

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

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

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

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

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

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

$$\Delta_{n,t} = 0 \quad (20)$$

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