The Closed Cycle Vapor Turbogenerator
A reliable cost-effective solution for pipeline rehabilitation

Jean Gropper, Sales and Marketing Manager
ORMAT Power, Inc.

1. ABSTRACT

Rehabilitating pipeline-coating systems represents a costly and time-consuming process that too often requires removing and replacing coatings in good condition along with the deteriorated coating.

In the pipeline's early life, a carefully controlled increase in installed cathodic protection grounded output may be the most cost-effective method for minimizing corrosion where coating deterioration is, or has, occurred.

Pipeline construction records, operational history, potential surveys and electronic pigging surveys must be carefully analyzed when selecting a short/long-term pipeline repair, rehabilitation, or replacement. In most cases, individual repairs must be completed at any cost on a non-negotiable basis.

The decision to rehabilitate or replace the line or sections of the line can be made after a review of all data. The first consideration in the decision should be to evaluate the effect of additional cathodic protection either with existing cathodic protection installations, or with new systems, which can be installed and operated in remote locations.

New impressed-current cathodic protection systems, in almost all cases, will be more cost effective than repairing or replacing sections of an existing pipeline.

Self-contained remote-power cathodic protection power generators have been successfully used for domestic and international pipeline corrosion control for over 30 years.

However, the most flexible and reliable power generator system is the Closed Cycle Vapor Turbogenerator (CCVT), based on user response and operational case histories.

2. INTRODUCTION

Rehabilitating pipeline-coating systems represents a costly and time-consuming process that too often requires removing and replacing coatings in good condition along with the deteriorated coating.

In the pipeline's early life, a carefully controlled increase in installed cathodic protection grounded output may be the most cost-effective method for minimizing corrosion where coating deterioration is, or has, occurred.

Pipeline construction records, operational history, potential surveys and electronic pigging surveys must be carefully analyzed when selecting a short/long-term pipeline repair,
rehabilitation, or replacement. In most cases, individual repairs must be completed at any cost on a non-negotiable basis.

The decision to rehabilitate or replace the line or sections of the line can be made after a review of all data. The first consideration in the decision should be to evaluate the effect of additional cathodic protection either with existing cathodic protection installations, or with new systems, which can be installed and operated in remote locations. **Existing pipeline supervisory control and data acquisition (SCADA) systems can be extended to optimize cathodic protection (CP) data acquisition and online analysis.**

New impressed-current cathodic protection systems, in almost all cases, will be more cost effective than repairing or replacing sections of an existing pipeline.

Self-contained remote-power cathodic protection power generators have been successfully used for domestic and international pipeline corrosion control for over 30 years.

However, the most flexible and reliable power generator system is the Closed Cycle Vapor Turbogenerator (CCVT), based on user response and operational case histories.

### 3. PIPELINE REHABILITATION CONSIDERATIONS

External pipe surfaces of buried systems are exposed to many different corrosive environments along the same and pipeline integrity is assured by the combined effect of coatings and cathodic protection.

All coatings have holidays that occur during the application or handling processes. If no cathodic protection is provided for the protection of the pipeline surface at holidays, penetration of the pipe steel may occur as fast as uncoated steel. Pipeline steel surfaces can be protected with cathodic protection and no coating, but the cost is prohibitive and the effectiveness is limited.

New or alternative performance standards create special problems for pipeline operators and their technical staff. Innovative methods are required:

- To determine cost-effective solutions for repair/rehabilitation of existing pipelines
- To recommend replacement when repair alternatives are not economical
- To recommend an increase in cathodic protection impressed current capability when appropriate.

### 4. EVALUATING COATING CONDITIONS

In the last few years, pipeline companies appear to be changing their criterion for establishing adequate cathodic protection on their pipelines. In the past, the standard criterion was -850 millivolts for the pipeline contact versus a copper-copper sulfate reference electrode.
In an attempt to improve the seasonal variability of the potential readings in different soil conditions and resistivities, several companies use the accepted reading as measured with the cathodic protection current momentarily interrupted. The "current off" potential measurement reduces the "current on" potential by eliminating the effect of IR drop, which is a function of applied current flowing through soil of varying resistivity.

The above monitoring technique of current interruption does not take into account the differences in native-state potential prior to the introduction of cathodic protection. This native-state potential will range from -400 to -800 millivolts, depending on soil resistivity, moisture content, and soil pH. In an older pipeline with extensive deterioration, it may be difficult, if not impossible, to reach -850 millivolts; current-on or current-off. Native-state potential values become an integral part of monitoring when two other criteria for acceptable cathodic protection are used:

- **4.1** Negative increase of 300 millivolts from native-state to applied cathodic protection current
- **4.2** Negative increase of 100 millivolts from native state to "instant off" potential with cathodic protection current momentarily interrupted.

The last criterion appears to be favored by pipeline companies, since this measurement includes the effects of both native-state potential and polarized potentials with current interrupted. Furthermore, the technique has important features, which increase the available options for pipe-line repair, rehabilitation, or replacement.

The only commercially available monitoring technique for fully determining pipeline condition is electronic or "smart" pigs. These surveys will not detect coating defects, but they will detect corroded areas where the coating is damaged or has deteriorated. In addition, electronic pigs are the only means of detecting corrosion damage in disbonded coating systems without excavation.

### 5. CORRECTIVE ACTION

In the pipeline's early life, a carefully controlled increase in installed cathodic protection groundbed output may be the most cost-effective method for minimizing corrosion where coating deterioration is, or has, occurred.

Individual repairs are required when a leak or break occurs anywhere on the line. Leaks or breaks are impossible to completely eliminate due to undetected construction weld defects and in-service mechanical damage.

Pipeline construction records, operational history, potential surveys (test station or close-interval), and electronic pigging surveys must be carefully analyzed when selecting a short/long-term pipeline repair, rehabilitation, or replacement. In most cases, individual repairs must be completed at any cost on a non-negotiable basis.

The decision to rehabilitate or replace the line or sections of the line can be made after a review of all data. The first consideration in the decision should be to evaluate the effect of additional cathodic protection either with existing cathodic protection installations, or with new systems, which can be installed and operated in remote locations.
New impressed-current cathodic protection systems, in almost all cases, will be more cost effective than repairing or replacing sections of an existing pipeline. However, the cathodic protection groundbeds, and impressed current power stations, should be located where the surveys indicate this protection is required. This design option is opposed to the concept of locating new or additional stations where construction is most convenient, such as near existing roads or existing power lines.

Using sacrificial anodes, for pipeline rehabilitation and life extension, is generally limited. Sacrificial anodes are best applied to protect structures immersed in water or where the soil has low resistivity. Applying sacrificial anodes to existing pipelines will provide much less flexibility to increase the level of required protection where coating deterioration is an ongoing process.

6. CLOSED CYCLE VAPOR TURBOGENERATOR (CCVT) UNITS FOR PIPELINE CATHODIC PROTECTION

The CCVT is a self-contained, fully assembled factory integrated, organic-fluid Rankine cycle turbogenerator system. On-site installation and commissioning is usually accomplished in a matter of a few days. The CCVT units have an integral walk-in service shelter and are site rated for 400-Watts to 3,000-Watts output, with units available to operate between -60°C to +425°C, at altitudes to 4,600 m.

CCVT units have multiple fuel capability and may operate from gas in the pipeline or from stored locally available fuels such as kerosene, diesel fuel, and liquefied natural gas or liquefied petroleum gas. Units may be converted in the field from one fuel to another. In addition, for applications in arctic environment, the CCVT units can heat an equipment building using excess heat from their boiler.

The CCVT is shown schematically in Fig. 1. The fuel is supplied to the burner, which heats the boiler where the organic motive fluid is vaporized. The vapors drive the turbine, which is on the same shaft as the brushless generator. The generator output is rectified, filtered and regulated to provide power to the station load. The vapors are then condensed in an air-cooled condenser, gravity-fed back into the turbogenerator, where they lubricate the hydrostatic/hydrodynamic turbine bearings before returning to the boiler to repeat the cycle.

This cathodic protection power system presents the following characteristics of flexibility and economy:

6.1 Multi-Fuel Capability
The system does not require any logistics, as the unit will operate directly from natural gas tapped from the pipeline. On crude oil or product pipelines the CCVT system operates from locally available fuels such as kerosene or diesel fuel, or from diesel fuel from the pipeline.

6.2 High Reliability
The field-proven MTBF of a gas fired CCVT is over 30,000 hours.
Fig. 1. Schematic diagram of Closed Cycle Vapor Turbogenerator

6.3 Virtually Maintenance-Free
Only one routine maintenance visit per year is required for the gas fired CCVT. No overhauls are required for CCVT lifetime (over 20 years).

6.4 On-Site Adjustment Capability
[CPVCM] can be adjusted on-site to work either on Constant Voltage, Constant Current or Constant Potential (reference cell) modes.
6.5 **Optimum Protection**

Capability of supplying optimum cathodic protection requirement, not only on new pipelines, but also on existing pipelines to ensure continuous operation and revenue to user.

6.6 **Flexibility**

CPVCM modules can be used where necessary, at any point along the pipeline where cathodic protection is required, to increase power for cathodic protection.

6.7 **Unit ratings**

CCVT units are rated 400 to 3,000 Watts. Fuel consumption is proportional to power output.

- Ease of transportation and installation.

Two men can perform installation and commissioning in two days. The CCVT is a complete power station package (Fig. 2).

6.8 **Impressed Current Cathodic Protection - Cathodic Protection Voltage Conversion Module (CPVCM)**

A widely used method of pipeline cathodic protection is by impressing an electrical current between the pipeline and an anode, which is buried in the ground near the pipeline to be protected. This impressed current protects the pipeline by neutralizing the natural corrosion cycle.

The CCVT with the integrated Cathodic Protection Voltage Conversion Module (CPVCM) is a self-contained power source designed to replace the conventional transformer-rectifier, where secure, continuous and reliable cathodic protection is required.

The CPVCM has been specifically designed for operation with the CCVT, to convert the fixed DC voltage of the CCVT output to a controlled voltage, continuously self-adjusting to a reference threshold.

The CPVCM facilitates field integration of the system.

Other design criteria are: (a) fully automatically controlled operation without batteries, (b) positive (+) grounded, (c) transmission of operating data and status by telecommunications and SCADA equipment systems, and (d) integrated line current interruption test capability.

The CPVCM is a variable DC voltage source operating on a switching concept, with voltage regulation by control of the Duty Cycle (time function) as illustrated in Figures 3 and 4. The control circuit of the CPVCM regulates and limits power output by referencing to preset values of output voltage, or output current, or a pipe-to-soil reference potential. This allows the system to operate automatically, operated in one of the following selected modes of operation:

1. Constant manually set output current
2. Constant manually set output voltage
3. Constant pipeline-to-soil potential
Figure 2. Remote telecommunications and cathodic protection station powered by CCVT along HBJ pipeline in India
The CPVCM delivers its output subject to the power rating of the CCVT, as shown in Figure 5.

### 6.9 Remote monitoring capability
Communication hardware with operating parameter-monitoring capabilities may be easily integrated to continuously monitor the cathodic protection system in constant voltage, constant current or pipeline potential mode.

The CPVCM can be operated in any one of three operation modes - constant voltage, constant current and/or constant potential. The user may choose the mode that is appropriate for the
application. For example, in soils subject to seasonal resistivity variations, the constant potential mode or constant current mode can automatically provide the correct level of cathodic protection for the pipeline. The constant voltage mode may be used to maintain the proper cathodic protection level if the coating resistivity is changing.

The CCVT accompanied by the cathodic protection voltage conversion module (CPVCM) provides pipeline operators and corrosion control specialists with the ability to supply impressed current cathodic protection at the levels and at the precise locations where needed on the pipeline. With remote monitoring capabilities, the overall system is a significant improvement over the usual means of designing and maintaining cathodic protection systems.

**Figure 5: CPVCM Typical Output Power Curves**
**6.10 SCADA Systems Integration**

Fiber optic cables installed along the pipeline right-of-way provide SCADA capabilities for pump or compressor stations as well as intermediate valve locations. These systems are easily extended to continuously monitor and measure CPVCM and CCVT performance parameters. Once acquired within the SCADA system the CP data can be trended, analyzed and transferred via local area networking to the CP Specialist Engineer’s desktop computer. Although CP data does not change rapidly, the alarming of failure modes and the availability of accurate and reliable pipeline CP conditions provides for cost effectiveness of CP data integration with existing SCADA systems.

**5. CONCLUSIONS**

The use of Closed Cycle Vapor Turbogenerator (CCVT) units provides the flexibility for installing impressed current stations with automatic control capability as well as sufficient power ranges to meet long-term cathodic protection requirements to protect both new and existing pipelines undergoing rehabilitation for life extension. As an example, lately recently CCVT units have been ordered and put into operation by PEMEX for this purpose along gas pipelines in Chihuahua, Monterrey and Lazaro Cardenas regions. (Fig. 6)

![Figure 6: CCVT for pipeline cathodic protection along PEMEX gas pipeline](image)

With its ability to operate from within the most difficult extreme arctic and desert conditions to the desert, due to its flexibility and multi-fuel capability, the Closed Cycle Vapor Turbogenerator (CCVT) has become the optimum choice for power and system support for major gas and oil pipeline projects.