NEW ZEALAND INSTITUTE FOR THE STUDY OF COMPETITION AND REGULATION INC.

A SCHEME FOR INCENTIVIZING INVESTMENT IN TRANSMISSION ENHANCEMENTS

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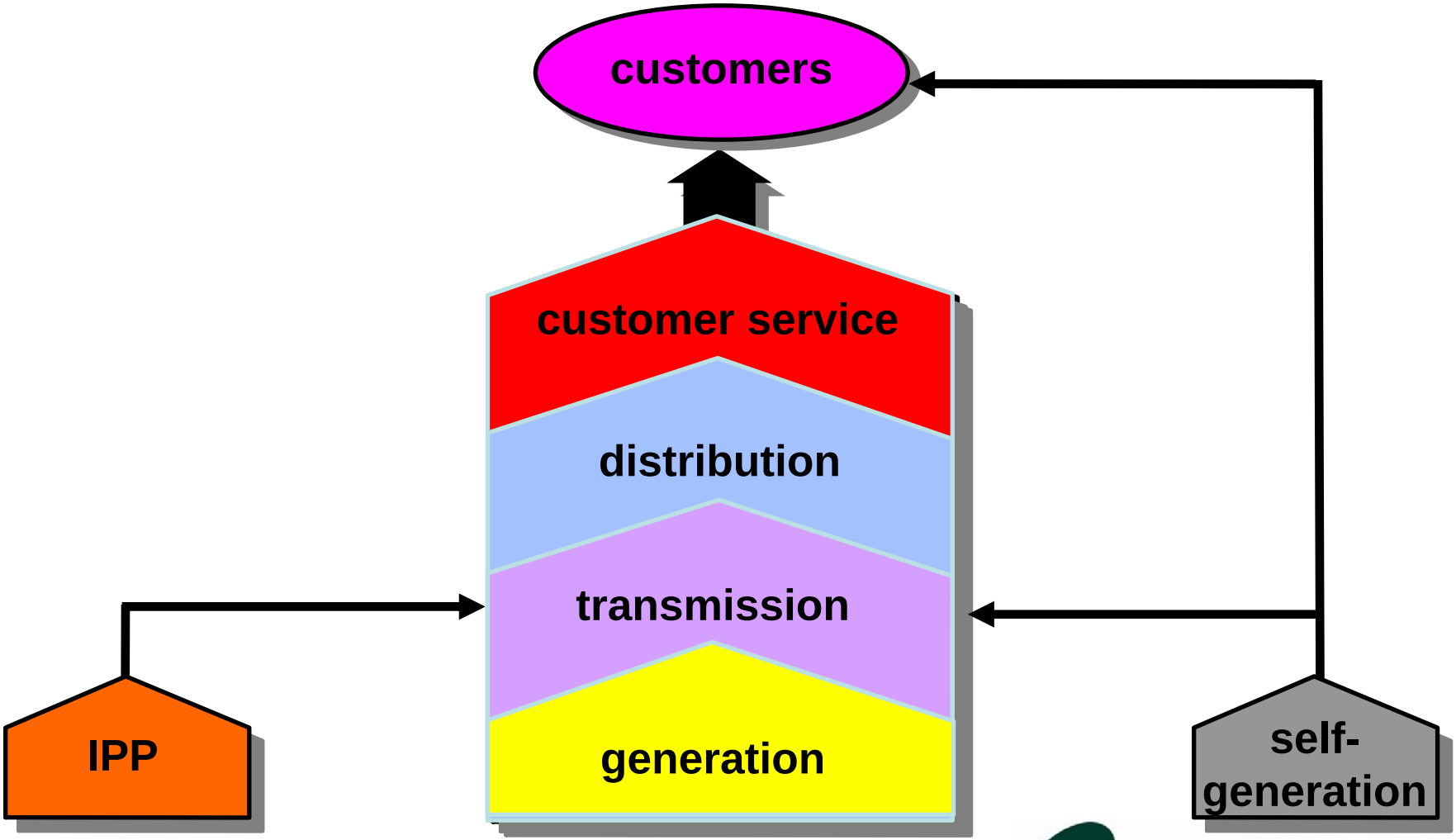
OUTLINE

- Planning in the competitive environment
- Centralized and decentralized transmission investment formulations
- Investment incentives in decentralized planning : the investment game
- Illustrative case study
- Concluding remarks
- Future work

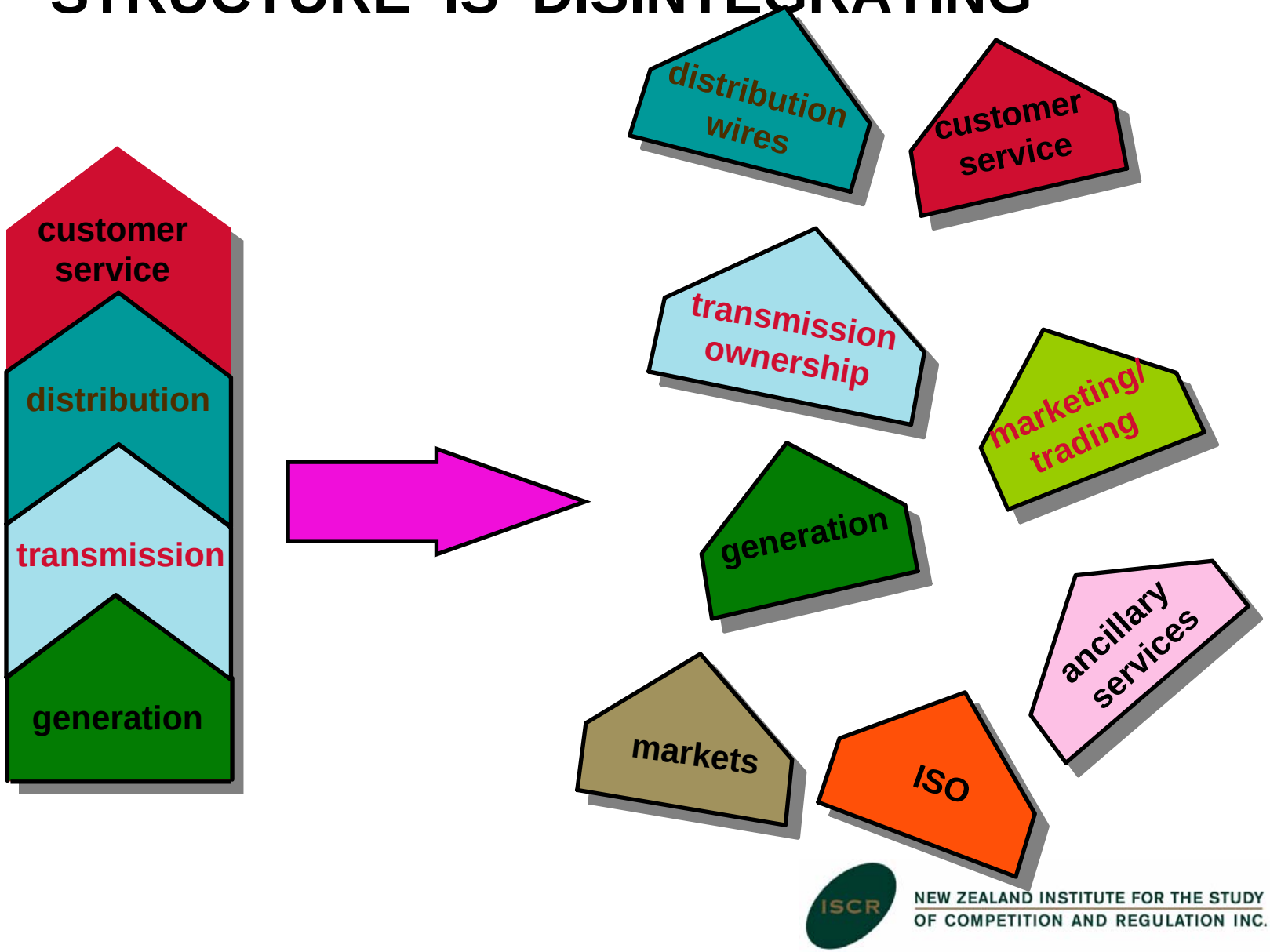
OBJECTIVES

- Incentive mechanism design for transmission network investment
- Cooperative game theory framework (Shapley value) to allocate payments to investors
- Payments based on added social welfare
- Compare decentralized and centralized transmission investment settings

THE VERTICALLY INTEGRATED UTILITY INDUSTRY STRUCTURE



VERTICALLY INTEGRATED UTILITY STRUCTURE IS DISINTEGRATING



PLANNING UNDER COMPETITION

- Major shift in the planning paradigm
  - cessation of the centralized integrated planning of the past
  - role of regional planning under the independent grid operator
  - unclear responsibility for implementation under the ownership/control separation
  - role of decentralized decision making

PLANNING UNDER COMPETITION

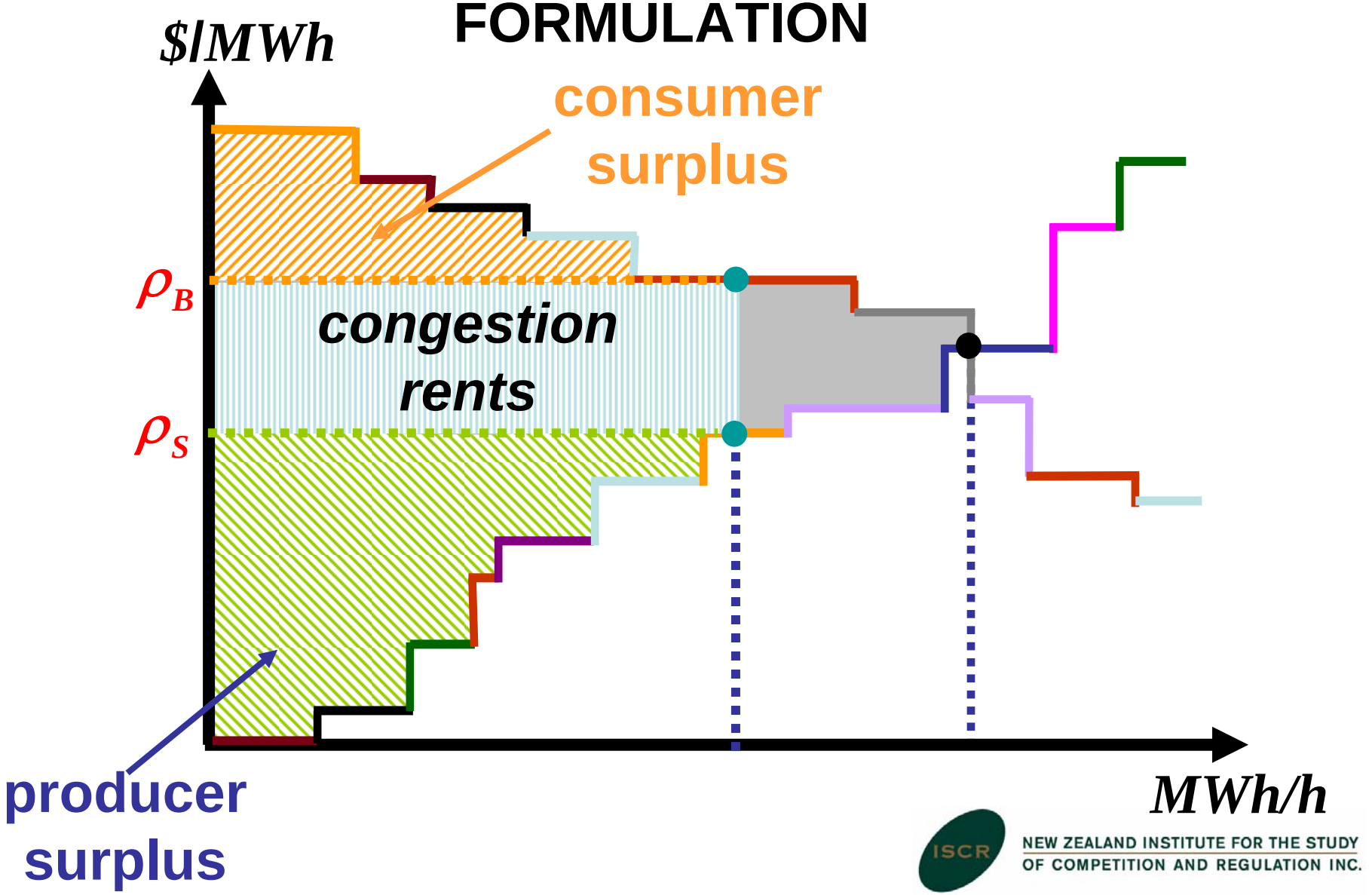
- Planning, to the extent it is performed in the new environment, is an asset management problem
  - investment under uncertainty
  - critical importance of effective risk management
  - subject to regulations in a continuous state of flux

CENTRALIZED TRANSMISSION INVESTMENT FORMULATION

- Maximize :
  - aggregate social welfare – investment costs

  subject to :
  - power flow balance equations
  - line flow equations
  - generator and demand limits
  - line flow limits
  - budget constraints to build lines

CENTRALIZED TRANSMISSION INVESTMENT FORMULATION



CENTRALIZED TRANSMISSION INVESTMENT FORMULATION

The solution of the problem determines:

- social welfare
- amounts sold and bought by the pool players
- new lines to be built
- cost of investment in new lines

DECENTRALIZED TRANSMISSION INVESTMENT FORMULATION

- Maximize :
  - aggregate social welfare

    subject to :
  - power flow balance equations
  - line flow equations
  - generator and demand limits
  - line flow limits
  - budget constraints to pay investors

DECENTRALIZED TRANSMISSION INVESTMENT FORMULATION

The solution of the problem determines:

- social welfare
- amounts sold and bought by the pool players
- new lines to be built
- payments to the line investors

DECENTRALIZED INVESTMENT INCENTIVES : THE INVESTMENT GAME

- The transmission planner (TP) needs to send incentives to the investors so that they maximize social welfare
- Value of a transmission asset for the system : increase in social welfare that the asset produces
- Bargaining process between the planner and the investors :
  - TP objective : increase social welfare
  - Investors' objective : specific Rate of Return (RoR)

DECENTRALIZED INVESTMENT INCENTIVES : THE INVESTMENT GAME

- The TP uses the Shapley value to calculate the individual investor contribution to the increase in social welfare
- Cooperative bargaining game :
  - TP : offers payments to investors based on social welfare increase calculated by the Shapley value
  - Players : investors accept / reject the offer compared to their RoR

DECENTRALIZED INVESTMENT INCENTIVES : THE INVESTMENT GAME

- Investment game defined by a pair (Y,∆SW) :
  - Y = set of all the investors
  - ∆SW = increase in social welfare
  - Shapley value allocation per investor

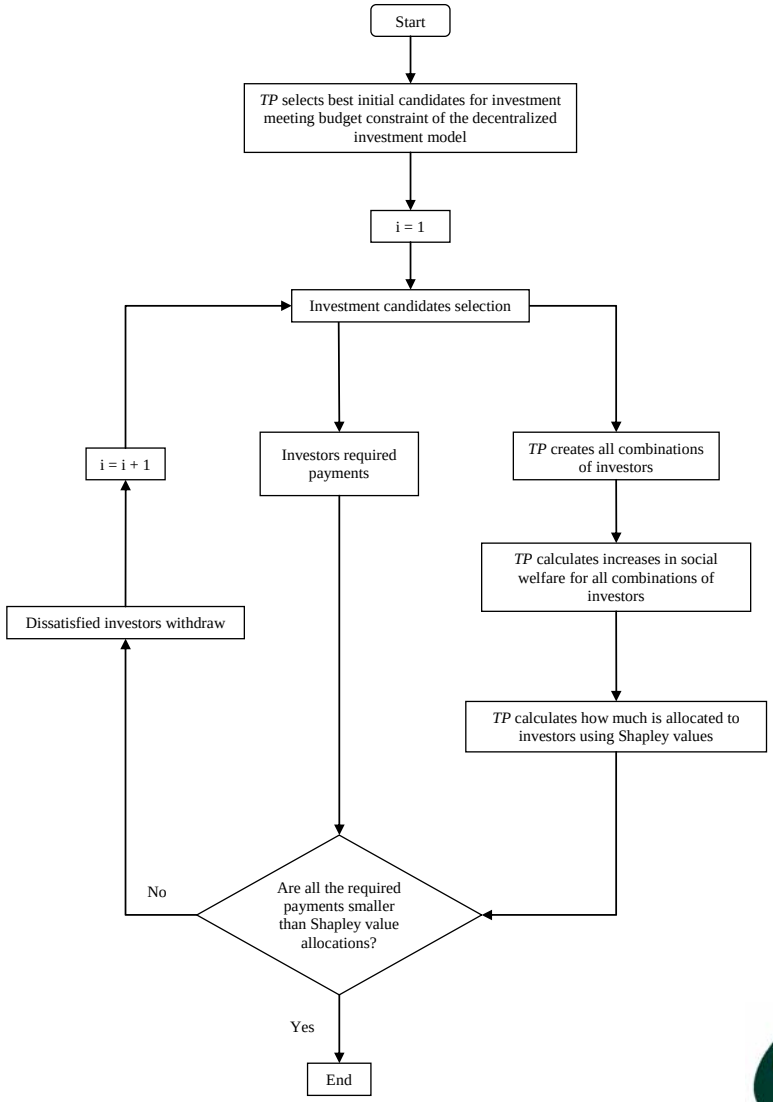
DECENTRALIZED INVESTMENT INCENTIVES : THE INVESTMENT GAME

- Shapley value : SV
  - It is one “fair” way to distribute the total gains to the players, assuming that they form coalitions
  - IF the coalition being formed one player at a time, with each player demanding their contribution as a fair compensation
  - THEN the SV is the average over the possible different permutations in which the coalition can be formed

DECENTRALIZED INVESTMENT INCENTIVES : THE INVESTMENT GAME

- Shapley value axioms :
  - The set of players receives all the resources available
  - A player that does not add value receives nothing
  - The value assigned to a player does not depend on the position in the set of players of a coalition
  - The SV is an additive function

DECENTRALIZED INVESTMENT INCENTIVES : THE INVESTMENT GAME



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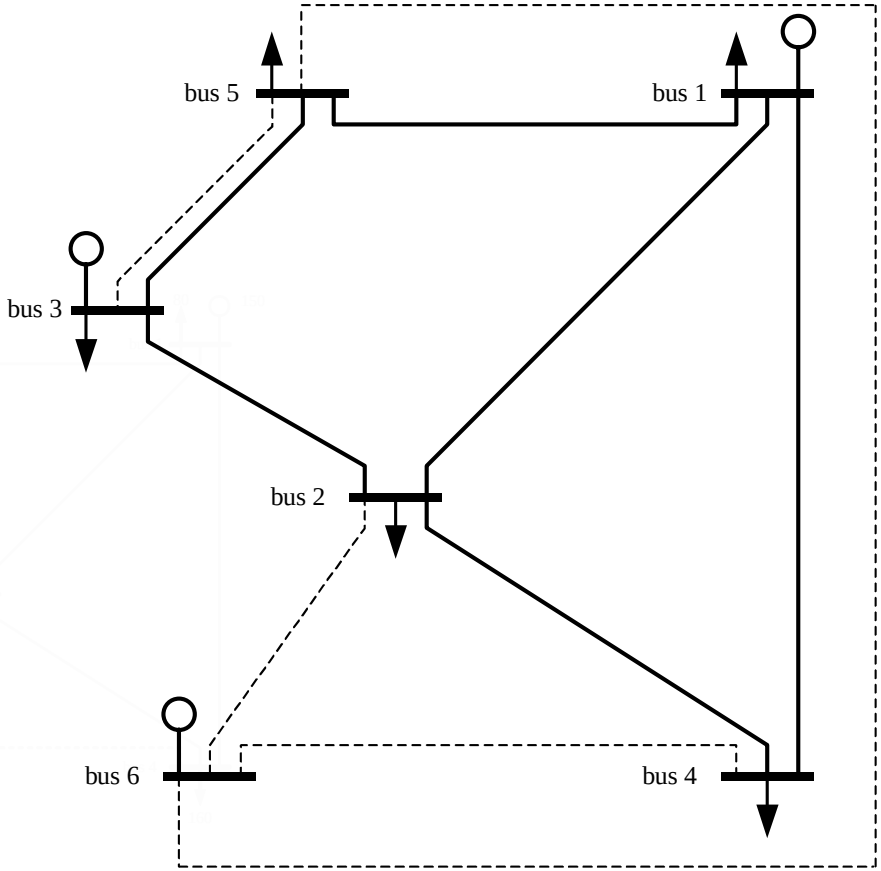
DECENTRALIZED INVESTMENT INCENTIVES : THE INVESTMENT GAME

- Step 1 : The transmission planner (TP) selects the initial set of investors
- Step 2 : The TP calculates the increase in social welfare (∆SW) per combination and makes payment offers to investors
- Step 3 : The TP verifies the investors that accept the offers
- Step 4 : The game ends if there are no new investors willing to build more transmission assets

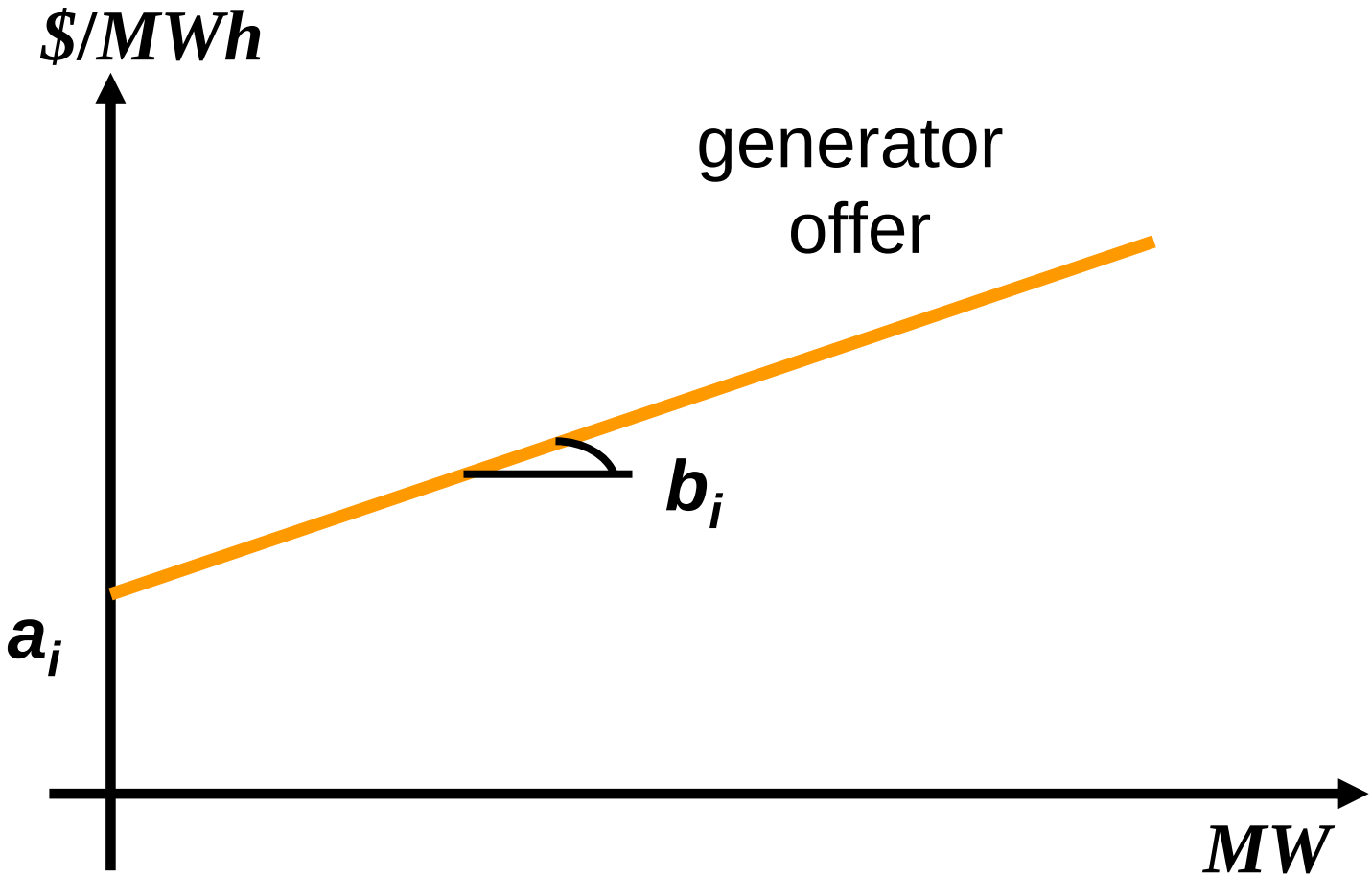
CASE STUDY : GARVER'S 6-BUS NETWORK

- Garver 6-bus system
- 3 generators and 5 loads
- 25 years of operating life
- 10% interest rate and 5% rate of return
- 3 parallel lines can be built per corridor
- Marginal offers and bids

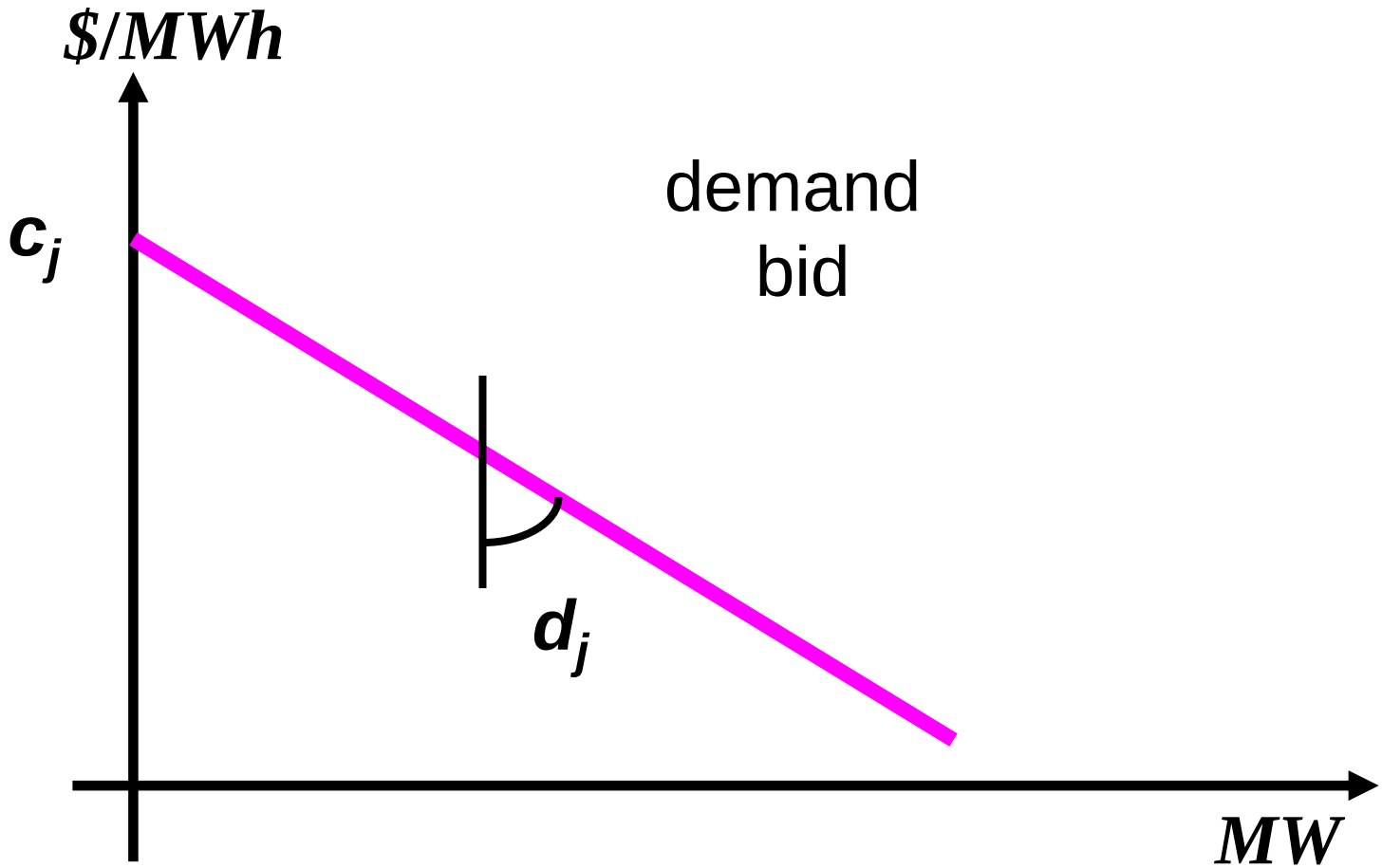
CASE STUDY : GARVER'S 6-BUS NETWORK



OFFER PARAMETERS



BID PARAMETERS



EQUIVALENCE BETWEEN CENTRALIZED AND DECENTRALIZED FORMULATIONS

- The centralized and decentralized solutions are equivalent in terms of social welfare if :
  - The payments are equal to the actual costs
  - The decentralized budget limit is equal to the optimal investment cost of the centralized problem

DISCUSSION OF THE RESULTS

- Decentralized investment models with no budget constraints produce more candidate lines
- Higher rates of return reduce the number of candidate lines
- Allowing more investors produces more competitive results
- Cost-based budget constraints in decentralized models produce similar results to centralized investment models

CONCLUDING REMARKS

- Scheme for the incentivizing of transmission asset investments
- Two models of investment, centralized and decentralized, are compared
- Incentives based on Shapley value allocation
- Effects of rate of return and budget constraints
- Equivalence between the two models

FUTURE WORK

- Combination of generation and transmission investments
- Modeling of uncertainty :
  - Change in load patterns
  - Change in bidding patterns
  - Entrance or exit of market players

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