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RE-EVALUATION AND RE-DESIGN STAND-ALONE PV SOLAR LIGHTING PROJECTS IN GAZA STRIP, PALESTINE

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Abstract*:* Recently, with the critical situation of siege on Gaza Strip, the need of alternative energy source instead of traditional energy sources becomes increasing day by day, especially Palestine is considered one of the sunny countries and percepts good solar radiation over the year, in this paper; the re-evaluation and re-design process were analyzed step by step, beginning with modeling the global solar radiation passing through Orinetation and tilting, ending to PV and Battery sizing. The research includes case study experiemnt on lighting an apartment with specific loads.

Keywords: Solar Radiation, Optimum Tilt Angle, Orientation, evaluation process, software development, PV and Battery sizing.

إعادة تقييم وتصميم أنظمة تحكم حديثة لمشاريع الإنارة بالطاقة الشمسية المنفذة في قطاع غزة – فلسطين

الملخص: مع الوضع الحرج والحصار المفروض على قطاع غزة منذ ما يقارب الأربعة أعوام ظهرت الحاجة إلى مصدر بديل للطاقة بدلاً من الطاقة التقليدية، وأصبح هذا الأمر ملحاً وخصوصاً مع استمرار انقطاع الطاقة الكهربائية وكذلك المحروقات عن قطاع غزة. حيث تهدف هذه الدراسة البحثية إلى إعادة تقييم وتصميم أنظمة تحكم هندسية لمشاريع الإنارة التي تم تطبيقها في قطاع غزة في الآونة الأخيرة وتحليلها بدءاً من نمذجة الإشعاع الشمسي في فلسطين مروراً بأهمية التوجيه والإمالة للخلية الشمسية وانتهاءً بتصميم البطاريات والخلايا الشمسية، حيث تم التركيز على السلبيات الحاسمة للتصاميم السابقة وكيفية التغلب عليها. لهذا الغرض أعد الباحثين تجربة عملية (كنموذج تحكم هندسي) لإضاءة شقة من خلال الخلايا الشمسية مع أخذ بعين الاعتبار المعايير والتوصيات المقترحة من قبل جمعية مهندسي الكهرباء والالكترونيات العالمية (IEEE).

I. INTRODUCTION

Palestine is located within the solar belt countries and considered as one of the highest solar potential energy, the climate conditions of the Palestinian Territories are predominantly very sunny with an average solar radiation on a horizontal surface about 5.4 kWh/m2.day [1]

Gaza Strip is 360km2 with a high density population of about 4,118 persons/km2 [2], so Gaza Strip represents one of the most densely populated areas in Middle East. As the population in Gaza Strip increases (population growth rate 3.349%/year [3]), the consumption of water and energy will increase; leading to significant rise in unacceptable levels of air pollution, and the defect in water supply and energy sources will increase; leading to severe economical crisis that will result in a significant rise in the probability of an outbreak of warfare.

For all previous reasons, using renewable energy has become a global and national trend, so the need of alternative and urgent power source to supply hospitals and medical centers is very important issue especially in situation as it in Gaza Strip; imposed siege, shortage in fuel supplies, and increasing in the mortality rate.

Several researches discuss the PV Systems' drawbacks separately; [4] and [5] discuss the global radiation model, where the orientation and tilt angles were discussed in [6], [7] and [8], and Sizing problems handled by [9].

The objective of this research to provide full technical information about Stand Alone PV Systems for lighting projects to avoid drawbacks in the previous designs. This technical information will be useful for both Architectures who interests in Building-Integrated Photovoltaic (BIPV) applications and Practitioner Engineers who interests in the utilization of renewable energy in Gaza Strip, Palestine to improve and enhance the efficiency of PV System used in their designs with reduced cost.

II. BACKGROUND

In this case, the project of Lighting Gaza Valley is discussed here. The solar panels used in the project are fixed with tilt angle 45° as shown in

Figure 1

Figure 1: Fixed Solar Panels for Lighting Gaza Valley way

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The Solar panels fixed with azimuth angle of 220°Nalong with Gaza Valley Street as shown in Figure 2.

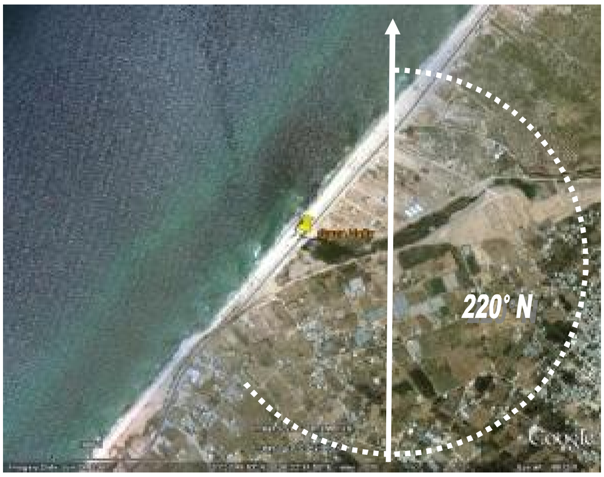

Figure 2: Gaza Valley Way Map by Google Earth®

III. RE-EVALUATION & RE-DESIGN

The study on all previous lighting projects leads to several drawbacks on these projects, such as lack of meteorological information of Gaza Strip, Palestine, incorrect orientation and tilting plan, and insufficient both PV and Battery Sizing as shown in Figure 3

Figure 3: Re-Evaluation and Re-Design Process

In this section, Re-Evaluation and Re-Design Process handles all previous drawbacks and working with them in Phases as shown below:

A. *Phase I: Developing Empirical Models for Estimating Global Solar Radiation*

Understanding solar radiation data and the amount of solar energy intercepts specific area are essential for modeling solar energy system and covering the demand. Therefore, precise knowledge of historical global solar radiation at a location of study is required for the design of any funded solar energy project.

Unfortunately, no meteorological stations available in Gaza Strip to measure the amount of intercepted solar radiation in Gaza Strip. So an alternative method for estimation of solar radiation is required.

In this Phase, Angstrom-type polynomials of first and second order have been developed [10] for estimating the global solar radiation in Gaza Strip, Palestine from a long term records of monthly mean daily sunshine hour values and measured daily global solar radiation on horizontal surface at several locations near Gaza strip or have the same climate conditions. The coefficients are derived by using least square regression analysis using MATLAB. These coefficients are generally valid for estimating the radiation in Gaza Strip, Palestine.

Researchers [10] compared their model to the observed meteorological data, it was observed that the estimated values of both models where in a good agreement with both observed values form Meteorological Stations as shown in Figure 4 and Table 1 , which strength the developed model, and could be easily applied to Gaza Strip, Palestine.

Table 1: Comparison between the observed and estimated blobal solar radiation for Gaza Strip

Locat.	**Estimated H_g (kWh/m^2.d)**		**Observed H_g (kWh/m^2.d)**		**Old Model**
Month	**Linear**	**Polyn.**	**Bet Dagan**	**METEO-TEST**	**Gaza Station**
Jan	2.9834	2.9156	2.61	3.24	2.70
Feb	3.8758	3.8965	3.4	4.01	3.12
Mar	4.7525	4.7671	4.7	5.32	3.67
Apr	5.969	6.0953	5.86	6.34	4.25
May	6.9008	7.0394	6.88	7.20	4.87
Jun	7.5887	7.563	7.55	7.65	5.27
Jul	7.5268	7.4659	7.29	7.80	5.35
Aug	7.0634	6.9779	6.67	7.16	5.18
Sept	5.8999	5.9523	5.69	6.29	4.67
Oct	4.7443	4.8104	4.25	4.94	3.87
Nov	3.4028	3.4568	3.09	3.89	2.94
Dec	2.8174	2.7753	2.48	3.03	2.61

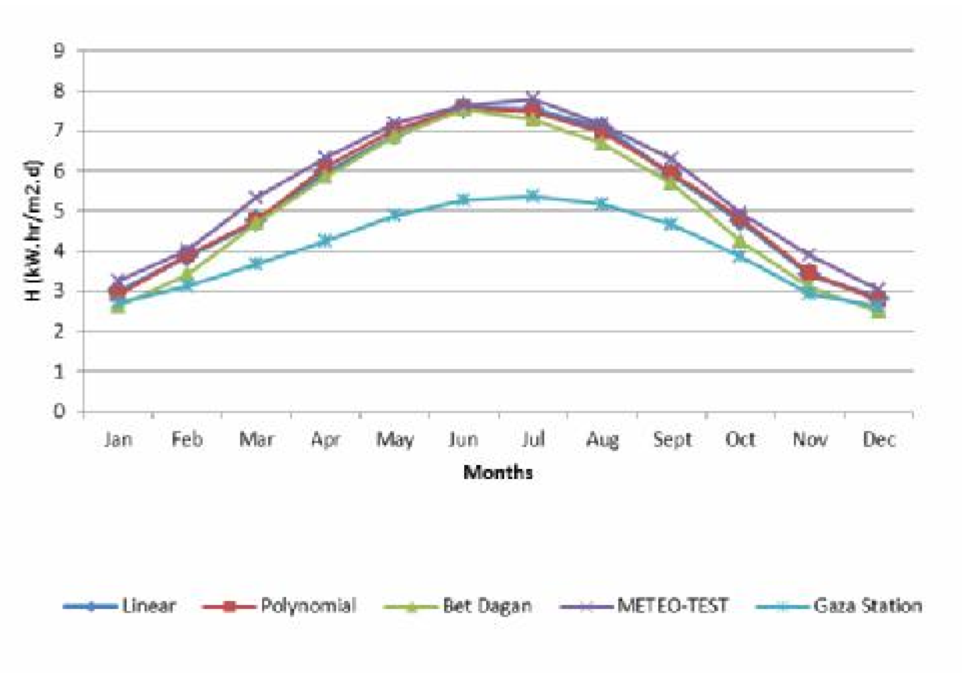

Figure 4: Comparison between the estimated and the observed values

B. *Phase II: Study on the Optimum Tilt Angle and Orientation for Photovoltaic Panels and Feasibility Study of One axis-two positions manual tracking Solar PV.*

Orientation of solar collector (SC) in space is the main factor influencing the quantity of absorbed solar radiation energy. In the case with optimal angles of a solar collector, we will have the maximum absorption of solar radiant energy.

In this phase, researchers provide technical information about tilt angle and orientation of PV Panels for both Architectures who interests in Building-Integrated Photovoltaic (BIPV) applications and Practitioner Engineers who interests in the utilization of renewable energy in Gaza Strip, Palestine to improve and enhance the efficiency of PV System used in their designs with reduced cost.

The optimal tilt angle and orientation were derived mathematically in [11], and verified by using MATLAB Software. Researchers showed that the previous designs ignored the optimum orientation and tilting angle, which degrades the performance of PV System.

Table 2 shows the mean values of solar angles for different tilt and azimuth angles, where the previous design of PV solar lighting projects oriented with 45° and 220° as a tilt and azimuth angles respectively. As shown the optimal tilt angle as derived mathematically in [11] is the location latitude 31.464°, and the azimuth angle is facing to the south 180°, the previous optimum angles leads to maximum mean value of solar angle.

Table 2: Mean values of solar angles for different tilt and azimuth angles

Tilt Angles	Azimuth Angles	Mean Value of Solar Angle
55	150	0.8239
8	20	0.7442
45	220	0.8492
28	40	0.5420
50	70	0.3945
13	180	0.9092
25	140	0.9030
50	90	0.5256
35	140	0.8896
31.464	**180**	**0.9586**

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Researchers in [11] proposed new idea to enhance the performance of the PV Solar lighting projects by adjusting the tilt angle twice a year manually. Their results as declared in

Table 3 showed that the power generation can be increased by 17% of the previous design, and can be increased by 3% of the optimum design without any additional cost.

As shown in Figure 5, the enhanced orientation leads to maximum performance other than the optimum or current orientation.

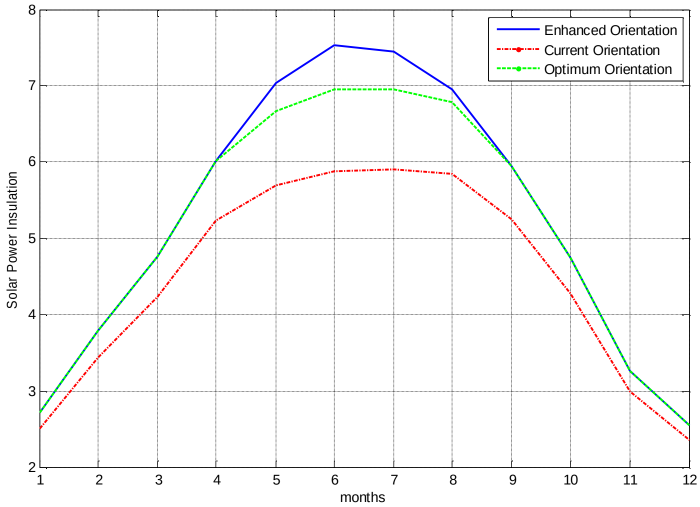

Figure 5: Improvement in Solar Power Insulation

Table 3: COMPARISON BETWEEN VARIOUS ORIENTATIONS

Orientation	**Tilt Angles**	**Azimuth Angles**	**Mean Value of Solar Angle**
Current	45	220	0.8492
Optimum	31.464	180	0.9586
Enhanced	31.464, 13	180	0.9777
Current to Enhanced Improvement	**17.0861 %**	**Optimum to Enhanced Improvement**	**2.7147 %**

C. *Phase III: PV and Battery Re-Sizing with Software Development forDesigners.*

The major aspects in the design of PV system are the reliable power supply of the consumer under varying atmospheric conditions and the corresponding total system cost [9]. So it is essential to select the number of batteries and PV modules to compromise between the system reliability and cost.

In this phase, researchers resizing the previous lighting project in Gaza, taking into account the consideration of IEEE Recommendations for Stand-Alone PV Systems in [12] and [13], which are applicable to all stand-alone PV systems where PV is the only charging source as in our case of previous lighting projects.

MATLAB Software is developed in [14] which generating full report of PV and Battery sizing design. Software prompts the user to enter the average load usage, nominal load voltage, autonomy period, maximum load current, and both battery and PV Specifications.

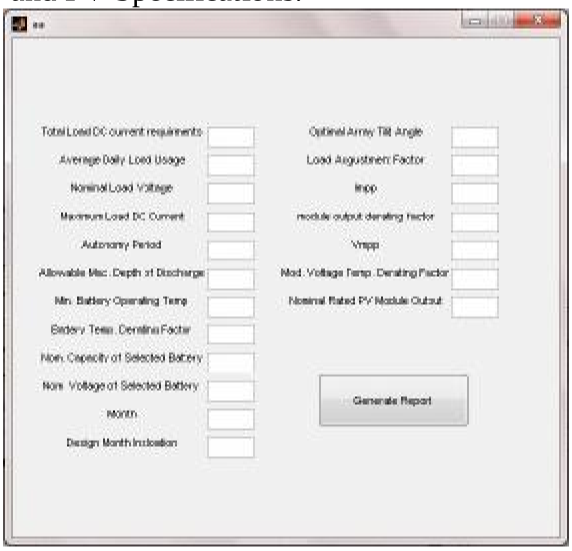

Figure 6: Developed Software for PV and Battery Sizing

Researchers found several drawbacks in previous design, which degrades the system performance. Table 4 shows the difference between the current and the recommended design for PV Lighting Project with the same previously selected batteries and modules. The major drawbacks in the previous design are the insufficient autonomy period, designing on the maximum month insulation and high percentage of DDOD, while the IEEE recommended settings acquire at least 3 days autonomy period, with designing on the average or minimum month insulation and the percentage of DDOD should be less than 20% daily.

The proposed redesign for the previous project with different selected batteries and modules is demonstrated in Table 4, where the number of batteries is reduced by selecting higher storage capacity, the estimated PV to load ratio is increased which indicated better performance.

Table 4: Difference of Sizing Summery between current and recommended designs with same and different selected batteries and modules

Sizing Summery	**Current Design**	**Recommended Design with the same selected Batteries and Modules**	**Recommended Design with different selected Batteries and Modules**
Lighting Load (Ah/day)	39	39	39
Average Month Insolation(kWh/m2/day)	**7**	5	5
Design Autonomy Period (days)	**<1**	3	3
Selected Battery (S×P)	1×2	1×4	1×2
Total No. of Selected Batteries(#)	2	4	2
Battery Storage Capacity (Ah)	120	240	300
Allowable Depth of Discharge Limit (%)	80	80	80
Average Daily Depth of Discharge DDOD (%)	32.5	16.2500	13
Selectd Module (S×P)	1×1	1×2	1×2
Total No. of Selected Modules(#)	1	2	2
Nominal Rated PV Module Output (watt)	135	135	135
Estimated PV to Load Ah Ratio	**1.3462**	**1.9231**	**1.9564**

IV. CASE STUDY

The practical experimental PV lighting system consists of 85 peak-watts PV module, a 100Ah lead-acid storage battery, a 12V DC boost regulator, and 12V DC/220V AC Inverter.

Figure 7-8 show the PV system components with additional change over circuit to protect PV components from damage, and to change the electrical supply from PV to grid network, the PV system should supply an apartment with the following electrical load as described in Table 5.

Figure 7: Solar Module mounted on Home Roof

(a)

(b)

Figure 8: (a) Voltage Regulalor, (b) DC/AC Inverter

Table 5: Apartment Electrical Load

Eelctrical Load	Watt
Lighting(5 units)	5×36
Wireless Telephone	7
DVD Player	18
DVB Digital Receiver	35
Television	85
Laptop(2 units)	2×80
ADSL Router	15
Total Load	**500**

Unfortunately, the PV modules, Voltage Regulators and inverters which available in Gaza strip is limited, so the system design is done backwardly, depending on the available PV modules and other components. The experiment covers an apartment with the previous load described in Table 5 for one hour approximate taking into account the IEEE Recommendations, while the proposed design should cover the same apartment for 6 hours as shown in

Table **6** .

Table 6: Sample and Proposed Design for an Apartment

Sizing Summery	Current Design (sample)	Proposed Design
Lighting Load (Ah/day)	26.25 (35A×0.75hr)	210 (35A×6hrs)
Average Month Insolation(kWh/m2/day)	5	5
Design Autonomy Period (days)	2	2
Selected Battery (S×P)	1×1	1×4
Total No. of Selected Batteries(#)	1	4
Battery Storage Capacity (Ah)	100	800
Allowable Depth of Discharge Limit (%)	80	80
Average Daily Depth of Discharge DDOD (%)	26.25	26.25
Selectd Module (S×P)	1×1	1×8
Total No. of Selected Modules(#)	1	8
Nominal Rated PV Module Output (watt)	85	135
Estimated PV to Load Ah Ratio	**1.3440**	**1.3714**

V. DISCUSSION & CONCLUSION

The Re-Evaluation and Re-Design process is about finding the most efficient pathway possible without compromising system quality and safety, which ignored by previous designs.

Developing Empirical Models for Estimating Global Solar Radiation for Gaza Strip, Palestine was the first phase to estimate the intercepted solar radiation, which considered the first model for Palestine. Researchers discussed the orientation and tilting angles as a second phase, which degrades the system performance for incorrect installation, also a new idea of one-axis two position manual tracking is developed as an enhancement on previous designs.

PV and Battery sizing is resized here as a third stage to meet the IEEE recommendations and system requirements, while the previous design do not taking into account several design requirements.

Researchers strongly recommend their re-evaluation and re-design model to be used in BIPV and Lighting Projects in Palestinian Territories.

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