DESIGN CONSIDERATIONS ON PEAK POWER CLIPPING THRESHOLDS IN MICROGRIDS

Thorsten Vogt[1], Norbert Fröhleke[1], Joachim Böcker[1], Stefan Kempen[2]
1. Power Electronics and Electrical Drives, University of Paderborn, 33095 Paderborn, Germany
2. AEG Power Solutions GmbH, 59581 Warstein-Belecke, Germany

ABSTRACT

One goal of grid coupled microgrid operating strategies is to reduce the maximum power drawn from the utility grid. This kind of operating strategy is called e.g. "peak load shaving", "peak power reduction" or just "peak shaving" and is applied to diverse applications and systems. This paper presents a method to determine the dependence between the maximum residual power and the respective required energy. Applied to operational strategies, this approach facilitates to find a plausible threshold for the peak power reduction. This method is broadly applicable to similar applications, e.g. for peak-shaving of PV power to limit the maximum feed-in power into the grid.

1. INTRODUCTION

Peak power reduction of microgrids provides different advantages as e.g. cost reduction for the microgrid owner, easy integration into the utility grid and less losses in the utility grid [1]-[3]. The peak power of interest occur at the point of common coupling (PCC) because the power at this point is the power which is drawn from the utility grid and causes costs and potential problems in the utility grid. Fig. 1 shows an abstracted structure of a microgrid and its point of common coupling.

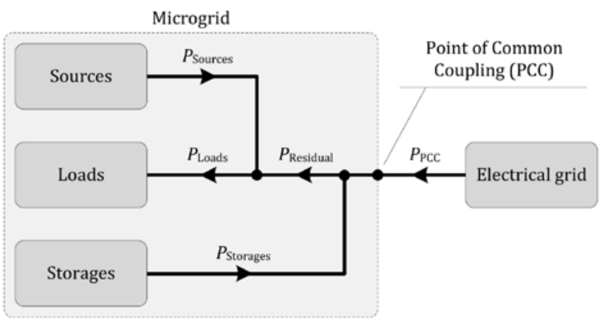

Fig. 1 Block diagram of a grid coupled microgrid

The considerations of peak power reduction are typically based on at least one threshold P_T. If the considered power exceeds or falls below this threshold the storage gets the command of charging or discharging. Although this threshold can decide on success or failure of the operating strategy goals, the determination of the thresholds are often treated only superficially and it is more focused on the methods to achieve the objectives as e.g. in [4] or [5]. Fig. 2 shows the consequences of an improper choice of this threshold. On the left side, peak power reduction to the threshold requires more power than the maximum power of the storage system. On the right side, the storage discharge limit is reached during peak power reduction. Especially the second case is problematic because in such a case the intended peak reduction is maybe not achieved at all.

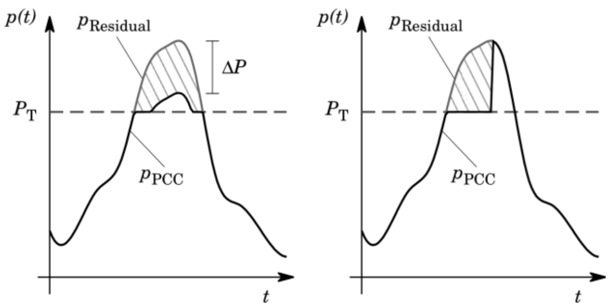

Fig. 2 Consequences of an improper choice of the threshold P_T (left: power limit, right: energy limit)

2. THRESHOLD DETERMINATION

2.1 Problems of Empirical Methods

The use of an empirical rule to determine the threshold, like "*the threshold is to be chosen to 80% of the historical maximum power peak*", is coupled with several problems. On the one hand side, the inclusion of storage system properties is problematic. On the other hand, assuming a daily potential peak power, it can be shown that neither the daily total required energy nor the peak power itself are adequate indicators to choose the threshold. Therefore, such rules cannot generally be applied in order to achieve a high utilization of the storage system.

2.2 Proposed Method

Basis of the proposed method in order to determine a plausible threshold, based on measured power curves and specific storage system properties, is a calculation algorithm (Fig. 3). This algorithm determines the energy flow $E_{Storage}$ for the given input data set in order to achieve the threshold level P_T. The maximum of this energy flow indicates the minimum required usable energy capacity of the storage E_{Req}. With the one-sided limited integrator ensures the algorithm the recharge restriction $E_{Storage} \in [0, \infty]$ so that only the already needed energy can be recharged. The algorithm involves charge and discharge efficiencies (η_C, η_D) and the charge power limitation of the storage system. The minimum required discharge power of the storage system results from the maximum of $P_{D\text{-}Storage}$.

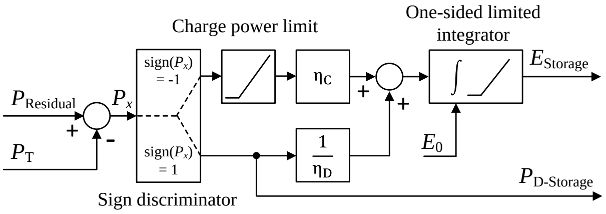

Fig. 3 Basic algorithm structure in order to calculate the necessary storage energy flow to achieve a given threshold

Repeating this calculation for a range of thresholds allows determining the relationship between the threshold and the required usable energy storage capacity, related to the individually data set and storage properties.

2.3 Exemplary Results

For exemplary results, the method is applied for the described microgrid application. Therefore the residual power over one year (Fig. 4) is used as input data.

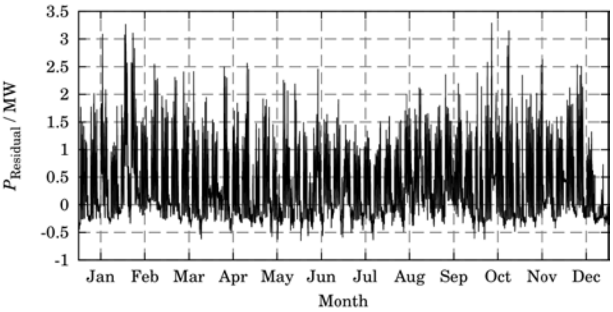

Fig. 4 Exemplary microgrid residual power curve

The calculation is executed with different storage system efficiencies. The resultant diagram (Fig. 5) shows the relationship between the power threshold level and the necessary usable energy capacity based on the dataset. An exemplary statement could be "*based on the given input data, the reduction of the residual power peak from 3.3 MW to 2.8 MW, requires at least 0.5 MWh usable energy storage capacity of a storage with the efficiencies of* $\eta_C = 0.6$ *and* $\eta_D = 0.8$". The choice of a safety margin depends on the validity of the given input data and can be include by scaling the residual power.

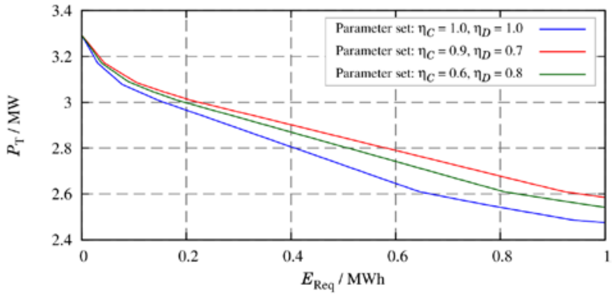

Fig. 5 Relationship between the power threshold level and the necessary usable energy capacity

3. CONCLUSION

The presented method provides the calculation of the individual relationship between a peak shaving threshold and the respective required usable energy storage capacity. This relationship can be directly used to choose a threshold for a given storage (also readjust when storage capacity reduces over time), or further processed to design a storage system including economic information. The methodology is transferable for similar applications, e.g. for PV peak power shaving.

4. ACKNOWLEDGEMENT

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REFERENCES

[1] R.J, Kerestes, G.F. Reed, A.R. Sparacino, "Economic analysis of grid level energy storage for the application of load leveling", *IEEE Power and Energy Society General Meeting, 2012*.

[2] R.A. Huggins, "Energy Storage", *Springer Scince+Business Media, LLC, New York, 2010*.

[3] I. Papic, "Simulation model for discharging a lead-acid battery energy storage system for load leveling", *IEEE Transactions on Energy Conversion (Volume:21 , Issue: 2) , 2006*.

[4] T.H. Mehr, M.A.S. Masoum, N. Jabalameli, "Grid-connected Lithium-ion battery energy storage system for load leveling and peak shaving", *Power Engineering Conference (AUPEC), 2013*.

[5] B. Aksanli, T. Rosing, E. Pettis, "Architecting Efficient Peak Power Shaving Using Batteries in Data Centers", *IEEE 21st International Symposium on MASCOTS*, 2013.