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Chronological Simulation of the Interaction between Intermittent Generation and Distribution Network

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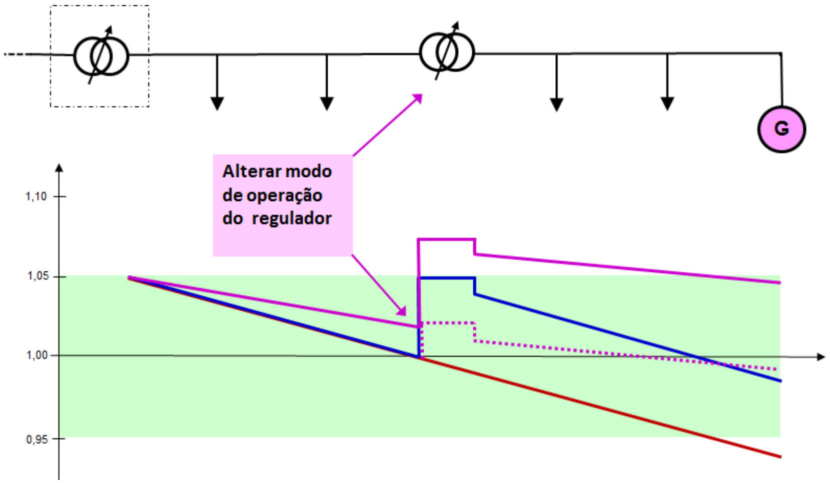
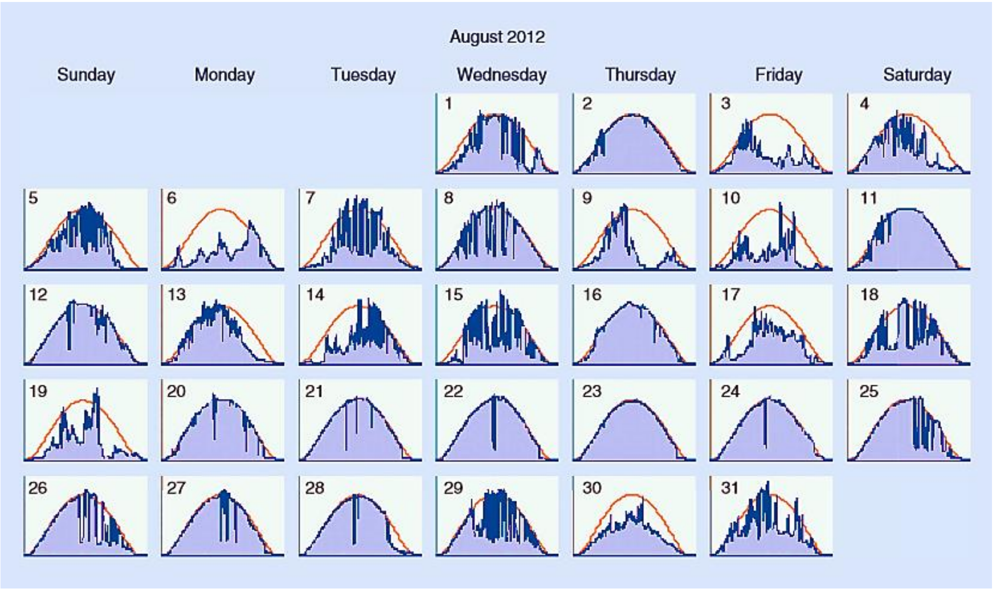
Scenario and Motivation

- **Growing presence of intermittent energy sources (wind, solar, etc.)**
- **Considerable part of it is on the form of distributed generation connected to the distribution network (MV and LV)**
- **Problems**
  - Steady-state and transient voltage regulation
  - Protection coordination
  - Power quality
  - Feeder loading
  - Reverse power flow
  - Etc.

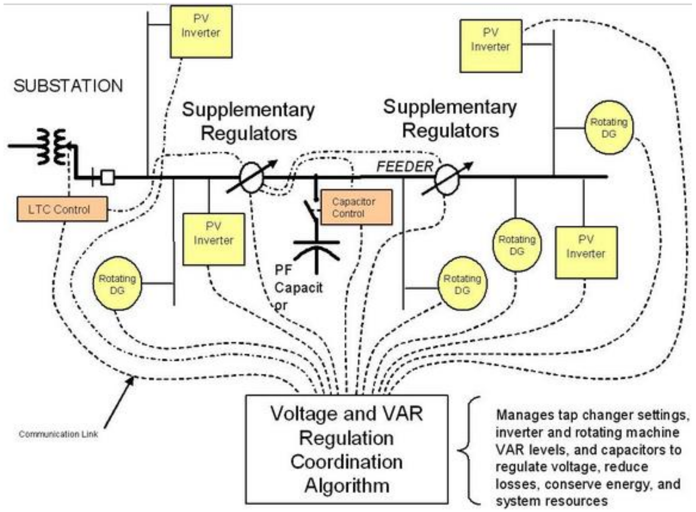




Fonte: C.Trueblood et alli., "PV Measures Up for Fleet Duty", IEEE Power and Energy, vol11, no. 2,pp. 33-44, Mar/Apr 2013.

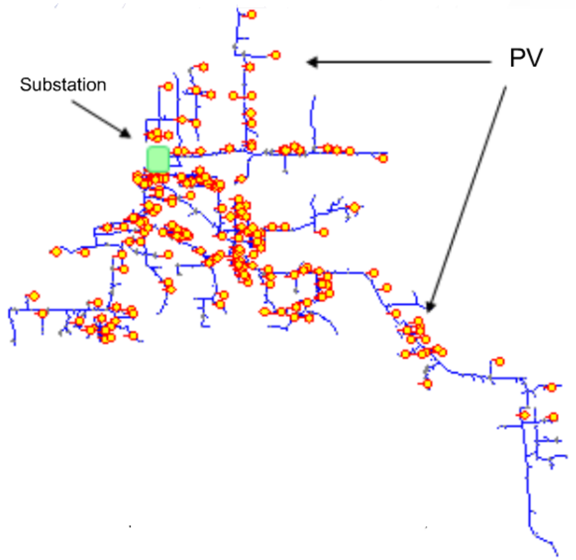
Smart Grid

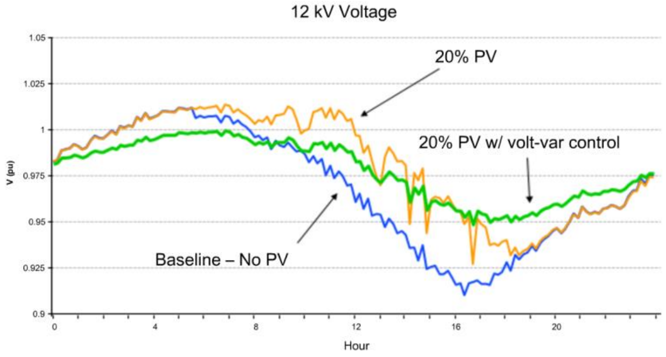
- **Smart Grid technologies are essential to cope with intermittent sources**
  - Advanced Metering Infrastructure (AMI)
  - Volt and Var Control and Optimisation
  - Microgrids
  - Virtual Power Plants
- **New analysis and simulation tools are required to design control systems and strategies**



Simulation Studies

- **Presently**
  - Most studies performed using only load flow software
  - Ad hoc treatment of the time variability
  - Limitation to represent the chronological action of controllers
- **Requirements of new simulations tools**
  - Quasi-dynamic simulation mode allowing modeling of the system time evolution with the adequate level of detail
  - Three phase modeling
  - Facilities to easily include new models of generators, control and protection devices, loads, etc.
  - Able to deal with time series of load and generation, including graphics display and analysis





Proposed Simulation Methodology

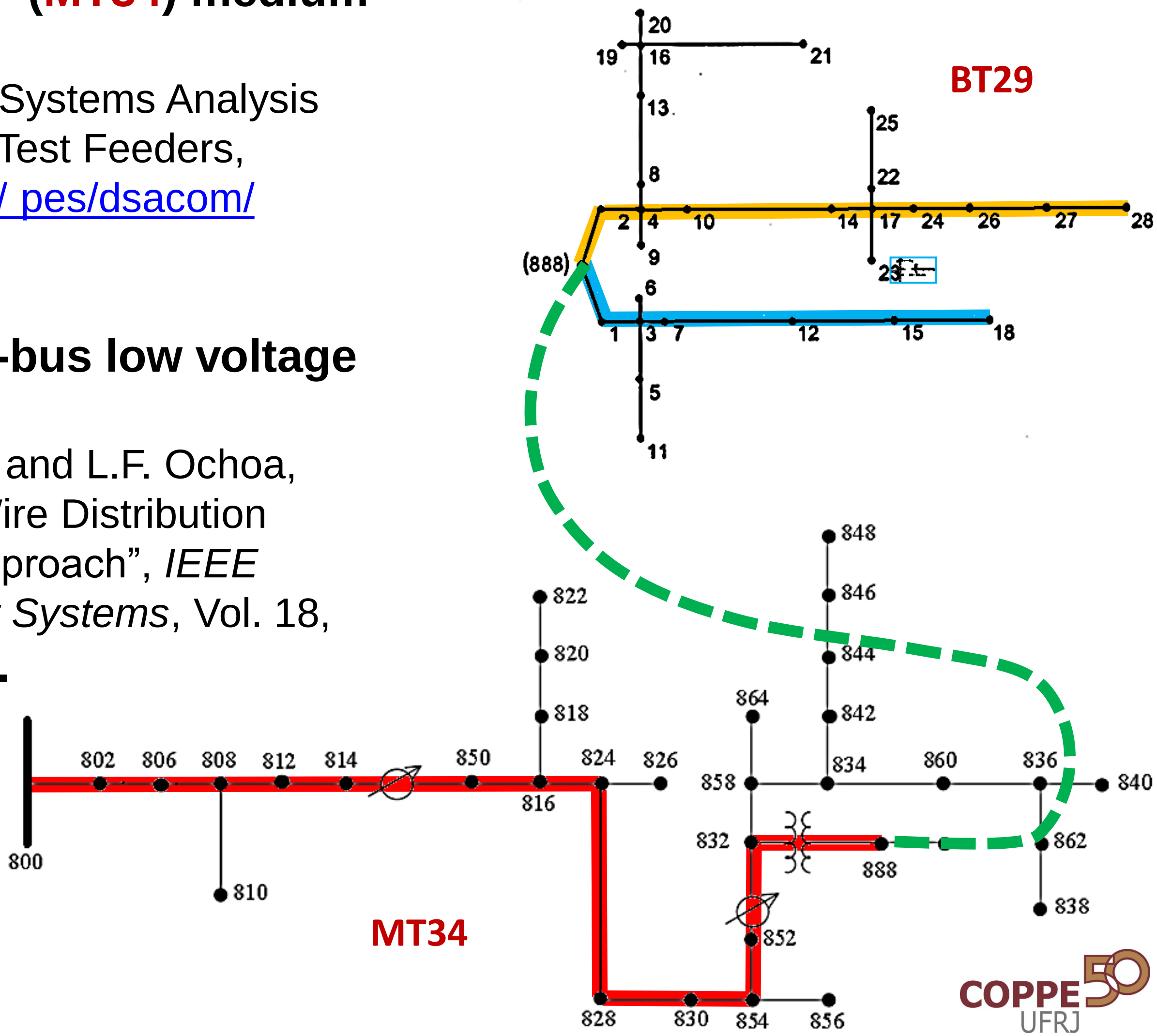
- **Based on an integrated computer environment comprising static simulation (power flow) and dynamic simulation (electromechanical) using a Three-Phase Single-Phase formulation**
- **Chronological Simulation**
  - Power Flow used for initialization
  - Electromechanical Simulation used to process all the points of the load/generation curves, considering:
    - The point of connection to the transmission system or sub-transmission is represented as a generator with classic model and very high inertia, behind the system short-circuit impedance
    - No voltage regulators and governor considered in the equivalent generator
    - Loads modeled as constant active and reactive power at each interval
    - The elements of control and protection are modeled as usual in long term electromechanical simulation studies
    - Large integration steps regulated by the load generation time series
    - Intermittent generation time series determined by information about solar radiation , wind, etc.

http://www.coep.ufrj.br/~tarang/Simulight/

Test Systems

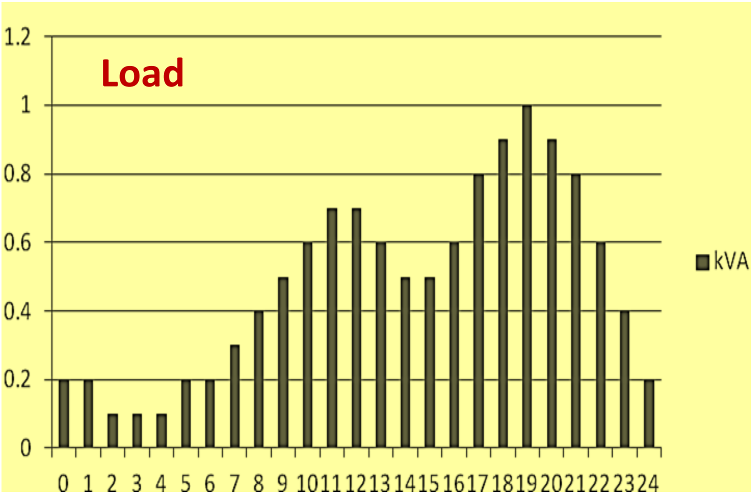
- **IEEE 34-bus feeder (MT34) medium voltage**
  IEEE PES Distribution Systems Analysis Subcommittee, Radial Test Feeders, http://ewh.ieee.org/soc/ pes/dsacom/ testfeeders/index. html

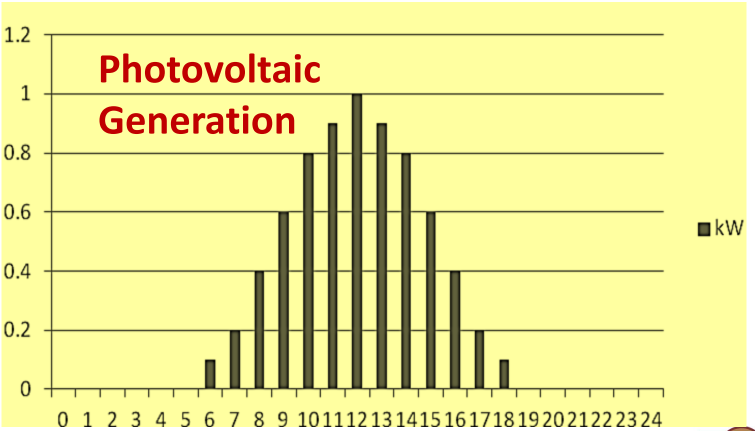
- **Actual Brazilian 29-bus low voltage network**
  R.M. Ciric, A.P. Feltrin, and L.F. Ochoa, “Power Flow in Four-Wire Distribution Networks—General Approach”, *IEEE Transactions on Power Systems*, Vol. 18, No. 4, November 2003.



Load and Generation Variation

- **The load in all load busses varies daily according to a normalized load curve modulated by the base case values**
- **Identical procedure for the one phase PV generation in the chosen busses**
- **Location (bus and phase) and capacity of the PV generator selected randomly**





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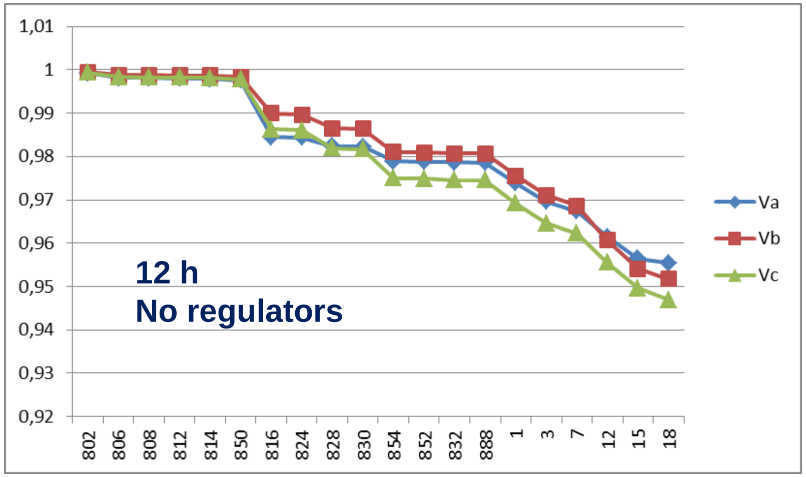
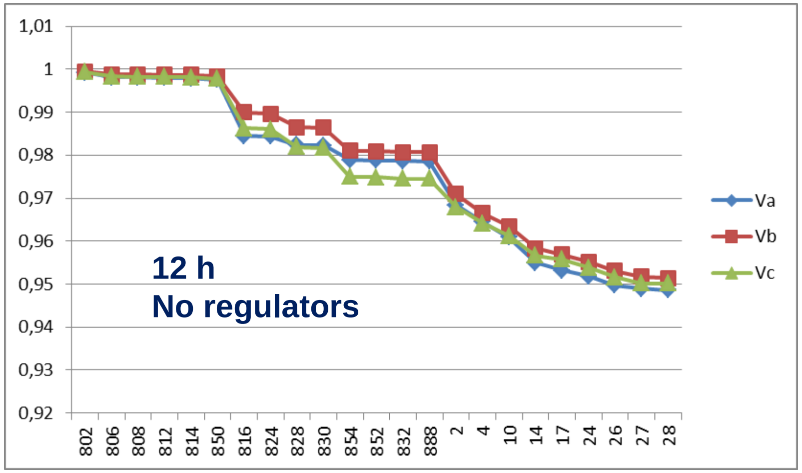
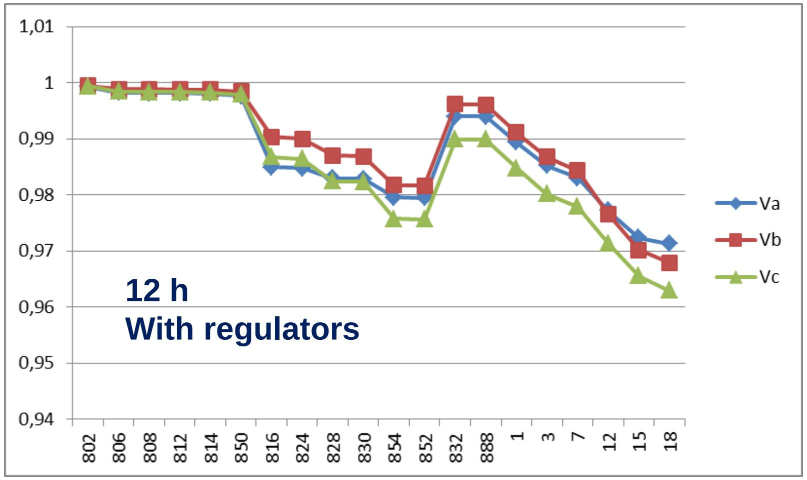
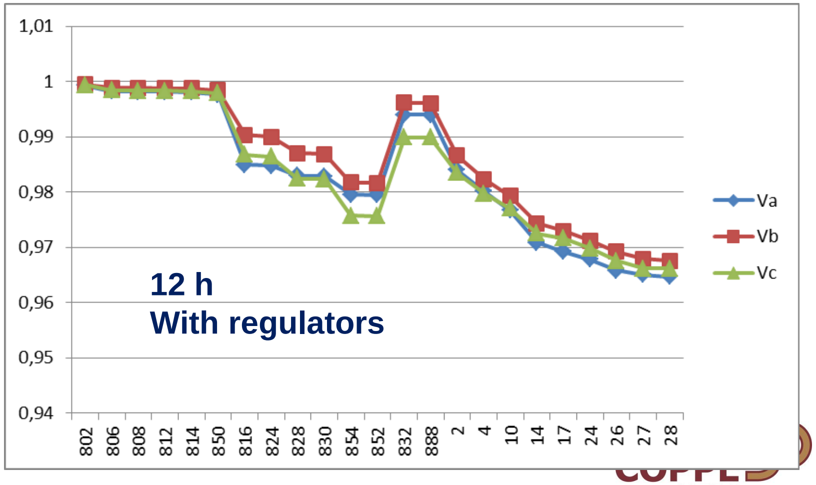
Results without PV Generation







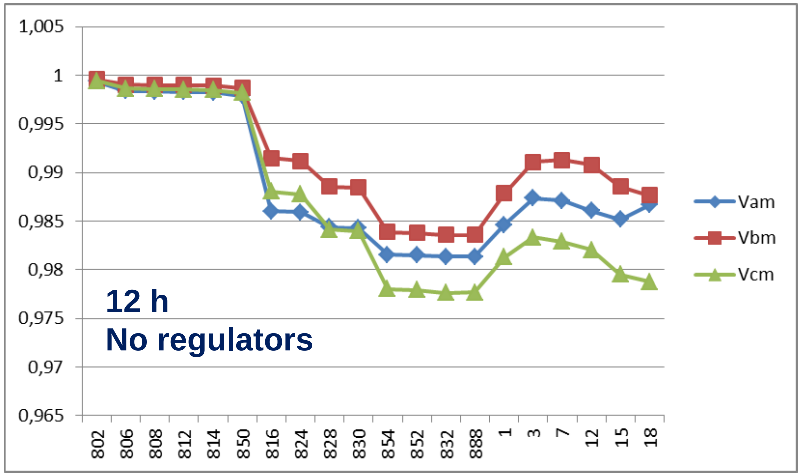


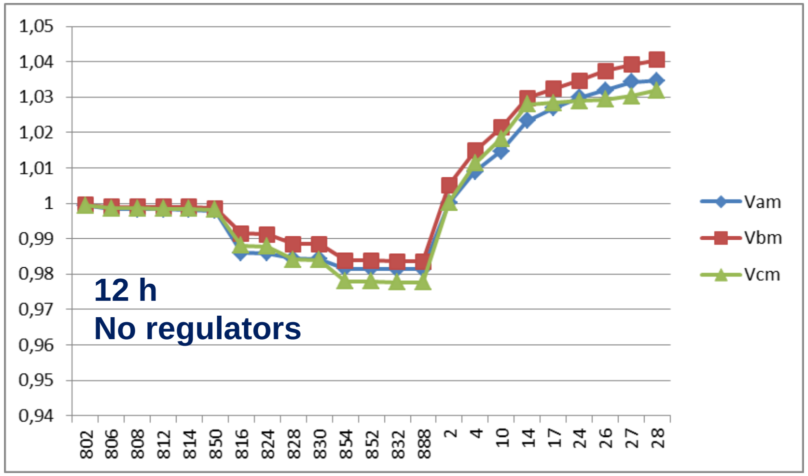
Results with PV Generation

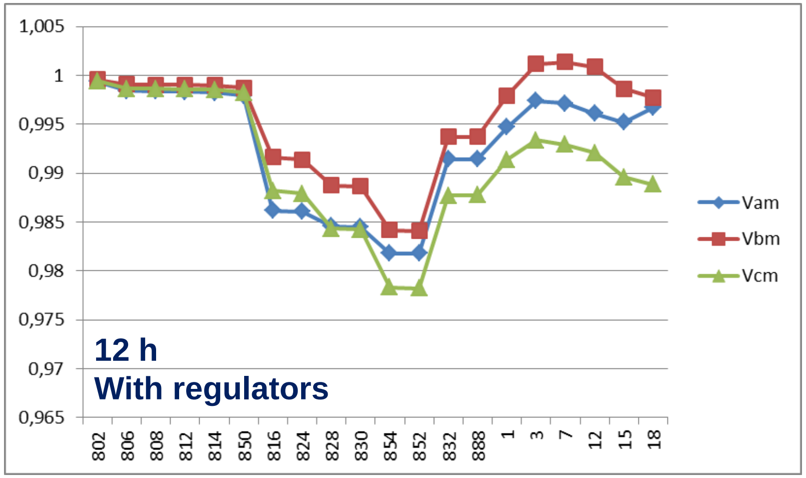
- Studies with PV in 10%, 50%, 80% and 100% if the LV buses
- Generation configuration for 10% penetration of PV generation in the LV network (BT29)
- Results shown the average values of the 10 configurations

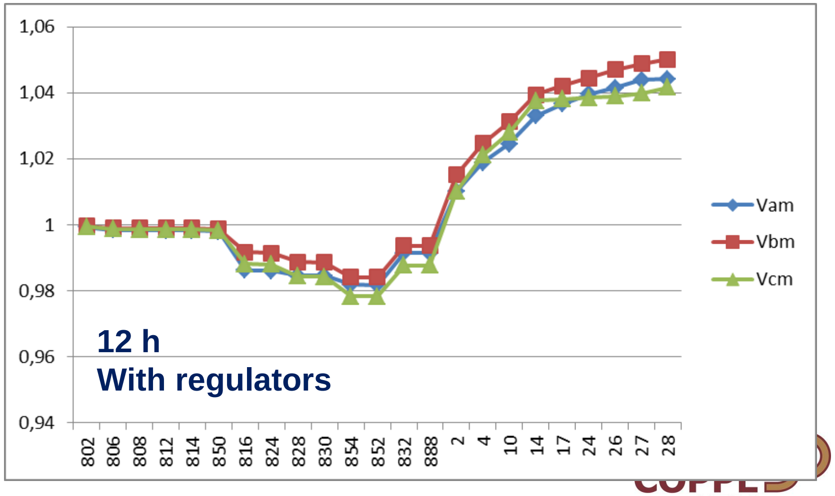
Bus	Phase	kWp	Bus	Phase	kWp
Configuration 1			Configuration 6		
17	c	5	19	a	1
8	a	4	2	c	5
12	a	3	23	b	1
Configuration 2			Configuration 7		
22	b	1	3	c	4
7	c	1	11	b	2
6	a	1	14	c	3
Configuration 3			Configuration 8		
7	b	4	23	b	4
1	c	5	13	a	1
17	b	1	14	a	2
Configuration 4			Configuration 9		
23	b	3	7	b	4
25	a	2	25	a	4
28	a	4	6	a	4
Configuration 5			Configuration 10		
17	b	5	22	a	4
20	a	2	18	a	1
2	a	1	23	b	1

Results with 100% PV Generation









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Conclusions

- **The proposed methodology combines static and dynamic simulations in an integrated computer environment without requiring great changes in the software**
- **The described methodology presents the advantage of modeling precisely the chronological effect of control devices action to respond to the time evolution of load and generation**
- **The methodology was tested by studying the connection of monophasic photovoltaic generation in a low voltage distribution network**
- **The results show the effectiveness of the methodology for this type of anlysis**

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