45 Years of Experience with Reliable Power Supply in Remote BGV/RGV Stations Along Pipelines - a Key Factor for Safe Gas Transportation Systems

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1. Introduction

Telecommunications, SCADA, RTU, cathodic protection in often remote difficult to access facilities along gas pipelines and on offshore platforms are mission-critical, carrying vital performance, telemetry and control data for the safe gas production and transportation.

A single day of power outage along pipelines or on a platform will result in an important loss of revenues due to lost production. Therefore, the choice of a reliable and virtually maintenance-free energy system is extremely important.

The objectives for high reliability in remote RGV operation, telecommunications, cathodic protection and SCADA systems in strategic projects have become staggering. In areas not serviced by commercial power, the problems faced by the power systems designers are very stringent since power generators must operate continuously on a 24 hour-per-day basis 365 days-per-year in severe environments under which these pipelines must continuously operate.

The use of specially designed, arctic type, Closed Cycle Vapor Turbogenerators (CCVT) and their associated non-electric heating systems in arctic telecommunication systems has solved two of the most stringent problems of the pipeline operators: reliable remote power up to 4 kW is provided with maintenance requirements reduced to a visit only once in 6 months or more, and required temperature ranges in equipment shelters are maintained, assuring correct operation of the sensitive electronics, without any need of electrical power.

This paper reviews the key criteria to consider in selecting energy systems solutions for remote site applications and case studies in different projects are presented, that demonstrate the field reliability and performance of CCVTs over the last forty five years.

2. Criteria for selecting power solutions for remote sites

There are a number of critical parameters which must be assessed when selecting a power solution for a network or a specific remote site. Hereunder there is a checklist of the most important criteria.

Reliability. Because these critical remote sites are difficult (and expensive) to reach – or are inaccessible for part of the year, reliable operation is extremely important. Reliability is typically measured in terms of Mean Time Between Failure (MTBF). CCVT technology has a proven performance history, demonstrating over 200,000 hours MTBF for the turbine and 30,000 hours MTBF for the entire system. These data are based on forty five years of field experience.

Operation in adverse environmental conditions. Remote sites are often characterized by very harsh environmental conditions. Often, these power systems must be able to withstand temperature extremes, preferably without incurring additional costs to heat or cool the power equipment. CCVTs operate over a very wide temperature range and can tolerate snow loads, strong wind and other adverse conditions. Standard arctic units can operate in ambient temperatures as low as -55°C and as high as +40°C.

Performance. A most important requirement is that the performance capabilities of the power system meet the performance needs at the particular remote site. Output capacity and output voltages are the most critical variables to consider. Developing a power budget for the site, considering the voltages and loads of all of the different telecommunications and operations equipment to be supported is a critical step in the evaluation process. CCVTs are available with output voltages of 24, 48 and 110 volts DC, the typical voltages most telecommunications equipment requires. Output can range from 400 to 4,000 Watts.

Cost. When “costs” are evaluated, both initial and operating costs over the life of the remote site must be calculated. The initial cost will include the cost of the equipment as well as the cost of transportation and installation at the remote site. The life cycle costs include maintenance costs, operating costs (including fuel costs), and replacement costs if the life span of the power equipment is less than that of the remote site. CCVTs are economical solutions for remote sites over the life cycle of the remote site, with a demonstrated life of more than 30 years and very low maintenance costs.

Low maintenance. Power solutions in remote areas that require frequent maintenance to assure start up or optimum performance will be very costly over the system’s life cycle. Thus low maintenance solutions are very desirable for these remote sites. To further manage costs, the maintenance requirements should coincide with scheduled site visits to maintain the communications and other site equipment. It is very desirable that routine maintenance tasks on the power system be simple enough that they do not require a special “power” technician to visit the site. CCVTs typically require simple annual maintenance that can be performed by the site technician who services the other site equipment.

Ease of installation. Because these sites are remote and difficult to access, it is important to consider ease of installation of the power system. The power system should be easy to transport and simple to install, with minimal infrastructure requirements.

Low environmental impact. Green, non-polluting power solutions are most attractive, especially in remote and often pristine locations. CCVTs are non-polluting and extremely quiet in operation.

The relative importance of these criteria will vary with the specific project and application, but all are important in evaluating the various options for providing reliable power at a remote site. Based on these criteria, CCVT technology is a very attractive and cost-effective solution for both prime and standby power in many applications.

3. Design Criteria

Good engineering practice for designing power systems for such applications is to try to minimize the power demand in order to avoid the use of large power generators requiring extensive maintenance.
However, this is not always possible, and there are projects where it is necessary to power loads in the range of 2 – 4 kW.

In addition, use of batteries requires special attention because of their sensitivity to temperature and limited life when used in frequent charge/discharge cycling, and their capacity is limited for practical (physical size) and economic reasons as well. Theoretically, a very large battery could enable station availability close to 100%, but the size, maintenance requirements and charging conditions make such a solution unrealistic. Therefore, the power systems will be designed around the power generators.

4. Closed Cycle Vapor Turbogenerator

Closed Cycle Vapor Turbogenerator (CCVT) technology has been deployed in the field for more than forty five years. It is a proven technology.

CCVT system overview. The Closed Cycle Vapor Turbogenerator (CCVT) consists of a combustion system, a vapor generator, a turboalternator, an air-cooled condenser and a rectifier. Figure 1 shows a cutaway of the CCVT.

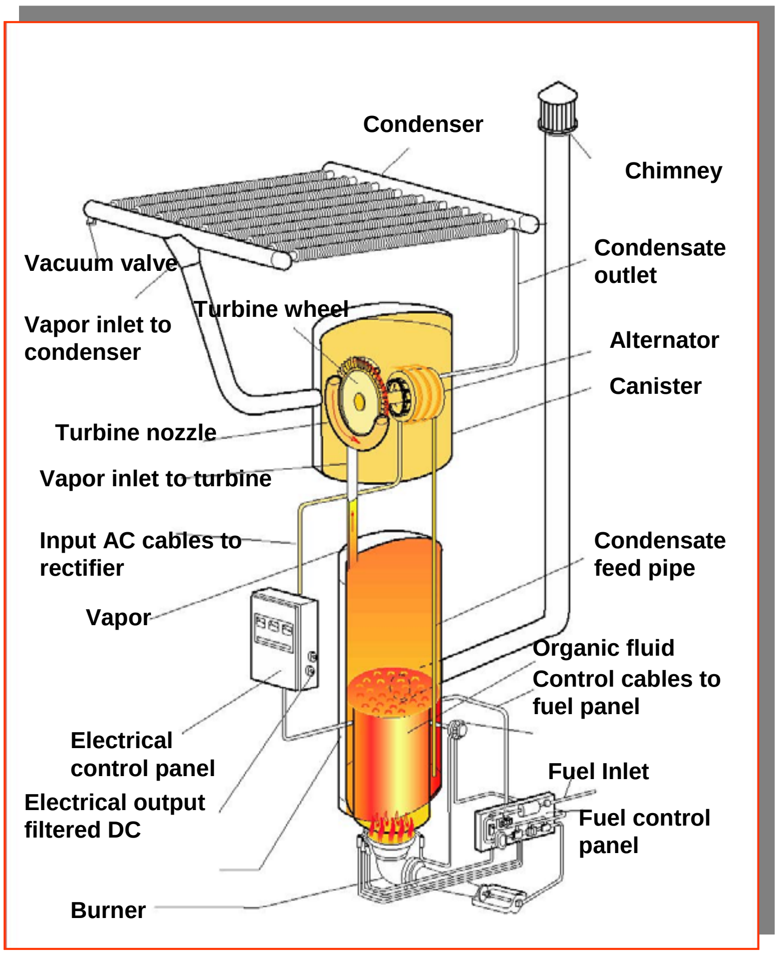
The CCVT utilizes a hermetically sealed Rankine cycle generating set which contains only one smoothly rotating part, the shaft, on which the turbine wheel and brushless alternator rotor are mounted. The turboalternator shaft is supported by a “working fluid film” bearing lubricant, which eliminates any metal-to-metal contact, thus providing years of maintenance-free, trouble-free operation.The fluid cycle is closed and requires only the application of external heat, for continuous production of power. Natural gas typed from the pipeline is an ideal fuel for the CCVT. Because of its purity, liquefied petroleum gas is often chosen as a desirable fuel for typical arctic applications.

The CCVT is a fully integrated and tested power system that can provide from 400 to 4000 Watts of filtered DC power on a continuous basis for 30 years or more, with minimal maintenance. It includes the self-contained power package, along with an alarm and control module, housed in a shelter.

CCVT operation. (See Figure 1). The burner heats the organic fluid in the vapor generator where some of it vaporizes and expands through a turbine wheel to produce shaft power to drive the alternator. The vapor then passes into a condenser where it is cooled and condensed back into the liquid state. The liquid passes back into the vapor generator, cooling the alternator on its way and lubricating the bearings. The cycle continues as long as heat is applied to the vapor generator. Because the liquid/vapor stainless steel canister is sealed, none of the organic fluid is lost in the process. Furthermore, the working fluid is totally immune to climatic conditions outside the sealed canister.

The turboalternator produces three-phase AC power, which is rectified and filtered. The standard output is 24 or 48 or 110 volts DC. Other DC voltages and auxiliary AC can be made available through the appropriate use of converters and inverters in the system. A digital turbine control unit controls the CCVT system.

Figure 1: Cutaway View of the CCVT Unit



5. Field Experience with CCVT

Over the last forty five years, CCVTs have been deployed in numerous applications in the oil and gas industry along pipelines and on offshore platforms. These power systems provide DC power for a wide variety of equipment including telecommunications networks, telemetry and SCADA systems, pipeline cathodic protection systems, motorized valve controls, navigational aids and remote emergency lighting. CCVTs have also been powering telecommunication applications, including repeater stations, telecommunications links and fiber optics sites in Antarctica, North America, South America (Andes Mountains and Patagonia), Siberia and Far East of Russia.

Trans - Alaska Pipeline Case History: Since 1976, 122 CCVTs, rated at 600 Watts, have powered the Remote Gate Valve (RGV) stations along the Trans - Alaska Pipeline. These RGV stations operate along 800 miles of the pipeline, which has transported over 11 billion barrels of crude oil. After their first 20 years of operation, the pipeline operator, Alyeska Pipeline Service Company, noted, "the energy converters have been operating at reliability levels above the manufacturer's specifications since their installation (and) are still providing dependable power. Not even one single station power outage has been observed."

The RGV station includes the gate valve, communications and control equipment, a battery bank as well as the CCVT and the fuel tanks. In addition to powering the gate valve and communications, control and supervisory equipment, the CCVT also maintains the float voltage on the battery bank. The integrated power module includes two propane fired CCVTs, a non-electric heating system for the equipment shelter and the distribution and control equipment, which is deployed in the incredibly harsh Alaskan winter environment (with temperatures falling to –60°C/-76°F in the winter with snow loads to 90 psi). To assure peak performance of the overall system, the entire power solution, including the CCVTs, the main shelter, the heating system and related equipment, was manufactured and integrated by Ormat. In this pristine, extremely harsh environment, one of the key concerns of the pipeline operator is to preserve the environment and minimize the potential for oil spills. These remote gate valves play a critical role in preventing oil spills.

Figure 2: CCVTs on the Trans - Alaska Pipeline

Today, CCVTs, originally designed for twenty years of service, are still in operation, exceeding design objectives by more than eighteen years. (See Figure 2)

After more than 30 years of continuous and successful operation of CCVTs along the Trans Alaska pipeline, the project operators, Alyeska Pipeline Services, decided to upgrade and replace the telecommunications /RTU/SCADA equipment in the RGV stations with new generation equipment that requires almost double the power than the original equipment. As a result, the capacity of the batteries in the stations had to be increased, and, in turn, it was necessary to increase the CCVT power from 600W to 1200W.

Alyeska Pipeline Services requested ORMAT to replace the old CCVTs with new units keeping absolutely the same mechanical and electrical interface between the CCVTs and the equipment shelter as in the original project, in order to avoid the expense of redesigning and installation of new infrastructure that would have otherwise been required.

In the Alaska project, to ensure that the mechanical and electrical interface between the new higher capacity CCVT's and the existing equipment shelter will be the same as in the original project, a pilot station was ordered and put into operation in 2007. The entire mechanical and electrical interface was tested in operation to the satisfaction of Alyeska Pipeline Services, and, as a result, they have recently started a program of gradually replacing over a period of several years, the old CCVT's, still operating since 1975, with the new 1200W CCVT units. The Figure 4 shows the installation of the new 1200W CCVT units in one of the Trans Alaska RGV stations.

Figure 3: New 1200W CCVT units in existing RGV station

Gazprom Gas Pipelines: Gazprom's experience with CCVTs has been equally successful. Gazprom is one of the largest natural gas production and transmission companies in the world and operates over 30,000 kilometers of pipeline stretching from Siberia to Europe. The Russian winters are very harsh and the stations may be inaccessible for months; temperatures may reach as low as -60°C for extended periods in winter and as high as +40°C in the summer months. However, the telecommunications, cathodic protection and control stations *must* operate without maintenance support during this period. After a careful analysis of all the available power solutions (e.g., solar, wind, thermoelectric generators, conventional electric generators) the CCVT was selected as the only approved power solution for these applications.

The reliability of CCVTs is confirmed by long-term experience of their application. In Russia alone, approximately 1000 CCVTs of various capacities rated from 400 to 4000 Watts are installed (see Figure 4) along such projects as the gas pipelines providing gas to Europe, Urengoy – Uzhgorod and Yamal - Europe. Among them, 75 units are in operation for more than 30 years, (some since 1975), with the MTBF being equal to 80,000 hours (a number of CCVTs have each reached MTBF of 245,280 hours). 13 failures only were recorded throughout all the operating period. The proven, recorded mean time to critical failure (MTBCF) is no less than 300,000 hours. Frequency of CCVTs maintenance services is no more than once a year. Gazprom has found them to be field-proven as dependable and cost effective, both in terms of fuel consumption and maintenance expenses.

Recently, more than 130 CCVTs have been installed for new gas pipeline projects in Kamchatka and in the Far East of Russia (Sakhalin – Khabarovsk – Vladivostok).

Figure 4: CCVTs in Kamchatka

Figure 5: CCVTs in a typical Gazprom site

Power Solutions for the Sakhalin II Project.

The Sakhalin II project is one of the most important pipeline projects built in the last 20 years. It consisted in the development of two offshore fields in the Sea of Okhotsk approximately twenty kilometers to the east of the Sakhalin Island coast, known as the Piltun – Astokhskoye field and the Lunskoye field. The development of the Piltun – Astokhskoye field concerns oil and gas production, whereas the Lunskoye field is predominantly a gas and condensate reservoir with a potential oil rim development.

The pipeline systems are **buried** and the **design life** for the pipelines and related systems and accessories is **30 years**.

Environmental conditions are typical difficult arctic.
Ambient temperature is between - 39ºC and +37ºC , with 192 days with mean average temperature below 0 ºC. The relative humidity is high throughout the year, the annual average being 80% and 89%.The maximum thickness of snow in the cold period is 135 cm, with an average of 47 cm. Snowstorms are frequent and there are 40 – 70 days with snowstorms/year with duration of up to 870 hours.
Average wind velocity is up to 30 m/s, with gusts up to 44 m/s.
The Sakhalin Island is known for its strong earthquakes. The seismicity, in accordance with SNIP II - 7- 81 is 9 points (Destructive) on MSK-64 scale.

The oil and gas dual onshore pipeline traverses 126 km of swamp crossings, 110 km of mountainous routes, more than 1,000 river, 18 rail and 10 road crossings. Large sections of the pipeline are located in remote arctic areas that are difficult – sometimes impossible – to access at certain times of the year.

Electric power is required at the offshore and onshore facilities as well as the 102 unattended locations along the pipelines. Because of the considerable distances involved, an integrated electrical supply system would not be economical. Sakhalin Energy Investment Company (SEIC) needed a remote power solution with a proven track record of reliability in extremely cold climates as well as predictable annual maintenance schedule. Because of the difficulty in sending supplies, it was important to use the fuel from the pipeline, which would require gas pressure reducing systems.

For **102 unattended locations** requiring power, in accordance to the Project Specifications, Ormat was selected to provide 102 remote Energy Power Systems (EPS) for the pipeline, based on **highly reliable,** single low maintenance power generation units with battery back-up were installed. These power generation units are used to power cathodic protection, SCADA, remotely operated valves, and telecommunication equipment along the pipeline route. For this important task on such a strategic project, **Closed Cycle Vapor Turbogenerators (CCVT)** operated with gas from the gas export pipelines have been selected. At the unattended locations, the batteries are only used as back-up power supply for the period the power generators are out of service.
Each EPS consists of one 4 kW Closed Cycle Vapor Turbogenerator (CCVT) and a specialized arctic equipment shelter to house the rest of the equipment.

For the Sakhalin II project, Ormat provided a Total Project solution of supplying the totality of the equipment required in the remote stations (see Figure 6).

The Energy Power Systems (EPS) comprises, besides the CCVT and the arctic equipment shelter, the following:

- Gas pressure reducing skid to enable use of gas from the pipeline
- Cathodic protection modules
- VRLA battery bank to enable a 24 hr backup.
- Non-electrical heating system that uses residual heat from the turbogenerator
- Telecom and RTU equipment to enable remote monitoring
- Power distribution panels and switchgears, to support 110VDC, 48VDC and 24 VDC
- Automatic certified fire detection and extinguishing system
- Heating and ventilation system

- Inverters, DC-DC converters
- MCCs for operation of remote gate valves.
- Stairs and walk-way for accessing CCVT and equipment shelter in all weather conditions
- Portable 3 kW Diesel Generators for black-start of remote stations

As the pipelines went into production, EPS ensure continuous, reliable pipeline operation throughout the coldest months of the year

Figure 6: Energy Power System along Sakhalin II project

Power Solutions for Kazakhstan – China Gas Pipeline Project

For the Phase II of the Kazakhstan – China gas pipeline project, integrated power systems consisting of CCVTs and arctic shelters similar to those in the Sakhalin II projects have been supplied and are actually under commissioning and start-up.

Twelve EPS consist of 2 (two) redundant 2kW CCVTs and a specialized arctic equipment shelter to house the rest of the equipment.

Distribution voltage for the unattended locations is 48 VDC. For electrical equipment installed in the stations that cannot operate at this voltage level, DC-DC converters are used to convert this 48 VDC to the appropriate voltage level, 24 VDC. Inverters are used for electrical equipment operating at 220 VAC.

Distribution voltage for the unattended locations is 48 VDC. For electrical equipment installed in the stations that cannot operate at this voltage level, DC-DC converters are used to convert this 48 VDC to the appropriate voltage level, 24 VDC. Inverters are used for electrical equipment operating at 220 VAC.

Figure 7: Energy Power System along Phase II of Kazakhstan – China gas pipeline

The EPS comprise, besides the CCVT and the arctic equipment shelter, the following:

- Gas pressure reducing skid to enable use of gas from the pipeline
- VRLA battery bank to enable a 24 hr backup.
- Non-electrical heating system that uses residual heat from the turbogenerator
- Telecom and RTU equipment to enable remote monitoring
- Power distribution panel, to support 220VAC, 48VDC and 24 VDC
- Automatic certified fire detection and extinguishing system
- Heating and ventilation system
- Inverters, DC-DC converters

6. CONCLUSIONS

Reliability and availability of power supply in remote BGV stations along the pipeline are paramount factors for pipeline operation and its revenues.

Selection of the most reliable power units and adequate redundancy are also extremely important factors.

CCVTs have been deployed with great success in a wide variety of applications in various configurations to provide reliable and economical power at remote operating sites.

With over 45 years of field experience, CCVT technology is proven to be highly reliable in the most adverse of environments. In addition, CCVTs have proven to be environmentally friendly and economical to deploy, especially when compared to alternatives such as diesel generators. CCVTs are very suitable for mission-critical applications where performance and reliability are important.