Waste Heat to Power: The Baseload Renewable You Already Have

Robert Emrich
Director of Sales & Market Development
Electra Therm

Continuous duty gensets provide baseload power generation in diverse applications around the globe. However, high fuel costs and engine maintenance are pain points felt by operators as they deliver this critical service. A low maintenance path to significant fuel savings and lower emissions is what the U.S. Department of Defense (DoD) had in mind when they approached ElectraTherm to integrate the Power+ Generator™ with a Cummins KTA-50 1.1 megawatt generator. The DoD wanted to investigate the performance impact and economics for their diesel engine fleet. Between the DoD project and the 50+ Power+ Generators running in the field, ElectraTherm has demonstrated more than 10% increase in fuel efficiency along with simple installation, mobility and low maintenance. The Power+ Generator can replace the engine's radiator entirely and deliver a payback of two years or less for diesel or heavy fuel oil-fired gensets. In effect, the engine's waste heat becomes a source of cost savings by displacing the radiator's capital cost and parasitic load, i.e. more power with a quick payback.

In the past, there were no proven commercial products for converting engine heat to power so operators had little choice but to accept the heat loss to the atmosphere. Today ElectraTherm has deployed more than 50 units worldwide with over 700,000 hours of cumulative fleet experience. ElectraTherm is the leader in small-scale, distributed power generation from waste heat; we utilize Organic Rankine Cycle (ORC) and proprietary technologies to generate power from low temperature heat ranging from 77-122°C. ElectraTherm's Waste Heat to Power (WHP) technology converts various sources of heat into power, including internal combustion engines, small geothermal, biomass, concentrated solar and process heat. ElectraTherm's primary market is waste heat from stationary internal combustion engines. With the typical engine running at about 33% efficiency, there is considerable waste heat between the jacket water and the exhaust. Typical engine sites include: prime power production in remote areas, island and developing nations, biogas gensets including landfill and wastewater treatment plants, natural gas compression stations and renewable biofuels.

Many Benefits of Heat-to-Power for Prime Power in Remote Areas

There are multiple benefits to integrating an ORC heat to power generator with an engine genset and we can confidently say that we have created the world's most efficient engine cooling device. The first benefit is clear: the additional electrical output from the conversion of the waste heat to electricity with no additional fuel consumption or emissions. Second and less obvious is the reduction or elimination of the parasitic load from the engine cooling fans. The Power+ Generator acts as the radiator and, therefore, the engine-driven radiator fans can actually be disconnected, allowing more work to be performed by the engine to generate additional electricity. A third benefit can be achieved in hot climates or seasonally high ambient conditions, due to the fact that the ORC has a greater cooling capacity than the engine requires. So for very high ambients when the engine radiator limits the output of the engine the increased cooling capacity provided by the ORC's radiator allows for increased performance. The Power+ electricity output combined with reduced parasitics account for 10%+ fuel efficiency gain depending on engine size and configuration. The additional benefit from decreasing the engine's de-rate period or the amount of de-rate will, of course, vary with ambient conditions.

The Department of Defense Projects

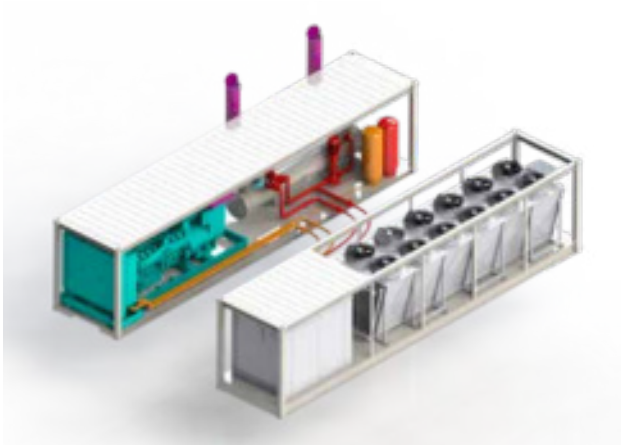
Our first project with the DoD was to simulate various engine models and ORC integration schemes, and fully test those configurations on ElectraTherm's test cell. A matrix was developed consisting of five engine models and two engine configurations over different ambient conditions for waste heat capture: jacket water only and jacket water boosted with exhaust energy for higher ORC efficiencies and output. U.S. Navy personnel visited ElectraTherm several times during the first project for training and inspection of our test cell and facilities. At the conclusion of this project a very favorable report was issued by the Navy.

The next step was to develop a higher output,

fully integrated ORC specific to a Cummins KTA-50 1.1 megawatt engine for DoD deployment. The ORC and all balance of plant was packaged in ISO shipping containers for ease of deployment and mobility throughout the world. Funding for this second project came from DoD's Environmental Security Technology Certification Program (ESTCP) through Southern Research Institute (SRI) who is independently monitoring the performance and fuel efficiency gains.

Figure 1 shows the configuration, comprised of two 40' ISO shipping containers. The Cummins genset, engine controls, switch gear and exhaust gas heat exchanger were housed in a Combined Heat and Power (CHP) module packaged under ElectraTherm's direction by Cummins Rocky Mountain from Denver, Colorado. The ORC module contained the Power+ Generator and associated controls, liquid loop radiator (combined radiator for the engine and ORC) and the corresponding balance of plant (piping, pumps and expansion tank, etc). The system was tested with the Mobile Utilities Support Equipment (MUSE) group at the Port Hueneme, CA Navy facility for fuel efficiency testing by SRI.

Figure 1. DoD funded ORC integration and replacement project



This project forced our engineering team to look hard at the question "Do we need both the engine radiator and ORC radiator?" All ORCs need condensing and all engines need cooling. Could it be done with one radiator, eliminating approximately $75,000 in capital cost for an engine this size? The answer is a resounding "YES". Advanced engine cooling with a payback was born, accomplished with an intermediate heat exchanger to optimize the return temperature to the engine and a bypass to ensure the engine cooling remained operating if the ORC is not running. The impact to the overall installed cost for an ORC can now be reduced by 20-30%.

ElectraTherm currently manufactures a 35 kW unit that fits well with ~500 kW gensets (our 4200 model), a 65 kW unit which fits well with ~800 kW engines (our 4400 model), and our project with the DoD is the first 110 kW unit (our 6500 model), well suited for 1-2 MW engines.

Figure 2. Electra Therm installed ten Power+ Generator 4400s at a district heating plant in Slovakia.

ElectraTherm's experience to date with genset integration has been very successful. Our applications include single engines and multiple engines utilizing jacket water heat alone as well as jacket water combined with exhaust heat. Engine models that have been integrated with the Power+ Generator include Jenbacher, Deutz and MWM engines in Europe as well as CAT and Waukashau engines in North America.

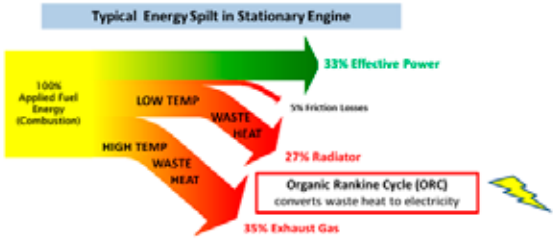
How it Works

ElectraTherm's Power+ Generator operates using a closed loop ORC, where hot water is the fuel. Hot water from the engine enters a heat exchanger to excite (pressurize) the non-flammable, non-toxic working fluid, driving the twin-screw expander and generator to create electricity. ElectraTherm's patented twin-screw expander is unique in its configuration, lubrication and specifications, but the core technology is based on reliable, proven compressor technology that has been around for more than 20 years.

The twin screw expander has a rotational speed

of 1800 - 4900 RPM, considerably less than turbo expanders. Unlike high speed turbo expanders, Screw expanders are robust units that tolerate "wet" dual phase flow. This allows the Power+ Generator to utilize more cost effective and compact heat exchangers that tolerate perturbations in both temperature and flow with turn down ratios of 6:1 available on demand. This is particularly advantageous in low temperature waste heat streams such as engine jacket water. Through a patented lubrication scheme, the Power+ Generator design is simplified and eliminates lubrication reservoirs, oil coolers, pumps, land filters, creating a simple, robust, and efficient system with fewer parasitic loads and maintenance requirements. Figure 3 shows why engine gensets are a great match for Power+ Generators from ElectraTherm since a significant portion of the waste heat is at low temperatures and engine throttle positions can vary widely depending on the electrical load demand.

Figure 3.



Distributed WHP systems for stationary engines are not yet well known or mainstream, but the technology is field proven, and the economics are now attractive. ElectraTherm's various packaged solutions are making it easier to economically capture waste heat and make emission-free and fuel-free power from sources that already exist. In planning your next genset application, or if you have an existing radiator replacement coming up – consider implementing waste heat to power, the renewable you already have.

Figure 61: Shazad Ibnul of Vector and Greg Schellenberg of S&C Electric Company

After morning tea presentations continued from the Allied members for session four which were based on utility case studies chaired by Mr. Apii Timoti, CEO, TAU. The first presentation was from Hydro Tasmania on Rarotonga Renewable Energy implementation followed by I S Systems Pty Limited on Case Study: Low cost inter island DC Electric Power transmission for Chuuk State. While Solomon Power presented on Solar – Hybrid mini Grid System – Recently Commissioned solar hybrid mini grid systems for two provinces and Sustainable Energie Partners presented on the practical application of solar power and battery storage in Pacific Island Countries.

Figure 62: Ray Massie of Hydro Tasmania, Craig Harrison of IS Systems, Pradip Verma of Solomon Power and Gregory Story of Sustainable Energie Partners

After afternoon tea presentations continued for session five which is based on new and emerging technology chaired by Tologata Tuimalealiifano Tile, GM, EPC. Vortex Group Limited presented on modernization of existing generation plant with PLC based control systems and Itron Australasia Pty Ltd presented on reducing energy costs with active grid. While Arthur D. Riley & Co. Ltd presented on Halo Solid Ring Main Unit and ComAp Pty Ltd presented on Cloud Cameras, saving fuel and cost. Electra Therm concluded the session presenting on waste heat to power. The base load renewable you already have.

Figure 63: Aidan Priestley of Vortex Group Ltd, Tim Wolf of Itron Australasia Ltd, Karl Henry of Arthur D. Riley Ltd, Richard Bird of CamAp Ltd and Robert Emrich of Electra Therma

Welcome! To New Allied Members

Eight (8) new companies have joined PPA as Allied Members since our last PPA Magazine. The new members are:

AKUO ENERGY PACIFIC: Akuo Energy Pacific is based in Sydney, Australia. Their primary activity is IPP and their secondary activity is EPC.

AUSTRALIAN WINDERS: Australian Winders is based in Western Australia, Australia. Their primary activity is power generator windings field service repair. Their secondary activity is generator ancillary product supplier.

CLEAN ENERGY TECHNOLOGIES, INC.: Clean Energy Technologies Inc. is based in California, United States of America. Their primary activity is executive, business development and operations.

COMAP PTY LTD: ComAp Pty Ltd is based in Melrose Park, Australia. Their primary activity is generator – power generation control. Their secondary activity is renewable energy systems.

GOUGH CAT POWER SYSTEMS: Gough Cat Power Systems is based in Christchurch, New Zealand. Their primary activity is electric power generation: diesel, HFP, Gas Microgrid/Hybrid Turn Key Solutions.

IMPS (UK) LTD: IMPS (UK) Ltd is based in Lincolnshire, United Kingdom. Their primary activity is power generation. Their secondary activity is utility management.

ORIGIN ENERGY: Origin Energy is based in Victoria, Australia. Their primary activity is LPG supply to the Pacific. Their secondary activity is energy solutions.

SIEMENS LTD: Siemens Ltd is based in Queensland, Australia. Their primary activity is energy efficiency. Their secondary activity is power generation.