Wind Power Generation Utilizing a Special Buildings Layout Design to Enhance the Wind Speed

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Doi: 10.19044/esj.2018.v14n6p303 URL:http://dx.doi.org/10.19044/esj.2018.v14n6p303

Abstract

There is a high growing interest for the use of wind power utilizing the building's layout design. The main objective of this work is to accelerate the wind speed before reaching the turbines by using spatial design of twin's buildings; this will generate more electric power. The variables which are affecting the wind speed directed to turbines are the angle between the twin buildings, the height and the length of buildings. The results have shown that the wind speed was accelerated in the intervening space between the buildings irrespective of the distance between the walls of adjacent buildings. Nine wind turbines were installed in three rows and three columns on the wall between the two buildings to generate the electricity. These turbines were located at the top of the wall to face higher wind speed because wind speed depends on height. Also the results showed that the wind speed was accelerated by about five times for the building layout design of the present study; while the generated power was about 125 times in comparison with the buildings do not have a spatial layout design (i.e. they do not enclose an angle between them). Finally the average power generated for the present work buildings dimensions with normal consumption of electricity will cover about 13% of the total normal consumption demand of the buildings (the power generated of the present work buildings layout design is about 0.23 GWh/year).

Keywords: Buildings dimensions (length and height), Turbine specifications, Wind speed and Angle Between Buildings (α)

Introduction

Wind is a form of solar energy which is caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover this wind flow, or motion energy, when "harvested" by modern wind turbines, can be used to generate electricity The use of windmills (or wind turbines) to generate electricity can be traced back to the late nineteenth century with the 12 kW DC windmill generator constructed by Brush in the USA and the research undertaken by LaCour in Denmark. However, for much of the twentieth century there was little interest in using wind energy other than for battery charging for remote dwellings and these low-power systems were quickly replaced once access to the electricity grid became available (Wind Energy Guide, 2016). In Germany, Professor Hutter (Al-Quran, A., 2016) constructed a number of innovative, lightweight turbines in the 1950s and 1960s. In spite of these technical advances and the enthusiasm, among others, of Golding at the Electrical Research Association in the UK there was little sustained interest in wind generation until the price of oil rose dramatically in 1973 The sudden increase in the price of oil stimulated a number of substantial Government-funded programmers of research, development and demonstration. In the USA this led to the construction of a series of prototype turbines starting with the 38 m diameter 100 kW Mod-0 in 1975 and culminating in the 97.5 m diameter 2.5 MW Mod-5B in 1987 (Ben Luce, 2011). Similar programmers were pursued in the UK, Germany and Sweden. In particular the financial support mechanisms in California in the mid-1980s resulted in the installation of a very large number of quite small (100 kW) wind turbines. A number of these designs also suffered from various problems but, being smaller, they were in general easier to repair and modify. The so-called 'Danish' wind turbine concept emerged of a three-bladed, stall-regulated rotor and a fixed-speed, induction machine drive train (Bowen, Y. and et al, 2016).

Problem Statement

This study is a theoretical analysis to study how the building's design can be utilized to generate electricity by using small turbines for electric power within buildings design and determine the appropriate size and type of turbines for this purpose and dimensions best suited to these turbines from buildings and equipping of a scale model of this design. Also studying the negative impacts of the presence of turbines near homes and try to reduce these impacts such as noise, this can be achieved by using the optimization of wind turbine performance curves by:

• Obtain insight into the influence of the angle shape between two buildings where the turbines will be
Located
• Obtain insight into the influence of performance curve parameterization.
• Obtain insight into the influence of the number of wind turbines in a small wind farm.

• Obtain insight into the influence of buildings height and the surrounding of the buildings.

Research Methodology

In order to achieve the overall objectives of the research, it is always important to have a systematic approach for the framework of research implementation. Thus, the following approach is adopted in the current study

- Literature survey: Reviewing the collection of research publications, books and other documents related to the research problem, in order to understand and evaluate of the current state of the research.
- Development of conceptual design of proposed system. This part includes the design and calculations of all energy efficient measures taken.
- Collect and analysis the data.
- Results arrangement and discussion
- Economical study of the proposed systems including life cycle cost analysis and compare it with conventional systems.

Wind Energy Conversion System (WECS) Technology:

A WECS is a structure that transforms the kinetic energy of the incoming air stream into electrical energy. This conversion takes place in two steps, as follows, the extraction device, named wind turbine rotor turns under the wind stream action, thus harvesting a mechanical power. The rotor drives a rotating electrical machine, the generator, which outputs electrical power. Several wind turbine concepts have been proposed over the years. There are two basic configurations, namely vertical axis wind turbines (VAWT) and, horizontal axis wind turbines (HAWT). Today, the vast majority of manufactured wind turbines are horizontal axis, with either two or three blades. HAWT is comprised of the tower and the nacelle, mounted on the top of the tower. Except for the energy conversion chain elements, the nacelle contains some control subsystems and some auxiliary elements (e.g., cooling and braking systems, etc.).

The energy conversion chain is organized into four subsystems:

- Aerodynamic subsystem, consisting mainly of the turbine rotor, which is composed of blades, and turbine Hub, which is the support for blades;
- Drive train, generally composed of: low-speed shaft – coupled with the turbine hub, speed multiplier
- High-speed shaft – driving the electrical generator; electromagnetic subsystem, consisting mainly of the electric generator;
- Electric subsystem, including the elements for grid connection and local grid.

All wind turbines have a mechanism that moves the nacelle such that the blades are perpendicular to the wind direction. This mechanism could be a tail vane (small wind turbines) or an electric yaw device (medium and large wind turbines).

Wind Turbine Aerodynamics:

The wind turbine rotor interacts with the wind stream, resulting in a behavior named aerodynamics, which greatly depends on the blade profile, the main types are:

a) Actuator Disc Concept

The analysis of the aerodynamic behavior of a wind turbine can be done, in a generic manner, by considering the extraction process. Consider an actuator disc as shown in figure-1 and an air mass passing across, creating a stream-tube

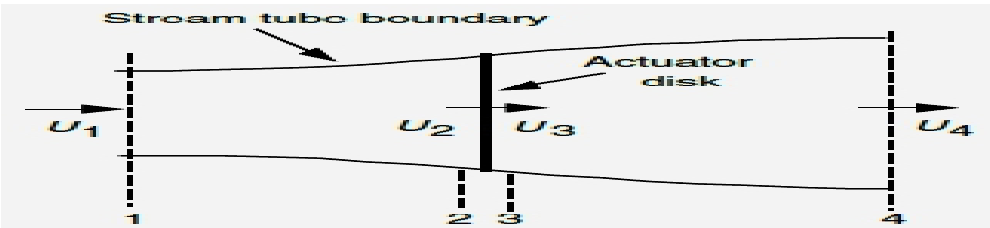

Figure-1 Actuator disc (Burton et al. 2011)

Upstream of the disc the stream-tube has a cross-sectional area smaller than that of the disc and an area larger than the disc downstream. The expansion of the stream-tube is because the mass flow rate must be the same everywhere. The mass of air which passes through a given cross section of the stream-tube in a unit length of time is ρAU, where ρ is the air density, A is the cross-sectional area and U is the flow velocity. The mass flow rate must be the same everywhere along the stream tube, it is usual to consider that the actuator disc induces a velocity variation which must be superimposed on the free-stream velocity. The stream-wise component of this induced flow at the disc is given by (a), where (a) is called the axial flow induction factor, or the inflow factor. (Burton and et al, 2011)

b) Apply the 1-D conservation of linear momentum:

Net force on the control volume = Time rate of change of the linear momentum

Force of the wind on the rotor (Thrust, T) = Net Force

Using the assumptions of an ideal rotor, it is possible to derive simple relationships between the velocities V_o, u_1 and u, the thrust T, and the absorbed shaft power P. The thrust is the force in the stream wise direction resulting from the pressure drop over the rotor, and is used to reduce the wind speed from V_0 to u_1: $T = \Delta p\ A$. Where $A = \pi R^2$ is the area of the rotor. The flow is stationary, incompressible and frictionless and no external force acts on the fluid up- or downstream of the rotor. Therefore the Bernoulli equation is valid from far upstream to just in front of the rotor and from just behind the rotor to far downstream in the wake as shown in figure – 2 **(** Martin O. L. Hansen ,2008)

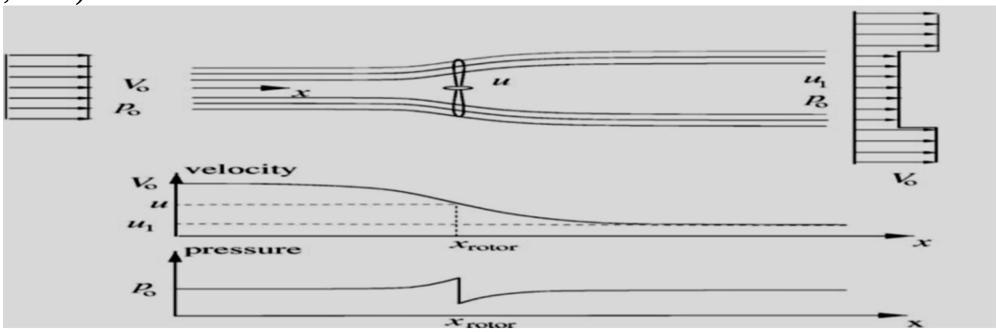

Figure -2 Illustrations of the streamlines (Martin O. L. Hansen, 2008)

The illustration of the streamlines past the rotor and the axial velocity and pressure up- and downstream of the rotor, as follows:

$$P_0 + \frac{1}{2}\rho V_0^2 = P + \frac{1}{2}\rho u^2 \quad (1)$$

And

$$\mathrm{P} - \Delta\mathrm{p} + \frac{1}{2}\rho u^2 = P_0 + \frac{1}{2}\rho \mathrm{u}_1^2 \quad (2)$$

Combining equation (1) and (2) yields:

$$\Delta\mathrm{p} = \frac{1}{2}\rho(V_0^2 - u_1^2) \quad (3)$$

Using the simplified assumptions of an ideal rotor

$$\rho u_1^2 A_1 + \rho V_0^2 (A_{cv} - A_1) + \dot{\mathrm{m}}\mathrm{side} V_0 - \rho V_0^2 A_{\mathrm{CV}} = -T \quad (4)$$

$\dot{m}_{side}$ can be found from the conservation of mass:

$$\rho A_1 \mathrm{u}_1 + \rho(A_{cv} - A_1)V_0 + \dot{\mathrm{m}}\mathrm{side} = \rho \mathrm{A}_{\mathrm{cv}} V_0 \quad (5)$$

Yielding:

$$\dot{\mathrm{m}}\mathrm{side} = \rho \mathrm{A}_1(V_0 - \mathrm{u}_1) \quad (6)$$

The conservation of mass also gives a relationship between A and A_1 as:

$$\dot{\mathrm{m}}\mathrm{side} = \rho \mathrm{uA} = \rho u_1 A_1 \quad (7)$$

Combining equations (6), (7) and (4) yields:

$$T = \rho \mathrm{u} \mathrm{A}(V_0 - \mathrm{u}_1) = \dot{m}(V_0 - \mathrm{u}_1) \quad (8)$$

$$u = \frac{1}{2}(V_0 - \mathrm{u}_1) \quad (9)$$

The flow is assumed to be frictionless and there is therefore no change in the internal energy from the inlet to the outlet and the shaft power P can be found using the integral energy equation on the control volume,

$$P = \dot{m}\left(\frac{1}{2}V_0^2 + \frac{P_0}{P} - \frac{1}{2}u_1^2 - \frac{P_0}{P}\right) \quad (10)$$

And since $\dot{m} = \rho\ u\ A$ the equation for P simply becomes:

$$P = \frac{1}{2}\rho u A(V_0^2 - u_1^2) \quad (11)$$

The axial induction factor (a) is defined as:

$$\mathrm{u} = (1 - \mathrm{a})\ \mathrm{V_o} \quad (12)$$

Combining equation (12) with (9)

$$\mathrm{u}_1 = (1 - 2\mathrm{a})\ \mathrm{V_o} \quad (13)$$

Which then can be introduced in equation (11) for the power P and into equation (8) for the thrust T, yielding:

$$P = 2\rho V_0^3 a(1-a)^2 A \quad (14)$$

The available power in a cross-section equal to the swept area A by the rotor is:

$$P\mathrm{avail} = \frac{1}{2}\rho A V_0^3 \quad (15)$$

The power P is often non-dimensional with respect to P available as a power coefficient Cp:

$$Cp = \frac{P}{\frac{1}{2}\rho V_0^3 A} \quad (16)$$

Similarly a thrust coefficient CT is defined as:

$$CT = \frac{T}{\frac{1}{2}\rho V_0^2 A} \quad (17)$$

Using equations (14) and (15) the power and thrust coefficients for the ideal 1-D wind turbine may be written as:

$$Cp = 4\,a\,(1 - a)^2 \quad (18)$$

And:

$$CT = 4\,a\,(1 - a) \quad (19)$$

Differentiating *Cp* with respect to (*a*) yields:

$$\frac{dcp}{da} = 4(1-a)(1-3a) \quad (20)$$

It is easily seen that *Cp, max* = 16/27 for *a* = 1/3. This theoretical maximum for an ideal wind turbine is known as the Betz limit. The ratio between the areas A_o and A_1 can be found directly from the continuity equation as: (Martin O. L. Hansen, 2008)

$$\frac{Ao}{A_1} = 1 - 2a \quad (21)$$

(c) Aerodynamic Loading:

The aerodynamic loading is caused by the flow past the structure, in other words the blades and the tower. The wind field seen by the rotor varies in space and time due to atmospheric turbulence as sketched in figure-3

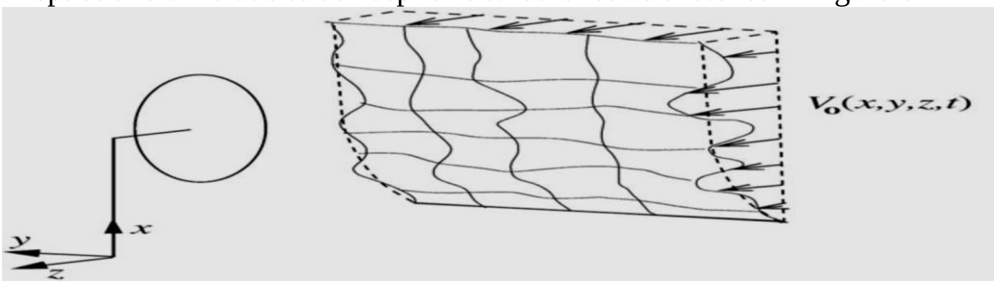

Figure -3 turbulent inflows seen by wind turbine rotor (Martin O. L. Hansen, 2008)

The wind field is characterized by shear; in other words the mean wind speed increases with the height above the ground. For neutral stability this shear may be estimated as:

$$\frac{V_{10\,min(x)}}{V_{10\,min\,(h)}} = \frac{1n\,(x/zo)}{1n\,(h/zo)} \quad (22)$$

$V_{10\ min(x)}$ is the time averaged value for a period of 10 minutes at a height *x* above the ground. $V_{10\ min\ (h)}$ is the time averaged value at a fixed height *h* and *zo* is the so-called roughness length. The roughness length depends on the surface characteristics and varies from 10^{-4} m over water to approximately

1m in cities. Values of *zo* can be found in Torne and Petersen (1989) and are summarized in Table (1).

Table (1) Roughness length table (Troen and Petersen 1989)

zo [m]	Terrain surface characteristics
1.0	City
0.8	Forest
0.2	Many trees and bushes
0.1	Farmland with closed appearance
0.05	Farmland with open appearance
0.03	Farmland with very few buildings, trees, etc
5×10^{-3}	Bare soil
1×10^{-3}	Snow surface
3×10^{-4}	Sand surface (smooth)
1×10^{-4}	

Venturi Effect

The Venturi effect is the reduction in fluid pressure that results when a fluid flows through a constricted section (or choke) of a pipe. The Venturi effect is named after Giovanni Battista Venturi (1746–1822), an Italian physicist (Colman J 2016, and Fairclough, C. 2015). In fluid dynamics, a fluid's velocity must increase as it passes through a constriction in accord with the principle of mass continuity, while its static must decrease in accord with the principle of conservation of mechanical energy. Thus any gain in kinetic energy a fluid may accrue due to its increased velocity through a constriction is balanced by a drop in pressure. Using Bernoulli's equation in the special case of steady, incompressible, in viscid flows (such as the flow of water or other liquid, or low speed flow of gas) along a streamline, the theoretical pressure drop at the constriction is given by:

$$p_1 – p_2 = \rho / 2 (v_2^2 - v_1^2) \quad (23)$$

Where ρ is the density of the fluid, v_1 is the (slower) fluid velocity where the pipe is wider, v_2 is the (faster) fluid velocity where the pipe is narrower. A Venturi can be used to measure the volumetric flow rate Q. (Caty Fairclough , 2015). Since

$$Q = v_1A_1 = v_2A_2 \quad (24)$$

Twin Buildings Design

In this work the principles of converge and diverge of the wind flow to accelerate the wind speed will be adopted by using a special design of twins buildings, and directed it into a nine horizontal turbines which will be installed on the wall connecting the two buildings, the wall will be designed in parabolic shape. The wall height is the same as the height of buildings (30) m, wide equals (20) m and thickness of (1.5) m as shown in figure-5

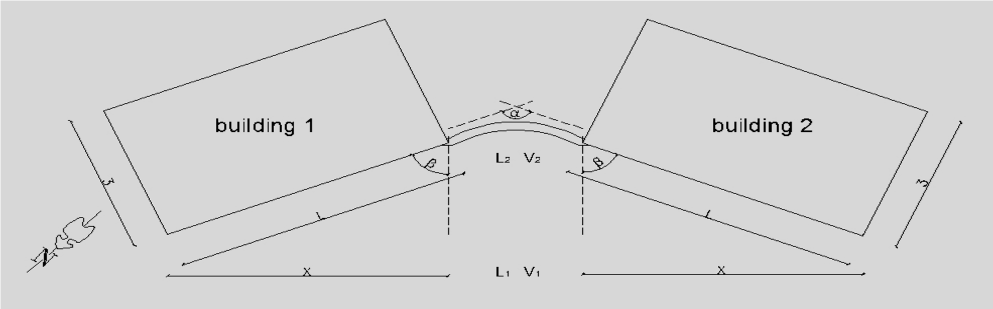

Figure -4 Flipchart of the Buildings

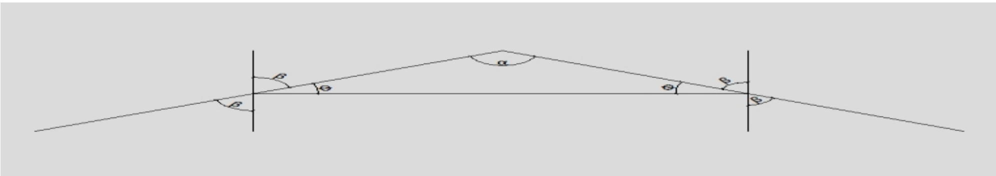

Figure -5 Angles scheme between the two buildings

The Relationship between the angle between the two buildings (α) and the space between buildings at inlet (L_1) , $2\theta + \alpha = 180$

$$2(90-\beta) + \alpha = 180$$

$$\alpha = 180 - 180 + 2\beta \quad \text{Then } (\alpha = 2\beta) \tag{25}$$

$$\sin\beta = (x/L) = ((L_1 - L_2) / 2)/L \tag{26}$$

$$L_1 = 2L\sin\beta + L_2$$

$$L_1 = 2L\sin(\alpha/2) + L_2 \tag{27}$$

Calculations

Amman city will be chosen for this study, because it's a big city and has suitable buildings to carry out this study they are used as offices, commercial buildings with huge spaces. So the wind speed should be studied inside the city, and its directions in order to decide which building going to be chosen, and the expected wind energy.

(a) Wind Speed and Direction:

Over the course of the year the typical wind speeds vary from 0 m/s to 9 m/s (calm to fresh breeze), rarely exceeding 13 m/s (strong breeze). The highest average wind speed of 8 m/s (moderate breeze) occurs around March 16, at which time the average daily maximum wind speed is 8 m/s (fresh breeze).The lowest average wind speed of 2 m/s (light breeze) occurs around October 14, at which time the average daily maximum wind speed is 6 m/s for moderate breeze as shown in figure-6 (Jordan weather, 2016)

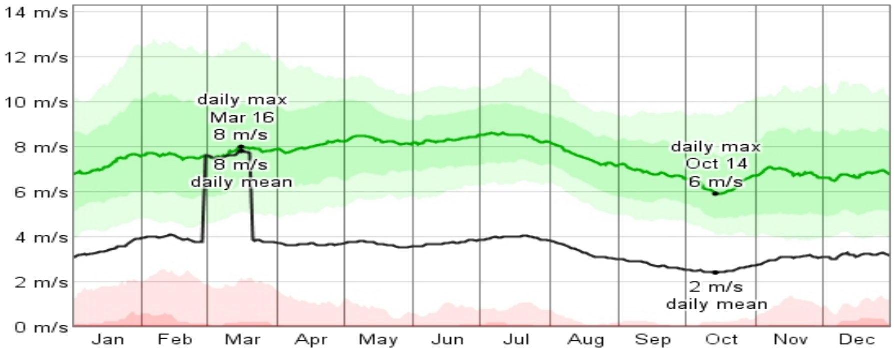

Figure-6 wind speed in Amman (Jordan weather, 2016)

The wind is most often out of the west (19% of the time) and North West (18% of the time). The wind is least often out of the south (2% of the time), north east (3% of the time), north (3% of the time), south west (4% of the time), and south east (4% of the time). The fraction of time spent with the wind blowing from the various directions over the entire year. Values do not sum to 100% because the wind direction is undefined when the wind speed is zero as shown figure-7 (Jordan weather, 2016)

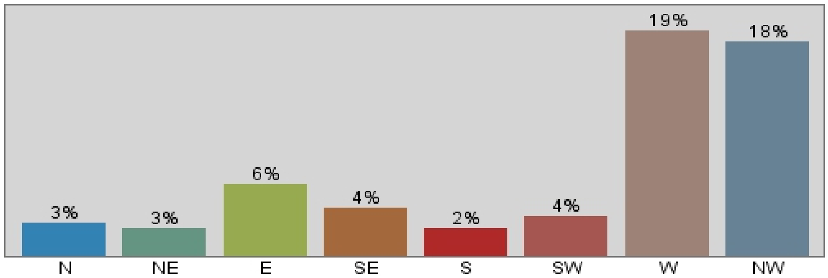

Figure -7 Wind Directions over the Entire Year Amman (Jordan weather, 2016)

The daily maximum wind speed will be taken 6 m/s (moderate breeze) as the initial wind speed before it will be accelerated by buildings is V_1 and the design of buildings layout will be in west direction to North West to collect the maximum portion of wind because the wind is most often out of the west or North West.

(b) Wind Speed Calculations:

The required calculations are to calculate how much initial wind speed will be accelerated based on the above hypothesis and buildings layout design depending on the best dimension of the twin buildings and the best angle between the buildings to obtain the best locations of turbines. So, to find how mach the buildings will accelerate the wind speed based on buildings layout and Venturi effect of fluid this is based on the followings:

$$A_1V_1 = A_2V_2$$

$$h\,L_1V_1 = hL_2V_2$$
$$L_1V_1 = L_2V_2$$
$$V_2 = L_1V_1/ L_2$$
$$V_2 = (V_1/ L_2)\,(2\,L \sin(\alpha/2) + L_2) \quad (28)$$

Where: V_1 (initial wind speed at inlet), V_2 (wind speed at outlet), L (building length) L_1 (space between the buildings in inlet), L_2 (space between building in outlet) and α (angle between building)

(1) Section one calculation

Study the variations of final wind speeds after acceleration with variation of angles between two buildings (α) at spatial initial wind speeds and length of buildings in different situations.

i. Lets ($V_{1\,max}$ = 6 m/s , L =30 m , L_2= 20 m , and α = (60,…….,180) then :

$$L_1= 2L*\sin(\alpha/2) +L_2$$
$$L_1 = 2*30* \sin(\alpha/2) + 20$$
$$L_1 = 60 * \sin(\alpha/2) + 20 \quad \text{and}$$
$$V_2 = (V_1/ L_2)\,(2\,L \sin(\alpha/2) + L_2)$$
$$V_{2(1)} = (6/20)\,(60*\sin(\alpha/2) + 20)$$
$$V_{2(1)} = 18\sin(\alpha/2) + 6$$

Then at different angles between building the wind speed $V_{2(1)}$ will different as presented in the next table **(**Table 2)

ii. Lets ($V_{1\,max}$ = 6 m/s , L =35 m , L_2= 20 m ,and α = (60,………, 180) then :

$$L_1= 2L*\sin(\alpha/2) +L_2$$
$$L_1 = 2*35* \sin(\alpha/2) + 20$$
$$L_1 = 70 * \sin(\alpha/2) + 20 \quad \text{and}$$
$$V_2 = (V_1/ L_2)\,(2\,L \sin(\alpha/2) + L_2)$$
$$V_{2(2)} = (6/20)\,(70*\sin(\alpha/2) + 20)$$
$$V_{2(2)} = 21\sin(\alpha/2) +6$$

Then at different angles between building the wind speed $V_{2(2)}$ will different as presented in the next table **(**Table 2)

iii. Lets ($V_{1\,max}$ = 6 m/s , L = 40 m , L_2 = 20 m ,and α = (60,………..,180) then :

$$L_1= 2L*\sin(\alpha/2) +L2$$
$$L_1 = 2*40* \sin(\alpha/2) + 20$$
$$L_1 = 80 * \sin(\alpha/2) + 20 \quad \text{and}$$
$$V_2 = (V_1/ L_2)\,(2\,L \sin(\alpha/2) + L_2)$$
$$V_{2(3)} = (6/20)\,(2*40*\sin(\alpha/2) + 20)$$

$V_{2(3)} = 24\sin(\alpha/2) + 6$

Then at different angles between building the wind speed ($V_{2(4)}$)will different as presented in the next table (Table 2)

iv. Lets ($V_{1\ max}$ = 6 m/s ,L = 45 m , L_2= 20 m ,and α = (60,…………,180) then

$L_1 = 2L*\sin(\alpha/2) + L_2$

$L_1 = 2*45*\sin(\alpha/2) + 20$

$L_1 = 90 * \sin(\alpha/2) + 20$ and

$V_2 = (V_1/L_2)(2L\sin(\alpha/2) + L_2)$

$V_{2(4)} = (6/20)(2*45*\sin(\alpha/2) + 20)$

$V_{2(4)} = 27\sin(\alpha/2) + 6$

Then at different angles between building the wind speed $V_{2(4)}$ will different as presented in the next table (Table 2).

Table -2 section one (the relationship between the two buildings and wind Speed)

α	α/2	V2(1)	V2(2)	V2(3)	V2(4)
60	30	15	16.5	18	19.5
70	35	16.3	18	19.7	21.5
80	40	17.6	19.5	21.4	23.4
90	45	18.7	20.8	23	25.1
100	50	19.8	22	24.4	26.7
110	55	20.7	23.2	25.7	28.1
120	60	21.6	24.2	26.8	29.4
130	65	22.3	25	27.8	30.5
140	70	22.9	25.7	28.6	31.4
150	75	23.4	26.2	29.1	32.1
160	80	23.7	26.7	29.6	32.5
170	85	23.9	26.9	29.9	32.9
180	90	24	27	30	33

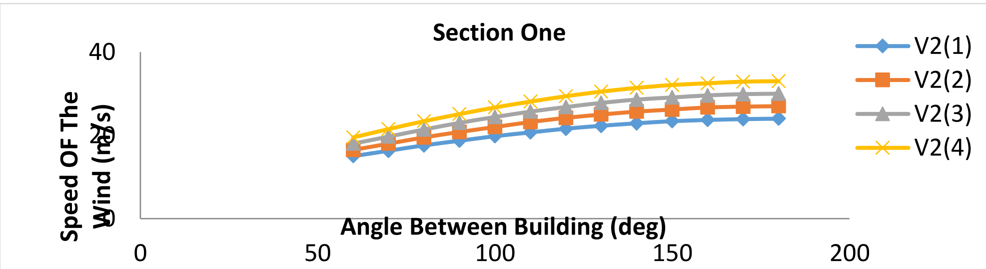

Figure -8 different wind speeds at different angles between buildings

The higher the value of α, the wind speed increases in all the previous studied cases from (1 to 4) , and this increase is noticed in the beginning in which the wind speed increase more than(1m/s) with the increasing of (α) ten degrees but the differences decrease to become less than (1m/s) for every ten degree increase in (α) value , and so after the angle ($130°$) and the differences decrease to reach (0.1m/s) after the angle (α) ($170°$). Figure-8 shows that the case $V_{2(4)}$ is optimum according to wind speed and at $L = 20\ m$, $L = 45\ m$, $V_1 max = 6\ m/s$ and according to the perfect angles it's between ($130° - 180°$) and here chosen the angle to be 140 because after this angle the acceleration is less than (0.5m/s)

(2) Section two calculations:

This section study variation the accelerated wind speeds V_2 with variation of building length at specific initial wind speeds and constant angle between buildings in different situations

i. Lets ($V_{1\,max}$ = 6 m/s , α = 100, L_2 = 20 , L = (25,…………..100)
Then:

$L_1 = 2L*\sin(\alpha/2) + L_2 = 2L*\sin(50) + 20$
$L_1 = 1.53L + 20$
$V_{2(1)} = (V_1/L_2)(2L\sin(\alpha/2) + L_2)$
$V_{2(1)} = (6/20)(1.53L + 20)$
$V_{2(1)} = 0.459L + 6$

The final results presented in next table (3)

ii. Lets ($V_{1\,max}$ = 6 m/s , α = 120 , L_2 = 20 , L =(25,……….,100)
Then:

$L_1 = 2L*\sin(\alpha/2) + L_2 = 2L*\sin(60) + 20$
$L_1 = 1.73L + 20$
$V_{2(2)} = (V_1/L_2)(2L\sin(\alpha/2) + L_2)$
$V_{2(2)} = 6/20)(1.73L + 20)$
$V_{2(2)} = 0.519L + 6$

The final result presented in next table (3)

iii. Lets ($V_{1\,max}$ = 6 m/s , α = 130, L_2 = 20 , L = (25,………100) Then:

$L_1 = 2L*\sin(\alpha/2) + L_2 = 2L*\sin(65) + 20$
$L_1 = 1.81L + 20$
$V_{2(3)} = (V_1/L_2)(2L\sin(\alpha/2) + L_2)$
$V_{2(3)} = (6/20)(1.81L + 20)$
$V_{2(3)} = 0.544L + 6$

The final results presented in next table (3)

iv. Lets ($V_{1\,max}$ = 6 m/s , α = 140, L_2 = 20 , L = (25,……….100) Then:

$L_1 = 2L*\sin(\alpha/2) + L_2 = 2L*\sin(70) + 20$

$L_1 = 1.88\ L + 20$
$V_{2(4)} = (V_1/\ L_2)(\ 2\ L\ \sin\ (\alpha/2) + L_2)$
$V_{2\ (4)} =\ 6/20)\ (1.88\ L + 20)$
$V_{2(4)} = 0.564\ L+6$

The final results presented in next table (3)

Table 3 section two (length of building and wind speed)

L	$V_{2(1)}$	$V_{2(2)}$	$V_{2(3)}$	$V_{2(4)}$
30	19.77	21.57	22.29	22.92
40	24.36	26.76	27.72	28.56
50	28.95	31.95	33.15	34.20
60	33.54	37.14	38.58	39.84
70	38.13	42.33	44.08	45.48
80	42.72	47.52	49.52	51.12
90	47.31	52.71	54.96	56.76
100	51.90	57.90	60.40	62.40

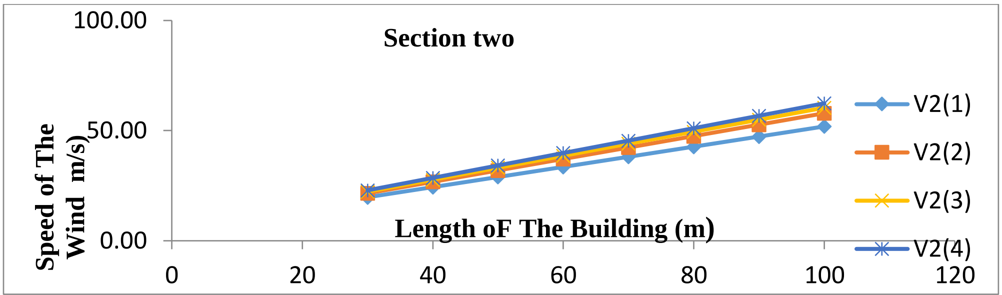

Figure -9 different wind speeds at different length of buildings

Table-3 shows that the wind speed accelerate clearly with the increasing with the building length (L) and in all cases in the study from $V_{2\ (1)}$ to $V_{2\ (4)}$ and from studying figure (9) can find that the highest speed was noticed in the forth case $V_{2(4)}$ which show highest speed in all the building length values (L) , this means that it can adopt this case with its conditions which are $(L_2 = 20m, \alpha = 140\ deg\ ,\ V_1 maX = 6\ m/s)$. So, whenever the building is higher the wind speed will be more and this depends on the building conditions and on the available space for the building. In this work the length will be taken equals 35 m to achieve the study purposes for the present buildings conditions

(a) Section three calculations

In this section the study will be how much wind speed will deferent at deferent elevations of wind turbines, in the present work every three turbines were installed in row in the same elevation at specific initial wind speeds and constant angle between buildings in different situations

1) Lets ($V_{1\,max}$ = 6 m/s , α = 130 , L_2 = 20 , L = 40, h = 20 m , Z_0 = 1 , Then:

$$V_2 = (V_1/ L_2) (2 L \sin (\alpha/2) + L_2)$$
$$V_2 = (6/20) (2*40*\sin (65)+20) = 27.75 \text{ m/s}$$
$$V_2(x) /V_2 (h) = \ln (x/Z_0)/ \ln (h/Z_0)$$
$$V_2(x) = V_2(h) * (\ln (x/Z_0)/ \ln (h/Z_0))$$
$$V_{2(1)} (x) = 27.75* (\ln (x/1)/ \ln (20/1)) = 9.26 \ln (x)$$
$$V_{2(1)} (x) = c* \ln (x), \text{ where, } c = 27.75* (1/ \ln (20/1)) = 9.26$$

The results will be in table (4)

2) Lets ($V_{1\,max}$ = 6 m/s , α = 130 , L_2 = 20 , L = 45, h = 20 m , Z_0 = 1 , Then:

$$V_2 = (V_1/ L_2)(2 L \sin (\alpha/2) + L_2)$$
$$V_2 = (6/20) (2*45*\sin (65)+20) = 30.47 \text{ m/s}$$
$$V_2(x) /V_2 (h) = \ln (x/Z_0)/ \ln (h/Z_0)$$
$$V_2(x) = V_2 (h) * (\ln(x/Z_0)/ \ln h/Z_0))$$
$$V_{2(2)} (x) = 30.47* (\ln(x/1)/ \ln (20/1)) = 10.17\ln (x)$$
$$V_{2(2)} (x) = c* \ln(x), \text{ where, } c = 30.47* (1/ \ln (20/1)) = 10.17$$

The results will be in table (4)

3) Lets ($V_{1\,max}$ = 6 m/s , α = 140 , L_2 = 20 , L = 40, h = 20 m , Z_0 = 1 , Then:

$$V_2 = (V_1/ L_2) (2 L \sin (\alpha/2) + L_2)$$
$$V_2 = (6/20) (2*40*\sin (70) +20) = 28.55 \text{m/s}$$
$$V_2(x) /V_2 (h) = \ln (x/Z_0)/ \ln (h/Z_0)$$
$$V_2(x) = V_2 (h) * (\ln (x/Z_0)/ \ln (h/Z_0))$$
$$V_{2(3)} (x) = 28.55* (\ln (x/1)/ \ln (20/1)) = 9.53 \ln (x)$$
$$V_{2(3)} (x) = c* \ln(x), \text{ where, } c = 28.55* (1/ \ln (20/1)) = 9.53$$

The results will be in table (4)

4) Lets ($V_{1\,max}$ = 6 m/s , α = 140 , L_2 = 20 , L = 45, h = 20 m , Z_0 = 1 , Then:

$$V_2 = (V_1/ L_2)(2 L \sin (\alpha/2) + L_2)$$

$V_2 = (6/20)(2*45*\sin 70) + 20) = 31.37 m/s$
$V_2(x) / V_2(h) = \ln(x/Z_0) / \ln(h/Z_0)$
$V_2(x) = V_2(h) * (\ln(x/Z_0) / \ln(h/Z_0))$
$V_{2(4)}(x) = 31.37 * (\ln(x/1) / \ln(20/1)) = 10.49 \ln(x)$
$V_{2(4)}(x) = c * \ln(x)$, where $c = 31.37 * (1/\ln(20/1)) = 10.49$

The results will be in table (4)

Table -4 turbines heights with wind speed of different sections

X	$V_{2(1)}$	$V_{2(2)}$	$V_{2(3)}$	$V_{2(4)}$
5	14.9	16.4	15.3	16.9
10	21.3	23.4	21.9	24.2
15	25.1	27.5	25.8	28.4
20	27.7	30.5	28.5	31.4
25	29.8	32.7	30.7	33.8
30	31.5	34.6	32.4	35.7
35	32.9	36.2	33.9	37.3
40	34.2	37.5	35.2	38.7
45	35.2	38.7	36.3	39.9

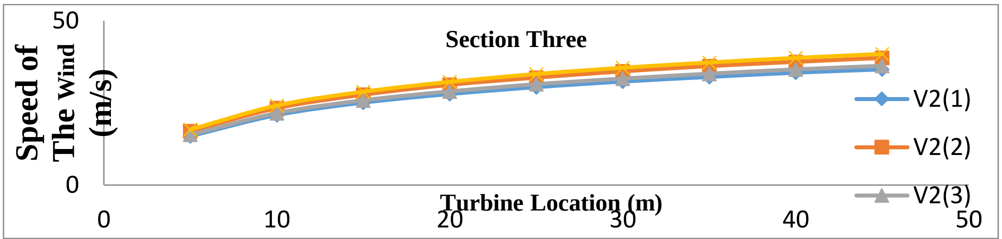

Figure -10 different wind speeds at different turbines heights

Table (4) shows the wind speed accelerates with the increase of turbine height this means that the wind speed will accelerate the turbines rotor and these turbines are arranged in a matrix form each row contains three turbines, so the turbines are installed on three locations with different heights and the distance between turbines is (1.5 m) in two directions, and the distance between the first turbine and the building is (4.75 m) from both sides as it is shown in figure (13). So, if the height of the wall holding the turbine (30 m) as it is suggested in the design, this means that the first turbine from above will be at a height of (27.25 m) and the following turbine will be at a height of (23.25 m) and the next will be at a height of (19.25 m).

Energy Calculations

The space enclosed between two adjacent buildings will force wind to drive the turbine, since the wind would be accelerated by blowing through buildings. As it was mentioned previously the most suitable turbines for using downtown buildings and urban areas is the Honeywell Wind Turbine: Model Star Gate, which has the following specifications as shown in Figure -11

Figure -11 Honeywell Wind Turbine: Model Star Gate (New York State Energy Research and Development Authority 2016)

A key characteristic of any wind turbine is its power curve, so the power curve for a wind turbine describes the expected amount of power output that can be generated as a function of wind speed and showing the cut-in and cut-out speeds. The power curve is a graph which describes the amount of energy that wind turbine will produce at different wind speeds at a hypothetical ideal site. Wind turbine suppliers will use power curves as a guarantee of their wind turbines' performance and warrant the associated power curve as part of a contract for a wind farm. Honeywell Wind Turbine power curve is given in Figure-12 (New York State Energy Research and Development Authority 2016)

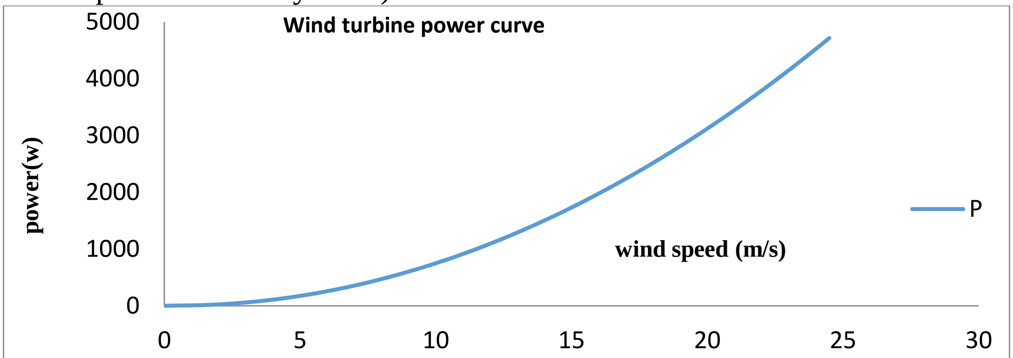

Figure -12 Honeywell Wind Turbine power curve (Gipe P. 2009)

While table-5 lists the specification of Honeywell Wind Turbine of 2.2 kW class. The rotor radius of this turbine is 1.05 m.

Table-5 Specifications of Honeywell Wind Turbine (New York State Energy Research and Development Authority 2016

Rotor Diameter:	6 ft (1.8 m)
Swept Area:	38.5 ft2 (3.6 m^2)
Rated Power Output:	2.2 kW
Rated Wind Speed	42 mph (19 m/s)
Cut-In speed	2 mph (1 m/s)
Maximum Wind Speed:	145 mph (64.8 m/s**)**
Acoustic Noise Emissions:	35 Db

Estimated Lifespan Of The Turbine: 20 years
Materials: Polycarbonate, aluminum, and steel

Power Calculations

In this work nine small turbines (Honeywell Wind Turbine) will be installed on a wall of about 30 m height linked between the twin buildings and arranged them in matrix form in the high center of the wall where the wind speed is optimum and the spaces between turbines equal 1.5 m. The directions of the holes diameters that carry the turbines are wider than the rotor diameter (2.1 m) which equals 2.5 m and distance between the first turbine and the outer side of building equals 4.75 m as shown in figure (13). So, the wind power will be calculated by:

$$P = (1/2) *\rho*A*Cp*Ng*Nb*V^3 \qquad (29)$$

Where, (P is wind power in(watts), ρ is air density at sea level in (kg/m^3), A is swept area in (m^2), Cp is coefficient of performance, Ng is generator efficiency, Nb is gearbox efficiency, V is wind speed in (m/s). From the previous manufacturer data we can get the next constant

$\rho = 1.225\ Kg/m^3$ at sea level
$A = \pi R^2 = 3.6\ m^2$
Cp = 0.35 for a good design
Ng = 0.80
Nb = 0.97
X (turbine height) m

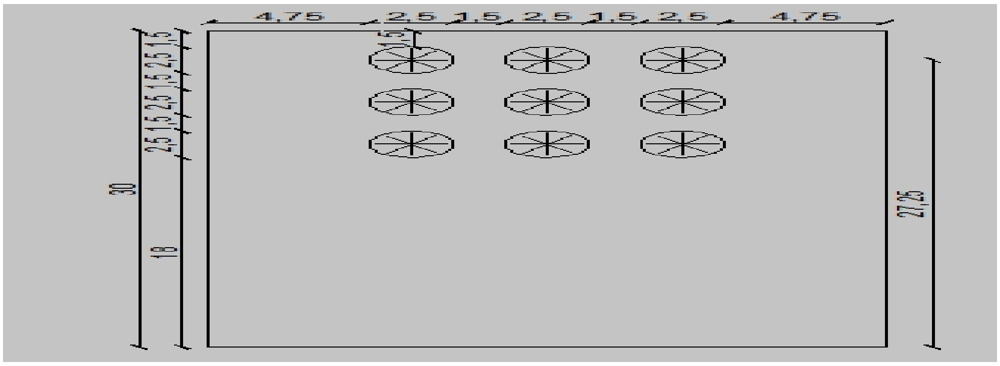

Figure -13 Turbines layout

I. The first row of turbines at X=19.25 m , turbines number = 3 , V_{1max} = 6 m/s from case three the best conditions is the fifth one where $V_{2(5)}$ =13.62 ln(x)

Then, $V_{2(5)}$ =13.62 ln (19.25) = 40.3 m/s

$P = (1/2) * 1.225 * 3.6 * 0.35 * 0.80 * 0.97 * (V_{2\ max})^3$

$P = 0.6 * (V_{2\ max})^3 = 0.6 * (40.3)^3$

P = 39.2 kW

There are three turbines in the same height then

$P_{total} = 39.2 * 3 = 117.6$ kW

II. The second turbines at X=23.25 m, turbines number = 3 at V_{1max} = 6 m/s. From case three the best conditions is the fifth one where $V_{2(5)}$ =13.62 ln (x)

Then, $V_{2(5)}$ =13.62 ln (23.25) = 42.9 m/s

$P = (1/2) * 1.225 * 3.6 * 0.35 * 0.80 * 0.97 * (V_{2\ max})^3$

$P = 0.6 * (V_{2\ max})^3 = 0.6 * (42.9)^3$

P = 47.2 kW

There are three turbines in the same height then

$P_{total} = 47.2 * 3 = 141.6$ kW

III. The third turbines at X=27.25 m , turbines number = 3,at V_{1max} = 6 m/s

From case three the best conditions is the fifth one where $V_{2(5)}$ =13.62 ln(x) then

$V_{2(5)}$ =13.62ln(27.25) = 4 m/s

$P = (1/2) * 1.225 * 3.6 * 0.35 * 0.80 * 0.97 * (V_{2\ max})^3$

$P = 0.6 * (V_{2\ max})^3 = 0.6 * (45)^3$

P = 54.7 kW

There are three turbines in the same height then

$P_{total} = 54.7* 3 = 164.2$ kW

Total power from nine turbines = 117.6+141.6+164.2 = 423.4 kW Maximum average daily energy from the nine turbines will be:

Turbines (E_{max}) = (total power) (N (number of one day hours)

$E_{max} = P * N$

E_{max} = 423.4 * 24 = 10161.3 kW h/day

Or, E_{max} = 10161.3 * 365 = 3.708 G W h/year

This energy will be collected from the wind if all conditions are perfect and if the wind speed equals to maximum average daily speeds which equal to 6 m/s and if the turbines worked all times in the year without stopping. If taking a typical day of wind speed at Wednesday 23 November 2016 as shown in table-6 for example of how much electrical energy the all turbines can generate in perfect conditions as in the following calculations:-

Table-6 Wind speeds at Wednesday 23 November (weather of Jordan/Amman, 2016)

Tuesday	Wednesday			
	Evening	Night	Morning	Afternoon
Forecast				
Temperature	15 °C	10 °C	10 °C	12 °C
	High level clouds.	High level clouds.	Mostly sunny.	More sun than clouds.
Feels Like	13 °C	7 °C	8 °C	9 °C
Wind Speed	18 km/h	21 km/h	19 km/h	19 km/h
Wind Direction	ESE ↑	ESE ↑	E ↑	E ↑

In the perfect conditions (where $L = 35m, \alpha = 140deg$, $L_2 = 20$ m, h =20 m, X_1 =19.25 m, X_2 =23.25 m and X_3 = 27.25 m) the outer wind speeds will be as following the wind speed calculations:

$V1 = 18$ km/h = 5 m/s

$V_2 = (V_1/ L_2) (2 L \sin(\alpha/2) + L_2)$

$V_2 = (5/20) (2*35*\sin (70)+20) = 21.4$ m/s

$V_2 (x) /V_2 (h) = \ln (x/Z_0)/ \ln (h/Z_0)$

$V_2 (x) = V_2 (h) * (\ln (x/Z_0)/ \ln (h/Z_0))$

$V_2 (x) = 21.4* (\ln (x/1)/ \ln(20/1)) = 7.1 \ln (x)$

At 19.25m $V_2(x) = 7.1\ln (19.25) = 21.1$m/s

At 23.25m $V_2(x) = 7.1\ln 9.3\ln (23.25) = 22.4$m/s

At 27.25m $V_2(x) = 7.1\ln (27.25) = 23.6$ m/s

Energy calculations at 19.25 m:

P = 3.4Kw

$E_{max} = P * N$

$E_{max} = 3.4* 6 =20.4$ kW h/day

P = 3.9 kW

$E_{max} = P * N$

$E_{max} = 3.9*6 =23.4$ kW h/day

At 27.25 m $V_2(x)$

P = 4.33 kW

$E_{max} = P * N$

$E_{max} = 4.33 * 6 = 26$ kW h/day

The wind speed calculations, $V_1 = 19$ km/h = 5.3 m/s

$V_2 = (V_1/ L_2) (2 L \sin(\alpha/2) + L_2)$

$V_2 = (5.3/20) (2*35*\sin (70)+20) = 22.7$ m/s

$V_2(x) /V_2 (h) = \ln x/Z_0)/ \ln (h/Z_0)$

$V_2(x) = V_2 (h) * (\ln (x/Z_0)/ \ln (h/Z_0))$

$V_2(x) = 22.71* (\ln(x/1)/ \ln(20/1)) =7.6 \ln(x)$

At 19.25m $V_2(x) = 7.6 \ln (19.25) = 22$ m/s

At 23.25m $V_2(x) = 7.6 \ln (23.25) = 23.9$ m/s

At 27.25m $V_2(x) = 7.6 \ln (27.25) = 25$ m/s

So, the energy calculations:

P =3.8 kW

$E_{max} = P * N$

$E_{max} = 3.8 * 12 = 45.6$ kW h/day

While at height = 23.25 m

P = 4.5 kW

$E_{max} = P * N$

$E_{max} = 4.5*12 = 54$ kW h/day

And at 27.25 m (cut-off wind speed) where V_2 =26 m/s

P = 0 kW

$E_{max} = P * N$

$E_{max} = 0 * 12 = 0$ kW h/day

The wind speed calculations, $V_1 = 21$ km/h = 5.8 m/s

$V_2 = (V_1/ L_2)(2 L \sin(\alpha/2) + L_2)$

$V_2 = (5.8/20) (2*35*\sin (70)+20) = 24.8$ m/s

$V_2(x) /V_2 (h) = \ln (x/Z_0)/ \ln (h/Z_0)$

$V_2(x) = V_2 (h) * (\ln (x/Z_0)/ \ln(h/Z_0))$

$V_2(x) = 24.8* (\ln (x/1)/ \ln(20/1)) = 8.3 \ln(x)$

At 19.25 m $V_2(x) = 8.3\ln (19.25) = 24.6$ m/s

At 23.25 m $V_2(x) = 8.3\ln (23.25) = 26$ m/s

At 27.25 m $V_2(x) = 8.3\ln (27.25) =27.3$ m/s

So, the Energy calculations:

V_2 her is more than cut off speeds (25 m/s) then the wind generator will not generate electricity then the energy equal zero

$E_{max} = P * N$

$E_{max} = 0*6 = 0$ kW h/day

The total energy generations for one day = (23.4+20.4+26)*3+(45.6+54)*3 = 508.2 kW h/day

Or, total energy/yr= 508.2 * 365 = 0.185494 GW h/yr.

It can be observed from the above calculations the energy collected by turbines in one day (Wednesday 23 November 2016) equals 508.2 kWh/day is much less than energy when the turbines all times generate electricity at initial wind speeds equals the maximum average daily speed (6 m/s) which equals (10161.3 kW h/day) for full times because when the wind speed exceed (25 m/s) the generator turn –off. Figure-14 for Amman shows how many days in Amman within one month can be expected to reach certain wind speeds.

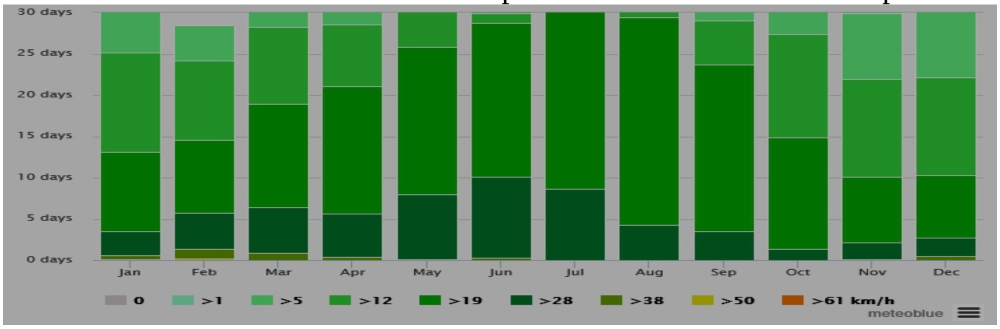

Figure-14 wind speeds in Amman (Weather of Jordan/ Amman 2016)

Also, from figure-14 can see the speed most frequently throughout the year is (5, 12, 19, 28) km/h. While table-7 shows each wind speeds with expected energy to be generated per year in the perfect conditions (L=35m, α=140deg, L_2=20 m) and the calculations as follows:

The Energy calculations: At V_1 = 5 km/h = 1.4 m/s

$$V_2 = (V_1/ L_2)(2 L \sin(\alpha/2) + L_2)$$

$$V_2 = (1.4/20)(2*35*\sin(70)+20) = 6.0 \text{ m/s}$$

$$V_2(x) /V_2(h) = \ln(x/Z_0)/ \ln(h/Z_0)$$

$$V_2(x) = V_2(h) * (\ln(x/Z_0)/ \ln(h/Z_0))$$

$$V_2(x) = 6.0* (\ln(x/1)/ \ln(20/1)) =2.0 \ln(x)$$

From figure-12 (power curve of wind turbine) the electric power at each wind speed are calculate as below

At 19.2 5m $V_2(x)$ = 2.0 ln (19.25) = 6.0 m/s

P = 0.26 kW

At 23.25m $V_2(x)$ = 2.0 l (23.25) = 6.3 m/s

P = 0.31 kW

At 27.25m $V_2(x)$ = 2.0 ln (27.25) = 6.6 m/s

P = 0.37 kW

Total power = 0.26+0.31+0.37= 0.94 kW

And total energy = 0.94* 24 * 36 = 812.2 kW h/yr

The Energy calculations: At V1 = 12 km/h = 3.3 m/s

$$V_2 = (V_1/ L_2) (2 L \sin (\alpha/2) + L_2)$$

$$V_2 = (3.3/20) (2*35*\sin (70)+20) =14.15 \text{ m/s}$$

$V_2(x) / V_2(h) = \ln(x/Z_0) / \ln(h/Z_0)$

$V_2(x) = V_2(h) * (\ln(x/Z_0) / \ln(h/Z_0))$

$V_2(x) = 14.15 * (\ln(x/1) / \ln(20/1)) = 4.8 \ln(x)$

From figure-12 (power curve of wind turbine) the electric power at each wind speed are calculate as below

At 19.25 m $V_2(x)$ at 19.25 m = 4.8ln (19.25) = 14.2 m/s

P =1.520 kW

At 23.25 m $V_2(x)$ at 23.25 m = 4.8ln (23.25) = 15 m/s

P =1.740 kW

At 27.25 m $V_2(x)$ at 27.25 m = 4.8ln (27.25) = 15.8 m/s

P =1.920 kW

Total power = 1.52+1.74+1.92=5.18 kW

And total energy = 5.18* 24 *88 = 10940 kW h/yr

At V1 = 19 km/h = 5.3 m/s

$V_2 = (V_1 / L_2)(2 L \sin(\alpha/2) + L_2)$

$V_2 = (5.3/20)(2*35*\sin(70)+20) = 22.73$ m/s

$V_2(x) / V_2(h) = \ln(x/Z_0) / \ln(h/Z_0)$

$V_2(x) = V_2(h) * (\ln(x/Z_0) / \ln(h/Z_0))$

$V_2(x) = 22.73 * (\ln(x/1) / \ln(20/1)) = 7.7 \ln(x)$

From -12 (power curve of wind turbine) the electric power at each wind speed are calculate as below

At 19.25 m $V_2(x)$ = 7.7 ln (19.25) = 22.73 m/s

P =4.120 kW

At 23.25 m $V_2(x)$ = 7.7 ln (23.25) = 24.2 m/s

P = 4.600 kW

At 27.25 m $V_2(x)$ = 7.7 ln (27.25) = 25.4 m/s

P = 4.710 kW

Total power =4.12+4.6+4.71=13.43 kW

And total energy = 13.43* 24 *200 = 64464 kW h/yr

At V1 = 28 km/h = 7.8 m/s

$V_2 = (V_1 / L_2)(2 L \sin(\alpha/2) + L_2)$

$V_2 = (7.8/20)(2*35*\sin(70)+20) = 33.45$ m/s

$V_2(x) / V_2(h) = \ln(x/Z_0) / \ln(h/Z_0)$

$V_2(x) = V_2(h) * (\ln(x/Z_0) / \ln(h/Z_0))$

$V_2(x) = 33.45 * (\ln(x/1) / \ln(20/1)) = 11.32\ln(x)$

From figure-12 (power curve of wind turbine) the electric power at each wind speed are calculate as below

At 19.25 m $V_2(x)$ =11.32 ln (19.25) = 33.45 m/s

P = 0 kW

At 23.25 m $V_2(x)$ = 11.32 ln (23.25) =35.6 m/s

P = 0 kW

At 27.25 m $V_2(x)$ = 11.32ln (27.25) = 37.5 m/s

P = 0 kW

Total energy = 0

Total energy from the turbines equal zero at initial speeds equal 7.8 m/s because when the wind speed V_2 accelerated at all locations much bigger than cut- out speed V_2>26 m/s then the generator will turn -off as was mentioned in the wind turbine specifications in table(5).

Table 7 list of energy per each wind speeds per one year

Wind Speed (km/h)	Wind Speed (m/s)	Number of days per year	Total power from three turbines (kW)	Total energy (kW h/yr)
5	1.4	36	0.94	812.2
12	3.3	88	5.18	10940
19	5.3	200	13.43	64464
28	7.8	37	0	0

From the table -7 the total electrical energy per year equals the summation of the energy collected by each wind speeds from three turbines per each row then:

Total energy = (812.2+10940+64464)*3 = 228648.5 kW h/yr = 0.23GW h/yr

Results and Discussion

The results of this study were focused on twofold; the first one is related to determine the buildings space and then comparing the predicted consumption to this space with consumption of similar buildings to predict their consumption of energy. While the second discussing the results related to energy produced by the turbines and compare its consumption of electricity. There are different values for wind speed that can be adopted to calculate the energy generated as mentioned previously, so the energy can be calculated depending on the followings:

(a) Setting of Building Size

This study assumes that two buildings in the model is multi-story commercial buildings with average floor space (25 *35) m^2 for each building The height of one floor is assumed as 3 m. The height of building should be set over the height of wind turbine to accelerate the wind by blowing through buildings; the height of buildings is set to 30 m and the angle between the buildings is taken α =140deg. The buildings were oriented toward the West and North West to collect more percent of wind as mentioned in figure (7).

So, the dimensions of each building were (25 *35) m with a height (30) m with total area equals to:

$$A_{total} = 25 * 35 * 10 * 2 = 17500 \text{ m}^2$$

The case-study in present work the government department's compound in Al-Karak district was to calculate the electrical demand, this building prescription use for offices and treading and the total area equals (6000 m^2). Electrical demand includes (lightings, air conditions, heating, lifting, computers, etc) the total actual electrical demand in year equals (0.61Gwh/yr); this was taken from Jordan Electrical Power Company. Now to collect the estimated energy demand for the suggested buildings in this work is:

$$E_{total\ demand} = (17500/6000) * 0.61 = 1.779 GW\ h/yr$$

Figure 4.1buildings and turbines layout in three dimensions

(b) The Power Generated by Wind Turbine

The wind at the area of the buildings case-study is sufficient to drive the wind turbines and the repetition wind speed will be about (5-25 km /h), as it was mentioned in table (7) and the calculated energy according to these statistics, the value will be:

Maximum total energy per year = 0.23 GW h/yr

So, this value is assumed to be reliable for the estimated wind speed. Therefore this value will generate an electricity about (0.23/1.779)*100 =13%) from the required demand.

(c) Cost and Economic Feasibility

The total Honeywell estimated price and installation costs of each turbine is about $10,000 – $12,000, so the total costs of nine turbines = (9 * 12000) = $108000 = 75600 JD.

Modern wind turbines are designed to work for about 120,000 hours of operation throughout their design lifetime for 20 years (i.e. 13.7 years non-stop) and the maintenance costs are from 1.5% to 2.0% of the original cost, per year. From Jordan Electrical Power Company energy cost 0.181/kW h

Therefore, the maintenance cost per year = 0.02 * 108000 =$ 2160/yr = 1512 JD/yr

So, the energy savings per year = 0.23* 1000000 *0.181 =$ 41630/yr =
29141JD/yr

The net annual savings =29141 - 1512= 27629 JD/yr

The “simple payback time”, that is, the time it takes the system to produce enough electricity savings to fully offset its cost, will range, before incentives, from 10-15 years at very good sites and 30 years or more for more marginal sites. So, payback time in this study can be calculated by: (Wayne C. Turner, 2001)

Simple payback period (SPP) = Initial cost / Annual savings

(SPP) =75600 / 27629= 2.736 years

This value is more than three years because the wind speed acceleration is in the optimum situation.

Conclusion

From the above analysis, the following main conclusions can be drawn concerning the use of special design and layout of twin's buildings with nine wind turbines:

a) The general advantages:

1. Using special design of buildings improves the wind speeds by about 700% times or more because the buildings layout accelerates the wind speed seven times from the initial speed of 5 m/s to be 36 m/s as shown in table (4)
2. The power from each turbines can be increased by 125 times in comparison with the power from initial wind speeds (i.e. 5 m/s)
3. Reducing the cost of electricity is about 13% in comparison with the same buildings without turbines installation.
4. Using Honeywell Wind Turbines made have proved that the environments impacts are negligible because they are very quite during operation (low noise level) and easy to accelerate by the wind speeds and consequently increasing the efficiency of the suggested system.
5. The installation of turbines between the buildings do not affect the aesthetic view of the buildings besides it is possible to exploit the space in front of the turbines wall as a garden or play areas or places of cars lining up.
6. The results have shown that for the present work buildings design and turbines sitting produced about 0.23GWh/year

The payback period is reduced from (5-10) year in good conditions to become about three years (i.e.

7. 30%)

b) The drawbacks of Turbines:

1. Using the special buildings design may accelerate the wind speeds to be more than 45 m/s which is much higher than cut -out speed for the Honeywell Wind Turbine because the generator will turn off at any speeds more than 25 m/s . This is a technical problem which makes a limitation on a power generation amount.
2. To be able to build two buildings of the proposed design to accelerate the wind will need a large land areas to be possible for implementing such projects

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