Improving the energy performance of wind turbines implemented in the built environment using counter-rotating planetary transmissions

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Abstract. Most of wind turbine applications for urban areas use electric generators with counter-rotating rotor and stator, able to ensure a better efficiency than the conventional turbines with one wind rotor and generator with fixed stator, and, hence, a higher production of electricity. These types of power systems have two independent wind rotors that require a complex control of the two independent input speeds to obtain the optimal output speed. This paper deals with the use of a 1DOF (Degree Of Freedom) compound planetary transmission with two inputs and two outputs and three sun gears, meant for the implementation in counter-rotating wind turbines, which has the properties of summing the input torques and determined transmission of the independent speed. Firstly, the kinematic and static analysis of the proposed planetary transmission, assuming friction of gears, is performed. Afterwards, the mechanism efficiency model is established depending on the ratio of the two input torques. The transmission efficiency is simulated and analysed, with determination and representation of power flows, in the four distinct operating cases according to the \( k \) ratio values. The paper results allowed formulating recommendations on the design of these mechanical planetary transmissions used in wind turbines and broadening a database for the conceptual synthesis of wind systems.

1. Introduction

The increase of wind turbines energy performances and the better use of wind potential can be achieved through various theoretical approaches and technical solutions in two main directions regarding the installed capacity increase and the optimization of wind energy conversion efficiency.

Thus, the technical literature presents various new concepts of wind turbines that meet the previous requirements, like the wind turbines of increased capacity that use several rotors [10], or several small rotors in different spatial disposal [16], or the counter-rotating wind turbines that use two coaxial rotors rotating in opposite directions [4].

Another direction consists in ensuring the optimal operation conditions of electric generators and, hence, a high efficiency of the mechanical energy conversion into electrical energy by maintaining a constant angular speed near its nominal value that can be achieved by: the integration of 2 degrees of freedom (DOF) planetary speed increasers into classical single rotor wind turbines where a servomotor [17] or a variable speed transmission [3, 12] is connected to one input, the use of electric generators with a mobile stator that allows the increase of the rotor speed versus the stator, and, thus, a higher efficiency [2].
The correlation of rotors’ smaller speeds to the generators’ higher speeds can be ensured by integrating speed increasers [4], which can have fixed axes for the lower kinematic ratios, or can be planetary transmissions working at higher speeds or included in counter-rotating wind turbines [14, 15]. The kinematics and statics, the efficiency and power flow modelling of complex planetary transmissions are presented and analysed in many scientific papers by using various methods: the graph theory applied in the kinematic analysis of planetary gear trains [9, 12]; the conjoint analysis and a general algorithm for the analysis of transmission ratios and efficiency for the 1DOF planetary transmissions with four, five and six constraints [13]; the graph and screws theory applied in efficiency computing [11]. A methodology for computing the power transmitted through complex gear mechanisms, including planetary gears and variable speed transmissions, is proposed in [8]. Del Castillo presents two general methods for the analytical modelling of planetary transmissions efficiency in [6], while Chao determined the efficiency of a 2DOF planetary transmission in different running cases and, therefore, in possible patterns of energy flow [5]. The running cases of planetary transmissions with a higher number of external links were also highlighted in the paper [1].

This paper proposes a new 1DOF planetary transmission with two inputs and two outputs to be used in counter-rotating wind turbines containing generators with mobile stators, which are able to sum up the input torques and to transmit an external motion in a determined way. This transmission is kinematically and statically modelled in the paper, its efficiency and power flow being further determined for the four running cases identified by the ratio of input torques. The properties and advantages of the proposed solution of planetary speed increaser are highlighted based on a numerical example.

2. Problem Formulation

The counter-rotating wind turbines typically contain 2DOF planetary speed increasers used to sum up the two input motions of the wind rotors and to transmit the torsion torques to the rotor of an electric generator with a fixed stator [14, 15]. Unlike these transmissions, the proposed 1DOF planetary speed increasers with two inputs and two outputs take the mechanical power from the two rotors with counter-rotating motions and transmit it to the mobile rotor and stator of the counter-rotating generator, which allows the weighted summing of the input torques and the transmission of the main wind rotor motion.

The proposed planetary speed increaser (figure 1) is a complex transmission consisting of two 1DOF planetary gears 1-4-5-H (PU-I) and 2-3-4-5-H (PU-II) in a parallel connection, having three sun gears (1, 2 and 5) and the same carrier H. The planetary transmission has four inputs and outputs ($L = 4$): conventionally, the main input is connected to the wind rotor $R_1$, while the secondary input to the wind rotor $R_2$; the two outputs are coupled to the rotor GR and stator GS of the counter-rotating generator. The secondary input $R_2$ is directly connected to the stator GS.

The transmission degree of freedom $M$ can be obtained based on Eq. (1) [7]:

$$M = M_1 + M_{II} - L_c = 1 + 1 - 1 = 1,$$

where $M_1$, $M_{II}$ is the degree of freedom of PU-I,II, and $L_c$ – the number of connections between the planetary gears ($L_c = 1$: $\omega_{H_1} = \omega_{H_2}$), figure 1e. Therefore, the complex planetary transmission has 1DOF and the following kinematic and static properties:

a) conventionally, the angular speed $\omega_{R_1}$ is considered independent, while the input angular speed $\omega_{R_2}$ and the output speeds $\omega_{GR}$ and $\omega_{GS}$ are dependent of $\omega_{R_1}$. Due to the rotor GR motion in the opposite direction relative to the stator GS, figure 1b, the relative angular speed rotor – stator $\omega_{GR-S}$ is higher than in the case of the fixed stator generator, and, also, than the input speed $\omega_{R_1}$. Therefore, the relative speed is given by relation (2):

$$\omega_{GR-S} = \omega_{GR} - \omega_{GS},$$

where $\omega_{GR}$ and $\omega_{GS}$ are speeds of opposite directions, $\omega_{GS} = \omega_{R_1}$ and $\omega_{GR} > \omega_{R_1}$.
b) the transmission function of the external torques is defined by the qualitative relation:

\[ c_1T_{R1} + c_2T_{R2} + c_3T_{GR} + T_{GS} = 0, \]

(3)

where \( c_i, i = 1..3 \) are constants. Based on the relation \( T_{GS} = -T_{GR} \) that characterizes the electric generator functioning, the static property regarding the input torques’ weighted sum for the 1DOF planetary speed increaser can be expressed as follows:

\[ T_{GR} = \frac{c_1T_{R1} + c_2T_{R2}}{1 - c_3} = \frac{c_1T_{R1} + c_2T_{R2}}{1 - c_3}. \]

(4)

Figure 1. The schemes of the 1DOF planetary speed increaser with two inputs and two outputs: (a) structural scheme, (b) speeds diagram, and (c) block diagram.

The transmission possible running cases and its performances’ dependence on the two main parameters (i.e. the amplification ratio and the input torques’ ratio) are identified in the paper starting from the previously stated qualitative properties of the 1DOF planetary speed increaser with two inputs and two outputs to be integrated into counter-rotating wind turbines with counter-rotating generators. As a result, a kinematic and static modelling of the planetary transmission and the analysis of the power flow and, hence, of the efficiency are further presented for the four running cases as a speed increaser: a) the torque of the secondary wind rotor is lower than the torque of the generator’s stator \( (|T_{R2}| < |T_{GS}|) \), b) is higher \( (|T_{R2}| > |T_{GS}|) \), and the particular cases - c) \( T_{R2} = 0 \), and d) \( |T_{R2}| = |T_{GS}| \).
3. Kinematic Modelling of the Speed Increaser

The kinematic and static transmission functions of the complex speed increaser can be obtained based on the equations that characterize the isolated planetary gears and the equations written for the internal and external links, according to the block diagram from figure 1c:

- the kinematic and static equations of the two planetary gears, considering friction:

\[
\begin{aligned}
&\begin{cases}
\nu_i = \nu_{0i} = \frac{\nu_{0iH_i}}{\nu_{0iH_i}} = \frac{z_5}{z_1} \\
\nu_i = \nu_{0i} = \frac{\nu_{0iH_i}}{\nu_{0iH_i}} = \frac{z_5}{z_1}
\end{cases} \\
&\begin{cases}
\nu_i - \nu_{0i} = \nu_{1H_i} (1 - \nu_{0i}) = 0 \\
T_i + T_s + T_{H_i} = 0 \\
T_i \nu_{0i} + T_s = 0 \\

\end{cases}
\]

\( \text{PU} - I: \)

\[
\begin{cases}
\nu_i = \nu_{0i} = \frac{\nu_{0iH_i}}{\nu_{0iH_i}} = \frac{z_5}{z_1}
\end{cases}
\]

\( \text{PU} - II: \)

\[
\begin{cases}
\nu_i - \nu_{0i} = \nu_{1H_i} (1 - \nu_{0i}) = 0; \\
T_i + T_s + T_{H_i} = 0 \\
T_i \nu_{0i}^w + T_s = 0
\end{cases}
\]

- the correlations for the internal links:

\[
R_i = H_I = H_{II} : \begin{cases}
\nu_{RI} = \nu_{HI} = \nu_{H_{II}} = \nu_H \\
T_{RI} - T_{HI} - T_{H_{II}} = 0
\end{cases}
\]

\( S = S' = S'' : \begin{cases}
\nu_S = \nu_{S'} = \nu_{S''} = \nu_S \\
T_S - T_S' - T_S'' = 0
\end{cases}
\]

\( 1 = GR : \begin{cases}
\nu_1 = \nu_{GR} \\
T_{GR} - T_1 = 0
\end{cases}
\]

\( 2 = R_2 = GS : \begin{cases}
\nu_2 = \nu_{R2} = \nu_{GS} \\
T_{R2} + T_{GS} - T_2 = 0
\end{cases}
\]

- the correlations for the external links (the power equilibrium equation in the premise of considering friction, and the equilibrium equation for coaxial torques):

\[
\begin{cases}
(\nu_{RI} T_{RI} + \nu_{R2} T_{R2}) \cdot \eta + \nu_{GR} T_{GR} + \nu_{GS} T_{GS} = 0 \\
T_{RI} + T_{R2} + T_{GR} + T_{GS} + T_3 = 0 \\
T_{GR} = -T_{GS}
\end{cases}
\]

The kinematic ratios of the two planetary gears can be obtained from the systems of equations (5) and (6) in the case \( \nu_S = 0 \) (figure 1):

\[
L_{H_i} = \frac{\nu_{1H_i}}{\nu_{0iH_i}} = \frac{\nu_{0iH_i} - \nu_{0iH_i}}{-\nu_{0iH_i}} = 1 - \nu_{0i}.
\]
The angular speeds of the generator’s rotor \( \omega_{GR} \) and stator \( \omega_{GS} \) can be obtained as functions of the main wind rotor speed \( \omega_{R1} \), from relations (12), (13) and the internal links correlations, rel. (7)...(10):

\[
\omega_{GR} = \omega_{R1}(1 - i_{0I}) , \tag{14}
\]

\[
\omega_{GS} = \omega_{R2} = \omega_{R1}(1 - i_{0II}) , \tag{15}
\]

and, therefore, the relative angular speed \( \omega_{GR-S} \) becomes:

\[
\omega_{GR-S} = \omega_{GR} - \omega_{GS} = \omega_{R1}(i_{0II} - i_{0I}) . \tag{16}
\]

Consequently, the amplification ratio \( i_a \) of the planetary transmission from the main input to the generator can be defined as follows:

\[
i_a = \frac{\omega_{GR-S}}{\omega_{R1}} = i_{0II} - i_{0I} . \tag{17}
\]

4. Efficiency and Power Modelling

The efficiency of the 1DOF complex transmission is established on the basis of the efficiencies of the two component planetary gears and is conditioned by the power flows, as in the block diagram from figure 1.c, for each of the following four running cases defined according to the correlation between \( T_{R2} \) and \( T_{GS} \):

- **PU-I** has a unique output through gear 1, in all the running cases: \( \omega_{15}T_1 < 0 \)

\[
\eta_{H1}^* = \frac{-\omega_{15}T_1}{\omega_{H15}^*T_{H1}} = \frac{-T_1}{T_{H1}} = \frac{i_{H1}^*}{i_{15}^*} = \frac{1 - i_{0I}}{1 - i_{0II}} . \tag{18}
\]

where:

\[
x = \text{sgn}(\omega_{15}T_1) = \text{sgn} \left( \frac{\omega_{15}T_1}{-\omega_{15}T_1} \right) = \text{sgn} \left( \frac{i_{0I}}{1 - i_{0II}} \right) = -1 ; \quad \overline{i_{0II}} = i_{0II} \eta_{0II}^* ; \tag{19}
\]

- **PU-II** can be found in two distinct cases of power flow:
  a) The gear 2 represents the output \( \omega_{25}T_2 < 0 \) if \( |T_{R2}| < |T_{GS}| \), case in which

\[
\eta_{H2}^* = \frac{-\omega_{25}T_2}{\omega_{H25}^*T_{H2}} = \frac{-T_2}{T_{H2}} = \frac{i_{H2}^*}{i_{25}^*} = \frac{1 - i_{0II}}{1 - i_{0II}} , \tag{20}
\]

where \( \overline{i_{0II}} = i_{0II} \eta_{0II}^* \) and

\[
w = \text{sgn}(\omega_{25}T_2) = \text{sgn} \left( \frac{-\omega_{25}T_2}{\omega_{25}^*} \right) = \text{sgn} \left( \frac{-i_{0II}}{i_{0II} - 1} \right) = -1 ; \tag{21}
\]
b) gear 2 represents the input \( \omega_{25}, T_2 > 0 \) if \( |T_{R2}| > |T_{GS}| \) and the planetary gear efficiency is obtained by relation:

\[
\eta_{2H_\mu}^* = \frac{-\omega_{H_\mu} S_{T_{H_\mu}} - \frac{T_{H_\mu}}{\omega_{25} T_2}}{\omega_{H_\mu} S_{T_{H_\mu}}} = \frac{\omega_{25} S_{T_{H_\mu}}}{i_{2H_\mu}^*} = 1 - \frac{i_{0H}}{1 - i_{0H}}, \tag{22}
\]

case in which

\[
w = \text{sgn}\left(\omega_{2H_\mu} T_2\right) = \text{sgn}\left(\frac{-\omega_{H_\mu} S_{T_{H_\mu}}}{\omega_{25} T_2}\right) = \text{sgn}\left(\frac{i_{0H}}{i_{0H} - 1}\right) = +1. \tag{23}
\]

The following relation is obtained by replacing \( T_i = T_{GR} \) from rel. (9) into rel. (18):

\[
T_{GR} = -\frac{\omega_{H_\mu} S_{T_{H_\mu}}}{\omega_{GR} T_i} \eta_{H_1,1}^* = -T_{H_1} i_{H_1} \eta_{H_1,1}^* = -T_{H_1} \frac{1}{1 - i_{0H}}. \tag{24}
\]

Similarly, the following correlation outcomes from relations (10), (20) and (22):

\[
T_{GS} = T_2 - T_{R2} = -\frac{1}{1 - i_{0H}} - T_{R2}. \tag{25}
\]

The torque on the generator’s stator is obtained for particular values of \( T_{R2} \) in two representative cases:

- for a null torque of the secondary rotor \( T_{R2} = 0 \):
  \[
  T_{GS} = -T_{H_\mu} \frac{1}{1 - i_{0H}}; \tag{26}
  \]

- for a torque generated by the secondary rotor equal to the module of the torque on the generator’s stator, \( |T_{R2}| = |T_{GS}| \):
  \[
  T_{GS} = -T_{R2} \text{ and } T_{H_\mu} = 0. \tag{26}
  \]

Knowing that \( T_{GR} = -T_{GS} \) (relation 11), the correlation between \( T_{H_1} \) and \( T_{H_\mu} \) can be obtained (figure 1c), allowing, thus, to determine the two torques as functions of the two wind rotors’ torques:

\[
T_{H_1} = -T_{R1} \frac{1 - i_{0H}}{i_{0H} - i_{0H}} - T_{R2} \frac{1 - i_{0H}}{i_{0H} - i_{0H}} \tag{28},
\]

\[
T_{H_\mu} = T_{R1} \frac{1 - i_{0H}}{i_{0H} - i_{0H}} + T_{R2} \frac{1 - i_{0H}}{i_{0H} - i_{0H}}. \tag{29}
\]

The following relation is obtained by considering that the generator’s resistant torque is equal to the rotor’s torque (\( T_{GR} \)), and by replacing rel. (28) into rel. (24):

\[
T_{GR} = -T_{R1} \frac{1}{i_{0H} - i_{0H}} - T_{R2} \frac{1 - i_{0H}}{i_{0H} - i_{0H}}. \tag{30}
\]
The relation of efficiency for the planetary transmission is generated from the energy equilibrium equation by neglecting the inertia forces [14]:

\[
\eta = -\frac{\omega_{GR} T_{GR}}{\omega_{R1} T_{R1} + \omega_{R2} T_{R2}}; \tag{31}
\]

if the ratio of the torques of the two wind rotors is denoted by \( k (k = T_{R2}/T_{R1}) \), the 1DOF complex transmission will have the efficiency:

\[
\eta = \left( \frac{i_{0II} - i_{0I}}{i_{0II} - i_{0I}} \right) \left[ \frac{1 + k(1 - i_{0II})}{1 + k(1 - i_{0II})} \right]. \tag{32}
\]

The power of the secondary rotor can be obtained from rel. (15) and from the input torques ratio \( k \):

\[
P_{R2} = \omega_{R2} T_{R2} = \omega_{R1} (1 - i_{0II}) T_{R1} k = k (1 - i_{0II}) P_{R1} = \lambda_{R2} P_{R1}, \tag{33}
\]

where parameter \( \lambda_{R2} = k(1 - i_{0II}) \) is the ratio between the secondary and the main rotors’ powers.

Similarly, the generator power \( P_G \) is obtained based on relations (16) and (30) as function of the main rotor power \( P_{R1} \) through the ratio \( \lambda_G \):

\[
\lambda_G = \frac{P_G}{P_{R1}} = \frac{(1 - i_{0II})(1 + k(1 - i_{0II}))}{1 - i_{0II}}. \tag{34}
\]

5. Numerical Simulations and Discussions

5.1. Efficiency and power ratios

According to rel. (32)...(34), the transmission efficiency \( \eta \) and the power ratios \( \lambda_{R2} \) and \( \lambda_G \) depend on the static ratio \( k \), the interior kinematic ratios \( i_{0I} \), \( i_{0II} \) and the amplification ratio, \( i_a = i_{0II} - i_{0I} \), implicitly, and the interior efficiencies of the component planetary gears. The numerical simulations for the parameters \( \eta \), \( \lambda_{R2} \) and \( \lambda_G \) are represented in figure 2, 3 and 4 for the values \( |k| = 0...1 \) (i.e. \( |T_{R2}| < |T_{R1}| \)), \( i_a = 5...80 \), \( i_{0II} = 2 \) and efficiencies of the spur gears \( \eta_{14} = \eta_{45} = \eta_{23} = 0.95 \).

![Figure 2](image-url) The transmission efficiency as function of: (a) the ratio of input torques \( k \) and (b) the amplification ratio \( i_a \).
Figure 3. The power ratio $\lambda_{R2}$ of the secondary rotor as function of the ratio of input torques $k$.

Figure 4. The power ratio $\lambda_G$ as function of: (a) the ratio of input torques $k$, and (b) the amplification ratio $i_a$.

The comparative analysis of the diagrams from figure 2 ... 4 highlights the following properties of the planetary speed increaser:

- the transmission efficiency decreases almost linearly with the increase of the module of input torques ratio $k$, registering a decrease of about 10% when the torque of the secondary wind rotor becomes equal to the main rotor’s torque ($k = 1$), regardless the amplification ratio $i_a$ (figure 2a);
- for a given value of the $k$ ratio, the efficiency decreases with the increase of the amplification ratio $i_a$, figure 1b: the decrease is more pronounced for lower values of the amplification ratios (with approx. 5% for $i_a = 20$ versus $i_a = 5$) and more reduced for high values (approx. 1% for $i_a > 20$);
- the power introduced in the system by the secondary rotor depends linearly on the ratio of the input torques, $k$, figure 3; for the particular case $i_{0II} = 2$, the angular speed of the secondary rotor is equal and opposite to the main rotor speed, and the power of the secondary rotor becomes equal to $P_{R2}$ for $k = -1$, implicitly. According to rel. (33), the input power generated by the secondary rotor does not depend on $i_{0I}$;
- the output power increases with the increase of the module of the input torques ratio, $k$ due to the additional power brought by the secondary wind rotor, figure 4. The increase of the amplification ratio causes the decrease of the output power by about 10% for $i_a = 80$ versus $i_a = 5$; it is noted that the output power has an insignificant variation for $i_a > 20$ and a given value of the $k$ parameter.
5.2. Power flow

The power is transmitted between the inputs and outputs on branches or unbranched depending on the amplification ratio \( i_a \) and the ratio \( k \), the power flow configuration influencing the efficiency of the planetary transmission. A limited value of the input torques ratio, \( k_{\text{lim}} \) at which the power flow through PU-II becomes null, i.e. the torque \( T_{II\alpha} = 0 \), and which demarcates the ranges for \( k \) variation that correspond to the two power flow directions, is associated to each value of the amplification ratio \( i_a \). This value sets out the fields of the two power flow directions through PU-II. The following relation comes out from equation (29):

\[
k_{\text{lim}} = k \bigg|_{T_{II\alpha} = 0} = \frac{1}{1 - i_a}.
\]  

(35)

According to figure 5, the value of \( k_{\text{lim}} \) is significantly reduced with the increase of the amplification ratio, the change of power flow direction through PU-II taking place at low values of the torque on the secondary rotor’s shaft. Four distinct running cases are obtained for the range \( k \in [-1 \ldots 0] \) and the limit value \( k_{\text{lim}} \); the case \( i_a = 10 \) (\( i_{II} = -8 \), \( i_{III} = 2 \)) and \( \eta_{14} = \eta_{45} = \eta_{23} = 0.95 \) (\( k_{\text{lim}} = -0.111 \)) is presented in figure 6:

![Figure 5. The ratio \( k_{\text{lim}} \) as function of the amplification ratio.](image_url)

- case 1: the torque of the secondary wind rotor is smaller than the torque of the generator’s stator (\( |T_{R2}| < |T_{GS}| \)), meaning \( k \in (k_{\text{lim}} \ldots 0) \). This case corresponds to lower values of power on the secondary rotor \( P_{R2} \); therefore, the power generated by the main wind rotor \( P_{R1} \) is transmitted in branches through both planetary gears PU I, II to the generator’s rotor (the entire power \( P_{GS} \) is ensured), and to the generator’s stator (in compensation to the power generated by the secondary rotor \( P_{R2} \)), figure 6a. The efficiency of the planetary transmission is \( \eta = 0.920 \) for \( k = -0.1 > k_{\text{lim}} \).

- case 2: \( |T_{R2}| > |T_{GS}| \), i.e. \( k \in [-1 \ldots k_{\text{lim}}) \). In this case, the power generated by the secondary wind rotor \( P_{R2} \) is higher than the required power on the generator’s shaft, and, therefore, part of the power \( P_{R2} \) is transmitted to the generator’s rotor, and the power flow direction through PU-II is reversed, implicitly (figure 6b). The transmission efficiency is \( \eta = 0.845 \) for \( k = -1 \), at an output power with ~67% higher than in the first case, due to the additional power brought by the secondary wind rotor.

- case 3: \( T_{R2} = 0 \), i.e. \( k = 0 \), figure 6c. This case takes place when the secondary wind rotor is set not to generate mechanical power, the transmission functioning with one input and two outputs at an efficiency \( \eta = 0.821 \).
case 4: \( T_{R2} = T_{GS} \), i.e. \( k = k_{\lim} \), figure 6d; in this case, PU-II is not participating in the mechanical power transmission and, thus, the two power inputs are decoupled: the power from the main rotor is transmitted unbranched (integral) to the generator’s rotor, while the secondary wind rotor ensures the required power of the generator’s stator. In this case, the transmission efficiency is \( \eta = 0.912 \).

According to the previous numerical simulations, the planetary transmission is functioning with higher efficiencies for reduced values of the torque on the secondary wind rotor \((k > k_{\lim})\), case that corresponds to a branched transmission of the power generated by the main wind rotor. Instead, the branched transmission of power from the secondary wind rotor \((k < k_{\lim})\) occurs at higher values of the transmitted power and at lower efficiencies.

Figure 6. The power flows in the planetary transmission: (a) \( k \in (k_{\lim}...0) \), (b) \( k \in [-1...k_{\lim}) \), (c) \( k = 0 \), and (d) \( k = k_{\lim} \).
6. Conclusions
The paper presents a new solution of 1DOF planetary transmission, which is obtained by a parallel connection of two planetary gears, designed to amplify the motions of two counter-rotating wind rotors and to transmit power to an electric generator with mobile rotor and stator. Based on the properties of 1DOF transmissions with two inputs and two outputs regarding the summing of torques / powers and the distribution of external speeds compared to conventional systems with one input and one output, the proposed transmission allows both the increase of the relative speed between the electric generator’s rotor and stator and an additional power / torque brought by the secondary wind rotor.

Besides the power increase, the use of these wind systems with counter-rotating components has the advantages of more efficient functioning of the electric generator by providing increased speeds, a compact design that allows their implementation in renewable energy systems with a reduced size, and a better dynamic balancing than in the case of a single input transmission.

The methodology for the kinematic and static analysis, the analytic models and the diagrams built for various case studies are useful to the researchers and designers in this field to establish favourable solutions of planetary speed increasers for counter-rotating wind turbine that integrate generators with mobile stators, systems that require increase both in speed and power.

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