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EVALUATION OF CAPACITY WHICH MAY BE RECEIVED BY THE WIND-DRIVEN POWER PLANT FROM THE WIND CURRENT CREATED BY THE TRAIN

The paper presents the results of the experimental research of the wind currents, created by a train, which was carried out with an aim of capacity evaluation, which might be taken from these currents by the wind-driven power plant, placed close to the railroad bed.

Reference words: *railway transport, wind-power engineering, wind currents, wind-driven power plant, capacity evaluation, experiment.*

Introduction

It is known [1, 2] that the capacity P_{wc} *(W),* taken form the wind current with the density ρ *(kg/m^3)* by the wind-driven power plant with the vertical-shaft wind-wheel generator and the axial section area of the wind wheel S_o *(m^2)* and capacity coefficient ε, is proportional to this area and velocity cube v_{wc} *(m/c)* of the wind current, that is

$$P_{wc} = \varepsilon \frac{S_o}{2} \rho v_{wc}^3 \qquad (1)$$

And everybody, who was standing on the railway platform during the fright train passing could be convinced that the speed of the wind currents, created by these trains on-the-move, may reach high values and with the super speed of the train it may reach the speed of the gale-force wind. The energy of these wind currents is dissipated in atmosphere, whilst it may be used for the generation of the electric energy by the wind-driven power plant, placed close to the railroad bed.

It should be pointed out that the auxiliary equipment (service equipment) of the railroad facilities is powered by the additional power transmission lines, conveyed along the railway, which implies for the significant expenditures as well as losses of electric energy [3]. There is also the problem of improvement of electric energy supply for the railroad facilities service equipment.

In our opinion, the significant contribution to the solution of the above issues may be made by the wind-driven power plant, placed close to the railroad bed, which shall be switched to the system of electric energy supply of the rail road facilities transforming the energy of the wind currents, created by trains, into the electric energy.

In work [4] we have already considered the creation of the new specialized wind-driven power plants (WPP) and determined the conditions for their location along the railways for transforming the energy of the wind current, created by the train on-the-move, into the electric energy, which is planned for powering the railway service equipment, populated arrears which are close to railways, or for energy recovery and accumulation. But this work does not consider the issue of quantitative assessment of energy, produced by the wind power plants, driven by the directed wind currents from the by-passing trains.

In [5] we had made the capacity quantitative assessment of the wind current created by the-moving train, but using data, given by the American Railroad Association in work [6].

To specify the results of this evaluation and approximate to the realities of operating the native railroad transport, we have carried out experiments on measuring the characteristics of the wind current, created by the train, using the original measuring unit, specially designed for measuring the wind currents, created by trains, detailed description of which is presented in work [7].

Description of conditions and site of an experiment as well as characteristics of the values measured

The location of the experiment was chosen on the railroad section not far from the city of Vinnytsia on the closed railroad crossing of the village Parpurivtsi. The site was allowed by the railroad administration since it is convenient for placing the measuring unit, has the automobile road and the high speed of passing trains.

Since the regulatory documents declare the safe distance for the railroad bed up to 3 meters, the experimental measuring unit was placed like that (fig. 1), straight across the railroad, that is, square with axis of the wind current, which moves along the train.

Fig. 1. Site for the location of the experimental measuring unit (sensor frame is marked in red)

As it is seen from the figure 1, the sensors were located in fours in three columns on the distance of 3, 4, 5 meters form the railroad correspondingly.

The computer was taking data simultaneously for each of the speed transducer with one second interval as the set of impulses, each of which contained some impulses, proportional to the sensor speed shaft (fig. 2). Calibration of each measuring channel was made in the wind tunnel, which belongs to the Department of Renewable Energy and Transport Electrical Systems and Complexes (RETESC) of Vinnytsia National Technical University, using the standard anemometr. For all the measuring channels there had been built the dependences of the wind mass dependences in the function of quantity of discrete impulsey of sensors [7].

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7,8,8,6,7,7,8,5,13,2,15
5,8,7,5,6,7,7,5,12,3,13
6,8,6,4,6,7,7,4,13,2,12
6,7,7,5,7,7,7,4,12,3,12
5,8,6,4,7,8,8,4,11,3,11
7,8,6,6,7,8,9,5,12,4,11
4,6,5,4,6,7,8,4,11,3,10
7,7,5,5,6,8,13,4,13,9,13
6,8,7,17,8,29,57,4,20,43,14
6,8,13,25,13,35,73,5,34,71,17
10,11,22,50,15,37,83,7,50,93,20
25,29,49,59,34,60,93,24,67,74,31
48,32,59,79,35,62,82,31,72,41,33
58,31,57,78,36,50,90,35,71,58,27
61,27,92,98,42,87,143,33,69,127,42
62,33,68,72,39,75,110,41,79,90,46
63,45,72,94,55,84,124,39,92,97,49
94,87,103,138,113,116,163,77,120,77,68
90,76,75,127,82,85,121,59,98,65,68
83,63,65,113,69,95,127,56,98,90,55
57,73,72,82,69,91,108,50,96,79,68
71,96,93,88,63,92,107,35,86,71,112
65,88,102,100,75,98,116,50,87,74,93
66,80,84,96,75,87,113,44,76,72,88
61,62,64,80,59,77,103,39,63,61,66
74,52,59,85,50,71,109,36,61,79,55
64,43,50,73,44,73,114,39,79,96,50
50,40,43,62,49,66,97,36,71,81,49
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Fig. 2. Format of the received experimental data

All the received sensor data during the train transit were entered on the matrix of the input values F1 in the package of the applied software (PAS) Mathcad (fig. 3).

The experimental data were taken during the transit of the fright train with the locomotive ВЛ80к and the mixed types of cars in the amount of 56. The train speed was 66 km. per hour and the travelling time along the experimental measuring unit was 45 seconds.

F1 =

	1	2	3	4	5	6	7	8	9	10	11	12
47	74	93	59	25	67	60	49	28	24	34	29	31
48	41	82	79	48	72	62	59	41	31	35	32	33
49	58	90	78	58	71	50	57	43	35	36	31	27
50	127	143	98	61	69	87	92	52	33	42	27	42
51	90	110	72	62	79	75	68	54	41	39	33	46
52	97	124	94	63	92	84	72	56	39	55	45	49
53	77	163	138	94	120	116	103	81	77	113	87	68
54	65	121	127	90	98	85	75	79	59	82	76	68
55	90	127	113	83	98	95	65	69	56	69	63	55
56	79	108	82	57	96	91	72	63	50	69	73	68
57	71	107	88	71	86	92	93	92	35	63	96	112
58	74	116	100	65	87	98	102	79	50	75	88	93
59	72	113	96	66	76	87	84	77	44	75	80	88
60	61	103	80	61	63	77	64	64	39	59	62	66
61	79	109	85	74	61	71	59	65	36	50	52	55
62	96	114	73	64	79	73	50	57	39	44	43	...

Fig. 3. Matrix of the input data for the PAS Mathcad

Having built the received dependences in the time function, we receive the graph, presenting the change of speeds for each measuring cannel in the time function which is presented in fig.4 in the coordinates: abscissa – seconds, ordinate axis – meters per second.

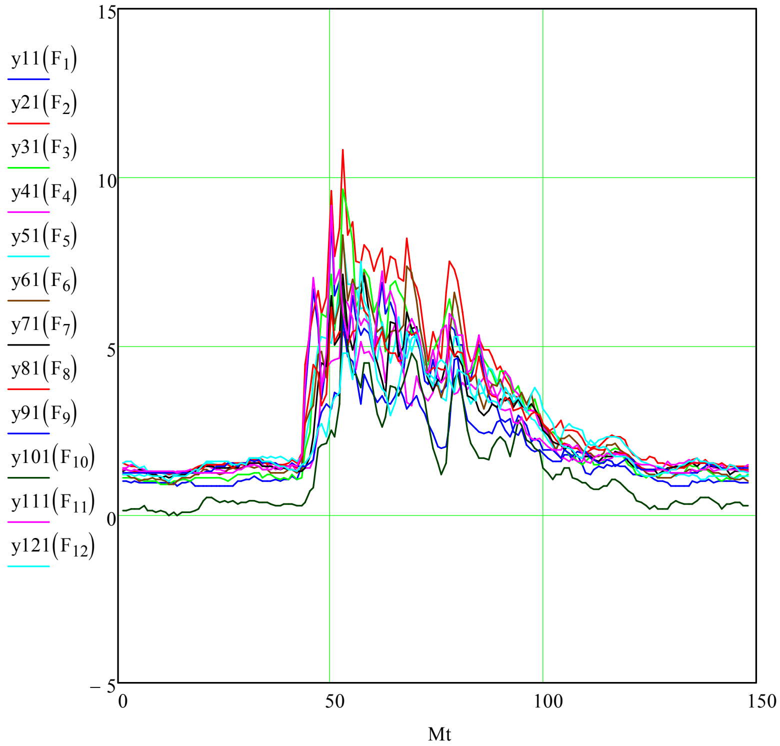

Fig. 4. Graph of speed of the wind currents, taken by each measuring channel

Fig. 4 clearly indicates the time moment ($M_t = 43\ s$), at which the train reaches the measuring unit, and shows that the wind current increases by some times in comparison with the values of the natural wind speed. An interesting fact is that some time t_n which makes up app.35 seconds with the speed of the train of 66 km per hour (up to M_t = 121 seconds) after the train transit (M_t = 88 seconds) there is the distinct increase in the speed of the wind current over its state in the normal state.

Processing the experimental results

For the determination of the capacity of the wind current which crosses the area of the measuring unit with 12 wind wheels of small diameter with the horizontal axis, serving as sensors, we use the expression (1) which for each measuring channel looks as

$$P_i = \varepsilon \cdot \rho \cdot \frac{S \cdot V_i^3}{2},\ i = 1,..,12 \tag{2}$$

where S – area of a circle with the diameter, which equals the diameter of the wheel of the wind sensor.

Using the speed performance curves, presented in fig.4, and the cubic splines for the realization of the expression (2) in PAS Mathcad, we receive

$$P_i(u) = \operatorname{int} erp\left(cspline\left(M_t, P_i\right), M_t, P_1, u\right) \tag{3}$$

The graphs of the capacities of the wind currents during the transit of the train on each of the measuring channel, calculated by the expression (3) are presented in figure 5 in the coordinates: abscissa – seconds, ordinate axis – losses.

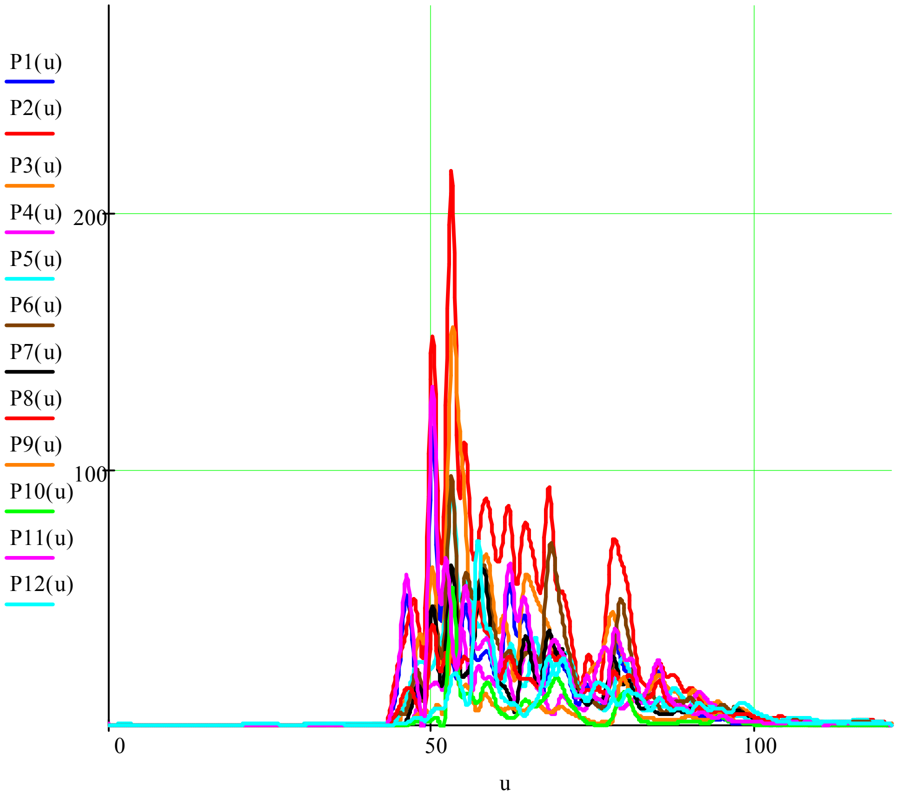

Fig. 5. Graphs of the capacities of the wind currents in the time function for each of the measuring channels

The graphs show that the capacities of the wind currents differ from each other depending on the place the sensor is located. For obvious illustration we show this on the three-dimensional graph, which demonstrates the quantity of the received capacity on each of the measuring channel in correspondence with their placement in frame of the measuring unit. Each of the dependences, which determines the capacity of the wind current on each measuring channel, shall be integrated within the time intervals from $M_t = 43\ s$ up to $M_t^* = 121\ s$ s and divided by the integration interval $\left(M_t^* - M_t\right)$ and in such a way find the mean power $Ps_i, i = 1, 2, \ldots, 12$ of the wind current on each measuring channel

$$Ps_i = \frac{1}{121-43}\int_{43}^{121} P_i(u)\,du\,,\ i = 1, 2, \ldots, 12 \tag{4}$$

To refer the values of the average capacity $Ps_i, i = 1, 2, \ldots, 12$ of the wind current to each measuring channel, calculated by the expression (4) to the places where the speed sensors are located, figure 6 presents the colored layout diagram of all measuring sensors in the framework of measuring unit, in the projection of “front view” following the train movement direction.

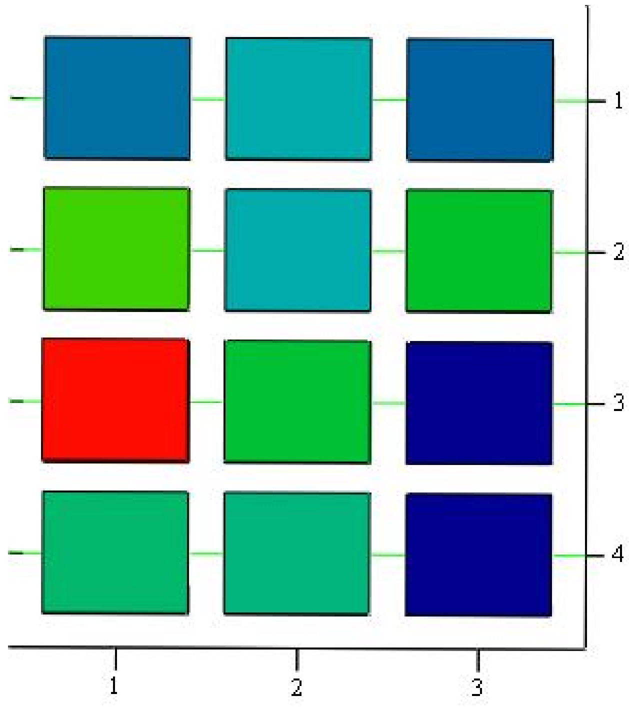

Fig. 6. Colored layout diagram of speed sensors in the framework of measuring unit (front view, following the train movement direction)

This layout diagram complies with the matrix of average capacities, which looks

$$Ps = \begin{pmatrix} Ps_4 & Ps_8 & Ps_{12} \\ Ps_3 & Ps_7 & Ps_{11} \\ Ps_2 & Ps_6 & Ps_{10} \\ Ps_1 & Ps_5 & Ps_9 \end{pmatrix}. \quad (5)$$

After the calculations upon the expression (4) this matrix shall be filled with the following values of the accumulative capacities (given in Watt):

$$Ps = \begin{pmatrix} 9.924 & 12.263 & 9.276 \\ 22.357 & 12.338 & 18.399 \\ 35.016 & 17.96 & 4.468 \\ 15.495 & 14.71 & 4.511 \end{pmatrix}. \quad (6)$$

Figures 7 and 8 show the spatial graphs of average capacities, calculated by the expression (4) which correspond with the presented in fig 6. location of speed sensors. Fig 6 presents the spatial pattern as the columns of the appropriate height, set by the matrix (6), and fig. 8 presents the smoothed surface, which presents the changes in the capacity values upon the whole area of the frame in the measuring unit, which houses the speed sensors.

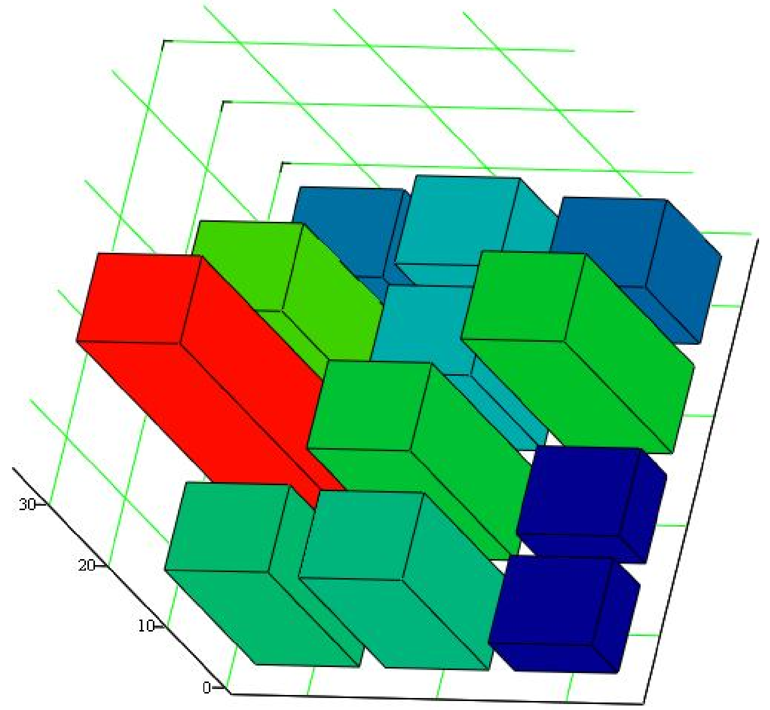

Fig. 7. Diagram of average capacities, received from each measuring channel in time $M_t^* - M_t$

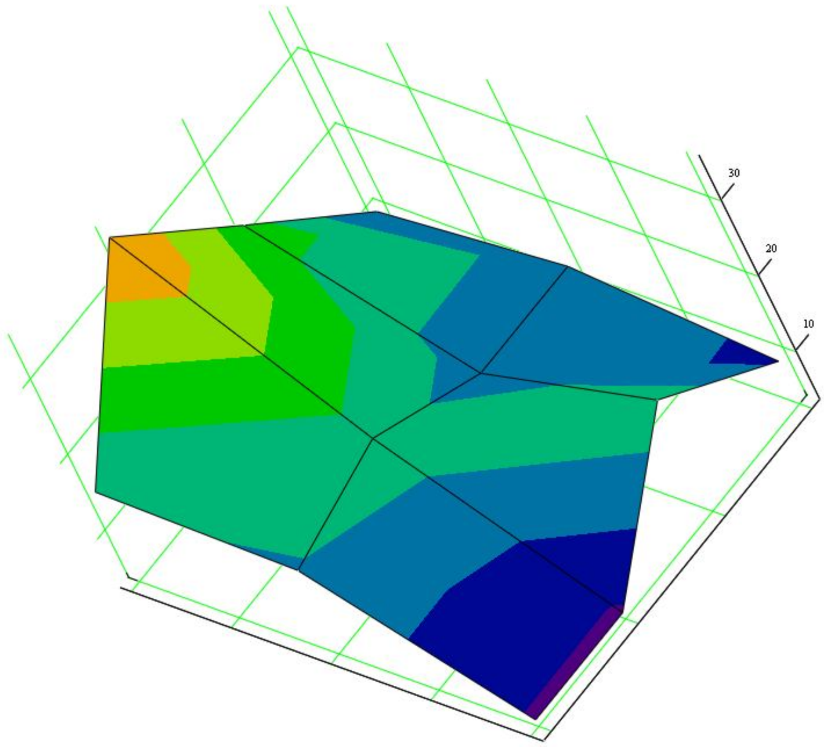

Fig. 8. The surface of the average capacity of the wind current, measured by the experimental measuring unit, presenting the contribution of each of the measuring channel

For the evaluation of the total capacity of the wind current Ps_{Σ} which moved through the sensor frame of the measuring unit during the excitation of the air mass, caused by the moving train, we calculate the sum capacities on all the measuring channels and find that

$$Ps_{\Sigma} = \sum_{i=1}^{12} Ps_i = 176.715 \text{ (W)}. \qquad (7)$$

Apart from the fright trains, some passenger trains with similar wind shape types of cars and local trains passed along the measuring unit during the experiment. The sensors of the experimental measuring unit registered the insignificant excitations of air mass and measured very low capacity values, which are taken from the wind currents, created by trains of this type, which are without the significant differences over the whole measurement area. That is, the side wind aerodynamic currents, created by these trains, are less powerful in comparison with those currents, which are created by the fright trains with different types of cars. They are more elongated behind the train and practically do not diverge as in case with the fright trains with different types of cars.

Therefore the use of WPP is of priority on the railroad sections with the high traffic intensity of the fright trains.

We have experimentally researched and determined the quantity of capacity, which may be taken from the wind currents, created by the fright train which passes the measuring unit with the speed of 66 kilometers per hour. But there are many railroad sections in Ukraine which allow the trains to travel 1,5 times quicker. And in the nearest future some sections of the railroad will allow the speed of the train twice as higher.

And since the capacity, taken by the WPP from the wind current is proportional to the speed cube of this current, then the increase in the speed of the fright train up to 100 km per hour will increase the capacity taken by the WPP from the wind current by 3,5 times. And if the speed of the fright train increases two times, that is, up to 132 km per hour, the capacity taken by the WPP from the wind current will be 8 times higher then that previously calculated, and this is the significant contribution to the alternative power generation.

Conclusions

The above-mentioned results allow to make the following conclusions:

1. Field testing the experimental measuring unit, developed by the Department of RETESC in Vinnytsia National Technical University for measuring speed of the wind currents, created by the railroad transport on the move, proved its high measuring and calculative efficiency and applicability.

2. It had been stated that pretty powerful wind currents on three meter distance from the railroad bed, allowed by the standard documents are created only by the fright trains with different types of cars which travel at speed, higher then 60 km per hour.

3. It had been suggested to consider the maintenance of the wind-driven power plants close to the railroad sections which are characterized by high intensity of fright trans traffic at speed of 90 km per hour and higher economically efficient.

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