An Novel Design of Solar System with Humidity to Water Conversion Feature

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***Abstract*—The rapid growth of industry and population in the world reflected on the increase demand of electricity and water. This paper gives a practical design and new concept of utilization of renewable energy system (solar system) and humidity to water conversion and harvesting technologies. The system can be built on the top of high rise buildings, which is the situation in Oman and Gulf Council Cooperation GCC countries, in order to provide clean energy (electricity) to that building to make it zero energy building. This system utilizes the advantages of GCC Deseret climate, i.e. high solar radiation and high humidity through the year especially in the summer, for green energy generation and free water supply (cold and hot). This system is designed to provide optimum surface area for solar panels installation which will be installed on the roof. In addition, humidity-water convertor features built-in to the system design. The system is recommended to be sited on the top of high rise buildings or structures with its appearance can be blended into the building architecture without negative visual impact. The water can be treated, stored, and used for general purposes. Also, it could be heated through integration of photovoltaic (PV) and solar thermal collectors to provide hot water for domestic demand. The design is also safer and suitable to be used in populated area. With these benefits, the renewable energy could be used as three in one to promote populated urban area.**

***Index Terms*— solar system, renewable energy, solar panel, humidity-water converter**

I. Introduction

THE rapid increase of population on earth has recalled human beings to find more efficient resources to generate energy and so, power. Most of those resources have a negative environmental side effect and a massive possibility of depletion, when used on a large scale. In order to maintain those resources and to prevent the nature from the undesirable side effects of depleted energies, renewable energy became the optimal alternative [1].

Renewable energy's industry has been growing lately as a potentially future main source of energy; as it is being studied and used all around the world; also it is an inexorable supply of clean, sufficient and efficient energy that depends on the nature. New technologies are being discovered to endorse the interest of companies and public which is a huge step to increase the publicity of renewable energy. Solar energy is the most famous type of renewable energy, because it deals with the solar radiation of the sun and the sun exists everywhere in the globe, while wind energy depends on geographical site, which is not available everywhere, may be used only on some parts of the world. Solar power is already taking a huge interest and a lot of investments in Europe [1] [2] and [3], however, solar power in the GCC countries are less applied but more efficacious and operative, because of the huge amount of solar radiation falling on the region. The Kingdom of Saudi Arabia, Bahrain, Oman, Kuwait, Qatar and United Arab Emirates (UAE) has been mainly interested in renewable energies and especially solar power because it has one of the most suitable sites for such a technology. The photovoltaic (PV) or the solar cells are majorly known for converting sun light into electricity as a Direct Current (DC) and it can be converted to an Alternative Current (AC) to supply machines, houses, buildings and so on. The idea of the present paper is to use three different technologies of renewable energy in one place to produce electricity, heat and water. With such technology the buildings in GCC countries can benefit from it, by having an independent source of energy to help supplying high-rise-buildings with electricity beside producing water; counting on the humidity and heating the water - if needed - using the solar radiation. Case study has been taken in Abu Dhabi.

II. General Arrangement and Working Principles

Combining the technology of photovoltaic (PV) and the technology of producing water via humidity would be a suitable idea for the buildings in UAE. The buildings in UAE are high with a number of more than 90 buildings that is taller than 180 meters [7]. The humidity could be converting to water using the proposed system. After The water is token from it place to another – or to be stored – by using pipes attached to the box and finally, heat and it can be done by having the pipes made of copper and colored in black to absorb heat and so, to heat the water inside it.

III. Feature of System

The features in this proposed system are designed and integrated to generate electricity from solar light, produce water from solar heat energy and humidity. The system is designed in an easy-access approach, which is located on

Manuscript received February 27, 2013; revised April 10, 2013. The research leading to these results has received Research Project Grant Funding from the Research Council of the Sultanate of Oman, Research Grant Agreement No. ORG SU EI 11 010. The authors would like to acknowledge support from the Research Council of Oman. Gratitude is also expressed to the Faculty of Engineering and Research and Industry Collaboration office in Sohar University.

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top of a building and can be accessed from the interior of building such that it is easily for installation and maintenance. Figure 1: Engineering design of the solar-humidity hybrid renewable energy generation system.

IV. Estimated Annual Energy Saving

The weather data were obtained from the reference [4] and average have been calculated and analyzed. The data supplied from NASA SSE model include solar radiation as well as humidity over 22 years, from year 1983 to year 2005.

TABLE I
MONTHLY MEAN DAILY VALUES OF DIRECT BEAM SOLAR RADIATION FOR ABU DHABI.

Months		Solar radiation, ($kWh/m^2/day$)	
	Ref [4] 2007	Ref [5] NASA SSE model (22-year average)	Average
Jan	5.16	5.89	5.53
Feb	4.95	6.06	5.51
Mar	5.56	5.43	5.50
Apr	5.89	6.44	6.17
May	5.92	7.54	6.73
Jun	4.77	7.47	6.12
Jul	4.25	6.06	5.16
Aug	3.63	6.23	4.93
Sep	5.74	6.68	6.21
Oct	5.69	6.9	6.30
Nov	5.31	6.63	5.97
Dec	4.07	5.57	4.82
Average	5.08	6.41	5.74

TABLE II
MONTHLY AVERAGE MEASURED TEMERATURE OF ABU DHABI.

Months		Temperature, (°C)	
	Ref [4] 2007	Ref [5] NASA SSE model (22-year average)	Average
Jan	20	19.2	19.60
Feb	22	20.4	21.20
Mar	25.5	23.5	24.50
Apr	31.1	27.9	29.50
May	35	32.5	33.75
Jun	36.1	34.5	35.30
Jul	36.2	36.3	36.25
Aug	35.5	36.2	35.85
Sep	34.8	33.6	34.20
Oct	32	29.5	30.75
Nov	27.5	25.1	26.30
Dec	21.1	21.3	21.20
Average	29.73	28.33	29.03

In this research work, the average of the two data in references [4] and (NASA website) has been used. These data have been utilized for analysis of variation of solar radiation and humidity. The power or energy gained from these parameters can be subsequently predicted.

TABLE III
MONTHLY AVERAGE RELATIVE HUMIDITY OF ABU DHABI

Months		Relative Humidity, (%)	
	Ref [4] 2007	Ref [5] NASA SSE model (22-year average)	Average
Jan	46	51	48.50
Feb	46	47.9	46.95
Mar	30	43.3	36.65
Apr	18	36.7	27.35
May	18	32	25.00
Jun	27	34	30.50
Jul	40	32.6	36.30
Aug	43	33.3	38.15
Sep	38.85	33.8	36.33
Oct	40.8	39	39.90
Nov	42.4	46.1	44.25
Dec	48.3	50.4	49.35
Average	36.53	40.01	38.27

A. Solar Photovoltaic Energy:

Based on the solar radiation data analyzed in reference [4] for Abu Dhabi, the solar energy generation, P_{solar} is estimated as follow [6]-[7]:

$$P_{solar} = G_s \cdot A_s \cdot \eta_{PS} \cdot K \tag{1}$$

where G_s : Annual mean daily global irradiance, kWm^{-2}

A_s : Array active area, m^2

η_{PS} : Module conversion efficiency

K : Solar power loss

Thus, the energy generated by solar system, E_{solar} is given by [5]:

$$E_{solar} = P_{solar} \cdot Y_H \tag{2}$$

where Y : Equivalent sunshine hours (12 hours)

B. Solar Thermal Energy:

To calculate the collected heat from the proposed system initial volume of water need to be converting to mass using the density of water (1000 kg/L). Volume of pipes: Diameter = 1.5 cm, Length = 3200 cm, Number of tubes = 3×32 = 96

ISBN: 978-988-19251-0-7
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

Water volume:
$V = [(\pi/4) \times (D)^2] \times L \times N = [(3.14/4) \times (1.5)^2] \times 3200 \times 96 = 542{,}592\ cm^3\ (542.592\ L)$ (3)

Mass of water:
$m = density \times volume = 1000\ kg/L \times 542.592\ L = 542{,}592\ kg$ (4)

Amount of energy:
Assume T = 92°C (which is the maximum temperature reached) and T_i =29 °C
Water heat capacity: $C_p = 4186\ J/kg.K$
Thermal amount of heat:
$Q = m \times C_p \times (T - T_i) = 143.1\ GJ$
(5)

From the results the temperature of water found to be 92°C in the middle of the day and the amount of solar energy from the sun is 143.1 GJ and considering that the sun shines approximately 12 hours daily in UAE, which could be more than enough for the usage of UAE buildings.

TABLE IV
ESTIMATED SOLAR ENERGY GENERATED IN ABU DHABI

Annual mean daily global radiation, G_s (kWhm^{-2}/day)	5.74
Solar panel area above the building (40m × 40m) m^2	1600
Estimated solar cell active area, A_s (32m × 32m) m^2	1024
Efficiency of solar panel, η_{PS}	0.15
Estimated power loss (electric transmission), K	0.8
Estimated solar energy generated, kWh/day	**750**
Estimated annual solar energy generated, kWh/year	**2574 45.8**

C. Humidity to Water Conversion:

The term humidity describes the fact that the atmosphere can contain water vapor. The amount of humidity found in air varies because of a number of factors. Two important factors are evaporation and condensation. The most commonly used measure of humidity is relative humidity. Relative humidity can be simply defined as the amount of water in the air relative to the saturation amount the air can hold at a given temperature multiplied by 100 [8]-[12].

Depend on the use of absorbent material which is chloride sodium salt to absorb the water vapor from the humidity during the night hours, where conditions are suitable for the absorption process steam generation and then using the energy absorber solar and condensed on the surface of a glass slash to get water. The operation of the system is saturated class cloth with a solution of sodium chloride high concentration and after the sunset the cover glass has to be open and fan installed on the side of the solar collector not work and then there is direct contact between air and saline solution is up to the process of absorption. At sun rise cover glass will be closed and fan start work to evaporate the water collected at night**.** This will lead to condensate the vapor on the glass and collected by pipes to the tank.

In summary of the process the result of the fall of the sun on the solar collector rise temperature and this results to the generation of water vapor absorber and then condensed on the glass designer at an angle of mile provides access to most of the light beam as well as facilitate the collection of fresh water, and so repeated the process of opening and closing the cover glass a day.

The amount of water produced in the process depending on the size of the unit; through the construction of a square length of 32 meters of the glass-box (or 1024 square meter), will approximately produce 3.2768 tons of water per day. According to reference [9] the average water needs of human beings is about 50 liter per person per day (drinking 5 liters, sanitation services 20, bathing 15 liters, cooking and kitchen 10 liters) , which means the system will provide enough water for approximately 65 persons. So if water is only produced to supply a person with drinking and sanitation services (25 liters) then 133 people will have access to water for the normal purposes that are needed which is the case on most high rise buildings in UAE, such as commercial buildings.

V. FUTURE WORK

1- The humidity hybrid renewable energy generation system can be developed to have a thermal collector or a (CSP), to absorb heat instead of light, beside reflectors located around the thermal collector to reflect the sun radiation on it.
2- Adding wind turbines to the system, that can be located behind the glass-box to supply the fans (that are located on the cover of the box) with electricity.
3- Combining the Photovoltaic system to the concentration solar power system, to have multi-solar- technologies within the system.
4- Increasing the height of the glass-box and adding towels to produce more water incase needed.

VI. CONCLUSIONS

The humidity hybrid renewable energy generation system is an operative, effective and efficient method to supply high buildings especially in the UAE, and it can produce enough pure water from humidity to supply 65 persons a day to fulfill all human needs and 133 persons for normal human needs. Besides that, the system has no environmental impact or noise. The design is a combination of solar system (PV) feature associated with humidity-conversion and water heating features. The design has no negative visual impact on the building that is installed in. This system can produce 750 kWh/day, and 3336 liters of water per day, beside that the water can be heated through the solar thermal energy system. The system is large step to marketing renewable energy applications and investments in UAE and the rest of urban regions.

AKNOWLEDGMENT

The research leading to these results has received Research Project Grant Funding from the Research Council of the Sultanate of Oman, Research Grant Agreement No. ORG SU EI 11 010. The authors would like to acknowledge support from the Research Council of Oman. Gratitude is also expressed to the Faculty of Engineering and Research and Industry Collaboration office in Sohar University.

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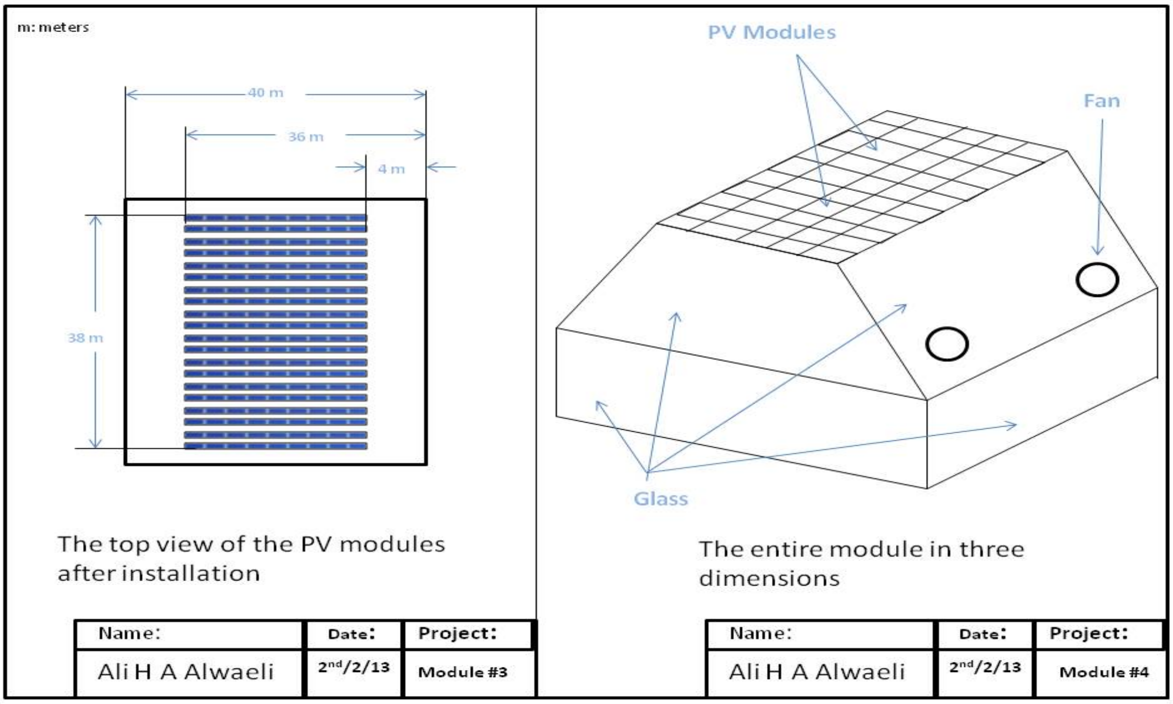

Fig. 1: Engineering design of the solar-humidity hybrid renewable energy generation system – (a) top view; (b) perspective view.

ISBN: 978-988-19251-0-7
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)