Plant modernization for energy efficiency and loss control

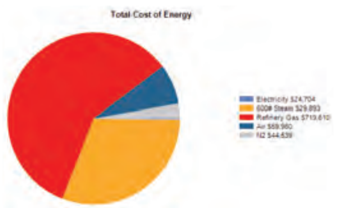
Plants are investing in modernization to add a second layer of automation focused on equipment, not on process, to improve energy efficiency and loss control, complementing the basic process control and safety provided by the DCS and SIS. By *Jonas Berge*.

Older plants are installing dramatically more sensors to enable performance monitoring and loss detection to address their energy challenges and compete with newer plants with these additional measurements already included. The same plant-wide wireless sensor network infrastructure and software also benefits other disciplines in the plant.

Energy challenges

Areas where energy is being wasted can be difficult to detect and pin-point. Traditionally, energy efficiency efforts have focused only on a few large energy consumers like fired heaters, boilers, and electricity for compressors etc. Now, plants are also turning their attention to the large number of smaller equipment responsible for energy consumption. These include:

- Pipe and flange leaks
- Equipment not turned off
- Performance degradation
- Steam trap failure
- Relief valve seat passing
- Relief valve release
- Heat exchanger fouling
- Cooling tower excess cooling
- Air cooled heat exchanger fouling and excess cooling.



Level 2	Level 3	EAC	Electricity $	600# Steam $	Refinery Gas $	Air $	N2 $
Conversion Units	Coker	Coker Common Energy	680.62	4,460.51	47,009.80	11,179.39	0.00
		Total	680.62	4,460.51	47,009.80	11,179.39	0.00
	FCCU	FCCU Common Energy	1,767.38	1,036.43	6,586.49	23,229.70	0.00
		Total	1,767.38	1,036.43	6,586.49	23,229.70	0.00
	Reformer	Reformer Common Energy	7,945.60	1,286.26	46,087.06	5,291.53	0.00
		Total	7,945.60	1,286.26	46,087.06	5,291.53	0.00
	Total		10,393.60	6,783.20	99,683.35	39,700.62	0.00
Crude Area	CDU-1	ACU-1 Column	0.00	2,462.88	0.00	0.00	0.00

Energy cost report

Most plants manually inspect for steam trap failure, passing relief valves, and the performance of certain pieces of equipment. These inspections are done on a periodic basis, typically only once a year, or rely on maintenance contracts. Plants are now modernizing with more automation to monitor for energy efficiency and loss control, becoming smarter and data-driven.

Leaks, equipment not turned off, and performance degradation

Running fans at excess speeds, failed steam traps, fouling, inefficient combustion, pipe and flange leaks, poor insulation on steam and condensate lines, passing relief valves, tank leaks, unused equipment not turned off, passing valves, and valves left open, are some of the reasons why plants are consuming more energy than they should.

Poor combustion control, especially when fuel heat content changes, wastes energy by causing excessive stack losses. Leaking compressed air systems and valves left open, when not producing, waste the electricity that was consumed to compress the air. Leaking steam systems waste the fuel that was consumed to generate steam. Pumps and fans left on, when not producing, waste electricity. Water leaking and condensate not recovered waste the water itself, plus the chemicals and energy required to treat it.

Energy consumption not managed

Most plants today only measure the energy streams with a single meter at the source; at the battery limits where water, gas, and electricity enter the plant, and from the air compressors, steam boiler, and utilities plant, etc. Data may get manually compiled in an Excel spreadsheet. Therefore, there is no visibility if there are leaks in an area somewhere in the plant, if consumption is higher than normal in some plant unit, or if some equipment is running when not needed.

By only looking at overall plant energy consumption, problems cannot be pinpointed, so there is little or nothing that can be done to improve and sustain. Energy managers at most sites do not have the information they need to drive energy management practices according to ISO 50001 to reduce energy consumption and losses. Whatever little data is available from the control system is infrequently put into spreadsheets manually.

Energy management information system (EMIS)

Energy management is not just about electricity. There are many energy streams flowing through a plant and all have to be accounted for in order to get a complete picture. By modernizing with additional flowmeters and wireless electric power meters at the plant area, unit, and equipment levels together with an Energy Management Information System (EMIS),, plants get the ability to manage consumption and loss of energy around the plant with much finer granularity.

Energy streams are measured for each plant area and each unit as well as for equipment with high consumption. There are five principal energy streams in plants (W.A.G.E.S):

- Water
- Air (compressed)
- Gas (fuel)
- Electricity
- Steam.

Depending on the type of plant, there may be additional energy streams such as H2, N2, and CO2. For air and other gases the line pressure is also measured for the stream. Some of the required measurements may be available from the DCS. The missing measurements must be added. Metering transmitters have to be deployed plant-wide to enable data-driven energy management. Note that these additional measurements feed directly into the historian and EMIS software; they need not go through the control system. Essential plant systems such as the water system, compressed air system, fuel gas system, electrical system, and steam system are all fully monitored.

Flow readings can be used for water balancing and other energy balances, that is, matching total energy production precisely against areas of consumption. For flow measurement, an orifice plate or Annubar slip between existing flanges or, if flow cannot be interrupted for installation, clamp-on ultrasonic flowmeters with WirelessHART adapters are used.

Energy management is done using built-for-purpose energy management software, not in the DCS. That is, the additional flow measurements for plant areas, units, and equipment are integrated directly to the historian together with existing measurements from the control system. The EMIS software analyzes the data from the historian to set energy targets, trigger alarms, and generate reports.

Energy Account Centers (EACs) are set up for plant areas, units, or individual equipment such as a large pump, heater, or reactor. Each EAC is set up to monitor the energy streams going into that EAC. This may include one or more of the standard water, air, gas, electricity, and steam streams consumed by the EAC as well as additional custom energy streams like N2 and CO2 etc. as necessary to customize for unique requirements of each plant. The software will report flow rate, target, cost, and where applicable also calorific value and enthalpy, for each energy steam of every EAC.

The software includes a target calculator model, which dynamically computes what the target energy consumption should be for any particular energy stream for a piece of equipment, plant unit, or area based on the production rate, environmental conditions, and other variables affecting energy consumption.

For instance, for a boiler the target gas consumption can be calculated from steam pressure, steam flow rate, and steam temperature. EMIS software with models for common process equipment designed specifically for the process industry, not a building management or discrete manufacturing, is available. For instance, the boiler efficiency model uses first principles and variables like feed-water temperature, and fuel flow to calculate enthalpy, efficiency, target fuel flow, specific energy, steam cost, etc.

Reports are available for each level of the plant hierarchy such as for the entire plant, unit, or equipment, and can be extracted based on a range of dates and time. Note that this information does not go to the operators, but is rolled-up into simple dashboard KPIs to those responsible for energy efficiency and loss prevention. A cost report shows the breakdown of energy consumption in the different plant areas with total cost for the areas and energy streams. For instance, the energy manager can drill down from plant level, to area, unit, and individual piece of equipment to see energy consumption and cost for each in the selected time period such as day, week, or month.

At the unit level, it is possible to see the minimum and maximum production cost, average, and production rate along with the consumption breakdown for equipment in the unit. Trend charts makes it easy to see when consumption exceeds the target. The time report shows if the target is being met, production rate, cumulative savings, total energy cost, total production, cost of production.

It is possible to drill down into a detailed report for an energy stream.

A status report shows if areas, units, and equipment are meeting their energy targets for each of the energy streams or not, making it easy to visualize overconsumption.

The EMIS software triggers overconsumption alarms if consumption exceeds the target. The alarms are logged and can be reviewed for plant, area, unit, or for a particular piece of equipment over a particular period of time, with the ability to zoom in on a particular energy stream. There is an alarm summary to easily identify points in time of overconsumption.

Overconsumption alarms are logged with start and end time, equipment tag, duration, and cost. Each event can be commented and a reason code assigned.

Start by deploying energy stream measurements in each area, then at a unit level, and lastly at the major energy consuming equipment.

Data-driven action

Measurement alone doesn't reduce energy consumption, but measurement enables excess consumption, to be detected and investigated so corrective action can be taken.

Since the flow of energy around the plant is measured with finer granularity, the energy manager gets the ability to detect and pinpoint overconsumption and leaks to a particular plant area, unit, or even an individual piece of equipment and investigate why. This in turn allows plants to uncover leaks, combustion inefficiencies, and equipment running when not necessary etc. By settling these issues sooner, a plant can improve and sustain energy efficiency to further reduce energy costs.

The energy manager can identify where and how much energy is being consumed across the plant and how much it is costing the plant and prioritize improvements accordingly. Conversely, the energy manager can also understand periods of best performance and make actions repeatable.

Heat exchanger fouling

Fouling builds up in heat exchanger bundles over time, impeding the heat transfer and thus reducing efficiency. In heating applications

Energy Stream	Causes of Energy Waste and Loss	Remedial Action
Water	Pipe leaks, flange leaks, tank leaks, passing valves, valves left open	Tighten joints, replace gaskets and packings, shut off when not producing
Air (Compressed)	Pipe leaks, flange leaks, valves left open	Tighten joints, replace gaskets and packings, shut off when not producing
Gas (Fuel)	Inefficient combustion, fouling	Tune combustion. Clean equipment.
Electricity	Unused equipment not turned off, excess fan speed, fouling	Shut off when not in use. Adjust fan speed to demand. Clean
Steam (at different pressures)	Failed steam traps, fouling, passing relief valves, poor insulation	Replace steam traps. Clean. Overhaul valves. Fix insulation
Others (Nitrogen, Hydrogen, Carbon dioxide etc.)	Pipe leaks, flange leaks, valves left open	

this in turn requires more fuel to fire burners to make up heat, unnecessarily driving up energy cost. In cooling applications it increases the need for cooling water. Additionally, this inefficiency may impact production throughput.

Overdue cleaning

The best practice in the past was to routinely pull out heat exchanger bundles one by one for cleaning or inject anti-foulant chemicals without much information about the condition of the heat exchanger bundles. However, dismantling and cleaning heat exchangers is very labor intensive and can consume considerable time. Heat exchanger bundles require a crane for removal.

Performance testing with calculations in an Excel spreadsheet is a somewhat better approach, but generally, the bundles are not individually instrumented thus not providing condition information for individual bundles. Temperature measurement at the inlet of the first bundle and outlet of the last bundle across the entire bank of bundles is not sufficient.

The measurements for individual bundle performance monitoring are missing. Periodically, testing dozens of heat exchanger bundles manually with a portable temperature probe is still very labor intensive and therefore, does not get done frequently enough, resulting in fouling and invisible energy loss that can continue for many months. Moreover, fouling is not always long term.

For instance, certain crude oil blends in the refining industry cause fouling at a faster rate than expected. Since with a manual approach, the four temperature points are not measured simultaneously, process dynamics result in inaccurate and often confusing results. Lastly, each performance check is a snapshot in time and excessive fouling can occur until the next manual survey.

Heat exchanger performance monitoring

By modernizing with wireless transmitters on heat exchangers in conjunction with built-for-purpose analytics software with a heat exchanger condition monitoring algorithm, condition monitoring is automated and plants get the ability to track the fouling in each heat exchanger bundle. Trend charts visualize how rapidly the performance deteriorates over time.

If performance deviates from a baseline, an alarm is triggered in the condition monitoring software prompting attention. Some of the required measurements may be available from the DCS such as process flow, but not the cooling water flow or heating steam flow and temperature points between bundles. The missing measurements must be added.

Wireless temperature transmitters can make use of existing thermowells between bundles, or non-intrusive clamp-on pipe surface temperature sensors can be used to provide a temperature profile. These are very easy to install and a low risk to deploy. The software and additional transmitters turns an ordinary heat exchanger into a smart heat exchanger by providing performance indication.

Note that this detailed information does not go to the operators, who see only a simple status indication, but to maintenance personnel responsible for cleaning the heat exchangers. Start deployment on exchangers in dirty service like crude.

How to combat fouling

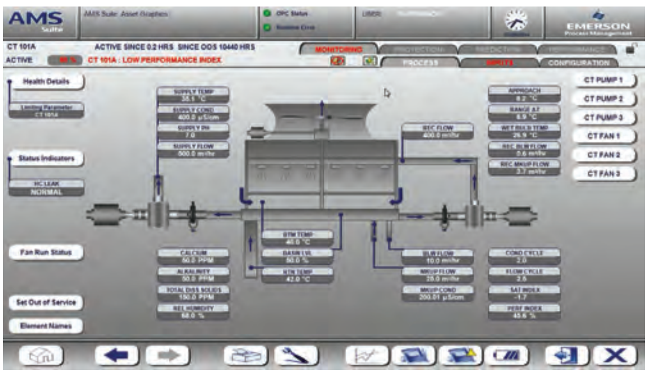
The fouling information can be used to make better decisions to combat fouling such as cleaning the heat exchanger bundles or to inject anti-foulant chemicals. This enables the maintenance manager to strike a balance between the need to clean the heat exchanger to improve energy efficiency, and the production outage associated with cleaning. Time is also saved not having to clean unnecessarily.

Cooling tower excess cooling

Cooling tower fans may be running unnecessarily or at unnecessarily high speed at night or even during the day at certain times of the year, wasting electricity. The same applies to Air Cooled Heat Exchangers (ACHE) as well.

Excessive fan operation

In most plants the actual capacity of each cooling tower cell is not known. Therefore, all fans are often left on, and at full speed, even when full cooling capacity is not required. Running more fans or running fans faster than required is a waste of money. This state may go undetected for long periods of time. Energy waste may continue for many months.



Cooling tower display

Performance monitoring and fan optimization

Fan power can be optimized without being cooling limited. Cooling towers can be comprised of both fixed and variable speed fans of various sizes. It may be possible to reduce power consumption by modulating the speed of variable speed fans or shutting down fixed speed fans.

The priority will be to run the available variable speed fans before running the fixed speed fans, as variable speed fans can be modulated to reduce power consumption by balancing the load across the available variable speed fans.

By modernizing with wireless transmitters on cooling towers in conjunction with built-for-purpose analytics software with cooling tower monitoring and a fan power optimization algorithm, the software recommends which fans must be turned on or can be turned off, and for which fans the speeds must be increased or can be decreased. Plants get the ability to reduce fan power consumption. The additional transmitters and software turns an ordinary cooling tower into a smart cooling tower by providing performance indication.

Fan power optimization

The fan power optimization information is used to turn fans on and off, and to adjust the speed of variable speed fans. Plants can thus reduce the fan power consumption.

Common platform

The information required by the energy efficiency and loss control manager and many other plant disciplines is not found on the DCS operator screens. By deploying wireless sensors throughout the plant, the information they need can be provided on the historian or Asset Management System (AMS). As WirelessHART gateways provide multiple connectivity options compatible with most or all historians and control systems it is possible to modernize just about any plant.

Deployment

By deploying a second layer of automation the plant gains the ability to uncover inefficiency and energy loss such as steam trap failure, relief valve seat passing and releases, heat exchanger fouling, cooling tower excess cooling, air cooled heat exchanger fouling and excess cooling, leaks, equipment not turned off, and performance degradation etc. in hundreds of points around the plant. Just wireless transmitters alone are not sufficient, software for performance monitoring, loss detection, and energy management is also required.

Additional measurements can deliver significant benefits to the plant for the long term. The additional measurements do not benefit the designer, process licensor, or contractor but they can earn a reputation of providing designs which are more energy efficient. The benefits go to the bottom line of the plant. Therefore users must specify these energy efficiency solutions.

New plants should be built, and existing plants modernized, with energy efficiency and loss control in mind. Start by incorporating energy efficiency solutions into current projects and to modernize existing sites. Request an energy efficiency expert to review current or proposed procedures for energy efficiency and loss control. **CEA**

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