T&D Technologies: Systems Integration Opportunities and Challenges

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Topics of discussion

- Technical opportunities and challenges
- Regulatory/pricing opportunities and challenges
- An illustrative example (with Dr. Phil Yoon)

Value of transmission service

- For implementing energy contracts (value of T to G/D)
- For maximizing social welfare (by enabling cheapest S to be delivered to D)
- For facilitating Customer Choice (T vs S, substitutes); level of desired reliability

Technical Opportunities

- Build new lines or upgrade/enhance the existing lines :
- -To reduce congestion

  -To deliver more without large transmission loss

  - To help reduce the need for expensive generation

  -To adjust/control delivery on specific paths

  -To implement flow-based contracts

  -To ensure reliability requirements

New technologies: FACTS, HVDC, HVDC-lite, superconductors, software,control,communications.

Technical challenges

- Either over-design not to run into technical problems
- Or, operate closer to the transmission capacity margin and face more engineering challenges, such as

-identify best locations/types of T&D technologies to meet given performance at least cost

-add new technologies to the existing grid without creating unexpected operating problems (avoid ``fighting'' of different devices)

-avoid maintenance problems due to switching

-rely on software to estimate and control system conditions

Long history of these types of problems

Technical solutions for system integration

- Careful coordination at different rates
- Real-time measurements and use of these measurements
- Wide-area measurements and communications
- Development of ISO-level software for predicting the grid conditions in order to coordinate different components with well understood effect on system-wide reliability by switching and controlling right devices at the right time (weak)
- Beat complexity by using DC technologies in between the control areas; even have backbone all DC and more control closer to the users

Possible new technical paradigm

- Very distributed, small scale technologies at all levels of industry (T&D controllable wires, demand response by various classes of customers to the price of electricity, transparent benefit to customers, meaningful mix of various sources of generation—including renewable energy)
- Law of large numbers, where many small actions control the system, instead of top down technologies
- Yet minimal coordination needed

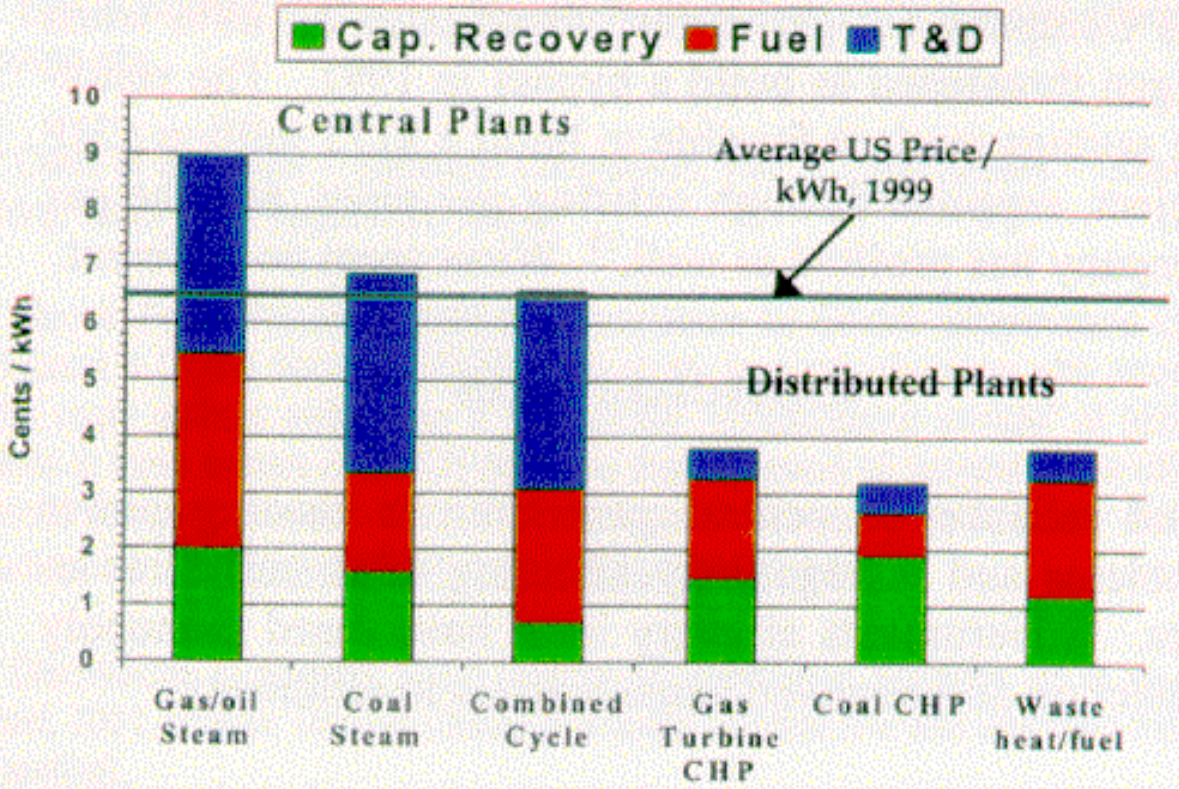
Financial/regulatory opportunities

- Need an industry environment in which there are clear signals about the substitutes to the customer needs (inexpensive generation+transmission is the same as expensive generation)
- Markets to nurture evolution of an ``optimal'' grid (capable of making room for equal playing field for different technologies-suppliers, customers and/or T&D)
- Separate effects of new components from the effects of the existing grid

Financial/regulatory obstacles

- Nothing is being built because of the regulatory uncertainties
- T&D (and, more generally, technologies) are not valued for reliability (back-up power value, value of the wire in case something fails, value of the interruptible customers)
- Misconception that there is no more transmission capacity and that it would be impossible and very expensive to increase delivery capacity, therefore overemphasis on DG (next graph, courtesy of Tri Gen Co)

Figure 5, New Power Plants – Price per kWh to Earn a Fair Profit



Conceptual regulatory challenges

- Tariffs to support optimal power system design (tradeoffs between T&D vs Demand technologies vs Power supply)
- Separate T&D values from the others, in order to give clear signal for investment in T&D when appropriate
- Give incentives to Transmission Owners to reduce congestion and to at the same time have sustainable business based on cheapest solutions (Case1, vs Case 2)
- Avoid slow stakeholders-based approval of T&D investments

Conceptual regulatory solutions

- Move from cost+ regulation for T&D to Performance Based Regulation with clearly defined transmission product (path provision service)
- The transmission owner does not have to justify to the export area or to the import area separately (not possible, because of the cost shift) –the job of a TO is to REDUCE CONGESTION AT THE COMPETITIVE TRANSMISSION PRICE (DIFFERENCE OF THE EXPECTED LBMPS IN THE TWO AREAS); THE COMPETITIVE ADVANTAGE IS CHOICE OF TECHNOLOGY (CASE 1 OVER CASE 2) TO REDUCE COST AT WHICH IT DELIVERS THE PROMISED PRODUCT.

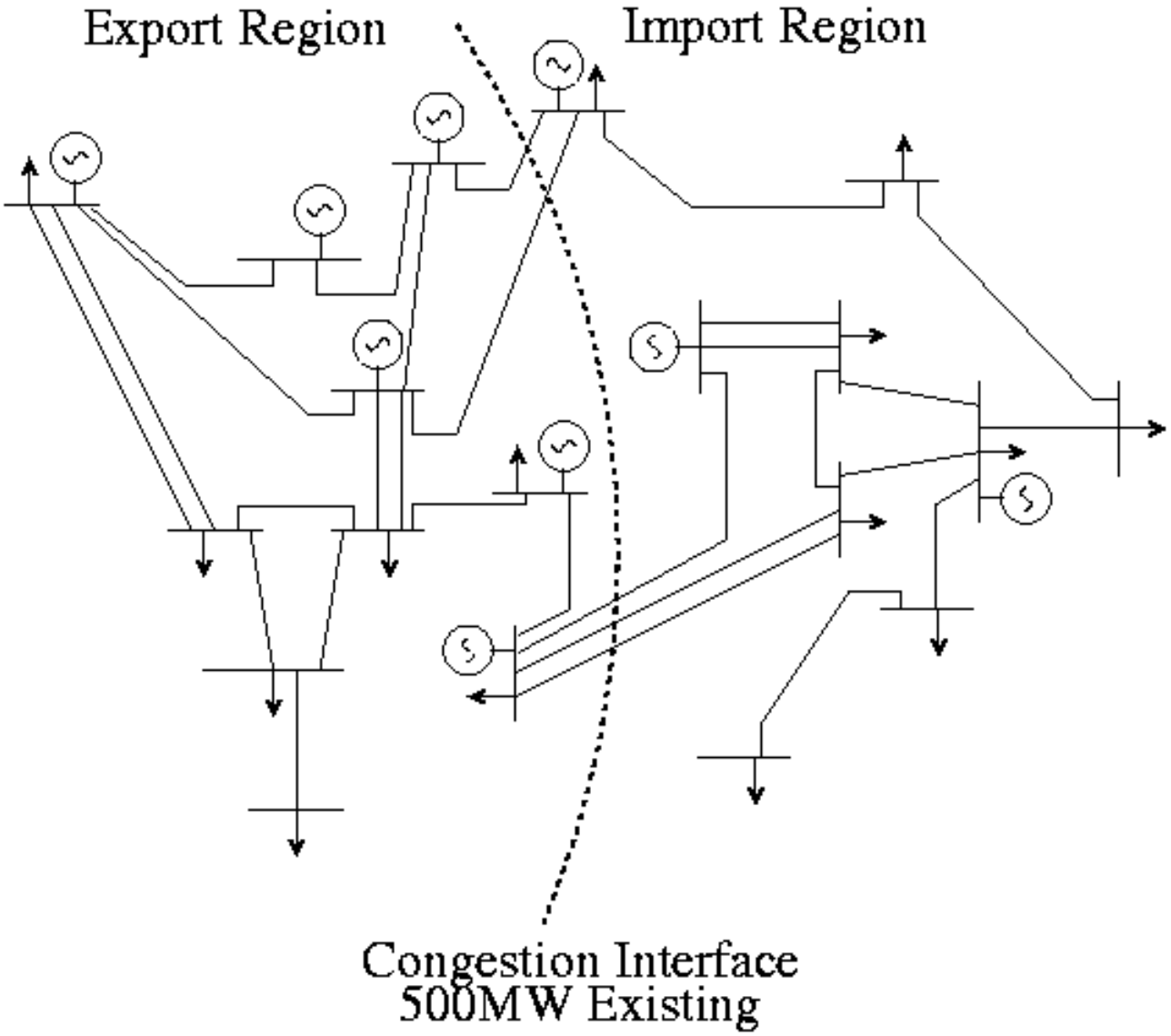
Our proposal

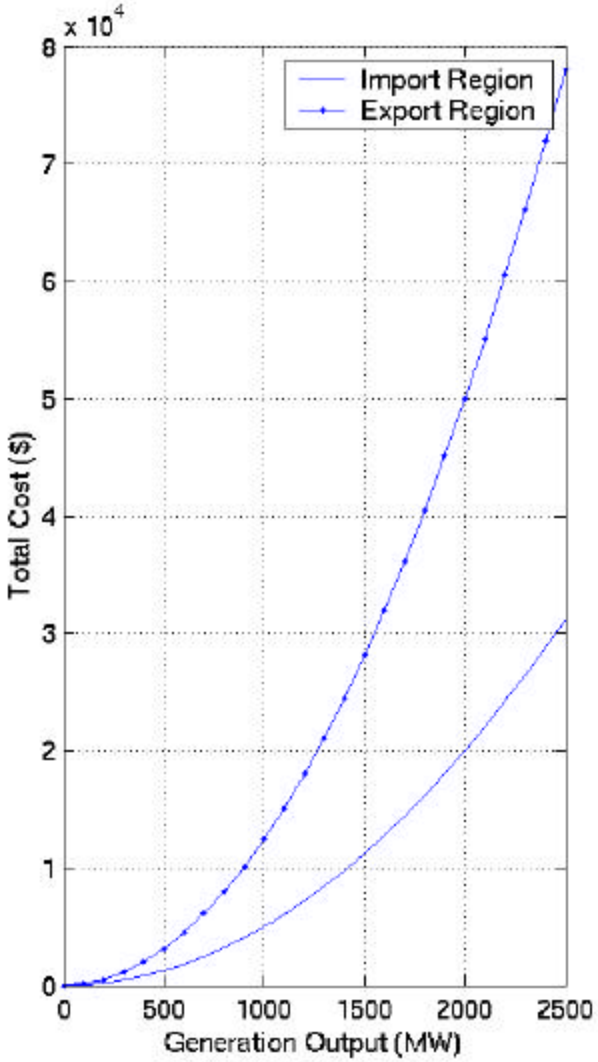
- We propose PBR designs for short-term transmission provision, and fully competitive forward transmission markets.
- If the long-term transmission markets overcharge, they would lose business to the spot PBR-based transmission provision.
- The example will show that conceptually there is no much difference between the PBR –based transmission provision and the T-market. The challenge is to estimate the competitive value of transmission provision.

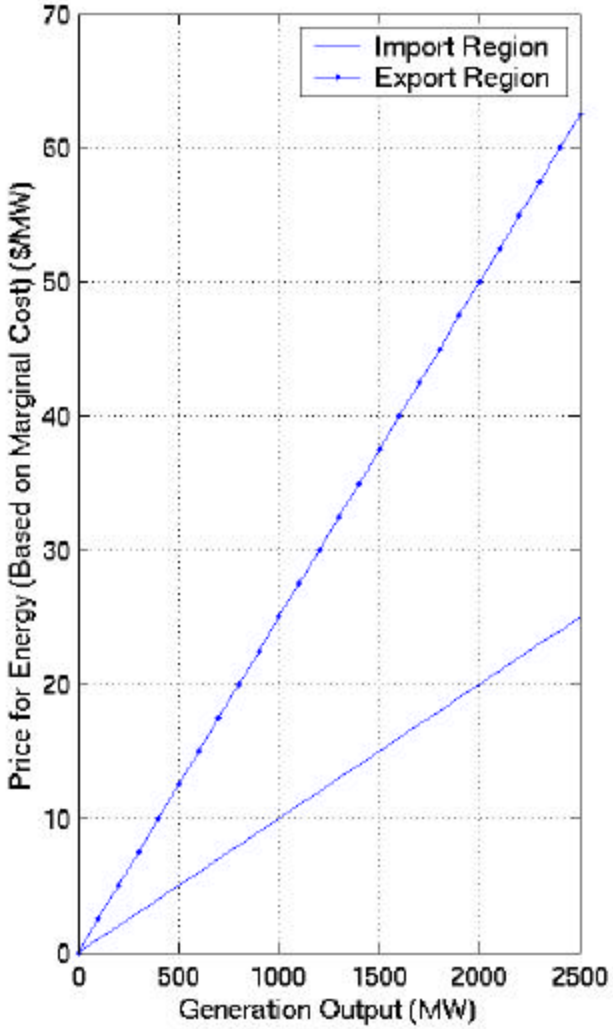
For multi-TO/RTO extension, minimal market –RTO be a market for inter-regional transmission; merchant transmission project fit in this design naturally, and are similar to any other TO within the RTO

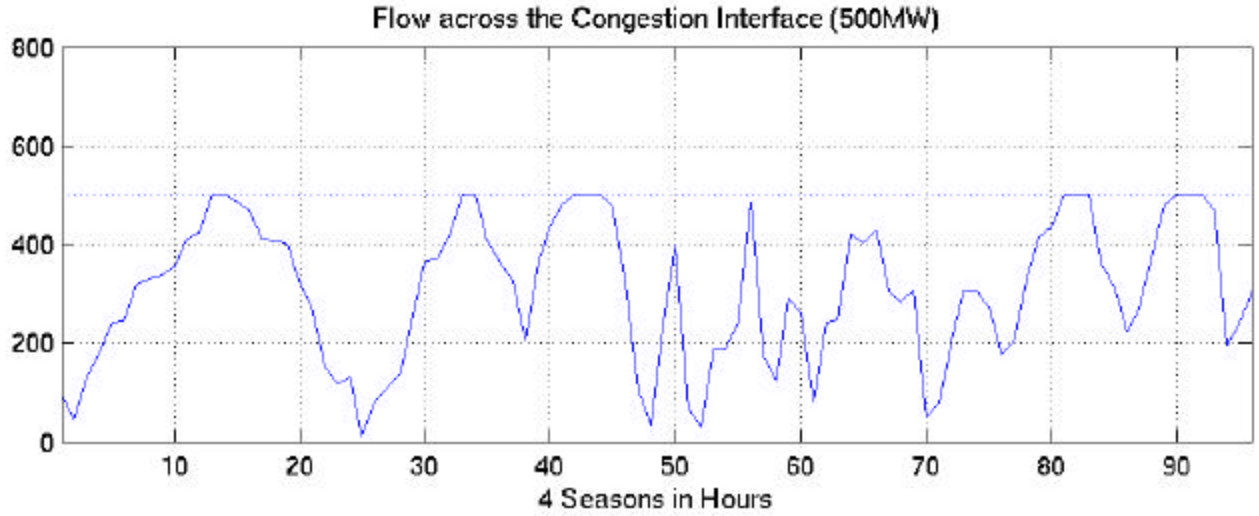
Example (with Dr Phil Yoon; ytyoon@alum.mit.edu)

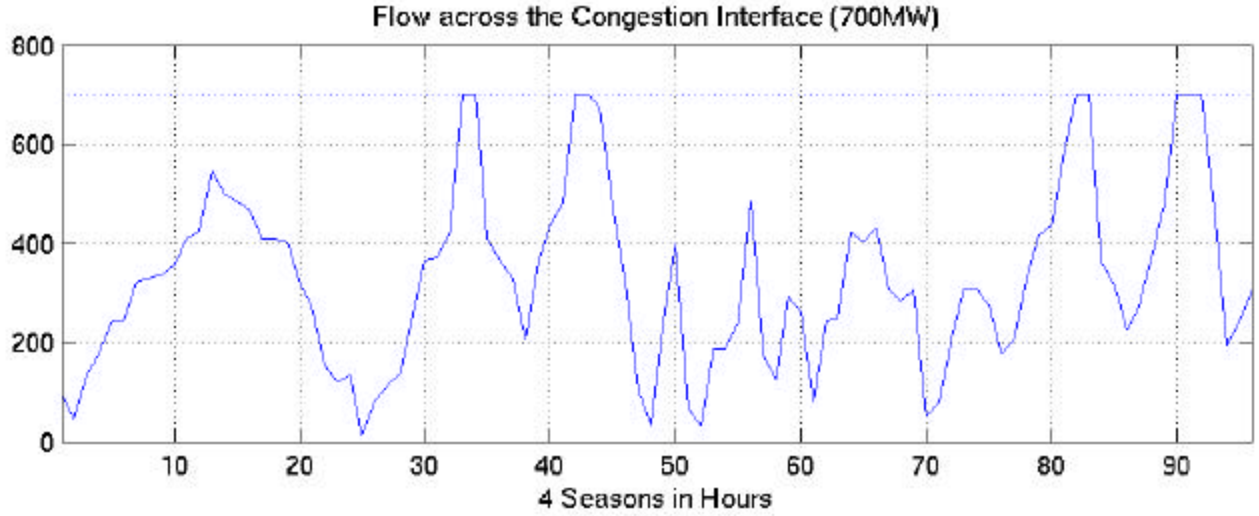
- Illustrates technical and regulatory opportunities, challenges and possible solutions outlined above.
- For more details, contact us.

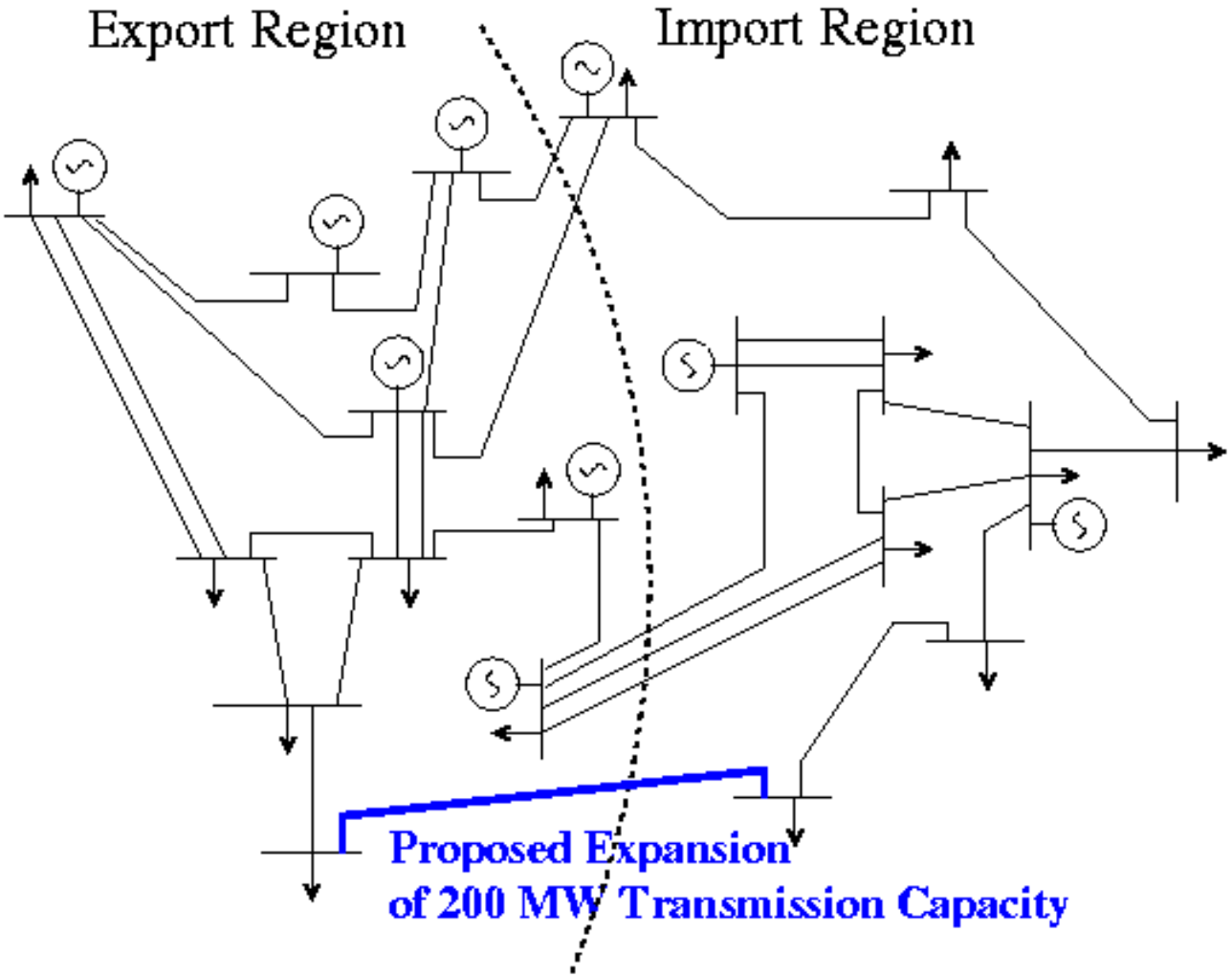

Export Region
Import Region
Congestion Interface
500MW Existing

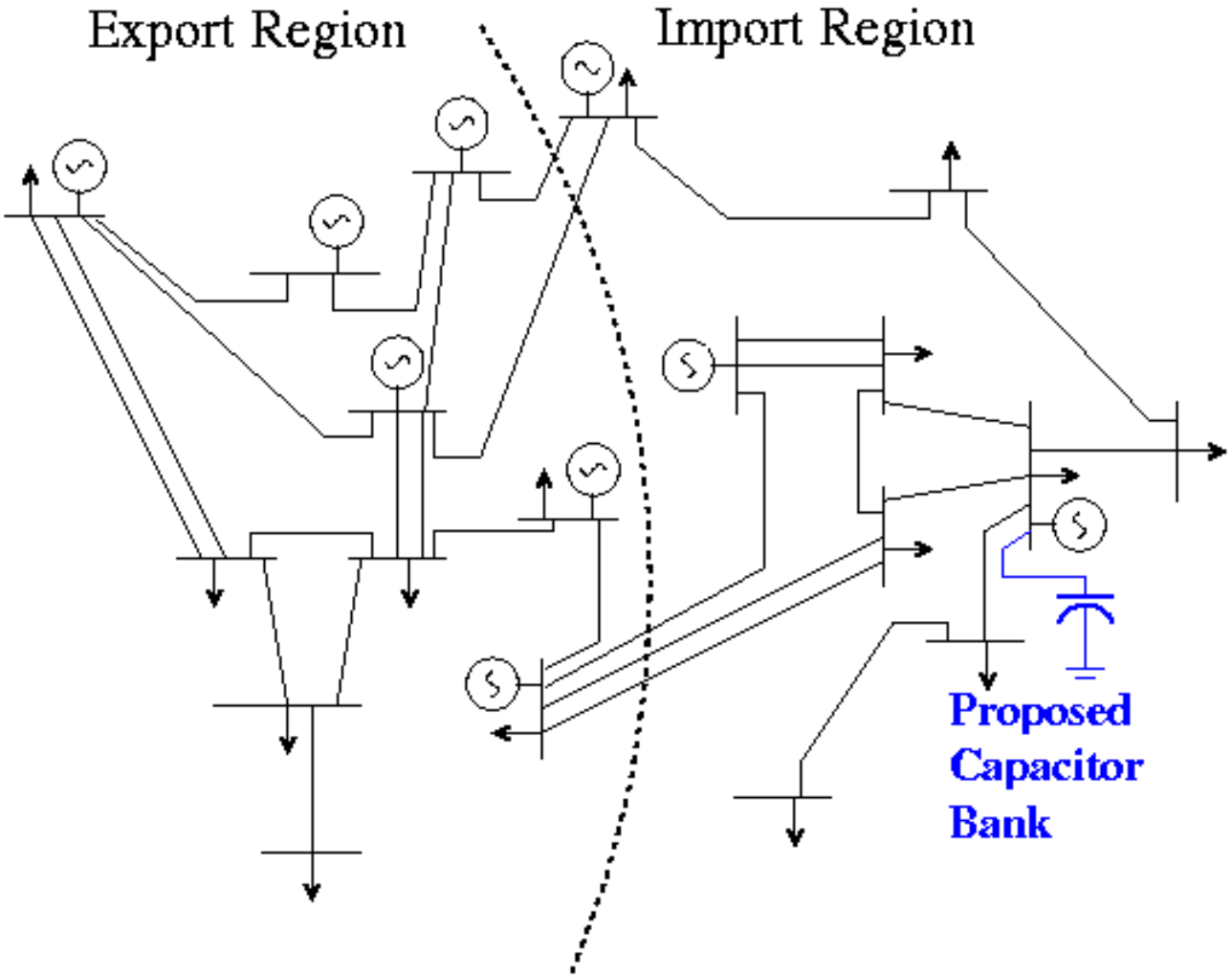

x 10^4
Import Region
Export Region
Total Cost ($)
Generation Output (MW)
0
1
2
3
4
5
6
7
8
0
500
1000
1500
2000
2500

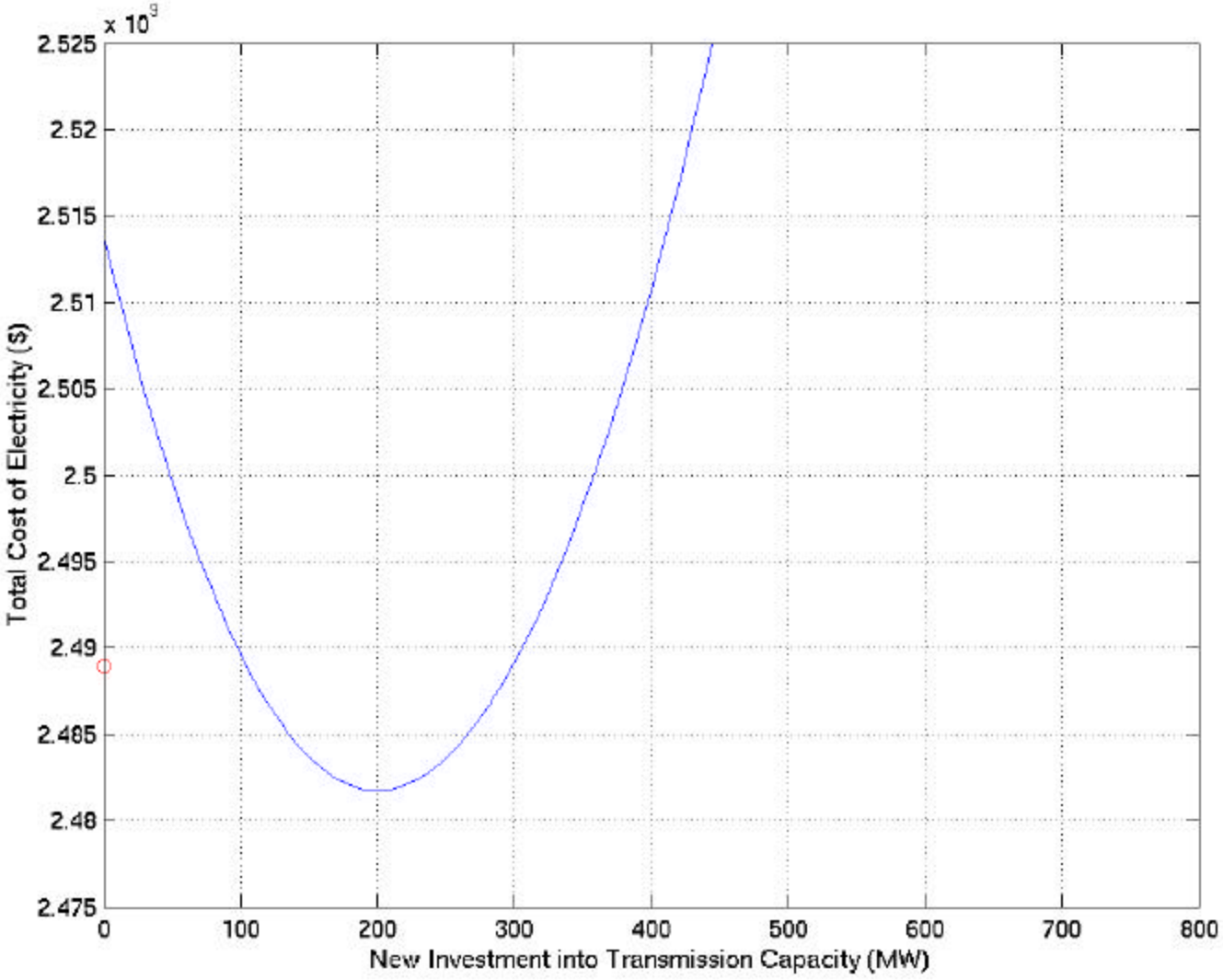

Import Region
Export Region
Price for Energy (Based on Marginal Cost) ($/MW)
Generation Output (MW)
0
10
20
30
40
50
60
70
0
500
1000
1500
2000
2500

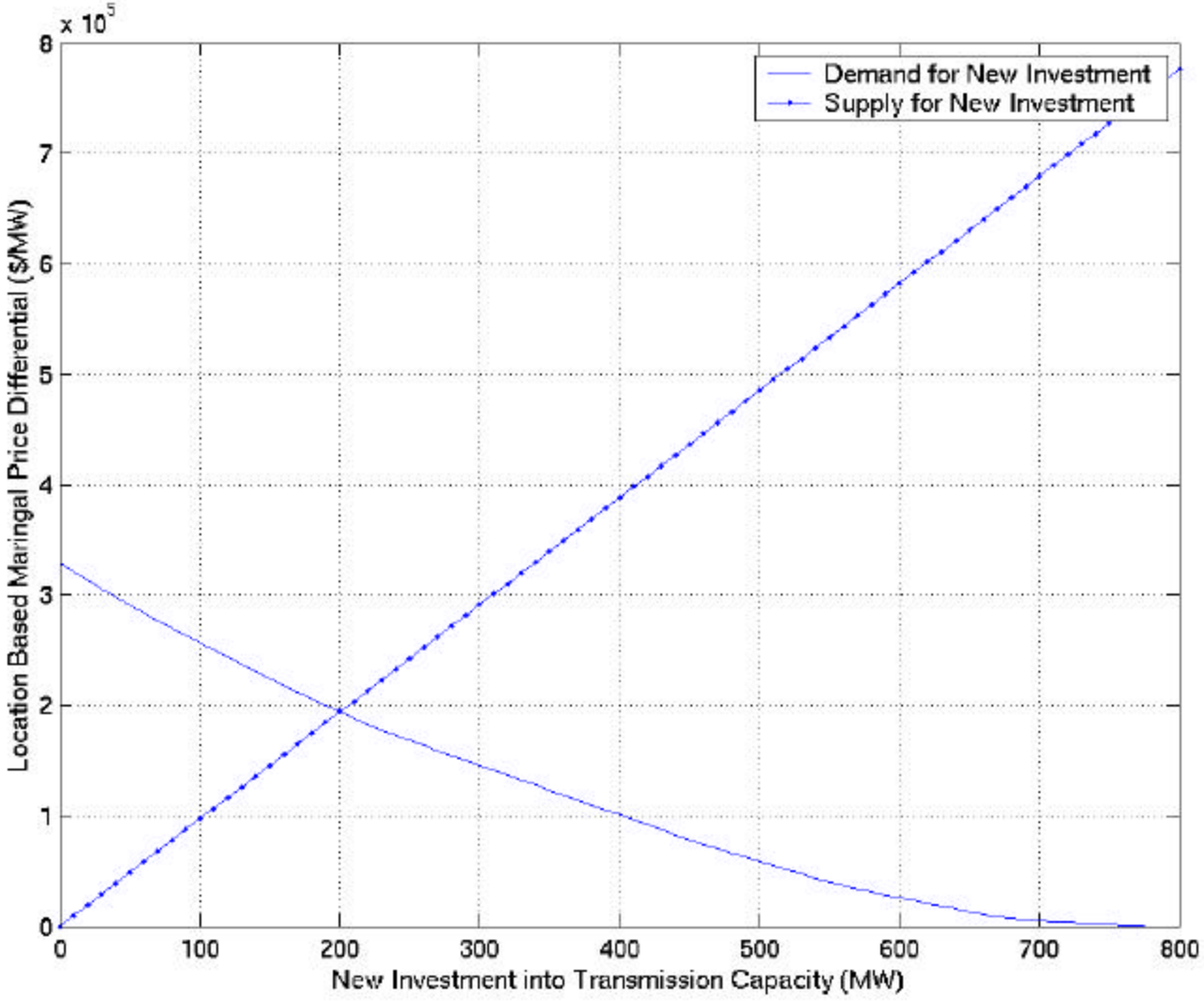

Flow across the Congestion Interface (500MW)
800
600
400
200
0
10
20
30
40
50
60
70
80
90
4 Seasons in Hours


Flow across the Congestion Interface (700MW)
800
600
400
200
0
10
20
30
40
50
60
70
80
90
4 Seasons in Hours


Export Region
Import Region
Proposed Expansion
of 200 MW Transmission Capacity


Export Region
Import Region
Proposed
Capacitor
Bank


x 10^3
2.525
2.52
2.515
2.51
2.505
2.5
2.495
2.49
2.485
2.48
2.475
Total Cost of Electricity ($)
0
100
200
300
400
500
600
700
800
New Investment into Transmission Capacity (MW)


x 10^5
8
7
6
5
4
3
2
1
0
Location Based Maringal Price Differential ($/MW)
0
100
200
300
400
500
600
700
800
New Investment into Transmission Capacity (MW)
Demand for New Investment
Supply for New Investment

Cost+ Regulation

Energy charge = nodal price • ld_demand
– ld_ratio • merchandise surplus

Transmission charge = ld_ratio • trans_cost

	Before investment		After investment	
	Energy Charge	**Trans Charge**	**Energy Charge**	**Trans Charge**
Export Region	**$2.35B**	**$234M**	**$2.32B**	**$255M**
Import Region	**$2.79B**	**$266M**	**$2.55B**	**$290M**

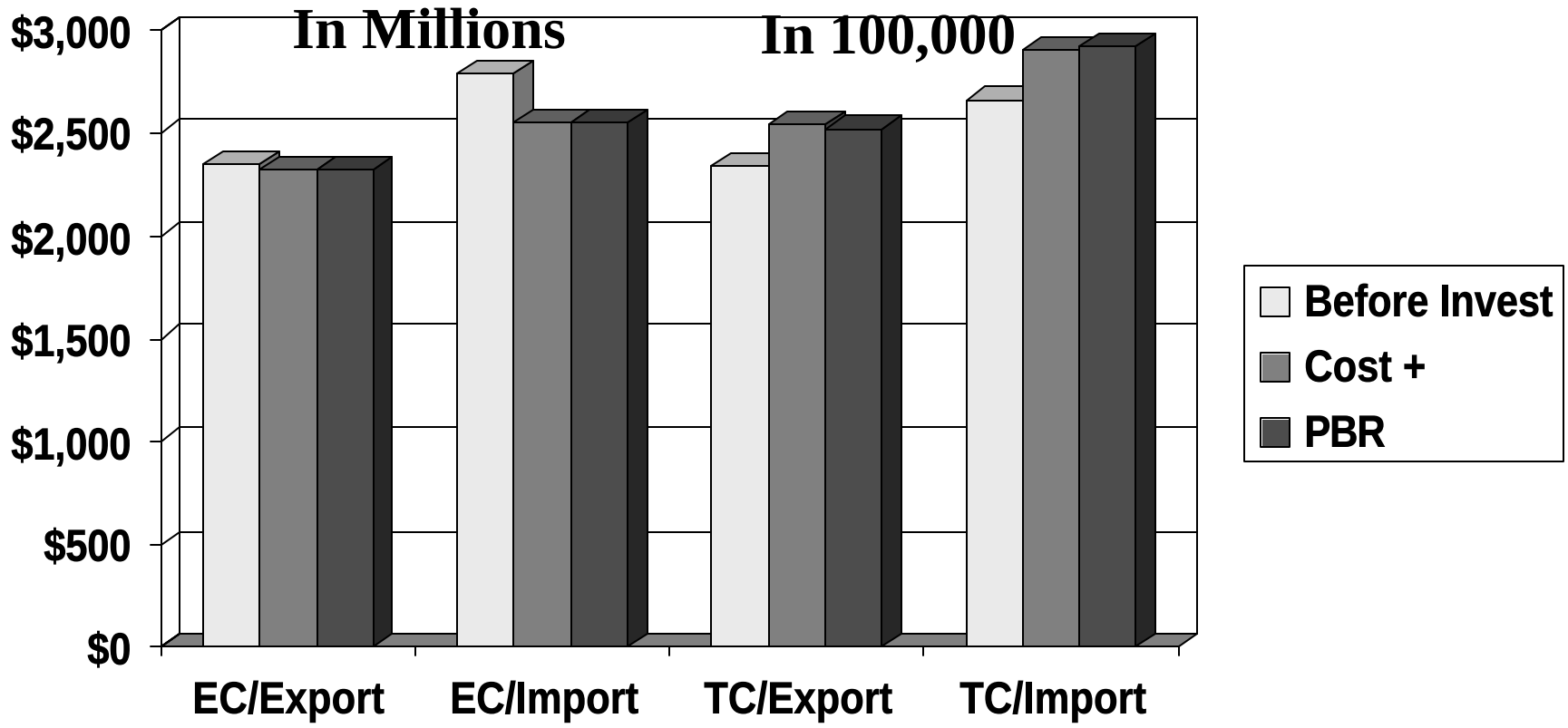
Performance Based Regulation

Energy charge = same as cost+ regulation

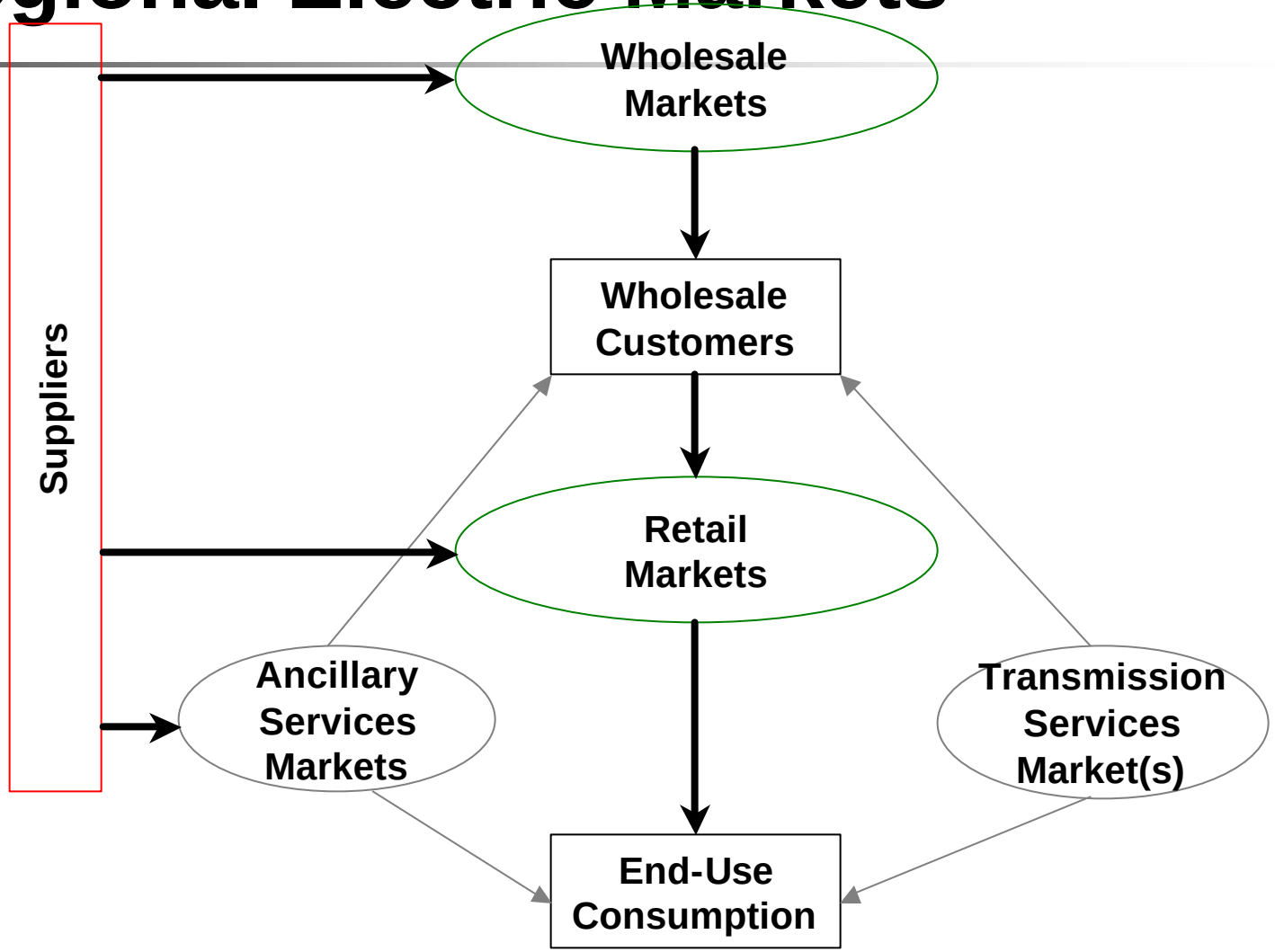
Transmission charge = nodal price • ld_demand + flow charge – energy charge

	Before investment		After investment	
	Energy Charge	**Trans Charge**	**Energy Charge**	**Trans Charge**
Export Region	**$2.35B**	**$234M**	**$2.32B**	**$252M**
Import Region	**$2.79B**	**$266M**	**$2.55B**	**$292M**

Summary of Charges

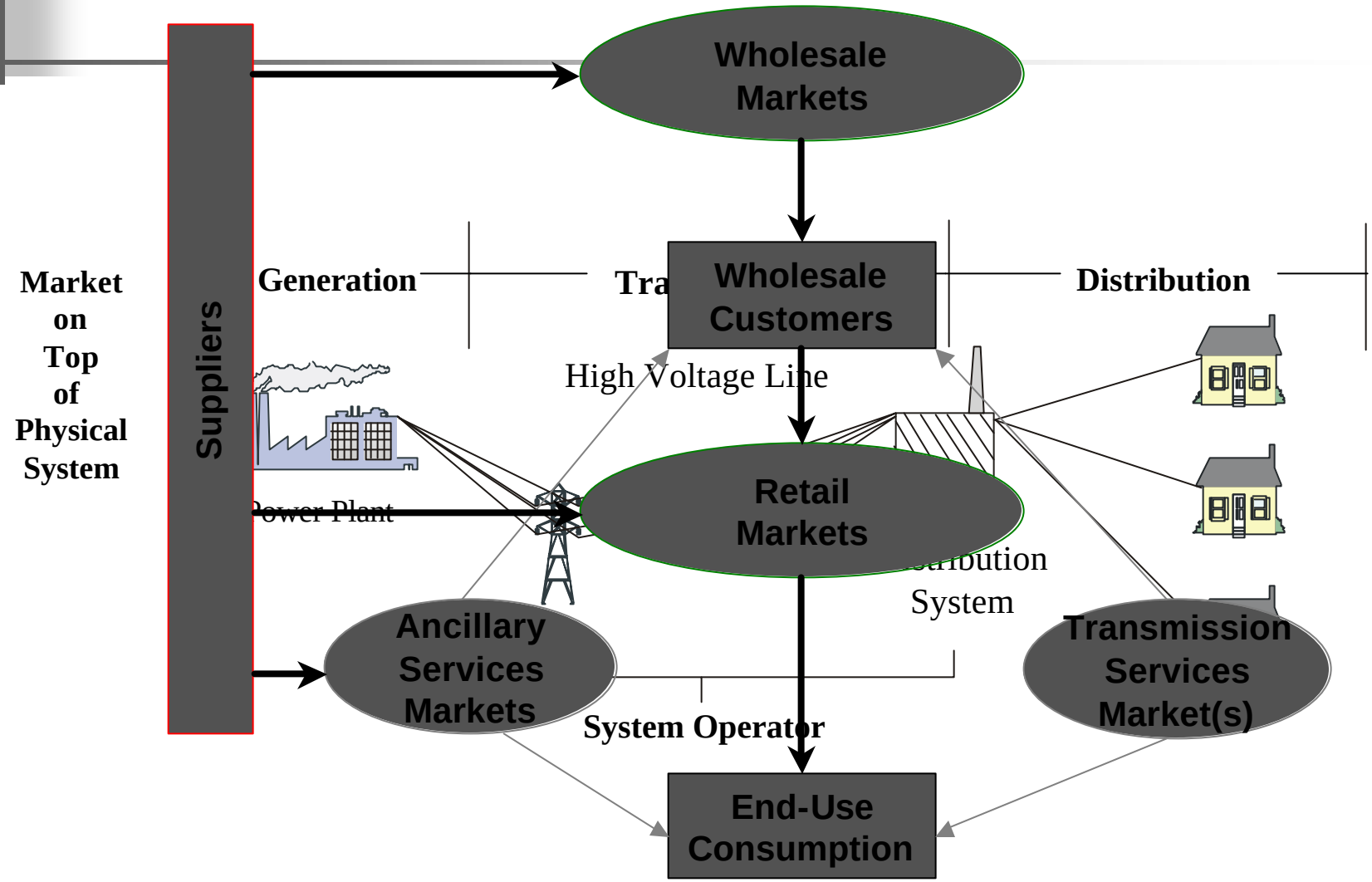


Regional Electric Markets



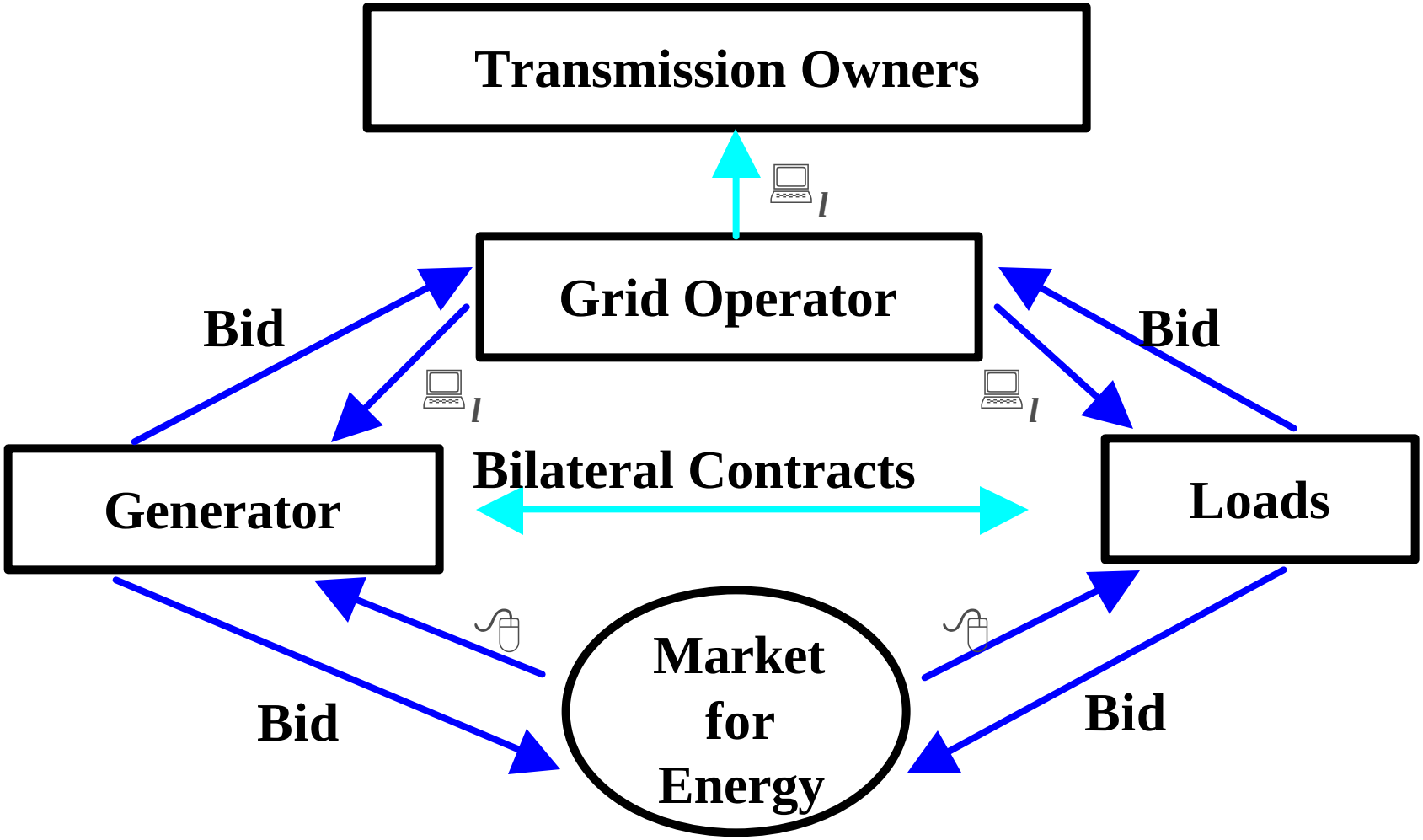
Source: DOE Electricity 2002 Conceptual Design

Regional Electric Markets



Source: DOE Electricity 2002 Conceptual Design

Interaction between Market and Physical System



Smart Transmission Networks

- Owners not the same as real-time operators
- Two cases 1) Transmission remains a fixed ROR -based business; 2) Transmission is a PBR-based business
- Conjecture: The IT tools (software) play critical role in making this a viable business

Smart Transmission Provider -- Fixed ROR

- Challenges (software for managing different requests for power delivery; firm, non-firm, long-term bilateral, short-term)
- Making information transparent to the users (data aggregation); from hierarchical to open access
- Non-discriminatory charges
- Congestion control (technical and/or price feedback design)

Smart Transmission Provider -- PBR-Based/Markets

- Insurance-like company selling guaranteed delivery at a price; non-linear pricing
- What is the demand for delivery?
- What is it worth?
- Auctions and/or top-down valuing
- Implementing simultaneous transactions over various time horizons without violating operating constraints (TLR problem)

TLR: Transmission Loading Relief

Dynamic investments

- Need for relating operations and long-term commitments (and investments)
- How should a transmission provider decide between serving a short-term request or paying penalty for not serving a long-term pre-committed market requests?

Smart Networks

- Definitive need for designing communications, computer, physical, financial networks to meet a specified performance (embedded software)
- Modeling, analysis and control approaches for power systems potentially useful to the newer networks
- Research needed on common underlying principles
- Major question: Scalability

Long-run Coordination for Provision of Transmission

- Minimization of Total Cost Maximization of Transmission Rent

$$\Leftrightarrow$$

$$\min_{I_l^T} \left\{ \int_{t_0}^{T} e^{-rt} \left[\min_{P_i} \sum_i C_i(P_i) \right] dt + \sum_l \int_{t_0}^{T} e^{-rt} \left[C_l^T\left(K_l^T(t), I_l^T(t), t\right) \right] dt \right\}$$

subject to

$$\sum_{i=1}^{n} P_i = 0 \quad \text{and} \quad \sum_{i=1}^{n} H_{li} P_i \leq K_l$$

IT-related Questions

- Type of data required to be made public for reliable and adequate industry (by the EIA, FERC, NERC)
- Design of internet-based information structures
- (Network) data aggregation for transparency; from hierarchical to open access
- Embedded software to implement smart suppliers, users and delivery services

Flexible OASIS

- Once the models/software exist for making the transmission providers smart, one employs internet to provide the relevant information on-line
- System users observe the status of the system, and internalize into their distributed objectives
- This is how coordination takes place

Open Research Problems

- Develop tools for going from sequential operations/planning to interactive iterative decision making over variety of time horizons
- Rate at which information is provided, type of information critical
- Many counterexamples possible to show market failure related to lack of adequate information