# SMART POWER APPLICATIONS AND PEAK LOAD MANAGEMENT IN DISTRIBUTION NETWORKS WITH ENERGY STORAGE SOLUTIONS

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## ABSTRACT.

*The paper presents the study results regarding the possibility of using energy storage solutions in distribution networks. The paper will give an overview concerning different possible applications of Energy Storage and the resulting benefits for customers.*

## INTRODUCTION

The following problems of existing and possible future distribution networks bear quite significant potential for optimization, from a technical as well as from an economical point of view.

### Security of supply and maximum peak loads

A major design problem of existing distribution networks is that in order to secure the power supply, networks need to be designed for the maximum possible peak loads. This results in expensive distribution network infrastructures whose full capacity is utilized during relatively short peak times only.
Additionally, the cost prices for peak load generation are in general way more expensive than for base load.
Considering those two expensive effects of peak loads, the economical improvements resulting from smart peak load management are quite significant.
From a technical point of view those improvements can only get achieved by peak load management close to the load, hence close to the electrical consumers.

### Renewable power generation

Additionally more and more renewable sources are getting connected to power distribution networks. Depending on the weather, energy production of renewable sources like solar and wind power vary heavily and randomly over time. This complicates the requirements to balance power generation and power consumption and limits the utilization of such renewable energy sources in distribution networks.
As a consequence of the statistical availability of renewable energy resources, conventional power plants have to be available in standby in order to deliver missing renewable energy.
The resulting effect is that energy costs in general and costs for customers with high peak power requirements are rising.
Apart from higher costs for security of supply, there are various effects of increasing renewable power generation on power quality in general.
Most existing grids are not able to cope with more than 20% to 30% of renewable generation like wind and solar power. From a technical point of view, more renewable generation would only be possible if the problems for security of supply and power quality could get improved close to those renewable sources.

### Challenges of future electricity distribution

Figure 1 shows a principal idea of the future electricity network. Power generation will become more decentralized and will get evenly spread over the different voltage levels. Load flow between transmission-, distribution- and end consumer level will become bi-directional. There will also be an increasing number of individual decoupled networks with own electricity production (mainly renewable sources), using the grid as a back up power supply only. Again the mismatch between power generation and consumption will need to get managed on the lower distribution level.

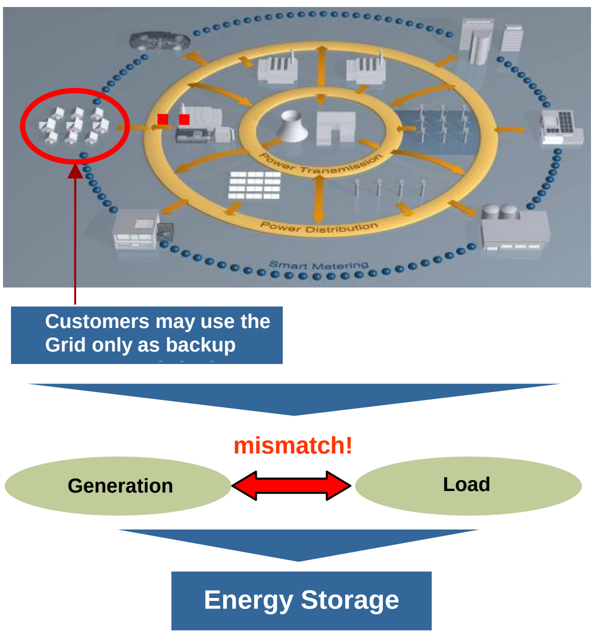


**Figure 1:** Challenge of future distribution networks

## ENERGY STORAGE SOLUTIONS CONCEPTS

In order to address the problems and challenges described above, new concepts are investigated, in which modern converter technology for network applications is combined with new high power battery technology.

## Components and Concepts

In the study, an integrated energy storage system based on 2-level converter technology as well as modular multi-level converter technology, both combined with Li-Ion batteries has been investigated.
Figure 2 shows the 2-level system and its components in principal.
Apart from the batteries, most components of the 2-level system are standard components available on the market. However, the successful integration of electrical storage into distribution grids requires a combination of application related know how, capabilities and experience regarding network design, storage system (incl. power electronics) and implementation as turn key solution projects.

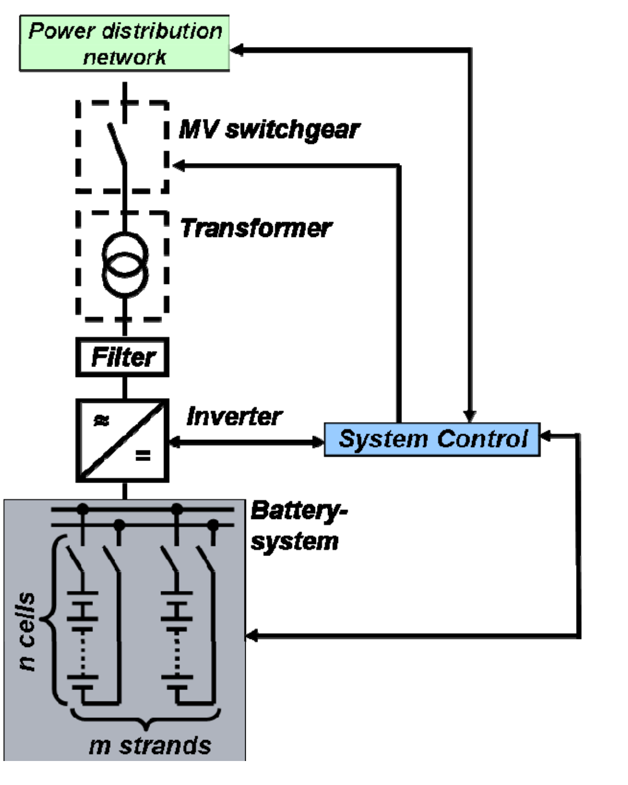


**Figure 2:** Energy Storage with batteries - components

### High Power Lithium Ion (Li-Ion) Batteries

The energy storage solution concepts investigated are based on new types of Li-Ion batteries. Li-Ion batteries have a number of advantages which enable the high-power applications described further below. Li-Ion batteries can get constantly charged and discharged with high currents. Their C-rate is in average 2 to 4 times higher than the one of other existing battery technologies. The energy density of Li-Ion batteries is very high. This results in relatively small footprints of energy storage solutions. Figure 3 shows typical dimensions and size of one modern Li-Ion cell. Depending on the chemistry chosen, such cell can have a single capacity of up to 50 Ah. Serial and parallel connections of those cells enable to size the battery system in terms of power and storage capacity as per the individual application specific requirements.

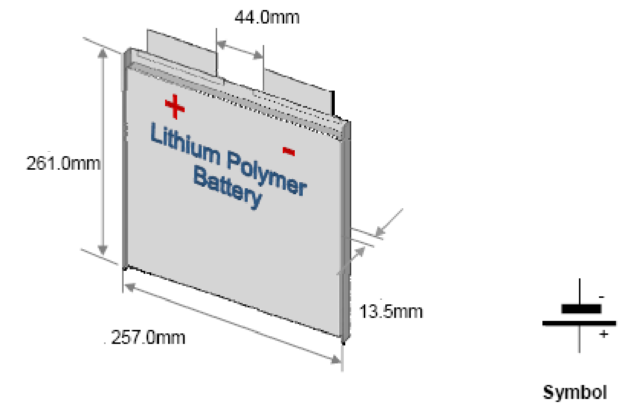


**Figure 3:** E.g.:Lithium Polymer Batteries with up to 50 Ah

Li-Ion Batteries can get recycled and are ecologically friendly. They have an insignificant self-discharge and no „Memory-Effect“. Compared to other battery technologies they have a deep discharge capacity which allows to use most of the capacity installed in the system. The ideal operating ambient temperature for those batteries is 30°C to 40°C which is easy to handle within electrical buildings. Disadvantages are that cycle-life time and the prices still need to improve in order to grow the number of economically reasonable use cases for energy storage systems based on Li-Ion batteries. However the latest development of those two key performance indicators are pointing into a positive direction.

### Converter Concepts

Initial studies have shown that for energy storage sizes up to approx. 1 MWh capacity and 4 MVA power capability, a system based on standard 2-level converter technology is feasible from a technical as well as an economical point of view. For bigger sizes, an energy storage system based on advanced modular multi-level converter technology seems to be more suitable.

## Energy Storage System and Sizes

The resulting environmental friendly energy storage solution portfolio enables all kinds of smart power applications in distribution networks. Some of those are described further below.
The energy storage solution portfolio based on Li-Ion batteries is of a modular type and proposed to cover storage systems in the range from 100 kWp up to approx. 20 MWp with capacities of 25 kWh up to approx. 5 MWh. The systems fast reaction time [within ms] and a good round trip efficiency [>75%] provides additional benefits.
Resulting from Li-Ion batteries' high energy density and

due to a modular system approach shown in Figure 4, such energy storage system can become quite compact.
Example: An energy storage solution based on Li-Ion technology, capable to provide 1,5 MW for 30 min would fit into a container of approx. 20 m x 3,5 m x 3,5 m (L x H x D).
Using modern converter technology especially designed for network applications, additional system functions like reactive power compensation, black start capability and active harmonic filtering (within a limited frequency range) are available.

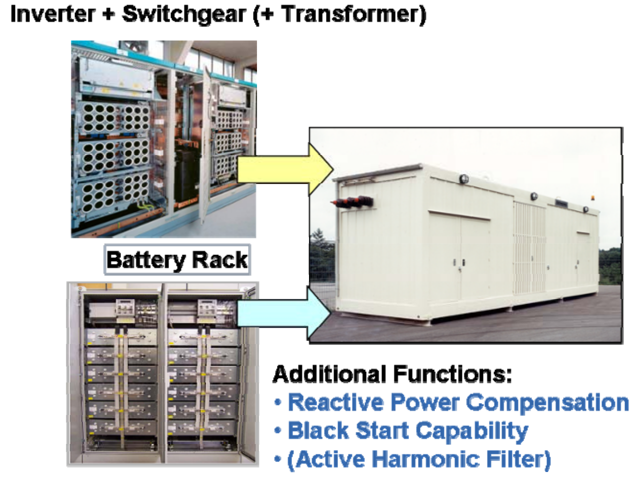


**Figure 4:** Containerized Energy Storage Solution

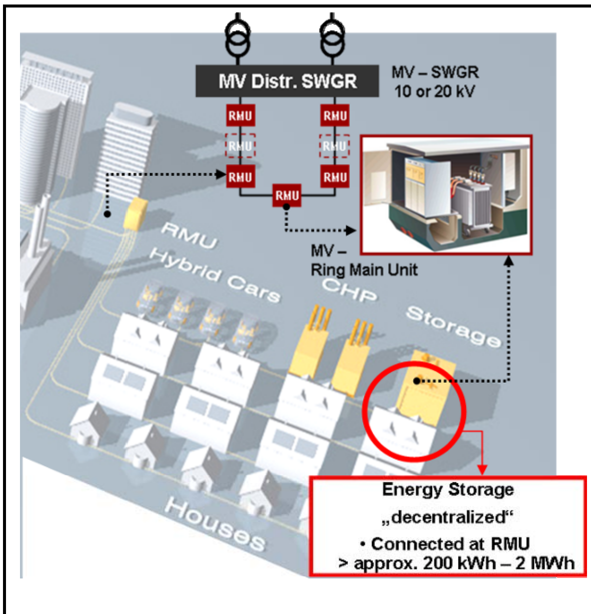


**Figure 5:** "Decentralized" Energy Storage

Figure 5 shows a typical decentralized installation: The energy storage is connected to a medium voltage ring-main-unit at a 10 or 20 kV distribution network. The study has shown that most "decentralized" applications require energy storage sizes in the range of 200 kWh to 2 MWh.

## APPLICATIONS AND BENEFITS

The following applications have been found suitable for the energy storage solution portfolio based on Li-Ion batteries:

### Peak Shaving

The focuses of this application are small distribution networks in the form of bigger size industrial networks or small utility-/city distribution networks. Using electrical energy stored during times of low demand (e.g. night times) load peaks are getting compensated during times of peak demand (see figure 6). This reduces the requirements regarding the design of distribution networks for peak demands and the related costs for installation as well as for peak load consumption. The Lithium-Ion technology is beneficial especially to provide high power during short time due to its high C-rate capability.

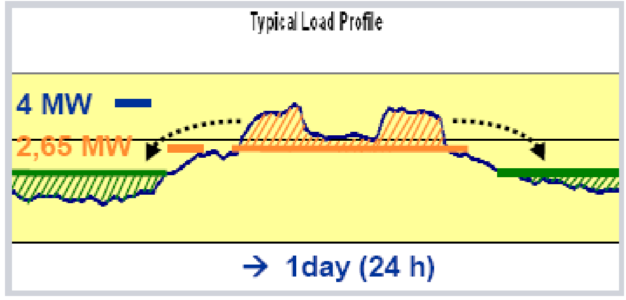


**Figure 6:** Peak Shaving example for Industrial Load

### Frequency Regulation

Energy storage consisting of modern converter technology for network applications combined with Li-Ion battery technology can provide regulating energy for primary reserve and frequency regulation within a few ms.

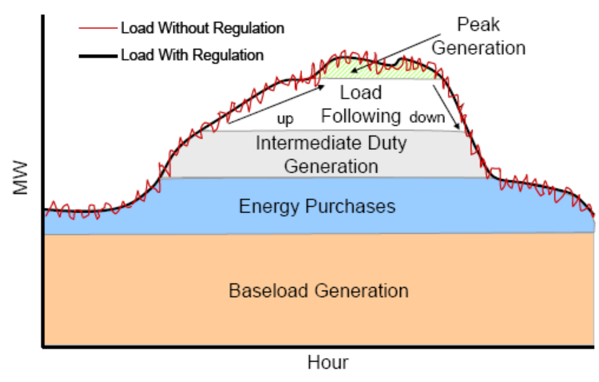


**Figure 7:** System Load with and without regulation [1]

Figure 7 shows typical system load with and without regulation. The power ripples in the red shown curve correspond to frequency ripples in the network. The statutory and contractual hurdles for the usage of energy storage for frequency regulation vary between countries and need to get adapted in some cases.

## Renewable Energy Firming

In this application, energy storage based on Li-Ion batteries (use case specific size) compensates stochastic power fluctuations of renewable power generation sources by directly interacting with the renewable power source itself. The principal of this application could be described as „constant power – principal“.
This application is mainly interesting in relation with photovoltaic installations, stabilizing their power generation, improving the operators production planning reliability and improving the power quality at the point of connection to the network.

## Avoidance of network enhancements

Energy Storage can help to avoid or postpone required enhancements of distribution networks and reduce the related investments. This mainly works for radial distribution systems where the storage can help to stabilize the radial distribution network during times of peak demand and resulting frequency drops. The converters being part of the energy storage solution can furthermore generate reactive power. This can contribute to stabilize the network voltage also.

Referring back to the introduction, significant potential for optimization of distribution networks was identified

1. If peak load management close to the electrical consumers would be possible.
2. If the problems for security of supply and power quality could get improved close to renewable power sources.
3. If the mismatch between power generation and consumption could get managed directly on the lower distribution level.

Customers using Energy Storage will be able to optimize their distribution networks in terms of peak power requirements and resulting costs. Regarding renewable power sources, energy storage can improve the problems related to security of supply and power quality. Energy Storage is also able to act as primary reserve for frequency regulation and to close future mismatch between power generation and consumption on the lower distribution level.

## CONCLUSION

The usage of renewable energy sources in existing distribution grids is limited_because power production of fluctuating renewable generation like solar and wind power varies heavily over time. This complicates the requirements to match power generation to power consumption**.** Energy storage can help to improve the situation in this respect.

Energy storage can avoid the expensive upgrade of existing distribution grids for resulting peak power requirements.

The successful integration of electrical storage into distribution grids requires a combination of application related know how, capabilities and experience regarding network design, storage system (incl. power electronics) and implementation as turn key solution projects.

The study has shown, that among all electrical energy storage options for distribution networks, an energy storage portfolio based on Li-Ion batteries and 2-level or multi-level converter technology is environmental friendly and has a broad scope of applications and advantages. However it is important to note that there is no universal solution in energy storage. The specific use case determines the most suitable solution.

## REFERENCES

For a paper citation:
[1] SANDIA Report SAND2010-0815