Liquid Solar Array Synergy with Hydropower

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Virtual Storage via Hydropower Dams

There are some very interesting opportunities that arise when a large scale solar power generator such as the LSA is combined with a hydropower plant. It is possible to achieve 'virtual storage' of the solar generated electricity without changing the basic hydropower installation at all. Any solar power generated can allow a corresponding reduction in the water flow through the hydropower turbines. This conserves that water for use at a later, and potentially more valuable time (such as the early evening peak load time that is typical in many locations).

Typically a hydro facility that increases its energy output by 3-5% is considered leading edge, whilst Sunengy's LSA technology is expected to potentially double the output once implemented at scale.

In most hydro installations it is not feasible to generate power at full capacity 24 hours per day because there is not sufficient annual flow through the dam catchment to maintain the average flow rate that is required at full power. Hence the turbines and their grid transmission line are used intermittently. The grid connection is therefore considerably under-utilised. This capacity utilisation factor for hydro seems to be mostly under 50% worldwide and even lower in dry periods when water (the fuel) is scarce. See http://en.wikipedia.org/wiki/Hydroelectric for statistics on capacity factors for whole countries' hydropower systems, showing a range from 0.2 to 0.6, mostly around 40%. The capacity factor is typically chosen by the designers to suit the site and load limitations.

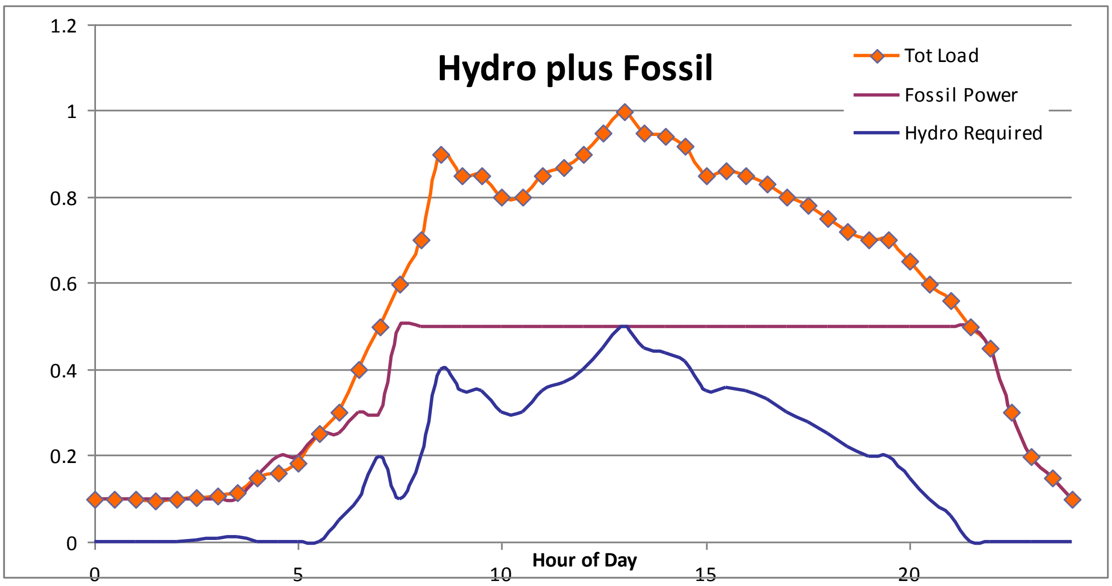
So, since the annual water flow availability through a hydro system is the principal limit to the hydropower energy resource in that location, a co-located solar component of generation can allow increased dispatch-able energy production, making more full usage of the grid connection of the hydro plant. This could potentially multiply the total energy delivered from the original hydro plant by two, just by adding the solar collectors on the dam.

One could also envision a situation where pumped-storage hydro could be employed to reuse the same water many times between two storage dams, fully storing the solar power, but this is a higher cost option better suited to lower rainfall areas.

Traditional and Solar-Enhanced Hydro

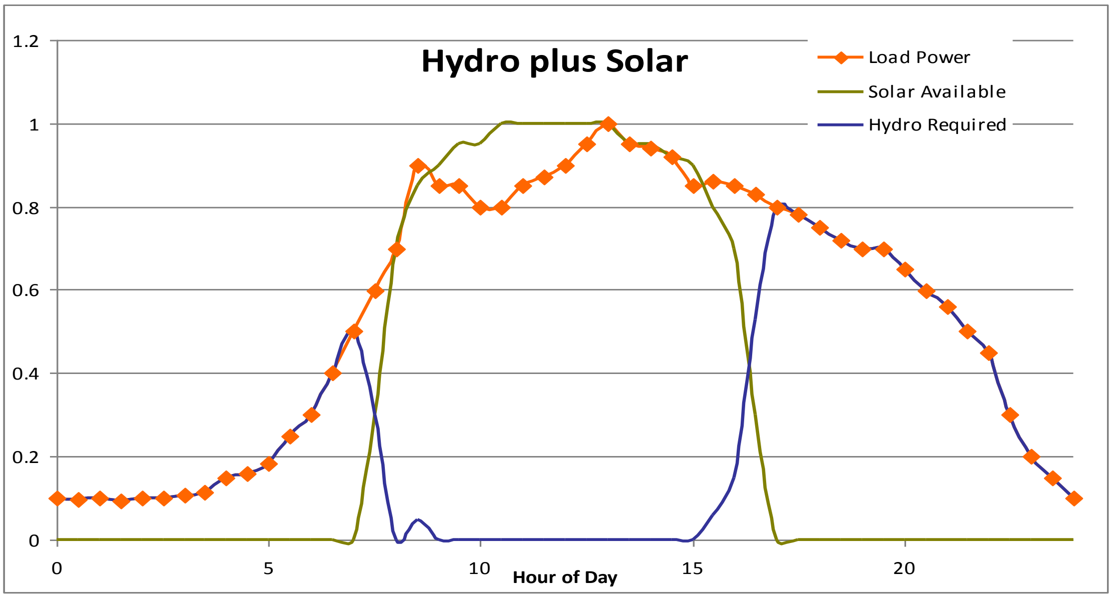
Hydropower is typically used as a supplement to fossil fuels as it is limited by the amount of water it has available to use on a daily and seasonal basis. **Chart 1** below illustrates how, say, coal and hydro are often combined to provide base and peak power loads.

Chart 1



If the solar generation capacity equals or exceeds the maximum hydroelectric output, almost no water need be consumed from 8am to 4pm on most days, as the power could be supplied LSA; with the hydro-generator always being available to fill in through cloudy periods and night-time. **Chart 2** below illustrates how they would combine.

Chart 2



The basic assets of hydropower dams are the annual flow, the volume of water stored and the head of water which together determine the power and energy outputs achievable. The LSA gives the dam an extra asset in its water surface area, using it to provide supplementary solar power.
If the solar generation capacity equals or exceeds the maximum hydroelectric output, we could expect that almost no water need be consumed from 8am to 4pm on most days, as nearly all the power could be supplied from the solar component; but with the hydro-generator always being available to fill in through cloudy periods and night-time.

Some Examples

- For instance, a study of three hydropower dams privately owned in India showed the following:
  There is a total existing power generation capacity of 447 MW.
  To generate 447 MW of power with LSA would require only 9.3sq km of water area using 3,724,851 LSA (125W) units @ 2.5sq m water surface per unit.
- The total water surface area of these dams is 250sq km so only 3.7% of this is required to match the hydropower output.

Typically most power is consumed in the 8am to 8pm period, with local variations of course. If the solar system is able to take nearly all the load from 8am to 4pm most days (8hrs) this leaves only four hours where full power is likely to be needed from the hydro generator on average days. Hence we might expect a potential reduction in water consumption of 66% if no changes are made to the hydro generator. An overall saving of just 50% water usage would potentially double the revenue of the hydro operation when this saved water is used to generate more power.

In general, it is possible to install very large LSA solar capacity on suitable dams at around 25 sq km of water surface area per Gigawatt. If the solar array is less than or equal to the hydro power capacity, very little change is need to the dam's infrastructure to greatly increase the total energy produced: only the solar collectors need to be added.

An interesting opportunity then arises to perhaps triple the turbine and generator peak capacity while overall using the same amount of water, going for instance from 500MW to 1500MW hydro capacity. As long as the solar component matches the increased peak hydro capacity, the peak capacity of the whole system is effectively tripled; though specific details depend on the daily load profile. This is a relatively cheap option as changes to be done to the dam are modest and thus it suits existing hydro installations (but larger transmission lines are required for this case).

The LSA is designed to be scaled up for industrial applications and this is a key strategy to drive the manufactured cost per Watt down; through economies of scale from mass production. Hydropower dams are ideal industrial applications as they have both large areas of water and a substantial grid connection.
The dual use of water eliminates the need, costs and complications associated with land acquisition to set up regular land based solar PV or solar thermal (CSP) systems.

Key facts and figures

- LSA has the potential to produce solar power at around half the cost of conventional solar technology right now and achieve price parity with fossil fuels in the medium term.
- Hydropower supplies 87% of the world's renewable energy and 16% of the world's power but is limited by its water resource. Total world Hydro capacity is 800GW.
- An LSA installation could match the power output of a typical hydro dam using less than 10% of its surface area and supply an additional six to eight hours of peak power per day.
- Modelling by Sunengy shows that a 240 MW LSA system could increase annual energy generation at the Portuguese hydro plant, Alqueva, by 230%.
- If India uses just one percent of its 30,000 square kilometres of captured water with our system, LSA could generate power equivalent to 15 large coal-fired power stations.
- For tropical monsoonal hydropower sites the low-solar periods correspond with high rainfall periods so the match with the LSA system is extremely good.
- The addition of the LSA solar generation capacity to a suitable Hydro dam can provide a package delivering double the overall energy, with power available "on-demand'" 24/7.
- Such a package is a much more reliable producer of power than hydropower alone, as the system is far less dependent on water supply: In drought conditions it will be possible to continue daytime solar power generation from the LSA with no consumption of water at all.

Conclusion

The LSA system is designed specifically for economical large-scale solar power generation on bodies of freshwater such as dams and natural lakes. This paper shows how the LSA fits perfectly with the characteristics of most existing hydropower installations to greatly increase their energy production at minimal cost, while providing fully backed-up solar power.