ONLINE PATTERN RECOGNITION: DISTILLATION TOWERS' JET FLOODING DETECTION

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Abstract

Originally this application was developed (December'00) in order to detect an abnormal behavior on highly cycling variables (temperatures) on the Delayed Coker unit analyzing firs and second derivatives, inflection, maximum, minimums, and their sequence. The very same algorithm has been used for flooding detection on our Cat Cracker's Light Ends deethanizer tower. Due to lack of appropriate standard measurements (delta pressure and temperature), the algorithm was used to detect singularities on available thermocouples readings.

Internal vapor and reflux traffic usually begins to "chatter", or get noisy prior to the onset of jet flooding affecting thermocouples located below the flooding zone.

In order to recognize the abnormal behavior, the algorithm just identifies when any temperature's second derivative is beyond its limits, triggering an alarm to the console operator some 45-60 minutes before jet flooding's classical symptoms become evident.

Introduction

Distillation tower operation is more efficient when working as close as possible to jet flooding limits. But when tower becomes flooded, you are not just losing efficiency but a considerable amount of time to recover from the upset while products remain out of specification. No doubt, nothing can replace direct measurement, but when required instrumentation is not available, something should be done to keep distillation tower operation as eficient as possible without running into an upset.

To cope with this problem, a Process Control Application created to recognize variables patterns in a semi batch process was successfully adapted to identify flooding temperatures' patterns in our Cat Cracker's deethanizer.

Problem

Deethanizer's objective is to recover as much LPG (Liquefied Petroleum Gases) as possible keeping at a minimum the ethane that can affect debutanizer and depropanizer performances. Consider a distillation tower without intermediate pressure transmitters at all, and with just few thermocouples (see Figure 1). Consider also, that Fluid Catalitic Cracker's deethanizer receive a highly variable quality feed. And that as in most distillation towers, you want to maximize fractionation but avoiding jet flooding upsets. Traditionally, incipient jet flooding is detected measuring pressure drop or inferred from trays' temperature gap. So, if you don't have the measurements, how to walk the narrow edge between maximum efficiency and jet flooding's upsets?

Onset of jet flooding can be defined as when the vapor traffic is sufficient to holdup the downcoming reflux, until the liquid holdup becomes sufficient to overcome the vapor traffic and slump down the tower. This disruption in equilibrium and internal vapor/reflux flow sets off disturbances that get amplified by the bottoms level control loop, bottoms temperature loop, and often the overhead pressure loop. After a flooding upset a single look to temperatures behavior is enough to understand what happened: curves' shapes are quite characteristic. Nevertheless, this post-mortem knowledge is of no use for process, when flooded, it will take many hours to recover the tower from the upset.

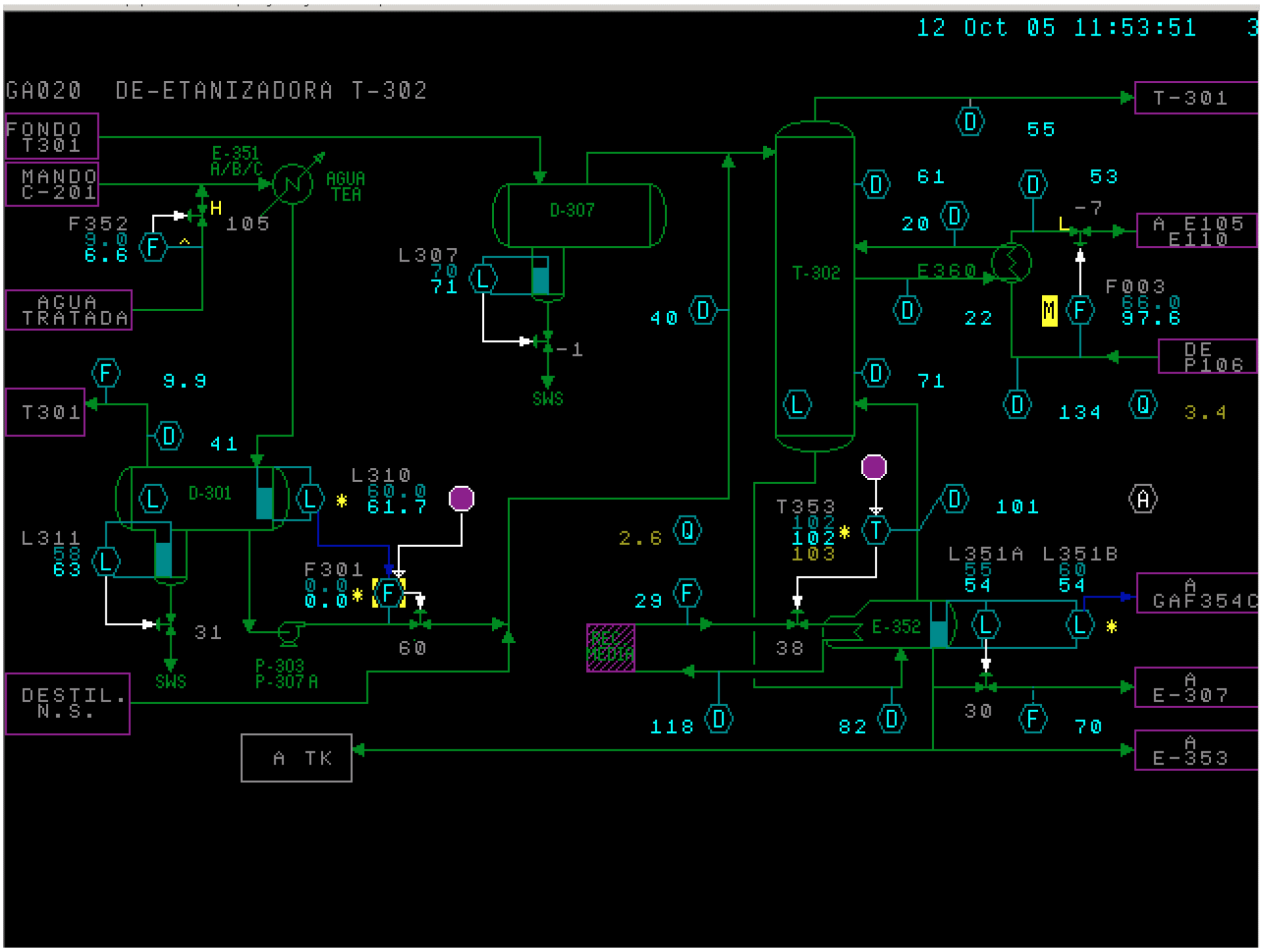

Figure 1: Deethanizer Process Control Schematic

In brief, the problem was how to identify incipient flooding conditions. Standard alarming was of no use (high/low, rate of change, deviation), so it was decided to adapt an old Process Control Application originally developed to do online pattern recognition on Delayed Coker unit (December'00).

On Line Pattern Recognition Application

This application was developed on Honeywell TDC3000's AM (Application Module) to detect an abnormal behavior (coking reaction interruption due unexpectedly drums cooling) on highly cycling variables (temperatures) on the Delayed Coker unit (see Process Control Schematic on Figure 2). Due to its cycling behavior (~50-450°C, see Figure 3), it is impossible to alarm deviations of these variables on the standard way.

In order to recognize a variable developing an abnormal behavior, a normal pattern identification algorithm was created based on the slope integration while the second derivative is null. In fact, the application is identifying "singularities" (second derivative not null), and evaluating the periods between singularities.

The first derivative is assimilated to the online calculation of the slope of the variable, using a minimum square linear regression of the three last PVs (Present Value) stored to evaluate it. So, the online second derivative calculation is assimilated to the difference between the actual PV and the extrapolated value using the previously calculated slope. The second derivative is considered null when its absolute value is lower than a certain constant used to tune the application in order to avoid false alarm triggering.

An application tag stores the integration of the calculated slope while the second derivative is null. If the second derivative is not null, the tag that keeps the slope integration is reseted to zero.

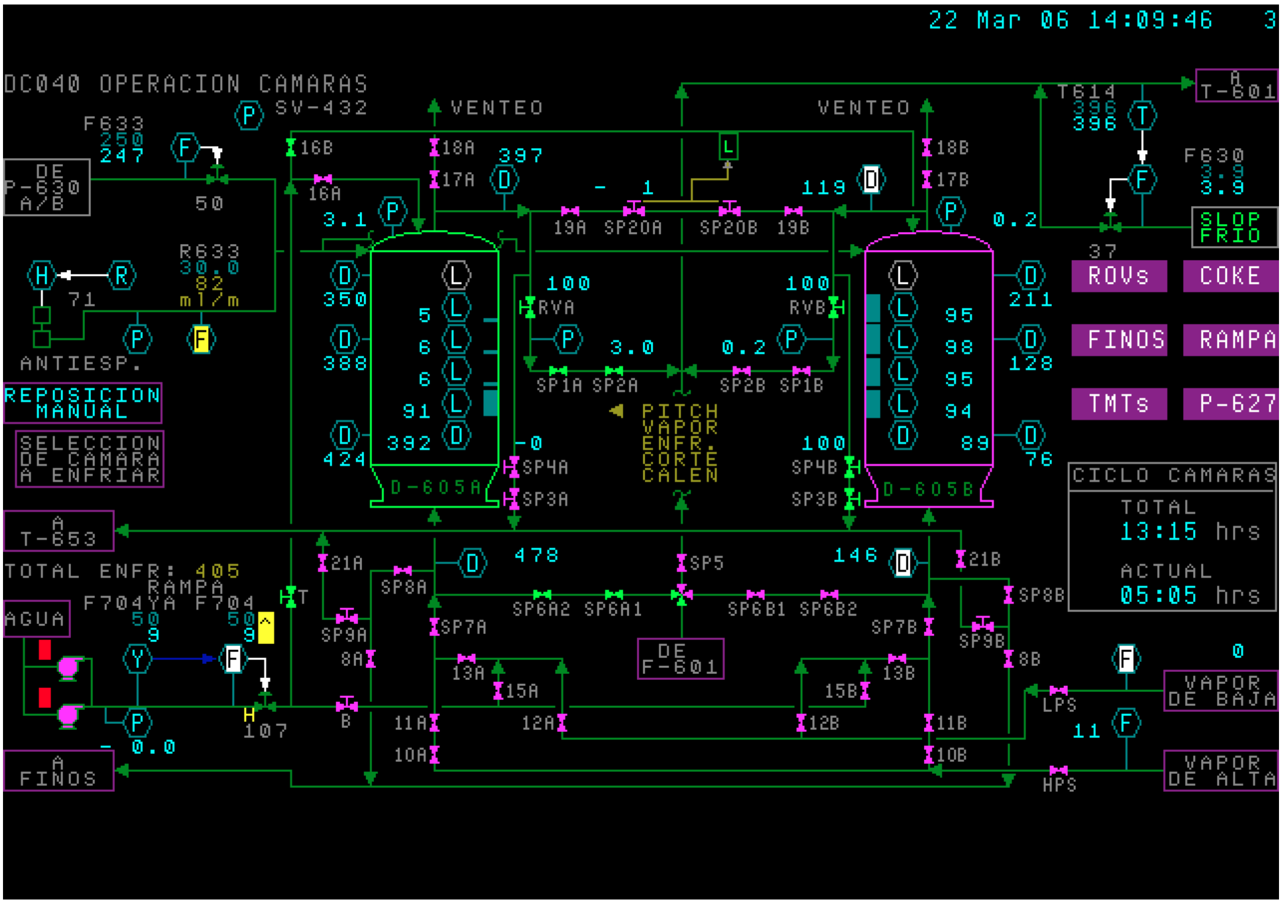

Figure 2: Delayed Coker Drums Process Control Schematic

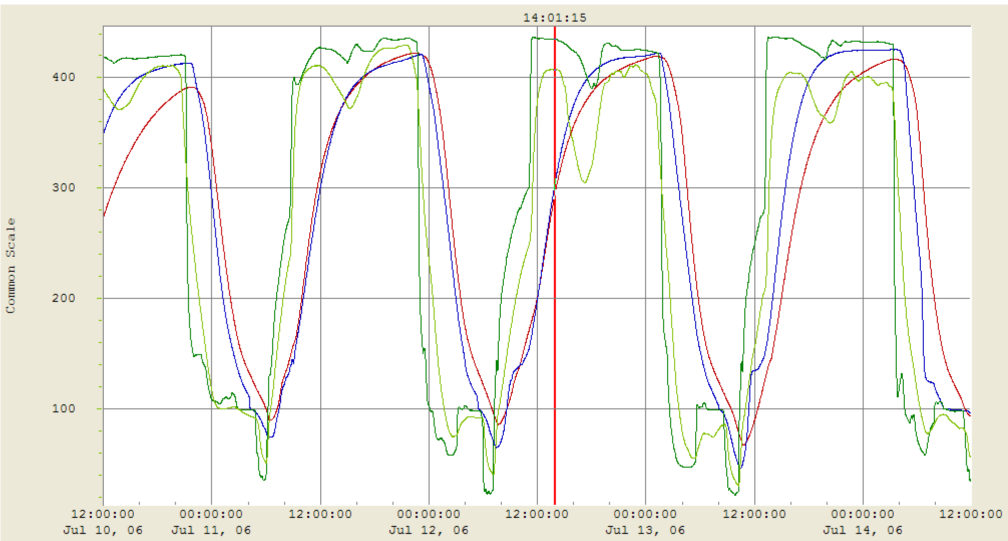

Figure 3: Delayed Coker Drum "A": Normal Temperatures evolution along four days

Simulations using historical data teach us that when the temperature cycle is completed without extra "singularities" the slope integration will always be greater or equal to zero. Other variables that could be of help to characterize the pattern, like total slope change through singularities, have not been used because they were not necessary for this problem.

To better understand how this algorithm works, singularities should be roughly associated to the beginning and end of the different batch operations (pre heating, on oil drum, stripping, cooling, etc.) carried out on through a Delayed Coker cycle. The slope integration can be associated with the operation by itself, being the final value of the integration not affected by variable operations lengths so common on Delayed Coker units. When an abnormal cooling happens, and it is so severe to jeopardize the coking reaction, a singularity is detected, the integration is reseted to zero, and a negative slope (due to unexpected cooling) integration will evolve that triggers a low PV alarm on the tag.

The final implementation looks to eight drum temperatures and triggers an alarm when the slope integration of any of them is below a certain value. On Figure 4 you can see Application's Process Schematics displaying the tags that keep the slope integration (DCGnnn tags).

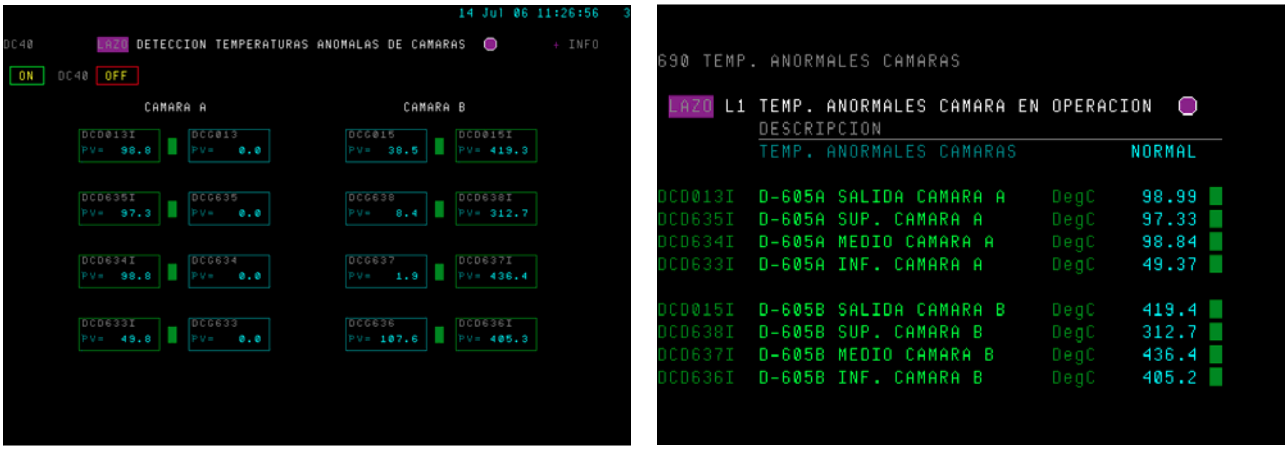

Figure 4: Delayed Coker On Line Pattern Recognition Process Control Schematics

Solution

The adaptation of the Online Pattern Recognition Application to detect deethanizer's incipient jet flooding was quite easy: it was just necessary to keep non null second derivative detection. Application tags are created to store the number of consecutive times the second derivative is null. So after a while, this tag displays its maximum value (see Application Schematic on Figure 5, tags GAGnnn displaying PV=120). When incipient flooding is detected, the tag is reseted to zero triggering a PV rate of change alarm that is seted in a value high enough to avoid alarm chattering.

Figure 5: Deethanizer On Line Pattern Recognition Process Control Schematic

Figure 6 displays in blue one of deethanizer's temperatures and in red the associated Online Pattern Recognition tag displaying six incipient jet flooding upsets. Also, in the same figure, we should highlight that temperature instabilities not related with flooding didn't trigger jet flooding alarms.

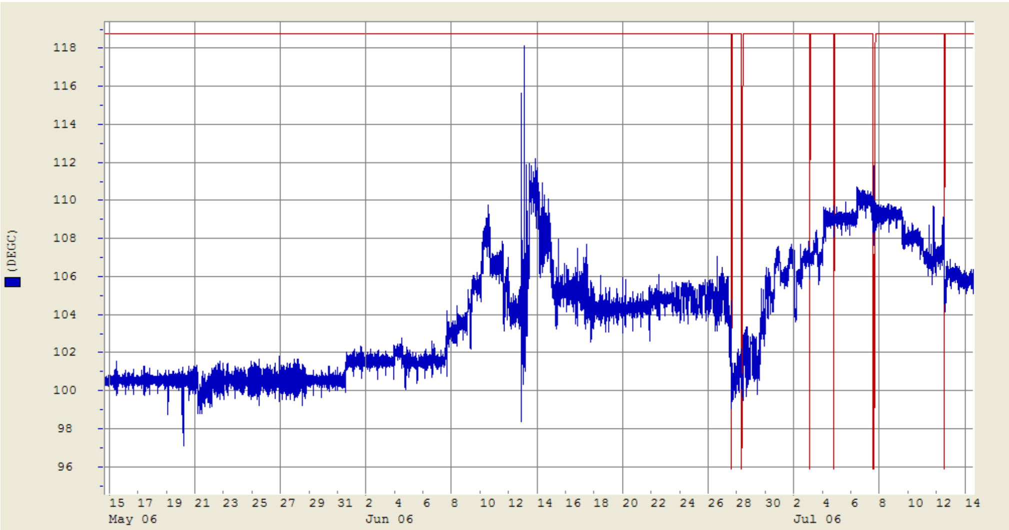

Figure 6: Deethanizer On Line Pattern Recognition Process Control Schematic

Deethanizer's temperatures On Line Pattern Recognition helps to detect pre-flooding conditions before massive internal vapor/reflux flow disruption occurs, avoiding long recovering times with products out of specification.

Conclusions:

Online Pattern Recognition, as we defined it, is a practical and flexible technology that can be easily deployed on Process Control Systems for early problems identification. The first tests of its use to identify Cat Cracker's deethanizer jet flooding triggered consistently the flooding alarm to Console Operator some 45-60' before jet flooding's symptoms become evident. Since its commissioning in January'02 no flooding upset has been produced in our deethanizer.

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Education

- Facultad de Ingeniería Química, Universidad Nacional del Litoral
- Instituto de Física Balseiro, Universidad Nacional de Cuyo/CONEA

Positions:
PASA

- **1978, Process Engineer:** Catalytic hydrochloric acid production viability test.

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- **1979, Process Engineer:** Physicochemical process simulations, energy conservation projects, Power House Foxboro Spectrum implementation.
- **1984, Senior System Analyst:** Computerized systems installation on ESSO's tankers, Lab & Process databases development and implementation, process data capture, business applications analysis.
- **1992, Design Engineer:** water treatment facilities evaluation, Honeywell Micro TDC3000 installation, Oil Spill Control Team member.
- **1995, Process Control Application Engineer:** Process Control Advanced Applications development, hot loop transfer to Honeywell TDC3000, Advanced Control Applications deployment, Multiple Secondaries Optimization algorithm development, Alarm System revision, Cat Cracker DMC development, Online Pattern Recognition application development, Cat Cracker U-Bends simulation, Plant Information System implementation (Uniformance), Power House loop transfer (Foxboro Spectrum) to Honeywell TDC3000, Power House Advanced Control Applications development and implemntation, gaseous effluents model (EPA, ISC3) integration with Process Databases, new cat Cracker and Light Ends DMC development.

Extracurricular Activities

- Lecturer at Escuela de Defensa nacional (Petroleum & Geopolotics, 1998).
- Analysis of Management Study Cases: Study of leading cases of management successes and failures, underlying factors and reasons.
- Government and Social Institutions Relationships: Interaction between government, army, church, civil organizations and private enterprises along the history in Europe, USA, and South America.
- Philosophical Mainstreams and their impact in present social environment.
- Roman, Cannon and English Law: the roots of present juridical systems.
- Effective Enterprise Organization: The Fall of the Perfect Executive Ideal.
- Petroleum Business Economics.
- Behavioral Principles. Genetic and Environmental Components in Human Behavior.
- Technology Impact Through Human Ages.