Replacement of the original radial flux PM-generator of the VIRYA-4.2 by the axial flux PM-generator of Hefei Top Grand type TGET380-10KW-1200R for 48 V battery charging

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KD 707

 Drawings of the VIRYA-4.2 windmill are no longer available. The main goal of writing this report KD 707 is not to introduce a new VIRYA design but to find the procedure how the P_{mech}-n and P_{el}-n curves for a 48 V battery load can be estimated from the specification of the manufacturer. Making this knowledge available, is the reason why this report is made public.

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1 Introduction

The VIRYA-4.2 has a 2-bladed rotor with wooden blades. The original rotor has a design tip speed ratio of 8 and is given on drawing 0401-01. An alternative rotor with a wider chord, a different airfoil and a design tip speed ratio of 7.5 is given on drawing 0401-01A. The 4-pole PM-generator is given on drawing 0401-02. The head frame is given on drawing 0401-03. The VIRYA-4.2 makes use of the slender 12 m high, 3-legs lattice tower given on drawing 0401-04. This tower is also used for the VIRYA-4.6B2. The VIRYA-4.2 with the original rotor has been built and tested by Kragten Design for some years. The original rotor will also be used in this new report KD 707 but some modifications are required.

The original VIRYA-4.2 rotor has two wooden blades with a constant Gö 623 airfoil and with a chord of 200 mm which is made on the whole blade length. Each blade has a length of 1.9 m. The two blades are connected to each other by a 1 m long connecting strip size 120 * 8 mm. Both sides of the strip are twisted 5.5° to give the blade the correct blade angle. The connecting strip is clamped in between a hub with a diameter of 80 mm and a clamping disk with a diameter of 80 mm. The hub has a central tapered hole. The geometry calculations for the original VIRYA-4.2 rotor are given in report KD 218 (ref. 1).

The VIRYA-4.2 makes use of a PM-generator made from an asynchronous motor frame size 112. This generator is used with a standard 230/400 V winding rectified in star for 48 V battery charging. The generator shaft makes a tilt angle of 5° with the horizon to make that there is enough space in between the blade tips and the tower.

Even if the standard winding can be used, manufacture of the generator is a lot of work and requires strong skills. This is because the original short-circuit armature has to be replaced by a 4-pole permanent magnet armature with a stainless steel shaft. This procedure is described in chapter 4 of report KD 341 (ref. 2). So it is investigated if an alternative PM-generator can be bought for the VIRYA-4.2. The original generator has a shaft with a diameter of 35 mm at the front bearing and a tapered shaft end. The hub of the rotor is pulled on the shaft by one central bolt M16.

An axial flux generator of Chinese manufacture has been chosen. Such generators are supplied by different Chinese suppliers like Hefei Top Grand, Xinda Green Energy, Hiestmotor and Qiangsheng Magnets. I have chosen Hefei Top Grand, website: www.china-topgrand.com because they gave the clearest answers on my questions. I have bought and tested a smaller generator type TGET165-0.15kW-500R at this company and they keep their promises. Measurements for this generator are given in report KD 595 (ref. 3).

For the VIRYA-4.2, I have chosen the largest generator which can be used for 48 V battery charging. This appears to be the generator with type TGET380-10KW-1200R (380 refers to about the housing diameter, 10KW refers to the nominal power in kW and 1200R refers to the nominal rotational speed in rpm). Hefei Top Grand supplies five types with frame size TGET380 and the chosen type is the one with the lowest voltage at a certain rotational speed. The generator is of the type “Outer Rotor” which means that the whole generator housing is rotating around the shaft. The rated voltage at n = 1200 rpm is specified as 220 VAC. So no DC voltage is specified but the loaded DC voltage can be calculated which is done in chapter 3. This generator has a 3-phase winding with an internal star point and three phase wires are coming out of the hollow generator shaft. The given voltage is the voltage in between two of the three phases and not the phase voltage U_f, which is the voltage in between the star point and one of the phases. U_f is a factor $\sqrt{3}$ lower, so 127.02 VAC. A large 3-phase rectifier (not included) must be used to get a DC current for 48 V battery charging. Rectification of a 3-phase current is explained in report KD 340 (ref. 4).

A data sheet about this generator can be found on the website of the supplier following the path: www.china-topgrand.com – product – Permanent Magnet Generator Outer Rotor – page 3 – TGET380-10kW-1200R. The data sheet gives: Shape Drawing at point 4, Performance Parameter at point 5 and Curve Graph at point 6. At point 3, Range Of Application, it is mentioned: “1 – 2 kW vertical axis wind turbine”. I think that this is mentioned because the generator has no oil seal on the rotor shaft. So no water will flow in the bearings if the shaft is mounted vertical. The same was the case with the generator model TGET165-0.15kW-500R which I have tested. However, the housing of this generator was provided with a chamber in which an oil seal can be mounted. I expect that this is also the case for the TGET380-10kW-1200R housing.

The nominal current I is specified as I = 26.24 A at n = 1200 rpm. So the nominal power generated by one phase is U_f * I = 127.02 * 26.24 = 3333 W. So the nominal power generated by three phase is 3 * 3333 = 9999 W. This matches with the given power of 10 kW.

The sticking torque of the generator is very low without an oil seal and is only caused by the friction of the bearings. It is specified that this torque is less than 0.3 Nm. An oil seal is needed if the axis is horizontal. The sticking torque will be much higher if an oil seal is mounted but it is expected that it is low enough for the VIRYA-4.2 rotor. The generator has a shaft with a diameter of 50 mm and this shaft must be strong enough for a horizontal axis wind turbine with a rotor diameter of 4.2 m. The generator housing has a collar with a diameter of 140 mm at the front side and ten, 20 mm deep threaded holes M12 at 36° and at a pitch circle of 120 mm. The original connecting strip and the original clamping disk of the VIRYA-4.2 rotor have to be modified such that they match with the hole pattern of the generator. Only eight of the ten threaded holes are used to connect the connecting strip to the generator. This is done by eight bolts M12 * 40 mm and eight locking washers for M12.

The head frame has a generator bracket which is in parallel to the shaft of the original generator. A construction is needed which can be bolted to the generator bracket and in which the 50 mm shaft of the alternative generator of Hefei Top Grand can be clamped such that the eccentricity e = 0.42 m and that the tilt angle of 5° is maintained.

2 Characteristics of the VIRYA-4.2 rotor

The 2-bladed rotor of the VIRYA-4.2 windmill has a diameter D = 4.2 m and a design tip speed ratio λ_d = 8. Advantages of a 2-bladed rotor are that no welded spoke assembly is required, that the rotor can be balanced easily and that it can be transported completely mounted. A disadvantage of a 2-bladed rotor is that the gyroscopic moment in the rotor shaft is fluctuating. However, this fluctuation is almost flattened because the blades are rather elastic and because the hinged side vane safety system which is used for the VIRYA-4.2 has a large moment of inertia of the head around the tower axis. This reduces the yawing speed and so it reduces the gyroscopic moment.

The rotor has wooden blades with a constant chord and no twist and is provided with a Gö 623 airfoil over the whole blade length. The Gö 623 is flat over 70 % of the chord. The maximum thickness is 12 % of the chord. The chord is chosen 200 mm, so the maximum thickness is 24 mm. The characteristics of this airfoil are given in report KD 463 (ref. 5). As an alternative it is possible to use the Gö 711-12% airfoil which is flat over 97.5 % of the chord and therefore easier to manufacture. The characteristics of this airfoil are given in report KD 333 (ref. 6). A blade is made out of a planed plank of good quality hard wood.

The rotor calculations of the VIRYA-4.2 rotor are given in report KD 218 (ref. 1). The P-n curves for certain constant wind speeds and the optimum cubic line are given in figure 4 of KD 218. This figure is copied as figure 1. Figure 4 of KD 218 also gives the measured P_{mech}-n and P_{el}-n curves of the original generator for a 230/400 V winding for 52 V star. It also gives the measured P-n curve for short-circuit in delta. These curves are removed and are replaced by the estimated curves for 48 V battery charging of the axial flux generator of Hefei Top Grand type TGET380-10kW-1200R. These curves are determined in chapter 4.

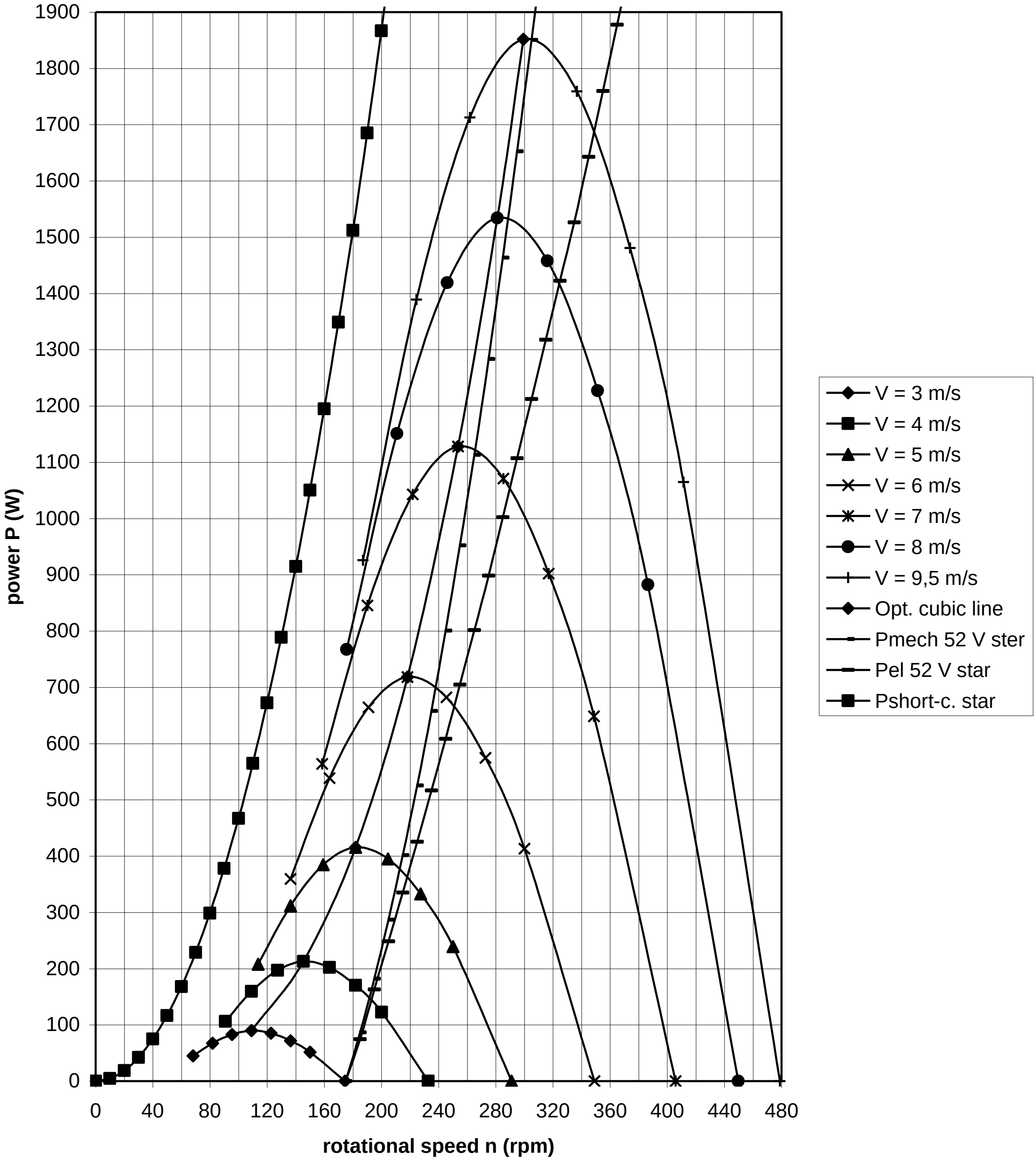

fig. 1 P-n curves of the VIRYA-4.2 rotor, optimum cubic line, estimated P_{mech}-n and P_{el}-n for 52 V star, estimated P-n curve for short-circuit in star

The P-n curve of the alternative generator for short-circuit of the winding in star is also determined in chapter 4 and given in figure 1. The star point can't be short-circuited as it is hidden somewhere in the winding. So one can only short-circuit the three wires coming out of the hollow generator shaft.

The generator can be used as a brake by making short-circuit in star because the P-n curve for short-circuit in star is lying at a large distance left from the P-n curve of the rotor for V = 9.5 m/s and higher. Short-circuit must be made as close as possible to the generator to prevent a voltage drop over the lines. In practice this means that the short-circuit switch must be placed before the rectifier at the tower foot and not at the batteries. The rectifier can also be placed at the tower foot, so there are only two cables from the tower foot to the batteries.

3 Derivation of the generator characteristics

For checking of the matching in between rotor and generator and for the determination of the P_{el}-V curve, measured P_{mech}-n and P_{el}-n curves of the generator for a 48 V battery load are needed. A 48 V battery is charged at an average charging voltage of about 52 V so the P_{mech}-n curve and the P_{el}-n curve should have been measured for this constant voltage. However, Hefei Top Grand supplies only a P_{el}-n curve for a resistance load. The resistance R is chosen that high that the electrical power is 10 kW = 10000 W at a rotational speed of 1200 rpm and a loaded alternating voltage of 220 VAC. But the characteristics for a resistance load differ very much from the characteristics for a constant voltage. So the characteristics for a constant voltage of 52 V have to be estimated to check the matching in between rotor and generator. This is done in chapter 4.

My PM-generator using a motor housing 5RN90L04V has been measured for different load conditions. The measurements are given in report KD 78 (ref. 7). The measurements for a constant resistance are given at chapter 7 and 9 of KD 78. The unloaded U-n curve is a straight line through the origin (see KD 78 figure 1) but it can be derived that the U-n curve and the Q-n curve for a resistance load are also about straight lines through the origin. Figure 31 and figure 32 of KD 78 show that the P_{mech}-n and P_{el}-n curves are about parabolas if the torque is not close to the maximum torque level which the generator can supply. This is in accordance with the U_{AC}-n and P_{el}-n curves given at point 6 of the data sheet of Hefei Top Grand. These curves give measuring points every 100 rpm but the values of the measuring points are not given. So these curves are estimated from the given values at n =1200 rpm.

The winding is a 3-phase winding connected in star. The star point is lying internal so only the three phase wires are coming through the hollow generator shaft. The given voltage is the alternating voltage U_{AC} in between two of the three phases. For battery charging, the winding must be rectified. The rectified DC voltage U_{DC} is a factor 0.955 * √ 2 = 1.3506 higher than U_{AC} (if the voltage drop of the rectifier diodes is neglected). The unloaded or open voltage U_{open} is also not specified. For a smaller generator type TGET320-1KW-350R, it has been found in chapter 3 of report KD 705 (ref. 8) that the ratio U_{open} / U_{DC} is about 68 / 56 = 1.2143. It is assumed that this ratio is also valid for the generator type TGET380-10KW-1200R. So for the loaded DC voltage U_{DC} at n = 1200 rpm it is valid that U_{DC} = 1.3506 * 220 = 297 VDC. For the open DC voltage U_{open} at n = 1200 rpm it is valid that U_{open} = 1.2143 * 0.955 * √ 2 * 220 = 361 VCD. The calculated values are given in the bottom line of table 1.

n (rpm)	U_{AC} (V)	U_{DC} (V)	U_{open} (V)	P_{el} (W)	η_{gen} (-)	P_{mech} (W)	Q (Nm)	P_{heat} (W)
0	0	0	0	0	-	0	0	0
100	18.3	24.8	30.1	69.4	0.85	81.7	7.8	5.3
200	36.7	49.5	60.2	277.8	0.85	326.8	15.6	49.0
300	55	74.3	90.3	625	0.85	735.3	23.4	110.3
400	73.3	99.0	120.3	1111.1	0.85	1307.2	31.2	196.1
500	91.7	123.8	150.4	1736.1	0.85	2042.5	39.0	306.4
600	110	148.5	180.5	2500	0.85	2941.3	46.8	441.3
700	128.3	173.3	210.6	3402.8	0.85	4003.4	54.6	600.6
800	146.7	198.0	240.7	4444.4	0.85	5228.9	62.4	784.4
900	165	222.8	270.8	5625.0	0.85	6617.8	70.2	992.8
1000	183.3	247.5	300.8	6944.4	0.85	8170.1	78.0	1225.7
1100	201.7	272.3	330.9	8402.8	0.85	9885.9	85.8	1483.1
1200	220	297	361	10000	0.85	11765	93.6	1765

table 1 U_{AC}, U_{DC}, U_{open}, P_{el}, η_{gen}, P_{mech}, Q and P_{heat} as a function of n

No rated torque Q is given for the generator. However, it is specified at point 5 of the data sheet that the generator efficiency η_{gen} is at least 85 %. In figure 33 of KD 78 (ref. 7) it can be seen that the efficiency for a resistance load is about constant for every rotational speed and that it is high if the load resistance isn't low. It is easy to give the efficiency as a factor of 1 and it is assumed that η_{gen} = 0.85 for all rotational speeds. As the generator has no iron in the coils, the heat losses P_{heat} are only caused by the copper losses in the winding. The P_{mech}-n, the P_{heat}-n and the Q-n curves of the generator can be derived by the formulas:

$$P_{mech} = P_{el} / \eta_{gen} \quad \text{(W)} \qquad (1)$$

$$P_{heat} = P_{mech} - P_{el} \quad \text{(W)} \qquad (2)$$

$$Q = 30\, P_{mech} / (\pi * n) \quad \text{(Nm)} \qquad (3)$$

First the values of P_{mech}, P_{heat} and Q are determined for n = 1200 rpm. Substitution of P_{el} = 10000 W and η_{gen} = 0.85 in formula 1 gives that P_{mech} = 11765 W. Substitution of P_{mech} = 11765 and P_{el} = 10000 W in formula 2 gives that the heat loss P_{heat} = 1765 W. Substitution of P_{mech} = 11765 W and n = 1200 rpm in formula 3 gives that Q = 93.6 Nm. These values are also given in the bottom line of table 1.

The values for other rotational speeds are now calculated assuming that the U-n and Q-n curves are straight lines through the origin and that the P-n curves are parabolas. The wanted curves can now be derived from table 2. The U_{AC}-n, the U_{DC}-n and the U_{open}-n curves are given in figure 2.

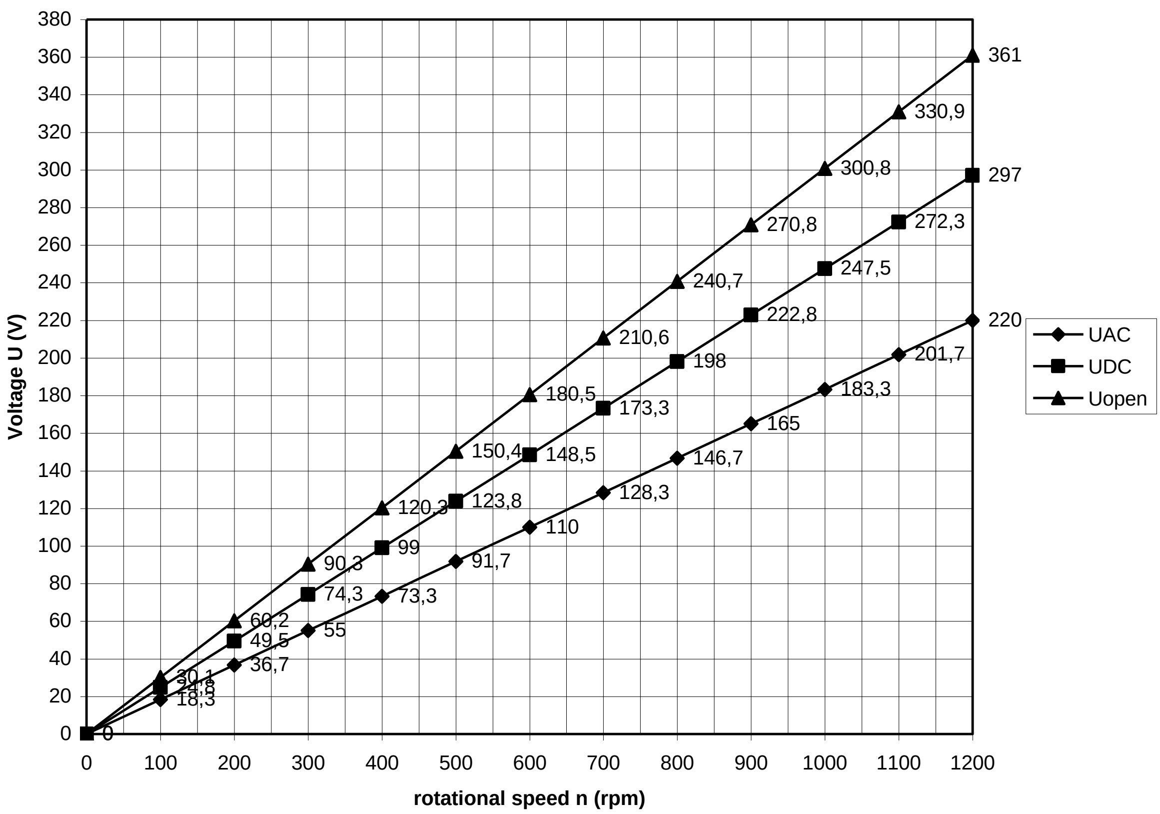

fig. 2 U_{AC}, U_{DC} and U_{open} as a function of n for a resistance load

The P_{mech}-n and the P_{el}-n curves are given in figure 3.

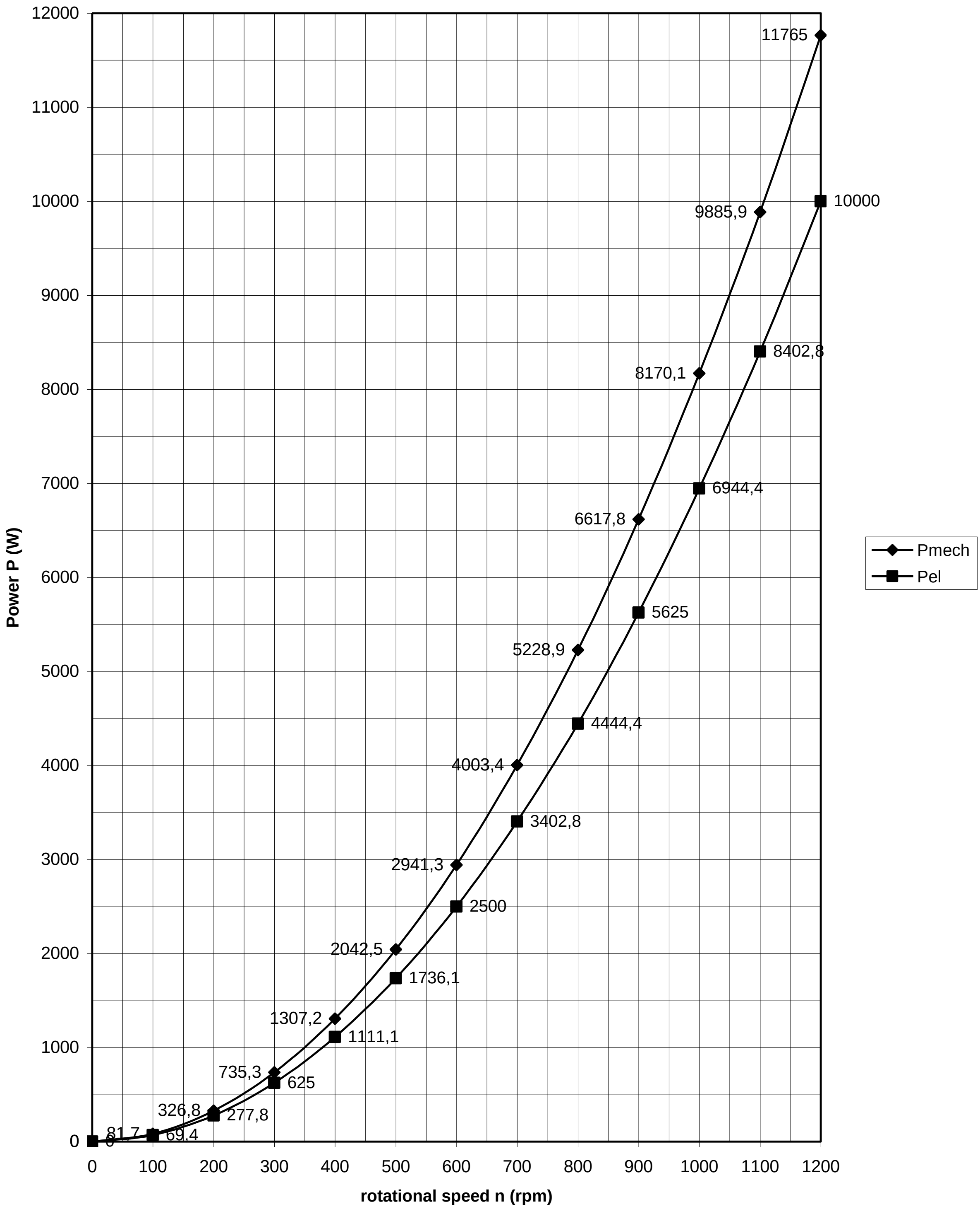

fig. 3 P_{mech} and P_{el} as a function of n for a resistance load

The Q-n curve is given in figure 4.

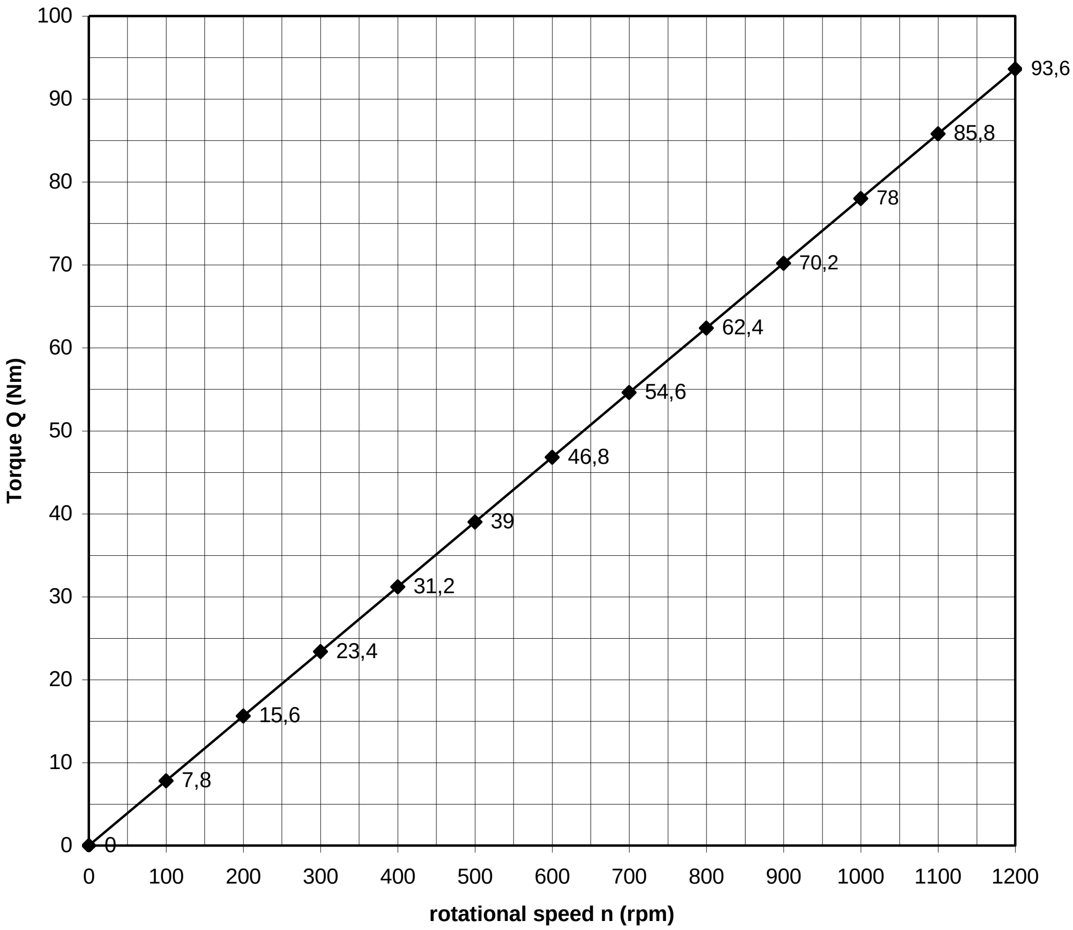

fig. 4 Loaded torque Q as a function of n for a resistance load

So figure 2, 3 and 4 are based on the manufactures specification for a resistance load at n = 1200 rpm. The load resistance R can be calculated if it is assumed that three identical resistors are connected in star to the three phase wires. The voltage over one resistor is equal to the phase voltage U_f = 127.02 V. The current I = 26.24 A at n = 1200 rpm. So according to the law of Ohm, the resistance R is given by R = U / I or R = 127.02 / 26.24 = 4.84 Ω.

If three resistors are used as load, the winding of one phase is used for all the time to generate power. This power varies according to a $\sin^2 \alpha$ function. The power fluctuation is given in figure 2 of report KD 340. If a 3-phase winding is rectified in star, only two of the three phases are generating power at the same time. This means that in one phase, power is only generated for 30° < α < 150° and for 210 < α < 330°. This means that no power is generated for 0° < α < 30°, for 150° < α < 210° and for 330° < α < 360°. The loss of generated power because of this effect is about 7 % of the power generated for a resistance load. But this effect is neglected and so it is assumed that the generator is able to generate a DC power of 10 kW at n = 1200 rpm.

4 Determination of the P_{mech}-n and the P_{el}-n curves for 52 V star

If this generator is used for 48 V battery charging, it is used at much lower rotational speeds than the nominal rotational speed of 1200 rpm. It is assumed that the average charging voltage for a 48 V led acid battery is 52 VDC. So P_{mech}-n and P_{el}-n curves for 52 V star are needed to check the matching in between rotor and generator and to derive the P_{el}-V curve. The best way is to buy a generator and to test it on a large accurate test rig. I have used the test rig of the University of Technology Eindhoven to test the original VIRYA-4.2 generator. But obtaining the generator and hiring of the test rig is expensive and I won't do that. So it is tried to estimate the wanted characteristics from the curves as given in chapter 3.

The PM-generator which is used for the measurements as given in KD 78 (ref. 7) was measured for different constant voltages rectified in star. The Q-n curves for 26 V star, 52 V star and 76 V star are given in figure 8 of chapter 4 of KD 78. The Q-n curve for short-circuit in star before the rectifier is given in figure 4 of chapter 3 of KD 78. If these curves are compared it can be seen that all curves have about the same shape but that the curve is shifted to the right if the voltage is higher. All curves have about the same maximum value of about 29 Nm. The first part of each curve, up to about 2/3 of the peak value, so up to a torque of about 20 Nm, is about a straight line but the curves bend to the right for higher torques. The curves start at the rotational speed for which the open generator voltage is equal to the average charging voltage. The phenomenon is used to derive the wanted characteristics of the alternative VIRYA-4.2 generator.

In figure 4 it can be seen that the nominal torque Q at 1200 rpm is 93.6 Nm. In figure 2 it can be seen that the loaded DC voltage U_{DC} is 297 VDC at n = 1200 rpm. So first the Q-n curve is determined for a constant voltage of 297 VDC. A horizontal line is drawn in figure 2 for U = 297 VDC until it intersects with the U_{open}-n curve. The point of intersection lies about at a rotational speed of 990 rpm. It is assumed that the sticking torque of the generator can be neglected and so the unloaded torque is zero at n = 990 rpm. It is also assumed that the nominal torque Q = 93.6 Nm is lying that far from the peak torque that it is allowed to assume that the Q-n curve for a constant voltage of 297 VDC is a straight line. Figure 4 is now copied as figure 5 and the Q-n curve for 297 VDC is added. So the Q-n curve for 297 VDC is a straight line going through the point Q = 0 Nm and n = 990 rpm and the point Q = 93.6 Nm and n = 1200 rpm. This curve is also drawn in figure 5. The difference in between the rotational speeds is 1200 – 990 = 210 rpm.

Next the Q-n curve for 52 VDC is determined by shifting the Q-n curve for 297 VDC to the left. It must be shifted that far, that is starts at the rotational speed belonging to an open voltage of 52 VDC. In figure 2 it can be seen that an open voltage of 52 VDC is reached at a rotational speed of about 175 rpm. To get a Q-n curve for 52 VDC which is in parallel to the Q-n curve for 297 VDC, the maximum torque of 93.6 Nm must lie at a rotational speed of 175 + 210 = 385 rpm. So the Q-n curve for 52 VDC is a straight line going through the point Q = 0 Nm and n = 175 rpm and the point Q = 93.6 Nm and n = 385 rpm. This curve is also drawn in figure 5.

Next the Q-n curve for short-circuit in star is determined by shifting the Q-n curve for 297 VDC that far to the left that it starts at the origin of the graph. So the Q-n curve for short-circuit in star is a straight line going through the point Q = 0 Nm and n = 0 rpm and the point Q = 93.6 Nm and n = 210 rpm. This curve is also drawn in figure 5.

It will be clear that the efficiency for short-circuit in star is zero as all generated power is dissipated as heat in the winding. The efficiency for 52 V star is only 0.85 for the point of intersection of the Q-n curve for a resistance load and the Q-n curve for 52 VDC. This point of intersection lies about at a rotational speed of 210 rpm. The efficiency may have a maximum of about 0.9 for a rotational speed of about 190 rpm. The efficiency for rotational speeds higher than 210 rpm will be lower than 0.85.

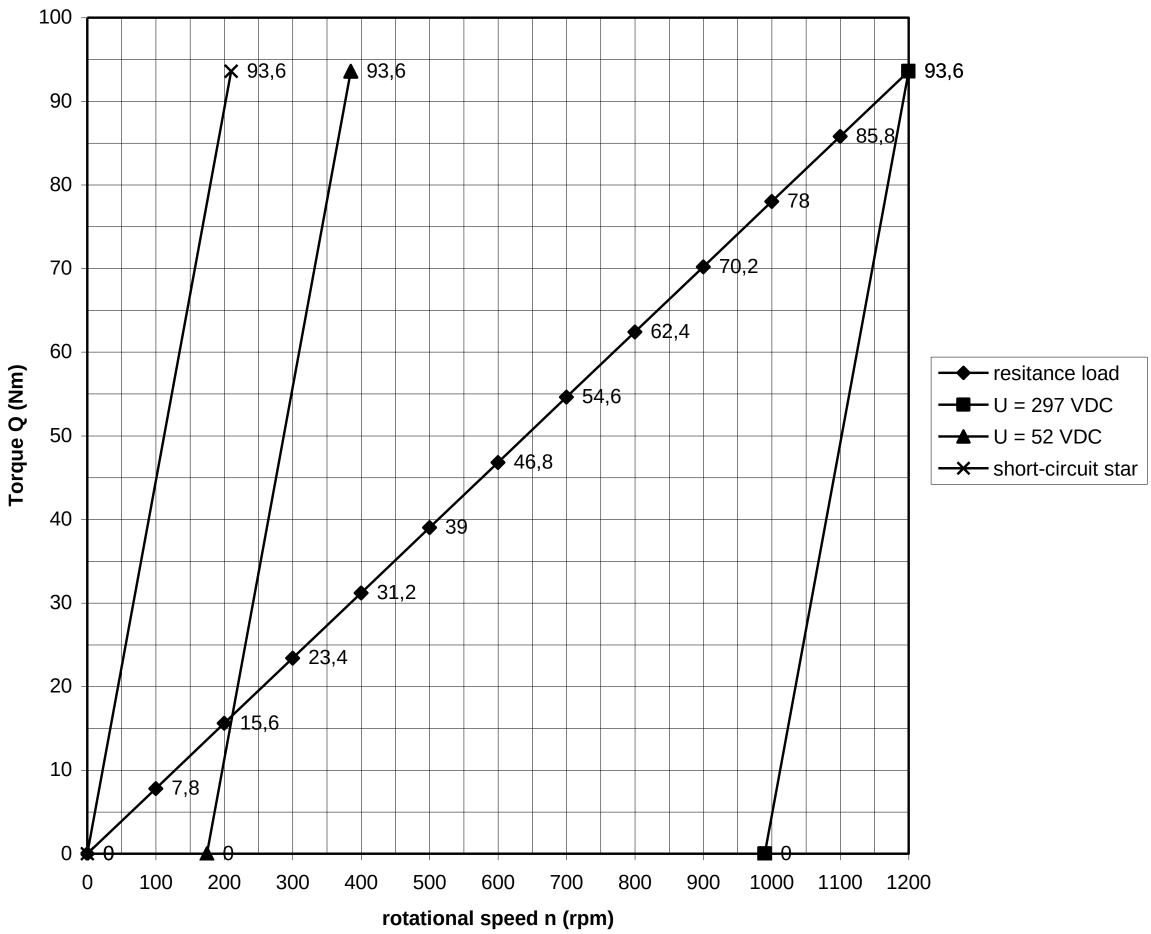

fig. 5 Q-n curve for a resistance load, for constant voltages of 297 VDC and for 52 VDC and for short-circuit in star

For the determination of the P_{mech}-n and the P_{el}-n curves it is necessary to take several points on the Q-n curves. The curves for 52 V star are determined first. The values of Q are determined for rotational speeds of 175 rpm up to 385 rpm in steps of 10 rpm. The results are given in table 2. P_{mech} and P_{el} are calculated with:

$$P_{mech} = Q * n * \pi / 30 \qquad \text{(W)} \qquad (4)$$

$$P_{el} = \eta_{gen} * P_{mech} \qquad \text{(W)} \qquad (5)$$

So for the determination of P_{el}, it is necessary to estimate a η_{gen}-n curve. The estimated η_{gen}-n curve is given in figure 6. It is assumed that the efficiency curve has a peak $\eta_{gen} = 0.9$ for n = 190 rpm and that $\eta_{gen} = 0.85$ for n = 210 rpm.

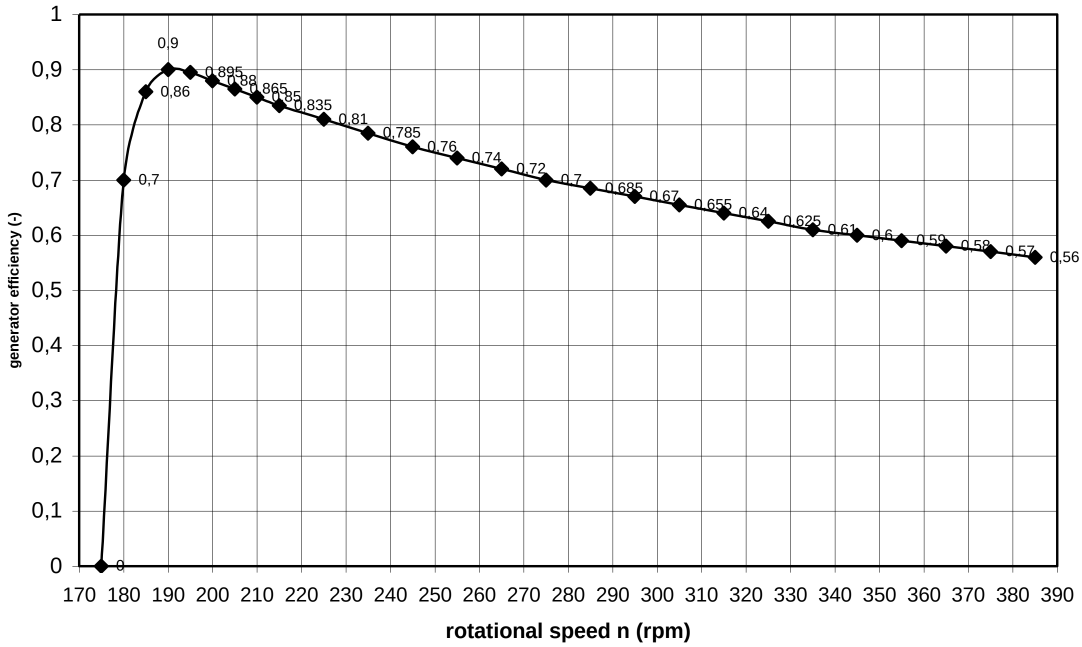

fig. 6 Estimated η_{gen}-n curve for 52 V star

n (rpm)	Q (Nm)	P_{mech} (W)	η_{gen} (-)	P_{el} W	P_{heat} (W)
175	0	0	0	0	0
185	4.46	86.4	0.86	74.3	12.1
195	8.91	181.9	0.895	162.8	19.1
205	13.37	287.0	0.865	248.3	38.7
215	17.83	401.4	0.835	335.2	66.2
225	22.29	525.2	0.81	425.4	99.8
235	26.74	658.0	0.785	516.6	141.4
245	31.20	800.5	0.76	608.4	192.1
255	35.66	952.2	0.74	704.7	247.5
265	40.11	1113.1	0.72	801.4	311.7
275	44.57	1283.5	0.70	898.5	385.0
285	49.03	1463.3	0.685	1002.4	460.9
295	53.49	1652.4	0.67	1107.1	545.3
305	57.94	1850.6	0.655	1212.1	638.5
315	62.40	2058.4	0.64	1317.4	741.0
325	66.86	2275.5	0.625	1422.2	853.3
335	71.31	2501.6	0.61	1526.0	975.6
345	75.77	2737.4	0.6	1642.5	1094.9
355	80.23	2982.6	0.59	1759.7	1222.9
365	84.69	3237.1	0.58	1877.5	1360.6
375	89.14	3500.5	0.57	1995.3	1505.2
385	93.6	3773.7	0.56	2113.3	1660.4

table 2 Calculated values of Q, P_{mech}, η_{gen}, P_{el} and P_{heat} as a function of n for 52 V star

The P_{mech}-n and P_{el}-n curves can now be derived from table 2 and are given in figure 1. It can be seen that the matching is good for wind speed above V = 5 m/s because the P_{mech}-n curve of the generator for 52 V star is lying close to the optimum cubic line of the rotor.

The P-n curve for short-circuit in star is determined in the same way as the P_{mech}-n curve for 52 V star. So the values of Q as a function of n are first given in table 3.

n (rpm)	Q (Nm)	P (W)
0	0	0
10	4.46	4.7
20	8.91	18.7
30	13.37	42.0
40	17.83	74.7
50	22.29	116.7
60	26.74	168.0
70	31.20	228.7
80	35.66	298.7
90	40.11	378.0
100	44.57	466.7
110	49.03	564.8
120	53.49	672.2
130	57.94	788.8
140	62.40	914.8
150	66.86	1050.2
160	71.31	1194.8
170	75.77	1348.9
180	80.23	1512.3
190	84.69	1685.1
200	89.14	1866.9
210	93.6	2058.4

table 3 Calculated values of Q and P as a function of n for short-circuit in star

Next, the P-n curve for short-circuit in star is also given in figure 1. It can be seen that the P-n curve for short-circuit in star is lying at a large distance left from the P-n curve of the rotor for V = 9.5 m/s and higher. So the generator can be used as a brake.

The point of intersection of the P_{mech}-n curve of the generator with the P-n curve of the rotor for a certain wind speed is the working point for that wind speed. The electrical power for that wind speed is found by going downwards vertical until the P_{el}-n curve is reached. The values of P_{el} found this way is given in the P_{el}-V curve of figure 7. The P_{el}-V curve starts at a wind speed of about 3 m/s so the $V_{cut\ in}$ = 3 m/s. This means that the VIRYA-4.2 can be used in regions with rather low wind speeds.

In chapter 4 of KD 218 it has been calculated that the starting wind speed V_{start} = 3.4 m/s if the sticking torque of the original generator is 0.9 m/s. The starting torque of the alternative generator with an oil seal mounted isn't given but it may also be about 0.9 Nm if the oil seal has run in. So the starting wind speed for the alternative generator will also be 3.4 m/s. This means that there is hysteresis in the P_{el}-V curve for $3 < V < 3.4$ m/s.

The maximum power is about 1200 W. This is 100 W higher than for the original VIRYA-4.2 generator. This is because the alternative generator has a higher efficiency.

The mechanical power at V = 9.5 m/s is about 1850 W. So this gives for the heat losses that P_{heat} = 1850 – 1200 = 650 W. This is much lower than P_{heat} = 1765 at n =1200 rpm with a resistance load (see table 1). So the generator can be used in combination with the VIRYA-4.2 rotor for 48 V battery charging.

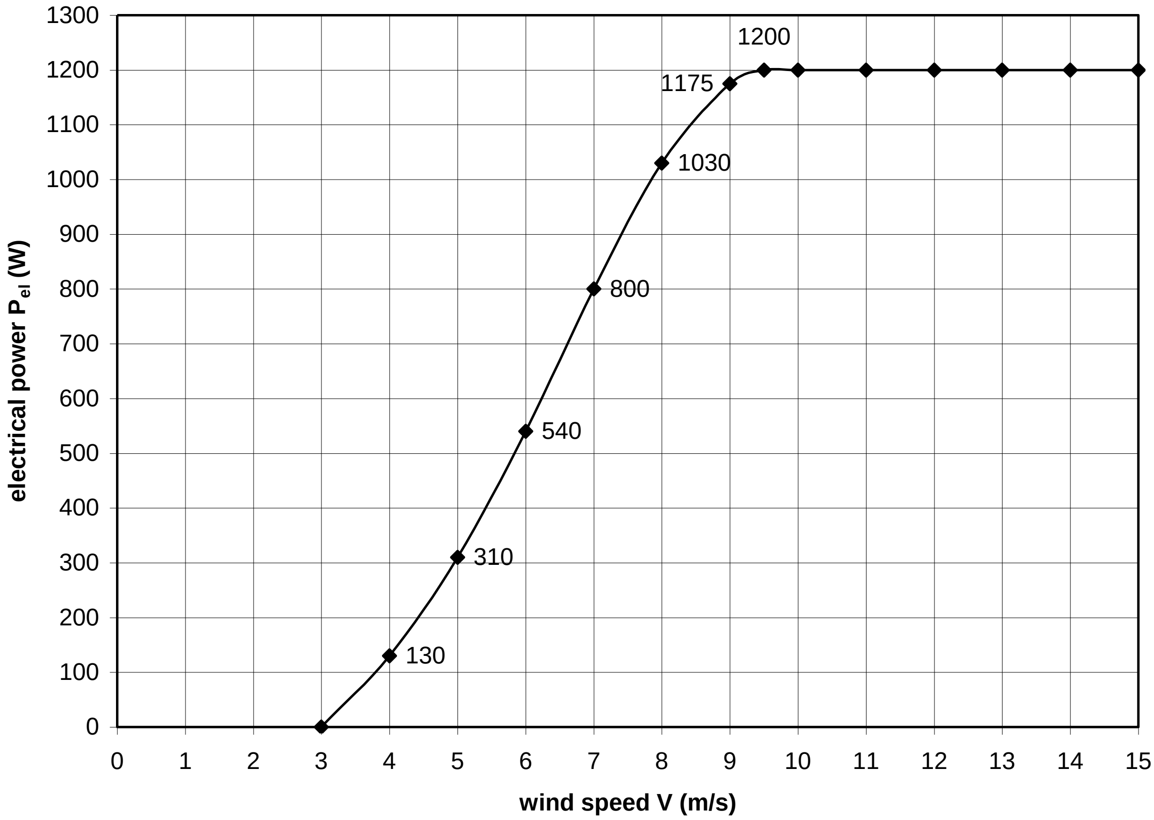

fig. 7 P_{el}-V curve for 52 V star

The P_{mech}-n, the P_{el}-n curves as given in figure 1 and the P_{el}-V as given in figure 7 are estimated and not measured like it was done for the original generator. The measured P_{mech}-n and P_{el}-n curves for 52 V star for the original generator are given in figure 7 of report KD 200 (ref. 9). Measured characteristics are more accurate than estimated characteristics. So to be sure that an acceptable matching is realised for the alternative generator of Hefei Top Grand, it is necessary to buy one and to test it at a large test rig with which it is possible to also measure the torque Q.

If such a test rig isn't available, at least one has to measure the open DC voltage as a function of the rotational speed and check if the real U_{open}-n curve is about the same as the estimated U_{open}-n curve as given in figure 2. It is also advised to connect the generator to a large almost empty 48 V lead acid battery and check if the measured P_{el}-n curve is about the same as the estimated P_{el}-n curve given in figure 1. If this is the case, one may assume that the P_{mech}-n curve is also almost the same and so the matching will be acceptable.

Building of the VIRYA-4.2 with this alternative generator is only possible if the drawings are available. These drawings are made on A1 format and therefore it is difficult to make them digital. From 1-1-2018 Kragten Design is no longer a commercial company and licences of the bigger VIRYA windmills are no longer supplied. A licence contained printed copies of all drawings and several manuals. The main goal of writing this report KD 707 is not to introduce a new VIRYA design but to find the procedure how the P_{mech}-n and P_{el}-n curves for a 48 V battery load can be estimated from the specification of the manufacturer. Making this knowledge available, is the reason why this report is made public.

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