DC Coupled Storage System: Feasibility Analysis

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As the integration of storage with PV solar systems has been expanding in the US energy industry, DC coupled systems have also been gaining momentum. Many vendors who are proponents of DC coupled systems are realizing numerous benefits including reduced EPC costs and increased round-trip efficiency by deploying these systems. The points mentioned below try to analyze the feasibility of DC Coupled system from developer's point of view.

1. **Reduced clipping loss**: In most of the cases, AC coupled systems have some clipping losses due to a high DC-AC ratio. Many vendors are claiming that deploying DC-DC converters between PV and battery systems reduces clipping loss and therefore increased production. Although this theory holds true, there is no substantial increase in production until we compare it with an AC coupled system with a DC-AC ratio higher than 1.3 (figure1) which is not the normal practice even at utility scale. However, when the DC-AC ratio is higher than 1.3, we can consider a DC coupled system.

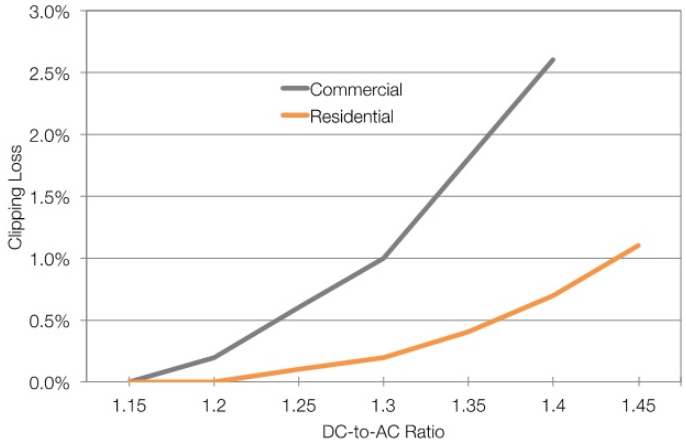

Figure 1[1]

2. **Voltage source capability:** We all aware of the fact that production from PV systems is not constant and fluctuates greatly based on solar insolation. Solar inverters work only when PV production reaches the threshold voltage. Below the threshold voltage, all of the production from PV system gets wasted. Now, it is claimed that DC coupling systems can help remove this problem because the

battery system before the inverter acts as voltage source, making sure that the output DC voltage is always above the threshold voltage.

This argument makes sense as sometimes input voltage goes down below the threshold DC input voltage when there are clouds, as shown in figure 2. This makes PV output completely zero even if the PV system is producing some power. DC-DC converter and storage coupling helps maintain DC input voltage at about threshold voltage. However, further analysis is required to calculate how much energy DC-DC inverters can help to increment on a daily basis as compared to an AC coupling system.

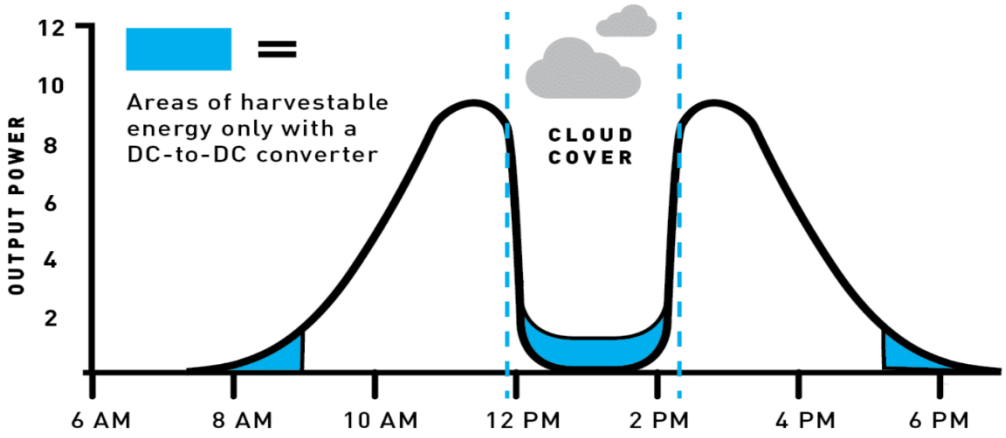

Figure 2[2]

3. **Lower installation and regulatory costs**

   With DC coupled systems, there would not be any need for separate AC equipment like switchgear, transformers, etc. A single AC system would work together with PV systems and storage. This will reduce the costs associated with installation & procurement — with vendors claiming almost a 10% reduction in EPC costs.

   What we need to do: Analyze the cost of DC-DC converters vs. AC interconnection equipment to come out with reasonable numbers for savings predictions.

4. **Higher round trip efficiency**: Vendors are making this a very big point, but the increase in efficiency due to DC coupled system is not more than 0.5 -1.0%. As the DC coupled system shows in figure 3 [3], discharging of the battery happens through a similar path, but it is the charging path which changes from DC-AC-DC to DC-DC — this change does not contribute much to increase the efficiency (figure

4). Although, it still holds true that round trip efficiency would increase but that increase would be minimal.

5. **Less metering required**: Unlike in the case of AC coupled systems, we don't need to add meter and control systems on the charging side of the battery, as all the power to the battery is coming from PV only. This removes the need to installing a meter to calculate whether the batteries are being charged from the PV or the grid.

Conclusion: Overall, efficiency and EPC cost savings lead us to believe that there is no harm in using DC coupled systems and in fact, as more and more storage integration takes place, there would be the expansion of DC coupled systems. However, the market is still very new for this equipment and we have little empirical data to validate vendor claims.

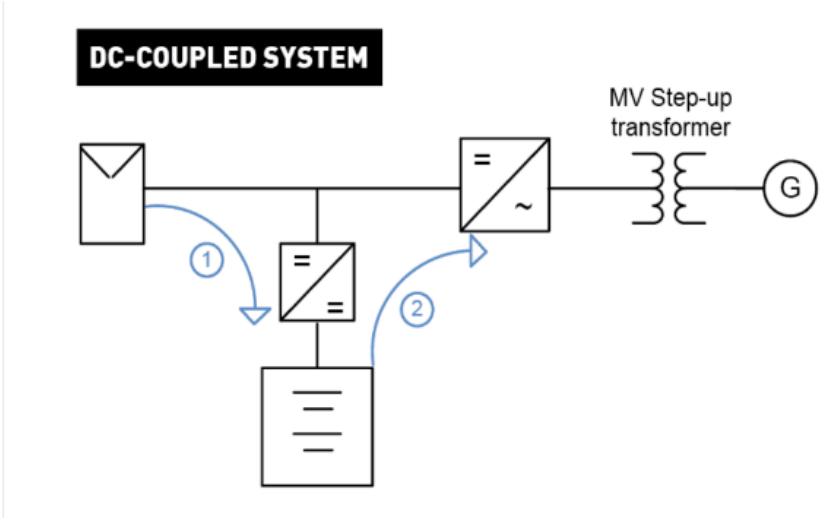

Figure 3[3]

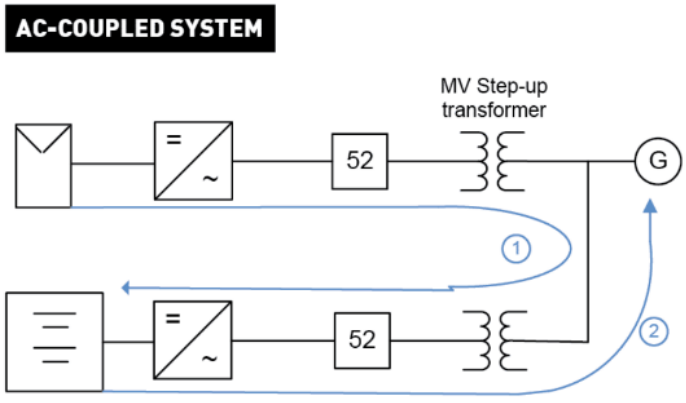

Figure 4[3]

A short comparison between DC-coupled storage and AC-coupled storage: DC-coupled storage is useful when the goal is to store excess solar energy gathered in daytime and use it during the peak time in the evening (no sun). This would be most appropriate in cases where the household does not consume much energy during the day. However, AC-coupled storage gives more flexibility through off-grid UPS modes (means the home has power even when the grid is down), grid charging, and network support capabilities (such as power factor correction — a requirement for solar grid connection on some networks).

The following part include some of the disadvantages of using DC-Coupled System rather than an AC-Coupled System:

- Setting up the DC Coupled System is much more complex, especially for larger systems above 3kW since they need multiple strings in parallel and string fusing. Also, setting up the DC Coupled System is more expensive for systems above 5kW since it needs multiple higher voltage solar charge controllers.
- DC Coupled System has lower efficiency for powering large AC loads in daytime (due to the conversion from DC-DC-AC).
- Many solar controllers are not compatible with DC coupled systems (it's easier for AC coupled systems to add to new and existing PV systems, with no need for an additional expense).

References:

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