

Department of Environment and Natural Resources	Environmental Compliance Certificate	10 – 12 months
Local Government Unit	Several Permits	1 – 3 months
Distribution Utility	Distribution Impact Study as applicable	2 – 4 months
Energy Regulatory Commission	Certificate of Compliance	6 – 12 months
National Grid Corporation	System Impact Study as applicable	10-12 months

A total of 50 permits has been identified. 30 of those are considered Primary permits that the owner or developer would need to secure while the rest are normally subcontracted to the EPC to facilitate.

Magat Floating Solar will be the first in the Philippines and there exist no agreed water lease fees. The National Irrigation Authorities has suggested a quite high percentage of all income from the FPV, which will give a far too low IRR, regarding the important investment cost. Negotiations are ongoing. Uncertainties on potential tariffs for a hybrid asset, makes the negotiations more complicated.

The most important issues for the local government and the local communities are related to fishing activities and transportation over the reservoir. Regarding fishing, it is important to plan for the floating solar panels not to interfere with the important locations for fish cage. Magat reservoir has also many transportation routes for small boats. The location of the floating solar rings should be located as close to the grid connection point as possible. The most used transportation routes today will be hampered by the planned location of floating solar, as their point of departure is at the dam entrance, next to the road. This location is also important for fish trading. Many of the boat transport drivers are waiting for their passengers, typically school students or people going to the nearest city for business.

In order to mitigate the inconveniences for fisher men and boat drivers, it is suggested to make a new quay structure, including access road, for both fishing boats and transport boats. The quay can be used during mounting of the floating solar ring. And the quay can also be equipped with freezer boxes for improving the fish trade. It is also possibilities to offer the boat drivers to have an additional income from cleaning the floating solar panels as they are waiting for passengers anyway.

There are also communities around Magat reservoir with indigenous people. Indigenous people have luckily a very good protection. If any areas with indigenous people are affect, a Free, Prior, and Informed Consent (FPIC) process is launched. A FPIC allows Indigenous Peoples to provide or

withhold/withdraw consent, at any point, regarding projects impacting their territories. It is therefore decided to make sure no areas with indigenous people are affected by Magat HyPP.

3.2 Financial solutions and Hybrid PPA's

The regulatory framework for commercial scale floating solar assets in the Philippines is still in the early stages. So is the framework for hybrid operation of assets. The two processes are mutual important to SNAP, as the possible value capturing in the merchant energy market is high for both technologies and can be increased if the solar and water resources could be co-optimized to stabilize the intermittent PV generation.

The well-developed energy market in the Philippines has both day-ahead energy market, with a 5-minute intra-day trading option, and three different Ancillary Service (AS) markets. The Contingency Reserve (CR) market is the spinning reserve, the Dispatchable Reserve (DR), market is when you can have black start, and the Regulating Reserve (RR) for frequency regulation in the grid. Magat Hydropower plant participates in all three AS markets, while BESS can only participate in CR and RR. The contract prices for all the three ancillary service markets are constant for 5 years at the time. As of today, a market participant cannot bid in a HyPP either on the spot market nor the AS markets.

Today, at the existing Magat hydropower plant, about 77% of revenue comes from Energy Sales and 23% comes from Ancillary Services. The high-income potential from ancillary services, suggests that the value of selling PV under a hybrid Power Purchase agreement, where the storage capacity in the hydropower reservoir and the BESS can be utilized to limit the need for volume being sold on the balancing markets, should create value to both the society and to the asset owner.

As only contracts for stand-alone assets (not hybridized assets) are available by now, a process towards the authorities, Department of Energy, National Electrification Administration and National Grid Corporation of the Philippines must be convinced about the mutual benefit of hybrid PPAs and hybrid asset participation in both spot and AS markets. SNAP takes the offensive approach and is working with the regulatory bodies and provides suggestions and feedback on the process.

3.3 FPV - Typhoons and insurance

To reach financial close of a floating solar project, insurance guaranties are needed. Ocean Sun is providing a proprietary technology for FPV power plants, and design and dimension the FPV system at Magat dam. The Philippines is a typhoon prone country, and typhoons represent a potential risk to FPV installations. Insurance guaranties is therefore important to mitigate this risk for the buyer. The system is designed to withstand a wind speed of 275km/h (Typhoon class 4).

The pilot FPV system installed at Magat has been in continuous operation for 4 years and has not been affected by the yearly Typhoon seasons. However, typhoons do represent a potential risk to FPV installations. Ocean Sun is working

closely with third party institutions such as Det Norske Veritas (DNV) and Bureau Veritas to verify various aspects of the technology, such as mooring, anchoring and the overall structural integrity of the system for a specific project location. DNV and Bureau Veritas are ensuring that the calculation methodology used by Ocean Sun is correct and that the design adheres to the relevant standards, thus reducing risks. Relevant standards include Ocean Sun's Design Basis and Hydrodynamic Design Premise, the aquaculture design code NS 9415 and the floating solar recommended practice DNV-RP-0584. This makes it easier to insure the system against damage caused by weather conditions, and at a lower premium. Ocean Sun has obtained insurance for the system.

3.4 Automated digital tool

To capture the value from hybridization, we need to prove that we can automate the optimization and develop a reliable tool for the production planners and operators. TGS Prediktor is developing a real-time hybrid EMS optimization software tool. The purpose of the tool is to optimize the energy service revenues by automatically allocating assets to different energy market services. The data taken into consideration is among other minute resolution market prices, second resolution weather and inflow data, asset design limitations (i.e., BESS cycle limitations, HEPP ramp-up dynamics) and license requirements (water volume release for irrigation, reservoir rule curves, etc). This real-time multivariate optimization challenge is solved using Model based Predictive Control (MPC) and Quadratic Programming (QP) algorithms [7]. It is designed to become generic and usable for any hybrid real-time EMS optimization challenge, communicating with the various SCADA- and control systems in the hybrid plant.

The main components of the real-time hybrid EMS optimization tool are shown in the inside the dashed square in the diagram below:

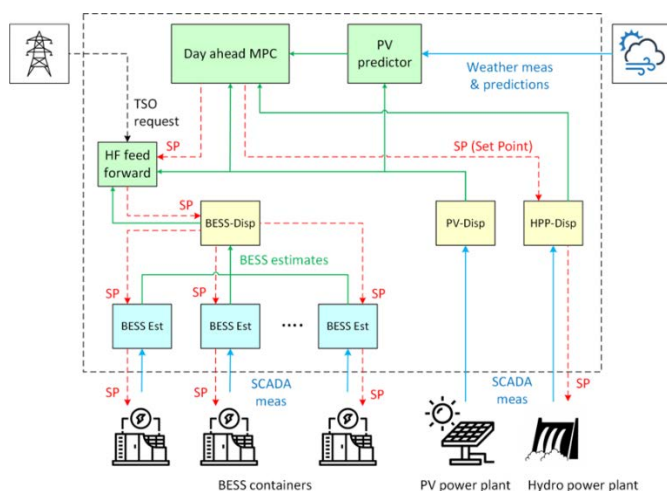


Figure 2 Overview of the real-time hybrid EMS optimization tool indicating the data flow.

As an example, assuming an agreement for delivering a fixed load through peak hours of a day, with some relevant weather conditions, a simulated scenario looks like this for the

predictions and control commands this system would make (ref [3], [4], [5] & [6]):

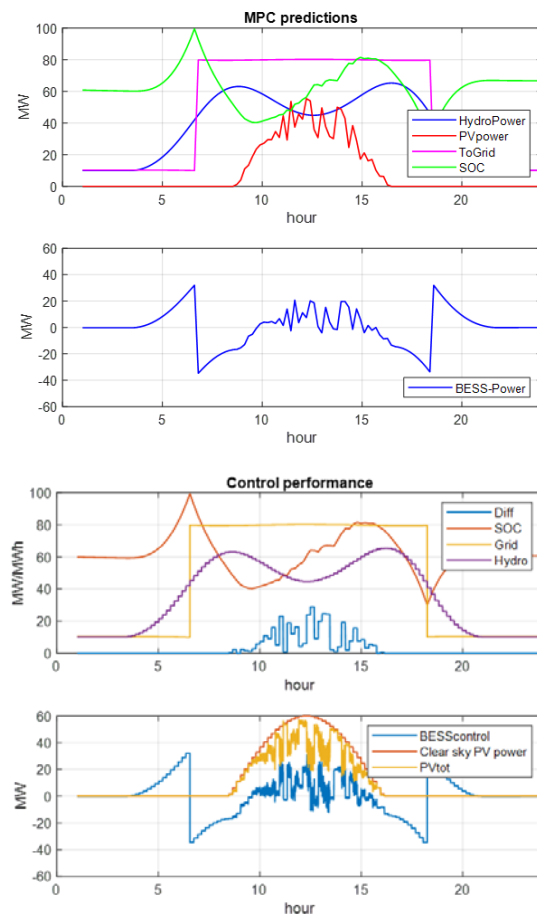


Figure 3 Snapshots from a simulation of the hybrid EMS optimization tool running the optimal predictions during a 24-hour horizon run. "MPC predictions" show the Model based Predictive Control predictions of the optimal power generation needed to deliver the specific power profile target to the grid and the BESS state of charge. In "Control performance", we see the control set-points the system will generate to the HEPP control system and BESS, given the simulated PV power profile, PVtot.

3.5 Value creation at Magat HyPP – SHOP results

The scheduling period is one year with hourly time resolution. Input data from 2021 is used as a reference year, as it was close to a median year in terms of inflow. The initial and end conditions in the optimization model are that both reservoirs start and end at the maximum water level. Evaporation from Magat Reservoir is considered, and FPV covers 1% of the reservoir's maximum surface area. It is assumed that the energy used for charging BESS cannot be bought from the market, only from own production (hydropower and solar).

Table 3 and Table 4 compare the results for the six scenarios defined in Section 2.2 without or with reserve obligations, respectively.

Table 3 SHOP results for a Day-a-head market

Asset combination	Net Annual Revenue [Bill. PHP]	Total Production [GWh]	Average price [PHP/MWh]
<u>Hydro only</u>	7.61	940	8.095
<u>Total stand-alone</u>	7.70	956	8.054
Hydro		940	
FPV (curtailed)		15.3 (-0.08)	
<u>Total hybrid</u>	7.93 [+3.0%]*	948 [-0.7%]*	8.359 [+3.8%]*
Hydro		937	
FPV (curtailed)		15.4 (0)	
BESS discharge		44	
BESS charge		-49	

Note: *Compared with the values in the Hydro + FPV alone scenario.

Table 4 SHOP results for a Day-a-head market + CR reserve and DR reserve.

Asset combination	Net Revenue [Bill. PHP]	Total Production [GWh]	Average price [PHP/MWh]
<u>Hydro only</u>	7.83	733	10.68
<u>Total stand-alone</u>	7.91	746	10.59
Hydro		731	
FPV (curtailed)		15.3 (-0.10)	
<u>Total hybrid</u>	8.23 [+4.1%]*	743 [-0.5%]*	11.07 [+4.6%]*
Hydro		734	
FPV (curtailed)		15.4 (0)	
BESS discharge		60	
BESS charge		-66	

Note: *Compared with the values in the Hydro + FPV alone scenario.

In a merchant market, as the current Philippine market, the hydropower plant, with reservoir storage, will always be optimized towards the market prices. Energy from FPV plant can always be sold at the same price as you can buy the same energy from the market. The value of hybrid operation and optimization of hydropower and PV in this merchant market is therefore not existing, and the value is equal to stand-alone assets. But when battery energy storage systems (BESS) are included in the mix, it is possible to capture more value, both for the hydropower plant and for the solar plant. The actual value of standalone BESS + PV is not modelled and should have been included for the total overview.

The added value from the hybrid operation is particularly related to charging the batteries when the solar would have been curtailed or there are negative prices in the market, improved performance in the ancillary service market and from saving water by using the batteries for provision of energy services during the ramp-up time for the hydropower plant.

The results from the SHOP model indicates that Magat HyPP, with hybridization of hydropower, PV and BESS can increase

the net annual revenues with 4 % in a market with both Day-a-head sales and ancillary service markets (CR and DR).

The reason why it is not possible to capture the demonstrated value now, is that there are currently no Hybrid PPA's available, and each power generation unit have to be registered and is dispatched as separate market participants.

3.5 Value capturing in other markets.

Scatec is developing HyPPs also in other markets. We are looking at an opportunity with an existing hydro power plant where the inflow has been reduced over the past decades, and the reservoir runs dry almost every year. There are now expansion plans for a PV plant, with approximately 50 % of the installed hydropower capacity (24 MW + 29.5 MW). There is existing base load fixed price PPAs which will give high captured prices for solar production in combination with the hydropower production on the base load contract. In addition, it is possible for this hybrid asset to participate in the Southern African Power Pool (SAPP), a merchant market with quite high volatility in the prices. This means that the solar production can provide for saving water for times with high prices, to the morning and evening peaks, and still fulfill the baseload contracts.

Simulations are run for a dry year, a median year and a wet year. Especially for dry years, but also for media years, the hybrid operation of the asset is very beneficial.

The technical development of Energy Management System and real time optimization of hybrid operation at Magat HyPP can be directly used in our new development of HyPPs in other markets.

4 Conclusion

The Magat Hybrid Power Plant in the Philippines exemplifies the potential and challenges of integrating renewable energy sources. While its innovative combination of hydropower, floating solar, and battery storage offers promising energy solutions, the current regulatory landscape poses hurdles. Despite these challenges, the insights and technologies developed at Magat hold significant value for the broader renewable energy sector. For engineers in this field, Magat serves as both an inspiration and a case study, highlighting the importance of adaptability and innovation in the face of regulatory complexities.

The lack of defined regulatory framework for construction of floating solar leads to an increased duration of the development phase, which hence increases the development costs. All energy development projects have some controversy. For Magat FPV, the area use at the reservoir can potentially have impact on fishing activities and boat transportation. Mitigation measures such as avoiding the most important fishing areas and boat transportation routes, in addition to construction of a new quay are found together with the local communities. There are also indigenous people living

around the reservoir, but it is decided to stay out of any communities where there are indigenous people.

Ensuring insurable guaranties for the FPV installations has been possible to do through Ocean Sun's work, with references to standards in aquaculture and offshore installations. These guaranties are essential for financial close of a floating solar project.

The value creation at a HyPP, can only be captured if it is possible to automatically allocating assets to different energy market services. TGS Prediktor has developed a real-time hybrid optimization software tool.

The SHOP model indicates that it is possible to increase the net annual revenues at Magat HyPP by up to 4 % with hybrid operation, compared to stand-alone assets. Unfortunately, the current energy market in the Philippines, where each power generation unit have to be registered and is dispatched as separate market participants, do not allow for the power producer to capture the value the Magat HyPP is providing. Despite this overall conclusion here, we can use the experience and the developed technology in other projects and in other markets. Especially markets with base load contracts or specified load profiles are well suited for implementing HyPPs. Or in other markets with "Blended Renewable & Storage Premium PPA".

The total value creation to the society will include the value of stable energy supply and the reduced need for grid upgrades. These numbers are not within the scope of this study, and we have restricted the value creation only to the possible value to the power producer.

Nevertheless, with Magat HyPP it should be possible to use the physical assets to manage different types of PPA structures, which in practise should turn hydropower storage and BESS storage into a physical hedge to complement the financial hedge of the FPV asset. Another option would be for the three assets to operate virtually independently, with a renewable PPA for the generation, and an optimisation agreement for storage. Or adding a price premium to the energy produced from the renewable asset by valuing-in the flexibility which allows better risk management of the energy.

The unique learning and benefits of developing solutions for concrete, large-scale pilot plants, such as the opportunity at Magat HyPP is essential to the entire energy industry. Our experiences highlight the need for large-scale pilot projects in the development of solutions for HyPPs. We would not have had the possibility to do this work without the financial support

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Magat HyPP has been one of the main full scale test cases in the HydroSun project. Nothing of the work would have been possible without the co-operation with the SN Aboitiz (SNAP) organization, with CEO Joseph Yu and the appointed project manager for HydroSun at Magat; Daryl Homer Ramos.

6 References

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