Working principle

The wind/diesel (WD) plants are designed and dimensioned for cogeneration with standard wind turbines having asynchronous generators.

The Danvest WD concept, which is based on standard diesel generator(s) equipped with the patented WD equipment, comprises of a complete WD standalone system, designed for safe, continuous and automatic operation.

Main Principle

The main principle is that during periods with sufficient wind power to cover the consumption, the diesel engines are disconnected from the generator by means of a magnetic clutch and shut down in order to save fuel. During these periods the grid is solely supplied from the wind turbines (100% wind penetration) and there is no idle consumption of the diesel engines.
The standby diesel engine is preheated for a fast start-up.
At increasing load or decreasing wind power the diesel generators are automatically started, supplementing the wind power.

Control of the Grid Frequency

The grid frequency is maintained by a fast control of the power balance between the fluctuating wind power, the dump load (pre-heater) and the consumer load. In periods where the diesel engine is in operation the frequency is controlled by the diesel engine governor. In periods with 100% wind power penetration the frequency is controlled by absorbing the surplus wind energy in a dynamic dump load.

Control of the grid voltage

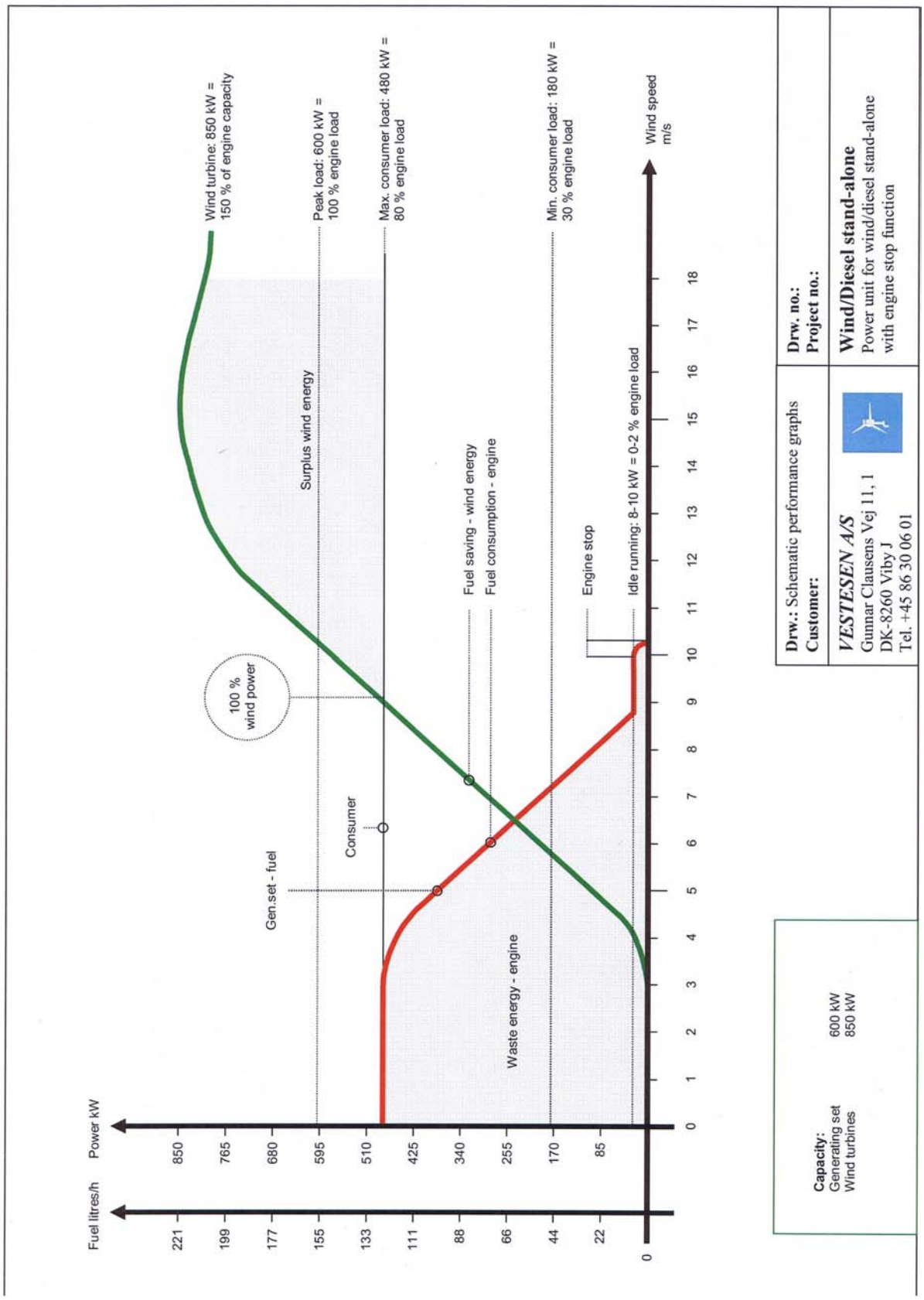
The grid voltage is maintained by the Automatic Voltage Regulator (AVR) of the synchronous generator - also supplying reactive power for energising the induction generators in the wind turbines.

Waste and surplus energy

All waste energy from cooling of the diesel engines (approximately same amount of energy as the electricity output from the diesel generators) - and the surplus wind energy (wind power production exceeding the consumer power demand) can be utilized for fresh water production based on desalination of sea or brackish water.

The enclosed graphs indicates the relation between wind speed, wind power, diesel generator load and fuel consumption for three load patterns of WD applications.

Schematic performance graph



Load and power production pattern

The power production from wind turbines varies during the day according to the variations in wind speed. In major grids these variations and fluctuations of wind power is absorbed by the strong grid, and this strong grid is thereby controlling the frequency and voltage.

At small and isolated grids the power balance has to be continuously maintained in order to keep frequency and voltage of the weak grid within predefined limits.

In the enclosed diagram examples are shown for the daily pattern of:

- wind speed
- wind turbine power production
- consumer consumption
- diesel generated power

The curves are based on 1 hour mean values, and fluctuations due to turbulence and switching of loads etc. are not shown.

Consumer consumption
During the night the consumption is low. From 4-8am the consumption increases to app. 80% of the maximum consumption. At middle of the day the consumption is app. 50% of the maximum consumption, increasing to the peak load in the evening at app. 7pm.

Wind speed/power
During the night the wind speed is too low for the turbines to operate. During the morning the wind speed is increasing, and at app. 5am the wind turbines starting operating. The maximum wind power production is reached at app. 2pm. During the afternoon and evening the wind speed is decreasing and the wind power production is gradually reduced.

Diesel generator(s)
During the night and the morning the diesel generators are supplying power to the grid. During the period from 10am to app. 4pm the diesel engine is stopped due to sufficient wind power production to cover the consumption. During the afternoon and evening the diesel generators resume the production of power supplied to the grid.

Operation of wind/diesel

During the day the wind power production and the consumer consumption varies independent of each other. Thus the power balance within the WD system must be adjusted. This is done by means of the automatic control of voltage and frequency of the diesel generator(s) and a dump load.

The day pattern and thus the operation of the WD system can be divided into different periods and modes, as indicated in the enclosed diagram and highlighted as mode a, b, c and d:

Mode a
The consumption of the power is fully supplied by the diesel generator(s) due to no wind power available. The voltage is controlled by AVR of the synchronous diesel generator and the frequency is controlled by the diesel engine governor.

Mode b
The consumption is partly supplied from the wind turbine(s) and partly from the diesel generator(s). The wind power penetration is increasing during the period. The voltage is controlled by the AVR of the synchronous diesel generator and the frequency is controlled by the diesel engine governor.

Mode c
The consumption is fully supplied by the wind turbine(s) and the diesel engine is disconnected from the generator and stopped. The surplus wind power, exceeding the power consumption, is absorbed by a dump load, thus maintaining the power balance within the system. The voltage is controlled by the AVR of the synchronous diesel generator, acting as a synchronous compensator, and the frequency is controlled by the dynamic variable dump load.

Mode d
When the power consumption exceeds the power production from the wind turbine(s) the diesel engine is restarted, supplementing the wind power production. The operation is controlled as in Mode b above.

Based on the project specific data for wind speed and power consumption on a daily basis, the following estimations can be made:

- potential wind energy penetration
- fuel savings
- waste and surplus energy and power potential
- possible drinking water production by desalination.

Load pattern