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"PVDIM Vers. 0.5" USER GUIDE

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These are preliminary lecture notes, intended only for distribution to participants.

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PVDIM Vers. 0.5

USER GUIDE

E. Negro

1. Installation

Create a directory \PVDIM. in the hard disk.
Insert the program the disk drive A and copy all the files in the directory C:\PVDIM.
To execute the program type PVDIM1 <CR>.
The executable program is about 300 kB, so it can run on whatever PC. Math coprocessor reduces the run time but is not strictly required : the program recognise its presence and, if necessary, it emulates the coprocessor. The run time required for a simulation is around 40 sec. with 486 CPU and 50 MHz clock, so it's strongly recommended the use of a powerful PC in order no to be stacked waiting the results

2. Main screen

At the beginning you have on the screen a pull-down menu listing all the options and a mimic windows (fig. 1) reporting the status of your PV system. On the windows are reported in yellow the PV components you have selected and in dark blue the components not present in the system.
The choices of the bar menu printed in dark grey are disactivated, either because the configuration doesn't require the use of that option or because other parameters have to be defined previously.
The selection of options is made by means of the mouse clicking once on the selected option or using the arrow keys to move the highlighting bar on the selected option and then <CR>.
If there are others menu descending from the selected option, these are activated and the selection is made within the options of the second level.
To remount in the menu structure use the key <esc> or click on the right button of the mouse.

The main bar contains 8 choices:

Files
SystDefin

ItemsChoice
PreSize
Calculation
Results
Help
Quit

Their order follows the order of the actions you have to do in the definition of a PV system, i.e. you have roughly to go through all the options from left to right before being enabled to launch the calculations.
In the case of a previously simulated system, if the results file is available, you can go directly from the loading of the configuration to the analysis of results, this action being forbidden if you have modified your configuration after the execution of calculations.

3. Files

The choice ***Files*** (fig. 2) gives you access to the data bases of the software. In particular you have access to data bases containing the parameters required for the simulation of the following components: PV modules, batteries, inverters; the choice of back-up generators and pumps, even if already present on the screen, is not yet implemented. You can create new components, visualise them on the screen, modify some of the parameters, print and suppress them. The choice of the component out of the data base is made through a window that reports the name and the reference of all the filed components.
In the same menu are reported the choice of the power consumption files and meteorological files. These files are characterised by the extension .CSM and .DAT respectively, and their visualisation is made with a window reporting all the files with the proper extension present in the current directory. This routine allow even to examine all the structure of the hard disk, to look for the proper file in other sub directories.
The file handling is always active and is independent from the PV system you are working on, save in the case of component suppression : if the component you suppress is used in your PV system, it will be automatically taken out of the system you are working on.
The option *Select.Printer* allows you to define the printing standard ; you are offered the choice between IBM/Epson and LaserJetII, the most widespread printing standard. In the same window appear the choice of the output port ; by default is set to LPT1, but you can want to use the other either if you have several printers connected to your PC or if you are working in network environment and you want to profit of the common printer. The settings you enter are recorded and will be used the next time you run the program. Unless you select a printing standard, any attempt to print something will be stopped.

4. System definition (*SystDefin*)

To run a simulation or a sizing you have to define the characteristics of the PV system using the option *SystDefin* (fig. 3).
The option *Present system* (fig. 4) is always active and visualises/prints a table reporting the main characteristics of the system, as defined up to that moment.
The option *System Configuration* brings you into the design of the system. You can at this level either choose a configuration you have already built and saved previously (fig. 5) using the option *Load config file* for the selection from a list of existing configuration files (extension .CFG). You can

also begin from here the definition of a *New configuration* : you will have to choose between stand-alone and grid-connected, the pumping being present but not active yet.
If you try to create or to load a configuration while you have another one, you will be prompted in order not to loose the previously calculated data, and you will have to *Reinitialise* your configuration.
The next option in the SystDefin sub menu is the *Type of calculation* you want to perform (fig. 6). You have to make a choice at this stage because the sizing or the simulation implies different choices in the following menus. The daily simulation, specific to pumping systems, is not active yet.
Simulation calculates the energy balances in the various branches of the PV system you have defined. The simulation covers one year time and is made with a time-step of 1 hour.
Sizing procedure aims to find, for a given load profile, meteorological data set and prescribed load coverage rate, the optimal couple array/battery bank size. The criterion used is to find out a size that allows the best energetic matching, that is the highest State of charge of the battery and the highest load coverage rate simultaneously (fig. 7). Several calculations have shown that this technical optimisation leads even to en economical optimisation.
The same window presents the choice of a load profile. This is an AC, DC (or both) hourly profile of power demand for one representative day for each season. At this level you can only visualise or choose the load profile within the existing *.CSM files. If you want create a new one you have to go back to the option *Files* on the main menu bar. The choice of a load profile (if a DC profile is included) determines the voltage of the system, rendering thus inoperative the option *System Voltage* ; if on the contrary you choose first the system voltage, afterwards the choice of load profiles will be limited to the one having the same DC voltage.
In the same way the option *Meteo* leads you to a window where are reported the files *.DAT containing data of a Typical Meteorological Year for some selected sites. The files contain an hourly sequence of global horizontal, direct radiation and air temperature. The data base contains at the moment 2 files for a site in south of France and in Corsica island. This data base will be extended to other European sites.
Total pressure head concerns the pumping systems and, as previously said, is not active yet.

5. PV components choice (*ItemsChoice*)

The side conditions being stated you can select the actual components of your PV system (fig. 8).
You can load, modify and deselect the PV modules, batteries and inverters in the same way used in *Files* option, save that now you can create new components.
The choice is guided, or forbidden, depending on the previous choices. For instance if the load profile doesn't include AC loads you can't select an inverter, with the exception of grid-connected systems that don't require strictly a load profile.

6. Presizing (*PreSize*)

The option *PreSize* (fig. 9) leads you to the definition of the size of the system (if you are performing a simulation) at to the choice of some parameters that rules the behaviour of a PV installation.

Batteries bank size calculates the number of series connected batteries, depending on the battery and system voltages, as well as asking the user how many branches of batteries will be connected in parallel. The total storage capacity C100 will be thus determined, in Ah, by the number of branches in parallel.

PV array size operates the same way as the sizing of the batteries, leading to the characterisation of the array architecture.

Depth of discharge is a critical parameters that affects the performances of your system. It's well known that an excessive discharge of batteries induces severe damages and limits their duration. It's suggested to run some simulations changing the depth of discharge in order to evaluate the effects on the overall behaviour of the system. The DOD is limited to 80%.

Power regulation affects the voltage thresholds that are used in the on/off power regulators. The histeresis of the system, represented by the splitting of the 2 thresholds, is mandatory in the reality, but is not strictly required in the simulation, because of the discreteness of the time-step.
The option proposes therefore same default values of the thresholds that are generally representative of the values of commercially available regulators. In the case of inverters working at fixed input voltage you have to state in this option the working point of your inverter, and thus of your PV array.

Array tilt angle asks you the albedo of the site, the array azimuth and guides you in the choice of the optimal tilt angle. An optimisation routine evaluate the optimal irradiation in the plane of array depending on the meteorological data, the albedo, the azimuth and the strategy of constant tilt over the year or variable over the 4 seasons. The optimal tilt so proposed maximise the total yearly production, but can be misleading because it increase the summer yield dropping the winter one. The choice of the tilt angle depends therefore on the type of loads you have.
Values par default are also proposed, depending on the latitude of the site.

Cabling losses proposes a percentage value of the derating of PV installations depending on modules mismatching, ohmic losses in the cables and voltage drops caused by the blocking diodes. Default values are proposed according to average values observed in several installations, but they can be modified by the user.

Investment costs evaluate the costs of your installation (the components prices, recorded in the data base, have to be representative to perform good economical evaluations) as the cost of components plus the ancillaries, the latter being evaluated as a default percentage of the total installation cost.

7. Calculations

If all the parameters describing the system (components depending on the type of configuration and the type of calculation selected) and characterising its size have been specified you are entitled to select the option *Calculations* on the main menu bar. On the contrary an alert windows advises the missing parameters.
The sub menu (fig. 10) presents the following options :

Load coverage rate to be chosen as side constraint when you run a sizing calculation. It specify the percentage of the demanded load power that will be covered by the PV system.

Initial State Of Charge (SOC) asks you the state of charge (in percentage of C100) of the battery bank when the simulation or the sizing are launched.

Time-step indicates the time-step used in the calculations. In the present version is fixed to 1 hour.

Launch calculation check again the coherence of the entered parameters and, in positive case, starts the calculation procedures.

In the case of a simulation the daily averages of relevant parameters are visualised during the calculations, together with the name of the month that is being calculated.

In the case of sizing the simulation run is automatically iterated until the optimal couple battery bank/array size is reached. Usually the procedure converges within 10 to 20 simulations.

8. Results

At the end of the calculations, or with a configuration file having the results file available, you can enter this option to analyse the behaviour of the PV system (fig. 11)
Present system, reminds the general characteristics of the system, as previously mentioned.
Yearly/monthly averages (fig. 12) reports a full set of the energy flows balances in the different branches of the system. They are presented in tabular format, month by month, or in a graphical format reporting 4 histograms on the screen representing the monthly balances or the daily averages (fig. 13).
Economical analysis (fig. 14) presents a summary of the installation costs and their actualisation according to different interest rates and duration of the investment. An indication on the cost of kWh PV is also provided.
Utility kWh cost allows the definition of the utility buying/selling prices, in order to evaluate correctly the profitability of a grid-connected system.
The *Balance utility/PV kWh* finally proposes (fig. 15) an economical comparison between utility only and mixed utility/PV grid-connected installation.

9. Data Saving

To save the configuration created or modified you have to choose on the main menu bar the option *Quit -> Save*. If you try to quit without having saved your modification a prompt message is visualised.
The saving of a configuration file leads to the saving of results in a file having the same name and extension .RST. It will be possible to visualise the performances of a system without having to repeat all the calculation. The existence of the results file is indicated in *Present system* table as *Results file: available.*

10. Printing

The printing of tables and histograms is made possible when they are visualised on the screen, by means of a choice menu in the lower part of the screen as *quit/print*.

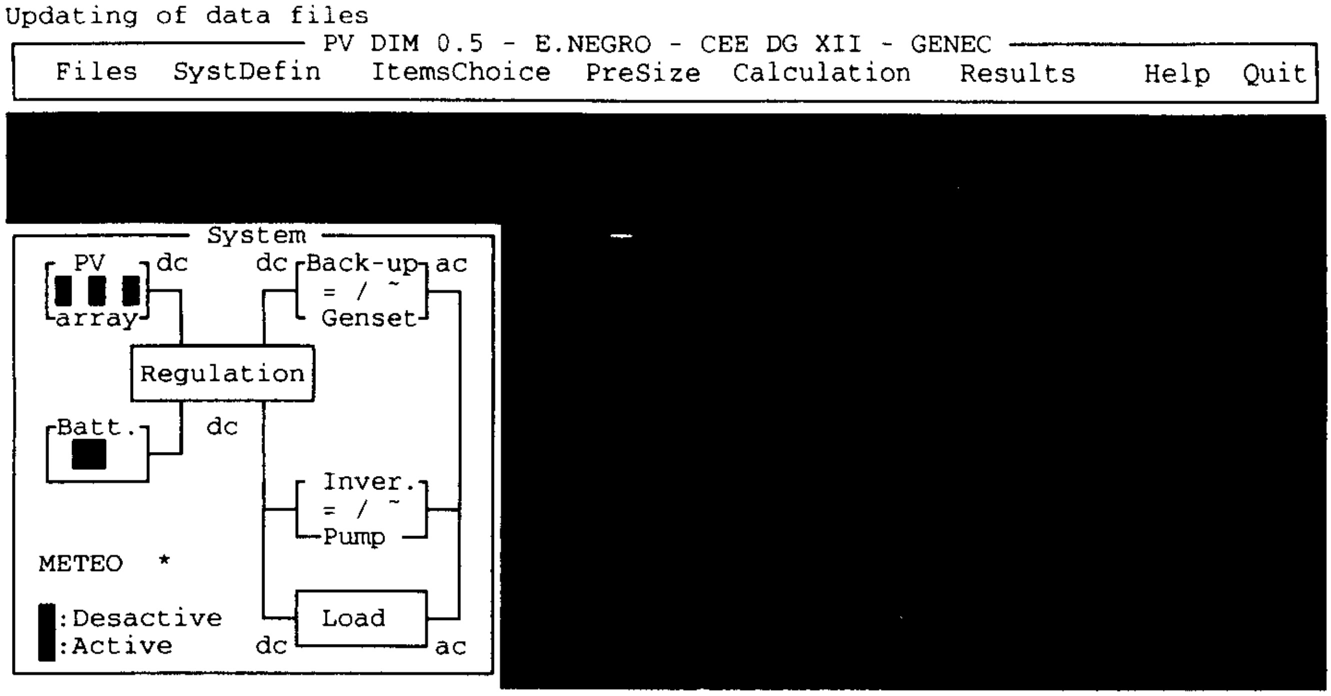

Fig. 1 : The opening menu bar with system mimic window.

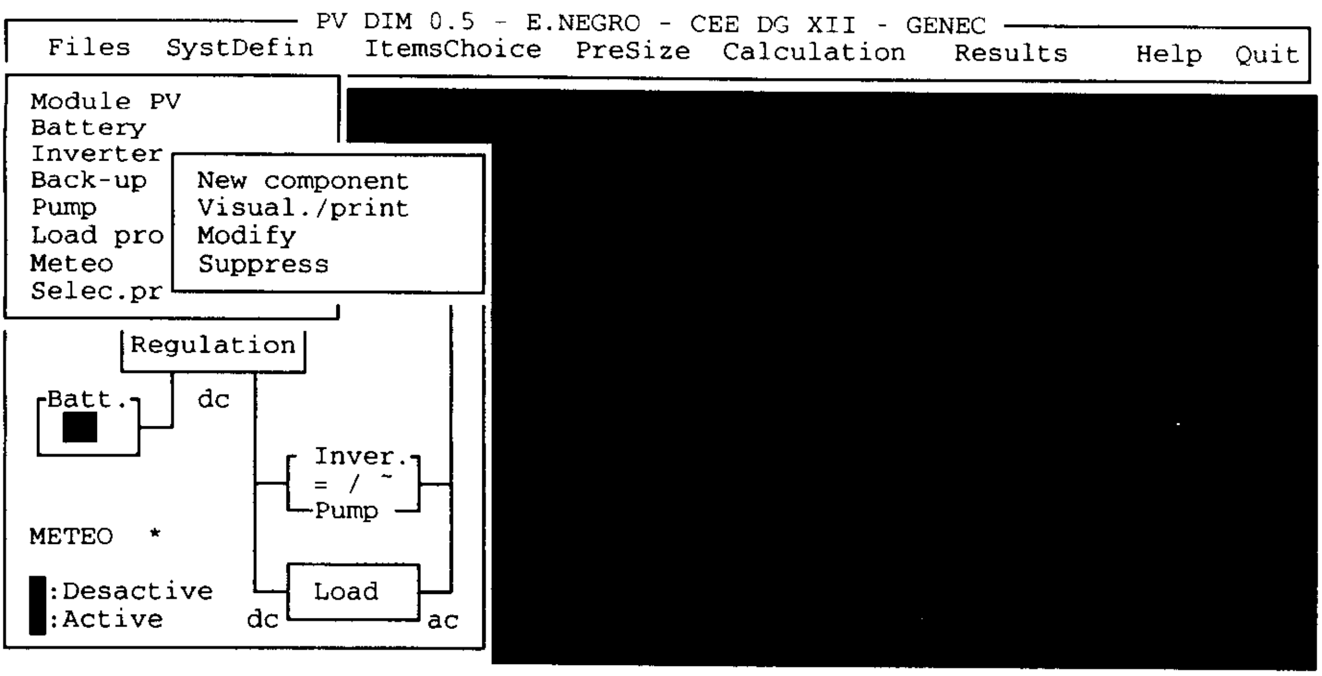

Fig. 2 : Sub menu *Files* options.

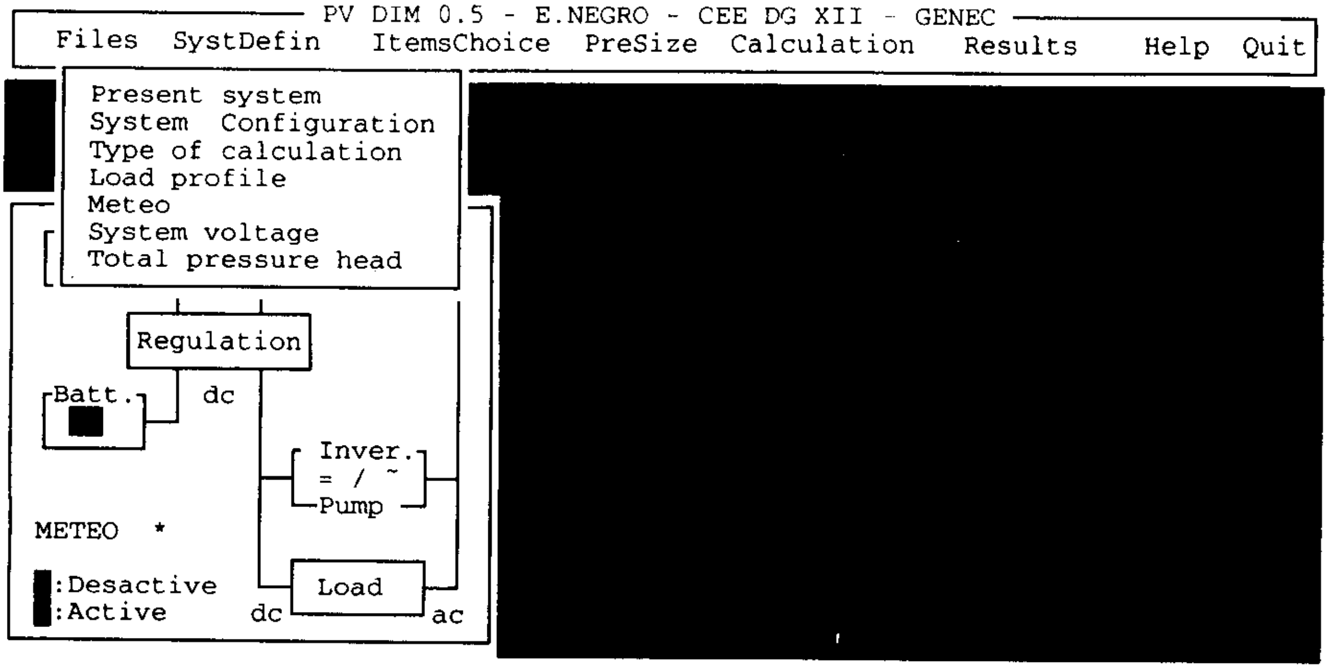

Fig. 3 : Sub menu *SystDefin* options.

SYSTEM CONFIGURATION: ESSAI1.CFG

Title		: essai	Voltage	(V) :	12
PV system		: with battery	Peak power	(W) :	900
Type of work		: Yearly simulation	Nb module series	:	1
Meteo file		: FRA_CAD_.DAT	Nb paral.branches	:	20
Load file		: CC_VAR.CSM	Stockage C100	(Ah) :	220
Module	name:	PHOTOWATT	Nb battery series	:	6
	ref :	PWX-500	Nb paral.branches	:	1
Battery	name:	OLDHAM TUS3	Depth discharge	(%) :	80
	ref :	220 AH 2V	Regulation thresh.	:	2
Inverter	name:		Branches aft.disct.	:	
	ref :		High threshold	(V) :	14.4 12.6
Back-up	name:		Inter.threshold	(V) :	
	ref :		Low threshold	(V) :	12.9 11.4
Pump	name:		Albedo	(%) :	20
	ref :		Pumping head	(m) :	
Results file		: present	Azimuth array	(°) :	0
PV modules price		: 35 kF	Tilt Jan-Mar	(°) :	50.0
Battery price		: 2 kF	Tilt Apr-Jun	(°) :	50.0
Inverter price		:	Tilt Jul-Agu	(°) :	50.0
Back-up price		:	Tilt Sep-Dec	(°) :	50.0
Pump price		:	Losses	(%) :	3
Ancillaries costs:		19 kF			

Fig. 4 : Summary table of the PV system characteristics.

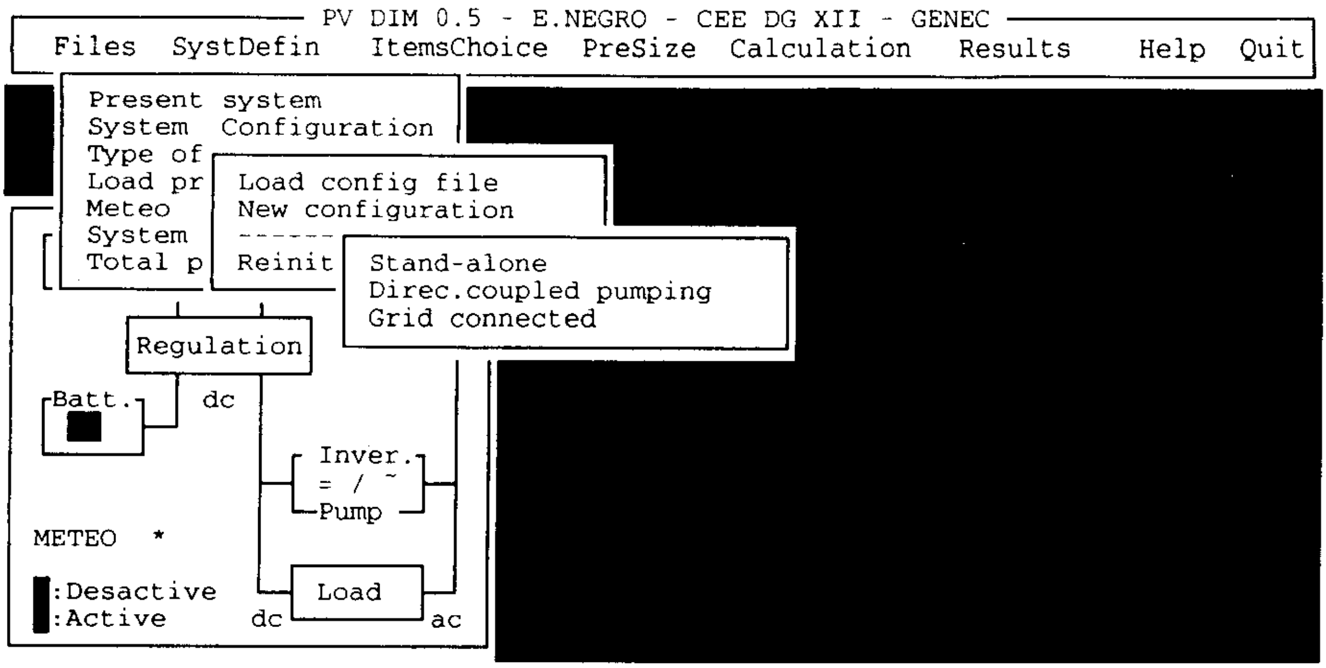

Fig. 5 : Sub menu *System Configuration* options.

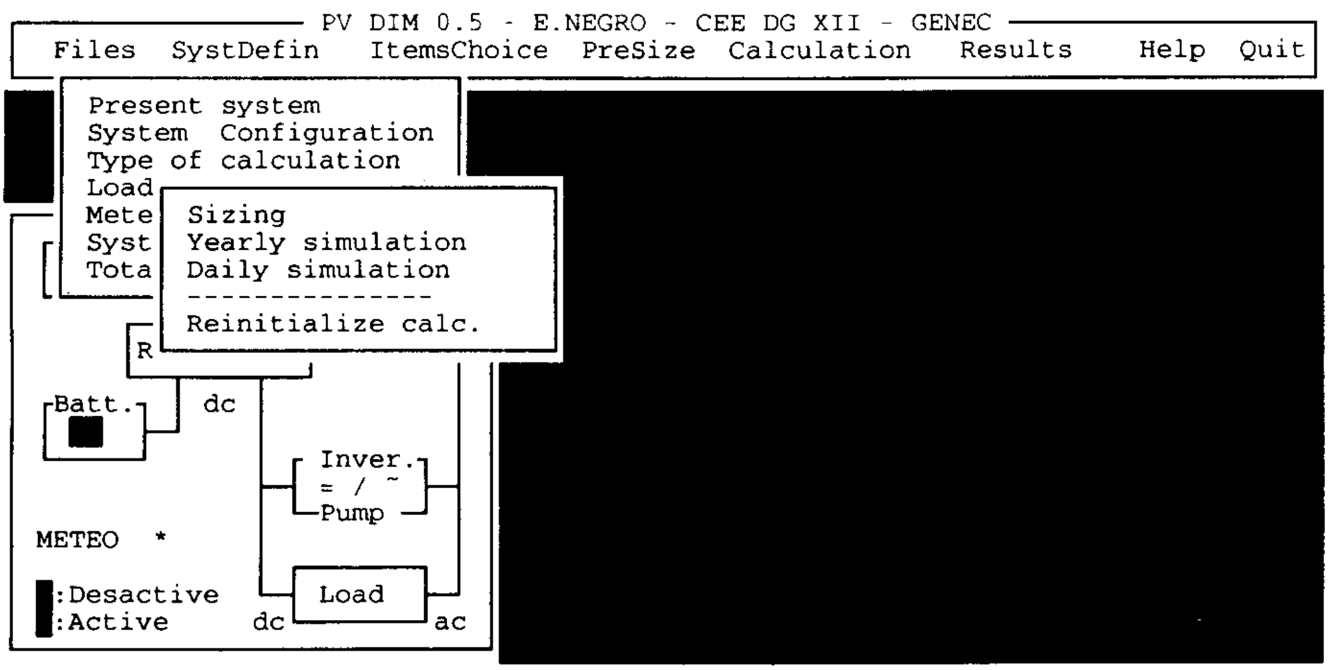

Fig. 6 : Sub menu *Type of calculation* options.

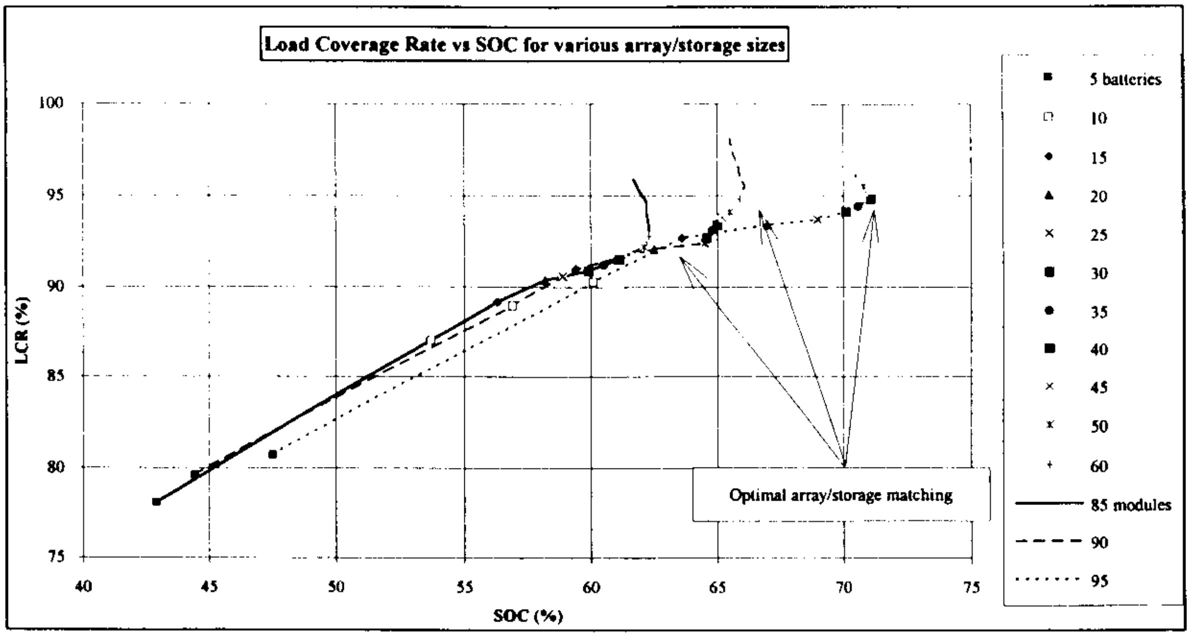

Fig. 7 : Load Coverage Rate vs SOC for several couples Battery/array sizes.
Case of constant power demand.

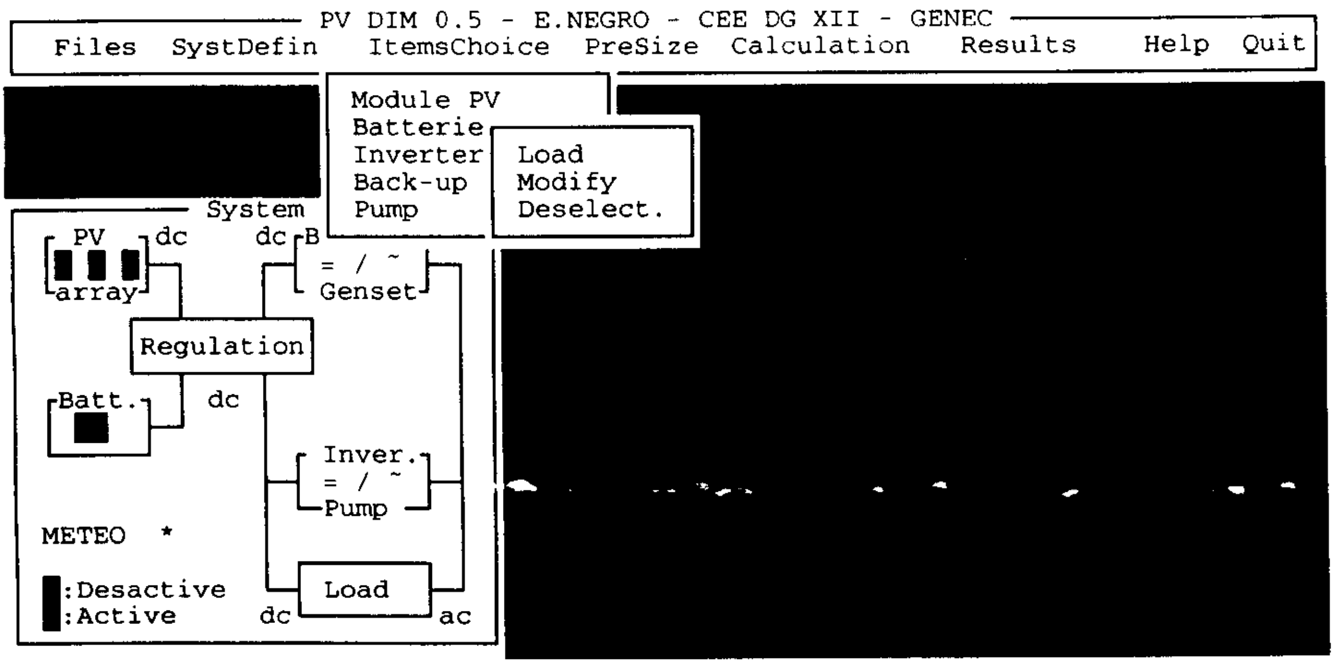

Fig. 8 : Sub menu *ItemsChoice* options.

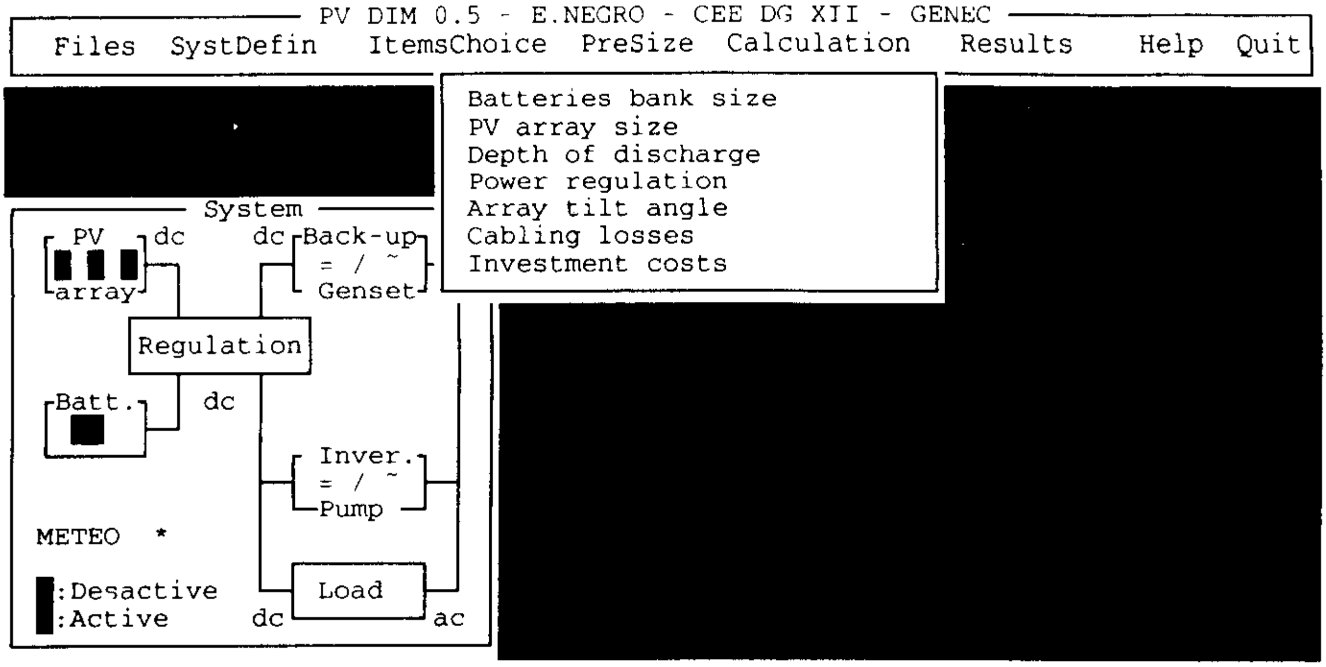

Fig. 9 : Sub menu *PreSize* options.

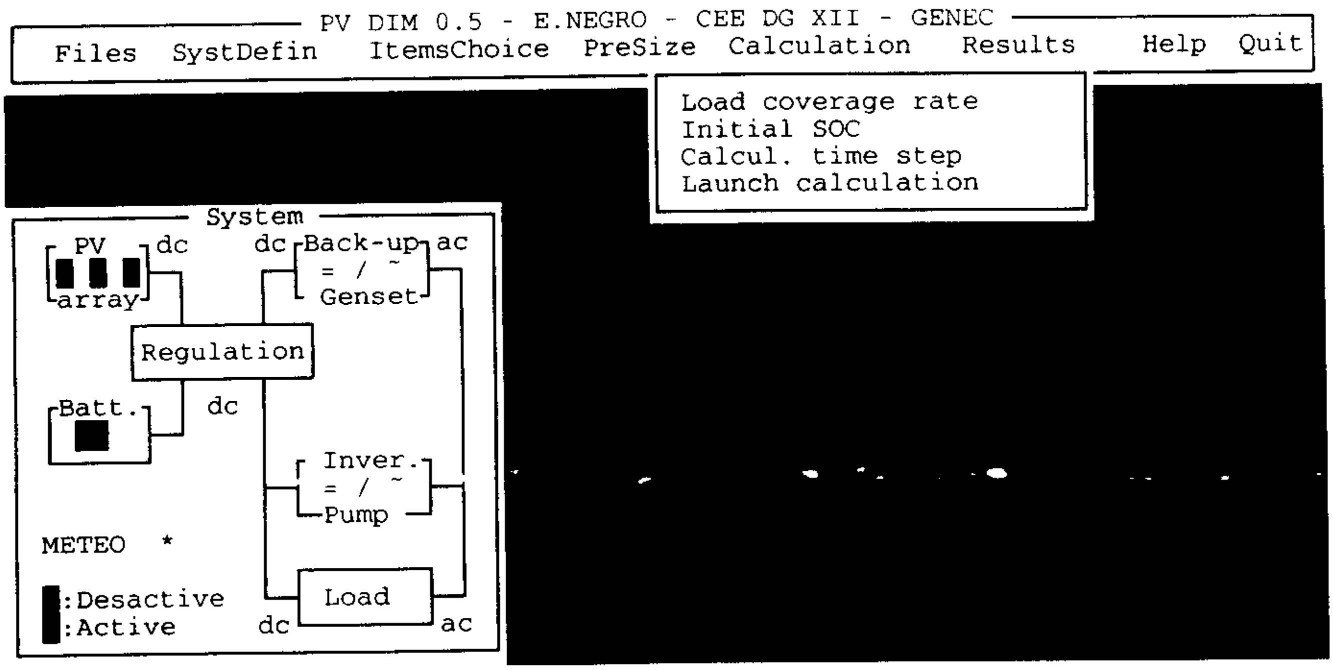

Fig. 10 : Sub menu *Calculations* options.

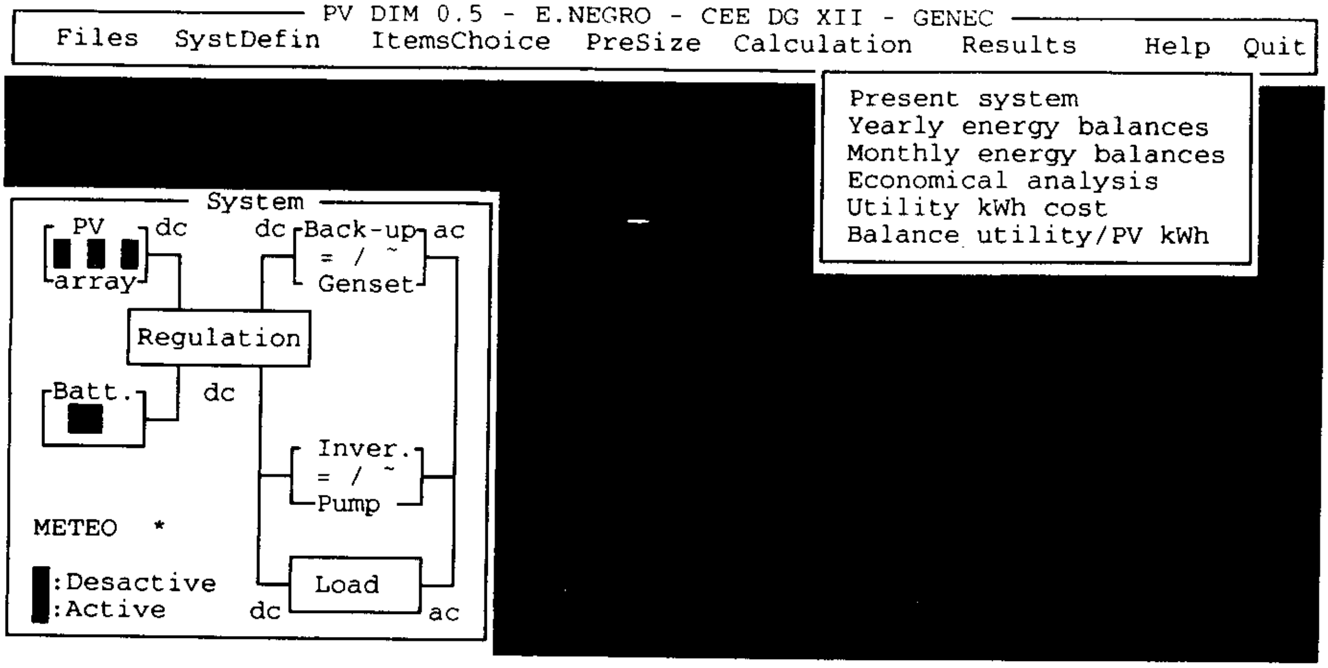

Fig. 11 : Sub menu *Results* options.

```
-----------YEARLY RESULTS - ESSAI1.CFG essai-----------
PV system with battery                    Yearly simulation
                                  Yearly (kWh/y) balances
                METEO                                         BACK-UP
Glob array irradi. (/m2)     1668.9 kWh  Back-up production
                PV ARRAY                 Fuel consumption
Gross array yield            1143.6 kWh  Daytime running hours
Energy losses                  37.8 kWh  Nighttime running hours
Net array yield              1105.9 kWh              GLOBAL SYSTEM
Losses for disconnections     298.3 kWh  Load requirements          1758.9 kWh
Used energy                   807.5 kWh  Covered load                807.7 kWh
Array load factor              73.6 %    Grid injected energy
                STORAGE                  Load coverage rate           57.5 %
Stocked energy               505.5  kWh  Load covered with PV         57.5 %
Destocked energy             505.7  kWh  Loss of power hours        3758.0 h
Charge/disc. efficiency       99.1  %    Consecutive losses           45.0 h
Charge/disch. losses           1.8  kWh
Storage balance               -2.0  kWh
Average SOC                   34.0  %
Average batt.cycling          49.1  %
                INVERTER
Average efficiency
```

Fig. 12 : Yearly balances results of a simulation.

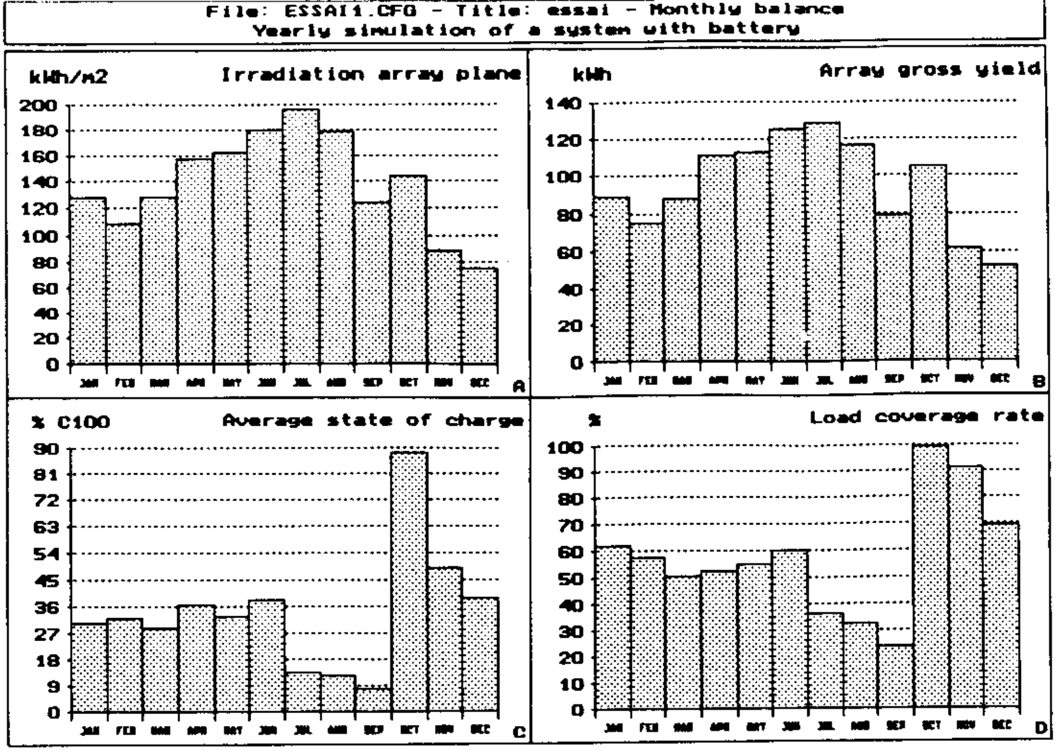

Fig. 13 : Exemple of graphical print-out.

ECONOMICAL RESULTS - ESSAI1.CFG essai

PV system with battery			Yearly simulation	
Nominal power	:	0.9 kWp	Storage size :	2.6 kWh
INVESTMENTS				
PV modules	:	35.0 kF	Back-up generator :	
Batteries	:	2.5 kF	Pump :	
Inverter	:		Auxiliairies :	18.7 kF
Total investment	:	56.2 kF	Installed Wp cost :	62.5 F/Wp
MAINTENANCE/FIXING				
PV system	:	1.7 kF	Back-up + fuel :	
YEARLY CASH FLOWS (kF)		10 yrs	15 yrs	20 yrs
Interest rate :	5%	7.9	6.2	5.3
	10%	9.8	8.1	7.4
	15%	11.9	10.3	9.7
YEARLY TOTAL COST (kF)				
Interest rate :	5%	9.6	7.8	7.0
	10%	11.5	9.8	9.1
	15%	13.5	12.0	11.4
kWh COST (F/kWh)				
Interest rate :	5%	11.9	9.7	8.6
	10%	14.2	12.2	11.2
	15%	16.8	14.9	14.1

Fig. 14 : Exemple of economical analysis print-out.

UTILITY/PV kWh COST BALANCES - RESEAU1.CFG essai

Grid-connected PV system — Yearly simulation

PV array power : 1.8 kWp Inveter power : 1.8 kW

UTILITY PRICES

KWh price : 0.50 F PV kWh buying price: 5.00 F
Yearly fixed costs : 1200.0 F

UTILITY SERVICE COSTS

Yearly consumption : 8760.0 kWh Coût réel kWh : 0.64 FF

MIXED UTILITY/PV COSTS

E.grid consumed : 6723.1 kWh E.grid injected : 160.4 kWh
Utility kWh price : 0.68 FF

kWh price (F/kWh)

Interest rate :	Paying off time: 10 yrs	15 yrs	20 yrs
5%	5.8	4.6	4.0
10%	7.1	5.9	5.4
15%	8.4	7.4	7.0

Fig. 15 : Example of utility/grid-connected system economical analysis.