Coupling Wind Power and CCS Coal Plants with Amine Storage

Rubenka Bandyopadhyay. Advisor: Prof. Dalia Patino Echeverri
Nicholas School of the Environment, Duke University

Abstract

- Carbon Capture and Storage has significant potential to reduce CO_2 emissions from coal fired power plants. However, there is reduced power output from the coal plants fitted with CCS. Of the different kinds of CCS technology available, the post-combustion amine-based CCS system is the most likely to be used for retrofitting coal plants. The loss of revenue due to energy penalty from installation of amine-based CCS could be reduced by installing an amine storage system. This would allow the coal plants to utilize price volatility in the electric power market. Integration of with an onsite wind farm could provide additional benefits:
- With an optimum size of amine-storage tank, it may be possible to use all of the wind power available regardless of its intermittency
- Transmission costs for connecting the wind farm to the grid are reduced because the wind farm is built at a location that is already connected to the grid
- Cost of integrating the wind power with the system (i.e. ancillary services costs) is reduced because the combined power output of the CCS-retrofitted coal plant and the wind farm will be less variable
- **Objective: Determine optimal size of amine storage tank and optimal wind power installed capacity to maximize profits from a CCS-retrofitted coal-fired power plant.**

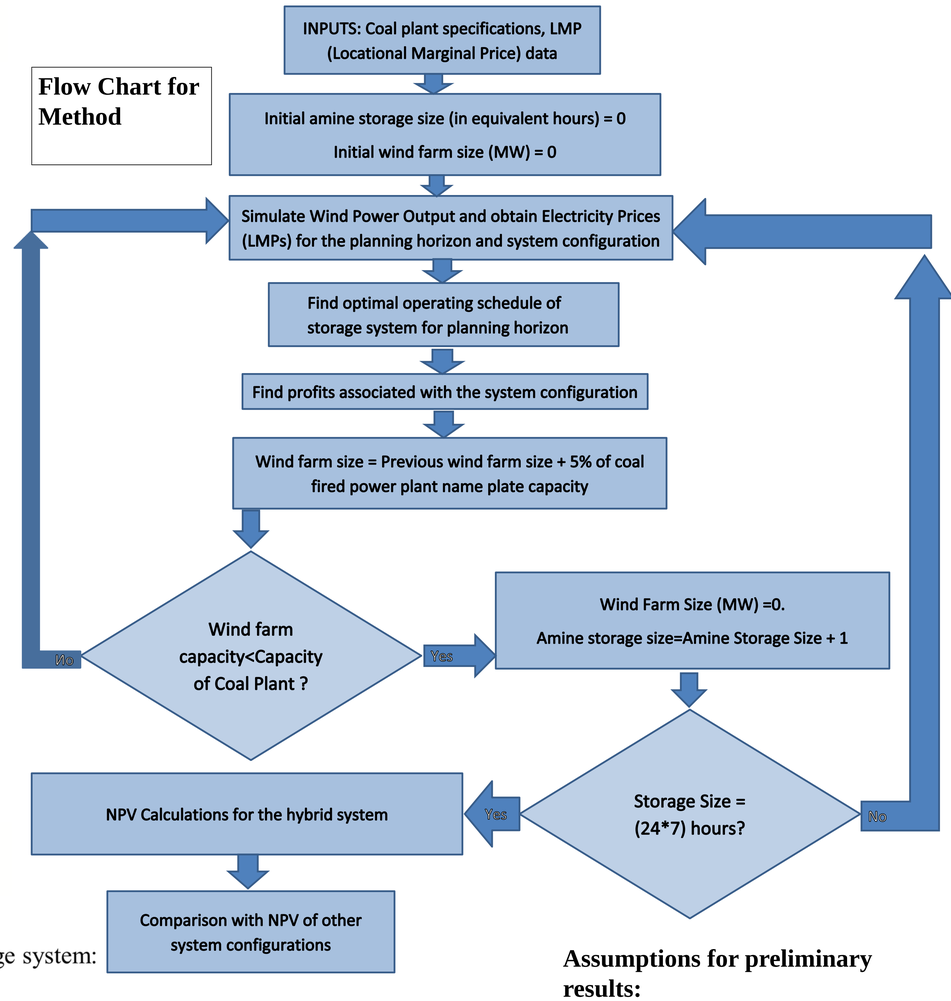
METHOD

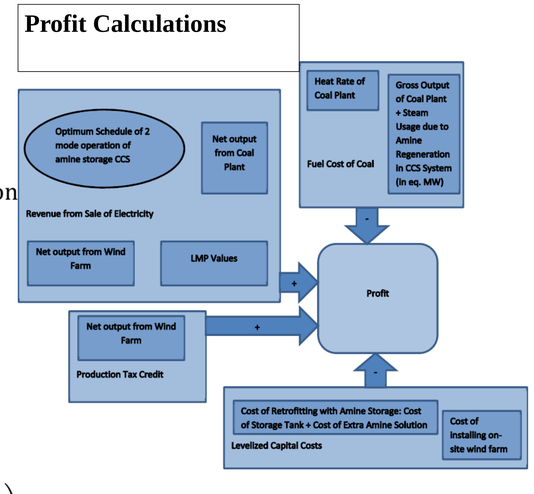
1. Formulation of daily profit maximization for a 2 mode amine storage system:

$O_{c,t}$ = Output of coal plant at time t when CCS operates continuously
$O_{w,t}$ = Output of wind farm at time t
E = CCS energy penalty that can be avoided during operation of CCS in storage mode
H_S = Maximum hours of operation in storage mode/Size of storage tank in equivalent hour
H_R = Number of hours to empty a tank with saturated solution
Z = Expression for profit of a wind-amine storage hybrid system
LMP_t = Locational Marginal Price at time t
U_t = Decision variable.
$U_t \rightarrow 0$, when operating in storage mode
$U_t \rightarrow 1$, when operating in regeneration mode

Profit Maximization Problem: $\max_{U_1,\ldots,U_{24}} Z$

$$Z = \sum_{t=1}^{24} (1 - U_t)(O_{c,t} + O_{w,t} + E) LMP_t + U_t \left(O_{c,t} + O_{w,t} - \frac{H_S^{\max}}{H_R^{\max}} E \right) LMP\_t$$





Assumptions for preliminary results:

1. Coal Plant characteristics are assumed to be identical to that of the Powerton Plant in Illinois, as given in EGRID [7]
2. Wind power simulations are obtained using 'training' data from EWITS [6]. Wind power data is simulated using Markov Chain Monte Carlo Simulations as in [2]
3. Energy Consumption due to CCS is obtained from IECM [4]
4. Capital Cost estimates are obtained from [1] and [3]
5. Fixed Charge Factor: 0.1128 [4]
6. Lifetime of Plant: 30 years
7. LMP data was taken from Chicago hub [5].

Preliminary Results

Optimum Configuration for case considered : 1000 MW wind farm, for a storage capacity of 3 hours.

Best Case Scenario*, with 33% of Gross Output Consumed by CCS	On-site Wind Farm integrated with 2-mode Amine Storage Coal Plant (Hybrid System)	2-mode Amine Storage Coal Plant	Coal Plant with continuous operation of CCS	Benefit obtained from hybrid system with respect to Coal plant with continuous operation of CCS
NPV Value (Million USD)	2,187	-867	-1,101	3,288

Worst Case Scenario*, with 33% of Gross Output Consumed by CCS	On-site Wind Farm integrated with 2-mode Amine Storage Coal Plant (Hybrid System)	2-mode Amine Storage Coal Plant	Coal Plant with continuous operation of CCS	Benefit obtained from hybrid system with respect to Coal plant with continuous operation of CCS
NPV Value (Million USD)	-722	-2,118	-2,974	2,251

Daily Profit ($) for best case scenario *	40% of Gross output consumed by CCS System	35% of Gross output consumed by CCS System	33% of Gross output consumed by CCS System
Low Capital Cost Estimate of Wind farm (1,913 $/kW)	483,335	535,635	556,335
High Capital Cost Estimate of Wind farm(2,120$/kW)	410,408	462,708	483,408

Daily Profit ($) for worst case scenario*	40% of Gross output consumed by CCS System	35% of Gross output consumed by CCS System	33% of Gross output consumed by CCS System
Low Capital Cost Estimate of Wind farm (1,913 $/kW)	-227,364	-179,364	-159,634
High Capital Cost Estimate of Wind farm (2,120$/kW)	-300,291	-252,291	-232,291

* The best and worst case scenarios correspond to days with wide fluctuations in LMP + High steady wind output close to 1,000 MW and days with almost no variations in LMP, and Low wind outputs, respectively

Conclusions and Work in Progress

-For this particular case studied, the hybrid system is likely to be more profitable than a coal + CCS system alone. A more detailed analysis considering suitable coal plants located in states with ambitious RPS standards and abundant wind resources are currently being analyzed. Research is underway to identify the optimal configuration for a 3-mode amine-storage CCS system. Optimization of a weekly schedule of operation instead of the daily schedule is also being explored.

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