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PHOTOVOLTAIC / WIND HYBRID OFF-GRID SIMULATION MODEL USING MATLAB™ SIMULINK™

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Abstract*-Renewable energy systems in rural and non-electrified location in Jordan in specific and throughout the world in general has a major weakness that they are highly dependent on the renewable resources that cannot be controlled and are intermittent in nature and in some cases are difficult to be predicted such as solar irradiance and wind energy. Hybrid systems solve part of this problem by combining two or more types of energy that complement each other,In this paper a flexible simulation model for a hybrid Off- Grid Photovoltaic / Wind using Matlab™ Simulink is presented, the model is thoroughly explained and the components are presented in great details .

Keywords–Renewable Energy; Solar Energy; Wind Energy; Off-Grid Systems; Simulation: Matlab Simulink.

I. INTRODUCTION

The system with combination of different sources of energy is called hybrid system and the hybrid system is not new concept it has gained more consideration during the last two decades by many researchers such as Diaf et al [1]. They presented a methodology to perform the optimal sizing of an autonomous hybrid PV/wind system. Their methodology aims at finding the configuration, among a set of systems components, which meets the desired system reliability requirements, with the lowest value of levelized cost of energy and assumed PV/wind hybrid system to be installed at Corsica Island, their results showed that the optimal configuration, which meet the desired system reliability requirements loss of power probability (LPSP = 0) with the lowest levelized cost of energy LCE, is obtained for a system comprising a 125 W photovoltaic module, one wind generator (600 W) and storage batteries (using 253 Ah).

Nandi et al [2] evaluated the feasibility of a proposed wind-PV hybrid power system in Bangladesh and showed that wind–PV-battery is economically viable as a replacement for conventional grid energy supply for a community at a minimum distance of about 17 km from grid. Saheb-Koussa et al [3], designed a hybrid energy system consisting of wind and photovoltaic with battery storage with the backup of a diesel generator to ensure continuous power supply in Algeria. Dihrab et al [4], proposed a hybrid system as a renewable resource of power generation for grid connected applications in three cities in Iraq and showed that it is possible for Iraq to use the solar and wind energy to generate enough power for some villages in the desert or rural. Brito et al [5], presented a quality analysis of the electric energy supplied by a small PV-wind-diesel hybrid system to the community of Tamaruteua, located in the county of Marapanim, on the coast of the state of Para-Brazil.

II. SYSTEM MATHEMATICAL MODEL

In order to have an appreciable sense of our design and calculations of the different elements of the system a mathematical model is built to each element that reflect its actual physical behavior, in this section the hybrid system components model design will be explained in detail.

III. WIND SPEED AND SOLAR IRRADIANCE SIMULATION.

As mentioned before renewable energies output depends greatly on the metrological data these are represented as signals varying in time using a signal builder, it's worthwhile to mention that each 1 sec of simulation is equivalent to 1 hour in real time, Solar irradiance is built in the same manner with the data inserted for the specific location.

IV. THE LOAD MODEL.

The load model is built using measured data or estimated data for multiple loads and multiple seasons of the year.

V. The complete system model

The system model consists of three main elements i.e. wind turbine model, PV panel model and the battery model the complete model consists of 8 blocks three of which are the wind speed, solar irradiance and Load demand which we mentioned, the other 5 blocks will be explained in detail in next sections, Fig 1 shows the model of the complete system ,

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block are connected by Goto – From tags rather than connecting lines this choice was made for better organization.

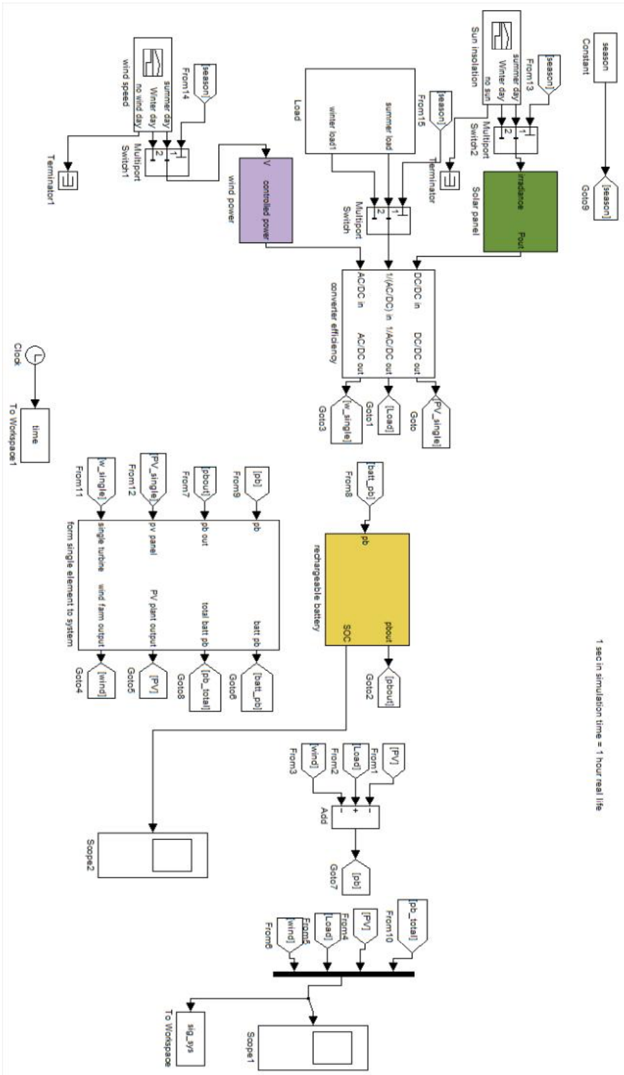

Fig. 1 Complete system model

THE WIND TURVINE MODEL.

The simplified wind turbine model act according to the following equation [6].

$$P_{wind_{turbine}} = \begin{cases} 0 & v < v_{cut_{in}} \\ \frac{1}{2}\rho A v^3 Cp & v_{cut_{in}} \le v \le v_{cut_{out}} \\ 0 & v > v_{cut_{out}} \end{cases}$$

(1)

And that's shown in Fig 2 as the characteristic curve of the wind turbine.

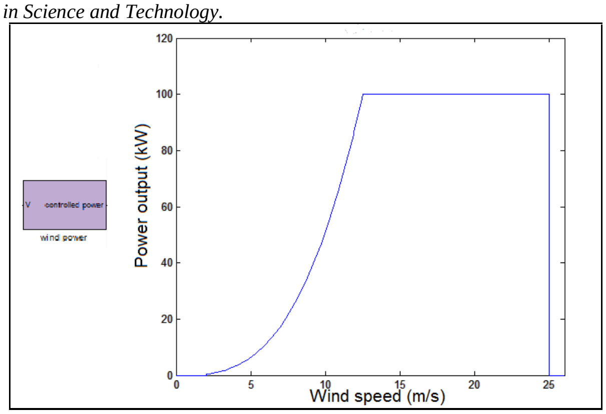

Fig. 2Wind turbine output characteristics on the right and wind turbine block on the left.

This characteristic is obtained by a control block in the wind turbine model as shown in fig 3 and 4.

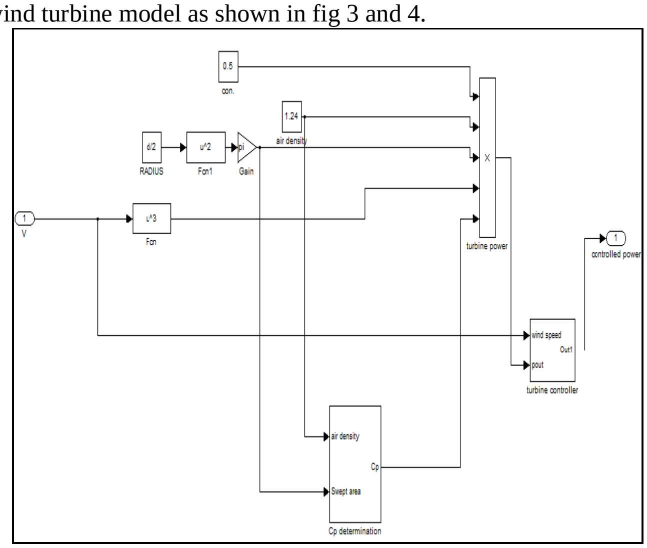

Fig. 3Wind turbine block components

The wind turbine components represent the wind turbine equation [6]

$$P = \frac{1}{2}\rho A v^3 (\qquad (2)$$

Cp depends on the specifications of the selected wind turbine and is found by dividing the nominal power by the power content of the wind at the nominal wind speed.

The control block is shown in Fig 4 it satisfies the equation (1) by using logic blocks.

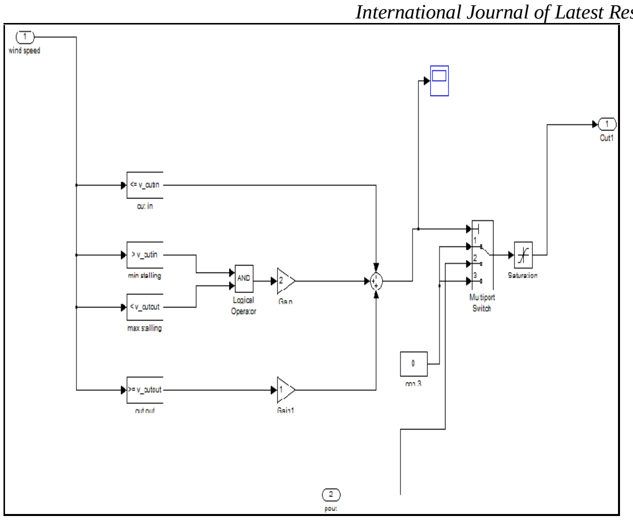

Fig. 4Wind turbine control block

PHOTOVOLTAIC MODEL

The simplified PV model used in the simulation is given by.

$$P_{panel} = \eta_{pv} A_{panel}\ I(t) \quad (3)$$

Were:

P_{panel}: PV panel output

$\eta_{\_pv}$: PV panel efficiency

A_{panel}: PV panel area

I(t): solar irradiance as a function of time

The model used is shown in fig 5.

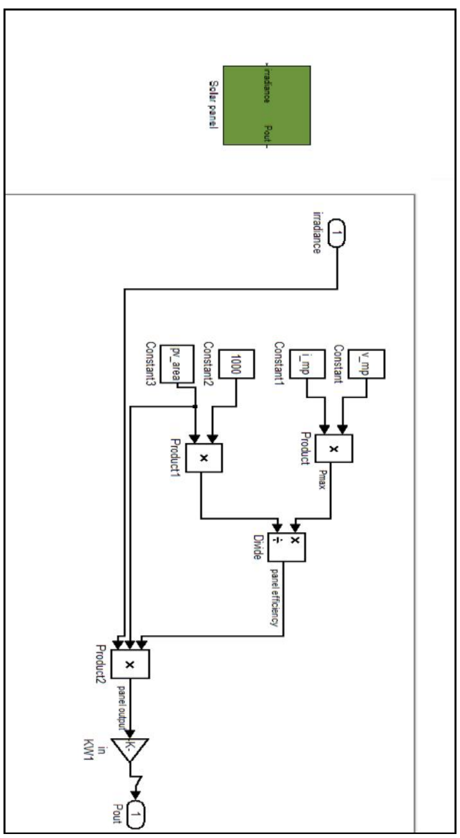

Fig. 5PV panel block and PV block components

BATTERY MODEL

Rechargeable battery model we used in our simulation and its control is given by [6] and is shown in Fig 6 the charge / discharge control algorithm explained earlier is represented in Fig 7.

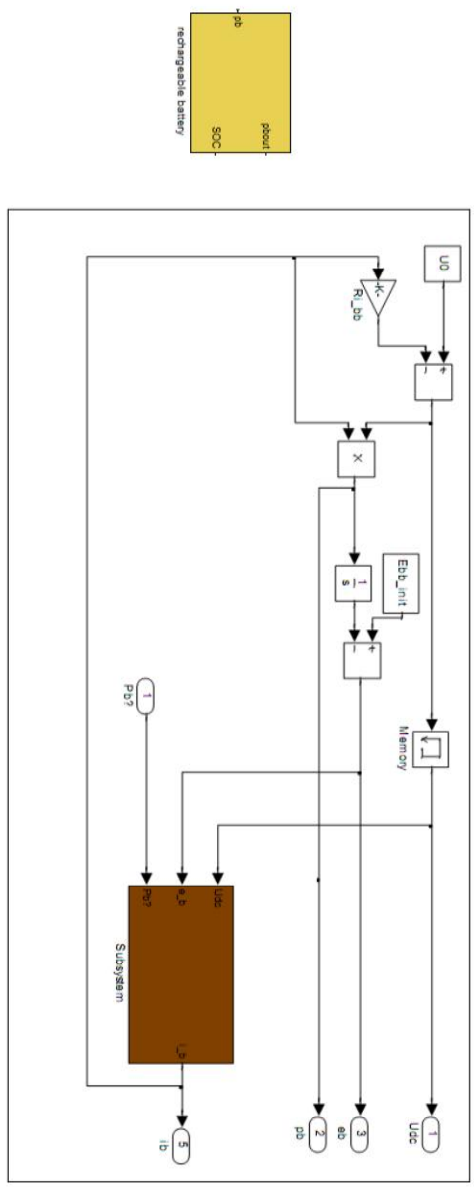

Fig. 6 battery block and components [6]

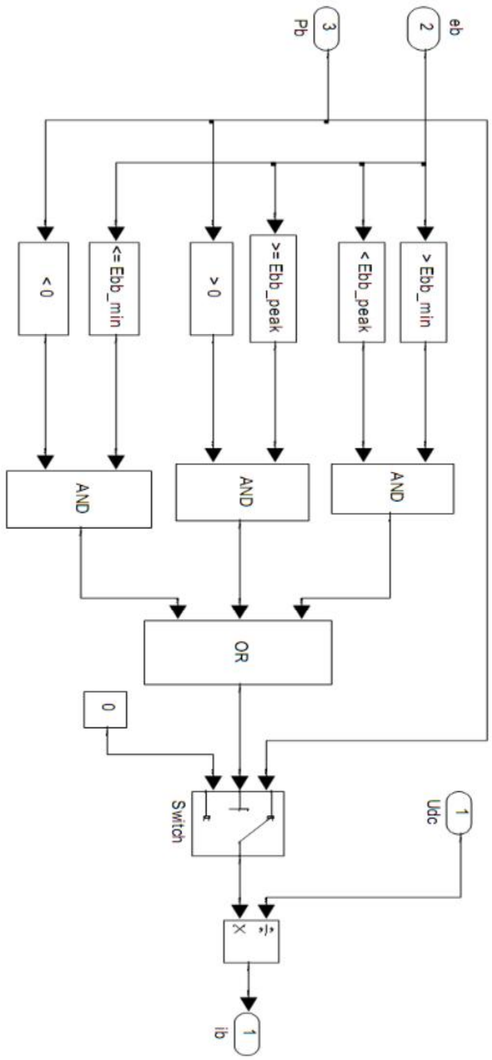

Fig. 7 battery control model [6]

The battery output power in this thesis is considered positive if the battery is discharging i.e. the load demand is greater than the supplied power, and negative in case the battery is charging i.e. the supplied power is greater than the load power demand.

CONVERSION LOSSES BLOCK

The convertors used to convert the powers from AC to DC and from DC to AC have efficiencies less than 100% this fact is reflected by the converter efficiencies block shown in Fig 8.This block is connected to the output of the PV panel and the wind turbine and depends on the converter efficiency and the connection topology of the hybrid power system.

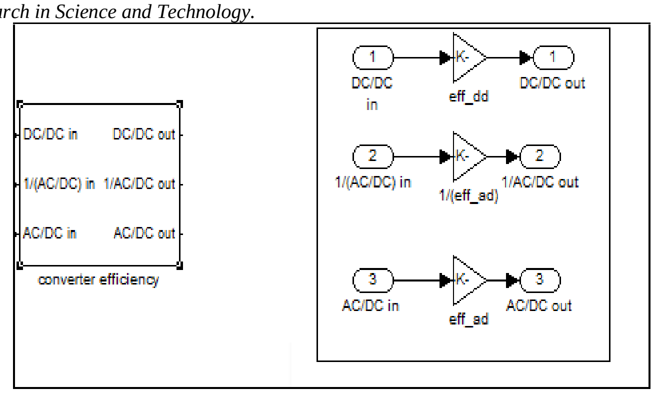

Fig. 8 Converter efficiency block

The sizing model

The sizing model has three inputs the load demand, the wind speed signal and the solar irradiation signal and the outputs are the total number of batteries, the total number of wind turbines and the total number of PV panels. The sizing model is composed of four main elements:

•the wind turbines capacity
•the PV capacity
•the PV sizing model
•the wind turbine sizing model
•the battery sizing model

Figs 9 shows the model of the sizing unit with the inputs and outputs, Fig 10 shows the components of the sizing model.

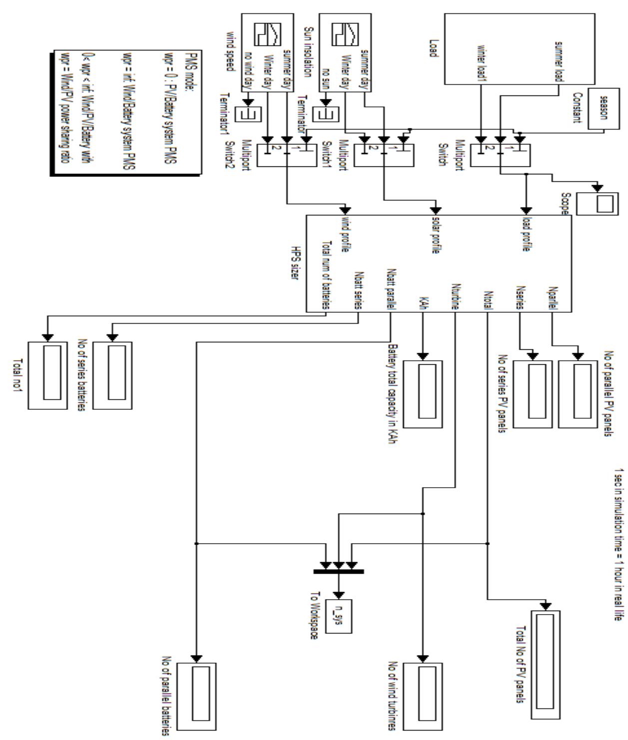

Fig. 9 sizing mode

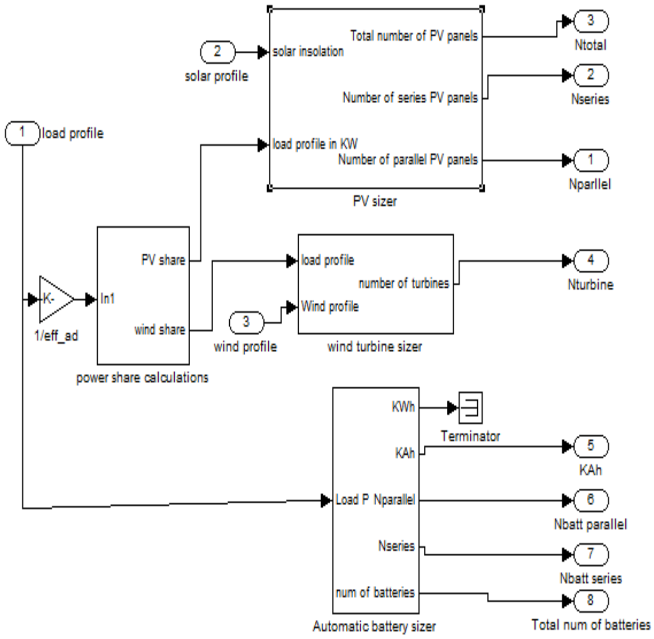

Fig. 10 components of the sizing model

The battery sizing model

The battery sizing block calculates the daily energy needed for supplying the load for the specified number of days with no supply i.e. the autonomy days and divides it by the capacity of a single battery, in this way we get the total number of batteries needed for the system.
The components of the battery sizing model are shown in Fig 11 the battery sizing equations are:

$$E_{daily\_load_{demand}} = \int_0^{24} P_{load}\, dt \quad (4)$$

$$BC = \frac{E_{daily\_load\_demand}}{\eta_b} \frac{DOA}{DOD} (Wh) \qquad (5)$$

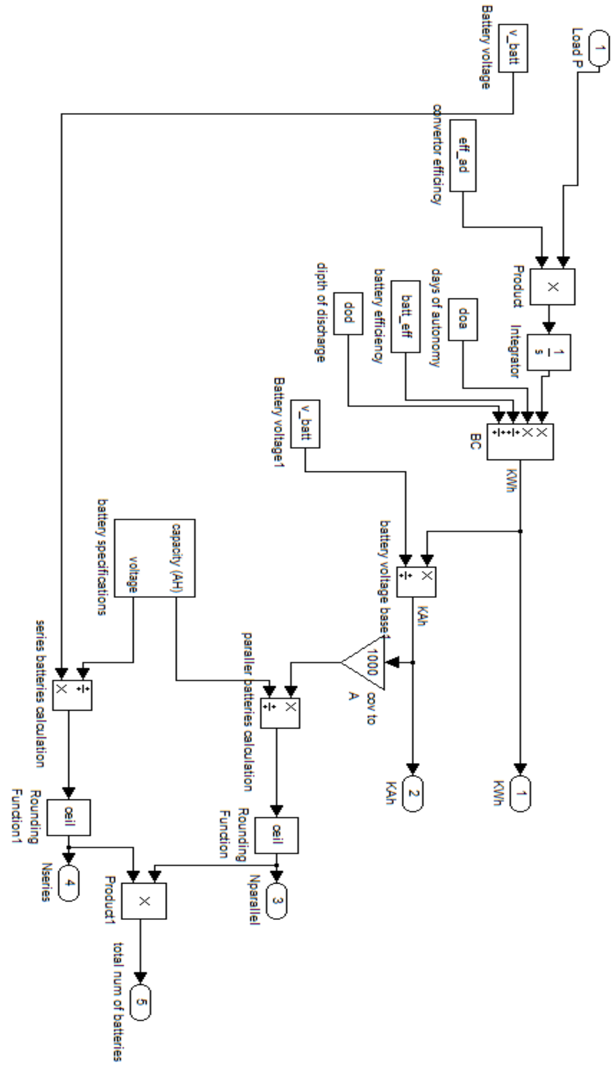

Fig. 11 the battery sizing model

The wind turbine sizing

The wind turbine sizing model inputs the energy needed output of the wind turbine and divides it by the energy produced by a single wind turbine, in order to calculate the total needed number of wind turbines, Fig 12 shows the components of the wind turbine sizing block.

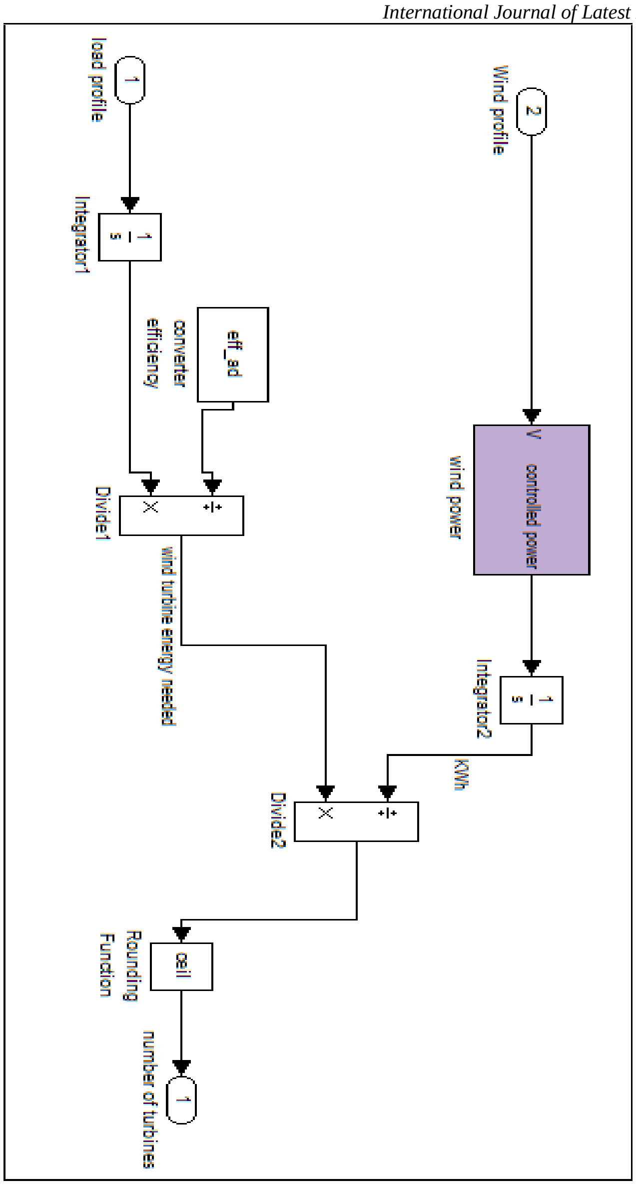

Fig. 12 Wind turbine sizing block

PV sizing block

The PV sizing block has the same principle of the wind turbine sizing block, figure 13 shows the components of the PV sizing block.

V. CONCLUSIONS

In this paper, a universal and flexible model for sizing and selecting hybrid off grid Photovoltaic and Wind energy system is proposed and discussed in great details, the simulation model is built using Matlab Simulink graphical modelling, and is composed of three main parts i.e. the PV subsystem, the wind subsystem and the battery system, the main goal is to develop a comprehensive model with the automatic sizing and selection of the optimum size of Wind PV and battery banks, the system depends on the electrical load to be supplied, the wind and PV resources and the needed backup time.

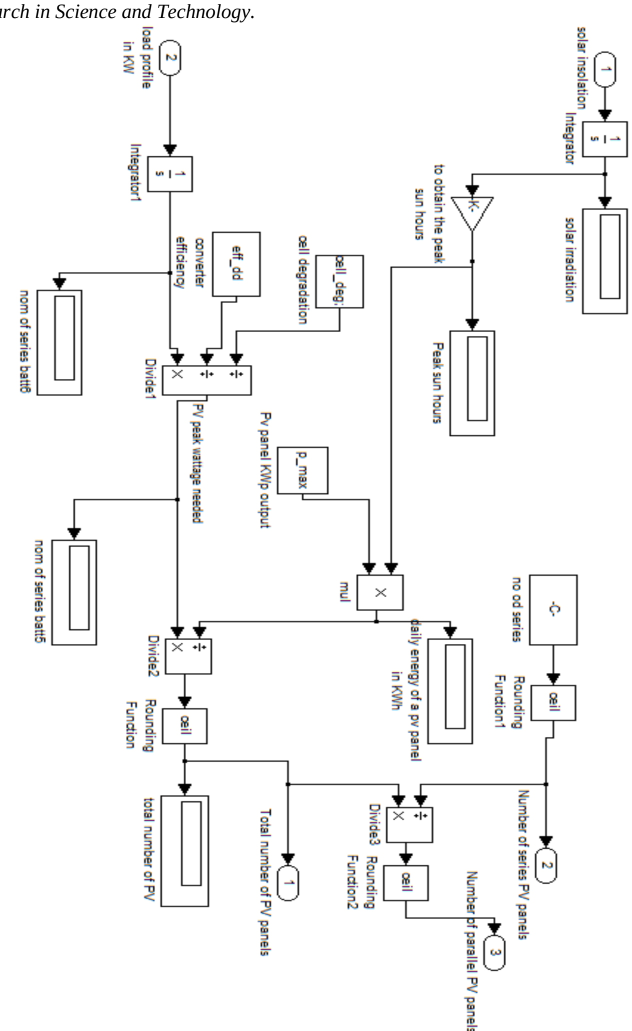

Fig. 13 the PV sizing block

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