254 Performance analysis of power flow strategies adjusted to a distribution network with non-linear loads and a PV system

Alejandra Martínez-Peñaloza
German Osma-Pinto
Gabriel Ordóñez-Plata

Department of Electrical, Electronic and Telecommunications Engineering
Universidad Industrial de Santander (UIS), Bucaramanga (Colombia)

alejandra2198146@correo.uis.edu.co, gealosma@uis.edu.co, gaby@uis.edu.co

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INTRODUCTION

- The study of power flows is a tool that allows analyzing the steady-state operation of an electrical system
- Iterative methods such as Backward/Forward have gain importance in the analysis of distribution networks since the mathematical approach used makes it easy to obtain accurate results
- Computational tools or software like PowerFactory by DIgSILENT or Simulink are use to analyse electrical systems at the level of generation, transmission and distribution
- Few studies on the analysis of harmonic power flows considers the simultaneous operation of distributed resources, load unbalance, and their non-linearity.
- The integration of non-linear devices in distribution networks demand the use of models in the frequency domain that consider the harmonic interaction between the supply voltage and the current demanded

This article presents a comparison of the performance of three power flow solution strategies that each one applies a different load model in the frequency domain, Backward/Forward uses the Norton equivalent model with coupled admittance matrix (BF-NC), Simulink uses the Norton equivalent model with decoupled admittance matrix (S-ND), and PowerFactory use the current source model (PF-FC).

STRATEGIES

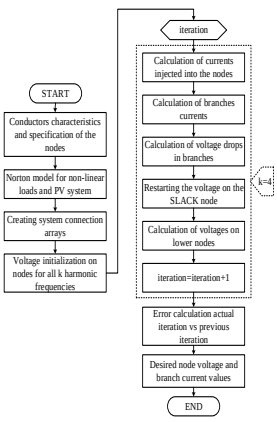

Figure 1. Backward/Forward strategy

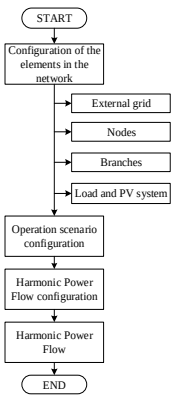

Figure 2. PowerFactory strategy

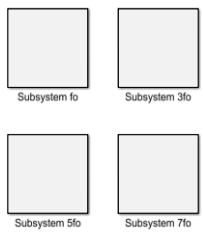

Figure 3. Simulink strategy

STUDY CASE

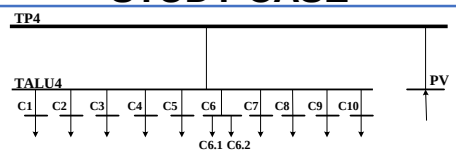

Figure 4. Single-line diagram of the study case grid

- There are lighting and ventilation loads conected to the TALU4 subpanel.
- The PV subpanel is the PCC between the power grid and the PV system.
- The non-linear devices and PV system are represented with Norton equivalent model with coupled admittance matrix for Backward/Forward strategy, Norton equivalent model with decoupled admittance matrix for Simulink strategy, and current source for PowerFactory strategy.
- Considering the operation of each load and the PV system were proposed 22 operation scenarios.

RESULTS

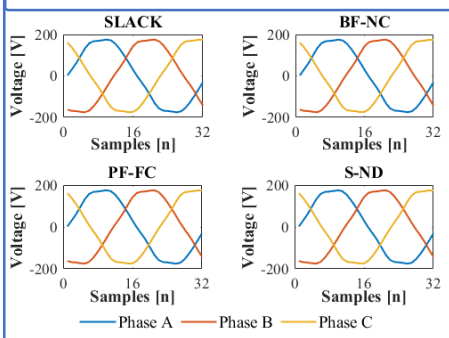

Figure 5. Voltage signal waveforms

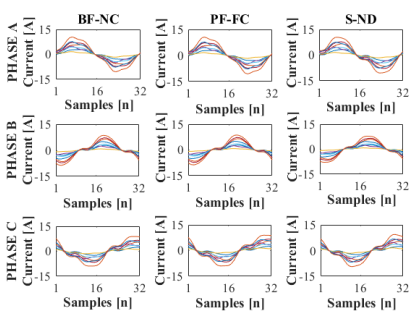

Figure 6. High Ginc current signals waveforms on the TP4-TALU4 branch

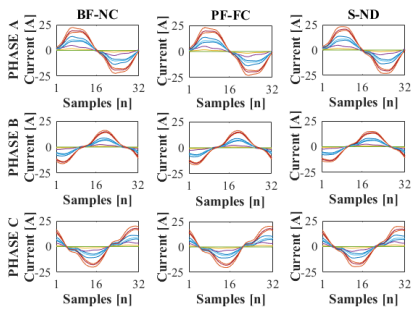

Figure 7. Low Ginc current signals waveforms on the TP4-TALU4 branch

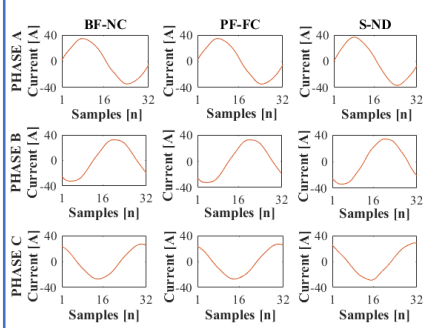

Figure 8. High Ginc current signals waveforms on the TP4-PV branch

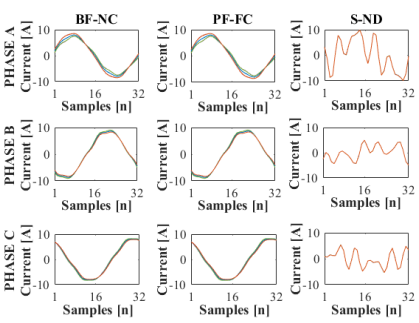

Figure 9. Low Ginc current signals waveforms on the TP4-PV branch

Table 1. Strategies performance in terms of the signals waveforms

	NODE	Voltage		BRANCH	Current	
		High Ginc	Low Ginc		High Ginc	Low Ginc
BF-NC	Performance	✓✓✓✓✓	✓✓✓✓✓	Performance	✓✓✓✓✓	✓✓✓✓✓
S-ND	Performance	✓✓✓✓✓	✓✓✓✓✓	Performance	✓✓✓	✓
	Maximum error	0.04%	0.05%	Maximum error	4.7%	41%
PF-FC	Performance	✓✓✓✓✓	✓✓✓✓✓	Performance	✓✓✓✓	✓✓✓
	Maximum error	0.04%	0.08%	Maximum error	0.4%	1.1%

Table 2. Strategies performance in terms of power parameters errors

	BRANCH	P		Q	
		High Ginc	Low Ginc	High Ginc	Low Ginc
BF-NC	Performance	✓✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓	✓✓✓✓✓
S-ND	Performance	✓✓✓	✓	✓	✓
	Maximum error	4.5%	89%	55%	1500%
PF-FC	Performance	✓✓✓	✓✓✓	✓✓✓	✓✓✓
	Maximum error	1.3%	3.2%	3%	3%

CONCLUSIONS

- The detailed analysis showed that the load model used in the harmonic power flow influences and impacts the performance of the strategies in terms of estimating variables and electrical parameters.
- The NRMSE errors of the voltage signals of the three strategies showed an excellent performance with errors less than 0.1%.
- In high solar irradiance scenarios, the three strategies acceptably estimate the current signals waveforms, with NRMSE errors of less than 5%.
- For low solar irradiance operation, the performance of the Simulink and PowerFactory strategies is unsatisfactory, with maximum NRMSE errors of 41% and 1.1%, respectively.
- In terms of power parameters errors, the performance of the PowerFactory strategy is acceptable. However, the performance of the Simulink strategy is unacceptable, with maximum errors exceeding the 55%.
- The power flow solution strategies analyzed can be adjusted and applied to electrical networks with characteristics similar to the network taken as a case study.
- Exist the possibility of integrating another distributed resource into their analysis.