Continuous Waveform Recording Advances Power Quality Awareness

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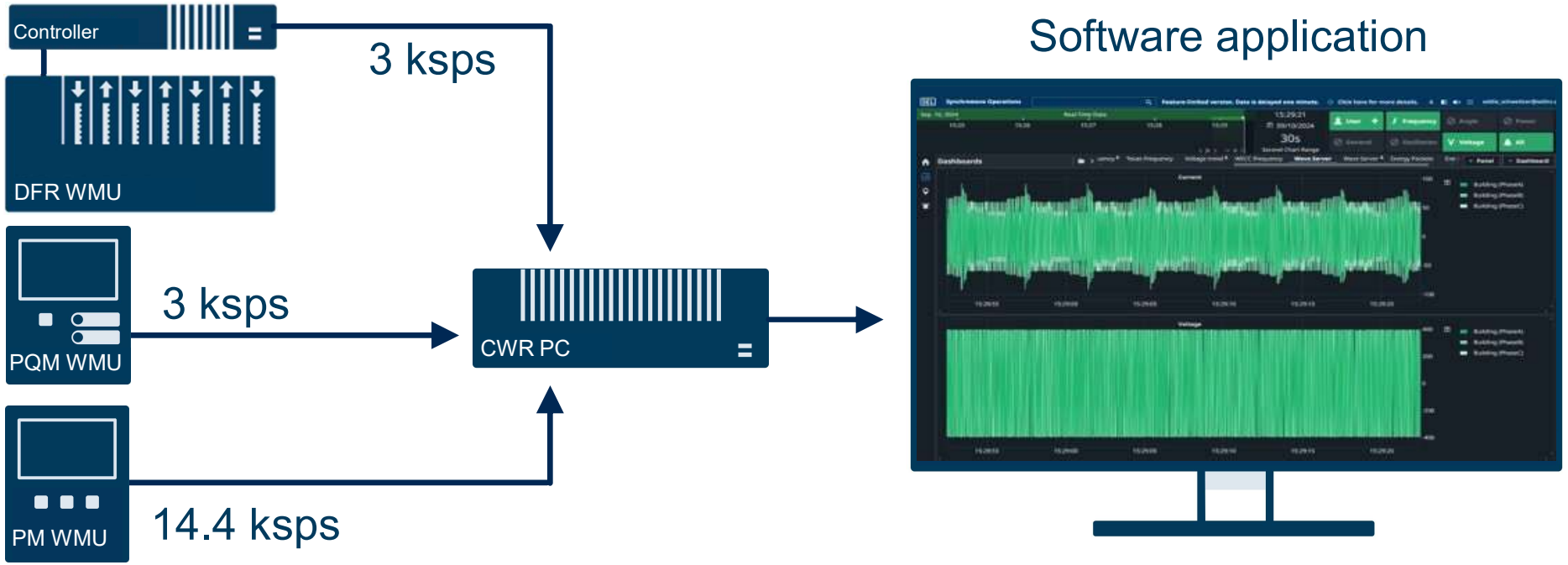
Continuous waveform streaming and recording – DFRs, PQMs, and PMs



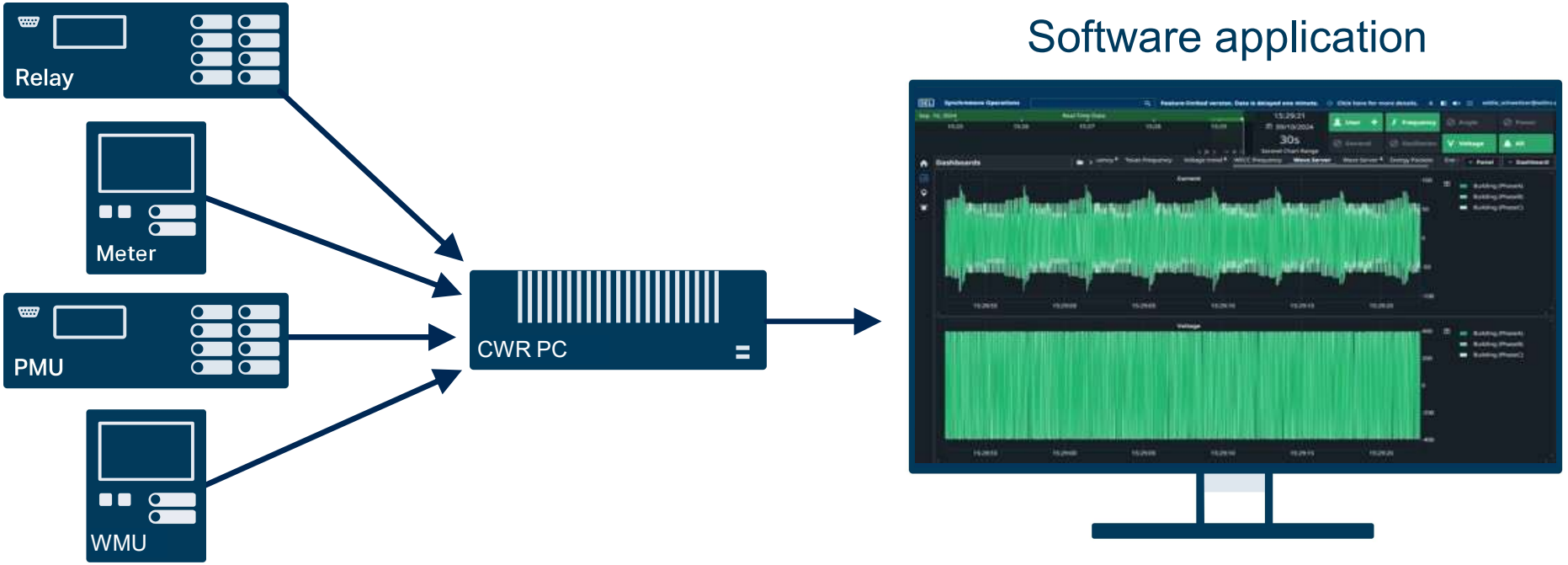
Software derived PMU and SCADA metering applications

Continuous waveform recording

PMU and SCADA metering

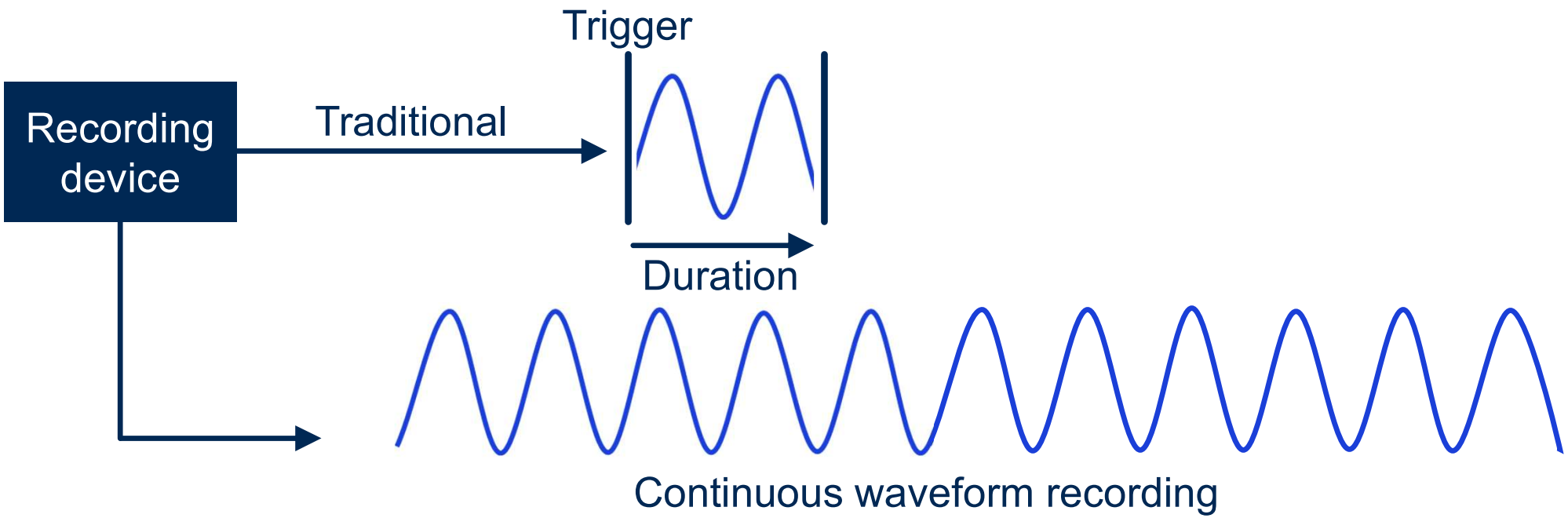
Quantity	Description
V, I, and Φ	10/12 cycle rms, fundamental
Frequency	1/2 cycle frequency
P, Q, and S	10/12 cycle rms, fundamental
Symmetrical components	fundamental
SSO/SSR	5 – 45 Hz
Harmonics	20th or 100th

Integrate various measurement rates from relays, meters, PMUs, and WMUs



Triggerless recording captures every disturbance

Use case 1



Trigger dependent systems can miss events

Traditional

```
=>>HIS
History Buffer Empty
=>>
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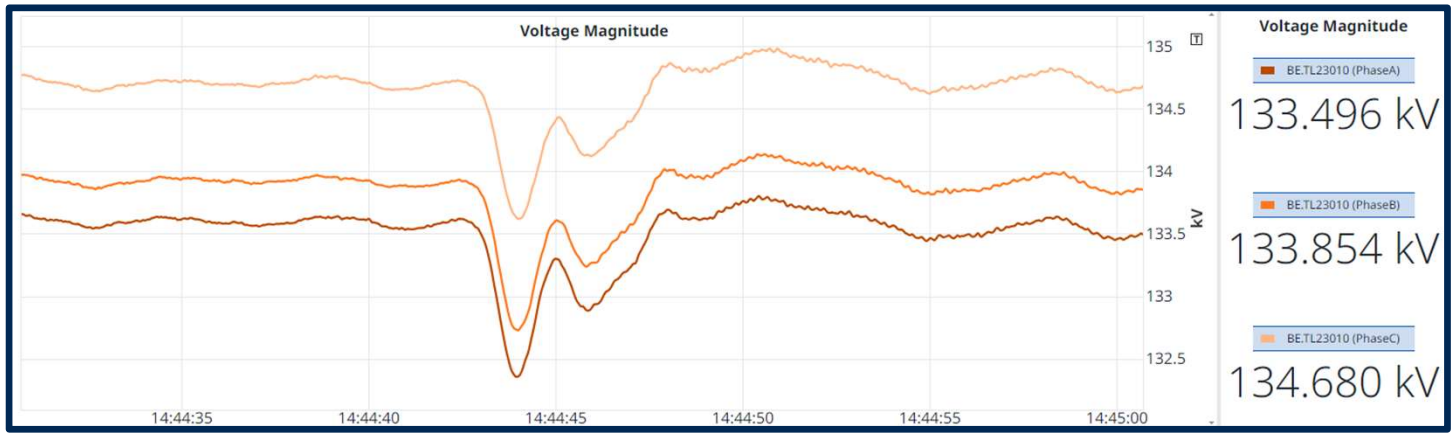
Continuous recording

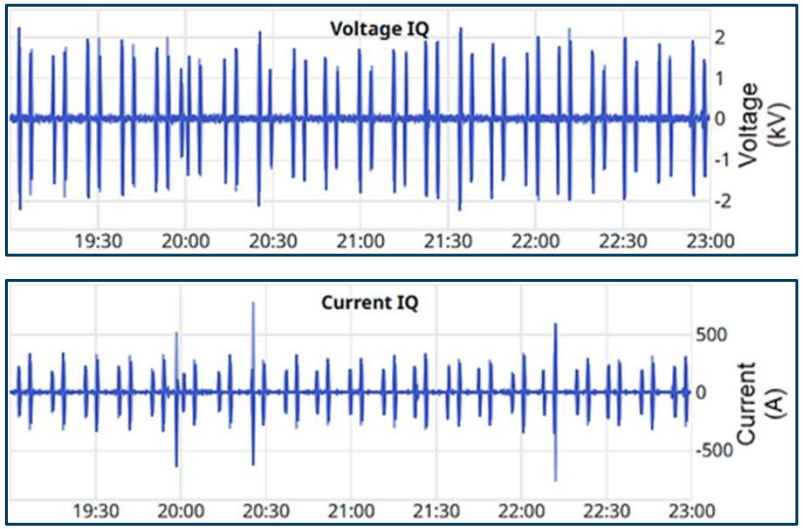


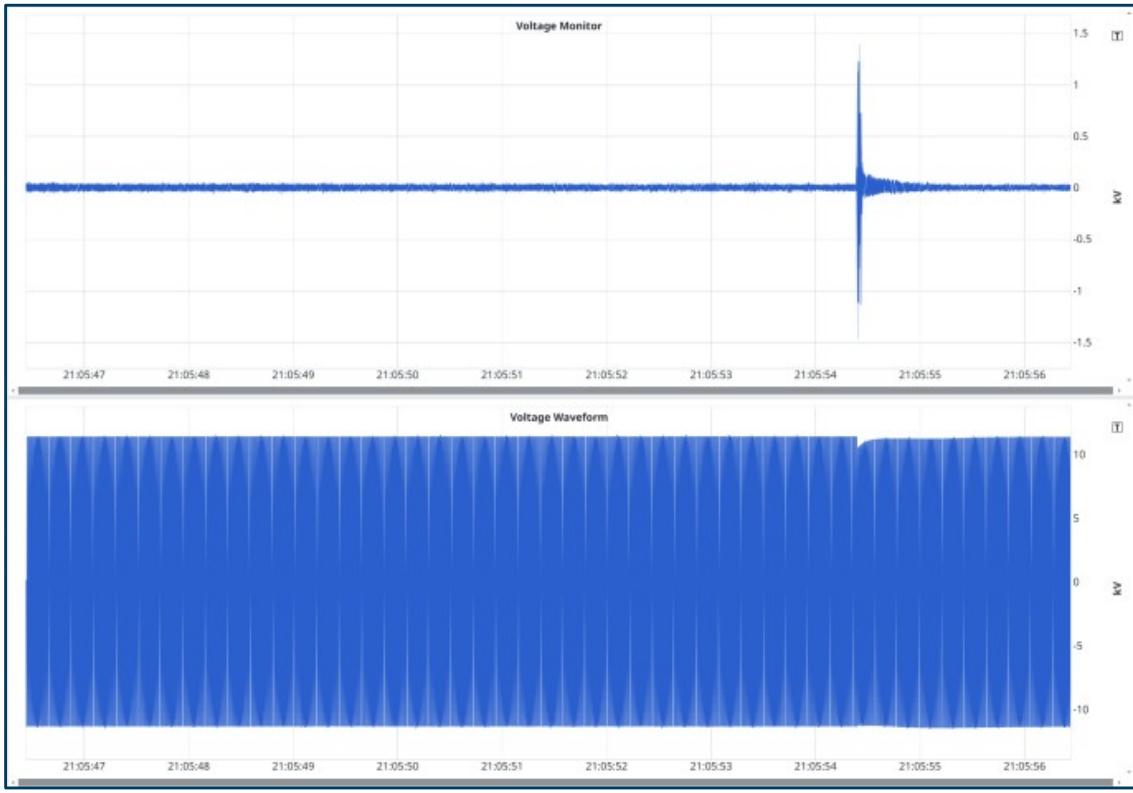
Identify disturbances in new ways

Use case 2

Incremental Quantities

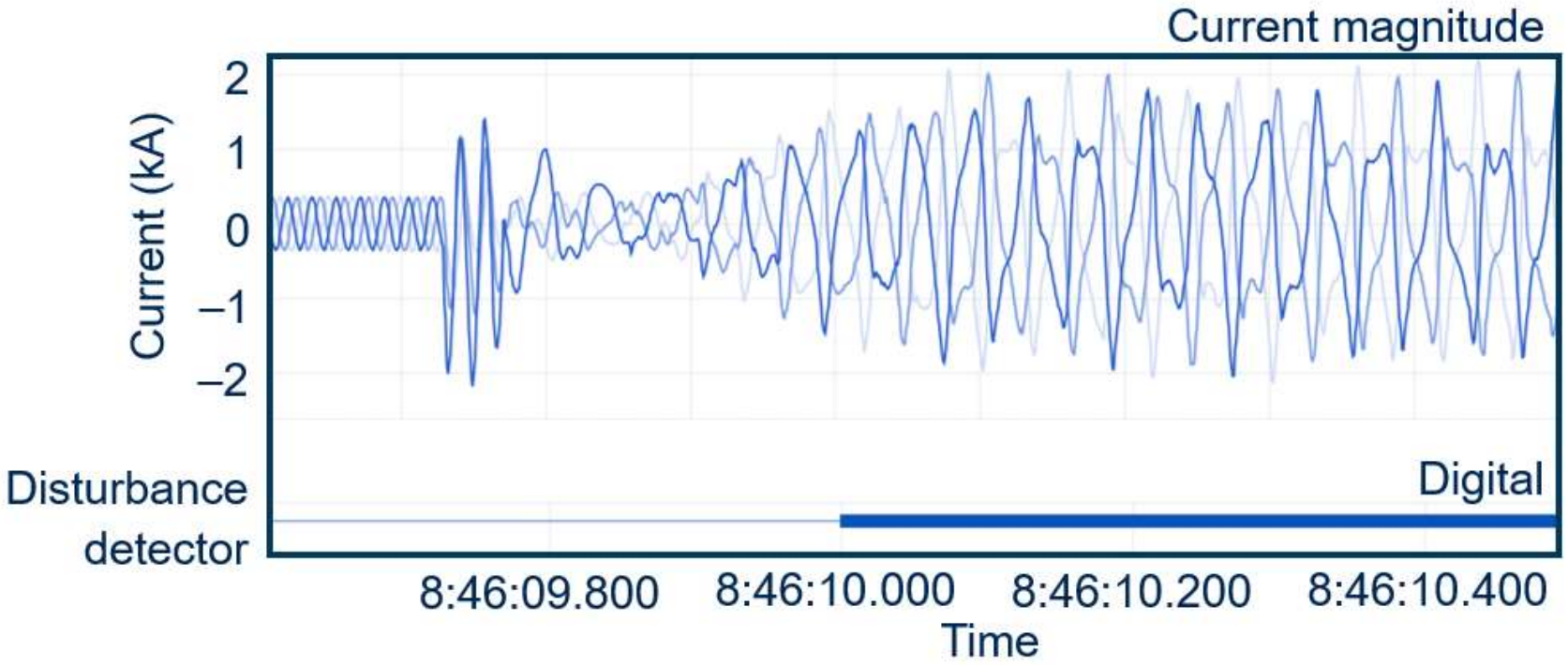
$$IQx[k] = x[k] - x[k-240]$$





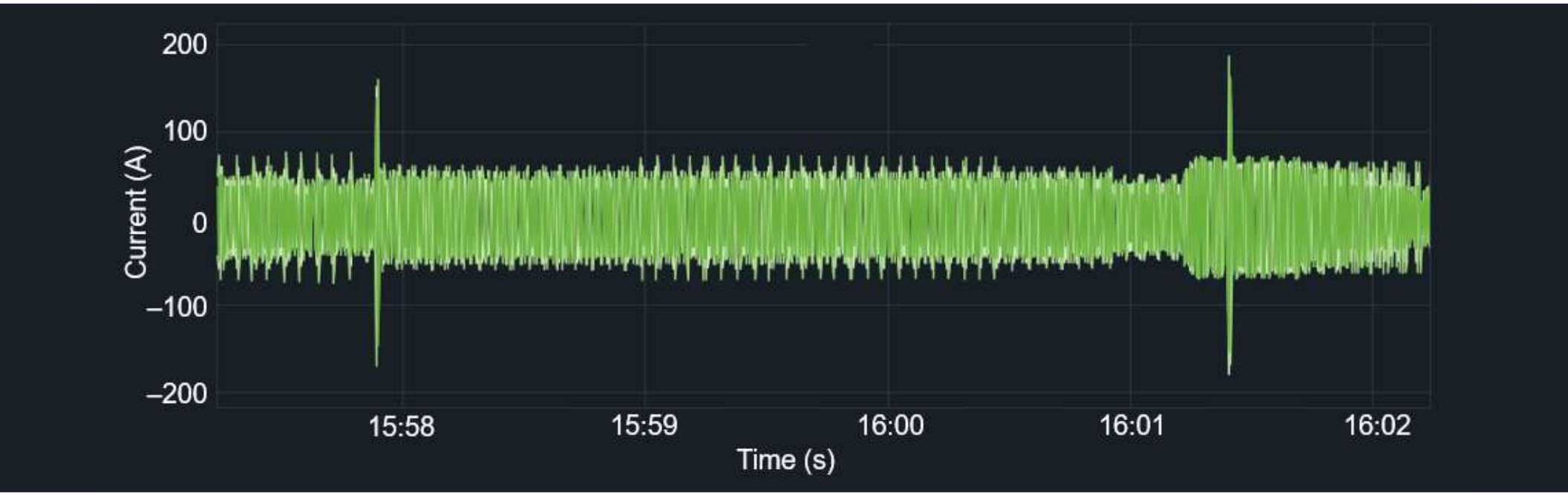
Increase visibility of power system dynamics

Use case 3



Identify equipment failure early

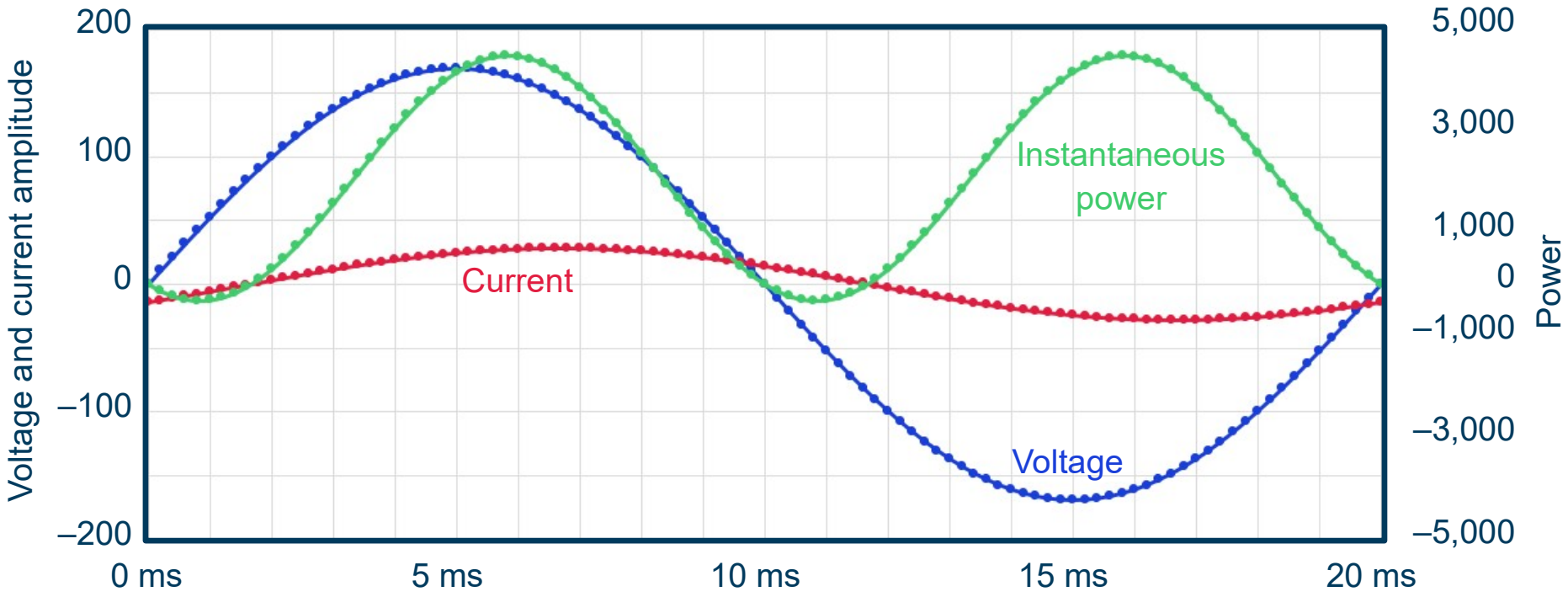
Use case 4



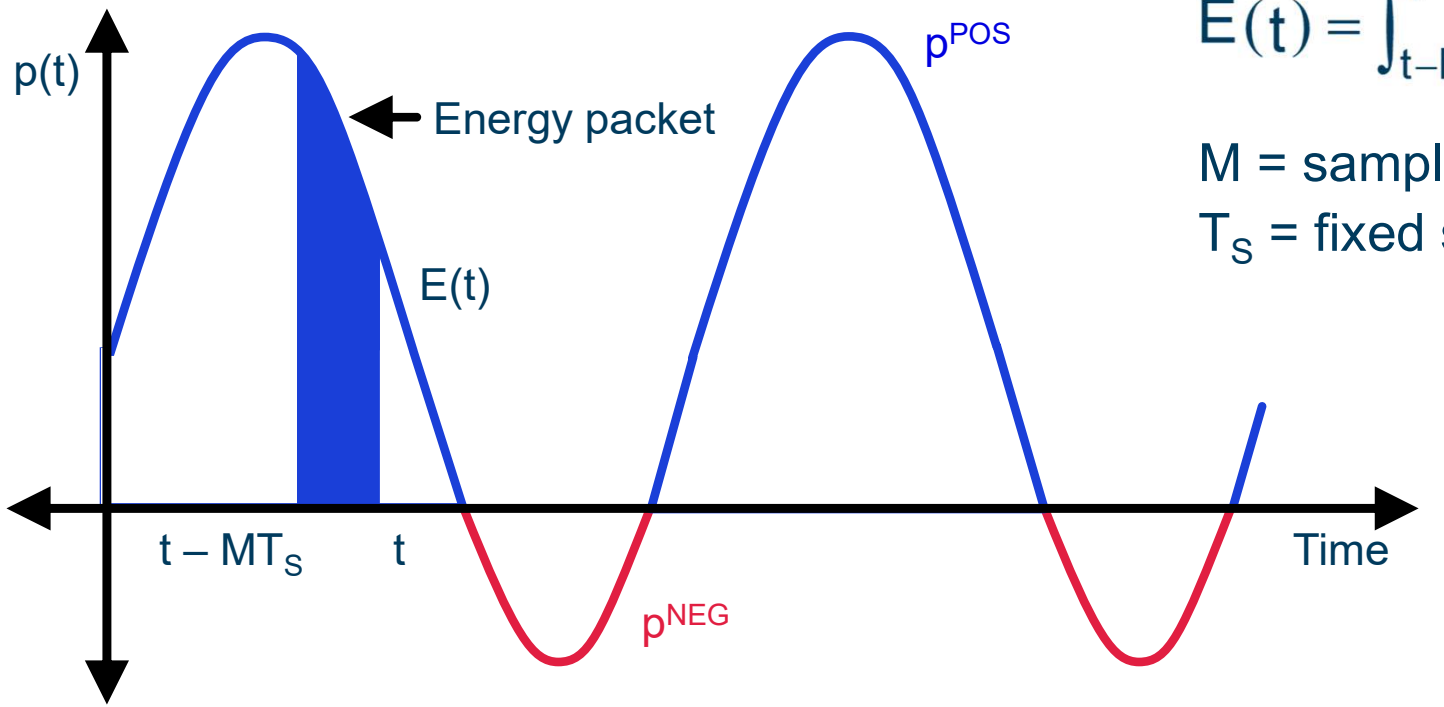
Instantaneous power is the basis for energy

Use case 5

50 Hz, 30˚ lag, V rms = 120 V, I rms = 20 A, and S = 2,400 VA



Energy packet theory – report energy in discrete time intervals

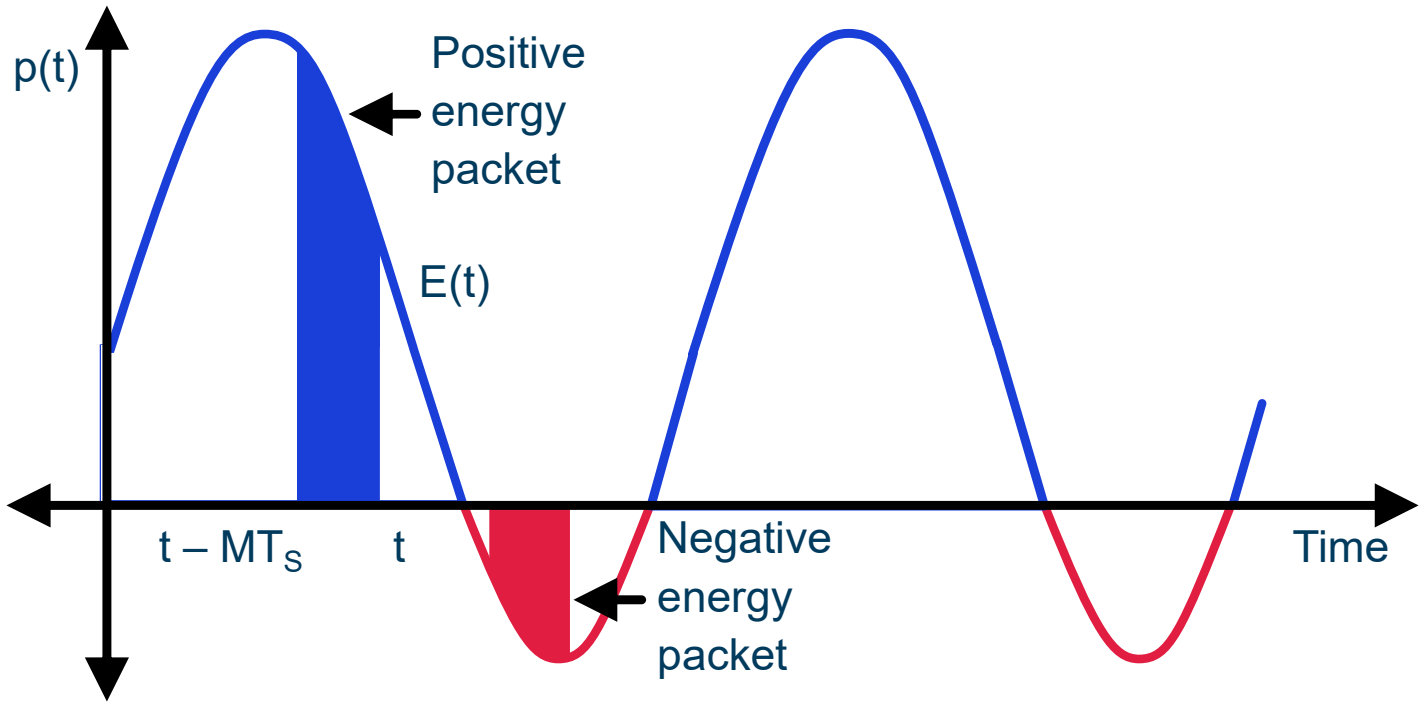


$$E(t) = \int_{t-MT_S}^{t} v(\sigma)\, i(\sigma)\, d\sigma$$

M = samples in interval

T_S = fixed sample rate

We now see bidirectional energy transfer in any time period



Useful calculations from energy packets

$$p[k] = v[k] \bullet i[k]$$

$$e[k] = v[k] \bullet i[k] \bullet T_S$$

$$p^{POS}[k] = \begin{cases} p[k] , & p[k] > 0 \\ 0 , & \text{otherwise} \end{cases}$$

$$p^{NEG}[k] = \begin{cases} p[k] , & p[k] < 0 \\ 0 , & \text{otherwise} \end{cases}$$

$$E^{NET}[n] = T_S \sum_{k=M(n-1)+1}^{k=Mn} p[k]$$

$$E^{POS}[n] = T_S \sum_{k=M(n-1)+1}^{k=Mn} p^{POS}[k]$$

$$E^{NEG}[n] = T_S \sum_{k=M(n-1)+1}^{k=Mn} p^{NEG}[k]$$

$$E^{ABS}[n] = T_S \sum_{k=M(n-1)+1}^{k=Mn} |p|[k]$$

THANK YOU

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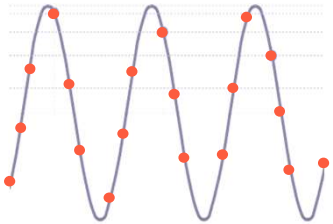
Consider network bandwidth and storage when streaming and recording ksps data



Model	Sample rate (ksps)	Channels	Network bandwidth (kbps)	Storage per channel (GB per day)
Meter	3.0	6	600	1
DFR	3.0	96	9,700	1
Monitor	14.4	17	11,100	5