Digital Displacement® technology

High-performance hydrostatic power-transmission for wind turbines

Artemis gratefully acknowledges support from these organisations

Recent awards

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Artemis was created in 1994 as a spin-out from fluid-power and renewable energy research at the University of Edinburgh. Its multi-disciplinary team of engineers performs research, development and technology-licensing associated with Digital Displacement® technology and other innovations in the control and transmission of fluid power.

The company works in partnership with leading global engineering companies across a range of market sectors. It has a long-standing relationship with Sauer-Danfoss with whom it is working on the introduction of Digital Displacement® machines into the off-road market. Artemis also has a licencing agreement with Bosch Rexroth for on-road equipment.

In 2008, a BMW 530i converted by Artemis to incorporate a fully-hybrid Digital Displacement® transmission was independently tested at Millbrook test facility. Its performance was compared with baseline tests carried out with its original manual gearbox and transmission. On the European Urban Drive Cycle the fuel consumption and CO2 emissions of the hybrid were less than 50% compared with the baseline performance. This work was supported by the Department of Transport and the Energy Savings Trust.

The development of the Artemis wind-turbine transmission has been supported by Carbon Trust and the Department of Energy and Climate Change’s Environmental Transformation Fund.

Following its acquisition in 2010 by Mitsubishi Power Systems Europe, Artemis has been focussing on the development of drive-trains for the next generation of multi-megawatt offshore wind-turbines.

Artemis Intelligent Power Ltd, July 2012.
Digital Displacement® was developed through a sustained effort to improve high-pressure oil-hydraulics - traditionally the most robust of power-transmission technologies with unrivalled power to weight ratios, but locked out of many markets because of low part-load efficiencies and poor controllability.

The defining characteristic of Digital Displacement® is the substitution of the mechanical flow-control of traditional hydraulic machines by computer-driven valve commutation, a development analogous to the introduction of common-rail direct fuel-injection in vehicles.

Most of the refinements for high performance are within easily swapped valves, electronics and software instead of within complex mechanisms. This liberates designers so that innovations can be made to machine layouts with further reductions in losses. Oil-compressibility energy is also naturally recovered with consequent reductions in noise.

All Digital Displacement® pumps and motors are inherently variable-displacement. Each pump cylinder has an active low-pressure valve and a simple non-return high-pressure valve. In motors the high-pressure valves are also active.

Digital Displacement® machines contain multiple cylinders arranged radially in banks around a single-lobed or a multi-lobed camshaft. The key operational concepts are cylinder ‘enabling’ and cylinder ‘idling’.

Pump and motor cylinders are enabled, on a just-in-time basis at bottom- or top-dead-centre if their contribution is required to satisfy the high-level needs of the system. Otherwise, they continue to idle - breathing oil in and out at low-pressure and thus placing very little parasitic burden on the active cylinders.

The special properties of Digital Displacement® machines and systems include:

- High efficiencies at all pressures and displacements
- Natural interface to complex computer control systems
- Components are modular and easily swapped out
- High bandwidth, with step change from zero to full power in half a revolution
- Inherent capacity for self-diagnosis, stress management and active work-around
Artemis Digital Displacement® wind transmission

The Artemis Digital Displacement® transmission is ready to challenge gearbox and direct-drive transmissions on weight, cost and performance. The basic components of the system are:

- Variable-displacement, low speed, ring-cam pump
- Variable-displacement, high-speed, generator drive-motor
- Medium or high voltage, wound-rotor, synchronous generator
- Hydraulic accumulators
- Low-level pump and motor controllers
- High-level transmission controller

The decoupling provided by the accumulators allows pump torque to be instantaneously varied so as to capture the most energy from changing winds and gusts whilst the generator is driven at a steady rate. The industry-standard synchronous generator connects directly to the network without the need for a power converter and has unrivalled low-voltage fault ride-through and network support performance.

As shown below, the natural controllability of Digital Displacement® machines allows the use of more than one generator, so that system efficiency in low winds can be further enhanced by turning off unrequired capacity. Because of the inherently balanced load distribution and pressure limiting nature of hydraulic machines, the transmission is extremely robust. However should partial or full rebuild be necessary it can be carried out within the nacelle using the internal crane.

Artemis has built a high-power, energy-recirculating test-rig to simulate variable wind conditions and has successfully tested its prototype Digital Displacement® wind-turbine transmission. The transmission comprises a 1.6 MW ring-cam pump and two generator drive-motors, each of 800 kW capacity at 1500 rpm. Artemis is now developing multi-megawatt class Digital Displacement® wind-transmissions.

1 Low-speed ring-cam pump
2 High-speed motors
3 Synchronous generators
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