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Increasing photovoltaic system power output with white paint albedo – a scenario in Al-Mausaib City using PVSyst. software

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ABSTRACT

Sundry circumstances influence on the photovoltaic (PV) performance, a ground albedo one of an important factor that effect on the PV panel work. This research study is to improving the output solar structures fixed on horizontal of the buildings of the even surface with adjustable roof albedo; this study incorporates integrating innovative PV and levelheaded surface techniques to boost the energy production of photovoltaic system. The modeling and simulation study were utilized as part of the system to examine the effectiveness of the solar structure installed on concrete horizontal even tiles structures with a roof albedo of 0.25, After that, white paint was applied to the concrete surface in front of the solar system to raise the albedo to 0.70. The important findings demonstrate that a rise in surface albedo from 0.25 to 0.7 will contribute to an increase in yearly solar PV power generation. The case study scenario in Al-Mussaib Technical College (L at 32° 46′ 59.99″ N, 44° 19′ 0.01 E), this paper will study the effects of two different materials top surface on the yield of PV module, for these studies, the PVSyst. program version 7.2 is utilized to analysis data from PV solar stand-alone systems.

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1. INTRODUCTION

Latin word 'Albedo' is intended whiteness. A surface albedo is a portion of the fallen sunbeams that the roof reflects. Sunbeam that is not reflected, but it is soaked up by the roof. An absorbing energy increases the roof heat, Albedo can be known as, the magnitude of a spread echo of sunbeam beyond the whole solar energy and evaluated on a gauge from 0, regular to a dark body that take in all fallen ray, to 1, matching to a form that echoes wholly incident radiation, it must be predictable that an albedo is not a basic possessions of a plane. As an alternative, for any roof, the albedo be subject to on the oblique and spectral scatterings of the episode sunlight, which in turn are administered by atmospheric arrangement and the direction of the ray of sunlight [1]. The effectiveness of a PV structure is essentially built on the meteorological circumstances of a specific location. Not all regions round the world have warm weathers. Thus, the fitting of photovoltaic panels in these areas might be unreasonable. Similarly, the repeated differences of the time of year are a main reason that has to be well thought-out. The complete effectiveness of a photovoltaic structure is affected by an amount of the parameters for example the solar cell material, setting up technique, preference or location of the structure [2], [3]. The entire incident radiation perpendicular or slanted on a plane for example a solar panel is the summation of ray, surface reflected radiation and sky-spread as of numerous planes. An albedo normally is denoted for example relation concerning land's reflected energy to the total event emission [4]. In spite of the verity of the snow-wrapped a ground reflectivity could be as 0.9, it is frequent to suppose a steady amount of reflectance of the ground is 0.2 for mild besides moist equatorial areas and 0.5 for arid equatorial areas [5]. PVSyst program for the sizing, learning method, and information investigation for the photovoltaic structure. The PVSyst-program splinted into stand-alone schemes, grid-connected structures, pumping organizations, and DC current systems for free transference (DC-grid). PVSyst-program too countenances a databank general and miscellaneous climatic information bases, as well as solar structure constituent information [6], [7].

The solar energy structure layout hangs on some features by way of described a theoretic origin, for instance the choice of environmental site, photovoltaic panels, superiority of the inverter, and PV panel location [8]–[11].PVSyst-simulation is calculated by these elements. This investigation centers on studying the effect of changing albedo values on the complete event energy on solar modules compared to a constant albedo value of 0.2, planned by [12]. This will support to appreciate the performance of photovoltaic modules On the other hand either the yield of solar modules numbers is raised or dropped [13].

a. Albedo and PV system methodology

Albedo or ground reflectance known as is the ratio of radiation that is reflected from the ground to global radiation that is incident on the ground [14] . The best PV system performance depends on choosing the installation location wisely and having a thoroughgoing considerate of ecological and electrical factors. For the installation of solar PV systems, it is essential to have a precise understanding of the radiation components (such as ground reflection, diffuse radiation, and direct beam) incident on PV modules [15]. Ground reflected albedo is a crucial characteristic and may be as high as 100 W/m^2 at some places, according to reference [7] According to [16] , different surfaces have varied albedos, and understanding the foreground type is necessary for an accurate assessment of ground reflected radiation. According to research, lakes, forests, and oceans reflect just a small portion of the incident sunlight and have low albedos. Large portions of incident sunlight are reflected by snow, sea ice, and deserts, which have higher albedo [17], [18]. The middling rate of 0.2, which defines the reflecting qualities of simple ground open of snowfall, has been used for the majority of calculations, however, where ground albedo measurements are unavailable [19]. Ineichen *et al*., [20] calculated the genuine ground reproduced energy for Geneva and equaled it to the constant rate of 0.2 proposed by Liu and Jordan [21], concluding that the constant value is excessive and ought to be dropped. Furthermore, Hansen [22] asserted that the constant value is unrealistic and unsatisfactory. Albedo values for several materials are provided in Table 1 for use in PV system calculations. Furthermore, a report from the army research laboratory mentions tabular albedo data for various ground surfaces [23].

Table 1. Typical albedo values for various surface types

Surface	Albedo	Surface	Albedo
Corrugated roof	0.1 - 0.15	Red/brown roof tiles	0.1 - 0.35
Coloured paint	0.15 - 0.35	Brick/stone	0.2 - 0.4
Trees	0.15 - 0.18	Oceans	0.05 - 0.1
Asphalt	0.05 - 0.2	Old snow	0.65 - 0.81
Concrete	0.25 - 0.7	White paint	0.5 - 0.9
Grass	0.25 - 0.3	Fresh snow	0.81 - 0.88
Ice	0.3 - 0.5		

b. Theoretical model

To enhance radiation exposure and minimize cosine and reflection losses in the PV system. collectors should be installed at an angle not horizontally that because the amount of radiation depends on the slope and orientation of the surface solar radiation (G_t)at flat surface absorbs beam (G_{Bt}), diffuse (G_{Dt}), ground reflected (G_{Gt}) can express it [24].

$$G_t = G_{Bt} + G_{Dt} + G_{Gt} \tag{1}$$

The beam radiation of horizontal surface (G_B) and beam radiation of tilted surface (G_{Bt}) are shown in Figure 1 can be expressed as:

$$G_B = G_{Bn} cos\ (\phi) \tag{2}$$

$$G_{Bt} = G_{Bn} cos\ (\theta) \tag{3}$$

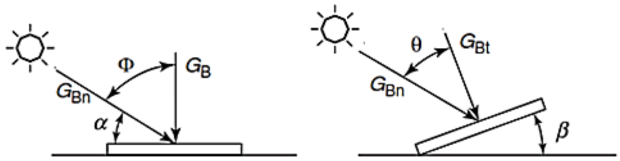


Figure 1. Horizontal and tilted surfaces beam radiation [24]

The beam radiation tile factor is:

$$R_B = \frac{G_{Bt}}{G_B} = \frac{cos\ (\theta)}{cos\ (\phi)} \tag{4}$$

for any surface the beam radiation is:

$$G_{Bt} = \ R_B G_B \tag{5}$$

– Incidence angle

Incidence angle is the angle formed by the sun's rays and a surface normal. the general expression of this angle as shown in Figure 2 is:

$$\cos\theta = \sin L \sin\delta \cos\beta - \cos L \sin\delta \sin\beta \cos Z_s + \cos L \cos\delta \cos h \cos\beta + \sin L \cos\delta \cos h \sin\beta \cos Z_s + cos\ \delta\ sin\ h\ sin\ \beta\ sin\ Z_s \tag{6}$$

θ incidence angle
Ø zenith angle
β surface tilt angle from the horizontal,
Z_s surface azimuth angle

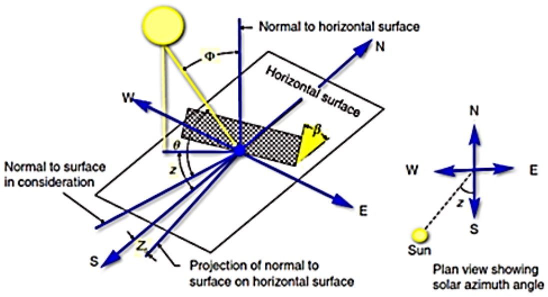


Figure 2. The diagram of solar angles [24]

For the case of horizontal surfaces, θ = ϕ , β = 0 (7) be:

$$cos\ (\phi)\ = sin\ L\ sin\ \delta\ + cos\ Lcos\ \delta\ cos\ h \tag{7}$$

on a horizontal shallow the diffuse emission can obtain as follow refined by:

$$G_D = 2\int_{2}^{\frac{\pi}{2}} G_R cos\ \phi\ d\phi = 2G_R \tag{8}$$

also, the tilted surface diffuse radiation G_D is,

$$G_{D_t} = 2\int_{2}^{2\pi-\beta} G_R cos\ \phi\ d\phi + 2\int_{2}^{\frac{\pi}{2}} G_R cos\ \phi\ d\phi \tag{9}$$

from (8), $G_R = \frac{G_D}{2}$ Substitute in second part of (9).

$$G_{Dt} = \frac{G_D}{2}\int_{2}^{2\pi-\beta} G_R cos\ \phi\ d\phi + \frac{G_D}{2}\left[sin\ \left(\frac{\pi}{2} - \beta\right)\ \right] + \frac{G_D}{2} = G_D\left[\frac{1+cos\ (\beta)}{2}\right] \tag{10}$$

in a similar way, the radiation of ground reproduced is gotten by ρ_G (G_B + G_D), ρ_G: ground albedo. So, the ground-reflected radiation G_{Gt} is obtained as follows.

$$\rho_G(G_B + G_D) = 2\int_2^{\frac{\pi}{2}} G_R cos\ \phi\ d\phi = 2G_r \quad (11)$$

G_r is the isotropic ground-reflected sparkle (W/m^2 rad). Ground-reflected emission on slanted planes,

$$G_{D_t} = \int_{\frac{\pi}{2}-\beta}^{\frac{\pi}{2}} G_r cos\ \phi\ d\phi \quad (12)$$

combining (11) and (12) as before,

$$G_{Gt} = \rho_G(G_B + G_D)\left[\frac{1-cos\,(\beta)}{2}\right] \quad (13)$$

therefore, substitute (10) and (13) into (1), we get:

$$G_t = R_B G_B + G_D\left[\frac{1+cos\,(\beta)}{2}\right] + (G_B + G_D)\rho_G\left[\frac{1-cos\,(\beta)}{2}\right] \quad (14)$$

then the total energy on a horizontal plane, (G) be the sum of horizontal beam and long-winded energy;

$$G = G_B + G_D \quad (15)$$

therefore, (14) can be written as:

$$R = \frac{G_t}{G} = \frac{G_B}{G}R_B + \frac{G_D}{G}\left[\frac{1+cos\,(\beta)}{2}\right] + \rho_G\left[\frac{1-cos\,(\beta)}{2}\right] \quad (16)$$

R: tilt factor of total radiation
From (13) in PV system installed on ground surface to increase the amount of diffuse reflection from the ground a surface with high albedo ρ should be chosen.

2. DESIGN METHODOLOGY

For this study PVSyst. -program7.2 is employed to analysis data from PV solar stand-alone systems. The field type fixed tilted plane, the plane tilt 31°, Azimuth 0°. The design with two different materials roof surface depends on changing albedo from albedo 0.25 for concrete roof surface and 0.70 for horizontal flat roof treated with white oil paint

2.1. Sizing of stand-alone PV system

2.1.1. Geographical location

As shown in Figure 3 the geographical location of Al-Mausaib Technical college ((L at 32° 46′ 59.99″ N, 44° 19′ 0.01 E), the PV modules are placed on a horizontal and flat concrete tiles exterior. The system is designed and analyzed PV, we have taken characteristic of light come from sun and effects the first effect is spectrum of beam light consist the three regen (UV) which have short long wave it mean cause of degradation in silicon and plastic material, (visible) light which it the useful band to generate electric by PV panel it have medium long wave, and third one is which have longest long wave the [25] mean effect of is heat this effect not usefully for traditional PV panel because increase in temperature let to descries in efficiency.

Show classification for PV schemes with extra purpose in the resulting we contemporaneous the maximum significant factors. On scheme level a number of percentages can be measured to rate a PV scheme´s parameters. The parameters percentage PR of a standard PV scheme is assumed [26], [27]:

$$PR = \frac{\sum_i^n EN_{AC,i}}{\sum_i^n P_{STC}\left(\frac{G_{POA}}{G_{STC}}\right)} \quad (17)$$

EN_{AC} : dignified AC electrical generation (kW); P_{STC} : summation of installed modules' power rating (kW); G_{POA} : dignified irradiance in the plane of array (POA) (W/m^2); I : guide a group of quantity outcomes at the identical period; G_{STC} : irradiance at normal test conditions (STC) (1000 W/m^2) [28]. Used for remaining joined PV schemes with or without battery-operated the grade o.f intake is specified.

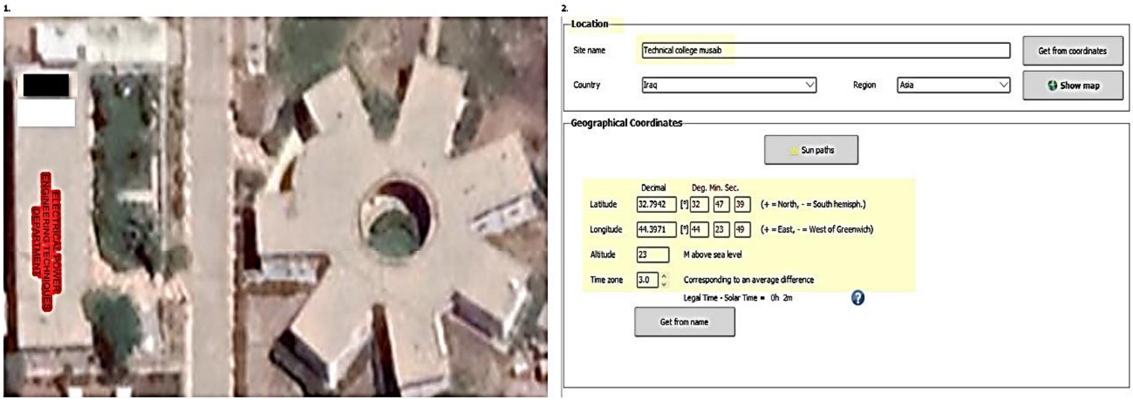


Figure 3. Geographical location Al-Mussaib Technical College

2.1.2. Solar panels tilt angle

From PV Syst. software chosen for PV panels is towards south, the field type fixed tilted plane, the field parameters plane tilt 31°, Azimuth 0° toward south to get the maximum plane tilt and maximum plane orientation, the optimization with respect to yearly irradiation yield, the yearly meteor yield according to this tilt angle will be as show in Figure 4.

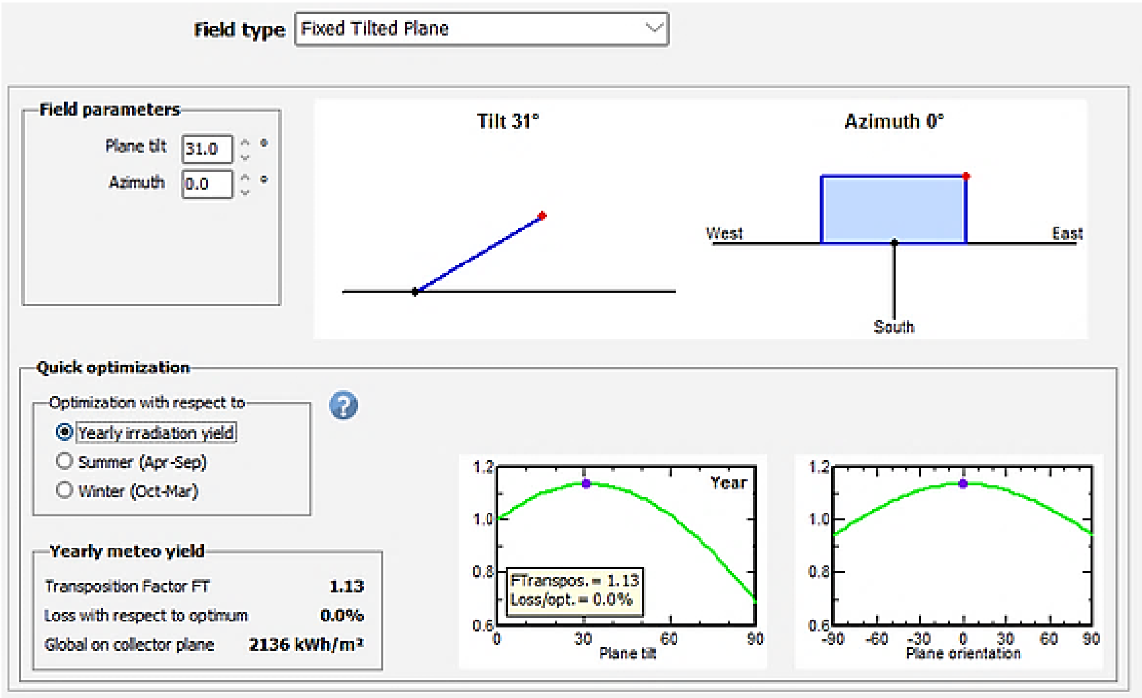


Figure 4. Orientation and tilt angle module [29]

2.1.3. Load calculation

In this simulation the daily consumption for the load which constancy (4 LED lamps, 1 TV, 2 fan, 1 fridge, 1 cloth-washer, 1 laptop). The daily energy for each load (252 Wh, 400 Wh, 1040 Wh, 2500 Wh/ 500 Wh, 320 Wh) respectively, the total daily energy 5156 Wh and monthly energy 154.7 kWh. Figure 5 provides other details information for load calculation (power, daily use, hourly distribution, daily energy, total daily energy and monthly energy

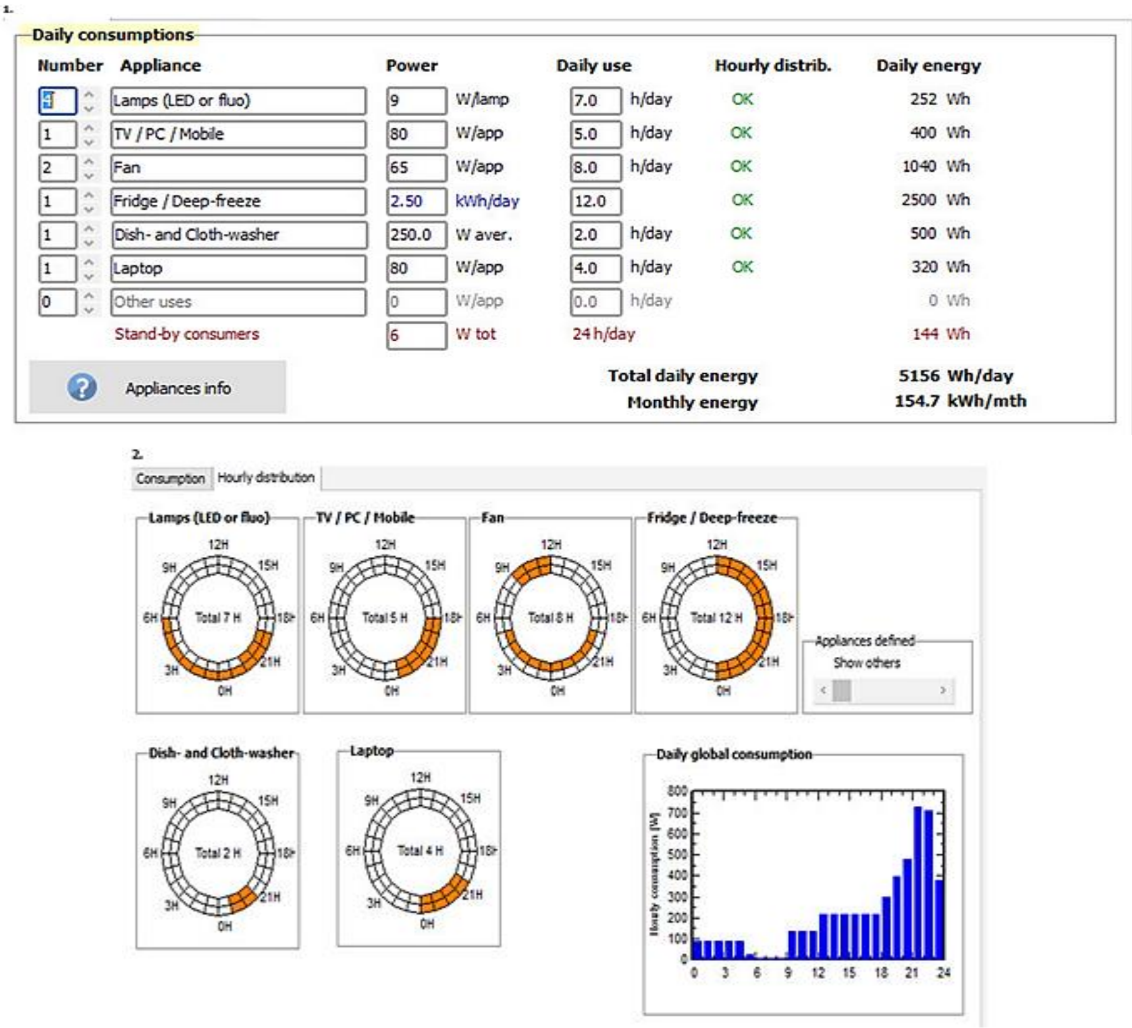
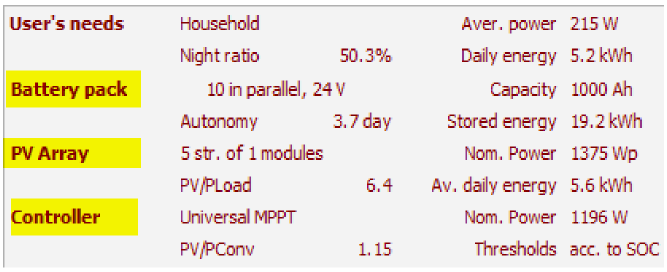


Figure 5. Load daily consumption and total monthly energy calculation [29]

2.1.4. Batteries, PV model and controller selection

Based on PVSyst. software the Figure 6 shows simulation test parameters selections of the battery pack 10 in parallel, 24 V it is capacity 1000 Ah, autonomy 3.7 day stored energy 19.2 kwh also PV array 5 string of 1 modules normal power 1375 Wp, the controller type universal MPPT with normal power 1196 W.



User's needs	Household		Aver. power	215 W
	Night ratio	50.3%	Daily energy	5.2 kWh
Battery pack	10 in parallel, 24 V		Capacity	1000 Ah
	Autonomy	3.7 day	Stored energy	19.2 kWh
PV Array	5 str. of 1 modules		Nom. Power	1375 Wp
	PV/PLoad	6.4	Av. daily energy	5.6 kWh
Controller	Universal MPPT		Nom. Power	1196 W
	PV/PConv	1.15	Thresholds	acc. to SOC

Figure 6. Parameters selections for the module

2.1.5. Albedo setting

The two types of materials that can be employed with albedo as ground reflectors. Table 1 will determine what value to use for albedo [22], [23].

- Concrete roof surface material with albedo 0.25
- layers of white oil paint roof surface Material with albedo 0.70 (average value as in Table 1 for white paint) (0.5-0.9).

The results of two type of choosing albedo for of both systems are shown in Figure 7.

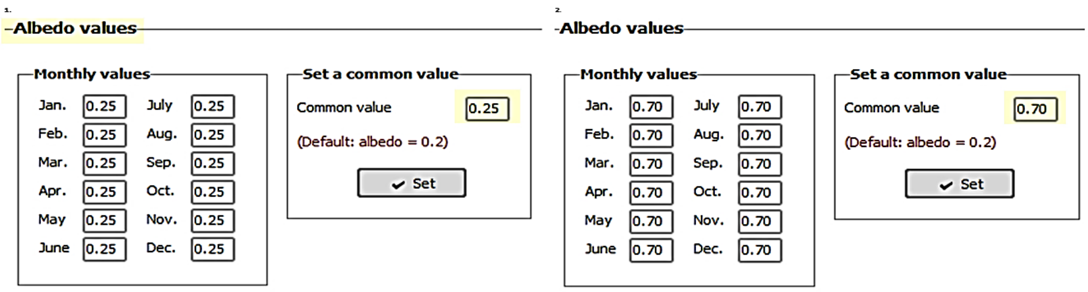


Figure 7. Albedo values selected for two type on PV Syst software [29]

2.1.6. The setup

- Hardware setup

One PV modules used in for this study. Two different materials roof surfaces used. The PV modules were mounted horizontal facing south with angle of 31^{o}. Roof reflectance; the old concrete roof surface of the PV modules will be treated with layers of white oil paint. The tendency angle of the reverberators (roof surface) stayed fixed horizontal at of 0 degrees. The space of preserved tiles surface measured as a minimum double that of the PV modules. These dimensions of reverberator are adequate and the

- Software arrangement

PVSyst. software version 7.2 is used to analysis data from PV solar stand-alone systems. The design with two different materials roof surface depends on changing albedo for a concrete roof surface material with albedo 0.25. After that, white paint was applied to the concrete surface in front of the solar system to raise the albedo to 0.70.

3. RESULTS AND DISCUSSIONS

Simulation results were obtained for a horizontal flat roof Stand-alone PV system of 1.350 KWp, average of 5.2 kWh/Day with total of 5 PV modules. The PV system is fixed to a support structure made of stainless steel that is tilted 31 degrees and faces south, two cases were simulated .one was at albedo of 0.25 as concrete. While the second simulation was considering higher albedo 0.70 as white oil paint. The Global horizontal irradiation energy of the sun for a year in the Babylon Governorate, (specifically for Al-Mussaib) according to results from PV syst. program for two cases is h = 1884 kWh/m^2 year.

3.1. Case 1 albedo 0.25

In this case, the simulation of PV System mounted on a concrete horizontal flat roof considering albedo 0.25 as shown in Figure 8. The main results are:

- Annually energy yield: 2231 kWh/year
- Indicated a performance ratio: 65.68%
- Specific production: 1624
- Effective global incident in coll. Plane: 2089.356 kWh/kWp/year
- At the panel surface, the level of radiation is 10.9% higher because the panels are tilted. This value is reduced for 2.57% because of the effect of incidence angle modifier (IAM)
- Effective global, corr. for IAM: 2035 kWh/m^2 year

3.2. Case 2 horizontal flat roof PV system at albedo 0.7

In this case the simulation of PV System mounted on a concrete horizontal flat roof treated with white oil paint as shown in the Figure 9 considering average reflectivity albedo 0.7(0.5-0.9). The main results are:

- Annually energy yield: 2246 kWh/year
- Indicated a performance ratio: 64.30 %

- Specific production: 1624
- Effective global incident in coll. Plane: 2149.644 kWh/kWp/year
- At the panel surface, the level of radiation is 14.1% higher because the panels are tilted. This value is reduced for 2.71 % because of the effect of incidence angle modifier (IAM)
- Effective global, corr. for IAM: 2091.4 kWh/m² year

The effect of increasing albedo to 0.7 to the system shown in Table 2. The disadvantage for increasing albedo is temperature rise on PV array therefore increase the PV loss as shown in Table 3.

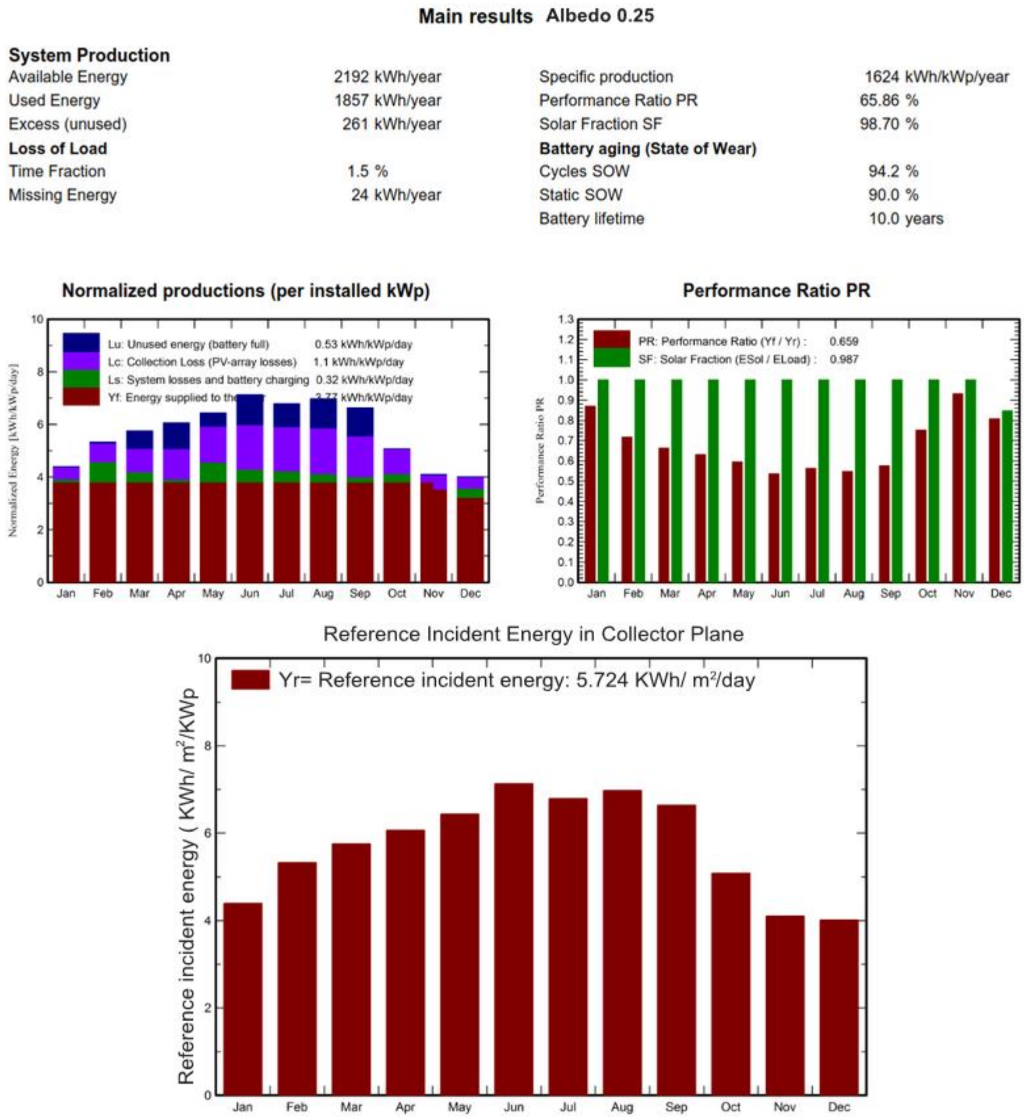


Figure 8. The normalized productions, performance ratio and reference incident energy in the collector plane results for case 1 with albedo 0.25

Table 2. the effect of increasing albedo from (0.25- 0.7) on PV System

	Albedo (0.25)	Albedo (0.7)
Global incident in coll. Plane	2089 kWh/m^2	2150 kWh /m^2
Available solar energy	2192 kWh	2246 kWh
Effective" Albedo, corr. For IAM and shadings	31.12 kWh/m^2	87.15 kWh /m^2
Albedo incident in coll. Plane	33.63 kWh /m^2	94.17 kWh /m^2
Array virtual energy at MPP	2278 kWh	2332 kWh

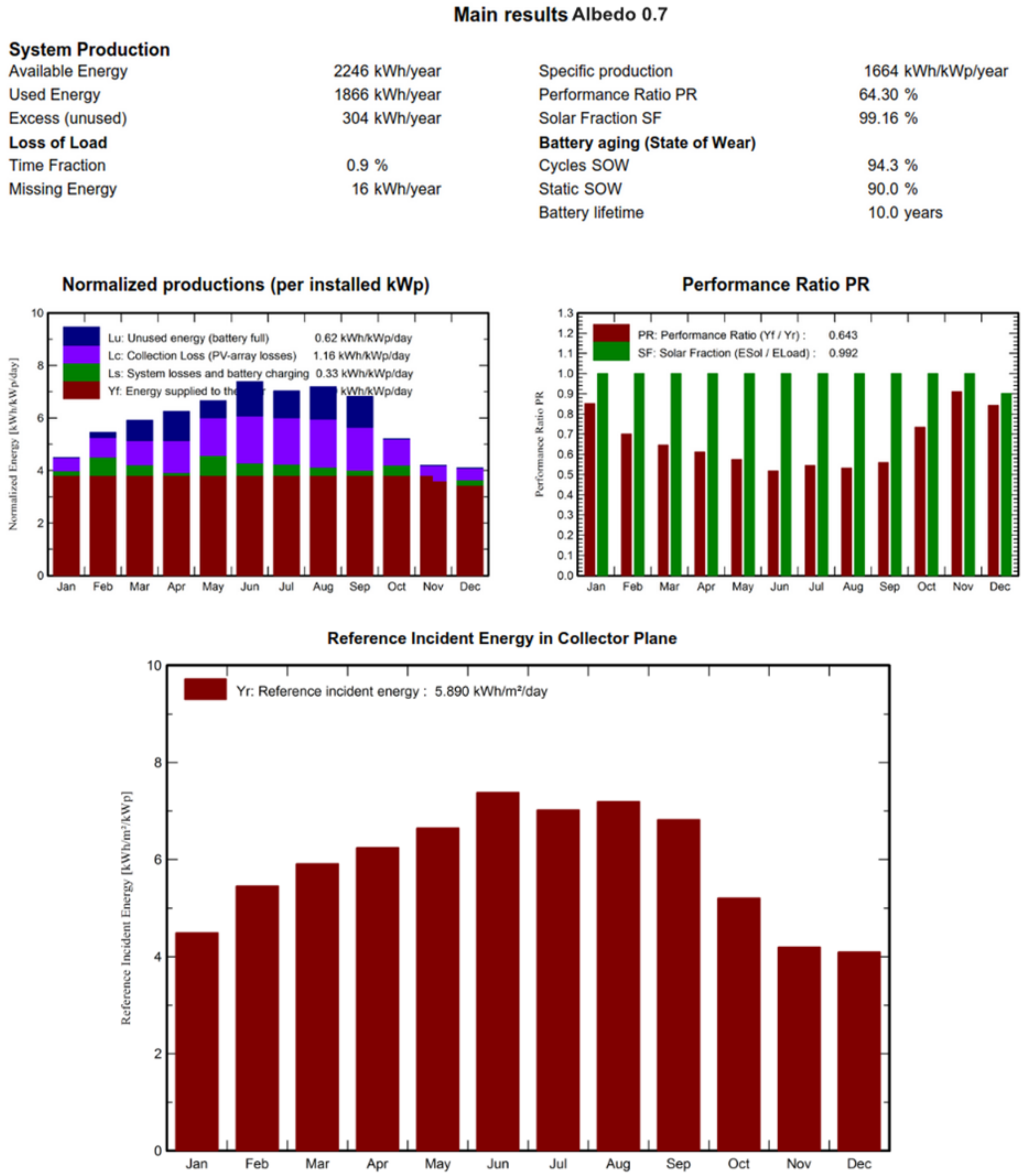


Figure 9. The normalized productions, performance ratio and reference incident energy in the collector plane results for case 1 with albedo 0.7

Table 3. The temperature losses due of increasing albedo from (0.2- 0.7) on PV system

	Incidence albedo loss, kWh/m²		Module temper weighted by globin		PV loss due to temperature kWh	
Month	Albedo (0.25)	Albedo (0.7)	Albedo (0.25)	Albedo (0.7)	Albedo (0.25)	Albedo (0.7)
January	0.1222	0.3421	35.2297	35.6832	7.7102	8.2143
February	0.1458	0.4081	42.1935	42.7761	14.2449	15.0512
March	0.2006	0.5617	46.9036	47.5648	21.7451	22.9701
April	0.2289	0.6408	55.4385	56.2005	30.8733	32.55
May	0.2794	0.7824	59.926	60.7048	38.8335	40.9669
June	0.3172	0.888	65.9526	66.813	48.8757	51.5938
July	0.3042	0.8517	68.334	69.1778	50.9833	53.6926
August	0.2856	0.7997	69.4267	70.2639	53.8098	56.4747
September	0.2324	0.6509	66.1976	66.9731	45.9453	48.0567
October	0.1651	0.4622	55.0006	55.5865	26.3506	27.506
November	0.1178	0.3299	42.3991	42.8546	11.8581	12.4328
December	0.109	0.3051	35.0316	35.4423	6.8944	7.3177
Total	2.508 kWh/m²	7.023 kWh/m²	55.71 Cº	56.46 Cº	358.1 kWh	376.8 kWh

4. CONCLUSIONS AND FUTURE WORKS

This study concentration on improvement the total solar radiation incident on the photovoltaic panel to increase the performance of the structure using considering the old concrete plane with white dye. By increasing the albedo from 0.25 to 0.7. The following is a summary of the work's outcomes: i) Using a high albedo reflector will enhance the amount of solar radiation that is absorbed on the collector. The solar panel's output power therefore rises; ii) Increasing albedo generated high temperature on the PV panel but the output power of the panel still more than low albedo; iii) Five panels made up these results. If we increase the size of the PV system, more energy will be generated because of more radiation falling the panel due to a higher albedo; iv) Therefore, to increase the output power, this system should be tested at different higher albedo reflector roofs materials like aluminum foil. Aluminum sheet, mirror. or using tracking reflector surface, changing the inclination of reflectors from horizontal to facing the North towards modules; v) As the albedo is increased to (0.7) in case 2, the temperature on the PV array will rise which will lead to more losses in system as shown in Table 3 but the available solar power and annual energy yield are still more than in case 1; and vi) As soon as likened the price of the PV structure with the price of the coat used to remedy the surface is negligible. Therefore, applying such paint to the roof surface is an affordable way to boost the PV system's output and also cheaper than using aluminum as a reflector.

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