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Dynamic calculation of an optimum arrangement of rotary wind turbines on floors of a compact multystoried wind farm

In view of the deterioration of the ecological situation on the planet Earth and decreasing feedstock for conventional sources of energy it has recently become urgent creation of non-traditional, non-polluting and renewable energy sources. Many farms of the Republic of Kazakhstan are interested in use of autonomous sources of electric energy and, first of all, the energy of a stream of wind which is available much in the most part of our country. It is generated by a variety of reasons – and remoteness of some farms from system of power supply, and forwarding character of certain consumers, and, at last, simply deficiency of the electric power in the republic and therefore desire to leave from tactical and market whims in distribution of fuel and energy resources. In al-Farabi Kazakh National University we have offered a compact multystoried wind farm (CMWF) representing a multystoried design on which floors wind turbines of various type of the small power settle down. For performance of conditions of compactness of CMWF it is necessary to define minimum possible (optimum) distance between three wind turbines on internal floors of a wind farm for free passing of a wind stream. For the solution of this task packages of application programs of Autodesk family have been used.
Key words: multi-storey wind farm, "Baiterek", wind turbine Darrieus type, optimal location, CMWF, Autodesk.

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Динамический расчет оптимального расположения карусельных ветротурбин на этажах компактной многоэтажной ветроэлектростанции

В виду ухудшения экологической обстановки на планете Земля и понижением сырьевых запасов для традиционных источников энергии в последнее время становится актуальным создание нетрадиционных, экологически чистых и возобновляемых источников энергии. Многие хозяйства Республики Казахстан заинтересованы в использовании автономных источников электрической энергии и, прежде всего, энергии потока ветра, имеющейся в избытке в большей части нашей страны. Это порождено рядом причин – и отдаленностью некоторых хозяйств от системы электроснабжения, и экспедиционным характером отдельных потребителей, и, наконец, просто дефицитом электроэнергии в республике, и потому желанием уйти от конъюнктурно-рыночных капризов в распределении топливно-энергетических ресурсов. В Казахском национальном университете им. аль-Фараби нами предложена оригинальная компактная многоэтажная ветроэлектростанция (КМВЭС) представляющая собой многоэтажную конструкцию, на этажах которой располагаются ветротурбины различного типа небольшой мощности. Для выполнения условий компактности КМВЭС необходимо определить минимально возможное (оптимальное) расстояние между тремя ветротурбинами на внутренних этажах ветроэлектростанции для свободного прохождения ветрового потока. Для решения этой задачи были использованы пакеты прикладных программ семейства Autodesk: Inventor и CFD Simulation.
Ключевые слова: многоэтажная ветроэлектростанция, "Байтерек", ветротурбина Дарье, оптимальное расположение, КМВЭС, Autodesk.

Кунакбаев Т., Нигметов Д., Туреханова В.

Көпқабатты желэлектростанцияның қабаттарында карусель типті желтурбиналарды тиімді орналастыру динамикалық есебі

Экологиялық жағдайдың құлдыраумен және щикызат қорының түсүімен бүкіл әлемде соңғы кезде әдетті энергия көзі орнына экологиялық таза және жаңартылатын энергия көзіні пайдалану өзекті болып табылады. Қазақстан Республикасының көптеген шаруашалықтарында автономдық электрлік көзін қолдану әсерінің маңыздылығы өсіп келеді, біріншіден, ол мемлекетіміздің көптеген бөлігінде артықшылығы бар жел ағымының энергиясы. Бұл бірқатар себептермен туындалған – біршама шаруашылықтарының электрмен жабдықтау жүйесінен алшақ орналасуымен және де жекелеген тұтынушыға, қарапайым электр қуатының жетіспеушілігіне, жағу-энергетика ресурстарынан коньюктур-базалық құбылыстарының өзгеруіне байланысты. Әл-Фараби атындағы Қазақ ұлттық университетінде біз көпқабатты конструкциядан құрастырылған желэлектростанциясын (КҚЖЭС) ұсындық, әрбір қабатта шағын қуатты әртүрлі желтурбиналары орналасқан. КҚЖЭС-тың жинақы шарттарын орындау үшін, желэлектростанциясының ішкі қабаттарында, жел ағымының тегін өтуіне, үш желтурбиналарының арасындағы қашықтық ықтималын шамасын (ең қолайлы) анықтау қажет. Бұл тапсырманы шешу үшін, Autodesk: Inventor және CFD Simulation қолданбалы геоақпаратты бағдарламаларының жиынтықтары қолданылған.

Түйін сөздер: көпқабатты желэлектростанция, "Бәйтерек", Дарье желтурбинасы, тиімді орналастыруы, КҚЖЭС, Autodesk.

1 Introduction

In view of the deterioration of the ecological situation on the planet Earth and decreasing feedstock for conventional sources of energy it has recently become urgent creation of non-traditional, non-polluting and renewable energy sources. Many farms of the Republic of Kazakhstan are interested in use of autonomous sources of electric energy and, first of all, the energy of a stream of wind which is available much in the most part of our country. It is generated by a variety of reasons – and remoteness of some farms from system of power supply, and forwarding character of certain consumers, and, at last, simply deficiency of the electric power in the republic and therefore desire to leave from tactical and market whims in distribution of fuel and energy resources [1].

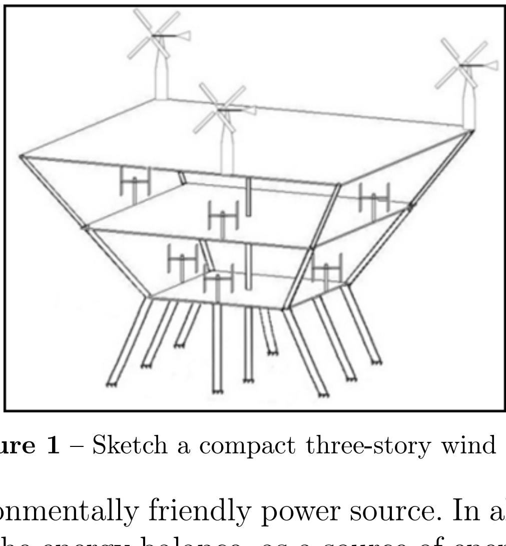

Figure 1 – Sketch a compact three-story wind farm

Wind – a natural, environmentally friendly power source. In all developed countries of the world, a significant role in the energy balance, as a source of energy, the wind begins to play.

Constantly expanding manufacture and installation of efficient wind turbines. In al-Farabi Kazakh National University we have offered a compact multystoried wind farm (CMWF) representing a multystoried design on which floors wind turbines of various type of the small power (fig. 1) settle down [2].

On internal floors CMWF advantageous to use rotary (vertical axis) wind turbine Darrieus type [2], at which the turbulence occurs around their themselves [3]. While there have propeller the turbulent trace which is a negative effect on neighboring wind turbine (Fig.2).

Figure 2 – The turbulent wake behind a propeller-type hydraulic turbines

The compact multystoried wind farm has the following advantages in comparison with usual land wind farms and separate wind turbines of identical power [2]: 1. Economy of the territory: CMWF occupies the territory several times smaller, than a usual wind farm of the same power with the wind turbines located to one floor on the ground. 2. A more sustainable use of wind power because of an arrangement of wind turbines at different heights as the speed of the wind flow has a different value depending on the height. 3. The space between floor overlappings forms the air passage promoting effective course of a wind stream as in a wind tunnel (effect of draft). 4. Simplicity of a design, her assembly and dismantling (as the Kazakh yurt) in comparison with the separate wind turbine of the same power. At the same time, the supporting structure of the separate wind turbine of big power will be less steady, than the multistoried CMWF supporting framework of the same power. 5. A possibility of a combination of different types of wind turbines with different speeds of rotation. 6. Than above the floor wind turbines settle down, subjects efficiency size them wind power increases as the speed of wind is usually higher at big heights. By us it is shown that installation on floors of CMWF of wind turbines in number of three is optimum [2]. Separate wind turbines of big power, occupying the small territory, have the following disadvantages: 1) complexity of a design; 2) big noise level; 3) the complexity of the installation and repair. CMWF is created for the first time in the world, there are no analogs [4]. The production technology of wind turbines of big power is rather difficult and it isn't in Kazakhstan. Whereas the production technology of wind turbines of low power is less difficult and is already created in Kazakhstan including us (a photo 2 and 3) [2]. Therefore in the countries where there is no production technology of wind turbines of big power (more than 100 kW), it is favorable to use CMWF. For performance of conditions of compactness of CMWF it is necessary to define minimum possible (optimum) distance between three wind turbines on internal floors of a wind farm for free passing of a wind stream [5]. Existence of the laminar stream passing between wind turbines will be the main criterion of receiving the required results. For the solution of this task packages of application programs of Autodesk family have been used: – Autodesk Inventor Pro© [6] for creation of solid-state models; – Autodesk Simulation CFD© [6] based on base of the equations of Navier-Stokes, for modeling of a flow a wind stream of the rotating wind turbines in the form of solid-state models.

2 Modeling

Process of research can be divided into the following stages: – to construct solid-state model of the wind turbine; – to build the internal floor of CMWF and to arrange on it 3 wind turbines; – to carry out numerical modeling of a task; – to analyse the received results. The three-blade wind turbine has been used, and as the cross section of a wing of the wind turbine the NACA 8416 profile has been chosen. In a software package of Inventor we create sketches of an axis of the wind turbine and three blades, for receiving three-dimensional model we squeeze out solid-state models of blades from our sketches we connect them to an axis as it is shown in figures 3 and 4 respectively:

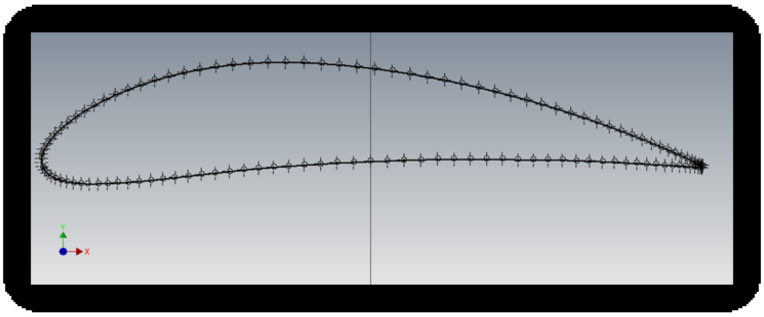

Figure 3 – Sketch of an blade cross section with a profile of NACA 8416

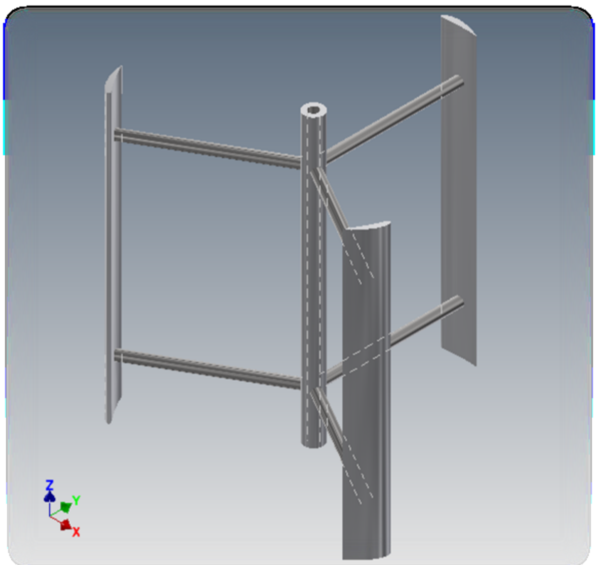

Figure 4 – The squeezed-out three-dimensional model of the wind turbine with three blades

By the same way it is received three-dimensional model of the floor of CMWF in the form of a hexagon with three three-blade wind turbines (fig. 5).

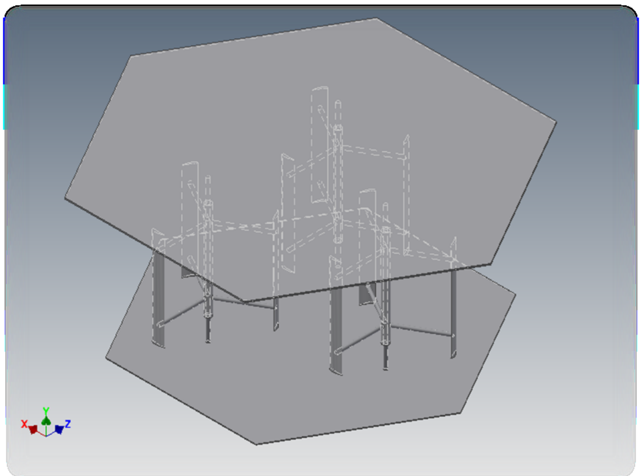

Figure 5 – Three-dimensional model of the floor of CMWF in the form of a hexagon with three three-blade wind turbines

Further, for modeling of a flow a wind stream of three wind turbines installed on the floor of CMWF we use the software package of Autodesk Simulation CFD©. For this purpose we create an environment which flows round wind turbines in the floor of CMWF – air, and we set boundary conditions: Entrance (inlet): size of speed of a wind stream; Exit (outlet): pressure – 0 Pas; Slip conditions on all surfaces. The settlement grid for the decision is built automatically, wind turbines have "free wheeling" and rotate under the influence of a wind stream, acts as a solver the model of turbulence SST k-omega, quantity of steps of the decision – 1000, with a temporary step – 1 second (fig. 6 and 7).

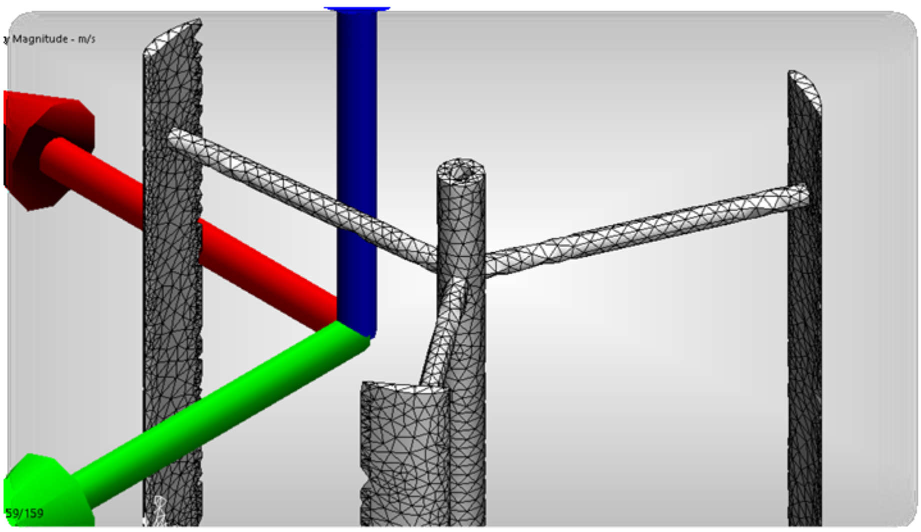

Figure 6 – A settlement grid on the example of the wind turbineы

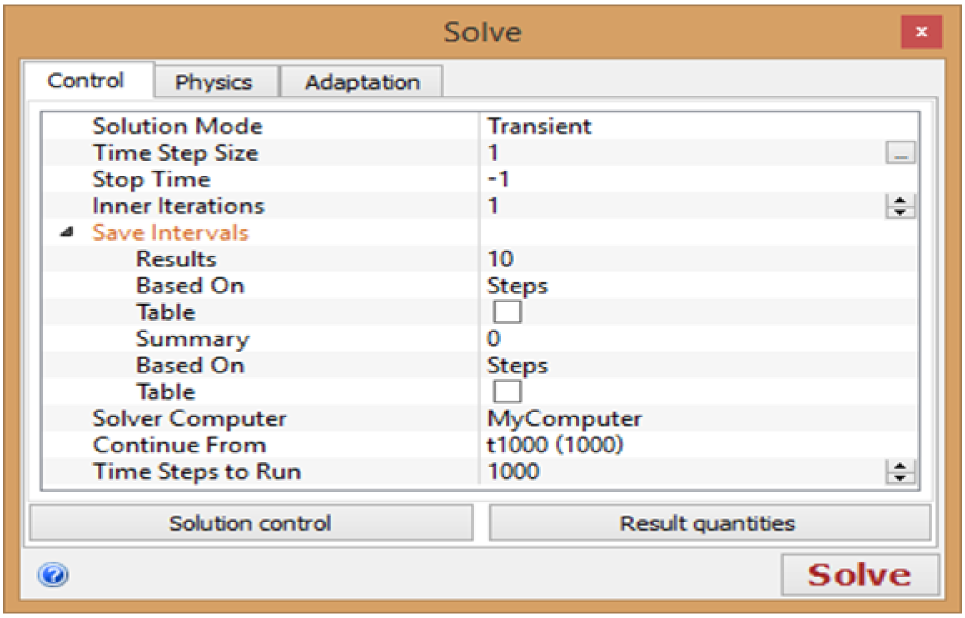

Figure 7 – Decision parameters

3 Conclusion

The received result in the form of animation of a flow are shown in figures 8.

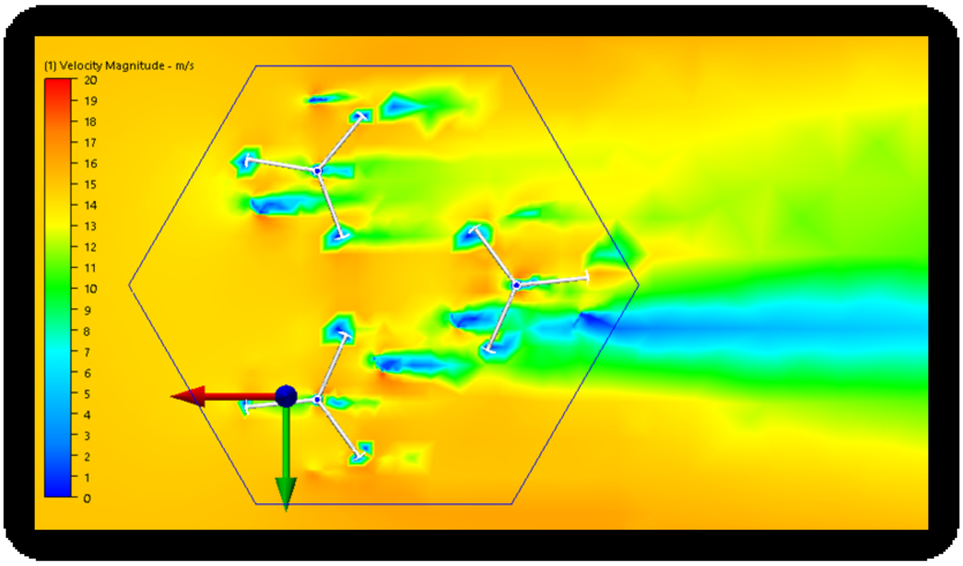

Figure 8 – Animation of a flow. Top view

From this picture it is visible what between wind turbines begins to pass a stream of air which speed is equal to tentative speed that will indicate emergence of a laminar flow between wind turbines. And at this moment the necessary minimum size of distance between wind turbines is defined. Results of calculations are given in a type of schedules (fig. 9).

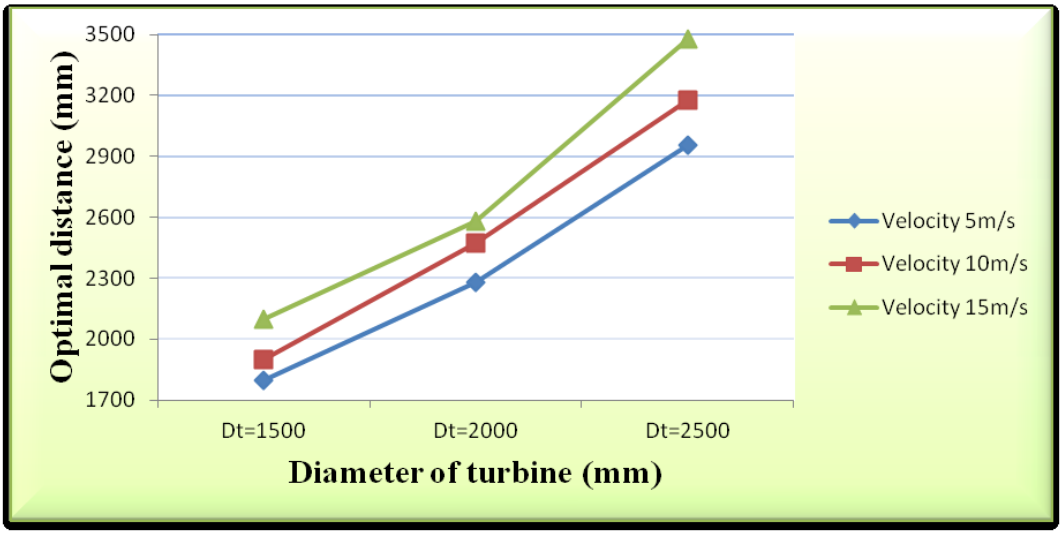

Figure 9 – The schedule of dependence of minimum size of distance between wind turbines from flow rates of air and dimeters of wind turbines

Thus, we have shown a possibility of finding of minimum possible (optimum) distance between three wind turbines on internal floors of CMWF with Autodesk family of software applications packages. This work was supported by the grant No 100 of the Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan, in affiliated state enterprise "Research Institute of Mathematics and Mechanics" (IMM) of the Republican state enterprise "al-Farabi Kazakh National University", under the direction of Candidate of Physical and Mathematical Science, the senior lecturer of the Department of Mechanics – Kunakbayev T.O.

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