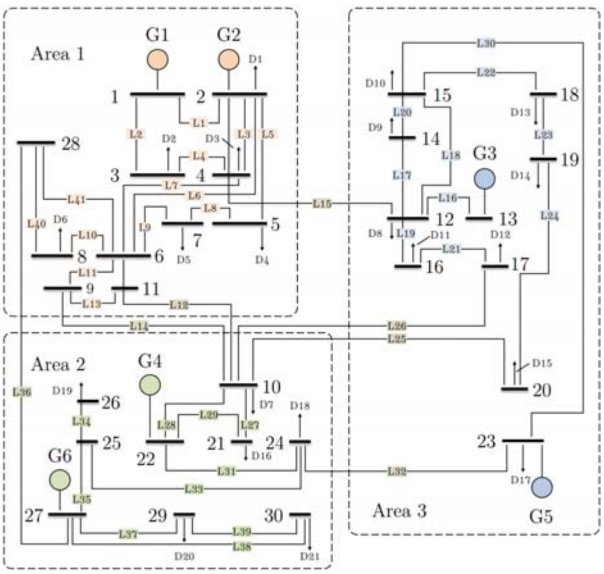
Cross-Border Transfer of Electric Power Under Uncertainty: A Game of Incomplete Information

Phen Chiak See and Olav Bjarte Fosso

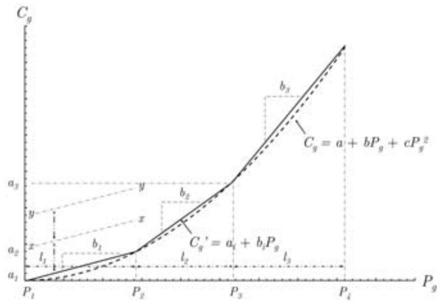
Department of Electric Power Engineering, Norwegian University of Science and Technology, 7491 Trondheim, Norway

phenchiak.see@gmail.com

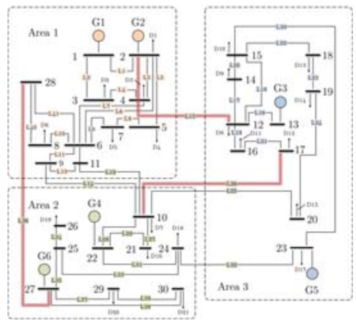
Cross-border transfer of electric power promotes collaboration in power generation between integrated electricity markets. It as well resolve grid reinforcement issues in existing transmission networks. Because of that, researchers have given higher attention to the field and have conducted various studies on the subject using technical simulation approaches. Yet, substantial works have to be done for quantifying the socioeconomic benefits of the mechanism. This paper intends to fill the gap by introducing a method for analyzing the mechanism by representing it as a game of incomplete information. The subject is modeled as Bayesian game in which the type of marginal generators located within one (or more) external market area is not known. Based on that, the Bayesian equilibrium which represent the state where all marginal generators would incline to converge is found. The authors suggest that the method is robust and can be used for quantifying the performance of a market coupling mechanism because it realistically consider all marginal generation scenarios.



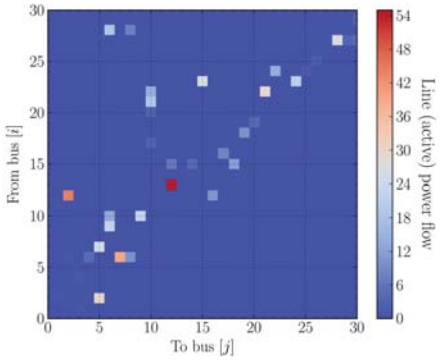
A slightly modified IEEE 30-bus test system



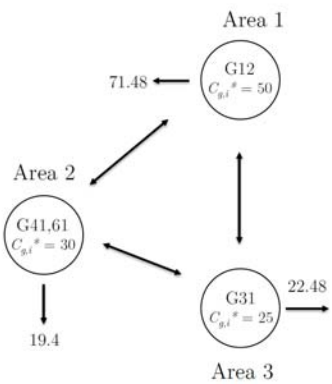
Upper piecewise approx. of generation cost.



PTDF, flowgate capacity computation



Base case power flow (DC-OPF)



Cross-border transfer model (FBMC)

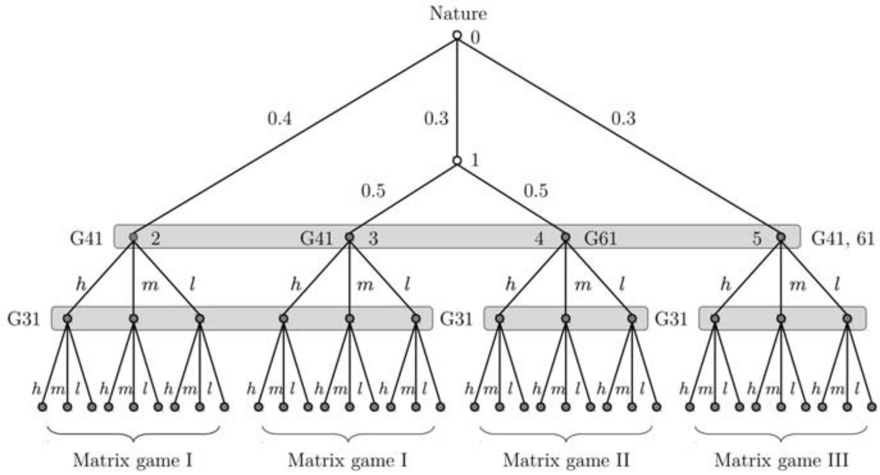
Formally, let θ_i be the type of player i in a game, and $p(\theta_{-i}|\theta_i)$ represents first order belief owned by player i towards the type of his opponent (given that the type of him is θ_i, which is known only to himself). The set of all types of player i is Θ_i and $\theta_i \in [0, 1)$ for all $\theta_i \in \Theta_i$. Under such conditions, a player would choose his action based on his types, and different actions may be assigned to different types. Based on that, he owns a strategy, s_i that maps Θ_i to A_i. Hence, $s_i : \Theta_i \to A_i$. Because Bayesian game theory suggests that the choice of a player's action follows θ_i and $p(\theta_{-i}|\theta_i)$, the expected payoff of by player i in the game becomes:

$$E[u_i(s_i|s_{-i}, \theta_i)] = \sum_{\theta_i \in \Theta_{-i}} u_i(s_i, s_{-i}(\theta_i), \theta_i, \theta_{-i}) p(\theta_i|\theta_{-i}) \quad (1)$$

where, $s_{-i}(\theta_i)$ is the strategy taken by players except player i, given that the type of player i is θ_i. A Bayesian equilibrium (BE) is the Nash equilibriums of the Bayesian game, formulated as follows.

$$E[u_i(s_i|s_{-i}, \theta_i)] \geq E[u_i(s_i'|s_{-i}, \theta_i)] \quad (2)$$

Upon achieving BE, player i receives lower expected utility if he uses a strategy other than s_i (denoted by s_i'). The existence of BE is guaranteed because of the proven existence of NE.



The Bayesian game in cross-border trade of electric power simulated in this work.

G31

G41

G41–G31	Low	Medium	High
Low	700, 1000	700, 800	700, 600
Medium	525, 1000	525, 800	525, 600
High	350, 1000	350, 800	350, 600

G61

G61–G31	Low	Medium	High
Low	700, 875	700, 700	700, 525
Medium	525, 875	525, 700	525, 525
High	350, 875	350, 700	350, 525

G41,61

G41–G31	Low	Medium	High
Low	1400, 466	1400, 373	1400, 592
Medium	1050, 466	1050, 373	1050, 600
High	700, 466	700, 373	700, 280

Payoff received by area 2: 910, area 3: 858

" ... In order to decide what we ought to do to obtain some good or avoid some harm, it is necessary to consider not only the good or harm in itself. But also the probability that it will or will not occur, and to view geometrically the proportions all these things have when taken together ... "

Arnauld and Nicole 1996, 273-4