Analysis of the magnetic coupling influence between different feeders on unbalanced distribution networks

Code: 12.004

Nélio Alves do Amaral Filho, Mariana Simões Noel da Silva, Leandro Ramos de Araujo, Débora Rosana Ribeiro Penido Araujo

Electrical Engineering, Federal University of Juiz de Fora, Minas Gerais - Brazil
Introduction

- Electrical distribution systems (DS) have attracted the attention of a growing number of researchers
  - Electric power quality
    - Unbalances
  - Increased demand for electricity
    - Operation under harsher conditions
  - Greater need to represent all DS-related characteristics and effects
  - An efficient representation of the system components
  - Tools able to evaluate and analyze the DS more accurately
Introduction

• Several possible analyses can be performed in distribution systems studies
  ✓ Electromagnetic coupling (mutual coupling) that occurs between two or more feeders when physically arranged in parallel

  ✓ Practice done by the utilities

  ✓ Feeders can be found traveling along
    ▪ the same path and sharing a common pole;
    ▪ the same power corridor on separate poles.

  ✓ The existing mutual coupling can significantly affect the system

  ✓ This coupling is usually neglected in most studies
Objectives

- Analysis of the electromagnetic coupling influence between different feeders
- Backward/Forward Sweep (BFS) Method
- Different constructive characteristics
  - Length of the distribution feeders sections
  - Separation distance between the conductors
  - Phase sequences and geometry of the conductors on the poles
Model of the distribution feeders in parallel

\[ Z_{ii} = r_c + r_d + j0.07537 \left( \ln \frac{1}{RMG_i} + 6.74580 \right) \] (1)

\[ Z_{ij} = r_d + j0.07537 \left( \ln \frac{1}{D_{ij}} + 6.74580 \right) \] (2)

\[ [Z_{phase}] = \begin{bmatrix}
Z_{aa} & Z_{ab} & Z_{ac} & Z_{aa'} & Z_{ab'} & Z_{ac'} \\
Z_{ba} & Z_{bb} & Z_{bc} & Z_{ba'} & Z_{bb'} & Z_{bc'} \\
Z_{ca} & Z_{cb} & Z_{cc} & Z_{ca'} & Z_{cb'} & Z_{cc'} \\
Z_{a'a} & Z_{a'b} & Z_{a'c} & Z_{a'a'} & Z_{a'b'} & Z_{a'c'} \\
Z_{b'a} & Z_{b'b} & Z_{b'c} & Z_{b'a'} & Z_{b'b'} & Z_{b'c'} \\
Z_{c'a} & Z_{c'b} & Z_{c'c} & Z_{c'a'} & Z_{c'b'} & Z_{c'c'} 
\end{bmatrix} \] (3)

\[ [Z_{phase}] = \begin{bmatrix}
Z_{abc}, F1 - F1 & Z_{abc}, F1 - F2 \\
Z_{abc}, F2 - F1 & Z_{abc}, F2 - F2 
\end{bmatrix} \] (4)
Backward Forward Sweep Algorithm

- **Variables initialization**
- **Layer separation**
- **Identification of sections that share the same pole**
- **Calculation of Nodal Currents**
- **Backward Sweep**
- **Forward Sweep**
  - Stop when a coupling section is found
- **Identification of sections that share the same pole**
- **Mutual coupling: Forward Sweep using eq. (5)**

**End**

**Convergence Test**

\[ |\Delta V| < \epsilon \]

\[ \begin{align*}
\Delta V_{abc, F1} &= \begin{bmatrix} Z_{abc, F1} & Z_{abc, F1} & Z_{abc, F1} - F2 \\ Z_{abc, F2} - F1 & Z_{abc, F2} - F2 & Z_{abc, F2} - F2 \\ I_{abc, F1} & I_{abc, F2} & I_{abc, F2} \end{bmatrix} I_{abc, F2} 
\end{align*} \]  

(5)
Simulated systems

IEEE 13M

IEEE 34M
Simulated systems

- To investigate the impact of the mutual coupling, 2 cases were analyzed
  - **Case 1**: ignoring the effect of the mutual impedances between different feeders (without the mutual coupling representation)
  - **Case 2**: considering the effect of these mutual impedances (mutual coupling)

- For comparison and results presentation
  - It was calculated the difference between the absolute values obtained from each case, for a same variable (voltage, current or electrical losses)

\[
\Delta V_k = \frac{|V_k^{C2}| - |V_k^{C1}|}{|V_k^{C1}|} \tag{6}
\]
Experimental results

Feeders length

IEEE 13M

- Phase A
- Phase B
- Phase C

Maximum voltage difference (%)

Factor k

IEEE 34M

- Phase A
- Phase B
- Phase C

Maximum voltage difference (%)

Factor k

12/11/2017
Experimental results

Distance between conductors

- Vertical distance between feeders on pole (m)
- Voltage difference in bus 890 (%)
- Voltage difference in bus 675 (pu)

IEEE 13M
IEEE 34M
Experimental results

Different phase sequences or conductor geometry on the pole

IEEE 13M

IEEE 34M

12/11/2017

Maximum difference (%)
The effect of the mutual coupling may become significant in certain conditions:
✓ System configuration;
✓ Long length of feeders sections that are in parallel;
✓ Small distances between the phase conductors, both vertically and horizontally;
✓ Specific phase sequences.

The mutual coupling influence can be considerable not only in the voltage, but also in both current and electrical losses.

The mutual coupling representation in the power flow analysis algorithms for distribution systems should not be neglected.
Acknowledgments

The authors thank the Pos-Graduate Program in Electrical Engineering (PPEE) of the Federal University of Juiz de Fora, CNPq, FAPEMIG, and CAPES for the incentive and support.
References


