IMMEDIATE COST FUNCTION

Camila Metello

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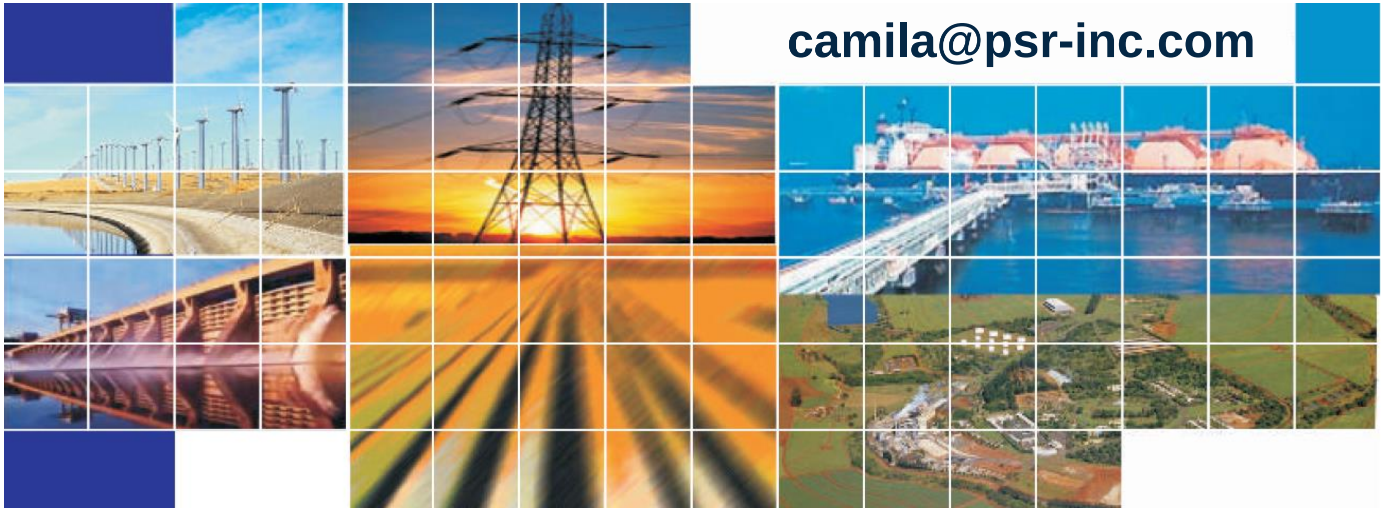

ICSP

June 2016

Outline

- Introduction
- SDDP
- Basic concepts
- Immediate cost function calculation method
- Results
- Final conclusions

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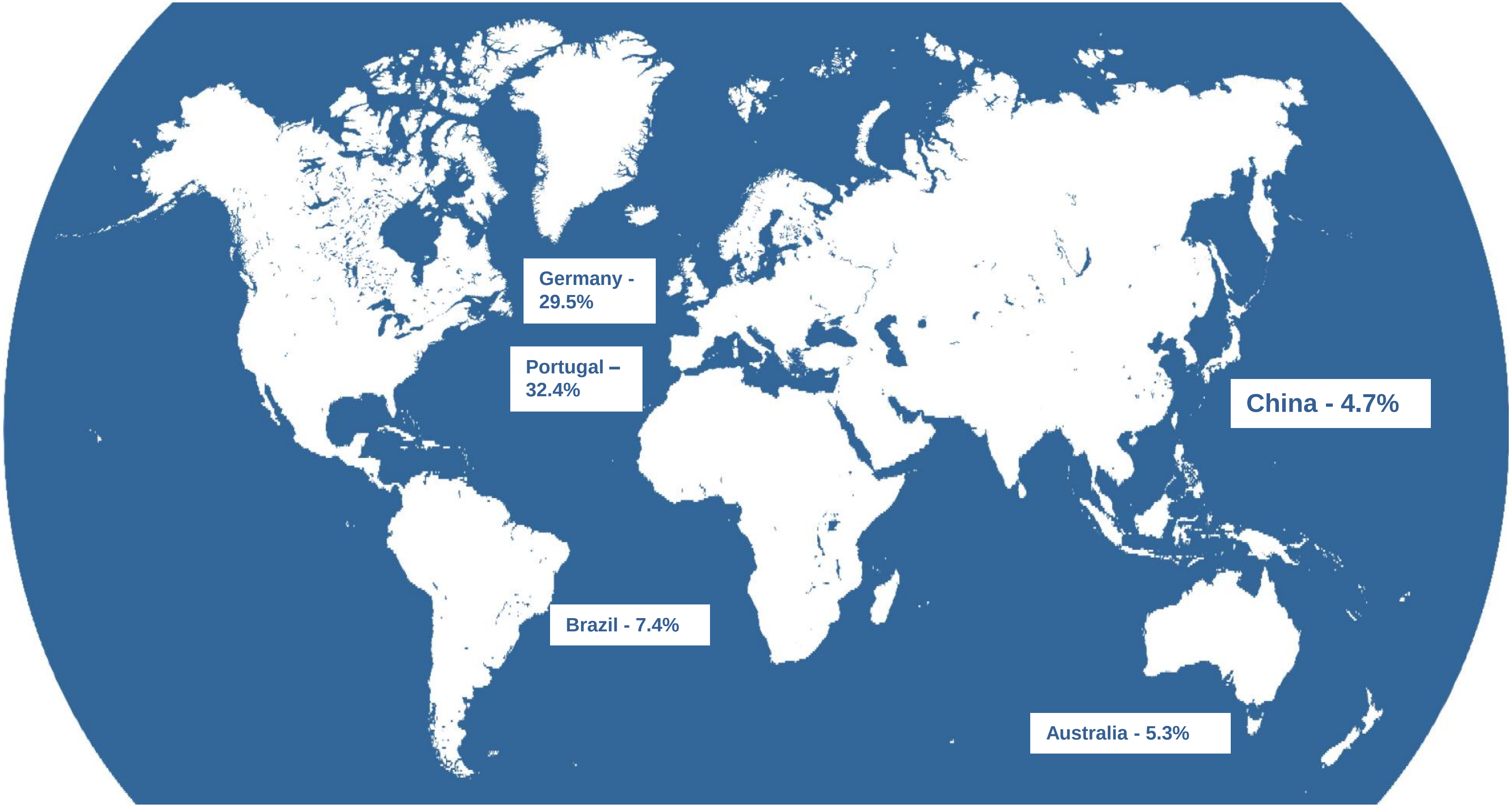
Introduction

- Non-hydro renewable generation in energy markets:

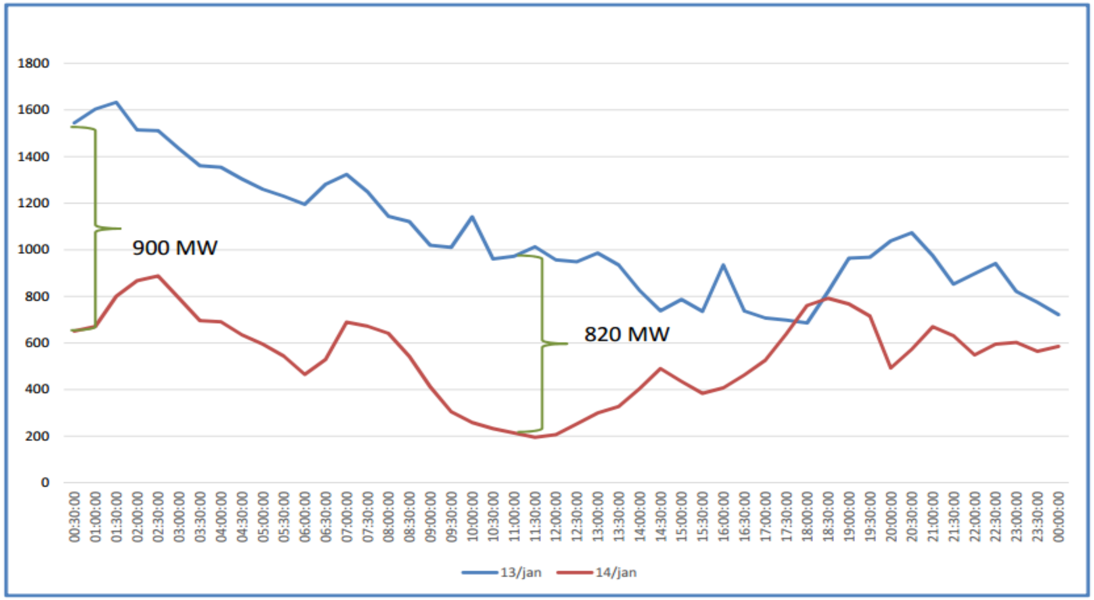


Introduction

- Renewable generation penetration in energy markets:
  - In Brazil:
    - 3% of total generation capacity is Wind power
    - Great solar generation potential
  - All over the world:
    - In 2015, over 60 GW of wind generation sources were installed in the world, half of this capacity in China
    - In Germany, the goal is to have renewable generation responsible for 80% of total yearly energy generation in 2050.

Introduction

- Renewable sources such as wind and solar bring small time frame generation uncertainties



Introduction

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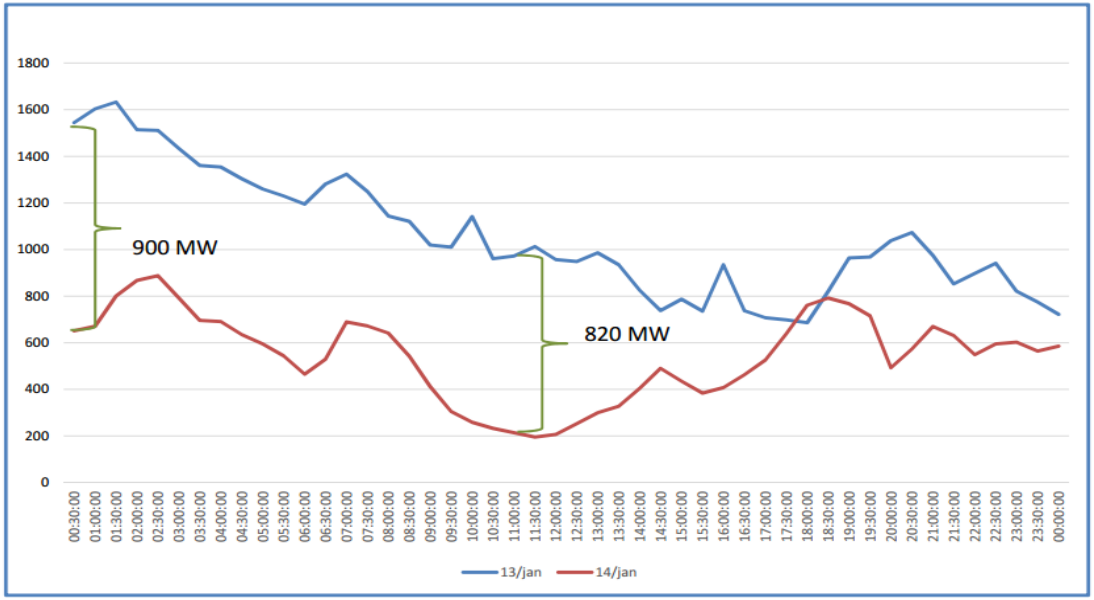

- We need hourly resolution !

Introduction

- Number of variables in the optimization problem for Brazil system (1 month)

Constraints	3 Block problem	Hourly problem
Water balance constraints	161	+ 117,000
Load balance constraints	12	+ 2,900
Maximum generation & turbining constraints	900	+219,000
Maximum & minimum volume constraints	322	+235,000
Total	1461	+573,000

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Total	1461	+573,000

How can we obtain hourly based results without representing hourly variables ?

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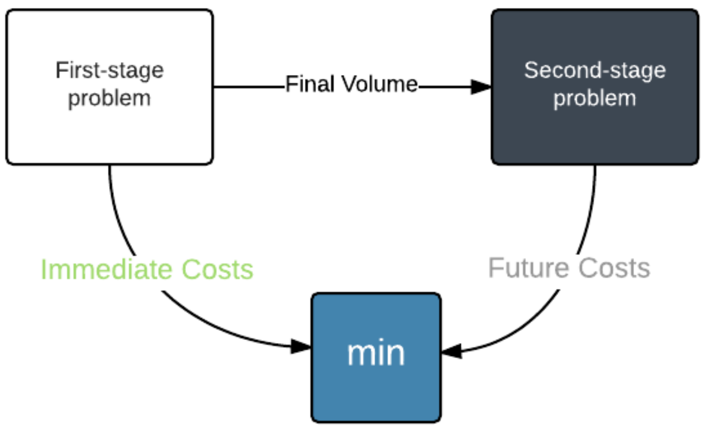
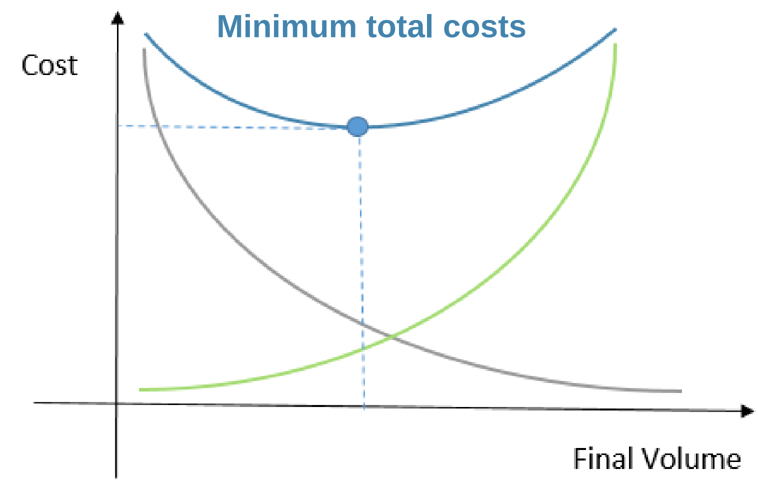
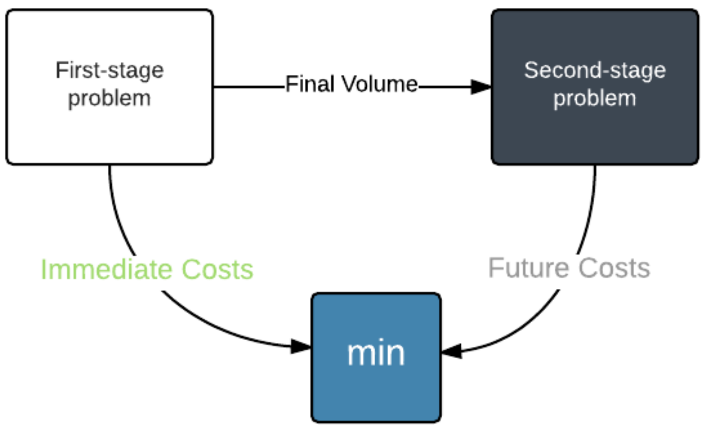
SDDP


First-stage problem
Final Volume
Second-stage problem
Immediate Costs
Future Costs
min


Minimum total costs
Cost
Final Volume

SDDP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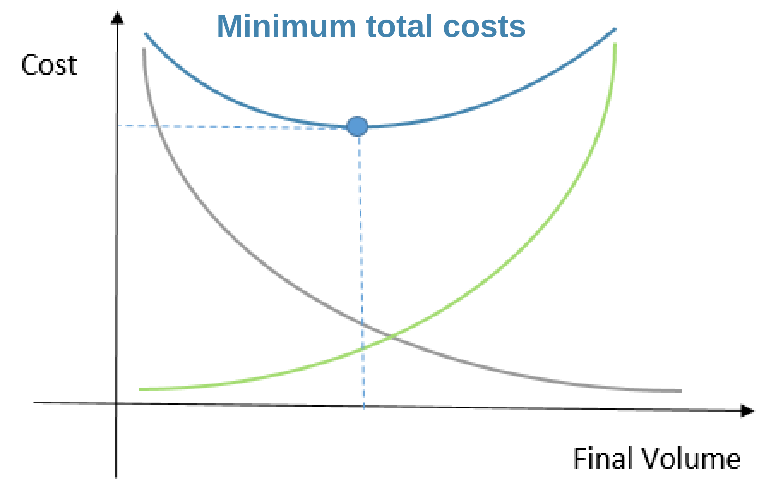
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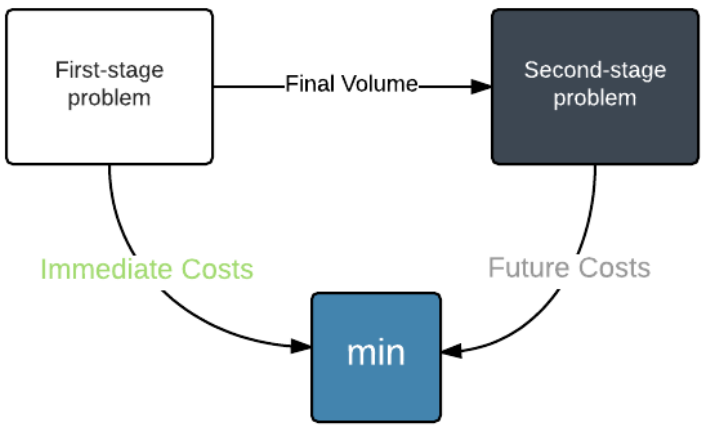
Cost

SDDP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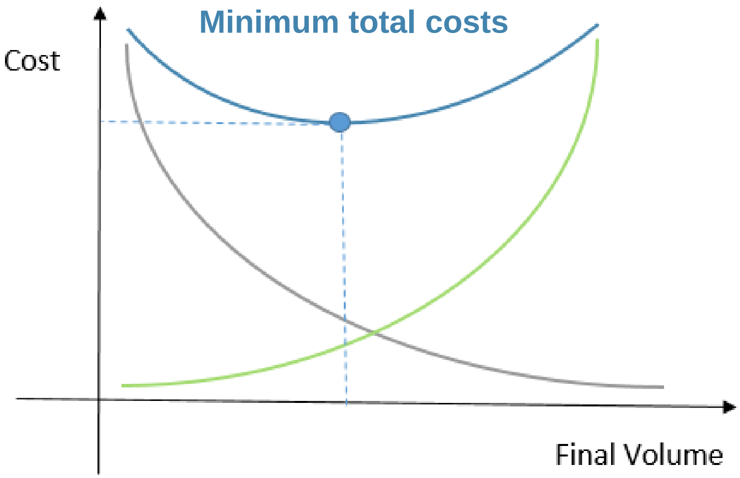
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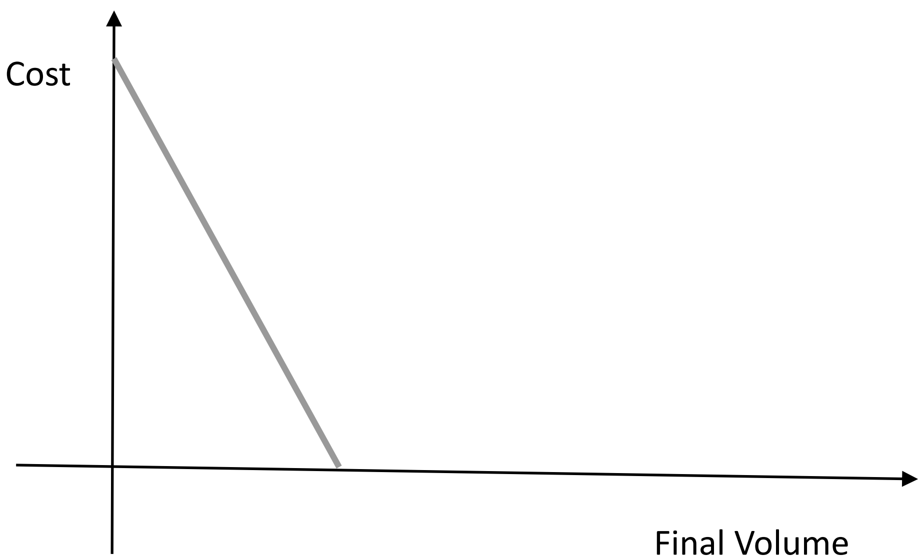
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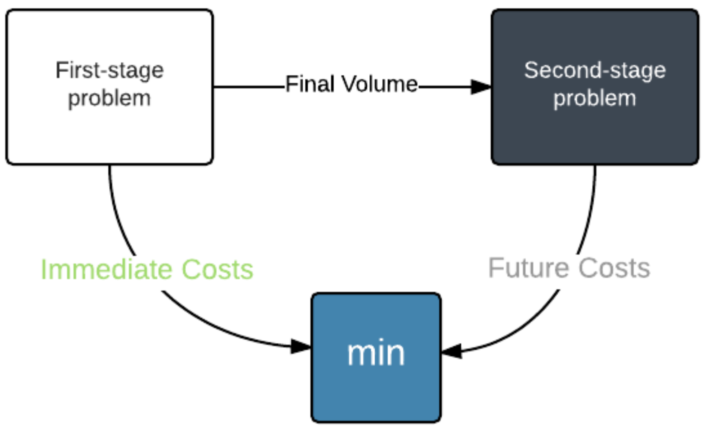
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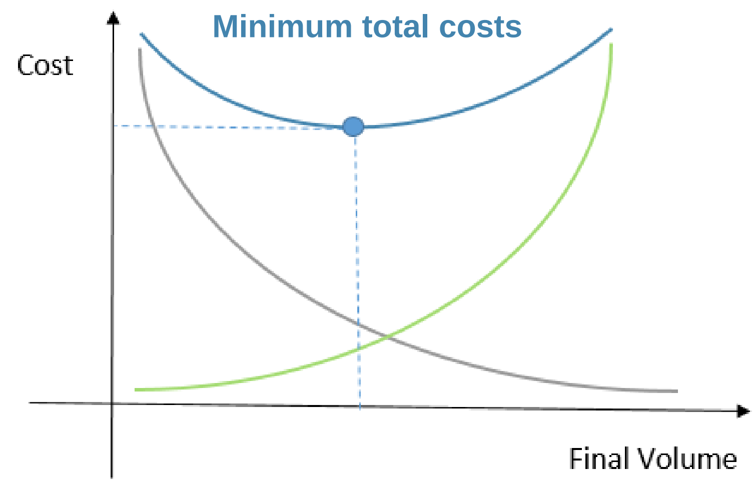
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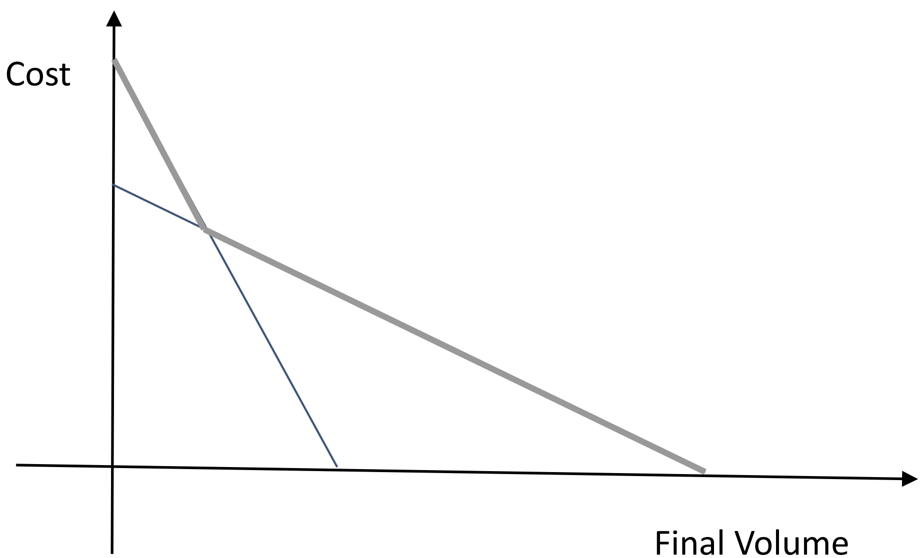
Cost
Final Volume


Cost
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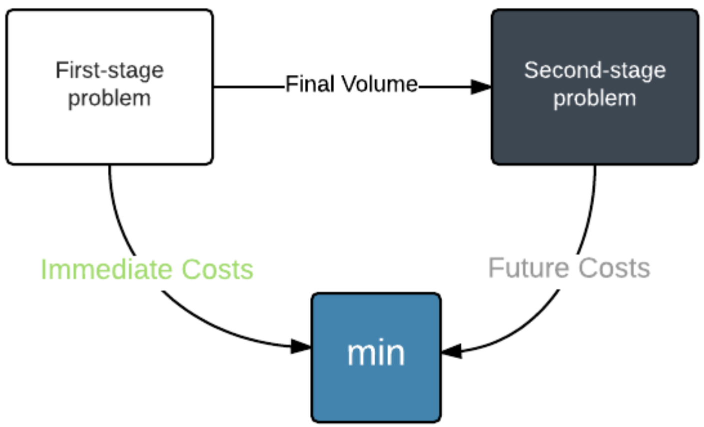
SDDP



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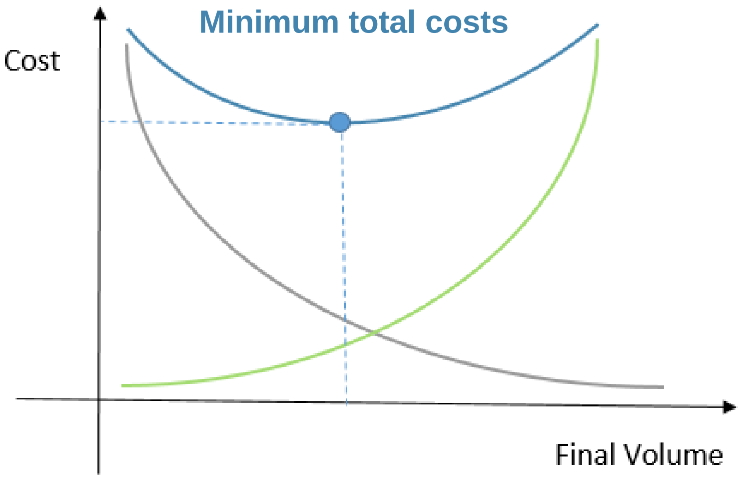
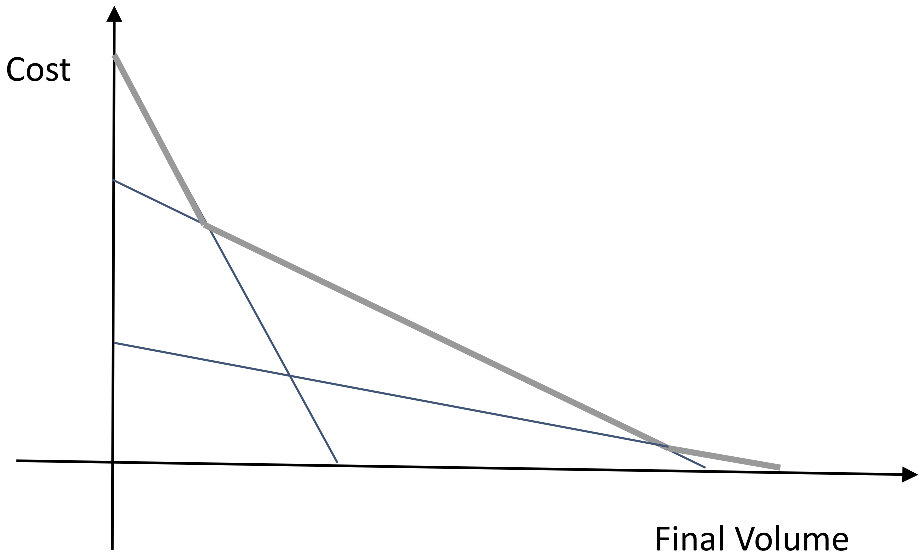


Cost
Minimum total costs
Final Volume



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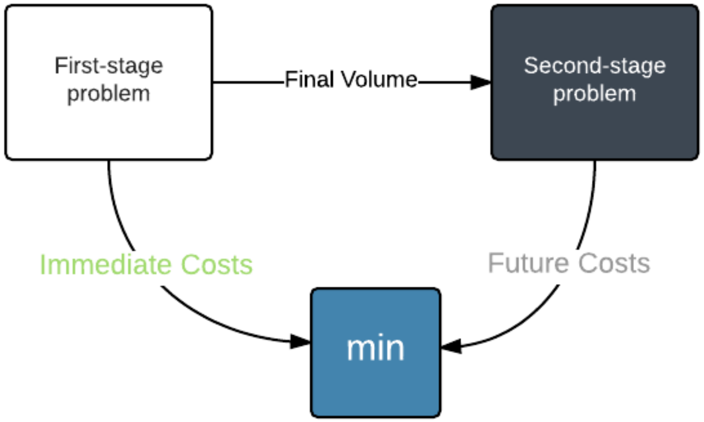
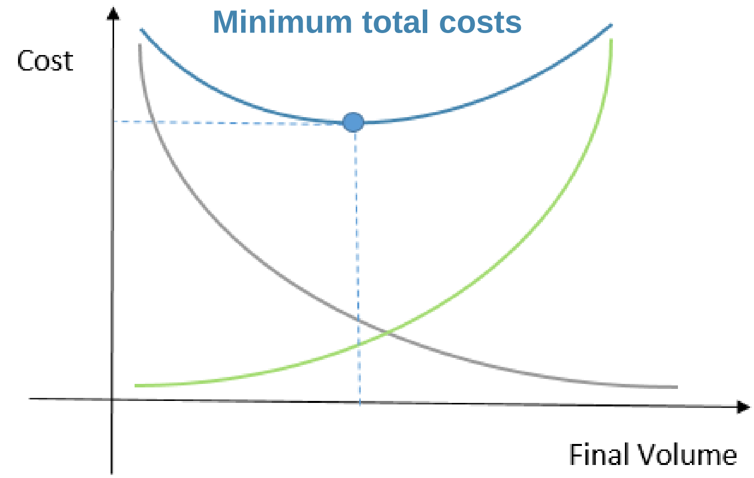
Basic concepts





$$\min \quad \sum cg \quad + \alpha$$

$$v_{t+1} = v_t + a - u - s$$

$$\rho u + g = d$$

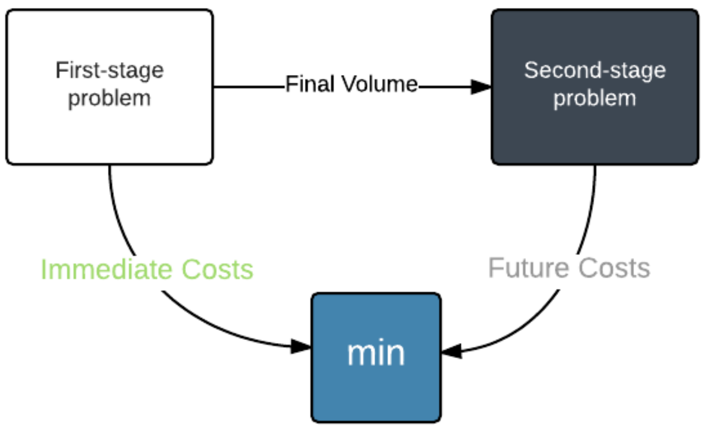
$$\rho u = e$$

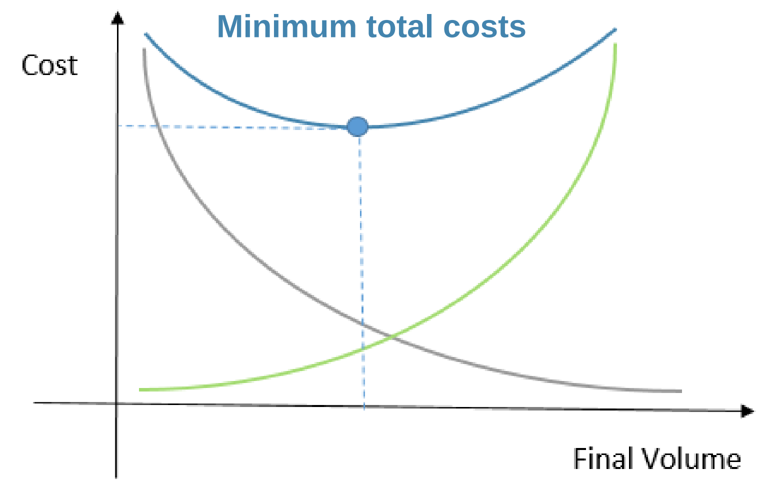
$$u \leq \bar{u}$$

$$g \leq \bar{g}$$

$$\alpha \geq b v_{t+1} + c$$

Basic concepts





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No thermal constraints and no hourly variables →

$$\min \quad \beta \quad + \alpha$$

$$v_{t+1} = v_t + a - u - s$$

$$\rho u - e = 0$$

$$\beta \geq be + c$$

$$\alpha \geq b v_{t+1} + c$$

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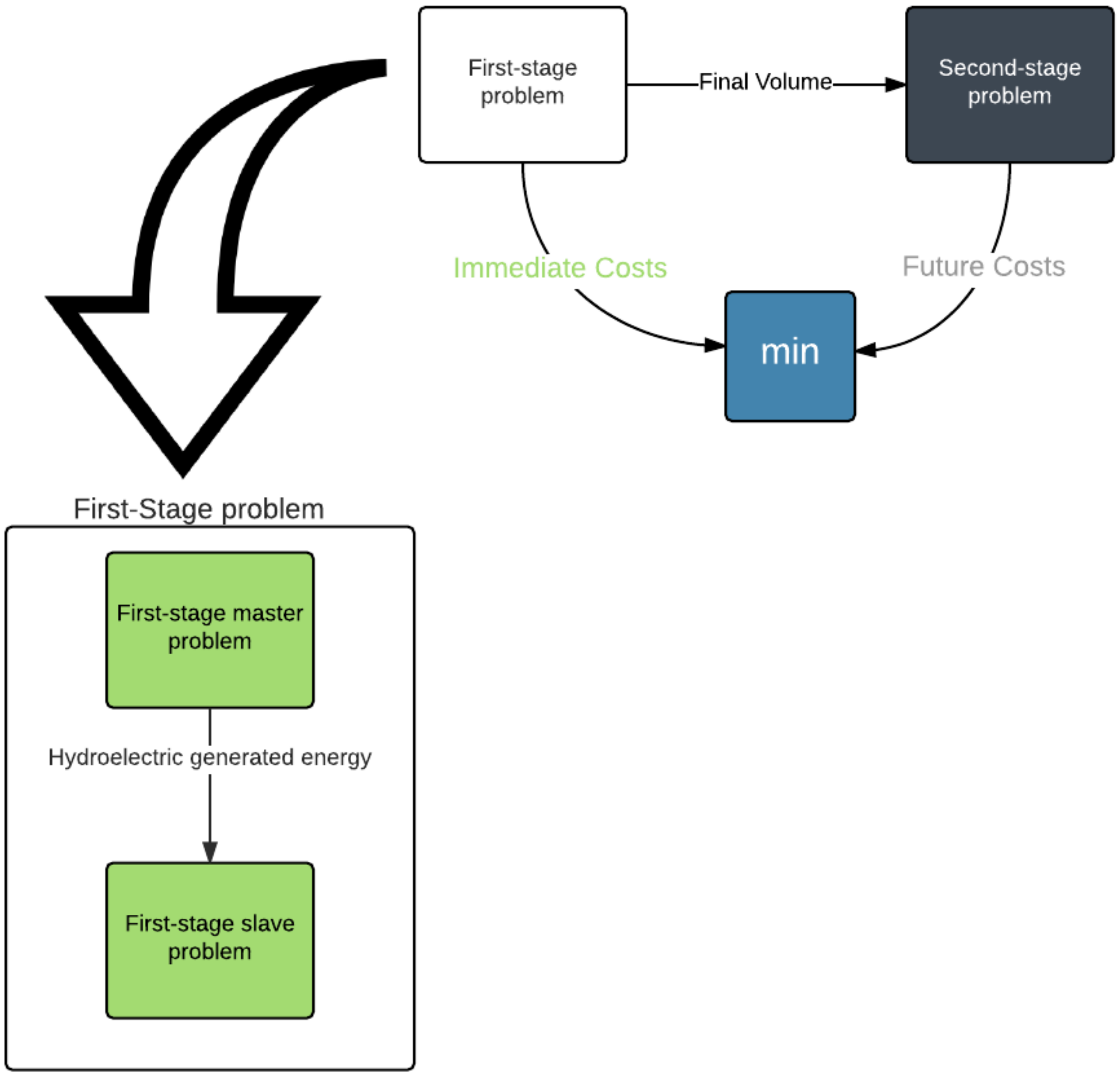

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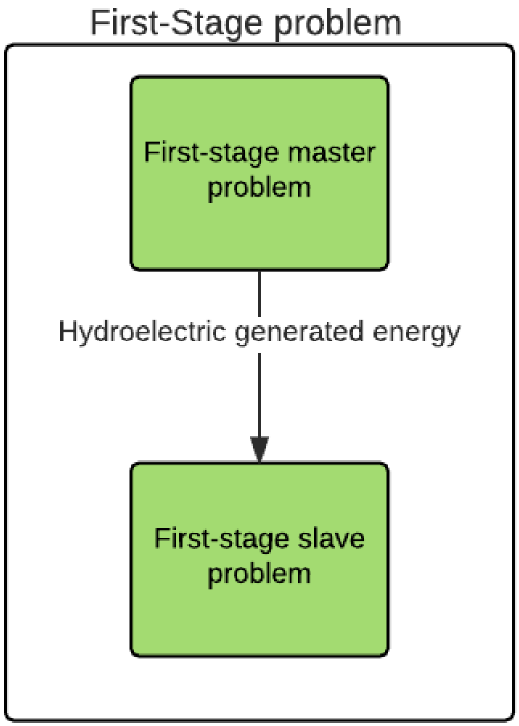

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$$e^*$$

$$\min \sum_{\tau} \sum_{j} c_j g_{\tau,j}$$

$$\sum_{\tau} e_{\tau} = e^*$$

$$e_{\tau} + \sum_{j} g_{\tau,j} = d_{\tau}, \forall \tau$$

$$e_{\tau} \leq \bar{e}, \forall \tau$$

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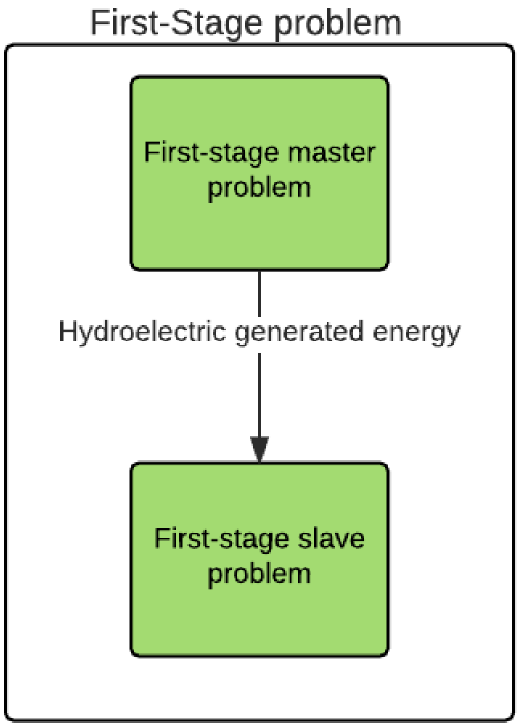

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$$\lambda\left(\sum_{\tau} e_{\tau} - e^*\right)$$

τ = 1

$$\min \sum_{j} c_j g_{\tau,j} + \lambda e_{\tau}$$

$$e_{\tau} + \sum_{j} g_{\tau,j} = d_{\tau}$$

$$e_{\tau} \leq \bar{e}$$

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...

τ = T

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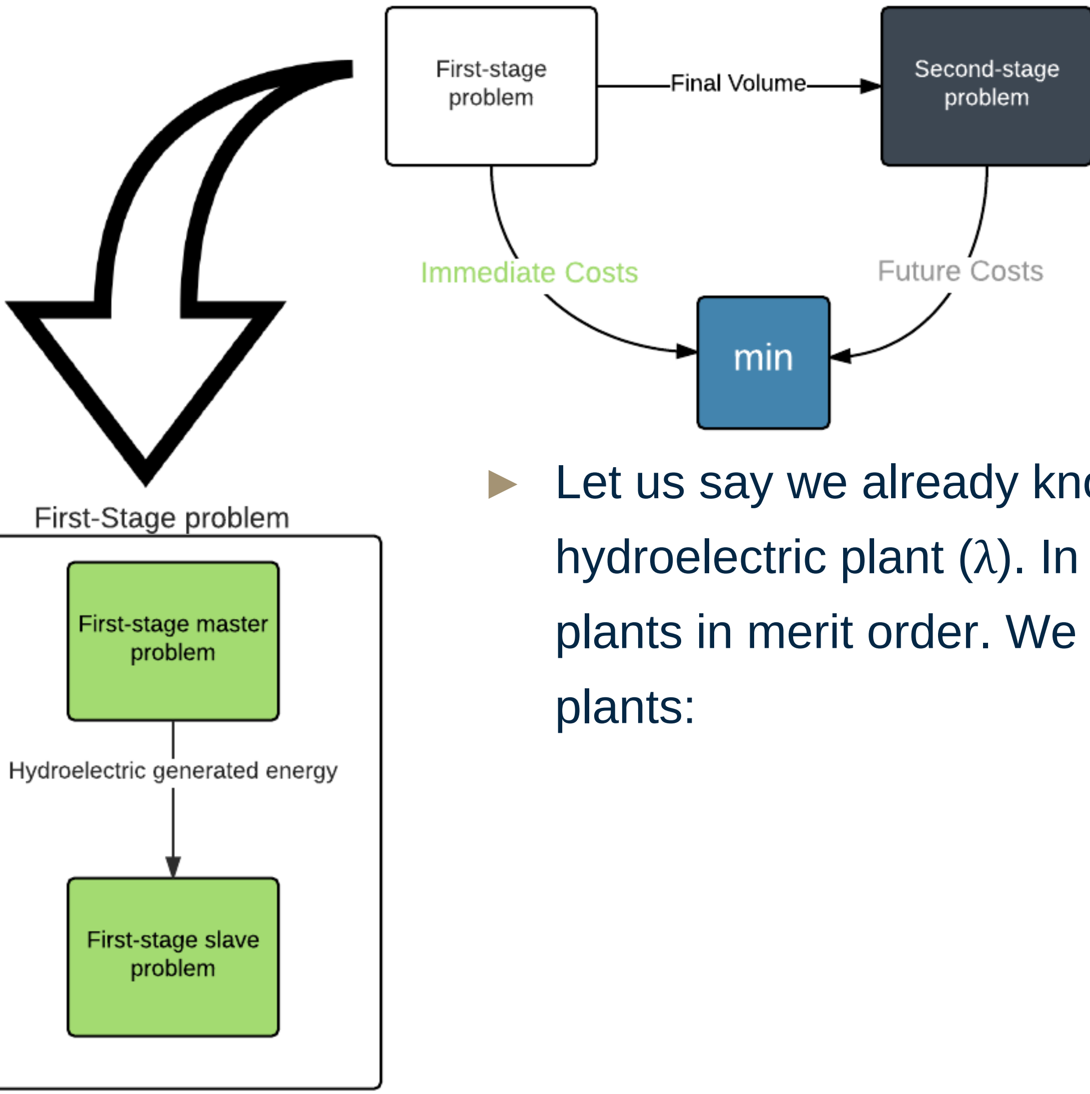

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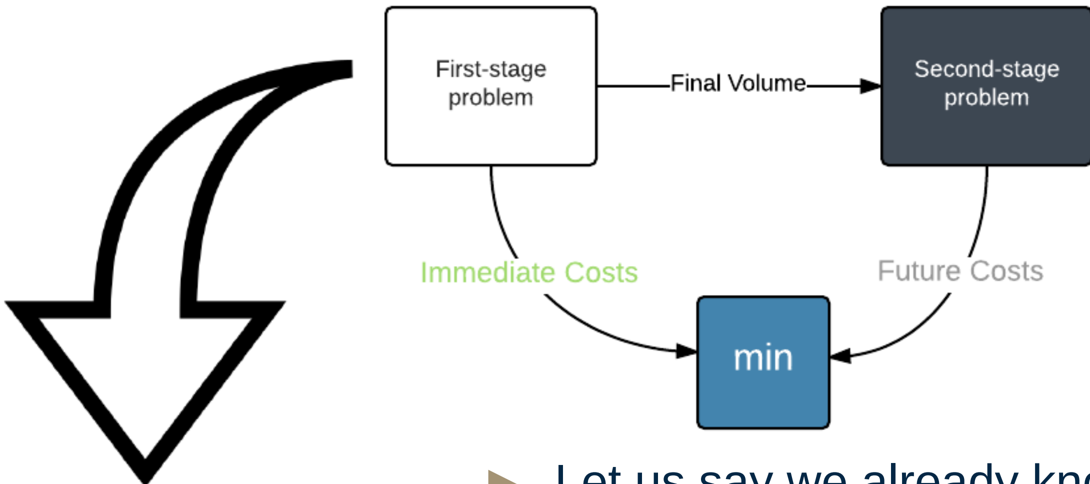
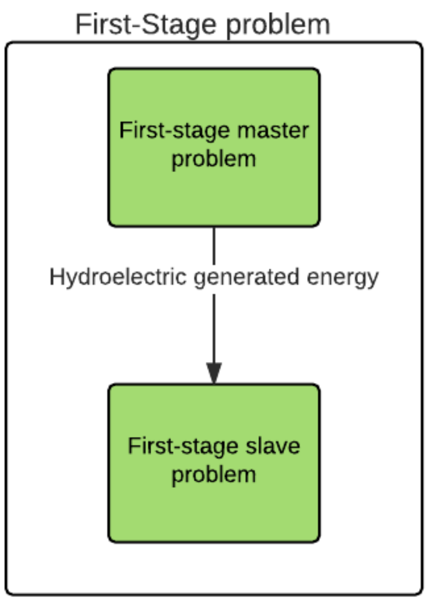
Basic concepts





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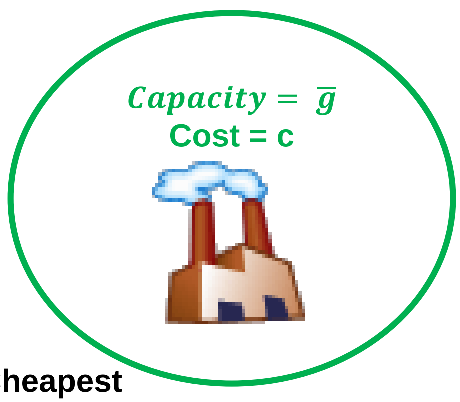
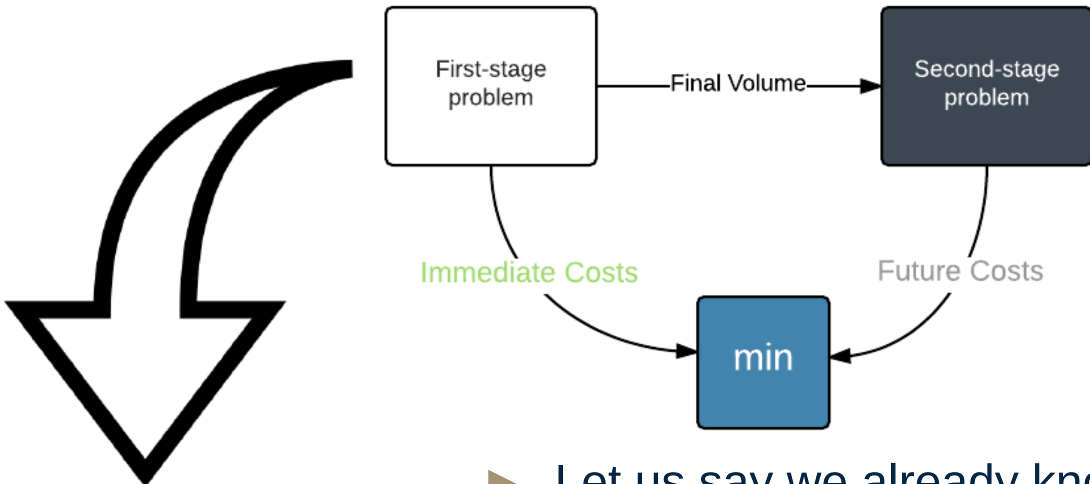
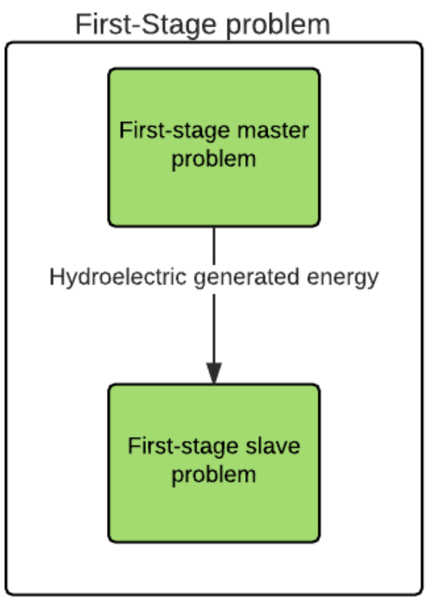


Cheapest

Basic concepts





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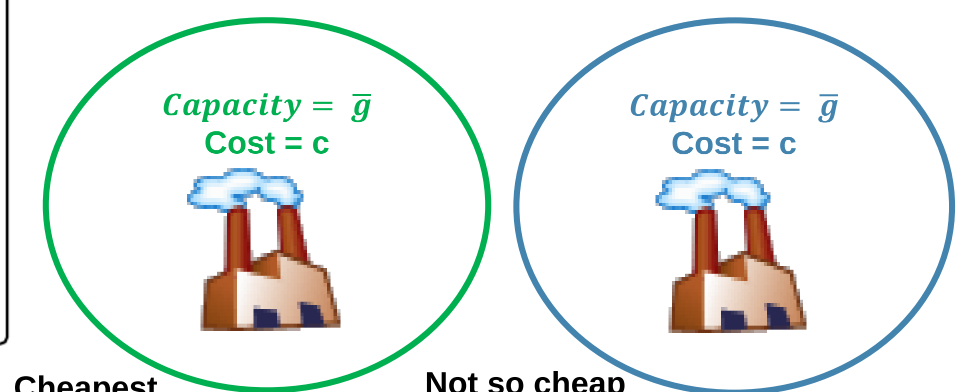

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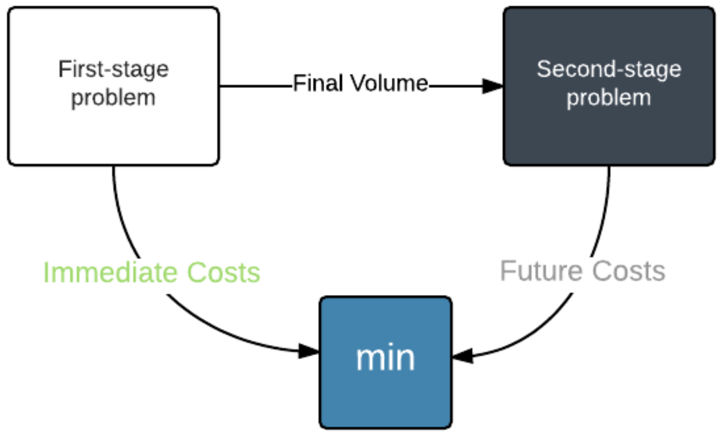

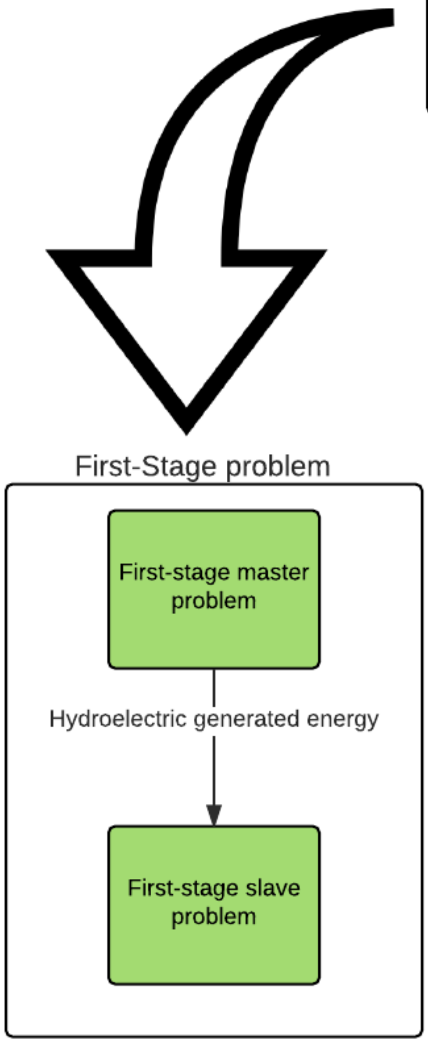

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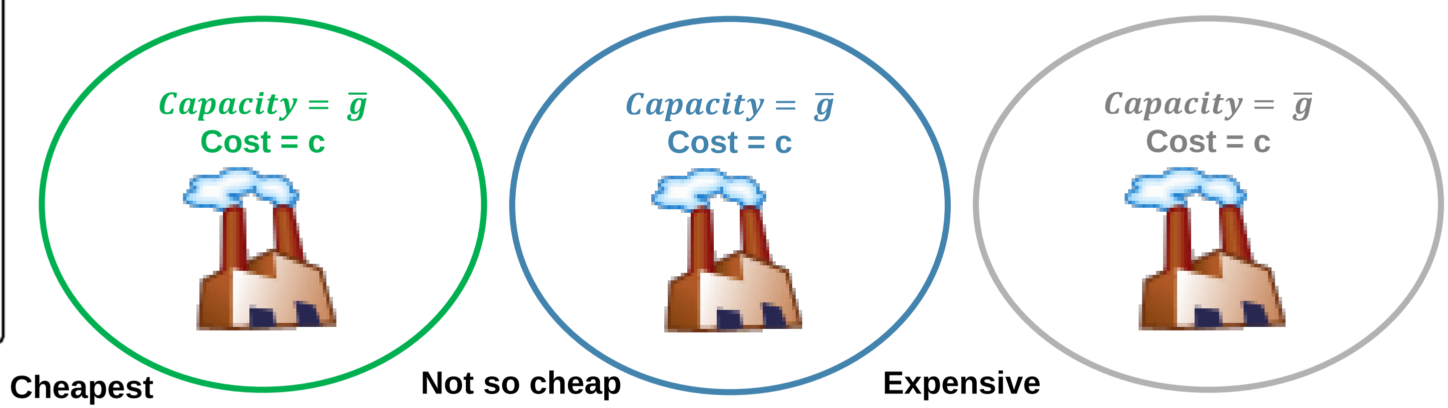

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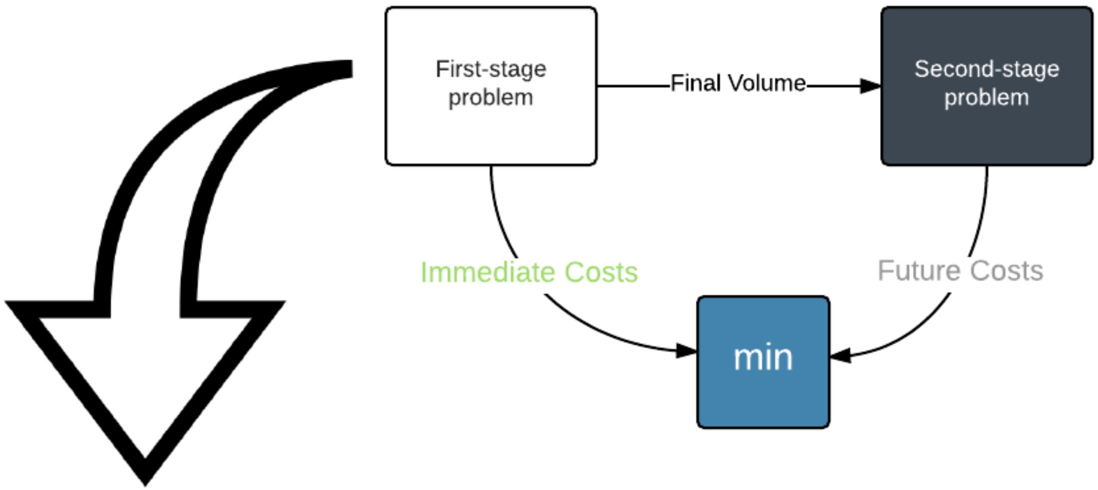

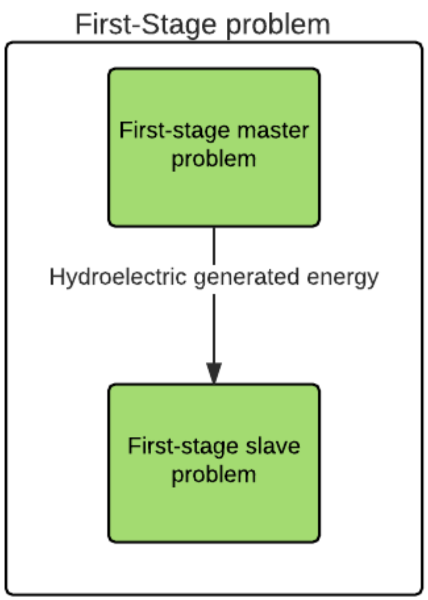

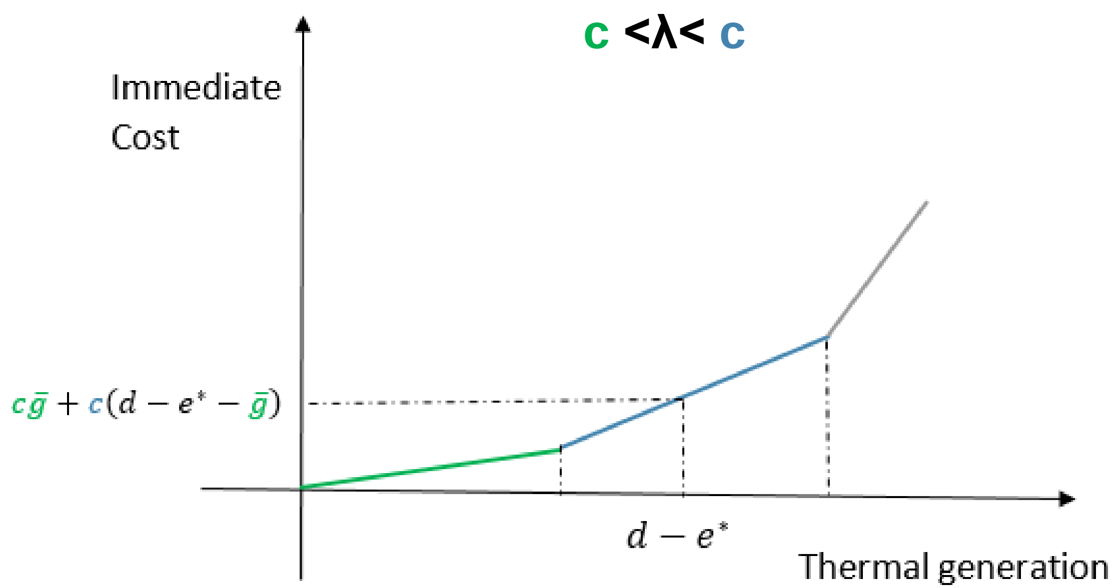

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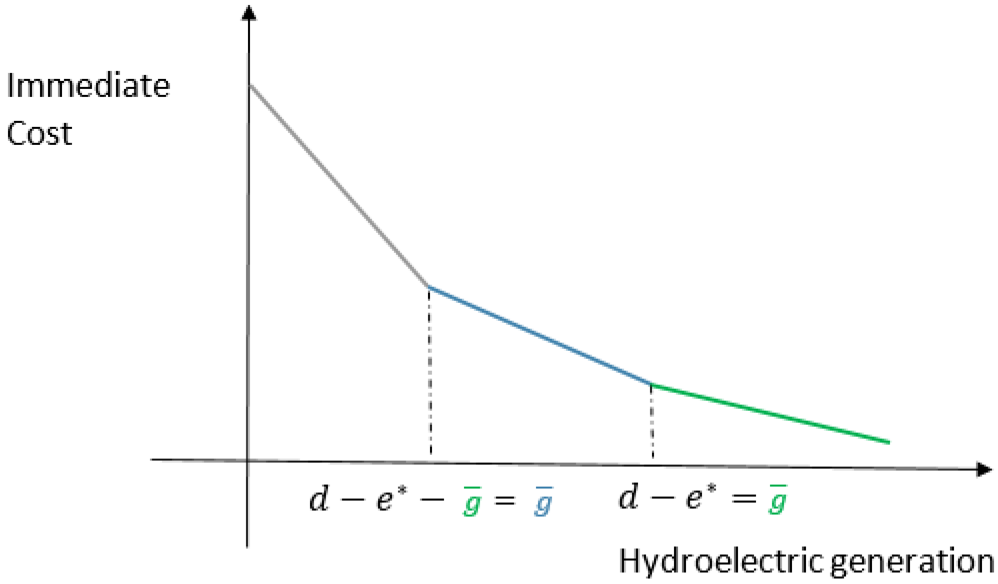
Immediate cost function calculation method

- How can we calculate de immediate cost function?
  - If we calculate the immediate cost for several possible hydroelectric generations scenarios:



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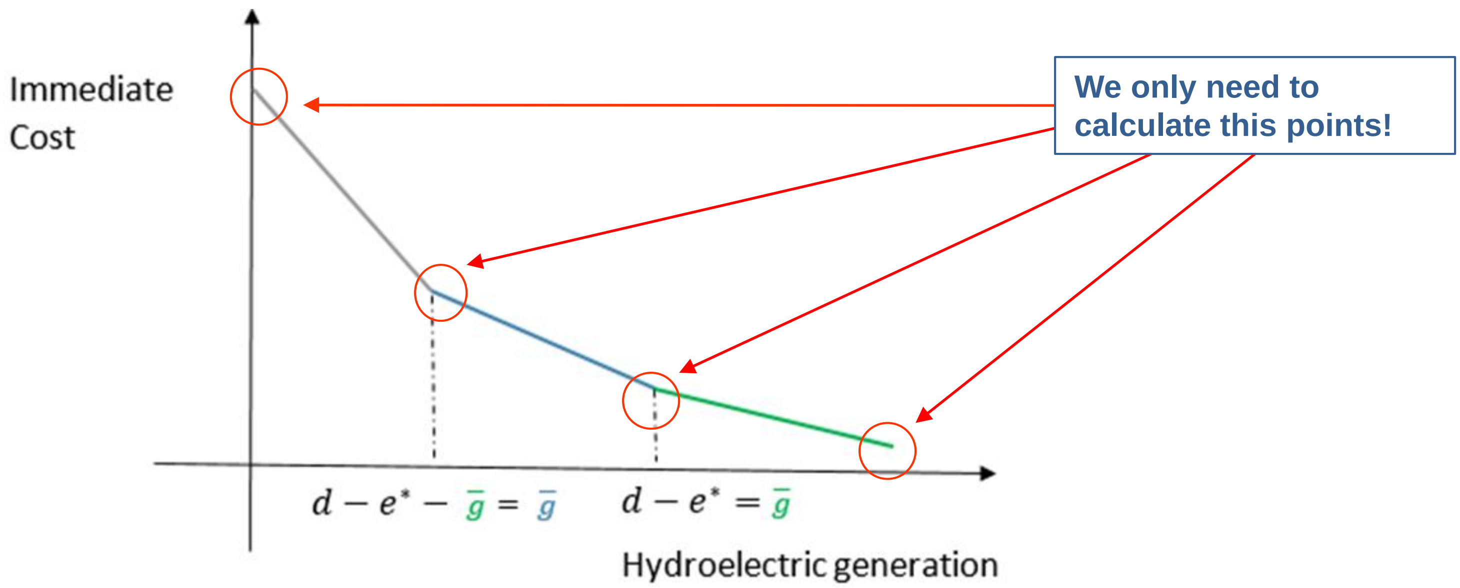
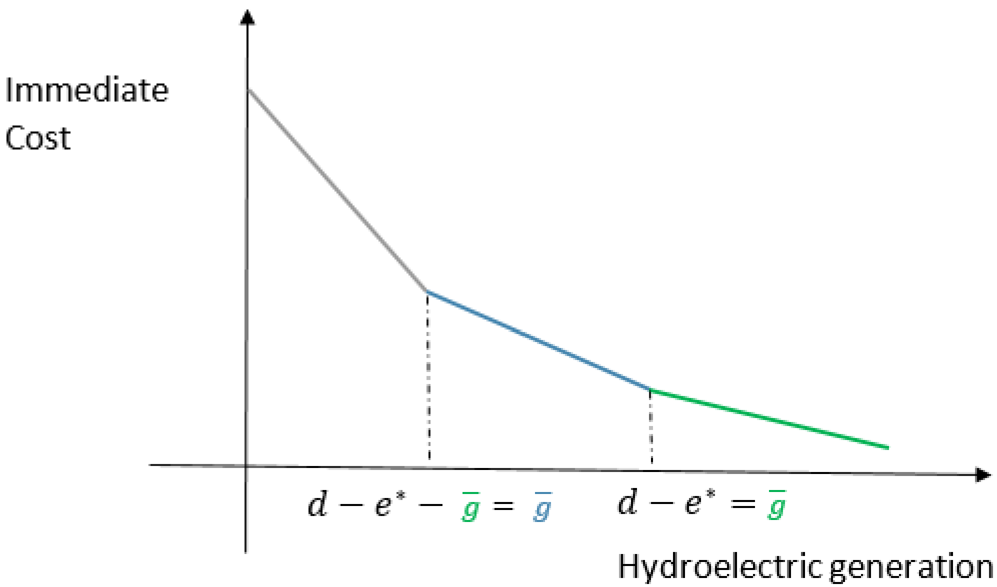
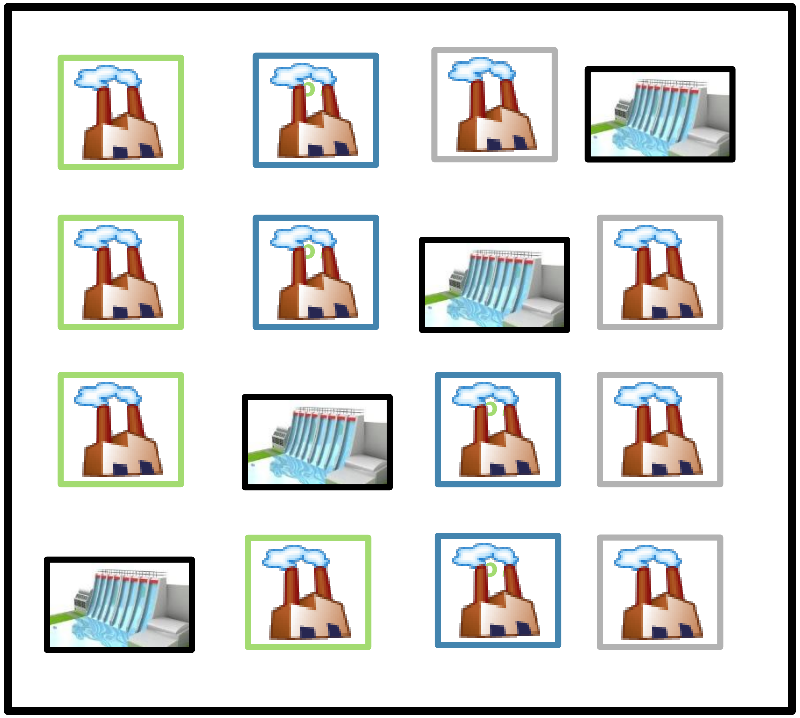


Immediate cost function calculation method

- We can calculate the immediate cost function by enumerating all possible hydroelectric positions:





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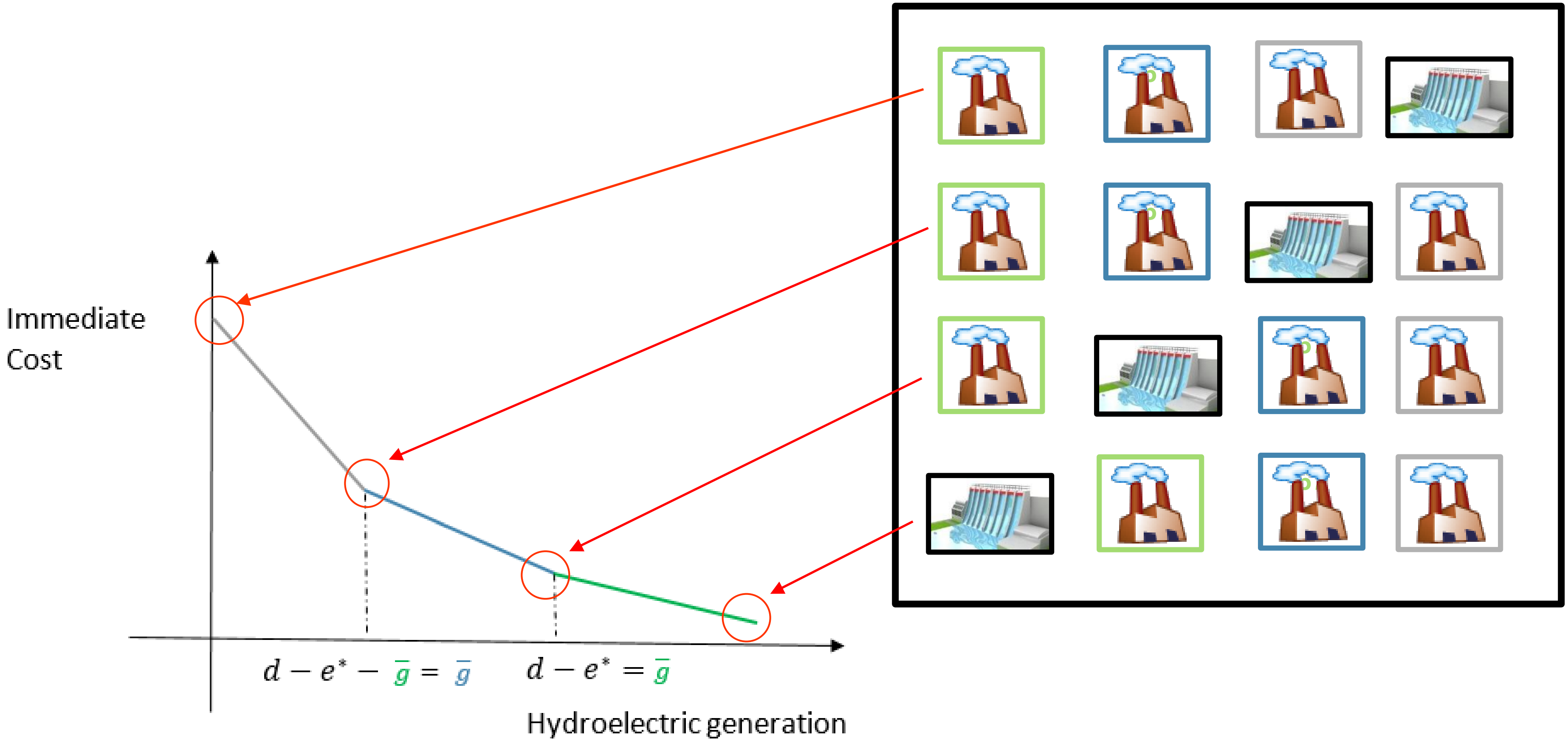


Immediate cost function calculation method

- Intersection points are related to hydro plant dispatch position
- For every hour of a given stage (month or week) and hydroelectric position, we can calculate the optimal immediate cost:
  - First, we need to calculate the optimal generation for every thermal plant i:

$$g_{\boldsymbol{i}} = \overline{g}_i \times \min\left\{1, \frac{\delta^\tau}{\overline{g}_i}\right\}$$

  - Where δ^τ is the residual demand considering all generators before i in dispatch order
  - The immediate cost is obtained by calculating $\sum_i c_i g_i$

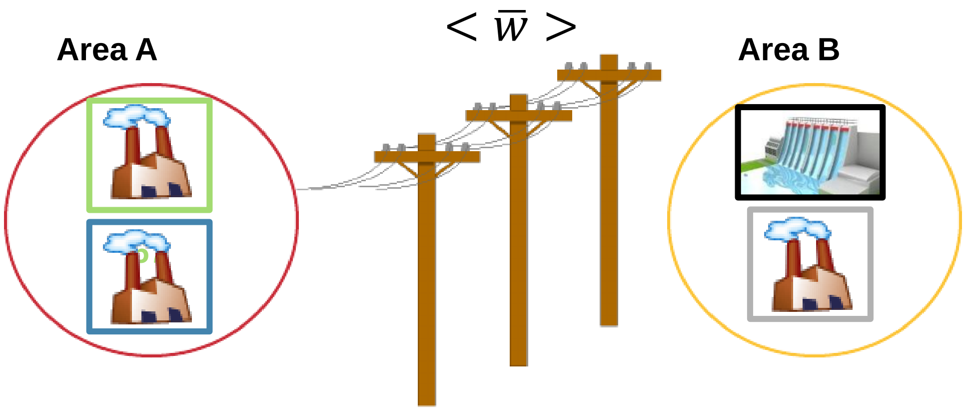
Immediate cost function calculation method

- Furthermore, we can discover mid dispatches only by having dispatches with the hydro plant in first and last positions.

Method	Number of operations
Optimization – discretization of function in equal intervals	100
Calculation of points for every hydro plant position	4
Calculation of points for hydro plant in first and last positions	2

Immediate cost function calculation method

- In multi-area systems, we need to use min cut approach:



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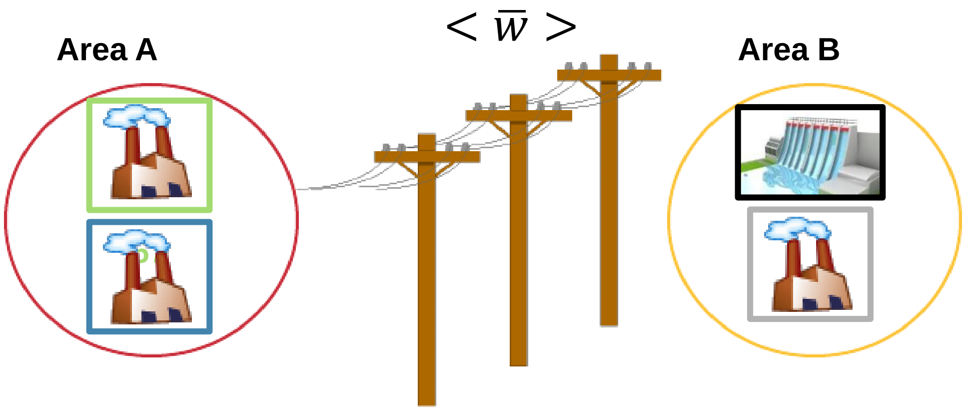

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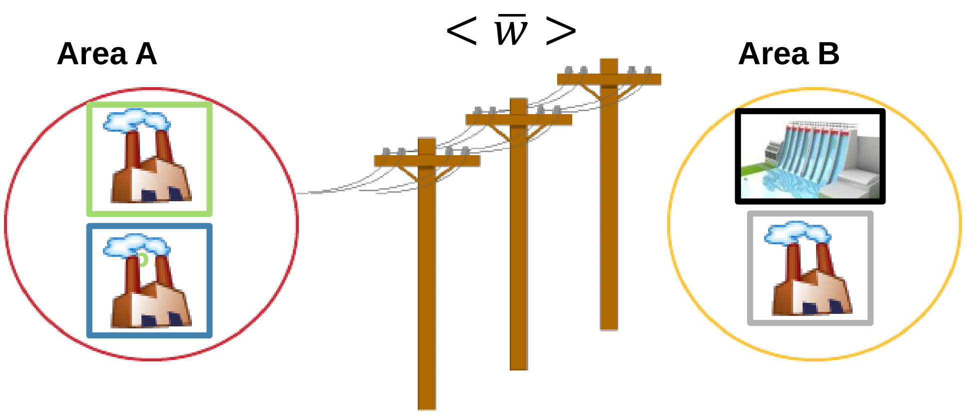

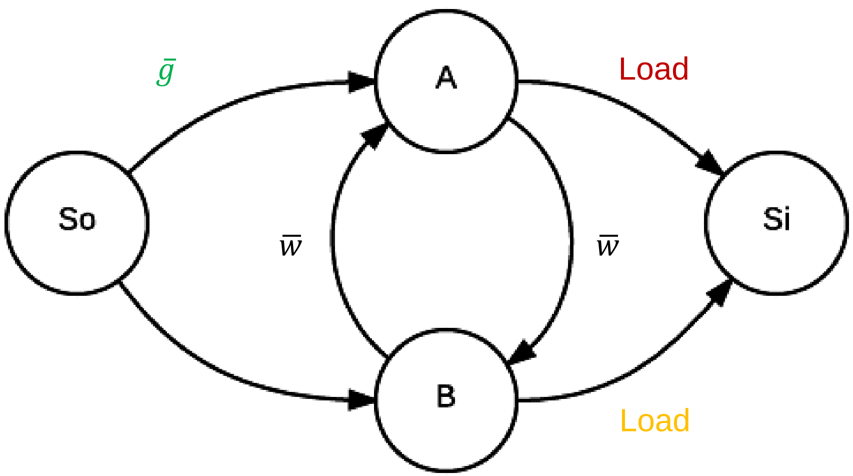

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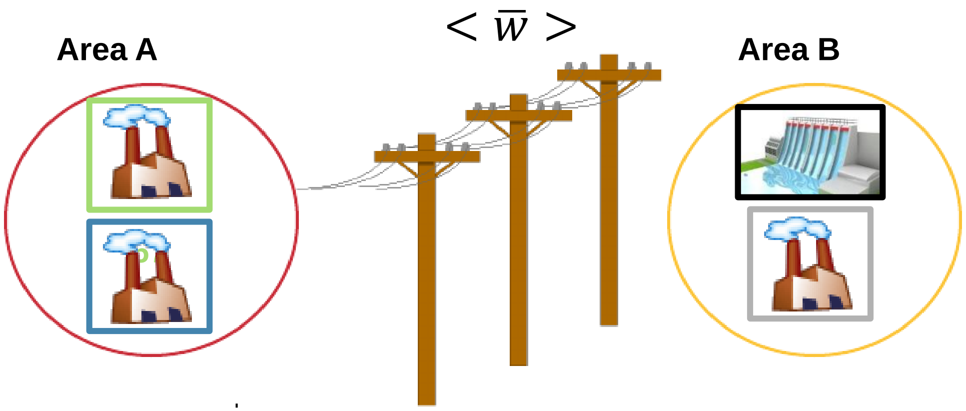

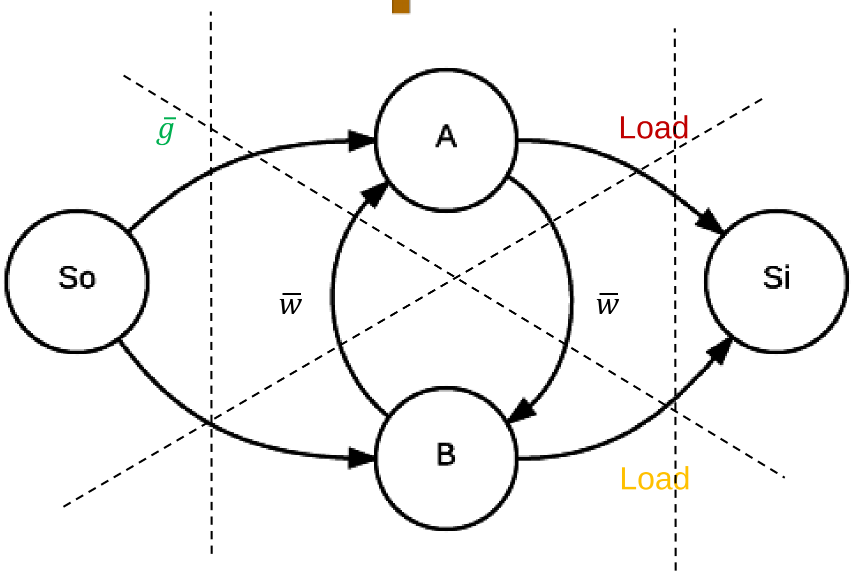

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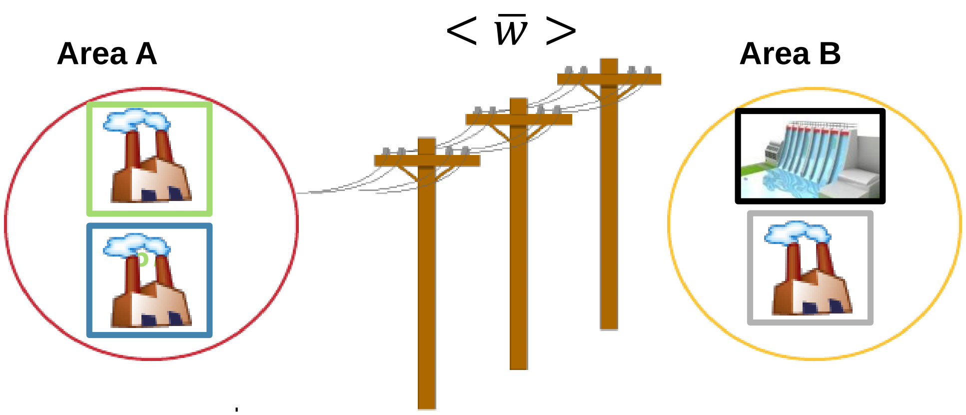

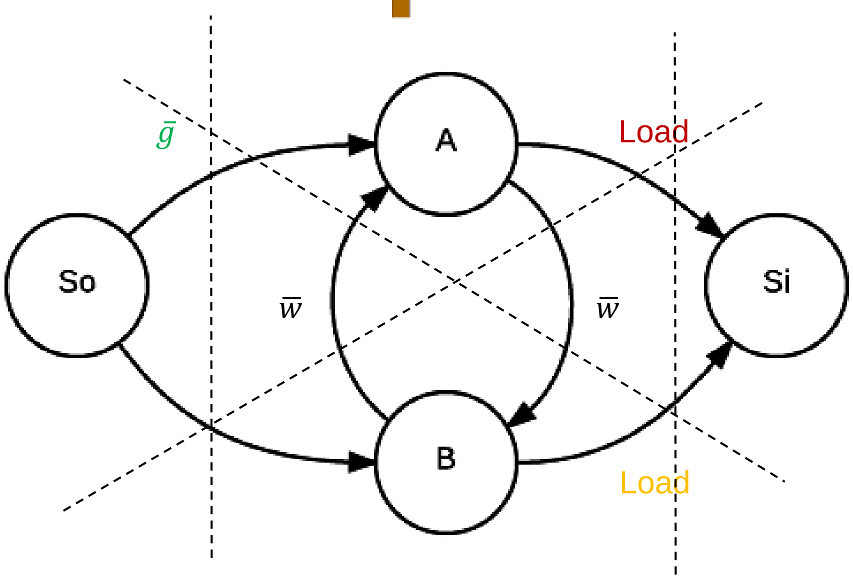

$\bar{g} + \bar{w}$ + Load

$\bar{g}$

$\bar{w}$ + Load

Load + Load

Min

Immediate cost function calculation method

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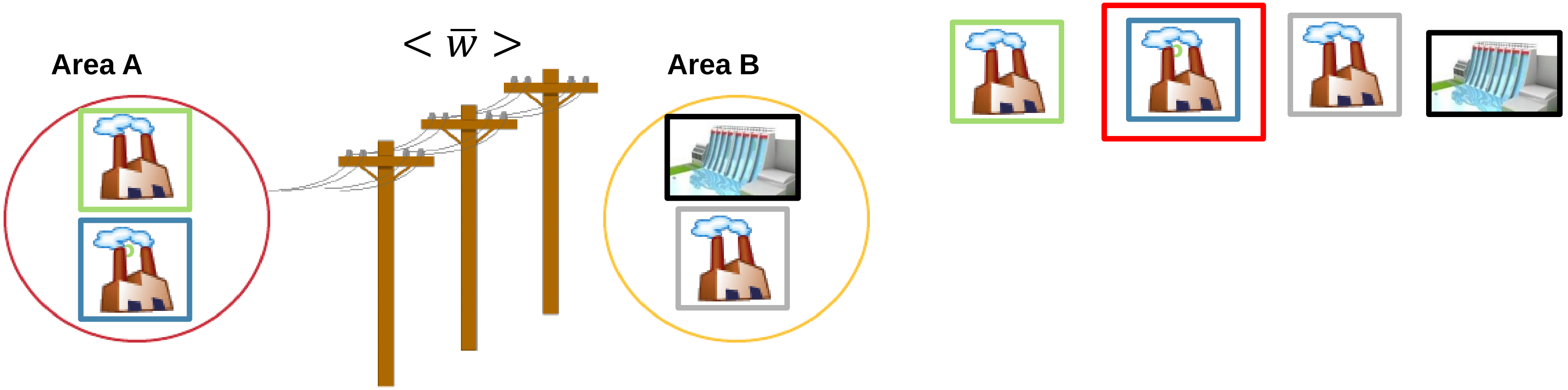

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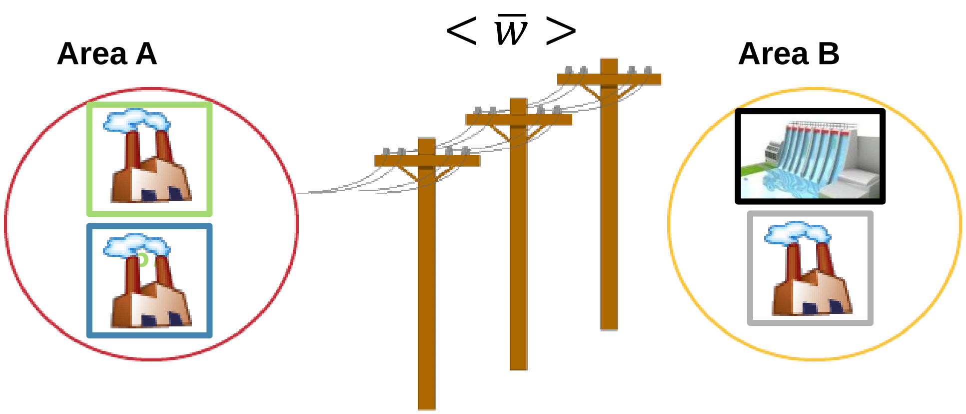

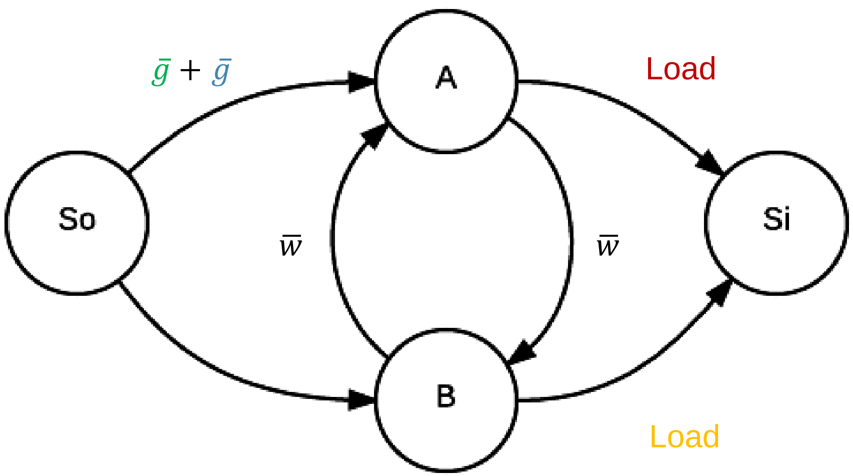

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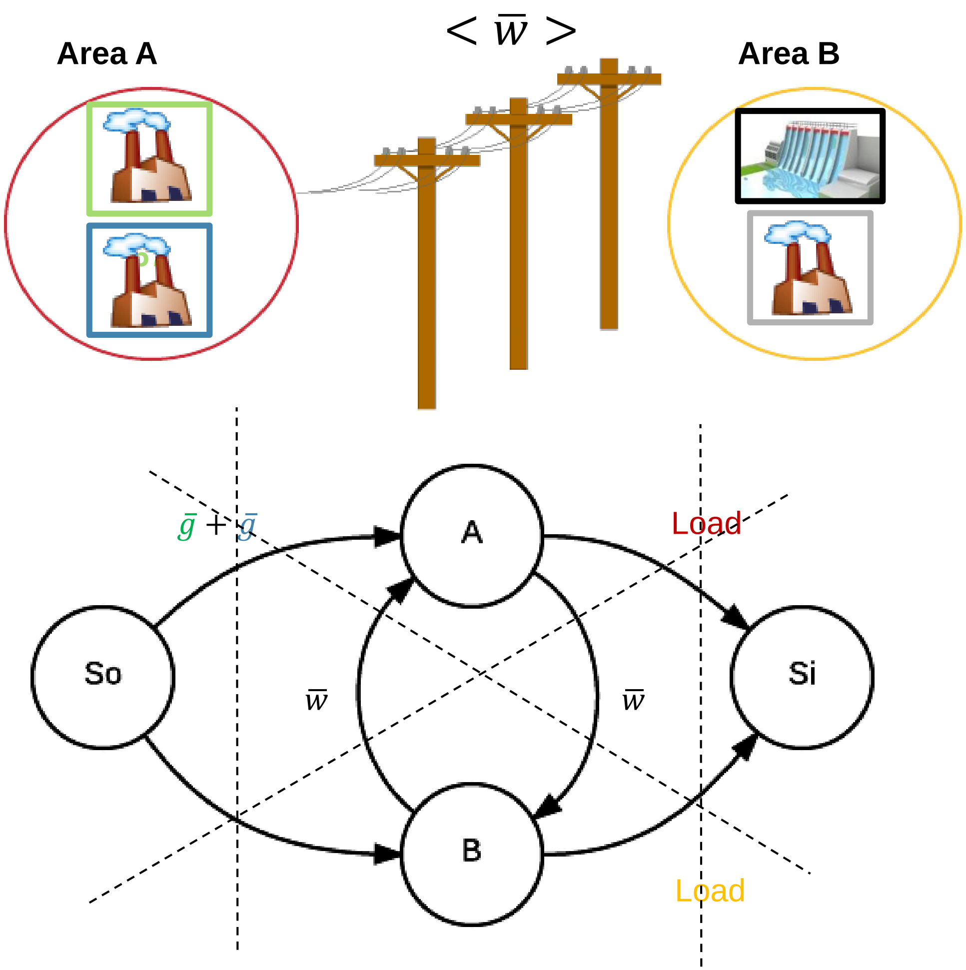

Immediate cost function calculation method

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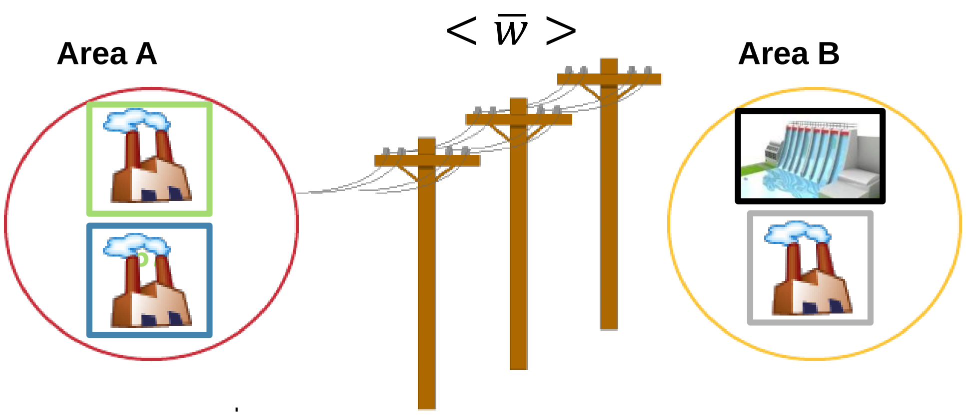

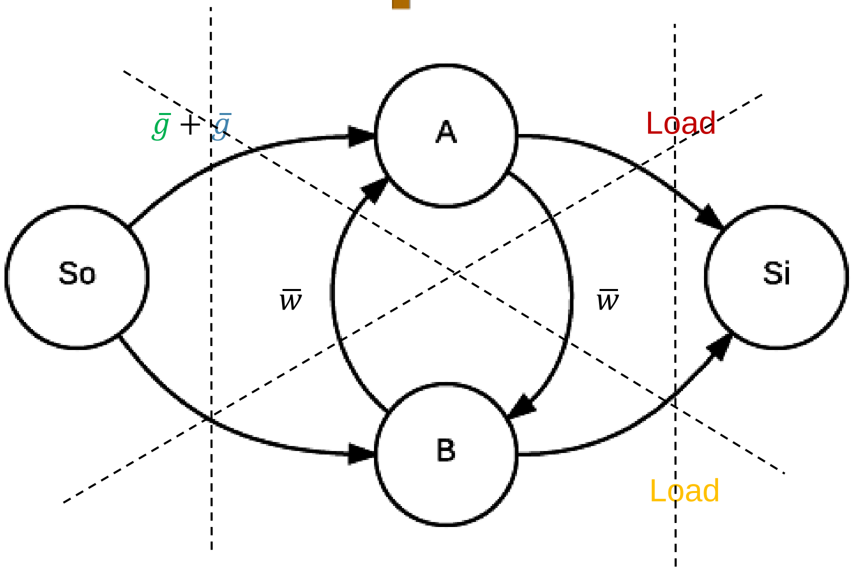

$\bar{g} + \bar{g} + \bar{w}$ + Load
$\bar{g} + \bar{g}$
$\bar{w}$ + Load
Load + Load

Min

Immediate cost function calculation method

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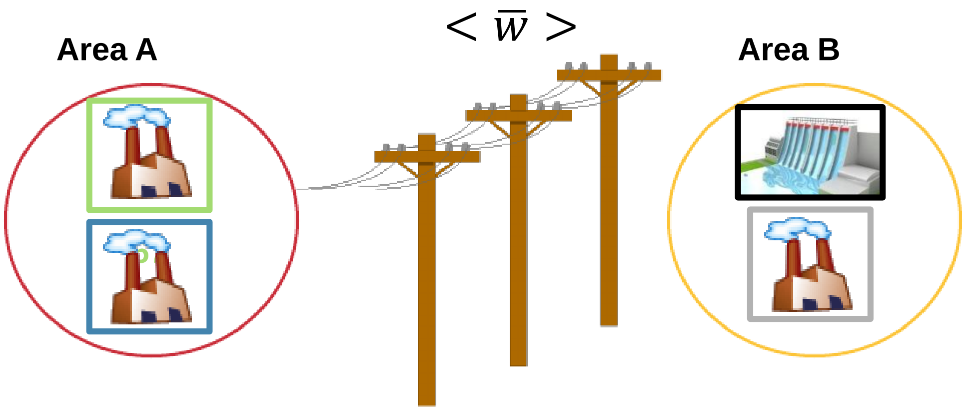

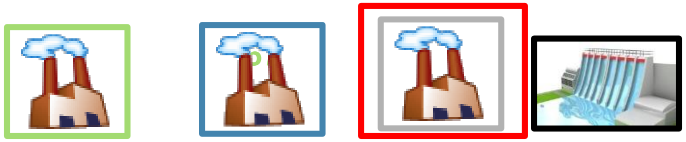

Immediate cost function calculation method

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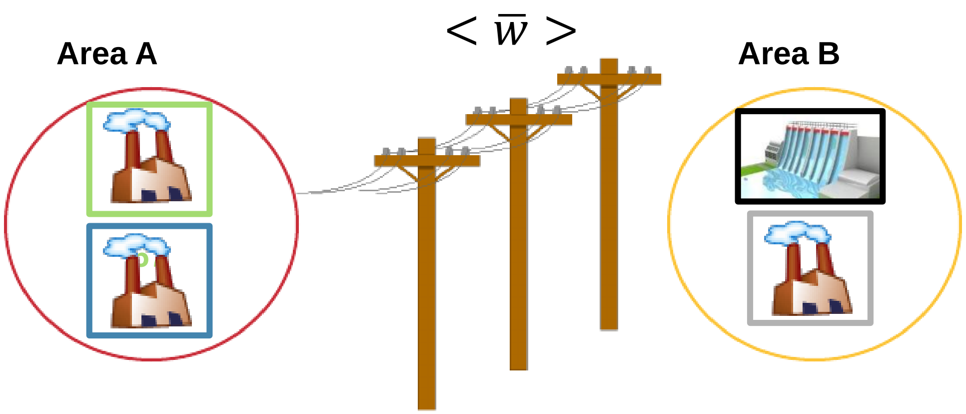

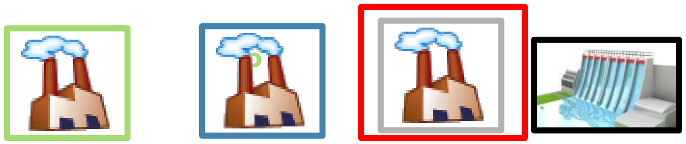

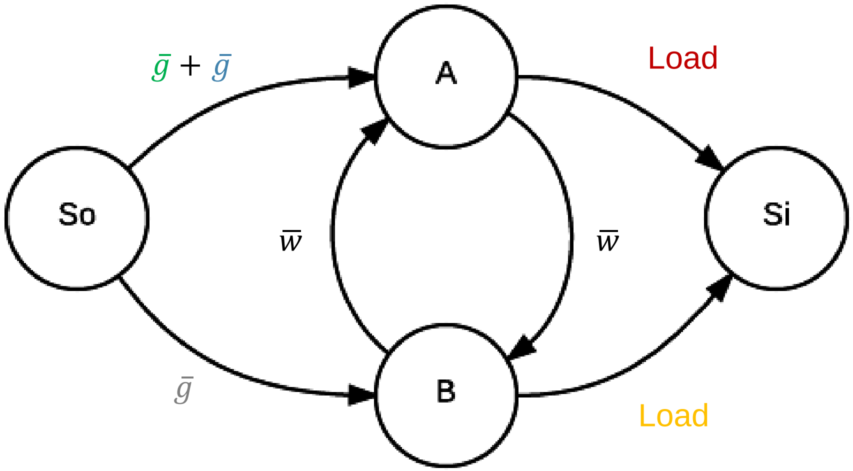

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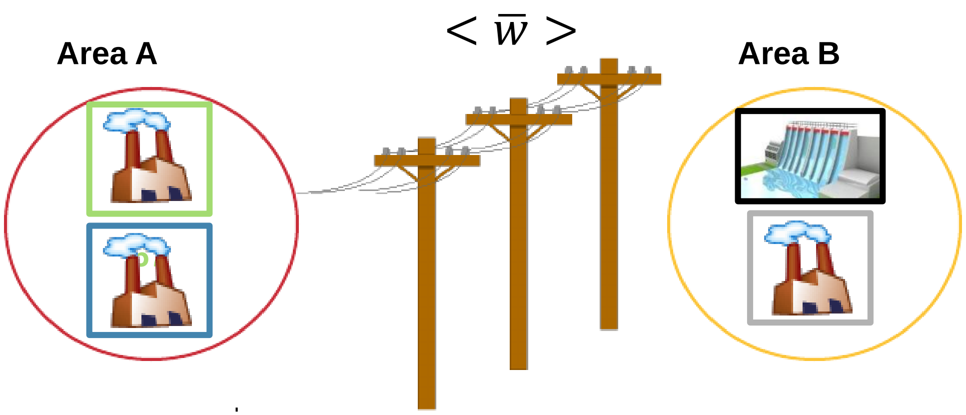

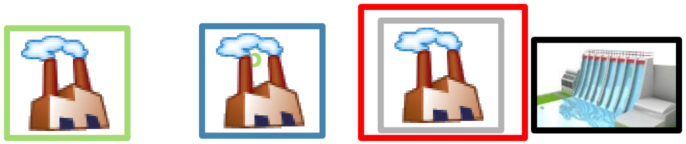

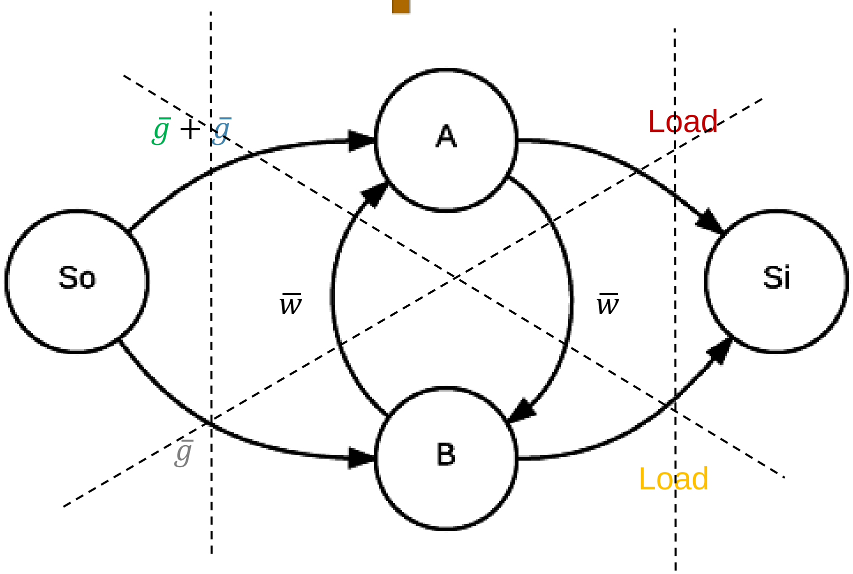

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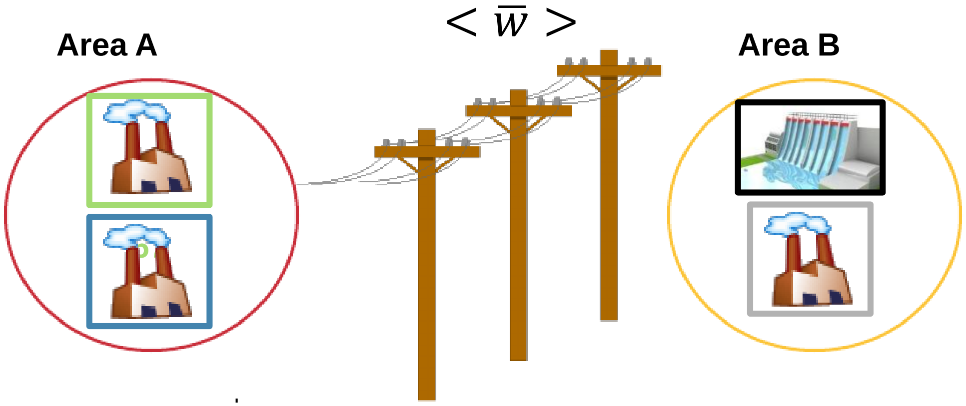

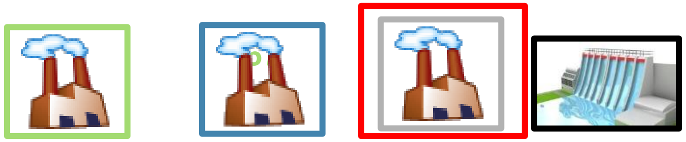

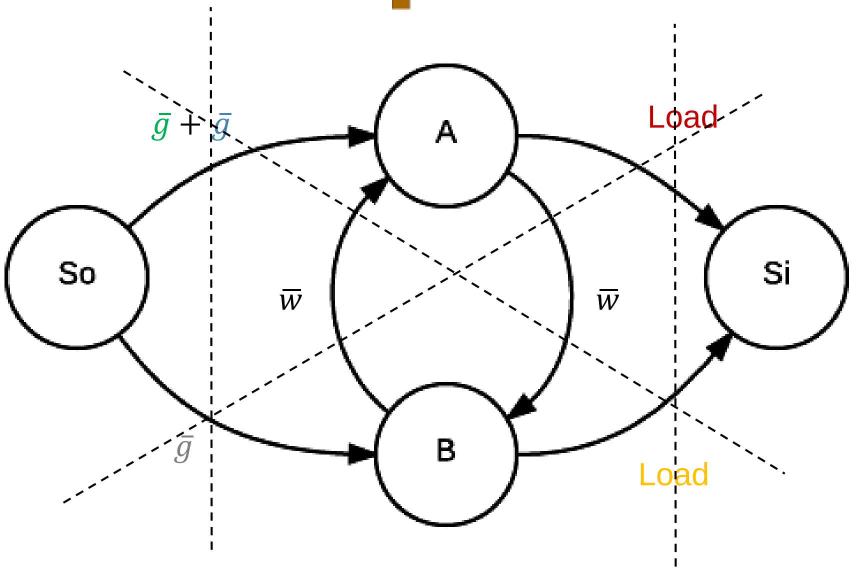

$\bar{g} + \bar{g} + \overline{w}$ + Load

$\bar{g} + \bar{g} + \bar{g}$

$\bar{g} + \overline{w}$ + Load

Load + Load

Min

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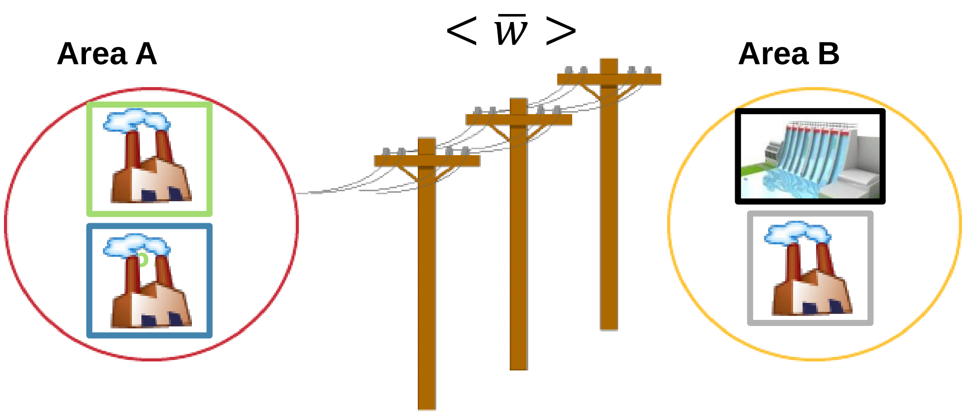

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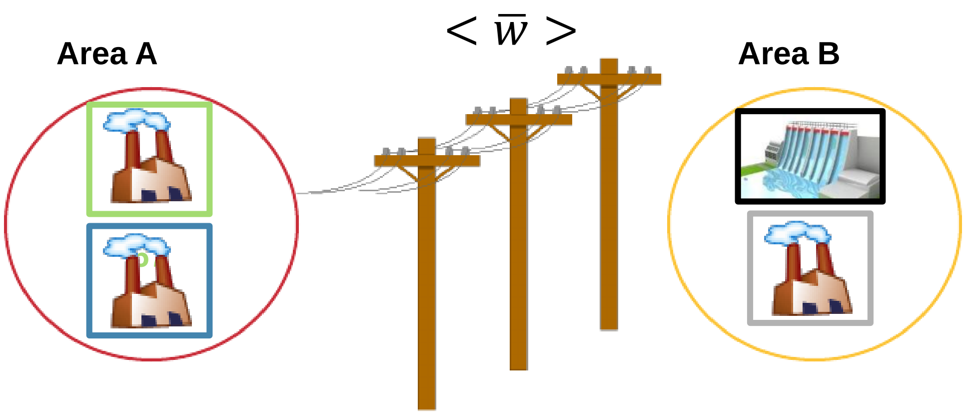

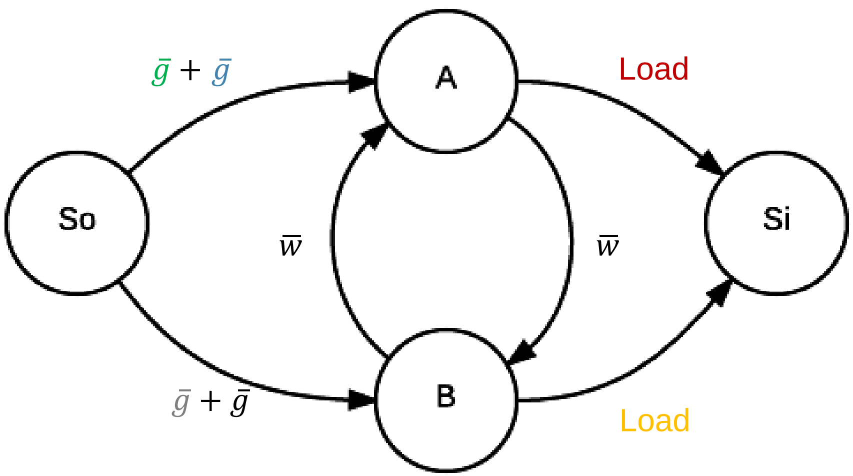

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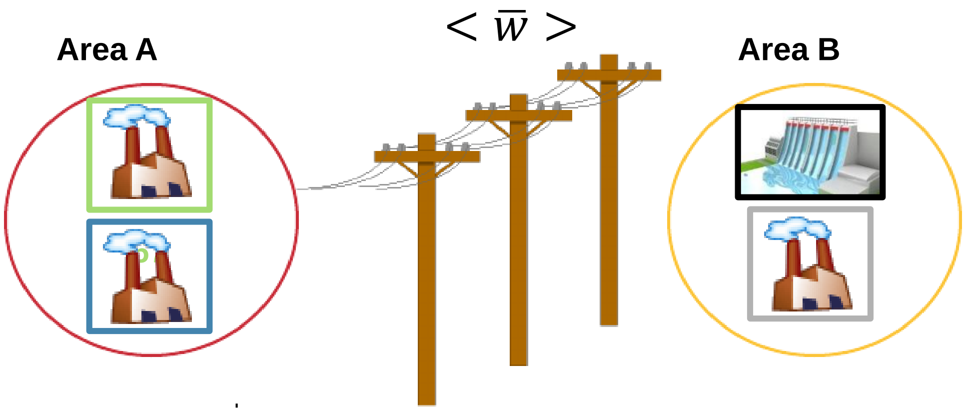

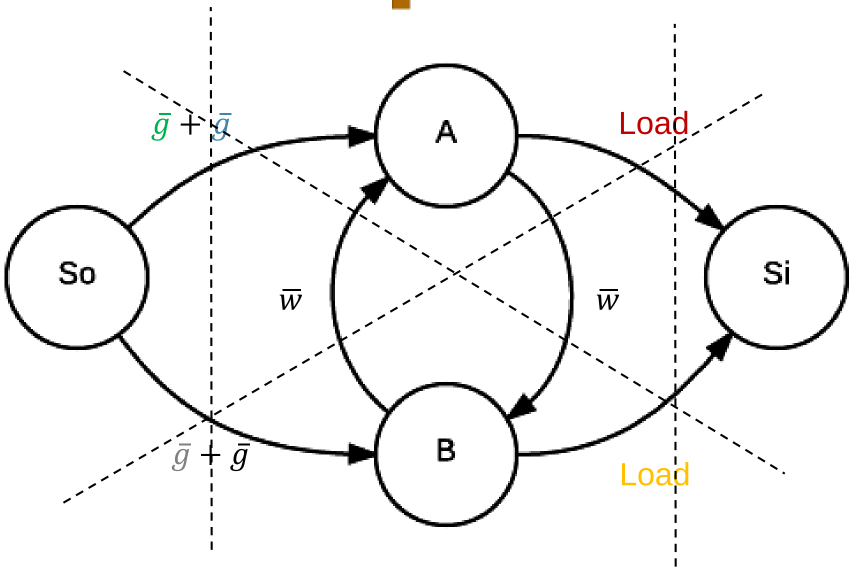

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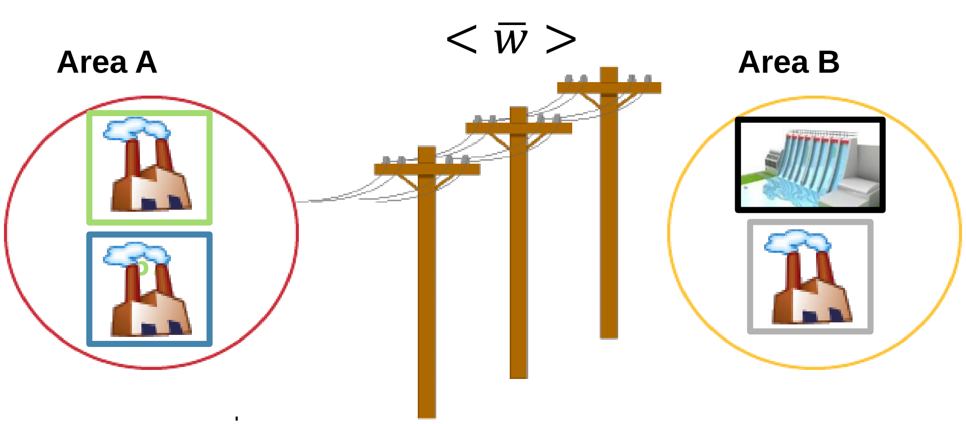
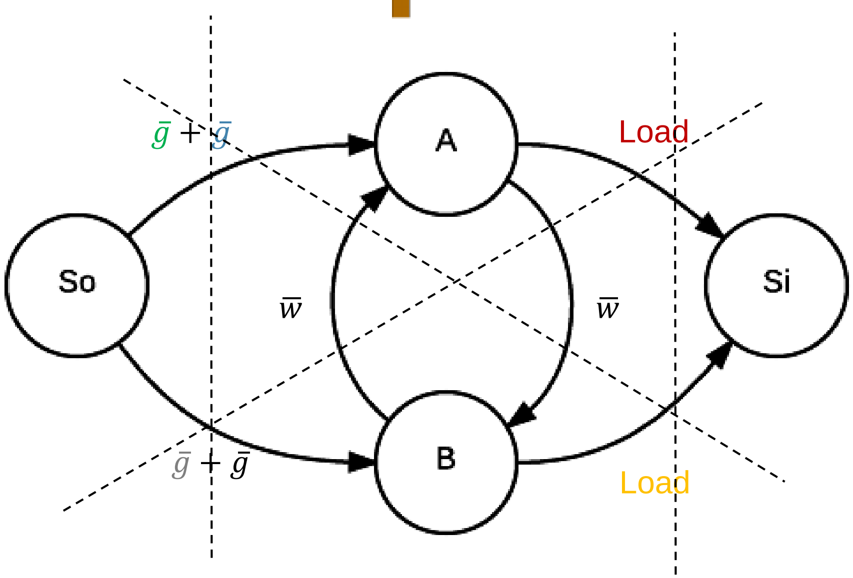




$\bar{g} + \bar{g} + \overline{w}$ + Load

$\bar{g} + \bar{g} + \bar{g} + \bar{g}$

$\bar{g} + \bar{g} + \overline{w}$ + Load

Load + Load

Min

Immediate cost function calculation method

- Immediate cost function calculations can be performed BEFORE SDDP execution, in parallel
- Points are then transformed into plans and inserted in SDDP just as FCF cuts.

Outline

- Introduction
- SDDP
- Basic concepts
- Immediate cost function calculation method
- Results
- Final conclusions

Results

- Panama, Costa Rica & Nicaragua

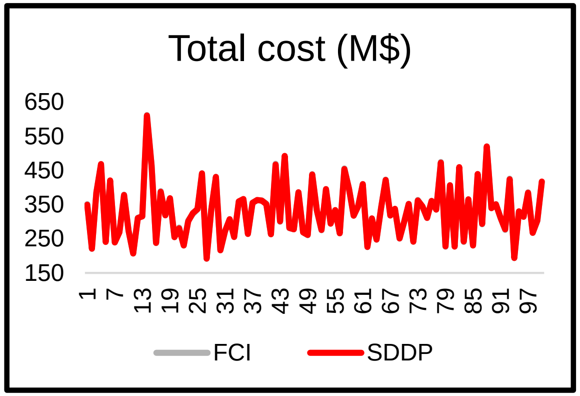
- SDDP simulation performed using immediate cost approach and hourly resolution

Results

- Panama, Costa Rica & Nicaragua

- SDDP simulation performed using immediate cost approach and hourly resolution

Panama



100 forward scenarios
42 hydroelectric plants
22 thermal plants

Results

- Panama, Costa Rica & Nicaragua

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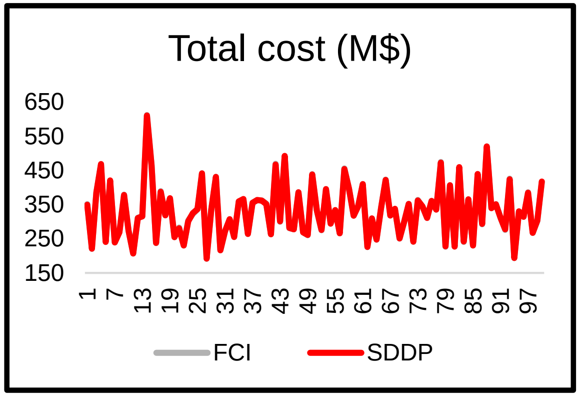
Panama



100 forward scenarios
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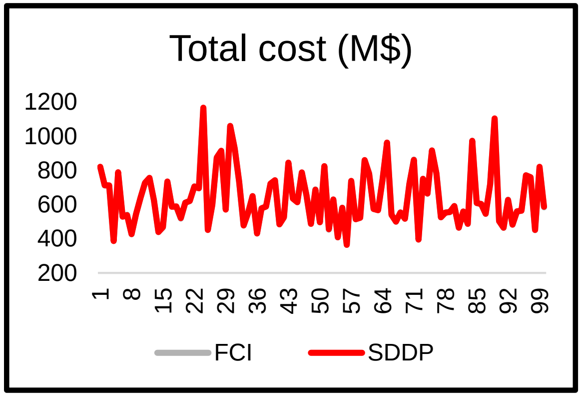
Panama & Costa Rica



100 forward scenarios
78 hydroelectric plants
34 thermal plants

Results

- Panama, Costa Rica & Nicaragua

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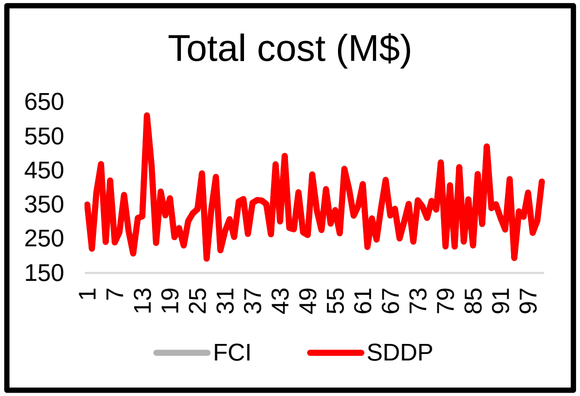
Panama



100 forward scenarios
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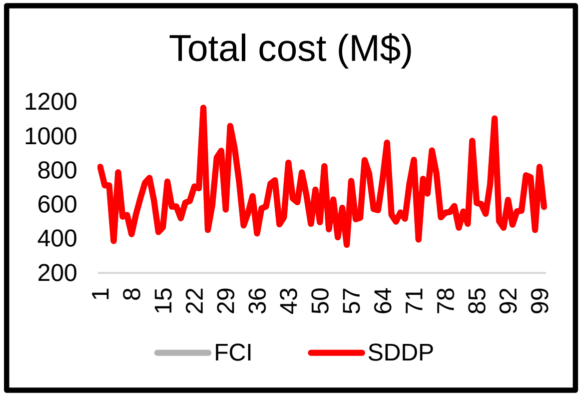
Panama & Costa Rica



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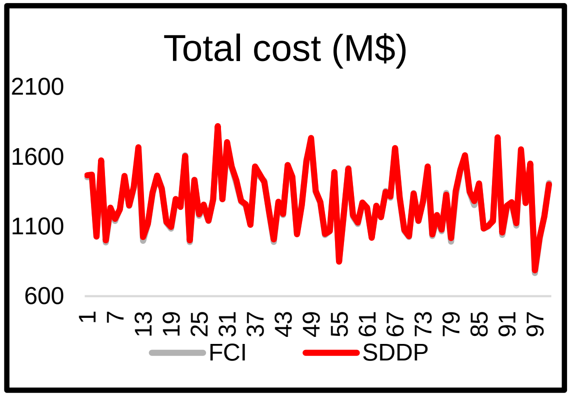
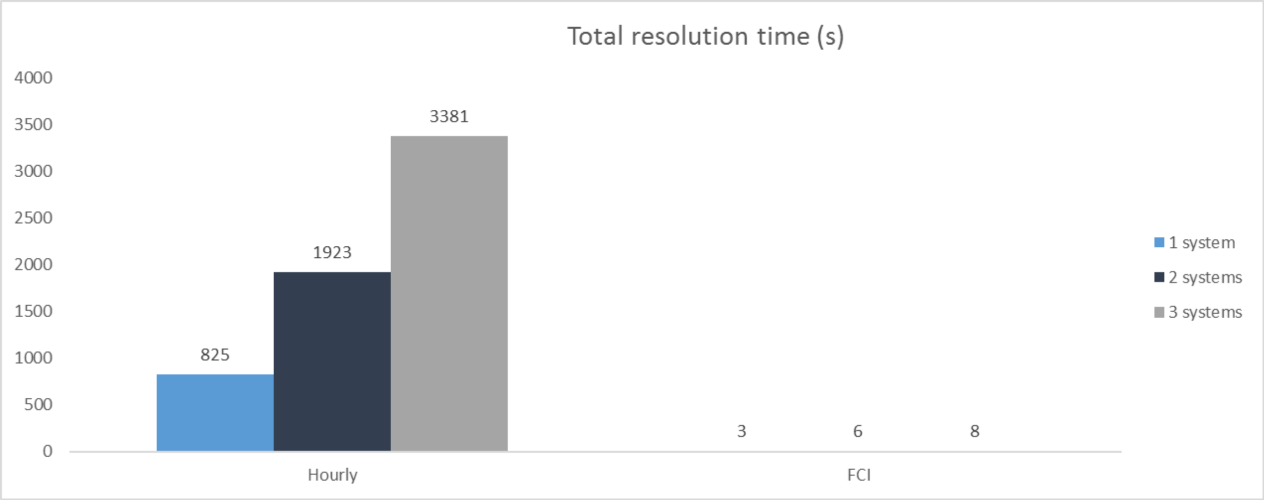
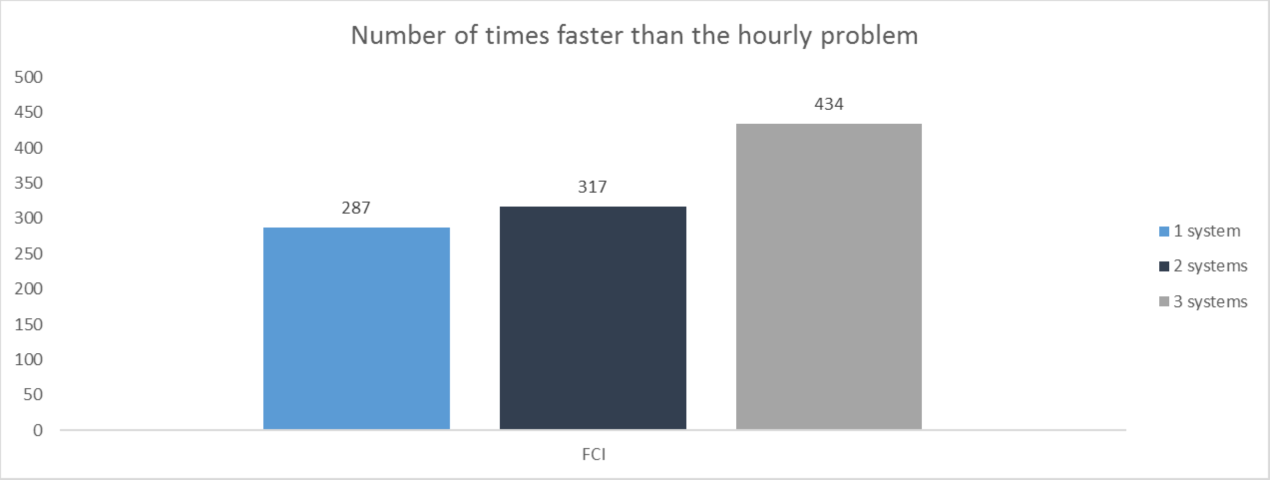


100 forward scenarios
83 hydroelectric plants
60 thermal plants

Results

- Panama & Costa Rica & Nicaragua





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Final conclusions

- Renewable generation variability demands hourly representation, which is time consuming in current SDDP
- The methodology enables the obtainment of costs based on hourly results without representing hourly variables
- SDDP execution time using this approach is close execution time using block representation
- The approach can also be used to represent batteries and run-of-river plants. In this case, we would use interconnected hourly graphs to represent intra-stage time dependence

PSR

THANK YOU