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# Designing interactive GUI to determine the required size of an independent photoelectric system to feed of an elevator (residential - service).

**Dr. Sahar AL Ali***
**Aous Mohammad****

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**□ ABSTRACT □**

The purpose of thesis is to determine the components of the photovoltaic system used to secure feeding for a (residential - service) elevator considering the following factors (transport capacity, people number, load, population, engine capacity, average daily consumption, photovoltaic panels, batteries, chargers and installation area). The results are displayed by designed interactive Matlab-Gui (Graphical User Interface). The designed program was tested for two phases: firstly, 8-storey residential building and secondly, a service building (hospital). The results were calculated professionally highlighting a fact that designing an elevator powered by solar energy - photovoltaic panels saves 61.53% of the energy comparing to traditional one who provides 43%. Besides, the designed program is also flexible as it can be used to create a dependent PV system for many applications.
**Keywords**: Photoelectric system, Solar PV System, daily consumption rate, load, clean Mobility, green design elevator.

* Assistant professor- Industrial Automation Engineering – Tartus University – Tartus - Syria.
** Postgraduate student - Industrial Automation Engineering – Tartus University – Tartus - Syria.

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# تصميم واجهة تخاطبية GUI لتحديد حجم نظام كهروضوئي مستقل مستخدم لتأمين تغذية لمصعد(سكني – خدمي)

**د. سحر العلي ***

**أوس محمد محمد ****

**(تاريخ الإيداع 27 /1 /2021 . قُبِل للنشر في 8 /4 /2021 )**

**□ ملخّص □**

تم في هذا البحث تحديد حجم مكونات النظام الكهرو ضوئي المستخدم لتأمين التغذية لمصعد (سكني – خدمي) من حيث (استطاعة النقل المطلوبة – عدد الأشخاص – الحمولة – عدد السكان – استطاعة المحرك – معدل الاستهلاك اليومي – عدد الألواح المطلوبة – عدد البطاريات – عدد الشواحن – مساحة التركيب)، تعرض النتائج من خلال واجهة تخاطبية Matlab–Gui تم تصميمها لهذا الغرض.

وتم اختبار البرنامج المصمم على مرحلتين: الأولى على مبنى سكني مؤلف من 8 طوابق والثانية على مبنى خدمي (مشفى)، وأظهرت النتائج قيم البارامترات المذكورة سابقاً بدقة عالية، وكما بينت أن تصميم نظام المصعد باستخدام الطاقة الشمسية يوفر طاقة بمعدل 61.53% مقارنة مع نظام المصعد الذي يستخدم نظام EERU الذي يوفر طاقة بمعدل 43%. كما يتمتع البرنامج المصمم بمرونة حيث يمكن استخدامه لتصميم نظام كهروضوئي مستقل يناسب العديد من التطبيقات.

**الكلمات المفتاحية:** نظام كهروضوئي مستقل، استطاعة النقل المطلوبة، معدل الاستهلاك اليومي، الحمولة.

*مدرس– قسم هندسة الأتمتة الصناعية – كلية الهندسة التقنية – جامعة طرطوس– طرطوس – سورية.

**طالب ماجستير– قسم هندسة الأتمتة الصناعية – كلية الهندسة التقنية – جامعة طرطوس – طرطوس – سورية

## Introduction

Energy is one of the main concerns for the rising future of any nation. Energy certainly plays a vital role in development and welfare of human being. There exists a direct correlation between the development of a country and its consumption of energy. The rapid increase of urbanization and the multi-storey buildings with elevators using the required latest mechanical, electrical and technical equipment in designing elevators. In spite of the highly demand of using elevators in high residential facilities, it is proved to be energy-consuming technology. So, It becomes a necessity to develop the elevator control system depending on one of the most important alternative energy; the PV systems as the following are the most important qualifications[1,8]:

1- No moving parts
2- Noiseless.
3- No need for maintenance.
4- Environment friendly No carbon emission.
5- Withstands harsh climatic conditions (storms, high temperatures). stable with immune to storms stand still, simply not affected with weather conditions strict sever circumstance.
6- The size of the panel matrix can be easily increased by connecting additional panels on the series to increase voltage or parallel to increase current.

## 1. Benefits from a Green Perspective:

Adapting green technology in Elevator design shall absolutely provide following standards [14]:

1- Create more usable space.
2- Use less energy (70-80% less than hydraulic elevators).
3- Use no oil.
4- Much lower cost than other elevators ride.
5- Quality is better due to gearless traction.
6- Operates at faster speeds than hydraulics.

Not to mention that all components are above ground-this takes away the environmental concern that was created by the hydraulic cylinder being stored underground.

## 2. Elevator Design Standards:

All new or refurbished elevators must meet or exceed the following minimum basic requirements. The number of personal elevators, loads, and speed of a specific building depends on the properties of the building, including [7]:

1- Storeys.
2- Residents of each storey.
3- The required transport capacity.
4- Distance between floors (building height).

### 2.1. Transport Capacity/Elevator Loading:

All elevators are not engineered for the same purpose. Some are designed as passenger elevators, some as service elevators, and some as freight elevators. Within each elevator type, there are also multiple Elevator Loading Classifications. The transport capacity varies to the different usage of the building, the minimum requirement to provide an elevator for the vertical movement of furniture, goods and people every (5) minutes with average from (10-25)% , if flow rate is not available 12% is supposed for residential buildings and 17% for the services building.

It can be assumed ($10m^2$) per person inside the building so the transport capacity can be calculated due to the following relationship [7]:

$P_t$

## 2.2. Elevator Speed:

Elevator speeds increase corresponding with the weights, costs, and the transport capacity of the elevator, Table (1) shows the elevator speed to the total number of floors in a building [7].

**Table (1): Elevator speed suitable for the total number of floors of the building.**

| Elevator speed (m/s) | Floor Number |
|---|---|
| 0.5 | 3 – 2 |
| 1 | 4 |
| 1.5 | 6 – 5 |
| 2 | 9 – 7 |
| 2.5 | 12 – 10 |
| 3 | 15 – 13 |
| 5 | 50 – 16 |
| 8 | more than 50 |

## 2.3. Elevator Loading:

The rated load of any elevator is related to the number of people in or the weights.

The table (2) shows the allowed people number to the elevator load or the area, width, height and length of the Hoistway, MRL Machine Room Less and the inside door. The table (3) shows the relationship between the elevator load and the dimensions of the elevator, Hoistway, MRL. The table (4) shows the relation between the elevator load and the dimensions of the elevator Cabin. The table (5) shows the relationship between the elevator load and the dimensions of the elevator, Landing Doors. The table (6) shows the relationship between the elevator load and the dimensions of the elevator, Machine room [7].

**Table (2): Elevator load corresponding to the number of passengers.**

| Rated Load (kg) | Passengers |
|---|---|
| 320 | 4 |
| 480 | 6 |
| 630 | 8 |
| 750 | 10 |
| 900 | 12 |
| 1200 | 16 |

**Table (3): the relationship between the elevator load and the dimensions of the elevator, Hoistway.**

| The Hoistway | | | | | Payload (kg) |
|---|---|---|---|---|---|
| Area (m2) | width (cm) | depth (cm) | depth of the hole | High vacuum | |
| 2.24 | 130 | 180 | 150 | 200 | 320 |
| 2.88 | 160 | 180 | 150 | 200 | 480 |
| 3.8 | 190 | 200 | 150 | 200 | 630 |
| 4 | 190 | 210 | 160 | 200 | 750 |
| 4.41 | 210 | 210 | 180 | 200 | 900 |
| 5.72 | 220 | 260 | 190 | 210 | 1200 |

**Table (4): the relationship between the elevator load and the dimensions of the elevator, Lift Cabin.**

| Elevator Cabin | | | | Payload (kg) |
|---|---|---|---|---|
| Area (m2) | Width (cm) | Depth (cm) | High (cm) | |
| 0.9 | 100 | 90 | 220 | 320 |
| 1.3 | 100 | 130 | 220 | 480 |
| 1.65 | 110 | 150 | 220 | 630 |
| 1.82 | 140 | 130 | 220 | 750 |
| 2.24 | 140 | 160 | 220 | 900 |
| 2.8 | 140 | 200 | 220 | 1200 |

**Table (5): the relationship between the elevator load and the dimensions of the elevator, Landing Doors.**

| Landing Doors | | Payload (kg) |
|---|---|---|
| Width (cm) | Length (cm) | |
| 70 | 200 | 320 |
| 70 | 200 | 480 |
| 80 | 200 | 630 |
| 80 | 200 | 750 |
| 80 | 200 | 900 |
| 110 | 200 | 1200 |

**Table (6): the relationship between the elevator load and the dimensions of the elevator, Machine room.**

| Machine room | | | | Payload (kg) |
|---|---|---|---|---|
| Area (m2) | Width (cm) | Length (cm) | High (cm) | |
| 6.66 | 180 | 370 | 230 | 320 |
| 8 | 200 | 400 | 230 | 480 |
| 8.8 | 200 | 440 | 260 | 630 |
| 8.8 | 200 | 440 | 260 | 750 |
| 16.8 | 330 | 510 | 270 | 900 |
| 18.5 | 350 | 530 | 270 | 1200 |

### 2.4. Engine Power:

The engine power of the elevator is given by the following relationship [7]:

$$P$$

Where:

$v$: Elevator speed [m/s]

$l$: Payload [kg]

$g$: Acceleration of gravity [m/s$^2$]

## 3. Elevator Photovoltaic System Design:

### 3.1. Componets:

Independent photovoltaic system consists of a variety of equipment:

1- Solar Panels.

2- Batteries.

3- Chargers.

4- Inverter.

5- Load.

**The figure (1) shows a PV system designed to operate independently of the public electrical network to provide the required DC and /AC loads on time [5,9]**

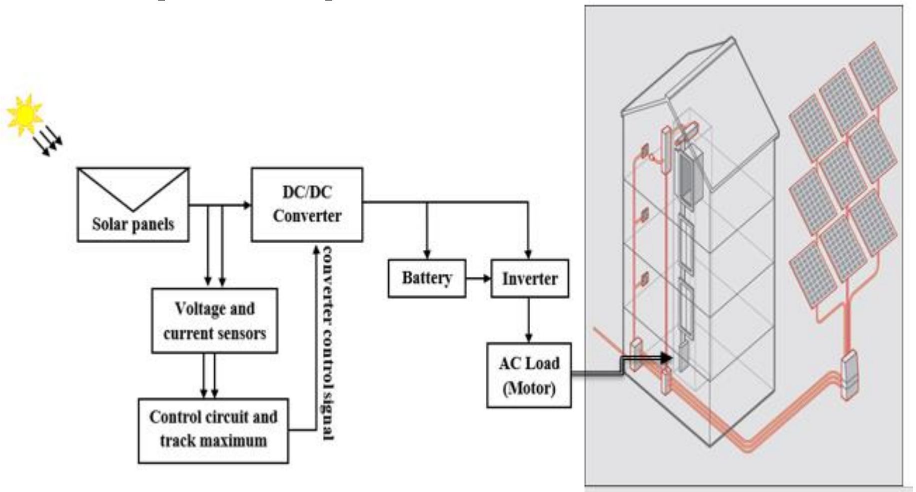


**Figure 1: Box diagram of independent PV system.**

### 3.2. Designing Factors of a PV System:

1- Daily consumed energy/ Current consumption.

2- Collecting solar radiation data of the solar panel at the installation site daily /monthly taking into account the orientation of the panel matrix and the slope angle of the panel matrix.

3- Available roof area.

4- Software for designing a photovoltaic system, PV Modules/Generator (Wp), DC charge controller / AC inverter (A, W) and batteries (Ah).

### 3.3. Panel Matrix:

Basically, the following list shall be determined:

1- Total energy consumed per day /Daily consumed energy.
2- Minimum average hours of solar radiation per day.
3- Continuous system voltage ($V_{DC}$).

Calculating the daily energy requirement of solar panels through the relationship is given by [1]:

$$E_r = \frac{E}{\eta_b \cdot \eta_i \cdot \eta_c} \qquad (3)$$

Where:

$\eta_b$: Battery efficiency [%].
$\eta_i$: efficiency of the exchanger [%].
$\eta_c$: charger efficiency [%].
E: Total energy consumed per day [wh].

The peak energy ($P_p$) is obtained according to the relationship [1]:

$$P_p = \frac{E_r}{T_{min}} \qquad (4)$$

Where:

$T_{min}$ The average daily minimum solar radiation hours [h].

The total current can be calculated according to the relationship [1]:

$$I_{DC} = \frac{P_p}{V_{DC}} \qquad (5)$$

Where:

$P_p$: Peak-Maximum energy /power [w]
$V_{DC}$: Direct voltage of the system [v].

To increase power productivity, panels should be connected in series-string and series according to the system voltage and current requirements and calculated as follows:

Consideration of system productivity is extremely important. A more productive system is able to pay for itself more quickly, bringing greater economic benefit to the client and better value to the system productivity goes well beyond component efficiency. It is tied directly to the structure of the array, not just the efficiency of the components and the quality of the installation.

The following discusses different approaches to system configuration. Subsequent sections address the issues that require attention to maximize PV system.

The series –string array configuration leads to a high-voltage system. The series-parallel array configuration leads a low-voltage system:

1- Number of serial panels[1]:

$$N_S = \frac{V_{DC}}{V_r} \qquad (6)$$

Where:

$V_r$: Nominal voltage per panel [v].

2- Number of parallel panels [1]:

$$N_P = \frac{I_{DC}}{I_r} \qquad (7)$$

Where:

$I_r$: Nominal current of a single panel [A].

OR:

$N_P$

Thus we can calculate the total number of panels according to the relationship [1]:

$N_m$

**3.4. The number of Batteries:**

First, calculating the stored energy due to the relationship [11]:

$E_{rough}$

Where:

E: daily consumption rate.

D: number of self-feeding days.

Safety procedure, we calculate the required safe stored energy according to the relationship [11]:

$E_{Safe}$

Where:

MDOD: Maximum Discharge Depth Allowed

the capacity of the storage system in ampere-hour can be estimated and calculated by the relationship [11]:

$C$

Where:

$V_b$: nominal voltage of the selected battery [v].

Selecting the used battery capacity storage system as the number of batteries in the storage system is calculated due to the relationship [11]:

$N_{battries}$

Where:

C: The total capacity of the storage system

$C_b$: Ampere - hour for the selected battery.

Batteries number in SERIES-STRING ARRAY parallel is calculated through the relationship:

$N_S$

Batteries connected in series–parallel array through the relationship [11]:

$N_P$

**3.5. The number of chargers:**

First, the current and voltage of the voltage regulator must be determined so the nominal current of the charging regulator can be obtained according to the relationship [3]:

$I$

Where:

$I_{SC}$: Short circuit current [A].

$F_{safe}$: Safety factor.

To determine the input voltage of the regulator ($CC_{Volt}$), must be considered the temperature changes that lead to the shift of the solar models working point from the maximum power point and this changes the voltage value of the panel ($V_m$) and we determine the voltage of the PV matrix according to the relationship [3]:

$$V_{PV} = V_m \,.\, 0.95 \,.\, N_S \qquad (17)$$

Where:

$V_m$: solar panel voltage at the maximum power point [v].

Energy losses must be taken into account along the cables that connects the solar panels to the storage system of charger ($\eta_{cable}$), and the losses in it are standard 5% and therefore the return is 95% and minimum the voltage of the array panels:

$$V'_{PV} = \frac{CC_{Volt}}{\eta_{cable}} \qquad (18)$$

Where:

$CC_{Volt}$: input voltage of the solar charger [v]

$\eta_{cable}$: cable payoff [%]

### 3.6. Power of the inverter:

The energy of the inverter is given by the relation [4,12]:

$$P_{inv} = 1.25(P_{sum} + 3P_{ind}) \qquad (19)$$

Where:

$P_{inv}$: power of the inverter [w]

$P_{sum}$: energy of all loads running at the same time [w].

$P_{ind}$: energy of all induction loads that sudden currents (large takeoff currents) [w].

The apparent power of the inverter can be calculated according to the relationship [3]:

$$S_{inv} = \frac{P_{inv}}{PF} \qquad (20)$$

PF: power factor value in general for most inverters (0.8)

The input current of the inverter [12] is:

$$I_{inv} = \frac{S_{inv}}{V_{DC} \,.\, \eta_i} \qquad (21)$$

### 3.7. Installation Area:

The area occupied by the panels, and the distance between the rows of the solar panels should be determined, so that any panel does not shade by anthers, the largest shadow distance from the solar panel occurred on December in winter, when the lowest angle of inclination of the sun ($\gamma_s$), as shown in **Figure (2-a)**. Also the shadow depends on the other inclination angle of the sun $\psi_s$ to the east or west, whether at the beginning or the end of the day, and is identical in both cases **Figure (2-b)**.

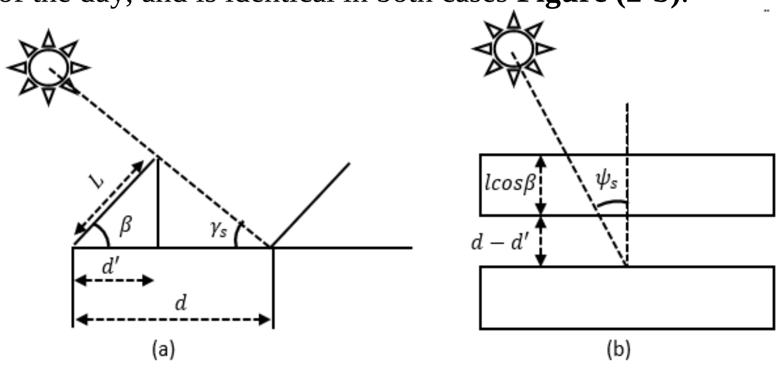


**Figure. 2: The distance between the panel array**

The distance between the panels can be calculated according to the relationship [10]:

$$d = l\cos\beta + \frac{l\sin\beta}{\tan\gamma_s}\cos(180$$

Where:

$l$: Length of solar panel [m]

$\gamma_s$: angle of inclination of the sun in Tartous, $\gamma_s$=(26)° and angle $\psi_s$ =(140)° [1].

It is possible to calculate the area covered by the panels from the roof of the building according to the relationship:

$$A_{PV}$$

where:

$L_P$: Length of the panels connected to the parallel [m].

$L_S$: Length of the connected panels on the series [m].

## 4. Calculating the cost of electrical energy:

The percentage of the saved electrical power was calculated due to the cost of the General Electricity Company in Syria at 0.4 kW is 33.5 S.P, for example :If there were an elevator Capacity (4 kw) working 13 hours a day (8 hours at morning and 5 hours at night) Hours basis, it would depend on solar panels during the day so the savings rate within a month is calculated as follows:

Monthly daylight fee = consumption rate during daylight hours $* 33.5 * 30$

$$= 4 * 8 * 33.5 * 30 = 32160\ s.p$$

Daily fee of a month= daily fee consumption rate $* 33.5 * 30$

$$= 13 * 4 * 33.5 * 30 = 52260\ s.p$$

$$\text{The cost rate} = \frac{\text{Monthly daylight fee}}{\text{Daily fee of a month}} * 100 = \frac{32160}{52260} * 100 = 61.53\ \%$$ [2]

## 5. Results:

MATLAB Graphical User Interface (GUI) is used to write a program to calculate system parameters through the relationships mentioned [1-23] that gives all the design requirements taking into account the above mentioned design rules such as specifying:

1- Transport capacity required.
2- Elevator speed.
3- Load capacity.
4- Engine capacity.
5- Number of solar panels.
6- Number of batteries.
7- Number of chargers.
8- installation area.

[1] https://www.esrl.noaa.gov/gmd/grad/solcalc/
[2] http://www.dec.gov.sy/

# 6. The validation:

## 6.1. The first application:

Used the proposed system to design an independent photovoltaic system to feed an 8-storey residential elevator according to the algorithm shown in **Figure (3)**, and the technical specifications used are shown in **Table (7).**

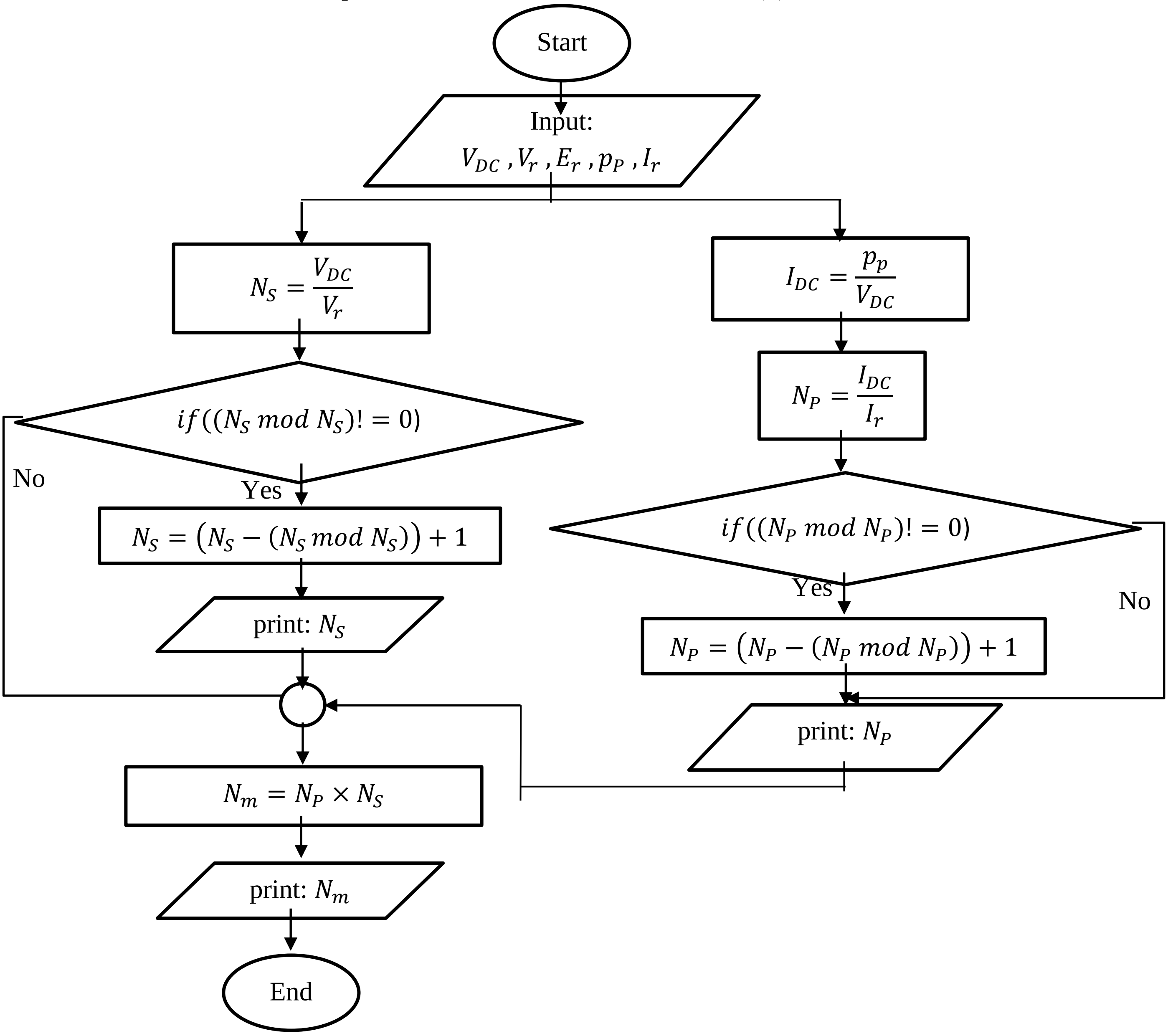


**Figure. 3: The algorithm used to calculate the number of panels required for system design.**

**Table (7): Technical Specifications of System Components for Feeding Residential Elevator**

| | |
|---|---|
| Selected panel type | Duracomm dcs-6p-72-305 |
| Maximum current at the maximum power point | 8.27 A |
| Maximum voltage at the maximum power point | 36.85 V |
| Maximum power | 304.7495 W |
| Open circuit voltage | 44.96 V |
| Short circuit current | 8.66 A |
| Width | 0.99 m |
| Length | 1.96 m |
| Continuous system effort | $V_{DC}$ =48 V |
| Minimum Solar Radiation | T_min =4h |
| Battery type | Deka 8G8D LTP Gel |
| Battery size | 300 Ah |
| Self-feeding days | 3 days |
| Output current charging regulator | 50 A |
| Floor height | 3.3 |
| Building area | 925 $m^2$ |

**The program was running and we obtained the results shown in Figure (4).**

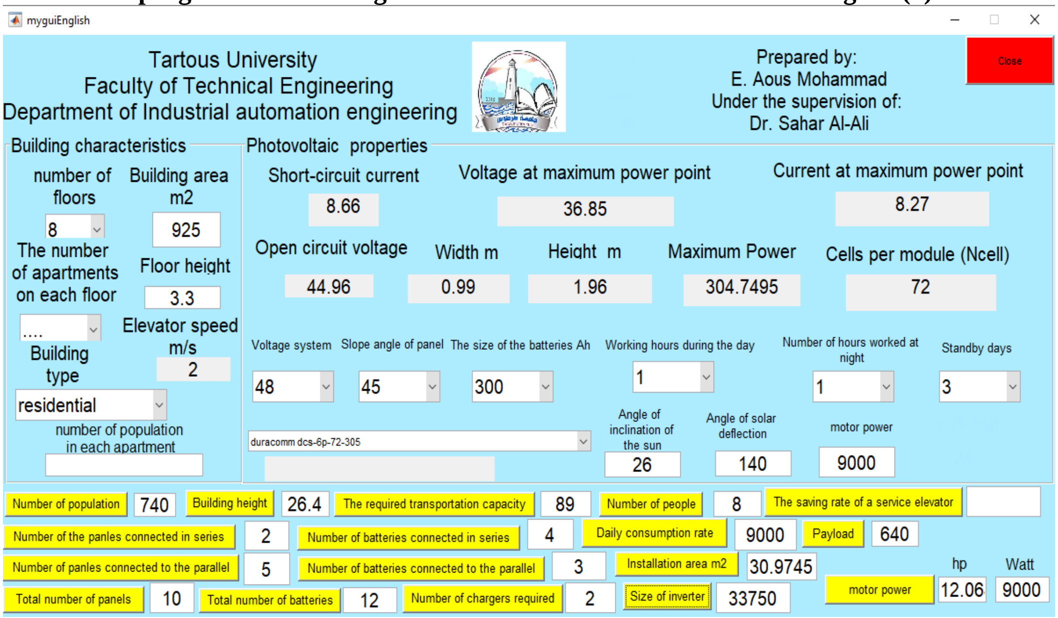


**Figure 4: Interface testing of photovoltaic system residential elevator.**

## 6.2. The second application:

The proposed system used to design a photovoltaic system to feed a service elevator (hospital). The technical specifications used are shown in the **table (8).**

**Table (8): Technical Specifications of System Components for Feeding a Service Elevator (Hospital).**

| | |
|---|---|
| Selected panel type | Duracomm dcs-6p-72-305 |
| Maximum current at the maximum power point | 8.27 A |
| Maximum voltage at the maximum power point | 36.85 V |
| Maximum power | 304.7495 W |
| Open circuit voltage | 44.96 V |
| Short circuit current | 8.66 A |
| Width | 0.99 m |
| Length | 1.96 m |
| Continuous system effort | VDC =48 V |
| Minimum Solar Radiation | T_min =4h |
| Battery type | Deka 8G8D LTP Gel |
| Battery size | 300 Ah |
| Self-feeding days | 3days |
| Output current charging regulator | 50 A |
| Floor height | 3.3 |
| Building area | 925 m2 |

The program was running and we obtained the results shown in **Figure (5).**

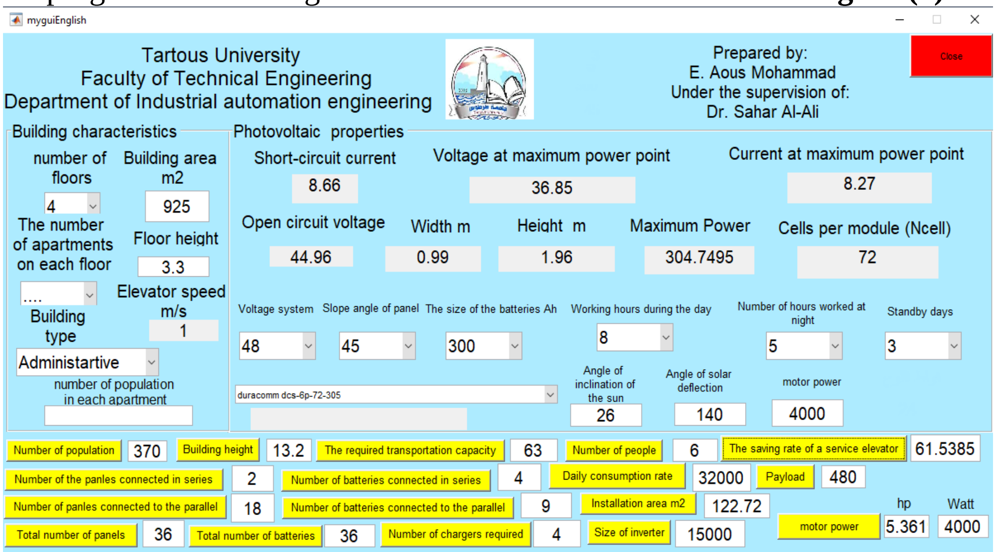


**Figure. 5:Interface testing to a PV system of hospital elevator.**

## 7. Conclusion:

1- Proposel system can be applied to any solar energy application.

2- Energy saving is nearly 61.53%

3- The designed interface enables researchers to simply calculate the PV system parameters by immediate processing of the site input.

## 8. Recommendation:

1- It is recommended that the proposed design be applied in practice in residential communities and government installations.

2- The design of the system can be generalized because the program is easily adjustable according to the requirements of applications such as (agricultural pumps - fruit drying device - home heating).

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