

Kunz, Friedrich; Neuhoff, Karsten; Rosellón, Juan

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## FTR allocations to ease transition to nodal pricing: An application to the German power system

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# Appendix

## 1 Nomenclature

### 1.1 Sets

$A(n)$	Mapping of plants to nodes
$l$	Transmission lines
$n, n'$	Nodes, Slack bus
$p$	Power plants
$t$	Time period

### 1.2 Parameters

$b_{n,nn}$	Nodal susceptance matrix
$cr_t$	Congestion rent
$d_{n,t}$	Load
$ds_n^{NP}, ds_n^{UP}$	Economic surplus of load in nodal pricing (NP) or uniform pricing (UP)
$g_{p,t}$	Generation of market clearing model in uniform pricing regime
$g_p^{max}$	Generation capacity
$g_{n,t}^{RES}$	Renewable generation
$gs_p^{NP}, gs_p^{UP}$	Economic surplus of generation in nodal pricing (NP) or uniform pricing (UP)
$h_{l,n}$	Branch susceptance matrix
$p_l^{max}$	Transmission capacity
$price_{n,t}$	Nodal price
$mc_p$	Marginal generation cost

### 1.3 Variables

$FTR_n^D$	FTR allocated to load
$FTR_p^G$	FTR allocated to generation
$FTR_n^{RES}$	FTR allocated to renewable generation
$\Delta_{n,t}$	Voltage angle
$G_{p,t}$	Generation
$G_{p,t}^{UP}$	Positive redispatch of generation
$G_{p,t}^{DOWN}$	Negative redispatch of generation

## 2 Model for Optimized FTR Allocation

$$\min_{FTR, \Delta} \sum_p (gs_p^{UP} - gs_p^{NP} - \sum_t (price_{slack,t} - price_{A(n),t})FTR_p^G)^2 + \sum_n (ds_n^{UP} - ds_n^{NP} - \sum_t (price_{n,t} - price_{slack,t})FTR_n^D)^2 \quad (15)$$

$$\sum_n FTR_n^D - \sum_p FTR_p^G = 0 \quad (16)$$

$$FTR_n^D - \sum_{p \in A(n)} FTR_p^G - \sum_{nn} b_{n,nn} \Delta_n = 0 \quad (17)$$

$$cr_t^{TSO} - \sum_p (price_{slack,t} - price_{A(n),t})FTR_p^G - \sum_n (price_{n,t} - price_{slack,t})FTR_n^D = 0 \quad (18)$$

$$\left| \sum_l h_{l,n} \Delta_{n,t} \right| \leq p_l^{max} \quad (19)$$

$$\Delta_{n',t} = 0 \quad (20)$$

$$FTR_{p,t}^G, FTR_{n,t}^D \geq 0 \quad (21)$$