Management of Renewable Energy Sources Integrated in a Micro Smart Grid

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***Abstract* — Future trends in the energy sector are crossing from centralized to distributed electricity production. A national and international organism encourages and informs consumers about the efficient use of energy. Such an approach of an efficient energy consumption lead to use of a certain number of renewable energy sources and a proper management of their. This paper, approach some issues of energy management and the use of unconventional sources of energy under the stochastic conditions. It showed a possibility of interconnection of renewable energy sources in a micro-smart grid. Four energy sources are proposed: the main source - power grid; secondary source 1 - photovoltaic generator; secondary source 2 - wind generator; secondary source backup 3 - diesel generator. The interconnection of these energy sources is achieved by a system of energy management and control based on a microcontroller structure type. Interconnection is based on the availability of energy sources and by energy consumption. The command and control algorithms for energy sources were implemented in Matlab Simulink software using specific functions and blocks. The energy management system ensures directing the flow of energy between sources and consumers. Also it manages the total energy distributed to consumers. The information can be stored and interpreted by a PC.**

Keywords *— renewable energy sources; smart grid; energy management.*

I. INTRODUCTION

Energy systems worldwide are subjected today due to challenges, on the one hand, population growth and energy consumption, climate change and the desire to protect the environment, promoting renewable energy in large quantities, and on the secondly because global economic crisis and political instability in some areas of the world [5].

To meet these challenges, it was launched the concept of ″Smart grids″.

A Smart grid is an electricity network that can intelligently integrate the actions of all users connected to it - generators, consumers and those that meet both capacities - in order to effectively provide electricity and to ensure power supply, sustainable economic and safe [4], [13].

Smart grids must allow bidirectional energy flow and real-time communications capable of "self-remedy" and to allow rapid restoration from supply disruptions to facilitate market operations and ensure to consumer possibility of choice and to be informed [3], [12];

This is reason why the concept of smart grids will be a real challenge for all distribution system operators.

Characteristics of Smart grids are:

1. It integrates all power sources for all capacities, technologies and storage options.

2. It facilitates information and active participation of consumers and ensures their ability to choose their supplier.

3. It reduces the environmental impact of the whole power supply system.

4. Ensure quality of energy for all requirements.

5. Optimize asset utilization and efficient operation.

6. Provides improved levels in terms of reliability and safety in power supply.

7. Make possible new products, services and markets.

To achieve these objectives, power networks should become more "active", allowing the integration of new technologies. In future electricity generation system will have two components, namely centralized and distributed. Distributed generators can be aggregated and controlled so as to form micro-grids or virtual power plants that will facilitate their integration into physical and electricity market (Fig. 1).

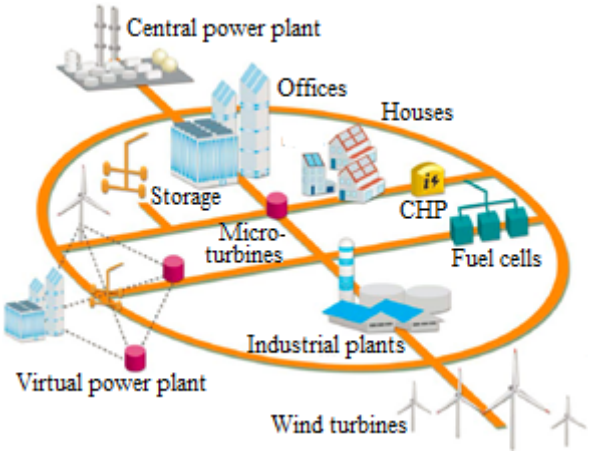

Fig. 1. Central and distributed power plants [11]

Operation of system will be shared between central and distributed generators. Control of distributed generators could be aggregated to form micro-grids or 'virtual' power plants to facilitate their integration both in the physical system and in the market [11].

A proportion of the electricity generated by large conventional plants will be displaced by distributed generation; renewable energy sources; demand response; demand side management; and energy storage [10], [11].

II. POWER PLANTS STRUCTURE

The proposed structure for the integration of renewable energy sources in a micro-smart grid is shown in Fig. 2.

This option allows the control connecting of power sources at a single network AC voltage whence are supplied directly to consumers.

The connecting/disconnecting of these sources are made via K_1 ... K_5 contactors, automatically controlled according to available energy consumers and energy needed.

The electricity excess from renewable sources is stored in batteries.

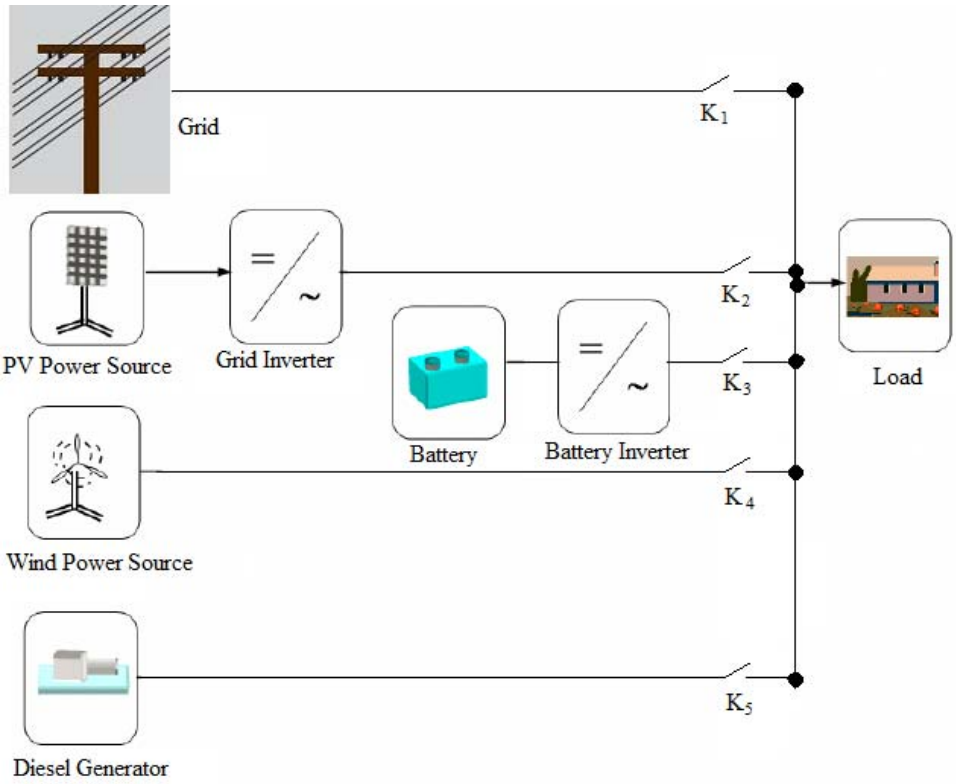

Fig. 2. The proposed principle scheme for the integration of renewable energy sources in a smart grid

Contactors of figure have the following meaning:
K_1- connecting the main source - power grid;
K_2- connecting the photovoltaic generator;
K3- connecting the batteries bank;
K4- connecting the wind generator;
K5- connecting the diesel generator.

The advantage of this solution is that the batteries can be recharged from any power sources. The battery inverter is bidirectional device, playing the role of inverter and rectifier.

III. MANAGEMENT AND CONTROL OF POWER SOURCES

A. Structure of management and control system for Power Sources

Advanced distribution automation concept refers to the distribution system management and to automation of distribution which across the whole distribution process control in order to optimization the distribution management exploitation.

Advanced distribution automation systems refer specifically to two terms:

- Distribution management system;
- Automation of distribution.

The command of contactors in the above proposed scheme as well as energy management is achieved using a control and management system based on intelligent microcontroller development systems or SCADA systems [1], [8].

Block diagram of the control system and energy management proposed is shown in Fig. 3.

The intelligent control and management of energy sources specific to the Smart Grid contains a basic set of functional blocks [9] (Fig. 3):

- Electrical energy sources - the main source (mains) and secondary sources (alternative energy sources - solar, wind, storage batteries, etc.);

- Power consumers;

- Smart Power distribution block, which is responsible both for the realization of commutations state to properly direct the flow of energy from sources to consumers and to obtain information on total energy distributed at a given moment to a consumer or another;

- a Central Unit with microprocessor that serves to control power distribution elements from composition of a block "Smart Power Distribution Block electrically" but the role of acquisition of electric units (voltage, current) and sending them to a data storage block;

- a computer for long term storage of the data of the Central Unit.

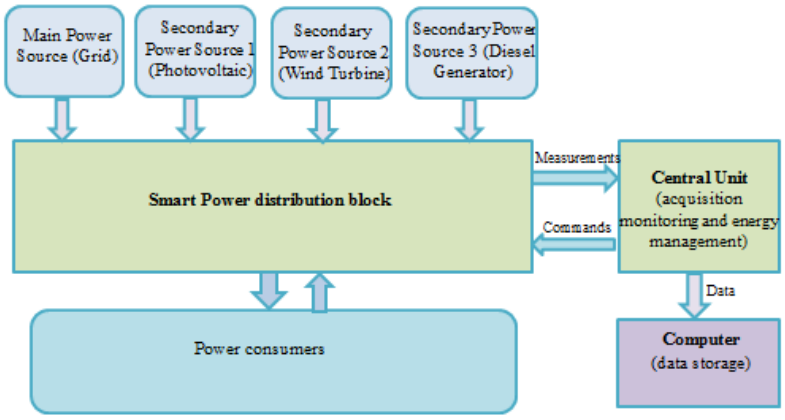

Fig. 3. The principle scheme of the Smart control and energy management system for Smart Grid

In this paragraph are shown fundamental aspects on control system for interconnection of energy sources in the Smart Grid [6], [7].

The starting point for the development of the model control system is the schematic block diagram shown in Fig. 4.

The main element which ensures the connection/disconnection control of energy sources is a microcontroller.

Command and control algorithm for connecting energy sources is based on the flowchart shown in Fig. 5.

The flowchart determines the order of connecting energy sources which supply the consumers.

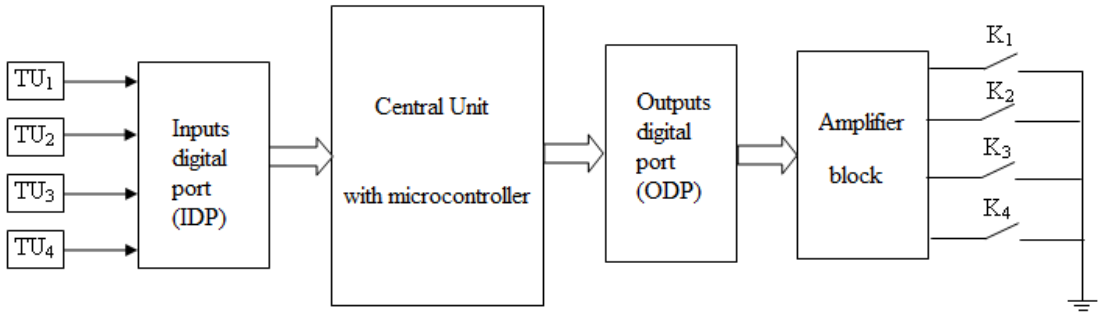

Fig. 4. The principle scheme of control system for power sources connection

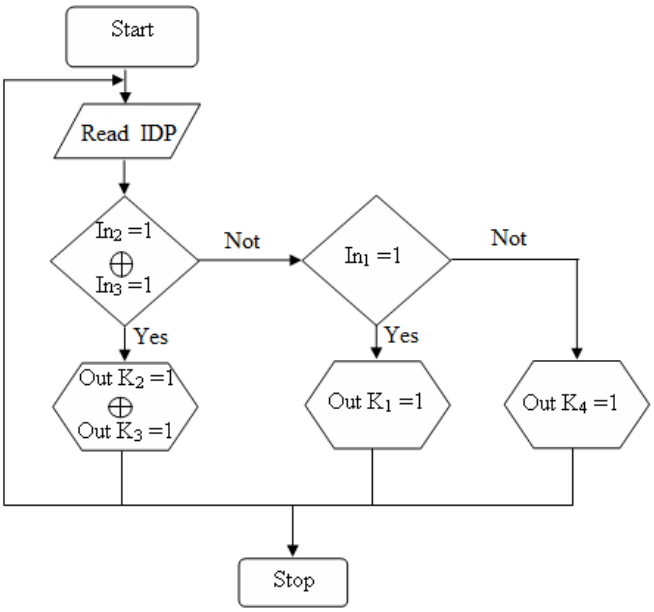

Fig. 5. The flowchart of control for connecting power sources

As shown in the schematic diagram (Fig. 4) the microcontroller inputs ($TU_1 \ldots TU_4$) are signals from the voltage transducers of energy sources. The analogue signals from transducers are converted into digital signals type "0" and "1" logic.

Is adopted such the following convention: if the value of voltage from transducers is more than 210 V, the microcontroller will interpret as a "1" logical; otherwise it will interpret as a "0" logical.

The Control protocol imposes that the renewable energy sources having priority (the wind power and photovoltaic power sources). If these do not produce energy or not produce enough energy to supply consumers, then consumers will be supplied from main power source (Power Grid Source). If the power grid is not available, then will automatically connect the diesel generator i.e. the backup power source.

Based on control flow chart the microcontroller program will be achieved.

B. Modeling and simulation of management and control system of Power Sources

Given the above, the next step is to implement in Matlab Simulink [14] the models and control algorithm above described.

The main structure of the control system developed in Simulink is shown in Fig. 6.

As shown in the figure, basic blocks of the Simulink model are: power sources; command and control system, represented by a block named "microcontroller"; contactors respectively, that connect the power sources to the grid of consumers.

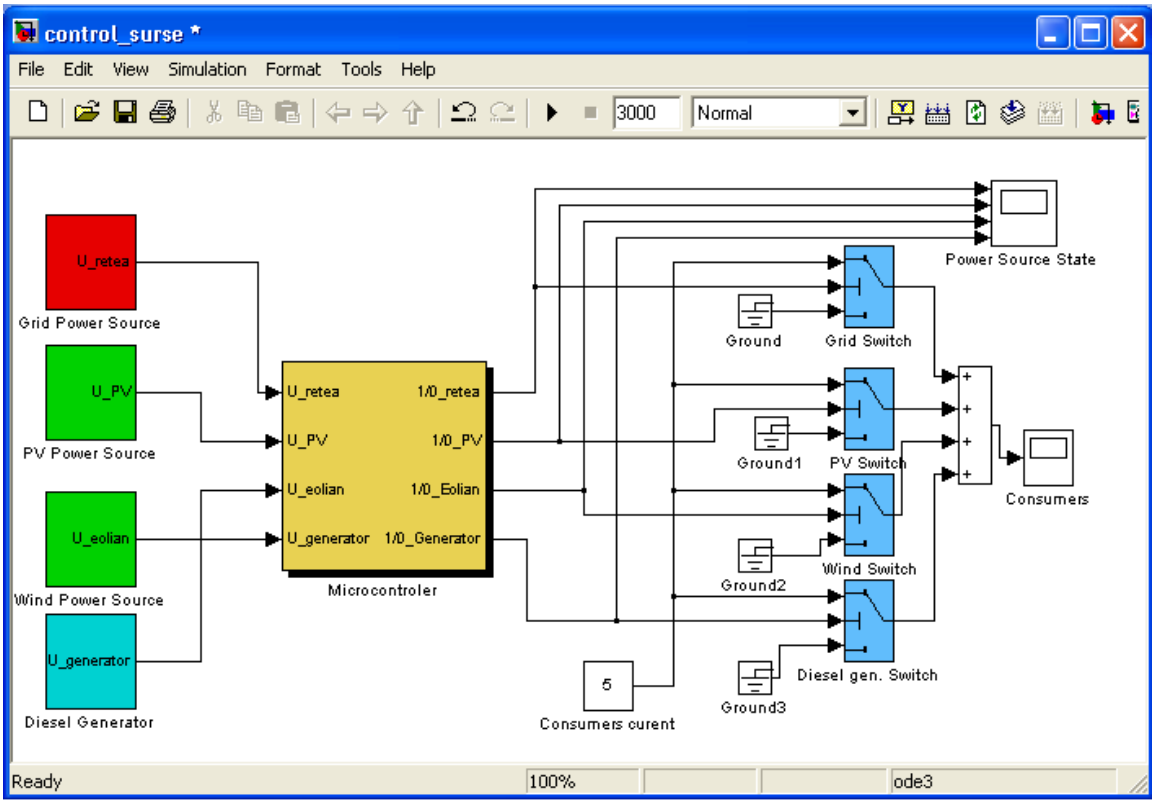

Fig. 6. The Simulink model of control system for power sources connection

As shown in Fig. 6, the main block that ensures the connecting control of power sources to Smart grid is the block type "microcontroller". The detailed Simulink model of this block is shown in Fig. 7.

One possibility for detecting the availability of power sources consists of measuring the time elapsed between two time points in which is exceed a certain threshold voltage threshold that is determined by calculating the minimum voltage peak value that is standardized (U_N-25%). One such equipment of lack tension detection allows the adjustment in order to achieve switching the power supply in times less than 10 ms. Besides identifying a lack of circuit voltage (effective value in this case is 0V) the algorithm allows and switching to lower its peak to peak value below a certain threshold.

The model has been designed to allow easy implementation, using a system based on a microcontroller with common resources, allowing its widespread implementation, without the need for substantial investments.

Was chose this method of detection because it is very easy of implement to a microcontroller structure and, moreover, does not require components with special features that are usually expensive.

In this case, the counter that is incremented between exceeding the threshold voltage can even be a timer of microcontroller. In addition, the increment of counter as well as the excess by a certain value by timer can be programmed as interrupt routine, which considerably simplifies firmware and gives safe operating.

Blocks of the four power sources (Grid Power, PV Power, Wind Power and Diesel Generator) were modelled with specific blocks of alternative voltage sources from the library SimPower Systems [14]. In Simulink model has been neglected the battery power source.

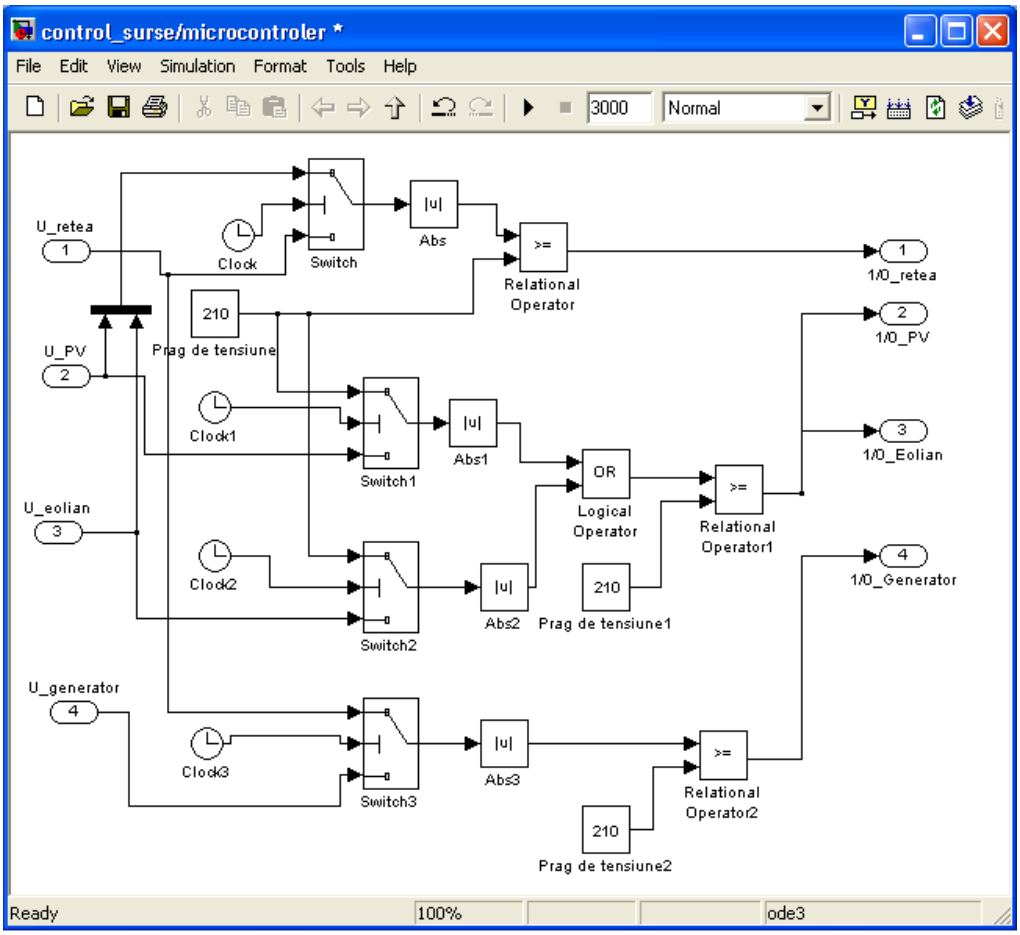

Fig. 7. Simulink model of microcontroller block

C. Simulation results

The simulation results are shown in Fig. 8 and 9.

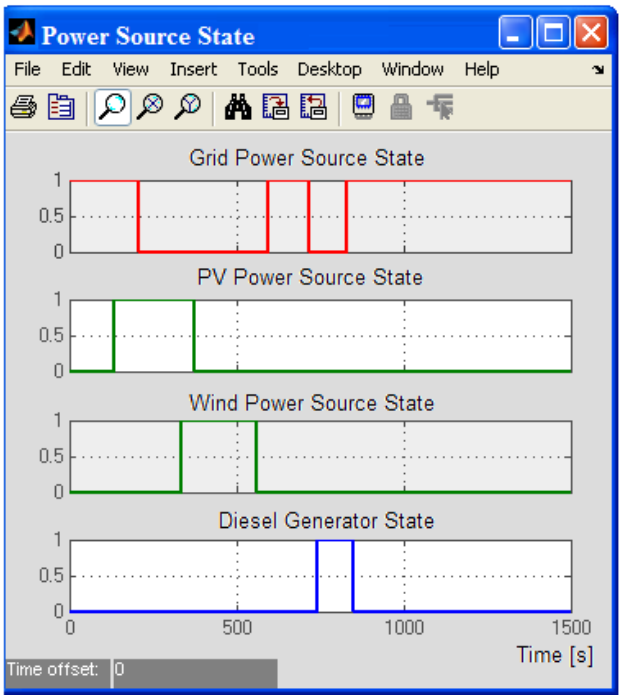

Fig. 8. Simulation results-state of power sources

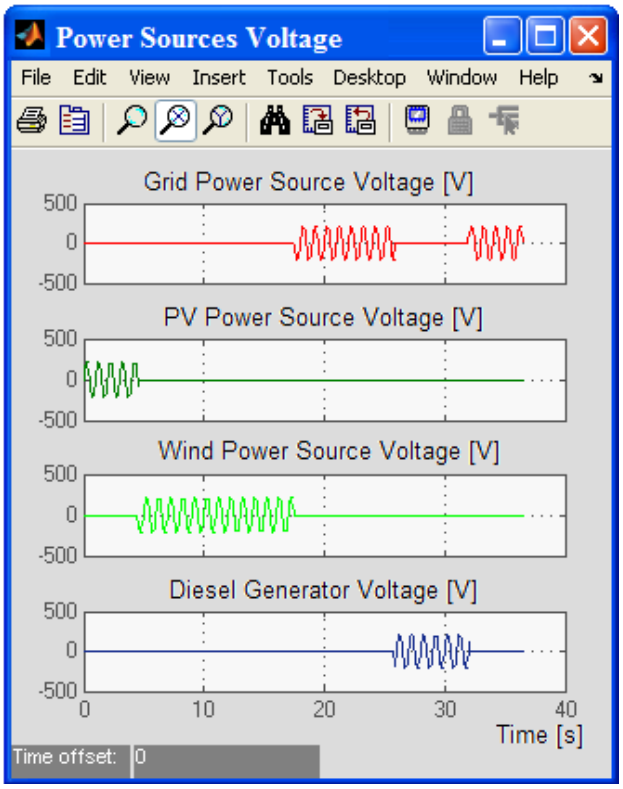

Fig. 9. Simulation results- voltage of power sources

Fig. 8 shows the status of power sources. The ″0″ state is that the power source is disconnected, and in the ″1″ state, power source is connected.

Fig. 9 highlights the voltages of power sources.

As seen in the first moment of the simulation is connected the PV power source. In next time is connected the wind power source and in the following time sequence, when these voltage is down, the grid power source is connected. To the disappearance of signal voltage of grid power, the diesel generator automatically connects and stays connected until the mains voltage reappearance.

IV. Implementation Of Management Energy System For Renewlable Energy Sources Integrated In A Micro Smart Grid

Energy management model shown above was implemented on a hybrid power system based on renewable energy sources existing at the Centre for Research in Electrical Engineering from the University of Craiova (INCESA). The equipment shown in Fig. 10 forms a hybrid electric power production system from renewable sources with maximkW.

Fig. 10. Hybrid power system: a) photovoltaic panels; b) wind turbine; c) diesel generator; d) grid inverter; e) battery bank an battery inverter; f) electric board; 1- contactors for power source connection (K_1 and K_2); 2- circuit breakers; indicator lamps for power sources status; enclosure connections.

The equipment included in this system furnishes the electricity to a Smart Grid with automatic performance The contactor K1 connects main grid to Smart grid and the contactor K2 connects renewable energy sources to Smart grid.

Principle control of the two contactors consists in evaluating the energy stored in the battery bank. Control voltage of contactors is 48Vcc, supplied voltage of batteries.

If the charge status of the batteries is below the 40%, the K2 contactor disconnects renewable energy sources from smart grid. Renewable power sources (photovoltaic and wind generator) in this case charge the batteries.

At this time the K1 contactor connects main grid to Smart Grid which is powered consumers.

If the battery charge state is over 80% and renewable energy sources furnishes energy, the contactor K2 is reconnected, and K1 is disconnected.

If renewables sources and the main grid are not available, the diesel generator automatically connects to the Smart Grid.

When main grid and renewable energy sources are available, the diesel generator is automatically disconnected due to connection of these sources of energy.

V. Conlusion

Smart grids of the future must be flexible, efficient, and reliable and ensure power supply safety. It must allow and capable to "auto remedy" and to ensure the rapid restoration of power, facilitate market operations and the possibility of informing consumers. Ensuring of these conditions is through by an advanced automation of power distribution and by new systems of integrated distribution management. In this paper has been presented the basic aspects to system of integrated distribution management.

The theoretical models proposed for energy management have been successfully implemented on a hybrid system of energy production based on renewable sources.

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