We3G-3

Precoded Supervising System Based on Smart Antenna Array for Electric Power Distribution Grid: Optimization Aspects

J. M. A. M. de Oliveira[1], A. Gomes Barboza[1], R. G. M. dos Santos[1], M. de Oliveira Alencar[1], J. H. de A. Dias Silva[1], M. F. B. Pedrosa[1], D. de Filgueiras Gomes[1], A. J. Belfort de Oliveira[1], M. T. de Melo[1], R.J.F.P.V. Padilha[2], B. A. Kleinau[2]

[1]Dept. of Electronics and Systems Federal University of Pernambuco, Recife, Brasil

[2]Celpe – Neoenergia CEP: 50050-902, Recife, Brasil

Summary

- Introduction
- Comparison of Optimization Algorithms
- System Setup
- System Error Rate
- Conclusion
- References

Introduction

- The electricity distribution concessionaires have an Integrated Operations Center (IOC);

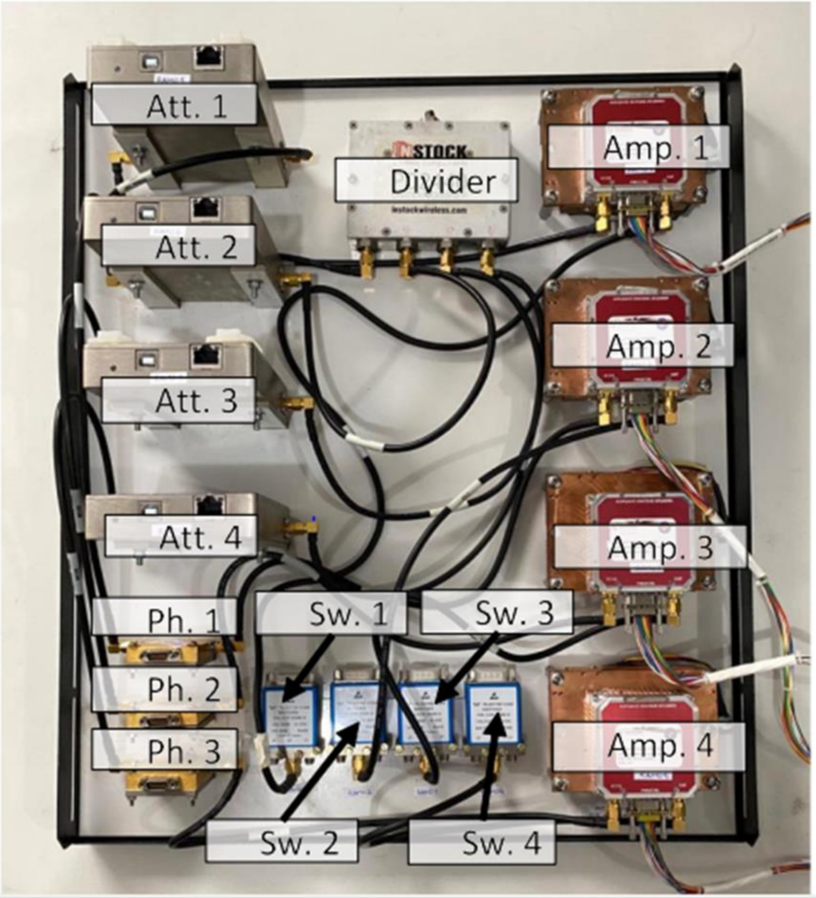
- Smart Antenna Arrays have electronically controlled antenna feeds so that the main beam can be pointed to different directions without having to mechanically move the antennas.

Introduction

- A beamforming circuit with 4 branches is used to control the direction of the main lobe by properly feeding the antennas, whose individual amplitude and phase are adjusted by a digitally controlled circuit;
- Three different optimization algorithms were selected for comparison and definition of the most efficient one, for the set of magnitude and phase parameters of the array;

Introduction

- A beamforming circuit with 4 branches is used to control.



Introduction

- Such algorithms are Evolution Strategy (ES), Genetic Algorithm (GA) and Particle Swarm Optimization (PSO), and the parameters were configured using the tangential vector finite elements technique of the Ansys High Frequency Structure Simulator (HFSS) software;
- To verify the accuracy of the system, packet loss was measured continuously for 14 hours. Packet loss and regression tests were performed on the collected samples in this paper.

Comparison of Optimization Algorithms

- Evolutionary optimization techniques are effective in solving function optimization problems and have already been applied in antenna design and expanded to Yagi-Uda antenna array design.
  - Evolution Strategy (ES)
    - ES optimization techniques are evolutionary algorithms inspired by biological evolution. Such candidate solutions are applied in a loop, whose iteration ends when a final criterion is met.

Comparison of Optimization Algorithms

– Genetic Algorithm (GA)

- GAs are algorithms belonging to the field of evolutionary computation, inspired by the concepts of natural selection and heredity.

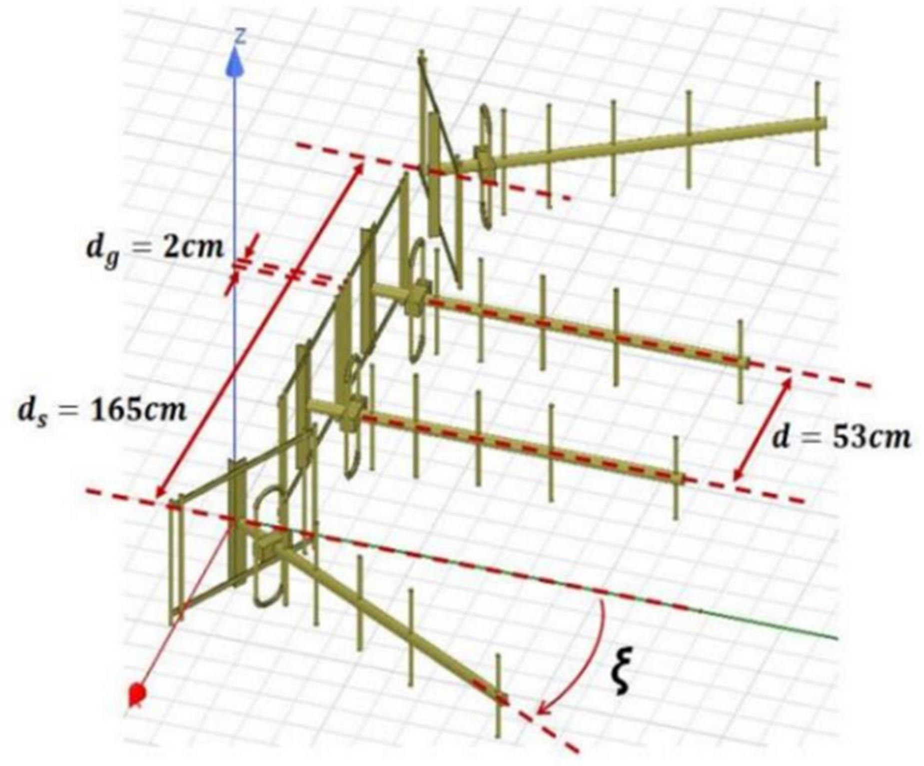
Comparison of Optimization Algorithms

– Particle Swarm Optimization (PSO)

- The PSO algorithm is a optimization method inspired by the social and biological behaviour of bird flocks. In this algorithm, individuals are referred to as particles and fly through the search space in search of the best global position that minimizes, or maximizes, a given problem.

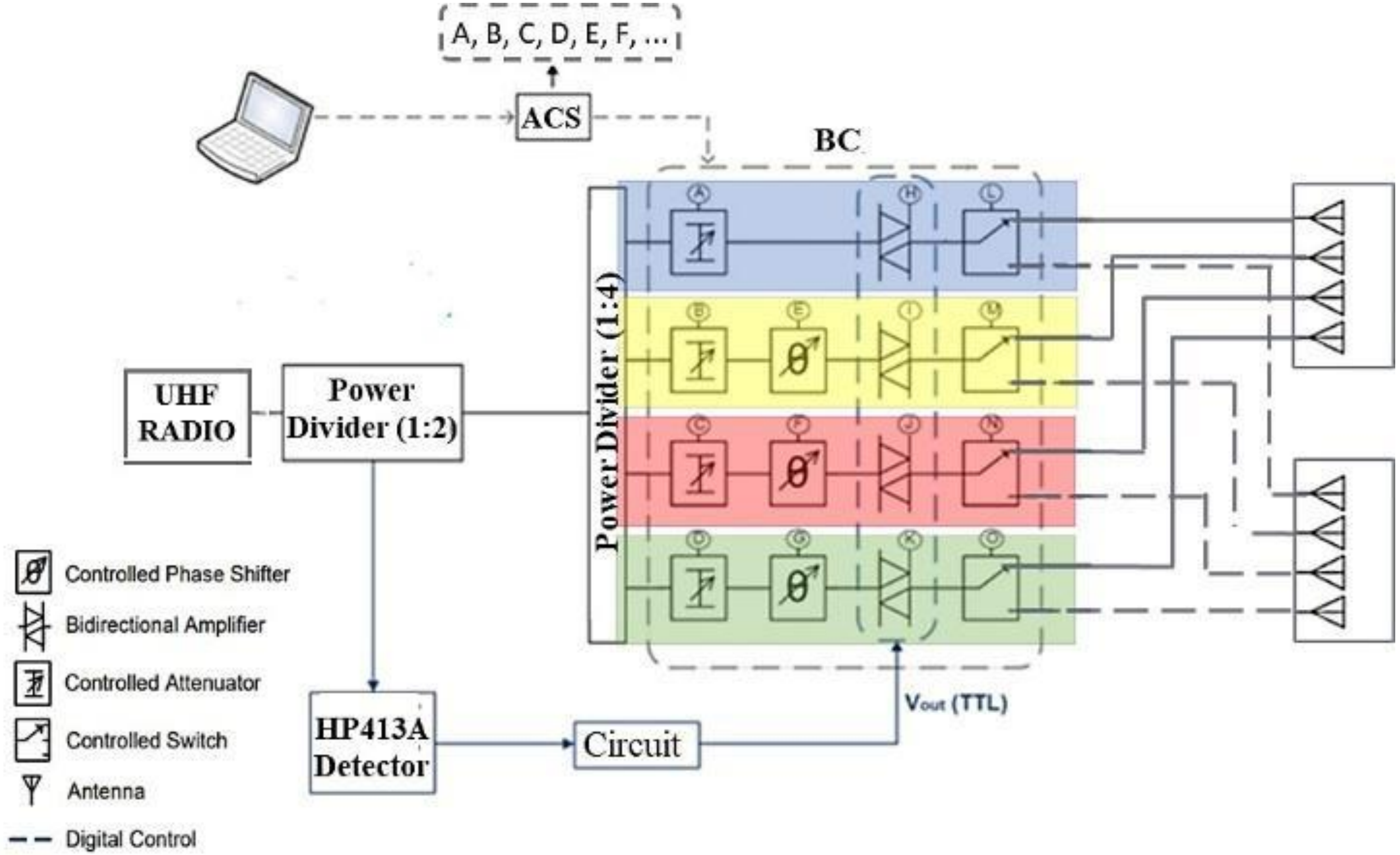
System Setup

- The antenna array used is composed of 4 identical Yagi-Uda antennas. It is able to operate from 440 up to 470 MHz.



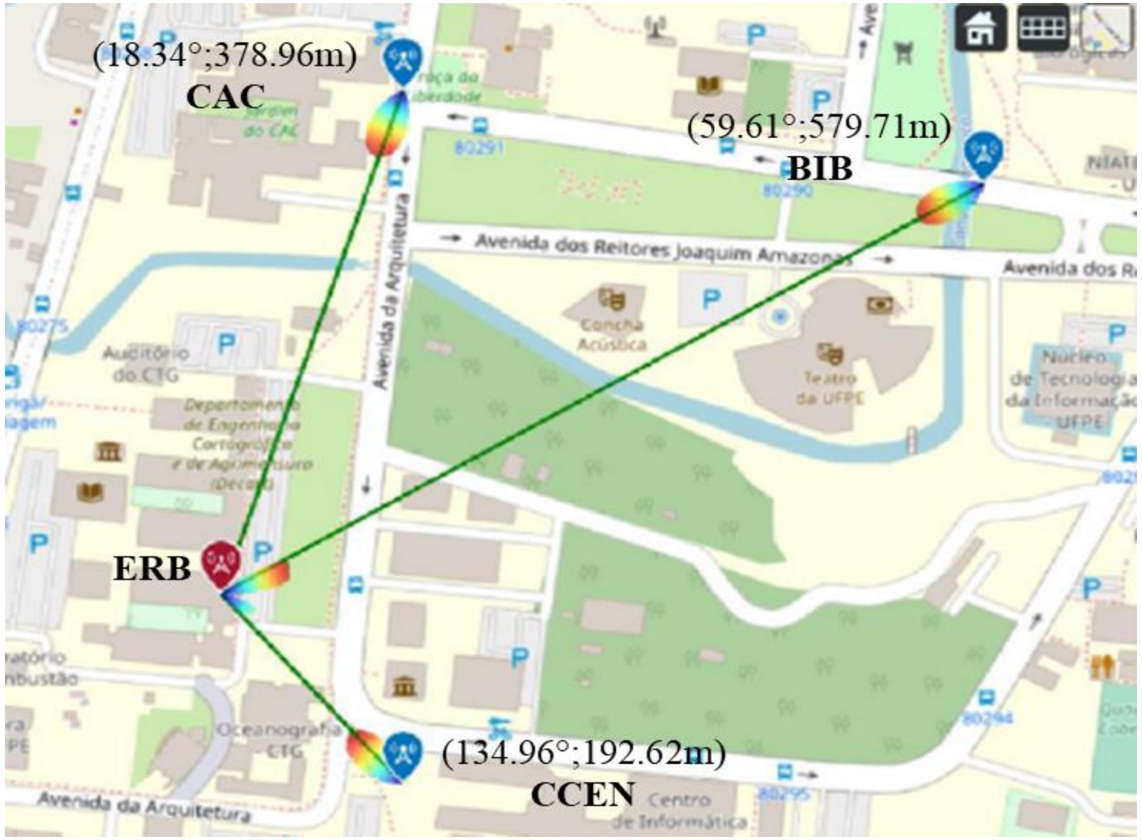
System Setup

- Diagram of the smart antenna system used in UFPE



System Setup

- Positions of the ERB and the three remote stations (here called CAC, BIB and CCEN) installed on the UFPE campus.



System Setup

- Photograph of the two Yagi – Uda antenna arrays installed on top of CTG.

System Error Rate

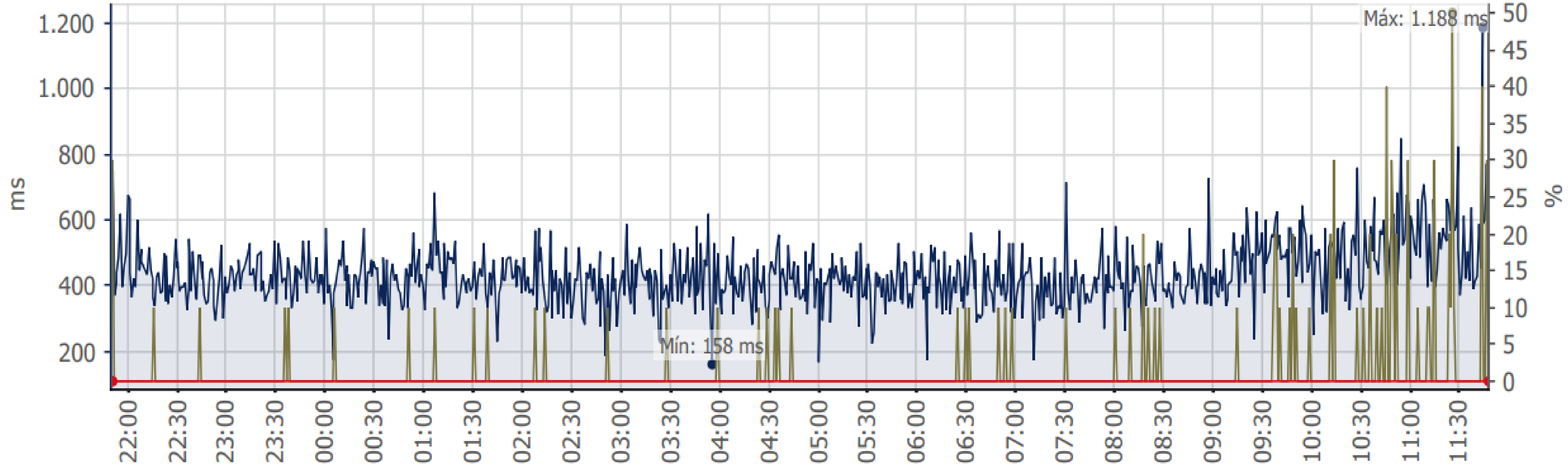
– Test and Results

Table 1. Mean values measured with PRTG during the experiment.

Uptime statistics (14hs)	Ping time in dark blue (436 ms)	Marked in brown packet loss (1%)	Percentage of downtime mark ed in red (0%)

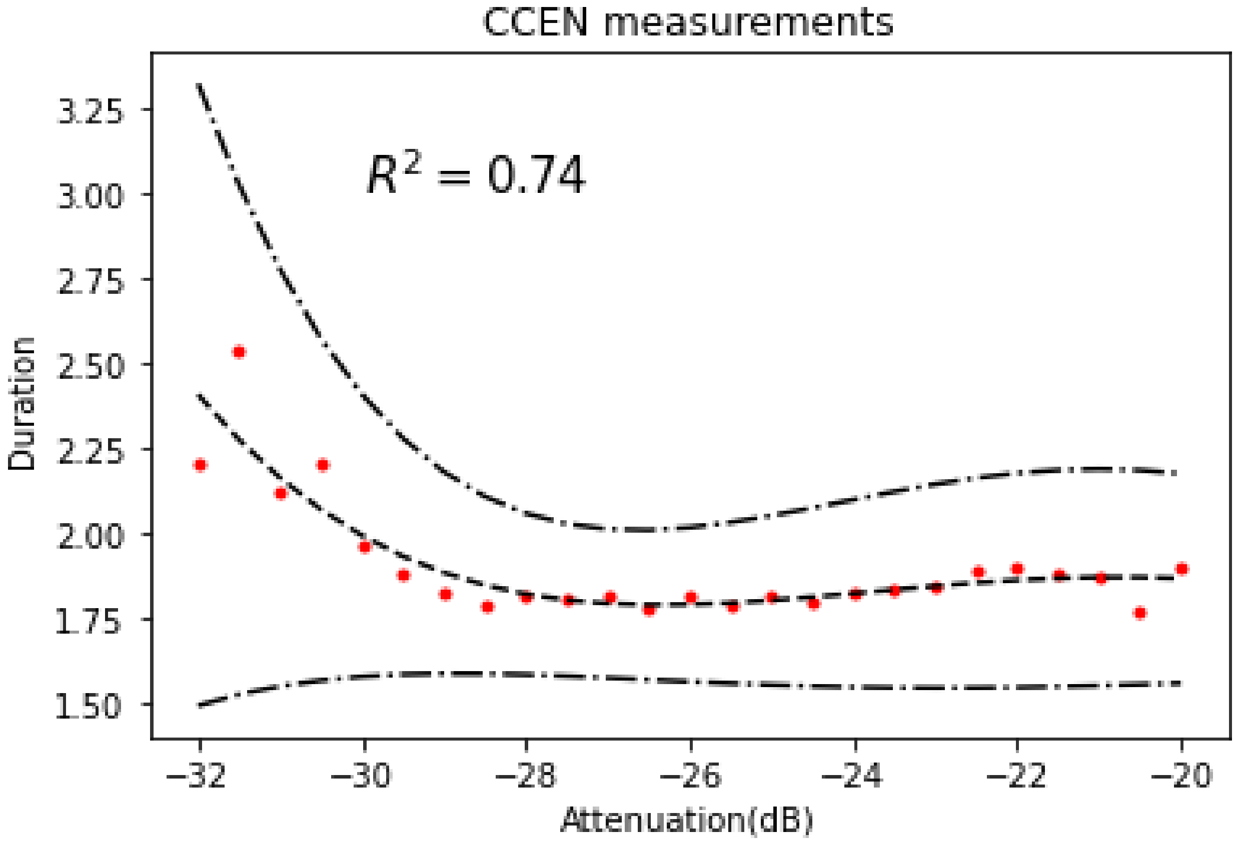
System Error Rate

- Measurement of Smart Antenna System packet loss. On the horizontal axis, uptime statistics (21:45h-11:45h).



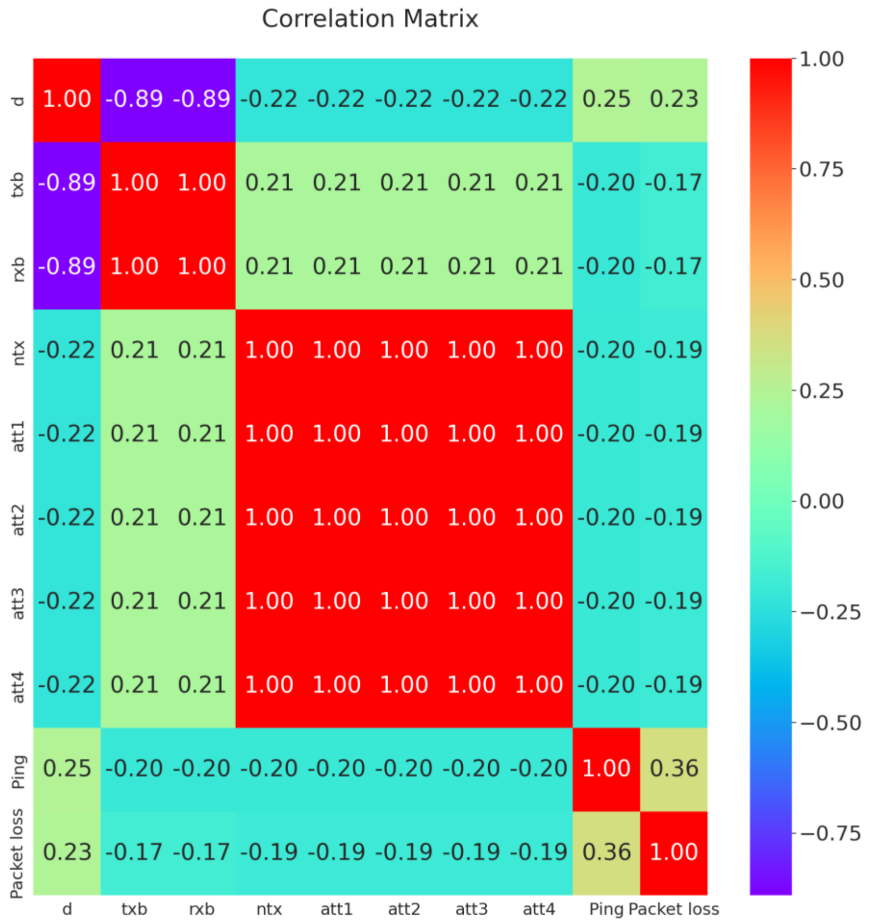
System Error Rate

- Variation of attenuation versus duration for sending packets.



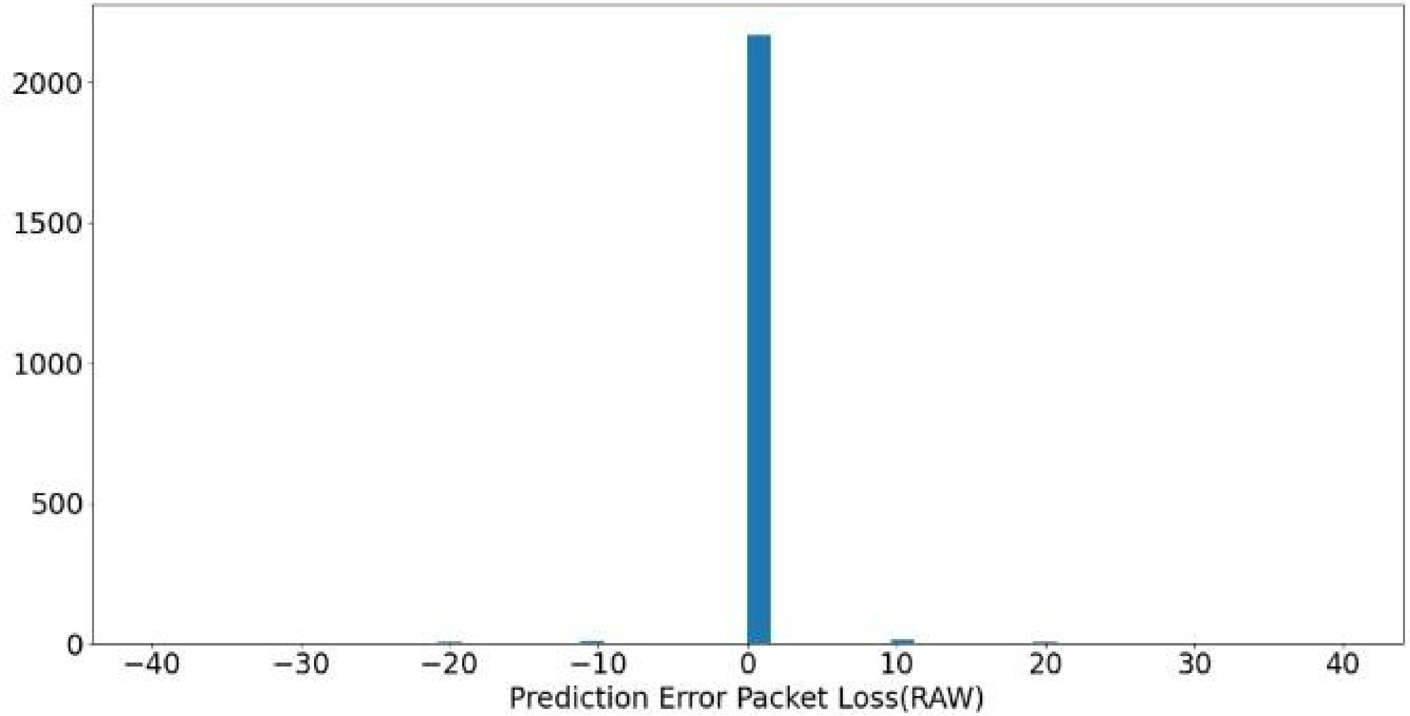
System Error Rate

- Correlation matrix between values measured during the test.



System Error Rate

- Histogram of Error technique Decision tree between real packet loss and predicted packet loss.



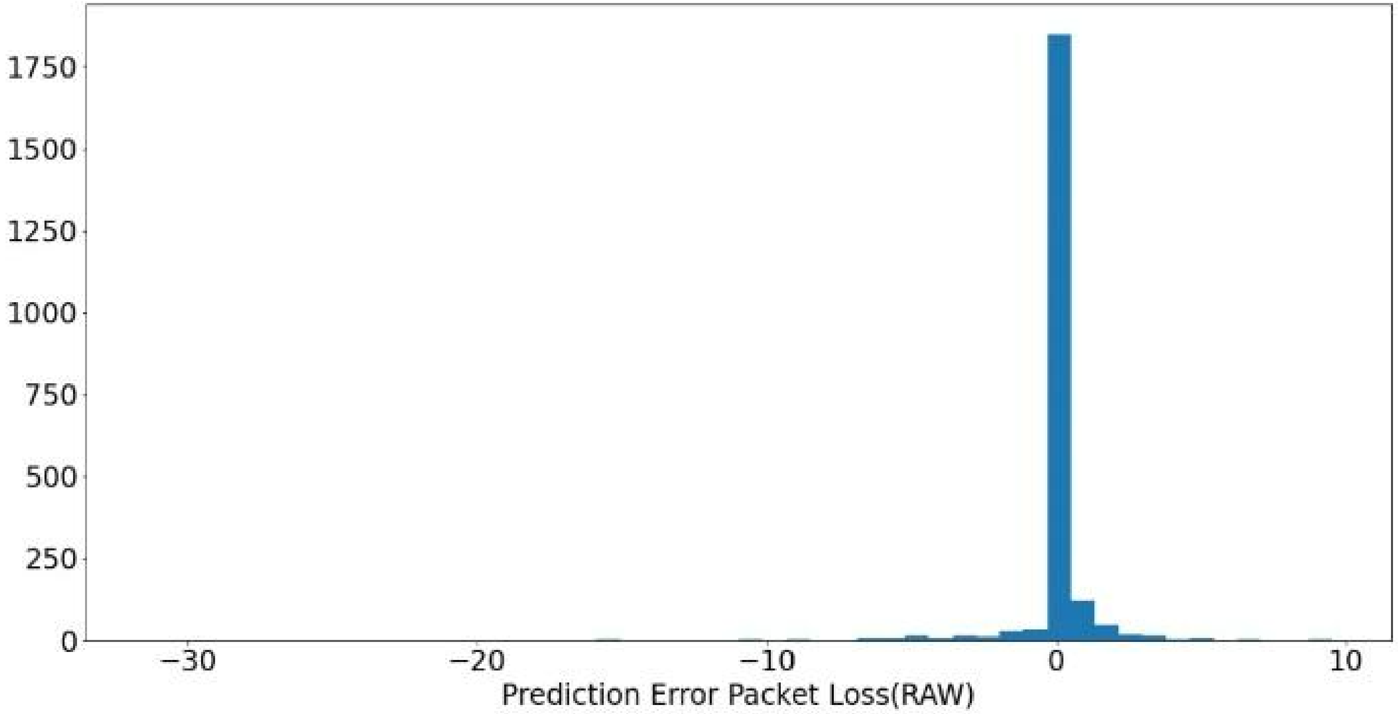
System Error Rate

- Decision Tree Result.
  - Accuracy, Mean Absolute Error (MAE) and Mean Square Error (MSE) results.

Regression Accuracy	0.9208100433033936
R2 square	0.9208100433033936
MAE	0.0636074511585642
MSE	1.272149023171285

System Error Rate

- Histogram of Error Technique Random Forest regression between real Packet Loss predicted packet loss.



System Error Rate

- Random Forest Regression Result.
  - Accuracy, Mean Absolute Error (MAE) and Mean Square Error (MSE) results.

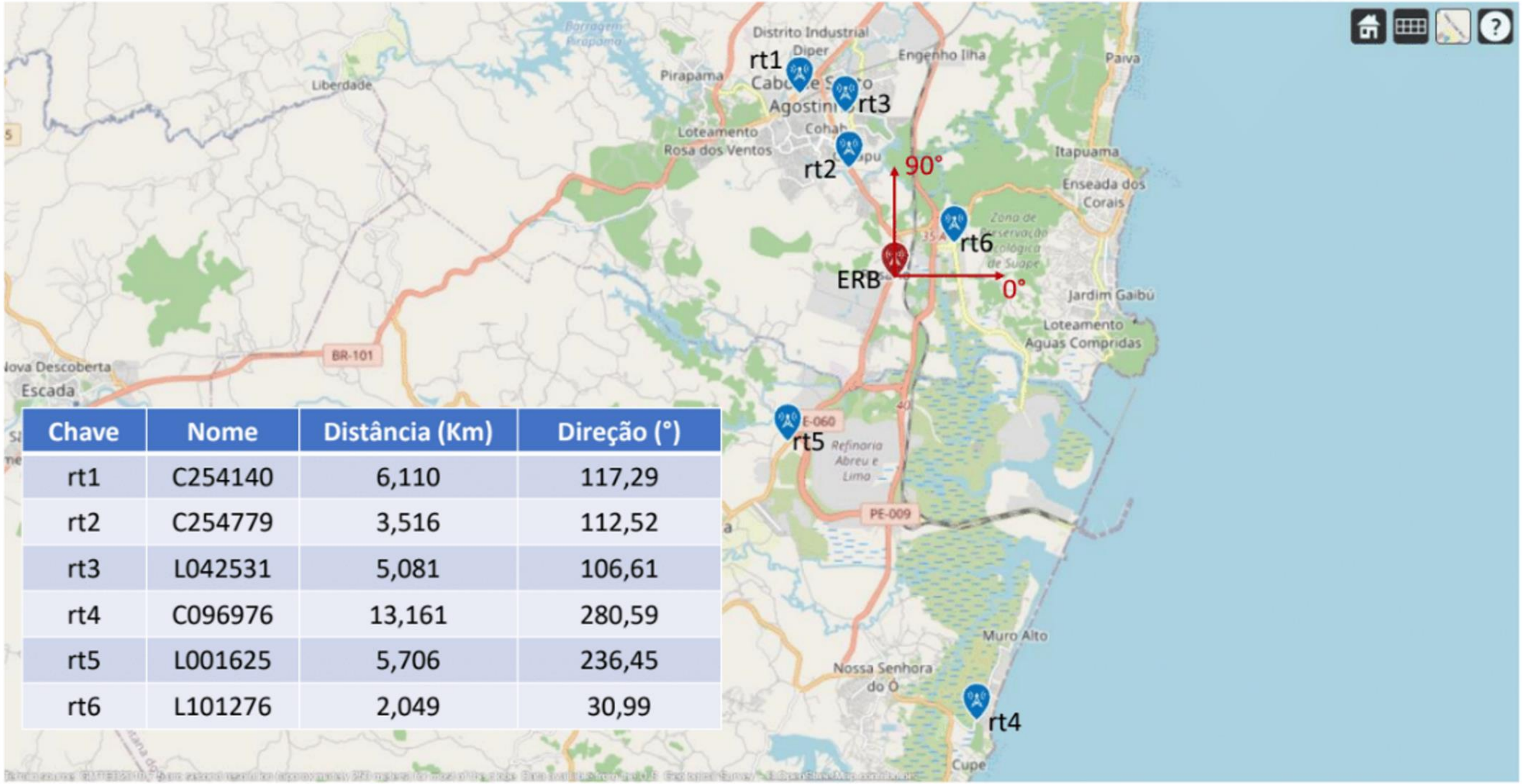
Regression Accuracy	0.9063156981269461
R2 square	0.9063156981269461
MAE	0.23228532485233988
MSE	1.5049937907011965

The Smart System Full

- Arrangement of Antennas and the control system installed at NEOENERGIA's BS.

The Smart System Full

- Positions of the ERB and the remote stations



Chave	Nome	Distância (Km)	Direção (°)
rt1	C254140	6,110	117,29
rt2	C254779	3,516	112,52
rt3	L042531	5,081	106,61
rt4	C096976	13,161	280,59
rt5	L001625	5,706	236,45
rt6	L101276	2,049	30,99

Conclusion

- Three stochastic techniques were tested using the HFSS electromagnetic simulator and the PSO presented better computational performance when simulation time is concerned;
- As a result of robustness tests performed continuously for 14 hours on the smart antenna system, subject to a large attenuation variation (-20dB to -32dB) on its digital attenuators, the system showed a very promising result of only 1% packet loss average.

Conclusion

- With the values of packet sending time, attenuation applied to the attenuators and transmission rate, two regression techniques were applied;

- It was found that the Decision Tree has a better prediction of loss packets than Random Forest Regression.

References

- Santos, M. R., de Oliveira, B. G. M., de Melo, M. T., de Oliveira, A. J. B., Santos, E. A. B., Freitas, R. D. "A smart antenna system for remote supervision" International Journal of Applied Electromagnetics and Mechanics, 2014, 45(1-4), p. 293–299.
- J. Robert J. Mailloux, Phased Array Antenna, Norwood: Artech House, 2018.
- Greda, L. A., Winterstein, A., Lemes, D. L., & Heckler, M. V. T. (2019). "Beamsteering and Beamshaping Using a Linear Antenna Array Based on Particle Swarm Optimization". IEEE Access, 1–1.
- Zhang, X., Lu, D., Zhang, X., & Wang, Y. (2019). "Antenna array design by a contraction adaptive particle swarm optimization algorithm". EURASIP Journal on Wireless Communications and Networking, 2019.
- Z. Cendes, "The development of HFSS". Proc. USNC-URSI Radio Sci. Meet., Fajardo, Puerto Rico, pp. 39–40, 2016.
- Hansen, N., Arnold, D.V., Auger, A. (2015). "Evolution Strategies. In: Kacprzyk, J., Pedrycz, W. (eds) Springer Handbook of Computational Intelligence". Springer Handbooks. Springer, Berlin, Heidelberg.

References

- Lambora, A., Gupta, K., & Chopra, K. (2019). “Genetic Algorithm- A Literature Review”. 2019 International Conference on Machine Learning, Big Data, Cloud and Parallel Computing (COMITCon).
- J. Kennedy and R. Eberhart, "Particle swarm optimization," Proceedings of ICNN'95 - International Conference on Neural Networks, 1995, pp. 1942-1948 vol.4.
- Freitas D, Lopes LG, Morgado-Dias F. “Particle Swarm Optimisation: A Historical Review Up to the Current Developments”. Entropy (Basel). 2020 Mar 21;22(3):362.
- Jain, N. K., Nangia, U., & Jain, J. (2018). “A Review of Particle Swarm Optimization”. Journal of The Institution of Engineers (India): Series B, 99(4), 407–411.
- Hassan, R., Cohanim, B., de Weck, O., & Venter, G. (2005). “A Comparison of Particle Swarm Optimization and the Genetic Algorithm”. 46th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference.
- Kachitvichyanukul, V. (2012). “Comparison of Three Evolutionary Algorithms: GA, PSO, and DE”. Industrial Engineering and Management Systems, 11(3), 215–223.
- Oliveira, J. M. A. M, D. L. de Melo, C. P. do N. Silva, A. J. B de Oliveira, Douglas C. P. Barbosa, D. de F. Gomes, A. Gomes Barboza, M. T. de Melo, B. A. Kleinau, R. J. F. P. V. de Almeida.(2022), “Control and Optimization of a Smart Antenna Array by PSO”. International

References

- Journal of Applied Electromagnetics and Mechanics, 70(2). 197 – 212, DOI: 10.3233/JAE-210116.
- Mohab Abd-Alhameed Mangoud and H. M. Elragal, Antenna Array Pattern Synthesis and Wide Null Control Using Enhanced Particle Swarm Optimization, Progress In Electromagnetics Research B, (2009), 17, 1–14, doi:10.2528/pierb09070205.
- Jian-feng Li, Bao-hua Sun, and Qi-zhong Liu, PSO-based optimization of broadband antenna array for space-division communication system. 2008 8th International Symposium on Antennas, Propagation and EM Theory (March 2008), doi:10.1109/isape.2008.4735206.
- T. H. Nguyen, H. Morishita, Y. Koyanagi, K. Izui and S. Nishiwaki, A Multi-Level Optimization Method Using PSO for the Optimal Design of an L-Shaped Folded Monopole Antenna Array, IEEE Transactions on Antennas and Propagation , 62 (1) (2014), 206-215, doi: 10.1109/TAP.2013.2288785.
- “Monitor your IT infrastructure with Paessler PRTG”. Accesso: 12 de December 2022. <https://www.paessler.com/prtg#products>
- Dibyendu Deb. “Comparing machine learning models for a regression problem”. Accesso: 03 de December, 2022. <https://dibyendudeb.com/comparing-machine-learning-regression-models-using-python/>.

We3G-3

Precoded Supervising System Based on Smart Antenna Array for Electric Power Distribution Grid: Optimization Aspects

J. M. A. M. de Oliveira[1], A. Gomes Barboza[1], R. G. M. dos Santos[1], M. de Oliveira Alencar[1], J. H. de A. Dias Silva[1], M. F. B. Pedrosa[1], D. de Filgueiras Gomes[1], A. J. Belfort de Oliveira[1], M. T. de Melo[1], R.J.F.P.V. Padilha[2], B. A. Kleinau[2]
[1]Dept. of Electronics and Systems Federal University of Pernambuco, Recife, Brasil
[2]Celpe – Neoenergia CEP: 50050-902, Recife, Brasil