

# **Additional Documents for Modeling Results of Wind/Diesel Retrofit Options for Santa Cruz, Galapagos**

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January 3, 2007

Attachments not specifically sited in the actual report.

- 1) Enercon – Stand alone systems
- 2) Enercon – DesalinationSystems Booklet English
- 3) PowerCorp – Company web brochure
- 4) PowerCorp – Powerstore Flores case study



**ENERCON WIND DIESEL  
AND STAND ALONE SYSTEMS**  
SELF-SUFFICIENT POWER STATIONS USING WIND ENERGY



*Shipment of an ENERCON Stand Alone System and two E-40 wind turbines (Utsira/Norway)*

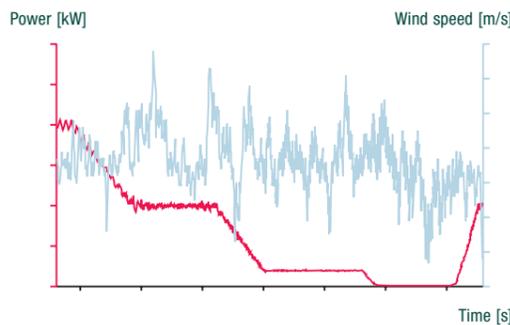
## **WIND-DIESEL OR STAND-ALONE**

### **CHOOSE YOUR PREFERRED OPTION**

ENERCON wind turbines up to 900 kW are well suited for locations on islands or in smaller rural communities to complement the diesel stations that normally supply the energy there.

In order to achieve a high penetration of wind energy in the energy mix for saving a maximum amount of diesel-fuel, ENERCON has developed the necessary equipment for grid stabilisation and system control.

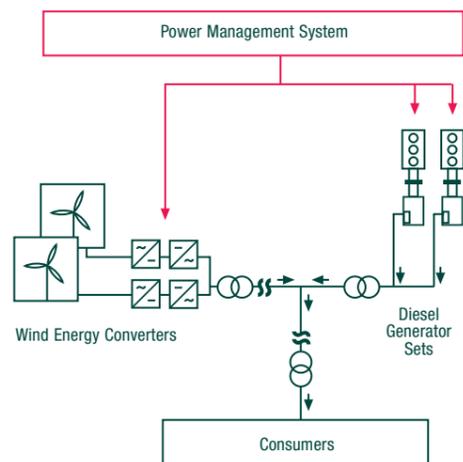
In order to get accustomed to wind turbines and their behaviour in the local diesel grid, the way towards a self-sufficient energy supply using only wind energy (diesel-off mode) is usually done in several steps.



### 1. WIND-DIESEL APPLICATION

With ENERCON wind energy converters and their standard integrated system controls for variable speed and variable blade pitch it is possible to safely connect and operate wind turbine capacity in the range of up to 35% of the installed diesel capacity in parallel to the diesel gen-sets. As the turbines power output is freely selectable and reliably controlled via rotor speed and blade pitch, no dump loads are necessary and a maximum use of the wind energy is possible while the diesel machines keep their grid forming tasks (diesel remains to be the main energy source).

In order to efficiently manage the supply and demand side and to control the interaction of diesel gen-sets and wind turbines, ENERCON offers a Power Management System for this application (see page 8).



Step1: Wind-Diesel

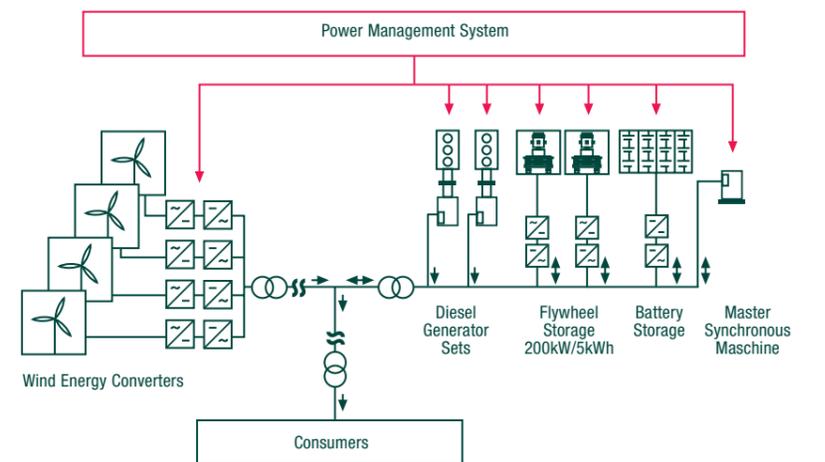
### 2. STAND-ALONE APPLICATION

If the fuel saving results are encouraging and the grid and/or power station operators are satisfied with the grid behaviour, it can be planned to increase the installed wind capacity. Then an energy storage system comes into play in order to balance the wind fluctuations and to allow for a diesel-off mode (“zero-emission”) where 100% of the energy demand can be supplied by the wind turbines, when the available wind power meets the demand of the consumers.

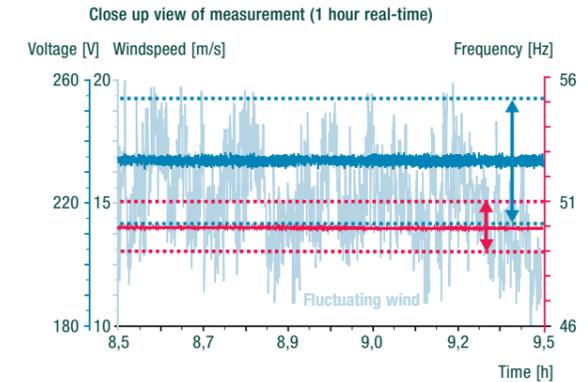
The schematic drawing below shows a stand-alone system with all necessary components. With such a system wind energy can completely supply the consumers, depending on the system layout, i.e. balance between wind turbine installed capacity and load demand (wind turbine takes over as main energy source).

ENERCON has developed all relevant system components including the main control system (Power Management System) and can thus even supply a complete power station (based on wind energy) to provide consumers with power at locations where no energy supply has been available so far or where old diesel engines have to be replaced.

In all configurations and operational modes the system delivers stable and uninterruptible power with very high grid quality (well within the limits of e.g. EN 50160 – see measurement on the right above). And this precisely according to the demand – which is the main challenge in small local grids. Only the required amount of energy is produced and dump loads to dispose of excess energy are not necessary.



Step 2: Stand-Along



The dotted lines show the allowed limits for grid voltage and frequency

Grid voltage and frequency in the ENERCON Stand Alone System are well within the admissible limit values according to EN50160



### COMPONENTS IN THE ENERCON STAND ALONE SYSTEM

#### Wind turbine

- Main energy source

#### Flywheel

- Short-term energy storage to compensate the wind energy fluctuations in the seconds range
- Frequency controller in the stand alone grid (diesel-parallel and diesel-off mode)

#### Battery storage

- Emergency back-up in the stand alone grid (diesel-off mode) for power supply in the minute range
- Frequency control in emergency cases

#### Master Synchronous Machine used in diesel-off mode for

- Voltage control
- Supply of reactive power
- Short circuit current supply
- Flicker filtering

#### Controls

- Power management in the wind-diesel mode or stand alone grid
- Safe and economic automatic operation of the system (manual mode also possible)
- Data processing and process visualisation

#### Diesel generator (or other combustion engine)

- System start-up
- Power supply at lack of wind and empty storage facilities

### FLYWHEEL STORAGE SYSTEM

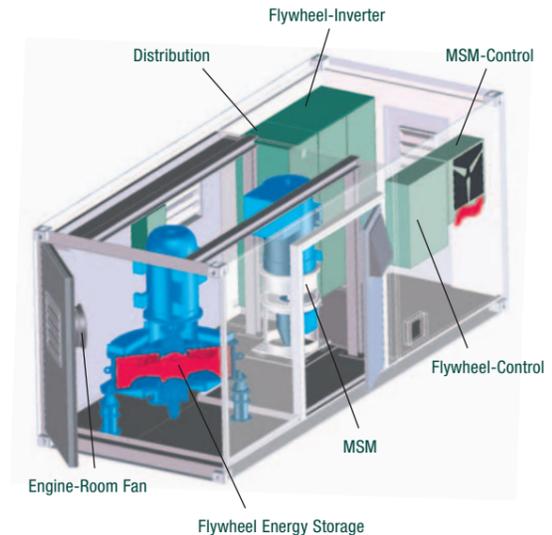
In the year 2000 ENERCON decided to develop an energy storage system specially suited to compensate wind power fluctuations. It has been designed according to the following requirements:

- Low cost
- Low maintenance
- Robust design
- Long lifetime
- Standard components and materials as far as possible
- Possibility for individual applications (modular, containerised etc.)
- Rated power 200 kW
- Energy storage capacity 5 kWh
- High efficiency / low losses
- Extremely fast reaction time
- Optimum grid behaviour

The ENERCON flywheel is a very simple and robust system, which is proven by more than 20,000 operating hours without maintenance work. The mechanical design using standard materials and well-proven components for example bearings and other machine parts ensures a reliable operation and a long-term supply with spare parts. Access to e.g. bearings is easy and for their replacement no specially trained personnel is required.

The use of standard well-proven ENERCON inverters ensures very high grid quality and allows for the use of standard spare parts necessary for wind turbine maintenance.

The ENERCON flywheel comes in a standard 20ft sea container convenient to transport and ready for connection to the grid. All components are installed and completely cabled. The system undergoes extensive testing before delivery. Thus the time for installation and commissioning on site is very short.



ENERCON standard energy storage container (example with flywheel)



ENERCON Stand Alone System  
(Utsira/ Norway)

#### POWER MANAGEMENT SYSTEM AND HMI/SCADA

The core component of the sophisticated power management system is the main control unit. It manages all components efficiently to ensure a reliable power supply under all operating conditions.

The main controller for the power management of the overall system is a standard industrial state-of-the-art controller. Because of its modular design it can be adapted to the specific requirements of each system.

The strategy for running the complete system in safe and economic automatic mode is implemented in the software of this controller. This software of course has to be adapted to each individual application (number and type of energy sources and consumers etc.).

A manual mode is also possible where all functions of the controller can be activated by the operator. For this, the so-called HMI (Human-Machine-Interface) is used. It is realised with an industrial PC with touch-screen connected via Ethernet-link to the main controller.

#### ITS TASKS ARE

- **Process visualisation of all details**

The main menu gives an online overview of the complete system with the status of all individual components. From there the sub-menus for each single component can be selected, showing all sensor data monitored (online).

- **Data processing**

On a 10-min basis, a selection of data, as well as all status messages are stored (starts, stops, alarms, etc.).

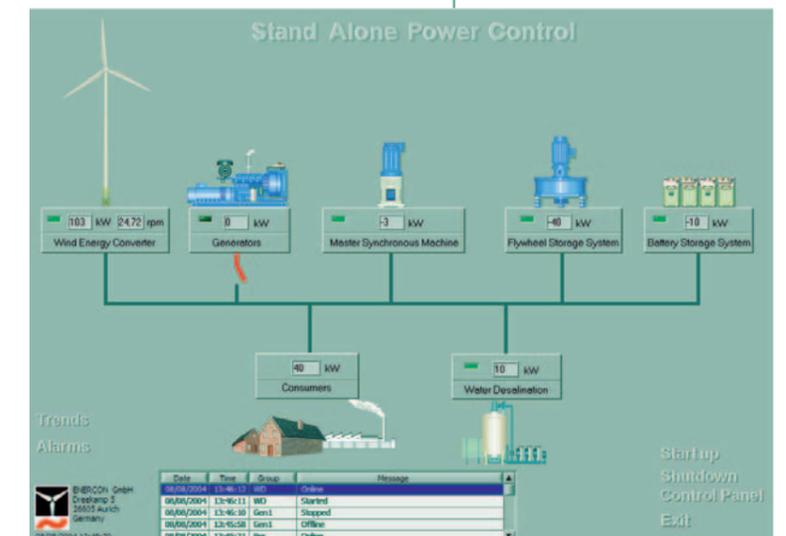
- **Manual operation**

Via the HMI, the operator has access to the main control panel and is able to give commands to all system components (start, stop, power set-point, operating mode etc.).

- **Scada**

The HMI is connected to an ISDN line offering the possibility of remote communication. The following functions are available:

- Sending alarm messages via SMS and/or email
- Online monitoring of the whole system from any office PC
- Access to the complete data stored in the system database



Main menu of the HMI  
(Human-Machine-Interface)  
of the Power Management System



#### ADVANTAGES OF THE ENERCON STAND ALONE SYSTEM

- ~ The wind turbine is the main energy source, wind penetration up to 100 % is possible (diesel-off mode, zero-emission). No dump loads required.
- ~ Continuous power supply is guaranteed, all emergency scenarios are backed-up.
- ~ Excellent grid quality through use of the well-proven ENERCON IGBT inverter technology.
- ~ High reliability, long service life, easy maintenance and good availability for spare parts due to the use of standard, robust, well-tested components.
- ~ Ideal mix of mechanical and chemical storage systems. Each type of storage is used according to its intended purpose, therefore long service life guaranteed.
- ~ Fully automatic control with state-of-the-art hardware technology.
- ~ Compact modular containerised design for easy transport and simple extension.
- ~ Quick on-site installation of pre-assembled components fully tested before delivery.
- ~ All components and overall responsibility from one supplier (wind turbine, flywheel, controls etc.) with long-term experience in wind turbine behaviour and controls.
- ~ Existing or new components can easily be integrated (e.g. diesel generators, photovoltaic systems, desalination units, hydrogen equipment etc.).





## ENERCON DESALINATION SYSTEMS

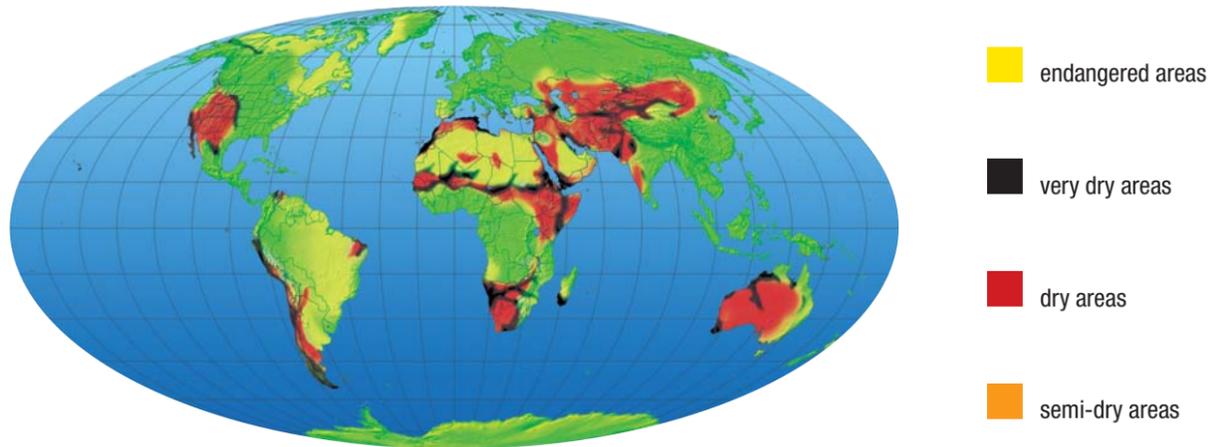
- Sustainable solutions for drinking water production -

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## WATER, THE ELIXIR OF LIFE

One of today's main problems is providing sufficient drinking water for the world's growing population. About three billion people have no direct access to clean potable water. Water is not only fundamental for human life, but is also essential for social development and prosperity. Global water shortage is already a source of great social tension and ecological problems.



## THE ENERCON COMPANY

As drinking water becomes ever more precious, seawater desalination and water purification are becoming more important. Even in regions where drinking water supplies are now adequate, it won't be long before new solutions are needed to secure them.

As the leading manufacturer of wind power turbines, ENERCON sees a major challenge to accelerate supply using regenerative solutions. Hence, besides the development, manufacture and optimisation of wind power plants, ENERCON's product portfolio includes research into and implementation of drinking water production systems.

ENERCON has been active in drinking water production since the mid-1990s. The modular and energy-efficient desalination systems developed by ENERCON have reached series maturity and represent a sustainable concept for the world's drinking water and energy supply.

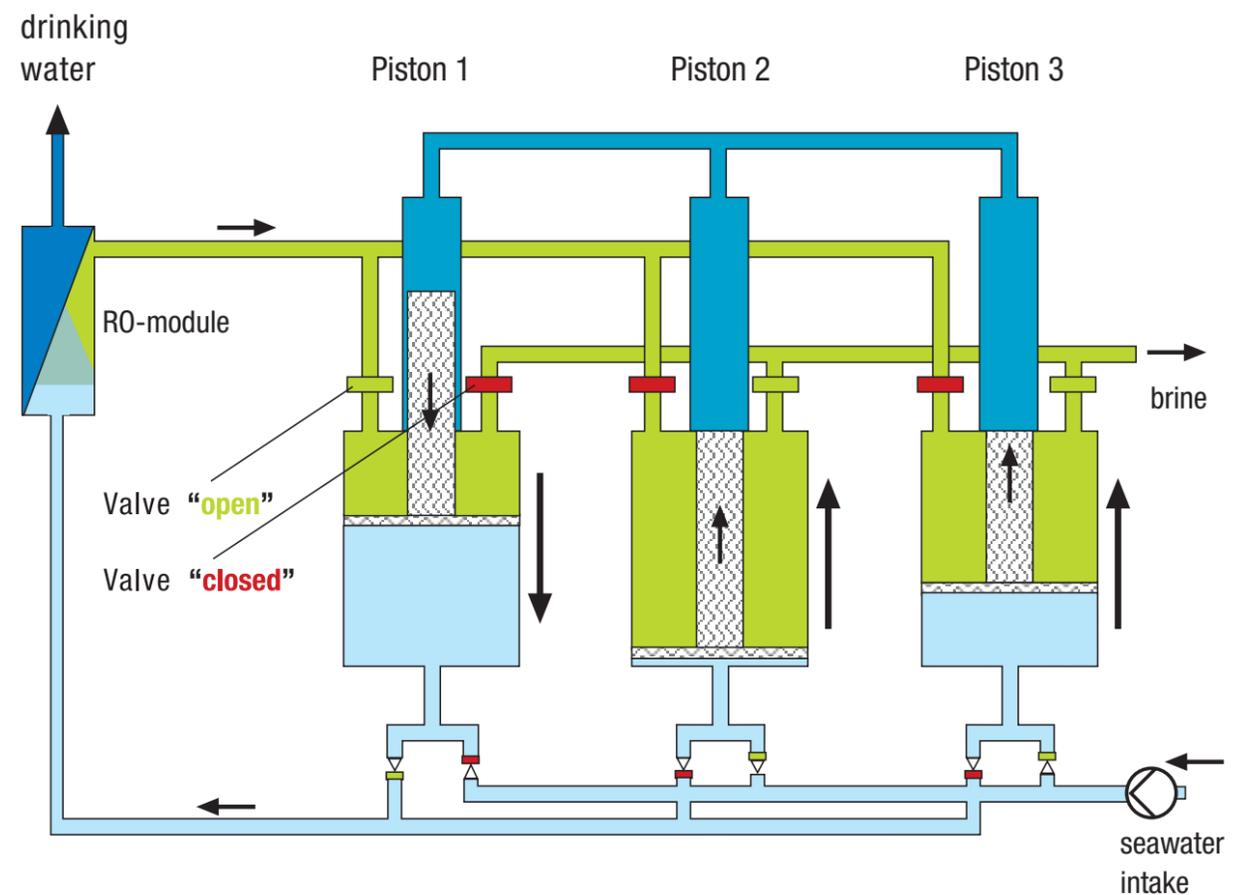
## ENERCON'S SEAWATER DESALINATION SYSTEM

### ENERCON'S ENERGY RECOVERY SYSTEM

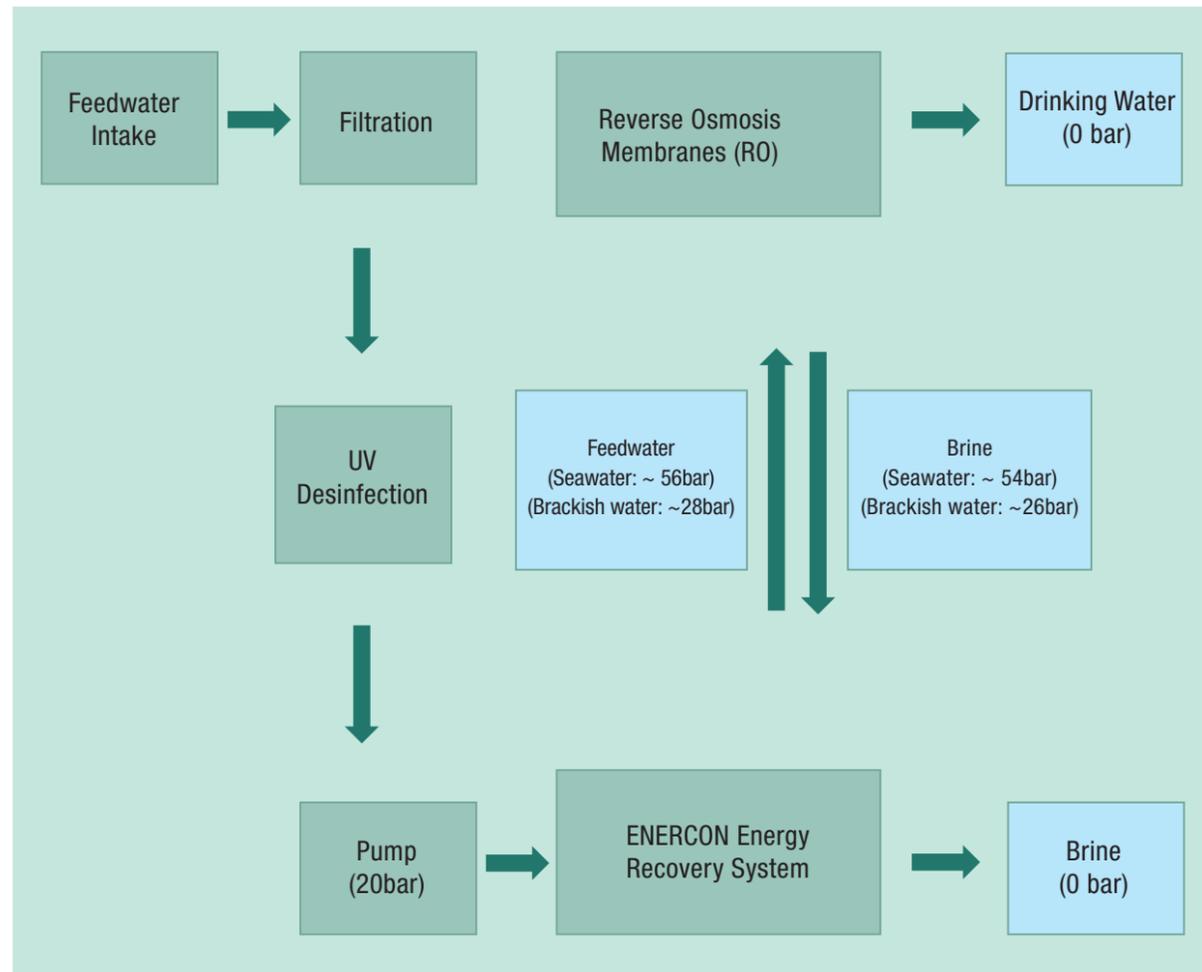
ENERCON's seawater and brackish water desalination systems are based on the principle of reverse osmosis (RO). In this process pressurised seawater flows over a membrane. The structure of the membrane retains the dissolved salts – water is able to permeate. The result is pure drinking water.

After passing the membrane, a three-piston system recycles the energy of the remaining seawater pressure with virtually no loss.

Thus desalination and energy recovery occur in a continuous complementary process, forming a cycle.



### BASIC FUNCTIONALITY OF ENERCON'S SEAWATER DESALINATION PLANT

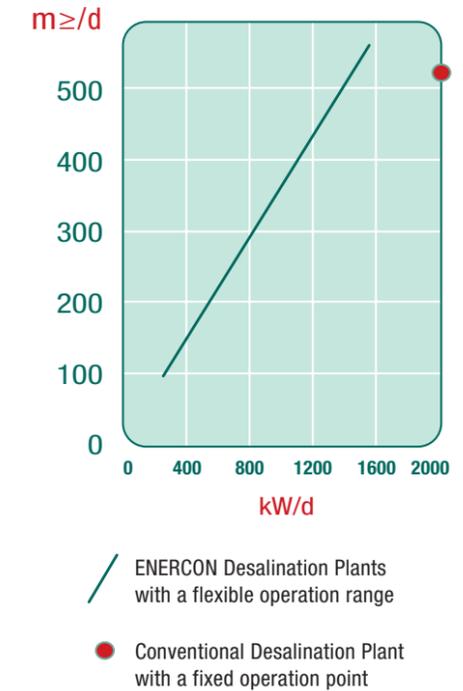


The feedwater flows through filters and an UV-disinfection system to the ENERCON Energy Recovery System. The pump pressure of 20bar is transferred to ~ 56bar/seawater or ~28bar/brackish water and flows to the RO-membranes. At the RO-membranes, feedwater separates into drinking water and brine. Drinking water leaves the system and brine, still under pressure, flows back to the energy recovery system to support the process.

### FLEXIBILITY IN POWER SUPPLY

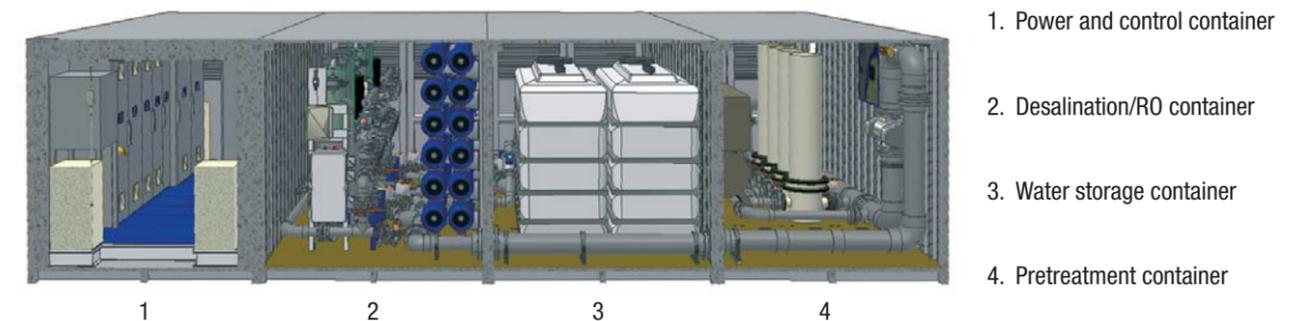
ENERCON plants have no fixed operating point. The water production can range between max. 12.5% and 100% of the nominal capacity by adjusting the piston speed according to demand. This has two main advantages: Firstly, operation is possible with a fluctuating energy supply, and secondly, output can be adjusted flexibly to water demand without shutting down the plant.

Only about 25% of the energy in the reverse osmosis process is used to produce drinking water, so without a recovery method, about 75% would go to waste. ENERCON's energy recovery system comprises a low-pressure pump (max. 20 bar) and a three-piston system, which raises the pressure up to 70 bar and simultaneously re-uses the remaining energy. There is no need for a second (high-pressure) pump. So this system consumes very little power and works extremely energy efficient.



### MODULAR CONTAINER DESIGN

ENERCON's seawater desalination plant is modular, comprising various containers. Each 20-foot container contains a separate part of the plant. This design enables easy worldwide transport and set-up logistics and also guarantees optimal protection of the plant from climatic influences.





#### CHARACTERISTICS OF ENERCON'S SEAWATER DESALINATION SYSTEM

- Very low energy consumption: The ENERCON recovery system saves 30% energy
- No need for chemicals: Physical control processes eliminate the need for chemicals
- Energy-efficient output adjustment: Without reducing efficiency, water production can be adjusted to demand and energy availability within a range of 12.5 % to 100%
- Based on the power and output variability, ENERCON seawater desalination plants can also be applied in weak power grid areas or as stand-alone systems
- Fully automatic operation, including re-start after a power failure, cleansing cycles, control depending on energy and feedwater availability
- Low operating costs; due to very low power consumption per m<sup>3</sup> of drinking water produced
- Low noise emission
- Remote plant monitoring with ENERCON's SCADA system: Monitoring regardless of location enables online viewing of all operating data. The data can be generated in tabulated or graphic form, statistical assessments can be calculated, etc.
- No 24 hour personnel necessary
- Combination with renewable energy systems, such as wind turbines

#### APPLICATIONS

##### DIRECT CONNECTION OF ENERCON'S SEAWATER DESALINATION PLANT TO THE PUBLIC GRID

Connecting the ENERCON seawater desalination plant directly to a stable grid poses no problem. The sea water is extracted from the open sea with a suction pipe or through a well and fed to the plant.

##### ENERCON'S SEAWATER DESALINATION PLANT IN COMBINATION WITH AN ENERCON WIND ENERGY CONVERTER AND LINKED TO THE PUBLIC GRID

The seawater desalination plant's primary power supply is generated by an ENERCON wind turbine. Coastal locations present excellent conditions for wind power, especially on islands. During strong winds, the surplus energy can be fed directly into the public grid. When there is insufficient wind the desalination plant can be powered from the grid.

##### ENERCON'S SEAWATER DESALINATION PLANT AS A STAND-ALONE GRID SYSTEM

ENERCON has developed a stand-alone grid system to guarantee a continuous, stable supply of energy and water to consumers in remote areas far away from the public grid. The seawater desalination plant's primary power supply is generated by an ENERCON wind energy converter. In combination with other system components, such as a synchronous machine, flywheel, battery and diesel generator, the system supplies and stores energy and water precisely according to demand. ENERCON's energy management system ensures ideal utilisation of the wind and water supply, while guaranteeing exceptionally high quality of the island grid.

#### DIFFERENT OPTIONS

TYPE	TYPE OF WATER	CAPACITY IN m <sup>3</sup> /DAY	NUMBER OF RO UNITS	NUMBER OF 20'' CONTAINERS	PUMPS PER RO UNIT
EDS SW 300	Seawater	175 - 350	1	4	1
EDS SW 600	Seawater	175 - 700	2	4	1
EDS SW 900	Seawater	175 - 1050	3	5	1
EDS SW 1200	Seawater	175 - 1400	4	5	1
EDS BW 600	Brackish	350 - 700	1	4	1
EDS BW 1200	Brackish	350 - 1400	2	4	1
EDS BW 1800	Brackish	350 - 2100	3	5	1
EDS BW 2400	Brackish	350 - 2800	4	5	1



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## The Powercorp Group



engineering innovative power solutions for a better world.

DYNAMIC POWER SYSTEMS  
POWER CONTROL SYSTEMS

# Innovative Power Solutions

... giving you the power to achieve your goals.



## Engineering innovations

The Powercorp Group is moving to become a world leader in distributed generation and related grid stabilisation technology. The Company has demonstrated its ability to achieve this by completing numerous commercially viable power systems in remote areas in which variable power generation has been stabilised to utility standards (without the use of battery storage).

### 1 Automation and control (Intelligent Power Systems IPS technology)

The COMMANDER to control and manage a power station.

MICROLINK for low cost automation by customers with the minimal need for engineering support.

### 2 Wind diesel power station high penetration technology .

DYNAMIC GRID INTERFACE (DGI), which dynamically adjusts its power consumption depending on frequency and voltage deviations, thereby stabilising the grid.

LOW LOAD DIESEL, a specially prepared diesel generator and DGI combination to provide low cost spinning reserve and grid support to power stations incorporating renewable energy sources.

### 3 Power quality and grid stabilising

POWERSTORE, a flywheel-based energy storage system. It is able to both absorb and deliver real power very quickly. This enables the technology to completely dampen energy fluctuations on any power line. It is able to do both voltage and frequency control and supply reactive power. It can work in conjunction with conventional SVC type solutions.

GRID STABILISING TECHNOLOGY, stemming from the power electronics research a variety of inverter configurations and component combinations are available to assist the stabilisation of power grids. This complex area requires mathematical modelling of the grid behaviours and for this we have available a POWERSTORE model prepared by an independent certified institution. Reactive power support, voltage control and fault management are available for applications such as compensation for large swinging loads, variable generation including poor step load response, and interface of such technologies as wind farms to utility grids.



## Experienced in grid stabilisation

Powercorp was formed in 1988 in Darwin, Australia, to automate the wide variety of diesel generator power stations in Northern Australia for the Power and Water Authority. This program encompassed some 60 communities and work has extended throughout Australia and internationally.

With the success of the automation program came the need to integrate renewable energy for fuel saving. This work and the demand side management capability of the control system led to advanced wind diesel systems in Western Australia for Western Power Corporation. With the winning of a Showcase grant from the Federal Government Powercorp pioneered high penetration wind diesel systems during the late 90's.

The chief problem facing wind diesel systems and indeed any renewable energy fuel saving technology when connected to isolated grids is the instability caused on the grid by power surging. Such surges and frequent loss of power can be caused by wind gusts and lulls or cloud cover in the case of solar systems. It is not possible for conventional generators to cope with these power instability issues and blackouts usually result. Even when the wind flow is low the fluctuations in wind speed can cause unacceptable generator response called "hunting" which uses more fuel and can cause engine damage.

The grid stability issue is seen in many small grids and at the end of long distribution lines. In the mining sector large electrical equipment such as winders and crushers can cause power fluctuations much the same as seen from renewable plant.

PowerStore the company's flywheel inverter system can absorb and deliver power very fast to dampen all instability to maintain the grid specifications to utility standards.

Powercorp developed expertise in inverter technology with specialization in high speed bi-directional control to solve the grid instability problem. With these solutions now a commercial reality Powercorp stands as the most advanced high penetration renewable energy company in the world. This work is expanding to encompass mine sites and industrial complexes.

The company is largely research engineering based with a strong manufacturing capability. It stands ready to serve any customer with grid instability problems.

**powercorp**

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# FLORES ISLAND POWERSTORE PROJECT, AZORES - PORTUGAL, 2005



The Azores is two hours flying time off the Portugal coast and has several islands that are powered by diesel generators and hydro power plant. There are two main islands with a population of 100,000 each and another 7 smaller islands. Over the last couple of years the local utility Electricidade de Açores (EDA) has installed a number of Enercon E-30 Wind Turbines on these islands to reduce the cost of diesel power generation. After the wind turbines were installed EDA found that they had to limit the amount of wind power injected into the system to avoid power fluctuations and blackouts.

In March 2005, EDA awarded to Powercorp the contract to supply one PowerStore flywheel energy storage system to the island of Flores to maximise the wind penetration on the island. The Flores power system consists of wind turbines, diesel generators and hydro generators all operated in manual by an operator.

The PowerStore container was delivered in August 2005 and subsequently commissioned in conjunction with Powercorp's local representative QEnergy. The PowerStore flywheel now smoothes out the wind power fluctuations and allows the operator to run the power station without any diesel generator online. This mode of operation was not possible before due to the slow frequency control of the hydro generators.

The annual savings in diesel fuel and reduced operating hours of the diesel generators are the main driver for EDA to install the equipment. In addition, PowerStore offers EDA the ability to expand the windfarm and therefore enabling higher wind penetration on the island.

## PROJECT INFORMATION

<b>title:</b>	Flores Island Power-Store Project
<b>region:</b>	Flores Island, Azores, Portugal
<b>customer:</b>	Electricidade de Açores
<b>commissioned:</b>	August 2005
<b>Power system type:</b>	Wind, Diesel, Hydro
<b>power system size:</b>	4.26 MW
<b># generators:</b>	Wind Turbine x 2, Diesel generators x 4, Hydro generators x 4.
<b># feeders:</b>	2

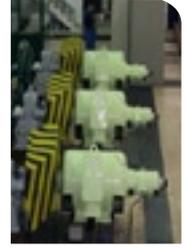


# FLORES ISLAND POWERSTORE PROJECT, AZORES - PORTUGAL, 2005



## TECHNICAL INFORMATION

diesel generators:	Caterpillar 625kVA x 3, 850kVA x 1
hydro generators:	370kVA x 3, 740kVA x 1
wind turbines:	Enercon E-30 x 2
max. demand:	1.5MW



## ABOUT POWERCORP

Powercorp is proudly 100% Australian owned and operated, which was established in 1988 to develop innovative solutions for remote diesel power stations in the Northern Territory of Australia. Over the years Powercorp engineers have developed sophisticated management systems for all levels of power station operation, which allow a variety of fossil and renewable energy sources to be integrated into the power supply system. This high level technology has led to applications throughout the world.

Systems are designed to provide maximum efficiency and reliability at the lowest possible cost. Projects often involve complete rehabilitation of an existing diesel power station and Powercorp's capability extends to the mechanical, civil and switch yard aspects of the work. Powercorp can also offer prime power equipment such as reciprocating engine driven generators, hydroelectric turbines and wind turbines. These are available either as a turnkey power station or as an individual generating plant. Complete solutions to the complex control system requirements of combined wind and diesel power stations are provided.

The company's philosophy of providing 'Intelligent Power Systems' (IPS), is supported by a highly skilled team of professional engineers. This allows Powercorp to either adapt its existing range of advanced products to a clients needs, or quickly develop new solutions for specific requirements.

For more information about Powercorp and its products please contact us on the details provided or visit

[www.pcorp.com.au](http://www.pcorp.com.au)