ACTIVE AND REACTIVE POWER FLOW TRACING

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ABSTRACT

In deregulated power systems new tools for control and operation are required. Among others, it is interesting to know, which power plants supply a particular line power flow and to what degree. In the paper, a new method for determining the generators' contribution to a line power flow is presented. This is achieved by using the generation distribution factors.

Novel method of the nodal generation distribution factors (NGDF-s) determines the share of a particular generator in each line power flow. It features a search algorithm, capable of handling the active and reactive powers since the transmission losses are taken into account as well.

1. INTRODUCTION

In deregulated power systems, it is interesting to know, which power plants supply a particular line power flow and to what degree. In the paper, a new method for determining the generators' contribution to a line power flow is presented. This is achieved by using the generation distribution factors.

Generation distribution factors are used in security and contingency analyses. On of such factors are the Generalized Generation Distribution Factors (GGDF-s) [1]. They determine the impact of each generator in the power system on a line active power flow; thus they can be negative as well. Since they are based on linearized DC model of the power system they can only be used for active power.

After the deregulation of several power systems, the question of methodologies for transmission service prices was risen. Among other, MW-MILE method was developed, where the shares' of each generator to the line power flow has to be determined. Since the GGDF-s determine the impact instead of the share, some new factors were derived. The most known are the Topological Generation Distribution Factors (TGDF-s) [2][3] and the factors based on the generation domains (DGDF-s) [4]. Both methods can not be applied for reactive powers since they do not take into account transmission losses, which can be relatively high comparing line reactive power flow. This was the reason for developing new method of the Nodal Generation Distribution Factors (NGDF-s).

Newly developed method of the NGDF-s determines the share of a particular generator in each line power flow. It features a search algorithm, capable of handling the active and reactive powers since the transmission losses are taken into account as well.

2. NODAL GENERATION DISTRIBUTION FACTORS

The NGDF method is based on a search algorithm. It searches for power flow directions, thus matrix calculations are not required. The method is suitable for active and reactive powers. Calculations for active or reactive powers are separated. Let symbol M represent either the active or reactive power:

$$M = \{P, Q\}. \qquad (1)$$

Let Ψ_i denote a set of all lines supplying the bus i and Ξ_i a set of lines supplied by the bus i. For the bus i, it can be calculated to what degree it is supplied by each generator in the system. Both, power inflows and generated power at the bus i have to be taken into account:

$$M_{i,k} = \begin{cases} -\sum\limits_{ip\in\Psi_i} \mathrm{L}_{ip,k} M_{ip} + M_i & ; k = i \\ -\sum\limits_{ip\in\Psi_i} \mathrm{L}_{ip,k} M_{ip} & ; k \neq i \end{cases}, \qquad (2)$$

where:

$\mathrm{L}_{ip,k}$ - nodal generation distribution factors for the line rj and for the generator at the bus k.

M_i - power generation at the bus i,

$-M_{ip}$ - power flow into the bus i from the bus p.

The calculation order is important since the NGDF-s for all lines belonging to the set Ψ_i have to be already determined, i.e. all $L_{ip,k}$ must be already known for $ip \in \Psi_i$. Moreover, this is a reason why calculation has to be evaluated for the source buses first. Power source buses are buses where all injected powers to connected lines are positive, thus bus i is a source bus if set Ψ_i is an empty set, i.e. $\Psi_i = \{\}$. The set of the source buses is a subset of a set of generator buses only.

Applying proportional sharing principle [2], which assumes a linear relation between the sum of the power inflows and particular outflow into the observed line, the NGDF-s for all lines supplied by the bus i can be determined:

$$L_{ij,k} = \frac{M_{i,k}}{\sum_{k \in \Gamma} M_{i,k}} \quad \text{for all } ij \in \Xi i, \qquad (3)$$

where Γ is a set of all generator buses in the power system. Described calculation has to be performed for all buses in the system resulting in the NGDF-s for all lines. These factors can be interpreted as proportion of each particular generation in a power flow on the discussed line. Values of the NGDF-s are always between zero and one:

$$0 \le L_{ij,k} \le 1, \qquad (4)$$

and

$$\sum_{k \in \Gamma} L_{ij,k} = 1. \qquad (5)$$

The algorithm can be applied for the active and/or reactive powers. Because of absence of any matrix manipulations, the proposed method is simple yielding fast calculation.

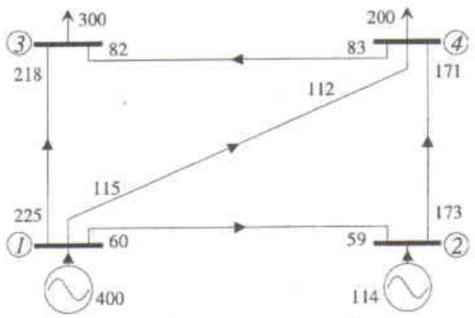

Figure 1: Four-bus test system, active power

Table 1: Generation distribution factors for generator at the bus 1:

Line	GGDF	DGDF	TGDF	NGDF
1-2	1,477	1,000	1,000	**1,000**
1-3	0,870	1,000	1,000	**1,000**
1-4	1,015	1,000	1,000	**1,000**
2-4	0,504	0,773	0,345	**0,341**
4-3	0,533	0,773	0,605	**0,602**

Table 2: Generation distribution factors for generator at the bus 2:

Line	GGDF	DGDF	TGDF	NGDF
1-2	-0,477	0,000	0,000	**0,000**
1-3	0,130	0,000	0,000	**0,000**
1-4	-0,015	0,000	0,000	**0,000**
2-4	0,496	0,227	0,655	**0,659**
4-3	0,467	0,227	0,395	**0,398**

3. NGDF-S FOR ACTIVE POWER

The new method has been intensively tested. In the following chapters, obtained numerical results for simple four-bus and for the New England 39-bus test system are presented.

3.1. Four-bus test system

Results of the new method of NGDF-s were compared for active power with three other methods for determining generation contributions to the line power flow:

Table 3: NGDF-s for all lines in the New England test system.

	Generator at the bus No.									
Line	30	31	32	33	34	35	36	37	38	39
1-2	0.52							0.48		
1-39	0.52							0.48		
2-3	0.52							0.48		
2-25								1.00		
2-30	1.00									
3-4	0.48			0.04		0.02	0.02	0.44		
3-18				0.52		0.21	0.27			
4-5		0.63	0.37							
4-14			1.00							
5-6		0.63	0.37							
5-8		0.63	0.37							
6-7		0.63	0.37							
6-11			1.00							
6-31		1.00								
7-8		0.63	0.37							
8-9	0.06							0.05		0.89
9-39	0.06							0.05		0.89
10-11			1.00							
10-13			1.00							
10-32			1.00							
11-12			1.00							
12-13			1.00							
13-14			1.00							
14-15			1.00							
15-16				0.52		0.21	0.27			
16-17				0.52		0.21	0.27			
16-19				1.00						
16-21				0.52		0.21	0.27			
16-24						0.43	0.57			
17-18				0.52		0.21	0.27			
17-27				0.52		0.21	0.27			
19-20				1.00						
19-33				1.00						
20-34					1.00					
21-22						1.00				
22-23						1.00				
22-35						1.00				
23-24						0.43	0.57			
23-36							1.00			
25-26								1.00		
25-37								1.00		
26-27								0.19	0.81	
26-28									1.00	
26-29									1.00	
28-29									1.00	
29-38									1.00	

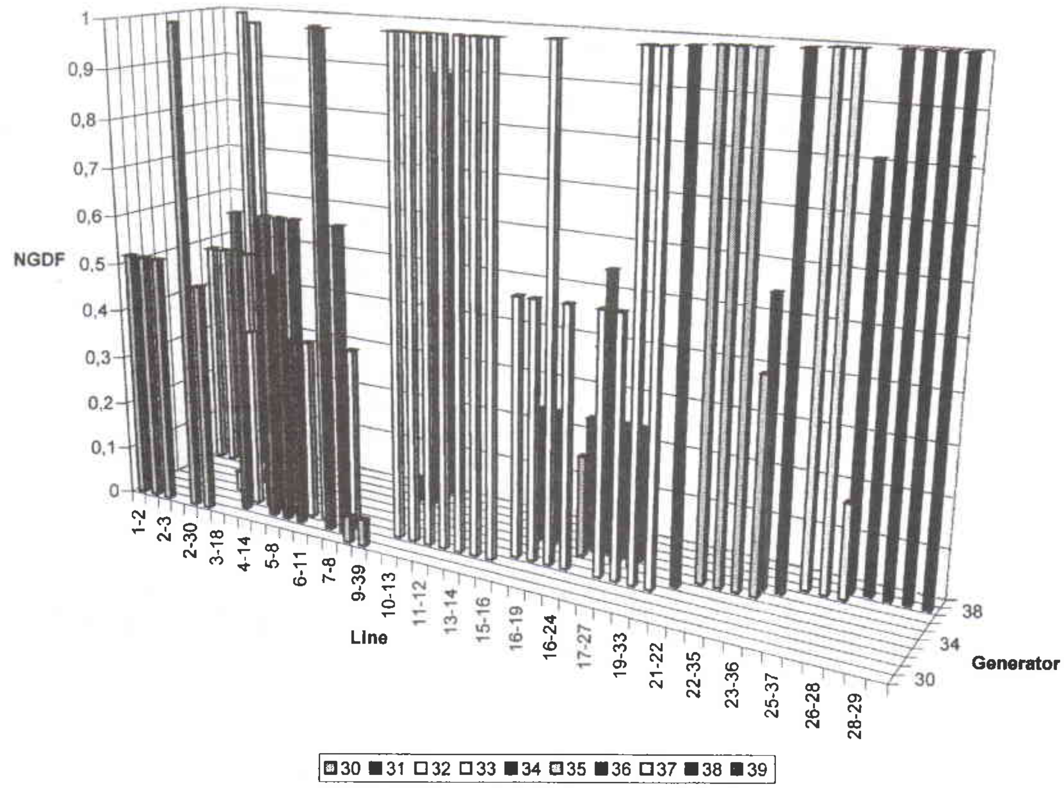

Figure 2: NGDF-s for all lines in the New England test system.

- Generalized Generation Distribution Factors (GGDF) [1],
- Method based on generator domains (DGDF) [4],
- Topological Generation Distribution Factors (TGDF) [2][3].

In Figure 1, generations, loads and line flows are given with numbers in MW.

The comparison of different methods for all power system lines concerning the generators at the bus 1 and at the bus 2 is given in Tables 1 in 2, respectively.

From the results it can be noticed that values for NGDF and TGDF are practical identical. The reason for this is that both factors represent the share of a particular generator in the total line power flow. However, the TGDF method requires the system matrix manipulation, while the NGDF method uses a simple search algorithm. The GGDF method yields quite different results in comparison with the TGDF and NGDF methods, since the GGDF represents the impact of a generator on a given line power flow. Also, that is the reason why the GGDF method sometimes produces negative results. The DGDF differs from the TGDF and NGDF because they basically represent generator's contribution in supplying particular "common" [4] rather than generator's contribution to the power flow of a selected line.

3.2. New England 39-bus test system

The NGDF-s for the New England test system are presented in Table 3 and in Figure 2, which present the generator contributions in each line active power flow and no number represents zero value. From results it can be seen that generally, only few generators usually contribute to a line power flow.

4. NGDF-S FOR REACTIVE POWER

As it was already mentioned, the method of the NGDF-s is also suitable for reactive powers. Since the other methods mentioned in the references are not

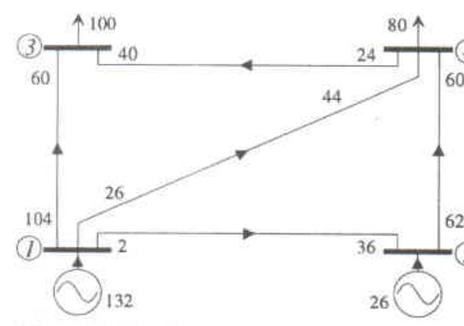

Figure 3: Four-bus test system, reactive power.

Table 4: NGDF-s for reactive power generator at the bus 1 and 2.

Line	G_1	G_2
1-2	1,000	0,000
1-3	1,000	0,000
1-4	1,000	0,000
2-4	0,581	0,419
4-3	0,758	0,242

suitable for the reactive power, only the results for the NGDF-s are given here. The test system was the same four-bus system as it was for the active power. Reactive power generations, loads and power flows are shown in Figure 3. The results for the NGDF-s are given in Table 4.

5. CONCLUSION

A new method of the nodal generator distribution factors (NGDF-s) is presented in the paper. The new nodal method offers a simple solution to the problem of generator contribution to the power flow of a selected line. It could equally be used for assessment of both, active and reactive powers contribution to the transmission lines. It utilizes the power flow directions and it does not employ any matrix calculation.

The new method has been tested on different power systems and for various operating states. The results demonstrate its efficiency for reactive power while for active power flows they show that results can be compared with some other methods of generation distribution factors.

The NGDF method can be used for transmission service pricing, for congestion management and for reactive power management.

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