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Photovoltaic Power for Remote Site Remediation

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Abstract

Photovoltaic (solar) power coupled with remediation technologies has presented innovative opportunities for remote sites. This paper focuses on the integration of these two technologies for remediation of salt and hydrocarbon contamination with the following applications:

- Groundwater Extraction
- Reverse Osmosis Treatment;
- Soil Vapour Extraction; and,
- Solar Mobile Power Station.

The success of these systems is attributed to the simplicity of the designs, maximizing system efficiency and minimizing operation and maintenance requirements. Depending on the remedial goals and technology used, photovoltaic powered systems can be designed to operate on an intermittent or continual basis. While continual operation implies higher system outputs, it also results in increased design complexity and inefficiencies. Our philosophy of a simple design balances these effects with the remedial goals.

As the technology behind photovoltaic power grows, both efficiencies and costs will continue to improve. This will increase the opportunity to showcase progressive use of renewable energy in remote site remediation, complementing our overall goal of improving environmental quality.

Introduction

A common problem for remote site remediation systems is a lack of on-site power to operate pumps and other equipment. Due to the nature of the work, remediation systems may be allocated limited budgets and manpower. Typical solutions involve operating propane or diesel powered generators in order to power equipment. This carries a high capital cost and a large operating budget due to refuelling and maintenance requirements. Add to this the contradictory nature of operating a remediation system with equipment that can be a source of additional contamination, and an opportunity for renewable energy has presented itself. Komex recognized this as an opportunity to use photovoltaic (PV) power as a reliable, maintenance free and cost effective power solution.

Photovoltaic Cells

PV cells consist of several layers of semiconductor material alternating between positive and negative character. As sunlight hits the cell, photons are absorbed and are able to free some electrons in the electric field between these two layers. The freed electrons move through an external current path, where their energy is available for work. Currently the technology is capable of converting approximately 15% of the energy in sunlight into direct current electricity.

Advantages of PV power include elimination of fuel requirements, emissions and maintenance. Modules are supplied with a 25 year guarantee and have proven to be very robust in a variety of operating environments. PV technology is well suited to environs with clear skies such as Alberta. Available sunlight tends to range from 8hr/day in the summer to 4 hr/day in the winter. While the energy produced from a PV module is available as DC, this can be manipulated to operate AC and pneumatic equipment as well.

As the technology and production of photovoltaic modules has increased in the last 10 years, the cost of production has reduced by 50%. This holds promise for future advances in efficiencies and decreases in costs. Currently a rule of thumb for the cost of a PV module is $10/W(CAD).

Remote Site Remediation

The primary design criteria of remote site remediation systems is to construct a system that is both reliable and robust. This minimizes the operating and maintenance requirements and associated costs. Systems that are simple in design also lend themselves to straightforward troubleshooting. Equipment needs to be easily repairable by personnel without highly specialized training.

Solutions to lack of on-site power vary from tying into the electric grid to use of a generator or occasionally vacuum truck hauling. While tying into the electric grid is the most reliable of these options it is often the most expensive, particularly for a temporary operation. Generator use and vacuum truck hauling have high operating costs and can be unreliable due to repairs and personnel scheduling. Integrating PV power into remote site remediation extends the design criteria of reliability and robustness.

PV powered remediation systems can be designed for 8hr/day to 24hr/day operation and seasonal to year-round operation. Relocating PV modules to different sites for pilot-testing or long-term operation of equipment is a simple and inexpensive task.

Applications

PV power has been used to operate a variety of remote site remediation systems, including:

- Dewatering
- Brine Recovery
- Reverse Osmosis
- Brine Evaporation
- Soil Vapour Extraction
- Sparging
- Aeration
- Biopile Irrigation
- Recirculation
- Chemical Injection
- Environmental Monitoring
- Stripper Well Oil Recovery

The following applications will demonstrate the level of success already achieved at some of the sites.

Groundwater Extraction

As is common with many operating oil and gas facilities, this gas plant in Central Alberta had a large chloride plume. In order to prevent further off-site migration and contamination of a neighbor's groundwater source, Komex constructed an interception trench with two extraction culverts just outside of the plant's facility. There was no power source at the interception trench and the client elected to use vacuum trucks to pump out the extraction culverts on a weekly basis. This was both an expensive and inconsistent method of operating the extraction trench due to the varying schedule of the vacuum truck operator.

In an effort to reduce costs, a pumping system was installed at the beginning of the second operating season. DC pumps were installed in each of the extraction culverts. Each pump operates on two solar panels (110 W each) at a rate of 8 lpm at 8m of head. The water is conveyed from the pumps to a sump tank inside the plant facility via a heavy-duty hose. The water level in the extraction culverts is controlled by a float switch. Pumped volumes are recorded with a flow totalizer.

This was a seasonal operation, from May to October, and is operating on its second year of PV power. The seasonal operation is complementary to PV power; this represents the 6 most productive months of solar energy and does not require freeze-protection of the pumping system.

Operating and maintenance requirements have been minimal and consist of:

- obtaining weekly readings from flow totalizer;
- obtaining monthly water samples; and,
- adjusting the level of the float once in a season.

Overall trench performance has improved due to consistent pumping, with an extraction rate of 86 m^3 in one season.

Reverse Osmosis Treatment

Remediation of chloride plumes may not occur until after the facility has been decommissioned. At this site in Southern Alberta the goal was not just to prevent off-site migration but to remediate the plume. Due to the decommissioning of the facility there was no longer any power available on-site. Operation of a pumping system with a generator was considered. While manpower was readily available close by, the continual operating costs were deemed too high. The client was enthusiastic to integrate PV power with remediation at this site.

In the first year of operation, one extraction well was installed. One PV array of 64 W powered a DC pump extracting 10 lpm at 15 m of head. The water was discharged to a storage tank where it was tested on a weekly basis and then disposed to a deep well injection system. The pumping system operated maintenance free for one season (May to October).

While operation was deemed effective, reliable and simple to operate it was not complete. Groundwater was not being treated as a resource and a significant portion of it was being injected downhole. In the second season a Reverse Osmosis treatment system was added downstream of the pump. This consisted of Reverse Osmosis filters, a high pressure pump (1700kPa) and a PV array of 1170W. The system produced a stream of fresh water suitable for release (permeate) and a stream of brine solution (concentrate) requiring disposal.

Chemical parameter concentrations for the permeate were reduced well below the Canadian Drinking Water Quality Guidelines as indicated below.

	Raw Water (mg/l)	Permeate (mg/l)
Chloride	3380	86
Sodium	1530	53
Hardness	2000	23
Manganese	4.4	0.021

Table 1. Chemical parameter concentrations for permeate

This water was used to irrigate the site, aiding in the remediation process by flushing addition chloride out of the soil. The volume of water requiring disposal (produced concentrate) was reduced by 50%.

In order to increase the speed of remediation, Komex installed two additional extraction wells. These wells were also equipped with DC pumps and the system was retrofitted to operate 24hr/day through use of additional solar panels and deep cycle battery storage. The complexity of the system has now increased to three extraction wells feeding the Reverse Osmosis system. While the complexity of the system has increased, the reliability has not decreased due to sound engineering and a design philosophy of simplicity. The client's request for a second system at another site was confirmation of the system's effectiveness.

Soil Vapour Extraction

Komex responded to a pipeline break in Central Alberta to determine the extent of the contamination and develop a remedial action plan for our client. Initial soil sampling identified the extent of the soil to be removed and replaced with clean fill material. The bulk of the hydrocarbon mass was removed in this method to a depth of 3m below ground surface. The extent of the contamination extended to a depth of 5m below ground surface and into the trees beyond either side of the right-of-way. At this point Komex recommended switching to an in-situ remediation technology. Soil Vapour Extraction (SVE) was recommended due to the high volatility of the hydrocarbon and relatively inexpensive equipment.

SVE involves extracting contaminated soil gas from the unsaturated zone through the application of vacuum in one or more extraction wells. The removal of hydrocarbon vapour causes increased volatilization and removal of the free product. Aerobic biodegradation of organic contaminants by naturally occurring bacteria is also enhanced due to increases in the subsurface oxygen concentration (bioventing).

Due to the remote location on-site power available was not available and pilot-scale testing was performed with a propane powered SVE unit. Results indicated SVE to be favourable to removing the residual hydrocarbons. When designing the full-scale system, Komex recommended powering the SVE with photovoltaic cells. The high alternative cost of tying into the electric grid made this an obvious choice. Additional benefits included eliminating operating costs and the availability of a portable power source at the end of the project. Performance of the SVE was also increased due to the cyclic generation of photovoltaic power. Intermittent application of the SVE vacuum enables previously voided soil pore space to recharge with hydrocarbon vapours thereby increasing overall recovery.

The full-scale SVE system consists of a 1hp blower powered by 12 x 85W solar panels. Operation of the system is year-round; 8hr/d in the summer and 4hr/d in the winter. The system is currently in its second year of operation and is extracting from one horizontal and two vertical extraction wells. Initial off-gas concentrations peaked at 15% LEL from all three wells. As this value decreased, the SVE was concentrated on the more prolific of the wells. Off-gas concentrations were as high as 42% LEL, declining to 25% LEL after two months of operation. Laboratory analyses have indicated an extraction of 1,000kg of hydrocarbon mass over the first year. With minimal maintenance this system has proven to be ideal for the remote location and robust operating conditions due to year-round operation.

Solar Mobile Power Station

In response to a number of client requests for a reliable power source for remote sites, Komex designed the Solar Mobile Power Station (Power Station). A complete power solution was required that offered both 24-hour operation and flexibility in terms of required manpower.

The Power Station is contained in a trailer that is conveniently towed from site to site, wherever the power is required. Photovoltaic panels mounted on top of the trailer create DC power, which is then stored in deep cycle batteries. The stored power is available at all times, whatever the atmospheric conditions. The Power Station was originally designed to provide constant in-situ power for pumps and blowers used for remediation, yet it is appropriately designed to be used in a variety of industrial applications. The portability of the Power Station has made it ideal for pilot-scale tests and remote construction sites.

The Power Station houses a total of 12 x 85W (1020W total) of PV arrays and 12 x 2V deep cycle batteries. Electrical power is available to the user in both DC and AC, via a 120V AC inverter. In addition, a compressor provides an air supply of 100psi to operate pneumatic pumps and instruments. In the occasion of a prolonged period of overcast skies, the photovoltaic panels will be unable to recharge the batteries. At this point an emergency 5kW generator will start operating automatically in order to recharge the batteries. With this level of self-sufficiency the Power Station can be relied upon to provide 24-hour operation with minimal maintenance and an increase in reliability to generator-only options.

Payback

The demonstration of PV power as a reliable and cost effective solution to remote site operations may be evident. Understanding the environmental payback is not always as obvious. A typical remediation system may require 1kW of energy to operate. Over the course of one year, a 1kW PV array will produce 1600kWh. Generating the same amount of power with a generator will produce 256kg carbon equivalent of CO_2 (1kWh = 160g carbon). Over the 25 year life of a PV array, this equates to 6.4 metric tons of carbon. This is a considerable sum considering the importance of emission reduction in industry. The typical economic payback on the same array is 4 years. Computer modeling allows determination of energy production, life-cycle costs and reduction in greenhouse gases of any of the PV powered systems versus conventional power and generators.

Summary and Conclusion

Integrating PV power with remote site remediation holds great potential for industry. While technology is improving and costs are decreasing, presently reliable systems will become more efficient and effective.

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