OVERSIZING WHITEPAPER

MAXIMUM FREEDOM WHEN OVERSIZING

More Flexibility and Higher Profitability for PV Projects With Sunny Central Inverters

Oversizing of PV power plants serves to increase the capacity of inverters and take full advantage of their capacity.

With oversizing, the PV power plant's nominal power is achieved faster in the morning, and the PV power plant remains connected to the grid longer in the evening. Calculated for the total operating time of the PV project, higher energy yields can thus be generated. Adequate oversizing increases the profitability of a PV power plant.

The Sunny Central inverters from SMA with their robust design offer maximum flexibility for project-specific oversizing. Therefore, the inverter's full load hours can be maximized throughout the total project duration—without greater wear or more frequent failures. The main criteria are explained below.

TREND TOWARD HIGHER OVERSIZING

Currently, PV power plants worldwide are already oversized on average between 120% and 140%. One of the main reasons to oversize the DC generator is that the theroretical peak power of the modules is often not achieved in reality. Thus, a certain minimum of oversizing is necessary to compensate for losses.

Reasons for this include:

- Irradiation values are not achieved (e.g., in the winter months)
- Ambient temperatures are too high
- Pollution of the modules
- Suboptimal orientation of the modules throughout the day (the factor decreases significantly with tracking systems)
- Module degradation: module performance drops annually by approx. 0.5%; after 25 years approx. 80% of the original nominal power still remains
- Mismatching losses caused, for example, by cable losses

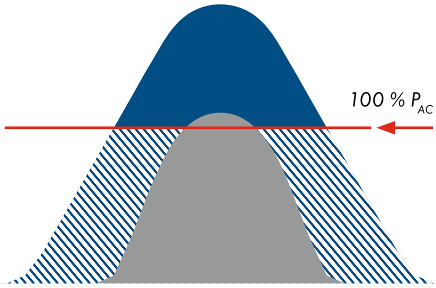


***Fig. 1:** Exemplary daily curve*
DC/AC ratio 80%
Surplus through 180% oversizing
DC/AC ratio 130%

However, there is a clear trend toward higher oversizing ratios. Due to further declining module prices, driven by factors, including by supply and demand, as well as the continuous improvement of the technology—and thus the possibility of using more modules per inverter—higher oversizing becomes more and more economical. The trend toward even higher DC/AC ratios will continue with module prices dropping further and steadily improving module technology (increasing efficiencies/better fill factors). Another big driving force in building PV plants with extrem higher DC/AC ratios will become the ‚DC – DC coupling technology' where not convertable energy will be stored on battery systems connected at the DC side of the system.

Another major impetus for the efficiency of higher oversizing in PV power plants is the steadily declining Purchase Power Agreement Rates (PPAR) worldwide, which is paid by the electric utility companies for generated kWh PV current. There are more and more published press releases about projects with the lowest prices/kWh paid to date.

Currently, the lowest PPARs are already below 2 cents/kWh—with a downward trend. Experts anticipate that the average PPAR paid in 2020 could already be at around 1 cent/kWh.

Due to declining PPARs, a low IRR (Internal Rate of Return/internal interest rate)are also to be expected for projects. A lower IRR also translates into lower interest payments on the additional yields generated due to oversizing. As a result, oversizing is becoming more attractive due to the low PPARs.

Furthermore, a higher oversizing rate can be used to compensate for high fixed investment costs throughout the project term. This applies especially to projects in Japan. There, project development costs and grid connection costs often exceed those of the actual costs for material, construction and installation of a power plant.

OVERSIZING IS THE KEY TO TECHNICAL AND ECONOMIC OPTIMIZATION OF PV POWER PLANTS

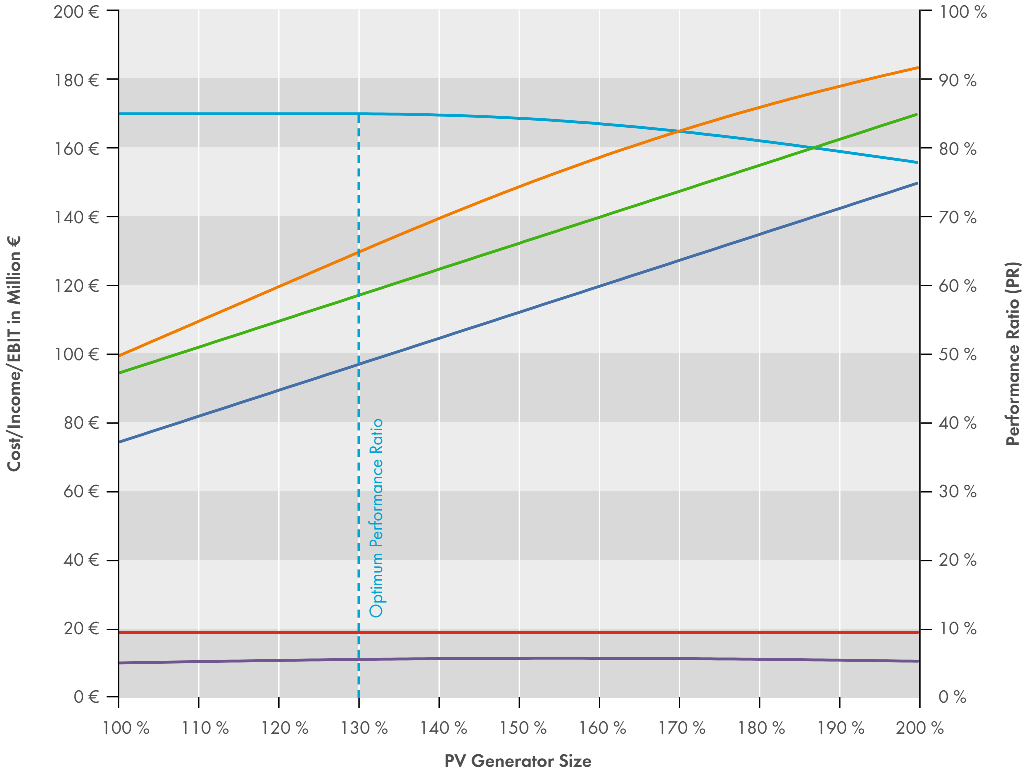
For high efficiency, it is important that the inverters in PV power plants run as often as possible under full load. This can be realized through intelligent oversizing.

The listed example (see Fig. 2) makes clear that the project profitability through oversizing can again be increased significantly when maximum efficiency is used as a criterion. Thus, the optimum here is already at about 170% DC/AC ratio, while from a technical point of view (performance ratio) it is about 130% DC/AC. It is therefore important to evaluate more than just the technical aspects. Since the performance ratio is based on the specific yield, this decreases starting at 130% oversizing, but the additionally generated (absolute) energy pays off in this example up to the maximum efficiency of 170% DC/AC and thus contributes to a higher NPV and IRR.

Figure 2 shows an example of how the optimum regarding oversizing of a 100 MVA PV power plant is calculated.

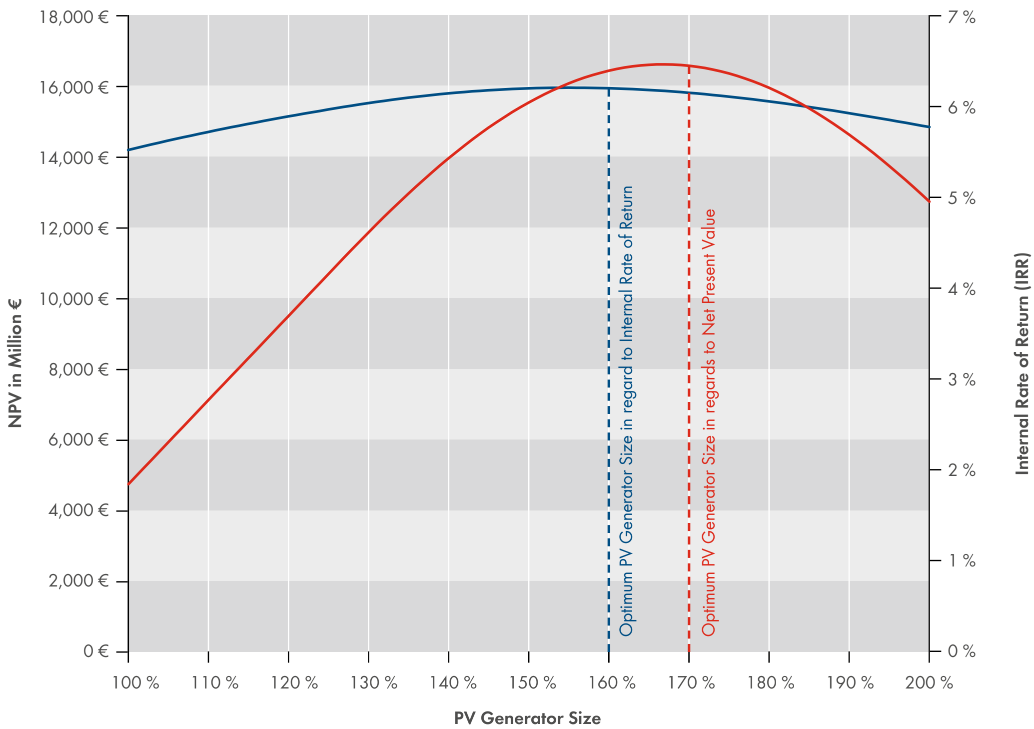
EXAMPLE FOR OVERSIZING IN 100 MVA PROJECT

Fig. 2



- Fixed costs (do not change with increasing DC oversizing relating to the AC inverter power)
- Variable costs (increase linearly to the DC oversizing)
- Sum of all costs (variable costs + fixed costs)
- Revenue (annual energy yield x feed-in tariff or PPA)
- Performance ratio (expected energy yield / actual)

Fig. 3



- Net Present Value
- Internal Rate of Return

Fig. 2 and 3:
Sample calculation of an optimal DC/AC ratio

FIT	*0,05 €/kWh*
spec. yields/a	*1419 kWh/kWp*
Variable cost (DC)	*750 €/kWp*
Fixed Cost (AC)	*200 €/kVA*
Interest rate	*5%*
Project time	*25 years*

DC/AC RATIO SCENARIOS

Fig. 4

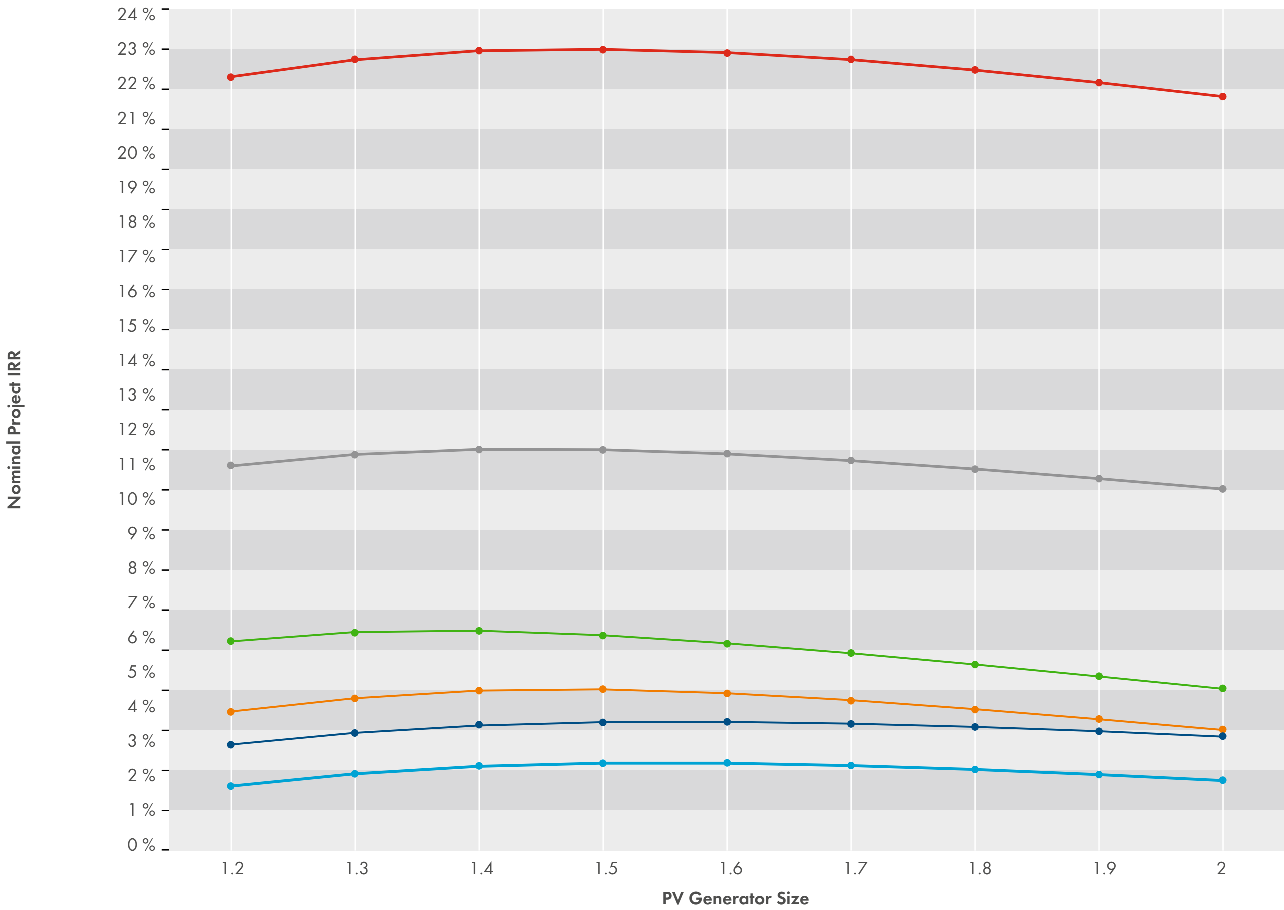
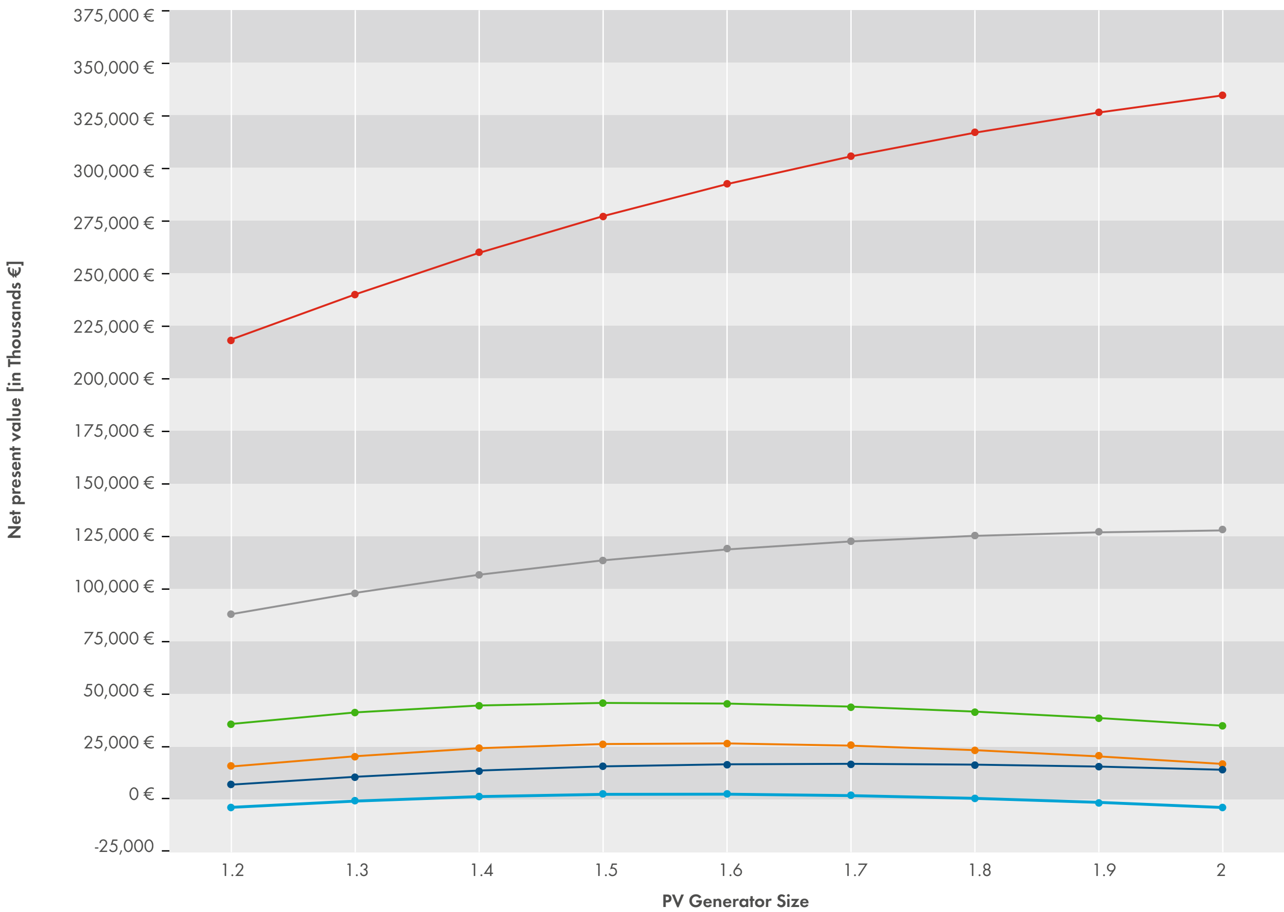


Fig. 5



IDEAL OVERSIZING

Differences for the maximum efficiency of a PV project are based on different preconditions:

- Project location
  - minimum and maximum temperatures
  - irradiation intensity
- Varying amounts of feed-in tariff/PPARs depending on location
- Individual cost structure of the project developer and local factors impacting the project costs

Figure 4 and 5 show the optimal DC/AC ratio each for selected locations worldwide.

- Sapporo
- Ottawa
- Tucson
- New Delhi
- München
- Melbourne

TWO APPROACHES ON OVERSIZING

There are basically two approaches on oversizing. The classic approach is that the grid connection power is the limiting factor, which means that any number of modules can be connected, but the number of AC power (i.e., the number of usable inverters) is limited. In this case, one is flexible and can connect any number of modules to an inverter up to the technical capacity limit of the inverter or as much as maximum efficiency allows.

This mostly affects countries where a lot of land is available but relatively limited utility grids such as in Australia or the U.S.

The second approach is the opposite: the land area is extremely limited but has a high grid connection capacity. In this case, the available area is fully utilized by the modules and cannot be expanded. Here, the flexible design with regard to oversizing is highly limited because the flexible factor in this case is the number of inverters. For projects with a low PPAR, it might make sense to spread the PV array (at the system level) over a smaller number of inverters and thus realize optimized efficiency with higher oversizing. An example of this is in Germany or are large projects on roof systems.

Fig. 4 and 5:
Optimal DC/AC ratio for selected locations worldwide

Assumptions for calculation:
** Country-specific project costs are not considered.*

TAKING THE MIRROR CLOUD EFFECT INTO ACCOUNT WHEN OVERSIZING

SMA takes the effect of short-term solar irradiation increase into account with an additional buffer in the oversizing capacity of the inverters. Thus, SMA inverters can still disconnect the PV array's short-circuit current up to 6,400 A. This corresponds to an oversizing (peak PV array power in relation to the maximum AC inverter power) of up to 250%.

If the required reserve of 25% is deducted from this due to a possible solar irradiation increase, the inverters still have an oversizing capacity of 185%. Typically, the average oversizing capacity of central inverters is 140%. If one were to take into account the effect of solar irradiation increase, many inverters might not be oversized by more than 105%.

BACKGROUND

With the exception of installations at high altitudes, the sun's maximum irradiation power remains constant at around 1,000 W/m². However, according to studies conducted by Mike Zehner, what are known as cloud effects can lead to a short-term increase in solar irradiation on PV modules, which is caused by reflection of solar irradiation from cumulus clouds. According to the study, this effect would increase the irradiation values to up to 25% over the usual 1,000 W/m² (i.e., to up to 1,250 W/m²). Based on minute values, record excessive irradiations of up to 1,400 W/m² have already been measured in systems by solar irradiation sensors known as pyranometers.

The mirror cloud effect depends on the location. To assess how much this effect should be taken into account when planning a system, the clear-sky index can be used as a planning aid. This index indicates at which locations cumulus clouds frequently form.

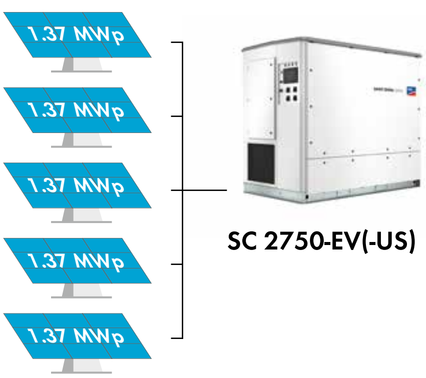
For further information please see:
www.mike-zehner.de/publications/epvsec10-IE-VP.pdf

OVERSIZING WITH OPEX BENEFIT

Technically, with Sunny Central inverters, it is already possible to build PV arrays with up to 250% oversizing. The inverters are designed for extra high DC/AC ratios to withstand the increased loads on the components. Thanks to their robust design, even a considerably higher load does not negatively affect the inverters' 25-year service life. Key features are the B6 stack technology with 38% voltage reserve and the series connection of 2 x 1,200 V IGBTS (please also refer to SMA's 1,500 V Whitepaper).

With Sunny Central inverters, developers have the opportunity to get the maximum efficiency out of their PV power plant through unrestricted oversizing capacity while maintaining the same life expectancy, availability and operating costs of the devices. Investors and operators benefit from lower OPEX costs, decreased project risks and a higher profitability.

6.85 MWp → 250 % DC/AC



SC 2750-EV(-US)

Maximum Design Flexibility With Sunny Central Inverters

- High PV voltages up to 1,500 V -> 38% design margin
- High PV short-circuit current -> 6,400 A (250% DC/AC) taking cloud effects into account 4,800 A (180% DC/AC)
- Oversizing up to 250%
- Connect more module power per inverter

MARKET PERSPECTIVE OF OVERSIZING

Two Questions for Carsten Wendt, Platform Product Manager at SMA

1. Why is oversizing more interesting today than in the past?

First, the markets for large-scale PV power plants have changed. In the past, markets such as Germany dominated, where there was a limitation of the PV array due to the Renewable Energy Sources Act (EEG) and/or limited area. More oversizing could only be achieved by reducing the inverters, which resulted in less yield for the project and thus was often not appealing. Currently, we mainly see markets where the grid connection is a limiting factor and oversizing results in an increased project yield. In this case, "only" the right degree of oversizing must be determined.

On the other hand, electricity prices negotiated in Power Purchase Agreements (PPAs) have dropped significantly in the past years and thus usually the Internal Rates of Return (IRRs) of the projects as well. An expected lower return is beneficial for oversizing because the expectations for additional modules are reduced and the PV array extension thus has a positive Net Present Value (NPV).

2. Which markets are currently particularly suitable for oversizing?

Due to strong IPP competition, the PPA rate is usually directly dependent on the local solar irradiation. However, if the project costs deviate significantly from global market prices, this can lead to a heavily changed oversizing situation. In Japan, the PPAs and the project development costs are incredibly high. This creates an extremely favorable ratio of PV array costs, IRR and PPA, which promotes extreme oversizing.

TECHNICAL ASPECTS OF OVERSIZING

Two Questions for Andreas Tügel, Technical Product Manager at SMA

1. What should you pay special attention to technically when it comes to DC oversizing?

On the one hand, the PV array has to be able to be disconnected when necessary, in which case it is important that the real-time, short-circuit current is not exceeded and that excessive irradiation effects are taken into account. Even with extreme oversizing, the inverter must be able to regulate its power at any time in the event of external grid support requirements. It is therefore important that the inverter can still curtail the power close to the open-circuit voltage. The more has been oversized, the higher the respective voltage will be in MPP operation.

A comprehensive analysis regarding the optimal oversizing by means of the clipping losses is important. Depending on the conditions prevailing on-site, like solar irradiation and temperature, the clipped yield from the PV generator (while the inverter is operating at its max. output power) can be compensate up to a certain oversizing ratio by the additional gained energy in the morning and evening hours.

2. Why do SMA inverters not experience higher attrition with extreme oversizing?

It was already apparent during the requirements phase of the new class of SMA Sunny Central inverters that, in the future, the trend, after achieving high efficiencies, would be more toward robustness and availability as well as high oversizing ratios. Accordingly, SMA Development has designed extreme load profiles for a 25-year product lifetime with regard to full load hours and temperatures for the design of all components with a special focus on the key components. A stack fan, for example, must therefore be replaced after 14 years at the earliest, regardless of whether the inverter had been oversized with 130% or 200%.

ENERGY
THAT
CHANGES

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