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Assessment of Alternatives Effects and Choosing the Optimized Demand Response Capacity of Automatic Lighting System

Optimal Demand Response Capacity of Automatic Lighting Control

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I. Introduction/Motivation

Why Automatic Lighting Control?

Electrical Usage for Lighting purposes:

- 14% Electrical Usage in residential buildings
- 35% in commercial buildings

499 billion kilowatt-hours in US in 2010

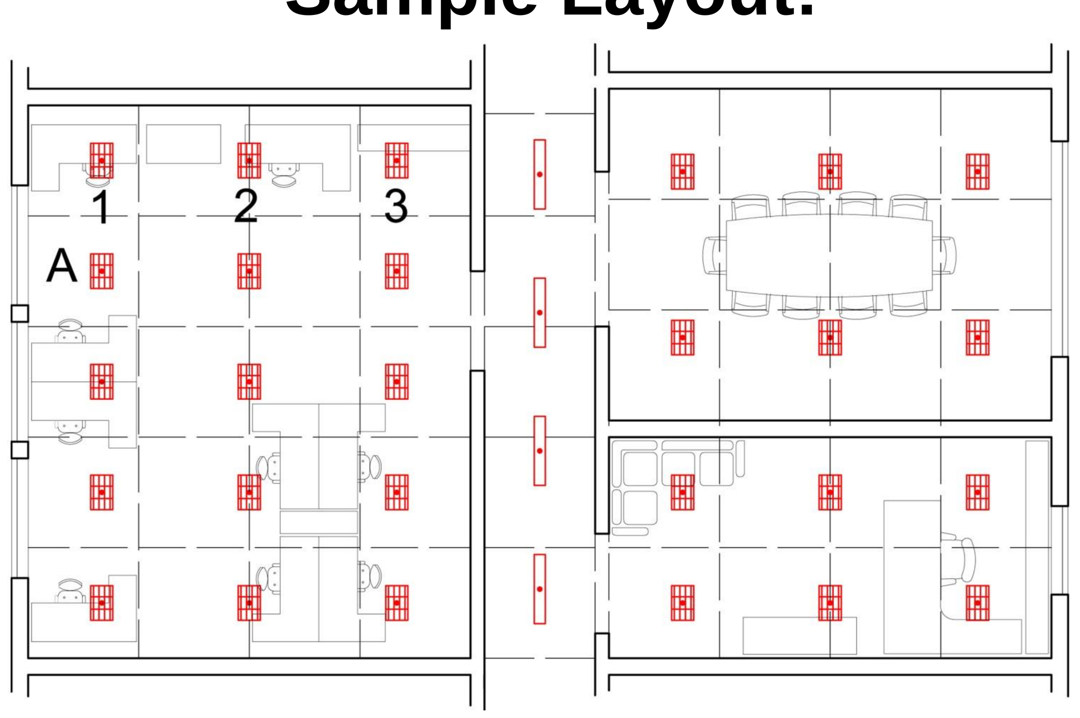
What is Demand Response?

Demand response programs seek to adjust the normal consumption patterns of electric power consumers in response to incentive payments that are offered by utility companies to induce lower consumption at peak hours or when the power system reliability is at risk.

Research Objective:

To take a systematic optimization-based approach to assess demand response capacity of automatic lighting control systems.

Sample Layout:



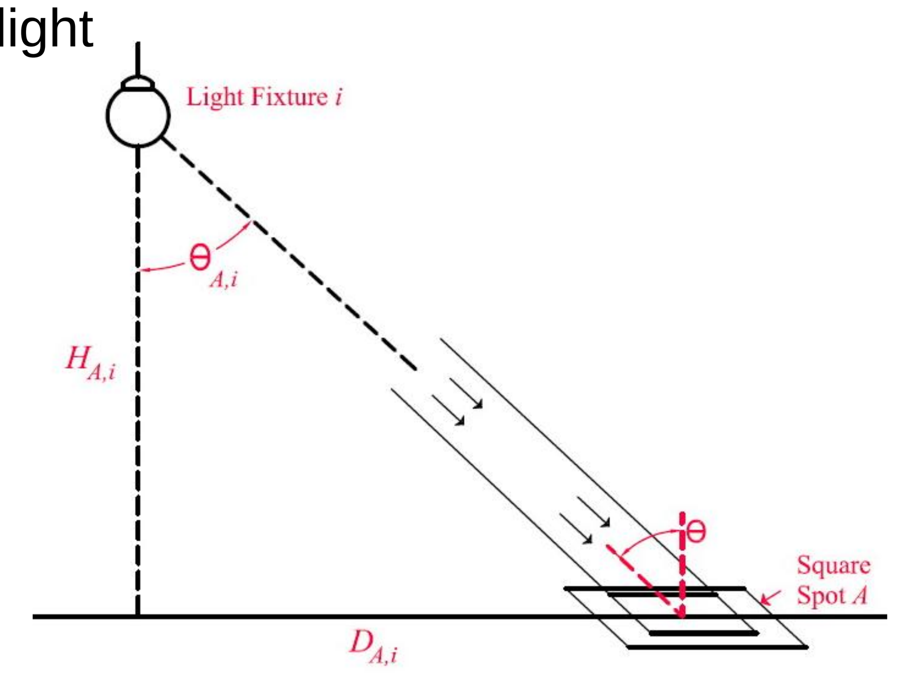
Dividing into several square spots.
Daylight comes through the windows.

II. System Model

The illumination of each spot:

$$I_A = f_A(P_1, \ldots, P_L, \omega)$$

Power consumption Daylight



Light intensity

$$I_{A,i} = \frac{C_i \cos^3(\theta_{A,i})}{H_{A,i}^2}$$

power consumption

$$C_i = \gamma_i P_i + \kappa_i$$

Light intensity

exterior vertical illumination

$$I_{A,\omega} = \tau_A \varphi_A \omega$$

transmittance of window wall coefficient of utilization

$$I_A = \sum_{i \in L} \alpha_{A,i} P_i + \beta_A \omega + \lambda_A$$

III. Optimal Demand Response

1- What is the feasible range of ΔP ?

Normal condition: $$P_{total}^{\max} = \min_{P} \sum_{i \in L} P_i$$

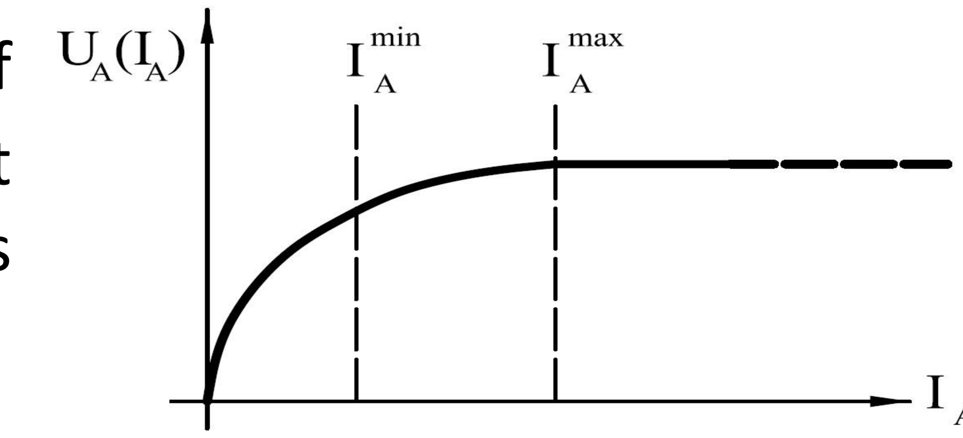
Subject to $$\sum_{i \in L} \alpha_{A,i} P_i + \beta_A \omega + \lambda_A \geq I_A^{\max}$$

Reduction request: $$P_{total}^{\min} = \min_{P} \sum_{i \in L} P_i$$

Subject to $$\sum_{i \in L} \alpha_{A,i} P_i + \beta_A \omega + \lambda_A \geq I_A^{\min}$$

2- What is the best way to reduce power consumption?

An example of utility function that describes the users lighting comfort

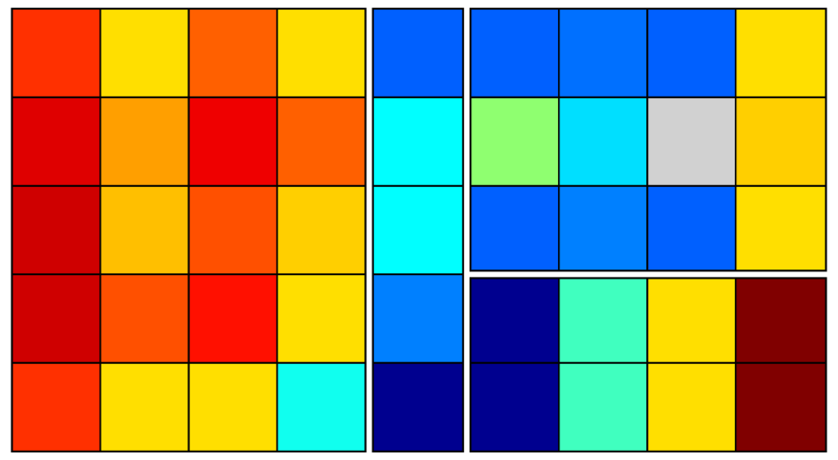


Maximize $$\sum_{A \in S} U_A\left(\sum_{i \in L} \alpha_{A,i} P_i + \beta_A \omega + \lambda_A\right)$$

Subject to $$\sum_{i \in L} \alpha_{A,i} P_i + \beta_A \omega + \lambda_A \geq I_A^{\min}$$

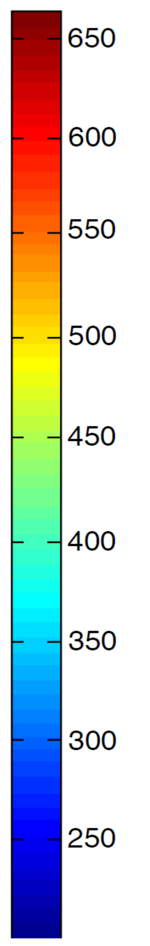
$$\sum_{i \in L} P_i = P_{total}^{\max} - \Delta P$$

IV. Results



Illumination level

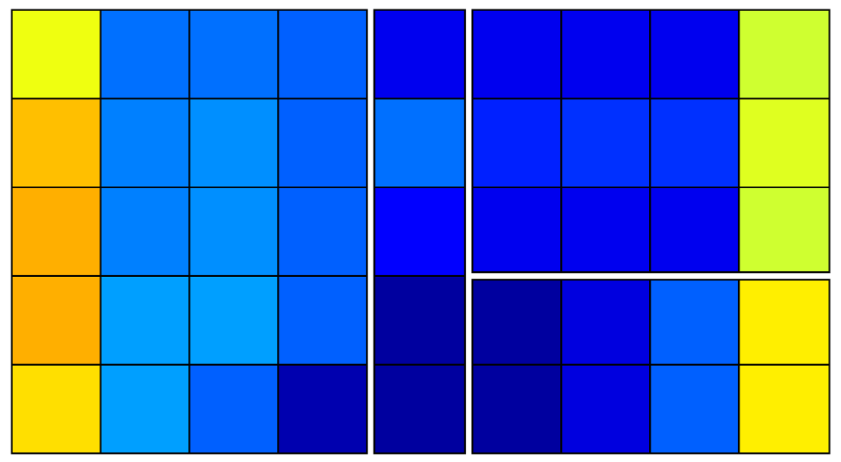
$P_{total}^{\max} = 1{,}483 watts$



$P_{total}^{\max} = 987 watts$

$\Delta P = 496 watts$

More than 30% reduction



The results show the significant potential of automatic lighting control in participating in demand response program.

V. Future Work

To change some of the constants to variables and try to find the demand response capacity in more realistic situations.