A FRACTIONAL CYCLE DIGITAL FOURIER
TRANSFORM PMU APPLIED TO POWER INVERTER
EVENT DETECTION

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LOCATION OF INSTITUTIONS INVOLVED AT THE RESEARCH

BRAZIL
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 offline.

But,

PMUs are enough for fast monitoring and control?
BLOCK DIAGRAM OF PMUs

- Voltage sensor
- Anti-Aliasing Filter
- AD Converter
- Digital Filtering
- DFT
- GPS
- PLL
- Frequency metering
- Frequency
- Rate of change of frequency
- Sincrophasor Amplitude and phase
- Current sensor

REPORT RATE
PMU is a DYNAMIC DEVICE
PMU APPLICATIONS

Applications For Dynamic Assessment

Applications For Energy Management Systems

Applications For Systemic Security Assessment

SAMPLE RATE

1 PHASOR/MIN

1 PHASOR/SEC

60 PHASORS/SEC

MORE THAN 60 PHASORS/SEC

Ultra Fast Applications

CONTINUOUS POINT OF WAVE

PMU
Fractional Cycle (FC-DFT)

- **D=1**
  - 1 PHASOR/CYCLE

- **D=2**
  - 2 PHASORS/CYCLE

- **D=4**
  - 4 PHASORS/CYCLE

**NUMBER OF DIVISIONS**
Continuous Point of Wave (CPOW)

Phasor measurements (up to 50/60 frames/s)

Frequency Domain

SCADA

Continuous Point of Wave (CPOW)

(Frequency Domain (FC-DFT)) no division

(Frequency Domain (FC-DFT)) 2 divisions

(Frequency Domain (FC-DFT)) 4 divisions

(Frequency Domain (FC-DFT)) 8 divisions

(Frequency Domain (FC-DFT)) 256 divisions

Fractional Cycle (FC-DFT)
TIME COMPARISONS BETWEEN CPOW AND FC-DFT

FC-DFT PMU
32 DIVISIONS

CONTINUOUS POINT OF WAVE
FC-DFT FREQUENCY RESPONSE
FC-DFT PHASE STEP TRACKING
FC-DFT HARMONIC TRACKING

Graph showing voltage versus time with different tracking methods.
HVDC MULTI-INFEED EXAMPLE

315 kV 60 Hz

L1

Rectifier

DC fault

Inverter valve fault

L2

230 kV 60 Hz

L3

Rectifier filters

L4

Inverter filters

315 kV 60 Hz

Rectifier

Inverter

Inverter filters

Inverter filters

Inverter

Inverter

Rectifier
FC-DFT BASED ACTIVE POWER FOR INVERTER VALVE FAULT (L2)

Fault Moment

FC-DFT

PMU P
INVERTER VALVE FAULT (L2)

HVDC Link DC Voltages

FC-DFT three phase active power

DC link Voltage

- Voltage Bus L4
- Voltage Bus L2

~20ms

Three phase power (pu)

zero crossing bus L2
zero crossing bus L4

22 ms

Time [s]

Three phase power L2
Three phase power L4

Time (s)
PATTERN RECOGNITION

DC FAULT

INVERTER VALVE FAULT

Power phase $A^*$

Time (s)

Power phase $A^*$

Time (s)
HARMONIC DETECTION
ISSUES

COMMUNICATION BANDWIDTH

CONTROL ROOM OPERATION
ISSUES
MEASUREMENT STANDARDS

Laboratory for studying Synchrophasor Systems
FUTURE WORKS

CONSTRUCTION OF A PROTOTYPE

DOING PERFORMANCE TESTS

PERFORMANCE TESTS

FC-DFT
FUTURE WORKS

DOING REAL TIME SIMULATIONS
THANK YOU!

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