True Cost Of Cycling Power Plants Enhances The Value Of Compressed Air Energy Storage (CAES) Systems

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INTRODUCTION

Compressed air energy storage (CAES) may offer electric utility systems significant added benefits that have been overlooked in the past. These benefits arise by recognizing the significant equipment damage to fossil power plants caused by stop-start and load-follow cycling that is significantly reduced with CAES. Cycling of conventional fossil units can be reduced with CAES by creating more electrical load at night and thus preventing the need for a fleet of mid-merit fossil units to cycle off. In addition, during daily peak hours CAES reduces the need of turning on peaking units for short periods of time.

In recent years, many utilities' thermal generation units, particularly older coal, oil, and gas units, have been forced to cycle—often on a daily basis. This is partially because of the commissioning of newer nuclear and large combined cycle units, and partially due to the infusion of power from efficient merchant power plants. What some utilities have found is that the true, or total, cost of cycling these older fossil units is many times the cost that they historically used in making dispatch and planning decisions (see Table 1). Aptech Engineering Services, Inc. (APTECH), a leader in power plant failure/performance analysis and damage mitigation/repair technologies, has evaluated the True Cost of Cycling on more than 200 units and found that cycling accelerates the wear and tear of many components of a generation unit. The result is that increased cycling leads to higher maintenance costs and durations, increased forced outage rates, higher heat rates (i.e., lower efficiencies), and shortened life expectancies. Figure 1 is an example breakdown of cycling costs for a fossil unit.

Why do we feel that the true cost of cycling is so important? Because it is an underlying cost factor that should have a significant impact on generation system dispatch and planning. Existing resources that can be used for load following with low "wear-and-tear cost", such as CAES and pumped hydro, should probably be used more for that purpose than current practice—and, conversely large fossil units should be cycled less. Furthermore, the value of resources such as CAES and pumped storage are significantly more than currently accounted for, if they can be used to avoid fossil unit cycles.

If cycling costs are correctly estimated and used in planning and dispatch, a utility can save up to 5% on its overall long-term production costs. This may seem small, but in an era of narrowing margins and increasing competition, 5% can mean the difference between financial health and financial disaster.

COSTS OF CYCLING AND CYCLING ADVISOR

We have helped many U.S. and foreign utilities estimate unit-specific total costs of cycling, which are then used to make better dispatch decisions, and to properly value resource opportunities such as base loaded merchant (or contract) power and flexible storage technologies such as CAES. When the true cost of cycling is properly accounted for, the value of CAES resources significantly increases by reducing damage related costs of mid-merit fossil units and peaking units. This added value of CAES is similar to that of a pumped storage facility, but CAES installation costs are often less than half that of pumped storage. APTECH has done an example benefits calculation for a large utility system using APTECH's system dispatch optimization and production cost model, Cycling⬍Advisor. This analysis tool allows consideration of all important system production costs, the largest being fuel and equipment damage related costs, and includes all system constraints and off-system transaction

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opportunities. Uniquely, it also accounts for cycling costs for all significant transients ranging from load following to cold starts and shutdowns, steady loads above unit ratings, and cycling-influenced dynamic heat rate effects (over and above the effects calculated from heat rate testing curves under ideal steady state conditions).

This paper presents a limited analysis of the added benefits of storage to a system that consists predominantly of large coal units and some peaking gas units. The primary benefits of storage in such a system must come from the increased use of low cost coal units and decreased use of high cost gas units. We used APTECH's Cycling⬍ Advisor to estimate these benefits for a large utility system over a ten day period. We then used the same model to estimate the added benefits of storage when taking cycling damage costs and dynamic heat rate effects into account. For the periods simulated, accounting for cycling damage and dynamic heat rate effects increases the total system benefits by a range of about 5% to 28%. This percent is generally higher for periods of more volatile system loads.

Our Cycling⬍ Advisor studies are based on hourly load variations and do not take into account damage to conventional generation units due to Automatic Generation Control (AGC), used to control second to second variations in the load-resource balance. With increased saturation of intermittent wind generation, the need for more AGC support will likely be needed. Again, CAES may be able provide AGC support with relatively low damage cost compared to that of conventional generation.

Table 1 — Comparing "Typically Used" vs. True Cycling Costs

Unit Type	Typical Cycling Cost Now Used*	Range to True Cost
Small Drum	$5,000	$15,000 — $100,000
Large Supercritical	$10,000	$50,000 — $300,000
Gas Turbine	$100	$300 — $10,000

*Based on fuel and auxiliary power used in unit startups.

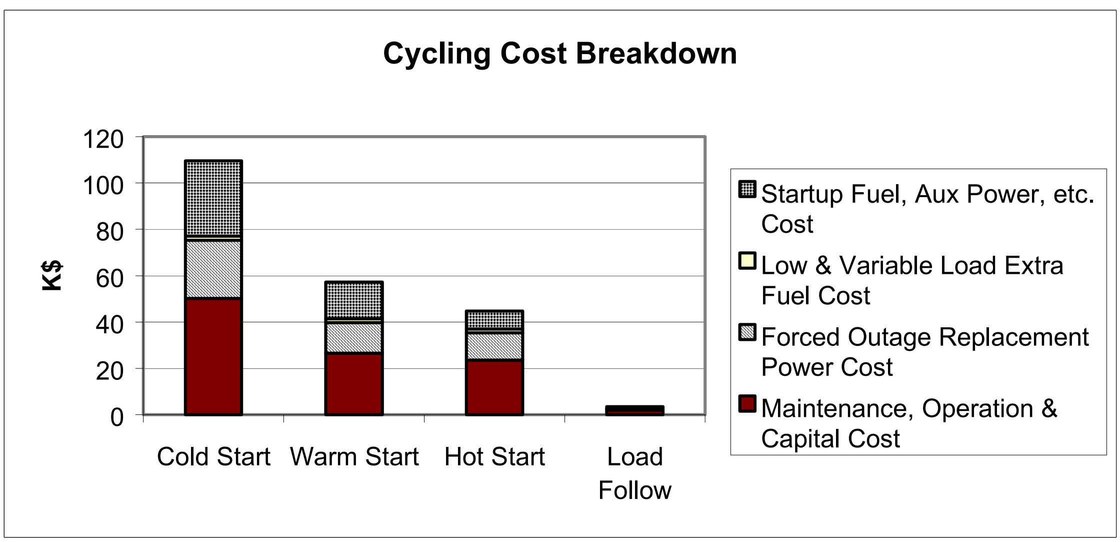

Figure 1 Example Cycling Cost Breakdown

SYSTEM MODELING RESULTS

APTECH analyzed the total cost of meeting the 10-day summer electric demand for a large utility system using APTECH's Cycling⬍ Advisor software for three scenarios. Three cases: a base case without CAES; a second case with 810 MW of CAES installed; and a third case 1890 MW of CAES installed, were examined and all significant production costs were optimized for each system with special emphasis on fuel and cycling costs.

The major financial results are tabulated in Table 1, Summary of Results, including cost savings from the utilization of CAES capacity. Some financial result highlights of cost savings for this 10-day period:

> 1) Adding 810 MW of CAES saves $2.4M in total costs, a 5.7% savings compared to the base case or $3000 per installed CAAM MW for the ten day period. This percentage savings is about the same for both the generation fuel cost (6.1%) and wear and the tear cost (6.4%) subtotals. Cycling costs dominate the wear and tear costs.
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> 2) Adding 1890 MW of CAES saves $5.1M in total costs, an 11.9% savings compared to the base case or $2700 per installed CAAM MW for the 10 day period examined. Comparing the wear and tear costs and generation fuel costs for Case 1 to Case 3, the percentage savings is less for generation fuel (11.8%) than for the wear and tear (21.1%) subtotal.[2]

These substantial savings may be increased as CAES technology improves. These savings should be extrapolated for all hours of the year and then compared with the capital costs of installing the CAES capacity (or annual carrying charges).

How did the CAES capacity achieve these results? For the base case without any CAES under this heavy 10-day demand, the 33 base loaded coal units run at a capacity factor (CF) of 90% and the 57 peakers run at a CF of 21.5%. These smaller peakers produce only 9% of the energy demand but their higher fuel cost results in their absorbing about 31% of the costs ($13.1M)

For Case 2 with 810 MW of installed CAES capacity, the coal units are forced to run at a higher capacity factor of 93% (to produce compressed air), adding about a million dollars in cost. An additional $2.4M in variable costs are added to run the CAES gas turbines. These added costs are much more than compensated by the $6M saved in fuel and cycling costs of the 57 expensive peakers which have their capacity factor now cut in half. (to CF = 10.5%). Cycling costs are generally lowered due to less demanding transients on both base loaded and peaker units.

For Case 3 with 1,890 MW of installed CAES, the trends continue with lopsided benefits to cycling costs as mentioned previously. The cycling costs dominate the wear and tear costs. The coal units' capacity factor increases to 95.5%. But now the use of the 57 expensive peakers is nearly eliminated, since the system can meet the required 0.7% of the demand with a capacity factor of only 1.8%. Even at this level, the peakers still cost $1.6M to run, but this is a small fraction of their cost to run in the base case system in the absence of CAES ($13.1M).

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[2] Other APTECH studies show that this Cases 1 vs. 3 result of greater percentage savings for cycling is highly system dependent. This suggests that Cycling Advisor is required to estimate CAES savings for each new system and substantial change in fuel costs, etc.

Table 2: Summary of Results

Case	Fuel for Generation	Wear and Tear	Start-up Fuel and Aux. Power	Purchases	Sales	Grand Total	Dollars
Total Cycling Costs of Low-Cost, High Revenue Strategy for 10-day Period of High Load Demand in Summer							Savings for Demand Co
1. Base case - representative system without 270 MW CAES	$39,972,036	$2,256,612	$216,085	$455,399	-$8,627	$42,891,508	
2. System with three x 810 MW of CAES	$37,536,448	$2,112,053	$169,102	$652,416	-$8,013	$40,462,008	$2,429,50
3. System with 1890 MW of CAES	$35,253,848	$1,779,688	$134,379	$625,183	-$6,020	$37,787,080	$5,104,42