V47–660 kW

with OptiTip® and OptiSlip®

One or two generators

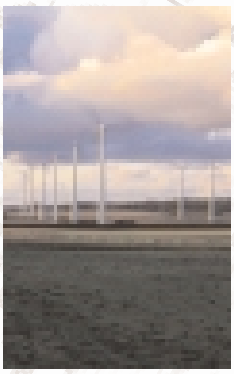
The V47-660 kW is delivered as standard with a single generator, which is highly efficient in the vast majority of wind conditions. However, a two-generator version is also available. This model contains a second, smaller, generator for use in wind speeds as low as 7 m/s. This means a lower sound level where it is most needed, as well as more efficient exploitation of modest wind conditions.

Optimal pitch with OptiTip®

Just like all other Vestas turbines, the V47-660 kW turbine is equipped with microprocessor-controlled OptiTip® pitch regulation, which ensures continuous and optimal adjustment of the angles of the blades in relation to the prevailing wind. The OptiTip® system makes it possible to find the best possible solution to the often contradictory requirements for high output and low sound levels, depending on the location.

OptiSlip®

As mentioned above, the V47-660 kW turbine features the unique generator principle OptiSlip®, which allows both the rotor and the generator to vary their RPM by up to 10% to cope during violent gusts of wind. In addition to minimising the load on various parts of the turbine, the OptiSlip® system also ensures an appreciably better power quality.



Lightning protection

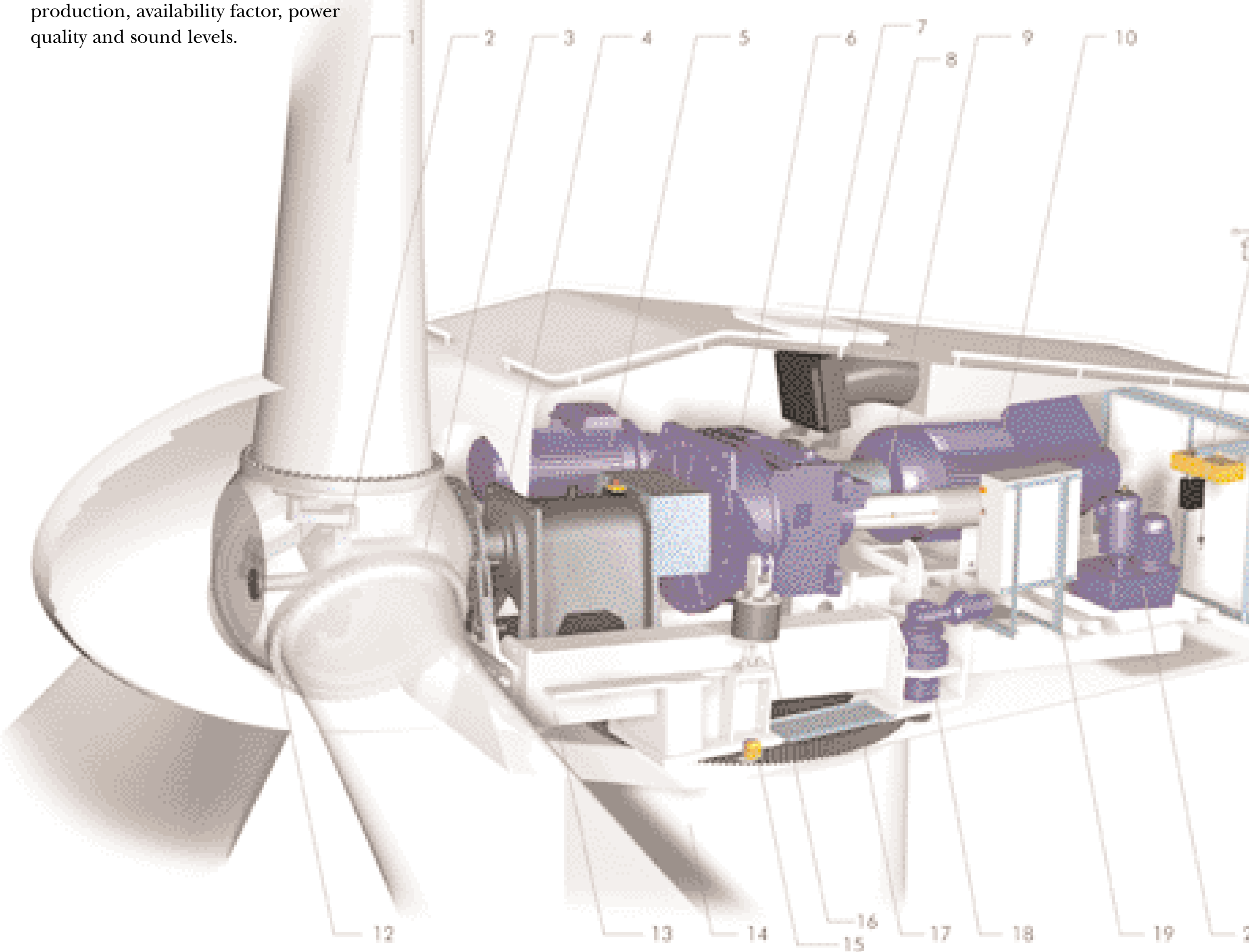
The V47-660 kW turbine is equipped with Vestas Lightning Protection, which protects the entire turbine from the tips of the blades to the foundations.

Flexible blades

Vestas always measures and tests all new products down to the smallest detail before releasing them on the market. The flexible blades underwent a 6-month dynamic distortion test under extreme loads – more than they would normally be exposed to in their 20-year service lives. The maximum loads and outward distortion of the blades were then checked in a static test. The blades passed all the tests and now make an appreciable contribution to the efficient production of the V47-660 kW turbine.

Proven Performance

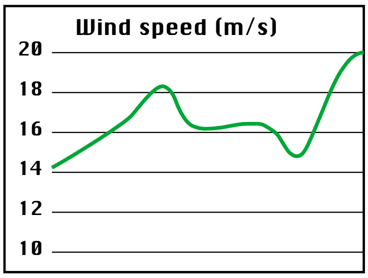
We have spent many months testing and documenting the performance of this Vestas turbine. When we were finally satisfied, we ran one last check by allowing an independent organisation to verify the results. This is standard practice at Vestas – a procedure we call Proven Performance. It is your guarantee that your Vestas turbines meet the very highest requirements for energy production, availability factor, power quality and sound levels.

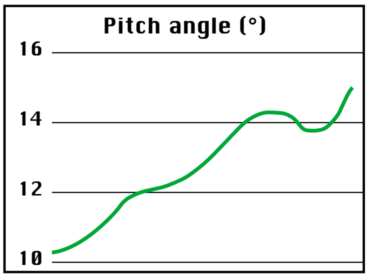


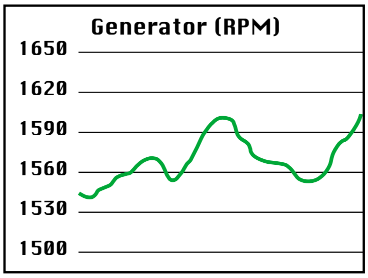
1. Blade	*11. Service crane*
2. Blade hub	*12. Pitch cylinder*
3. Blade bearing	*13. Machine foundation*
4. Main shaft	*14. Tower*
5. Secundary generator (V47-660/200 kW)	*15. Yaw control*
	16. Gear tie rod
6. Gearbox	*17. Yaw ring*
7. Disc brake	*18. Yaw gears*
8. Oil cooler	*19. VMP top control unit*
9. Cardan shaft	
10. Primary generator	*20. Hydraulic unit*

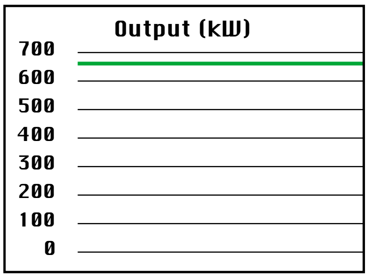
ROTOR		
	V47-660 kW	V47-660/200 kW
Diameter:	47 m	47 m
Area swept:	1,735 m²	1,735 m²
Revolution speed:	28.5	26/20
Number of blades:	3	3
Power regulation:	Pitch/OptiSlip®	Pitch/OptiSlip®
Air brake:	Feathered	Feathered
TOWER		
Hub height (approx.)	: 40-45-50-55 m	40-45-50-55-60-65 m
OPERATIONAL DATA		
Cut-in wind speed:	4 m/s	3.5 m/s
Nominal wind speed (660 kW):	15 m/s	16 m/s
Stop wind speed:	25 m/s	25 m/s
GENERATOR		
Large generator:	Asynchronous with OptiSlip®	Asynchronous with OptiSlip®
Nominal output:	660 kW	660 kW
Operational data:	50 Hz 690 V 1,515-1,650 rpm	50 Hz 690 V 1,515-1,650 rpm
Small generator:		Asynchronous
Nominal output:		200 kW
Operational data:		50 Hz 690 V 1,500-1,516 rpm
GEARBOX		
Type:	Planet /parallel axles	Planet /parallel axles
CONTROL		
Type:	Microprocessor-based control of all turbine functions with the option of remote monitoring. OptiSlip® output regulation and OptiTip® pitch regulation of the blades.	

Actual measurements of a Vestas 660 kW turbine with OptiSlip®

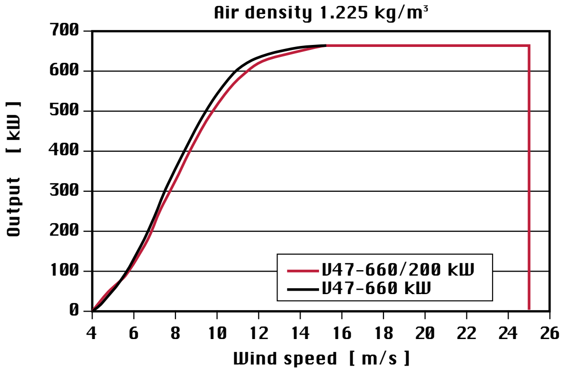








OptiSlip® allows the revolution speeds of both the rotor and the generator to vary by approx. 10%. This minimises both unwanted fluctuations in the grid supply and the loads on the vital parts of the construction.



Worldwide popularity

If you stand next to one of these turbines and look up, it is tempting to think that the V47-660 kW model must be the largest turbine Vestas has ever built. It is not, although it is no more than a few years since this turbine was launched as the Vestas flagship.

When the V47-660 kW turbine was introduced in 1997, it was a genuine innovation. The blade design in particular set new standards, but the turbine as a whole, with its futuristic design and innovative technology, became a model for the giant turbines that have since begun to roll off the production lines.

Today, the V47-660 kW model is still a popular turbine that exploits the power of the wind reliably and efficiently whereever it is erected. Turbines of this model currently operate in locations as diverse as New Zealand, California, Spain, Germany and South Korea – and in many other places where there is a demand for profitable wind power.

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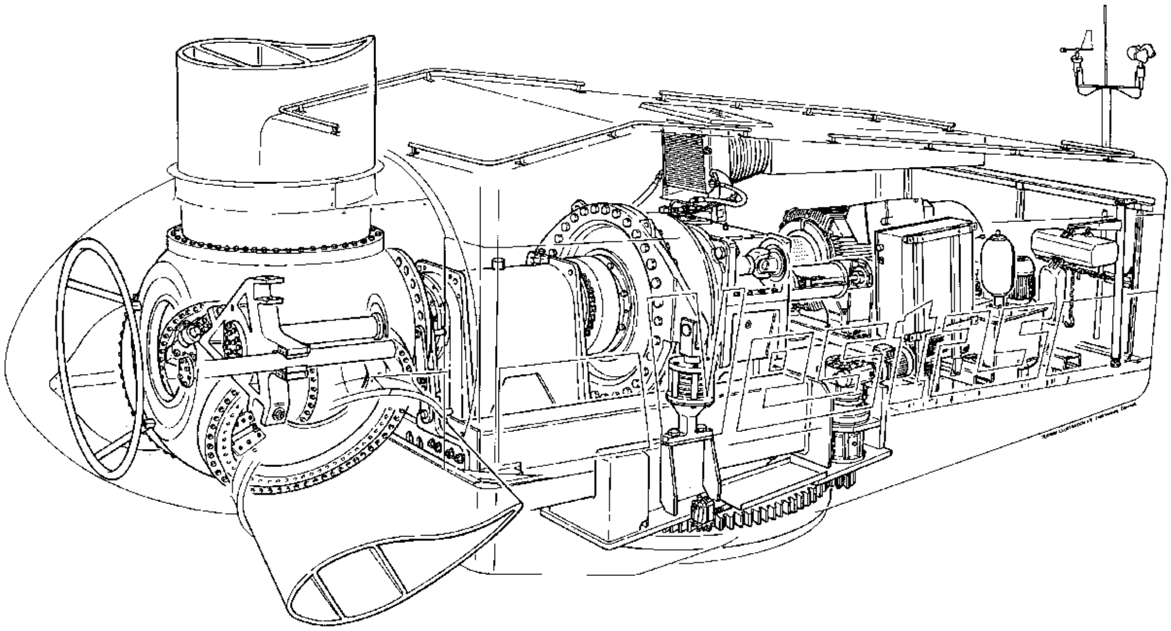
General Specification

660 kW Variable Slip Wind Turbines



V47 - 660 kW

V47 - 660/200 kW

Item no.: 943111.R4

Vestas 660 kW, Variable Slip Wind Turbines

Contents.. Page

1. Introduction

The Vestas 660 kW wind turbines are based on the experience gained from the V39-500 kW and V39/42/44-600 kW wind turbines.

The Vestas 660 kW wind turbines are available in two versions with the same swept areas and the same climatic conditions. The difference between the two versions consists in the V47-660 kW having a synchronous rotor speed of 28.5 rpm and one generator. The V47-660/200 kW has two seperate generators running at two different synchronous speeds (26 and 20 rpm).

The V47 turbines uses the superior variable slip concept, which was introduced in the Vestas 600 kW turbines (V39/42/44). This feature ensures a smooth power output and at the same time reduces the loads significantly.

The special Vestas Optitip® feature is standard on both Vestas 660 kW turbines. This feature provides the optimum tip angle at all times with respect to power performance and noise emission.

2. Type Approvals

The wind turbines are designed in accordance with IEC 1400-1 , DS472 (“Teknisk Grundlag”), Germanisher Lloyd IV part 1 and NEN 6096/2.

3. Climatic Conditions

The wind climate for a given site is normally specified by a Weibull distribution. The Weibull distribution is described by an A and a C factor. The A factor is proportional to the mean wind speed and the C factor defines the shape of the Weibull distribution or in other words long term variations of hours at different wind speeds. Turbulence is the factor which describes short term wind variation/fluctuations. In the table below the design wind conditions for the Vestas 660 kW wind turbine are listed.

Version	Mean wind speed	Turbulence	Hub height [a)]
V47 - 660 kW	Max. 10 m/s	Max. 17%	40 - 55 m.
V47 - 660/200 kW	Max. 10 m/s	Max. 17%	40 - 65 m.

[a)] Vestas modular tower.

Table 1 Wind speed and turbulence according to IEC/GL at hub height.

The stop wind speeds are a design parameter. The maximum wind speeds are also important for the loads on the wind turbine. The maximum allowable extreme wind speeds are listed in table 2 next page.

Version	Max. 10 min. mean	Max. 3 sec. mean	Gust max. acc.	Stop wind speed/ Restart wind speed
V47 – 660 kW	50 m/s	70 m/s	10 m/s^2	25 m/s 20 m/s
V47 – 660/200 kW	50 m/s	70 m/s	10 m/s^2	25 m/s 20 m/s

Table 2. Wind speed according to IEC/GL.

The above tables can be used to determine if a Vestas V47 turbine is appropriate for a given site in other countries than Denmark, Germany and the Netherlands. For these countries table 3 below must be consulted.

Country	Turbine	Conditions		Hub height a)
		Class	Stop/start	meter
Denmark	V47-660	all classes	25 / 20 m/s	40 - 55
Denmark	V47-660/200	all classes	25 / 20 m/s	40 - 65
Germany	V47-660/200	DIBt III	20 / 18 m/s	55 - 65
Netherland	V47-660	Den Helder	25 / 20 m/s	40 - 55
Netherland	V47-660/200	Den Helder	25 / 20 m/s	40 - 65

[a)] Vestas modular towers

Table 3. Country specific conditions and approvals.

Concerning park installations the conditions of section 9 are to be observed, and for other conditions Vestas must be consulted.

3.1 Stop wind speed / restart wind speed

The turbine stops for high wind speed when the exponential mean wind speed averaged during 100 seconds is above the stop wind speed level.

The turbine restarts when the exponential mean wind speed averaged during 100 seconds, is below the reset wind speed, and stays below the stop wind speed for 1 minute.

3.2 Site specific loads

The turbines can be placed under various climatic conditions: where the air density, turbulence intensity and the mean wind speed are the parameters to be considered. If the turbulence intensity is high the turbine loading increases and the turbine lifetime decreases, on the contrary the loading will be reduced and the lifetime extended if the mean wind speed or/and turbulence is low. Therefore, the turbines can be placed on sites with high turbulence intensity if the mean wind speed is suitable low.
Vestas has to examine the climatic conditions if the prescribed is exceeded.

3.3 Low Temperature version

The VestasV47-660 kW turbine is also available as a Low Temperature version.

This version is equipped with special heat treated steel components when necessary, and the nacelle has built in heaters. Also the wind vane and anemometer are heated. Other modifications have also been necessary to enable this version to operate down to -30°C. This version is designed for a temperature range from -30°C to +40°C. (Standard -20°C to +40°C). For non-operational conditions a temperature range of -40°C to +40°C is allowed. Please note that because of the higher density of the air at low temperatures, the LT version has lower extreme wind speed limits.

Version	Max. 10 min. mean	Max. 3 sec. mean	Gust max. acc.	Stop wind speed/ Restart wind speed
V47 – 660 kW, LT	42.5 m/sec.	59.5 m/s	10 m/s^2	25 m/s / 20 m/s

Table 4. V47-660 kW LT wind speed according IEC 1400-1.

4. Power curve and annual production (calculated)

See enclosure 1 for the measured power curve.

4.1 V47 - 660 kW

Power curves calculated on basis of NACA63.600 and FFA-W3 airfoil data.

Wind speed: 10 minutes average value, at hub height and orthogonal to the rotor plane.

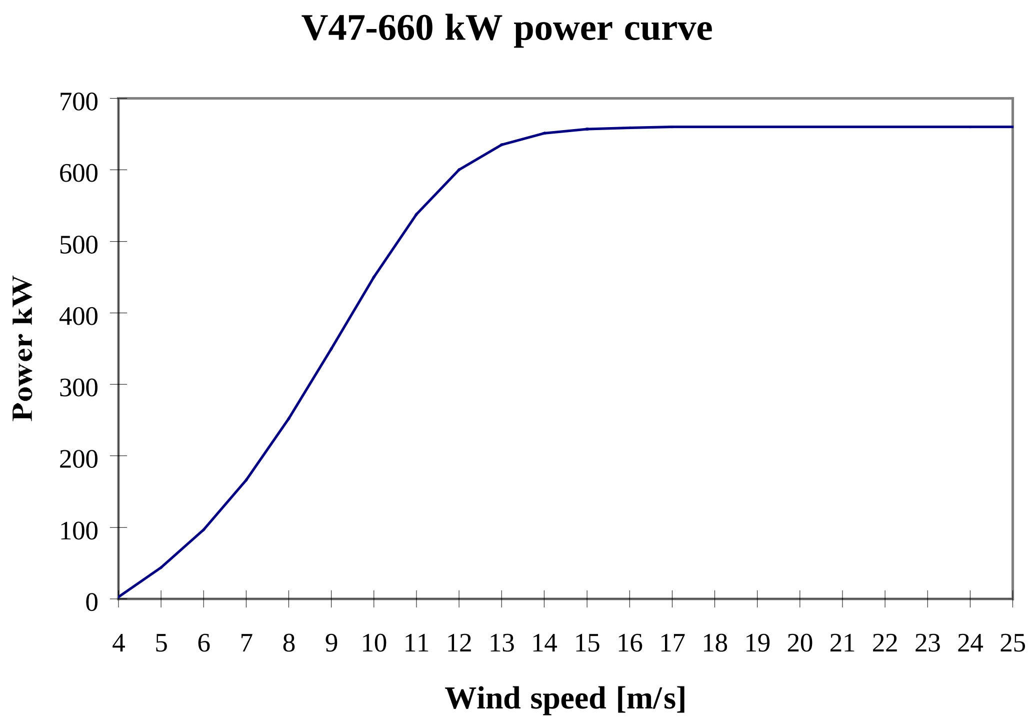
Parameters for calculated curves: 50 Hz/60 Hz

Tip angle:	Pitch regulated.
Turbulence:	10 %.
Rotor speed (Synchr.):	28.5 rpm.

EL-power [kW] as a function of wind speed [m/s] and air density [kg/m^3]:

V10	**1.225**	1.06	1.09	1.12	1.15	1.18	1.21	1.24	1.27
4.0	**2.9**	0.6	1.1	1.5	1.9	2.3	2.7	3.1	3.5
5	**43.8**	36.2	37.5	38.9	40.3	41.7	43.1	44.5	45.8
6	**96.7**	81.8	84.5	87.2	89.9	92.6	95.4	98.1	101
7	**166**	141	146	150	155	159	164	168	173
8	**252**	215	222	228	235	242	248	255	262
9	**350**	300	309	318	327	337	346	354	363
10	**450**	392	402	413	424	435	446	455	464
11	**538**	480	491	502	512	523	534	542	549
12	**600**	554	563	572	580	589	598	602	607
13	**635**	607	612	618	623	629	634	636	639
14	**651**	637	640	643	646	648	651	652	653
15	**657**	652	653	654	655	656	657	658	658
16	**659**	657	658	658	659	659	659	659	659
17	**660**	659	659	660	660	660	660	660	660
18	**660**	660	660	660	660	660	660	660	660
19-25	**660**	660	660	660	660	660	660	660	660

4.1.1 V47-660 kW power curve



The curve will vary at other turbulence and air density values.

The V47-660 kW is especially developed for sites where noise concerns are less critical.

4.2 V47 - 660/200 kW

Power curves calculated on basis of NACA63.600 and FFA-W3 airfoil data.

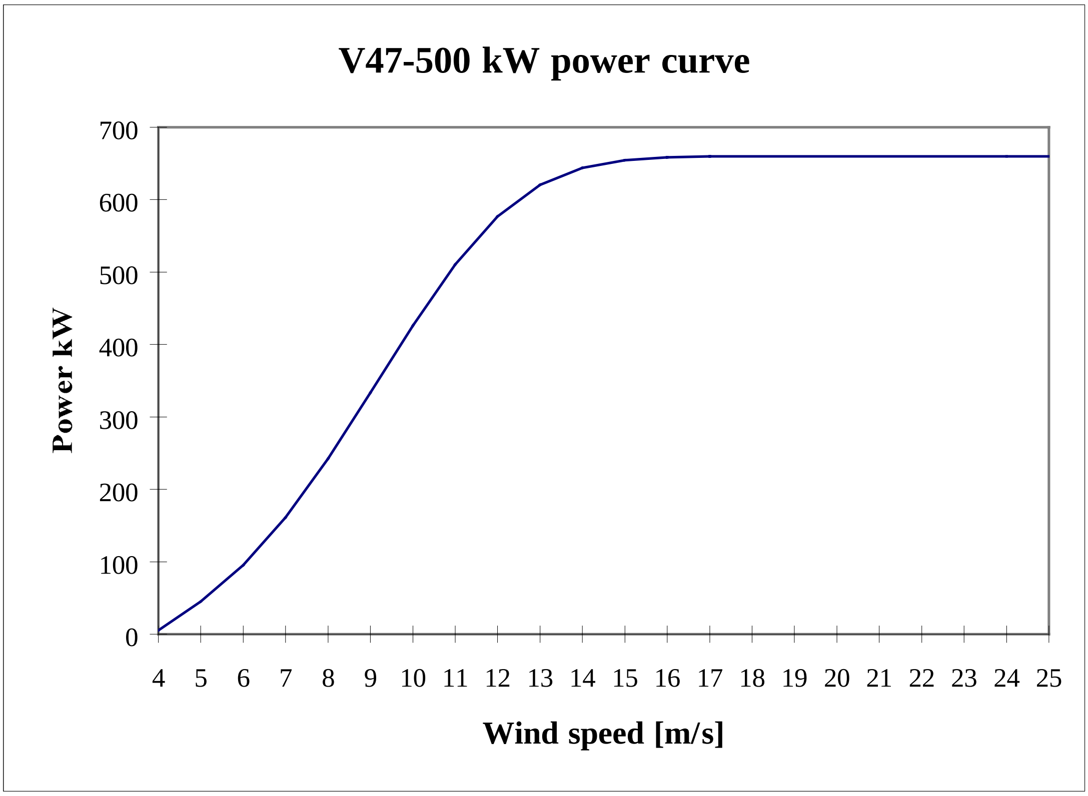
Wind speed: 10 minutes average value, at hub height and orthogonal to the rotor plane.

Parameters for calculated curves:		50 Hz/60 Hz
	Tip angle:	Pitch regulated.
	Turbulence:	10 %.
	Rotor speed (Synchr.):	26 and 20 rpm.

EL-power [kW] as a function of wind speed [m/s] and air density [kg/m^3]:

V_{10}	**1.225**	1.06	1.09	1.12	1.15	1.18	1.21	1.24	1.27
4	**5.3**	0.8	1.6	2.4	3.2	4.1	4.9	5.7	6.5
5	**44.9**	35.2	37.0	38.8	40.5	42.3	44.1	45.8	47.6
6	**95.4**	79.0	82.0	85.0	88.0	91.0	93.9	96.8	99.7
7	**161**	136	141	145	150	155	159	163	168
8	**242**	206	213	219	226	233	239	246	252
9	**334**	285	293	302	311	320	329	338	347
10	**426**	366	377	389	400	410	421	432	442
11	**511**	446	459	471	484	495	505	516	526
12	**577**	519	531	543	556	564	573	581	589
13	**620**	578	587	597	607	612	618	623	628
14	**644**	619	625	631	637	640	643	645	648
15	**654**	642	645	648	652	653	654	655	656
16	**658**	653	655	656	657	658	658	658	659
17	**660**	658	658	659	659	659	660	660	660
18	**660**	659	660	660	660	660	660	660	660
19-25	**660**	660	660	660	660	660	660	660	660

4.2.1 V47-660/200 kW power curve



The curve will vary at other turbulence and air density values.

The V47-660/200 kW is especially designed for sites, where noise requires special attention.

4.3 Production/year

Production/year for different mean wind speeds and different Weibull distributions.

Mean wind speed m/sec. Production in MWh (C = 2.0)					
	6	7	8	9	10
V47 - 660 kW	1366	1890	2377	2803	3155
V47 – 660/200 kW	1321	1825	2307	2729	3081

Mean wind speed m/sec. Production in MWh (C = 1.5)					
	6	7	8	9	10
V47 - 660 kW	1476	1894	2254	2544	2766
V47 – 660/200 kW	1434	1844	2199	2488	2709

Mean wind speed m/sec. Production in MWh (C = 2.5)					
	6	7	8	9	10
V47 - 660 kW	1259	1843	2411	2924	3363
V47 – 660/200 kW	1216	1777	2329	2835	3273

Danish roughness class at hub height 45 meter - Beldringe correction. Production in MWh				
Turbine	Class 0	Class 1	Class 2	Class 3
V47 - 660 kW	2513	1756	1454	1023
V47 - 660/200 kW	2465	1702	1406	991

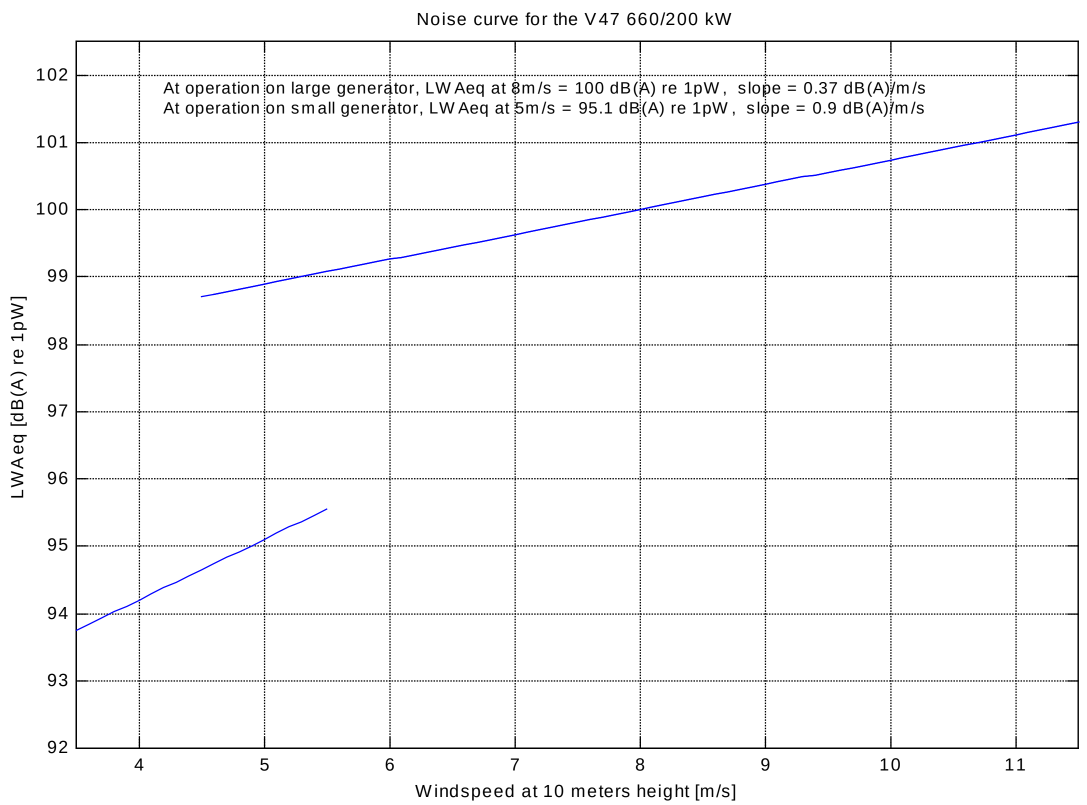
5 Noise emission

See enclosure 2, Noise resume.

5.1.1 Noise level: (sound power level)

According to DK 304	V47-660 kW	V47-660/200 kW
In dB (A) re 1 PW	102	100

The noise emission for the V47-660/200 kW is given for the large generator in operation at a synchronous rotor speed of 26 rpm, as the generator shift is approximately at 7 m/sec and the reference wind speed for the noise measurements is 8 m/sec. The noise emission of this turbine will be significantly lower at low wind speeds, when the turbine is operating at the lower synchronous rotor speed (20 rpm) with the small generator connected.



Wind speed measured in 10 meters height. Roughness length = 0,05 m and hub height = 45,7 m (45 m tower).
The wind speed from 10 meters height can be calculated to a wind speed in 45,7 m height, by using the multiplying factor 1,2868 (valid only for a roughness length and 0,05 m). Example,

$V_{10\ meter} = 5$ m/s ==> $V_{45,7\ meter} = 6,43$ m/s
$V_{10\ meter} = 8$ m/s ==> $V_{45,7\ meter} = 10,29$ m/s

6. Variable slip, Optislip®

So far the normal way of operating asynchronous wind turbine generators has been that of constant speed. An induction generator operates with almost constant speed normally within 100% to 101% of nominal speed. For a four pole generator this means operation from 1500 rpm (no load) to 1515 rpm (full load) at 50 Hz frequency. This small variation is considered insignificant, and this is why operation mode is called constant speed.

When the wind speed changes it will result in corresponding power output changes. When nominal power is reached power fluctuations are undesirable. Vestas introduced pitch regulation because this feature enables maximum power to be limited to nominal as an average at high wind speeds. However, with a fixed speed generator, power fluctuations are so fast that it is only possible to keep the average power constant, and therefore rapid fluctuations will occur. These rapid fluctuations contribute to the loading of the turbine. In order to minimise the loads Vestas introduced the variable slip concept together with the V39/42/44-600 kW wind turbine and reused this concept for the Vestas V47 turbine. This feature means that it is possible electronically to vary the slip within 10% (1500 - 1650 rpm).

The variable slip feature is used when a wind gust hits the rotor. The controller then allows the speed of the generator to increase slightly in response to the gust. At the same time the pitch system turns the blades to a less aggressive angle and thereby decreases the rotor rpm. The result is a 100% constant and smooth power output with a minimum of loads on; blades, main shaft and gearbox.

The variable slip is a very simple, reliable and cost effective way of achieving load reductions compared to more complex solutions such as full variable speed using full scale converters.

7. General specification

7.1 Structure of machinery

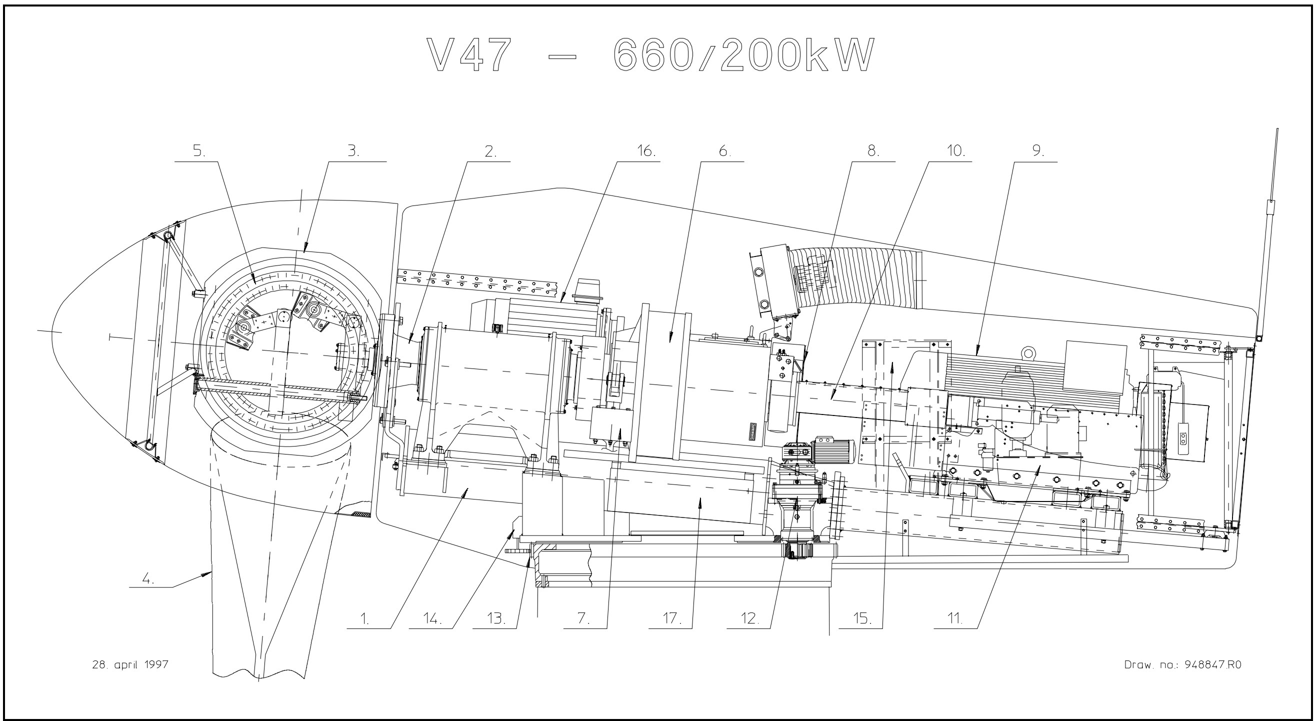


Figure 1 Structure of V39/V42/V44-600 kW and V47-660 kW wind turbine.

1.	Base frame	9.	Generator
2.	Main shaft	10.	Cardan shaft
3.	Blade hub	11.	Hydraulic unit
4.	Blade	12.	Yaw gear motor
5.	Blade bearing	13.	Yaw ring
6.	Gearbox	14.	Yaw control
7.	Gear tie rod	15.	VMP top control unit
8.	Disc brake	16.	Small generator
		17.	Generator shift box

8.Technical specifications

8.1.1 Rotor

	V47-660 kW	V47-660/200 kW
Diameter:	47 m	47 m
Swept area:	1735 m^2	1735 m^2
Rotational speed, rotor:	28.5 rpm	26/20 rpm
Rotational direction:	Clockwise (front view)	

8.1.2 Tubular tower

Top diameter (for all towers): 2.0 m

Type	**Exact Hub Height**	**Bottom diameter**	**Weight**
2-parted, modular tower (40 m)	40.7 m	3.0 m	approx. 28900 kg
2- parted, modular tower (45 m)	45.7 m	3.0 m	approx. 33000 kg
2- parted, modular tower (50 m)	50.1 m	3.3 m	approx. 38000 kg
2&3- parted, modular tower (55 m)	55.1 m	3.3 m	approx. 50700 kg
3- parted, modular tower (60 m)	59.7 m	3.6 m	approx. 58500 kg
3- parted, modular tower (65 m)	64.6 m	3.6 m	approx. 66400 kg

The exact hub height includes 0.4 m (distance from foundation section to earth).

Paint system, outside:	
Surface treatment:	Metallizing + painting
Sand blasting:	SA 3 ISO 8501-1
Metallizing:	DSI/ISO 2063, 60 µm Zn
Sealing with twocomponent epozyprimer:	Approx. 20 µm
Primer:	Min. 90 µm
Top coat:	UV resistant, min. 50 µm
Corrosion class (DS/R 454):	3
Paint system, inside:	
Surface treatment:	Paint
Sand blasting:	SA 2.5 ISO 8501-1
Zinciferous primer:	Min. 40 µm
Top coat:	Min. 100 µm
Corrosion class (DS/R 454):	2

8.1.3 Foundation sections

Type	Height	Max. diameter	Weight
For 35,40,45 m modular tower	2.1 m	3.2 m	approx. 3100 kg
For 50,55 m modular tower	2.1 m	3.5 m	approx. 3400 kg
For 60,65 m modular tower	2.1 m	3.75 m	approx. 4500 kg

8.1.4 Gear, V47-660 kW

Type:	Planetary/helical gear
Ratio:	52.6514

8.1.5 Gear, V47-660/200 kW

Type:	Planetary/helical gear
Ratio:	58 & 75

8.1.6 Large generator

Type:	Asynchronous, variable slip
Rated power:	660 kW
Voltage:	690 VAC
Frequency:	50 Hz
Class of protection:	IP54
Number of poles:	4
Rotational speed:	1515-1650 rpm
Rated current:	628 A
Power factor:	0.88
Resultant power factor:	0.98
Resultant current:	564 A

8.1.7 Small generator

Type:	Asynchronous, cons. slip (1.1%)
Rated power:	200 kW
Voltage:	690 VAC
Frequency:	50 Hz
Class of protection:	IP54
Number of poles:	4
Rotational speed:	1500-1516 rpm
Rated current:	190 A
Power factor:	0.89
Resultant power factor:	0.99
Resultant current:	171 A

8.1.8 Controller:

Electrical data:

Voltage:	3x690 V, 50 Hz
Lockable circuit breaker:	630 A
Power supply for light:	1x10 A/230 V
Generator cut in:	By thyristors
Power factor correction:	250 kVAr

Top processor:

Supervision/Control:	Yawing Hydraulic Surroundings (Wind, temperature) Rotation Generator Pitch system

Bottom processor:

Supervision/Control:	Grid Power factor correction Thyristors Remote monitoring

Operator panel:

Information:	Operating data Production Operation log Alarm log
Commands:	Run/Pause Manual yaw start/stop Maintenance routine

8.1.9 Remote monitoring:

Possibility of connection of serial communication e.g. Vestas Remote Panel.

8.1.10 Weight:

The listed masses is maximum values

Complete nacelle:	Approx. 20400 kg
Rotor V47, (incl. hub):	Approx. 7200 kg

9. Installation

Terrain:

If the terrain within a 100 m radius of the turbine has a slope of more than 10°, certain considerations may be necessary.

Climatic conditions:

The turbine is designed for an ambient temperature range from -20°C up to +40°C, (10 min. average). The temperature range for the LT-version is –30°C up to +40°C (10 minutes average). Outside these temperatures the turbine will stop and certain considerations may be necessary.

The turbine can be placed in wind farms with a distance of min. 5 rotor diameters (235 m) between turbines. If the turbines are placed in only one row (perpendicular to the predominant wind direction) the distance between the turbines must as a min. be 4 rotor diameters (188 m).

For operation under different conditions contact Vestas.

The humidity can be 100%, (max. 10% of the time). Corrosion protection according to corrosion class 3 outside, and 1 to 2 inside, (DS/R 454).

Grid connection:

Intermittent or rapid power fluctuations of utility grid frequencies may cause serious damage to the wind turbine. Steady variations within +1/-3 Hz are acceptable. The voltage operational range shall be within +10/-6 of nominal.

Grid drop-outs should only take place once per week as an average over the lifetime of the turbine.

A ground connection of max. 10 Ω must be present. Furthermore, it is recommended that the turbine is connected to a TN-grid.

In case of small independent grids, it will be necessary to check the actual conditions.

The 5th and 7th. harmonics are sinusoidal voltage with frequencies at 250Hz and 350Hz respectively. Harmonics are caused by different equipment (e.g. welding machines), which via a transformer is connected to same power supply systems as the wind turbine. Harmonics in the power supply systems reduce the lifetime of the capacitor.

The impedance voltage of the transformer and the size of the power factor correction are very important for the acceptable level of harmonics.

- If a 800kVA transformer with 4.5% impedance voltage is used together with the 250 kVAr power factor correction, the 5th and 7th harmonics have to be below 3% and 2% respectively.
- If a 800kVA transformer with 6% impedance voltage is used together with the 250 kVAr power factor correction, the 5th and 7th harmonics have to be below 3% and 1% respectively.

It is recommended to use a 800kVA transformer with 4.5% impedance voltage for a V47-660kW wind turbine.

10. General reservations

Derating of nominal power may occur with a combination of e.g. high wind, low voltage or frequency and high temperature.

In general it is recommended that the grid voltage is as close to nominal as possible. A stationary frequency below nominal will influence the power curve.

In connection with a grid drop-out and very low temperatures, a certain time of heating-up must be expected before the turbine restarts after re-establishing of the grid.

If the wind turbine is placed in more than 1000 m above sea level, a higher temperature rise than usual might occur in generator, transformer and other electrical components. In this case a periodic reduction of rated power might occur, even if the ambient temperature is within the specified limits.

Furthermore, also at sites in more than 1000 m above sea level there will be an increased risc of icing up.

Due to continuous development and updating of VESTAS products, VESTAS reserves the right to change the specifications.

11. Enclosure 1, power curve measurement

Power Curve measurement V47 660 kW wind turbine

11.1 Power curve measurement on the V47-660kW Wind turbine

1. The measurement is carried out by:

   Tripod Wind Energy Aps
   Gladsaxe møllevej 21
   2860 Søborg
   Phone 39666622
   Fax 39666699

   Tripod Wind Energy is authorized by the Danish Ministry of Energy to carry out power curve measurements and type testing in accordance with the Danish system for approval of wind turbines.

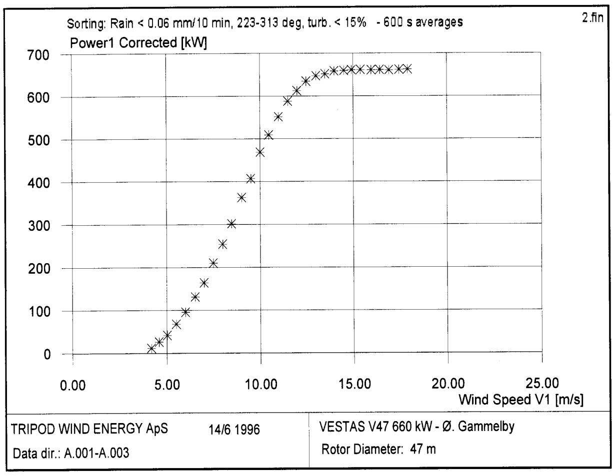
2. This resumé is made the 24. November 1997 by Vestas Wind Systems A/S

3. The measurements are reported in “TWE-report 970615-2”, which is dated June 1997. The measurements are carried out in the period 8/4-1997 to 6/5 1997.

4. The Windturbine type is: VESTAS V47-660kW

5. The measurement was performed according to the “Recommandation for wind turbine power curve measurements [Risø-I-745(EN), November 1993]”.

6. Results.



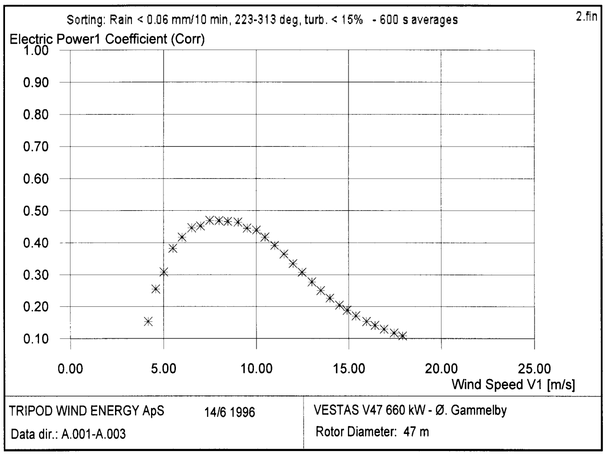
TRIPOD WIND ENERGY : 14/6-1997 14:59 (2.fin)

Object of bin-analysis : Sorting: Rain < 0.06 mm/10 min, 223-313 deg turb. < 15%
: VESTAS V47 660 kW - Ø. Gammelby
: Rotor diameter: 47 m
Data directories : \A.001 - \A.003
Basic averaging time : 60.00 secs
Final averaging time : 600.00 secs

X-axis (bins) : Wind speed V1 [m/s]
Y-axis (binned) : Power1 Corrected [kW]

X-bin	# data	mean(Y)	rms(Y)	min(Y)	max(Y)
4.17	4	11.75	1.58	9.41	13.31
4.58	36	26.46	7.22	11.77	42.61
5.02	90	41.79	8.35	25.42	57.86
5.50	97	67.86	12.85	43.90	121.74
6.00	119	95.69	14.21	65.51	165.56
6.51	133	131.45	18.04	95.44	230.63
6.99	142	164.31	17.77	119.24	205.93
7.49	128	209.85	20.23	174.14	268.28
7.99	83	253.80	22.68	193.43	318.20
8.47	69	301.19	22.79	262.51	360.79
9.02	68	362.48	27.29	308.11	423.27
9.51	60	406.70	31.41	322.22	482.98
10.01	67	468.74	38.10	378.42	548.99
10.47	70	508.55	36.66	393.63	614.14
10.99	86	551.26	26.27	476.08	602.81
11.50	59	587.82	27.41	498.62	649.74
11.99	48	612.36	16.74	577.32	647.15
12.48	41	634.38	15.86	592.10	657.99
13.01	33	646.79	12.15	609.59	661.80
13.49	25	651.40	10.01	626.58	660.70
13.99	24	658.40	4.63	645.43	662.67
14.50	32	659.46	3.61	645.79	662.79
14.91	13	661.11	1.85	656.63	662.91
15.39	11	661.16	1.54	658.73	662.91
15.96	7	660.87	1.04	659.71	662.91
16.42	8	661.22	1.27	659.83	662.79
16.91	6	660.49	0.99	659.71	662.67
17.45	4	661.47	1.16	660.08	662.79
17.91	1	662.42	0.00	662.42	662.42
Total	1564				

The measured power curve is corrected to the standard air density of 1.225kg/m^3.



TRIPOD WIND ENERGY : 14/6-1997 14:59 (3.fin)

Object of bin-analysis : Sorting: Rain < 0.06 mm/10 min, 223-313 deg turb. < 15%
: VESTAS V47 660 kW - Ø. Gammelby
: Rotor diameter: 47 m
Data directories : \A.001 - \A.003
Basic averaging time : 60.00 secs
Final averaging time : 600.00 secs

X-axis (bins) : Wind speed V1 [m/s]
Y-axis (binned) : Electric power1 (corr.) coefficient Cp [-]

X-bin	# data	mean(Y)	rms(Y)	min(Y)	max(Y)
4.17	4	0.153	0.021	0.123	0.177
4.58	36	0.255	0.057	0.142	0.379
5.02	90	0.308	0.046	0.208	0.411
5.50	97	0.382	0.061	0.271	0.695
6.00	119	0.417	0.051	0.305	0.709
6.51	133	0.446	0.047	0.344	0.735
6.99	142	0.452	0.037	0.334	0.538
7.49	128	0.469	0.036	0.375	0.561
7.99	83	0.468	0.040	0.341	0.557
8.47	69	0.466	0.030	0.396	0.553
9.02	68	0.464	0.028	0.390	0.515
9.51	60	0.445	0.028	0.380	0.528
10.01	67	0.439	0.030	0.361	0.515
10.47	70	0.417	0.028	0.326	0.480
10.99	86	0.391	0.020	0.332	0.454
11.50	59	0.364	0.016	0.319	0.401
11.99	48	0.334	0.013	0.302	0.361
12.48	41	0.307	0.009	0.290	0.329
13.01	33	0.277	0.011	0.255	0.298
13.49	25	0.250	0.007	0.237	0.263
13.99	24	0.226	0.006	0.215	0.235
14.50	32	0.204	0.006	0.194	0.214
14.91	13	0.188	0.003	0.182	0.193
15.39	11	0.171	0.003	0.163	0.175
15.96	7	0.153	0.003	0.149	0.157
16.42	8	0.141	0.003	0.137	0.145
16.91	6	0.129	0.003	0.124	0.131
17.45	4	0.117	0.003	0.112	0.120
17.91	1	0.108	0.000	0.108	0.108
Total	1564				

The annual energy output is calculated on the assumption that the availibility is 100% and that the stop wind speed is 25m/s. The annual energy output is calculated using a Rayleigh distribution with an annual mean wind speed of 5 - 10 m/s.

Annual mean Wind speed	Annual Energy Output	Uncertainties	
[m/s]	[MWh]	[MWh]	[%]
5	862	50,6	5,9
6	1386	57,2	4,1
7	1918	60,0	3,1
8	2410	60,1	2,5
9	2838	58,5	2,1
10	3187	55,9	1,8

The Annual Energy Output in the 4 Danish roughness classes is calculated, using a Weibull distribution, by Vestas Wind Systems A/S. The annual energy output is calculated on the assumption that the availibility is 100%, 45 m hub height and 25m/s stop wind speed. The uncertainties are estimated from the above mentioned uncertanties, which is calculated by Tripod Wind Energy Aps.

Roughness class	Annual Energy Output	Uncertainties	
[-]	[MWh]	[MWh]	[%]
0	2584	59,4	2,3
1	1791	59,3	3,3
2	1480	57,7	3,9
3	1039	52,8	5,1

11.2 Power curve measurement on the V47-660/200kW Wind turbine

1. The measurement is carried out by:

Windtest
Kaiser-Wilhelm-Koog GmbH
Sommerdeich 14b
D-25709 Kaiser-Wilhelm-Koog
Phone +49 48569010
Fax +49 485690149

Windtest Kaiser-Wilhelm-Koog GmbH is authorised by the German accreditation council DAR to carry out power curve measurements.

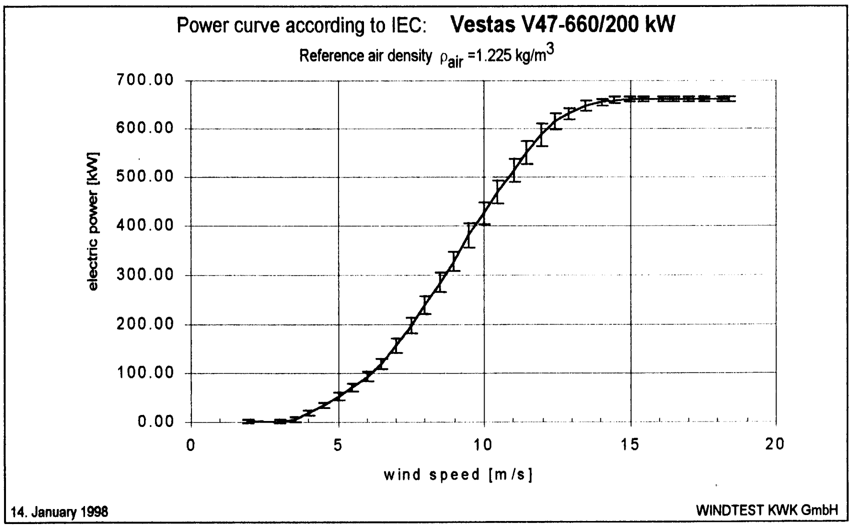
2. This resumé is made the 19. January 1998 by Vestas Wind Systems A/S

3. The measurements are reported in “WT 761/97”. The measurements are carried out in the period 24/10-1997 to 25/12 1997.

4. The Windturbine type is: VESTAS V47-660/200kW

5. The measurement was performed according to IEC/TC88 “Wind Turbine Generator Systems, Part 12:Power Performance Techniques” .

6. Results.



The measured power curve is corrected to the standard air density of 1.225kg/m^3.

MEASURED POWER CURVE: V47

reference air density: 1.225 kg/m³ cut-out windspeed: 25 m/s				category A	category B	combined uncertainty
bin no.	hub height wind speed [m/s]	power output [kW]	no. of data sets (10 min. avg.)	standard uncertainty [kW]	standard uncertainty [kW]	standard uncertainty [kW]
1	1.90	1.34	123	0.03	4.22	4.2
2	3.03	1.18	95	0.12	4.21	4.2
3	3.51	5.28	104	0.43	4.39	4.4
4	4.01	19.13	156	0.50	5.78	5.8
5	4.51	33.92	215	0.53	6.02	6.0
6	5.02	52.56	218	0.59	6.84	6.9
7	5.50	72.07	222	0.58	7.63	7.7
8	6.00	93.28	227	0.66	8.09	8.1
9	6.50	118.30	239	1.01	9.60	9.6
10	7.01	156.90	259	1.14	14.34	14.4
11	7.51	196.50	312	1.05	15.76	15.8
12	7.99	239.10	329	1.27	18.28	18.3
13	8.51	284.70	264	1.40	19.29	19.3
14	8.99	327.50	212	1.81	20.29	20.4
15	9.49	380.30	156	2.16	24.87	25.0
16	10.00	425.40	125	2.48	22.29	22.4
17	10.49	468.20	123	2.19	22.57	22.7
18	11.02	514.00	97	2.40	23.58	23.7
19	11.46	549.70	95	2.12	23.02	23.1
20	11.95	587.60	41	4.43	22.85	23.3
21	12.44	614.70	26	2.81	17.34	17.6
22	12.92	630.90	25	3.12	11.70	12.1
23	13.46	647.30	17	1.21	11.12	11.2
24	14.02	654.20	27	0.96	6.71	6.8
25	14.48	658.40	20	0.50	6.17	6.2
26	14.97	659.70	16	0.21	5.38	5.4
27	15.43	660.30	12	0.38	5.15	5.2
28	16.09	661.30	8	0.15	5.17	5.2
29	16.48	661.4	14	0.14	5.14	5.1
30	17.01	661.4	17	0.12	5.13	5.1
31	17.52	661.3	11	0.17	5.14	5.1
32	18.11	661.4	10	0.20	5.14	5.1
33	18.37	661.1	5	0.20	5.16	5.2

The annual energy output is calculated on the assumption that the availibility is 100% and that the stop wind speed is 25m/s. The annual energy output is calculated using a Rayleigh distribution with an annual mean wind speed of 4- 11 m/s.

ESTIMATED ANNUAL ENERGY PRODUKTION (AEP)

extrapolation of the power curve between the highest measured wind speed and the cut-out wind speed considering the same as the measured at highest measured wind speed				type of WTGS: V47 cut-out wind speed: 25 m/s reference air density: 1.225 kg/m³
hub height annual average wind speed (Rayleigh) [m/s]	AEP-measured (measured power curve) [MWh]	uncertainty of measured power in terms of standard deviation of AEP [MWh]	[%]	AEP-extrapolated (extrapolated power curve) [MWh]
4.0	433.8	58.8	13.5	433.8
5.0	845.7	78.7	9.3	845.8
6.0	1333.3	94.9	7.1	1336.9
7.0	1818.9	104.7	5.8	1844.6
8.0	2233.8	108.4	4.9	2323.2
9.0	2538.9 *	107.7	4.2	2745.0
10.0	2727.3 *	104.0	3.8	3093.5
11.0	2813.2 *	98.7	3.5	3360.9

values marked with *: power curve incomplete acc. IEC criteria for data base

The Annual Energy Output in the 4 Danish roughness classes is calculated, using a Weibull distribution, by Vestas Wind Systems A/S. The annual energy output is calculated on the assumption that the availibility is 100%, 45 m hub height and 25m/s stop wind speed. The uncertainties are estimated from the above mentioned uncertanties, which is calculated by Windtest.

Roughness class	Annual Energy Output	Uncertainties	
[-]	[MWh]	[MWh]	[%]
0	2487	107,8	4,3
1	1721	102,7	5,9
2	1426	96,7	6,7
3	1012	84,2	8,3

11.3 Enclosure 2, noise measurement

11.4 Noise resume of VESTAS V47-660 kW Wind Turbine

1. The measurement has been done by:

   Acoustica as
   Fælledvej 3
   8800 Viborg

   under the accreditation, registration no. 134, from DANAK.

2. This resume has been worked out on September 3, 1996 by Vestas Wind Systems A/S.

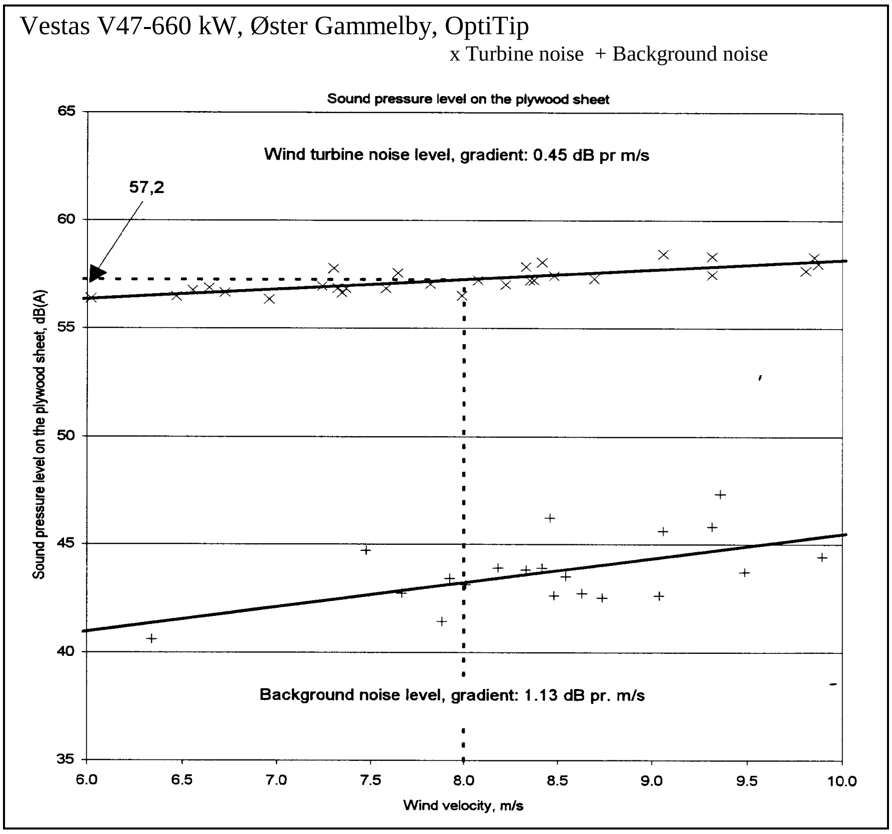
3. The noise measurements have been reported in Acoustica report no. P4.010.97 dated August 6, 1997. The noise measurements has been carried out July 28, 1997.

4. The measurements were carried out to determine the noise emission from a VESTAS V47-660 kW.

5. The noise emission has been determined according to statutorial order no. 304 of may, 14, 1991, and relevant parts of Guideline no. 6/1984, “Noise from Industrial Plants”, from the Danish Ministry of the Environment.

6. Results of Measurements:

6a.



The apparent A-weighted sound power level can be calculated from the equivalent continuous A-weighted sound pressure level, using the following expression:

$$L_{WA} = L_{Aeq} + 10 \cdot \log(4 \cdot \pi \cdot (d^2 + h^2)) - 6 \text{ dB}$$

Where, d = distance from the base of the wind turbine to the measurement position (d= 75m).
h = hub height (h = 40,5m + 0,5m).

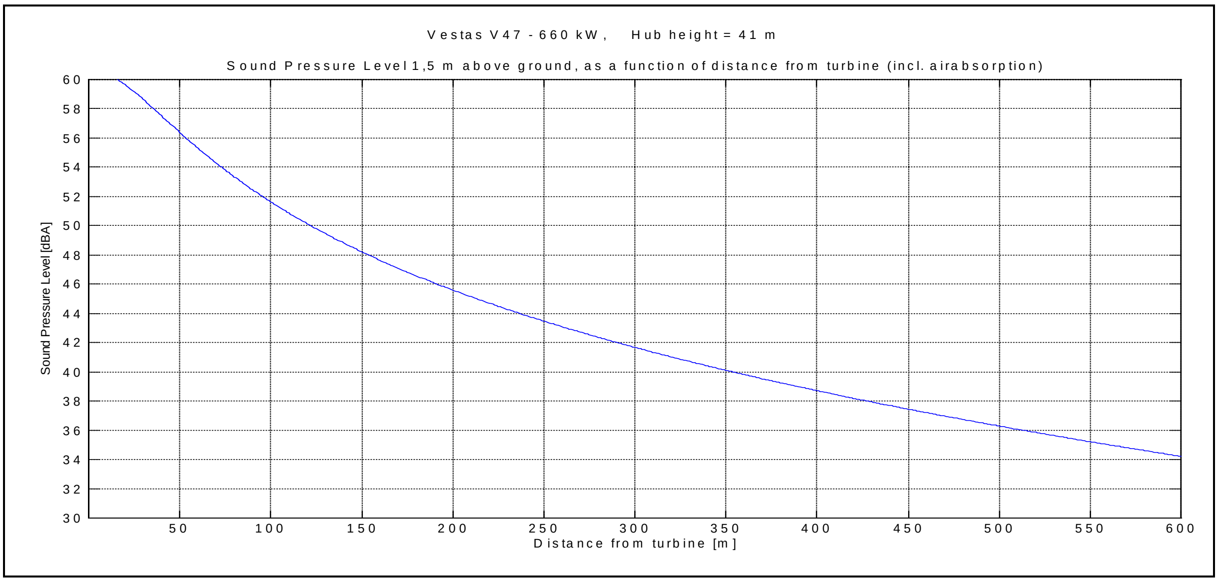
6b. The measurement show the following results at a wind speed of 8 m/s. The measurements is given respectively, as the A-weighted sound pressure level $L_{Aeq,ref}$ and the A-weighted sound power level $L_{WA,ref}$.

Frequency	$L_{Aeq,ref}$ [dB(A)]	$L_{WA,ref}$ [dB(A)]
1/1 octave 63 Hz	34,6	78,2
1/1 octave 125 Hz	42,5	86,1
1/1 octave 250 Hz	46,2	89,8
1/1 octave 500 Hz	51,6	95,2
1/1 octave 1 kHz	53,4	97,0
1/1 octave 2 kHz	49,2	92,9
1/1 octave 4 kHz	44,2	87,9
1/1 octave 8 kHz	25,6	69,2
A-weighted, total	57,2	100,8

According to statoturial order no. 304 of May 14, 1991, from the Danish Ministry of the Environment, the degree of accuracy on the results is ±2 dB.

6c. An analysis of the noise in a distance of 75 meter show, that the noise from the turbine contains no clearly audible tones or impulses. The analysis has been performed according to guideline no. 6/1984, "Noise from Industrial Plants", from the Danish Ministry of the Environment.

6d.



11.5 Noise resume of VESTAS V47-660/200 kW Wind Turbine

1. The measurement has been done by:

   Acoustica as
   Fælledvej 3
   8800 Viborg

   under the accreditation, registration no. 134, from DANAK.

2. This resume has been worked out on September 3, 1996 by Vestas Wind Systems A/S.

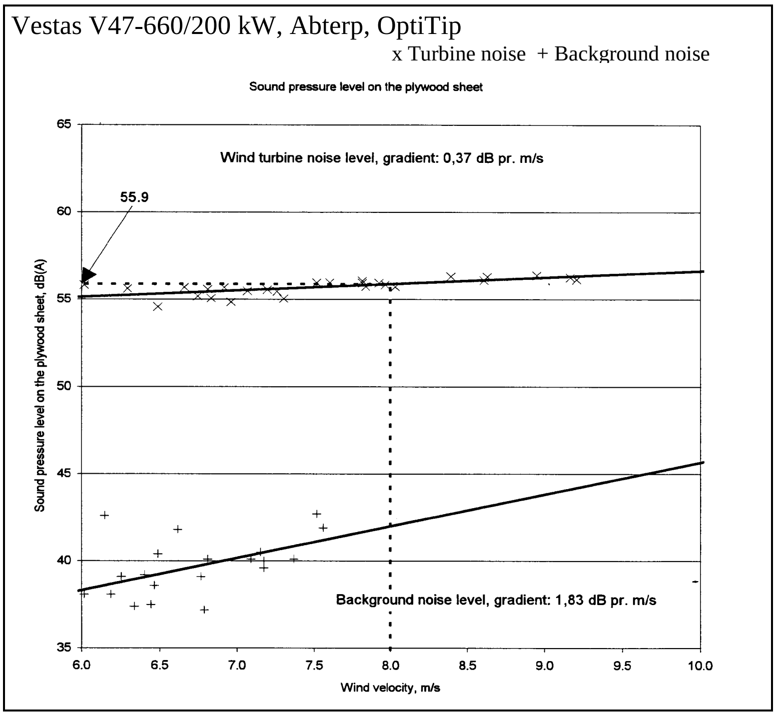
3. The noise measurements have been reported in Acoustica report no. P4.011.97 dated August 6, 1997. The noise measurements has been carried out July 30, 1997.

4. The measurements were carried out to determine the noise emission from a VESTAS V47-660/200 kW.

5. The noise emission has been determined according to statutorial order no. 304 of may, 14, 1991, and relevant parts of Guideline no. 6/1984, “Noise from Industrial Plants”, from the Danish Ministry of the Environment.

6. Results of Measurements:

6a.



The apparent A-weighted sound power level can be calculated from the equivalent continuous A-weighted sound pressure level, using the following expression:

$$L_{WA} = L_{Aeq} + 10 \cdot \log(4 \cdot \pi \cdot (d^2 + h^2)) - 6 \text{ dB}$$

Where, d = distance from base of wind turbine to measurement position (d= 75m).
h = hub height (h = 45,0m + 1,0m).

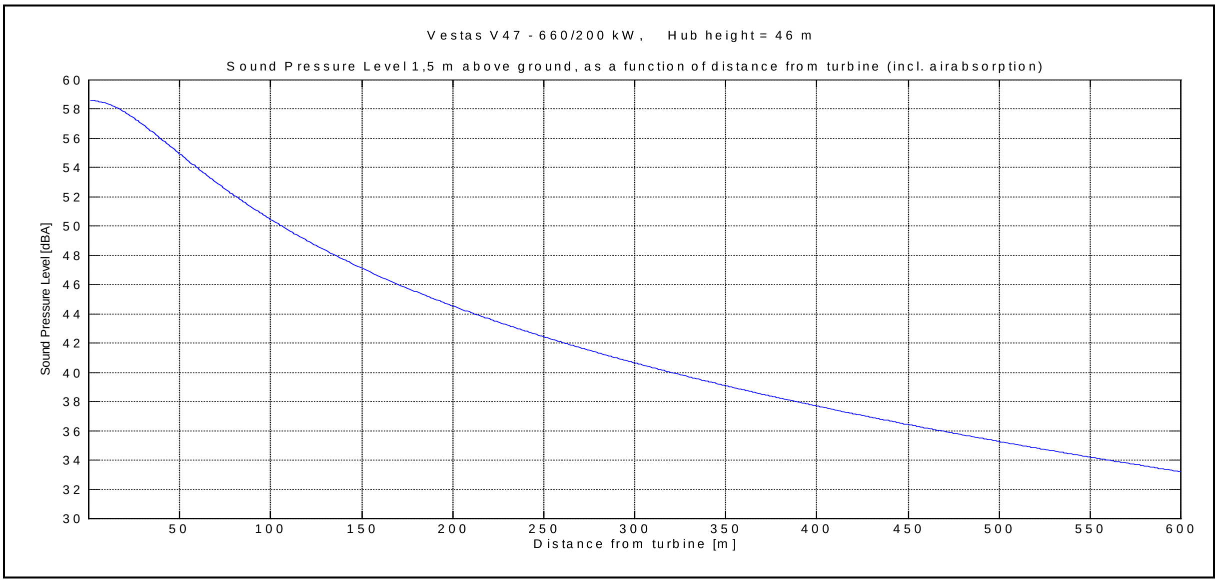
6b. The measurement show the following results at a wind speed of 8 m/s. The measurements is given respectively, as the A-weighted sound pressure level $L_{Aeq,ref}$ and the A-weighted sound power level $L_{WA,ref}$.

Frequency	$L_{Aeq,ref}$ [dB(A)]	$L_{WA,ref}$ [dB(A)]
1/1 octave 63 Hz	32,6	76,5
1/1 octave 125 Hz	40,2	84,1
1/1 octave 250 Hz	46,7	90,6
1/1 octave 500 Hz	52,1	95,9
1/1 octave 1 kHz	50,8	94,7
1/1 octave 2 kHz	45,8	89,7
1/1 octave 4 kHz	39,8	83,7
1/1 octave 8 kHz	24,8	68,7
A-weighted, total	55,9	99,8

According to statoturial order no. 304 of May 14, 1991, from the Danish Ministry of the Environment, the degree of accuracy on the results is ±2 dB.

6c. An analysis of the noise in a distance of 75 meter show, that the noise from the turbine contains no clearly audible tones or impulses. The analysis has been performed according to guideline no. 6/1984, “Noise from Industrial Plants”, from the Danish Ministry of the Environment.

6d.



ELECTRICAL DATA

VESTAS V47 - 660 kW
VESTAS V47 - 660/200 kW

Controller:
VMP-660kW-690V-50Hz

ITEM No.: 943117.R1

(13c)

V47 Electrical Data

Contents.. Page

1. V47 Wind Turbine

Vestas V47-660 kW with VMP-660kW-690V-50Hz controller.

The Vestas V47 wind turbines is available in two versions, V47-660/200 kW and V47-660 kW. The 200 kW generator operates at low wind speeds. This 200 kW generator ensures that the noise from the blades is kept at an absolute minimum. The rotor rotates slowly and an increased power production is achieved.

Vestas V47-660 kW wind turbine is a pitch regulated wind turbine, in consequence of which the blades are always pitched in the optimum angle during production as well as stop situations. The generator is a special asynchronous generator with integrated electronics, which is able to operate with a variable slip between 1 % and 10 %. Among the advantages of a pitch regulated wind turbine with variable slip the following should be mentioned:

- Optimum production under all wind conditions.
- Output is limited to 660 kW.
- Power output is smoothed.
- No motor start.
- Cut in of generator at synchronous speed.
- Turbine can be stopped without using the mechanical brake.
- Minimising of fluctuations in the mechanical transmission system.

2. The VMP-Controller

The wind turbine operates fully automatically by means of the VMP-controller (Vestas Multi Processor controller), which serves the following functions:

- Before connection to the grid, the speed of rotation is synchronised to the grid frequency in order to limit the cut-in current.
- Thyristor cut-in of the generator to limit the cut-in current.
- Cut-in current is lower than nominal current.
- Automatic yawing of the nacelle in accordance with the wind direction.
- Cut-in and cut-out of the power factor correction. Power factor correction covering no-load consumption of the reactive generator power is standard.
- Monitoring of the utility grid in accordance with DEFU report KR111 (Report from Danish Association of Electricity Supply Companies, 1998-04-08).
- Monitoring of the operation.
- Stop of the turbine in case of faults.
- As an option a capacitor assembly for 100 % power factor correction can be bought. The assembly contains impedance coils which protect the capacitors from the overcurrents caused by the 7th and 11th harmonics on the grid (voltage distortion).

The VMP-controller consists of a top controller and a ground controller. The top controller is located in the nacelle. The location of the ground controller depends on the choice of tubular tower or lattice tower. The ground controller is outlined on drawing 924785.

3. Tubular Tower

The ground controller is located at the bottom of the tower, see drawing no. 948606. The grid cables are led through 2 pieces of 160 mm tubes in the foundation and into the grid connection section of the ground controller.

4. Lattice Tower

If the turbine is installed on lattice tower, the ground controller is located in a wooden shed between the corner legs of the lattice tower, see drawing 948600. Vestas can supply the wooden shed. The wooden shed must be secured to a concrete foundation, and the grid cables are led through 2 pieces of 160 mm tubes into the grid connection section.

5. System Earthing

The transformer must have the lowvoltage gridside connected in star and this starpoint must be earthed, and connected to the earthingsystem of the turbine.
It is recommended to make the grid connection as a TN-system, see IEC 364 section 312.2.1. and 413.1.3. In consequence there of, the earthing system of the turbine must be connected to the earthing system of the transformer. The connection can be made either with a separate conductor (e.g. bare copper conductor) or through the neutral conductor in the grid cable, see drawing no. 948636. If the neutral conductor is used, it must be marked with green/yellow tape at both ends and defined as a PE-conductor, according to IEC 364 section 514.3.3.

6. Turbine Earthing System/Lightning Protection

The system should be made at the same time as the foundation work.

The earthing system must be accommodated to local soil conditions. The resistance to neutral earth should normally be no higher than 10 Ω. (In the Netherlands the resistance to neutral earth must be below 2.5 Ω, when the earthing system and concrete reinforcement are connected, see drawing 948678).

The earthing system shall be made as a closed ring conductor with earthing rods, see drawing 946056 or 922543. This gives the following advantages:

1. **Personnel safety.**
   The ring conductor limits step and contact voltage for persons, staying near the tower foundation in case of a lightning stroke.

2. **Operational safety.**
   The earthing rods ensure a steady and low resistance to neutral earth for the whole earthing system.

The earthing system is made as follows:

1. Ring conductor in 50 mm^2 Cu is established at a distance of 1 m from the foundation and approx. 1 m below ground level.

2. The ring conductor is supplemented with 2 copper coated earthing rods each of 6 m (Ø14). The earthing rods are rammed down on each side of the tower/lattice tower (180° between the earthing rods).

3. The ring conductor is connected to two tower legs or two opposite points on a tubular tower. The ground controller is connected to one of these points, see drawing no. 946056.

If the resistance to neutral earth is not sufficiently low, the earthing system can be improved.

1. The two earth rods can be extended to 10 m.

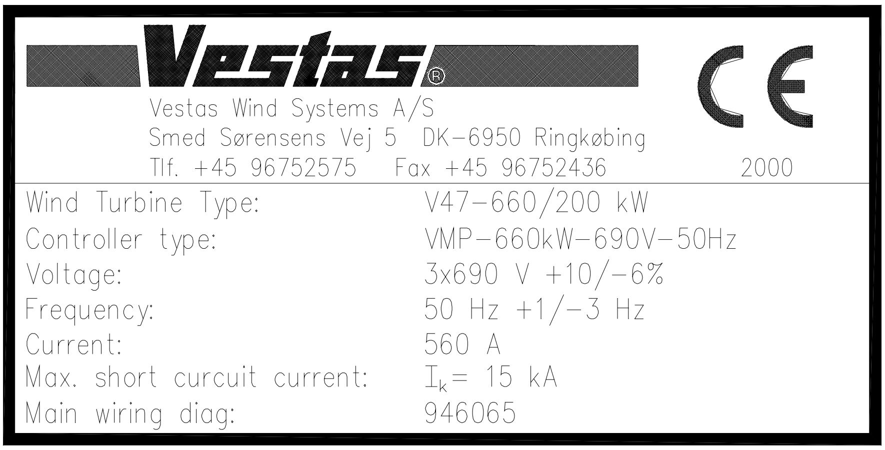
2. Two extra earth rods of each of a length of 10 m can be added (90° between the 4 earth rods).

7. Rated Electrical Data and Power Factor Correction

V47-660 kW have one generator at 660 kW.
V47-660/200 kW has two seperate generators one of 660 kW and one of 200 kW.

Power	:	**660 kW**	**200 kW**
Generator type	:	Asynchronous with VRCC	Asynchronous
Building size	:	400	280
Degree of protection	:	IP54	IP54
Voltage	:	690 Vac	690 Vac
Frequency	:	50 Hz	50 Hz
Number of poles	:	4	4
Slip regulation interval	:	1-10 %	1.1 %
Generator power factor (cos ϕ):	:	0.88	0.89
Generator current	:	628 A	190 A
Power factor correction	:	250 kVAr	75 kVAr
Resulting power factor (grid side)	:	0.98	0.99
Resulting current (grid side)	:	560 A	169 A

8. Nameplate on the Ground Controller



9. Grid connection

The ground controller consists of 5 sections, see drawing 924785. In the bus bar section there is one circuit breaker for the generator (Q8) and one circuit breaker (F30) for the control circuit and light located. The control circuits can be disconnected with one circuit breaker (Q16).

Circuit breakers Q8 and Q16 are lockable. When Q8 and Q16 are disconnected there will still be power for the light installation.

Beneath the bus bar section the grid connection section is located, please see drawing 922551. The grid cables are conducted through 3 pieces of 110mm tubes in the foundation to the grid connection section in the ground controller. There are four terminals for respectively L1, L2, L3 and PE. The grid cables must be mounted with cable lugs. Two pieces of M12x50 bolts in each terminal are used for mounting the cable lugs. This work has to be carried out by an authorised electrician.

Circuit breakers	Generator / Q8 ABB S6N 630	Controller / F30 ABB MS325 + PROLIM
Breaking capacity, I_{cu}, I_{cs}	20 kA/15 kA	50 kA
Thermo release, I_{th}	630 A	6,3 A
Magnetic release, I_m	3.8 kA	108 kA

Do not connect wind turbine when the short circuit current is above 15kA.

9.1 Harmonics freqeuncies

The 5th and 7th. harmonics are sinusoidal voltage with frequencies at 250Hz and 350Hz respectively. Harmonics are caused by different equipment (e.g. welding machines), which via a transformer is connected to same power supply systems as the wind turbine. Harmonics in the power supply systems reduce the lifetime of the capacitor.

The impedance voltage of the transformer and the size of the power factor correction are very important for the acceptable level of harmonics.

- If a 800kVA transformer with 4.5% impedance voltage is used together with the 250 kVAr power factor correction, the 5th and 7th harmonics have to be below 3% and 2% respectively.
- If a 800kVA transformer with 6% impedance voltage is used together with the 250 kVAr power factor correction, the 5th and 7th harmonics have to be below 3% and 1% respectively.

It is recommended to use a 800kVA transformer with 4.5% impedance voltage for a V47-660kW wind turbine.

10. Monitoring of the Grid

The generator and the power factor correction will be disconnected if the voltage or the frequency exceeds the limits which are determined in the DEFU report KR111.

Nominal phase voltage: $U_{P,nom}$ = 400 V. Grid voltage: U_N

The generator and the power factor correction will be disconnected if:

	U_P	U_N
The voltage is 10% above the nominal voltage for 60 s.	440 V	762 V
The voltage is 6% below the nominal voltage for 60 s.	376 V	651 V
The frequency is above 51 Hz for 0.2 s.		
The frequency is below 47 Hz for 0.2 s.		

The power factor correction will be disconnected if:

The voltage is 11% above the nominal voltage for 0.08 s.	444 V	769 V

The generator will be disconnected if:

The voltage is 13.5% above the nominal voltage for 0.2 s.	454 V	786 V

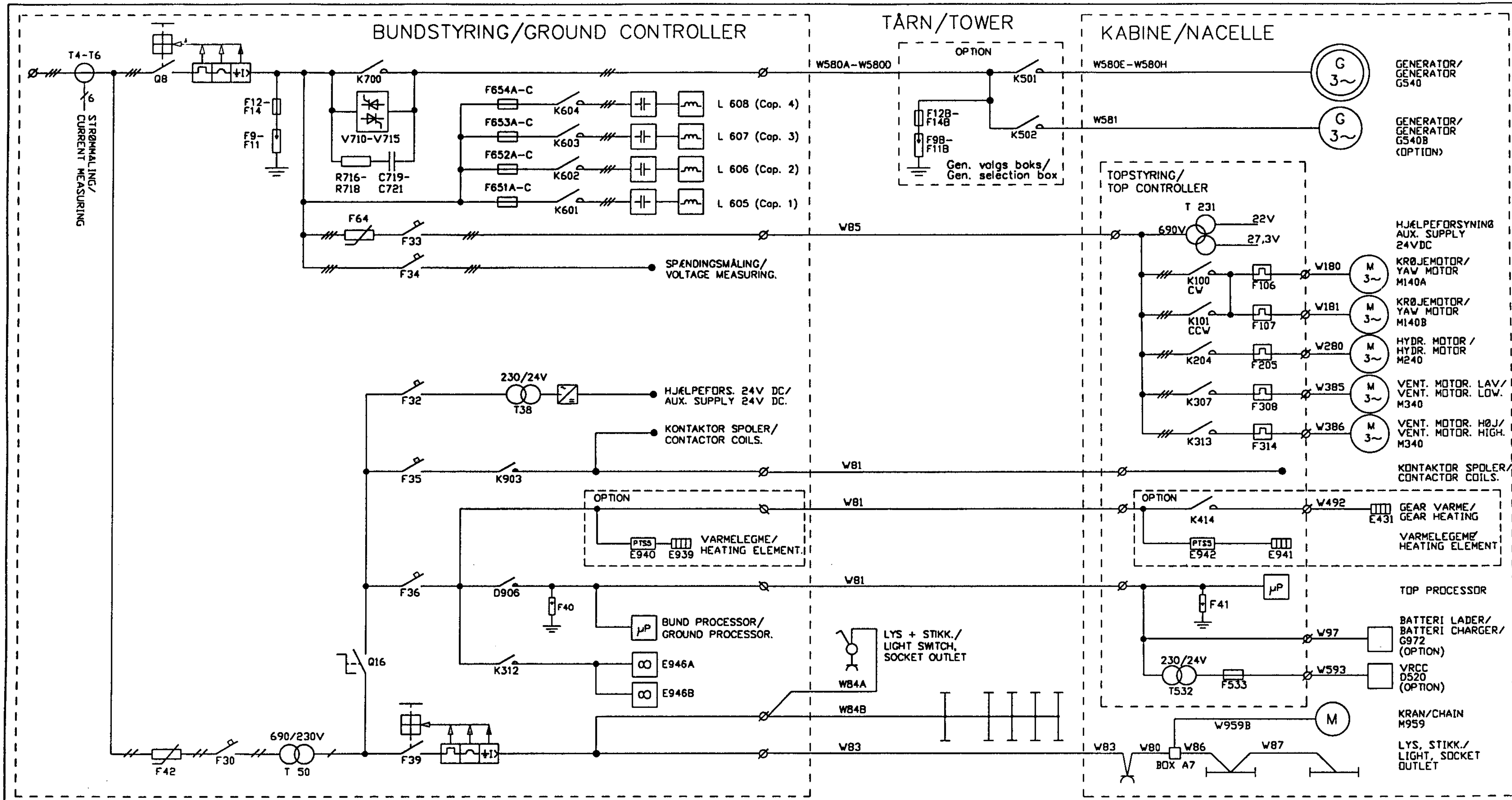
If a fault on the grid interrupts the voltage supply to the VMP-controller, the emergency stop circuit will be opened immediately and generator and power factor correction will be disconnected at the same time.

11. kWh-meter Arrangement

Vestas recommends that the kWh-meter arrangement is located in the transformer housing. The kWh-meter(s) should be located behind a window so that they can be read from outside. The kWh-meter(s) shall be connected to measuring transformers. Following measuring transformers can be used:

- Current transformer : class 0.2, 600/5 A or 600/1 A.
- Voltage transformers : class 0.2, 400/230 V (line-neutral).

12. Drawings



ITEM Hovedstrømskema. VMP-660kW-690V-50Hz.

Main wiring diag. VMP-660kW-690V-50Hz.

REV.DATE. / SIGN. I APPD. R	990302 JAW, MK	2	3	4	JOURNAL NO.
5	6	7	8	9	MATR.
DATE 970812	SIGN. LRA	APPD. MK	SCALE 1:1	DRWG. NO. 946065	

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Vestas

VESTAS WIND SYSTEMS A/S
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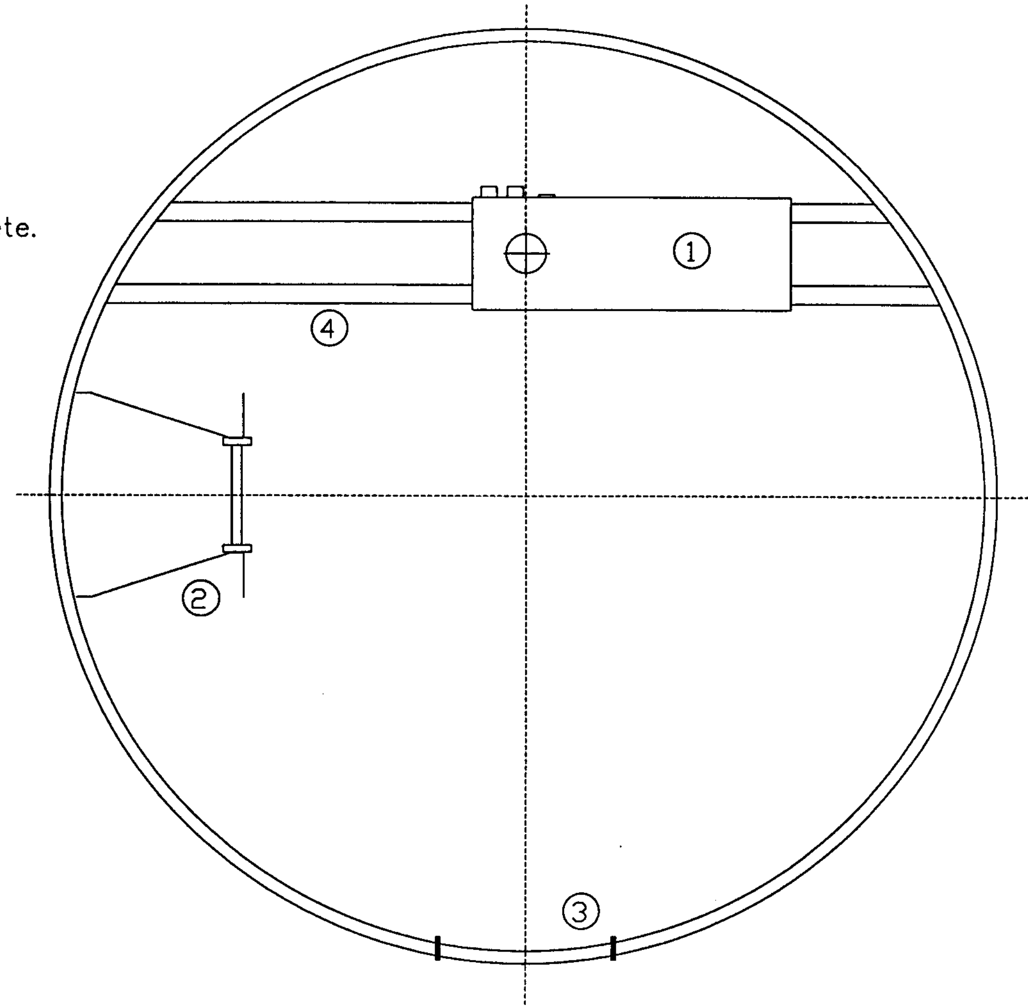
Telefax +45 96752436

1. Bundstyring/Ground controller
2. Stige/Ladder
3. Tårndør/Tower door
4. I-jern/skumfyldt C-profil, i beton/
   I-iron/foam filled C-profile, in concrete.

Tårndiameter 3,0m/3,3m/3,6m/
Tower diameter 3,0m/3,3m/3,6m.



ITEM					
Plac. af styring i rørtårn. VMP-BUND-500/600/660kW.					
Plac. of ctrl. in tubular tower. VMP-GND-500/600/660kW.					
REV.DATE. SIGN. / APPD. R	940803 FP, MK 1	960422 LRA, MK 2	970522 LRA, MK 3	4	JOURNAL NO.
5	6	7	8	9	MATR.
DATE 911111	SIGN. FP	APPD. MK	SCALE 1:20	DRWG. NO. 948606	

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VESTAS WIND SYSTEMS A/S
SMED HANSENSVEJ 27 DK-6940 LEM
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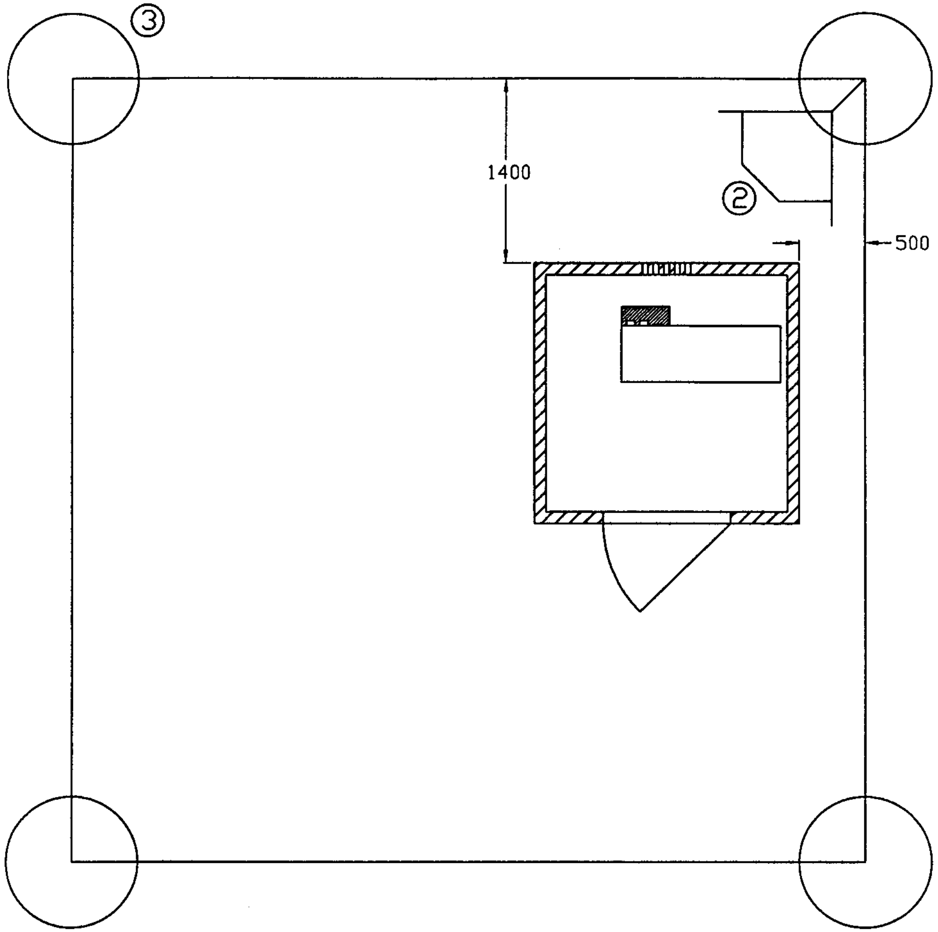
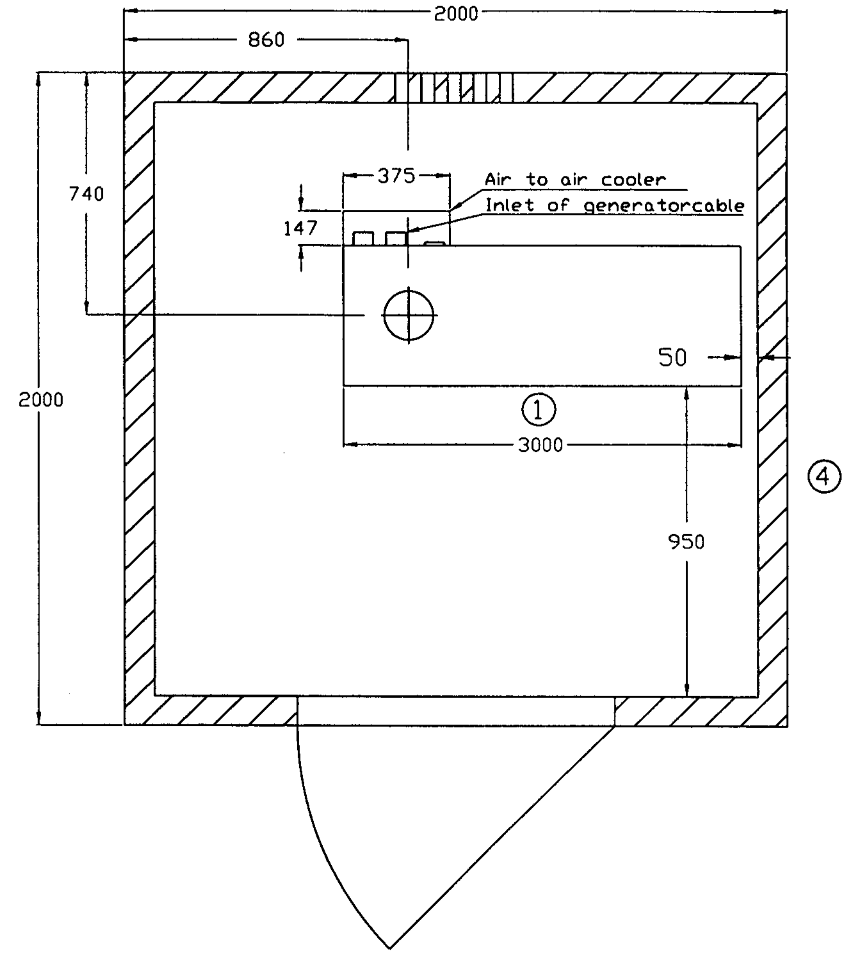
Telefax +45 97341420





① Bundstyring/Ground controller.
② Stige/Ladder
③ Ben på gittermast/Leg on lettice tower
④ Træhytte/Wooden shed

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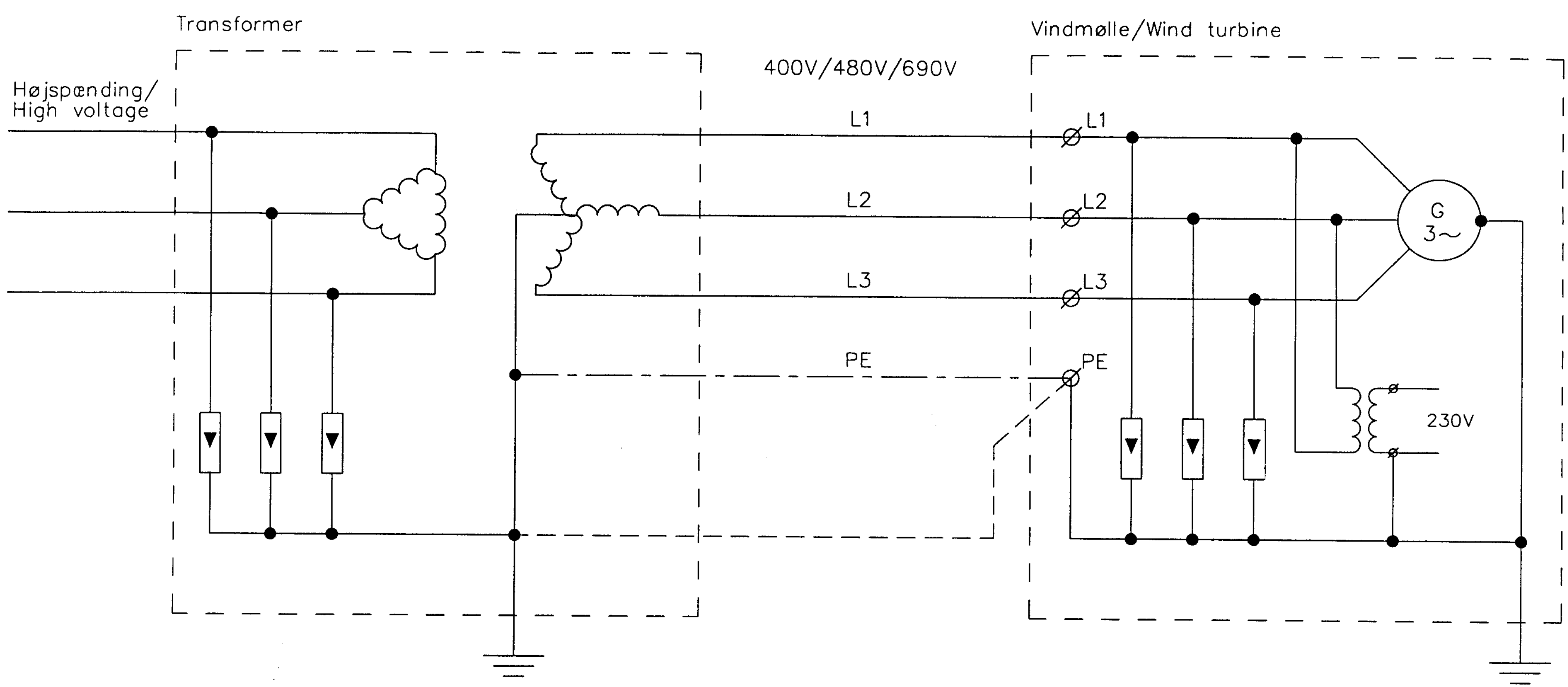
Vestas VESTAS WIND SYSTEMS A/S SMED SØRENSENS VEJ 5, DK-6950 RINGKØBING Tlf. +45 96752575 - Fax +45 96752436			PROJ.	EMNE Plac. af træhytte. VMP-bund-500/600/660kW.
			CAD / COMMENT ACAD 14	
MATERIAL X			FORMAT A3	ITEM Plac. of wooden sheed. VMP-GROUND-500/600/660kW.
LAST REV. DATE 990804	SIGN. JAW	APPD. MK	MASS [kg] X	
DATE 911018	SIGN. FP	APPD. MK	SCALE 1:40	DRAWING NO. 948600 — REV. 3



TN–system : IEC 364 312.2.1. (Elektriske installation)
TN–system : IEC 364 312.2.1. (Electrical installation)

– – ——— – – PE leder i forsyningskabel/
PE conducter in supply cable.

eller/or

– – – – – – – Separat blank Cu–leder/
Separate bare Cu–conducter.

ITEM						
Systemjording. TN–S.						
System earthing. TN–S.						
REV.DATE. SIGN. APPD.	R	940427 FP MK 1	940624 FP MK 2	970731 LRA, MK 3	4	JOURNAL NO.
	5	6	7	8	9	MATR.
DATE 920127	SIGN. FP	APPD. MK	SCALE – –	DRWG. NO. 948636		

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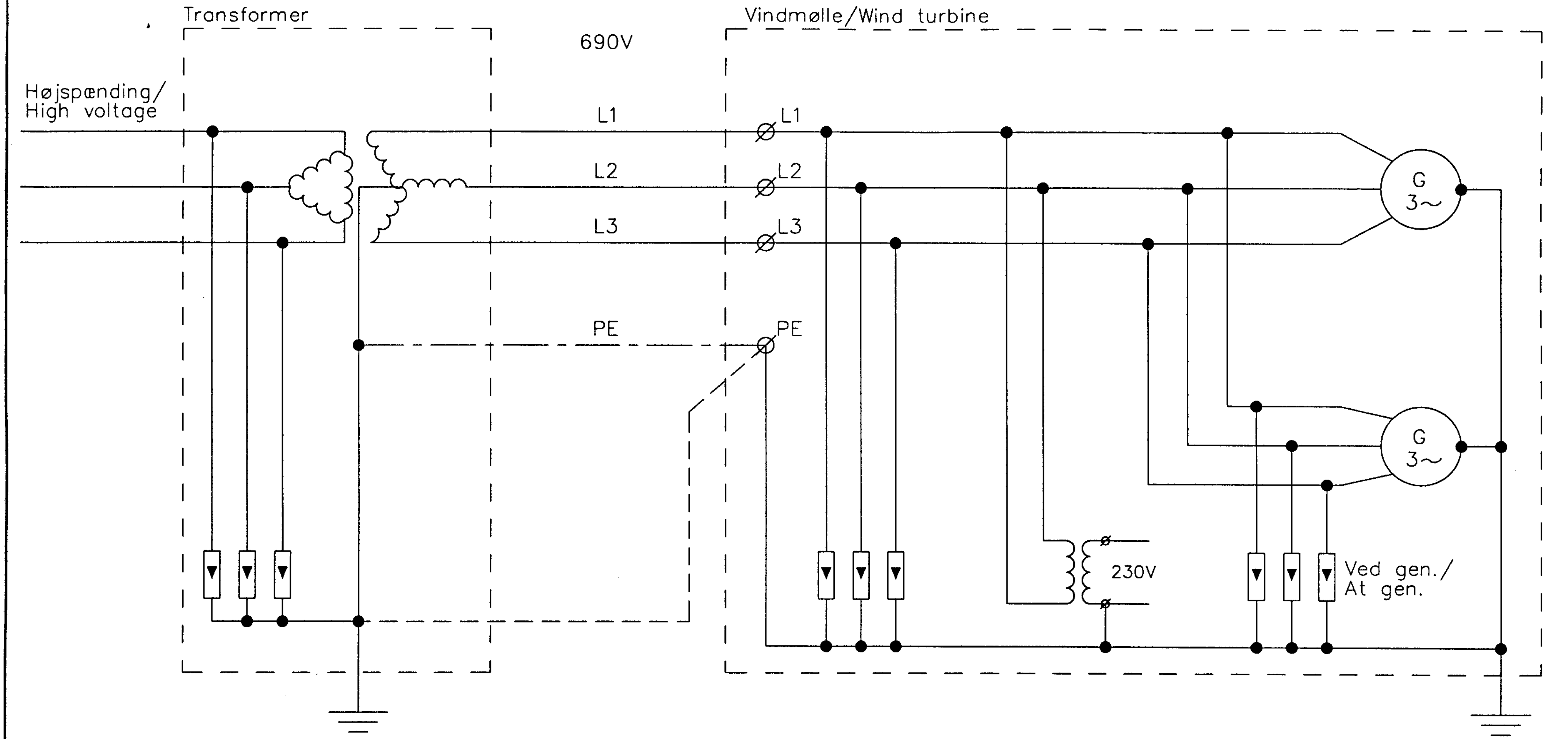

TN-system : IEC 364 312.2.1. (Elektriske installation)
TN-system : IEC 364 312.2.1. (Electrical installation)

- - ——— - - PE leder i forsyningskabel/
PE conducter in supply cable.

eller/or

— — — — — — Separat blank Cu-leder/
Separate bare Cu-conducter.

ITEM Systemjording. (2 generator drift) TN-S.					
System earthing. (2 generator operating) TN-S.					
REV.DATE. SIGN. I APPD. R	1	2	3	4	JOURNAL NO.
5	6	7	8	9	MATR.
DATE 970805	SIGN. LRA	APPD. MK	SCALE --	DRWG. NO. 946141	

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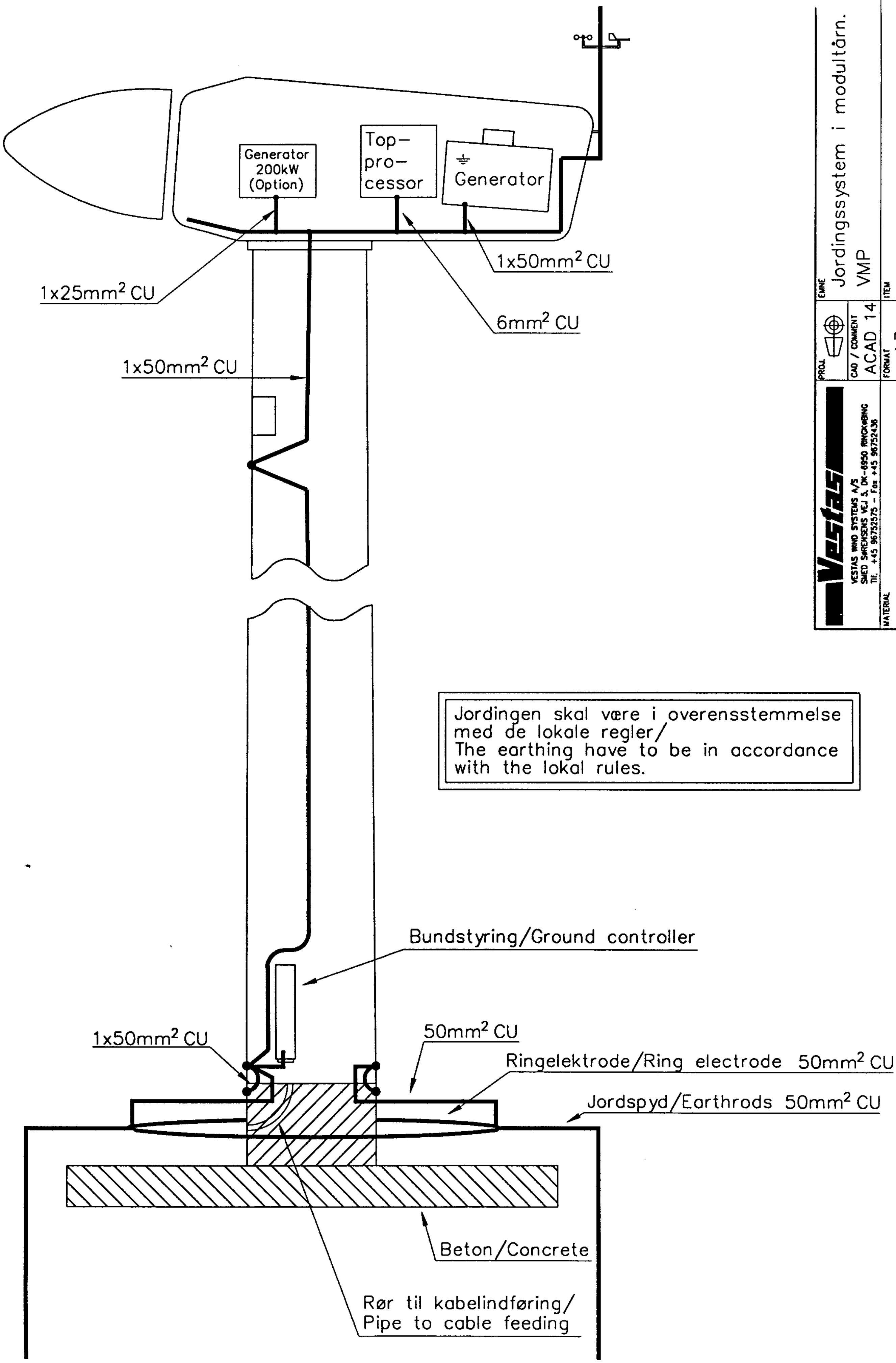

Jordingen skal være i overensstemmelse med de lokale regler/
The earthing have to be in accordance with the lokal rules.

EMNE	Jordingssystem i modultårn. VMP
ITEM	Earthingsystem in modular tower VMP
DRAWING NO.	946056
REV.	4
CAD / COMMENT	ACAD 14
FORMAT	A3
MASS [kg]	
SCALE	-:-
LAST REV. DATE	990520
SIGN.	MVE
APPD.	MK
DATE	960415
SIGN.	LRA
APPD.	MK

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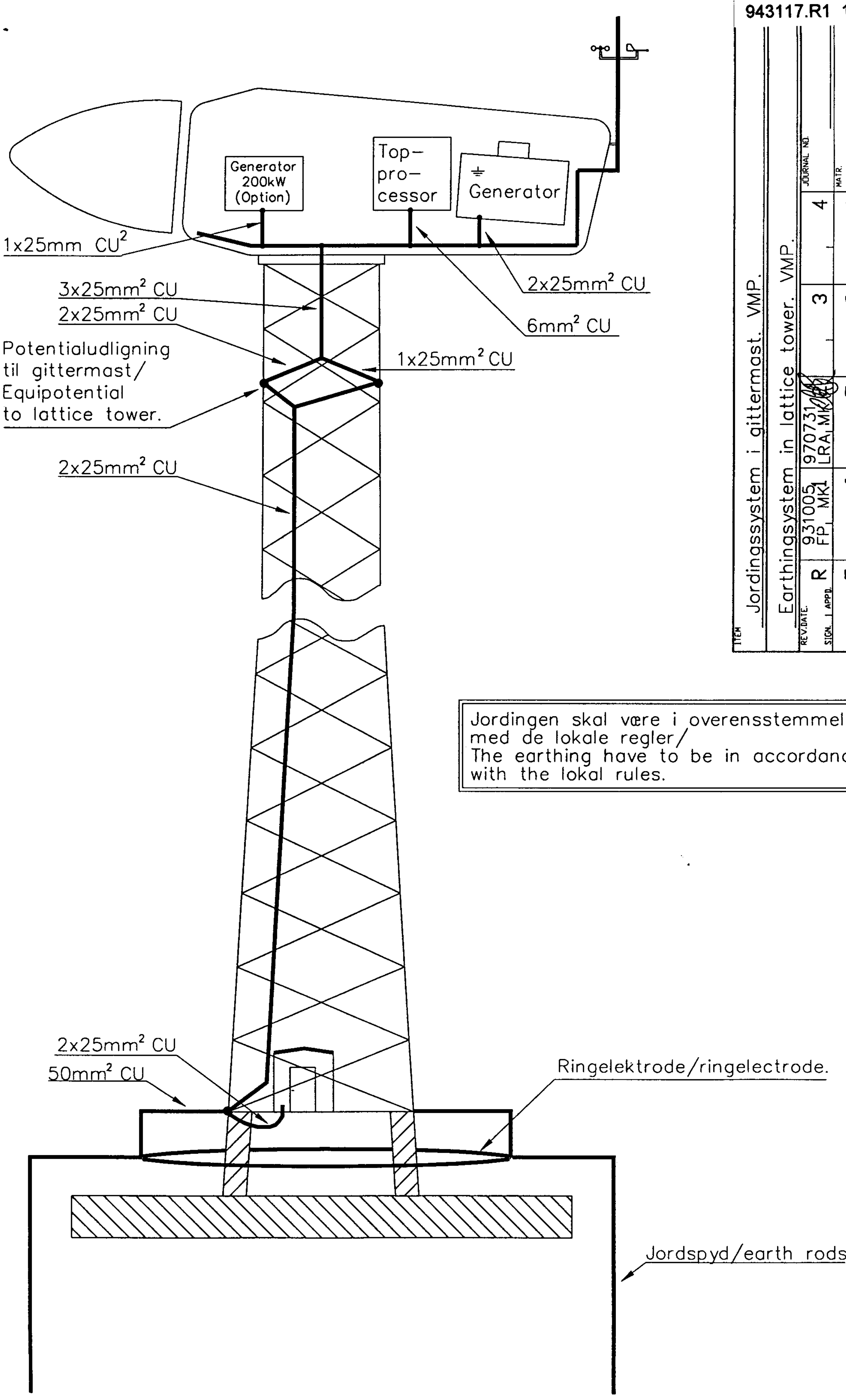
943117.R1 15



Jordingen skal være i overensstemmelse med de lokale regler/
The earthing have to be in accordance with the lokal rules.

ITEM	Jordingssystem i gittermast. VMP.		
	Earthingsystem in lattice tower. VMP.		
REV.DATE	R	931005	970731
SIGN. / APPD.		FP MK1	LRA MK
	3	4	
	5	6	7
	8	9	
DATE	911120	SIGN. FP	APPD. MK
SCALE	--	DRVG. NO.	922543

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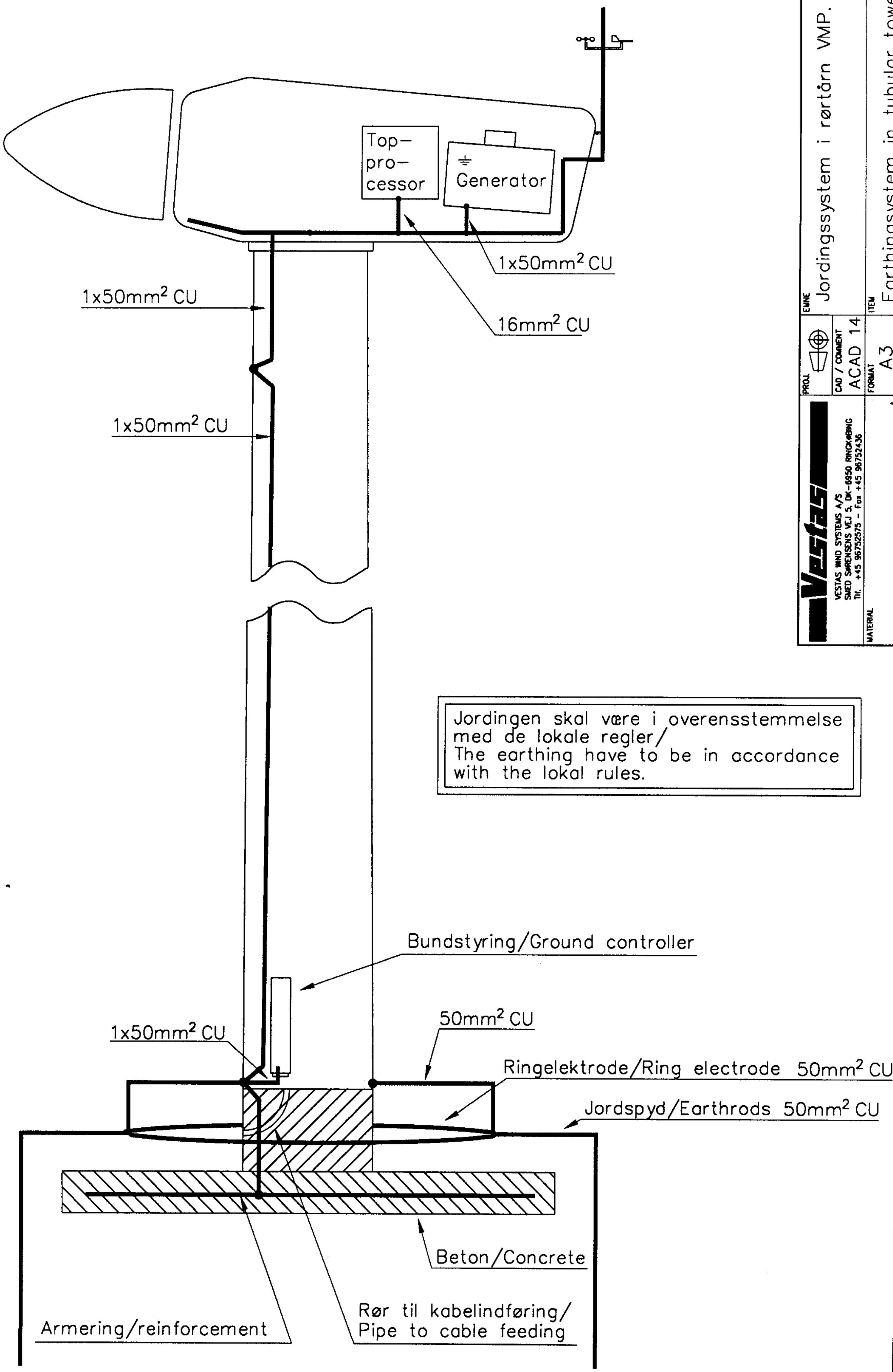
Vestas



EMNE	Jordingssystem i rørtårn VMP.
ITEM	Earthingsystem in tubular tower VMP.
DRAWING NO.	948678
REV.	1
PROJ.	
CAD / COMMENT	ACAD 14
FORMAT	A3
MASS [kg]	
SCALE	--
MATERIAL	
LAST REV. DATE	000112
SIGN.	JAW
APPD.	MK
DATE	931005
SIGN.	FP
APPD.	MK

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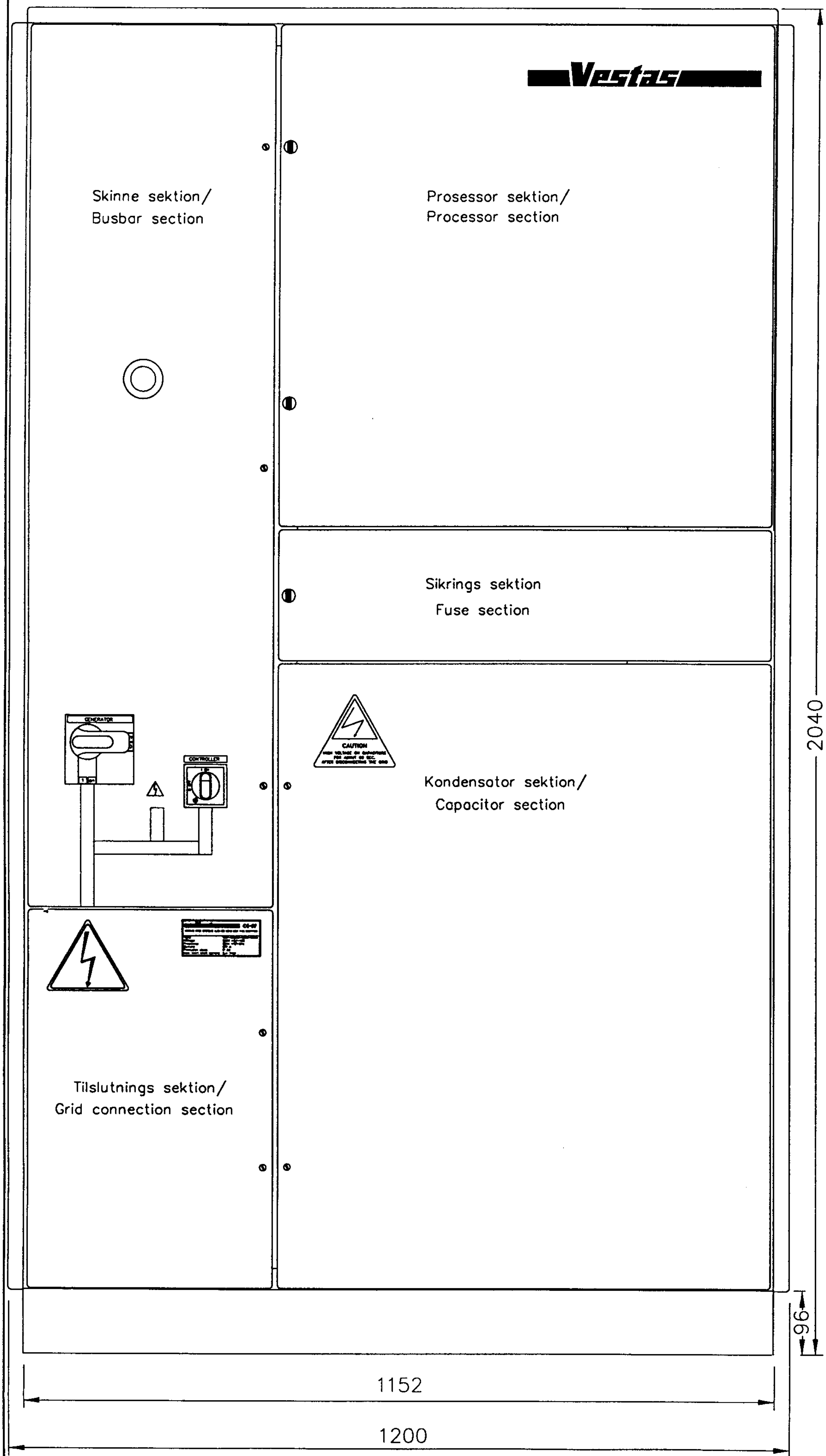
Tlf. +45 96752575 – Fax +45 96752436



Tavle set forfra. VMP-BUND-500/600/660kW.

Front view. VMP-GROUND-500/600/660kW.

REV. DATE	R 970521	2	3	4	JOURNAL NO.
SIGN. / APPD.	LRA MK	5 / 6	7 / 8	9	MATR.

DATE	SIGN.	APPD.	SCALE	DRWG. NO.
970114	LRA	MK	1:6	924785

VESTAS WIND SYSTEMS A/S
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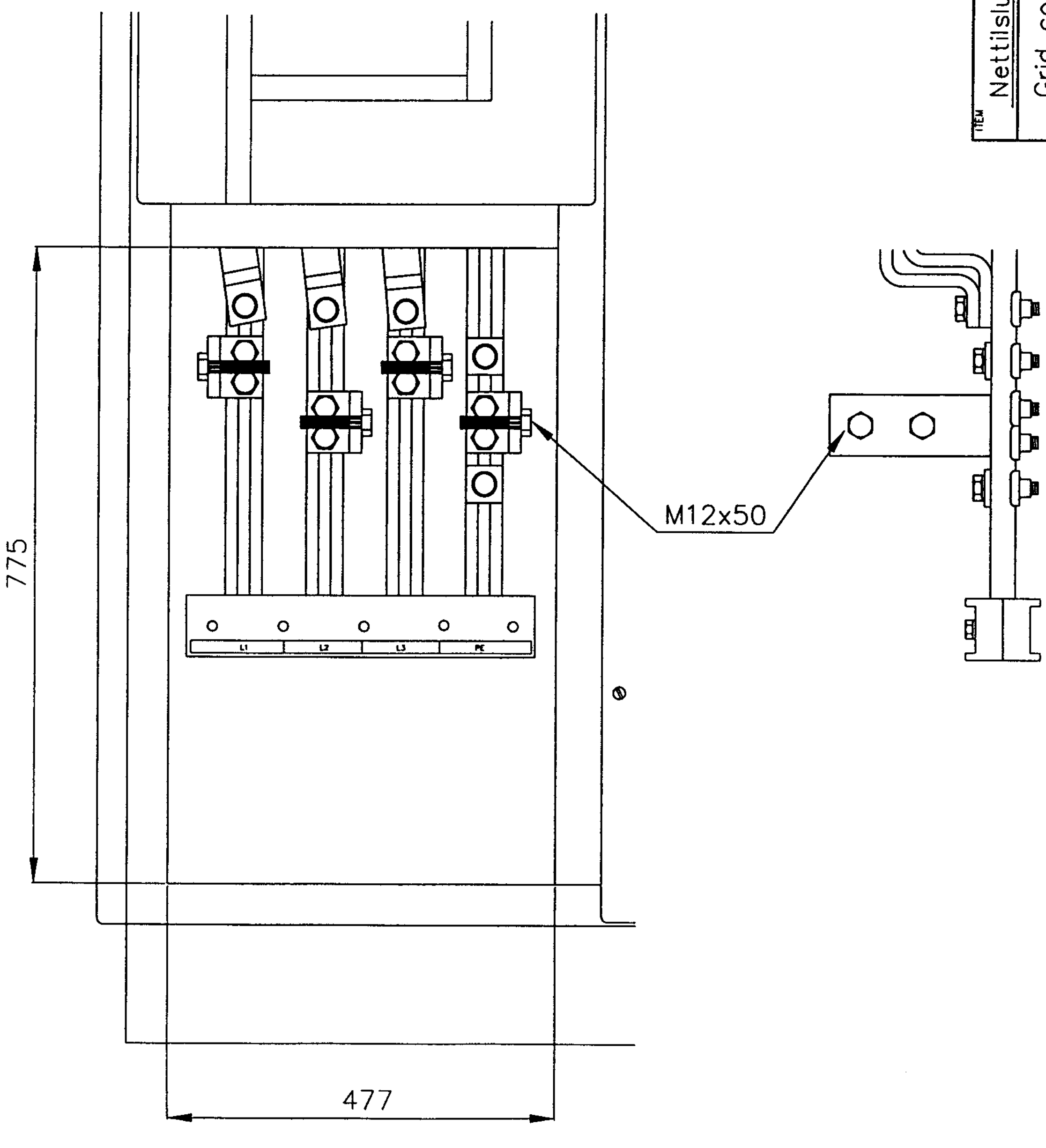
Telefax +45 97341420

Sokkeldybde = 384mm
Tavledybde m. låger = 432mm

Pedestal depth = 384mm
Panel depth with doors = 432mm

Tilspændingsmoment på M12 bolt = 70Nm
Torque on M12 bolt = 70Nm



ITEM
Nettilslutningssektion. VMP-BUND-500/600/660kW.
Grid conn. section. VMP-GROUND-500/600/660kW.

REV.DATE / SIGN. / APPD.	R					JOURNAL NO.
		931006 FP MK1	940803 FP MK2	961015 LRA,MK 3	970523 LRA,MK	
	5	6	7	8	9	MATR.
DATE 911115		SIGN. FP	APPD. MK	SCALE 1:4	DRWG. NO.	922551

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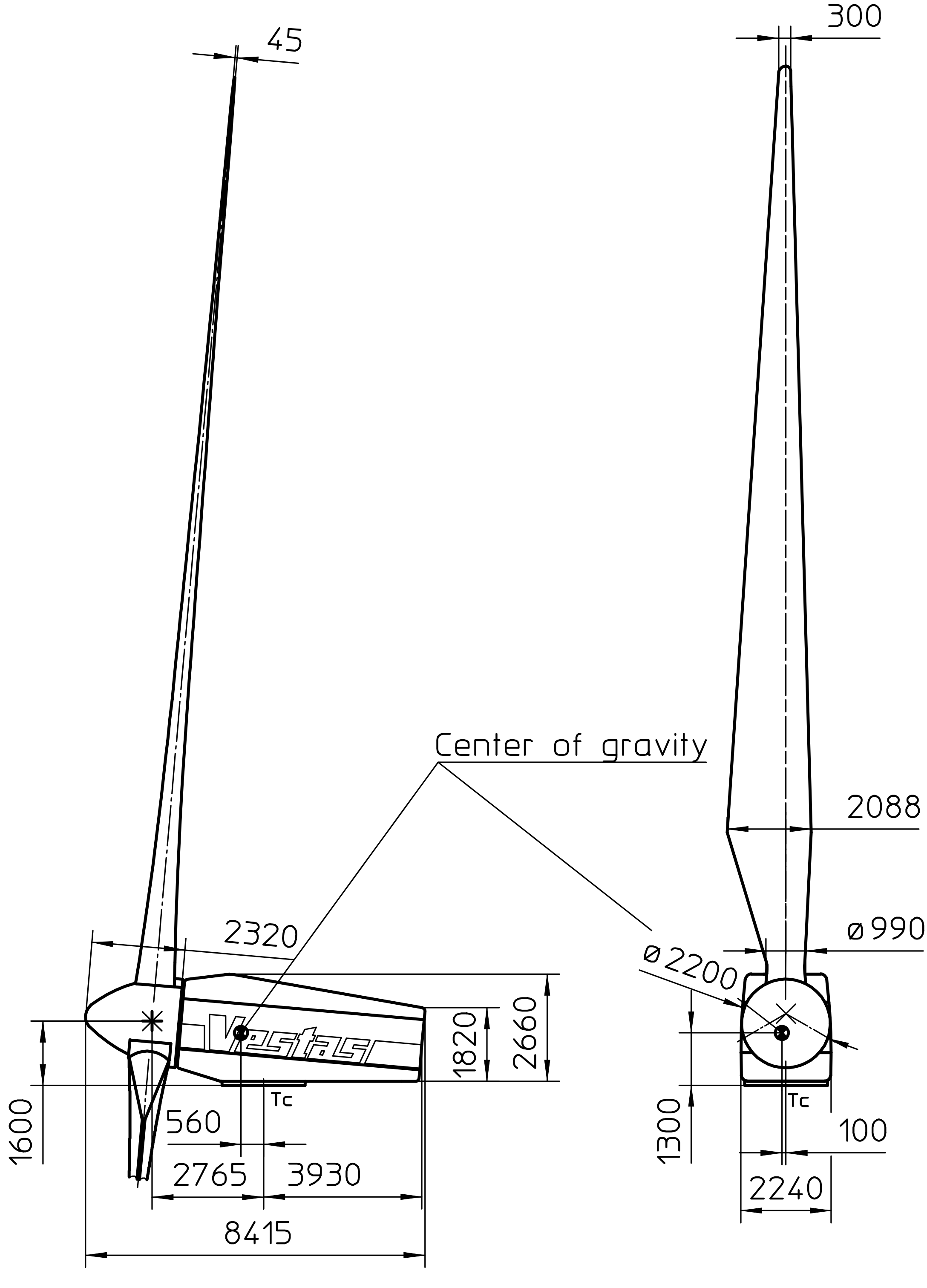
V47 – 660 kW



03. juli 1997

Draw. no. 948873r1

Vestas V47 Foundation loads.

This document gives the tower top and the foundation loads for a Vestas V47- 660 and 660/200 kW with different hub heights for general IEC/GL placement as given in the GL regulations (1993 Ed. With MArch 1994 supplement).

The climate and wind conditions is given in the General Specifications for the V47-660 and 660/200 kW turbines.

In the following table the coordinate system with horizontal X and Y axis in Figure 1 has been used and all loads in this document do not contain any load factors.

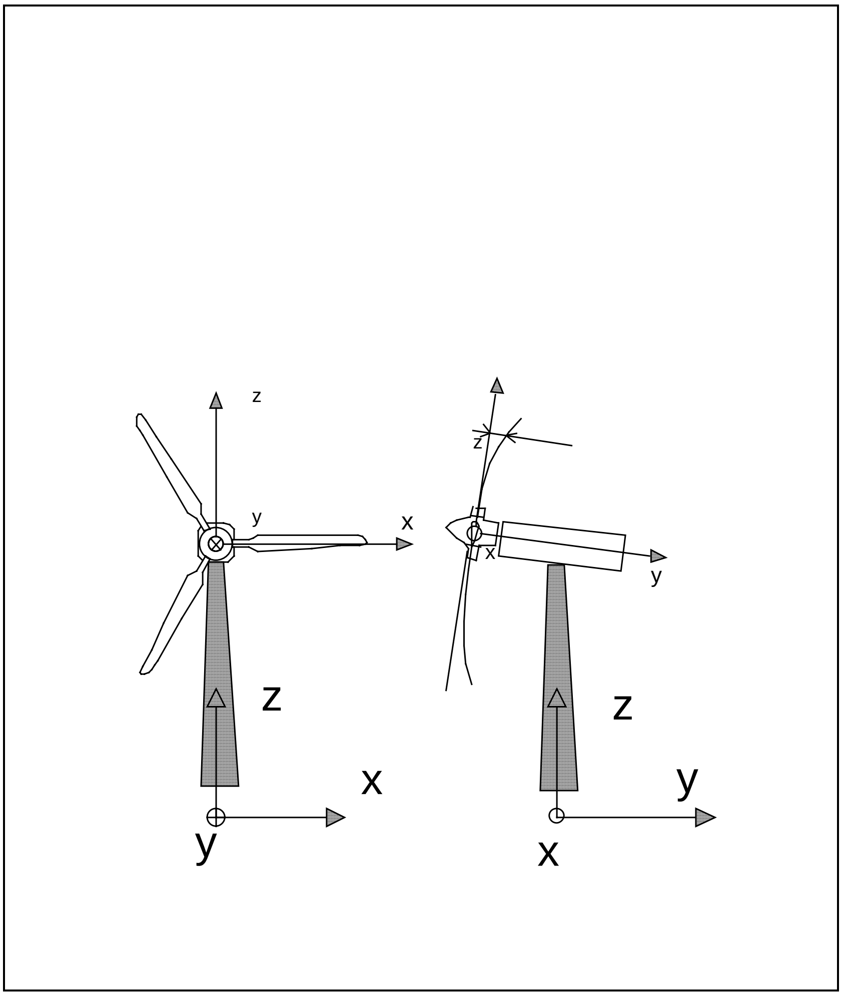


Figure 1 : Koordinatsyst. Definition

(19a)

The extreme load in the document has been calculated based on the loads from the load case EWP47b15 in the IEC load document (Item no. 943499).

Loads on tower top, tubular tower.

Following table list the tower top loads for the Vestas V47-660 and 660/200 kW turbines. It is assummed, that a standard Vestas tubular tower design is used and a Wöhler exponent m = 4 has been used for calculation of the equivalent fatigue loads.

VESTAS V47. Tower top loads. IEC placement		
	Extreme load	Fatigue load at $n = 10^7$ Peak to Peak
F_x (kN)	180	0
F_y (kN)	-7	54
F_z (kN)	-286	42 [a)]
M_x (kNm)	480	500
M_y (kNm)	358	197
M_z (kNm)	578	471

[a)] Only aerodynamic contribution.

Table 1. General tower top loads.

Loads on top of concrete foundation, tubular tower.

Following tables list the foundation loads for the Vestas V47-660 and 660/200 kW turbines. It is assummed, that a standard Vestas tubular tower design is used and a Wöhler exponent m = 4 has been used for calculation of the equivalent fatigue loads.

VESTAS V47, hub height 40 m. IEC placement			
	Extreme load	Fatigue load at $n = 10^7$	
		Peak to Peak	Mean
F_x (kN)	223	-	0.6
F_y (kN)	159	54	79
F_z (kN)	-553	42[a)]	-553
M_x (kNm)	-2280	2590	3082
M_y (kNm)	8240	197	236
M_z (kNm)	578	471	25

[a)] Only aerodynamic contribution.

Table 2. General foundation loads - hub height 40 meter.

VESTAS V47, hub height 45 m. IEC placement			
	Extreme load	Fatigue load at n = 10^7	
		Peak to Peak	Mean
F_x (kN)	229	0	0.6
F_y (kN)	183	54	79
F_z (kN)	-592	42 [a)]	-592
M_x (kNm)	-3120	2860	3476
M_y (kNm)	9380	197	239
M_z (kNm)	578	471	25

[a)] Only aerodynamic contribution.

Table 3. General foundation loads - hub height 45 meter.

VESTAS V47, hub height 50 m. IEC placement			
	Extreme load	Fatigue load at n = 10^7	
		Peak to Peak	Mean
F_x (kN)	237	0	0.6
F_y (kN)	212	54	79
F_z (kN)	-640	42[a)]	-639
M_x (kNm)	-4020	3100	3823
M_y (kNm)	10450	197	241
M_z (kNm)	578	471	25

[a)] Only aerodynamic contribution.

Table 4. General foundation loads - hub height 50 meter.

VESTAS V47, hub height 55 m. IEC placement			
	Extreme load	Fatigue load at n = 10^7	
		Peak to Peak	Mean
F_x (kN)	245	0	0.6
F_y (kN)	246	54	79
F_z (kN)	-758	42 [a)]	-758
M_x (kNm)	-5280	3380	4233
M_y (kNm)	11730	197	244
M_z (kNm)	578	471	25

[a)] Only aerodynamic contribution.

Table 5. General foundation loads - hub height 55 meter.

VESTAS V47, hub height 60 m. IEC placement			
	Extreme load	Fatigue load at $n = 10^7$	
		Peak to Peak	Mean
F_x (kN)	253	0	0.6
F_y (kN)	274	54	79
F_z (kN)	-834	42 [a)]	-834
M_x (kNm)	-6430	3620	4580
M_y (kNm)	12860	197	247
M_z (kNm)	578	471	25

[a)] Only aerodynamic contribution.

Table 6. General foundation loads - hub height 60 meter. Only V47-660/200 kW

VESTAS V47, hub height 65 m. IEC placement			
	Extreme load	Fatigue load at $n = 10^7$	
		Peak to Peak	Mean
F_x (kN)	260	0	0.6
F_y (kN)	306	54	79
F_z (kN)	-911	42 [a)]	-911
M_x (kNm)	-7840	3890	4967
M_y (kNm)	14160	197	250
M_z (kNm)	578	471	25

[a)] Only aerodynamic contribution.

Table 7. General foundation loads - hub height 65 meter. Only V47-660/200 kW

Note that these loads do not contain any load factor. In other words characteristic loads

Natural frequencies - Tower and foundation stiffness.

Frequencies	1 p, Hz	3 p, Hz
V47-660	0.475	1.43
V47-660/200 large generator	0.43	1.3
V47-660/200 small generator	0.33	1.00

Table 8. Rotor frequencies-synchronuous.

Frequencies of the combined turbine, tower and foundation must be within +/- 5 % of the values listed below.

Hub height m	Eigenfrequens f_0 Hz
40	0.70
45	0.61
50	0.58
55	0.56
60 [a)]	0.54
65 [a)]	0.50

[a)] Only V47-660/200 kW

Table 8. Tower frequencies.

Conclusion.

The loads listed in this document are only useable for placements comparable with the General Specifications for this turbine. Moreover it is pressumed, that towers similar to a standard tubular Vestas tower has been used.

For different towers and climate conditions Vestas need to be contacted.

VESTAS WIND SYSTEMS A/S

STANDARD FOUNDATION FOR VESTAS V47-660/220 & V47-660

38,7 m. TOWER.

<u>Ground water level below foundation.</u>

Drawings

Specification

Virring 97.09.01

(27a)

OLE THISTED

Sag nr. 97.069

Rådg. Ingeniørfirma ApS FRI Hvidballegaard, Virringvej 69, Virring, 8660 Skanderborg, Tlf. 86 92 64 88

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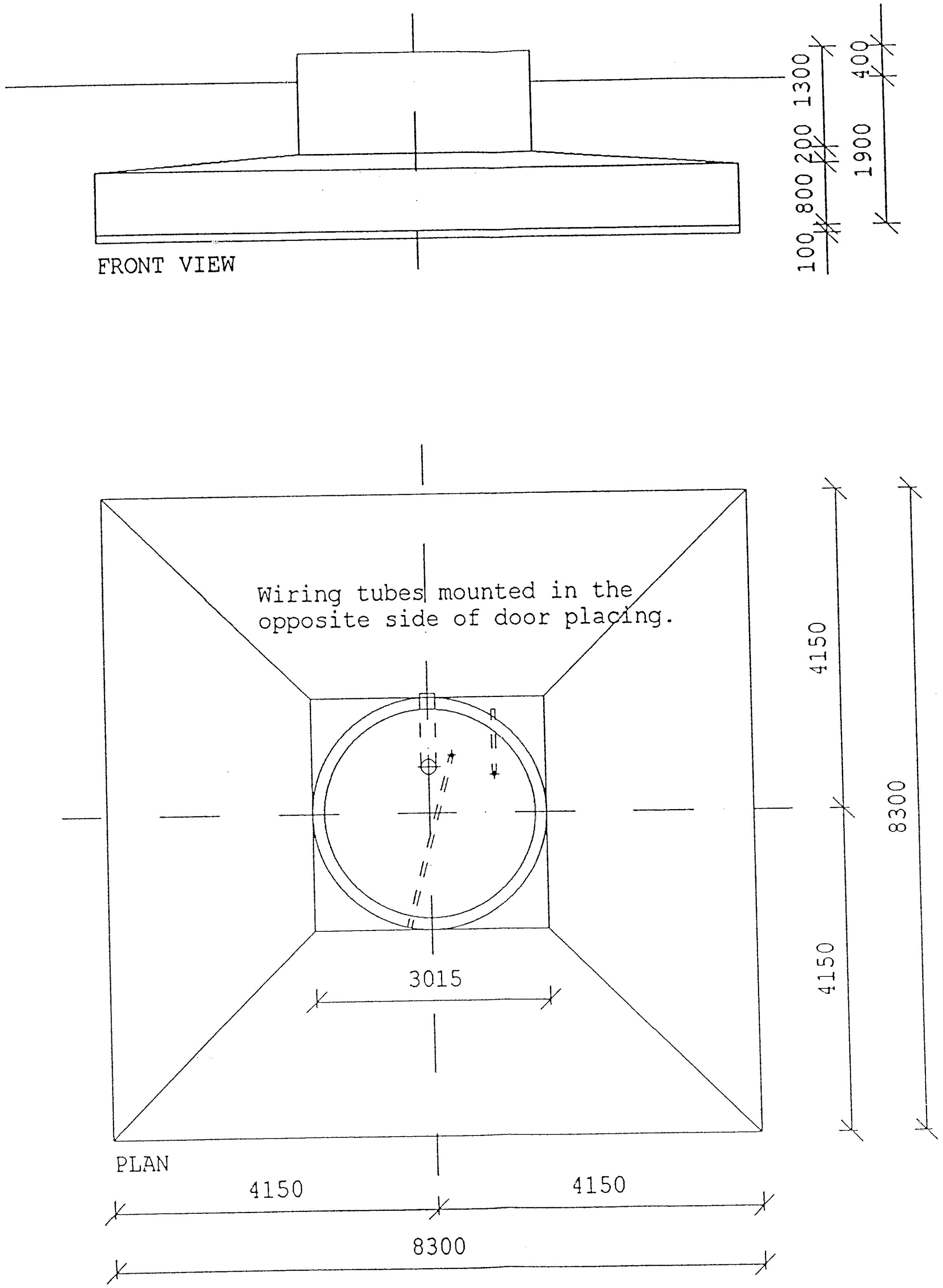
Drawings:

Description for carrying out the foundation:



SOIL

The soil, on which the foundation is placed, must fulfill the following conditions.

Foundation upon sand	:	φ	$\geq$ 30°
Foundation upon clay	:	Cv	$\geq$ 80 kN/m²
Effective density of filling soil	:	γ	$\geq$ 16 kN/m³
Dynamic bearing capacity	:	Es, dyn	$\geq$ 75000 kN/m²

Highest ground water level is presumed to be below foundation.
Soil survey has to be done, to secure the bearing capacity and effective density.

LOADS

The foundation is calculated for the following extreme loads, stated by VESTAS.

Nd	=	553 kN	(Normal load)
Vd	=	252 kN	(Transverse force)
Md	=	8685 kNm	(Bending moment)
Mvd	=	515 kNm	(Twisting moment)

In the mensioned loads following safeties are included :
1,0 on dead load
1,3 on wind load
Calculation for fatigue load.

SPECIFICATIONS

For the carrying out, the following is current.

Concrete structures	:	DS 411
Foundation	:	DS 415
Basisbetonbeskrivelsen	:	BBB

REMARKS

All dimensions are in mm.
Concerning further demands and conditions, for the carrying out of foundation, see detail drawings and specifications.

Sag
VESTAS WIND SYSTEMS A/S
SMED HANSENS VEJ 27, 6940 LEM

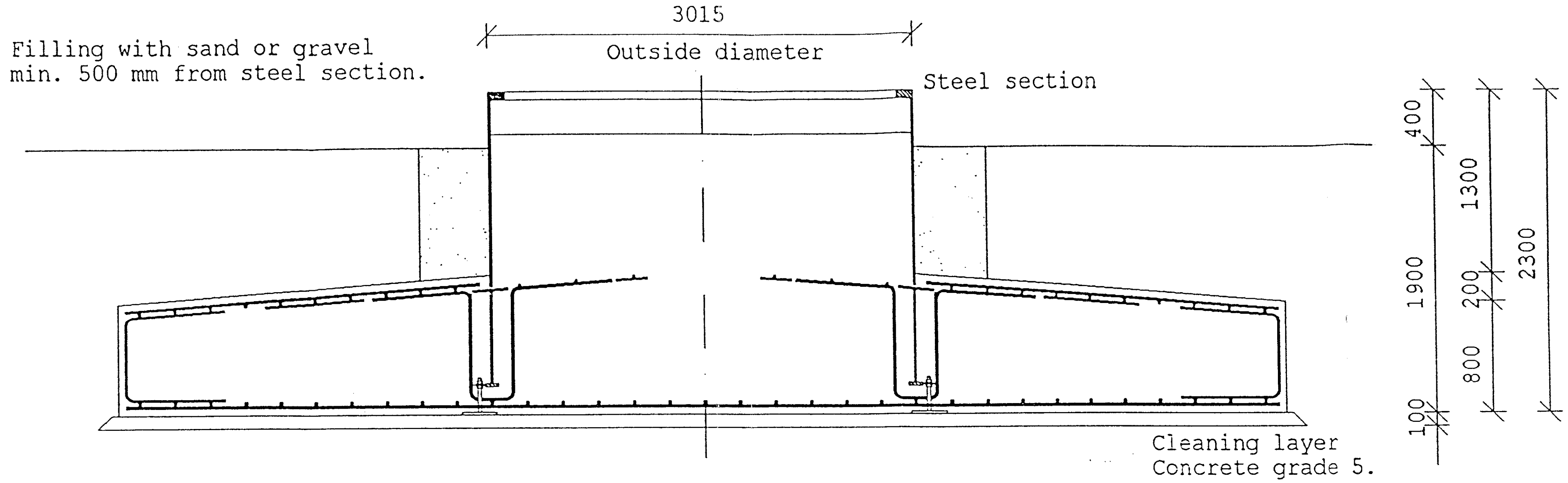
Sag nr. 009-97

Emne
FOUNDATION FOR VESTAS V47 - 38,7 m. MODULE TOWERS
VIEW PLAN - GWL BELOW FOUNDATION

Tegn.nr. V47.10.E
Mål 1:75
Dato 97.09.01.
Rev. 97.10.22

THISTED ApS
Rådgivende Ingeniørfirma
Hvidballegaard, Virringvej 69, Virring,
8660 Skanderborg, Tlf. 86 92 64 88

Sign. JN/sm



FOUNDATION SECTION

The steel section is delivered by VESTAS.
Regulation screws, bracings, wiring tubes, etc. are mounted at delivery.
The steel section is set upon the cleaning layer, after laying out the bottom reinforcement net.
The section is adjusted to accurate level, vertical as well as horizontal, by use of the 3 regulation screws, after which the counter nuts are tightened.

The steel section is delivered with surface treatment.
The section may not touch the reinforcement, neither in top nor in bottom of the foundation plate.

During casting, which must be done simultaneously both inside and outside the steel section, great accuracy must be shown, to secure that it doesn't displace.
Max. vertical deviation, after concreting, may be ±4 mm.

For further information, see specification.

REINFORCEMENT

Y = rib bar Ks 550 (fyk ≥ 550 N/mm²).

CONCRETE

The concrete must be composed, mixed and prepared according to "Basisbetonbeskrivelsen (BBB)".
Following defines the types of concrete:

Environment class	Moderate
Strenght class	30 MPa
Control class	Normal
Max. gravel size	32 mm
Water/cement	0,55

Covering concrete layer against form work = 50 mm.
Covering concrete layer against soil = 100 mm.
Concrete control according to "Dansk Ingeniørforenings Code" DS 411.

REMARKS

All dimension are in mm.

Sag: VESTAS WIND SYSTEMS A/S SMED HANSENS VEJ 27, 6940 LEM	Sag nr.: 009-97
Emne: FOUNDATION FOR VESTAS V47 - 38,7 m. MODULE TOWERS VERTICAL SECTION - GWL BELOW FOUNDATION	Tegn.nr.: V47.11.E Mål: 1:40
THISTED ApS Rådgivende Ingeniørfirma Hvidballegaard, Virringvej 69, Virring, 8660 Skanderborg, Tlf. 86 92 64 88	Dato: 97.09.01. Rev.: 97.10.22.
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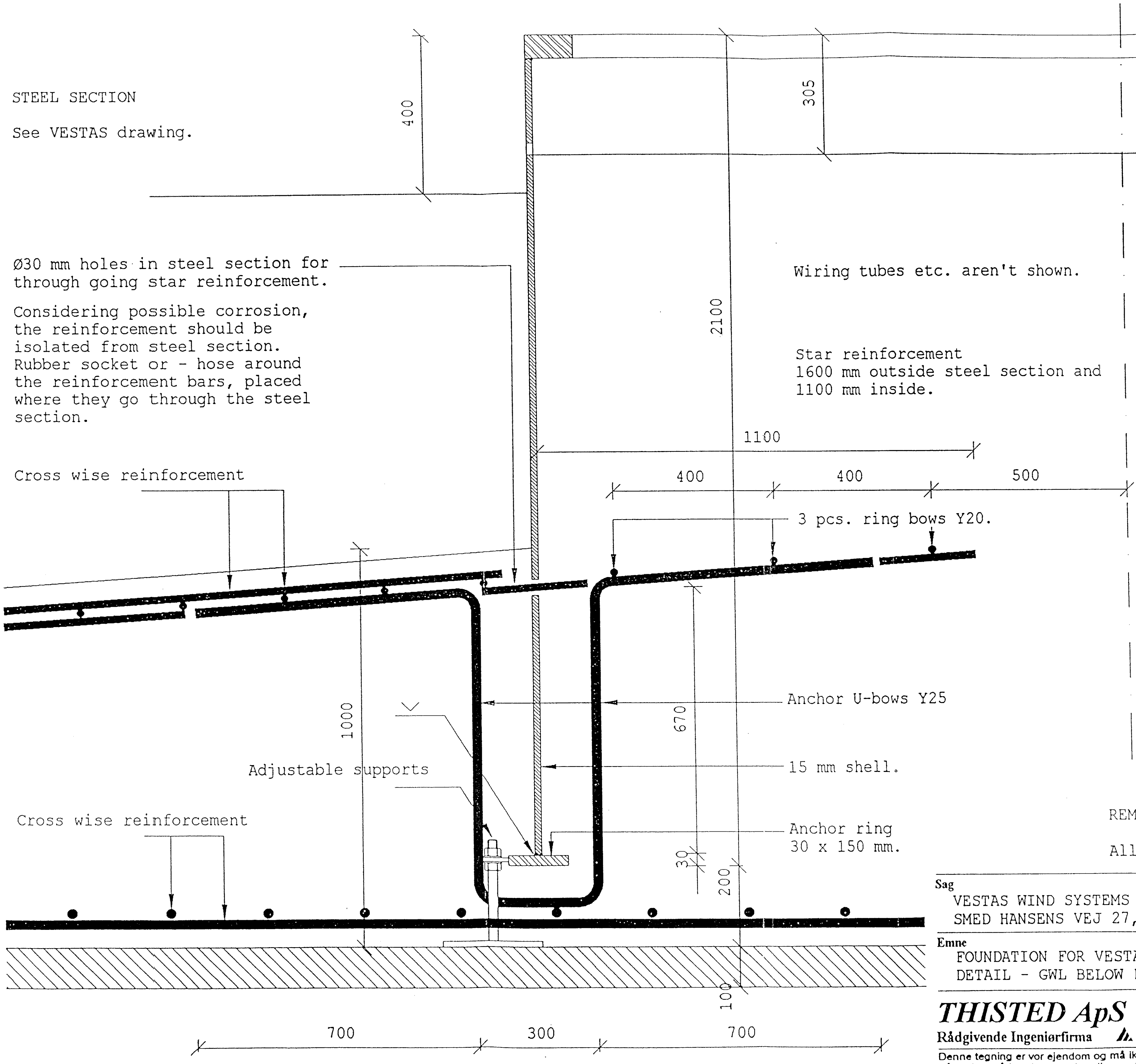
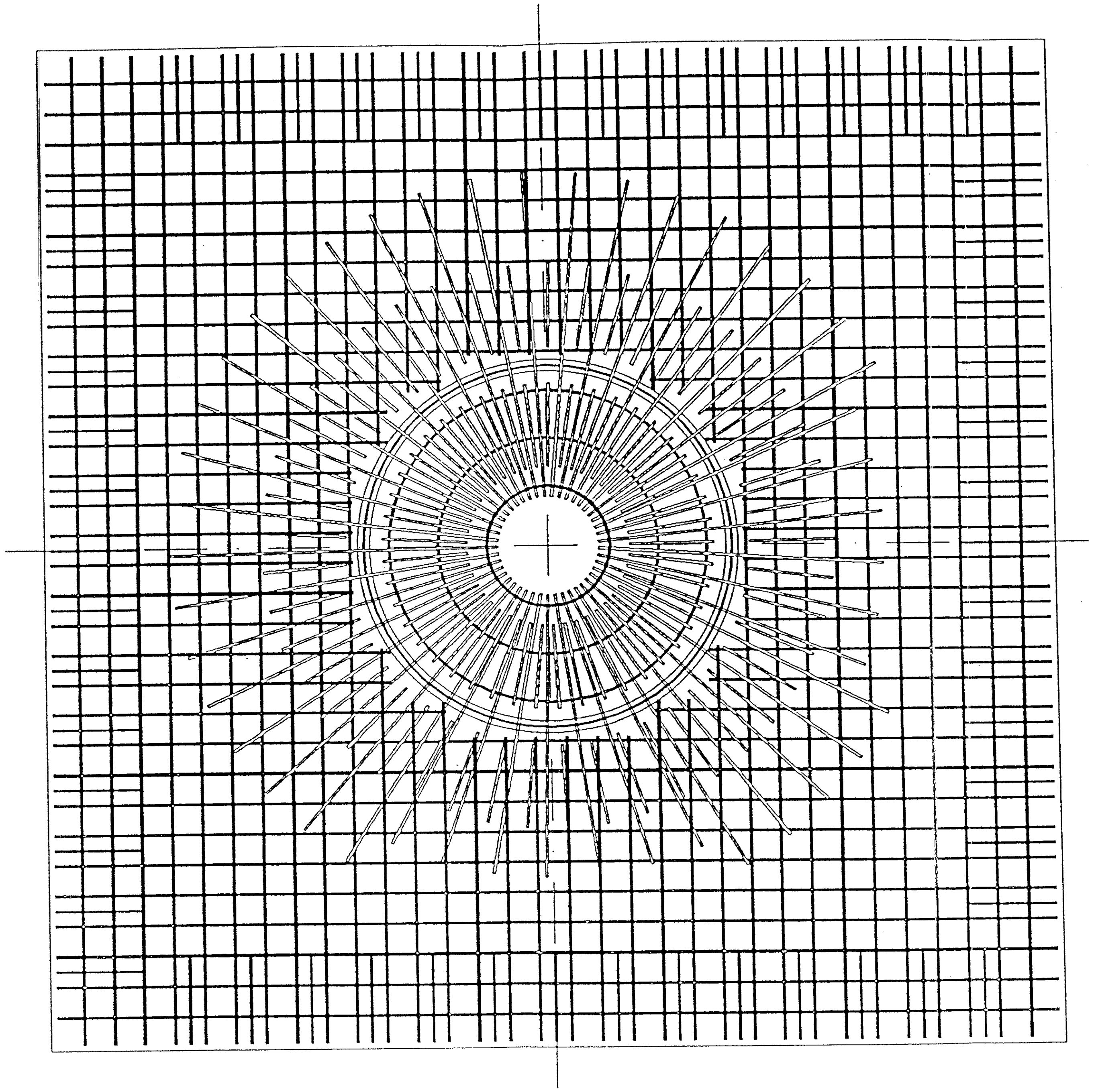


REMARKS

All dimensions are in mm.

Sag VESTAS WIND SYSTEMS A/S SMED HANSENS VEJ 27, 6940 LEM	Sag nr. 009-97
Emne FOUNDATION FOR VESTAS V47 - 38,7 m. MODULE TOWERS DETAIL - GWL BELOW FOUNDATION	Tegn.nr. V47.12.E Mål 1:10 Dato 97.09.01. Rev. 97.10.22.
THISTED ApS Rådgivende Ingeniørfirma Hvidballegaard, Virringvej 69, Virring, 8660 Skanderborg, Tlf. 86 92 64 88	
	Sign. JN/sm



TOP REINFORCEMENT

3015

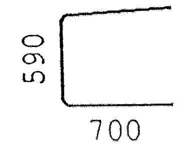
8300

TOP REINFORCEMENT

Cross wise reinforcement - 40 pcs. Y20/250 mm - L = 8200 mm.

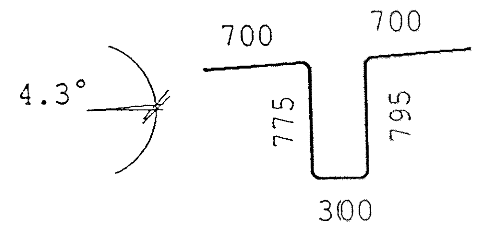
The reinforcement bars opposite the steel section
24 pcs. Y20/250 mm - L = 2500 mm
16 pcs. Y20/250 mm - L = 2800 mm
8 pcs. Y20/250 mm - L = 3250 mm

Edge bows Y20/500 mm 52 pcs.

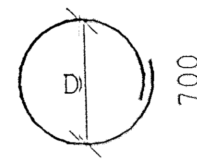


Star reinforcement through holes in steel section -
45 pcs. Y20 - L = 2700 mm.
1600 mm outside steel section and 1100 mm inside.

45 pcs. Y25 anchor U-bows, placed as shown
in drawing V47.12.E.



3 pcs. Y20 ring bows - in steel section.
D = 1000, 1800 and 2600 mm.
All dimensions are at centre lines.
Min. bending diameter is D = 6xd.



Supports for top reinforcement in the necessary amount.

REMARKS

All dimensions are in mm.
The reinforcement is tied up in every second cross.

Steel section, with through going reinforcement, is rotated,
to place the tower door in right direction.

Sag: VESTAS WIND SYSTEMS A/S SMED HANSENS VEJ 27, 6940 LEM	Sag nr.: 009-97
Emne: FOUNDATION FOR VESTAS V47 - 38,7 m. MODULE TOWERS HORIZONTAL SECTION - GWL BELOW FOUNDATION	Tegn.nr.: V47.13.E Mål: 1:50
THISTED ApS Hvidballegaard, Virringvej 69, Virring, Rådgivende Ingeniørfirma 8660 Skanderborg, Tlf. 86 92 64 88	Dato: 97.09.01. Rev.: 97.10.22.
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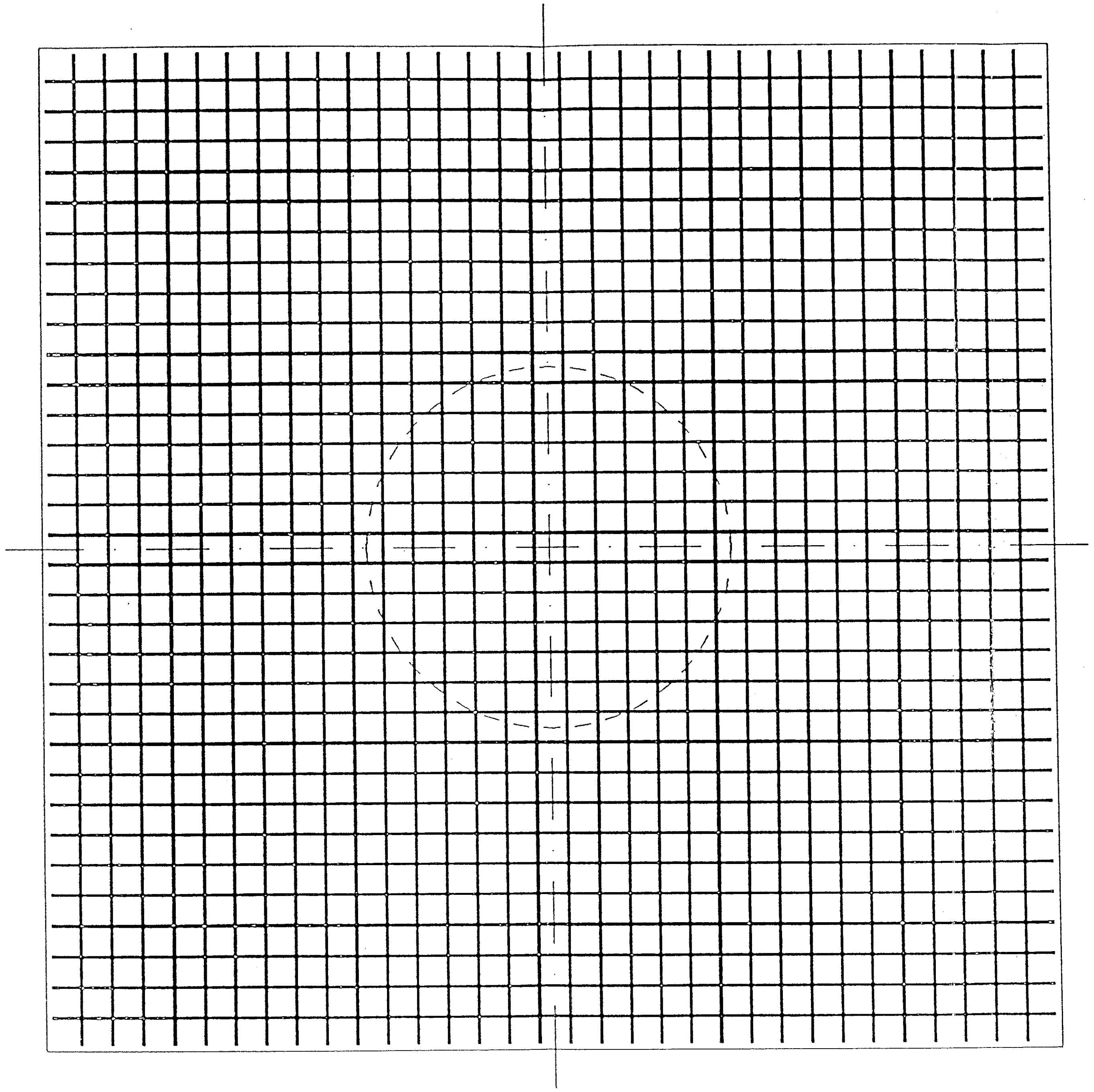

BOTTOM REINFORCEMENT

8300

BOTTOM REINFORCEMENT

Cross wise reinforcement - 64 pcs. Y25/250 mm - L = 8200 mm.

Supports for top reinforcement in the necessary amount.

REMARKS

All dimensions are in mm.
The reinforcement is tied up in every second cross.

Steel section, with through going reinforcement, is rotated, to place the tower door in right direction.

Sag VESTAS WIND SYSTEMS A/S SMED HANSENS VEJ 27, 6940 LEM	Sag nr. 009-97
Emne FOUNDATION FOR VESTAS V47 - 38,7 m. MODULE TOWERS HORIZONTAL SECTION - GWL BELOW FOUNDATION	Tegn.nr. V47.14.E Mål 1:50
THISTED ApS Hvidballegaard, Virringvej 69, Virring, Rådgivende Ingeniørfirma 8660 Skanderborg, Tlf. 86 92 64 88	Dato 97.09.01. Rev. 97.10.22.
	Sign. JN/sm

Sag 97.069
Dato 97.09.01

OLE THISTED
Rådg. IngeniørfirmaApS FRI

STANDARD FOUNDATION WITH STEEL SECTION FOR VESTAS V47-660/220 AND V47-660.

Introduction

The foundation, shown in the drawings and like wise described in the specification, is a standard foundation.

The project is carried out on a presuming basis, concerning the conditions of the soil.

To make use of the foundation in a current site, it is very important to fulfill the conditions, which are shown in the project. Soil survey must be carried out, as well as supervision and control is done, as described in the following.

If the conditions are not fulfilled in all respect, the foundation can not be used. A special foundation, based on the current conditions, has to be carried out.

Quality control

Quality control according to § 4.2 in the regulations from the construction administration dated 12. november 1986 , dealing with quality control on construction.

To ensure fulfillment and dokumentation of the project demands, the contractor has to organize his control program, to fulfill the specifications concerning the carrying out.

The contractor has to work out a satisfactory control program according to the demands.

The control program has to describe quality demands, accept criteria, places of control, methodes of control, extent of control, the responsible and dokumentation as described in the following individual paragraphs.

The contractor has to keep journals og control and matching dokumentation for at least 5 years.

The contractor and his colleagues have to participate in going through the project before the beginning of the work.

Generally

The foundation has to be carried out according to the drawings and this specification.

The foundation is carried out according to Dansk Ingeniørforening's codes.

Ordinary conditions corcerning work and deliverances (AB 92).
Concrete structures - DS 411.
Foundation - DS 415.
Basisbetonbeskrivelsen BBB.

From VESTAS is delivered the steel section with stiffenings, regulation scews and wiring tubes mounted as shown on the drawing.

The siting of the turbine (level and deposit point) is presumed to be selected by the owner.

Soil survey has to be done, to ensure that the demands put to the soil on location, are fulfilled.

The soil survey has to be sent to the consulting engineer, for control and additional calculation of the standard foundation, for the current soil conditions.

Excavation

Excavation to the depth shown on the drawing has to be done. The bottom of the excavation is levelled and carefully cleaned for loose parts.

If the ground water level is high, water in the excavation during the work must be expected. The necessary arrangements such as pumping to drain off the water has to be carried out, to ensure that the work can be done in a dry excavation.

The excavation has to be done without rooting up the bottom, and without using heavy machinery on the finished excavation level.

If poor conditions or water break through is detected any where in the excavations, the digging <u>must</u> stop immidiately. Consult supervision before continuation.

Too deep an excavation is compensated with filling of sand og concrete decided by superviser.

Considering the danger of softening the bottom through a longer time of inundation, the work in the excavation is started immediately after the last of soil in the excavation is removed.

An effective draining is started.

Bottom of excavation is compacted, and a cleaning layer of minimum 100 mm concrete is layed out.

Presuming that the soil is in such condition, that formwork to the sides of the foundation is dispensable, it is allowed to cast the sides directly against soil, on condition that the covering concrete layer is increased to a minimum of a 100 mm.

Steel section and plate reinforcement

The reinforcement bars is delivered by the producer or importer, who holds certifying licence and every deliverance must be clearly signed according to DS.

The reinforcement control, which is subjected to DS-licence arrangement, <u>must</u> include acceptance check, which means inspection (apperance, signing, condition) and control of delivery note.

The reinforcement bars, which are delivered bended, <u>must</u> be accompanied by a delivery note holding information about type of reinforcement and manufacturing works.

Measuring control of bended reinforcement bars is done at the supplier previously, arranged between supplier and contractor, possibly as a spot test control according to DS 1051.
Control results <u>must,</u> if requested, be shown to the superviser.

The contractor must check by delivery, that type and dimension of reinforcement bars are correct.

This dokumentation, delivery notes etc. must be included in control journal.

Binding wire must be anneal wire with diameter larger than or similar to 1,5 mm.

The work begins with setting the bottom reinforcement in the right dimensions. The reinforcement layer is set and blocked up 50 mm above the cleaning layer.

After that the delivered steel section is to be placed upon the cleaning layer, which has been hardened.

The top of the steel section <u>must</u> be completely horizontal, and this is done by adjusting the 3 regulation screws. The work must be carried out very carefully, so that there is no risk, that the tower is standing unbalanced after the assembling.

Please note, that the contractor is responsible, that the top of the steel section does not deviate more than 4 mm from horizontal level, and that the circular shape is preserved.

Then the Z-bows is led under the steel section, from both the outside and inside.

The star reinforcement is to be led through holes in steel section, and ring bows are mounted inside the pedestal.

The top reinforcement can now be set, with Z-bows, star reinforcement and edge bows as support.

Supports, which make space during the reinforcement- and casting works, are placed as necessary.

All reinforcement must be tied up in every second intersetion.

Considering a possible corrosion of the steel section and reinforcement, the reinforcement <u>must</u> be keept isolated from steel section.

The reinforcement work <u>must</u> be supervised before casting.

Supervision of the reinforcement must include control of right type of reinforcement, dimension and amount. Check that the reinforcement bars are bended, set and corretcly held, and that the covering layer on the reinforcement is fulfilling the demands been made.

Concrete

The concrete must be composed according to the demands stated on the drawings.
The concrete must besides that, be composed, mixed and prepared according to Dansk Ingeniørforening's Code, DS 411 - Concrete structures, and
what is written in "Basisbetonbeskrivelsen BBB".

Control journals, according to DS 411, must be prepared.
When factory concrete is used, the control of the concrete

composition can possibly be based on the results from the factory quality control, If this is organized and done according to DS-principals and if the factory is connected to a recognized control arrangement.

Casting

Casting must be done in **one work operation**, and there may be **no construction joints.**

Control journals are prepared.

The formwork must be supervised before every casting, and occasionally conctrol of casting as well as hardening and after-care is done.

Control journals must give information about:

Temperature of concrete and air, concerning winter casting.

The differences of temperature in the concrete.

The time for starting and finishing the different sequences of the castings and possible interruptions during casting.

Time of formwork removal.

Inspection of the hardening concrete.

Great care must be shown during casting. Exceptional great care must shown by casting inside the steel section, to ensure that it does not deviate, but stays in centre of the plate and with horizontal top.
The reinforcement and the steel section must be absolutely clean before casting. Make sure, at casting, that the reinforcement is covered by concrete, as shown on the drawings.

The top of the concrete in steel section must be finished with a slope from centre against drainholes, to ensure that there is no concrete above this level. This, out of consideration to the bolted joint between steel section and tower.

The top is to be screeded with a board made of wood (no glazing).

At casting vibrator must be used, **and the concrete supply under the lowest flange/rolled ring must be complete, so that there is no cushions at any place.**

Covering and insulation

Immediately after the casting, the free surfaces of concrete have to be covered with insulating mats (Winter mats must be used both summer and winter).
Filling can profitably be used as cover, when the concrete has hardened (after 24 hours).

The concrete has to be insulated from both loss of heat and loss of moisture for at least 7 days and nights, summer as well as winter. If the modelling is done before the mentioned 7 days and nights, the soil covering must take place immediately after, and the part of foundation, which is visible, must be insulated form loss of heat and loss of moisture.

Filling

The steel section is protected on the top, on the external side. Before filling, make sure that the surface is intact. Possible damages are to be mended with paint delivered by VESTAS.

Filling around and over the foundation must take place before erecting the tower.

Soil, which is used for backfilling, must fulfill the demands to

effective density, which are mentioned in the project.
The possibility of using the excavated soil, is valued and agreed with the superviser.
If supply is necessary, it has to fulfill mentioned demands.

At a distance of 500 mm from the pedestal, the filling must be sand or gravel. This, to prevent corrosion of steel section because of possible aggressive soil.

Mounting of tower and start-up

Presuming that ordinairy Portland-cement is used for the concrete, full strength at normal conditions is achieved after 28 days and nights of hardening.
If rapid hardening Portland-cement is used, the corresponding time is 14 days and nights.

The wind turbine can be mounted and started-up, when the concrete has achieved enough strength.

Please note, that velocity of the strength development depends very much on temperature- and moisture conditions on location.
Normally the concrete has achieved 80% of the strength after half of the hardening time.

Maintenance

It is recommended, with suitable annual intervals, for instance in connection with maintenance of the tower, to inspect the surface of the steel section.
If corrosion attacks are discovered, a repair work of the surface <u>must</u> take place.

VESTAS WIND SYSTEMS A/S

STANDARD FOUNDATION FOR VESTAS V47-660/220 & V47-660

38,7 m. TOWER.

Ground water level below foundation.

Calculations

Virring 97.09.01

OLE THISTED

Sag nr. 97.069

Rådg. Ingeniørfirma ApS FRI Hvidballegaard, Virringvej 69, Virring, 8660 Skanderborg, Tlf. 86 92 64 88

Sag 97.069
Dato 97.09.01

OLE THISTED
Rådg. Ingeniørfirma ApS FRI

GENEREL VIEW

DESIGN LOADS ON TOP OF THE FOUNDATION

Vestas V47-660/220 and V47/660 - 38,7 m. TOWER

LOADS

The loads are stated by the windmill producer
for EXTREME WINDLOAD
FATIGUE LOAD

The loads are stated as shear forces in the center of the tower, on the top of the foundation (see sketch).
The system of co-ordinats is calculated rotating 360 degrees, for wind in arbitrary direc tion.

The loads includes partial coefficients according to DS 472:

gf = 1.30 on windloads
gf = 1.00 on dead loads

gf = 1.00 on fatigue loads

Fatigue loads:
Max. = mean + 1/2*width
Min. = mean - 1/2*width

FOUNDATION LOADS		EXTREME	FATIGUE LOADS AT n = 10^7			
			Mean	Width	Max.	Min.
Fx	(kN)	229	0	0	0	0
Fy	(kN)	107	75	42	96	54
Fz	(kN)	553	553	31	569	538
Mx	(kNm)	8590	3273	1977	4262	2285
My	(kNm)	1275	220	138	289	151
Mz	(kNm)	515	26	327	190	-138

FOUNDATION LOADS IN ARBITRARY DIRECTIONS

Nd	(kNm)	553	31	569	538
Vd	(kNm)	252	42	96	54
Md	(kNm)	8685	1982	4271	2289
Mdv	(kNm)	515	327	190	-138

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Sag 97.069
Dato 97.09.01

CALCULATION

SQUARE FOUNDATION WITH CIRCULAR PEDESTAL

Vestas V47-660/220 and V47/660 - 38,7 m. TOWER

Extrem load case - GWL below foundation

The assumptions are the given general data, given load data, given soil data and the chosen foundation geometry.

Soil pressure are calculated to compare with the bearing capacity of the ground. The internal forces are calculated in 4 lines through the pedestal, see sketch.

Codes:

Dansk Ingeniørforenings codes:

DS 409 Definitions of safety

DS 415 Foundation

GENERAL DATA

The construction class according to the codes

Safety class	(lav/normal/høj)	:	normal
Foundation class	(lempet/normal/skærpet)	:	normal

LOAD DATA

Design loads on top of foundation

Normal (dead load)	Nd	=	553	kN
Transverse (wind)	Vd	=	252	kN
Moment (wind)	Md	=	8685	kNm
Torsion (wind)	Mdv	=	515	kNm

Safety factors included in the above mentioned loads

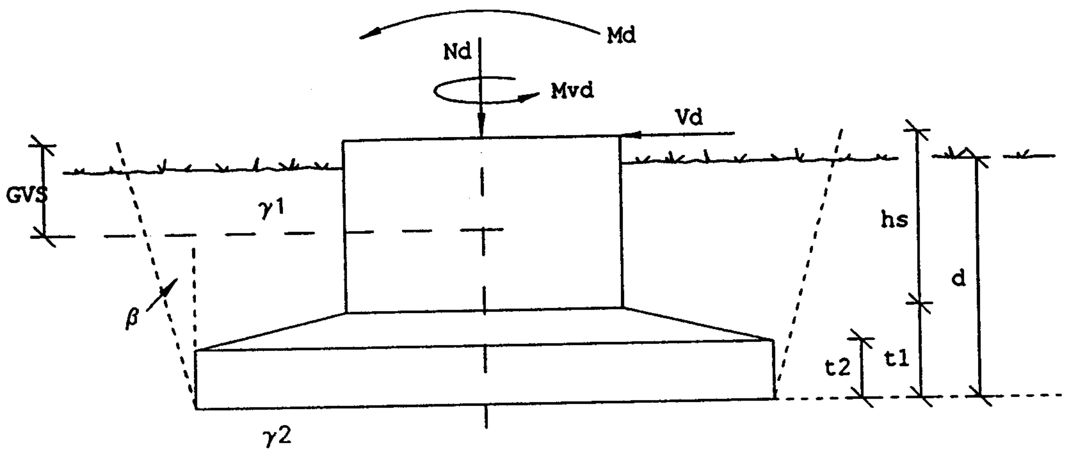
Permanent loads	gfg	=	1,00
Wind loads	gfp	=	1,30

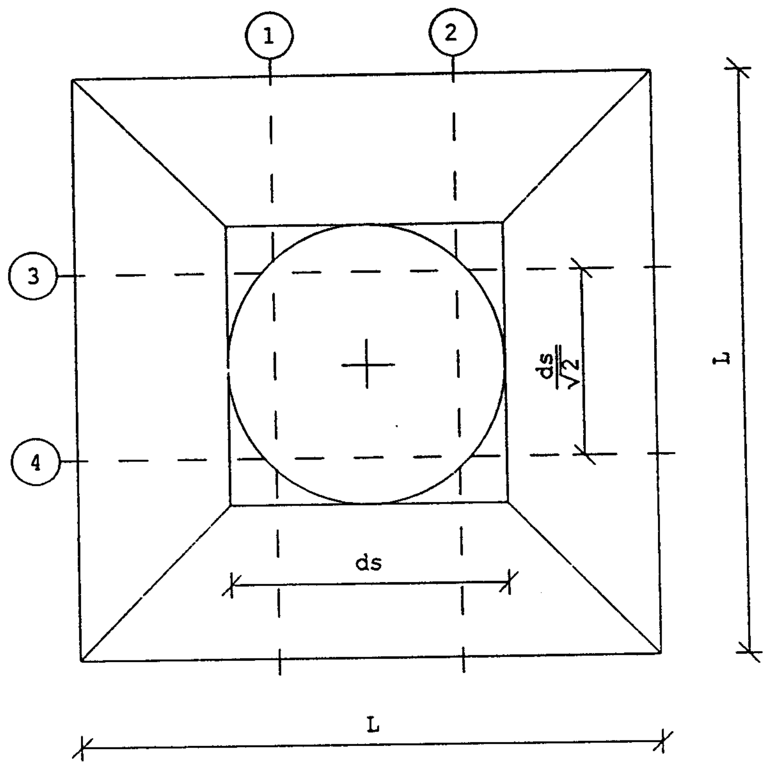
Loads working in all directions.

The foundation are calculated for loads in 2 directions - parrellel to the sides and 45 degrees to the sides.
All intermediate directions are assumed to be fulfillede by this.

Because there are no proportion between the loads and the ground pressure, an additional calculation is carried out with an increased loadfactor on the wind load.
Jordtryk og snitkræfter sammenholdes med materialestyrker med gm = 1,00

stability gfx = 1,50


Md
Nd
Mvd
Vd
GVS
γ1
hs
d
β
t2
t1
γ2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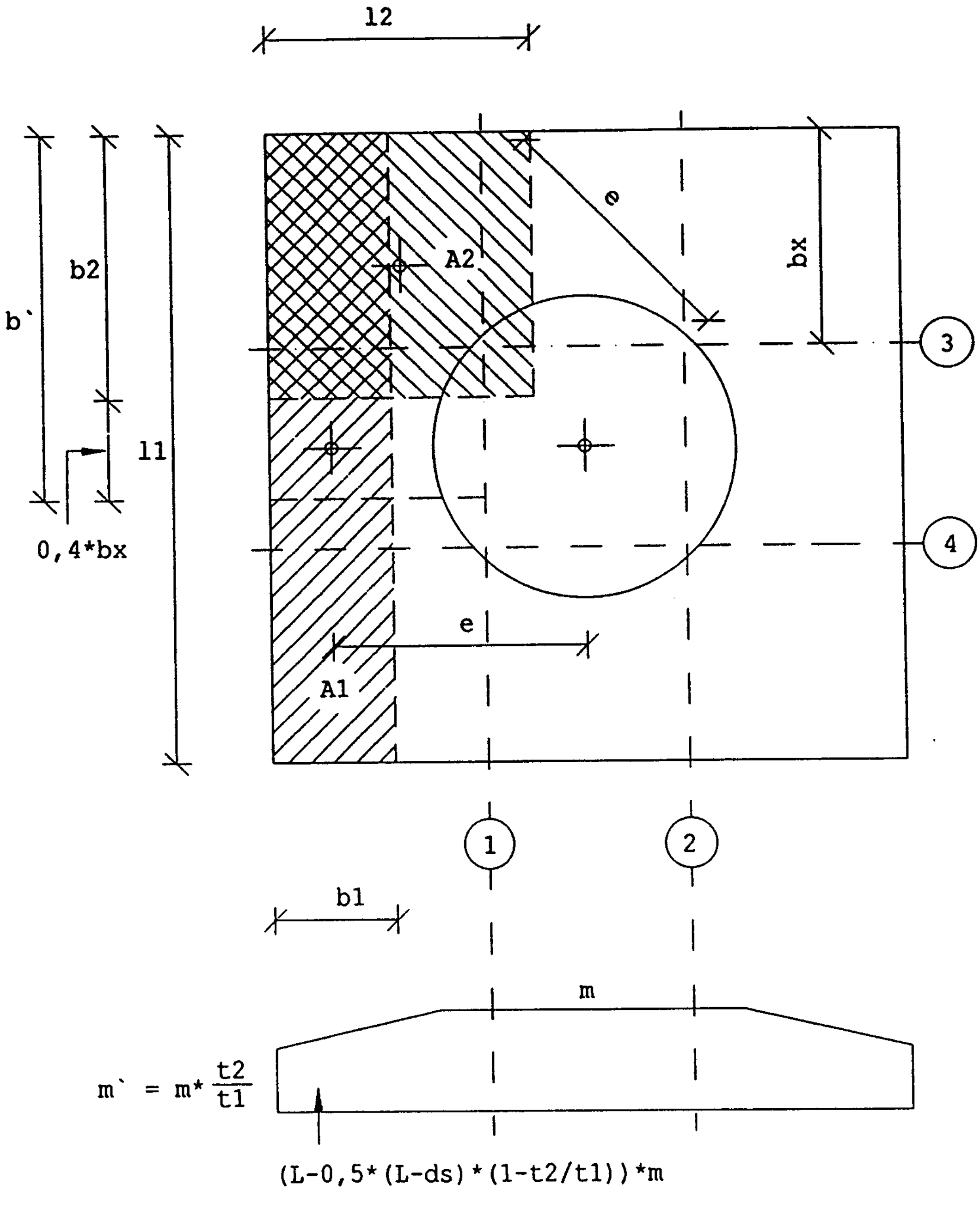
12
e
bx
b2
b`
A2
3
11
0,4*bx
4
e
A1
1
2
b1
m
m` = m* t2/t1
(L-0,5*(L-ds)*(1-t2/t1))*m

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Sag 97.069
Dato 97.09.01

SOIL DATA

Calculation for clay and or sand.

If both types of ground are given,
calculation for both.
Min. bearing capacity is basic for
the calculation of the foundation.

Sand or gravel:	Friction angle	fi=	30	deg
Clay:	Shearing strength	cu=	80	kN/m2

(0 states that the type is not given)

Densities:	Over foundation level	g1=	16	kN/m3
	Under foundation level	g2=	10	kN/m3
Ground water:	Depth under ground	Gvs=	1,90	m
	Ground dead load	beta=	0	deg

FOUNDATION DATA

Squre base of footing with one cirkular
pedestal (see sketch).

Plate	Length = with	L=	8,30	m
	Thickness at pedestal	t1=	1,00	m
	Thickness at edge	t2=	0,80	m
	Depth of foundatio	d=	1,90	m
Pedestal	Diameter	ds=	3,02	m
	Height of pedestal	hs=	1,30	m

Average thickness of plate) 0,900 m)

CALCULATION

Weight of foundation incl. buoyancy:

Plate	=	1487,5	kN
Pedestal	=	222,8	kN
Soil (incl. beta)	=	999,8	kN
Buoyancy (on concr	=	0,0	kN
G	=	2710,0	kN

Design factors at ground capacity (DS 415 - 5.2)

Tangens to frict.angle	gfi=	1,20
Cohesion at bear.cap.	gcl=	1,80

Design factors at ground material:

Sand and gravel	fid = atan(tan(fi)/gfi)	=	25,7	grader
	Ng	=	7,26	
	Nq	=	11,47	
Clay	cud = cu/gcl	=	44,4	kN/m2

FOUNDATION CALCULATION - SOIL PRESSURE/BEARING CAPACITY

The pressure is calculated equally spread over the effective part of the foundation plate, which is symmetric around the vertical load (see sketch).

Design pressure on the ground is compared with the design bearing capacities for 2 load cases in 2 directions.

If the vertical load has large eccentricity (e > 0.3*L) then the calculation is carried out for a soil break down under the foundation part without load.
Also calculation for sliding caused by horizontal loads. (Vd og Mvd).

* states that the ground type is not given or that e for the actual case is less than 0.3*L.

e = (Md + Vd*(hs+tl)) / (Nd+G) = Mdf / (Nd+G)
f = (Nd+G) / A

GROUND PRESSURE		GIVEN LOAD		STABILITY	
	Direction	Parallel	Cross	Parallel	Cross
Moment at ground level	Mdf (kNm)	9265	9265	10691	10691
Eccentricity	e (m)	2,84	2,84	3,28	3,28
	b (m)	2,62	4,28	1,75	3,67
Areas	A1 (m2)	21,76		14,50	
	A2 (m2)		18,36		13,44
Ground pressure	f (kN/m2)	150	178	225	243
BEARING CAPACITY					
Sand and gravel	ss(kN/m2)	376	424	565	668
Clay	sl(kN/m2)	256	281	430	488
	At large eccen. (e>0.3*L / e>0.3*L*sqrt(2))				
Sand and gravel	ss(kN/m2)	193	*	280	*
Clay	sl(kN/m2)	263	*	463	*
Min. bearing capacity	s (kN/m2)	193	281	280	488
		OK	OK	OK	OK

SLIDING	Safety control	Vd' = sqrt(Vd^2+(Mvd/e)^2)			
Sand and gravel					
(Nd+G)*tan(fid)/Vd'	=> 1	5,05	5,05	5,49	5,49
Clay A*cud/Vd'	=> 1	3,11	2,63	3,38	3,14
0.4*(Nd+G)/Vd'	=> 1	4,20	4,20	3,80	3,80
	Kontrol	OK	OK	OK	OK

INTERNAL FORCES IN PLATE

The internal forces are determined in the 4 lines through the pedestal edges, as shown on the sketch, and in the fourth part devided distances fra the edges.

Moments, transformed to tension in the base plate, are positive. Transverse loads are positive in the upper direction.

Dead load of the foundation is egually spread over the plate.

Dead load $g= 39,34$ kN/m²

If the plate surface is with a slope a equivalent, uniform thickness of the plate is calculated, to maintain an egual bearing capacity.
The thickness of the plate to use in calculation of the bearing capacity of the reinforced concrete is

Section at pedesta	tm0 =	936	mm
1/4*bx from pedest	tm1 =	926	mm
2/4*bx from pedest	tm2 =	895	mm
3/4*bx from pedest	tm3 =	853	mm

DESIGNED MOMENTS IN PLATE (kNm/m)

Top mo = -1/2*g*bx^2

Bottom mu = f*b*(bx-b/2) + mo for b<=bx
mu = f/2*bx^2 + mo for b> bx

Compared to DS 411 - 6.1.2. moments are spread over the width
b' = b+0.4*bx (max. b' = L)

Max. moments: kNm/m	GIVEN LOAD mu	GIVEN LOAD mo	STABILITY mu	STABILITY mo
Section at pedestal	510,1	-187,1	681,9	-187,1
1/4*bx from pedestal	296,0	-105,2	460,6	-105,2
2/4*bx from pedestal	138,0	-46,8	220,7	-46,8
3/4*bx from pedestal	37,6	-11,7	55,2	-11,7

DESIGNED TRANSVERSE LOADS IN PLATE (kN/m)

Downwards vo = -g*bx

Upwards vu = f*b + vo for b<=bx
vu = f*bx + vo for b> bx

Max. transverse loads kN/m	GIVEN LOAD vu	GIVEN LOAD vo	STABILITY vu	STABILITY vo
Section at pedestal	304,3	-121,3	438,8	-121,3
1/4*bx from pedestal	255,9	-91,0	357,3	-91,0
2/4*bx from pedestal	178,9	-60,7	286,2	-60,7
3/4*bx from pedestal	97,5	-30,3	143,1	-30,3

CALCULATION

SQUARE FOUNDATION WITH CIRCULAR PEDESTAL

Vestas V47-660/220 and V47/660 - 38,7 m. TOWER

Max. fatique load

The assumptions are the given general data, given fatique loads and the chosen foundation geometry

Soil pressure are calculated ot compare with the bearing capacity of the ground. The internal forces are calculated in 4 lines through the pedestal, see sketch.

Codes: Dansk Ingeniørforenings codes:

DS 409	Definitions of safety	(1982)
DS 415	Foundation	(1984)

DATA IN GENERAL — Th construction class according to the codes

Safety class	(lav/normal/høj)	:	normal
Foundation class	(lempet/normal/skærpet)	:	normal

LOAD DATA — Designed loads on top of foundation

Normal (dead load)	Nd =	569	kN
Transverse (wind)	Vd =	96	kN
Moment (wind)	Md =	4271	kNm
Torsion (win	Mdv =	190	kNm

Safety factors included in the above mentioned loads

Permanent loads	gfg=	1,00
Wind loads	gfp=	1,00

Loads working in all directions

The foundation are calculated for loads in 2 directions - parallel to the sides and 45 degrees to the sides. All intermediate directions are assumed to be fulfilled by this.

Because there are no proportion between the loads and the ground pressure, an additional calculation is carried out with an increased loadfactor on the wind load. Jordtryk og snitkræfter sammenholdes med materialestyrker med gm = 1,00

stability gfx = 1,00

SOIL DATA	Calculation for clay and or sand.			
	If both types of ground are given, calculation for both. Min. bearing capacity is basic for the calculation of the foundation.			
Sand or gravel:	Friction angle	fi=	30	grader
Clay:	Shearing strength	cu=	80	kN/m2
	(0 states that the type is not given)			
Densities:	Over foundation level	g1=	16	kN/m3
	Under foundation level	g2=	10	kN/m3
Ground water:	Depth under ground	Gvs=	1,90	m
	Ground dead load	beta=	0	grader
FOUNDATION DATA	Squre base of footing with one cirkular pedestal (see sketch).			
Plate	Length = with	L=	8,30	m
	Thickness at pedestal	t1=	1,00	m
	Thickness at edge	t2=	0,80	m
	Depth of foundatio	d=	1,90	m
Pedestal	Diameter	ds=	3,02	m
	Height of pedestal	hs=	1,30	m
	Average thickness of plate) overflade.	tm=	0,900	m)
CALCULATION	Weigth of foundation incl. buoyancy:			
	Plate	=	1487,5	kN
	Pedestal	=	222,8	kN
	Soil (incl obelisk	=	999,8	kN
	Buoyancy (on concr	=	0,0	kN
	G	=	2710,0	kN

Design factors at ground capacity (DS 415 - 5.2)

Tangens to fricti	gfi=	1,20
Cohesion at bearing capacity		1,80

Design factors at ground material:

Sand and gravel	φd = atan(tan(fi)/		=	25,7	grader
		Ng	=	7,26	
		Nq	=	11,47	
Clay	cud = cu/gcl		=	44,4	kN/m2

FOUNDATION CALCULATION - SOIL PRESSURE/BEARING CAPACITY

The pressure is calculated equally spread over the effective part of the foundation plate, which is symmetric around the vertical load (see sketch).

Design pressure on the ground is compared with the design bearing capacities for 2 load cases in 2 directions.

If the vertical load has large eccentricity (e > 0.3*L) then the calculation is carried out for a soil break down under the foundation part without load.
Also calculation for sliding caused by horizontal loads. (Vd og Mvd).

* states that the ground type is not given or that e for the actual case is less than 0.3*L.

e = (Md + Vd*(hs+t1)) / (Nd+G) = Mdf / (Nd+G)
f = (Nd+G) / A

GROUND PRESSURE		GIVEN LOAD		STABILITY	
	Direction	Parallel	Cross	Parallel	Cross
Moment at ground level	Mdf (kNm)	4492	4492	4492	4492
Eccentricity	e (m)	1,37	1,37	1,37	1,37
	b (m)	5,56	6,36	5,56	6,36
Areas	A1 (m2)	46,15		46,15	
	A2 (m2)		40,48		40,48
Ground pressure	f (kN/m2)	71	81	71	81
BEARING CAPACITY	ved direkte fundering				
Sand and gravel	ss(kN/m2)	504	517	864	882
Clay	sl(kN/m2)	286	301	494	520
	At large eccen. (e>0.3*L / e>0.3*L*sqrt(2))				
Sand and gravel	ss(kN/m2)	*	*	*	*
Clay	sl(kN/m2)	*	*	*	*
Min. bearing capacity	s (kN/m2)	286	301	494	520
		OK	OK	OK	OK
SLIDING	Safety control	Vd' = sqrt(Vd^2+(Mvd/e)^2)			
Sand and gravel					
(Nd+G)*tan(fid)/Vd'	=> 1	9,37	9,37	11,24	11,24
Clay A*cud/Vd'	=> 1	12,18	10,69	21,93	19,23
0.4*(Nd+G)/Vd'	=> 1	7,79	7,79	7,79	7,79
	Kontrol	OK	OK	OK	OK

INTERNAL FORCES IN PLATE

The internal forces are determined in the 4 lines through the pedestal edges, as shown on the sketch, and in the fourth part devided distances fra the edges.

Moments, transformed to tension in the base plate, are positive. Transverse loads are positive in the upper direction.

Dead load of the foundation is egually spread over the plate.

Dead load g= 39,34 kN/m2

If the plate surface is with a slope a equivalent, uniform thickness of the plate is calculated, to maintain an egual bearing capacity.
The thickness of the plate to use in calculation of the bearing capacity of the reinforced concrete is

Section at pedesta	tm0 =	936	mm
1/4*bx from pedest	tm1 =	926	mm
2/4*bx from pedest	tm2 =	895	mm
3/4*bx from pedest	tm3 =	853	mm

DESIGNED MOMENTS IN PLATE (kNm/m)

Top mo = -1/2*g*bx^2

Bottom mu = f*b*(bx-b/2) + mo for b<=bx
mu = f/2*bx^2 + mo for b> bx

Compared to DS 411 - 6.1.2. moments are spread over the width
b' = b+0.4*bx (max. b' = L)

Max. moments: kNm/m	GIVEN LOAD mu	GIVEN LOAD mo	STABILITY mu	STABILITY mo
Section at pedestal	150,8	-187,1	150,8	-187,1
1/4*bx from pedestal	84,8	-105,2	84,8	-105,2
2/4*bx from pedestal	41,0	-46,8	41,0	-46,8
3/4*bx from pedestal	11,3	-11,7	11,3	-11,7

DESIGNED TRANSVERSE LOADS IN PLATE (kN/m)

Downwards vo = -g*bx

Upwards vu = f*b + vo for b<=bx
vu = f*bx + vo for b> bx

Max. transverse loads kN/m	GIVEN LOAD vu	GIVEN LOAD vo	STABILITY vu	STABILITY vo
Section at pedestal	97,8	-121,3	97,8	-121,3
1/4*bx from pedestal	73,3	-91,0	73,3	-91,0
2/4*bx from pedestal	53,2	-60,7	53,2	-60,7
3/4*bx from pedestal	29,2	-30,3	29,2	-30,3

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CALCULATION **SQUARE FOUNDATION WITH CIRCULAR PEDESTAL**

Vestas V47-660/220 and V47/660 - 38,7 m. TOWER

Min. fatique load

The assumptions are the given general data, given fatique loads and the chosen foundation geometry

Soil pressure are calculated ot compare with the bearing capacity of the ground. The internal forces are calculated in 4 lines through the pedestal, see sketch.

Codes: Dansk Ingeniørforenings codes:

DS 409	Definitions of safety	(1982)
DS 415	Foundation	(1984)

DATA IN GENERAL Th construction class according to the codes

Safety class	(lav/normal/høj)	:	normal
Foundation class	(lempet/normal/skærpet)	:	normal

LOAD DATA Designed loads on top of foundation

Normal (dead load)	Nd =	538	kN
Transverse (wind)	Vd =	54	kN
Moment (wind)	Md =	2289	kNm
Torsion (win	Mdv =	138	kNm

Safety factors included in the above mentioned loads

Permanent loads	gfg=	1,00
Wind loads	gfp=	1,00

Loads working in all directions

The foundation are calculated for loads in 2 directions - parallel to the sides and 45 degrees to the sides.
All intermediate directions are assumed to be fulfilled by this.

Because there are no proportion between the loads and the ground pressure, an additional calculation is carried out with an increased loadfactor on the wind load.
Jordtryk og snitkræfter sammenholdes med materialestyrker med gm = 1,00

stability gfx = 1,00

SOIL DATA	Calculation for clay and or sand.			
	If both types of ground are given, calculation for both. Min. bearing capacity is basic for the calculation of the foundation.			
Sand or gravel:	Friction angle	fi=	30	grader
Clay:	Shearing strength	cu=	80	kN/m2
	(0 states that the type is n			
Densities:	Over foundation level	g1=	16	kN/m3
	Under foundation level	g2=	10	kN/m3
Ground water:	Depth under ground	Gvs=	1,90	m
	Ground dead load	beta=	0	grader
FOUNDATION DATA	Squre base of footing with one cirkular pedestal (see sketch).			
Plate	Length = with	L=	8,30	m
	Thickness at pedestal	t1=	1,00	m
	Thickness at edge	t2=	0,80	m
	Depth of foundatio	d=	1,90	m
Pedestal	Diameter	ds=	3,02	m
	Height of pedestal	hs=	1,30	m
	Average thickness of plate) overflade.	tm=	0,900	m)
CALCULATION	Weigth of foundation incl. buoyancy:			
	Plate	=	1487,5	kN
	Pedestal	=	222,8	kN
	Soil (incl obelisk	=	999,8	kN
	Buoyancy (on concr	=	0,0	kN
	G	=	2710,0	kN

Design factors at ground capacity (DS 415 - 5.2)

Tangens to fricti	gfi=	1,20
Cohesion at bearing capacity		1,80

Design factors at ground material:

Sand and gravel	φd = atan(tan(fi)/		=	25,7	grader
		Ng	=	7,26	
		Nq	=	11,47	
Clay	cud = cu/gc1		=	44,4	kN/m2

FOUNDATION CALCULATION - SOIL PRESSURE/BEARING CAPACITY

The pressure is calculated equally spread over the effective part of the foundation plate, which is symmetric around the vertical load (see sketch).

Design pressure on the ground is compared with the design bearing capacities for 2 load cases in 2 directions.

If the vertical load has large eccentricity (e > 0.3*L) then the calculation is carried out for a soil break down under the foundation part without load.
Also calculation for sliding caused by horizontal loads.
(Vd og Mvd).

* states that the ground type is not given or that
  e for the actual case is less than 0.3*L.

e = (Md + Vd*(hs+t1)) / (Nd+G) = Mdf / (Nd+G)
f = (Nd+G) / A

GROUND PRESSURE		GIVEN LOAD		STABILITY	
	Direction	Parallel	Cross	Parallel	Cross
Moment at ground level	Mdf (kNm)	2414	2414	2414	2414
Eccentricity	e (m)	0,74	0,74	0,74	0,74
	b (m)	6,81	7,25	6,81	7,25
Areas	A1 (m2)	56,55		56,55	
	A2 (m2)		52,55		52,55
Ground pressure	f (kN/m2)	57	62	57	62

BEARING CAPACITY	ved direkte fundering				
Sand and gravel	ss(kN/m2)	548	552	945	949
Clay	sl(kN/m2)	295	303	508	522
	At large eccen. (e>0.3*L / e>0.3*L*sqrt(2))				
Sand and gravel	ss(kN/m2)	*	*	*	*
Clay	sl(kN/m2)	*	*	*	*
Min. bearing capacity	s (kN/m2)	295	303	508	522
		OK	OK	OK	OK

SLIDING	Safety control	Vd' = sqrt(Vd^2+(Mvd/e)^2)			
Sand and gravel					
(Nd+G)*tan(fid)/Vd'	=> 1	8,11	8,11	9,73	9,73
Clay A*cud/Vd'	=> 1	13,04	12,12	23,48	21,81
0.4*(Nd+G)/Vd'	=> 1	6,74	6,74	6,74	6,74
	Kontrol	OK	OK	OK	OK

INTERNAL FORCES IN PLATE

The internal forces are determined in the 4 lines through the pedestal edges, as shown on the sketch, and in the fourth part devided distances fra the edges.

Moments, transformed to tension in the base plate, are positive. Transverse loads are positive in the upper direction.

Dead load of the foundation is egually spread over the plate.

Dead load	g=	39,34	kN/m2

If the plate surface is with a slope a equivalent, uniform thickness of the plate is calculated, to maintain an egual bearing capacity.
The thickness of the plate to use in calculation of the bearing capacity of the reinforced concrete is

Section at pedesta	tm0 =	936	mm
1/4*bx from pedest	tm1 =	926	mm
2/4*bx from pedest	tm2 =	895	mm
3/4*bx from pedest	tm3 =	853	mm

DESIGNED MOMENTS IN PLATE (kNm/m)

Top mo = -1/2*g*bx^2

Bottom mu = f*b*(bx-b/2) + mo for b<=bx
mu = f/2*bx^2 + mo for b> bx

Compared to DS 411 - 6.1.2. moments are spread over the width
b' = b+0.4*bx (max. b' = L)

Max. moments: kNm/m	GIVEN LOAD		STABILITY	
	mu	mo	mu	mo
Section at pedestal	86,0	-187,1	86,0	-187,1
1/4*bx from pedestal	48,4	-105,2	48,4	-105,2
2/4*bx from pedestal	21,5	-46,8	21,5	-46,8
3/4*bx from pedestal	5,9	-11,7	5,9	-11,7

DESIGNED TRANSVERSE LOADS IN PLATE (kN/m)

Downwards vo = -g*bx

Upwards vu = f*b + vo for b<=bx
vu = f*bx + vo for b> bx

Max. transverse loads kN/m	GIVEN LOAD		STABILITY	
	vu	vo	vu	vo
Section at pedestal	55,8	-121,3	55,8	-121,3
1/4*bx from pedestal	41,8	-91,0	41,8	-91,0
2/4*bx from pedestal	27,9	-60,7	27,9	-60,7
3/4*bx from pedestal	15,4	-30,3	15,4	-30,3

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CALCULATION	SQUARE FOUNDATION - EXTREME LOAD				
	The internal forces are determined in 4 section				
PLATE DATA	Plate width	b=	1000	mm	
	Covering concrete	c=	50	mm	
	Concrete quality	fck=	30	N/mm2	
	Reinforcement qual	fyk=	550	N/mm2	
Safaty class	(lav/normal/høj)	:	normal		
Control class	(lempet/normal/skærpet)	:	normal		
Design	gc = 1,80	fcd =	16,7	N/mm2	
factors	gs = 1,40	fyd =	392,9	N/mm2	
CROSSING TOP	Diameter	do=	20	mm	
REINFORCEMENT	Spacing	ao=	250	mm	
	Computed area	Aso=	1257	mm²/m	
	(half reinforcement is presumed in section 2 an				
CROSSING BOTTOM	Diameter	du=	25	mm	
REINFORCEMENT	Spacing	au=	250	mm	
	Computed area	Asu=	1963	mm²/m	
	(half reinforcement is presumed in section 2 an				
Min. reinforcement	As min (< AsO og	=	1231	mm²/m	
			OK		

INTERNAL FORCES		Sect. 0	Sect. 1	Sect. 2	Sect. 3
Moments (kNm/m)	Top	187,1	105,2	46,8	11,7
	Bottom	510,1	296,0	138,0	37,6
Transverse(kN/m)	Top	121,3	91,0	60,7	30,3
	Bottom	304,3	255,9	178,9	97,5
Plate height	t (mm) =	936	926	895	853
	hefo =	866	856	825	783
	hefu =	861	851	820	778
				< 1/2 reinforcemen	
Bearing capacity	Mud o.s.	420,4	415,4	201,8	191,4
- method A		OK	OK	OK	OK
kNm/m				< 1/2 reinforcemen	
	Mud u.s.	646,6	638,8	311,8	295,6
		OK	OK	OK	OK
Transverse stress	to N/mm2	0,16	0,12	0,08	0,04
in plate	tu N/mm2	0,39	0,33	0,24	0,14
	0.7*ftd =	0,67	0,67	0,67	0,67
	---------	OK	OK	OK	OK

CALCULATION	SQUARE FOUNDATION - STABILITY				
	The internal forces are determined in 4 section				
PLATE DATA	Plate width	b=	1000	mm	
	Covering concrete	c=	50	mm	
			0		
	Concrete quality	fck=	30	N/mm2	
	Reinforcement qual	fyk=	550	N/mm2	
			0		
Safaty class	(lav/normal/høj)	:	normal		
Control class	(lempet/normal/skærpet)	:	normal		
Design factors	gc = 1,00	fcd =	30,0	N/mm2	
	gs = 1,00	fyd =	550,0	N/mm2	
CROSSING TOP REINFORCEMENT	Diameter	do=	20	mm	
	Spacing	ao=	250	mm	
	Computed area	Aso=	1257	mm²/m	
	(half reinforcement is presumed in section 2 an				
CROSSING BOTTOM REINFORCEMENT	Diameter	du=	25	mm	
	Spacing	au=	250	mm	
	Computed area	Asu=	1963	mm²/m	
	(half reinforcement is presumed in section 2 an				

INTERNAL FORCES		Sect. 0	Sect. 1	Sect. 2	Sect. 3
Moments (kNm/m)	Top	187,1	105,2	46,8	11,7
	Bottom	681,9	460,6	220,7	55,2
Transverse(kN/m)	Top	121,3	91,0	60,7	30,3
	Bottom	304,3	255,9	178,9	97,5
Plate height	t (mm) =	936	926	895	853
	hefo =	866	856	825	783
	hefu =	861	851	820	778
				< 1/2 reinforcemen	
Bearing capacity - method A kNm/m	Mud o.s.	590,8	583,9	283,1	268,6
		OK	OK	OK	OK
				< 1/2 reinforcemen	
	Mud u.s.	910,7	899,9	437,9	415,2
		OK	OK	OK	OK
Transverse stress in plate	to N/mm2	0,16	0,12	0,08	0,04
	tu N/mm2	0,39	0,33	0,24	0,14
	0.7*ftd =	1,21	1,21	1,21	1,21
	---------	OK	OK	OK	OK

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CALCULATION	SQUARE FOUNDATION - FATIQUE				
	The internal forces are determined in 4 section				
PLATE DATA	Plate width		b=	1000	mm
	Covering concrete		c=	50	mm
	Concrete quality		fck=	30	N/mm2
	Reinforcement qual		fyk=	550	N/mm2
Safaty class	(lav/normal/høj)		:	normal	
Control class	(lempet/normal/skærpet)		:	normal	
Design	gc =	1,80	fcd =	16,7	N/mm2
factors	gs =	1,40	fyd =	392,9	N/mm2
CROSSING TOP	Diameter	do=		20	mm
REINFORCEMENT	Spacing	ao=		250	mm
	Computed area	Aso=		1257	mm²/m
	(half reinforcement is presumed in section 2 an				
CROSSING BOTTOM	Diameter	du=		25	mm
REINFORCEMENT	Spacing	au=		250	mm
	Computed area	Asu=		1963	mm²/m
	(half reinforcement is presumed in section 2 an				

MAX.FATIQUE INTERNAL FORCES		Sect. 0	Sect. 1	Sect. 2	Sect. 3
				<1/2 reinforcem	
Moments (kNm/m)	Top	187,1	105,2	46,8	11,7
	Bottom	150,8	84,8	41,0	11,3
Transverse(kN/m)	Top	121,3	91,0	60,7	30,3
	Bottom	97,8	73,3	53,2	29,2

MIN. FATIQUE INTERNAL FORCES		Sect. 0	Sect. 1	Sect. 2	Sect. 3
				<1/2 reinforceme	
Moments (kNm/m)	Top	187,1	105,2	46,8	11,7
	Bottom	86,0	48,4	21,5	5,9
Transverse(kN/m)	Top	121,3	91,0	60,7	30,3
	Bottom	55,8	41,8	27,9	15,4

Plate height	t (mm) =	936	926	895	853
	hefo =	866	856	825	783
	hefu =	861	851	820	778

FATIQUE

Fatique control in the concrete according to Aas-Jakobsens formula:
log n = (1-smax/fcf)/0.0064/(1-smin/smax)

Fatique stress in the reinforcement according to DS 412-B.6.6.1 curve b:
fdfat = (k*10^12/10^7)^(1/m)/gsfat*f1
f1 = 1.00/1.10/1.15 for Fe360/Fe/430/Fe/510

BENDING STRESS
METHOD B

Section 0

		Max.	Min.	Stress width
Concrete stress	sco N/mm2	2,7	2,7	
	scu N/mm2	1,8	1,1	
	Frequency	No fatiqu	OK	
	log n => 7	376	OK	
Reinforcement stress	sso N/mm2	184,1	184,1	0,0
	ssu N/mm2	95,9	60,3	35,6
	fdfat =		OK	105,7

Section 1

		Max.	Min.	Stress width
Concrete stress	sco N/mm2	1,5	1,5	
	scu N/mm2	1,0	0,6	
	Frequency	No fatiqu	OK	
	log n => 7	341	OK	
	sso N/mm2	104,8	104,8	0,0
Reinforcement stress	ssu N/mm2	55,2	31,5	23,7
	fdfat =		OK	105,7

Section 2

		Max.	Min.	
Concrete stress	sco N/mm2	1,0	1,0	
	scu N/mm2	0,6	0,3	
	Frequency	No fatiqu	OK	
	log n => 7	316	OK	
				Stress width
Reinforcement stress	sso N/mm2	94,9	94,9	0,0
	ssu N/mm2	49,2	25,8	23,4
	fdfat =		OK	105,7

Section 3

		Max.	Min.	
Concrete stress	sco N/mm2	0,3	0,3	
	scu N/mm2	0,2	0,1	
	Frequency	No fatiqu	OK	
	log n => 7	325	OK	
				Stress width
Reinforcement stress	sso N/mm2	25,0	25,0	0,0
	ssu N/mm2	15,7	8,3	7,5
	fdfat =		OK	105,7

TRANSVERSE STRESS IN PLATE

Section 0

According to DS 411 - 6.2.2.1 the formal transv stress is t = Vd*1000/b/hef/0.9.

Condtion t <= 0.7*ftd

	Max.	Min.
to N/mm2	0,16	0,16
tu N/mm2	0,13	0,07
0.7*ftd =	0,67	0,67
		OK
Frequency	No fatiqu	OK
log n >= 7	296	OK

Section 1

Condtion t <= 0.7*ftd

	Max.	Min.
to N/mm2	0,12	0,12
tu N/mm2	0,10	0,05
0.7*ftd =	0,67	0,67
		OK
Frequency	No fatiqu	OK
log n >= 7	312	OK

Section 2

Condtion t <= 0.7*ftd

	Max.	Min.
to N/mm2	0,08	0,08
tu N/mm2	0,07	0,04
0.7*ftd =	0,67	0,67
		OK
Frequency	No fatiqu	OK
log n >= 7	293	OK

Section 3

Condtion t <= 0.7*ftd

	Max.	Min.
to N/mm2	0,04	0,04
tu N/mm2	0,04	0,02
0.7*ftd =	0,67	0,67
		OK
Frequency	No fatiqu	OK
log n >= 7	309	OK

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Rådg. Ingeniørfirma ApS FRI

Sag 97.069
Dato 97.09.01

CALCULATION	**STAR REINFORCEMENT**				
	Star reinforcement are put through the holes in the steel section, as replacement for the top reinforcement in plate which are cut.				
Pedestal:	Diametre	ds =	3015	mm	
Reinforcement in top:	Diametre	d =	20	mm	
	Distance	a =	250	mm	
Moments:	In section	Mo =	187,1	kNm/m	
	Capacity	Mud =	420,4	kNm/m	
STAR REINFORCEMENT:	Diametre	dr =	20	mm	
	Number	nr =	45	pcs	

Calculation:

Necessary top reinforcement in cut

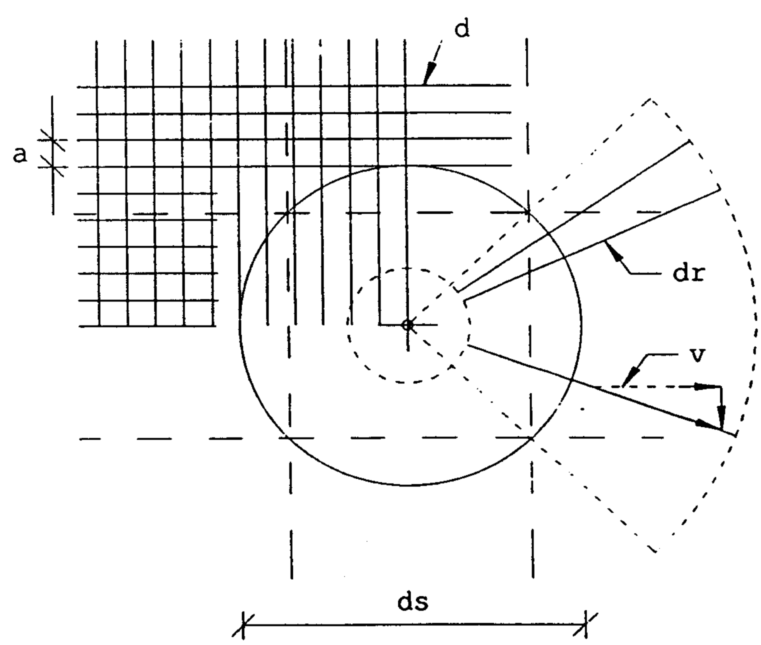
As = D/a*pi/4*d^2*Mo/Mud = 1686 mm2

Star reinforcement:

v = 360/no = 8,00 deg
Number of bars inside
an 90 deg. angle 11,25 pcs

Asr = pi/4*dr^2*sum(cosv) = 3346 mm2

\> As OK



Sag 97.069
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CALCULATION STEEL SECTION WITH ANCHOR RING

The calculation according to danish code DS 412 - Steel structures.

Calculating fatique loads on steel construction, it is the width which is essential.

LOADS Design loads on top of pedestal.

	Extreem load	Fatique loads Width at n = 10^7
Nd (kN)	553	31
Vd (kN)	252	42
Md (kNm)	8685	1982
Mvd (kNm)	515	327

At anchor ring

Mda (kNm)	9192	2066,3

Vd and Mvd pick up partly side pressure and friction between steel section and concrete.

Pedestal geometry

Outer diameter	ds =	3015	mm
Pedestal height	hs =	2011	mm
Plate thickness	ts =	15	mm
Reinforcement holes	nh =	45	pcs
Diameter	dh =	30	mm
Anchor ring Thickness	ta =	30	mm
Width	ba =	150	mm
Welding class	cl =	1,0	

Materials

Steel plate	fyk =	235	N/mm2
Anchor ring	fyk =	235	N/mm2

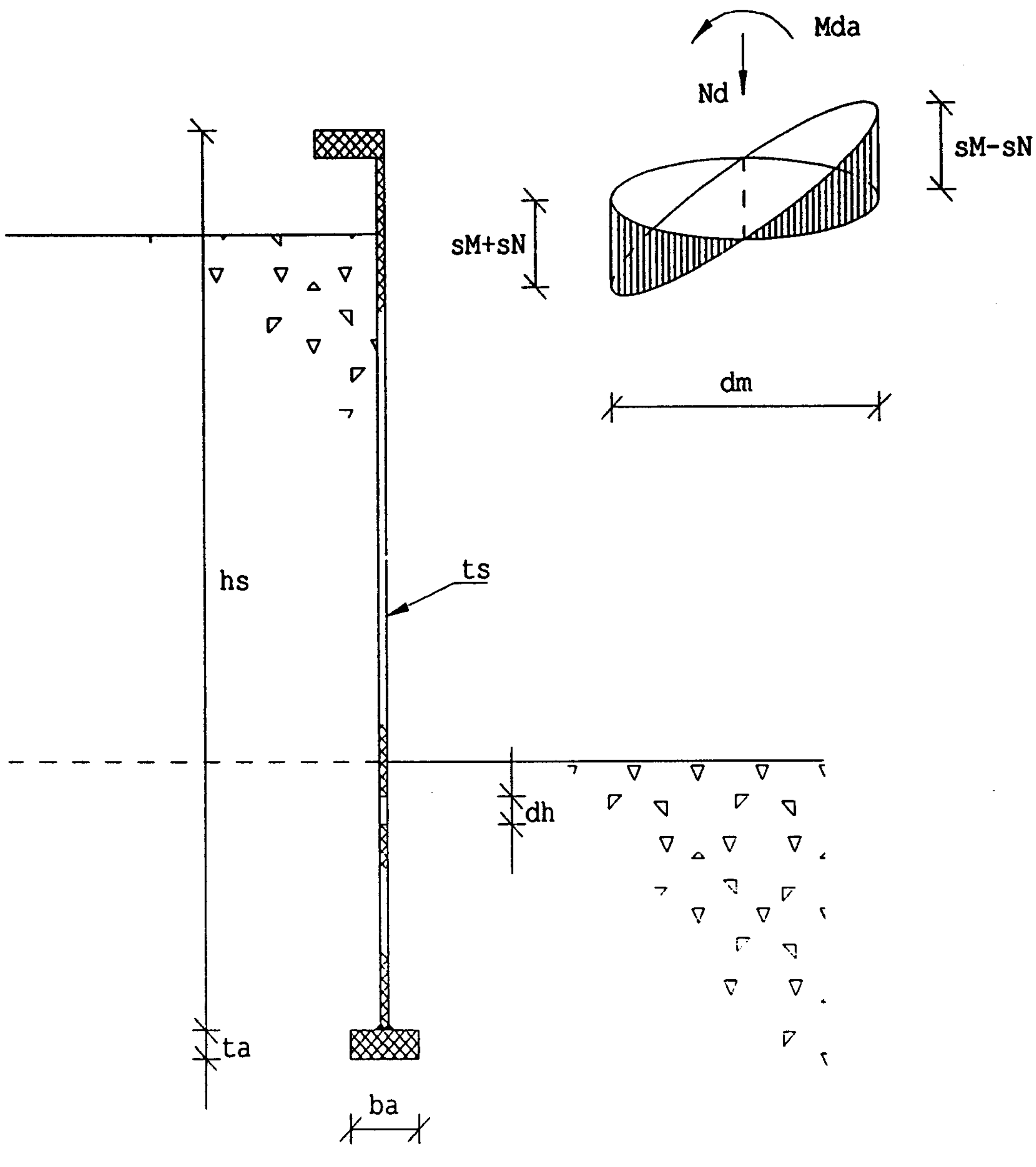
Safety class	Normal	gm =	1,28
Control class	Normal	gmfat =	1,56

PEDESTAL PLATE Section:

dsi = ds-2*ts	=	2985	mm
dm = ds-ts	=	3000	mm
A = pi/4*(ds^2-dsi^2)	=	141,37	*10^3 mm2
W = pi/32*(ds^4-dsi^4)/ds	=	105,50	*10^6 mm3

Section at holes:

Ared = A-nh*dh*ts	=	121,12	*10^3 mm2
tred = Ared/pi/ds	=	12,79	mm
dsired = ds-2*tred	=	2989	mm
Wred = pi/32*(ds^4-dsired^4)/ds	=	90,14	*10^6 mm3


Mda
Nd
sM-sN
sM+sN
dm
hs
ts
dh
ta
ba

Strees in material (N/mm2)	s = Nd*10^3/A +- Mda*10^6/W fyd = fy/gm				
Fatique	fdfat = (k*10^12/10^7)^(1/m)*f1/gmfat				
	Curve		b	d	e
	m		= 4,76	3,00	3,00
	k		= 110000	1,51	1,03
	f1 = 1.00/1.10/1.15 for Fe360/Fe430/Fe510				
		Ekstemlast		Fatique loads	
		s	fyd	sfat	fdfat
Plate	Pressure	91,0	183,6	19,8	82,5
	Tension	-83,2		-19,4	curve b
			OK		OK
At holes	Pressure	106,5	183,6	23,2	34,1
	Tension	-97,4		-22,7	curve d
			OK		OK

Folding of the steel plate is not taken into consideration, because of the concrete inside the pedestal.

ANCHOR RING

Attachment between steel plateand concrete is not taken into consideration.

The load on the anchor ring is shaped as the surface of a cylinder hoof.

			Extreme load	Fatique load
Loads		sN = Nd*10^3/pi/dm	58,7	3,3
		sM = Mda*10^6/pi/dm^2*4	1300,4	292,3
Concrete pressure	(N/mm2)	sco = (sM-sN)/(ba-ts)	9,2	2,1
		scu = (sM+sN)/ba	9,1	2,0
Bending	(Nmm/mm)	m = sc*((ba-ts)/2)^2/2	20955	
		mfat= sM/2*(ba-ts)/6		3289
Stress	(N/mm2)	sm = m/(1/6*1*ta^2)	139,7	21,9
	<	fyd and fdfat (curve d)	183,6	34,1
			OK	OK
WELDING	(N/mm2)	s = (sN+sM)/ta*c1	90,6	19,7
	<	fyd and fdfat (curve e)	183,6	30,0
			OK	OK
Stratification		Tension vertical to the surface of the anchor ring according to DS 412-6.1.7.		
	(N/mm2)	st = (sM-sN)/(ts+ta)	27,6	6,4
	<	1/2*fyd og 1/2*fdfat	91,8	17,1
File VIND-04E			OK	OK

CALCULATION	ANCHORING - STEEL SECTION IN CONCRETE PLATE
Codes:	DS 411 - Concrete structures DS 412 - Steel structures

LOADS

			Extreme load	Fatique load Max.	Min.
on surface of pedestal	Nd	(kN)	553	569	538
	Vd	(kN)	252	96	54
	Md	(kNm)	8685	4271	2289
	Mvd	(kNm)	515	190	138
At anchor ring	Mda	(kNm)	9192	4464,3	2398,1

Geometry pedestal	Outer diameter	ds =	3015	mm
	Pedestal height	hs =	2011	mm
	Plate thickness	ts =	15	mm
	Width of anchor ring	ba =	150	mm
Concrete plate	Plate thickness	tl =	1000	mm
		tu =	200	mm
Anchor reinforcement:	Number (1/2*no of Z)	nf =	45	stk
	Diameter	df =	25	mm
Material:	Concrete	fck =	30	N/mm2
	Reinforcement	fyk =	550	N/mm2

Safety class	normal	gc = 1,80	gcfat = 2,00
Control class	normal	gs = 1,40	gsfat = 1,60

ANCHOR STRESS

Attachment between steel plate and concrete is not taken into consideration.

The load on the anchor ring is shaped as the surface of a vertical cylinder hoof.

s = Nd*10^3/pi/dm +- Mda*10^6/pi/dm^2*4
Fc = 2*dc*s+
Ft = 2*dt*s-

		Extreme load	Fatique load Max.	Min.
Line load (N/mm)	s+	1359	692	396
	s-	-1242	-571	-282
Total load (kN)	Fc	4261	2274	1389
	Ft	3557	1550	704

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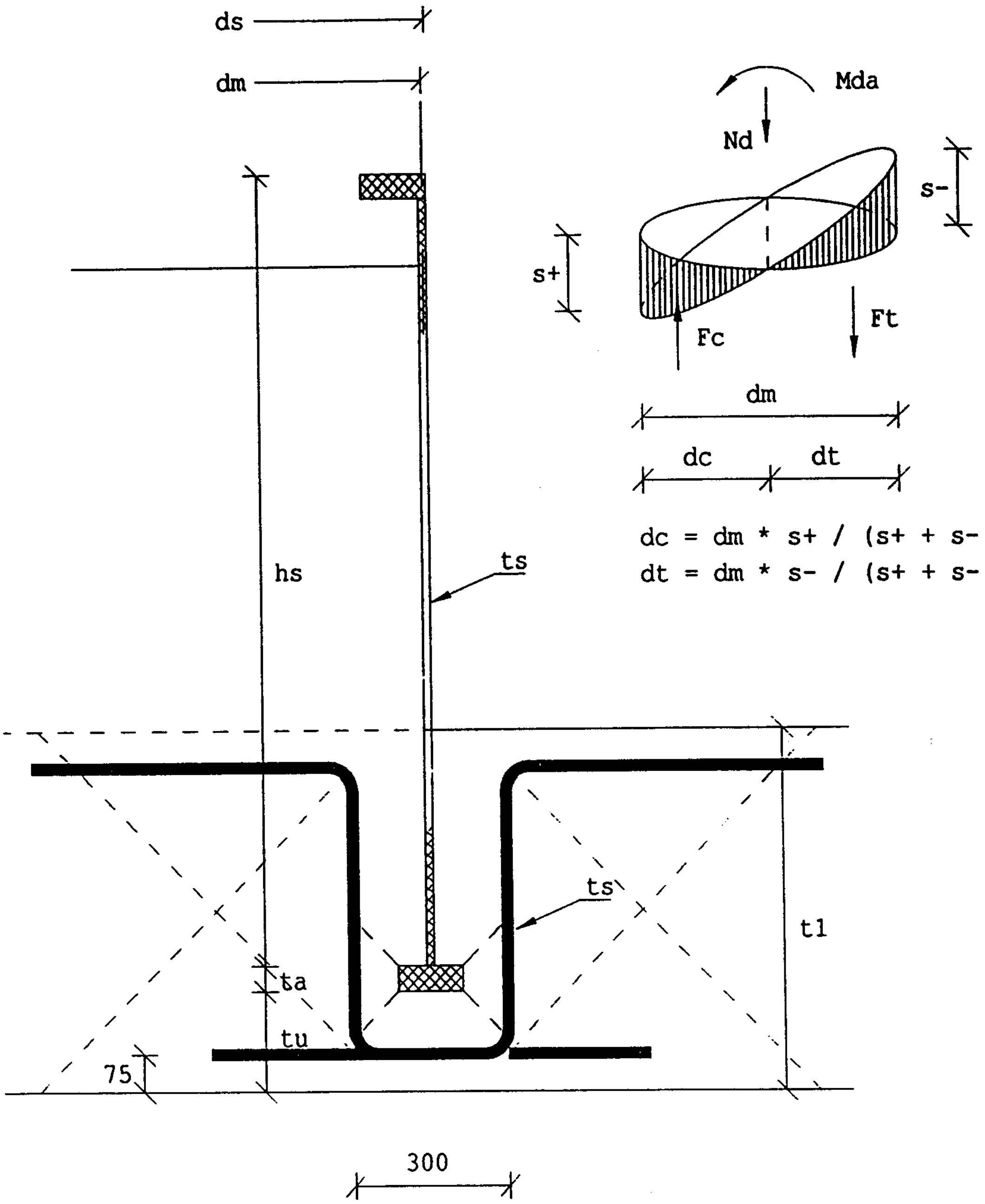
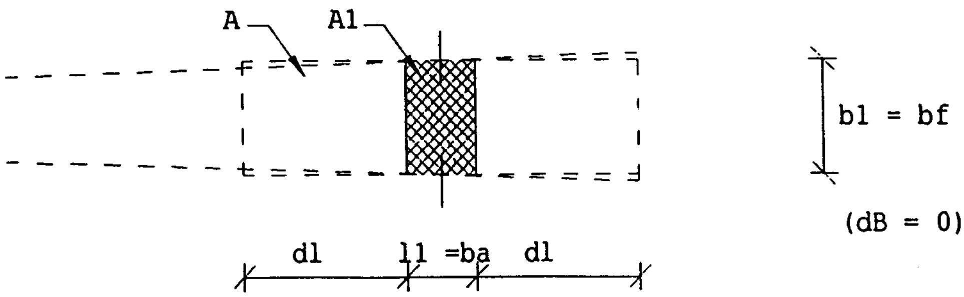
Rådg. Ingeniørfirma ApS FRI

Sag 97.069
Dato 97.09.01





BEARING PRESSURE on the concrete, under/over the anchor ring

Bearing pressure sl = s+/ba and s-/(ba-ts)

Control for local breaking:
(see sketch)
bl = bf = dm*pi/nf = 209,4 mm

Condition dl<=4*bf (idet db=0)
A1 = ba*bf
A = bf*(ba+2*4*bf)
flcd = sqrt(0.5*A/A1)*fck/gm (N/mm2)

Fatique control according to Aas-Jakobsens

log n = (1-smax/fcdfat)/0.0064/(1-smin/smax)

Splitting is insured by the cross reinforcement in top and bottom of plate.

		Extreme load	Fatique load Max.	Min.
Concrete stress N/mm2	sl+	9,1	4,6	2,6
	sl-	9,2	4,2	2,1
Breaking	flcd =	41,1 OK		
Number log n => 7			253,3 OK	
			221,7 OK	

ANCHORRING REINFORCEMENT

The shear stress in concrete is not computed.

On the safe side, the hoops are absorbing the full amount of pressure and tension.

The stress in the reinforcement is:
sb = F*10^3/(nf*2)/(2*pi/4*df^2)
fyd = fyk/gs (N/mm2)

Fatique stress (DS 412-B.6.6.1) curve b
fdfat = (k*10^12/10^7)^(1/m)/gsfat*f1
f1 = 1.00/1.10/1.15 for Fe360/Fe430/Fe510

		Extreem load	Fatique load Max.	Min.	Width
Stress in reinforcement	sb+	192,9	102,9	62,9	40,1
	sb-	161,0	70,2	31,9	38,3
	fyd =	392,9			
	fdfat =				92,5
		OK			OK

PUNCHING

Control of shear stress outside the anchor reinforcement.

Control perimeter:
Af = (t1-75)*(pi*dm+2*(300+2*(t1-75)))
= 12695 *10^3 mm2

According to DS 411-6.2.4.2 must
t = F*10^3/Af <= 0.12*2/sqrt(fck)*fcd

Fatique control according to Aas-Jakobsens

		Extreme load	Fatique load Max.	Fatique load Min.
Shear stress N/mm2	tc	0,34	0,18	0,11
	tt	0,28	0,12	0,06
	td =	0,73 OK		
Number			163,4 OK	
log n => 7			170,6 OK	

The infuence from the filling concrete in the pedestal is not taken into consideration in the calculating of the anchoring.

TRANSVERSE

Vd picks up the side pressure on the concrete.
sc = Vd'10^3/ds/(t1-tu)

		Extreme load	Fatique load Max.	Fatique load Min.
Concrete stress N/mm2	sc	0,10	0,04	0,02
	fcd =	16,7 OK		

TORSION

The moment is picked up by friction in the bearing surface between anchor ring and concrete. The star reinforcement and adhesion between steel plate and concrete, are not taken into consideration

According to DS 411-6.2.2.4 - my = 0.5
(Fc+Ft)*my*dm/2000 => Mvd

		Extreme load	Fatique load Max.	Fatique load Min.
Bearing (kNm) capacity	Mvd'	5864 OK	2868 OK	1570 OK

File VIND-05E

THISTED A/S
Rådgivende Ingeniørfirma FRI

Sag 009-97
Dato 97.10.22

Standardfoundation for :

Vestas V47/660 - 38,7 m. tower.

Groundwater level below foundation

The below mentioned concrete and reinforcement amount is theoretical calculated and have to be checked before order.

CALCULATION OF CONCRETE AMOUNT

Plate dimension	=	8300 mm
Height at socket	=	1000 mm
Height at edge	=	800 mm
Socket diameter	=	3015 mm
Socket height above plate	=	1300 mm
Settling of concrete inside socket	=	305 mm
Thickness of cleaning layer	=	100 mm
Plate	=	62,0 m^3
Socket	=	7,1 m^3
Total concrete amount	=	**69,1 m^3**
Cleaning layer amount	=	6,9 m^3

CALCULATION OF REINFORCEMENT AMOUNT

	Dim.	Pcs.	Lenght	Weight	
Cross wise reinforcement in the bottom	25	64	8200	2083	kg
Cross wise reinforcement in the top	20	40	8200	833	-
	20	24	2500	152	-
	20	16	2800	114	
	20	8	3250	66	-
Edge bows	20	52	1990	263	-
Star reinforcement	20	45	2700	309	
Anchor U-bows	25	45	3270	584	-
Ring bows	20	3	-	48	-
Total reinforcement weight			=	**4453**	kg

Supports for top reinforcement is placed in the necessary amount.