OPTIMAL DESIGN OF A HCPV SYSTEM TOPOLOGY: CASE STUDY OF CARREFOUR MARKET IN TUNISIA

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Integration of green energy technology in our electrical grid offers considerable payback for the environment and the sustainable development. Photovoltaic energy is extremely the amplest in the studied location. This manuscript deals with designing of a HCPV System for supplying the energy demand of a Carrefour Market at Gabes-Tunisia. The whole HCPV System (HCPV plant, DC-DC converters, batteries, bidirectional DC-DC converters and DC-AC inverters) was designed with appropriate and optimal system topology. This work was based on real load flow profile information with about 10.2 mega Wh/day daily energy required and faithful corresponding location (Latitude: 33.879, Longitude: 10.103) meteorological information (the annual global solar radiation is about 5.13 kWh/m²/d). Via a methodical approach and based on the relativity philosophy of day and night in PV system, the results show that only 803 HCPV multi-junctions solar cells modules are considered necessary for supplying the required energy of the OPE. Considering backup technique in HCPV System and linked to available components from manufacturers, string inverters topology with common DC bus was chosen.

Keywords: Battery, DC-DC Converter, DC-AC Inverter, Design, Energy, HCPV, Photovoltaic, PV System, Topology

Nomenclature

SVPWM: Space Vector Pulse With Modulation
OPE: Opened to Public Establishment
LFBM: Load Flow Balancing Method
PGF: Panel Generation Factor
STC: Standard Test Conditions
DOD: Depth of Discharge
DC: Direct Current
AC: Alternative Current
MPP: Maximum Power Point
HCPV: High Concentration Photovoltaic
FF: Fill Factor

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1. Introduction

Tunisia was never ranked among countries based on conventional resources. Budget section reserved for energy sector is significantly important. However, global irradiation and solar resources are the main green energy available in Tunisia with minimum average daily sum of direct normal irradiation 1800 kWh/m²/year [1]. Furthermore, PV panel price decreased from 10 US $/Wp in 1982 to 0.5$/Wp in 2016 [2]. On the other hand, Opened to Public Establishments OPE (hostel, hospital, supermarket …) start to be a big electrical load [3-4] which is due to the increasing uses of lighting, cooling and heating systems. That's why the primary energy demand is greater than the primary energy resources from 2011 to 2014 in Tunisia [5]. The National Agency for Energy Management of Tunisia (ANME) announces that the additional installed PV capabilities between 2016 and 2018 are 246 units (low voltage connection: 75 units, medium voltage connection: 88 units, high voltage connection: 70 units and 13 units for the national electricity company). A simple analysis of these numbers shows that each governorate of Tunisia has installed only one low voltage connected to grid photovoltaic unit during one year from 2016 to 2018. This number is very negligible compared to the solar field in Tunisia on one hand and developed countries such as USA [6] on the other hand. For these raisons, this paper aims to design a HCPV System for supplying energy to a Carrefour Market situated in the south of Tunisia. Nowadays, HCPV multi-junction solar cell technology is the most efficient in market (Spectrolab 41.6%) [7-8]. Objective of this work is to design the HCPV system intended to supply the Carrefour Market with electricity provided from HCPV multi-junction solar cell panels as shown in Fig 1.

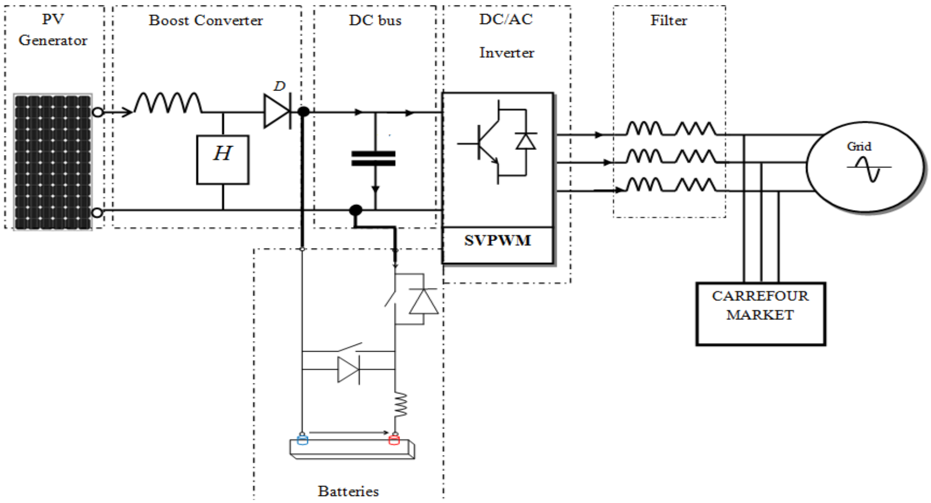

Fig. 1.The main objective of the manuscript

The manuscript started by Carrefour Market modeling method based on collecting all information's about each small or big electric load part of this commercial building. Exact metrological information's for corresponding location (Latitude: 33.879, Longitude: 10.103) are a key step for properly design a HCPV System. Steps for design all system components (HCPV plant, DC-DC converters, batteries, bidirectional DC-DC converters and DC-AC inverters) are described suitably with consideration of real technical specifications from manufacturer of all components. Finally, it was contributed that the best corresponding topology for the studied system is string inverters topology [9].

2. HCPV System Design Methodology

The finest grid connected HCPV system must be designed as standalone HCPV System firstly to maintain its autonomy. It is composed of a HCPV generator, storage batteries, DC-DC converters, charge controllers (bidirectional DC-DC converters), DC-AC inverters and AC and/or DC loads as illustrated in Fig. 1. A HCPV generator is usually consisted of a HCPV array that is composed of a number of string in parallel connected, in each string are joined in series many HCPV modules, while each HCPV module is composed of a number of multi-junction solar cells [10]. To supply nonstop electrical power to the Carrefour Market, the use of energy storages batteries in HCPV systems is usually adopted [11]. When the power produced by the HCPV generator exceeds the required energy, batteries stores energy and discharges it in the case of lacking solar production. The loads demand for the studied case is a commercial building (Carrefour Market) and it is composed by one-phase and three-phase AC loads. In order to conditioning power between components of HCPV System, it will be used different interfaces:

- DC-DC Boost converters: located between HCPV panels and DC bus for maximum power extracting via appropriate algorithm [12].
- Bidirectional DC-DC converters: situated between batteries and DC bus, these interfaces are used for controlling the charge/discharge batteries through energy management algorithm [13].
- DC-AC inverters: utility of these components is to connect the DC bus to the AC bus (AC load or grid) by means of synchronization algorithm [14-15].

a. Input data for Load profile

The influence study of the load flow variation on the HCPV system optimal configuration is the main criteria to carry out an optimal design. In literature, some researchers focus their interest in this step by considering variation of load demand during 24 hours [16-17]. However, others researches used to optimize operation strategies of the system without searching data and information about the load [18-19] or within a novel techniques such as energy pay-back analysis [20]. The method used in this research paper is to gather the maximum number of information about load (CARREFOUR MARKET). For this, the purpose of our manner is to get all specifications for each component of the OPE like power, voltage, night appliance use, day appliance use. All information contained in the table A (annex) are a real values provided from building owner. In order to arrange an optimal renewable energy source design, the step described in the table A is required. With the aim to simulate on Matlab/Simulink the total electrical loads of the OPE studied, we must proceed conforming to the method LFBM by considering the load flow during 24 hours [21]. Other aspects of unbalanced building with integration of photovoltaic systems were studied [22]. Bases of the method mentioned in the last paragraph are in the figure 2.

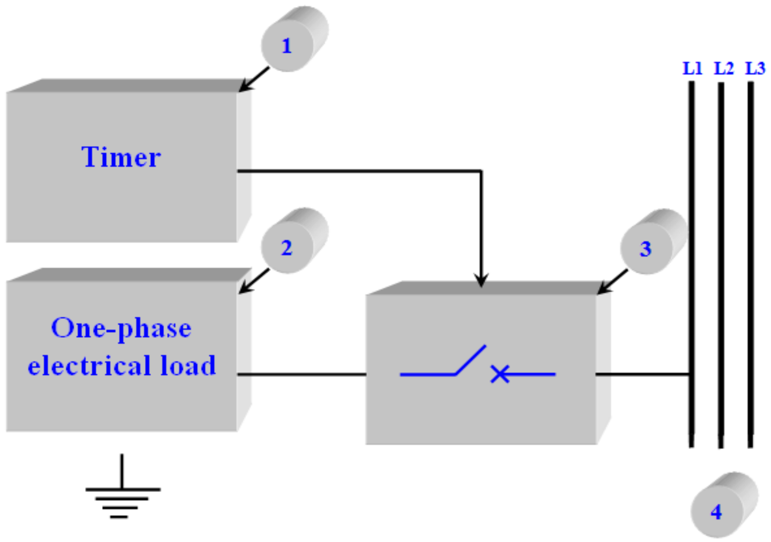

Fig. 2. Modeling method used in Matlab/Simulink

In this figure, every component present:

- 1: timer: its role is to define exactly the moment of switching on/off off the breaker witch replace the appliance use.
- 2: one-phase electrical load: it presents characteristics of each Carrefour Market electrical component.
- 3: breaker: it replaces the real breaker used to command and protect this electrical load.
- 4: 0.4 KV distribution smart-grids.

All Carrefour Market electrical loads are modeled like the same method illustrated in the previous figure. Fig 3 and Fig 4 show respectively evolution of Carrefour Market three-phase currents during a summer typical day.

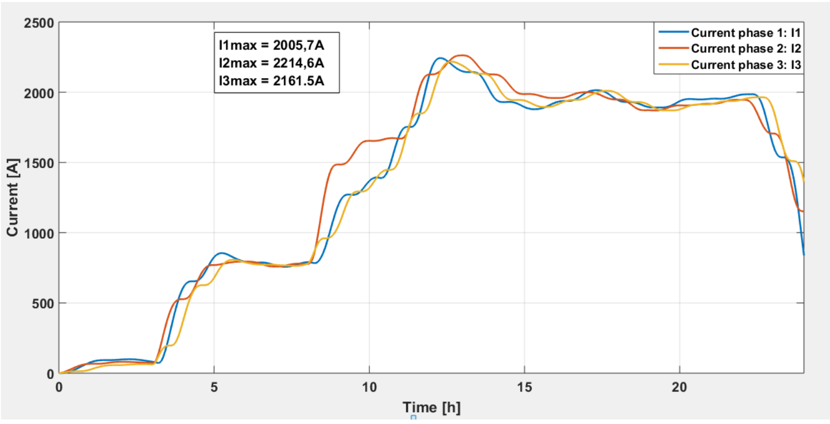

Fig. 3. Currents evolution during summer typical day

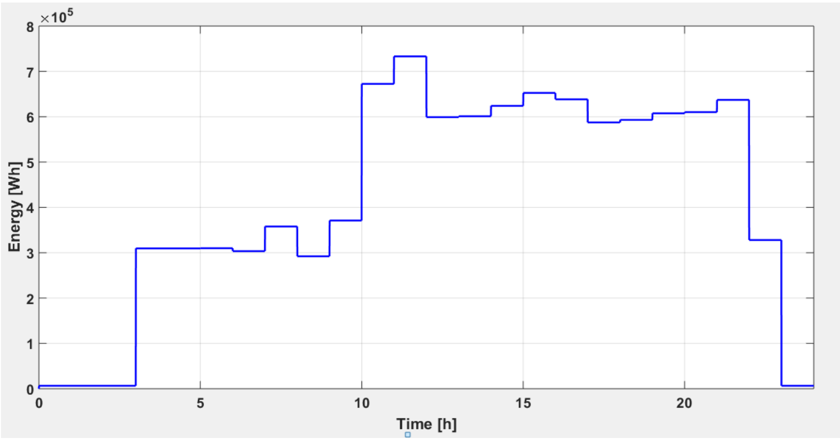

Fig. 4. Required energy evolution during summer typical day

Simulation and load parameters are taken for a typical summer day because of the load peak is the higher in the summer [23]. It's clear according to figure 3 and 4 that energy demand from the commercial building is focused between 7 am to 8 pm so distributed between day and night. For this, we estimate that storage system will be considerable with big capacity adding to the size of HCPV generator aimed to supply this energy demand. Solar field is the main resource to provide the energy needed. It's related to the site location and description considering quantity of annual global solar radiation. The next paragraph is reserved to describe the site location of Carrefour Market. This step will be realized basing on exact coordinates (longitude, latitude) of the location.

b. Site description: Annual global solar radiation

In order to pre-size a HCPV system, we need the value of the annual global solar radiation [24]. In our case, the site is located in Gabes-Tunisia with Latitude of 33.879 and Longitude of 10.103. Figure 5 describes satellite view and the sun path at the commercial building studied on 21 December which is the year shortest day.

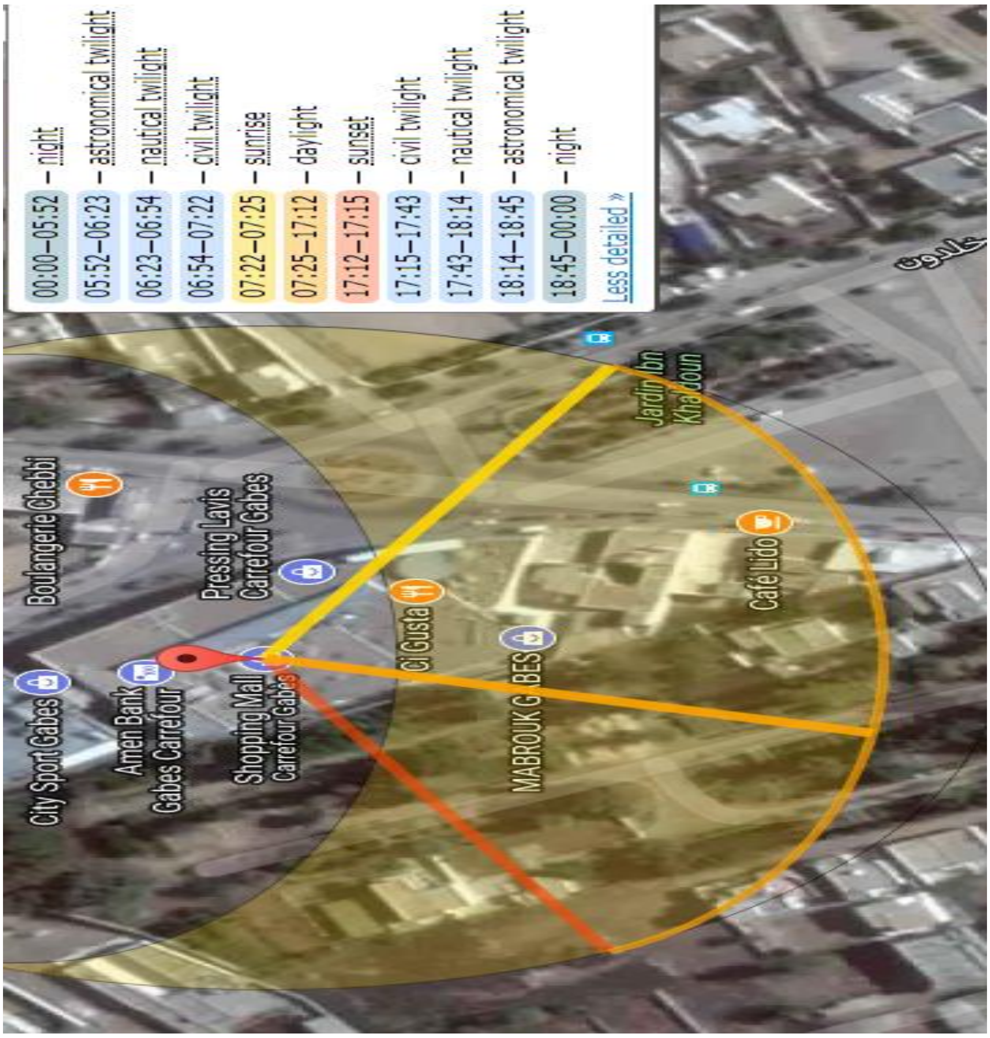

Fig. 5. Satellite view and sun path at Carrefour Market on December 21

The daylight started from 7:25 to 17:12. That means beyond these time there will not be daylight so HCPV panels will not produce electricity. For those site parameters, the average annual global solar radiation is about 5.13kWh/m²/d (NASA surface meteorology and solar energy). Figure 6 shows evolution of global horizontal irradiation during one year in Gabes- Tunisia.

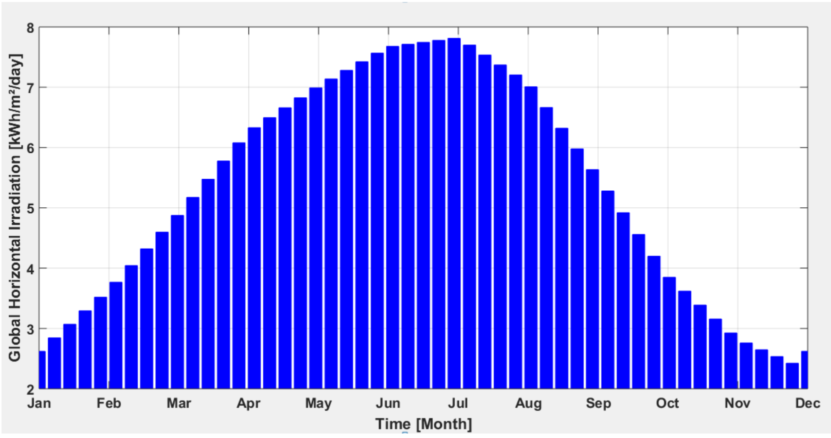

Fig. 6. Solar Energy available in Gabes – Tunisia

Using the annual global solar radiation, we can calculate the PGF (Panel Generation Factor) [25] which is necessary for determining the energy demand of the OPE.

$$PGF = \frac{\text{Average Annual Global Solar Radiation}}{\text{Standard Test Conditions Irradiance for PVpanels}} \tag{1}$$

Standard Test Conditions Irradiance for HCPV panels is 1000W/m². In our site, PGF is equal to 5.13.

c. Energy demand by the CARREFOUR MARKET

After finding the primordial parameter PGF, the next specification is the energy demand by the OPE (the CARREFOUR MARKET), it is necessary to know how many electrical loads will be included in the system and different parameters for each load (electrical power, number of hours per day...). In the case of CARREFOUR MARKET, every electrical loads and their approximate daily and annual energy consumption are listed in table 1. The basic formula for energy calculation is:

$$E = P * t \tag{2}$$

Where:

- E: energy [Wh],
- P: power [W],
- t: time [h],

In the case of n electrical loads, the total energy required from n load Et is:

$$E_t = \sum_{i=1}^{n} P_i * t_i \tag{3}$$

Where:

- Pi: load number "i" power,
- t_i: time uses for load number "i".

According to the table 1, Carrefour Market energy demand E_d is 10136.4kWh/day. Using this parameter (energy demand), we can proceed to find out the total energy required from the HCPV plant.

d. Energy required from the HCPV plant

Energy required from HCPV plant must be greater than the daily energy demand of the CARREFOUR MARKET in order to compensate for system losses. System losses in HCPV system C_f are generally taken as 30% [25]. Considering the system losses, we can calculate the energy required from the HCPV plant E_r as following:

$$E_r = E_d * C_f \tag{4}$$

In this study, the energy required from the PV plant is:

E_r= 10136.4*1.3 = 13177.32 kWh/d.

e. Number of HCPV module required

Each kind of PV panels is specified by the kWp or "rated" amount of power the solar panel will produce. So the watt peak Wp power of a HCPV plant is the higher power that can be produced under ideal conditions (STC: G=1000 W/m², T=25°C).

$$W_p = \frac{E_r}{PGF} \quad (5)$$

In the case of CARREFOUR MARKET:
Watt Peak of PV Plant=13177.32/5.13=2568.67 kW_p
A HCPV multi-junctions solar cells panel was identified for this PV plant because of its high efficiency and value of watt peak power. The full specifications of the selected module ADAM (3C30M) can be found in the Table 1.

Table 1:

ADAM 3C30M HCPV module technical specifications

I_{sc} [A]	V_{oc} [V]	I_{MPP} [A]	V_{MPP} [V]	P_{MPP} [kW_{MPP}]	FF [%]	η [%]	Module size [cm]
53	76	50	64	3.2	79.5	32.0	17.8*12.7

According to information in the previous table, using the PMPP, we can define the total number of modules required for the proposed plant. The total number of module required Nm is equal to the Watt Peak of HCPV Plant Wp divided by the power on maximum power point PMPP of the HCPV module.

$$N_m = \frac{W_p}{P_{MPP}} \quad (6)$$

The application of this equation to the studied system gives 803 modules.
For special situation like shading mode or partial failure of PV panel, we expect an extra number (30%) of PV panels to provide reserve energy. The new number of PV panel is:

$$N_{t,m} = 1.3 * N_m \quad (7)$$

The total number of PV panels is 1044.
In this study, all meteorological information's are token for 2 axes tracker system so all HCPV modules will be mounted in the cited tracking system. The tracker unit is composed by 2*2 arrays of ADAM (3C30M) modules. Every array contains 261 modules, so the entire system includes 261*4 = 1044 panels. Fig 7 describes the tracking system and it's configuration that will be used.

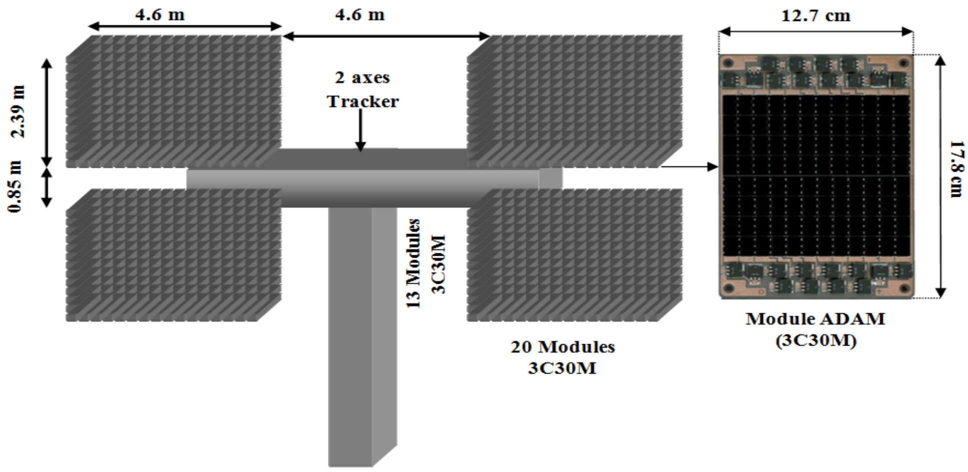

Fig. 7. Tracking system for HCPV generator

When we look at the previous figure, the total area A_{PV} needed to install our HCPV plant is:

A_{PV} = 4.6*3*(2.39*2+0.85) = 78 m².

The real Watt Peak of HCPV Plant P_{PVmax} according to the configuration of 2 axes tracker will be: P_{PVmax} = 1044*3.2 = 3340.8 kWp.

This paragraph was reserved to establish the total number of HCPV panels needed to supply electricity for Carrefour Market. However, at night and after sunset, our HCPV plant don't produce electricity, that's why the next paragraph will describe the storage system aimed to supply electricity for our OPE in the nocturnal consumption.

f. Storage system sizing

To design a power plant aimed to supply energy for an OPE; we need always integration of a storage medium. Our site is located in Gabes – Tunisia where the cloud days are insignificant. So, the principal role for the batteries is to store sufficient energy to operate the appliances at night. The philosophy of day and night in HCPV system is related to relativity. Every day in the year has its own sunrise and sunset, so its own day and night. When we have sun, we have production of electricity, however from the sunset we are in the night and we need a backup source of electricity (batteries). As long as we know the load flow variation of the CARREFOUR MARKET during 24 hours and to design an optimal storage system, we must raise the evolution of the irradiation during the shortest day of the year (21 December). According to the progression of the irradiation during the shortest day in the year described in Fig 8, we remark that we have 9 hours of day with sun (from 7h to 16h) and 15 hours of night without sun (from 16h to 7h).

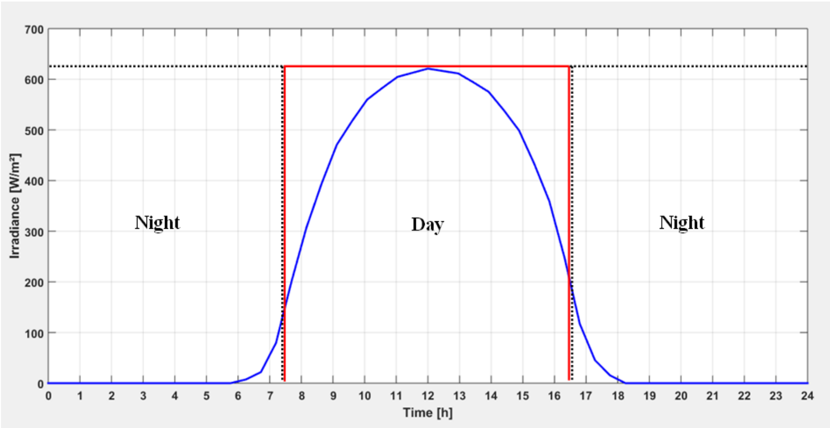

Fig. 8. Irradiation evolution during 21 December

Regarding the table A, the energy required from battery as backup for CARREFOUR MARKET in the night consumption is:
Energy required from battery = Night Energy demand = 5241.06 kWh/d.

Of manufacturers' batteries available, we select Lithium Ion batteries for several raisons. In low temperatures, the capacity of lead acid battery is 40-60% of its overall potential however this fall is only 10% for Lithium-Ion battery [26-27]. Lithium-ion solar batteries cycle life is longer than that of lead acid batteries [28]. The recycling process of lead acid battery is more frequently than the other one [29-30]. Finally, Lithium-Ion batteries are smaller than lead acid batteries. The battery capacity required is related to the next parameters:

- Daily energy demand (Eb),
- Nominal battery voltage (Vb)
- Daily and maximum depth of discharge (DOD),
- Number of days of autonomy (Nd),
- Battery efficiency (ηb).

The OPE needs one day of autonomy. Table 2 presents the technical specifications of battery (SMART BATTERY Technology) used in our study to design the storage system.

Table 2:

Battery technical specifications

Type	Technology	Nominal capacity	Nominal voltage	Battery Efficiency	DOD max
Battery (SMART BATTERY)	Lithium Iron Phosphate (LiFePO4)	100 Ah	12.8 V	90%	80%

The equation used to find the battery capacity required C_b is:

$$C_b = \frac{E_b * N_d}{V_b * DOD * \eta_b} \quad (8)$$

The battery capacity required for Carrefour Market is 568691.4 Ah.
Relation between battery capacity required, nominal battery capacity C_n and number of batteries N_b is:

$$N_b = \frac{C_b}{C_n} \quad (9)$$

To provide electricity to the commercial building in the nocturnal energy demand, we need to install 5687 batteries.

g. Inverter sizing

The DC/AC inverter is used whether in grid connected or standalone photovoltaic systems as the interface between the PV plant and the electric grid or the load. The maximum input power to the inverter P_{INmax} is equal to the real Watt Peak of PV Plant: $P_{INmax} = P_{PVmax} = 3340.8$ kW_p.

In our case, appliances types are motors, compressors, pumps; so inverter size should be biggest than the maximum input power to surge current during starting. Using electronic starting system, these starts peaks will be reduced. So we can consider that the inverter size P_{Inv} is only 30% bigger than P_{INmax}.
$P_{Inv} = P_{INmax} * 1.3 = 3340.8*1.3 = 4343$ kW.
As long as we are in the process of preparing a real design for HCPV System, we have to select a DC-AC inverter from different manufacturers. Our choice is described in table 3.

Table 3:
Central inverter technical specifications

Central Inverter: ABB PVS800-57B-1732kW-C			
Input DC			
Maximum input power $P_{PV,max}$	DC voltage range $U_{DC,mpp}$	Maximum DC voltage $U_{DC,max}$	Maximum DC current $I_{DC,max}$
2598 kWp	580 to 850 V	1000 V	3700 A
Output AC			
Nominal power $P_{AC,n}$	Maximum output power	Nominal AC current $I_{AC,n}$	Nominal output voltage $U_{AC,n}$
1732 kW	2078 kW	2500 A	400 V

According to the nominal power of the inverter selected in the previous table, the total number of inverters required N_{Inv} depends to inverter size P_{Inv} and nominal output AC power of the selected inverter:

$$N_{Inv} = \frac{P_{Inv}}{P_{AC,n}} \qquad (10)$$

In the HCPV system topology expected to provide electricity for Carrefour Market, the number of DC-AC inverters is 3.

h. PV Systems topology

The HCPV associated system, the uncomplicated system including a big number of components, can be configured by the appropriate architecture and topology. These configurations can be classified into central converter topology and string converter topology. For the large HCPV plant system, the central inverter topology is the simplest one [31-32]. However, in the central inverter topology, only one inverter is installed, in case of failure of this latter and without a backup inverter, there will be a break in the system operation. For this, in our study we selected two inverters for the string topology or modular configuration system [33]. Even if one of the inverters is defective, the installation doesn't break up. After choosing the appropriate HCPV system topology, it's necessary to design the PV plant. The first step in system topology designing is to find the size of the array: the number of modules to be connected in series N_s. This number depends on the inverter maximum DC voltage $U_{DC, max}$, DC voltage at MPP min of the inverter $U_{DC,mppmin}$, DC voltage at MPP max of the inverter $U_{DC, mppmax}$ and V_{oc} of the module used.

$$\begin{cases} N_s < \dfrac{(1\text{-}\alpha)*U_{DC,max}}{V_{oc}} \\ \dfrac{(1\text{-}\alpha)\,U_{DC,mppmin}}{V_{mpp}} < N_s < \dfrac{(1\text{-}\alpha)*U_{DC,mppmax}}{V_{mpp}} \end{cases} \qquad (11)$$

$$\begin{cases} N_s < \dfrac{1000*0.5}{76} \\ \dfrac{580*0.5}{64} < N_s < \dfrac{850*0.5}{64} \end{cases} \Rightarrow \begin{cases} N_s < 6.6 \\ 4.5 < N_s < 6.6 \end{cases}$$

In the last equation α is the duty cycle of the DC-DC converter. We will choose 5 modules connected in series. In literature, a comparative study of the different PV array configuration types was proposed [34] in order to reduce losses caused by shading effects of PV arrays and faulty PV conditions [35]. It was approved that series strings configuration is the best one regarding indicators of comparative study (I_{sc}, I_{mpp}, V_{oc}, V_{mpp}, R_s, FF and V_{te}). However, this configuration is costly than series parallels strings configuration. For example, our load needs 1044 HCPV panels, the maximum number of modules per string is 6, so we will need about 174 DC-DC converters. That's why we will choose this combined configuration between serial and parallel strings in order to reduce the number of DC-DC converters and cost. As it was already mentioned, every string will be composed by 5 PV modules connected in series. Our choice is to connect each 27 strings to a DC-DC converter. Series and parallel connections of batteries are an important aspect of storage system design and operation. It doesn't have a big difference in the process of charging and discharging for different connections types [36]. Searching to boost the capacity of a battery [37], it's necessary to connect battery cells in parallel. This is the one reason for which we select to this kind of connections. As long as the DC bus voltage of our system is 704 V and the battery voltage is 12.8 V, we need 55 batteries connected in series to achieve the DC bus level. Following the backup technique and due to the number of batteries (5687), instead of connecting the whole number of batteries to one bidirectional DC-DC converter, we decided to choose two converters. Fig 9 is a recap of this work.

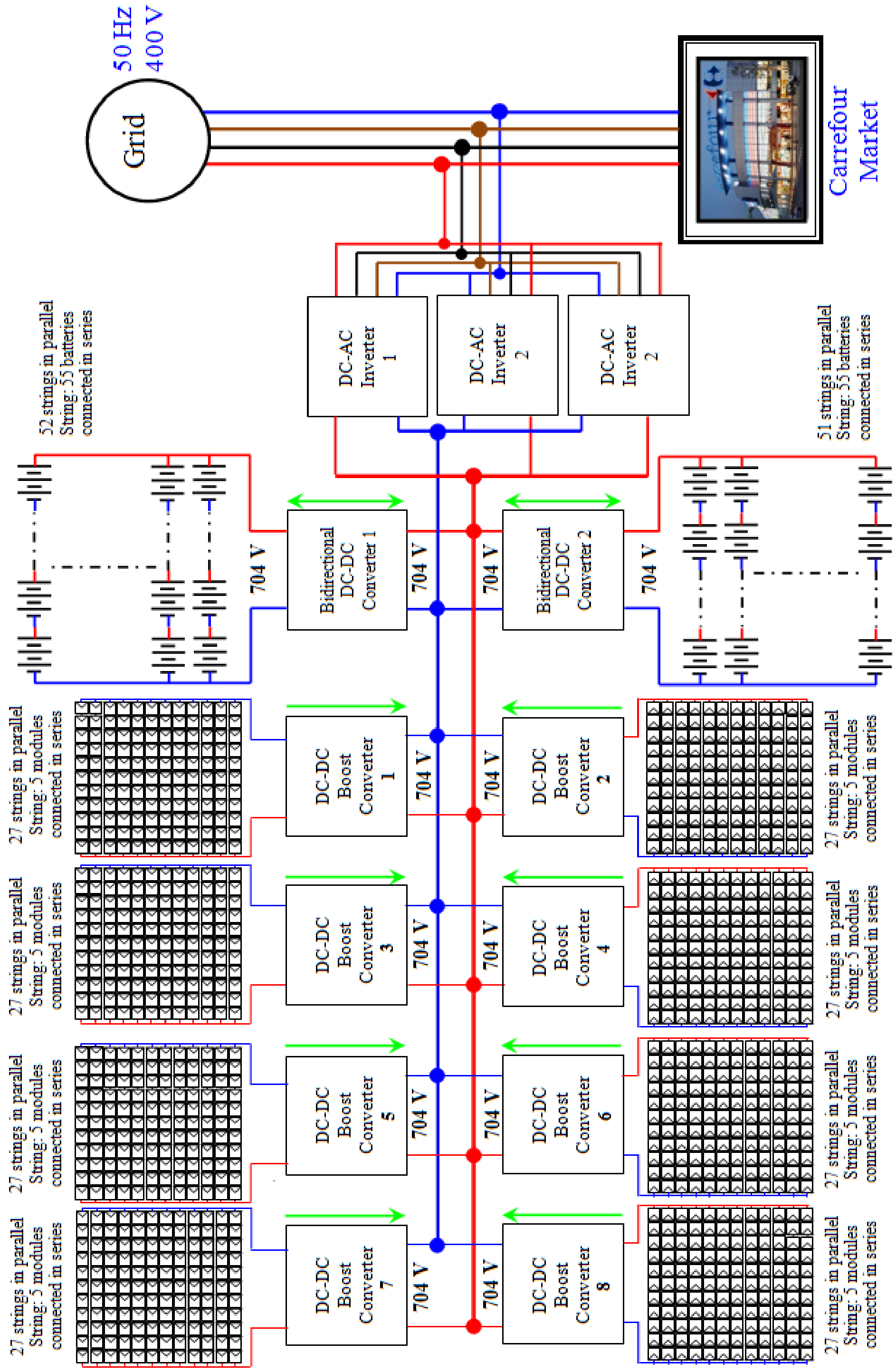

Fig. 9. HCPV System topology

3. Cost and energy payback of grid connected PV system

The cost-benefit analysis in this project was based on System Advisor Model (SAM) from National Renewable Energy Laboratory (NREL). The version of the software used is SAM 2017.9.5. Results of our financial and cost studies of grid integration PV system varies from location to location with dependence on many parameters such as energy price, materials lifetime, generation portfolio, etc.

Financial and payback analysis of the project studied in this paper are described in the table 4.

Table 4:

Cost-benefit description of grid connected PV system

Metric	Value
Net capital cost	$12,357,339
Electricity bill without system (year 1)	$396,780
Electricity bill with system (year 1)	$-1,013,444
Net savings with system (year 1)	$1,489,580
Payback period	6.9 years
Discounted payback period	10.5 years

A description of the cumulative discounted payback period, the cumulative payback with expenses period and the cumulative payback without expenses period are described in the figure 10.

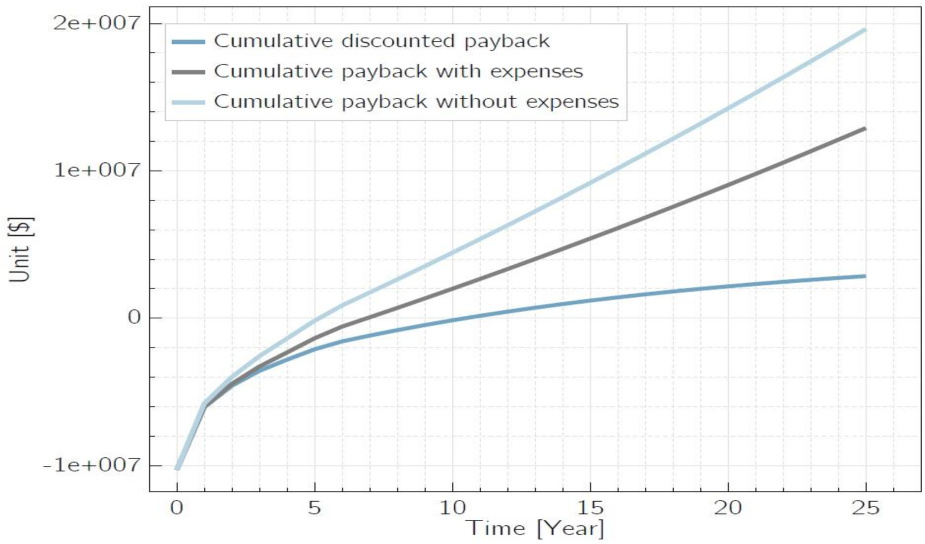

Fig. 10. Payback description of grid connected PV system

4. Conclusions

This manuscript has studied a HCPV system topology for electricity supplying to Carrefour Market in Gabes-Tunisia and examines different steps of dimensioning with real characteristics of load, products from manufacturer and exact meteorological information's. The findings of the presented study are concluded as:

- The 3340 kWp system designed for the Carrefour Market requires 1044 HCPV modules of 3.2 kWp with an array containing 5 modules each,
- The whole plant requires an area of only 78 m^2 and this thanks to use of HCPV panel technology,
- To ensure an optimal operation in the MPP (with optimization algorithm), we used to install 8 DC-DC boost converters of 432 kWp for each,
- To guarantee the supply of electricity to the Carrefour Market at night demand, it was designed a storage system of 568691.4 Ah,
- In order to manage energy flow from and to DC bus, 2 bidirectional DC-DC converters are dimensioned,
- To provide an AC power to the commercial building, 3 central DC-AC inverters are designed with 1732kW for each one.

In this study, the backup theory was used in selection of inverter topology and bidirectional DC-DC converters. In conclusion, according to this study, string-inverters topology with common DC bus is the best topology for operation continuity. As a perspective of this work, the HCPV System topology designed will be modeled and simulated in Matlab/Simulink. The improvement of power quality for PV generator interfaced with the grid utility can be established [38].

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ANNEX

Table A:

Carrefour Market Electrical Parameters

Equipment	P [kW]	Daily appliances use [h]	Night appliances use [h]	24 hours energy required [kWh/d]	Night energy required [kWh/d]
Sales area lighting	42	14 [8:22]	6 [16:22]	588	252
Traffic lights	2.5	8 [8:10+12:14+16:18+20:22]	4 [16:18+20:22]	20	10
Exterior lighting	6.1	12 [18:06]	12 [18:06]	73.2	73.2
Stand-alone emergency lighting unit	0.4	14 [05:19]	5 [05:07+16:19]	5.6	2
Checkout	6	14 [08:22]	6 [16:22]	84	36
Single-phase power outlet 1	4.6	3 [8:10+15:16]	0	13.8	0
Single-phase power outlet 2	21	3 [11:13+16:17]	1 [16:17]	63	21
Curtain door	6	4 [8:9+11:12+13:14+21:22]	1 [21:22]	24	6
Extractor	5.55	8 [10:14+18:22]	4 [18:22]	44.4	22.2
Smoke extraction unit	17.6	1 [11:12]	0	17.6	0
Air-conditioners	171.76	14 [08:22]	6 [16:22]	2404.64	1030.56
Pump 1	11	6 [09:13+19:21]	2 [19:21]	66	22
Pump 2	4	6 [09:13+19:21]	2 [19:21]	24	8
Hose station pump	4	1 [11:12]	0	4	0
Air Handling Unit MAIL	11	16 [07:23]	7 [16:23]	176	77
Air Handling Unit FOOD COURT	7.5	16 [07:23]	7 [16:23]	120	52.5
Refrigerator group 1	49.6	18 [03:8+10:23]	11 [03:7+16:23]	892.8	545.6
Refrigerator group 2	49.6	18 [03:8+10:23]	11 [03:7+16:23]	892.8	545.6
Elevator 1	12	5 [07:09+11:12+13:14+21:22]	1 [21:22]	60	12
Elevator 2	12	5 [07:09+11:12+13:14+21:22]	1 [21:22]	60	12
Escalator	15	11 [09:12+14:22]	6 [16:22]	165	90
Service access elevator	12	5 [07:09+11:12+13:14+21:22]	1 [21:22]	60	12
Sales area hoist	24	3 [09:11+15:16]	0	72	0
Travelator 1	11.7	11 [09:12+14:22]	6 [16:22]	128.7	70.2
Travelator 2	11.7	11 [09:12+14:22]	6 [16:22]	128.7	70.2
Positive cold group	120	18 [03:08+10:23]	11 [03:07+16:23]	2160	1320
Negative cold group	80	18 [03:08+10:23]	11 [03:07+16:23]	1440	880
Three-phase power outlet 1	6.92	3 [09:11+15:16]	0	20.76	0
Three-phase power outlet 2	4	3 [10:12+16:17]	1 [16:17]	12	4
Three-phase power outlet 3	4	3 [08:10+14:15]	0	12	0
Three-phase power outlet 4	4	3 [11:13+17:18]	1 [17:18]	12	4
Lift pump	8.2	7 [09:16]	0	57.4	0
Cold laboratory room	3	18 [03:08+10:23]	11 [03:07+16:23]	54	33
Oven 10 plates	19	6 [09:12+14:17]	1 [16:17]	114	19
Oven 5 plates	11	6 [09:12+14:17]	1 [16:17]	66	11
	Total [kWh/d]:			**10136.4**	**5241.06**