Quantifying the Impact of Adding Renewable Energy on the Grid from the Economic Point of View

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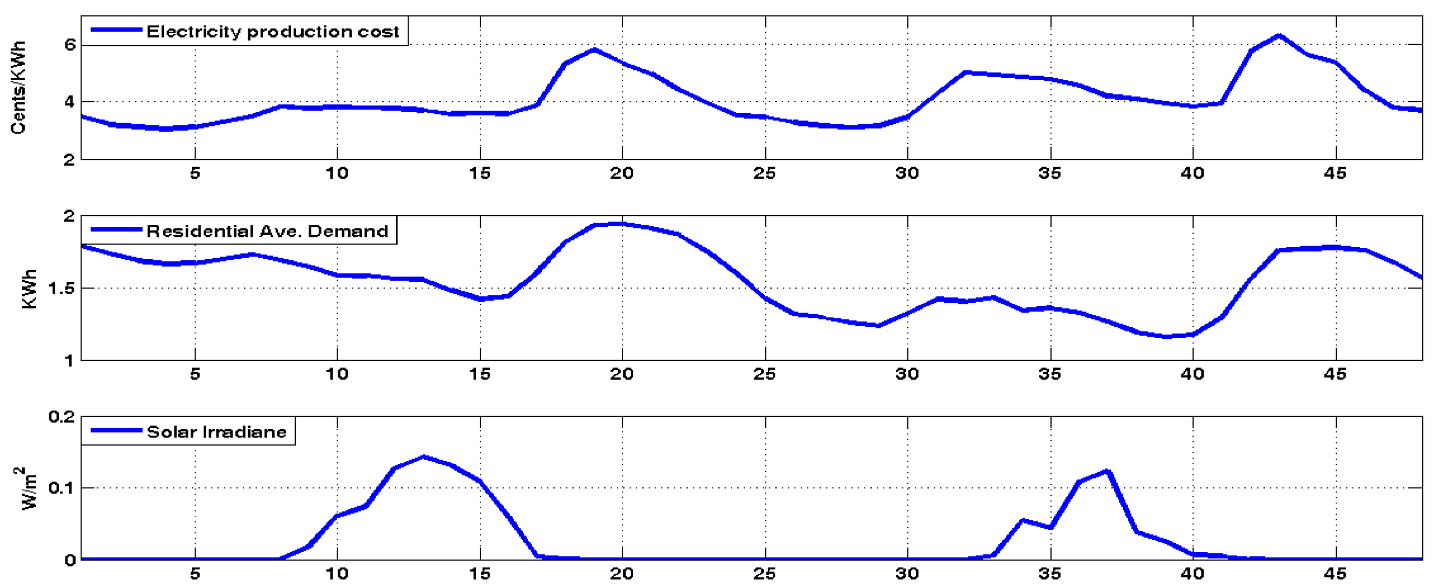
I. Introduction/Motivation

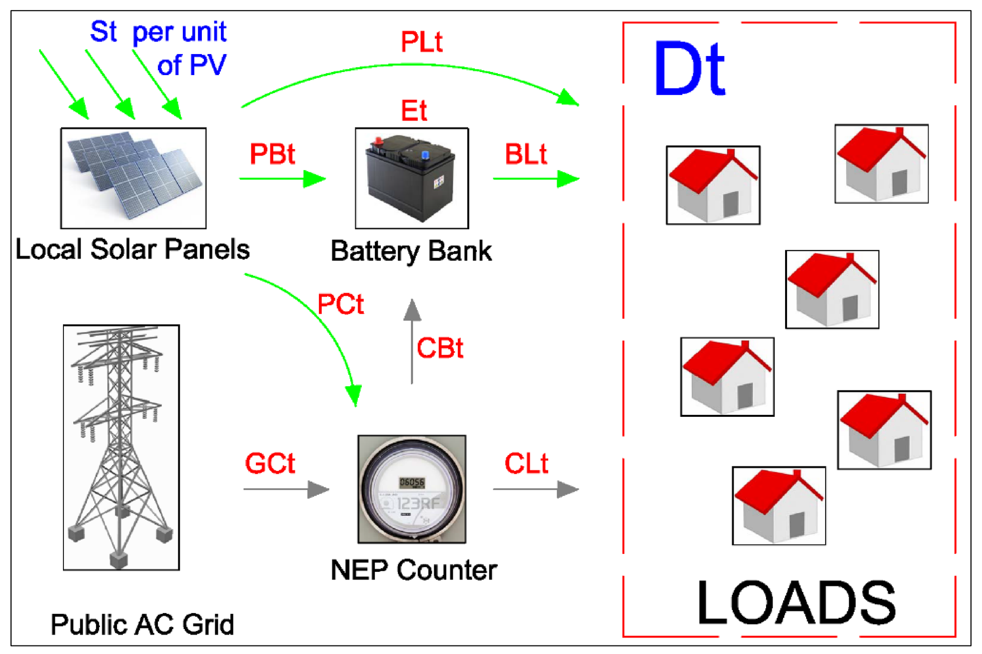
Growth in renewable energy, has been rapid over the past decade. However, the problems of adding them, specifically from the point of view of the stability and reliability of the grid have gradually come to light. Nowadays rather than uncertainty behind the demand behavior, electricity entities have to deal with uncertainty behind the renewable energy generation. Substantial research is going on in order to remedy the problems of stabilizing the grids having a notable percentage of renewable energy on the grid. One of the best offered solution is adding storage systems. The aim of the proposed research is to pair the offered solutions of stabilizing the grid to the economic assessment.

Observation:



Demand vs. Wholesale Market Price vs. Solar Irradiance in Dayton, OH (Source: Duck Energy and Nrel)

II. System Model



With storage system and direct connection of PV to loads

Primary Objective:

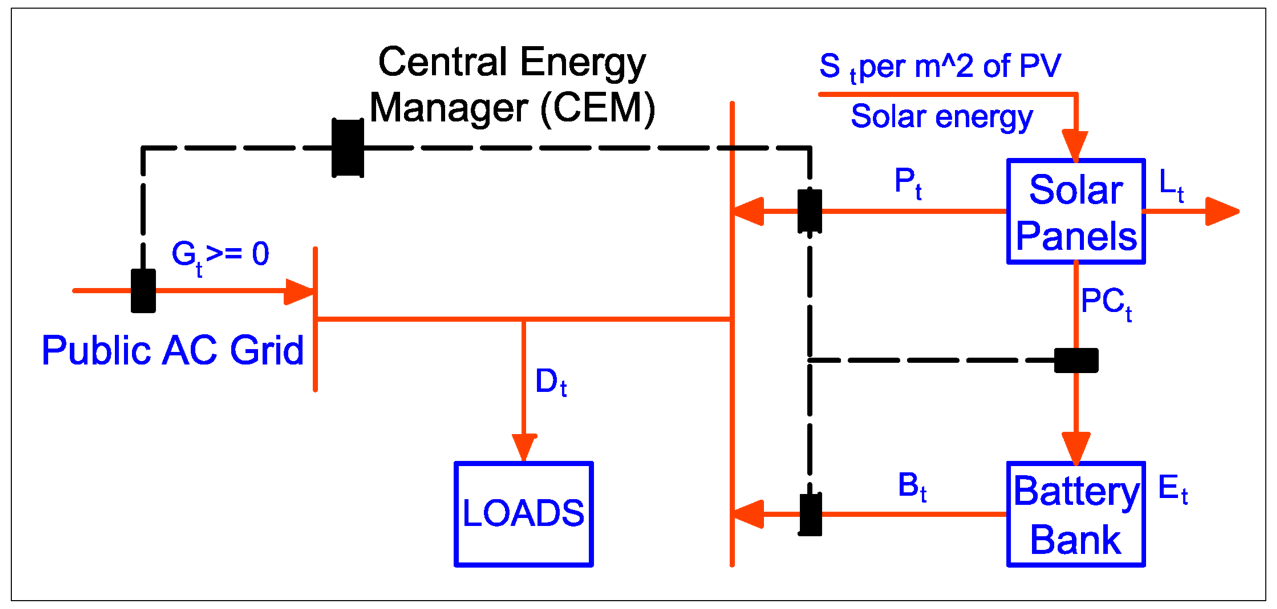
Design a Central Energy Manager (CEM) to **minimize electricity bill** by managing flow of power between solar panels, storage, grid, and loads.

Questions to be answered:

1) At each time what percentage of the solar panels' output must flow directly to the loads, and what percentage to the batteries?

2) At what time, for how long, and for how much, batteries should the be charged and discharged?

3) What is the best size of the solar panels and battery bank? (Capitalized cost)



III. Formulation

Objective Function:

$$min \quad f(G_t) = a * max(G_t) + b * (sum(G_t)) + c$$

Equality Constraints:

- $D_t = G_t + P_t + B_t$

- $S_t * PV_{size} = P_t + PC_t + L_t$

- $E_t = \sum_{i=1}^{t-1} (B_{eff} * PC_i - B_i)$

Inequality Constraints:

- On the grid: $G_t \geq 0$

- Stored Energy:

$$\sum_{i=1}^{t-1} (PC_i - B_i) + E_0 \geq 0$$

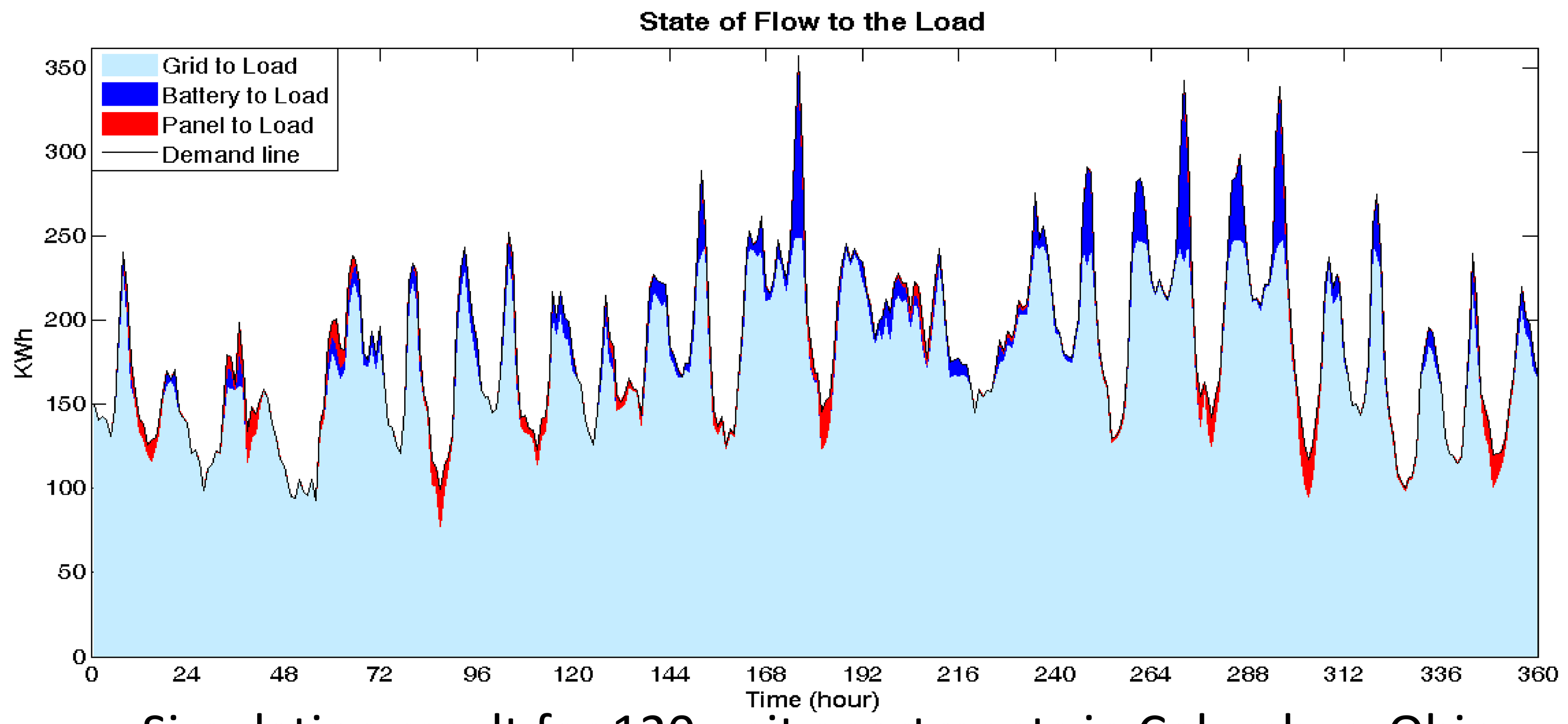
- Battery size: $E_t \leq E_{max}$

- Battery Discharge: $B_t \leq E_t$

IV. Simulation Results

Electricity Bill Minimization:

For 200 square meter of PV and 200 KWh of battery :



Simulation result for 120 unit apartments in Columbus, Ohio

Result for Feb 2014

V. Future Works

Utility retailers like this:

Bill cost	Battery size in KWh	PV size in square meter					
Initial was:		0	100	200	300	500	800
$3,645.15	50	2895.87	2924.45	2954.575	2983.395	3042.091	3128.945
	100	2481.524	2489.902	2496.907	2505.407	2524.082	2744.291
	200	1656.122	1679.605	1710.86	1690.858	1750.619	2344.301

Environmentalists like this:

Consumption	Battery size in KWh	PV size in square meter					
Initial was:		0	100	200	300	500	800
113135.59KWh	50	113245.8	111758.2	110180.7	108669	105602.1	101085
	100	113453.9	111909.6	110403	108879.6	105811.5	101162.9
	200	115590.3	113663.7	111419.7	110946	107037.9	101955.7

Power Engineers like this :

Load factor	Battery size in KWh	PV size in square meter					
Initial was:		0	100	200	300	500	800
0.47	50	0.548137	0.540924	0.533294	0.525987	0.51114	0.489231
	100	0.591212	0.585907	0.580852	0.575594	0.564846	0.528888
	200	0.681979	0.674025	0.66436	0.665047	0.647668	0.572175