

Transmission Expansion: Market-Based and Regulated Approaches

Concept of Reference Network: A Tool for Transmission Regulation and Expansion

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A few questions to start with...

- Monopoly
 - Improve existing and create new regulatory approaches
 - How to measure cost and quality performance?
 - How to allocate cost?
- Consensus
 - What should be build and who should pay for it ?
- Merchant
 - What is the right framework? What if it does not work?
- Coexistence of regulated and merchant
 - How to ensure harmony?

Transmission as a regulated business

- A monopoly service
 - Users are concerned that charges for use of transmission are too high and the service quality is too low.
 - Regulatory bodies purchase the service on behalf of the users.
- How than the regulator decides on:
 - A “reasonable” charge for the use of the network (a reasonable revenue transmission company needs to carry out efficient investment programmes).
 - Incentives schemes design (performance targets, both cost and quality) to ensure efficient operation and investment.
 - How transmission cost should be allocated among competitive players, both operational and investment.
- Lack of quantitative approaches to regulation

Reference Networks

- **Definition**

- Reference transmission network, in its simplest form, would be *topologically identical* to the *existing* network, with the existing generation and load layouts and cost characteristics, would operate at the same voltage levels as the real one, but the individual transmission circuits would have *optimal* capacities.
- Reference network is determined by balancing transmission driven operating and investment cost
- If we assume that the transmission capacity can take *any size*, the resulting reference network would have *exactly* the *optimal* amount of congestion to which the *optimal* amount of investment cost would be associated, such that the *total* investment and operating cost are *minimised*
- Reference network versus planning: instead of optimising the capacity of only a few *newly* proposed circuits to be added, this is done for *all* transmission circuits, both existing and new.
- Calculations: DC based investment inclusive OPF

Application

- The reference network is the network against which the real one could be “objectively” compared.
- Optimal (reference) investment cost and the optimal (reference) congestion cost can be quantified and then compared with these achieved on the real system.
- Contrasting the capacities of the individual circuits on the reference and real network, the “usefulness” of these can be quantified and the need for new investment identified.
- Reference network as regulatory tool for quantifying the benchmark costs
- Reference network as tool for setting cost and performance relate targets (design of incentive schemes)
- Using the reference network concept, the transmission company can be effectively made competing with its own reference model.

Recovery of transmission investment cost/1

- **Significance:**

- LMPs (known to efficiently allocate and price the use of scarce transmission resource in the short term) associated with FTRs may not be sufficient to fund transmission investment.
- Transmission investment costs are being allocated to the competitive segments of the industry (generation and retailers) – this will influence (i) relative competitiveness of individual participants in the energy market, (ii) future location of new generators and demand and (iii) development of the networks themselves (transmission is in the business of connecting wrongly placed players).

- **Network Pricing based on Reference network:**

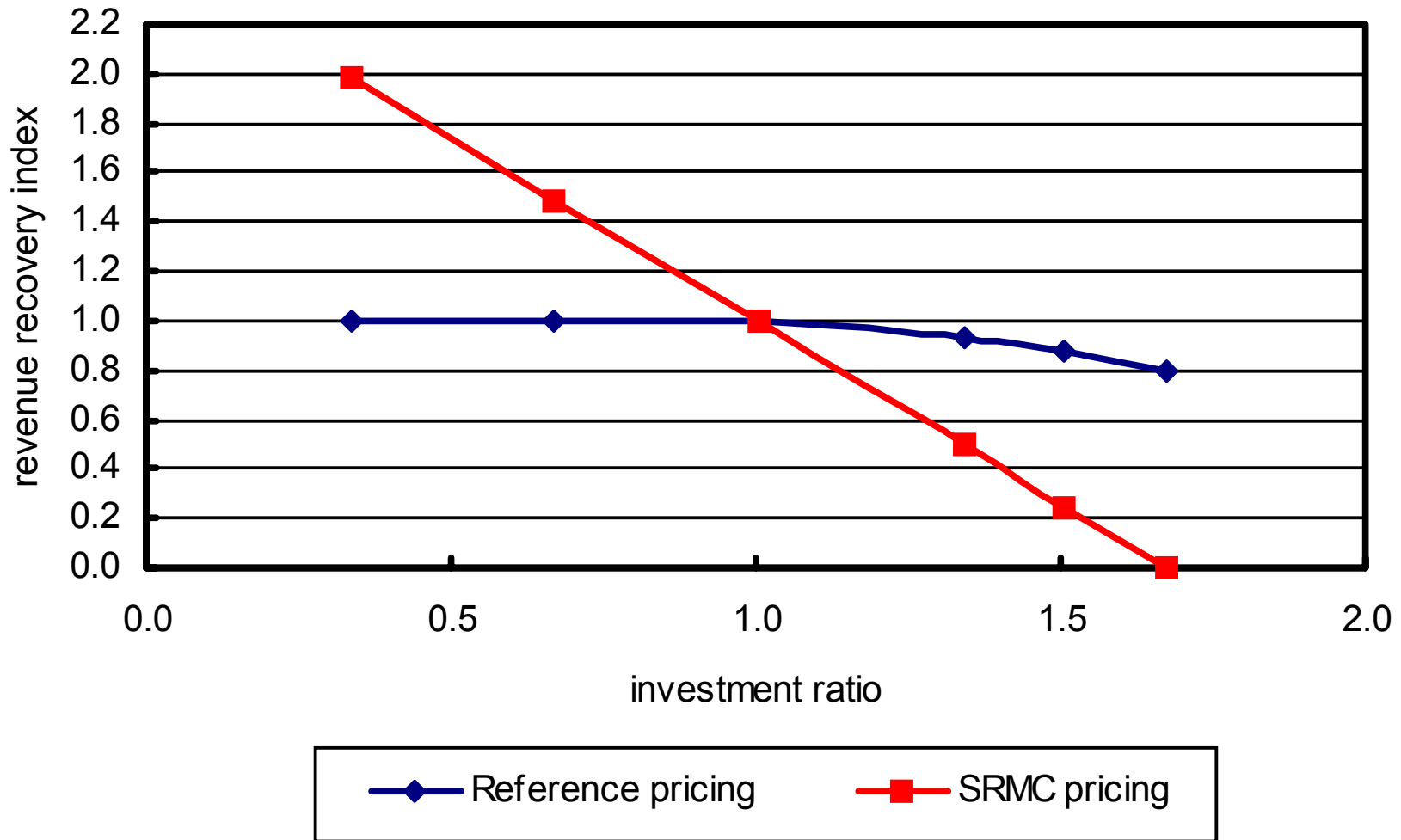
- One of the main features of the reference network approach is that the *transmission investment prices* for each of the transmission circuits, are determined on the *reference* network, not the *existing (real)* network.
- The prices calculated for the reference network are *also optimal for the existing network of any capacity*.

Recovery of transmission investment cost/2

• Network Pricing based on Reference network (cont):

- As the capacities of the circuits in the reference network are optimal, there *will always* be occasions when power flow through each circuit will be exactly equal to its capacity (in the security constrained sense).
- In accordance with the concept of marginal pricing (investment related in this case), charges for the use of each particular transmission circuit apply when the flow equals circuit reference capacity. At all other times, charge is zero.
- The concept of reference network provides a consistent framework for this purpose and can be used on its own or in conjunction with LMP.

LMP versus reference network based pricing: Revenue recovery



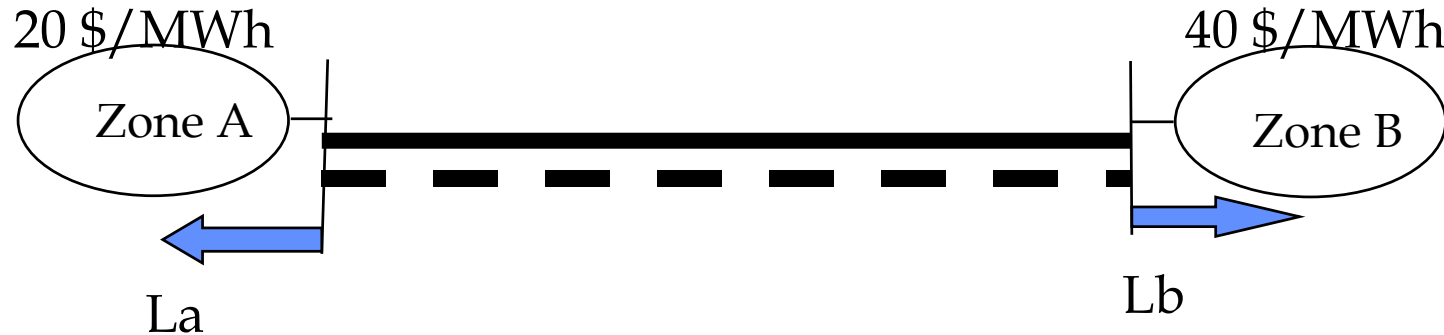
Investment ratio = ratio between existing and optimal capacity

Example: recovery of over-invested transmission

- System operator will take advantage of any excess capacity and reduce congestion and operating cost below their optimal values.
- Consistent with the concept of marginal investment pricing, investment charges are imposed during periods when the reference *flow* equals the reference *capacity* (each circuit with respect to the optimal network). The benefit, if any, of an over-investment will be in the extra energy delivered (across the over-invested circuits) above that that would have been delivered if the network capacity were optimal.
- Over-investment may provide some benefit to network users, as it could reduce the level of congestion. In effect, congestion cost will be reduced *below* its optimal value at the expense of over-investing in the network. In other words, the excess in transmission capacity may not be completely wasted. The reference network based allocation can take this effect accurately into consideration and in case of an over-invested system, the revenue recovered is less than investment (as it should be), but it will always be considerably greater than the corresponding SRMC revenue.

Beneficiaries of transmission investment

(Example from Jose Rotger & Frank Felder paper, Nov 01)



- Prior to project:

	Zone A	Zone B
Load(MWh)	18,000	2,000
Price(\$/MWh)	20	40
Cost(\$)	36m	8m

- Subsequent to project (cost \$1m):

	Zone A	Zone B
Load(MWh)	18,000	2,000
Price(\$/MWh)	21	21
Cost(\$)	37.8m	4.2m

•OPTIONS
 (1) Socialise
 (2) Only B
 (2) A gets compensated

Beneficiaries of transmission investment

(Allocation of transmission investment cost)

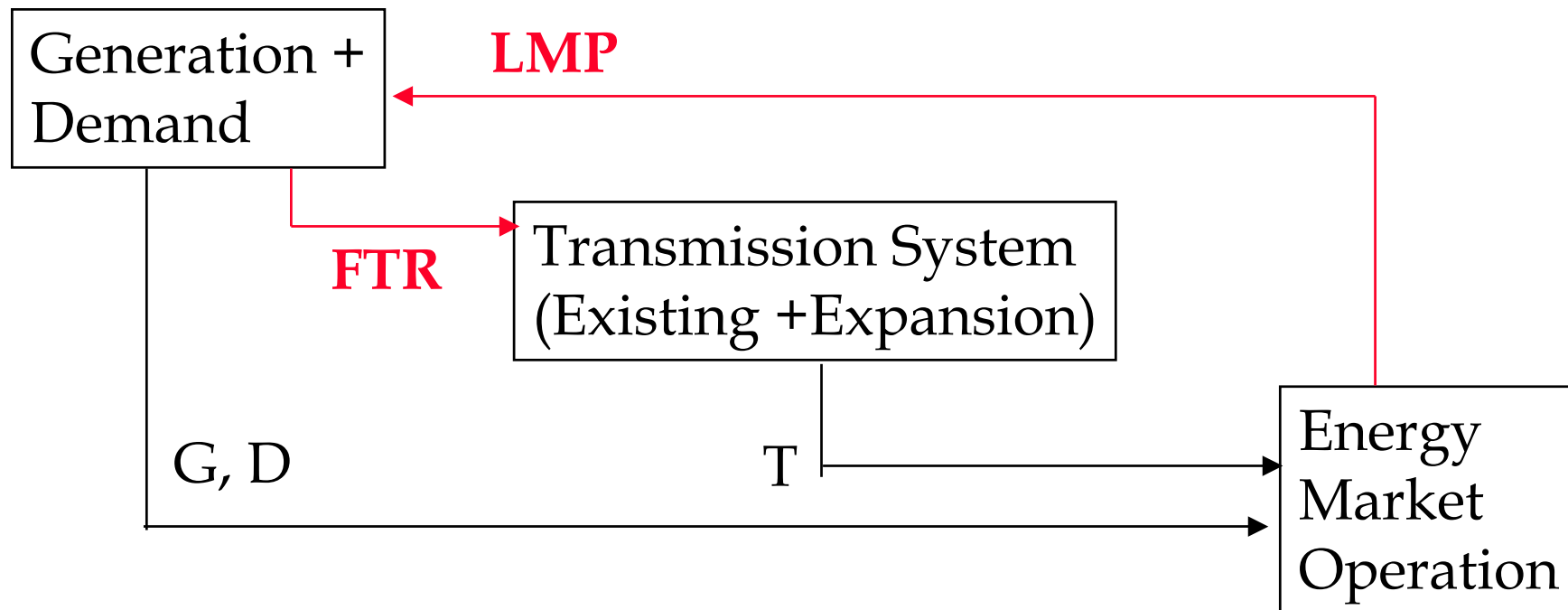
- Pricing based on the reference network allocates existing and new transmission investment efficiently among network users (avoids cross subsidies, both temporal and special)
- Mechanics: (1) determine the reference network capacity and investment cost (2) convert the circuit transmission prices to nodal transmission prices (associate charges with nodal power injections, as compared to monitoring users' contributions to each line flow).
- By allocating circuit prices to nodes prices become *location-specific*, and by applying circuit prices during the period when optimal line flows are binding, prices become *time-of-use specific*.

Beneficiaries of transmission investment

(Allocation of transmission investment cost)

- The transformation of the reference circuit to reference nodal prices can be carried out by using the conventional sensitivity analysis. By definition, the sensitivities measure the impact of an incremental change in injection on a particular line flow. In this case the process is reverse, where the circuit price (that corresponds to a line flow) is transformed into nodal prices (that correspond to power injections).
- Prices for demand generation connected to the same node would have the same magnitudes but different polarities.
- Although circuit prices are always *positive* (representing circuit annuitised investment cost), nodal reference investment prices can be *positive or negative*, depending on the impact the particular injection has on the flow in the binding circuit.

Merchant based expansion



LMP – efficient allocation of scarce transmission recourse

Relationship between LMP and transmission investment ?

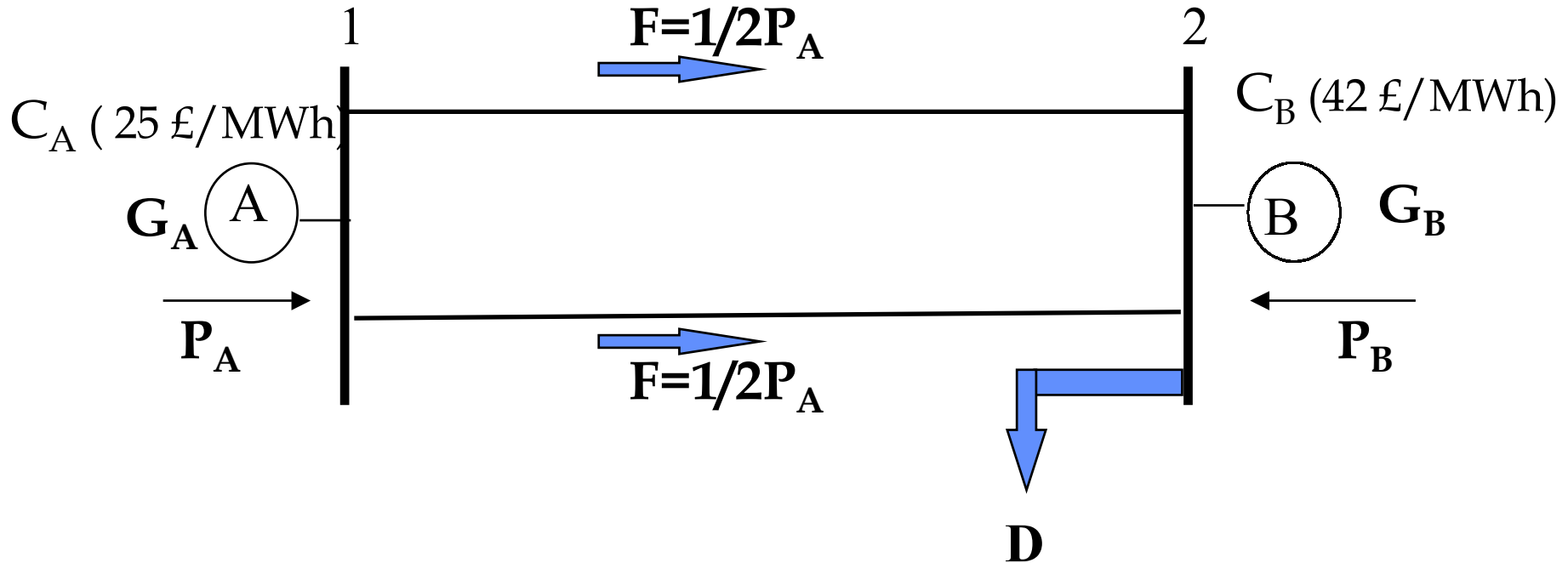
LMP and transmission investment

- While the optimal investment price associated with a particular circuit is different from zero *only* when the circuit power flow reaches its capacity, LMPs across the same circuit may be different from zero even when the flow through the circuit is below its capacity.
- The presence of congestion on one circuit produces price differentials not only across this circuit but also across *many* other *non-congested* circuits.
- A *direct* relationship between LMPs across a particular circuit and the capacity (investment) of this particular circuit cannot be established on a *meshed* transmission system. Strictly speaking, LMPs reflect the need for investment *only* on *radial* transmission networks (in special cases).
- On a meshed system, the price differentials across transmission circuits, as calculated through LMP, *cannot* be directly linked with the investment related to these circuits.
- The extent to which this effect may be significant in practice will be system specific and would not be a problem for interconnections.

A few observations

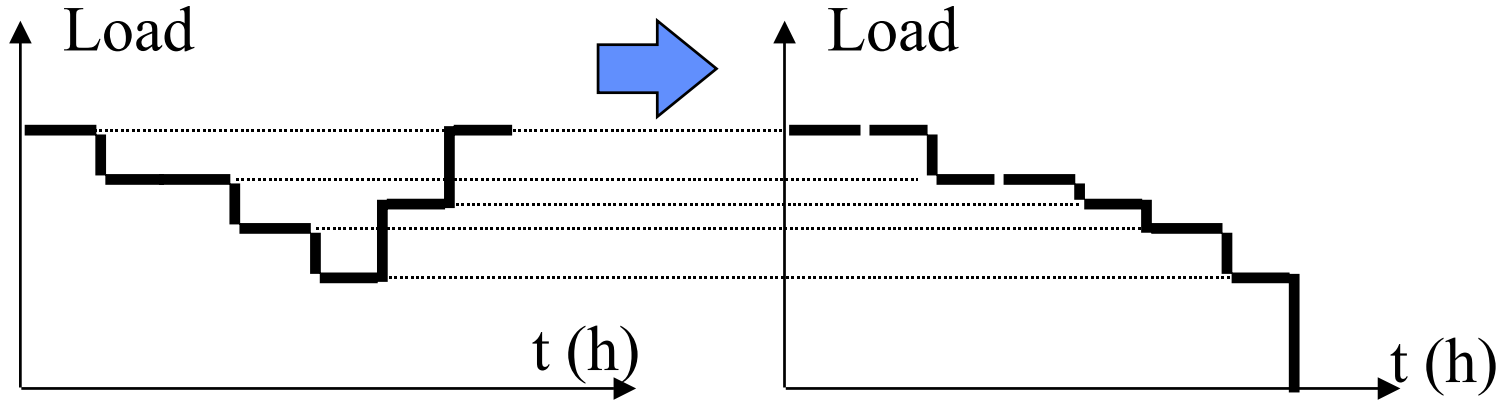
- A few potential benefits of the concept
 - Tool for regulation
 - Reference network based pricing rewards useful investment and discourages over-investment
 - Efficient allocation of investment cost
 - Tool for cost-benefit analysis
 - Identification of beneficiaries of expansion
 - Can deal with alternatives to transmission
- A few potential problems of the concept
 - Involves predictions of future loads and generation location and characteristics
 - Over what time horizon?
 - How to get all to agree with inputs?
 - Although forecasts are always wrong - we need to plan anyway.

Example

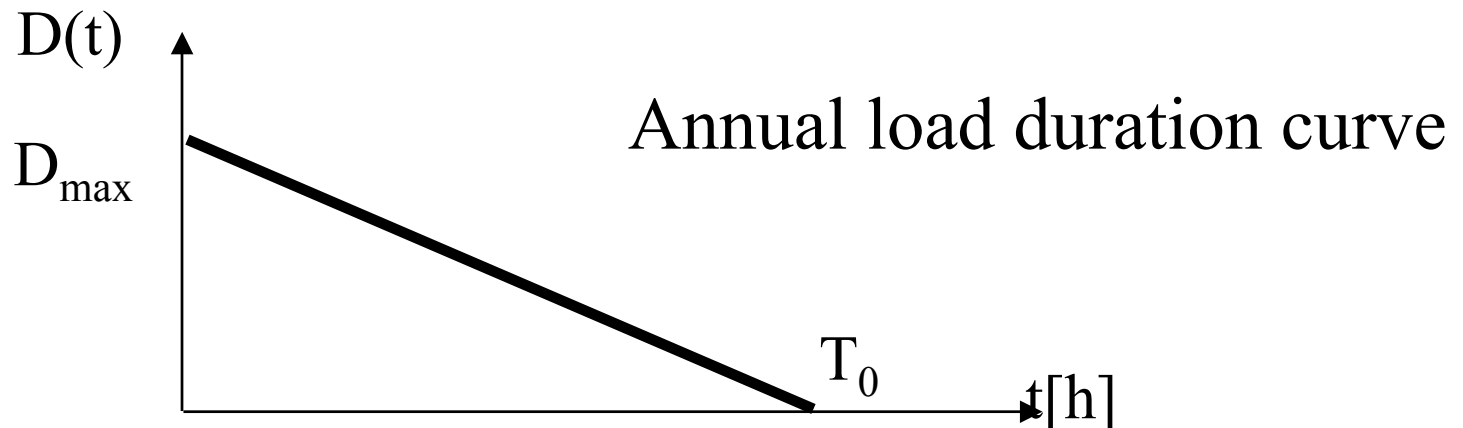


- Two identical transmission circuit connect areas A and B
- Demand is connected to area B
- Generation capacities in A and B exceed maximum load demand
- N-1 Security criterion

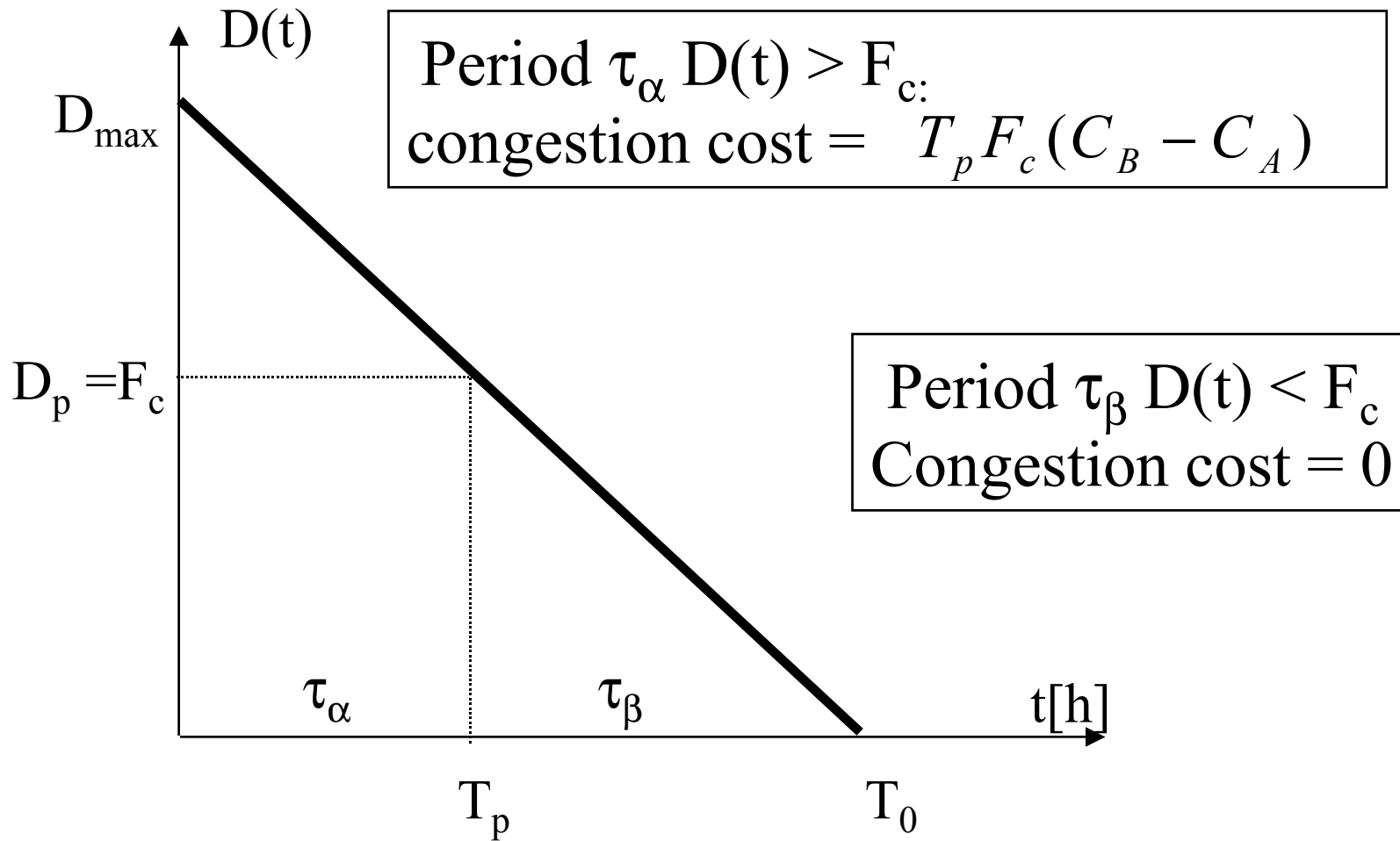
Chronological and load duration curves



Chronological load curve Load duration curve



Two characteristic periods



Optimal transmission capacity

$$C_A = 25 \text{ £/MWh}$$

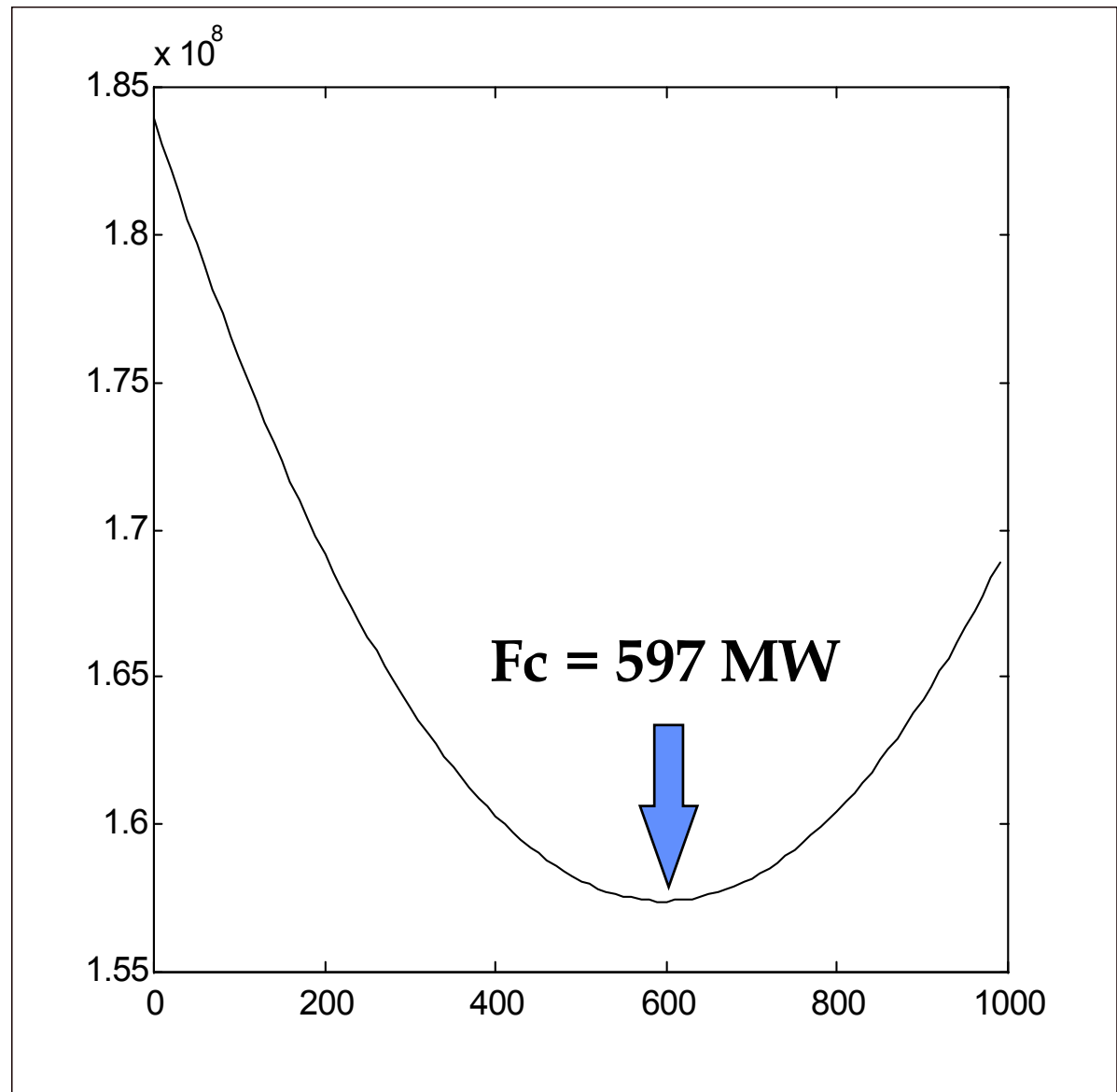
$$C_B = 42 \text{ £/MWh}$$

$$k = 30 \text{ £/MW, km, year}$$

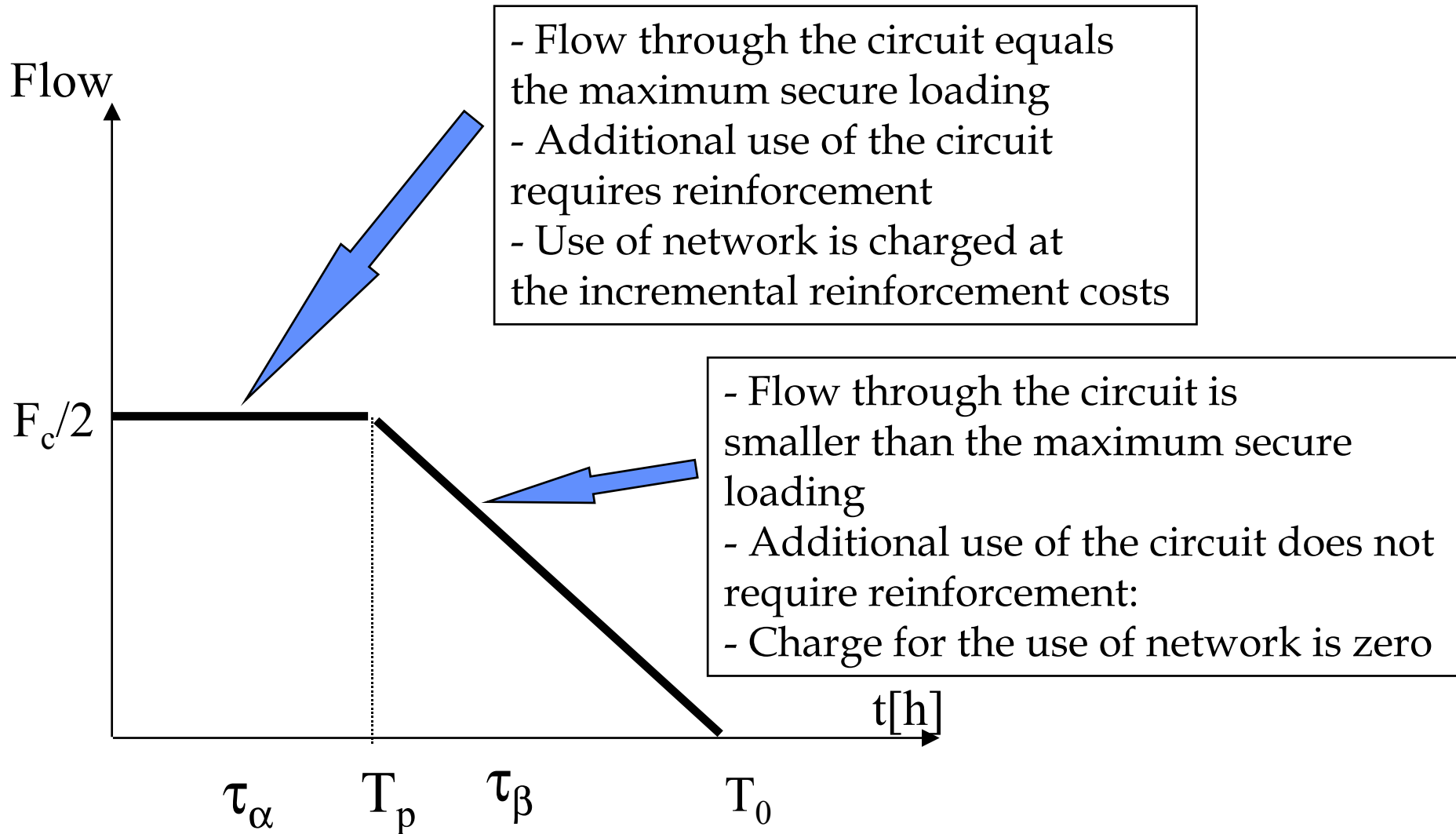
$$\lambda = 1000 \text{ km}$$

$$D_{\max} = 1000 \text{ MW}$$

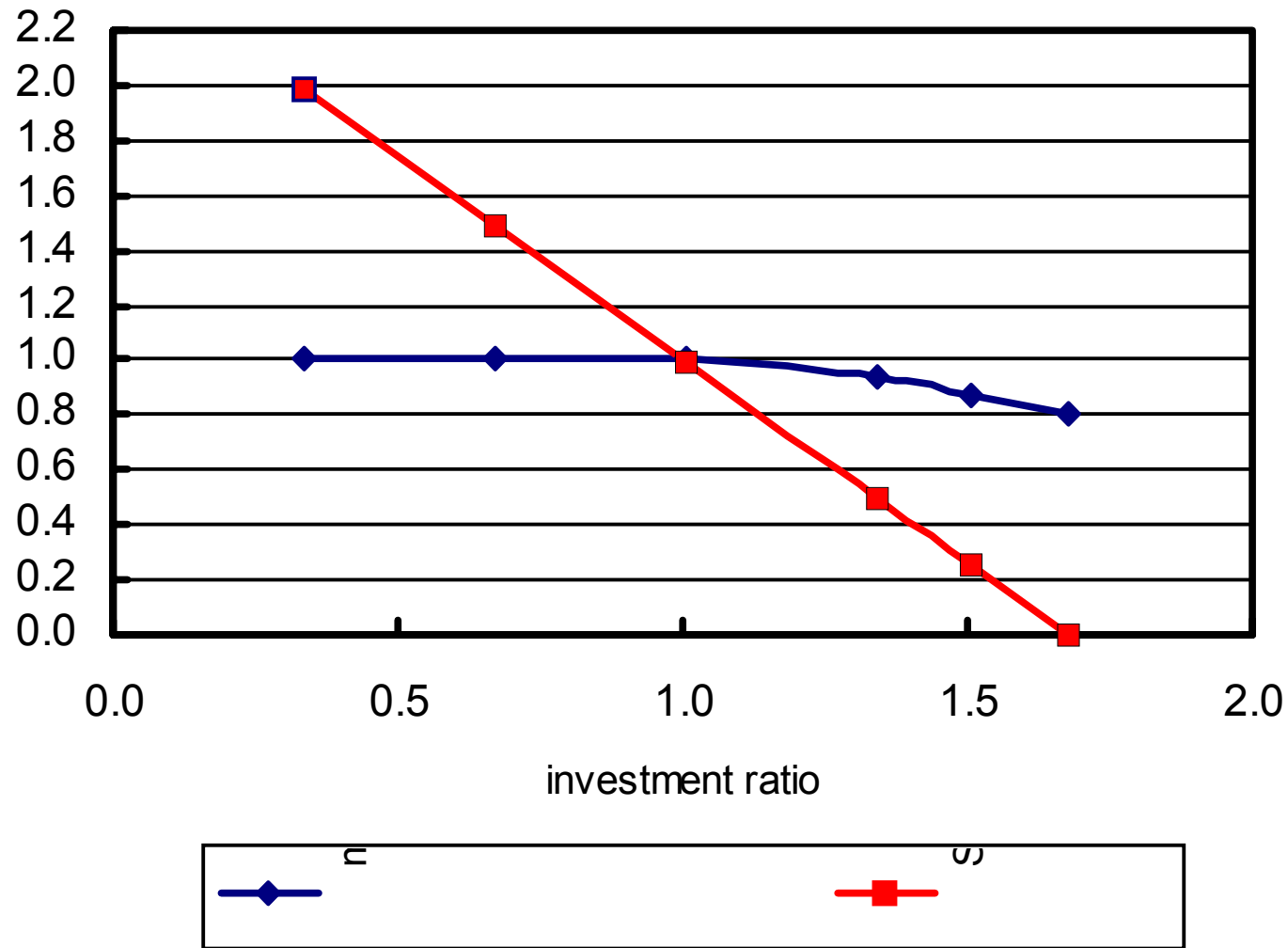
k - Annuitised circuit
marginal investment cost



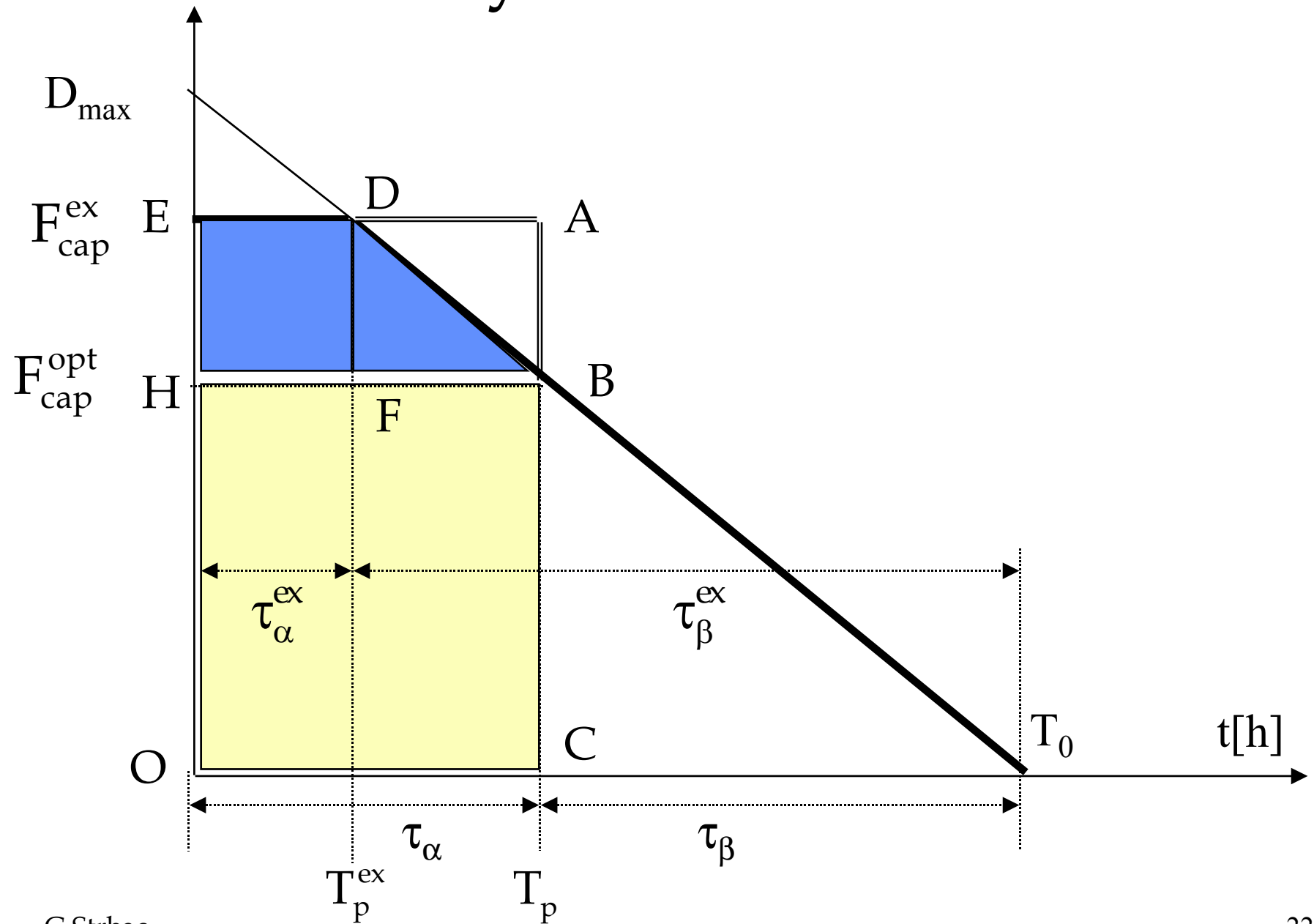
Pricing the use of the network



LMP versus reference network based pricing: Revenue recovery



Recovery of over-invested transmission



Recovery of over-invested transmission

- In computing the revenue in the over-invested system, it is important to note that the system operator will take advantage of the excess capacity. Consistent with the marginal pricing charges are imposed during the peak period (τ_α) with respect to the optimal network.
- The total revenue is proportional to the area COEDB representing the energy delivered from node 'A' to node 'B' during the time when transmission prices are applied. Clearly the benefit of over-investment is the extra energy delivered above that that would have been delivered if the network capacity were optimal. This shows that over-investment may provide some benefit to customers, as it reduces the level of operating costs. The area BHED in
- In effect the congestion cost is reduced below the optimal value at the expense of over-investing in the link. In other words, the excess in transmission capacity may not be completely wasted.
- Transmission revenue loss due to over-investment is proportional to the area DAB.
- The period during which the maximum flow from node 'A' is limited by the capacity of the existing circuit. Knowledge of τ_α enables computation of the total energy delivered from node 'A' to node 'B' and hence revenue. This was done for several values of capacities above the optimal level. Previous figure shows the revenue recovery index defined as the ratio of revenue raised by applying the optimal price to revenue required to cover the investment. Investment ratio, which is a measure of the degree of over-investment, is simply the ratio of actual capacity to optimal network capacity.

Prices and revenues

Price at A (£/MWh)	10.64
Price at B (£/MWh)	-6.36
Difference (£/MWh)	17
Revenue from G_A (£)	22,431,765
Revenue from G_B (£)	-4,518,914
Total revenue from Generation (£)	17,912,970
Revenue from demand (£)	17,912,970
Transmission revenue (£)	35,825,940