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FTR Allocations to Ease Transition to Nodal Pricing: An Application to the German Power System

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Outline

- Introduction
- Optimization models
- FTR Allocation in a Three-Node Network
- FTR Allocation for the German Power System
- Conclusions

Introduction

- Increasingly accepted that nodal pricing is most efficient way of operating a power system
- Major obstacle: implied distributional impacts from a change from uniform to nodal prices
- Generators in low-price and loads in higher-price zones might lose out with new pricing system
- A successful element of implementation of nodal pricing has been the parallel allocation of FTRs
- *Initial* allocation of FTRs: highly disputed element of market liberalization processes

Introduction

- Initial provision of FTRs boils down to sharing the pie among various market participants
- NYISO: early implementation of an FTR market to deal with “grandfather” contracts
- New Zealand: nodal prices date back to 1989, FTRs were not immediately implemented
- Australia: zonal pricing system developed that has complicated the initial allocation of FTRs
- Europe: lack of nodal prices makes unlikely that revenue-adequacy for FTR allocations is met

Introduction

- Develop model to explore how initial free allocation of FTRs (at the time of transition to nodal pricing) is designed
- Three node network: analyze effects of different modalities to allocate FTRs
- Models for uniform pricing, nodal pricing and for optimal allocation of FTRs
- Simplified FTR allocation methods available in practice. We compare across them
- Application to the German power market

Optimization Models

- Three optimization models.
- First model: current German electricity market clearing approach with a uniformly priced national spot market, and subsequently congestion management based on curative power plant redispatch
- Second model: follows idea of nodal pricing and combines the economic dispatch of power plants and optimal operation of the physical transmission network

Optimization Models

- Models differ in the way congestion in the transmission network is handled
- Uniform pricing model uses curative methods, whereas preventive congestion management is applied in the nodal pricing model
- Third model: deals with allocation of FTRs to market participants based on results of the uniform and nodal pricing market models
- Feasibility and the revenue adequacy of the FTR allocation are checked out

$\min_{G} \sum_{p,t} mc_p G_{p,t}$

Uniform Pricing Model

Market Clearing

$$\min_{G} \sum_{p,t} mc_p G_{p,t}$$

$$\sum_{n} d_{n,t} - \sum_{p} G_{p,t} - \sum_{n} g_{n,t}^{RES} = 0$$

$$0 \leq G_{p,t} \leq g_p^{max}$$

Congestion Management

$$\min_{G^{UP}, G^{DOWN}, \Delta} \sum_{p,t} mc_p (G_{p,t}^{UP} - G_{p,t}^{DOWN})$$

$$d_{n,t} - \sum_{p \in A(n)} \left(g_{p,t} + G_{p,t}^{UP} - G_{p,t}^{DOWN}\right) - g_{n,t}^{RES} - \sum_{nn} b_{n,nn} \Delta_{n,t} = 0$$

$$0 \leq G_{p,t}^{UP} \leq g_p^{max} - g_{p,t}$$

$$0 \leq G_{p,t}^{DOWN} \leq g_{p,t}$$

$$\left| \sum_{l} h_{l,n} \Delta_{n,t} \right| \leq p_l^{max}$$

$$\Delta_{n',t} = 0$$

Nodal Pricing Model

$$\min_{G} \sum_{p,t} mc_p \, G_{p,t}$$

$$d_{n,t} - \sum_{p \in A(n)} G_{p,t} - g_{n,t}^{RES} - \sum_{nn} b_{n,nn} \, \Delta_{n,t} = 0$$

$$0 \leq G_{p,t} \leq g_p^{max}$$

$$\left| \sum_{l} h_{l,n} \Delta_{n,t} \right| \leq p_l^{max}$$

$$\Delta_{n',t} = 0$$

FTR Allocation Model

- Two approaches for initial allocation FTRs.
  - First approach allocates FTRs to conventional and renewable generators based on historical production.
  - Second approach relies on installed generation capacities to determine the amount of FTRs
- On the demand side, FTRs are allocated relative to consumption given the total amount of FTRs allocated to generation
- For both allocation approaches, we explore different levels or amounts of total FTRs

FTR Allocation Model

$$\min_{\Delta} \; \varepsilon$$

$$\sum_n FTR_n^D - \sum_n FTR_n^{RES} - \sum_p FTR_p^G = 0$$

$$FTR_n^D - FTR_n^{RES} - \sum_{p \in A(n)} FTR_p^G - \sum_{nn} b_{n,nn} \Delta_{n,t} = 0$$

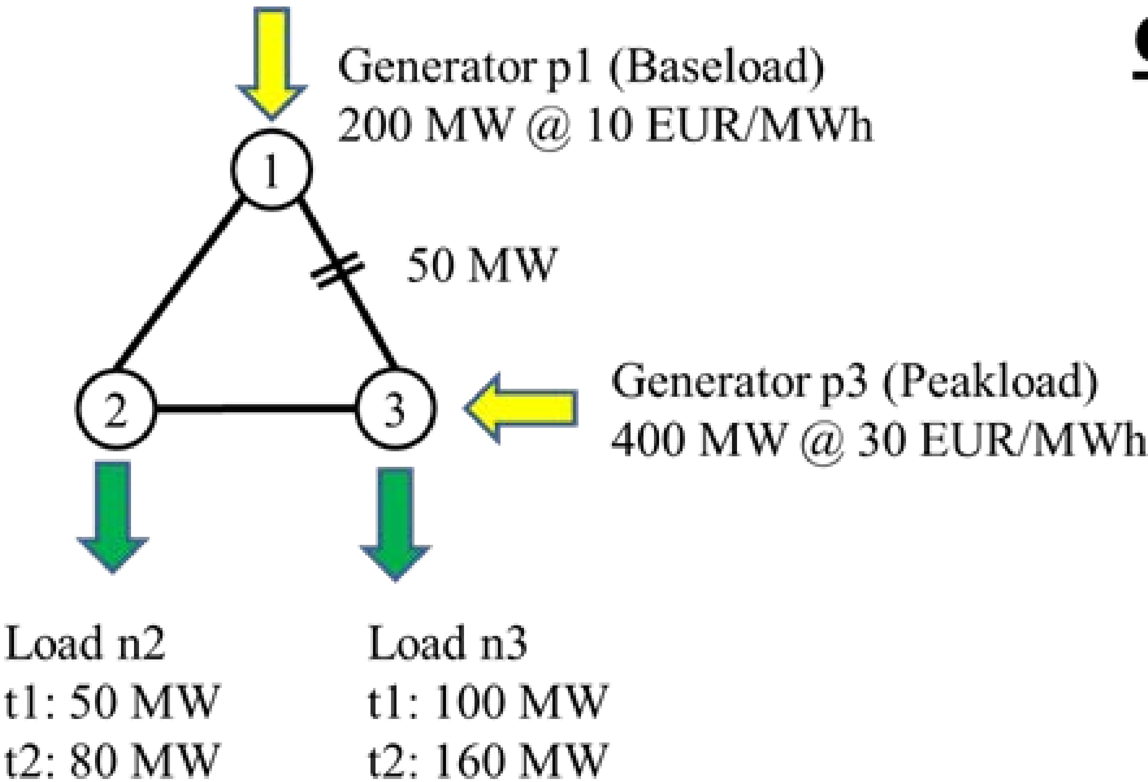
$$cr_t^{TSO} - \sum_p \left(price_{slack,t} - price_{A(n),t}\right) FTR_p^G - \sum_n \left(price_{slack,t} - price_{n,t}\right) FTR_n^{RES}$$

$$- \sum_n \left(price_{n,t} - price_{slack,t}\right) FTR_n^D = 0$$

$$\left| \sum_l h_{l,n} \Delta_{n,t} \right| \leq p_l^{max}$$

$$\Delta_{n',t} = 0$$

FTR Allocation in a Three-Node Network



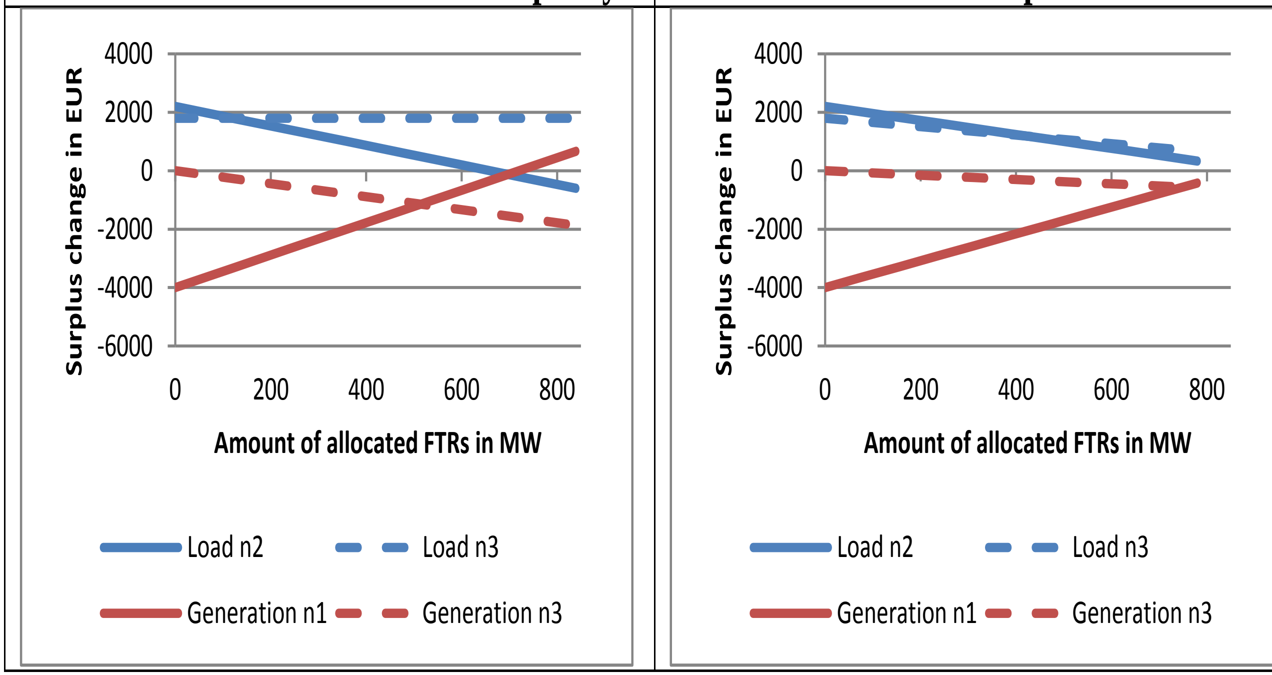
Characteristics

- Time periods: t1, t2
- Generation: p1, p3
- Load: n2, n3
- Equal line characteristics
- Line capacity unlimited except for line n1-n3 = 50 MW

Summary of market participant’s revenue, costs, and surplus in different pricing regimes

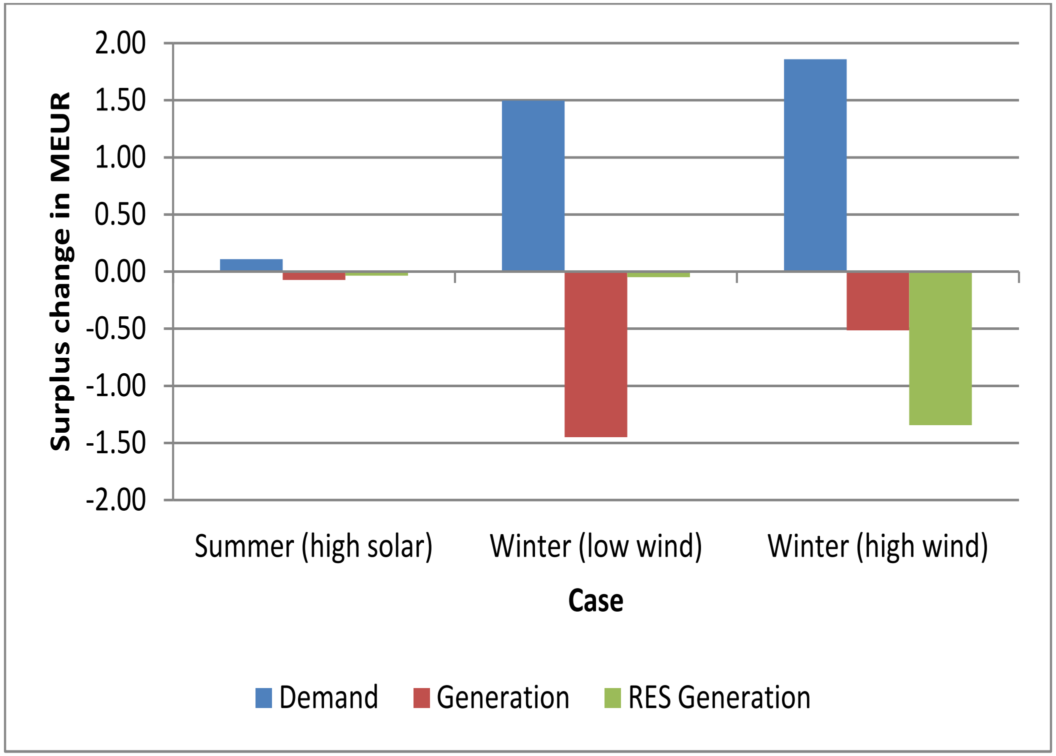
	Uniform pricing	Nodal pricing	Surplus change including socialized transmission surplus
Load			
n2			
Revenue	0	0	--
Costs	3800	2600	--
Surplus	**-3800**	**-2600**	**+2200**
n3			
Revenue	0	0	--
Costs	7600	7800	--
Surplus	**-7600**	**-7800**	**+1800**
Generation			
p1			
Revenue	6150	2150	--
Costs	2150	2150	--
Surplus	**4000**	**0**	**-4000**
p3			
Revenue	5250	5250	--
Costs	5250	5250	--
Surplus	**0**	**0**	**0**
Transmission			
Revenue	1350	3000	--
Cost	4050	0	--
Surplus	**-2700**	**3000**	Socialized to load

FTR allocation based on installed capacity	FTR allocation based on production

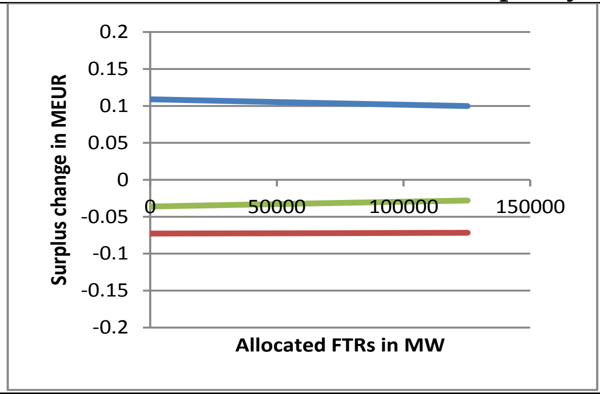
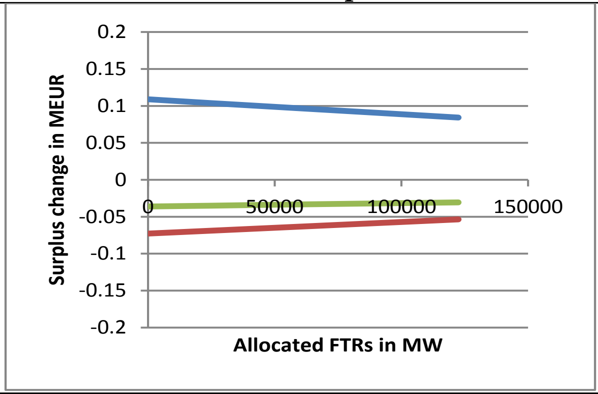
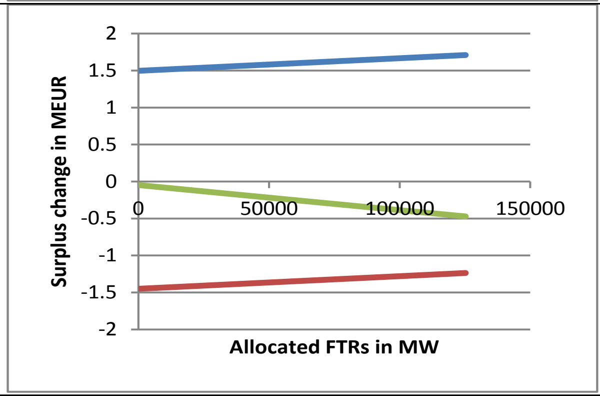
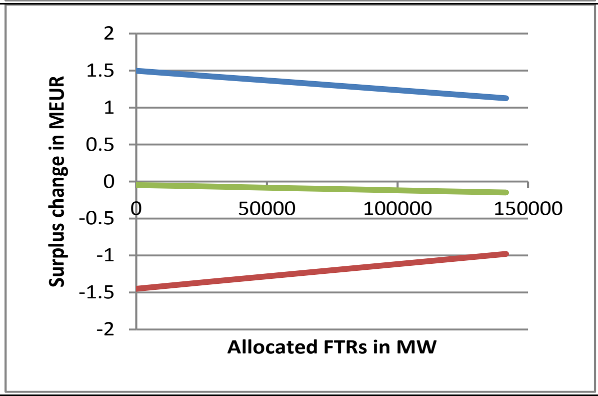
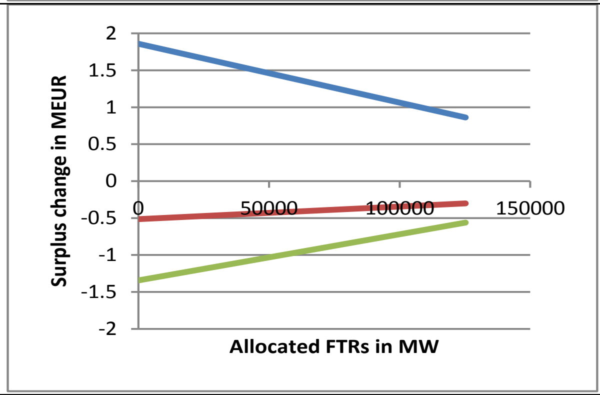
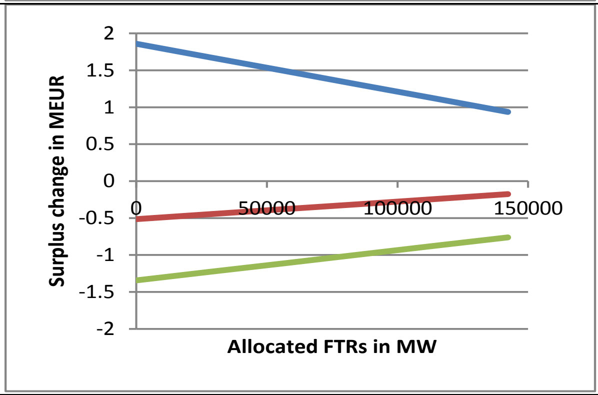


Change of market participant's surplus between uniform and nodal pricing considering different initial FTR allocation regimes in the three-node setting

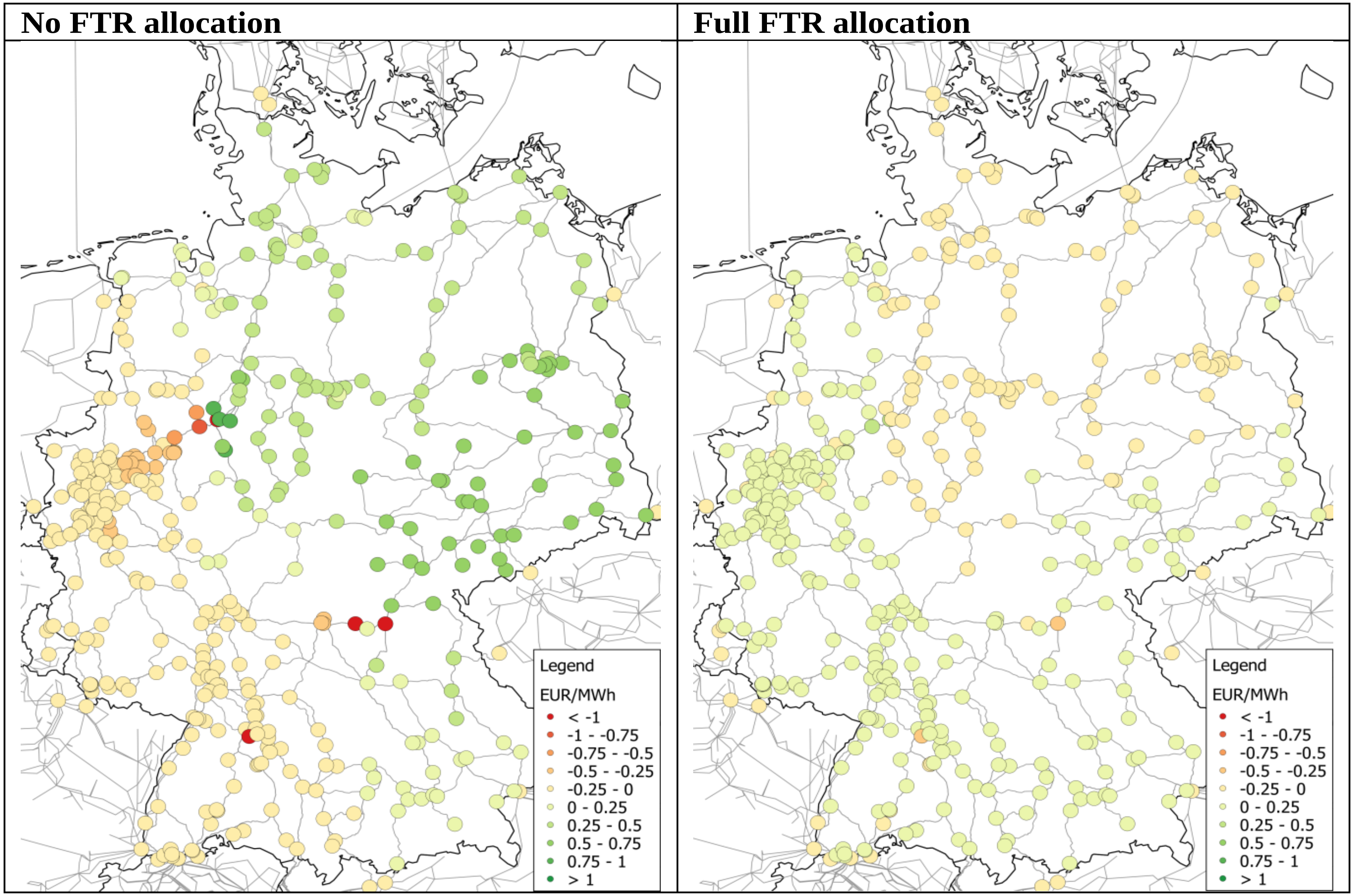
FTR Allocation for the German Power System



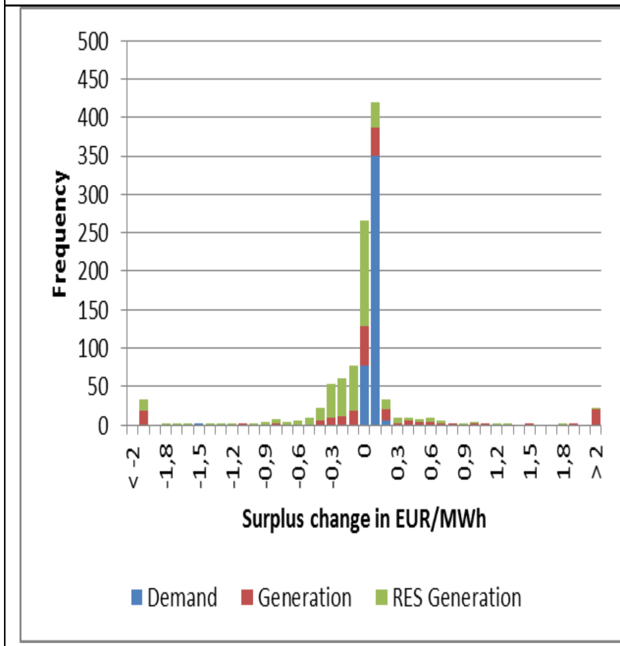
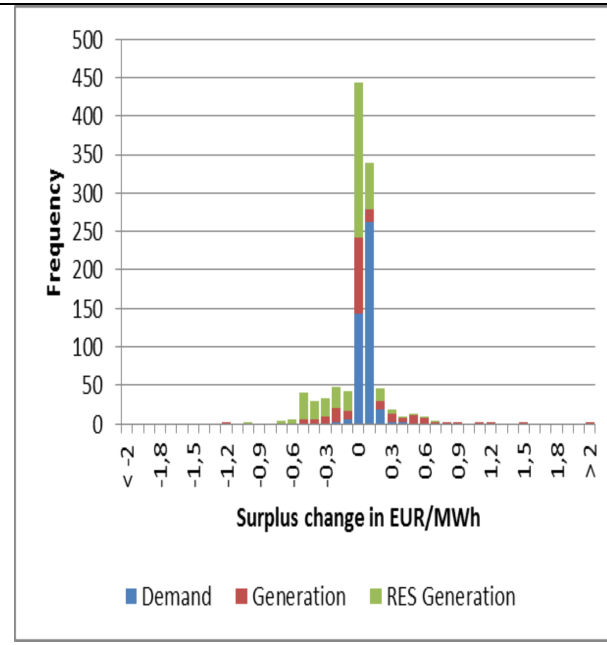
Change of surplus between uniform and nodal pricing

	FTR allocation based on installed capacity	FTR allocation based on production
Summer (high solar)		
Winter (low wind)		
Winter (high wind)		

Change of market participant's surplus between uniform and nodal pricing considering different initial FTR allocation regimes (Blue: load; Red: conventional generation; Green: renewable generation)



Average change in surplus of demand in the high wind winter week under production-based allocation approach

FTR allocation based on installed capacity	FTR allocation based on production
	

Histogram of average nodal surplus changes in the high wind winter week with capacity-based (left side) and production-based FTR allocation (right side)

Conclusions

- Major challenge for implementation of nodal pricing is the distributional impact of price changes facing generation and load in different locations of the system
- Implementation of nodal pricing accompanied with free allocation of FTRs to market participants to mitigate distributional effects
- In a three node network allocation in proportion to annual production volume allows to better compensate the distributional impact than allocation in proportion to installed capacity

Conclusions

- Modeling in the German power system with full nodal representation:
  - FTR allocation can mitigate almost all distributional effects for the demand side, and a large share for conventional generation
  - For intermittent renewables the allocation of FTR obligations can mitigate fewer of the distributional effects
  - This points to the need of more complex FTR designs
- Further assessment of numerical results