QUESTIONS AND ANSWERS
ON THE PROPOSED
HVDC TRANSMISSION SYSTEM
FOR RURAL ALASKA

In recent months, many interested persons have asked a variety of questions about the proposed HVDC system for rural Alaska. To increase understanding of the proposed project, system and technology, we have prepared this compilation of questions and answers about the project. This compilation provides more detail about the information highlighted in our HVDC White Paper. They are written for those that wish to better understand the HVDC technology and its benefits. Questions and Answers are listed in the index below.

If you have additional questions or would like more information, please contact Earle Ausman, P.E., or Joel Groves, P.E. at (907) 258-2420, or by e-mail at:

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Q1: What is HVDC?

HVDC stands for High Voltage Direct Current. Direct current is the type of electrical current provided by a battery, such as that used for a flashlight or to operate the radio and headlights on a car.

The world's first electrical utility in the 19th century used direct current. This system was started by Thomas Edison in New York City and used buried cables to move direct current from his power plant to nearby customers. Edison could not boost the voltage of his system, so he had to use large cables to carry enough current to meet his customers' energy demand. Edison's system became limited by the expense of the massive cables needed to move power through the city. Alternating current (AC) technology, promoted by George Westinghouse, presented an elegant solution to the problem of boosting voltage, enabling Westinghouse to use smaller cables and more economically move power to customers. The AC system promoted by Westinghouse became the dominant electrical system that we use today.

By the mid 20th century, the technical challenge of changing DC voltages was solved, and high voltage direct current (HVDC) was introduced as a superior means of electrical transmission in certain applications. Because of the massive equipment needed to increase the DC voltage for transmission, early HVDC applications were limited to moving a lot of power over long distances.

Subsequent technological advances have further improved HVDC technology, enabling it to be a viable and superior option for ever shorter and smaller power transmission projects. Unfortunately, even today's commercially available HVDC technology is still unable to make HVDC an affordable alternative to AC transmission in places like rural Alaska.

The proposed project will take several existing and breakthrough technologies and adapt them to an HVDC system specifically designed and optimized for rural Alaskan conditions. By so doing, this project will demonstrate that HVDC is a cost effective and superior means of interconnecting rural communities. This paper discusses the specific advantages of this HVDC system that make it a viable technology for Alaska.

Q2: How does HVDC work?

An HVDC system would consist of the following major components:

- A converter module located in a village, most likely at the village power plant. The converter would be connected to the village's power grid. The converter would take electricity off the village's AC grid, convert it to DC electricity, and feed it onto a high voltage (HVDC) transmission wire.
- The HVDC transmission wire would convey power from the converter module to the nearest load (village). This wire could be a buried cable, an undersea cable, or

an overhead wire on poles. This wire would be at a high voltage (60,000 volts for the proposed system).

- The HVDC transmission wire would end at an identical converter module at the next village. This converter would receive the power, convert it back into 3-phase AC electricity, and discharge it to the village grid.
- For an earth ground-return system, the HVDC side of each converter would be attached to grounding rods or mats in the earth. Return current would flow via these grounding rods and the terrain between the villages. This current and voltage would be very diffuse and safe, somewhat like the white 'common' wire on a household circuit.
- For a wire ground return system, both converters would be attached to a second wire connecting the villages. This wire could be part of a cable, or a second wire strung on poles. Just like the earth ground return, this wire would be like the white 'common' wire in a house. Many villages in Alaska could use an earth ground return instead of a wire ground return.

Q3: What can HVDC do for Alaska?

The proposed HVDC system has the potential to reduce the cost of power interties in rural Alaska by up to 50%. This will make many more interties economically viable to construct, enabling many rural communities to enjoy less costly and more reliable power. These advantages will be realized in a number of different ways:

- Today, most villages in Alaska burn diesel fuel in small generators to produce electricity. This is not very efficient, and requires each village to store over a years' supply of diesel fuel to provide power. By making it less costly to connect villages together, this HVDC system can help to reduce or eliminate redundant bulk fuel farms and small generating plants in nearby villages.
- The small diesel generators used in most villages are relatively inefficient on a electricity-per-gallon basis. By connecting villages together, larger more efficient generators can be installed and the linked villages can enjoy the efficiency savings.
- Larger more efficient generators can be located in villages with the best bulk fuel farms, or the lowest delivered cost of fuel, to achieve maximum cost savings for all connected villages.
- By connecting multiple villages together, the combined power demand of a rural grid will be large enough to justify development of more local and regional renewable energy resources. This will reduce the amount of fuel that must be imported, and will move these villages closer towards sustainability. Potential local energy resources include small hydro, wind, geothermal, gas, coal, biomass, and others.

Q4: What Can HVDC do for tapping Alaska's local energy resources?

Rural Alaska possesses numerous local energy resources, many of which are renewable. These include excellent sites for wind, small hydro, geothermal, tidal energy, and others.

Rural Alaska also possesses a variety of local gas, coal, and other non-renewable resources that could provide power for villages.

To date, very few of these local resources have been tapped. The single biggest reason for this is that the demand of an individual village is too small to justify the costs of a local generation facility, and the costs of connecting multiple villages together are too high.

By lowering the costs of power transmission, multiple villages can be interconnected, and their combined load will achieve the economies of scale necessary to tap and develop more local energy resources.

Q5: Why should the government fund an HVDC demonstration project?

The proposed HVDC demonstration project has the potential to significantly reduce the cost of power transmission in rural Alaska, and thereby significantly reduce both the cost of electricity and the cost of capital infrastructure in interconnected villages. In so doing, this project has enormous potential to extend the reach and benefits of state and federal monies allocated to rural power projects in Alaska. It is in the public interest to stretch the funds allocated to rural Alaska to benefit as many people for as long as possible. This project will do just that.

The state and federal governments invest large sums of money into rural Alaska's power infrastructure. These investments include bulk fuel facility upgrades funded through the Denali Commission, power plant upgrades funded by the Alaska Energy Authority, grants by the U.S. Department of Energy, U.S. Department of Agriculture Rural Utility Service, and others. In many cases, the state and federal governments are already funding rural power connections. Also, the state's power cost equalization fund (PCE) provides large sums to rural Alaska to offset high power costs. Many of these costs can be ameliorated by substituting renewable and indigenous energy sources for diesel fuel.

The requested $6.025 million in funding for this project will pay for development and testing of the HVDC system, and also pay for a 26-mile intertie between St. Mary's and Mountain Village. The estimated cost of a conventional AC intertie between these two villages is $7.8 million. Even in this first project, which includes significant one-time funds for development and testing, the HVDC system is significantly less costly than existing alternatives.

Q6: Who is proposing to develop HVDC?

The Alaska Village Electric Cooperative, Inc. (AVEC), and Polarconsult Alaska, Inc. (PCA), an Alaskan engineering consulting firm, are proposing to develop HVDC. Both AVEC and PCA believe that the proposed HVDC system can revolutionize rural power systems – lowering power costs, increasing reliability, and improving lives and increasing opportunities in many communities in rural Alaska.

Q7: Are there other HVDC transmission systems currently in use?

There are many HVDC transmission systems in current use throughout the U.S. and worldwide. One well-known system is the HVDC line that transmits power from the Columbia River region in Washington and Oregon to southern California. There is also an HVDC system using undersea cables from Washington to Vancouver Island. Power from China's new Three Gorges Dam on the Yangtze River is transported to Shanghai with an HVDC transmission system. A new HVDC system has been proposed that would transmit 1500 MW from Washington to northern California via an offshore route. HVDC transmission systems also exist under the North Sea in Europe, in South America, and elsewhere.

HVDC is asynchronous (it has no frequency or phase), so HVDC transmission is often used to connect different power grids together. Texas utilizes HVDC connections between its domestic AC power grid and the AC power grids of adjacent states. Quebec Hydro used HVDC to connect with Canada's Maritime Provinces, and also to connect with the northeastern U.S. power grid.

Q8: How would this HVDC system differ from existing AC transmission systems?

Most existing power transmission lines in rural Alaska are three phase alternating current (AC) lines operated at 7,200 or 14,400 volts. Typically, these lines consist of wooden poles either buried directly in the ground or, in poor soils, bolted to steel piles driven into the ground. These poles are about 40 feet long, and are spaced as much as 300 feet apart. Each pole has a cross arm at the top that supports the three wires and maintains separation between them.

This conventional AC system has several shortcomings in rural Alaska:

- Wooden poles come as a single piece, and are heavy, awkward, and therefore expensive to transport and install.
- Cantilevered (free-standing) poles are a poor choice in weak soils, because the soil is weakest near the surface, where it needs to be strongest. A guyed pole is a better choice in poor soils.
- Driving steel piles into weak soils for pole foundations is very expensive, and can require heavy equipment to be mobilized to the remote work site. This increases construction and replacement costs.
- The limitations imposed by poor soils and cantilevered foundations results in many short poles being used to construct the line. This results in high costs for materials, shipping, and construction..
- Pole and cross-arm structures must support three wires, mandating stronger poles and higher costs.

This HVDC system has been designed to solve the above-listed shortcomings of AC systems in rural Alaska. Some of the specific technical advantages of HVDC are discussed below.

- The first important change is that this HVDC system uses one wire instead of three. The HVDC converters in each village still output three phase AC power, but the transmission part of the system uses only one wire. This reduces the weight and forces that must be supported by the poles by a factor of about three.
- By reducing the forces on the poles, the pole foundations become simpler. The HVDC system utilizes guyed poles instead of buried poles, because the foundations for guyed structures are much less costly in poor soils. Foundations for the HVDC system will use compact, light weight elements such as micro piles, soil nails, soil anchors, and similar technologies that are less costly to ship and can be installed with equipment generally available in rural Alaska.
- By utilizing a single wire instead of three, there is no need for a cross arm at the top of the pole. This eliminates a significant amount of hardware and assembly time, reducing shipping and labor costs.
- the HVDC system will utilize hollow fiberglass poles. These poles are stronger, more durable, and much lighter than wood poles. They are also sectional, and can be shipped in manageable lengths and assembled in the field. Depending on the final design, the various pole segments might be nestable, which would reduce shipping volume and shipping costs.
- By reducing the loading on the poles and using guyed fiberglass poles, the poles for this HVDC system can be significantly taller than the wooden poles used on AC systems. The proposed system would use 70-foot tall poles, allowing spans as long as 1,000 feet. This significantly reduces the number of poles required for the transmission line, further reducing costs for materials, shipping, and installation.

Q9: What are HVDC's advantages?

HVDC's major advantages as they apply to Alaskan conditions and applications are summarized and discussed below. Many of these advantages are discussed in greater detail in answers to other questions.

1. HVDC can move more power for a given operating voltage and conductor size than a comparable AC system. Please see "How would this HVDC system differ from existing transmission systems?".

2. HVDC, using ground return, can use a single wire, instead of the three wires needed for an AC transmission system. Please see "What is Ground Return?".

3. HVDC is asynchronous. This is advantageous when connecting different power grids together, as it eliminates the need to match the frequency and phase of different AC systems. Please see " What Does Asynchronous Mean, and Why is it Desirable?".

4. HVDC's overhead transmission system will be significantly less costly than conventional AC construction. Please see " How would this HVDC system differ from existing AC transmission systems?".

5. HVDC transmission systems can use cables over long distances. AC transmission systems develop reactive power losses, and cannot easily use cables for long distances. Please see the “Land and Submarine Cable” part of the answer to "What is done with the transmission to use DC’s properties?".

6. HVDC can be advantageous for some renewable energy technologies such as wind and hydro.

   Using an asynchronous HVDC system, wind and hydroelectric generators are not limited to standard AC 60 Hz speeds, and can operate at the most efficient speed for the generator or turbine. The proposed HVDC system can then convert this AC frequency to a standard 60 Hz AC frequency.

Q10: What are HVDC's disadvantages?

1. HVDC is best suited for point-to-point transmission of power.

   An HVDC transmission system is designed to move power between two or more converter stations on a dedicated HVDC transmission line. Homes and businesses cannot easily tie into this dedicated line for electrical service. In rural Alaska, if an HVDC line passes by a fish camp or other small potential customer, that customer will not be able to receive electricity from the HVDC line unless they can afford a converter station at a cost of hundreds of thousands of dollars.

2. HVDC converter modules are relatively expensive.

   The primary reason HVDC has never been implemented in rural Alaska is because the converter modules that convert AC to DC and back have been too costly. The only commercially available HVDC converter module in the small size needed in rural Alaska (ABB's "HVDC Lite" technology) was estimated to cost $4 million per module, or $8 million for a two-village system[1]. This has prevented HVDC from being a cost effective alternative in rural Alaska.

   The converter proposed by Princeton Power Systems should be significantly less costly than any other on the market. Combined with the optimized transmission system designed by Polarconsult, this HVDC system lowers costs to the point that HVDC interties are less costly than AC interties and affordable for rural Alaska.

3. Alaska has a lack of experience and familiarity with HVDC.

   Because HVDC has never been an affordable alternative, there are no HVDC systems in Alaska. Many of the people in the utility industry are unfamiliar with HVDC, and understandably wary of this new technology.

[1] Cost Analysis for the Green's Creek – Hoonah power intertie.

Low voltage DC systems are proven, and reliably operate just about every car, truck, ATV and snow machine in rural Alaska. High voltage DC (HVDC) systems have been used for power transmission all over the world for decades, and are a proven, reliable, and competitive transmission alternative to AC.

This HVDC technology promises to benefit numerous villages and people throughout rural Alaska. The development risks for HVDC are low. This project is designed to move this technology forward in a measured manner that will incrementally develop, test and validate HVDC's suitability for use in rural Alaska. Through this project, the legitimate questions that utility professionals may have about HVDC will be thoroughly addressed and answered.

Q11: What about birds and HVDC's proposed guyed poles?

Alaska is an important flyway and habitat for many species of birds. Some existing transmission systems in rural Alaska have become controversial because birds sometimes fly into the lines and can be hurt or killed.

The guyed poles that are proposed for this system may pose a hazard to birds in some areas. In these areas, a buried cable may be a suitable alternative. If an aerial system is necessary, the HVDC system is expected to have fewer bird kills than a comparable AC system for two principal reasons:

1) The HVDC system will have less wire aloft than a comparable AC system. This is because the HVDC system uses one wire instead of three. Even factoring in the guy wire at each pole, the total wire aloft is less than for an AC system. Also, at 70 feet high, the HVDC system will be taller than a conventional AC line, so some of the wire will be higher than most birds fly.

2) Birds cannot cause a short across conductors and be electrocuted on the proposed HVDC system. On an AC system, large birds can simultaneously touch two conductors, causing a short between the wires and being electrocuted. On the proposed HVDC system, there is only one wire. Birds cannot be electrocuted because there is no short circuit path within their wing span.

Q12: What is a converter?

A converter is a device which changes alternating current (AC) electricity to direct current, or direct current to AC. Converters have been built around several different technologies over time. The earlier HVDC converters used mercury arc valves, and were massive systems that took up significant space, similar to a large electrical substation or switchyard.

Modern converters generally use various solid-state switches to function. Most designs require extensive and expensive filter banks to remove electrical noise from the AC output. Unfiltered, this noise wastes power, and it can also harm sensitive appliances and electronics.

Solid state switching technologies used in converters include silicon controlled rectifiers (SCRs) and insulated gate bipolar transistors (IGBTs). Each technology has its merits and challenges, both in terms of function, reliability, and cost.

Q13: What Does Asynchronous Mean, and Why is it Desirable?

All connected AC power systems are synchronized, meaning that they are coordinated so their alternating voltage and current fluctuate at the same phase and frequency. When separate AC systems are connected, they must be synchronized, which can be difficult to do.
Because HVDC does not have a frequency or phase, it is asynchronous. In rural Alaska, asynchronous connections between villages will significantly simplify power interconnections. On a simple two-village intertie such as the proposed St. Mary's – Mountain Village project, one village will generally be the generator and the other the consumer of electricity, and the asynchronous property of HVDC will not usually be employed. On the more complex multi-village grids that would likely radiate out from Bethel, Naknek, Dillingham, Kotzebue, and Galena, an asynchronous HVDC grid would have significant advantages as one or more power plants combine to meet the electrical demand of the grid.

Larger HVDC projects, such as the proposed Bradfield Connection in Southeast Alaska would have significant advantages over AC. Not only is an asynchronous HVDC intertie technically preferable to an AC intertie, but it may have significant regulatory advantages as well. FERC rules do not apply to HVDC transmission across state lines, but they do apply to AC transmission. By utilizing HVDC on the Bradfield Intertie, Alaska might avoid having all power systems in the state fall under FERC jurisdiction.

Q14: Why are Princeton's converter systems better?

The major criteria needed for a converter to be viable for power transmission in rural Alaska are:

1. Affordable life-cycle costs (combined capital, maintenance, repair and operations costs).
2. Low power losses in power conversion (both AC-DC and DC-AC).
3. Compact, robust hardware that can withstand shipping and conditions in rural Alaska.
4. Relatively small power capacity, 1 MW and 5 MW units are envisioned.
5. Highly automated operation, requiring minimal specialized operator knowledge for routine operations.
6. Modular design, allowing for quick field replacement of failed components.

There is commercially available technology that meets some of the criteria listed above, but none can meet all of these criteria. The AC-Link^{TM} system developed by Princeton Power Systems (PPS) is the first commercially available technology that is both adaptable to HVDC service and capable of meeting all of the above criteria.

PPS' AC-Link^{TM} system is already commercially deployed for a variety of applications, including in military marine propulsion systems, wind turbine power conversion applications, and others. The AC-Link^{TM} technology has not been commercially adapted for use as HVDC converters, but the technology is capable of functioning in this capacity.

A one MW AC-Link^{TM} converter is expected to be the size of two refrigerators. It is expected to have losses of about 1.5%. This efficiency and size is comparable to a conventional AC transformer of similar capacity.

The solid state switching technology employed in an AC-Link^{TM} converter, silicon controlled rectifiers (SCR), is a low cost, robust, and proven technology. The converters would be built to allow SCRs to fail closed, so a single switch failure would not impair the function of the converter. The converters would be constructed in a rack configuration, allowing most components, such as the SCR modules and central capacitor to be quickly replaced in the event of failure. Critical components could be stocked on-site to improve reliability.

The AC-Link^{TM} converters would sense power demand on the HVDC line and automatically control power flow between villages. Power would be able to flow in either direction along the HVDC line.

Q15: Why has this not been done before?

Existing HVDC transmission technology is tailored for moving large amounts of power over long distances. Smaller commercially available HVDC converters have appeared on the market in the past decade, but the smallest currently available converter, ABB's 'HVDC Lite' system has a single converter cost of about $4 million, and a capacity of 5 MW. This is still too large and costly to make HVDC feasible in rural Alaskan markets.

Polarconsult has identified the technology and products developed by Princeton Power Systems as adaptable and scalable to the criteria needed for HVDC systems in Alaska. The technological breakthroughs commercialized by PPS, when tailored for HVDC transmission applications and combined with the innovative transmission systems developed by Polarconsult, will be the first viable HVDC system at the size and functionality required for rural Alaska and other remote areas throughout the world.

Q16: What do HVDC's properties do for transmission options?

Overhead Transmission

Many of the ways that HVDC's unique properties are used to optimize the transmission are discussed elsewhere in this document. Because they are central to the advantages of the proposed HVDC system, they are discussed here in greater depth.

Superior Electrical Properties

- Suitable for ground return
- No reactance losses, no need for voltage compensation
- No charging current problems
- Corona losses are diminished
- Less cable insulation is required at a given voltage
- Asynchronous connection of isolated AC systems simplifies intertie operation
- Asynchronous connection is more robust to system perturbations

Superior Mechanical Properties

- Fewer wires so structures and foundations can be lighter
- Cross arms are eliminated, and hardware is reduced
- No need to maintain phase-to-phase separations
- Higher voltage is used than for a typical rural AC system, so a smaller wire can be used.
- Fewer wires, stronger wire, and reduced possibility of conductor clashing allows longer spans
- Longer spans means fewer poles, reducing material costs, shipping costs, installation time, and environmental disturbance
- Lower cost and fewer foundations required

For HVDC systems that can use single wire ground return, and with the proposed high strength conductor, it is practical to use light, tall structures to span long distances. On straight sections of line, the proposed system can have spans of about 1,000 feet, similar to the spans along Turnagain Arm north of Girdwood.

A single pole without cross arms can be used to support the conductor. The weight and lateral wind forces on the single conductor are reduced by a factor of up to three as compared to an AC system. Phase-to-phase clearance problems are eliminated, and phase-to-ground clearances are reduced. The number of insulators and hardware required is similarly reduced.

Because of the higher voltage, ground wire can be used for most of the conductors. Such ground wire is used to shield large transmission lines in lightning prone areas and is comprised of Alumoweld wire. This wire has been used with a fiber optic core for information transmission, and is extremely strong and more robust than the commonly used ACSR conductors.

The HVDC poles' foundation will carry the relatively modest vertical loads and can be supported by small-diameter micro piles. Lateral loads such as from wind or angles in the line will be carried by guy wires. The guy wires are connected to screw anchors, grouted soil anchors, or freeze-back pin anchors depending on the soils.

For comparison, the equivalent conventional 75-foot tall AC pole installed in good soils would be an 85-foot long pole buried about 10 feet in the ground. This pole is very heavy, awkward and expensive to transport to rural Alaska. In the poor soils or permafrost common in rural Alaska, the conventional solution is to drive a steel pile 20 to 40 feet into the ground and bolt a wooden pole to the pile. This approach requires mobilizing a pile driver to the remote project site, and then moving the pile driver around in an area with poor soils. This is expensive, and can cause a significant disturbance to the local environment. Also, the connection between the pole and pile is typically the weakest point of the system, but is about where the most strength is needed.

Construction of a mile of straight HVDC transmission line would require only 6 small foundations, 18 guy anchors and connections, plus six insulators, stringing blocks, clamps and armor rod units. Only one conductor is pulled and set in place. The construction calls for climbing the poles or using powered ascenders only six times per mile to tie in the single conductor. All other work is done on the ground. Each pole assembly can be lifted by the small helicopters readily available in Alaska. Each pole assembly is sufficiently light to be erected from the ground using a small crew with a bipod and a small winch.

Land and Submarine Cable

HVDC is far superior for cable applications than AC. Because it is not constantly alternating voltage and current flow, HVDC does not induce rapidly changing fields and currents in the ground nor in the cable shields. This significantly reduces the high capacitive value associated with AC cables. Because of these capacitive values and reactive power losses, the length of AC cable systems is generally limited. HVDC cable lengths are not subject to these limitations.

Because of different voltage stress distributions and lower peak voltages, a DC cable requires less insulation than an AC cable operating at an equal voltage. As an example, a 35 kV AC cable operated at 20 kV to ground would use the same amount of insulation as a 60 kV DC cable operating at 60 kV to ground. This is one factor that will lower costs for DC cables compared to AC cables. The result is that one DC cable will carry the power of three AC cables of similar size.

These electrical advantages of DC cables also result in mechanical advantages. A DC submarine cable of given capacity will be smaller than an AC cable. This is because an AC cable will typically be a bundle of three cables, with thicker insulation, and also with more armor and shielding to protect the cable from physical damage. The lighter DC cable can be laid with smaller equipment, and will be easier to handle. Once in place on the seabed, the lighter DC cable is less likely to be damaged because it is lighter and can make tighter bends. If the cable needs to be repaired, the lighter DC cable is easier to raise to the surface than a heavier AC cable.

Q17: Are there submarine cables in Alaska?

Numerous submarine cables are currently in service in Alaska. These include:

- 138 kV cables under Knik Arm connecting Anchorage to the Beluga power plant.
- Cables under Taku Inlet connecting Juneau to the Snettisham project.
- 69 kV cable crossings between Juneau and Green's Creek.
- AC cable between Skagway and Haines.
- AC cable connecting Cordova to the Humpback Creek project.

In addition to the power cables listed above, numerous communications cables are also in service beneath Alaska's waters. Many of these communications cables also have power lines inside them for signal repeaters. These communications cables are of particular interest, as they are more comparable in size and configuration to an HVDC single cable than are the multiple-conductor massive AC cables.

Even though these cables are not HVDC cables, they provide valueable data and experience on the mechanical cable hazards and reliability under various conditions. This data can be used to judge the performance, risk, and reliability of submarine HVDC cables in Alaska.

Q18: Why is a single wire used on this HVDC system?

A single wire is used on this HVDC system because:

- Using a single wire lowers construction costs for the intertie
- The single wire technique is safe and appropriate to use in most rural Alaskan areas

This issue is discussed more fully in answers to other questions. See "What is Ground Return?".

Q19: What is "Ground Return"?

All electrical systems require a path for current to flow from the generator to a load, and a return path back to the generator. Without a return path, the electrical system will not function. Normally, the return path is a second wire, such as the white 'common' wire in a house. On three-phase AC transmission systems, the three phase-separated transmission wires can serve as return paths for each other. On single phase AC systems, there is usually a second wire for the return. Very few DC or HVDC systems also utilize a second ground wire for the return path. 'Ground Return' means that the earth is used for this return path instead of a second wire.

Most large HVDC systems are bipolar, meaning that the systems have two main wires energized to positive and negative voltages to complete the electrical circuit. Relative to ground, these two main wires will be energized at a voltage such as minus 60,000 volts and plus 60,000 volts. The positive and negative halves of the HVDC system both move ½ of the power of the total system. These large systems will sometimes have a third ground connection that is used only for emergency operations.

This two-conductor bipolar HVDC configuration is not practical or necessary for a small rural Alaskan HVDC system. A bipolar HVDC system requires two converters at each village (one plus and one minus), and also requires two high voltage wires. This would approximately double the cost and capacity of a rural intertie, eliminating most of the cost advantages of this proposed system and providing additional capacity that is not needed.

The proposed system is a monopolar HVDC line that will use ground return, often called Single Wire Ground Return (SWGR). Ground return is a technique where the second wire on a single phase AC or a DC system is eliminated and the ground, or earth, is used instead to complete the electrical circuit. In developed areas, SWGR is rarely used because it induces modest ground currents and voltages that can rapidly corrode some buried metals, such as utilities. Ground return is best suited to rural areas with limited or no buried metallic utilities. For the proposed HVDC system transferring 1 MW of power, the widely dispersed ground return current would be less than 17 amperes, about equal to that used by a hand held circular saw.

SWGR is advantageous because it eliminates the cost and complication of a second wire on the transmission system. In rural Alaska, there are few buried utilities for a ground return system to corrode. The line between Bethel and Napakiak utilized a single phase AC ground return, and this ground return system has functioned very well. Australia, New Zealand, and Africa have successfully installed 1,000's of miles of single phase AC circuits with ground returns. These systems are used in rural areas with loads of up to about one MW.

The technical suitability of ground return will be individually evaluated for each intertie project, but the technique will lower costs for many of the potential rural interties in the state.

Q20: How long will it take to develop the system?

It is estimated that Phases one and two of the project will be completed in about 18 months. At this time, samples of all of the key technology and components associated with the HVDC system will be designed, fabricated, tested, and ready for demonstration on the St. Mary's – Mountain Village demonstration project.

Q21: When will construction start on the line between St. Mary’s and Mt. Village?

Design on the St. Mary's – Mountain Village intertie will begin after phases one and two are completed, or about 18 months after the project is funded. The construction schedule will be determined as part of the design work for the intertie.

One deliverable from phases one and two of the project is to refine the cost estimates, labor requirements, and installation methods for the HVDC system. This information will be used to develop an engineering design and final cost estimate for the St. Mary's – Mountain Village intertie. Construction will begin after the final design and notice to proceed is provided.

Q22: What are the reasons for interconnecting St. Mary's and Mt. Village?

The generation systems and bulk fuel farms for both of these communities are old and need to be replaced. With an interconnection, only one location requires the new generators and fuel farms. This would reduce costs, increase efficiency, and thereby help control the price of power.

Q23: What information is there to assure the converters will work?

Princeton Power Systems (PPS), the company that holds the converter technology and would develop the converters, has extensive experience developing and commercializing devices similar to the HVDC converter. These previously commercialized devices are based upon the same technology as the proposed HVDC converter, and include:

- Ship propulsion drives for the U.S. Navy. These drives have a rated power up to 37 MW, and operating voltages from a few hundred to 50 kV. The drive systems are modular.
- AC-AC power conversion and management modules for wind turbines, using the same AC-Link™ technology that is the basis of the proposed HVDC converters.

Their experience provides a high degree of assurance they can successfully develop, construct and commercialize the HVDC converters. As further assurance, PPS will prototype a converter module and thoroughly test it in phase one of the project.

Q24: What will be done with the funding if the Converters do not work?

The project has been designed so that any unforeseen problems with the converter technology will be identified as early as is practicable. If the converters do not work, unspent funds will be returned to the funding organizations.

Q25: What are the risks with this transmission hardware?

The risks associated with this transmission hardware and system are very low. As a worst case scenario, an HVDC intertie could be constructed with conventional line hardware and wooden poles, although many of the cost benefits of the proposed system would be sacrificed.

A second fallback option would be to employ an overland, buried or underwater cable as the transmission link.

One of the key cost-saving innovations featured in this project is the transmission system design tailored to rural Alaskan conditions and HVDC's technical requirements. The proposed system hardware utilizes a variety of existing commercially available components and technologies and combines them to produce a transmission system that has not been previously attempted in rural Alaska.

Q26: In addition to the remote communities, will the railbelt benefit?

All of Alaska benefits with this technology. While rural communities stand to benefit the most from this technology, the railbelt communities may also be able to more economically extend their systems to reach nearby communities, and also to reach large and small renewable energy resources such as wind, hydro, and others.

The railbelt, and Alaska generally, will benefit directly and indirectly from lowered costs in rural communities. When costs of living decrease and opportunities for employment increase in rural Alaska, all of Alaska benefits. Rural Alaska is a very important economic and cultural component of the state.