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Transmission Network Services in the National Electricity Market

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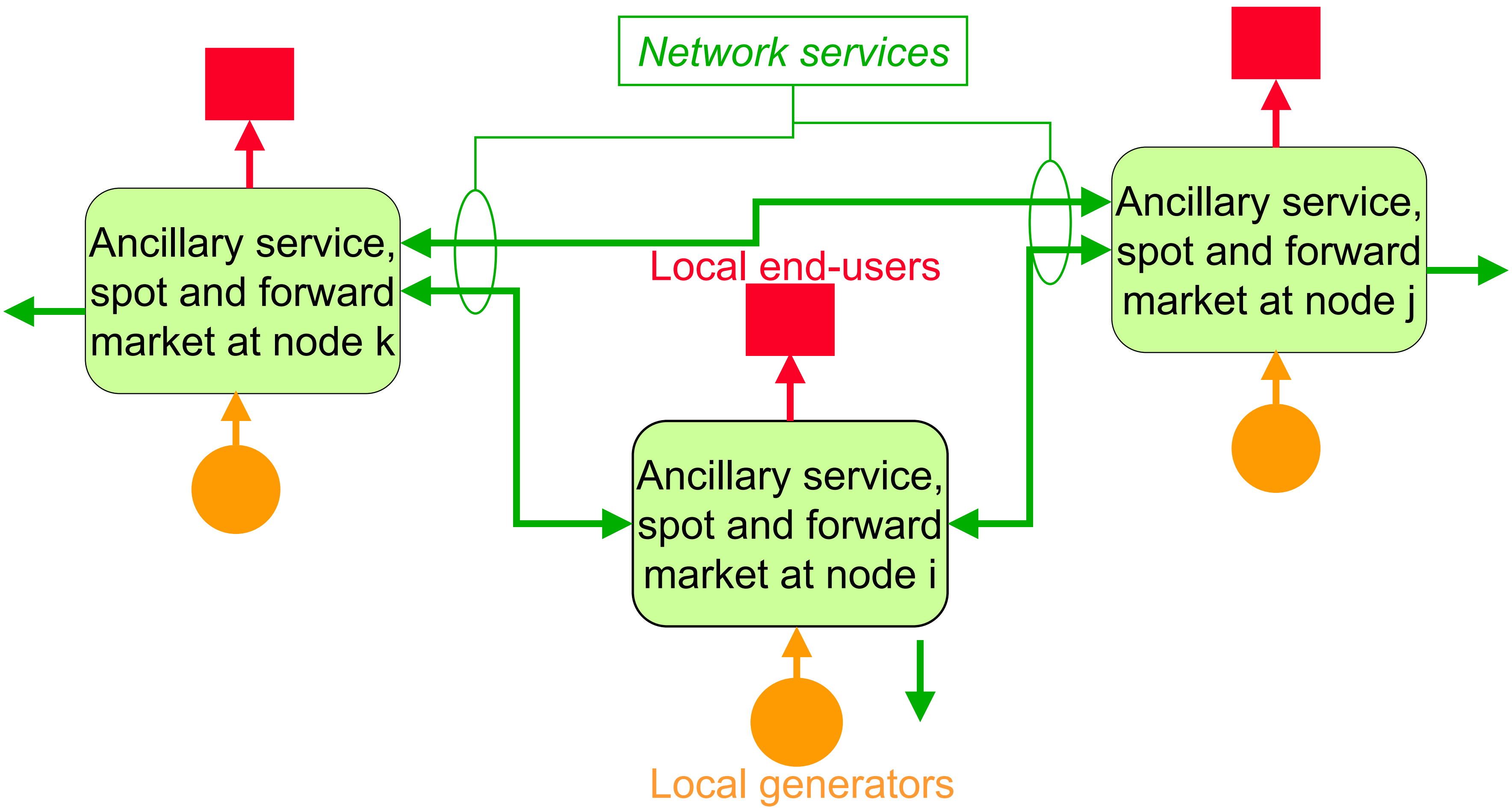
Outline

- Ideal - nodal market at each connection point:
  - Ancillary services, spot energy, future risk
  - Network services compete with local resources
  - Requires active demand-side participation
- Impractical near term, uncertain long term:
  - Complexity, market power, uncertainty
- Practical approaches depend on context:
  - Regional markets & negotiation frameworks
  - Network service pricing & investment protocols:
    - Designed to allow distributed resources to compete

Ideal: competitive electricity industry modeled by nodal markets

- Based on a market at each node:
  - Local generators & end-users
  - Flows to & from the network
  - Nodal ancillary service, spot & forward markets
  - Nodal spot prices set by simultaneous auction
- Network flows determined to maximise the benefits of trade (network-based arbitrage):
  - To exploit diversity in resource availability
  - Subject to network losses & flow constraints

Network services: arbitrage between nodal markets



Much of the value of network services derives from ancillary service & investment timescales

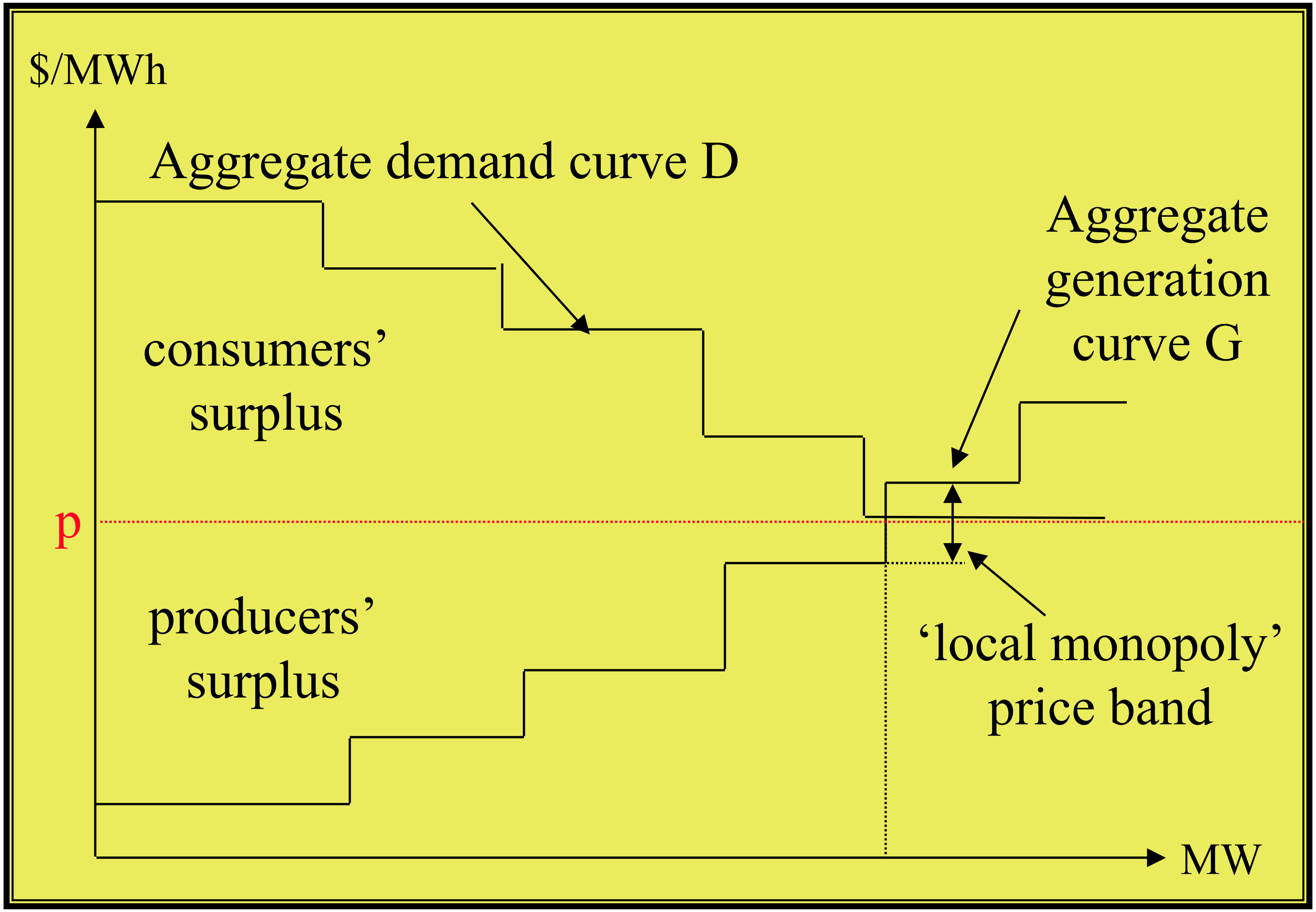
A definition of network services in an ideal competitive electricity industry

- Arbitrage between nodal markets
  - In ancillary services, spot energy & future risk
- Subject to:
  - Availability of network elements
  - Energy losses in network components
  - Maximum ratings of network elements
  - Operating limits imposed for system security:
    - Influenced by the characteristics of generators, loads & network elements as well as the system operating state
    - Matters of judgement rather than objectively set

Solving nodal spot markets that include a network model

- Single node assumption (or strong network):
  - All sellers & buyers at one location
- Two node model:
  - Sellers at one node, buyers at the other:
    - Constrained line but no losses
    - Unconstrained line with line losses
    - Competing options to relieve a network flow constraint
- Three node models:
  - Interaction between lines in a meshed network

Single node spot market

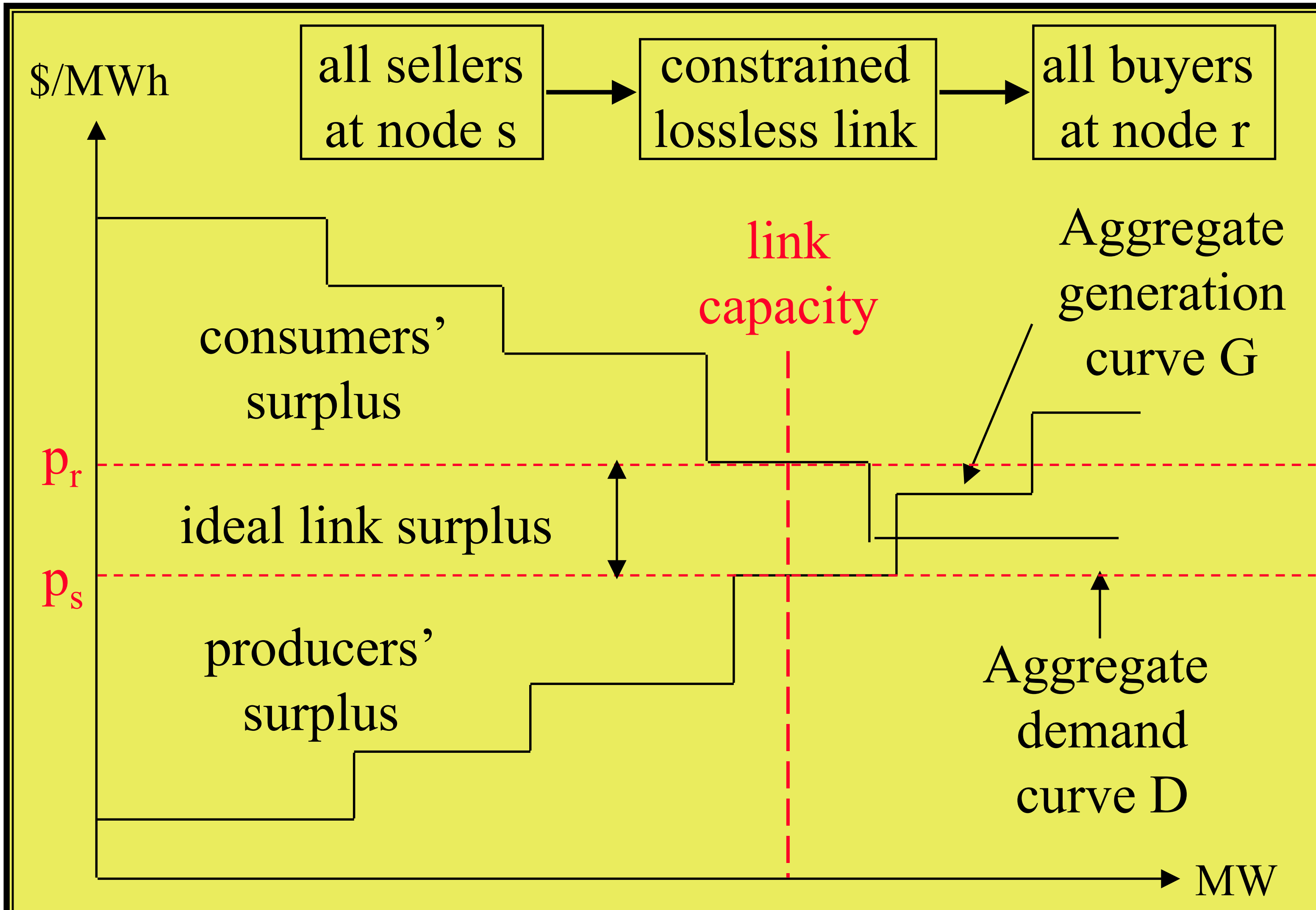


one marginal price 'p'

Issues illustrated by one node example (all participants at one location or strong network)

- Buyers & sellers see the same nodal price
- No revenue to network operator:
  - No network-based arbitrage
- The marginal buyer or seller may have a ‘local monopoly’:
  - The ability to set price within a limited band
  - More likely with fewer participants

Two-node spot market with constrained lossless link

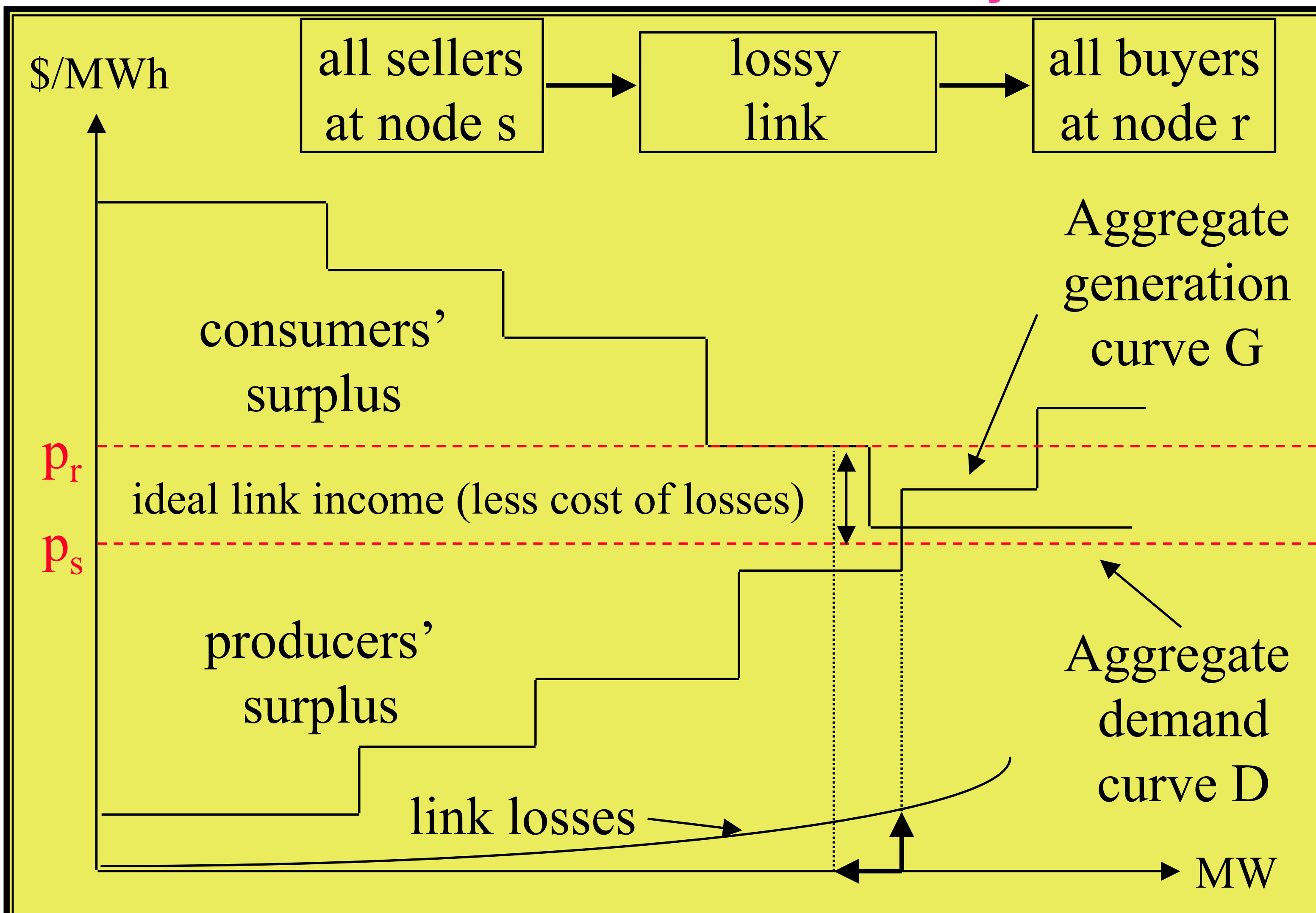


two marginal prices p_r & p_s

Issues illustrated by 2 node example: constrained, lossless link

- Nodal prices are set to constrain flow to link capacity (quantity rationing):
  - $p_r > p_s$ (always true for radial case)
  - link outage causes market collapse
- Link owner has a perverse incentive:
  - to constrain link capacity (but not to zero)
- Sellers & buyers may capture some of ideal link surplus due to 'local monopoly':
  - Local market power greater if link constrained

Two-node spot market with unconstrained lossy link



related nodal prices p_r & p_s

Issues illustrated by 2 node example: unconstrained, lossy link

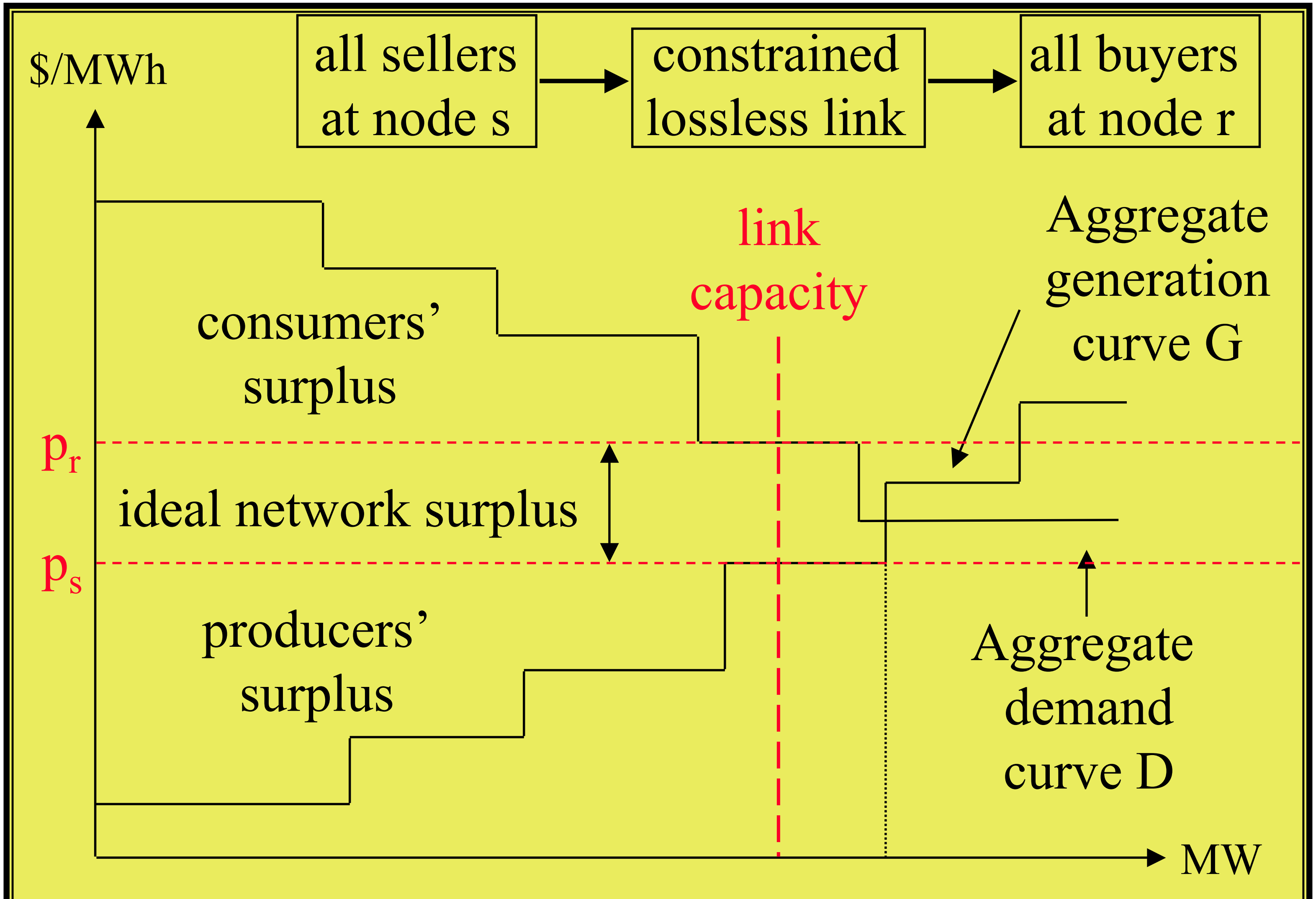
- Unconstrained, lossy link between all sellers & all buyers
- Link operator buys at sending end, sells at receiving end, increasing link flow until:
  - cost of next increment of flow = its sale value:

    i.e. $p_s(\Delta X+\Delta L) = p_r \Delta X$ [ΔX = sale, ΔL = loss]
    hence: $p_r = (1+ \Delta L/ \Delta X)\, p_s$
- Thus nodal prices are related by the incremental loss of an unconstrained link

Relieving network flow constraints

- Link flow constraints can be alleviated by:
  - Investment in additional link capacity
  - Investment in distributed resources:
    - Appropriately located generation, storage or load
  - Relaxation of QOS criteria (accept greater risk)
- Investment underwritten by forward markets:
  - Generator: sell CFD or call option at node ‘r’
  - Load: buy CFD or CO at node ‘s’
  - Link: buy CFD/CO at node ‘s’ and sell CFD/CO at node ‘r’

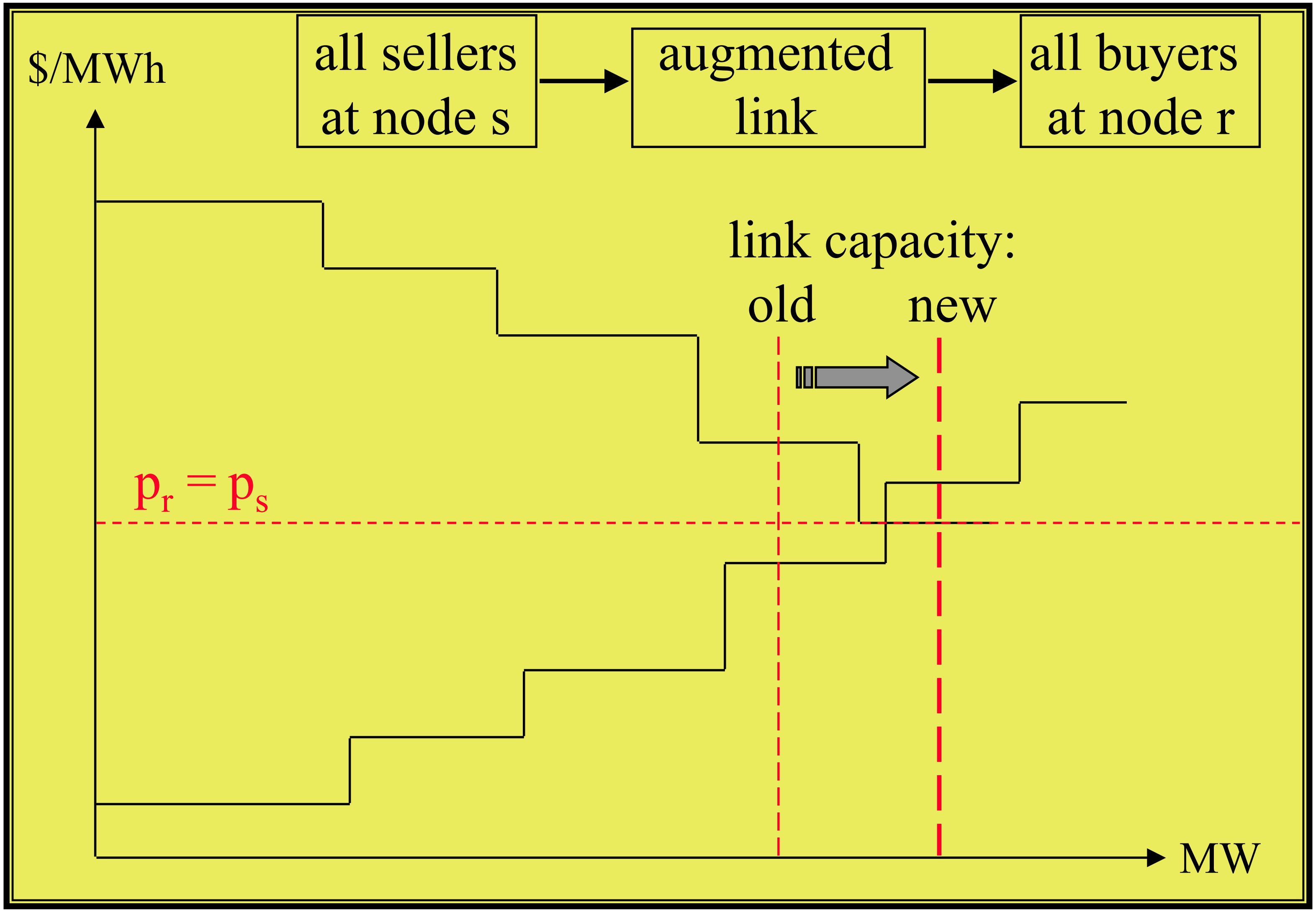
Relieving network flow constraints:
Situation prior to resolution of constraint



two marginal prices p_r & p_s some network surplus

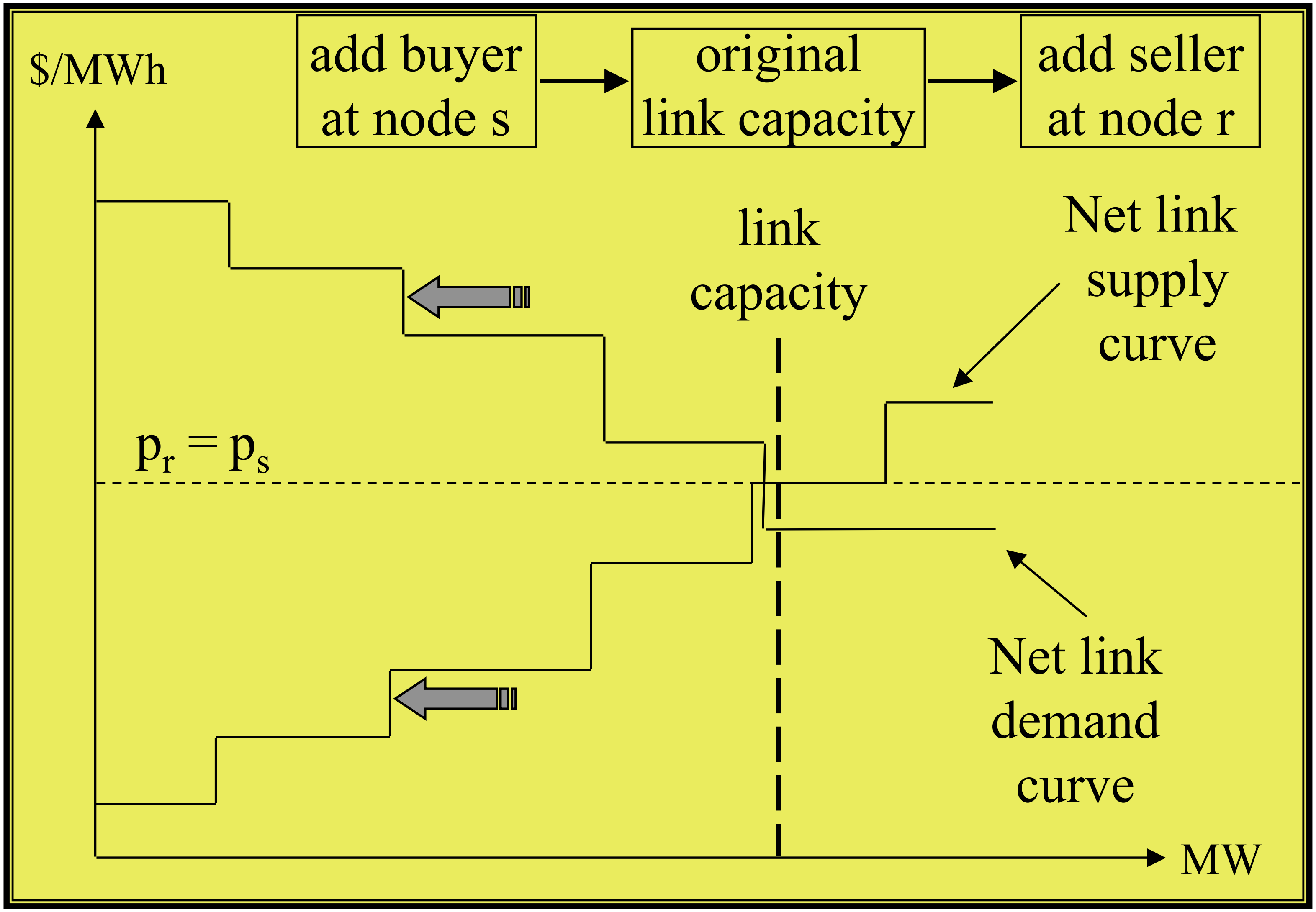
Relieving network flow constraints:

Option 1 - augment link capacity



one marginal price $p_r = p_s$, no network surplus

Relieving network flow constraints: Option 2 - add distributed resources



one marginal price $p_r = p_s$, no network surplus

Relieving network flow constraints: Selecting the best option

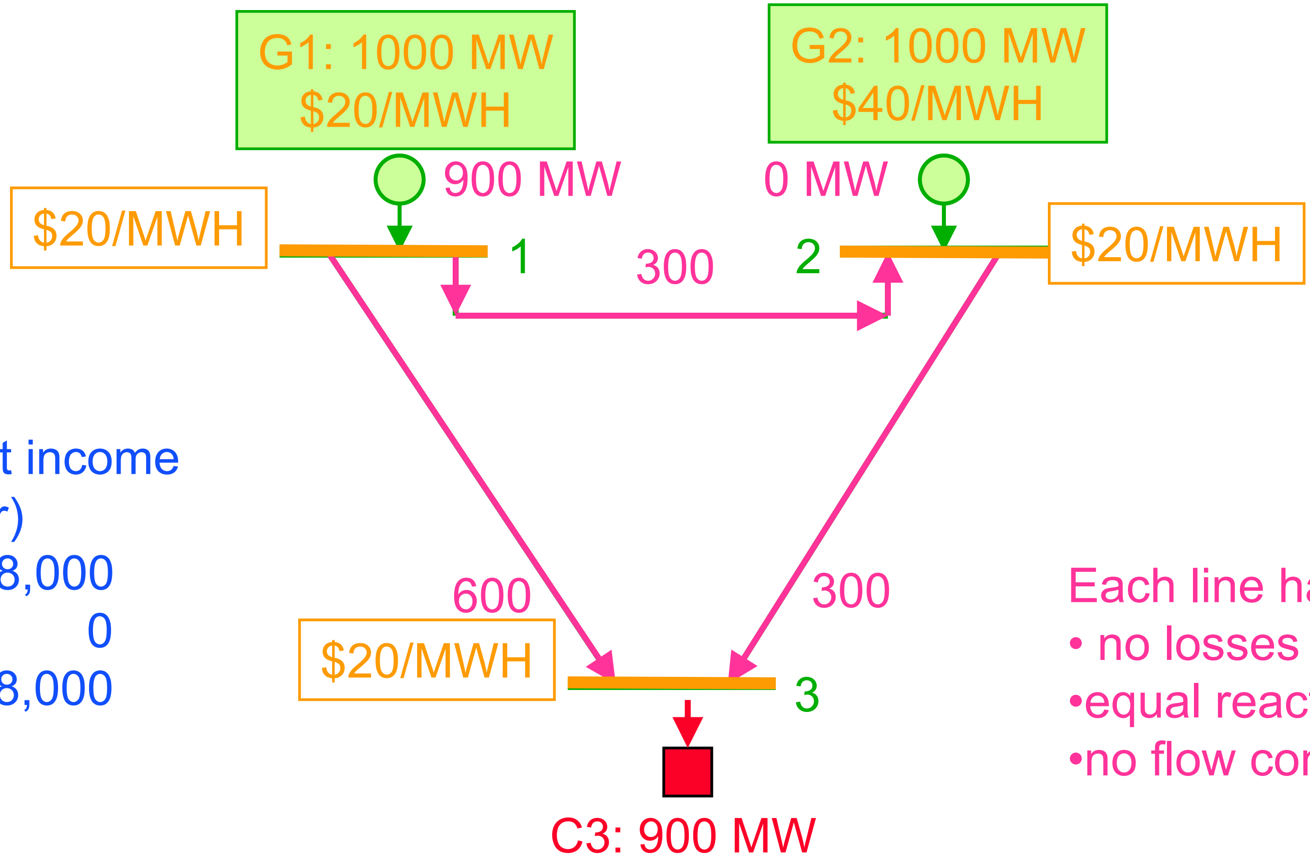
- Traditional approach:
  - NSP augments link, recovers cost from users
- Ideal competitive industry approach:
  - Link and distributed resource options compete:
    - Return on investment not guaranteed by regulator
    - Whichever investment option first achieves a bankable project (eg adequate contract cover) will proceed
    - Spot price difference falls if link capacity augmented:
      - Unless link capacity can be controlled & bid into the market
- Without liquid AS, spot & forward markets:
  - Regulator could facilitate a negotiated outcome

Meshed networks

- A meshed network contains at least one loop:
  - At least two network elements operate in parallel
- Flows in parallel network elements are inversely proportional to element impedances
  - Voltage drops across parallel elements are equal
- Impedance = reactance if no network losses:
  - Element resistances are then all zero
- Flow constraints can propagate through the network

Nodal spot markets: 3-node meshed network

No network flow constraints or losses



Spot market income ($/hr)

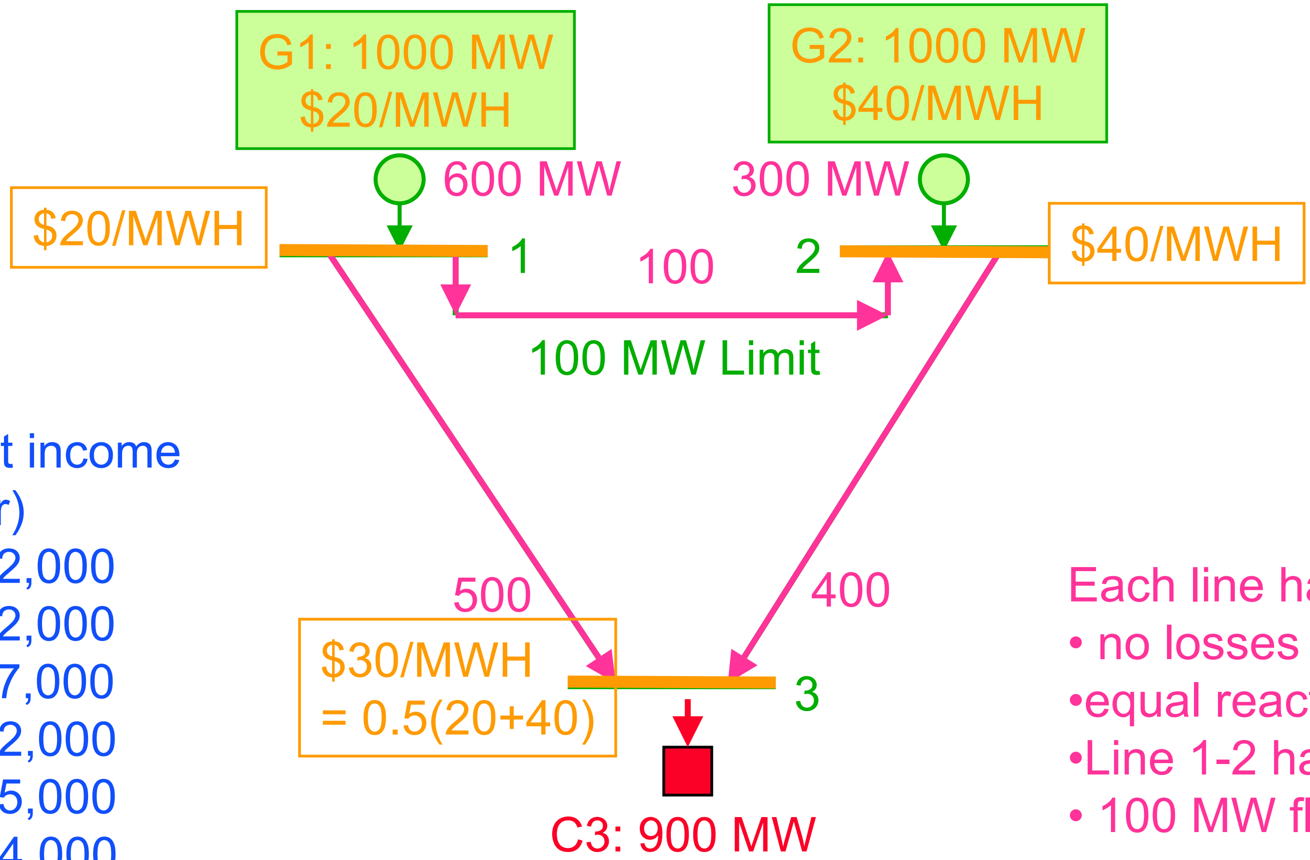
- G1: +18,000
- G2: 0
- C3: -18,000

Each line has:

- no losses
- equal reactance
- no flow constraints

Nodal spot markets: 3-node meshed network

One constrained link

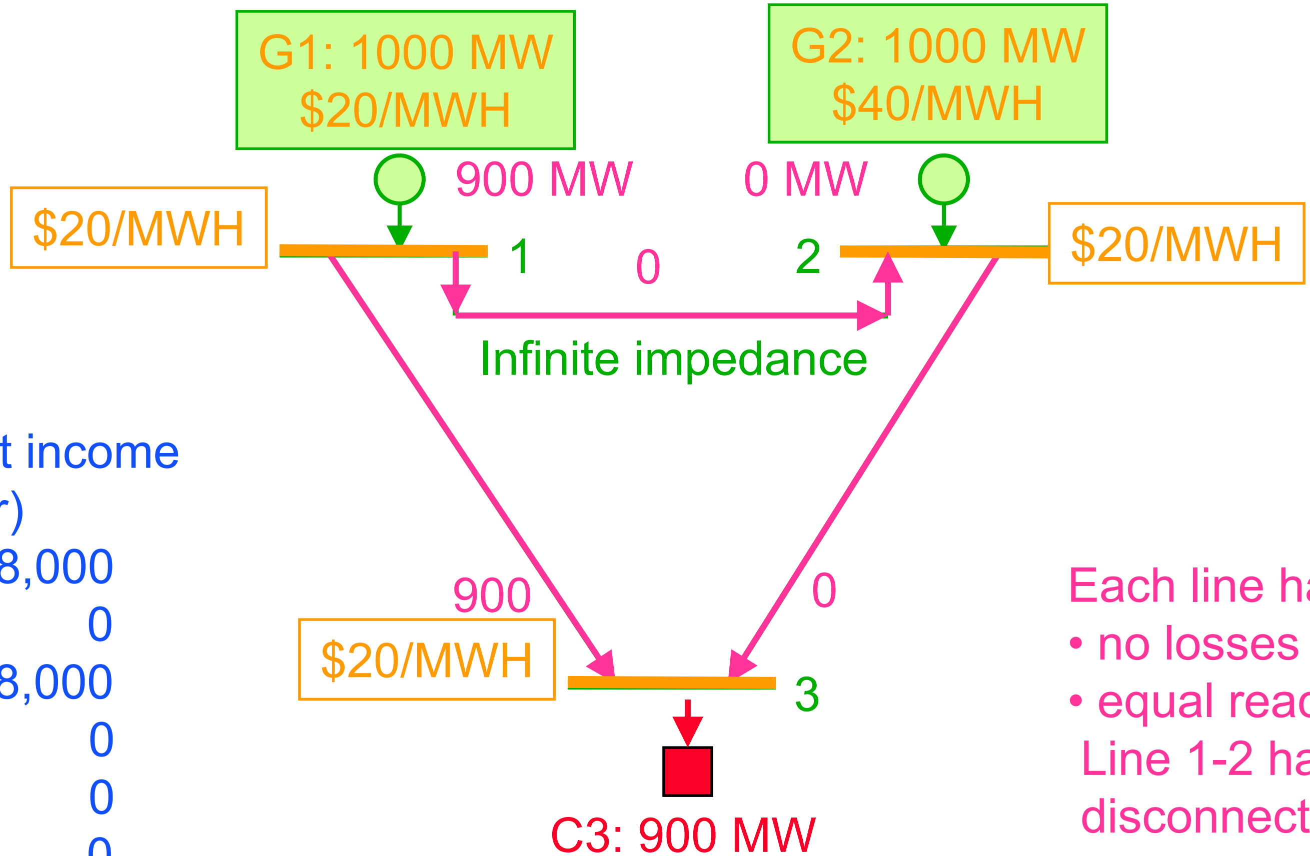


Spot market income ($/hr)
- G1: +12,000
- G2: +12,000
- C3: -27,000
- L12: +2,000
- L13: +5,000
- L23: -4,000

Each line has:
- no losses
- equal reactance
- Line 1-2 has:
- 100 MW flow limit

Nodal spot markets: 3-node meshed network

Constrained link disconnected



Spot market income ($/hr)

- G1: +18,000
- G2: 0
- C3: -18,000
- L12: 0
- L13: 0
- L23: 0

Each line has:

- no losses
- equal reactance

Line 1-2 has been disconnected

Nodal spot markets: 3-node meshed network
Implications

- Meshed network elements are mutually dependent:
  - Unless they can be independently controlled
  - Switching 'weak' elements off may even improve economic outcome (unlike radial network)
- Spot market alone gives perverse incentives:
  - Network earns more when flows are constrained
  - Some generators may benefit from constrained network operation

Limits to the effectiveness of nodal markets

- For a given network, more nodal markets:
  - Mean fewer participants in each nodal market:
    - Local participants & network owners gain market power
    - Ancillary services, spot energy & risk harder to price
  - Require a more accurate network model
  - *There is a lower limit to the level of network detail that nodal markets can resolve*
- Regional markets provide one option:
  - Place major flow constraints on region boundaries:
    - Models of "notional interconnectors" then required
  - Resolve intra-regional network flow constraints by negotiation under regulatory supervision

NEC treatment of network losses & capital costs

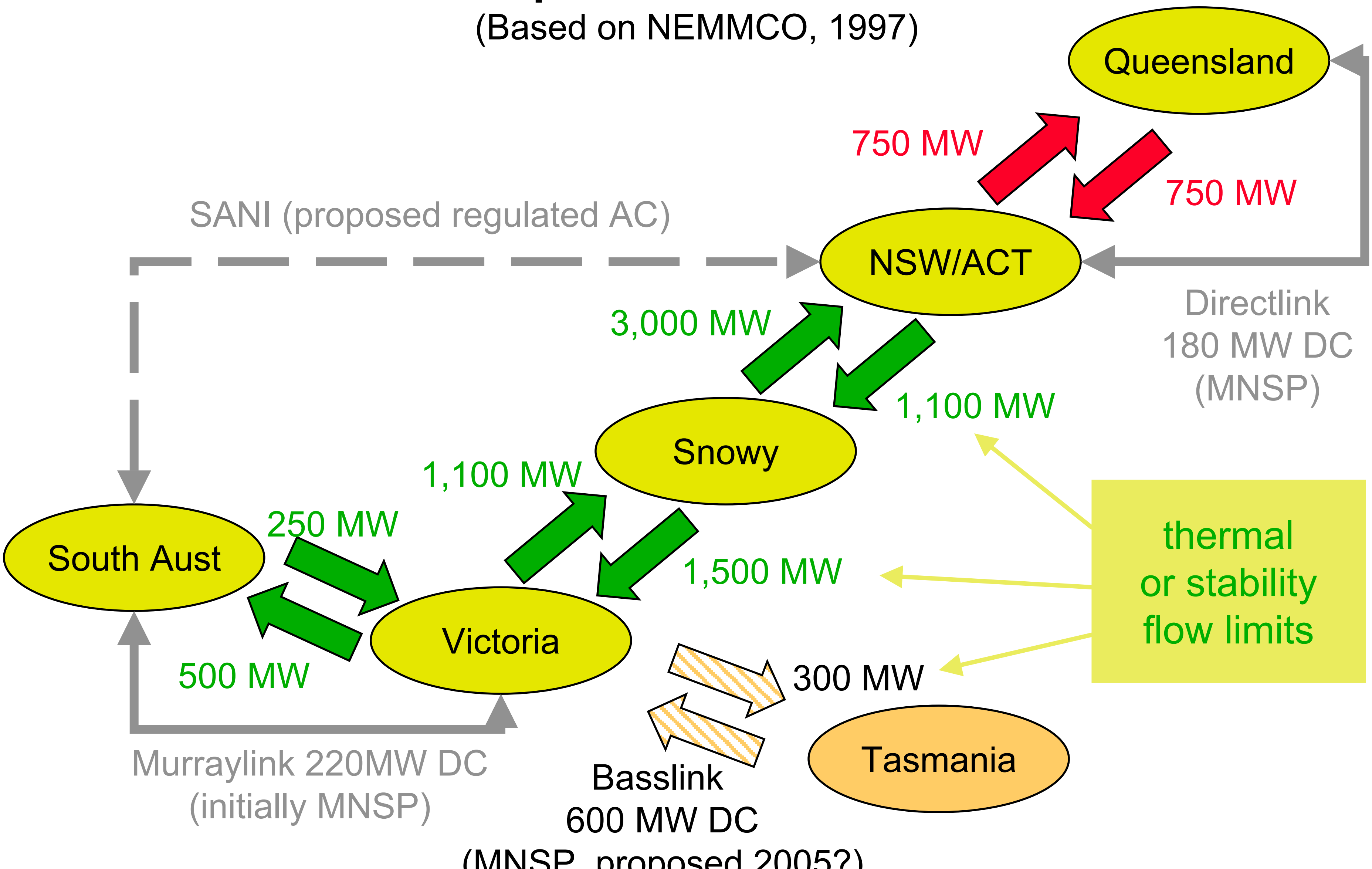
- NEC contains NEM rules & access regime:
  - Both address network issues
- National Electricity Market trading rules:
  - Notional regulated interconnectors & associated settlement residue auctions
  - Market Network Service Provider (unreg intercon)
  - Intra-regional network loss factors & constraints
- Network access and pricing:
    - Revenue cap for regulated network service providers
      - Jurisdictional derogations in some states

NEC treatment of network flow constraints

- NEMMCO documents inter- & intra-regional flow constraints:
  - these are inputs to the dispatch process
- Significant transmission constraints appearing 50 hours/y or more:
  - To be placed on market region boundaries:
    - Where practical to reset the boundaries to do so

Scope of the NEM

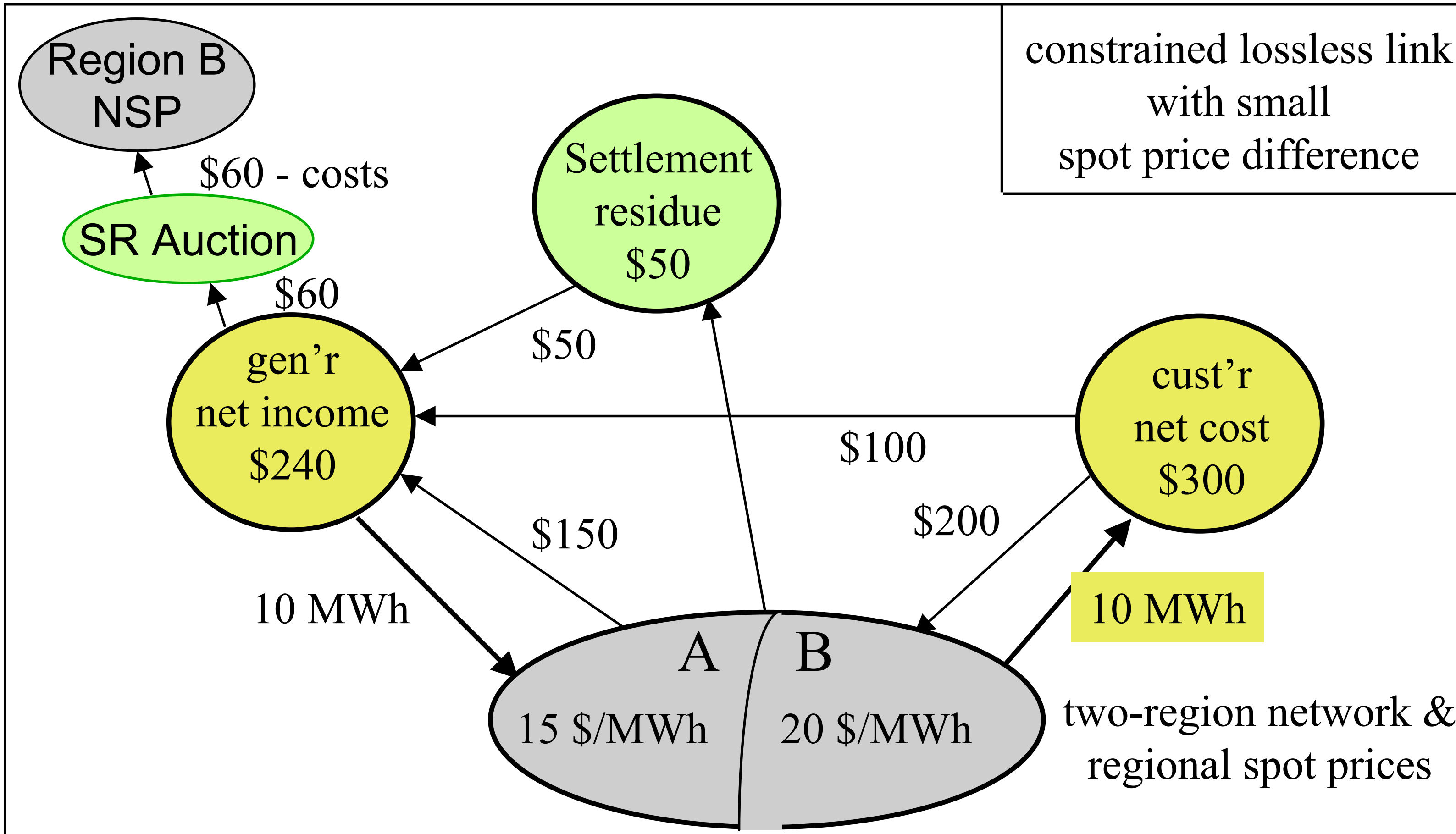
(Based on NEMMCO, 1997)



Inter-regional hedges for regulated interconnectors

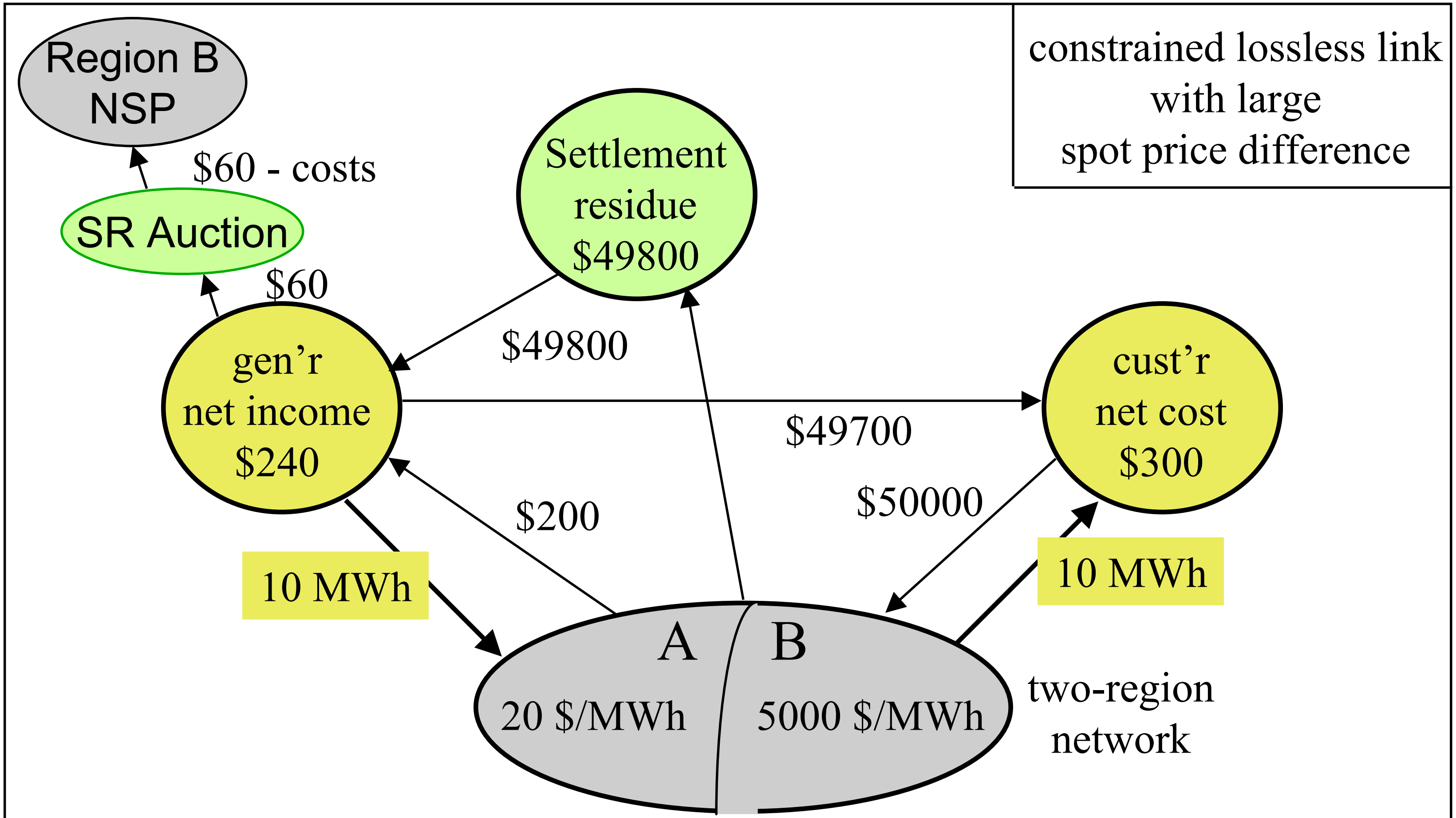
- A hedge against differences between regional spot prices for one direction of flow
- Based on interconnector settlement residue:
  - Difference in regional reference prices multiplied by interconnector power flow
    - for each spot market interval
- 3-monthly auctions of settlement residue
  - For each regulated interconnector (directional)
- Incomplete hedge:
  - doesn’t cover interconnector losses or outages

Inter-regional hedge example #1



Generator sells a 10 MWh hedge contract on region B price to customer at $30 MWh & buys a directed 10 MWh hedge (B-A) from NEMMCO SR auction at cost of 6 $/MWh (expected spot price difference between regions)

Inter-regional hedge example #2



Generator sells a 10 MWh hedge contract on region B price to customer at $30 MWh & buys a directed 10 MWh hedge (B-A) from NEMMCO SR auction at cost of 6 $/MWh (expected spot price difference between regions)

NEC Treatment of Transmission & Distribution Pricing (Chapter 6)

- Principles for network pricing:
  - Promote competition in the provision of services
  - Be transparent & non-discriminatory
  - Seek similar outcomes to a competitive market
- ACCC Regulatory test for T&D augmentation:
  - Reliability:
    - Minimises the cost of meeting an objective criterion
  - Market benefit:
    - Maximises NPV of market benefit having regard to alternative projects & market scenarios

Transmission pricing
(existing arrangements; under review)

- Allowed annual revenue (AAR) for network
  - Set by regulator (ACCC), based on:
    - 'Optimal deprival' value of the network assets:
      - How would each asset be replaced today if it disappeared?
        - Considering network & distributed resource options
      - Existing assets and audited five-year expansion plan
    - Allowed rate of return:
      - Depends on the assessed risk of the business
  - Five year reset, (CPI-X) annual adjustment:
    - Pressure to control costs between assessments
    - Incentive to further reduce costs, because profits are retained at least until the next assessment

Transmission pricing within regions
(existing arrangements; under review)

- Recovering AAR from network users
  - Based on assessed use of the network
  - Network elements considered individually:
    - Overall network AAR is assigned to individual elements in proportion to their optimised replacement cost
  - Each network element allocated to a category:
    1. Serve particular network users (*entry or exit*)
    2. Provide a *common service* to all network users
    3. Shared by market customers in an identifiable way:
       - these costs to be allocated in an ‘equitable’ fashion
       - At present using “Cost Reflective Network Pricing”