Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 1, Number 9; October, 2014 pp. 25-29

http://www.krishisanskriti.org/jbaer.html

Urban Integration of Solar – Wind Hybrid System

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Abstract: **Energy is vital for sustaining life on earth. It's the basic foundation for economic stability, prosperity and quality of life. This energy has been produced majorly by fossil or hydro carbon fuels such as petrol, coal, diesel etc. With the fast paced development, the need for energy is going up exponentially. The hydro carbons cannot fulfill the energy demand for a long time. The world is standing on the verge of hitting the bottom of our finite non- renewable energy resources.**

The excessive use of non- renewable energy resources has resulted in energy deficit, pollution and expensive supply of non-renewable energy. India being the fifth largest consumer of commercial energy, represents approx. 33% of total electricity consumption in building sector whereas interior lighting energy consumption in commercial buildings accounts for 20%-40%.

Buildings, being huge energy guzzlers, will make a big dent on the energy demand if Building Integration of renewable energy systems is done. This inevitable event had triggered the research and use of renewable energy resources to fuel the global fast paced development.

Solar and wind energy stand in the forefront of all available green energy sources, making the hybrid solar and wind systems an all-around winner. Buildings consume 40% of the global energy usage, which makes integration of renewable energy in them a straightforward choice. Renewable energy integration at urban level will make a significant impact on India's energy usage.

Though there has been a lot of movement towards use of such systems with the help of Government schemes and the increasing awareness but as the path is untrodden, there is inefficient implementation happening.

This paper talks about the architectural integration of solar wind hybrid systems in the urban fabric for optimum harnessing of energy. The focus is on incorporating such systems in urban designing and planning from conception stage.

1. INTRODUCTION

Energy is vital for sustaining life on earth. It's the basic foundation for economic stability, prosperity and quality of life. This energy has been produced majorly by fossil or hydro carbon fuels such as petrol, coal, diesel etc. With the fast paced development, the need for energy is going up exponentially. The hydro carbons cannot fulfill the energy demand for a long time. This has resulted in energy deficit, pollution and expensive supply of energy.

India being the fifth largest consumer of commercial energy, represents approx. 33% of total electricity consumption in building sector whereas interior lighting energy consumption in commercial buildings accounts for 20%-40% [1]. Buildings, being huge energy guzzlers, will make a big dent on the energy demand if Building Integration of renewable energy systems is done. India has 300 sunny days/year and nearly receives an average hourly radiation of 200 MW/Sq km [2]. so this literally bottomless pit of energy storage is available, ready to be utilized. Optimum, economical and aesthetically pleasing usage of renewable energy systems in building will take us towards cleaner and greener future. For better efficiency of solar as well as wind hybrid system, the design of building and the site has to be optimized to aid in the working of such systems. Normally few PV panels added on the roof as an afterthought or the solar thermal systems are considered to be the end of renewable energy application in the buildings by the architects. All aspects of such systems are neither understood nor applied normally.

2. SOLAR WIND ENERGY PHENOMENA

Most renewable energy ultimately comes from the sun and 1-2 % of the sun's energy reaching the earth is converted into wind. The behavior of wind is quite irregular depending upon the surroundings i.e. open land, dense populated areas, trees, tall buildings and streets. Wind is found everywhere which makes the transport cost almost nil and makes the energy available to the most remote areas.

The systems are economical on a larger scale with very low operating costs. But they are fluctuating in nature and carry non – uniformly distributed energy so the energy storage costs are added. The systems are loud and big in size. The best wind resources tend to be in remote areas so grid connectivity becomes tricky. India's wind power potential has been assessed at 45000 MW [3].

Solar energy is the largest exploitable renewable resource as more energy from sunlight strikes Earth in 1 hour than all of the energy consumed by humans in an entire year. It is abundantly available, economically feasible and utilises the unusable land for installation. On the other hand, its non-concentrated which makes the system less efficient, increases the capital investment and the land requirements. The energy density is very low (0.1-1 KW/sq. m.) And it changes with days and seasons.

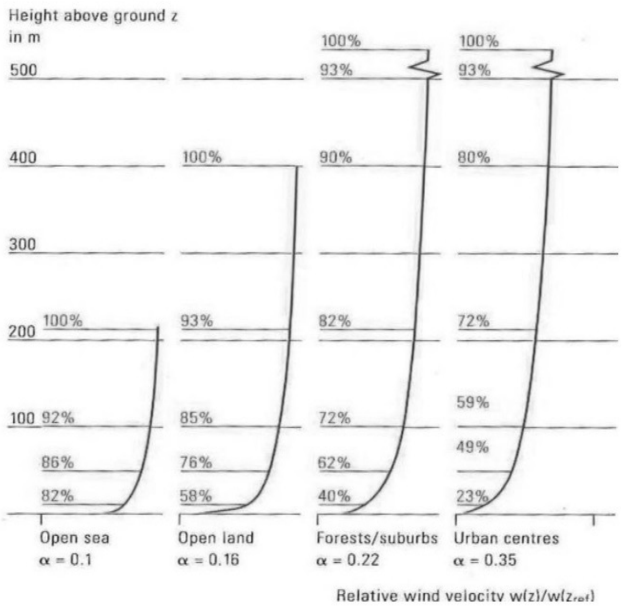

Fig. 1: Height – Velocity Graph [5]

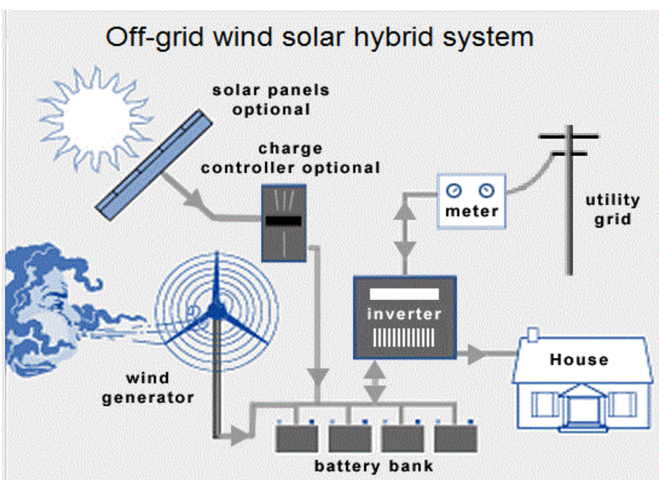

Fig. 2: Solar Wind Hybrid System [6]

The fluctuating nature of these sources has led to the conception of hybrid systems. Such systems could be defined as "a combination of different, but complementary energy supply systems at the same place, i.e. solar cells and wind power plants." Hybrid systems provide better reliability, reduce pollution and are a good tool for the utility for demand side management [4]. Hybrid systems capture the best features of the selected technologies and generate "grid- quality" electricity. The most popular hybrid system is solar and wind. But the biggest drawback of such systems is there cost as multiple components are required. They need an adequate study period as each system is unique and requires optimization based on site – specific conditions [7].

Hybrid systems strongly push towards decentralized electrification because they could be designed as stand-alone grids. Generally, the independent use of both energy resources may result in considerable over-sizing, which in turn makes the design costly [8]. The benefits of the hybrid systems are coming to forefront in such a manner that the governing bodies are also providing subsidies and generating schemes for encouraging its installation on a grand scale.

Table 1: Subsidy Scheme as per MNRE website

	Type of System	System specifications			Output		Financial		
		Rated System Capacity* (kW)	Wind Component (kW)	Solar Component (kW)	Expected annual output* (kWh/year)	Average daily output** (kWh/day)	Ex Works***	MNRE Subsidy	Cost to Customer***
1	Wind	5	5	-	9100	25	Rs 728,000	Rs 500,000	**Rs 228,000**
2	Wind	10	5+5	-	18200	50	Rs 1,310,400	Rs 1,000,000	**Rs 310,400**
3	Wind-Solar Hybrid	6	5	1	11100	30	Rs 904,000	Rs 600,000	**Rs 304,000**
4	Wind-Solar Hybrid	7	5	2	13100	36	Rs 1,078,000	Rs 700,000	**Rs 378,000**
5	Wind-Solar Hybrid	8	5	3	15100	41	Rs 1,425,000	Rs 800,000	**Rs 625,000**

*in location with mean wind speed of 5.0 m/s and Solar Irr. Equivalent to 5.5 h

**please note actual output will vary from day to day

3. INTEGRATION OF SOL-WIND HYBRID SYSTEMS IN THE URBAN FABRIC

The awareness about the solar – wind hybrid technologies has led to their incorporation in building design and to some extent they have moved from pasted on features to seamless design integration in the building skin. But there are huge areas available like streets, landscape plains, in large projects which go untouched. The first step is assessing the physical characteristics of a building i.e. form, height etc. to provide the best possible background for a system. The second step is to select an appropriate system and location on the façade. The following 3 "S" (Structure, Street and Scape) design approach intends to provide consolidated guidelines to be followed for urban integration of the turbines and PV panels.

3.1 Architectural Assessment:

The integration of wind turbines in built form must start from the form modification of the building itself. Shaping of tall buildings can be used effectively to enhance the performance of wind turbines by creating Venturi effect. A set of forms {Boomerang, blade, reverse blade, oval and seed shapes (Figure 3)} were placed in the wind tunnel under steady winds to judge the accentuation or negation created by them on the power generation capacity . A 45° rotation raises the generation potential considerably and the air flow around the building becomes less intrusive to other buildings and pedestrians. The angle must not be increased more than 45° to avoid structural damage to the building due to the wind resistance. The blade design is a modified oval design (Inspired from the wings of an air plane), which allows smooth movement of air whereas the narrower back minimizes the turbulence. This design has lesser turbulence then the oval and rectangle. This shape provides more performance and possibilities for power generation. Wind turbine can be integrated in between the buildings and at the curved outer edges of the windward side.

A reverse blade design creates sharp acceleration but creates a lot of turbulence. The major advantage of the seed shape is that it provides more area on a smaller site than other shapes. The boomerang shape is an exaggerated model with a larger funnel opening and smaller outlet. This has the best acceleration of wind till 90° angle but with a large disturbance behind the building which needs some modifications.

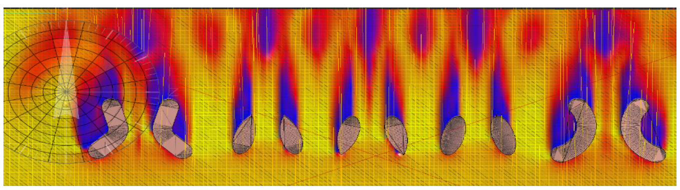

Fig. 3: Wind Tunnel Studies for Various Forms

3.1.1 Street Integration: Streets cover a large area of any settlement and are normally ignored for such installations. Street geometry and orientation influence the amount of solar radiation received by street surfaces and also airflow in urban canyons. A street canyon refers to the space which is formed by two typically parallel rows of buildings separated by a street and it creates the basic unit of urban planning. Further studies of the same forms arranged to create street profiles how clear channelization and acceleration of winds, which makes the streets a hotspot for wind energy harnessing.

According to the most related studies, street canyon geometry's parameters (height-to-width ratio (H/W)) and the street orientation directly affect the potential of airflow at street level and solar access. The wind speeds are slower and more stable in the deep canyon (0.4 m/s) in both winter and summer seasons [9].

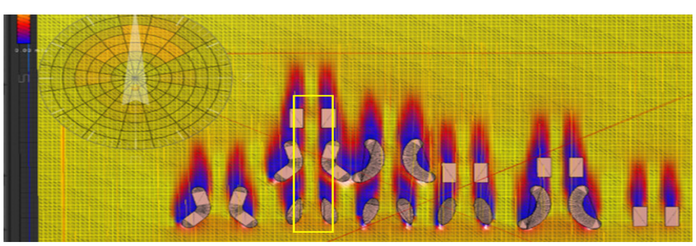

Fig. 4: Wind Tunnel Studies showing wind acceleration in the streets (yellow box)

It has been proved that narrow street canyons (4 m and less) could increase wind speed passing through it but create eddies at bending angle. Strategically placing a few blocks of high-rise towers improves the velocity within the street canyon when the airflow in parallel or perpendicular to the canyon. By placing some high rise towers, the velocity is increased by up to 90% for parallel flow and up to 10 times for perpendicular flow. Installing micro turbines above pedestrian level will help in utilizing this effect [9].

Solar energy falling on an urban area is received either by buildings facades and roofs or by the ground between buildings. From the urban street canyon point of view, the amount of solar radiation could directly influence the solar access and hence, the power generation by the PV panels integrated into the façade. By reducing the H/W ratio the amount of solar energy received by the street surfaces increases [10]. The solar panels can be integrated in the design taking place of the design elements, which reduces the cost of the material, provide insulation and aesthetic view. So shading devices, roof, and skylights etc. features should be planned from the beginning.

3.1.2 Scape Assessment: There is a large potential to be harnessed by integrating solar-wind systems in the open areas like parking lots, landscape designs. Urban Roughness acts to slow the wind, through aerodynamic drag, and increase its turbulence so regulating it with design features is the main concern.

3.2 Architectural Integration

After selecting the perfect forms and facades, the second step is selection of PV and turbine especially. It's an iterative process which depends on the space, location and wind flow at that point. Similarly the selected turbine or PV will influence the design.

Fig. 5: BIPV in skylights [11]

Solar photovoltaic (SPV) is the process of converting solar radiation (sunlight) into electricity using a device

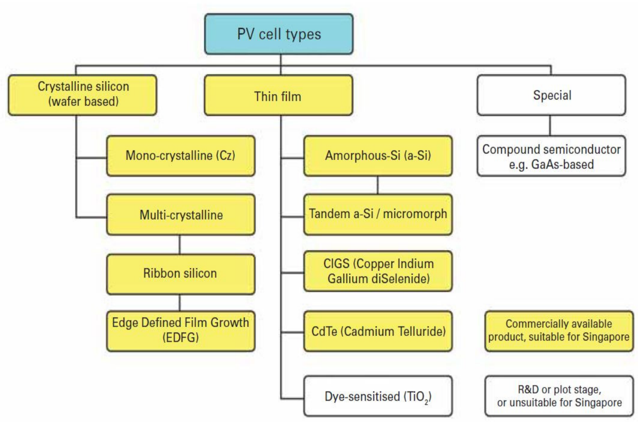

Fig. 6: Types of PV Cells [12]

called solar cell. Solar cells are connected in series and parallel combinations to form modules that provide the required power [13]. Common PVs available are mono-crystalline silicon, polycrystalline silicon and thin film silicon called amorphous silicon (A-Si) [14]. The selected panel (as per load and space calculations) can be incorporated in the building to become a part themselves.

Fig. 7: BIPV in shading devices [15]

Conventionally wind turbines are of two types: horizontal axis and vertical axis. In the recent times, quieter and more aesthetically pleasing turbines have entered the market. Few of them are: Ropatec, Euro wind, Turby, QR5 etc. these can be augmented into the buildings at the time of designing itself as features.

Fig. 8: AeroVironment AVX1000 & Energy Ball Turbine [16] [17]

4. CONCLUSIONS AND RECOMMENDATIONS

The complementary phenomena of solar and wind holds the potential to decrease the energy demand to a very large extent. The integration must be site – specific, involving keen thinking from the project‘s conceptual stage only. Wind channeling and solar optimizing forms planned with turbines and PV as design features will be able to fuel the building. Thorough planning of streets, parking areas and landscaped zones can provide more canvas for the solar wind hybrid systems. Seamless integration at urban level can only be possible if these systems take a centre stage in our planning process, instead of being just an afterthought. Modification in the urban planning guidelines and byelaws is necessary to kick start this process, just as the Government provides motivation with its schemes for use of renewable energy at building level. As there are many universities (including 5 IITs) proposed in the Union Budget and 5 year plans, implementation of the 3 S design phenomena in them will provide live example of the performance of the above mentioned systems. This step will pave the way for a cleaner and greener future.

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