

USAGE OF ACCUMULATION TO SUSTAIN THE DAILY DIAGRAM OF ELECTRICITY PRODUCTION IN PHOTOVOLTAIC POWER PLANT

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Abstract

The output of each photovoltaic or wind power plant is very depended on the actual atmospheric condition. These causes, that the output power varies many times in huge range. These rapid variations have some significant side effects to the quality of electricity, such as voltage variation, switching of tap changers, etc. In the other case, these variations also make the difference between the prediction and real electricity production. Generally, the goal of the accumulation of electricity, is to charge the storage element in surplus of electricity and discharge when the energy is insufficient. In this paper, the accumulation of electricity in photovoltaic power plant is not used for this purpose, but to charge and discharge the storage element with respect to the prediction of electricity. The main usage of such controller of storage element is to sustain the output power in photovoltaic power plant at the predicted value.

1 Network model - IEEE 37 Node Test Feeder

For the simulation of a storage element operation, the IEEE37 test feeder model was used. It is a part of 4.8kV distribution network feed from Transformer 230/4.8kV, 2500kVA. Some of the properties of this model were changed. In the node 725, the load was replaced with the photovoltaic power plant including the battery as a storage element. The voltage regulator at the feeder transformer was eliminated. The network topology with the place of photovoltaic power plant is displayed on the figure (Fig. 1).

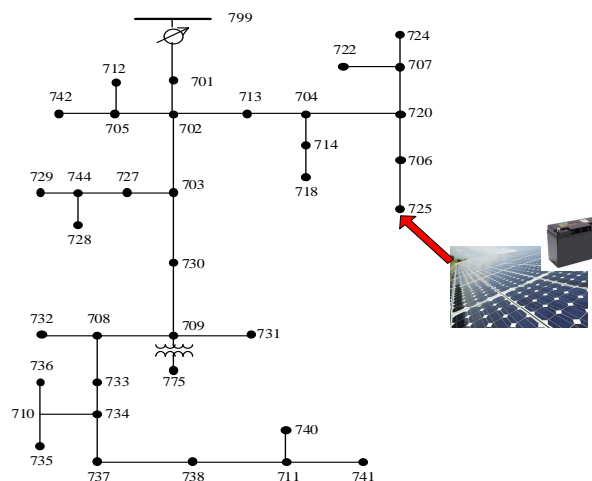


Figure 1: IEEE 37 test feeder with photovoltaic power plant

All the other nodal loads are balanced with the same load shape multiplication factor. This load shape curve defines the variation in p.u. of the loads during the weekly simulation (Fig. 2).

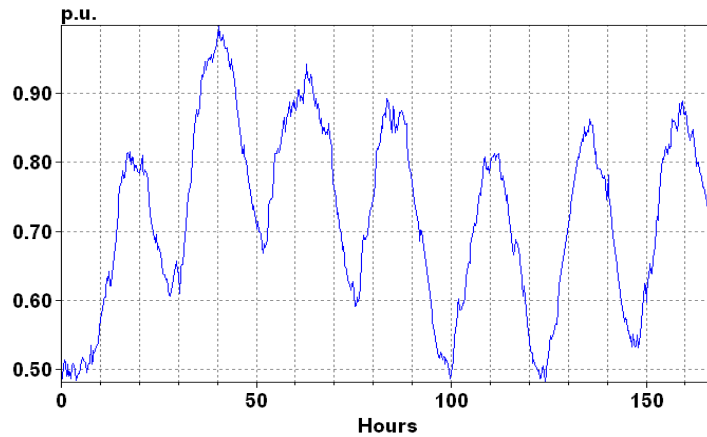


Figure 2: weekly load shape multiplier

2 Prediction of electricity production in photovoltaic power plant

The prediction in photovoltaic power plant is based on real photovoltaic power plant (PtP) parameters. The long time prediction is calculated using the program PVGIS (Photovoltaic Geographical Information System) with the meteorological condition typical for that place, where the PtP operates. The parameters of the PtP are:

- Installed power: 950kWp
- PV Technology: crystalline silicon
- Type of construction: stationary system
- Module inclination: 36° (optimal)
- Module orientation: -1° (optimal)
- Estimated losses due to temperature: 7.2%
- Estimated loss due to angular reflectance effects: 2.8%
- Other losses (cables, inverter etc.): 14.0%
- Combined PV system losses: 24.0%

Prediction of the electricity production in PtP is calculated for cloudy and clear sky. This is due to demonstrate, how the precision of electricity prediction can affects the designing of such accumulation system.

3 Storage controller operation

The operation of battery within the photovoltaic power plant is demonstrated on the weekly simulation. To control the dispatch mode of battery, the controller communicates with the OpenDSS and PVGIS software. The algorithm of battery controller was developed in Matlab software. The load flow calculation for each time step is executed by the OpenDSS software. OpenDSS also includes the network topology, loads, PtP, properties of power devices, etc. The concept of communication between Matlab, OpenDSS and PVGIS software is shown on the figure (Fig. 3)

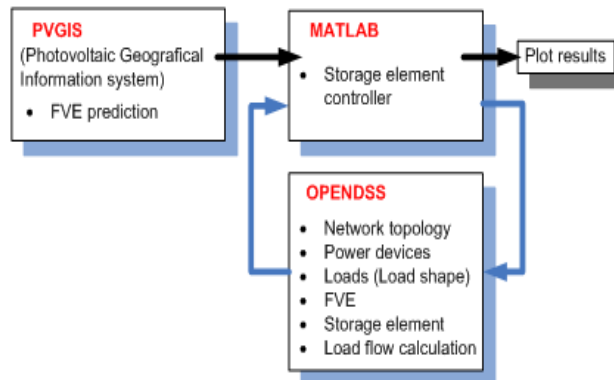


Figure 3: concept of controller communication

The battery controller ensures the charging and discharging commands for the battery with respect to the prediction values from PVGIS and the real production. The controller evaluates also the required amount of power for dispatch. Dispatch commands and the required power of battery for both states (charge and discharge state) are calculated by algorithm shown on the figure (Fig. 4). The controller calculates the required output power and sends the commands to charge and discharge the battery to keep the output power of PTP for each period at or near to the predicted value. The controller operation was simulated with the 350kWh battery capacity ($kWh_{reserve} = 1\%$).

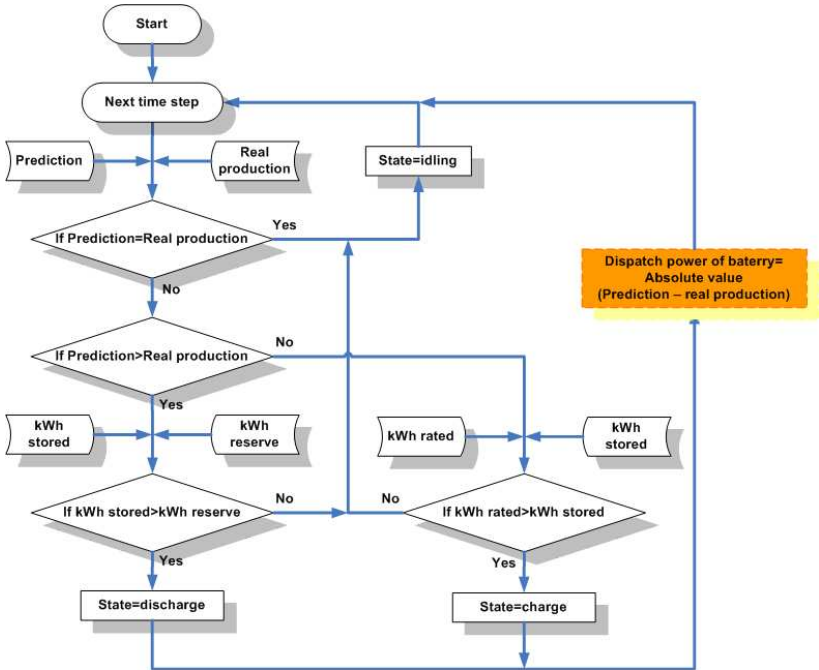


Figure 4: The algorithm of storage controller

The battery executes the discharge command, until the present amount of stored energy is greater than kWhreserve value. The battery will only take charge when the present amount of stored energy is less than rated storage capacity (kWhRated). The basic concept of battery is shown on the following figure (Fig. 5)

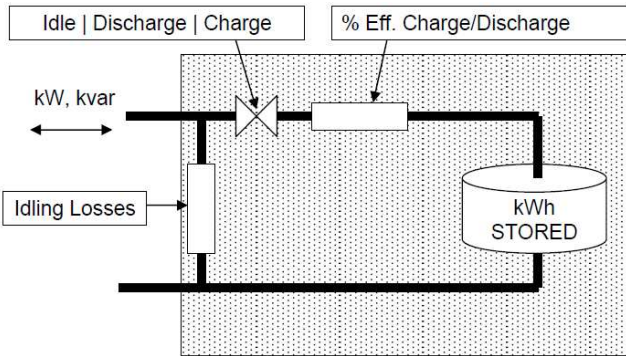


Figure 5: Basic concept of battery

4 Controller simulation results

Operation of the controller was simulated in both conditions with respect to the prediction for cloudy and clear sky. The next figures (Fig. 4, Fig. 5, Fig. 6, Fig. 7) show the weekly simulation results of the real production in PtP measured at its output terminal, the power supplied to network with the 350kWh battery and the predicted values ($kWh_{reserve} = 1\%$). The charge and discharge cycles of battery and the kWh stored value are also displayed to show the present lack of stored energy.

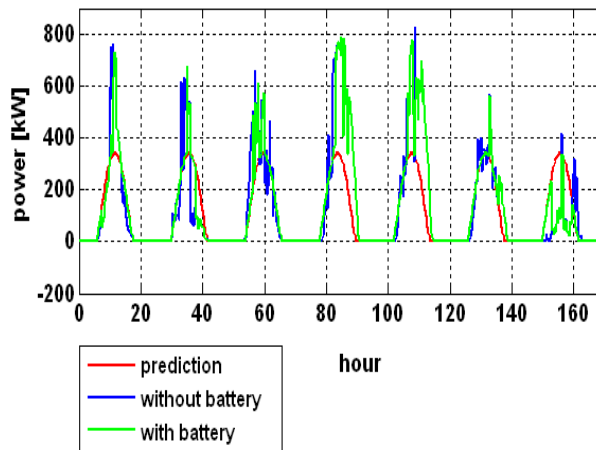


Figure 4: simulation results of storage controller operation with cloudy sky

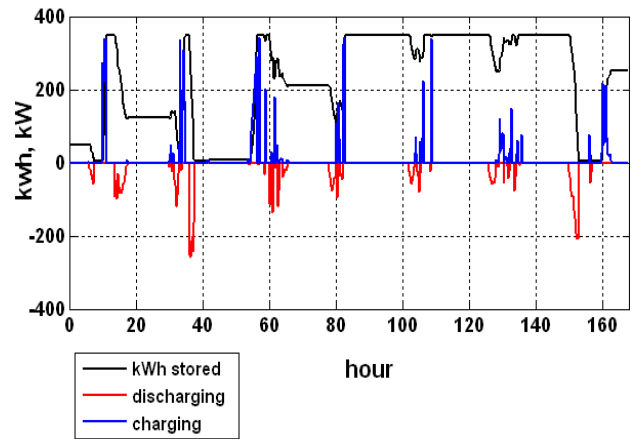


Figure 5: Battery cycles with cloudy sky

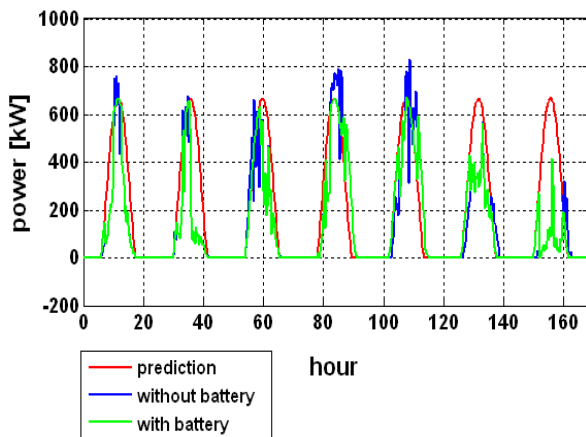


Figure 6: simulation results of storage controller operation with clear sky

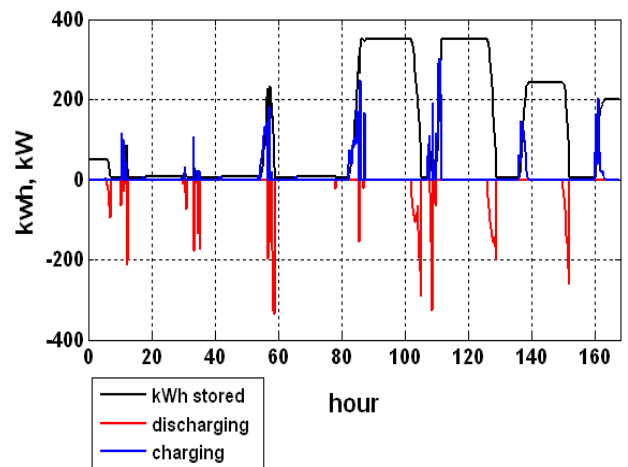


Figure 7: Battery cycles with clear sky

The next figure (Fig. 8) shows detailed power curves for one day to understand the controller algorithm and to see the differences between the particular curves. During the first part of the day, the battery was able to keep the output power of PtP on the predicted value.

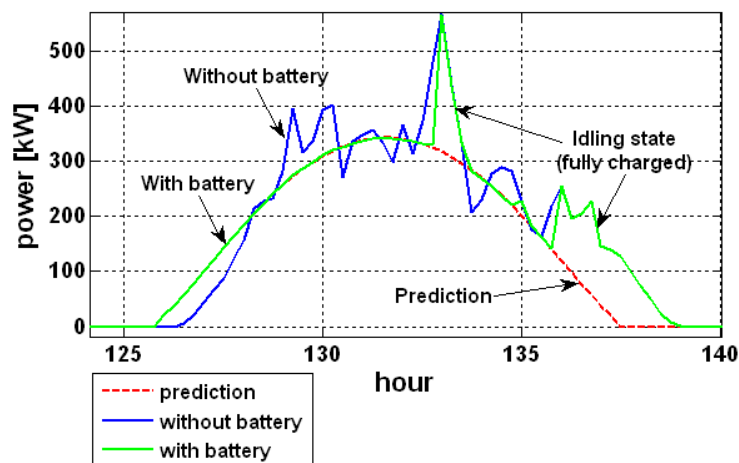


Figure 8: one day simulation results

It is possible to see, that if the stored energy is insufficient, or the battery is fully charged, the battery switch to idling state and the curves have the same shape. If the lack of stored energy allows to

charge and discharge battery, the real power supplied to the network from PtP is equal to prediction. Next figure (Fig. 9) shows the total absolute value of deviation after one week. This deviation is calculated as a sum of the absolute values between the real production with battery and the prediction after one week for each time step. This deviation is evaluated for four different capacities of battery.

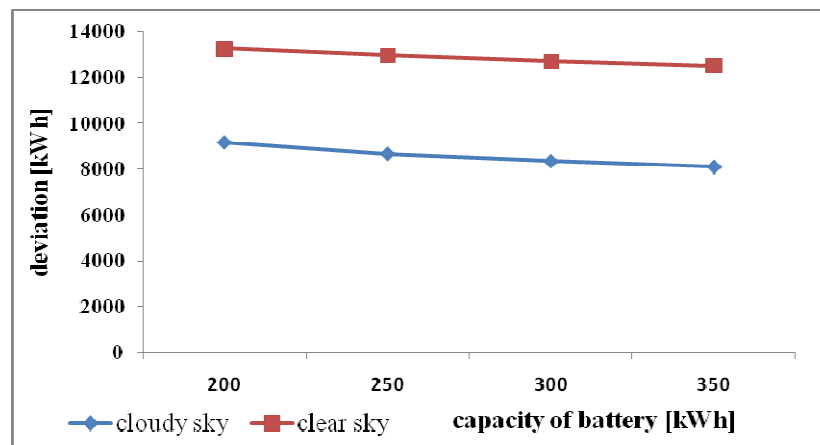


Figure 9: total weekly deviation

If the controller dispatches the battery with respect to the prediction calculated for cloudy sky, the total deviation is much better. Increasing the stored capacity doesn't change significantly the total deviation.

5 Conclusion

The controller operation based on the algorithm ensures that the battery sustains the daily diagram of production at or near to the predicted values. In this paper, the controller operation was simulated with one photovoltaic power plant in one week duration. This concept with Matlab, OpenDSS and PVGIS usage can be used for assessment and development of accumulation systems in more complicated systems, such controlling the accumulation within the smart grids, yearly simulations with several photovoltaic power plants including the synergy effect in decentralized production, etc. The simulations of battery controller demonstrate also the importance of electricity prediction in the term of accumulation of energy.

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