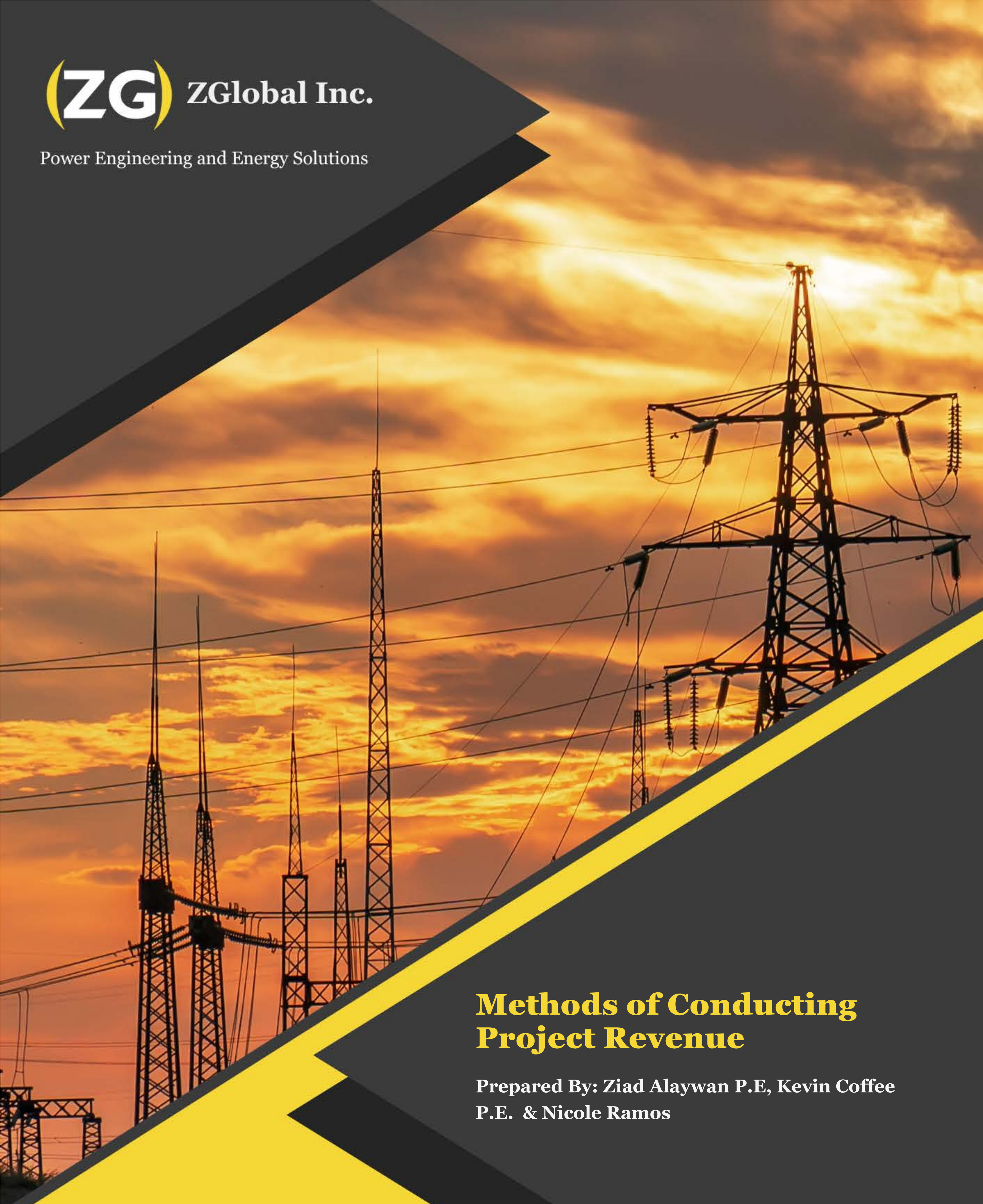
ZGlobal Inc.

Power Engineering and Energy Solutions



Methods of Conducting Project Revenue

Prepared By: Ziad Alaywan P.E, Kevin Coffee P.E. & Nicole Ramos

In this case study, we will delve into our advanced techniques, focusing particularly on the intricacies of generation optimization, which holds a central role in the maximization of resource and generating plant revenues, while meticulously adhering to the inherent physical attributes of these resources.

Generation Optimization Process

ZGlobal has adopted a comprehensive approach to resource optimization, harnessing the capabilities of our proprietary in-house optimization platform, eGrid. At the heart of eGrid's functionality lies the integration of PLEXOS[1], a well-regarded commercial optimization software engine acclaimed for its proficiency in modeling load and supply dynamics within the domain of both the CAISO (California Independent System Operator) system and the WECC-wide (Western Electricity Coordinating Council) region. This is executed through the sophisticated application of the Security Constrained Unit Commitment (SCUC) and Economic Dispatch (ED) algorithm, underpinned by Mixed Integer Programming (MIP) techniques. This algorithmic framework enables the minimization of a cost function or maximization of resource revenue while meticulously respecting the full spectrum of operational constraints.

The intricacy of optimizing a portfolio surge in tandem with the expansion of resource optionality, a challenge that becomes more pronounced as energy storage systems become increasingly integrated into the energy landscape. Whether these systems function autonomously or are amalgamated with renewable resources, their introduction considerably enhances the capability to align energy supply with demand on both an hourly and sub-hourly basis.

At ZGlobal, we have dedicated substantial resources to perfecting the dispatch of energy storage, recognizing its immense value. We have meticulously developed a process that entails the input of all pertinent variables into the PLEXOS software, and, equally crucial, the careful tailoring of both input and output to suit our unique requirements. These bespoke PLEXOS models and associated input and output including transmission and generation modeling performed by ZGlobal are colloquially referred to as eGrid.

The eGrid platform comprehensively encompasses a wide array of parameters, encompassing CAISO's and other Balancing Authorities' transmission grids and footprints and adjacent grid infrastructure, various transmission and generation constraints, generation and load profiles, gas price data, outage statistics, hydrological modeling, and a myriad of other pertinent features that underpin the process of resource optimization. The multifaceted utility of eGrid extends to both planning and operational tools, designed with the singular objective of maximizing the worth of energy storage resources and generating resources in general. This is accomplished through the precise determination of optimal charging and discharging periods for energy storage systems. This determination is made while meticulously accounting for the limitations inherent to these systems, interconnection prerequisites, solar energy availability, forecasts (particularly pertinent for solar/energy storage hybrid systems), and compliance with power purchase agreement (PPA) stipulations, where applicable.

[1] https://www.energyexemplar.com/plexos

The accompanying diagram serves as a visual aid, offering a comprehensive overview of ZGlobal's approach to resource optimization:

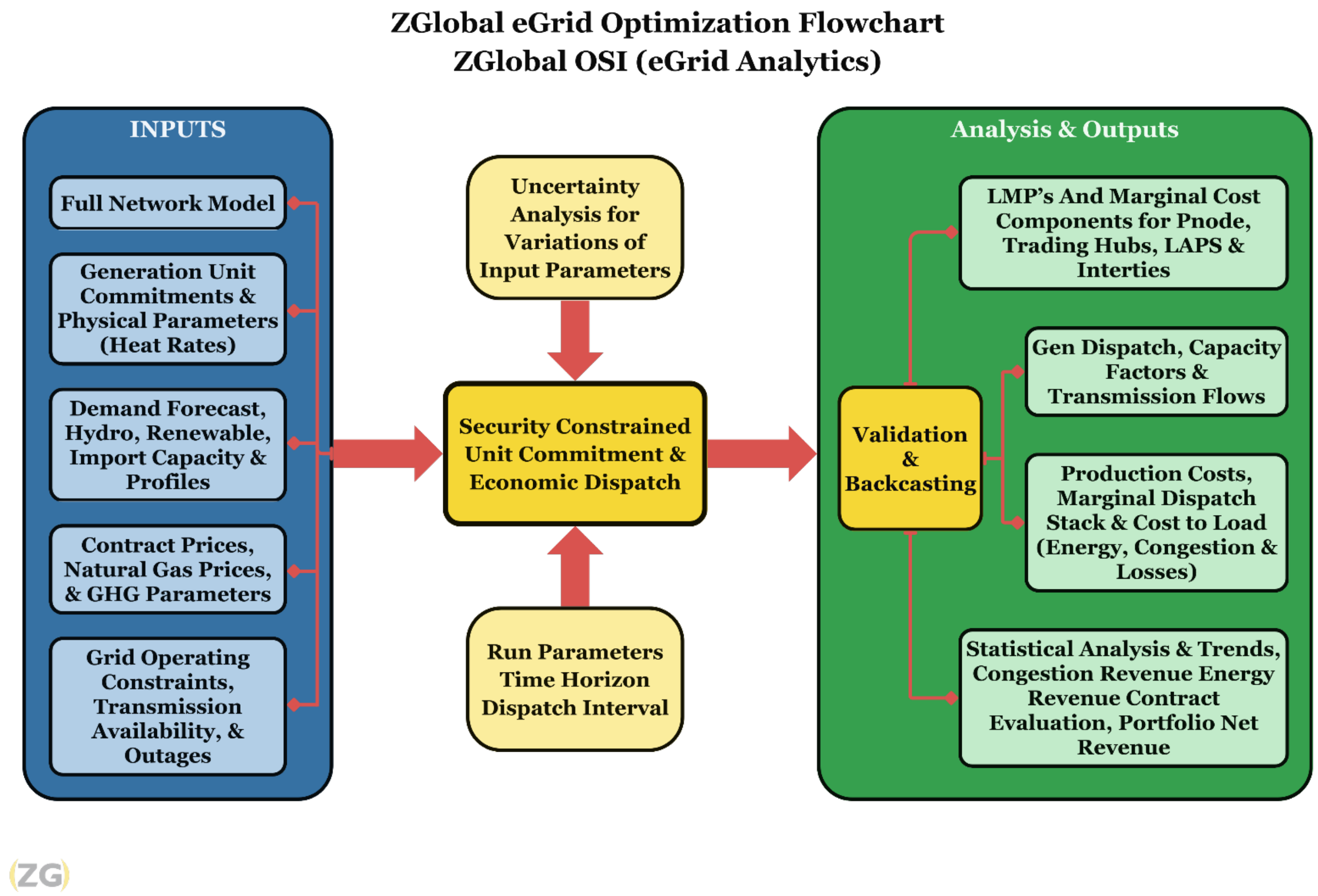


Figure 1: ZGlobal Model & Resource Optimization Functions

Resource Modeling and Operational Insight

In our ongoing commitment to effective resource optimization, ZGlobal's eGrid is not limited to its role in the modeling of the present; it extends its reach to forecast future scenarios, encompassing the CAISO, WECC, ERCOT, and SPP systems. Within this ambit, we analyze anticipated developments in generation, load, and infrastructure. Through this comprehensive modeling, we ascertain a plethora of critical parameters, including Locational Marginal Prices (LMPs), the driving factors behind price fluctuations, the cost-to-load ratio, expected generator revenue, system constraints, and sensitivities that wield significant influence over outcomes.

To compile the data essential for producing high-quality results, our team meticulously mines information from a diverse range of sources, including the CAISO's transmission planning process, interconnection queue data, mandates from the California Public Utilities Commission (CPUC) and the Public Utilities Commission of Texas (PUCT), load data from the California Energy Commission (CEC), and other pertinent sources. Our team's operational expertise plays a pivotal role in ensuring that the data and results generated are not only accurate but also practical in their application.

The central information that eGrid yields encompasses LMPs at P-nodes, revenue projections for generators, potential curtailment scenarios for renewables, congestion analyses, cost assessments for energy and ancillary services relative to load, incremental system benefits associated with new projects, system bottlenecks, and potential strategies for relieving such bottlenecks.

Operational Integration and Strategy Refinement

A resource optimization strategy is a fusion of system design and operational characteristics, which are sourced from the facilities themselves. These characteristics offer invaluable insights into plant monitoring and system operations, which, in turn, serve as crucial inputs to our optimization process.

The precise terms of Power Purchase Agreements (PPAs) dictate the delivery requirements and compensation structures for the resource. Within the broader framework, our Day-Ahead bidding and scheduling activities play a pivotal role in crafting a daily plan for market operations. This involves determining and submitting Day-Ahead bids into the CAISO Day-Ahead market.

Real-Time Operations is an integral facet of our approach, responsible for monitoring the operational outputs of the facility, particularly concerning charging and discharging activities. It ensures that these operations align seamlessly with our bidding, scheduling, and pricing strategies, all while maintaining fidelity to system operating parameters. In the event of alarms or deviations, Real-Time Operations promptly notifies the relevant personnel, ensuring swift responses to emerging operational issues.

Post-operation, ZGlobal engages in a comprehensive review of facility performance for the day in question. This review considers the efficacy of the bidding and scheduling strategy and compares it against broader operational trends. Should results indicate a need for strategic adjustments, ZGlobal proactively communicates these findings to the client and discusses potential alternatives to enhance performance or better align with evolving market dynamics. Upon client direction, we readily implement and execute the modified strategy.

Key Constraints within the ZG Model

Within the framework of the ZGlobal Model, several critical constraints are meticulously considered. These constraints encompass:

a) Net Qualifying Capacity (NQC), Depth of Charge/Discharge, Number of Cycles, Ancillary Services, Ramping, and Battery Efficiency: These factors are integral to the assessment and optimization of energy storage systems, ensuring that they meet operational and performance requirements.

b) Congestion Revenue Rights (CRRs): Congestion management is pivotal in mitigating grid bottlenecks and ensuring efficient electricity flow.

c) Real-Time Energy Losses (RTE or Losses): Analyzing and minimizing energy losses are paramount to efficient resource optimization.

ZGlobal's resource optimization approach is a highly sophisticated and meticulously orchestrated process, integrating a broad spectrum of data inputs, operational monitoring, and strategic refinement to deliver value to our clients while promoting sustainability and efficiency within the energy sector.

Daily Optimization Example

To illustrate our resource optimization process, we have chosen a recent timeframe, specifically from September 1, 2023, to October 9, 2023. In this demonstration, our focal point is October 2, 2023, which serves as an exemplary day, while providing a broader context for the period. Our primary objective within this exercise is to maximize revenue, all the while adhering to specific operational constraints:

a) Fully charge energy storage by HE17: Ensuring that the energy storage system is fully charged by a specific hour, in this case, Hour Ending 17 (HE17).

b) Energy storage charged from solar only: Restricting the source of energy for charging the storage system to solar power exclusively.

c) Output to grid limited by Point of Interconnection (POI) MW: Imposing constraints on the maximum power that can be fed into the grid, in accordance with the capacity of the Point of Interconnection.

POI MW	**161**
Solar MW	161
Energy Storage MW	80
Energy Storage MWh	320
Min SoC	10.0%
Max SoC	98.5%
Efficiency	85.0%
NQC	80.00
On-Peak CRRs	6.50
Spin MW	5.00
Non-Spin MW	3.00

Table 1: Summary of Modeled Hybrid Project

In this demonstration, we will delve into a hybrid resource comprising 161 MW of solar generation capacity and 80 MW/320 MWh of energy storage. The essential operational characteristics of this hybrid project are concisely summarized in Table 1.

Optimal Dispatch and Revenue Maximization:

We have harnessed our ZG Locational Marginal Price (LMP) forecast model to meticulously analyze and optimize the operation of this resource. Our goal was to generate an optimal dispatch schedule for a 24-hour period on October 2, 2023, with the singular aim of maximizing the revenue generated by the hybrid plant.

The results of this optimization exercise are succinctly encapsulated below. Note the results do not account for losses.
The results of this optimization exercise are succinctly encapsulated below:

	Typical Hourly integrated Solar and Battery Dispatch
HE6	Solar Forecast is zero, Battery charge at 32 MWh
HE7	Solar forecast 20 MW, 2 MW released to the Grid, and 18 MW to charge the Battery. Battery charge is 50 MWh
HE8	Solar forecast 48 MW, 4 MW released to the Grid, and 44 MW to charge the Battery. Battery charge is 94 MWh
HE9	Solar forecast 55 MW, 4 MW released to the Grid, and 51 MW to charge the Battery. Battery charge is 145 MWh
HE10	Solar forecast 161 MW, 80 MW released to the Grid, and 81 MW to charge the Battery. Battery charge is 226 MWh
HE11	Solar forecast 94 MW, 13 MW released to the Grid, and 81 MW to charge the Battery. Battery charge is 307 MWh
HE12	Solar forecast 92 MW, 79 MW released to the Grid, and 13 MW to charge the Battery. Battery charge is 320 MWh
HE13	Solar forecast 161 MW, 161 MW released to the Grid. Battery charge is 320 MWh
HE14	Solar forecast 161 MW, 161 MW released to the Grid. Battery charge is 320 MWh

HE15	Solar forecast 161 MW, 161 MW released to the Grid. Battery charge is 320 MWh
HE16	Solar forecast 53 MW, 53 MW released to the Grid. Battery charge is 320 MWh
HE17	Solar forecast 3 MW, 80 MW released to the Grid in which 77 MW is discharged from the battery. Battery charge is 243 MWh
HE18	Solar forecast 0 MW, 80 MW released to the Grid in which 80 MW from the battery. Battery charge is 163 MWh
HE19	Solar forecast 0 MW, 80 MW released to the Grid in which 80 MW from the battery. Battery charge is 83 MWh
HE 20	Solar forecast 0 MW,46 MW released to the Grid in which 46 MW from the battery. Battery charge is 37 MWh
HE21 to HE 6	Solar forecast 0 MW, 0 MW released to the Grid in which 0 MW from the battery. Battery charge is 37 MWh

Table 2: 24-hr LMP Forecasted Model for October 2, 2020

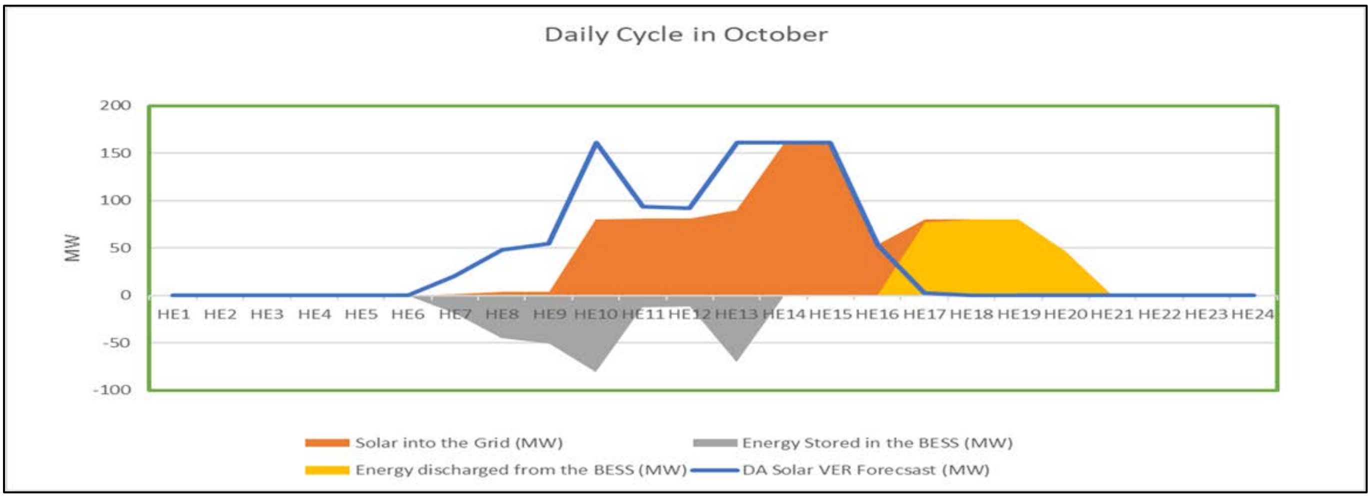


Figure 2: 24-hr LMP Forecasted Model for October 2, 2020

The results demonstrate our optimized dispatch strategy, showcasing our expertise in maximizing economic value from the hybrid resource while ensuring efficiency, sustainability, and innovative energy solutions.

ZG Optimization Performance

Our comprehensive analysis has resulted in the development of an hourly MW schedule, in tandem with their associated bids. The following table, Table 3, provides a succinct summary of this scheduling and bidding data:

Hour	DA Solar VER Forecast (MW)	DA VER MW to Grid	DA BESS MW	DA BESS MWh SoC	DA Total MW to Grid	DA A/S MW	DA Price	Energy Revenue	A/S Revenue	Cumulative Revenue
HE1	0	0	0	32	0	0	$32.14	$0.00	$0.00	$0.00
HE2	0	0	0	32	0	0	$32.03	$0.00	$0.00	$0.00
HE3	0	0	0	32	0	0	$29.76	$0.00	$0.00	$0.00
HE4	0	0	0	32	0	0	$28.63	$0.00	$0.00	$0.00
HES	0	0	0	32	0	0	$29.13	$0.00	$0.00	$0.00
HE6	0	0	0	32	0	0	$31.37	$0.00	$0.00	$0.00
HE7	20	2	-18	50	2	5	$36.07	$72.14	$5.00	$77.14
HE8	48	4	-44	94	4	5	$33.25	$133.00	$5.00	$215.14
HE9	55	4	-51	145	4	5	$27.07	$108.28	$5.00	$328.42
HE10	161	80	-81	226	80	5	$23.96	$1,916.80	$5.00	$2,250.22
HE11	94	13	-81	307	13	5	$26.12	$339.56	$5.00	$2,594.78
HE12	92	79	-13	320	79	5	$29.82	$2,355.78	$5.00	$4,955.56
HE13	161	161	0	320	161	5	$34.88	$5,615.68	$5.00	$10,576.24
HE14	161	161	0	320	161	0	$38.59	$6,212.99	$0.00	$16,789.23
HE15	161	161	0	320	161	0	$44.79	$7,211.19	$0.00	$24,000.42
HE16	53	53	0	320	53	5	$52.91	$2,804.23	$5.00	$26,809.65
HE17	3	3	0	243	77	5	$76.77	$5,911.29	$25.00	$32,745.94
HE18	0	0	0	163	80	5	$141.38	$11,310.40	$25.00	$44,081.34
HE19	0	0	0	83	80	5	$143.00	$11,440.00	$25.00	$55,546.34
HE20	0	0	0	37	46	0	$75.26	$3,461.96	$0.00	$59,008.30
HE21	0	0	0	37	0	0	$49.28	$0.00	$0.00	$59,008.30
HE22	0	0	0	37	0	0	$45.14	$0.00	$0.00	$59,008.30
HE23	0	0	0	37	0	0	$38.65	$0.00	$0.00	$59,008.30
HE24	0	0	0	37	0	0	$34.58	$0.00	$0.00	$59,008.30
Total	**1,009**	**703**	**-288**	**137 *(Average SOC)***	**1,001**	**55**	**$47 *(Average DA Price)***	**$58,893**	**$115**	**$59,008.30**

Table 3: Hourly MW Schedule and Associated Bids

Furthermore, our analysis has projected the total anticipated revenue for a 24-hour period in October 2023, as indicated in Table 4:

	DA Price	Spin Price	Non-Spin Price
24-Hr Avg	$47.27	$1.96	$0.49
Min	$23.96	$1.00	$0.25
Max	$143.00	$5.00	$1.25
Charge Bid	**$38.59**	7	**Charge Hours**
Discharge Bid	**$75.26**	4	**Discharge Hours**
Revenue		**$59,008.30**	

Table 4: Total Anticipated Revenue for 24-hrs in October 2023

Our optimized strategy is anticipated to yield an impressive $59,008 for a single day in October through participation in the CAISO Markets. It's important to note that this figure represents only the revenue generated directly from market participation and does not encompass additional income streams such as Renewable Energy Credits (RECs) and capacity payments, which lie outside the purview of CAISO's market dynamics.

When comparing the performance of ZGlobal Optimization versus dispatching based on prior day clearing prices, we see the following results:

- A substantial **23% increase in total revenue** is achieved through ZG optimization, underscoring the significant financial gains made possible by our approach.
- During peak hours[2], ZG Optimization excels, resulting in an impressive **61% higher revenue** compared to static strategies. This remarkable performance underscores the critical role our optimization techniques play during periods of high electricity demand.
- In off-peak hours, there is a modest **5% decrease in revenue** due to energy storage strategies. This highlights the inherent trade-offs involved in energy storage and demonstrates the sophistication of ZG Optimization.
- When examining standalone solar performance, ZG Optimization attains **comparable results to static strategies**, ensuring consistent and competitive returns.

Daily Revenue comparison	CAISO DA Revenue $/MWh	ZG Revenue Optimization Results ($/MWh)	Comparison
Average (All hours)	$47.27	$58.33	23.38%
Average off-peak hrs	$34.80	$32.84	-5.62%
Average Peak hrs (17-21)	$97.00	$156.95	61.80%
Average standalone Solar (Solar Hours)	$34.63	$34.63	0.00%

Table 5: Daily Revenue Comparison when Utilizing ZG Optimization

[2] CAISO peak and off-peak definition

After the hours modeled have transpired, we conduct a comprehensive evaluation of how closely our forecasts align with the actual CAISO Locational Marginal Prices (LMP). This comparison, spanning from September 1, 2023, to October 9, 2023, is visually represented in Figure 3:

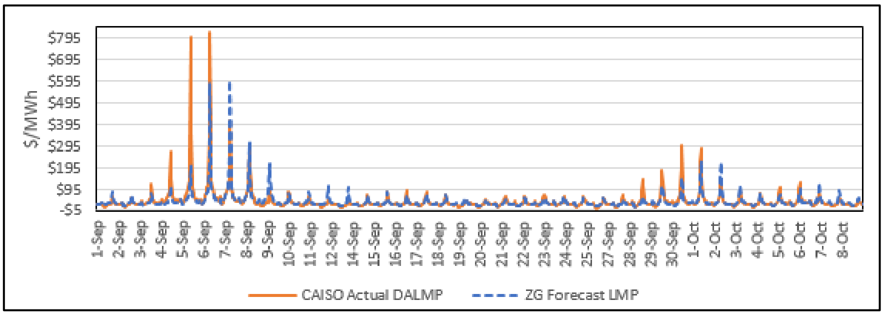


Figure 3: CAISO Actual LMP's vs ZG Forecasted LMP's

Throughout this study period, the average error in our LMP forecasting is calculated at -5.8%. The actual CAISO Day-Ahead (DA) average LMP was $43.1/MWh, whereas our ZG forecast projected a value of $40.7/MWh. This translates to a notable 5.8% increment in revenue for the resources, primarily due to the MWh dispatch optimization realized through our ZG model.

To further understand the performance of our model, we closely examine peak hours and price spikes in Figure 4.

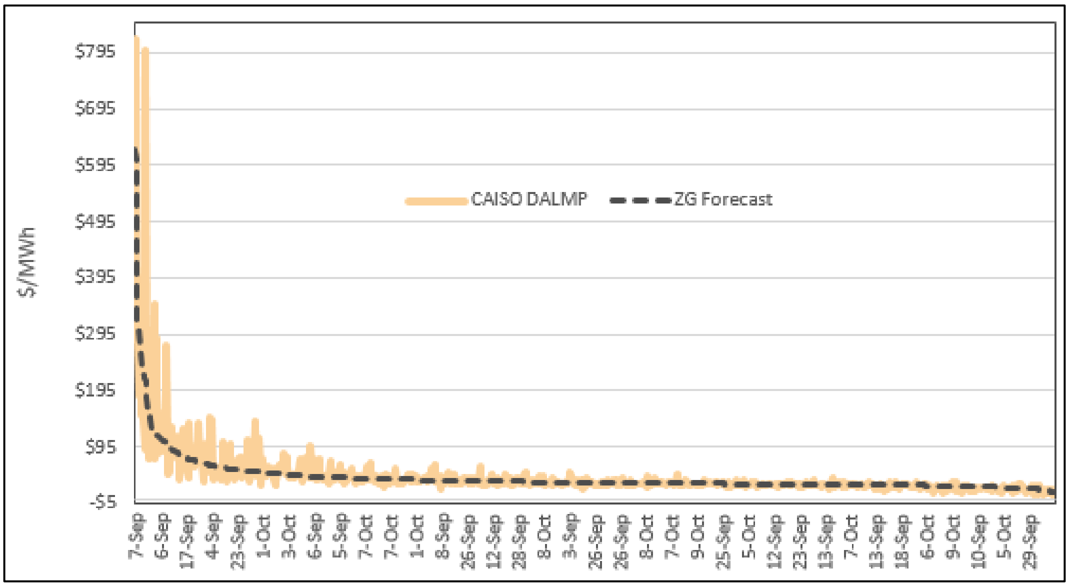


Figure 4: CAISO Actual LMP's vs ZG Forecasted LMP's (Peak Hours)

While our model effectively predicts the occurrence of spikes in LMP, it tends to slightly underestimate the magnitude of these spikes. The unpredictability of spike magnitude, often influenced by administrative and manual interventions by CAISO operators, contributes to this disparity. Consequently, the ZG model forecasts a more conservative and lower LMP than the actual CAISO LMP, aligning closely with the CAISO's actual LMP in practice.

In summary, the ZGlobal model plays an essential role in predicting the optimal resource schedule, contributing to revenue gains for the resource. It excels in understanding LMP trends, even though it occasionally underestimates the magnitude of price spikes due to their unpredictable nature. The result is a more resilient and informed approach to energy resource optimization.