Building-Integrated Wind Turbines in the Aspect of Architectural Shaping

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Abstract

Today, the use of wind energy is becoming one of the most developed areas of alternative energy. Introduction of means of alternative power engineering in structure of the building demands special events on safety measures that is strongly reflected in space-planning decisions. Increase of energy efficiency of system of the power active building, as a rule, depends on a form of its material and constructive structure. Thus, speaking about integration of means of alternative power engineering into structure of the building, we mean special approach to an architectural shaping. Efforts of architects and engineers are directed on that having united ideas of use of energy of renewable sources, function of the building and art of creation of an architectural form, to receive harmonious result. Search is directed on a choice of forms and designs, not only elements, but also actually buildings which promote increase in amount of the transformed energy.

1. Introduction

The issue of energy saving in construction has become the object of attention with the 70-ies of XX century [1-8]. The main reason was the recognition of the necessity to save energy after the world energy crisis of 1974, and the creation of innovative concepts of sustainable development and its adoption by most developed countries of the

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Peer-review under responsibility of the organizing committee of SPbUCEMF-2015

Keywords: architecture, renewable energy, shaping, wind energy, energy-efficient buildings, energy-efficient technologies, Building-integrated wind turbines.
Development of the first principles in the field of energy efficiency of buildings was the result of criticism from the International energy conference of the United Nations. Opponents of WEC were made by the experts, who spoke about the huge reserves of increase of energy efficiency of buildings. In response to this, in 1976, the WEC was formulated the basic principle of energy conservation. He stated that energy can be used more effectively if the measures that are technically feasible, economically justified, and acceptable from an environmental and social point of view.

Today, the use of wind energy is becoming one of the most developed areas of alternative energy. Throughout Europe there are wind power plants, but they are not able to fully provide the population and the city all the necessary energy. This raises the question about the possibility of implementing wind turbines on buildings, as engineering support each home, thus providing the necessary energy to the population of cities, using only renewable energy source.

Interdependence of the architectural form with function is one of constant topic of discussion in the architectural theory [9-18].

Increase of energy efficiency of system of the power active building, as a rule, depends on a form of its material and constructive structure. Thus, speaking about integration of means of alternative power engineering into structure of the building, we mean special approach to an architectural shaping. Efforts of architects and engineers are directed on that having united ideas of use of energy of renewable sources, function of the building and art of creation of an architectural form, to receive harmonious result. Speaking of the architecture of buildings, we can safely call the use renewable energy as form design factor in architecture [19-29].

Building-integrated turbines, where buildings are designed with wind energy in mind, are an option for consideration by developers tuned into the change surrounding sustainable living [30-35].

2. Wind-driven generator in in architecture buildings

Building-integrated turbines are of course limited to new developments in relatively windy areas and will have natural constraints in the size of turbines they can accommodate. The vision behind integrating a turbine into a building, in some cases, is perhaps less a practical solution to be widely adopted than an architectural and cultural statement. The value of the possible cultural benefits should not be underestimated as architecture simultaneously reflects and influences culture and cultural changes. Having these powerful dynamic symbols integrated directly into the heart of urban communities could help change mindsets and have positive knock-on effects in terms of environmental action (e.g. homeowners improving energy efficiency or engaging directly in renewable energy).

Despite their more limited applicability (relative to large-scale stand-alone turbines), it is thought that they can be viable and efforts have been made in this area. There is a project in which (in the presence of a moderate wind) the high-rise building would "eat" air streams almost for 100%.

![Fig. 1. Twin skyscrapers from Project Web. Source [36]](image)
It was developed by the "Wind Energy for City Environment" organization (Wind Energy for the Built Environment — Project Web) sponsored by the European government. The pioneering design of a twin-tower building with three integrated 35m diameter, 250kW horizontal axis wind turbines has now become an iconic form representing this field. Figure 2 present this design together with the first serious attempt which has since emerged to emulate these ideas – the World Trade Centre, Bahrain (constructed in 2007–2008). This building has three 29m horizontal axis turbines suspended between two 34-storey towers of prime office space. Both of these towers have been designed to catch and accelerate the prevailing winds. In the case of Bahrain’s World Trade Centre it should be noted that these are mild coastal winds and the building form is not fully aerodynamically optimized.

![Fig. 2. First large-scale building-integrated turbine project World Trade Centre in Bahrain, 2008 (Ahmed Hussain). Source [37]](image)

There may be a number of concerns which come to mind when considering these large-scale building-integrated turbines. Some require very careful consideration while others can be settled with some brief deliberation. Some designs for horizontal axis building-integrated turbines, require the blades to be fixed facing one direction (unlike conventional HAWT which can yaw into changing wind directions). For those cases where the blades are fixed, it should be noted that, although very little energy will be gathered when the wind blows from some directions, a well-designed building will accelerate or concentrate the wind from certain key directions. If there are strong prevailing winds then this type of technology can be viable if the building is appropriately shaped and orientated. However, noting some of the conclusions from the physical testing carried out in Project WEB, a non-yawing building integrating turbine can (if appropriately designed):

- accelerate winds (power enhancement) from winds +/- 75° from the direction of the prevailing wind (if the axis of the turbine is orientated with the prevailing wind);
- generate some energy even when winds are blowing 90° from the prevailing wind direction;
- generate at least twice as much energy from the prevailing wind than a ‘free-standing’ equivalent turbine.

Project WEB involved a high degree of large-scale physical testing using a turbine on a tower at 4.5m (see Fig. 1). Although the results quoted above only apply to this particular geometry they give an indication of what can be achieved. It is expected that a further optimized geometry could outperform this configuration although it should be noted that a poorly conceived/tested geometry will fare much worse.

As turbines do not start generating until the wind speed exceeds the ‘cut-in’ speed, any acceleration is welcomed. In urban areas, where winds are milder than open-field sites in the same region, accelerated winds can make all the difference.

In 2006, planning permission was granted for Castle House – a 43-storey landmark residential building in the centre of Elephant and Castle, London. The design envisages that the top of the building house three 9m diameter turbines in shrouds conceived to accelerate winds and help create more energy.
Fig. 3. The centre of Elephant and Castle, London. Source [38]

Usually, when considering the distance between turbines and residential areas, the separation distance is large. However, building-integrated turbines can have a physical barrier between the emission source and the occupant. In the case of Castle House there is the opportunity for a considerable physical barrier between the turbines and the nearest residential unit directly below.

Vertical axis wind turbines (VAWTs) can also be integrated into buildings. Project ZED (Towards Zero Emission Urban Development), one of the first concept projects for zero CO emission buildings, was part sponsored by the EU APAS (European Commission DG XII) between 1995 and 1997. It brought together teams from London (Future Systems, BDSP Partnership), Toulouse, France (Ecole D’Architecture), Berlin, Germany (RP+K SOZIETÄT) and Cologne, Germany (TÜVRHEINLAND). The London team incorporated a large bespoke vertical axis wind turbine in the centre of an aerodynamically shape building designed to maximize wind acceleration while simultaneously demonstrating a high performance building envelope and a visually striking architectural form.

A real-life example of VAWT integration can be found at Technisches Rathaus, Munich, tower. This turbine powers a large slowly rotating external artwork during the day and lighting at night. The rotor was designed by Neuhäuser Windtec GmbH and is rated at 40kW. Vertical axis wind turbines can be favoured by some purely on the basis of aesthetics. As will be seen, the VAWT in particular can take a variety of forms and can still remain as efficient as HAWTs.

The Burj al-Taqa (Energy Tower), Dubai, proposed by architectural firm Gerber Architekten international GmbH (and environmental engineers DS-Plan) 12 uses a bespoke VAWT (Patent No. 4-06-05-6331). The 68 storey 322m tower is conceived to be a 100 per cent energy self-sufficient building with 15,000 square metres of building-integrated solar cells. An additional ‘island’ of solar panels has been proposed to be built adjacent to the building with links to energy storage systems involving hydrogen and hot water.

The energy-efficient building envelope has a solar shield and mineral coated ‘vacuum glazing’. The fresh air supply is driven by wind forces acting on atria and pre-cooled by sea water.
The example of transformation of the design and form of the building promoting concentration and the organization of the formed vortex streams increasing the volume of the developed energy is presented by the realized project also in London designed by the British bureau of the architectural projects "Waugh Thistleton".

The building in the plan represents a sail which "collects" the air streams which are bending around construction surfaces and with acceleration directs them to the wind turbines located on all height on one side.

Having analysed world experience of design and construction of the building with integrated by means of wind energy it is possible to make classifications:

- in the wind-driven generator location on the building
- taking into account influence of wind power, as shaping factor
- taking into account type of the applied wind installations

Introduction of means of alternative power engineering in structure of the building demands special events on safety measures that is strongly reflected in space-planning decisions. And increase of energy efficiency of system of the power active building, as a rule, depends on a form of its material and constructive structure.

Thus, speaking about integration of means of alternative power engineering into structure of the building, we mean special approach to an architectural shaping.

3. Conclusions

The given examples all are realized and today function. Every year popularity of use of wind power grows. Perhaps, in the future the wind generator will become an integral part of the house. Then the form and volume of the building will depend directly on a problem of development of energy by means of wind force. Such examples of projects are, the truth they so far only the conceptual.

Development of power active buildings means special approach to design process. Introduction of means of alternative power engineering in structure of the building demands special events on safety measures that is strongly reflected in space-planning decisions. And increase of energy efficiency of system of the power active building, as a rule, depends on a form of its material and constructive structure. Thus, speaking about integration of means of alternative power engineering into structure of the building, we mean special approach to an architectural shaping.

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