Wind-Do inc.

CONTINIOUS AND MODULATED STIMULATION OF WIND TURBINES

ABSTRACT

THE SMALL AND MEDIUM WIND TURBINE HAVE SIGNIFICATIVELY LOWER EFFICIENCY THAN GIANT ONE. PERMANENT STIMULATION OF TURBINE WILL INCREASE THEIR ROTATION SPEED, MAKE THEM MORE EFFICIENT, AND MODULATE STIMULATION WILL OPTIMIZE THE ROTATION SPEED TO CURENT WIND PROFILE.

PATEN PENDING US 61/819,784

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FIELD OF THE INVENTION

[001] The present invention is related to the production of electricity with wind turbine. The disclose system allow a more efficient production of electricity for small and medium size apparatus. The system allows a better utilization of wind, considering that wind speed vary every second, especially when the turbine is not far from the ground. With permanent stimulation that is continuously adapted to the wind variation, the rotation speed of the turbine is always according to an efficient harnessing of the wind.

BACKGROUND OF THE INVENTION

[002] High-speed wind turbine (that used blade lift to harness wind) needs to be started to access sufficient rotation speed to be operational. There is different way to manage that process (gearbox, blades angle, etc..) that are base on same principle: The used of a motor/generator that supply energy to the turbine when wind speed is not enough to maintain rotation, and that switch its function to produce energy when sufficient wind speed is available. Very large wind turbines harness wind with a reasonable success, but smaller machine have very often poor efficiency due to their incapacity to harness in the same time the high and the low portion of wind speed that change every second.

[003] Wind turbines are tested in wind tunnel. If you test a turbine for a wind speed of 5 meters per second, you know that this wind have 77 watts of kinetic energy available per square meter. Base on those test, some will publish a power curve of their turbines that does not fit reality, sometime with huge difference. *On site, a wind of 5 m/s simply does not exist*. We always have to talk about an average wind speed of 5 m/s that could include a blend of 4, 5 and 6 m/s instant wind speed, and very often short periods at 2 or 8 m/s.

[004] As kinetic energy include in wind vary at the cube of its speed, we must calculate that an average wind speed of 5 m/s include more energy than a fix wind speed of 5 m/s. To make this evident, consider an average wind of 5m/s that is a blend of 50% wind of 2 m/s and 50% wind of 8 m/s. We then have a wind that have a kinetic energy of 50% x 5 watts + 50% x 314 watts = 159 watts per sq.m. A wind turbine that could harness 50% of the energy include in this wind pattern will produce 79 w/sq.m, which is more than the total 77 watts of energy include in a fix 5 m/s wind.

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SUMMARY OF THE INVENTION

[005] The present invention disclose the way to improve the harnessing of wind energy by computing all the very short term variation of speed it may include, and used this data to calculated a permanent and modulate stimulation to the turbine. This invention can be applying both for vertical or horizontal axis wind turbines.

[006] We will make the demonstration that physically separated the stimulation of the turbine and the harnessing of the energy will highly improve the overall efficiency of the wind turbine. In other words, we will show that wind turbines should have a separated motor and generator.

[007] We will also make the demonstration that the permanent stimulation of the wind turbine can and must be adapted and optimize for the wind profile of the moment. We will show how optimized stimulation can improve low wind harnessing; give quick response to wind gust; and improved overall electricity production.

[008] The present invention possesses numerous benefits and advantages:

[009] The installation of a permanent stimulation system on a wind turbine will increase the overall energy output of the apparatus.

[0010] In most configurations, the installation of a permanent stimulation system will favour the production of energy in low average wind period, increasing the overall availability of wind energy from a wind farm.

[0011] The stimulation of the turbine can be cancel when there is no used for it, mostly when average wind is to low for energy production, or when average wind is very high and stimulation become useless.

[0012] There is no used for a larger electricity generator for any wind turbine as stimulation motor will be cut when the apparatus is close to his nominal capacity.

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[0013] The programmable stimulation will favour a better synchronization within the capacity of the turbine and the one of the generator.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] In the appended drawings:

[0015] **Figure 1** is a graph that shows the efficiency of a wind turbine in function of the wind speed and the rotation speed of the turbine.

[0016] **Figure 2** is a graph that shows the energy production of a wind turbine in function of the wind speed and the rotation speed of the turbine.

[0017] **Figure 3** is a graph that shows the relation within the capacity of a wind turbine and his generator.

[0018] **Figure 4** is a graph that shows the relation within the capacity of a wind turbine and another generator that favor low wind.

[0019] **Figure 5** is a graph that shows the relation within the capacity of a wind turbine and another generator that favor high wind.

[0020] **Figure 6** is a graph that shows the relation within the capacity of a wind turbine and his generator with a 50 watts stimulation.

[0021] **Figure 7** is a graph that show the relation within the capacity of a wind turbine and his generator with a 80 watts stimulation.

[0022] **Figure 8** is a graph that show the relation within the capacity of a wind turbine and his generator with a 150 watts stimulation.

[0023] **Figure 9** is a graph that show an example of instant wind speed at every second for 2 minutes.

[0024] **Figure 10** is a sketch of few possible embodiments of turbine – motor – generator that allow permanent turbine stimulation.

DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0025] *The efficiency of a wind turbine highly depends on the power synchronism within the turbine and the generator.* The relation within the rotation speed and the power production is relatively linear for the generator; this is not the case for the turbine.

[0026] **The figure 1** shows some efficiency curves for a specific wind turbine. The power production of a turbine is related to its rotation speed, which result of the torque that is induce by the lift effect of the blade minus the drag force produce by the resistance of the air to the movement. The curve of efficiency for a 3 meters per second wind show the more clearly that at a low rotation speed, the lift force do not inducing enough torque, and, on the other end of the curve, that the drag force eventually overcome the torque, and the efficiency become negative. The curve for a wind of 7 m/s show also that low rotation speed can induce negative efficiency.

[0027] Still in **figure 1,** we can see that the turbine of our presentation have different productive zone in function of wind speed. For wind of 3 meters per second, the turbine have efficient production between 8 to 17 radians per second. From 11 to 30 rad/s for wind of 4.5 m/s, from 14 to more than 30 rad/s for wind of 6 m/s, and above 18 rad/s for wind of 7.5 m/s. We also notice that at some points, there is very low or negative efficiency.

[0028] On **figure 2**, we have a more pertinent information that show the power curves of the turbine in function of the wind speed and the rotation speed of the turbine. *Those measurements are in a*

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relation with our vertical axis prototype of rural wind turbine that face 1.25 sq.m. of wind. Other turbines will present different curves that will also fit our innovation. The first information we will note is the difference of energy production within low and high wind. For this turbine, the peak production for a wind of 3 m/s will be 11 watts, but it will reach 190 watts with a wind of 7.5 m/s. This mean that one second of good production of electricity at 7.5 m/s worth 17 seconds of electricity production at 3 m/s.

[0029] **The figure 3, 4 and 5** present the same power curves in relation with different generators. The relation within power production and rotation speed is relatively linear for a generator. The three figures may represent the same generator with different gearbox, or direct drive generators adapted for different situations.

[0030] The generator show in **figure 3** can be consider as a compromise within low and high wind speed. The system will tend to reach an equilibrium within the power deliver by the turbine and the power produce by the generator. This equilibrium is reach at the junction of the two power curves. When the power output of the turbine is above the power used by the generator, the turbine will accelerate and the power output will increase. On the other side, if the power of the turbine for a specific rotation speed is lower that the one of the generator, the speed of the turbine will decrease. With the actual technology, the set point of the generator (the rotation speed where it's switch from generator to motor) make sure that the turbine always have enough rotation speed to used wind when his there. Intelligent wind turbine will have a variable set point in function of the average wind.

[0031] Still on **figure 3**, we can see that with a wind speed of 3 m/s, the equilibrium within the turbine and the generator is around 6.5 rad/s. At this point, our wind turbine will produce +/- 8 watts, which is not his most efficient point. This set up is not efficient for a wind of 4.5 m/s. the power of the turbine is relatively even with the one of the turbine within 6 to 8 rad/s. At this point the system produce less than 20 watts, which is half of its potential. Wind of 6 m/s is also a problem as the system is only operational within 9 and 12 rad/s. This mean there is no natural transition from a wind that change from 4.5 m/s to 6 m/s. To be able to used the machine with wind of 6 m/s or above, the set point of the motor should be 9 rad/s, which mean we have to abandon the electricity production for wind bellow 6 m/s. If the system reach 12 rad/s, the machine produce +/- 65 watts, which is closer to his 85 watts potential. If wind of 7.5 m/s appear, the set point of the motor need to be adjusted to 10 rad/s. At this level we still can use with success a wind of 6 m/s, and we can reach the full potential of the system at 28 rad/s, which is a relatively high speed of 6 rotations per second.

[0032] Consider now **figure 9** that is a graph of instant wind speed over 2 minutes. Those numbers come from real measurements on site. The average wind speed is 4.4 m/s that theoretically include 52 watts of power per sq.m. (65 watts for our turbine example of **figure 3**). In reality, the average power is 76 watts per sq.m. If you establish the set point of the motor at 10 rad/s, in order to be able to used the high wind, you will produce electricity 25% of the time, and used a small amount of it for the rest. The average output will be low, and difficult to use directly with the grid.

[0033] Consider now **figure 4** that is an arrangement generator/turbine that favour lower wind. We can see on power curve that there is always a rotation speed that favour transition within 3, 4.5 and 6 m/s wind, and most important we can reach the full potential of the turbine for common wind of 4.5 and 6 m/s. The problem with this configuration is the use of high-energy wind. On standard wind farm site, 85% of the energy produced come from wind above 7 m/s, this high wind is hardly used to his potential with that configuration due to extreme rotation speed require.

[0034] Configuration of **figure 5** present an arrangement that favour high wind. In this case we will have strong productivity for wind above 7 m/s, which will provide much more Kwh then previous arrangements. The problem with that configuration is that it will provide only high power on small period and no energy most of the time, which is unacceptable for the grid, or even for off grid locations. On wind profile of **figure 9**, this system will provide high energy only in two spots of 3 and 5 seconds over a period of 2 minutes.

[0035] The presentation from **figures 3, 4 and 5** explain why present technology of small and medium wind turbines result in a much less efficient electricity production than large one. The end of the blade of giant wind turbine always run at high speed (+/- 200 Km/h), this speed cannot be reach by smaller engine. The giant wind turbine are sophisticated apparatus that also adjust the pitch of its blades to optimize wind harnessing in function of its speed. This kind of flexibility is not available at reasonable cost for the smaller engines.

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[0036] **Figure 10** present different embodiments of the present invention. The examples **A, B and C** introduce some mechanical solutions base on our discovery. Other arrangements are possible and will still be base on our innovation. In all examples, **51** is the turbine that harness wind, **52** is the generator that produce electricity, and **53** is the motor that stimulate the system.

[0037] Still in **figure 10,** the permanent stimulation of the system is provide by the motor **53**. This motor wills received power supply by a variable power source that is controlled by a computer. The system will continuously analyze the wind profile for optimization, and adapt the power supply for stimulation.

[0038] Still in **figure 10,** the motor **53**, the generator **52**, and the turbine **51** are linked and work together. This link could be direct, like in **example A**, or indirect like in **example B**. In all cases, the motor **53** stimulate both the turbine **51**, and the generator **52**. The energy supply by the motor **53** can be used for three purposes: The friction of the system; the resistance of the turbine to turn at higher speed; and the production of more power from the generator due to the increase of rotation speed of the system. The motor do not added friction lost to the system and this data will not be computed. In most case, the increase of rotation speed will induce an improvement on turbine efficiency, which is the purpose of this invention. No lost of power will be computed for that function. This mean that all the energy supply by the motor **53** will be transfer to the generator **52**. The only energy lost of this operation is then the efficiency of the two apparatus. Both motor and generator fabricants claim efficiency from 95 to 98% for their engines. We will count an energy lost of 10% of the energy supply thru the system by motor **53**, knowing that we have high probability of smaller lost.

[0039] Still on **figure 10**, the **example C** show a separated motor **53** and generator **52** that are imbedded in the same housing.

[0040] **Figure 6** show the power curves of our 1.25 sq.m. wind turbine with a fixed stimulation of 50 watts. The computation is simple, we have the same generator, and we increase the power supply by the turbine by the 50 watts of the motor.

[0041] Still on **figure 6**, we can see that with a wind of 3m/s and a 50 watts stimulation, the system will stabilize at 10 rad/s. At this rotation speed, our turbine will produce 3 watts more if we

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compare to the unstimulated system of **figure 3**. If we consider the lost of 10% on stimulation, which is 5 watts, we have a net result of minus 2 watts. With a wind of 4.5 m/s, our system will stabilize at 11 rad/s, which will end with a gain of 12 watts for the turbine, and 7 watts net. *What is important to remark here, is the energy available for the transition within a wind of 3 m/s and a one of 4.5*, this with only one rad/s in rotation increase to reach the new equilibrium. Wind of 6 m/s will stabilize at 13 rad/s with a gain of 30-5=25 watts **(or 60%),** here again with easy transition. The 7.5 m/s wind will also reach its peak, but with a net loss of 5+5 watts. The important point here is the fact that we do not have to sacrifice the low wind to access the high-energy wind, which is an overall important gain.

[0042] Back on **figure 9**, we see that we have very often rapid transition from low to high wind. For example, at time 14 we pass from 3.4 to 6 m/s in only one second, at time 38, from 1.9 to 6.9 m/s in 6 seconds… Back on **figure 6**, we can see that transition within low and high wind have low torque at the very beginning. This low force have to overcome the inertia of the system to reach the new equilibrium rotation speed, which mean many seconds without the full power, and maybe the end of the wind gust before we reach it.

[0043] Consider now the **figure 7** that show the same graph with a stimulation of 80 watts. For a wind of 3 m/s, the turbine will stabilize at 12 rad/s. If we compare to the 50 watts stimulation of **figure 6**, it's a net loss of 3 watts as turbine produce the same energy but stimulation now cost 8 watts. This stimulation level is better for wind speed of 4.5 and 6 m/s as they both reach their best efficiency level. For a wind of 4.5 m/s, this is only a net gain of 1 to 2 watts, but for wins of 6 m/s, the gain is 16-18 watts **(or 25% above the 50 watts stimulation that already present 60% incensement).**

[0044] Still on **figure 7**, if we consider the wind of 7.5 m/s, there is a small gain at equilibrium that compensate the cost of additional stimulation. The important improvement here is the potential of transition from low to high wind with efficiency. If we consider the case of a rapid wind transition between winds of 3 to 7.5 m/s, *we have 350% more torque at the beginning*, if we compare to the 50 watts stimulation. This mean that more or less, we will transit from a production of 11 watts to the production of 190 watts of electricity in one third of the time. *As wind gust generally last only few seconds, this may mean an enhancement of more than 100% of the energy production for that short period*. We can see that transition within wind of 4.5 or 6 m/s to 7.5 m/s will also be shorten with a 80 watts stimulation.

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[0045] Base on information's collect on graphs of **figure 6 & 7**, we can estimate that a stimulation of 50 watts will be more productive if wind profile include only wind of 3 to 4.5 m/s. With a wind that include gust of 6 or 7.5 m/s, a stimulation of 80 watts will be more profitable.

[0046] Consider now **figure 8** that show an important stimulation of 150 watts. With a potential stimulation cost of 15 watts and a torque that will only induce 11 watts with a wind of 3 m/s, we start with the sacrifice of all wind under 3.3 m/s. The advantage of that stimulation is the extreme flexibility for the transition from a lower to a higher wind speed. *From 3 to 4.5 m/s, 4.5 to 6 or 6 to 7.5, we already have the maximum torque of the new wind speed to reach the new equilibrium point.* Even if we jump from 3 to 7.5 m/s wind, we start with 75% of the torque of the high wind. By shorten all transition to higher wind speed, we increase the overall output of a wind profiles that include a good proportion of high energy wind.

[0047] Permanent modulated stimulation of wind turbine mean that the stimulation will vary in order to achieved the best possible efficiency of the apparatus. There is many ways, algorithms or computations that could produce stimulation patterns for the system, they are all subordinate to the present invention.

[0048] We can classify the optimization process of the stimulation of wind turbine in two categories: **1-** We can fix an optimal level of stimulation base on the analysis of the recent wind profile, and continuously re-evaluate this stimulation level after a period of time. This system will be call step stimulation. **2-** We can used a network of detectors around the wind turbine and predict every wind gust. The stimulation is then adjusted in real time to maximize the utilization of every breath of wind.

[0049] The step stimulation will start with a compilation on the wind speed that received the turbine for the last 2 or 5 minutes. This pattern, like the one of **figure 9**, will be used by the computer to calculated the best level of stimulation that could have been used for what append in that period. Knowing all the characteristics of the system, the computer will apply several stimulation level to the wind profile and simulated its effect on net energy production. The computer choose the best solution and apply it to the system.

[0050] Step simulation can work with many times ranges. For example, the stimulation level can be adjusted every minute or every 15 seconds. The speed profile can cover the last 2 or 5 minutes, but it may also be moderate by data from the last 10 minutes or 2 hours. This calculation is relatively simple, it thus can be achieved by a smartphone that could also received external weighting, for example from climate station.

[0051] Real time optimization of the stimulation work differently. Instead of computing on the recent history of wind profile, we try to predicted what's coming with a network of detectors. The real time optimization compute the actual characteristics of the system (wind speed, rotation speed of the turbine, actual stimulation…) and the knowledge of what will be the wind speed in the next 5 or 10 seconds. From there, the computer calculate several short term variations of stimulation to push the rotation of the turbine at appropriate speed to received the wind. Optimization come from the best net energy output for this very short period to come.

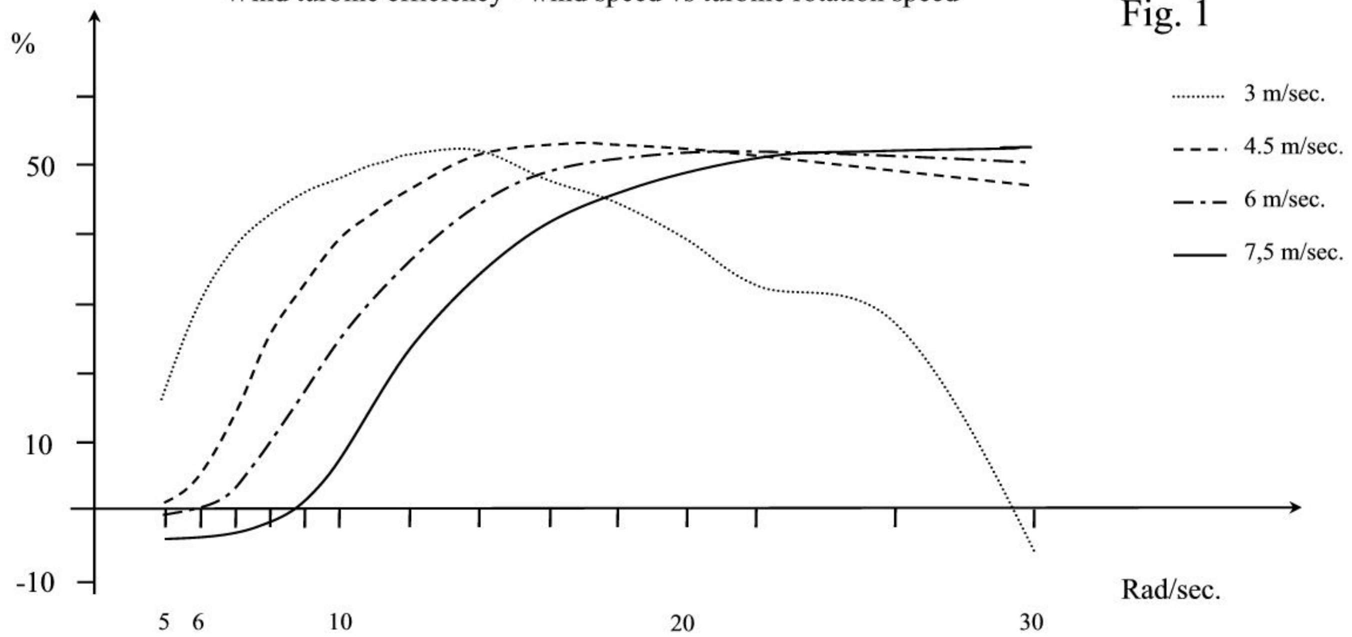
[0052] Real time optimization will be more efficient, but it's need an infrastructure that fit more a network of wind turbines than a single installation.

Conclusions:

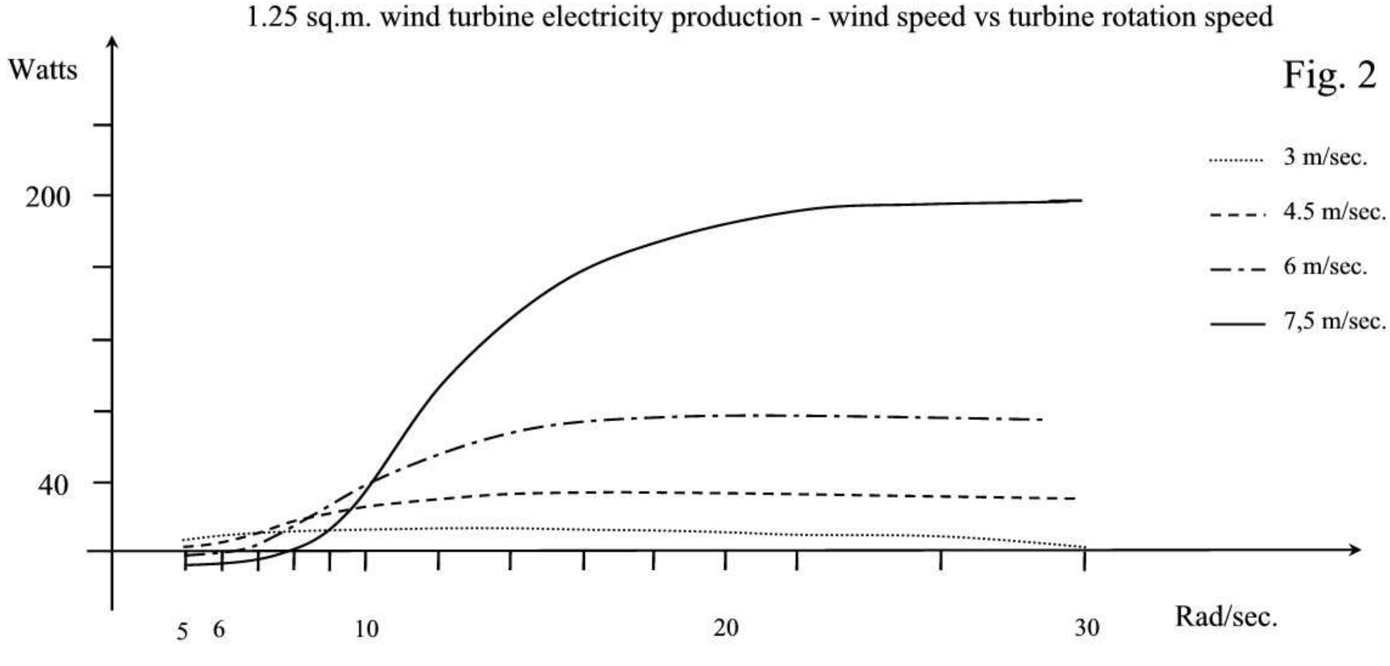
Permanent and optimised stimulation of small and medium wind turbines that used the lift effect will open a new age of efficiency for that class of equipment. As the rotation speed of the turbine will always be optimise for the current wind profile, transition within very short-term wind variation will be efficient, and high energy of wind gust will be harness in large proportion.

There is significatively more energy available in wind than what is suggesting by wind average. Apply to the Wind-Do rural wind turbine, optimise stimulation may push the efficiency of the apparatus up to 60% harnessing of average wind measurement, which still is only 45% efficiency on instant wind speed.

Wind turbine efficiency - wind speed vs turbine rotation speed



1.25 sq.m. wind turbine electricity production - wind speed vs turbine rotation speed



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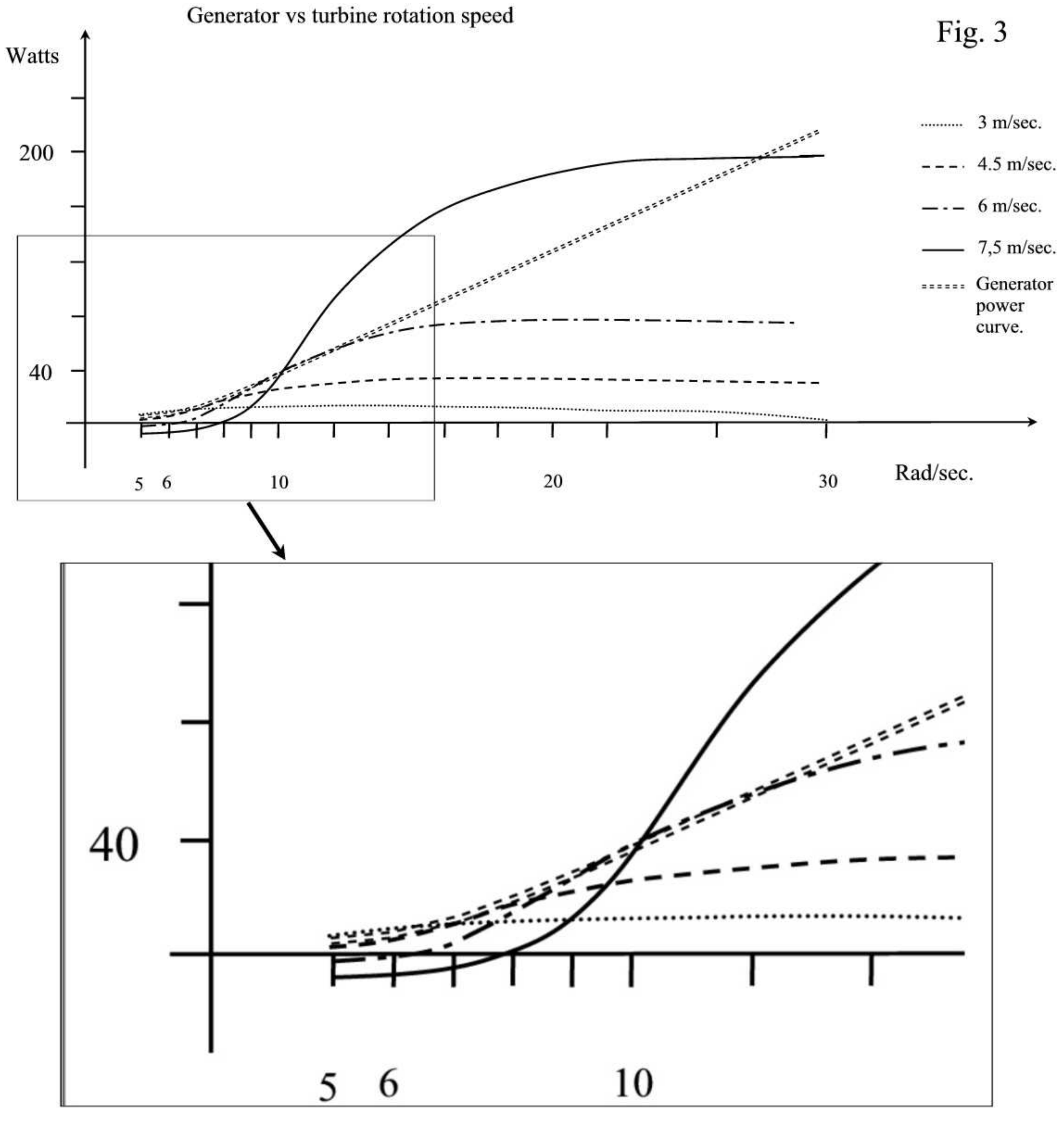
Generator vs turbine rotation speed
Fig. 3
Watts
200
40
3 m/sec.
4.5 m/sec.
6 m/sec.
7,5 m/sec.
Generator power curve.
5
6
10
20
30
Rad/sec.
40
5
6
10

Generator vs turbine rotation speed

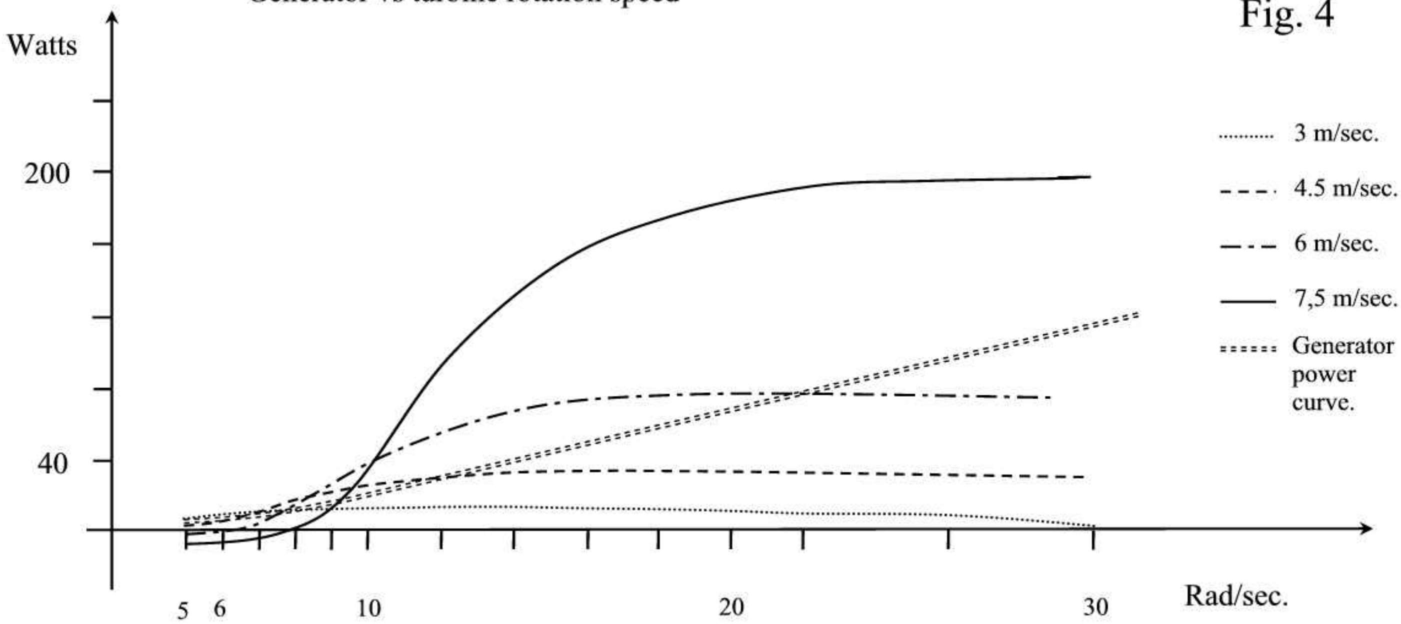

Fig. 4

Generator vs turbine rotation speed

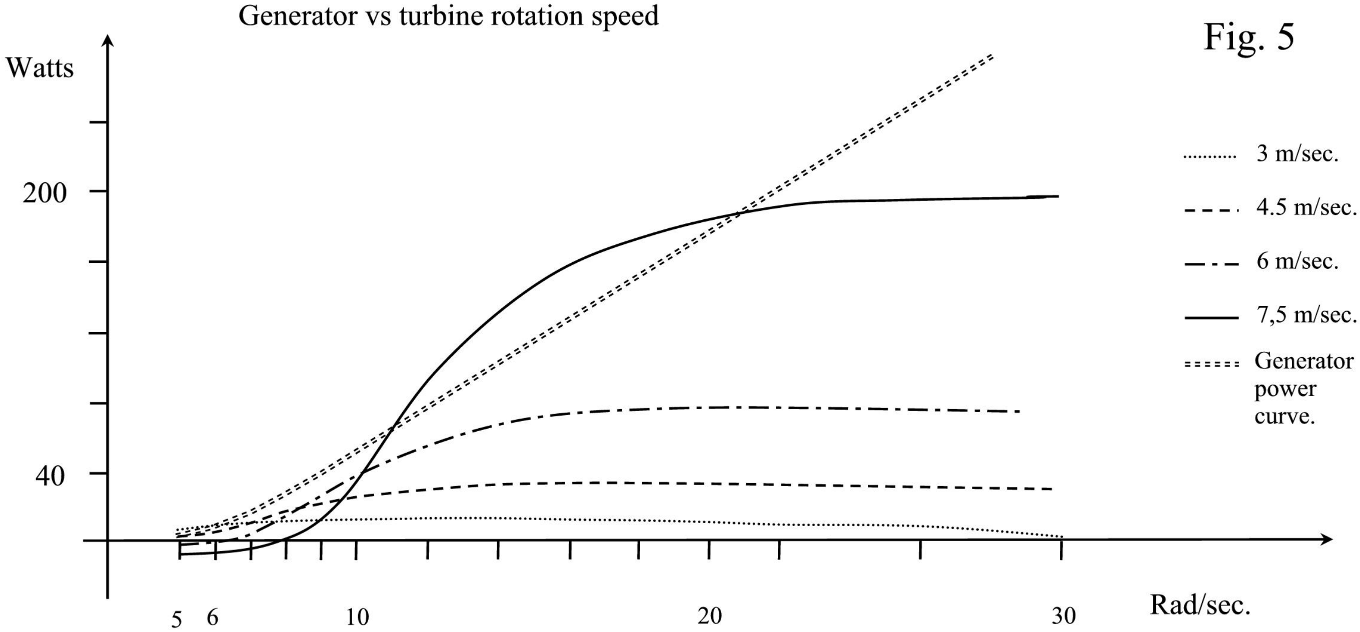

Fig. 5

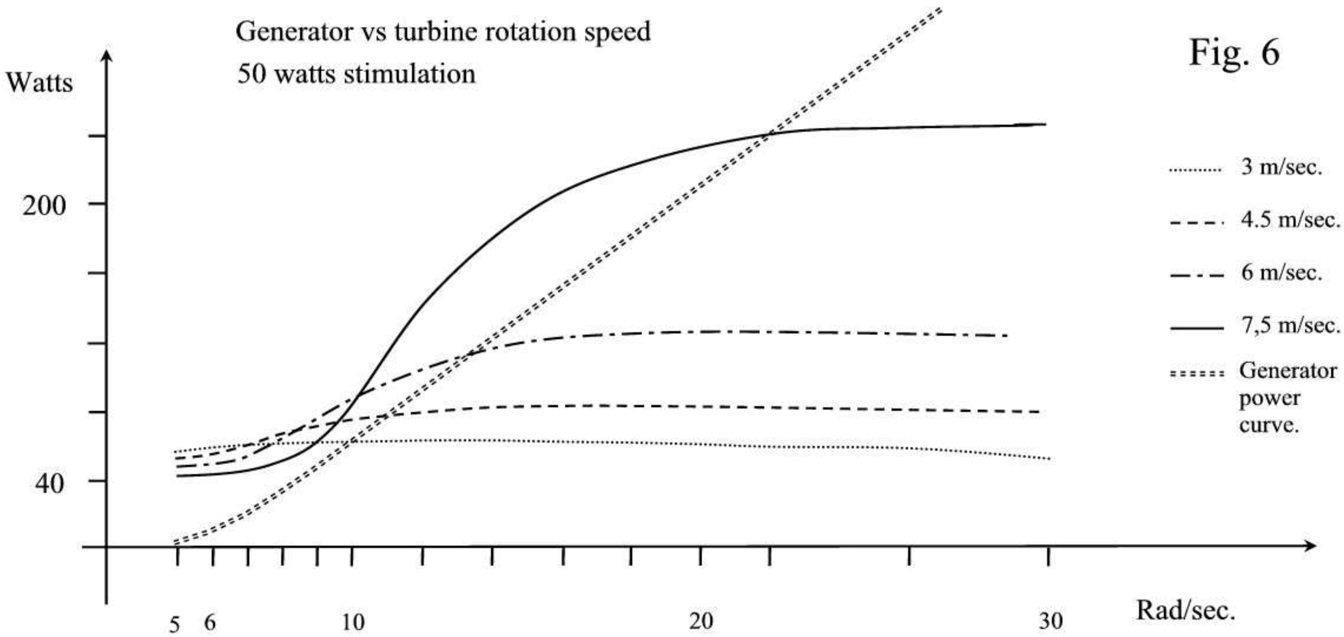
Generator vs turbine rotation speed
50 watts stimulation
Watts
200
40
5
6
10
20
30
Rad/sec.
3 m/sec.
4.5 m/sec.
6 m/sec.
7,5 m/sec.
Generator power curve.

Fig. 6

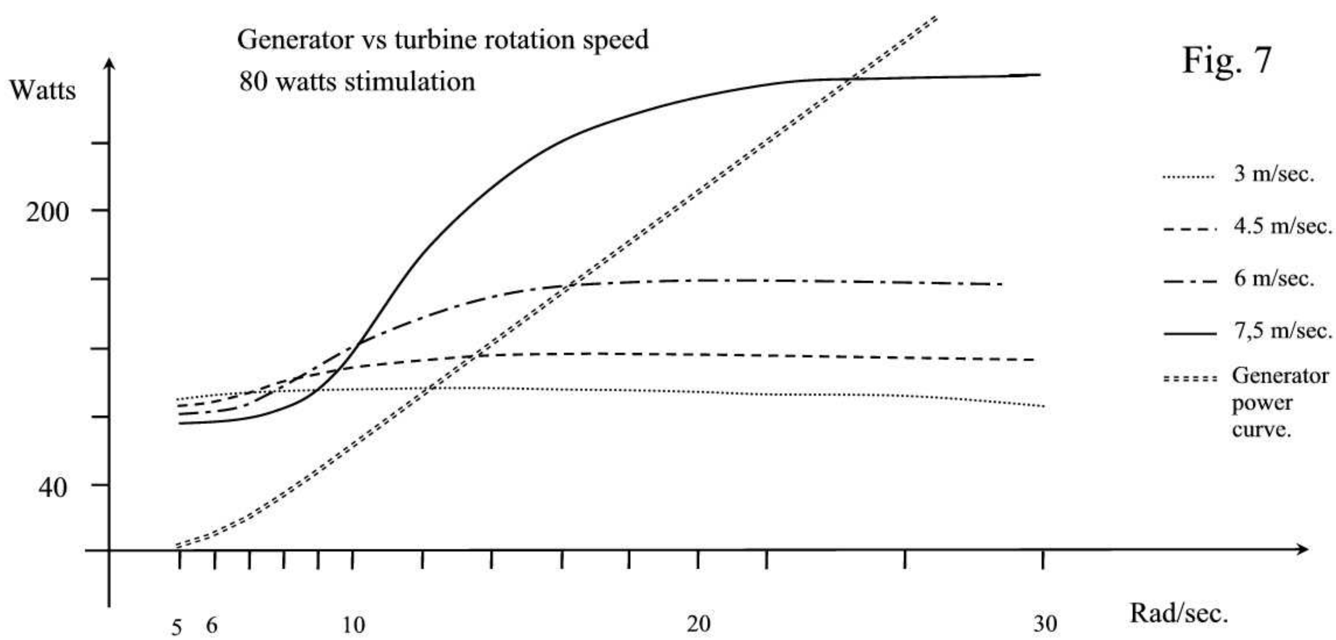
Generator vs turbine rotation speed
80 watts stimulation
Watts
200
40
5
6
10
20
30
Rad/sec.
3 m/sec.
4.5 m/sec.
6 m/sec.
7,5 m/sec.
Generator power curve.

Fig. 7

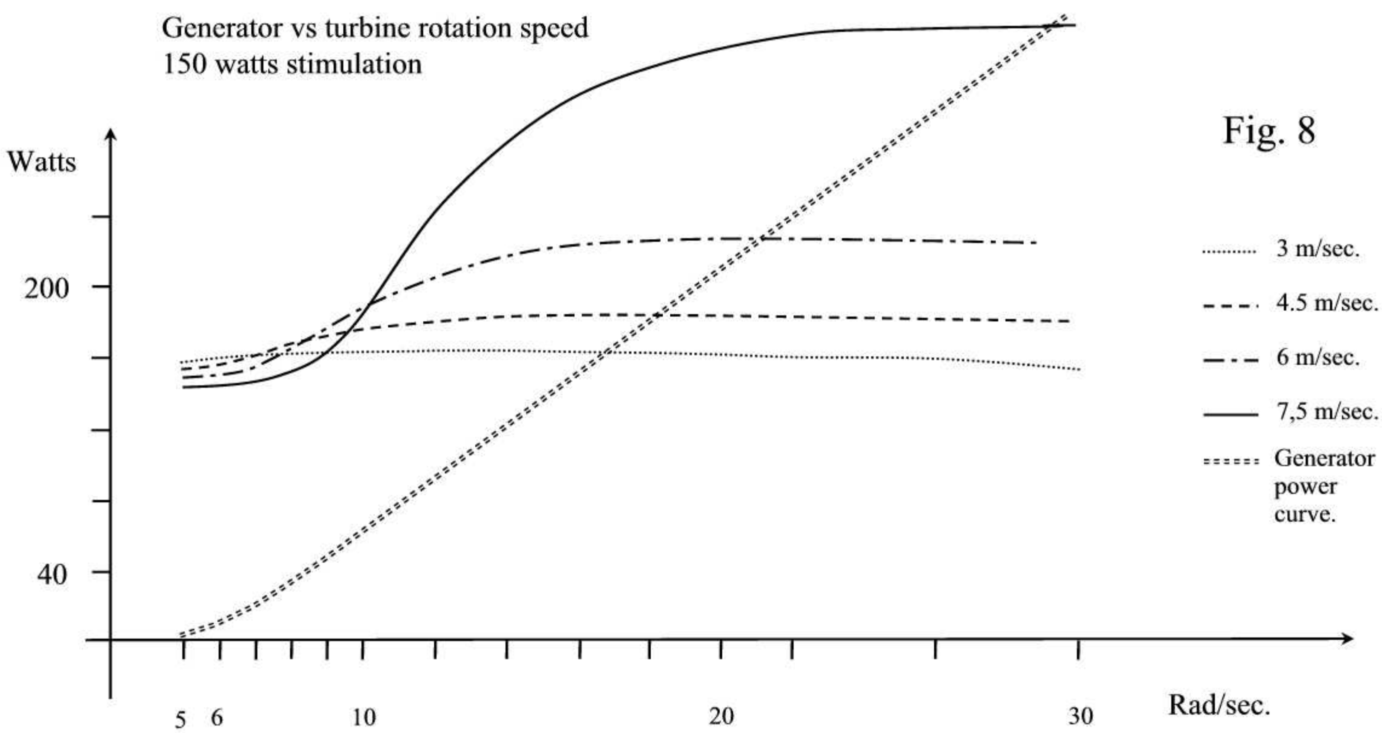

Fig. 8

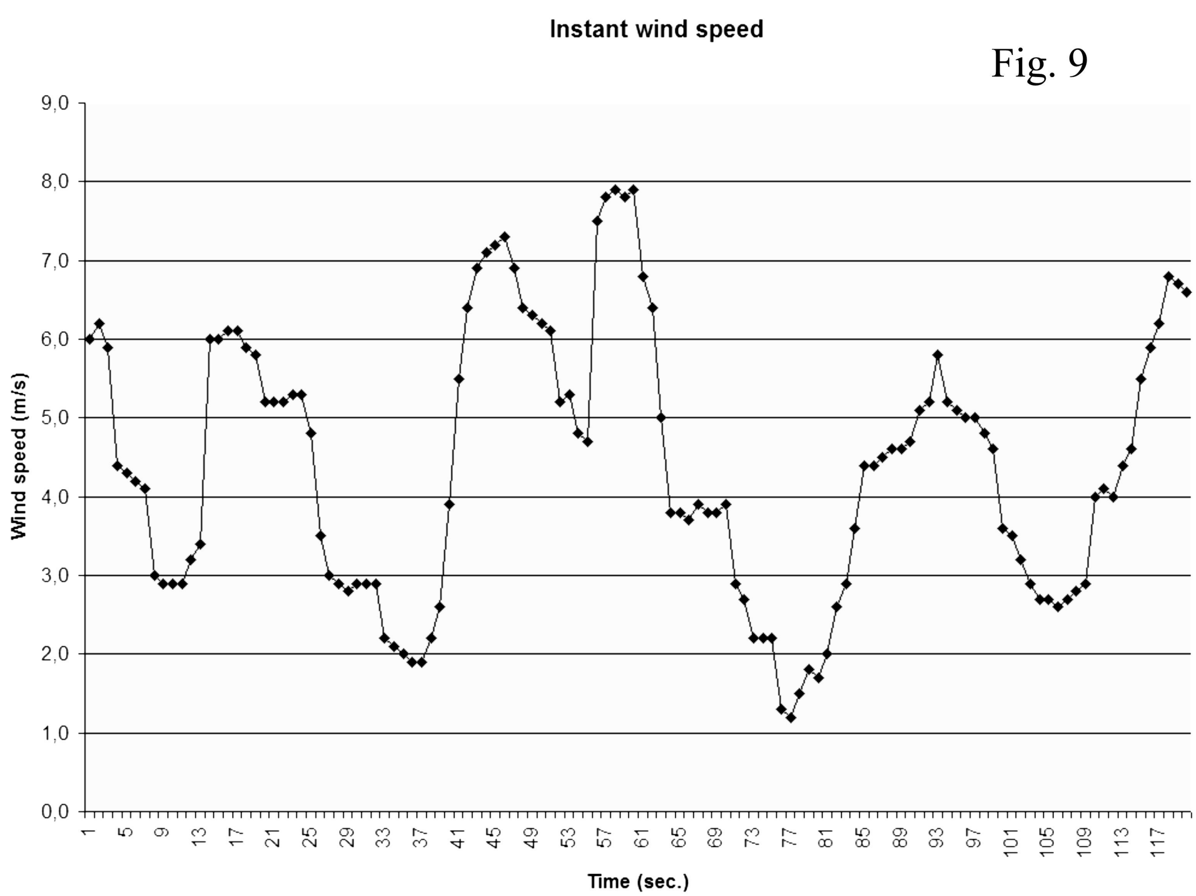

Fig. 9

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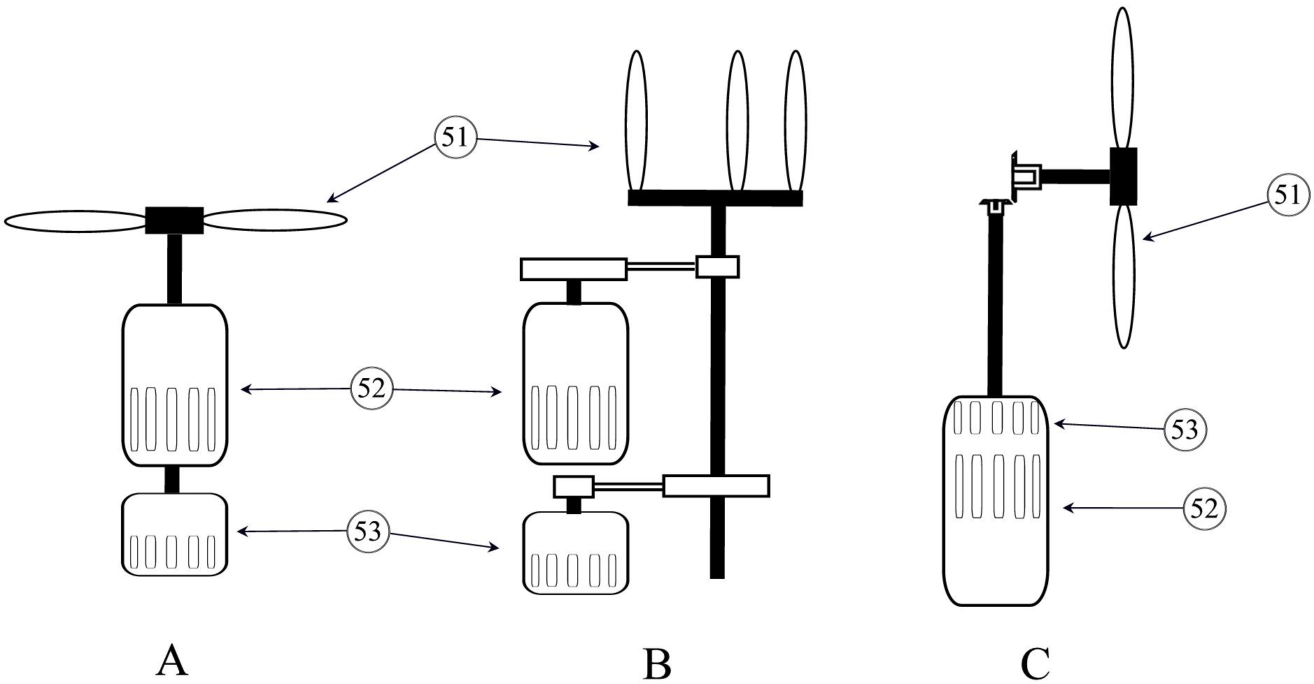
Fig. 10



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