Algorithm for optimizing the lifetime of solar batteries and the energy consumption of a smart house

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Abstract. The increase in energy demand as well as the problems related to the environment are two main factors that push developing countries to focus their interest on the smart house. Their installation will allow to reduce greenhouse gas emissions, fight against global warming and save energy. Indeed, a smart grid must be instrumental in both setting up a good management of the decentralized production which provides a reliable electrical supply, and in organizing the storage of energy in batteries which are the weak point of a smart house installation. The modeled and simulated system represents the most reliable management method, using an algorithm that will improve the photovoltaic production, to minimize the use of the public grid in order to reduce the energy cost. This algorithm decreases the charge/discharge cycle of the battery, and increases their longevity. The coming further researches would allow the identification of useful parameters that increase the lifetime of solar batteries in order to solve the current smart house problem.

1. Introduction

Faced with the current environmental problems, the consumption of energy from renewable sources has become increasingly important. In fact, in recent years, there is a great interest in the so-called clean sources, given their use in various applications such as embedded applications, stationary and especially in microgrids, which is a concept that interests all countries in the world.

As defined, "the integration of decentralized energy resources, storage systems, electrical loads and the main distribution network through the common coupling point is called a microgrid". [1]

The smart house includes electrical production sources that are subject to the vagaries of the weather. To avoid these unpredictable events, a storage system can be integrated into the grid or/and connected to the public grid. The generated energy is either consumed on site or stored in batteries for later use during peak hours, depending on the energy management strategy applied in the middle of the system.

These management strategies are classified according to network autonomy as well as storage system integration:

- Micro network connected to the network without storage system [2]
- Micro network connected to the network with a storage system [3].
- Micro network not connected to the network (Isolated) without storage system [4]

In our topic, the presented microgrid is non autonomous. To meet the needs of consumers, we buy energy from the main grid during off-peak hours and in parallel the photovoltaic production will be stored in batteries to be used in peak hours. The objective is to find solutions that allow a good optimization of the energy management in order to optimize the exploitation of this local production.

The problem is to find a reliable algorithm that reacts from the components of the microgrid and allows a minimization of energy costs, while reducing the use of the public grid.

In addition, the charge of the battery can be regulated by a solar regulator, which should not exceed 90%, nor should it fall below 40%, because overcharging as well as discharging too deeply damages these batteries and decreases their lifespan. [5]

2. Methodology

The studied global microgrid is connected to the main electrical grid. It consists of a photovoltaic production system and a load. Moreover, to avoid the intermittency of the solar panels, the integration of batteries inside the system is mandatory. To cover the needs of the load

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without having access to the public grid during peak hours, and to reduce the amount of charge/discharge of the batteries a management strategy must be applied at the microgrid level.

In our case, we will implement an algorithm that will be inserted in the Chart block on the state flow logic tool using a simplified model of a microgrid in Matlab Simulink.

2.1 Description of the system

The stand-alone power system is a single-phase AC system, connected to the power grid via a transformer that lowers the voltage from 6.6 kV to 200 V. It consists of a photovoltaic generator (maximum power is 5 kW), a battery system with a total nominal capacity of 6936 Ah and is controlled by a batter controller. These two last components are DC power sources that are converted to single-phase AC. And finally, it consists of a load that is represented as three houses (maximum energy consumed is 2.5 KW) (see Fig. 1).

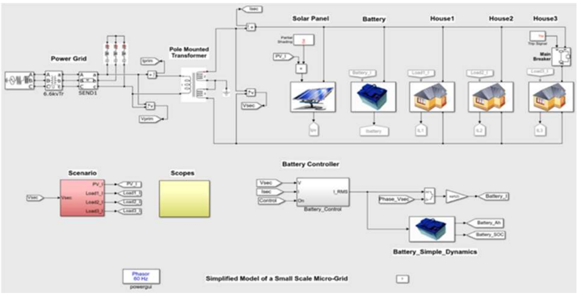

Fig. 1 Simplified model of a microgrid on Matlab/Simulink [6]

2.1.1 Simulation

Between 12 pm and 6 pm (off-peak hours), the load is fed by energy from the public grid because the energy cost during this period is reduced. At the same time, the energy produced by the solar system is stored in batteries to be consumed during the peak hours (from 12 am to 12 pm and from 6 pm to 12 am). During this time, the three houses reach a peak consumption of 6,500 W at 9 am, and 7,500 W at 7 pm and 10 pm. The photovoltaic production reaches the peak (5KW) from 2 pm to 3pm.

In addition, when there is excess to power in the system, this surplus will be injected into the main grid and the batteries are monitored by a battery controller to track their state of charge/discharge.

2.1.2 Modeling tool

The modeling tool used is the state diagram (see Fig. 2) which describes graphically the functioning of the system. To facilitate this, we used the flow chart which is a graphic representation of the functioning of a process allowing the visualization of a set of steps (see Fig. 3). Its purpose is to minimize access to the public power grid as well as to extend the life of the batteries. To achieve these goals, we will modify the minimum state of charge (SOCmin) parameter until a reliable result is obtained.

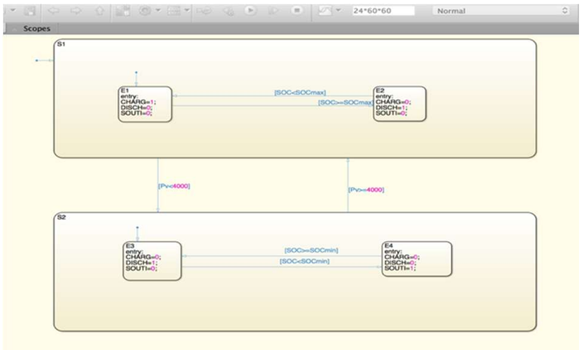

Fig. 2. System status diagram.

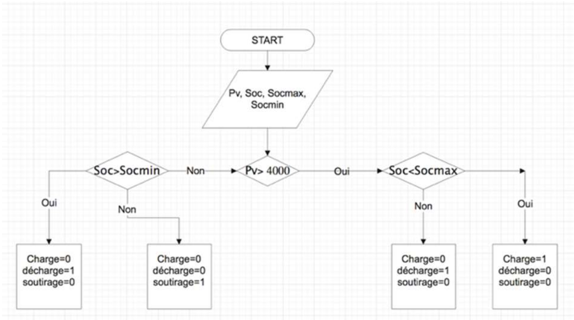

Fig. 3. The flowchart of the proposed optimized system

With

- Pv: photovoltaic production
- Soc: the state of charge of the battery
- Socmax: the maximum state of charge of the battery
- Socmin: the minimum state of charge of the battery
- 4000: From this power value the photovoltaic production starts to reach its maximum up to 5000W

In our algorithm, we have first the case where the photovoltaic production is higher than 4000 W (Pv>=4000 W). Before charging the batteries, we have to check if the state of charge of the batteries is lower than the maximum state of charge, if it is the case, the charging action (CHARG) is going to be activated, if not, the discharging action of the batteries is going to be launched, that is to say that the need of the consumers is going to be covered with the help of the storage system.

In case Pv < 4000 W, the load consumes the energy coming from the batteries, but first it is necessary to check if their state of charge is higher than the minimum state of charge, if it is the case, the discharging action (DISCH) will be activated, if not, the drawing action (SOUTI) from the network will be launched.

2.1.3 Experimentation

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The studied microgrid contains a photovoltaic system that reaches a maximum power of 5 KW, a battery system with a total nominal capacity of 6963 Ah and three houses that consume a maximum energy of 2.5 KW. The maximum state of charge is set at a value of 80%. For letting the minimum state of charge will take five different values, later on, it will be fixed in a threshold that allows a minimization of the energetic cost as well as the decrease of the number of cycle of the battery that is directly related to the depth of discharge. Indeed, the more deeply a battery is discharged, the shorter will be the life span of this battery.

Indeed, beyond 72%, we will have two drawdown cycles during the same period, which is not the purpose of our work.

2.1.4 Results

In order to understand the behavior of the battery, different values of the minimum state of charge will be simulated, in a way, to observe the time of withdrawal of electrical energy from the main grid that the load does, as well as the number of cycles inside the smart house (see Fig. 4,5,6,7).

- Socmin=55%:

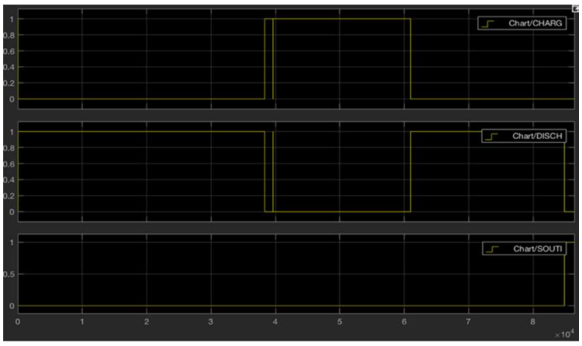

Fig. 4. The charge withdrawal time and the number of charge/discharge cycles of the battery in the case where SOCmin=55%.

- Socmin=60%:

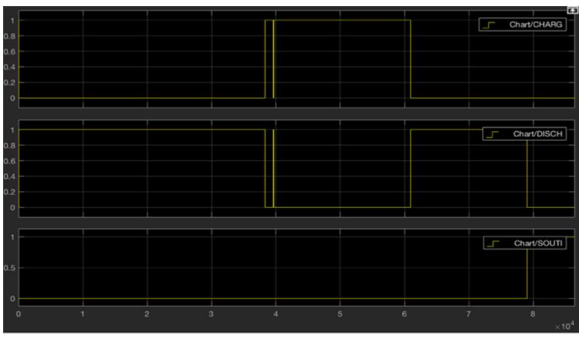

Fig. 4. The charge withdrawal time and the number of charge/discharge cycles of the battery in the case where SOCmin=60%.

- Socmin=65%:

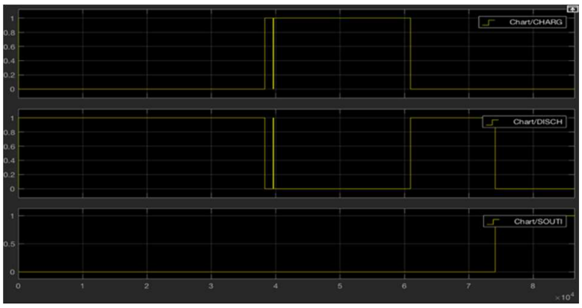

Fig. 6. The charge withdrawal time and the number of charge/discharge cycles of the battery in the case where SOCmin=65%.

- Socmin=70%:

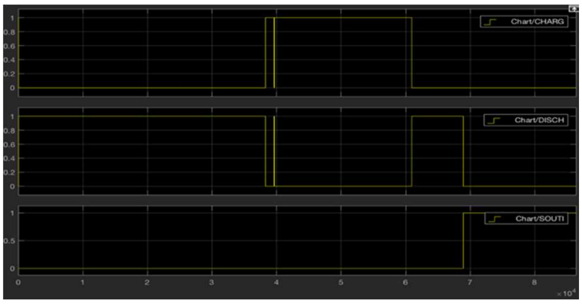

Fig. 7. The charge withdrawal time and the number of charge/discharge cycles of the battery in the case where SOCmin=70%.

After plotting the withdrawal time (Ts) versus the minimum state of charge (SOCmin) (see Fig. 8).

Table1. Minimum state of charge as a function of withdrawal time

Socmin	Ts(s)
55	1725,773
60	7515,464
65	12414,433
70	17536,082

After plotting the withdrawal time (Ts) versus the minimum state of charge (SOCmin) (see Fig. 8).

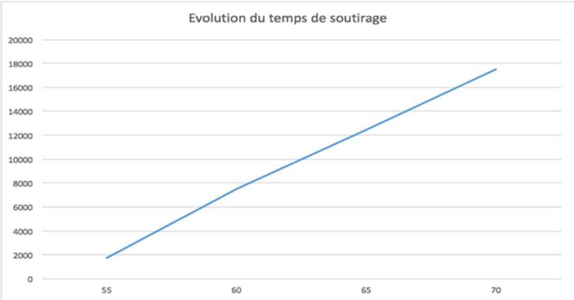

Fig. 8. Evolution of the withdrawal time as a function of the minimum state of charge

2.1.5 2.1.5 Discussion of the results

Analysis of Figure 8 and Table 1 reveals that the drawdown time that the load takes when consuming energy from the public grid sets the minimum state of charge of a solar battery to be the minimum time at drawdown. This increases the battery's lifetime, which partially confirms the hypothesis of this work.

3 Conclusion

In conclusion, the results of this paper show that as the minimum state of charge increases, the drawdown time also increases. This allowed to set the percentage of battery discharge to an optimal value of 55%, which guarantees a longer life of the battery. They also show the optimization of photovoltaic production, which is stored in batteries during peak hours for later use during off-peak hours.

Indeed, the proposed algorithm can be applied in several smart grids that include wind generation or any other renewable generator.

Within the framework of a 'green' growth, electric cars can be used as a means of energy storage during the night at home while respecting the peak and off-peak hours in order to remain in the same objective of decreasing the energy cost.

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