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Medium Voltage Direct Current Power Electronics for Alaska Remote Community Interties

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Fig. 1b. The Yukon-Kuskokwim Delta. Villages within green circle considered for MVDC network
Source: https://i0.wp.com/www.ykhc.org/wp-content/uploads/2018/06/YK-Service-Area-Map-no-logo-18-2.png?ssl=1
Accessed: 18-SEP-2018

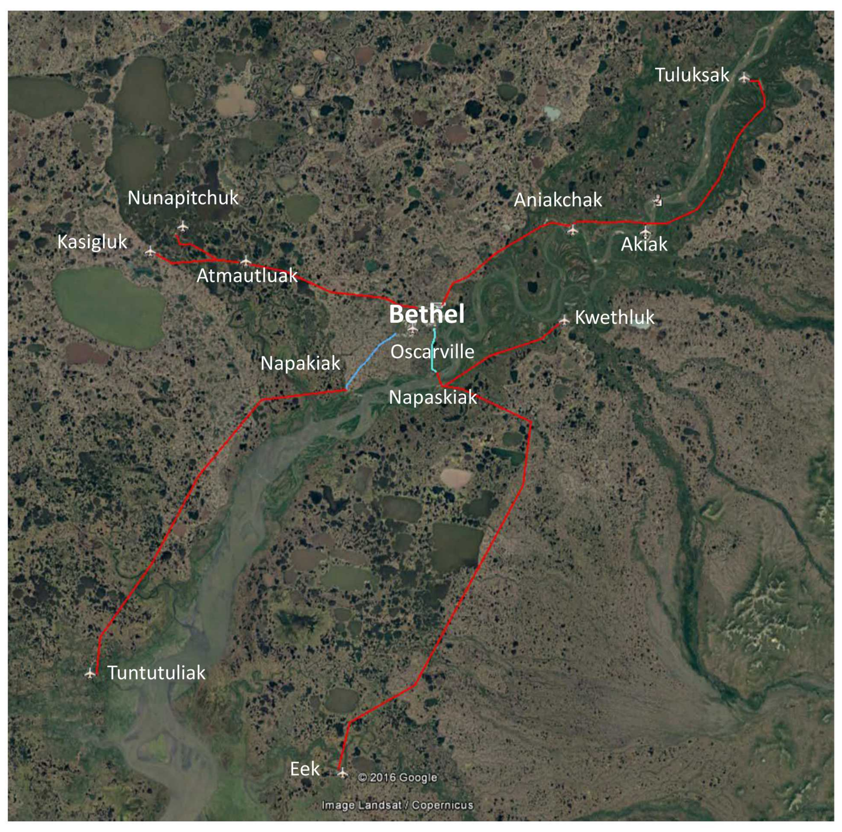

Fig. 1c. Googlemap overlay by Bill Stamm of AVEC

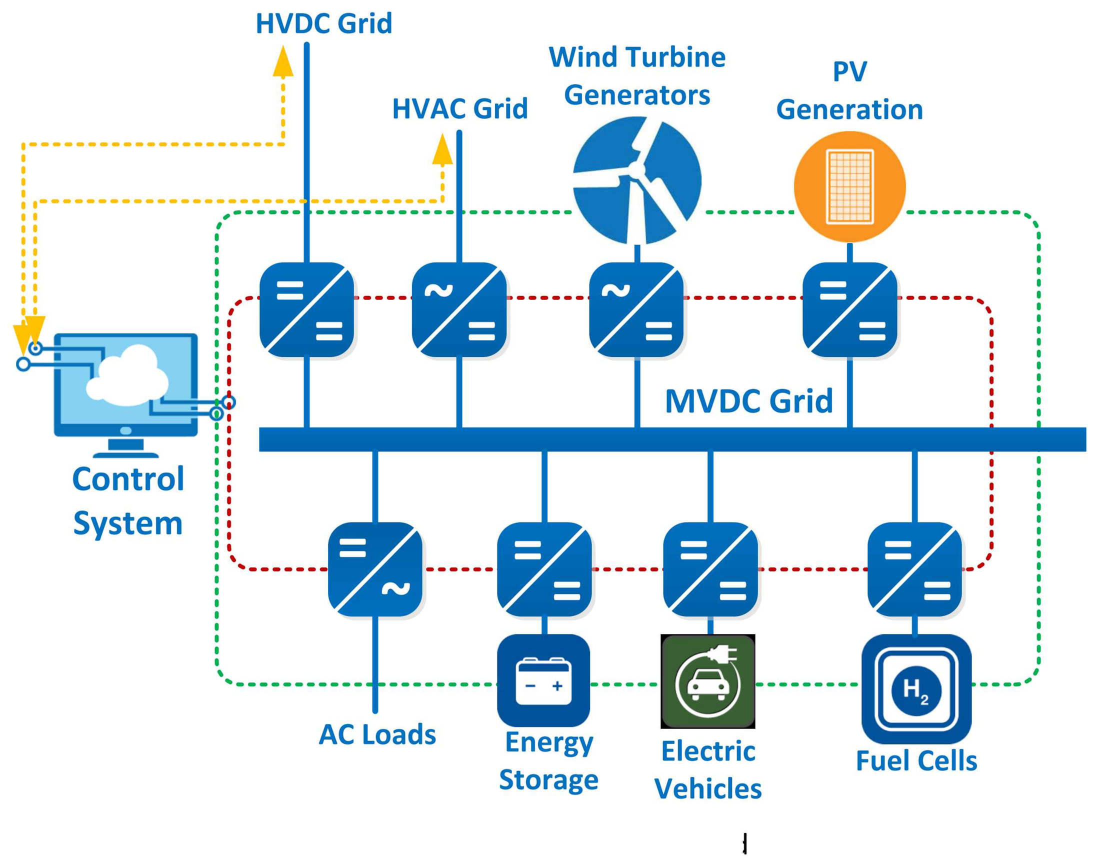

Fig. 2. MVDC Network

Background:

- High cost of energy in remote Alaska communities: 2018 average cost in 200 remote Alaska communities (combined 50 MW load) was $0.36/kWh
- Overhead MVAC interties reduce operating costs, but expensive to install and limited in distance: Cost of $350K-$700K/mile and limited to ~20 mi.
- Cable based distribution offers lower installation costs across remote and permafrost terrain but charging current limits distance for AC distribution

MVDC interties:

- MVDC cable interties offer longer distance coverage, reduced voltage drop, and reduced conduction losses.
- MVDC networks also facilitate integration of large-scale **battery energy storage systems**, PV and wind power plants.
- MVDC networks offer enhanced **flexibility and scalability** than their AC counterparts due to simplified synchronization and controllable power flows
- Availability of sub-MW MVDC power electronics is currently the most significant factor limiting exploration of MVDC interties in Alaska.

Objectives and approach:

- Identify region and **utility partner** to perform techno-economic feasibility and for potential future deployment opportunities
- Explore techno-economic feasibility of MVDC interties to connect villages in remote Alaska, comparing cost of MVDC intertie vs. MVAC intertie vs. continued islanded operation (in progress)
- Identify state-of-the-art in MVDC power converters and most promising architectures for lower power applications
- Validate dynamic performance of the MVDC network using switching-level controller hardware-in-the-loop simulations (future)

Partners:

- Alaska Center for Energy and Power, University of Alaska Fairbanks
- Sandia National Laboratories
- Alaska Village Electric Cooperative

Period of Performance:

- August 22, 2018 – August 21, 2021

Activities to date:

- Identified utility partner and target region for techno-economic analysis;
- Studied state-of-the-art and trends in HVDC and MVDC converter topologies, cable, and manufacturers. Identified dual-active bridge (DAB) in conjunction with low voltage AC-DC as most promising topology for lower voltages and power levels.
- Compared costs of AC vs. DC and overhead vs. underground transmission.

LINE #	CONNECTION	LENGTH (MILES)	UP STREAM PEAK LOAD (KW)	RATED VOLTAGE (KV)	MAX RESISTANCE (Ω)	CONDUCTOR DIAMETER (INCH)	CONDUCTOR SIZE (AWG)
1	Oscarville to Napaskiak	1.89	213.68	25	146.244	0.048	<#2
2	Bethel to Atmautluak	18	826.93	25	37.791	0.292	1/0
3	Atmautluak to Nunapitchuk	6.5	671.58	25	46.532	0.158	<#2
4	Bethel to Akiachak	16	1169.40	25	26.723	0.327	2/0
5	Akiachak to Akiak	7	744.93	25	41.950	0.173	<#2
6	Akiak to Tuluksak	17	180.00	25	173.611	0.132	<#2
7	Akiachak to Kwethluk	7	313.68	25	99.622	0.112	<#2

Fig. 3. Preliminary conductor sizing for Bethel area MVDC distribution

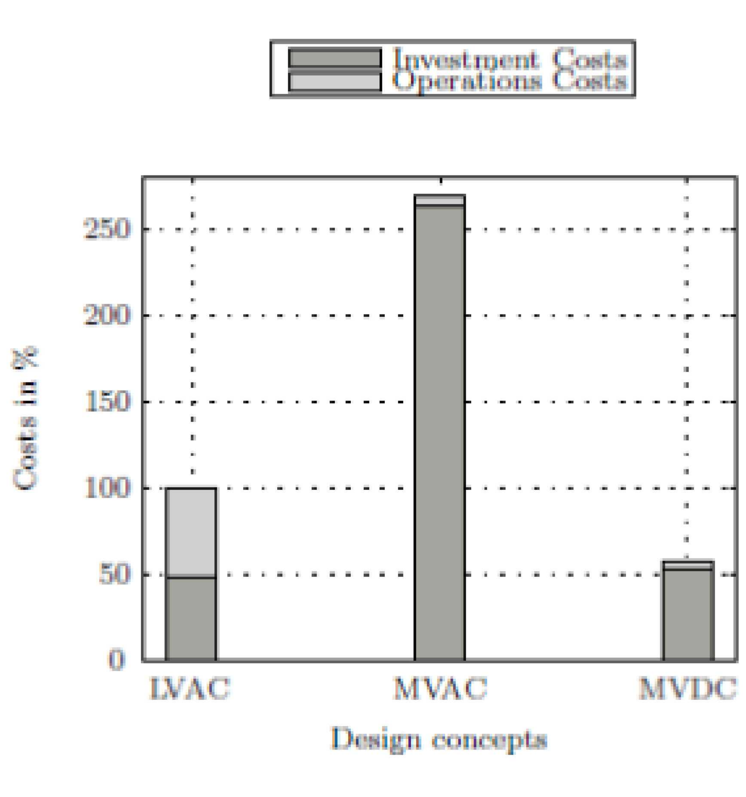

Fig. 3. A 2016 case-study in Germany [3] shows the cost comparison among LVAC (400V), MVAC(6.6kV) and MVDC(± 5kV) systems based on 5 MW (1,300 households) power level. Dual-active bridge (DAB) based DC-DC converters replace the 50/60 Hz transformer at ±5 kV MVDC.

References:
[1] E. Csanyi, "Analysing the costs of HVDC transmission," Electrical Engineering Portal, Online Aug 2014, Available: https://electrical-engineering-portal.com/analysing-the-costs-of-high-voltage-direct-current-hvdc-transmission

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