Expert System Ensures Pipeline Efficiency and Safety through Real-Time Monitoring and Diagnosis

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Abstract

Tennessee Gas Pipeline, an El Paso Energy wholly owned interstate pipeline system, improved the efficiency, reliability, consistency and safety of its 16,000 mile transmission system by creating Proactive Controller's Assistant (ProCA) based on Gensym's G2 software. ProCA is used for real-time monitoring and maintenance of pipeline efficiency, creating virtual pressure transmitters to protect equipment, predicting demand patterns to reduce engine and compressor maintenance, and providing operators with enhanced decision support to identify and avoid potential problems before they reach the problem stage.

1. Introduction

El Paso Energy Corporation provides total energy solutions worldwide through its regulated and non-regulated business units. Founded in 1928, (NYSE symbol: EPG) is now one of the nation's largest natural gas companies with combined transmission, gathering, processing and marketing volumes in excess of 22 billion cubic feet of gas per day. El Paso Energy Corporation is based in Houston, Texas.

El Paso Energy Corporation operates natural gas transmission, energy resources, and international energy development project. EPG's federally regulated gas transmission system is the nation's only coast to coast natural gas pipeline. EPG accesses all major markets and supply basins via a 27,000 mile pipeline. EPG has an annual throughput of over 3.5 trillion cubic feet of natural gas. EPG's natural gas transmission operations include El Paso Natural Gas Company and Tennessee Gas Pipeline Company.

- **El Paso Natural Gas Company** operates two wholly owned interstate pipeline systems, El Paso Natural Gas and Mojave. Mojave owns an interest in the TransColorado pipeline, currently under construction in Colorado. The El Paso system transports gas from southwestern United States supply basins to the Texas, California and the mid-continent market.

- **Tennessee Gas Pipeline Company** operates three separate interstate pipeline systems, including Tennessee Gas Pipeline, East Tennessee Natural Gas, and Midwestern Gas Transmission. Tennessee Gas Pipeline Company also dispatches for Channel Industries Gas and the Viosca Knoll gathering system. The Tennessee system serves twenty of the northeast and mideast states. Tennessee Gas supervises all of these pipelines and compressors assets (approximately 18,000 miles of pipe and 1.5 million horsepower) from a single gas control center located northwest of Houston. This gas control center was built underground during the Cuban-US missile crisis. Today "Gas Control", as it is known to employees and vendors, is underneath a private company owned country club and golf course.

2. Commitment and Focus

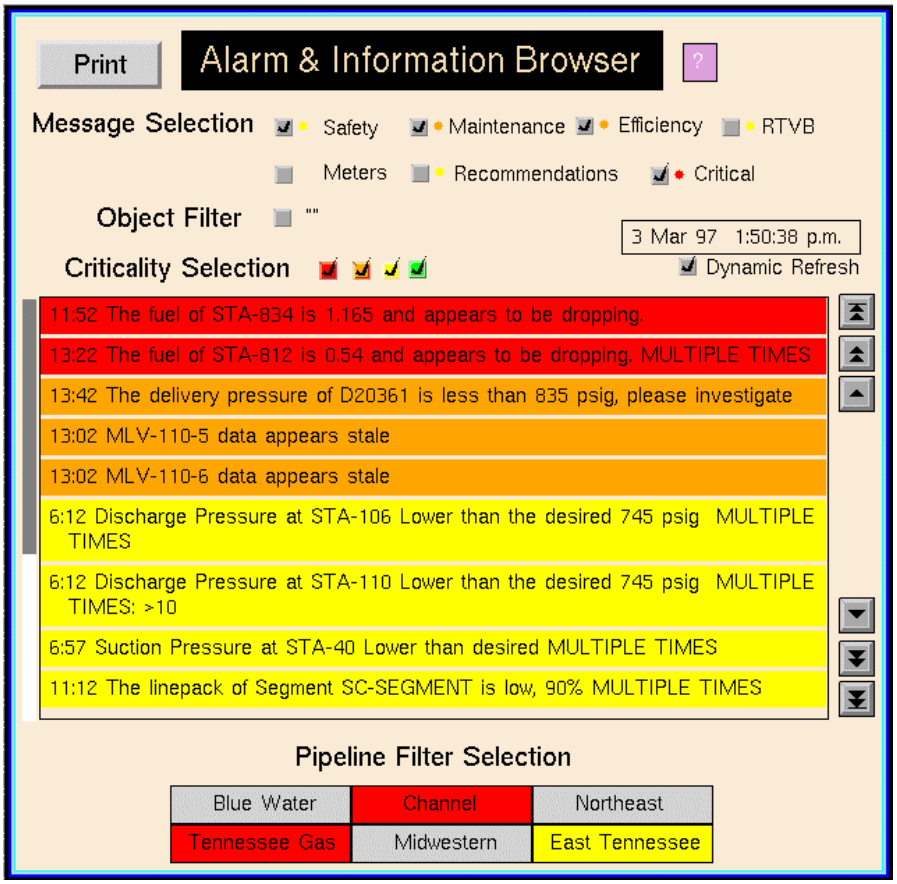
Quality and Reliability are prerequisites in the energy transmission industry. Seeking to improve quality and reliability, competitive advantage, lower operation costs and maximization of resources, Tennessee Gas Pipeline Company researched the intelligent real-time systems software marketplace. Tennessee Gas Pipeline Company selected Gensym for it's development environment, object oriented, what-if, and real-time inferential reasoning (unmanned computing) abilities. Today Tennessee Gas Pipeline Company uses **Gensym's G2 Expert System** as a standard tool for meeting these objectives. The core purpose of this tool was to provide real-time information for enhanced operator decision support. The core tool model is today known as the **Proactive Controller's Assistant** or **ProCA**. **ProCA** provides operator recommendations for a more efficient, reliable and safer pipeline.

The heuristic knowledge of the best "Gas Control" controllers was re-created in **ProCA** (using G2) to replicate, with G2's rules and procedures the "Gas Control" daily operations. G2 programmers supporting the Gas Control Room add/modify information to the **ProCA** knowledge base daily to reflect current conditions. The result is a dynamic, constantly improving system that not only supports the controllers in their operations, but also the measurement and communications departments' requests for special studies as well. The current **ProCA** focus areas are:

- Alarm Management
- Pipeline Efficiency
- Reliability
- Fuel Efficiency
- Controller Development

Alarm Management

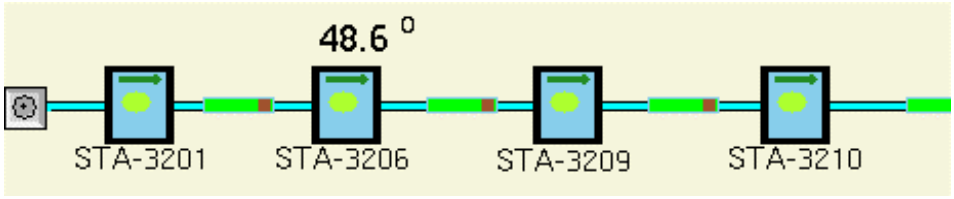
Alarm management is a concern for "Gas Control". To assure a prompt problem response, controllers should be shielded from superfluous or redundant alarm information. Gensym's G2-based Optegrity software manages real-time alarms generated in the **ProCA**. Gensym's Optegrity groups multiple alarms logically and by area or related devices. Alarms are prioritized and color coded. Red critical alarms are easily distinguishable. Optegrity includes a filter routine that distinguishes between important and unnecessary message information. Individuals that are colorblind controllers benefit from the Optegrity system because simple on/off filters allow them to turn off low priority messages.



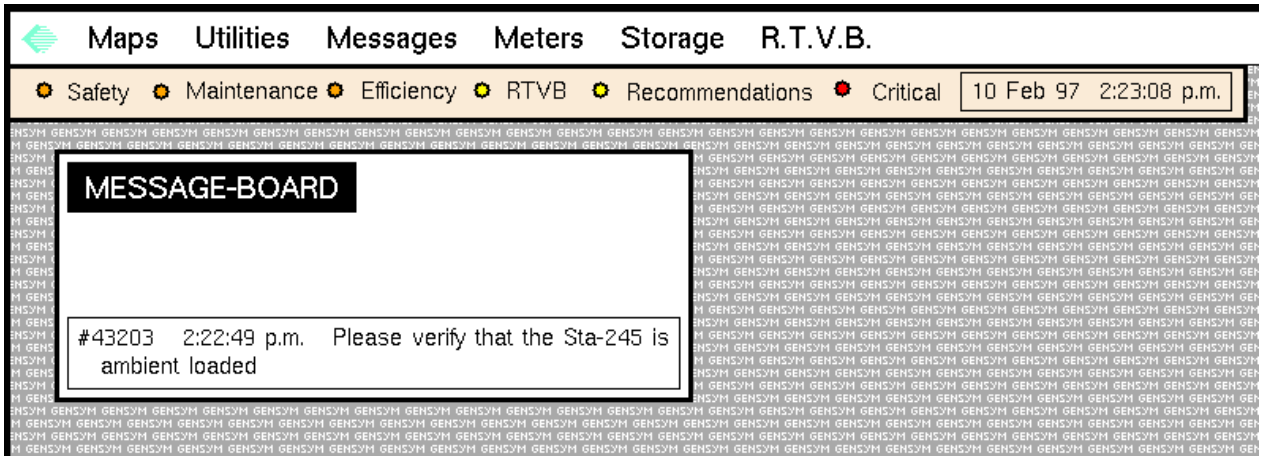
Optegrity permits the controller to suppress alarms from out of service equipment. Repetitive alarms are grouped into a single message that increments itself as new alarms are received. Alarms clear themselves after the status returns to acceptable and a predetermined time limit has expired. All messages are logged to a 30-day file that is retrievable for analysis when desired.

Pipeline Efficiency

Maintaining pipeline efficiency is a constant challenge. Morning demands are intense as residential usage increases and industry swings into production. Evening gas demand can drop by as much as 50%. The controllers labor to maintain the pressures required to meet consumer demand. **ProCA** displays the efficiency of pipe section and identifies pipes where pressures are falling. The efficiency is color-coded: green is optimal, followed by yellow and then red.



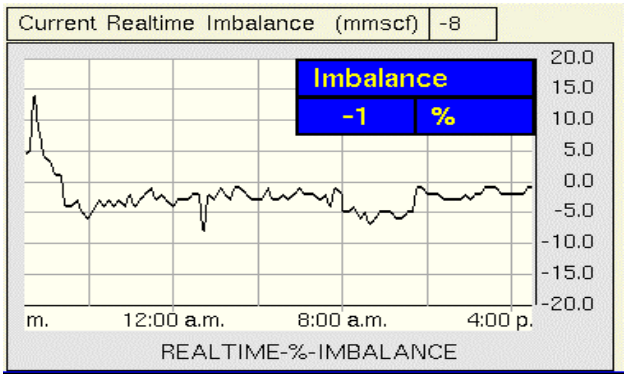
In critical areas **ProCA** (via G2) generates an options list for each controller as anomalies are noted automatically. This options list is created from the current pipeline conditions (weather and demand sensitive). The actions and options were originally generated by the controllers and then coded into G2.



Trend Charts provide feedback to the controller. The trend below informs the operator about the difference between the inlet and outlet flow of gas over the last 24 hours.

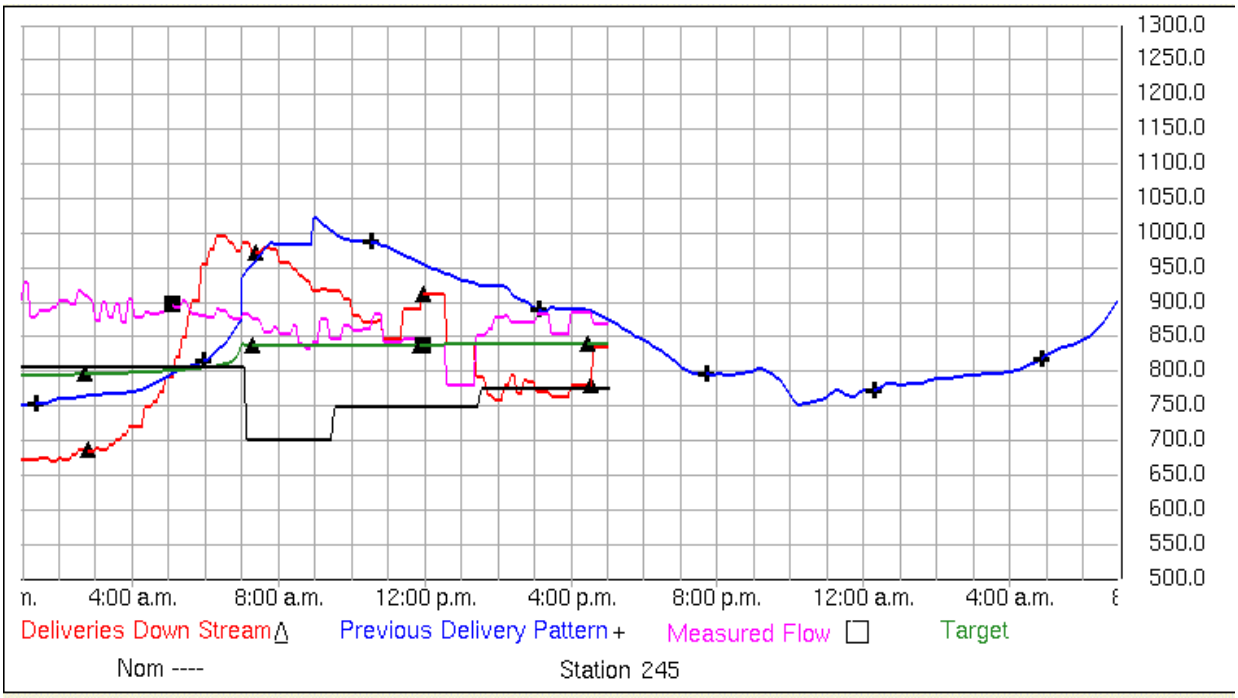
Reliability

Tennessee Gas' primary business concern is to transport energy reliably and safely. We use the ProCA program to help us protect our equipment. For example, if a pressure transmitter's reading should become unavailable on the pipeline, due to a lightning strike or damaged power lines, we create a virtual transmitter in G2. We compute a theoretical pressure based on information from surrounding pressure transmitters, (the nearest transmitters maybe more that twenty miles away.) In real world situations we have computed pressures that were within 1% of the measured value.



ProCA is also used to predict and/or recognize flow patterns so we use our horsepower efficiently.

Wide swings in consumer demand not only impact efficiency but also the reliability of the compressors. Using linear regression techniques the Controllers attempt to predict what the demand will be (flow pattern) and base load the available horsepower to meet the days' requirements. Linepack, gas stored in the pipe, is used to meet the demand swings. Trend charts created in G2 help the Controllers see what is happening and infer future adjustments. Predicting the future flow patterns and controlling linepack has helped reduce engine and compressor maintenance associated with excessive start-ups and shutdowns.



Generally during the day the Measured-Flow should be less than the Deliveries-Down-Stream because load drops off at night. We should be drawing on linepack during the day. G2 will issue a warning under Recommendations if linepack is being drawn too low, ie. G2 thinks that you will not be able to build the linepack up during the evening.

Fuel Efficiency

Tennessee Gas Pipeline has 70 plus compressor stations and fuel costs range from $1,000 - $20,000 per day for each station. To reduce cost, Tennessee Gas must reduce fuel consumption. Station fuel costs are estimated daily. Using Gensym's NeurOn-Line, "Gas Control" project engineers created neural models based on historical data to help the controllers compare their current fuel consumption to predicted fuel consumption. Tennessee Gas Pipeline has realized many benefits from the implementation of the controller's Assistant in the last year. The controllers are embracing the new technology and requesting additional information that makes the program more useful.

3. Development

The controller's operating experience is coded in **PCA** via G2's rules and procedures. Rules are placed (and optionally displayed) next to their corresponding objects. As a controller receives messages, he can select the message and choose to go to the originating object. At the object level, a controller sees

detailed data and determines why the message was generated. The controller can also view the generating messages rule and glean the thought process behind the message.


```
if the status of 25-C-01 = "Running" and the
    discharge-pressure-1 of sta-25 < the
    maximum-discharge-pressure of sta-25 -
    20 and the rpm of 25-c-01 < 750 and 25-
    engine-run >= 4 and the throughput-1 of
```

Electric motor driven compressor and partial rule from Station 25

The above graphic is from the **ProCA** controller's operation screen. This visual representation display operating conditions controller graphically. A controller can tell if the unit is running and the operation profile by reading the rule. Concurrently the controller is prompted for potential optimizations and intended operating ranges of the unit.

4. Why build PCA in Gensym's G2? Options to G2 considered?

Gensym is the global leader in expert systems. G2 expert systems differentiate themselves from the typical Man Machine Interfaces (MMI's) by evaluating real or near-real-time data. Using Gensym's G2 and the real-time data, **ProCA** notifies the Controller of potential implications or future trends and then suggests possible system improvements in advance of any problem. A man machine interface will only disclose problems after they have transpired.

For example, when pressures are building in a section of pipe the controller may be occupied analyzing a meter flow with a customer, and be unaware of impending pressure build-up. (Each controller potentially has over one thousand points of information about his system) The expert system rules used to create **ProCA** are designed to alert the controller that if the *pressure-increase* trend continues, the pipeline pressure may reach a point requiring an immediate response. In high demand areas **ProCA** will provide a list of recommendations or actions available to alleviate the undesirable condition or how to take advantage of the change by slowing down compressors to save fuel. With **ProCA** we do not have wait until we have triggered an alarm; but are able to alleviate potential situations before they reach the costly problem stage.

ProCA serves as a starting point for new controllers. The English-like syntax of G2 helps everyone involved understand the pipeline operation and limitations in an easy-to-use and cost effective manner.

5. Results

Using **ProCA** we have avoided the costs associated with installing additional transmitters because we create virtual transmitters and other pipeline devices on-line for the controllers when they need data fast. Our ability to add objects that contain computations based on available data have allowed us to operate the pipeline efficiently without compromising safety: even when we suffer partial communications outages due to weather extremes.

Using Gensym's Expert System programming language G2, Tennessee Gas has created a **"Proactive Controller's Assistant". ProCA** not only warns the controller when a parameter is moving in an undesirable direction but it also suggests possible changes based on the past experiences of the best controllers that result in improved reliability and safety.