of the energy and the costs incurred to it.

2.1 Considerations of insulation system

The insulation system is one of the main important factor of the trace heating system as it prevents from heat loss to the surroundings. The heat loss can be reduced by the appropriate choice of the insulator which has low K-factor i.e; low thermal conductivity. Here insulation and the K-factor are inversely related. Other than this the choice of insulation also depends on the insulation material's thermal characteristics, resistant to the moisture, range of temperature, resistance to fire, chemical compatibility, resistant to the smoke, toxicity tolerance, cost of the insulation and the maintenance of the insulation.

we can state the different insulation materials has diversified characteristics as the materials like Mineral wool and polyiscocyanurate are resistant to the moisture in the atmosphere and have good thermal conductivity with a limited temperature exposure. Expanded perlite and Calcium silicate can found to be having higher thermal conductivity and shows rigidity with high temperature exposures. Some insulation are used under stress so that they can be compressed under load and are found to be soft mechanically. These types of insulators are fiber glass and mineral wool. For the insulation optimization there are various parameters which are to be considered such as thickness of the layer, manylayered insulation usage and the type of insulation. Resistance towards moisture, maximum exposure temperature limit and rigidity are also included. For the energy saving an insulation type with low K-factor has to be chosen if that can be availed so that the costs can be reduced. Depending on the availability of the space inside the cable and the cost incurred in the insulation material the insulation can be made multilayered to reduce the heat loss and energy usage.

Now analyzing the given case study by using different insulation technologies provides us with an optimized insulation system which is either calcium silicate or mineral for the above given case. As we can observe from the table, polyurethane and polyiscocyanurate are not considered even though they are rigid because of the low maximum exposure temperature. Here we are observing the difference by using different thickness of the insulation and obtain an optimized solution. From the table we can observe that the mineral wool is the better system as save 37% of the energy with insulation of 3" thickness and calcium silicate gives 14% with 3" thickness. Even though if we use 2" thickness of mineral wool it gave 22% savings which is still better than the rest of the systems. In this case the cable used is mineral-insulated (MI) cable. In addition to the conservation of the energy it helps in the optimization of the whole design of the trace heating system with fewer circuits and long length of circuits. This analysis shows that the insulation optimization is one of the major key factor of the optimized design of trace heating as it involves in saving of many millions of dollars.

2.2 Trace heaters and different considerations of power distribution

2.2.1 Self-regulating heaters

Self-regulating heaters are one of the most popular and the most effective form of electric heat-tracing and are mostly used by all the industrial users for the heat tracing systems. Self-regulating heat-tracing stand out to be different because of the parallel resistance technology which accounts for an advantage as compared to the other trace heat technologies by eliminating the burning of the heater cables internally due to the increase in dissipation occurred through the overlapping of the resistance. Self-regulating tracers has a heating cable run alternatively between line and neutral so giving an advantage to be cut to any desired length and field-installed within the limitations of the voltage drop on the bus wires. They have good impact resistance and are routinely handled in the field. Its feature provides in reduction of operating and installation costs and provides an increase in reliability. Because of its parallel-resistance feature, It provides an element of safety unlike any other form of electric resistance tracing product because the heater cannot be destroyed by its own heat output. The only disadvantage is its limited operating temperatures 366°F (186°C) for constant exposure and 420°F (215°C) for intermittent exposure.

2.2.1 Zone Heaters

In the beginning of the trace heating systems zone heaters were the most used technologies by the industries because of its parallel resistance of the heaters in the cable so gradually they have started to substitute the self regulating heaters. The major advantage of zone heaters is that they can be cut to any desired length which gives a constant wattage output as the power output obtained by these heaters is independent of the circuit length. Along with this advantage is another incentive in terms of cost reduction in operation and installation of this technology. The parallel design of the circuit of zone heaters accounts for a major advantage as there won't be any heat out because of the excessive voltage unlike series configuration as the resistance used are also thin and are fed with the standard voltages. These are less damage prone and are subjected to moisture and can withstand an with an exposure temperature up to 1000°F (538°C) which accounts for the use of Fiber glass-insulated cables. The presence of a fluoro-polymer jacket on the insulation, the rating of the temperature exposure is got down to 545°F (285°C) by giving the moisture protection. The main disadvantage of the zone heaters is that they are subjected with the excessive heat and there happens a burnout internally which results in the damage of the zone heaters.

2.2.2 Mineral-Insulated Cable Heater

Mineral-insulated (MI) cable is a different but another most employed technology which has constant-wattage characteristic, and have a configuration of series resistance design which consists of a thick resistance wire running across the length of the pipe and cannot be cut to the required length but can withstand a very high temperature range. By using the good conductor sheaths made of conductive alloys it can withstand a temperature of 1500°F (800°C).Because of its distinct features of high resistance and its tolerance to high temperature it can be used ruggedly. The important key drawback of MI is that they cannot be varied according to the pipe length during the process as they cannot be cut down. So it becomes difficult in designing length as it has to be predefined before the installation and its requires an special designing of these cables. Here in these kind of cables make use of the variable control of voltage at different positions along the pipe which are distributed for short lengths. Because of its series configuration, even if anyone part or the piece of resistance is failed it results in the failure of the whole heat tracing system which also accompanies with a draw of excessive heating and less conductivity due to its thickness.

3 Control of the trace heating system and strategy of monitoring

The control and the monitoring of the trace heating system is very important to maintain the temperature and can be used for the reliability of the system as it senses the deficiency and immediately alarms the operator. With the use many temperature sensors placed across the pipe and the indicators using an light circuits in the end can help in improving the flexibility to maximum by detecting the very low temperature, failure of any sensors like thermostat, ground faults, low line current etc. For the implementation of these control and monitoring methods the temperature of the process has to be maintained at Maintenance temperature (70°F) and the parameters present in the given case other than maintenance temperature are same.

Proper software installation and control architecture, proper communication and the networking between many components and the placement of equipment also accounts to the total costs greatly in addition to control and monitoring methods. Controlling defines as the system ability to find and the control the deficiencies and to restore them within the safe range so that the energy will be saved.And monitoring can be defined as the operating status indication through the use of some sensors.

4 Various control methods

4.1 Uncontrolled or Self-Regulating Control

Here the system is not controlled and is continuously given with full power supply by using self regulating and constant wattage heaters; the heater has been controlled for different applications of heat. Here the energy usage is more as it is fully supplied all the time with 8-10% for freeze protection and 15-20% for maintaining the temperature.

4.2 Ambient-Sensing Control

In this type of control we use a temperature sensor like thermostat to measure the temperature and it will turn on the heater below the ambient temperature and it will be above ambient temperature. Here the thermostat is set to all the temperatures below the maintenance temperature.

4.3 Line-Sensing Control

It measures the maintenance temperature only and the heater circuit will be on or off or controlled according to this temperature. It is used for wide ranges of temperature and the most energy saving control.

4.4 Proportional Ambient Sensing

In this control method, the heater sets its control between the minimum ambient temperature and the maintained temperature and the heater is initially set at the minimum ambient temperature. Here the power output is decreased as the actual ambient temperature reaches the required maintenance temperature. This control is also a energy saving control used frequently.

Out of all these control methods it is observed that the line-sensing control is the most energy saving control with an energy saving of 91% with 70^{o}F maintenance temperature. Here the heater is chosen with respect to the minimum heat loss produced by the cables at the minimum ambient temperature.

5 Discussion

It is observed that the proper implementation and design of the application and technologies of heat tracing system have resulted in the conservation of energy greatly. With the help of the mentioned case studies it is observed that the savings can be done to a maximum of 91% with proper monitoring and the control technology and has an energy reduction resulted in a savings of 37% using proper insulation system and the trace heating technology and its electrical distribution. Overall the optimal usage of the resources available in this technology can result in a millions of savings in cost. Here the end user has to choose the technology optimally which can result in an overall best performance of the system. So that's why the user has to test these independently resulting in an optimized solution. Then there has to be holistic view taken for the whole system and decide the proper system for the most energy savings. In addition to these technologies are the different other parameters which result in a great costs reduction are the proper networking facilities and infrastructure of the system, proper sensing and alarming equipments, appropriate software implementation for control and monitoring strategies.

6 Conclusions

From the usage of the energy efficient technologies of the heat tracing system has resulted in a great amount of energy savings in many industries which has also resulted in the reduction of the carbon footprints. By using these methods it is very easy to save overall energy to 50%. But the appropriate design of this whole heating system is a very tedious and complex method. It requires an in-hand experience and knowledge about the different components used in the system which also includes various parameters like the process temperature and the flow of the material passages and the other performance affecting parameters. In a single facility it requires a customized solution of each and every circuit as every circuit has different application. So application of different solution is not the best method to be applied instead the solution has to be considered by combining all the optimized methods to obtain the best possible solution. In addition to these energy conservation goals the industrial vendor should also keep in mind the low cost investment as there incurs costs in installation of heater and its wiring, termination circuits and the electrical and mechanical systems.

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