Optimization of Photovoltaic Solar Electric Power for Renewable Energy Generation and DSM Strategies in Singular Apartment Buildings

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Abstract. This work presents a procedure of optimization (algorithms) for the supervision, control, and management of photovoltaic solar electric power (PVSEP) in singular buildings dedicated mainly to apartments.

The basic principles of performance are kept within two big guidelines denominated Renewable Energy Generation (REG) and Demand Side Management (DSM).

From the point of view of GER it is assumed that the more electric power is generated -and therefore sent to the electric net- the more income will be obtained. On the other hand, distribution electric nets recently are having problems of apparent impossibility to attend to the demand peaks. For these reasons, from the energetic efficiency point of view it is very interesting to develop a system able to reduce the demand peaks of the buildings, that is to say, to use DSM techniques.

Some procedures (algorithms) useful to justify the installation of photovoltaic panels in buildings have been obtained and are presented in this paper. These procedures are expected to be the core of quality scientific production in our group, including some patented designs and utility models.

Keywords
Photovoltaic solar electric power (PVSEP), Renewable Energy Generation (REG), Demand Side Management (DSM), Optimization algorithms, Ecologic buildings.

1. Introduction

The presented system is subdivided, from the point of view of functionality, in two systems: Physical system and Logical system.

The physical system consists of an Uninterrupted Power Subsystem (UPS), type "on-line", adapted to the system, and with an appropriate dimensioning.

The photovoltaic electric power subsystem feeds the bus of continuous current of the UPS, with three continuous current wires, by means of an appropriate stage of load adaptation and regulation. On the other hand the UPS is feed of the distribution net of the electric company. The UPS feeds in a dual and controlled way the building (consumption, DSM) and/or the distribution net (generation, GER).

The logical system consists of the optimization algorithms for the supervision, control, and administration of the system.

They have been implemented in PC by means of industrial software. The PC will be located in the technical room. It will have communication by WLAN with the different subsystems, as well as with the possible inputs and/or outputs, analogical and/or digital, that have to be read/written in any area of the building. The chosen software, on which the application has been implemented, belongs to the firm SIEMENS ®. Concretely WinAC ® for controlling, and WinCC Flexible® for supervising. Routines of optimization have been implemented on both software applications.

WinAC® and WinCC Flexible® are technologically innovative products, on which novel and original code has been implemented. The application STEP7 Professional Edition ® have been used for programming WinAC ®, and the programming package SCL ® have been used to generate function blocks in pseudoPascal, according to normative EN. Algorithms of optimization have been implemented in WinCC Flexible ® by means of VBS ® in order to standardize them.

The presented logical system is characterized to be a deterministic real time system, what allows to satisfy the most demanding prospects.

2. Physic system

The physical system, as commented in the previous section, consists of:

A. Uninterrupted power subsystem.
B. Electric net power subsystem.
C. PVSEP power subsystem.
D. Building power subsystem.
E. PVSEP generation subsystem.

A. Uninterrupted Power Subsystem.

The UPS will be dimensioned depending on of the demanded power in the building, on the system of PVSEP, and on the level of performance of the DSM. There exists in the market modular UPS, with high power, by means of which it is possible obtain, without problems, 1000 KVA. These powers are enough for the field of the present article, which is singular buildings, and basically apartment buildings.

It consists of:
1) Rectifying stage.
2) Storage electric power stage.
3) Inversion stage.
4) Control stage.

1) *Rectifying stage.* It consists of a three-phase bridge of diodes that rectify from 50 Hz alternating current to direct current. This power is sent to the direct current bus.
2) *Storage electric power stage.* The electric power, as such, can only be stored in form of direct current. For this reason the necessary energy for loading the batteries is obtained from the direct current bus.
3) *Inversion stage.* The energy sent to the building should be 50 Hz alternating current, the European standard, and then the power energy obtained fro the direct current bus must be converted.
4) *Control stage.* All the input/output parameters of the system are read/written by means of the Profibus standard protocol.

B. Electric Net Power Subsystem.

It consists of the general box of protection, undertaking and installation of connection of the building with the existing distribution net of low voltage. This net can be underground or aerial; in the late case cable clipped in the facade. If the power demanded by the building overcomes 50 KW, a transformation center should be foreseen, which must be fed by the medium voltage distribution net.

In both cases the homologated measure equipment should be provided by the distribution company in order to invoice the electric power.

C. PVSEP Power Subsystem.

The PVSEP power subsystem consists of:
5) Photovoltaic panels.
6) Electric power measuring equipment.
7) Bus adapting and control equipment.

5) *Photovoltaic panels.* They will be dimensioned according to the characteristics of the building and its location.
6) *Electric power measuring equipment.* This equipment will be provided in order to count the power produced by the photovoltaic subsystem. This is necessary in order to obey the current normative about generation of renewable photovoltaic power.
7) *Bus adapting and control equipment.* This equipment adapts the voltage and regulates the current that give to the direct current bus of the UPS.

D. Building Power Subsystem.

The Building Power Subsystem consists of the general supply line, which will feed the centralized meter or meters (counters) of the building.

E. PVSEP Generation Subsystem

The PVSEP Generation Subsystem consists of:
8) Control Equipment
9) Protection and Control Relays.
10) Generated Electric Power Measuring Equipment.

8) *Control Equipment.* This team usually works in passive way, that is to say, it just play a function of connector in "t". Nevertheless for advanced functions it can be used to regulate the generated electric power.

9) Protection and Control Relays. They are the usual relays of max. / min. – frequency / voltage / current / protection that are normalized to sell photovoltaic renewable electric power to the net

10) Generated Electric Power Measuring Equipment. The homologated measuring equipment will be provided by the distribution company in order to invoice the electric power.

3. Logical system

The logical system consists of the optimization algorithms for the supervision, control, and management of the system (software) implemented in a PC (hardware).

Therefore, the logic system consists of:
11) Software.
12) Hardware.

11) Software. Consists of two separate items: the packages and the applications. Two different package have been chosen: WinCC and WinAC_RTX. WinCC is a SCADA package and WinAC is a programmable logic controller for Windows. Both products belong to the SIMATIC series from SIEMENS, A.G.

The applications permit to develop the necessary programming code to implement the system optimization and control algorithms. Two different programming languages have been used: Visual Basic Script for the WinCC code and Pascal (SCL) for WinLC_RTX.

12) Hardware. Consists of a standard PC with a CP5613_A2 processor PCI card. This card provides the PC with PROFIBUS and ET200M distributed periphery-processing capacities. The ETM200M distributed periphery acquires the inputs and outputs digital or analogical signals related to the different subsystems described.

4. Optimization algorithms

These algorithms consist of the implemented procedures in programming code, both in VBS and SCL according to the prior description. In this paper the algorithms are procedures oriented to:
13) REG algorithms.
14) DSM algorithms.

13) REG Algorithms. They are usually oriented to maximize the production. Often they do not take into account the consumption distribution. The objective is to sell the generated electrical energy to the power supply network in order to obtain the maximum profit, because the present electrical market regulations favor this kind of energy. In this paper the following characteristic has been considered: the raw material for this type of power generation (the sun) is not controllable. Therefore, the produced energy is stored in the UPS, in order to be sold when the profit is highest.
P_GEN1 is the power generated by the photovoltaic panels.
P_GEN2 is the power generated and sent to the power supply network to be sold.
The programmed algorithms optimize P_GEN2, giving priority to the consumption peak reduction.

14) DSM algorithms. These algorithms are a new development. They aim to reduce the consumption peaks, when this is possible, in order to increase the performance of a building, and to try to decrease the problems showed by the present power supply networks. For this reason, these algorithms calculate the electric energy that is necessary to provide the building with, in order to reduce the energy consumed from the power supply network. In other words, the purpose is to find the optimal P_CON1.

P_CON2 is the variable that represents the instantaneous power consumed by the building. The optimization of P_CON1 must be done using the stored energy in the UPS. In this paper all the system is shown modeled to allow subsequent tests of different DSM adjustments. In order to test the results from the models, the following parameters can be modified:
P_BAT is the power supplied from the UPS to the inverter.
P_Base. If P_CON2 is higher to this P_Base power value, the previous power supplying will be activated.
Con, connection hysteresis adjustment.
Des, disconnection hysteresis adjustment.

Next, the different computer screens where the parameters can be adjusted are shown. Moreover, the trend graphs where the test results are displayed can also be found.

Fig.1. Screen which shows the SCADA package.

By means of this first screen, the application made for the "TORRE ONYX" building, that comprises offices and apartments, is shown. This building is closed with an outside wall of tempered colored glass. The plant building appears as a comet shape. One of the building walls is perfectly south oriented. Therefore, the building shows an important advantage for photovoltaic panels installation. Moreover, the installation on the roof of several photovoltaic panels with automatic orientation on 1 and 2 axis, will be analyzed.

On the other hand, it is already in a study phase the installation on the building of other renewal energy sources; for instance eolian and hydraulic. They will be added to the contribution of the ESFV to the UPS.
The eolian energy will complement the solar energy generation because its production period will extend also to the night. The hydraulic energy generation, in small scale, provides a controllable power supply, almost only useful for DSM techniques of consumption peaks reduction.

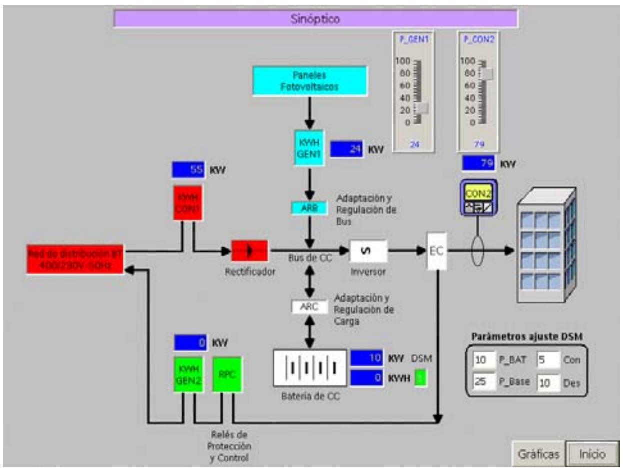
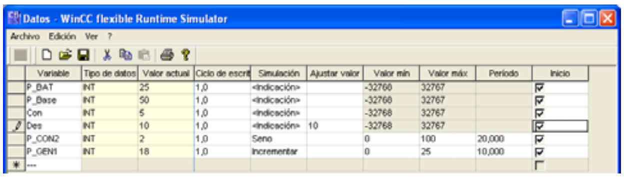


Fig. 2. Synoptic screen of the SCADA package

In this second screen, the synoptic layout of the described system is shown. The previously mentioned subsystems can be found in it. Besides, the real time values of the different controlled variables can be seen. On the other hand, the user can also find some linear manual adjustments to modify the values of the variables that will be simulated, for example P_GEN1 and P_CON2.


Datos - WinCC flexible Runtime Simulator

Variable	Tipo de datos	Valor actual	Ciclo de escrit	Simulación	Ajustar valor	Valor mín	Valor máx	Período	Inicio
P_BAT	INT	25	1,0	<Indicación>		-32768	32767		☑
P_Base	INT	50	1,0	<Indicación>		-32768	32767		☑
Con	INT	5	1,0	<Indicación>		-32768	32767		☑
Des	INT	10	1,0	<Indicación>	10	-32768	32767		☑
P_CON2	INT	2	1,0	Seno		0	100	20,000	☑
P_GEN1	INT	18	1,0	Incrementar		0	25	10,000	☑
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Fig. 3. screen for variable simulation.

The variables simulator is a very complete tool for this software. Using the modeled system, the user can perform a lot of test to know the way the real installation will behave. It is very useful to check the different changes that produce the largest optimization effects.

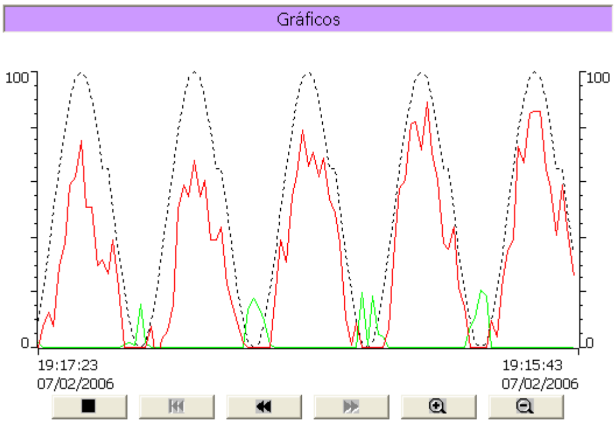

Fig. 4. Screen with the trend graphs 1.

This screen show the experimentation results in a graphic way, in particular the instantaneous values of the tested variables.

In red color, it is shown the P_CON1 variable, that is to say the power consumed by the power supply network. This power quantity is aimed to be optimized.
In black color, and represented with a dotted line, it is shown the variable P_CON2. This is the instantaneous power consumed by the building.

In black color, it is shown the variable P_GEN2, or the power obtained from the ESFV that is supplied to the power supply network. This power quantity is also aimed to be optimized.

The demand graph (P_CON2) has been simulated with sinus trend. It can be seen that the supply of the power provided by the UPS, will reduce the peak consumption from the power supply network. The energy sold to the power supply network consists only of the quantity that exceeds the needs of the system (P_GEN2). For this reason, it is only produced in case that there is not power consumption from the building side. P_GEN1 is the energy supplied by the photovoltaic panels. It has been simulated as a stochastic variable. The most random situation is obtained in sunny days with an appreciably amount of clouds. For this reason the red graph shows some unstable trend. The optimization values can be modified in order to make the consumption graph more flat. Nevertheless, this goal may need more power supply from the UPS.

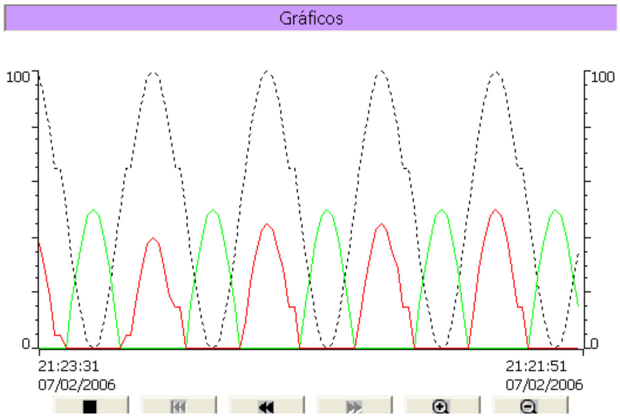

Fig. 5. Screen with the trend graphs 2.

As previously mentioned, it can be appreciated that the power obtained from the power supply network has been attenuated in a very noticeably way and has been also smoothed.

5. Conclusions

Several optimization algorithms implemented in a SCADA package have been presented. The system has also been modeled, allowing testing the different parameter adjustments in order to obtain very important consumption peaks reductions. Moreover, the performance of the systems with ESFV will be increased by means of supplying the excess of energy to the power supply network.

A procedure framed in the programs of European R+D+i for renewable energy and ecologic buildings has been presented. Some patents and utility models, as well as more scientific productions, are expected to be obtained from it.

Acknowledgement

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