



# **CEPEL's new PMU Laboratory LabPMU**

**José Eduardo Alves Jr. (CEPEL)**

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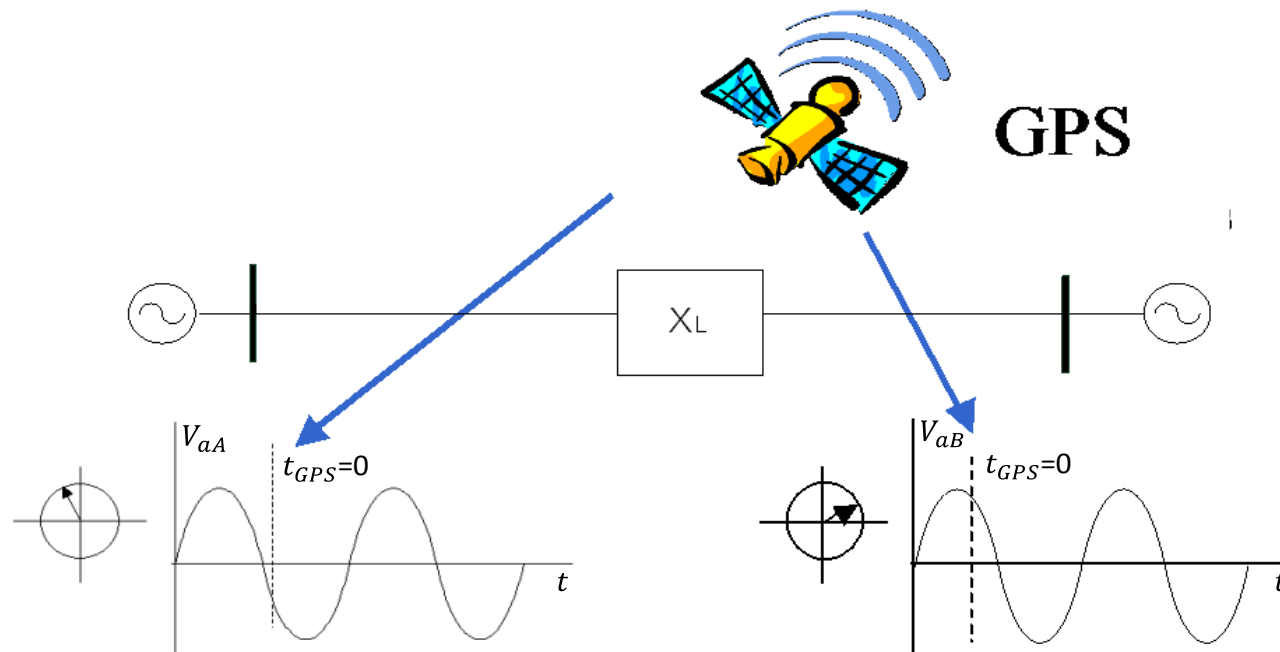
1. Introduction
2. Driver
3. Laboratory
4. Previous Works
5. Discussions

You control what you measure.

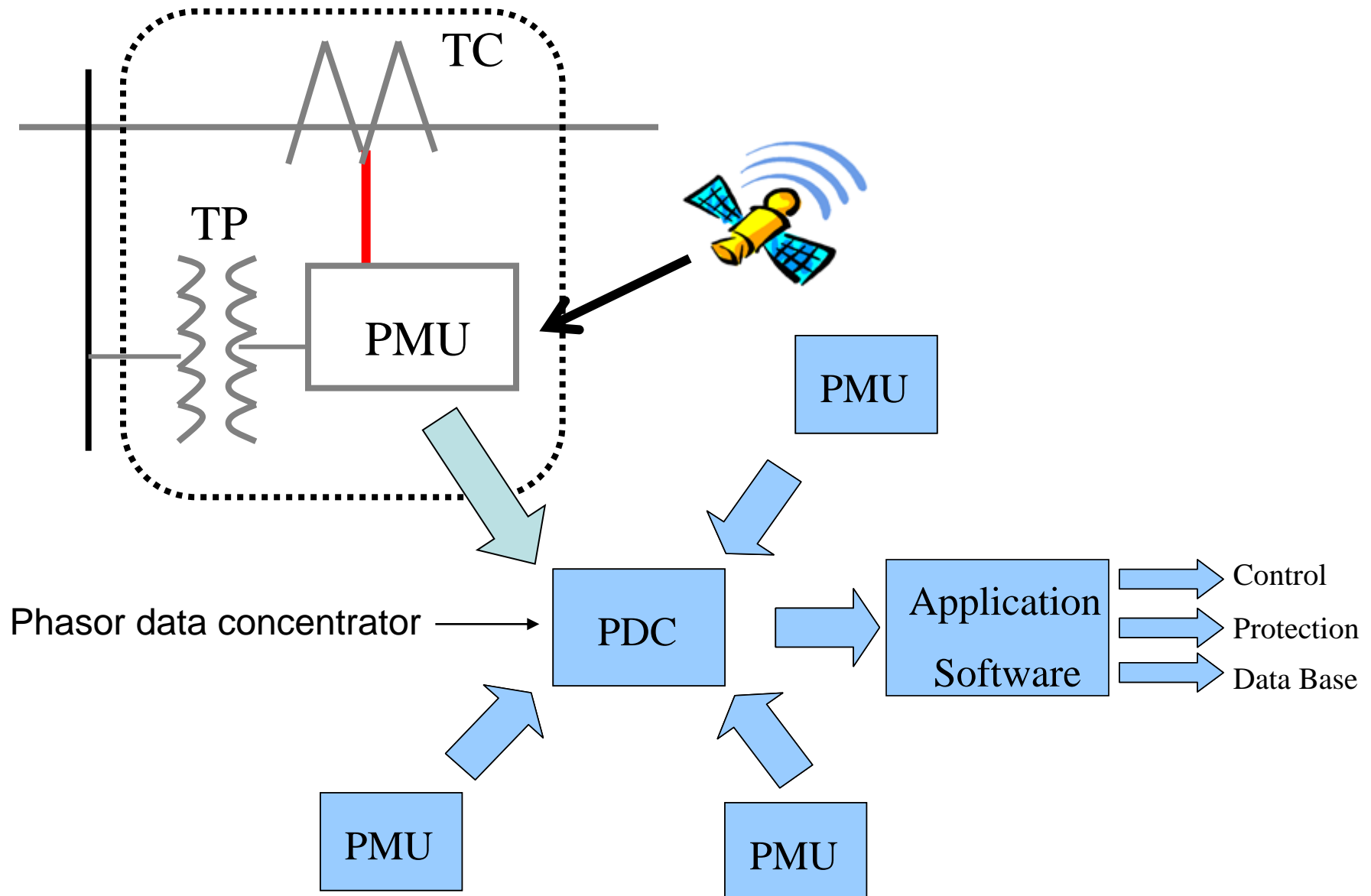
If you measure more precisely and quickly you will control better.

PMUs may provide better measurements in real time and help analysis off line.

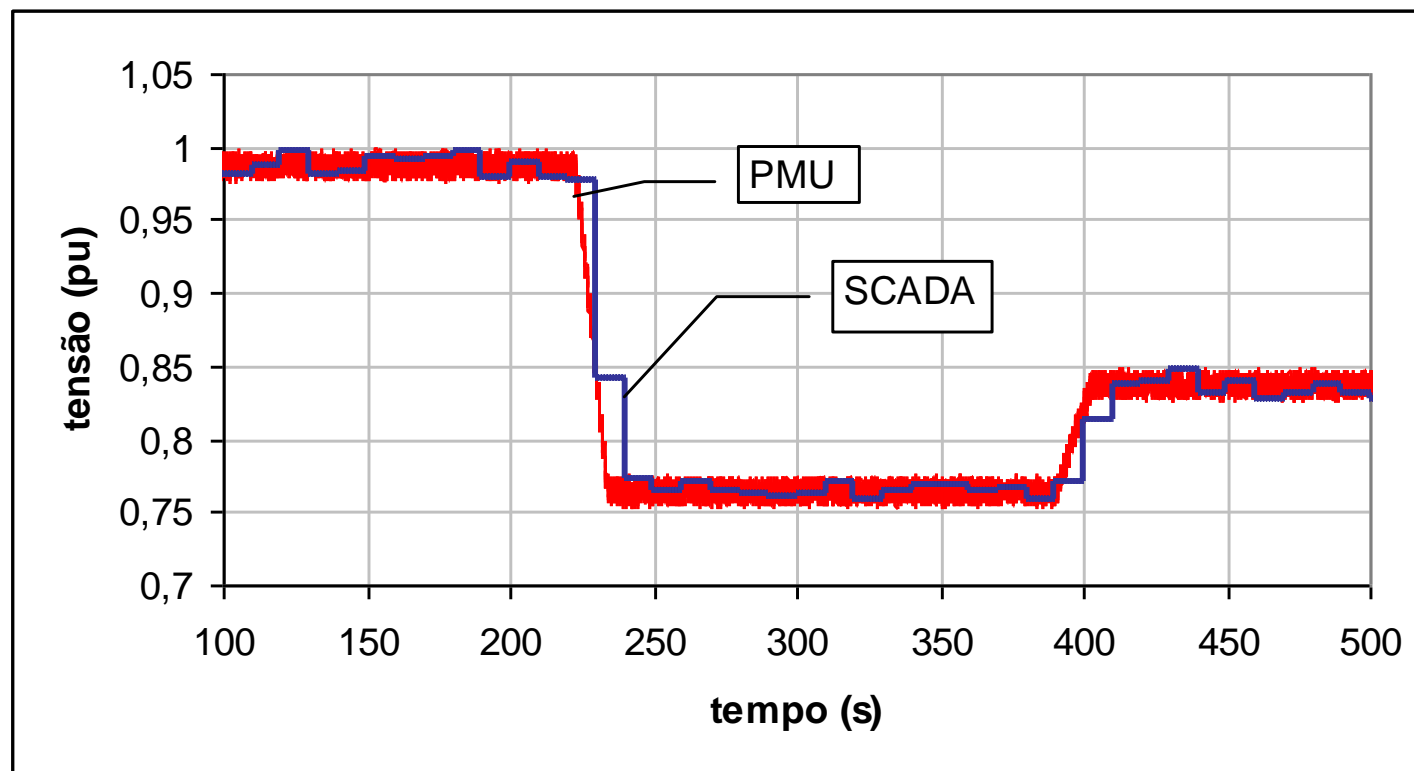
# CONCEPT OF PMUs



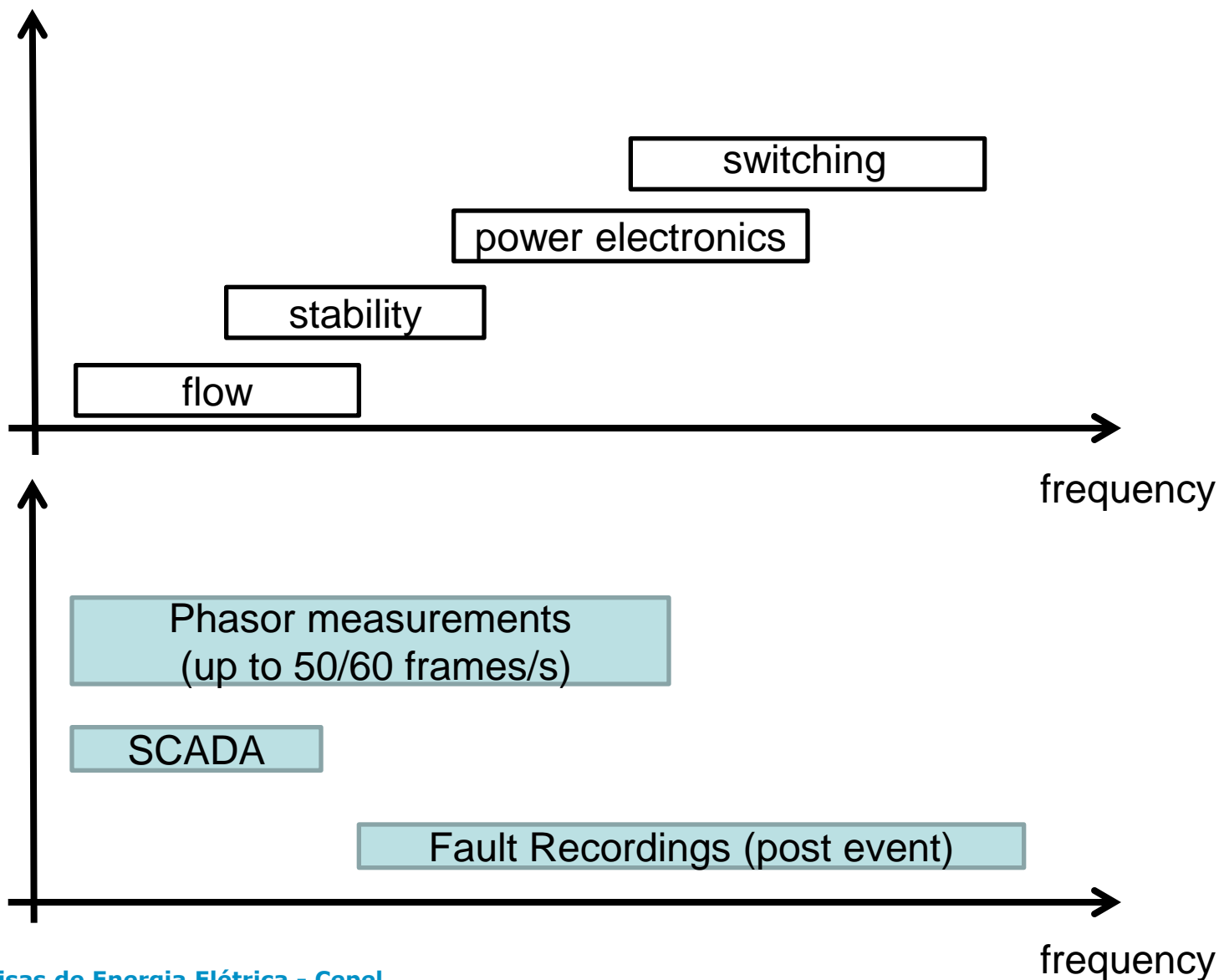
# CONCEPT OF PMUs



## PMUs and SCADA



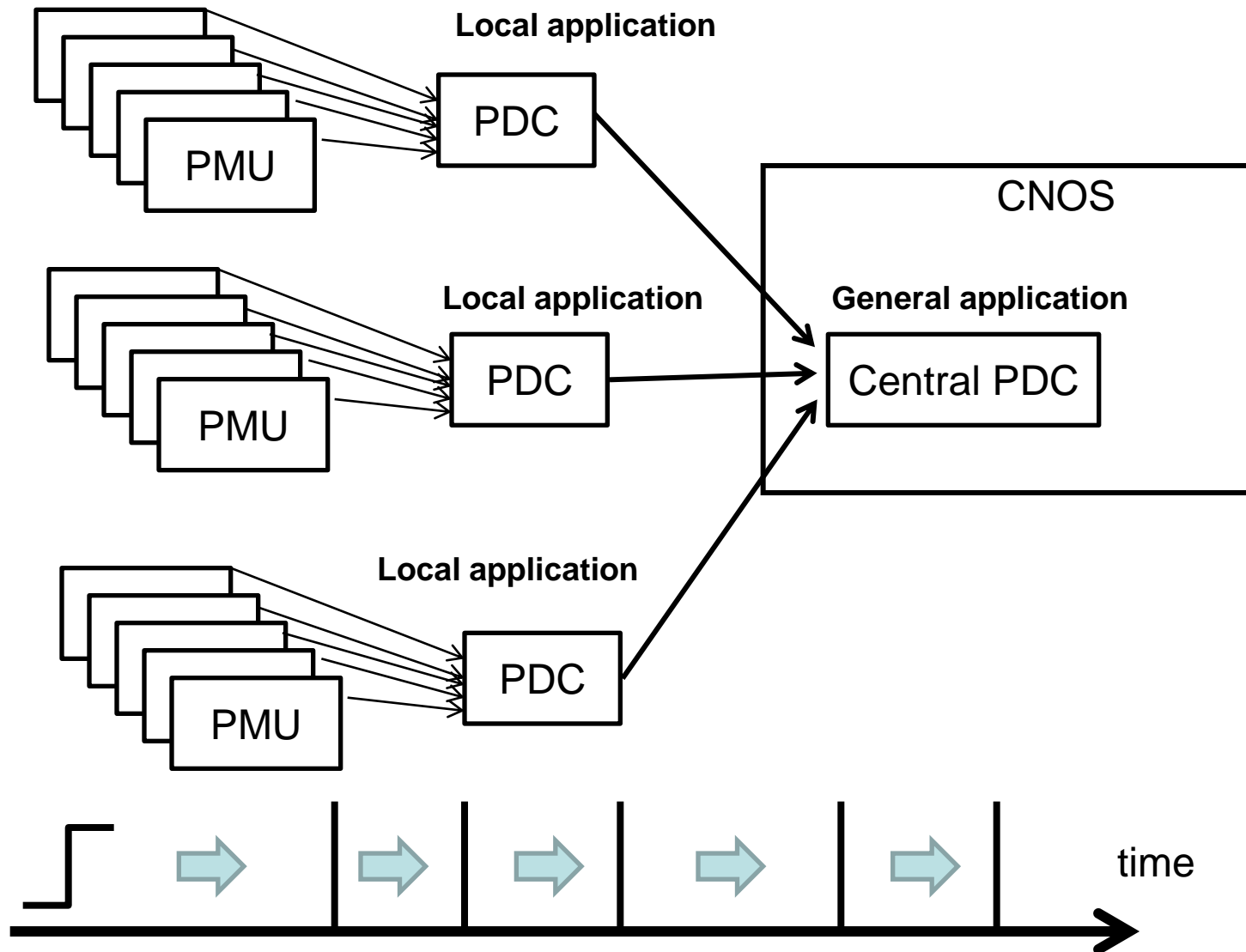
# CONCEPT OF PMUs



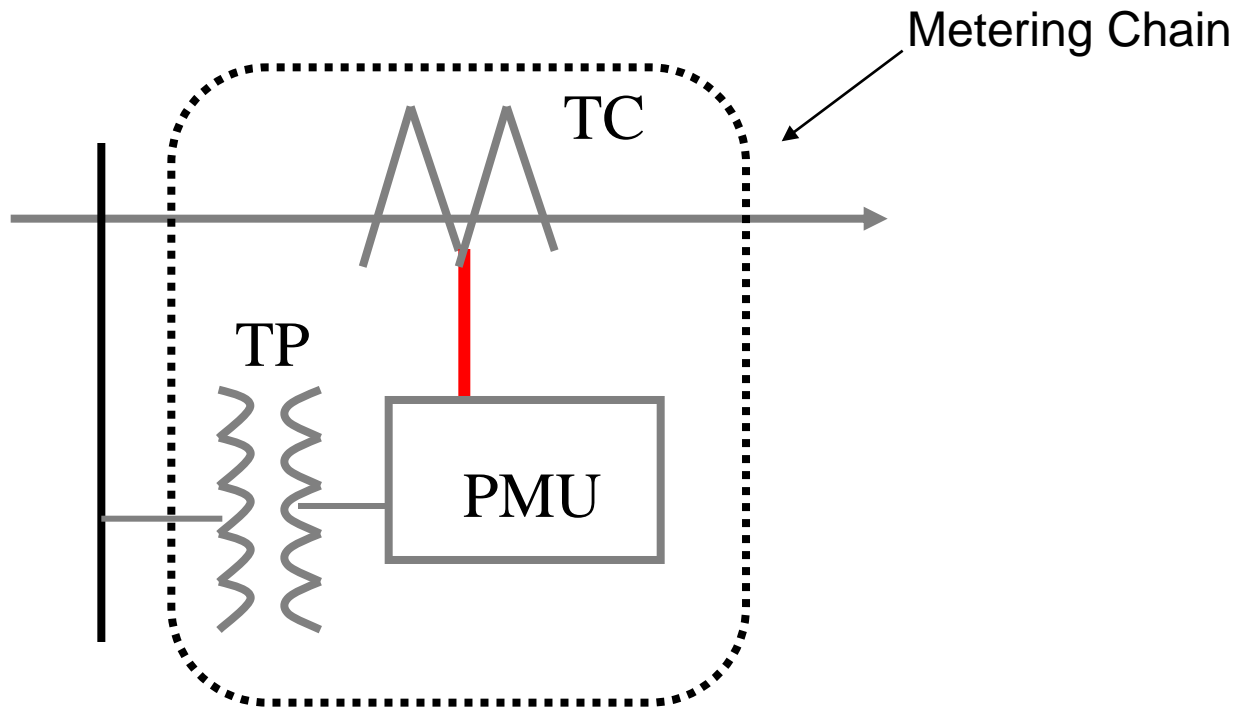
- Off-line:
  - Post event diagnostics.
- Real time:
  - Monitoring, protection and Control.
  - Examples: enhance state estimation, monitoring critical angles, monitoring oscillations, FACTS equipment control.



# MOTIVATION: APPLICATIONS



# MOTIVATION: METERING CHAIN



## Synchrophasor Laboratory

- **To give technological support to :**
  - 1. Study the PMU applications.**
    - **Simulating in real time using real PMUs and virtual PMUs if necessary.**
  - 2. Study PMU performance using a metrological test bed based on NIST's SynchroMetrology Lab.**

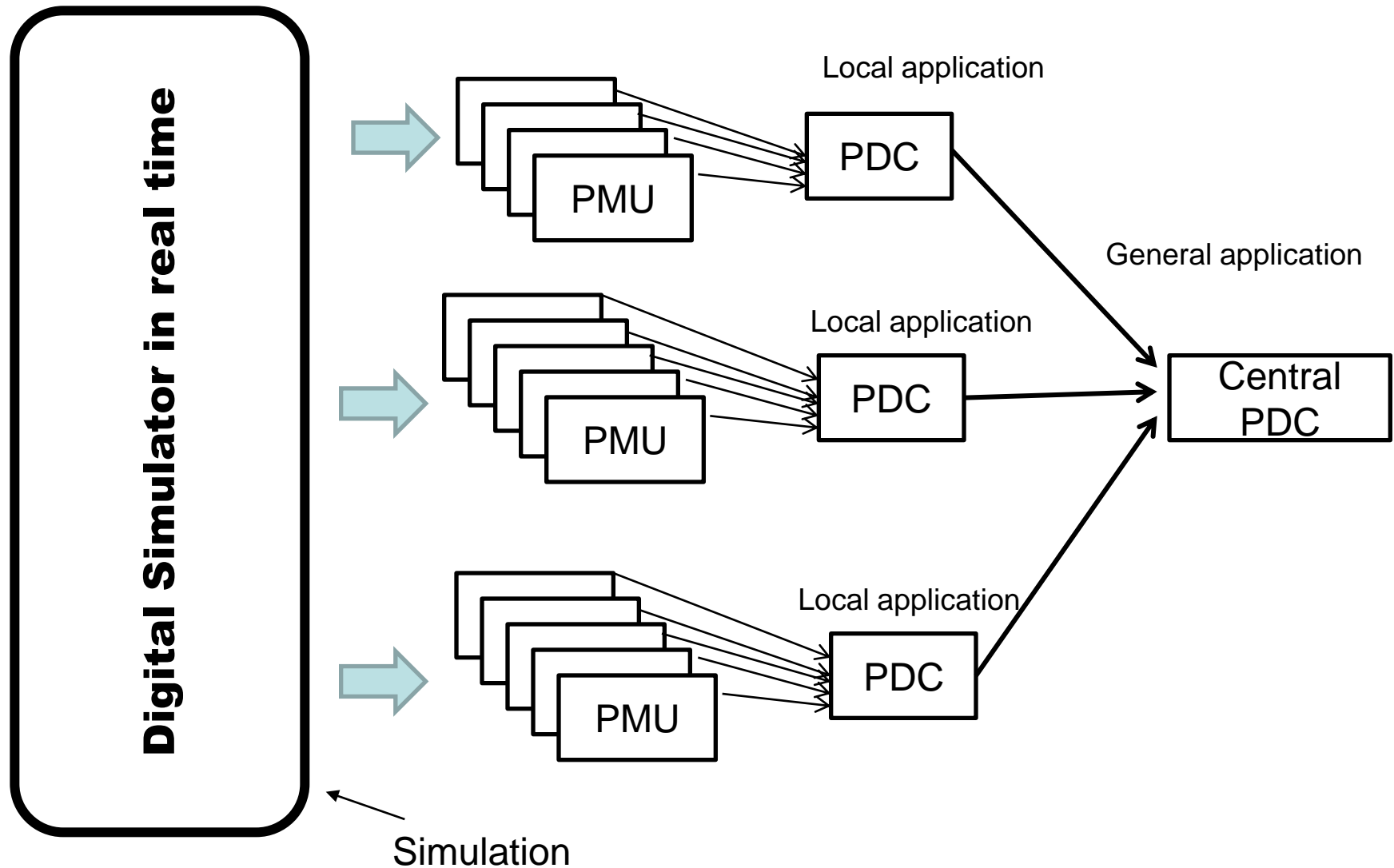
## Synchrophasor Laboratory

1. Real time simulator;
2. PMUs and PDC;
3. PMU test bed instrumentation;
4. Auxiliary instrumentation.

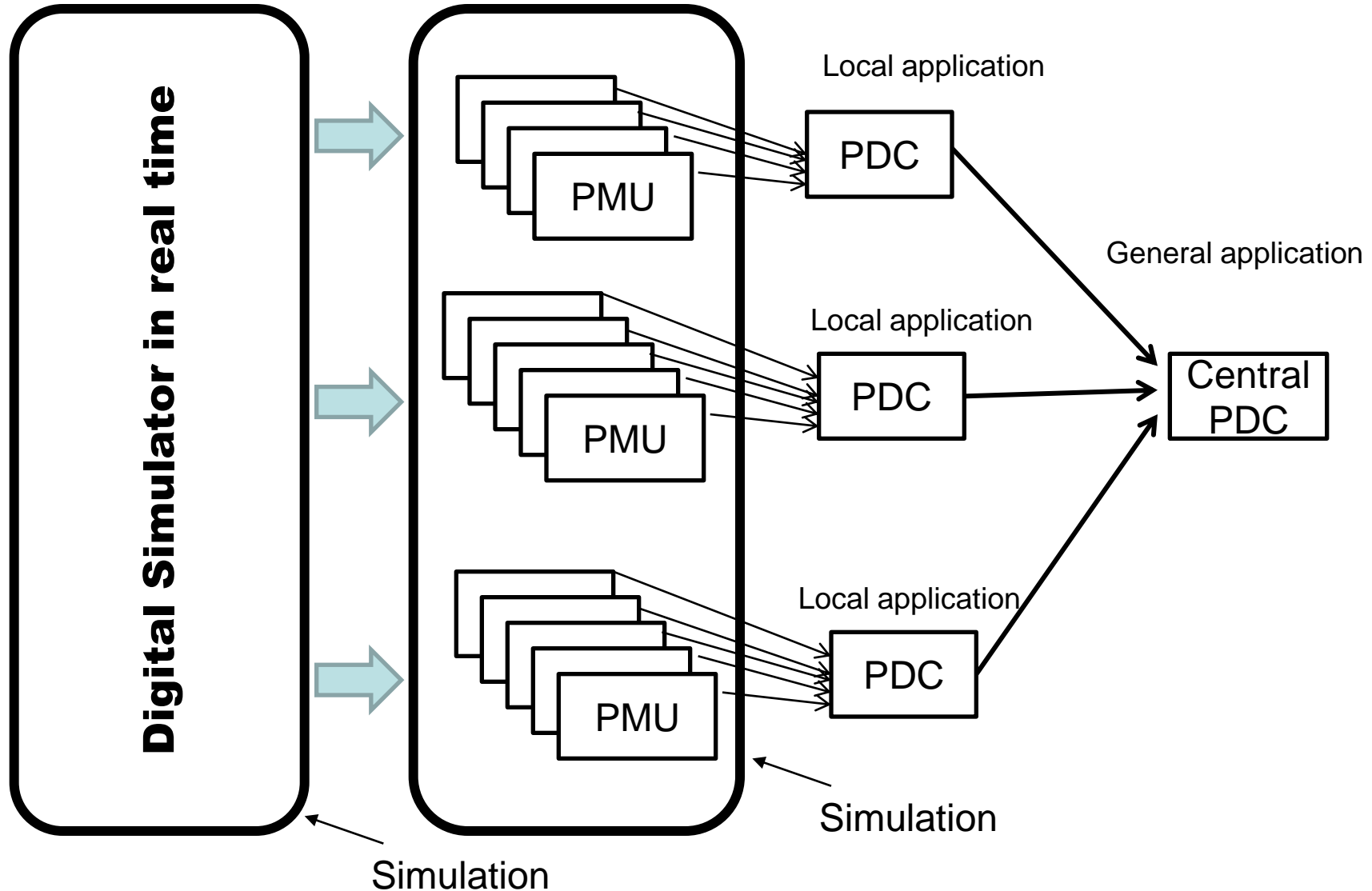
## Synchrophasor Laboratory

- **What equipment should have?**
  1. Flexible equipment
  2. Up to date equipment
- **What applications should study first?**
  1. We are beginning discussions about it. Monitoring oscillations should be a good guess.

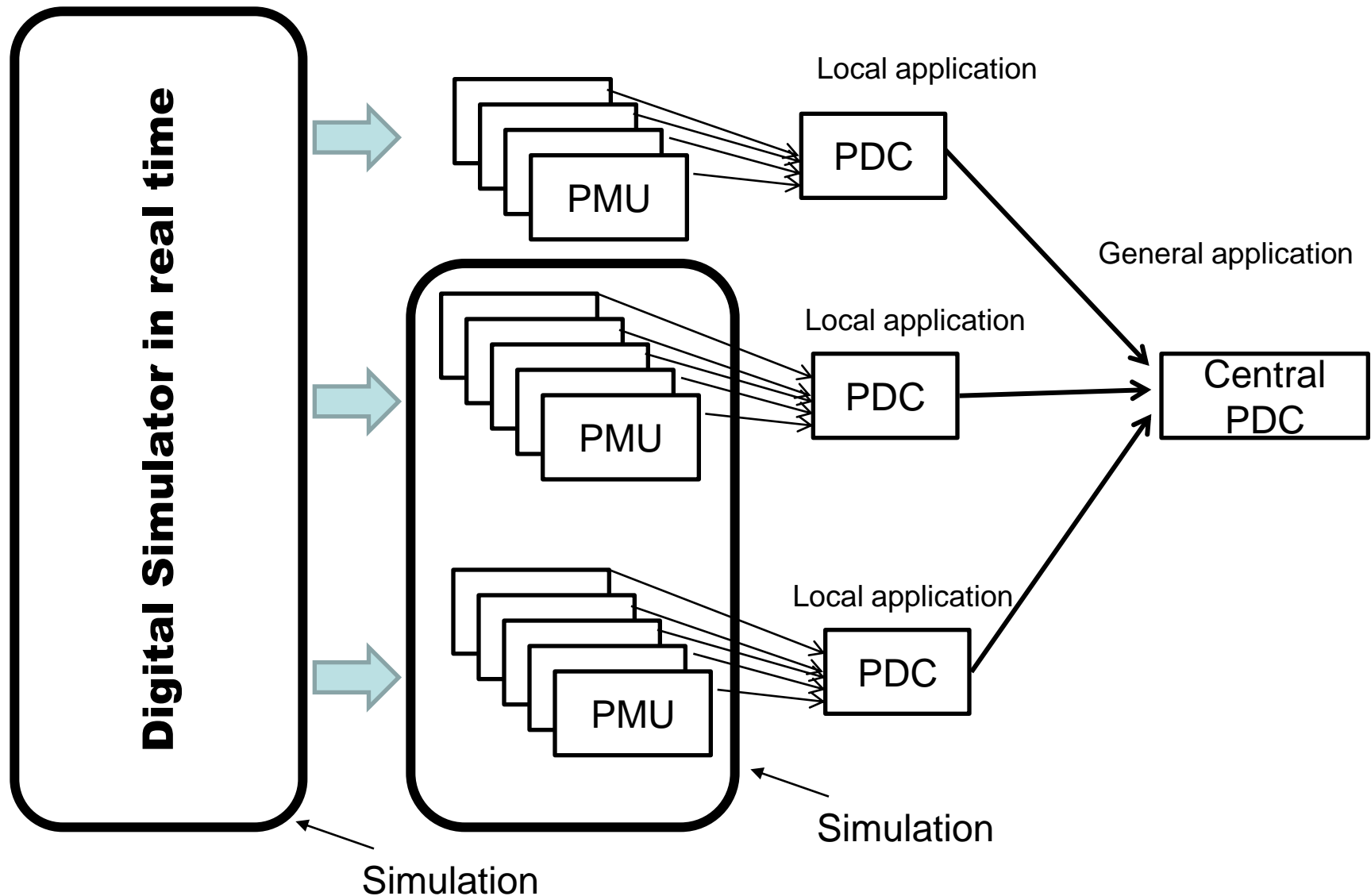
# POSSIBLE CONFIGURATIONS



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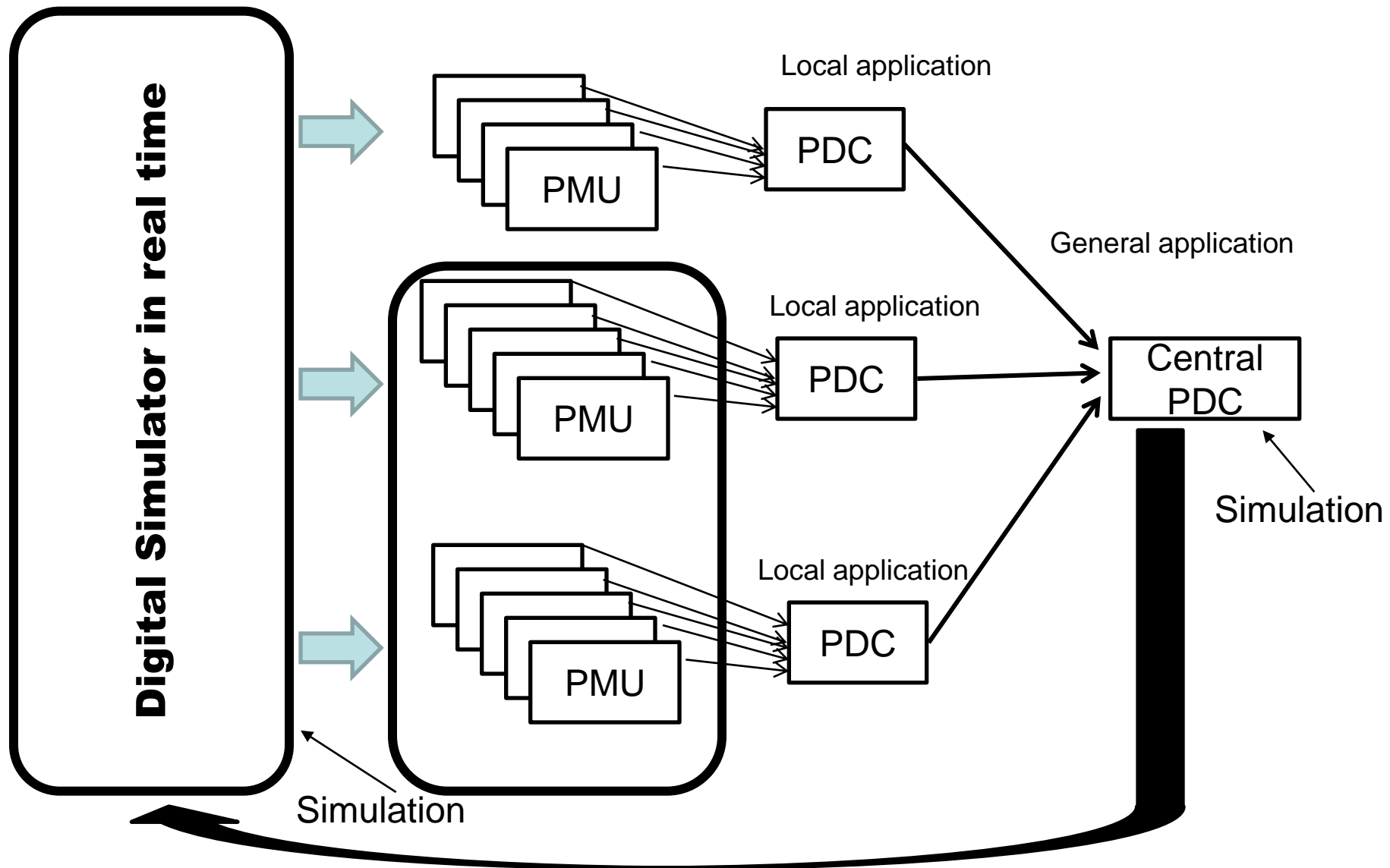


# POSSIBLE CONFIGURATIONS





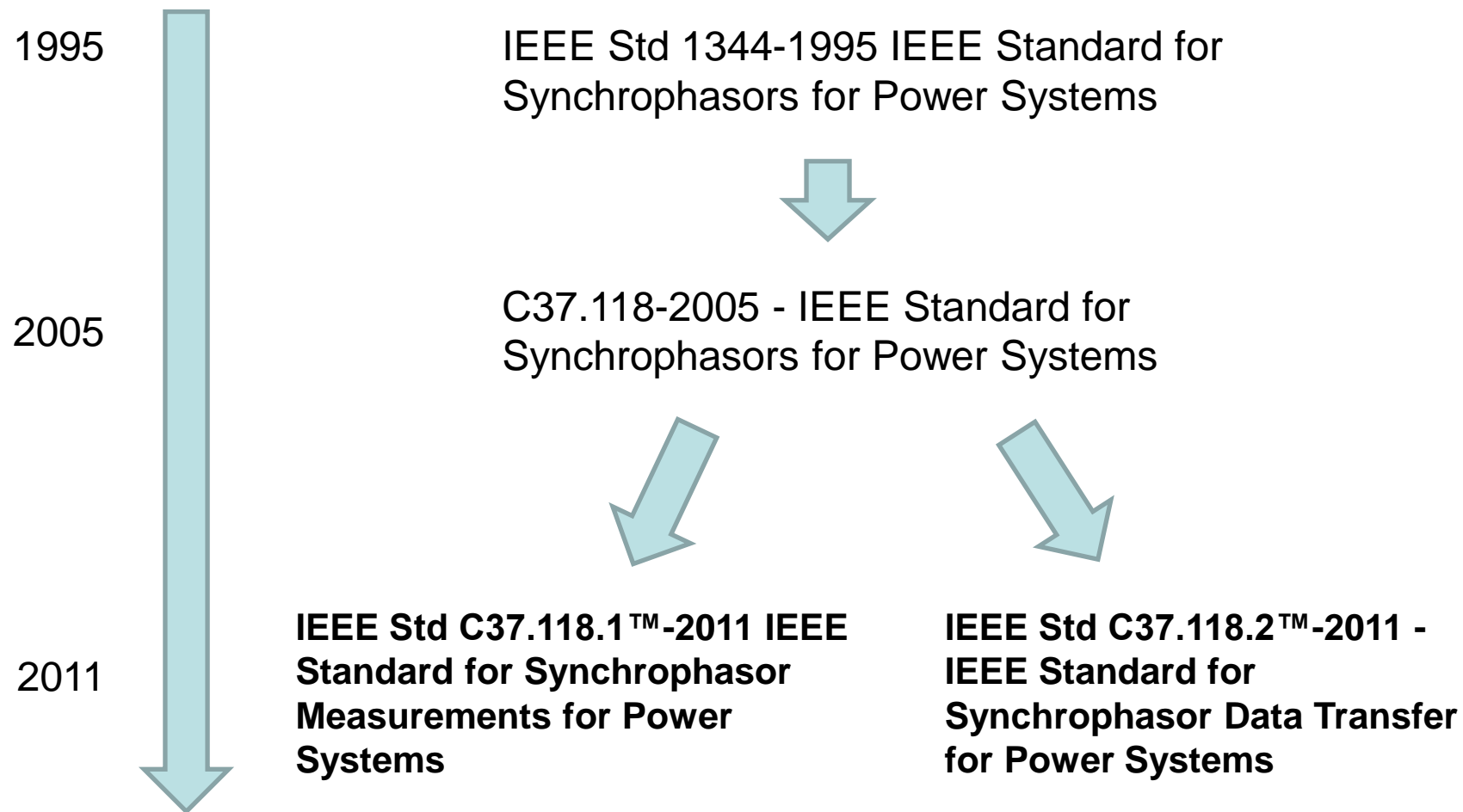
# POSSIBLE CONFIGURATIONS: Control in the loop



## Synchrophasor Laboratory

- **What equipment should have?**
  1. Precision equipment
  2. Up to date equipment
  3. Flexible equipment
- **What tests should be applied?**
  1. IEEE Standard tests
    - C37.118.1 (metering)
    - C37.118.2 (communication)

# STANDARD ASPECTS



- Categories:
  - P (protection)      Based on: Accuracy **X** Speed
  - M (metering)
- To evaluate the performance of PMUs:
  - TVE
  - FE (**F**requency **M**easurement **E**rror):
  - RFE (**R**ate of change of **F**requency measurement **E**rror): ROCOF

- Tests:

- Static

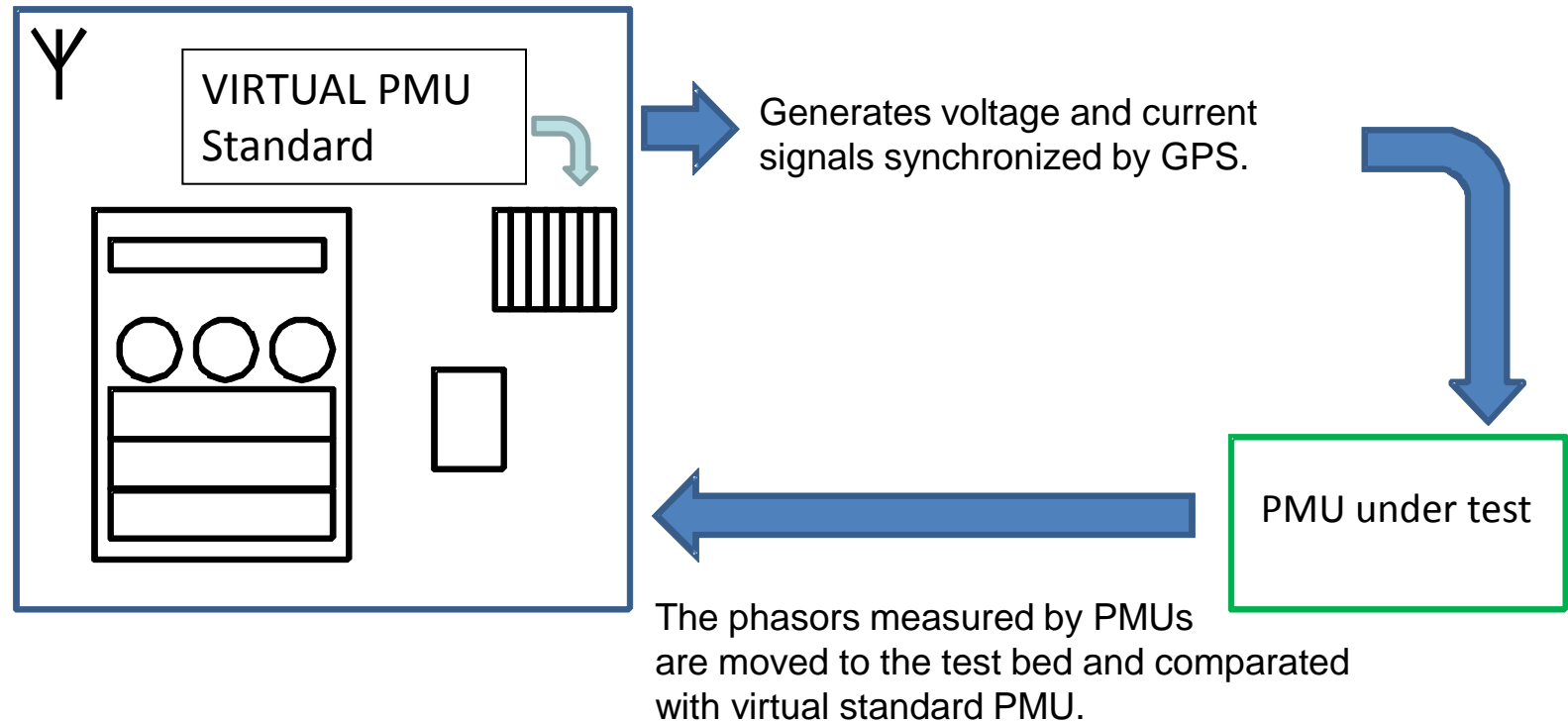
- Dynamic

- Ramp

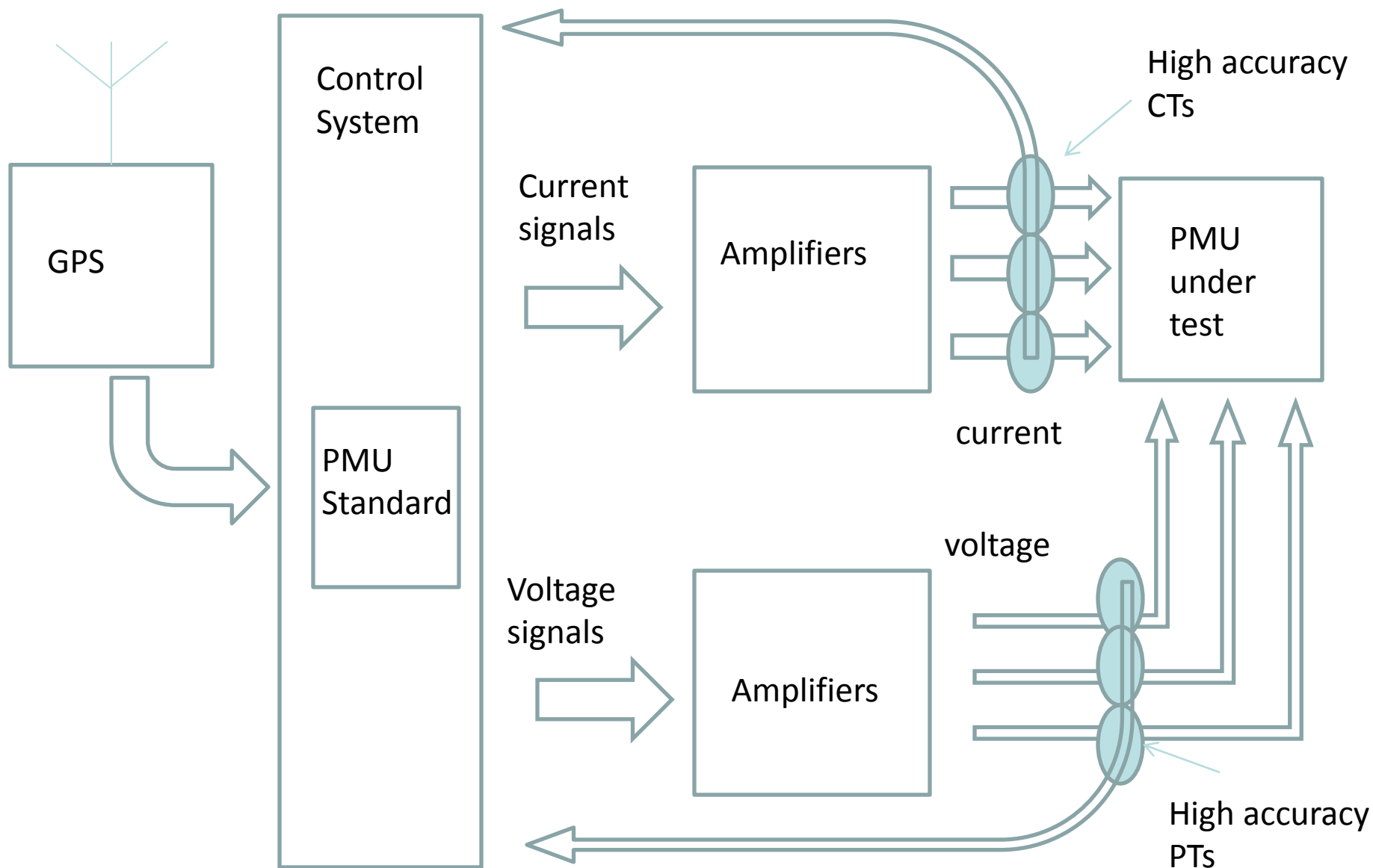
- Step

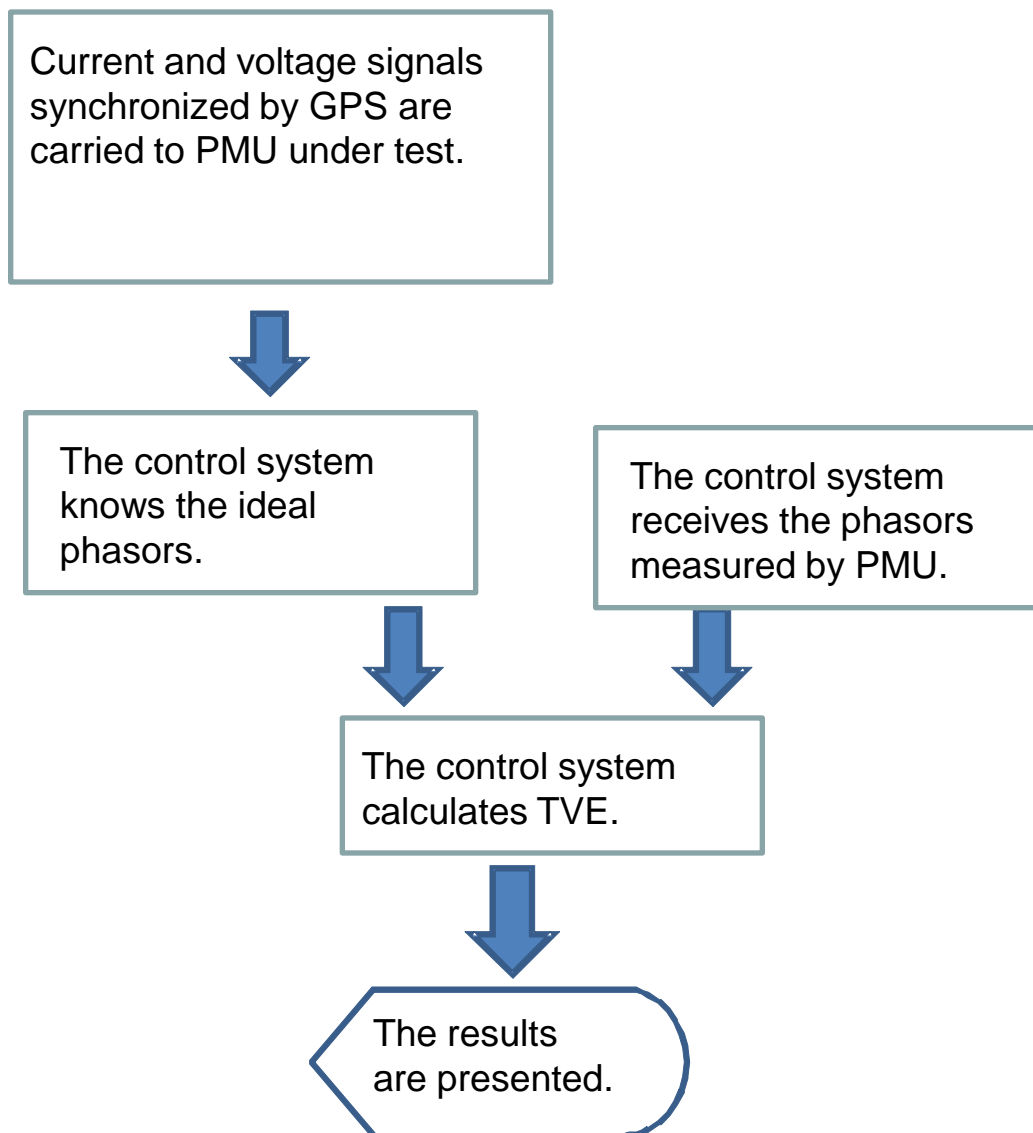
- Amplitude and phase modulation

# METROLOGIC TEST BED: NIST



# METROLOGIC TEST BED PROPOSED

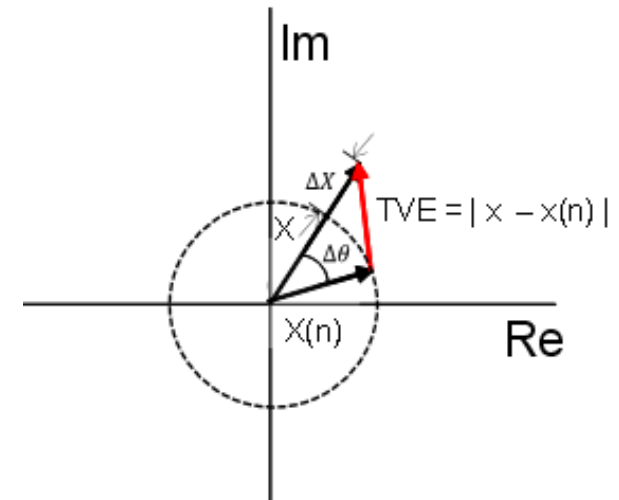






# CHALLENGES

- $TVE < 1\%$   uncertainty of test bed much be smaller.



- Dynamic tests must be done with the same small uncertainty
- The standards continue to be in discussion.



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## PREVIOUS WORKS

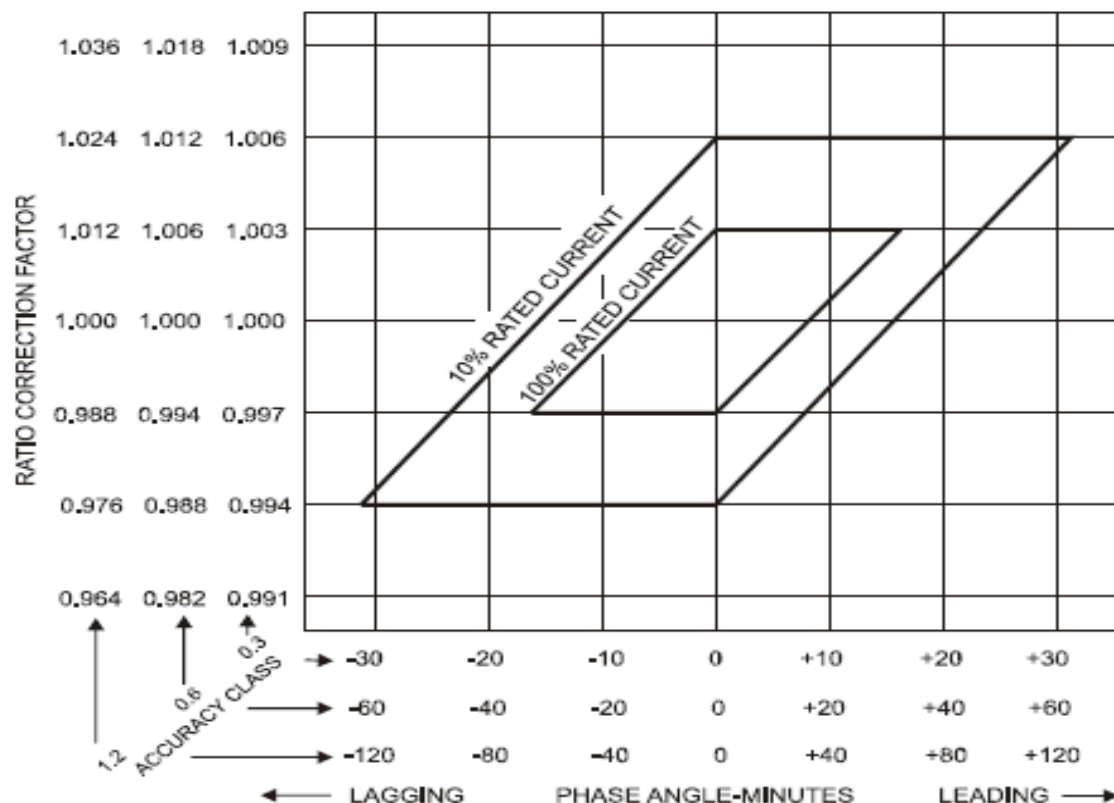


# Study of Metering Chain (CTs) Thesis of Luiz Carlos Grillo (CEPEL) COPPE-UFRJ

Advisors: Prof. Glauco Taranto e José Eduardo



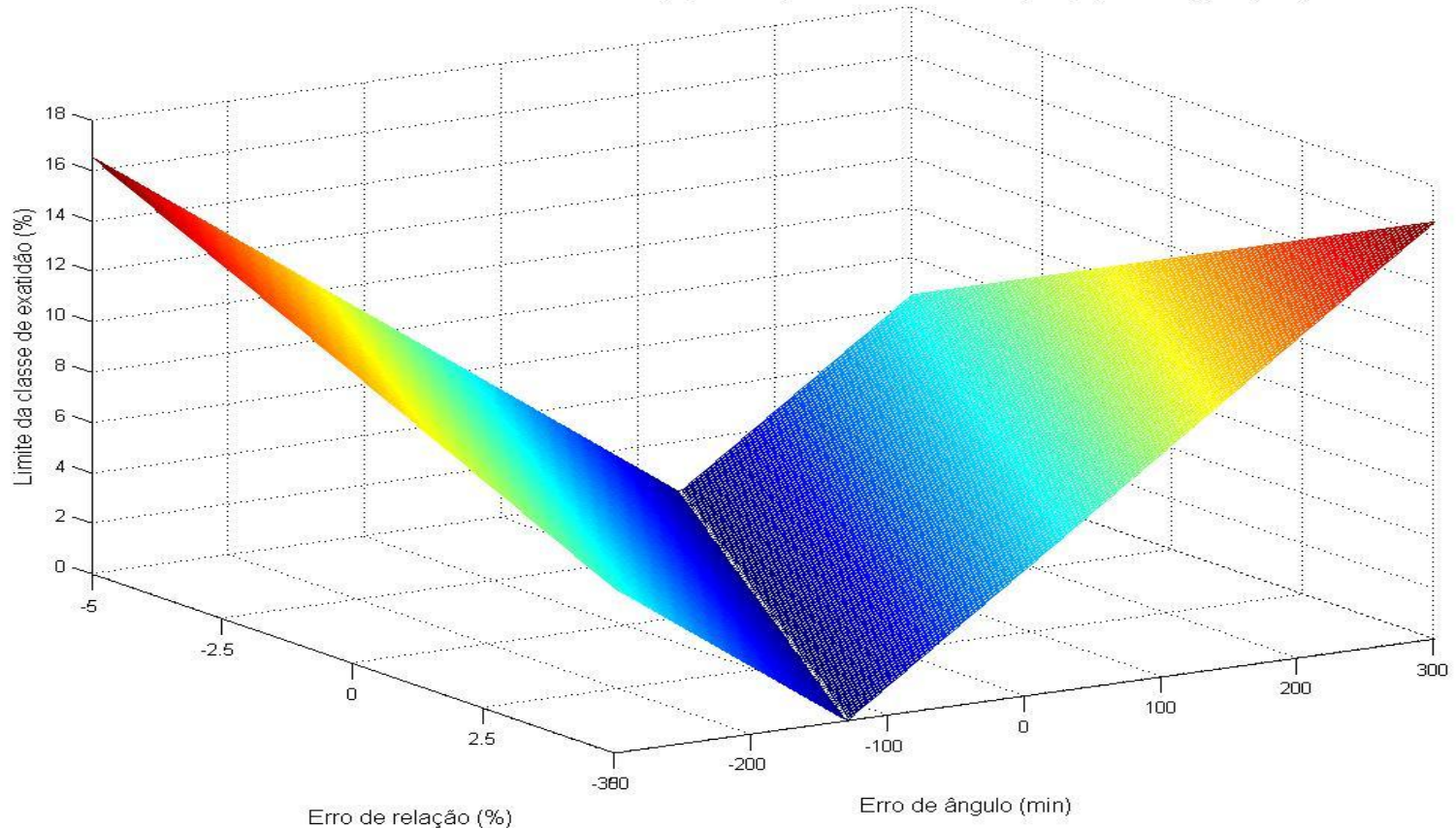
# Accuracy Standard of metering current transformers





## ACCURACY CRITERIA ACCORDING CT STANDARD

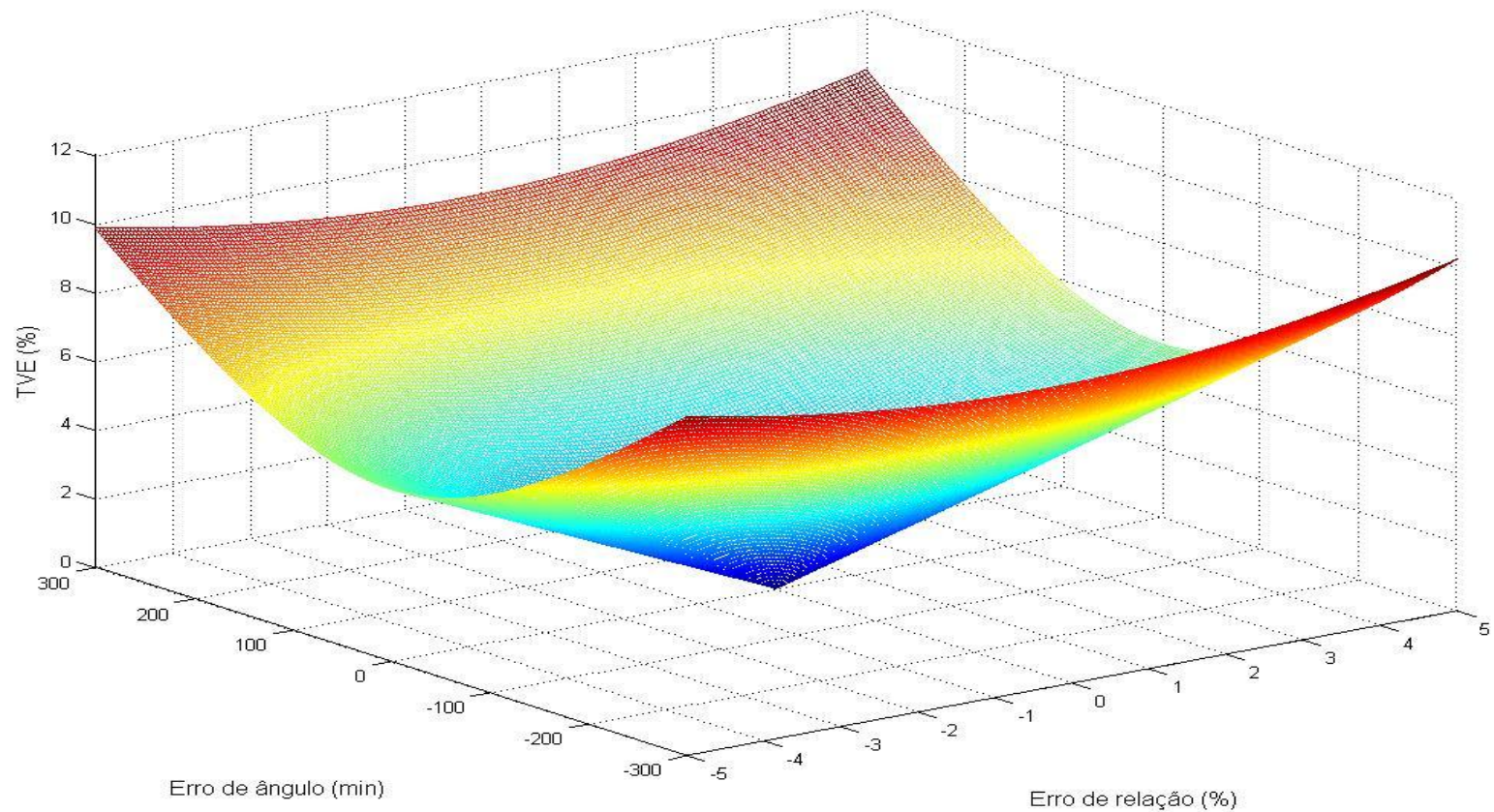
Gráfico do limite da classe de exatidão (%) em função dos erros de relação (%) e de ângulo (min)





## ACCURACY CRITERIA ACCORDING PMU STANDARD

Gráfico do TVE (%) em função dos erros de relação (%) e de ângulo (min)

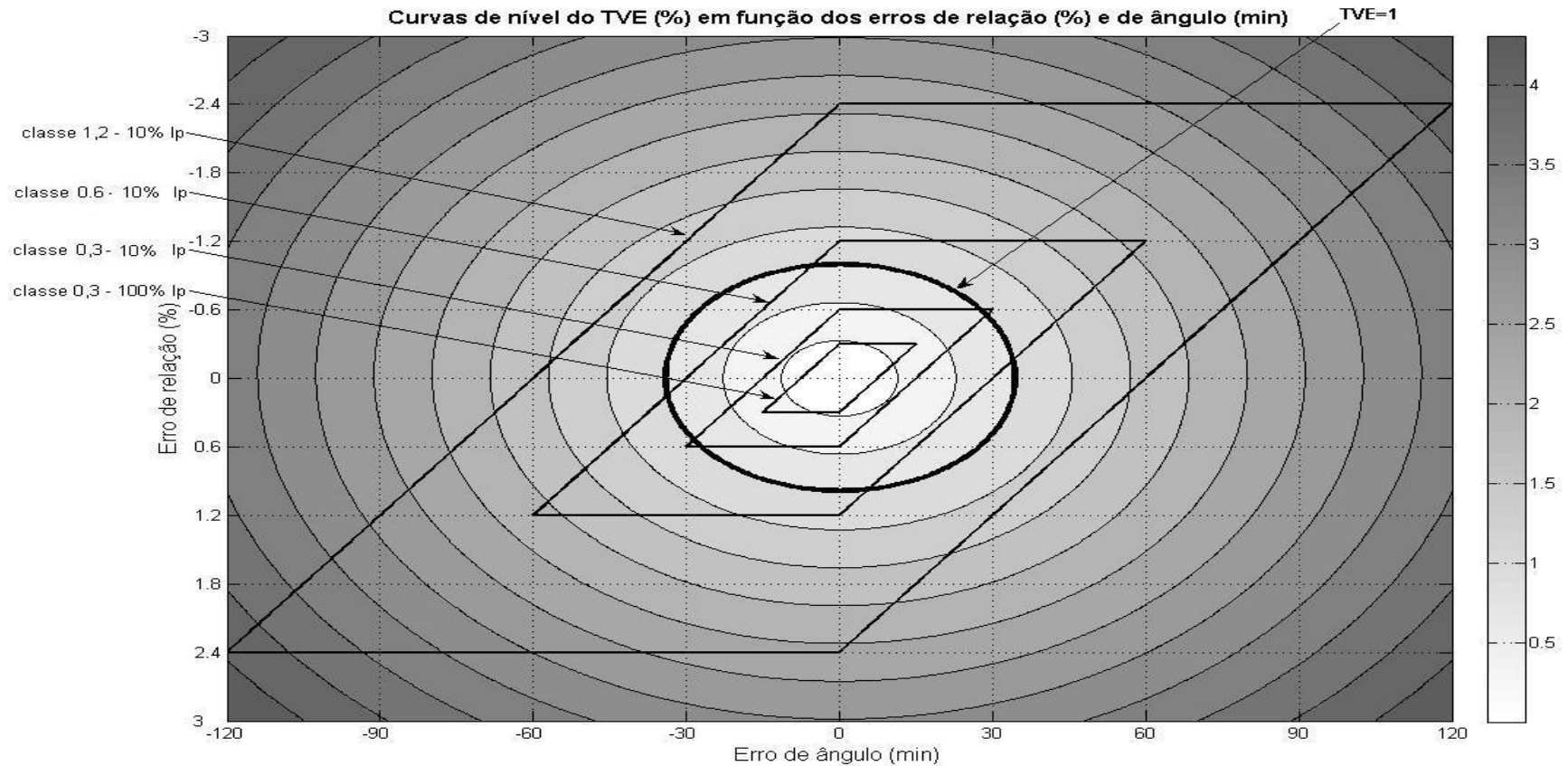






## ACCURACY CRITERIA CTs X PMU

Curvas de nível do TVE (%) em função dos erros de relação (%) e de ângulo (min)





# PREVIOUS WORKS

<b>Magnitude error (%)</b>	<b>Angle error (MINUTES)</b>	<b>TVE (%)</b>	<b>ACCURACY LIMIT (%)</b>
-2,4	120	4,2	2,22
-1,2	40	1,7	0,34
-8,05	182,6	9,5	1,03
-2,4	20	2,5	1,63
0,6	-31,2	1,1	0,6



## CONCLUSION:

THE CT STANDARDS SHOULD CONSIDER THE  
PMUS STANDARDS





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# PREVIOUS WORKS



## Study of Internal Algorithms of PMUs Thesis of Suzana C. Oliveira (CEPEL) COPPE-UFRJ



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Advisors: Prof. Edson Watanabe e José Eduardo



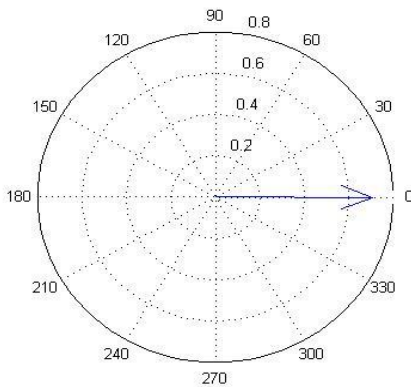
- Learn about the internal algorithm of PMUs.
- Tests at NIST (2009) “PMU Interoperability, Steady-State and Dynamic Performance Tests” by Moraes and all.



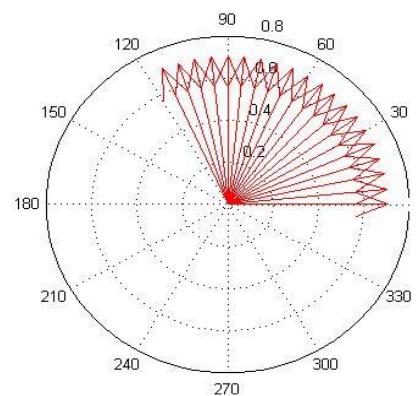
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# STUDY OF SYNCHROPHASOR CONCEPT

$$V = \cos(2\pi 60 + 0^\circ)$$



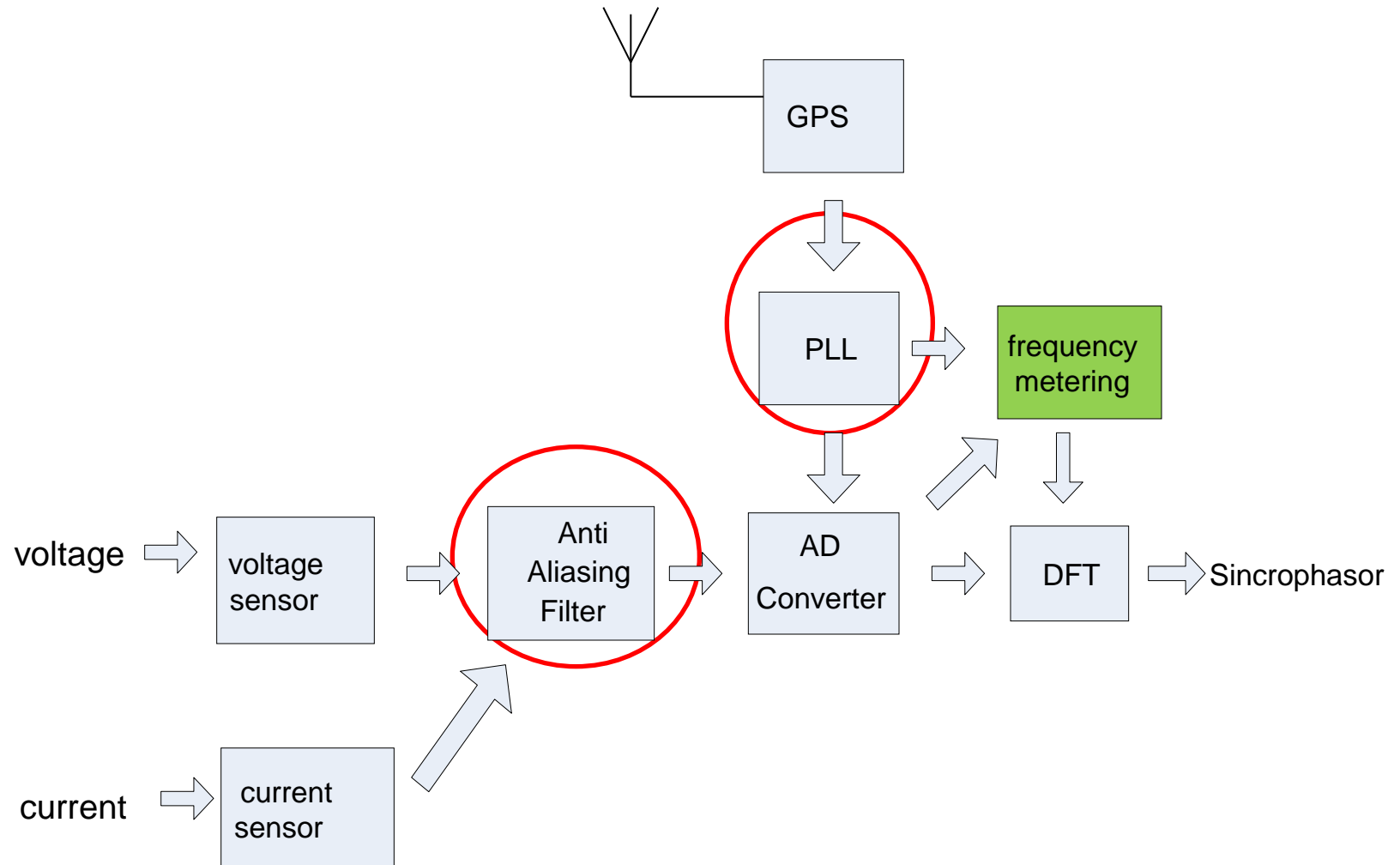
$$V = \cos(2\pi 61 + 0^\circ)$$



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
$\Theta$	0°	6°	12°	18°	24°	30°	36°	42°	48°	54°	60°	66°	72°	78°	84°	90°	96°	102°	108°	114°

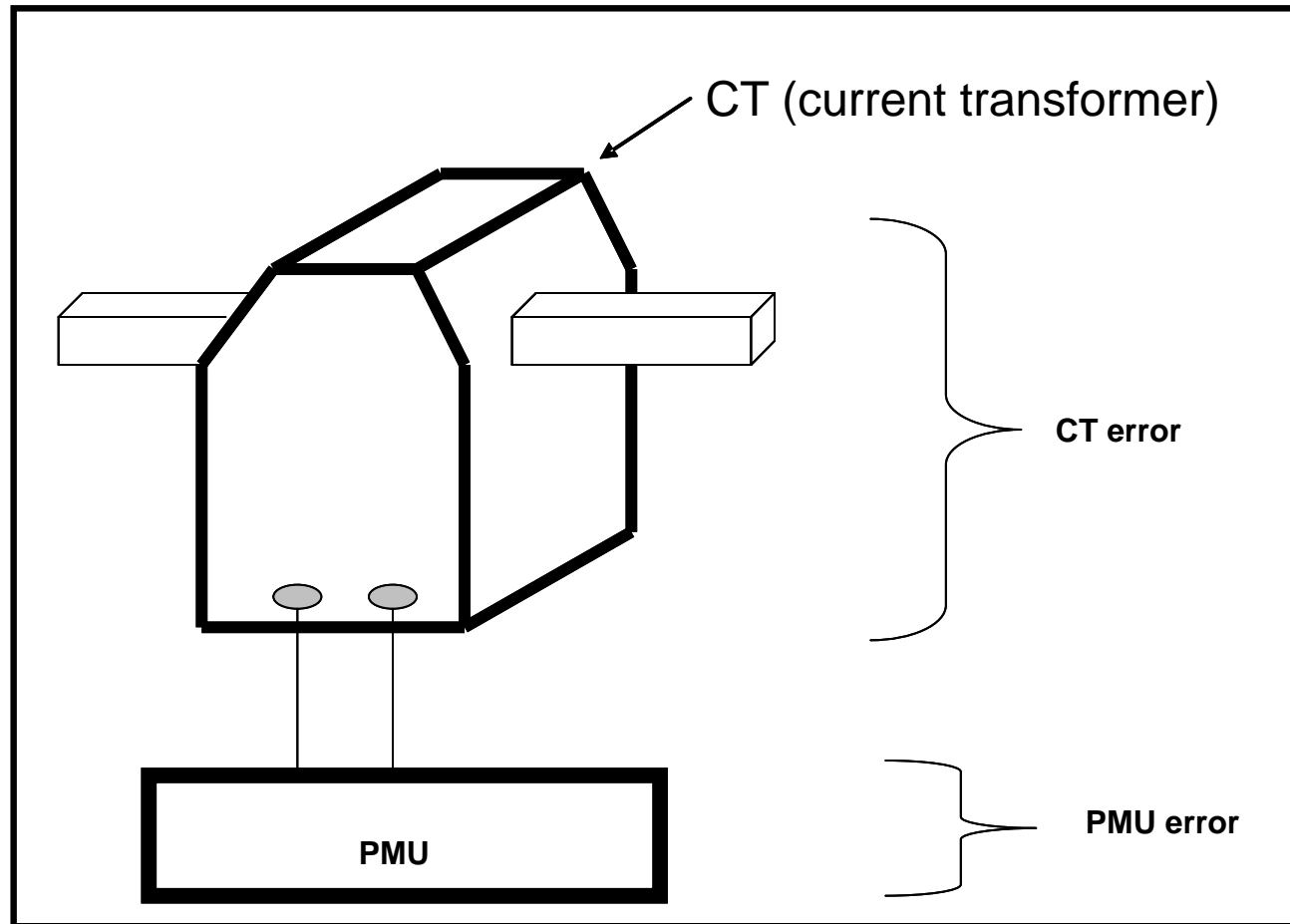


# BLOCK DIAGRAM OF PMUS



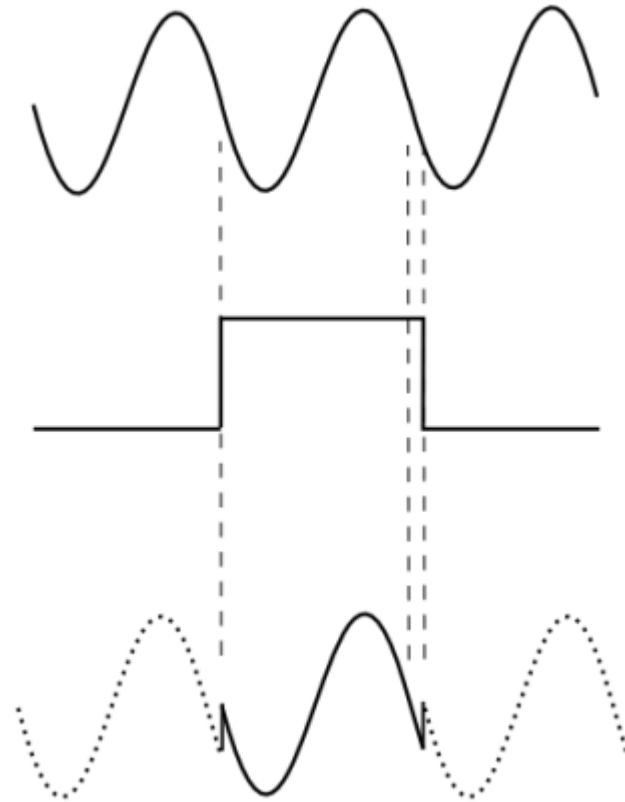
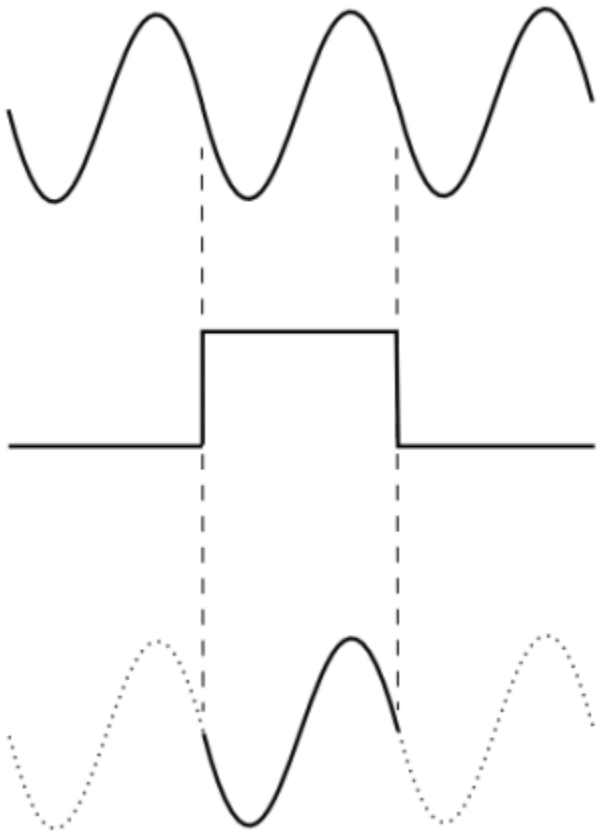


# BLOCK DIAGRAM OF PMUS QUANTIZATION



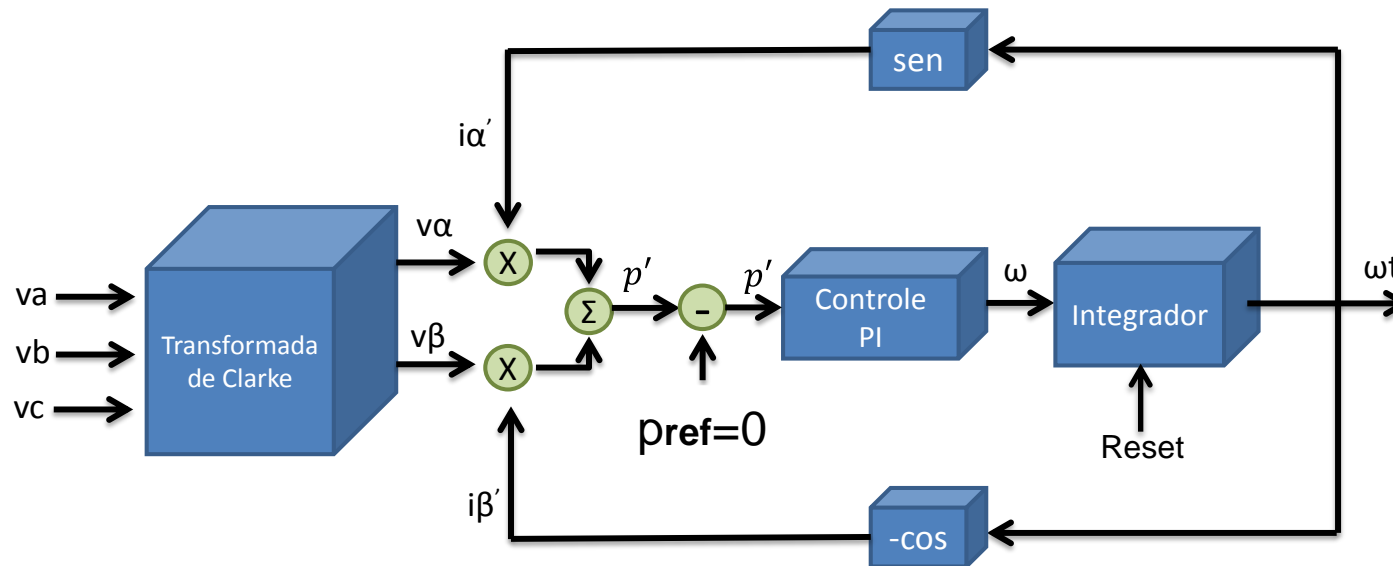


## Leakage effect





- PLL proposed to measure the frequency





## CONCLUSION:

THE ALGORITHMS AND INTERNAL FILTERS  
SHOULD BE CONSIDERED CAREFULLY.



# We are at the beginning!

THANKS AND DISCUSSIONS

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