GIOVENZANA

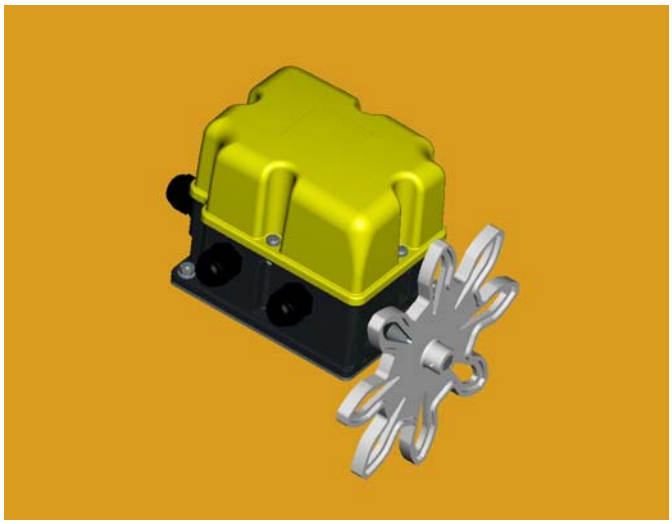
INTERNATIONAL B.V.

FGR 3 Rotary gear limit-switch for wind turbines

"Green evolution"

GIOVENZANA INTERNATIONAL B.V.

SUBJECT: ***"YAW CONTROL DEVICE WITH INTEGRATED ENCODER FOR POSITIONING OF THE NACELLE"***



GIOVENZANA INTERNATIONAL B.V.

Issued by: Ing. Luca Pedroncelli

ROTARY GEAR LIMIT SWITCH FOR WIND TURBINES
FGR3

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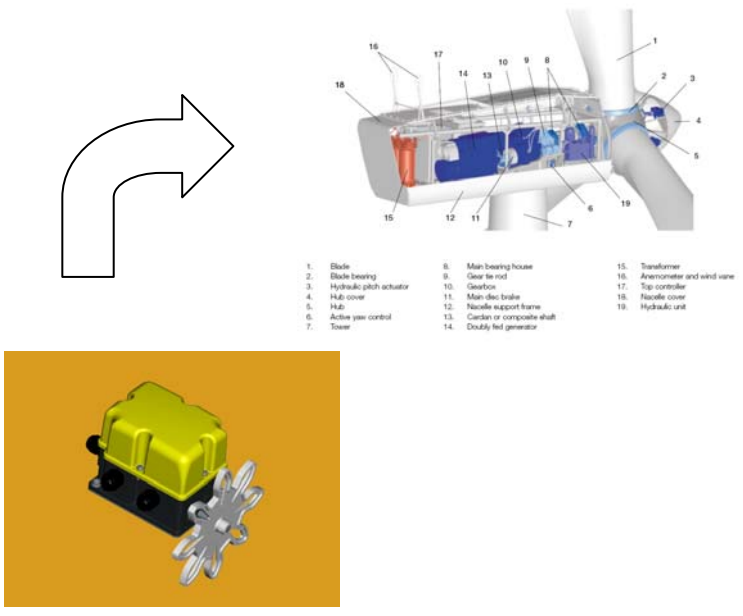
1. Project focus and market area

GIOVENZANA INTERNATIONAL has developed, during this year, the Rotary gear limit switches to equip the wind energy turbines, with a main characteristic of flexibility to adapt our product to a big range of customization by clients.
We began to research in this field to manufacture a product deleting the defects of the principal competitors, the actual owner of the limit switches range (like as TER and Stromag) in the market. Our engineering studies, shoot for supply an high quality standard product in terms of reliability and availability of the equipment. Using advanced technological approaches (i.e. materials, simulation techniques, …), we aim a developing a product that could become, in short time, a reference system in the market nowadays. The project has been developed to warrant, in the same time, the correct functionalities of the rotary switch and overall the resistance to the high critical working conditions (determined by temperature, humidity and position to hook up the box in its seat), and very high precision to control and regulate the rotation of the nacelle.
We have had a lot of experience and competence in the limit switch products; as a consequence, with the introduction of this innovative product in the market, we have overcome the problems related to this kind of equipment and we are able to warrant the best performances during a long life-time. All above characteristics are not only a paper declaration, but will be shown thanks to the several tests which have the purpose to stress the product in its "real" working conditions. Finally, we are sure to achieve the leadership using the best equipment components and looking for the high quality plastic materials.



Picture 1 –Complete product rendering and position

Picture 2 –Destination's product

2. Rotary gear limit switch for wind turbines: Giovenzana's code and detailed description.

The new code of our product will be a "speaking code", in which each single number means a specific functionality. The code provides all the information which can be used for defining the different customization which we'll be able to supply to our customers. In fact, one of the main characteristics of the equipment here shown is its flexibility, as it is possible to state by following examples:

FGR3 X X XXX X X

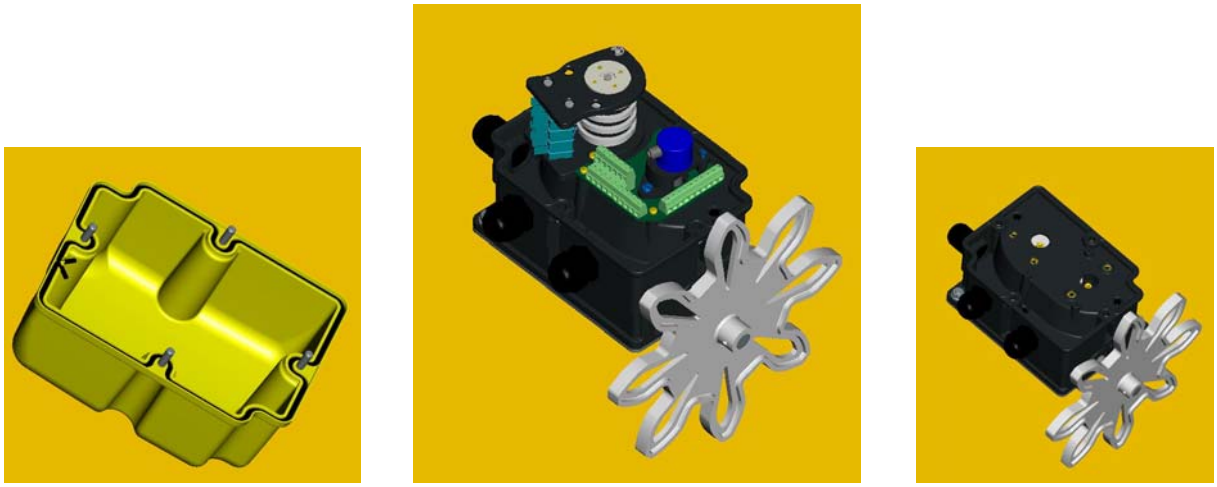
FGR3 0/1/2 060-999 1-4 50

ENCODER		POTENZIOMETER		RATIO GEAR	N. MICROSW.	LENGHT OF THE SHAFT
0	1	0	2		1 / 2 / 3 / 4 / 5 / 6	00 to 99 [mm]
NO	YES	NO	YES	N. ratio gear min 001 to max 999	Number of cams and their microswitch	Lenght of the shaft outside from the plastic box

For example, our first prototype which we manufactured has the following code:

FGR31006040

It means the following product description: Rotary gear limit switch for wind turbines, with encoder, gear ratio cams group 1:60, with n.4 microswitches, finally equipped by standard shaft.



Picture 3 –Rendering of FGR3 inner view the plastic box

- **Gear wheel and components specifications:**

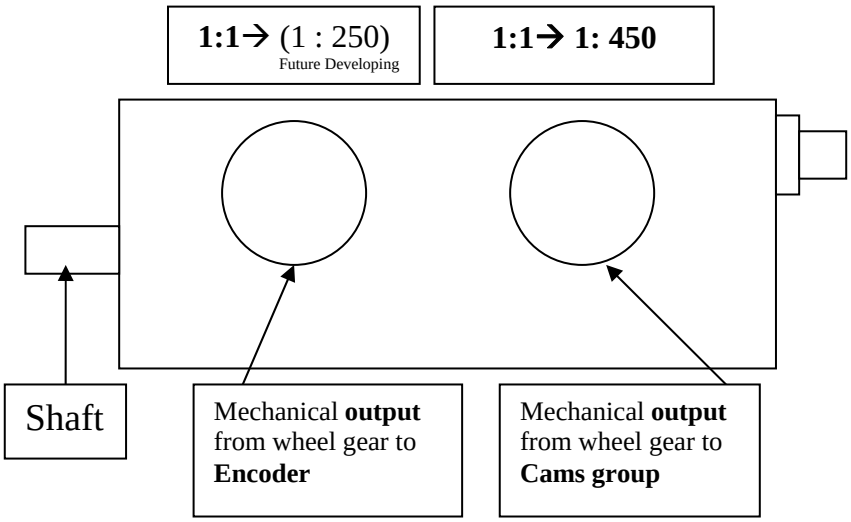
The main functionalities of our rotary gear limit switch are two;

- ✓ To monitor the position of the nacelle.
- ✓ To manage the safety issues of the nacelle in order to avoid the cables to get twisted.

About the gear wheel, it is possible to find different gear-ratios. For the most common items this ratios can be 1:50 1:100 or 1:150, but it some situations we can have different values (for instance ratio = 1:450 from wheel group to cams group, using "two steps" ratios). In general, we can manage this ratio according to the customer requirements. At the basis of the gear wheel, you find the bushing made by brass which receives the movement by the shaft and drive a set of thermo-plastic gear wheels which are responsible to mechanical drive to the encoder. Simultaneously, you find also the thermo-plastic screw wheels which are responsible to mechanical drive to the cams group.
The calculations for the gear-ratio (RE-shaft ro to cam-shaft) are shown in a separate file called "table ratio group.xls", you could see the ATTACHMENT n.02.

Picture 4 –Rendering of gear wheel inner the plastic box

Ratio in/output from the wheel gear group:
First of all, it here worth mentioning that the shaft receives the rotation movement from the external pinion coupled with the gear grill.



Picture 5: Ratio in/output scheme

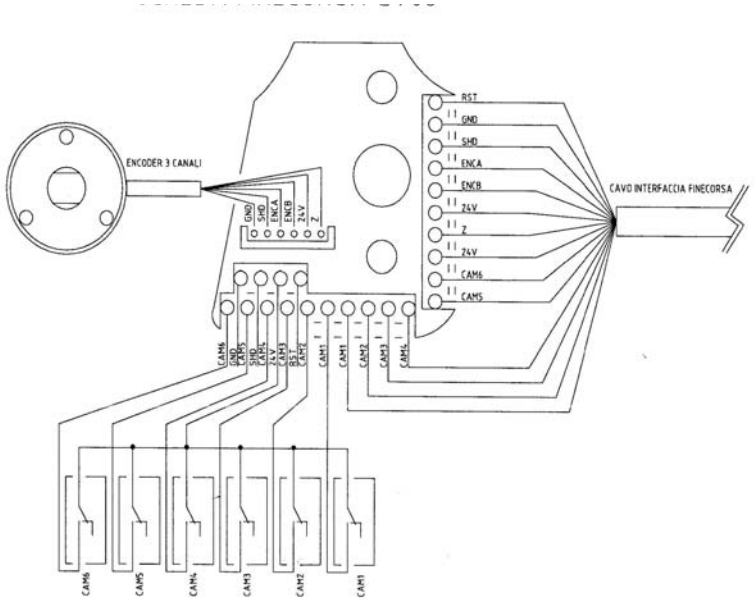
From Picture 4, it is evident the different gear ratios achievable from this product. More in detail, it is necessary to specify the different needs of component. Encoder needs very high values of precisions, therefore it is necessary to design a ratio = 1:1 (mechanical output from wheel gear to Encoder). However, if costumer needs different requirements, it is possible to modify this ratio till 1:250. Cams group does not need high precision but "commercial" precisions are enough. As a consequence, this product allows to achieve ratios till 1:450 (mechanical output from wheel gear to Cams group).

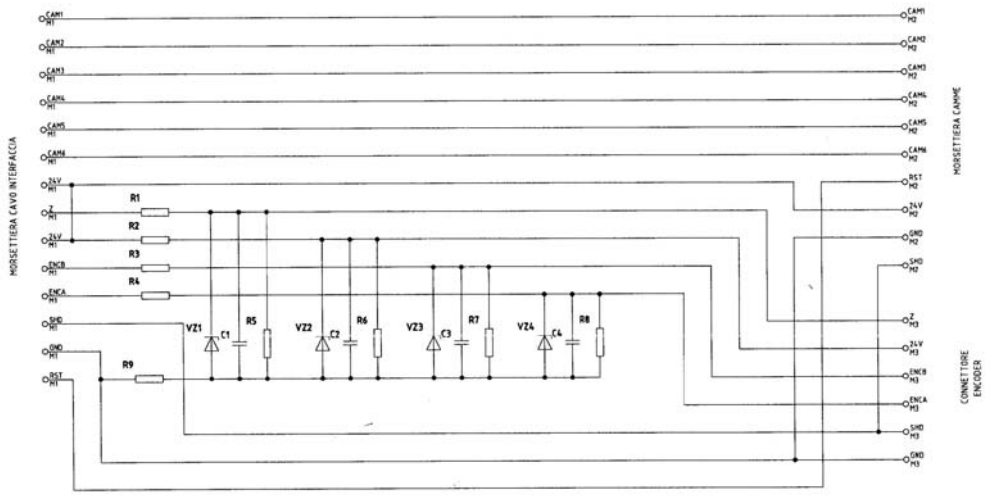
- **PCB boards and electrical components specifications:**

The encoder, which is the most important component of our product, aims at providing the precise position corresponding to max wind-power direction, overall gives a signal to measure the exact position of the nacelle which is done by the average of this incremental encoder built in our limit switch. The encoder allows to define the accurate position of the nacelle with a resolution of ± 1°. From common knowledge, the possibility to move the nacelle in the suitable direction should improve machine energy performance by 30%.
The optical encoder is connected to the stack of four cams in order to establish the rotation angle.
The resolution of encoder is determined by the pulse/Rpm, which depends of the sort of encoder required.
For Technical Data Sheet of the incremental encoder, please see the ATTACHED 02

Picture 6 –Rendering of the PCB boar and mini incremental encoder

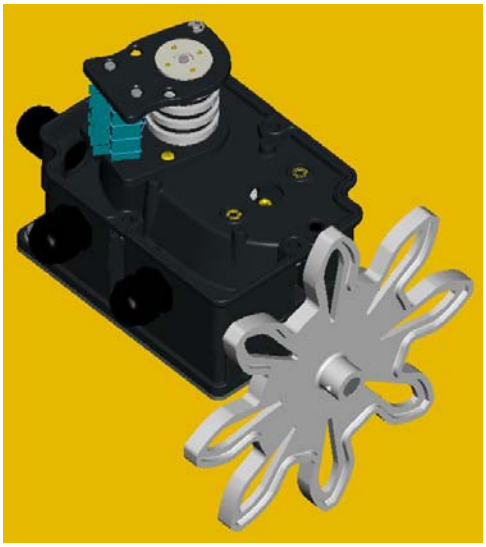
In this page the electrical connection schemes:





- **Cams group output, controller function specifications:**

Cables carry the current from the wind turbine generator down through the tower. The cables, however, will become more and more twisted if the turbine by accident keeps yawing in the same direction for a long time. The wind turbine is therefore equipped with a cable twist counter which indicates the controller that it is the time to necessary untwist the cables.
The four/six cams are adjustable relative to each other. Each of the four/six cams activates its own snap-switch (fast acting, forced-opening switches).



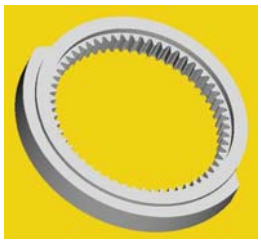
Picture 7 –Rendering of the cams group

We could equip different **n.5 sort of cams**:

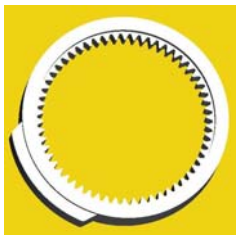
- Singular tip cam, Contact normally open (0 = deactivated). When activated (1 = activated), it indicates that the cables are twisted, CCW, while within another opposite cam you could control CW direction;

- Singular opposite tip cam, with one point is the opposite of the above mentioned singular cam;

- Cam tip 180 degrees which switches for 180 degrees of a full turn of 360 degrees;



- Cam tip 60 degrees which switches for 60 degrees of a full turn of 360 degrees;



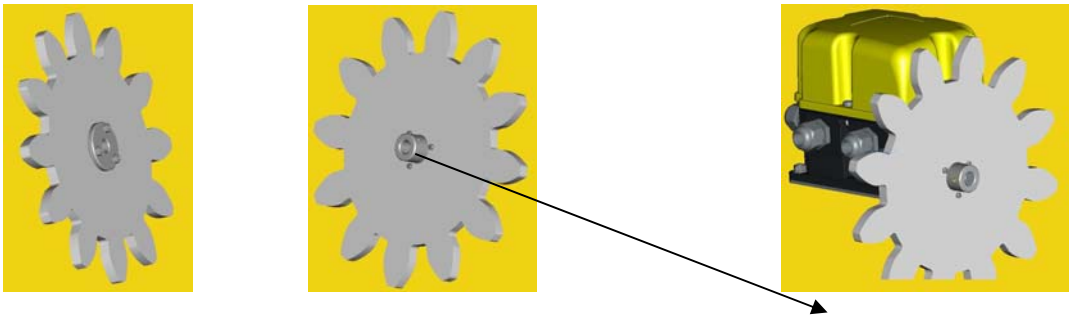
- Cam with n.10 tips whose purpose is to be sure that the control system is working well.

3. Pinions connected with the coupled wheel

The choice of the pinions is highly connected to the technical specifications of the coupled wheel. As a consequence, customer can choose the most suitable pinion between several ones we can propose. For the complete list of pinion, please see the following table:

GIOVENZANA'S CODE	DESCRIPTION	MATERIAL	Metal flange coupling
16020051	Pignone M20 Z12	PA66	added 16020050
16020052	Pignone M14 Z17	PA66	added 16020050
16020053	Pignone M22 Z10	PA66	added 16020050
16020054	Pignone M18 Z12	PA66	added 16020050
16020055	Pignone M16 Z13	PA66	added 16020050
16020056	Pignone M10 Z17	PA66	added 16020050
16020057	Pignone M6 Z13	PA66	added 16020050
16020058	Pignone M20 Z8	PA66	
16020059	Pignone M16 Z10	PA66	
16020060	Pignone M12 Z12	PA66	
16020061	Pignone M14 Z10	PA66	
16020062	Pignone M12 Z10	PA66	
16020063	Pignone M10 Z12	PA66	
16020064	Pignone M8 Z12	PA66	
16020065	Pignone M6 Z11	PA66	

Picture 8 –List of size pinions catalogued by module and number of teeth



Picture 9 –Sequence shown the pinions (worked by watercutting of the material) mounted with a metal flange

4. Steps of design

The main points to design this rotary gear limit switch had been the following three “must”:

- Max reliability and availability;
- Reducing the number of components but improving the quality of the materials
- Complete changeable with the products of our competitor already in the market.

It is moreover necessary to clarify that the design of the product has been carried on using modern design for reliability and availability techniques which allows to improve the equipment performance and its lifetime.
Finally, it is worth mentioning that the product has been submitted to a deepen FMEA process. In figure 2 you can see the format of FMEA worksheet used for the analysis of this product and also of other products produced by GIOVENANZANA INTERNATIONAL B.V. The FMEA is carried out in cooperation with Consorzio Intellimech and KilometroRosso Science and Technology Park (private led Technology Park founded mainly by owner of Brembo Braking Systems).

FMEA WORKSHEET Failure Mode & Effects Analysis

System	FGR3
Subsystem	FGR31006040
Lead	Ing. Luca Pedroncelli (Electra Engineering)
Core Team	R&D by Electra Engineering, Quality Department

Customer	GIOVENZANA INTERNATIONAL B.V.
RFC#	
Original Date	September 2009
Revision Date	November 2009

Code	Sub-System	1st Level	2nd Level	3rd Level	Potential Failure Mode	Potential Effects of Failure	S E V	Potential Causes	P R O B	Current Controls	D E T	R P N	Recommended Actions	Responsibility & Target Completi	Action Taken	S E V	P R O B	D E T	R P N

Picture 10 -FMEA Worksheet used in GIOVENZANA INTERNATIONAL B.V.

Basics of FMEA

A Failure Modes and Effects Analysis (FMEA) is a procedure in operations management for analysis of potential failure modes within a system for classification by severity or determination of the effect of failures on the system. It is widely used in manufacturing industries in various phases of the product life cycle and is now increasingly finding use in the service industry.

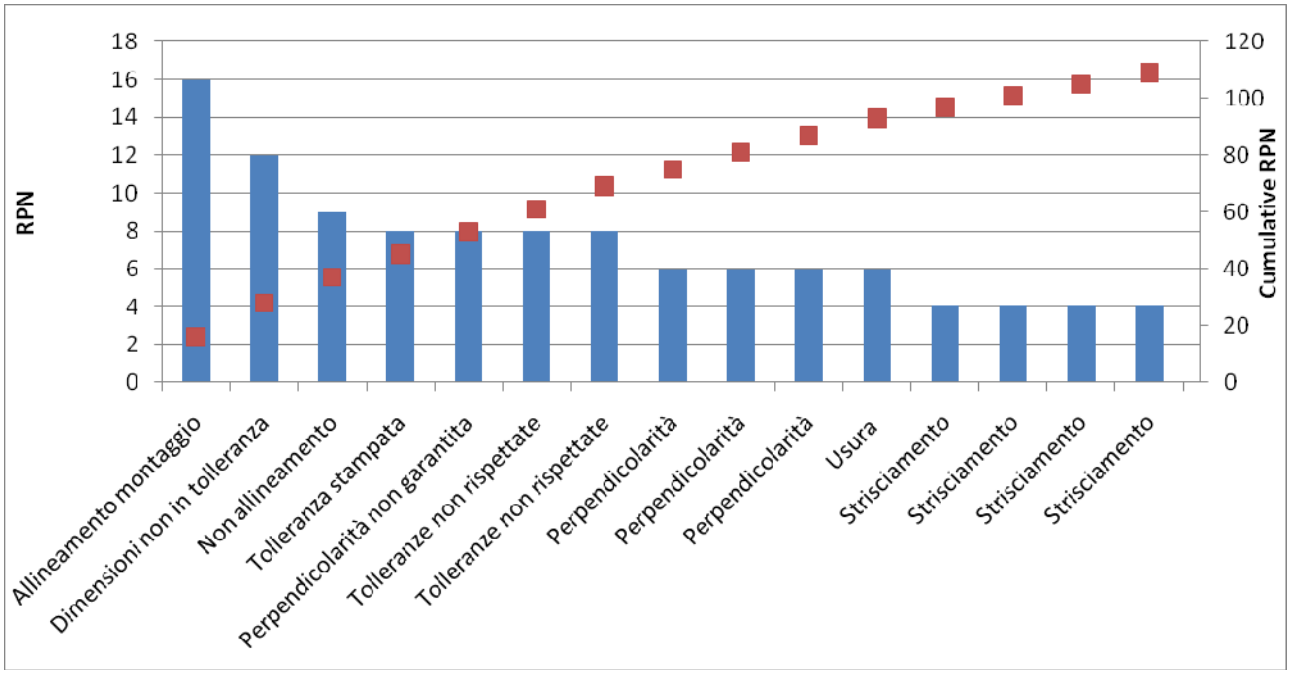
In FMEA, failures are prioritized according to how serious their consequences are, how frequently they occur and how easily they can be detected. An FMEA also documents current knowledge and actions about the risks of failures for use in continuous improvement. FMEA is used during the design stage with an aim to avoid future failures. In this context, the purpose of the FMEA is to take actions to eliminate or reduce failures, starting with the highest-priority ones. It may be used to evaluate risk management priorities for mitigating known threat vulnerabilities. FMEA helps select remedial actions that reduce cumulative impacts of life-cycle consequences (risks) from a systems failure (fault).

FMEA can provide an analytical approach, when dealing with potential failure modes and their associated causes. When considering possible failures in a design – like safety, cost, performance, quality and reliability – an engineer can get a lot of information about how to alter the development/manufacturing process, in order to avoid these failures. FMEA provides an easy tool

to determine which risk has the greatest concern, and therefore an action is needed to prevent a problem before it arises. The development of these specifications will ensure the product will meet the defined requirements.

FMEA Application

The product has been studied with the support of FMEA. The first step was to involve different departments in this analysis: quality, research and development, production. This allows to identify the all failure modes affecting the rotary gear box and is made possible to take actions both in design and in production phases in order to increase product reliability. In the following figure, it has been represented the results coming out from FMEA process with the identification of the most important criticalities of a product which have been discussed and solved with corrective actions.



Therefore, it is possible to conclude that FMEA has allowed identifying the key limits of the product and plan actions in order to overcome them. This contributes for the reliability of the product.

5. Mechanical characteristics

Overall dimensions
120X160X145h mm (obviously without pinion) with a weight about 1,5 Kg

Fixing
The product fixing has been developed by four holes to clamp a metal flange. This choice is due to the flexibility of the product since it can be changeable with the products developed by competitors manufacturer like:

- TER – Mod. GF4c
- STROMAG – Mod. Light-CAM

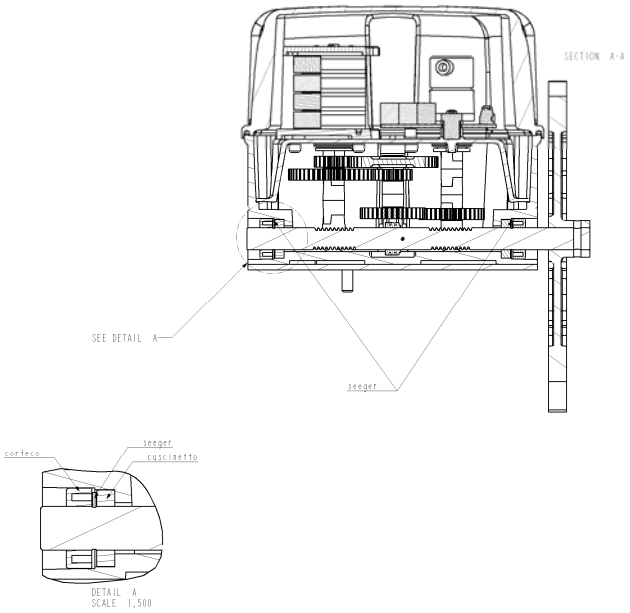
we refer to the holes distances of the flanges fixed under the plastic box and overall dimensions

Cables of the product
The product is equipped by N.3 cable exit with the cable-glande M20.

Waterproof
The limit switch is tested for IP66. This property is warranted by a rubber gasket of all perimeter on the coupling plane between the plastic black box and yellow cover and two “corteco” caps mounted on the side shaft holes. This product is frost smoke - resistant.

Mechanical stress
Max Rpm : 50rpm
Max radial force: 14N

The shaft is mounted with ball bushing



Picture 11 –Mechanical equipment for shaft within ball-bushing

6. **Quality standards**

Mechanical performance system

The life-test of the ratio wheel gear group and cams group: 1'800 h (75 days), like estimated as three time more the working life time, at the max working rotation speed in discontinuous working environment with highly critical temperature (range between -40°C to +90°C). The functionalities in such working conditions are achievable using the better thermo-plastic/techno-polymer materials self-lubricating. For **more details you could look the Attachment 03** of this document.
The product, with these characteristics, will work in extreme environmental condition with a 5 years warrant, excluding the microswitch (**Schaltbau)** and mini incremental encoder **(Scancon)**, which have the supplier commercial warrant.
Last but not least, as suggested by Deming cycle for continuous improvement, we perform six-sigma analysis in order to reach the best performance and zero-faults.

Checking List of inner tests planed:

The product we're testing for be sure of its reliability and availability over the 5 years, guarantee period for mechanical components. In order to design the tests, it is first of all necessary to focus the attention on the working conditions of the product. We can summarize the **Time and Environmental**, as follows:

- Working time: 20 min /day corresponding to (considering 365 days / year) = **122 h/year**
- Guarantee period life-test= 5 years
- Useful life of product to be guaranteed: **610 h**
- Speed = 50 rpm
- Operating temperature: from -40°C to +90°C
- Humidity condition: from 5% to 100% RH

Starting from this assumptions, two tests have been designed.

Test n° 1:
This first test is responsible of analysing the MTBF of the product. In particular, a set of product will be analysed. The test has the following characteristics:

- ✓ Speed rotation (CW) and (CCW)= 50 → 100 rpm (both with and without stoppages, equal to a discontinuous working);
- ✓ Working time: until the failure (in this way it could be possible to determine the MTBF of the product). However, we think that a test could be considered positive if product reaches a working time >> 610 h, means 25 days, to be guaranteed (approximately 2 or 3 times more)
- ➢ Statistical analysis for calculating product MTBF

Test n° 2:
This test is responsible of reliability / availability analysis. The test has the following characteristic:

- ✓ Speed = 50 → 100 rpm (both with and without stoppages, equal to a discontinuous working);
- ✓ Working time = 610 h, means 25 days. This is due to the fact we want to be sure about the reliability of this product during guarantee period.
- ➢ Statistical analysis using statistical techniques for establishing the reliability and how it changes during the time.

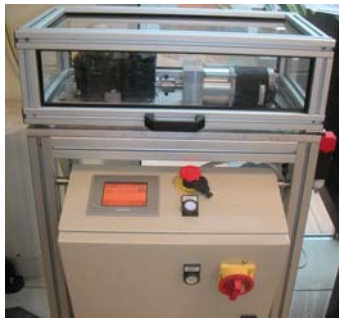
Checking List of tests planed by GIOVENZANA INTERNATIONAL B.V. :
After the quality check and control of all components with mechanical dimensions and internal tests, we're doing within our certified test-laboratory **INTEK S.p.A. which is an independent Laboratory, member of ALPI (Association of test laboratories and independent certification bodies), is quality certified according to standard EN 45001 ISO17025 is recognized by IMQ (Italian quality Mark Institute),** the following tests:

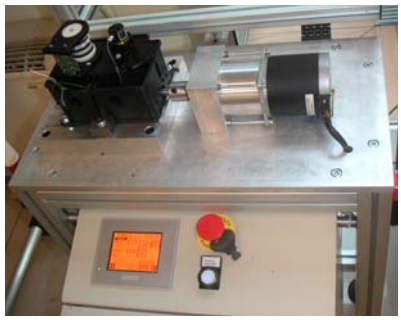
- Operating temperature: from -40°C to +90°C
- Humidity condition: from 5% to 100% RH
- Protection class: IP66 acc.EN60529
- EMC / Transient protection: Generic emission according with EN50081-1
  Generic immunity according with EN50082-2
- Vibration test: Sinusoidal vibration: IEC 60068-2-6
  Random vibration: IEC 60068-2-64

  Drop test: IEC 60068-2-32
  Shock test: IEC 60068-2-27
- The lifetime testing applying the above conditions of **Time and Environmental working.**

Both cycles are made in our laboratory with the climatic room and the product running with the dedicated machine like you see in the below pictures:

Picture 12 –Climatic room





Picture 13/14 –Machine to run the FGR3

The **preliminary test in our laboratory** were made by this test-machine, following a real running cycles like:

Product complete conditioning in climatic-room, n.6 hours -40°C.
After than we went ahead n. 50 cycles programmed as the following list:
CW rotation → 180 Rpm for 70 minutes
Pause with stop rotation 7 minutes TOTAL running time: **122 h 30'min**
CCW rotation → 180 Rpm for 70 minutes

Product complete conditioning in climatic-room, n.6 hours +90°C.
After than we went ahead n. 50 cycles programmed as the following list:
CW rotation → 180 Rpm for 70 minutes
Pause with stop rotation 7 minutes TOTAL running time: **122 h 30'min**
CCW rotation → 180 Rpm for 70 minutes

The touch-screen to set up the running cycles to submit FGR3

Picture 15 –Touch screen panel of the testing machine

7. Quality declaration standards and product's omologations

Omologation: CE, UL/CSA (US market), on request CCC, Ghost and RINA).

Giovenzana rotary gear limit switch for wind turbines will be applied the most updating laws like:

- Standard 2006/95/CE (Low tension)
- Standard 98/37/CE with reference to 2006/42/CE (Machinery Directive)
- Standard 89/336/CE with reference to 2004/108/CE (Directive electromagnetic compatibility)

Elenco di norme disponibili che possono essere usate per calcolare il "failure rate" (FIT) dei componenti.
IEC 60319, Presentation of reliability data on electronic components or parts
IEC 60300-3-2, Dependability management Part 3-2: data collection
IEC 60300-3-5, Reliability test conditions and statistical test principles
IEC 60050-191, International Electrotechnical Vocabulary (IEV) - Part 191; Dependability and Quality of service
IEC 60721-1 Classification of environmental conditions - Part 1: Environmental parameters and their severities
IEC 60706-3, Verification and collection analysis and presentation of data
IEC-62380-TR - Reliability Data Handbook - Universal model for reliability prediction of electronics components, PCBs and equipment.

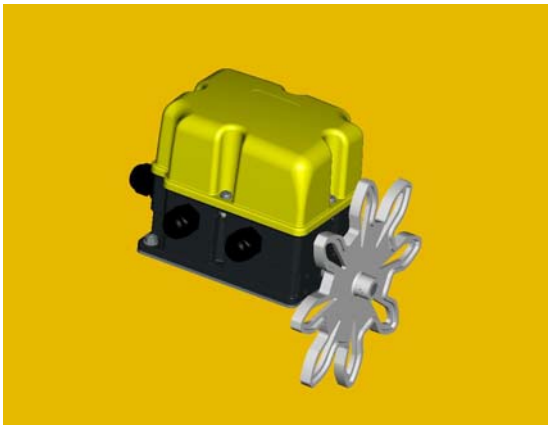
Known the FIT of each components we can calculate the MTBF following:
IEC 61709 Electronic components - Reliability - Reference conditions for failure rates and stress models for Conver
CEI EN 61124 (CEI 56-34): Reliability tests.

Further reliability laws
IEC 60605-6, Equipment reliability testing - Part 6: Tests for the validity and estimation of the constant failure rate and constant failure intensity
EN 60812 (CEI 56-1) – Analysis method for system reliability. Analysisi Failure Mode & Effects Analysis (FMEA)
CEI EN 61124 - CEI 56-34 – Reliability tests

ATTACHMENT 01

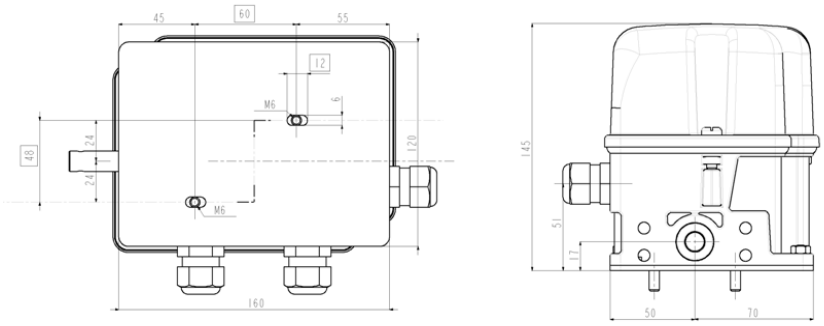
ROTARY GEAR LIMIT SWITCH FOR WIND TURBINES

TECHNICAL DATA SHEET FGR3



Specifications	Option of the FGR3
Weight:	appx. 1,5 Kg
Housing material:	Thermo plastic material
Shaft :	stainless steel shaft, 12mm diameter (AISI 304 INOX)
Ball bushing	
Pinion gear:	Options with different pinions n. 16 different size, from M6 to M22
Gear ratio:	Options for modular pinion gearwheels, range from 1:1 to 1:500
Internal helical gear:	Thermo plastic material auto-lubrificated to cams group and brass helical to encoder
Power supply	range 5-30VDC
Indipendent mechanical output	2 output
Max radial load :	14N
Start torque:	<0.01Nm
Max Rpm:	900 Rpm
Protection class :	IP66 acc.EN60529
EMC / Transient protection:	certified according with EN50081-1/EN50082-2
Vibrations:	(10-2000Hz)/10G
Bump:	10G-16ms (1000x3 Axis)
Enviromental temperature working:	From -40°C to +90°C
Enviromental temperature stockage:	From -40°C to +90°C
Fixing product:	Options equipped by different coupling flange
Mini shaft encoder incorporated in switch	
Durable electronic terminal board	
Possible direct connection to PLC	
Product certification	CE and UL

Sketch of the Mechanical dimension:



FGR3 has been producted with 3 output to be equipped by cable-glande M20.

The inner wires connection can be supplied with flange mounting connection follow the scheme in the table:

Connection / Terminals									
	CAM2	CAM1							
Shield	Reset	A sig.	Bsig.	24V	Ground	CAM4	CAM3	CAM5	CAM6
Terminal output for inductive sensor									
Shield	Ground	24V	Reset						

Main Specifications of mini-encoder

Output waveform	Incremental A, B, Z and inverted
Zero or index pulse	(Z) one pr./rev.
Supply voltage	Min 4.5V to max 30V Reverse polarity protection
Current (no load)	35 mA
Max load per output	20 mA
V out low	Max 500mV at current out low I=10mA
Operation Temperature	-40°C a +85°C
Storage Temperature	-40°C a +85°C
Max pulse frequency	200KHz
V out high	Min(Vin -0.6)@ I=-10mA Min(Vin -1.3)@ I=-25mA
Cable Data	5(0.14mm2)or 8-leads(0.005mm2)shielded
Max Rpm	(Max freq/pulses pr rev.)*60
Phase diff.	90° ± 20%
Duty cycle	50° ± 10%
Cable	5x0, 14mm2 shielded
Output signal	Standard, Inverted or differential
Certified acc.to:	EN50081-1 e EN50082-2

More details you could see in the Att.05

Connecting wire for encoder

Colour	wire	function
White	1	Ground.
Brown	2	24V
Yellow	3	B
Green	4	A
Shield	5	Shield

Main Specifications of microswitch

Weight appx.	12g
Contacts	Positive opening contacts according with EN60947-5-1
Contact material	Golden contact
Release force	Min. 0.4N
Actuating force	Max. 2.25N
Ith	6A
Terminal leads	Blade terminals quick-connect 6.3mm x 1 or 6.3mm x 2.5; DIN 46247
Operating temperature	-40°C to + 85°C
Protection class	IP40 IP00(terminals) according with EN60529
N. of micro/cams	Std. from 4 to 6

More details you could see in the Att.05

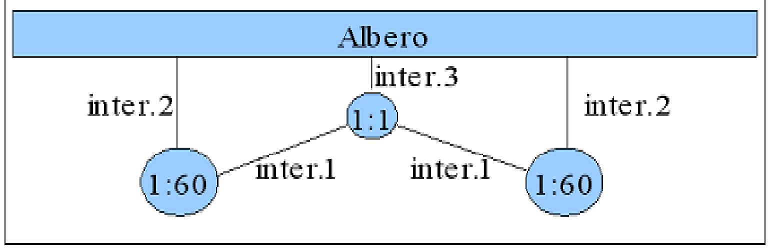
GIOVENZANA INTERNATIONAL B.V.

ATTACHMENT 02

ROTARY GEAR LIMIT SWITCH FOR WIND TURBINES
FGR3 **Table scheme of ratio gear wheel**

	Modulo	1					**50**	**49**	**48**	**42**	**40**	**36**	**34**	**32**	**28**	**26**	**20**	**19**	**18**
N°ruote	Z Pignone	D piede	D testa	Z Condotta	Riduzione		2,778	2,579	2,400	1,615	1,429	1,125	1,000	0,889	0,700	0,619	0,417	0,388	0,360
2	18	15,6	20	**50**	2,777778	2,778	7,716	7,164	6,667	4,487	3,968	3,125	2,778	2,469	1,944	1,720	1,157	1,077	1,000
3	19	16,6	21	**49**	2,578947	2,579	7,164	6,651	6,189	4,166	3,684	2,901	2,579	2,292	1,805	1,596	1,075	1,000	0,928
4	20	17,6	22	**48**	2,4	2,400	6,667	6,189	5,760	3,877	3,429	2,700	2,400	2,133	1,680	1,486	1,000	0,931	0,864
10	26	23,6	28	**42**	1,615385	1,615	4,487	4,166	3,877	2,609	2,308	1,817	1,615	1,436	1,131	1,000	0,673	0,626	0,582
12	28	25,6	30	**40**	1,428571	1,429	3,968	3,684	3,429	2,308	2,041	1,607	1,429	1,270	1,000	0,884	0,595	0,554	0,514
16	32	29,6	34	**36**	1,125	1,125	3,125	2,901	2,700	1,817	1,607	1,266	1,125	1,000	0,788	0,696	0,469	0,436	0,405
18	34	31,6	36	**34**	1	1,000	2,778	2,579	2,400	1,615	1,429	1,125	1,000	0,889	0,700	0,619	0,417	0,388	0,360
20	36	33,6	38	**32**	0,888889	0,889	2,469	2,292	2,133	1,436	1,270	1,000	0,889	0,790	0,622	0,550	0,370	0,345	0,320
24	40	37,6	42	**28**	0,7	0,700	1,944	1,805	1,680	1,131	1,000	0,788	0,700	0,622	0,490	0,433	0,292	0,271	0,252
26	42	39,6	44	**26**	0,619048	0,619	1,720	1,596	1,486	1,000	0,884	0,696	0,619	0,550	0,433	0,383	0,258	0,240	0,223
32	48	45,6	50	**20**	0,416667	0,417	1,157	1,075	1,000	0,673	0,595	0,469	0,417	0,370	0,292	0,258	0,174	0,162	0,150
33	49	46,6	51	**19**	0,387755	0,388	1,077	1,000	0,931	0,626	0,554	0,436	0,388	0,345	0,271	0,240	0,162	0,150	0,140
34	50	47,6	52	**18**	0,36	0,360	1,000	0,928	0,864	0,582	0,514	0,405	0,360	0,320	0,252	0,223	0,150	0,140	0,130

		Z	M	D primitivo
	RC	60	0,7	42
	Vite senza fine	1Princ	0,7	16,75
	Ingranaggi		34	inter.1
Interasse	RC-Albero		29,375	inter.2
	1:1		16,875	inter.3



ATTACHMENT 02

Ratio Gear wheel to output		
Reduction 1:1	**Rpm**	**60**
9		540
8,333		500
7,737		464,211
7,2		432
7,164		429,825
6,714		402,857
6,667		400
6,651		399,058
6,273		376,364
6,217		373,016
6,189		371,368
5,87		352,174
5,808		348,485
5,772		346,316
5,5		330
5,435		326,087
5,392		323,541
5,371		322,286
5,16		309,6
5,093		305,556
5,046		302,746
5,018		301,091
5,009		300,544
4,846		290,769
4,778		286,667
4,728		283,684
4,696		281,739
4,68		280,779
4,556		273,333
4,487		269,231
4,436		266,147
4,4		264

Ratio Gear wheel to output		
Reduction 1:1	**Rpm**	**60**
4,379		262,733
4,286		257,143
4,218		253,086
4,166		249,96
4,128		247,68
4,103		246,19
4,091		245,455
4,034		242,069
3,968		238,095
3,916		234,971
3,877		232,615
3,85		230,971
3,833		230
3,828		229,679
3,8		228
3,736		224,138
3,684		221,053
3,644		218,667
3,615		216,923
3,596		215,782
3,587		215,217
3,581		214,839
3,519		211,111
3,468		208,094
3,429		205,714
3,399		203,915
3,378		202,657
3,375		202,5
3,365		201,913
3,315		198,925
3,267		196
3,228		193,655
3,197		191,837
3,182		190,909
3,175		190,505
3,161		189,632

Ratio Gear wheel to output		
Reduction 1:1	Rpm	60
3,153		189,2
3,125		187,5
3,078		184,686
3,04		182,4
3,01		180,591
3		180
2,987		179,221
2,971		178,261
2,962		177,692
2,958		177,504
2,946		176,768
2,901		174,079
2,865		171,871
2,835		170,095
2,829		169,714
2,812		168,715
2,795		167,702
2,784		167,037
2,778		166,708
2,778		166,667
2,735		164,115
2,7		162
2,671		160,276
2,667		160
2,648		158,909
2,631		157,871
2,619		157,143
2,619		157,143
2,612		156,711
2,579		154,737
2,545		152,727
2,518		151,071
2,514		150,811
2,496		149,736
2,478		148,696
2,469		148,148

Ratio Gear wheel to output		
Reduction 1:1	Rpm	60
2,466		147,931
2,457		147,429
2,453		147,179
2,432		145,895
2,4		144
2,374		142,424
2,368		142,105
2,352		141,136
2,335		140,112
2,327		139,64
2,322		139,333
2,313		138,786
2,308		138,462
2,306		138,354
2,292		137,544
2,263		135,771
2,238		134,286
2,231		133,846
2,218		133,058
2,201		132,065
2,193		131,579
2,188		131,29
2,179		130,72
2,172		130,345
2,169		130,159
2,161		129,644
2,133		128
2,11		126,612
2,1		126
2,091		125,455
2,075		124,506
2,066		123,932
2,063		123,75
2,053		123,174
2,046		122,769
2,042		122,529

Ratio Gear wheel to output		
Reduction 1:1	Rpm	60
2,036		122,161
2,011		120,649
1,989		119,365
1,976		118,537
1,971		118,286
1,957		117,391
1,944		116,667
1,944		116,667
1,935		116,1
1,928		115,682
1,923		115,407
1,921		115,271
1,918		115,061
1,895		113,684
1,875		112,51
1,859		111,515
1,857		111,429
1,845		110,683
1,833		110
1,829		109,756
1,824		109,455
1,817		109,038
1,812		108,746
1,81		108,571
1,809		108,514
1,805		108,316
1,785		107,077
1,767		106,015
1,752		105,111
1,744		104,651
1,739		104,348
1,729		103,714
1,72		103,2
1,72		103,175
1,713		102,797
1,708		102,5

Ratio Gear wheel to output		
Reduction 1:1	Rpm	60
1,705		102,304
1,703		102,207
1,698		101,9
1,68		100,8
1,664		99,853
1,651		99,043
1,639		98,355
1,636		98,182
1,63		97,778
1,622		97,303
1,615		96,923
1,615		96,899
1,611		96,633
1,607		96,429
1,605		96,307
1,596		95,789
1,58		94,829
1,567		94
1,555		93,287
1,545		92,677
1,536		92,162
1,533		92
1,529		91,733
1,523		91,385
1,519		91,111
1,515		90,909
1,515		90,909
1,513		90,776
1,512		90,71
1,499		89,963
1,486		89,143
1,474		88,432
1,464		87,818
1,455		87,291
1,447		86,842
1,441		86,465

Ratio Gear wheel to output		
Reduction 1:1	Rpm	60
1,436		86,154
1,435		86,087
1,432		85,905
1,429		85,714
1,426		85,58
1,425		85,5
1,425		85,473
1,42		85,185
1,407		84,402
1,395		83,721
1,385		83,129
1,377		82,616
1,37		82,174
1,363		81,795
1,358		81,474
1,353		81,206
1,35		80,988
1,347		80,816
1,345		80,69
1,343		80,606
1,343		80,565
1,34		80,426
1,329		79,71
1,318		79,088
1,309		78,545
1,301		78,073
1,294		77,662
1,288		77,306
1,283		77
1,279		76,738
1,275		76,518
1,272		76,336
1,27		76,19
1,268		76,079
1,267		76
1,266		75,953

Ratio Gear wheel to output		
Reduction 1:1	Rpm	60
1,25		75
1,241		74,468
1,233		74,005
1,227		73,6
1,221		73,247
1,216		72,939
1,211		72,671
1,207		72,439
1,204		72,24
1,201		72,071
1,199		71,93
1,197		71,815
1,195		71,724
1,194		71,657
1,194		71,613
1,193		71,591
1,163		69,796
1,157		69,444
1,152		69,138
1,148		68,87
1,144		68,635
1,14		68,43
1,138		68,251
1,135		68,095
1,133		67,961
1,131		67,846
1,129		67,749
1,128		67,669
1,127		67,605
1,126		67,556
1,125		67,521
1,125		67,5
1,125		67,493
1,08		64,8
1,077		64,626
1,075		64,474

Ratio Gear wheel to output		
Reduction 1:1	Rpm	60
1,072		64,34
1,07		64,224
1,069		64,121
1,067		64,032
1,066		63,953
1,065		63,886
1,064		63,827
1,063		63,778
1,062		63,736
1,062		63,702
1,061		63,676
1,061		63,656
1,061		63,643
1,061		63,636
1		60
0,943		56,571
0,943		56,566
0,943		56,554
0,942		56,537
0,942		56,513
0,941		56,483
0,941		56,446
0,94		56,402
0,939		56,351
0,938		56,291
0,937		56,222
0,936		56,144
0,934		56,054
0,933		55,952
0,931		55,837
0,928		55,705
0,926		55,556
0,889		53,339
0,889		53,333
0,889		53,317
0,888		53,289

Ratio Gear wheel to output		
Reduction 1:1	Rpm	60
0,888		53,251
0,887		53,2
0,886		53,137
0,884		53,061
0,883		52,972
0,881		52,867
0,879		52,747
0,877		52,609
0,874		52,451
0,871		52,273
0,868		52,07
0,864		51,84
0,86		51,579
0,838		50,286
0,838		50,27
0,837		50,239
0,837		50,192
0,835		50,129
0,834		50,049
0,833		49,951
0,831		49,834
0,828		49,697
0,826		49,538
0,823		49,357
0,819		49,149
0,815		48,913
0,811		48,646
0,806		48,343
0,8		48
0,79		47,398
0,789		47,368
0,789		47,319
0,788		47,25
0,786		47,16
0,784		47,048
0,782		46,913

Ratio Gear wheel to output		
Reduction 1:1	Rpm	60
0,779		46,753
0,776		46,568
0,773		46,355
0,769		46,111
0,764		45,833
0,759		45,519
0,753		45,164
0,746		44,762
0,745		44,685
0,744		44,662
0,744		44,615
0,742		44,545
0,741		44,451
0,739		44,332
0,736		44,186
0,734		44,013
0,73		43,81
0,726		43,575
0,722		43,306
0,717		43
0,711		42,653
0,704		42,261
0,702		42,118
0,702		42,105
0,701		42,066
0,7		42
0,698		41,907
0,697		41,818
0,696		41,786
0,694		41,635
0,691		41,455
0,687		41,241
0,683		40,994
0,678		40,709
0,673		40,385
0,667		40,016

Ratio Gear wheel to output		
Reduction 1:1	Rpm	60
0,661		39,687
0,661		39,658
0,66		39,6
0,66		39,6
0,659		39,512
0,657		39,394
0,654		39,244
0,652		39,13
0,651		39,062
0,647		38,844
0,643		38,591
0,638		38,298
0,633		37,963
0,626		37,582
0,623		37,38
0,622		37,333
0,621		37,254
0,619		37,152
0,619		37,143
0,617		36,998
0,614		36,818
0,611		36,667
0,61		36,602
0,606		36,348
0,601		36,053
0,595		35,714
0,589		35,329
0,587		35,223
0,586		35,189
0,585		35,122
0,584		35,02
0,582		34,892
0,581		34,884
0,579		34,711
0,575		34,5
0,573		34,4

Ratio Gear wheel to output		
Reduction 1:1	Rpm	60
0,571		34,25
0,566		33,957
0,56		33,621
0,554		33,236
0,553		33,176
0,553		33,158
0,552		33,105
0,55		33,016
0,548		32,89
0,547		32,8
0,545		32,727
0,542		32,525
0,538		32,308
0,538		32,283
0,533		31,997
0,528		31,667
0,521		31,288
0,521		31,231
0,52		31,194
0,519		31,12
0,517		31,008
0,514		30,857
0,514		30,857
0,511		30,667
0,507		30,435
0,506		30,37
0,503		30,16
0,497		29,839
0,491		29,469
0,49		29,381
0,489		29,323
0,487		29,227
0,485		29,091
0,484		29,048
0,482		28,914
0,478		28,696

Ratio Gear wheel to output		
Reduction 1:1	Rpm	60
0,476		28,571
0,474		28,433
0,469		28,125
0,463		27,768
0,461		27,659
0,46		27,619
0,459		27,54
0,457		27,42
0,456		27,36
0,454		27,259
0,451		27,056
0,448		26,897
0,447		26,809
0,442		26,515
0,436		26,173
0,434		26,02
0,433		26
0,432		25,939
0,431		25,837
0,43		25,781
0,428		25,694
0,425		25,507
0,422		25,333
0,421		25,277
0,417		25
0,411		24,675
0,408		24,46
0,407		24,419
0,406		24,336
0,405		24,3
0,404		24,211
0,401		24,042
0,398		23,871
0,397		23,83
0,393		23,571
0,388		23,265

Ratio Gear wheel to output		
Reduction 1:1	Rpm	60
0,383		22,972
0,382		22,909
0,382		22,909
0,38		22,803
0,378		22,654
0,375		22,5
0,374		22,461
0,37		22,222
0,366		21,936
0,36		21,6
0,36		21,595
0,359		21,552
0,358		21,467
0,356		21,338
0,354		21,212
0,353		21,165
0,349		20,946
0,345		20,68
0,339		20,366
0,338		20,281
0,338		20,26
0,337		20,195
0,335		20,087
0,333		20
0,332		19,935
0,329		19,737
0,325		19,493
0,32		19,2
0,317		19,027
0,316		18,984
0,315		18,897
0,314		18,857
0,313		18,766
0,31		18,59
0,306		18,367
0,302		18,097

Ratio Gear wheel to output		
Reduction 1:1	Rpm	60
0,297		17,829
0,296		17,778
0,296		17,764
0,294		17,654
0,292		17,5
0,288		17,3
0,284		17,053
0,279		16,757
0,279		16,727
0,278		16,684
0,277		16,596
0,274		16,463
0,271		16,286
0,268		16,062
0,263		15,789
0,261		15,674
0,261		15,652
0,26		15,586
0,258		15,476
0,255		15,321
0,252		15,12
0,248		14,872
0,244		14,667
0,244		14,623
0,242		14,535
0,24		14,402
0,237		14,224
0,233		14
0,228		13,702
0,227		13,636
0,225		13,526
0,223		13,371
0,22		13,171
0,214		12,821
0,213		12,778
0,212		12,69

Ratio Gear wheel to output		
Reduction 1:1	**Rpm**	**60**
0,209		12,558
0,206		12,381
0,2		11,978
0,199		11,957
0,198		11,891
0,196		11,782
0,194		11,628
0,186		11,17
0,185		11,127
0,184		11,04
0,182		10,909
0,173		10,395
0,172		10,33
0,17		10,222
0,162		9,694
0,161		9,651
0,159		9,565
0,15		9,021
0,15		9
0,149		8,936
0,14		8,376
0,139		8,333
0,129		7,755
0,12		7,2
0,111		6,667

ATTACHMENT 03

ROTARY GEAR LIMIT SWITCH FOR WIND TURBINES
FGR3

Data table to compare with our most important competitors:

DATA TO COMPARE	**GIOVENZANA STRENGHT**		**COMPETITORS WEARNESSES**	
	FGR3		***TER***	***STROMAG***
RANGE T	+90	-40	+80 -40	+80 -40
TRASMISSIONE	Bushing		Bearing	Bushing
(dorati)	YES		NO	YES
IP	66		65	65
FIXAGE ADAPTABLE	YES		NO	NO
PINIONS	YES		YES	YES
CONNECTORS	YES		NO	YES
PROTECTOR	YES		YES	YES