Web Service Framework for Power Quality Monitoring

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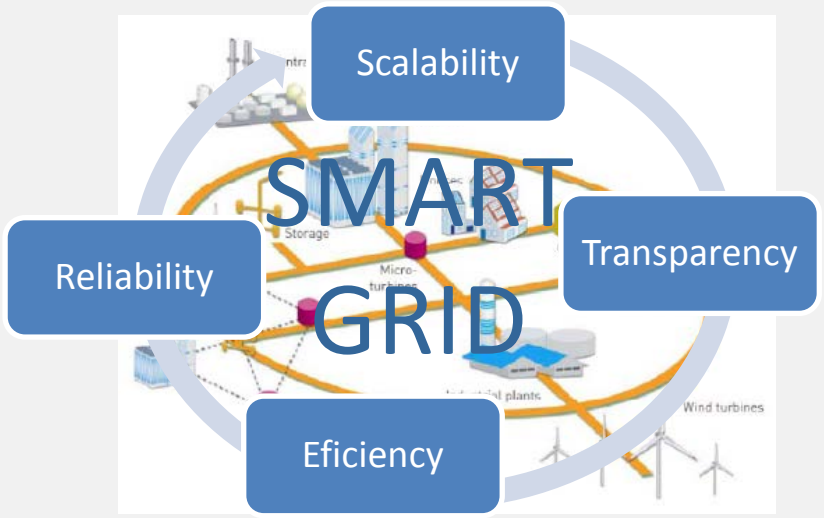
- "Real time" management of energy data and monitoring the quality of energy supply
- Research and development of new services that control the quality of electrical signals
- Investigation of how different elements of the power network and information systems may interact and share information in "real time"



- Intelligent Monitoring POwer NETwork (IMPONET)
  - *Eureka ITEA2 no 09030 - TSI-020400-2010-103*

- Design and implement a service-oriented architecture for Power Quality Monitoring
  - Design and implementation of specific Web Services for processing Power Quality Monitoring methodology
  - Test and evaluation the performance of Web Services with real measurements from power disturbances
  - Integration of Web Services as components of the IMPONET project

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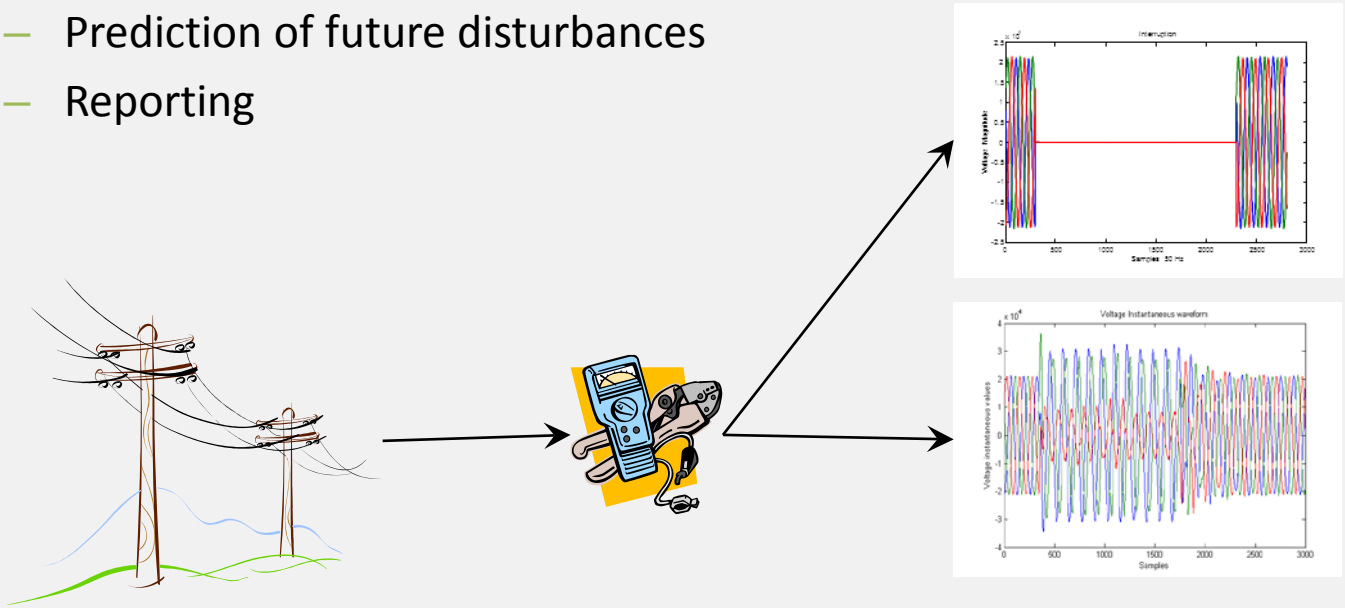
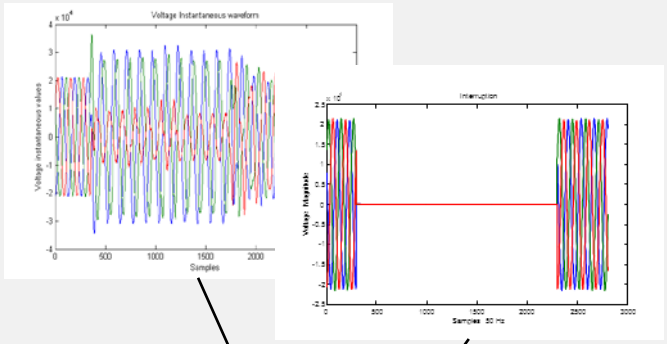
- Power Quality study of both voltage and current disturbances
- Power Quality Monitoring analyzes single or multiple measurements from electrical network for detection and identification of **power disturbances**
  - Classification of faults
  - Identification of causes
  - Prediction of future disturbances
  - Reporting



- Application of Power Quality Monitoring



Extraction and computation of features/attributes

S. No.	Categories		Duration	Voltage Magnitude
I	*Short Duration Variation*			
(a)	Sag	Instantaneous	0.5-30 cycle.	0.1-0.9 pu.
		Momentary	30 cycles-3 sec.	0.1-0.9 pu.
		Temporary	3sec-1min.	0.1-0.9 pu.
(b)	Swell	Instantaneous	0.5-30 cycle.	1.1-1.8 pu.
		Momentary	30 cycles-3 sec.	1.1-1.4 pu.
		Temporary	3sec-1min.	1.1-1.2 pu.
(c)	Interruption	Momentary	0.5cycles-3sec.	<0.1 pu.
		Temporary	3sec-1min.	<0.1 pu.
II	*Long Duration Variation*			
(a)	Interruption, Sustained		>1min	0.0 pu.
(b)	Under-voltage		>1min	0.8-0.9 pu.
(c)	Overvoltage		>1min	1.1-1.2 pu.
III	*Transients*			
(a)	Impulsive	Nanosecond	<50nsec.	
		Microsecond	50-1msec.	
		Millisecond	>1msec.	
(b)	Oscillatory	Low frequency	0.3-50msec.	0-4 pu.
		Medium freq.	20µsec.	0-8 pu.
		High freq.	5µsec.	0-4 pu.
IV	*Voltage Imbalance*		Steady state	0.5-2%
V	*Waveform Distortion*			
(a)	Harmonics		Steady state	
(b)	Notching		Steady state	
(c)	Noise		Steady state	

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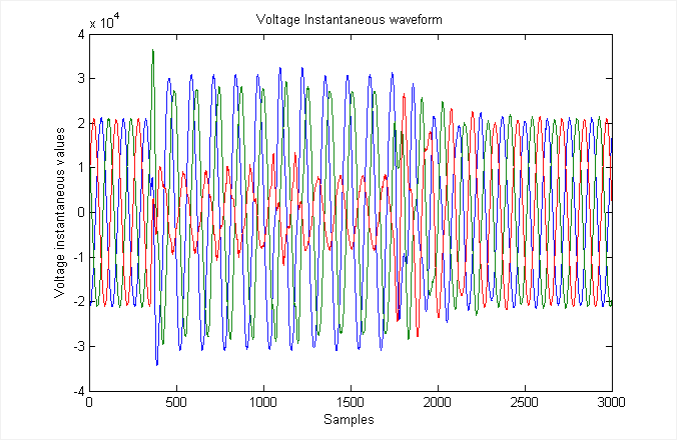
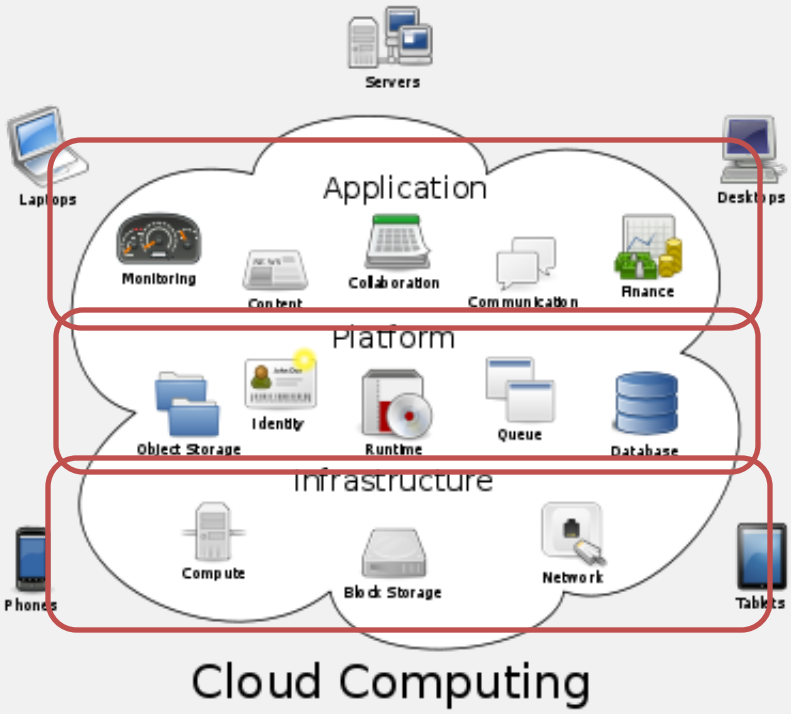
- From the classification of disturbances, we focus on:

- Voltage Sags
  - Reduction of voltage under 10% of nominal value, 20ms -> 1 min
  - Affect the quality of the waveform

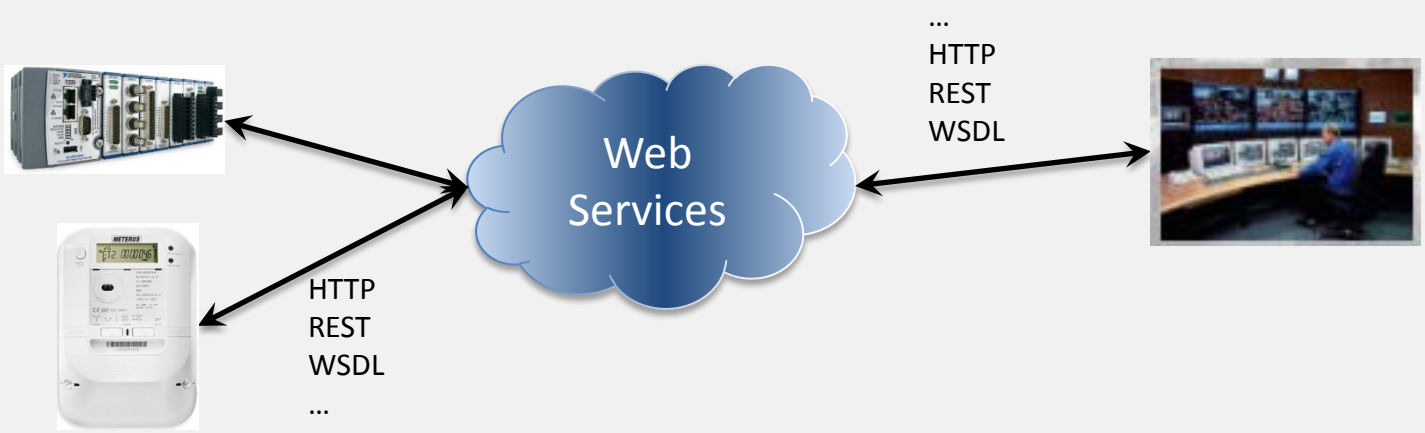




- Cloud Computing: On-Demand network access to hardware and software resources
- Provide on-demand services
  - Infrastructure as a Service (IaaS)
  - Platform as a Service (PaaS)
  - Software as a Service (SaaS) model

→ WEB SERVICES

- Software system designed to support interoperable machine-to-machine communication
- On-demand software
  - Knowledge of communication messages
  - Processing of communication messages



	SOA	SMART GRID	PQM
G. Q. Tang, 2011	☒	☑	☒
A. Singhal, and R. P. Saxena, 2012	☒	☑	☒
M. Music, 2012	☒	☑	☑
F. Zavoda, 2010	☒	☑	☑
Zeeb, E. et al., 2007	☑	☒	☒
Yuhong Yan et al., 2005	☑	☒	☒
Khan A and Mouftah H, 2011	☑	☑	☒
Asad O, et al., 2011	☑	☑	☒
Bollen, M. et al, 2007	☒	☒	☑
M. McGranaghan; S. Santoso, 2007	☒	☒	☑
Barrera, V. et al., 2012	☒	☒	☑
Yes, we can!	☑	☑	☑

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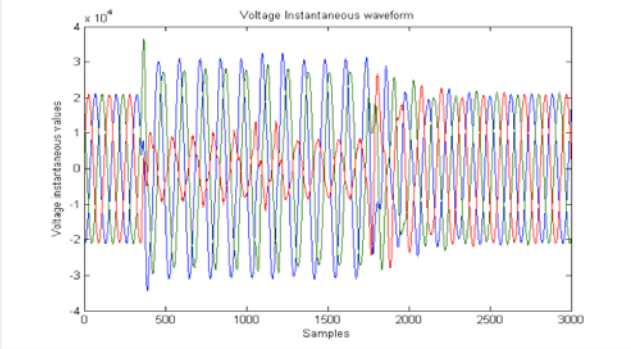
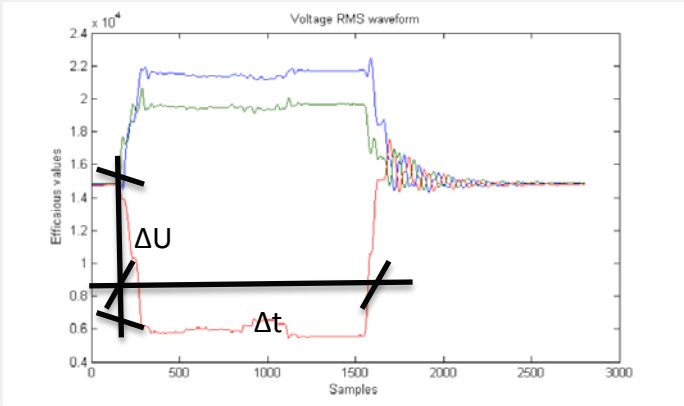
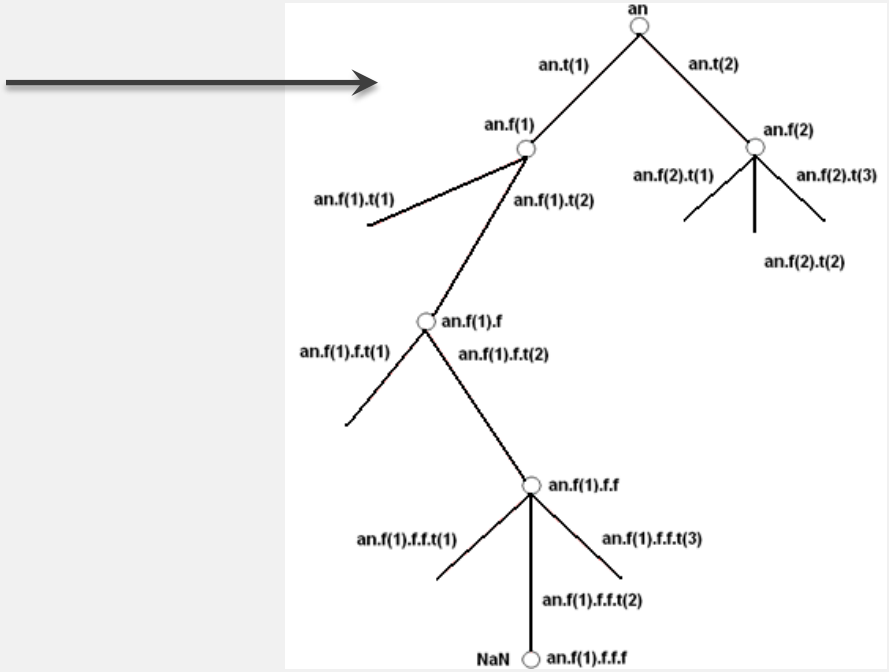
- Data structure for Voltage Sags: features describing the waveform that characterize voltage sags





- Power Quality Event (PQE)
  - Instant values waveform (V/A)
  - RMS values waveform (V/A)
  - Fault Duration (s)
  - Fault Magnitude (%)
  - Pre-fault value (V/A)
  - Minimum voltage (V)
  - Maximum current (A)
  - Origin (upstream / downstream)
  - Fault Impedance (Ω)
  - Fault location (distance) (km)

- Need a data structure for distribution network
- Power Distribution Network
  - Voltage Sags
    fault location (distance)
  - Node
    - Identification
    - Distance
    - Electrical Resistance
    - Electrical Reactance
    - Nominal Power
    - Reactive Power
    - Nodes
    - Lines
  - Line
    - Identification
    - Name
    - Longitude
    - Electrical Resistance
    - Electrical Reactance
    - Type of Cable

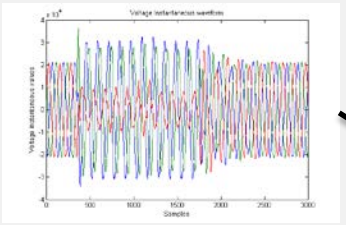


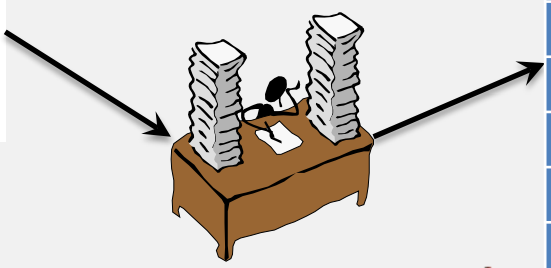
- Web Services different processing purposes

  - On-line performance,
    - Feature extraction and computation
    - **Processing Web Services**

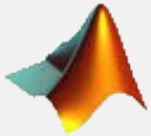
  - Off-line performance,
    - Evaluation of sets of power disturbances
    - **Modeling Web Services**

- PROCESSING Web Services
  - Identification and analysis of power disturbances from one measurement point
- WS_PQM_PROCESS_PQEvent



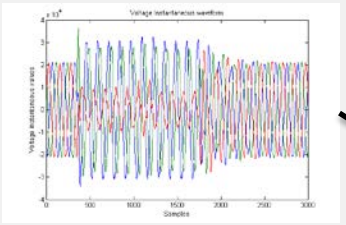


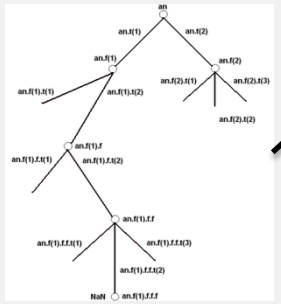
- Fast Fourier Transformation
- Kalman Filter



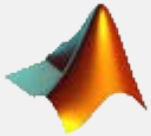
	Fault Attributes	
RMS values	[..., 15245, 13192, ...]	[..., 15245, 13192, ...]
Pre-Fault Voltage value	14714,87	14714,87
Pre-Fault Current value	105,91	105,91
Max. duration (ms)	146,41	157,3
Min. voltage value	4530,29	8250,33
Max. current value	523,62	354,72
Faulted Phase	A	B
Impedance	47,78	31,28
Relative Location	Downstream	Donwstream

- PROCESSING Web Services
  - Identification and analysis of power disturbances from one measurement point
- WS_PQM_PROCESS_FaultLocation

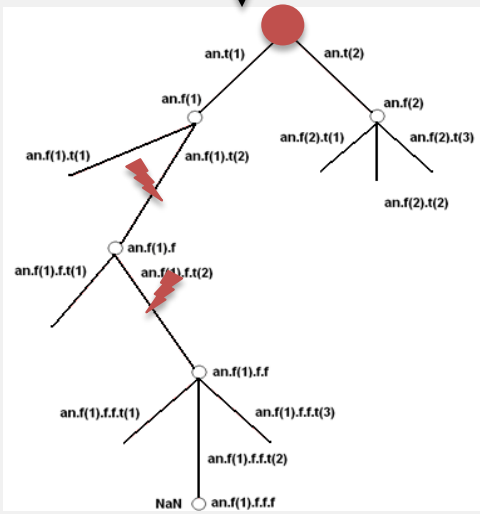




- Fast Fourier Transformation
- Ratan Das

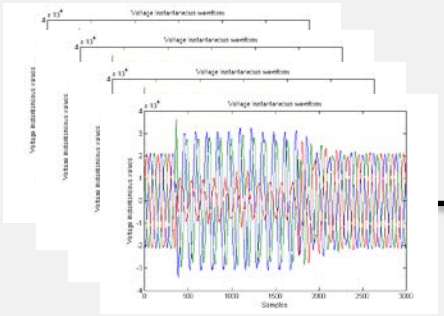


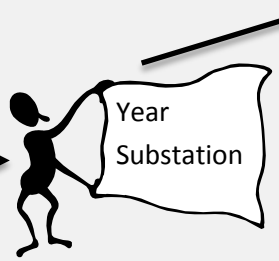
	Fault Location	
Origin Node	1206	1212
End Node	1207	1213
Line name	F5312 | F9-PA30499	D.S5233 | S5282
Km	13,994	14,212



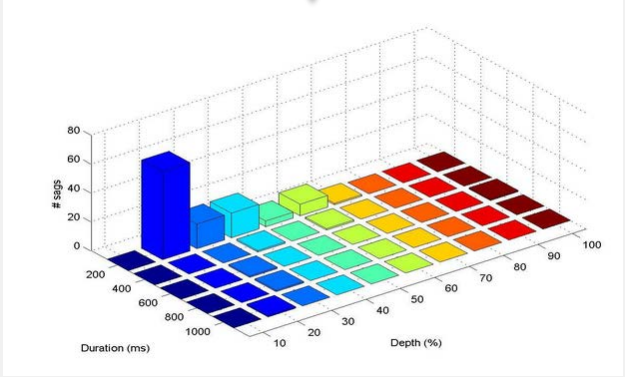
- MODELING Web Services
  - Aggregation of disturbances from multiple measurements points

- WS_PQM_MODEL_SagsTable



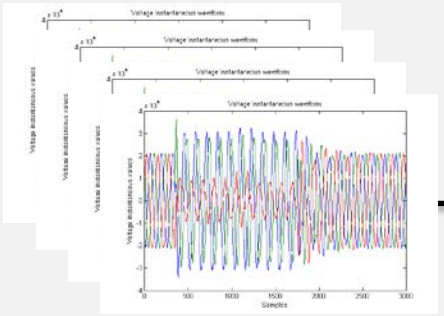


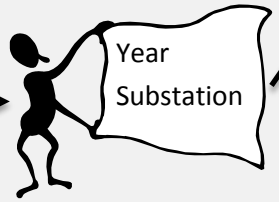
Number of voltage sags	Magnitude (%)							
		<10	<20	<30	<40	<50	...	≤100
Duration (ms)	<200	125	15	2	1	0	...	0
	<400	23	0	5	1	0	...	0
	<600	2	0	0	0	0	...	0
	<800	0	0	0	0	3	...	1
	≤1000	0	0	0	0	0	...	0



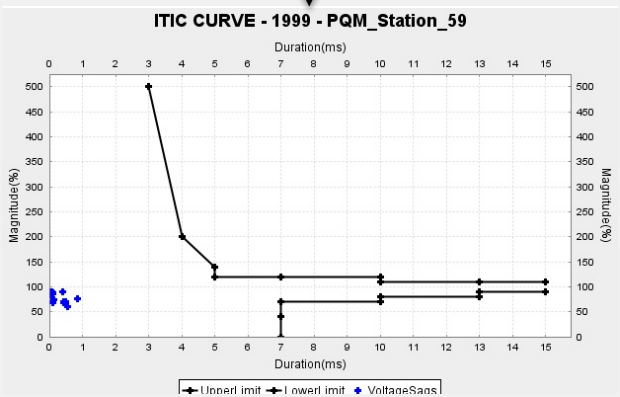
- MODELING Web Services
  - Aggregation of disturbances from multiple measurements points

- WS_PQM_MODEL_CBEMACurve





	Set of voltage sags							
Duration (ms)	125	166	197	351	365	321	178	315
Magnitude (%)	85	80	82	73	81	75	77	83



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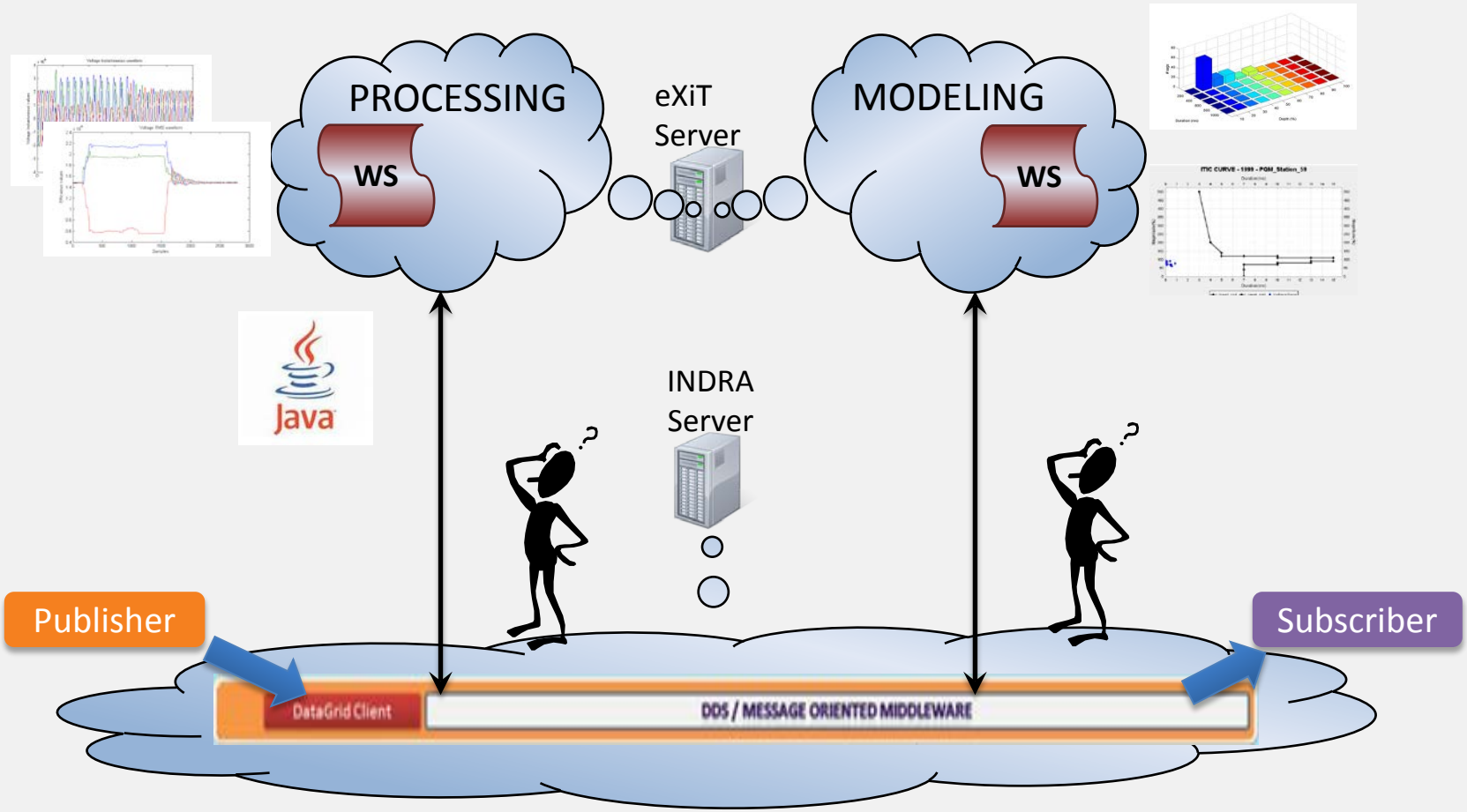
- Integration with the DDS middleware



- DDS Communication: creation of a common language to send/receive information of PQE

  - String resourceId;
  - short sampleTime;
  - float latitude;
  - float longitude;
  - long timeStamp;
  - double[][] voltageValue;
  - double[][] currentValue;

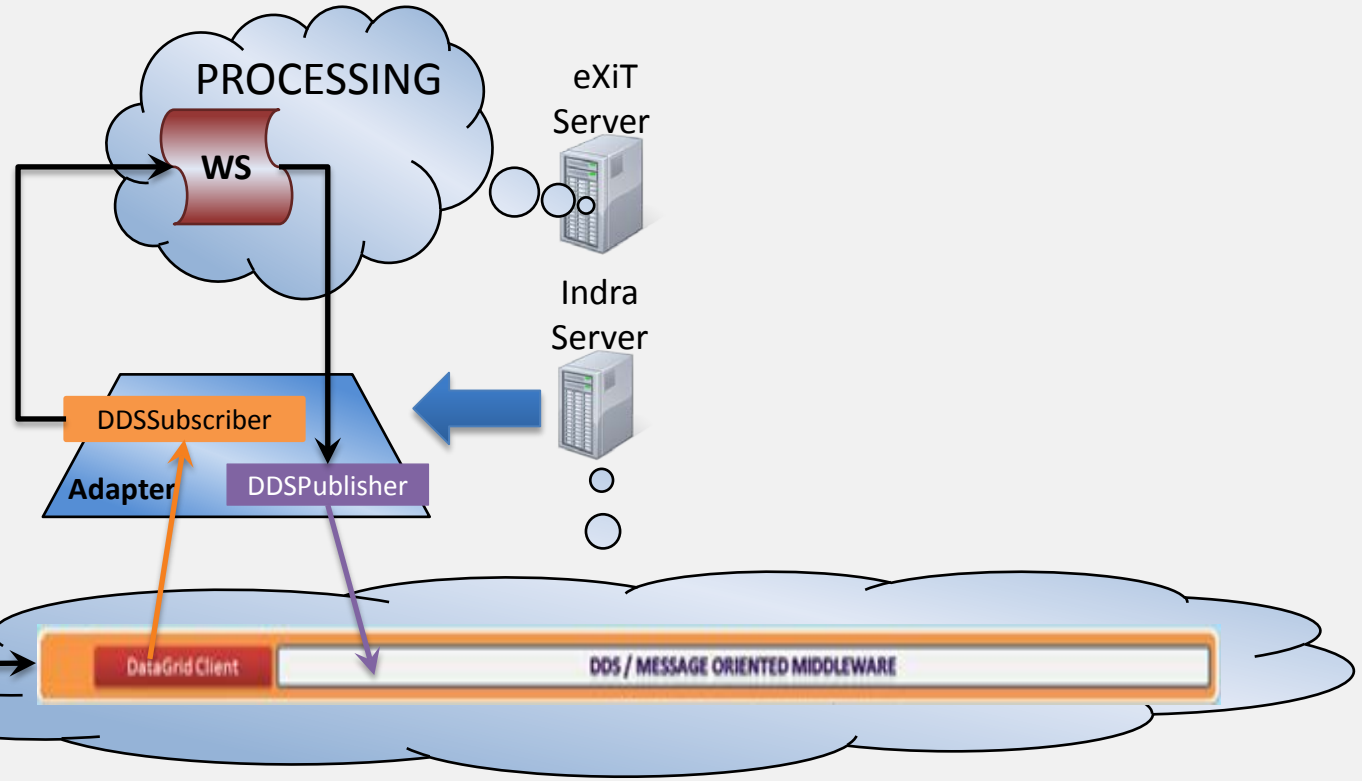
  → Injected in the DDS

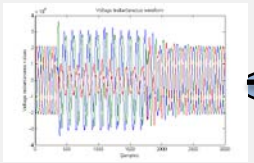
  - double[][] voltageRMS;
  - double[][] voltageAngle;
  - double[][] currentRMS;
  - double[][] currentAngle;
  - double elapsedTimeA;
  - double elapsedTimeB;
  - double elapsedTimeC;
  - double elapsedTimeMax;
  - float minVoltage;
  - float prefaultVoltage;
  - short insertFaultAngle;
  - float maxCurrent;
  - float prefaultCurrent;
  - short source;
  - Complex impedance;
  - float distance;

  → Calculated by WS

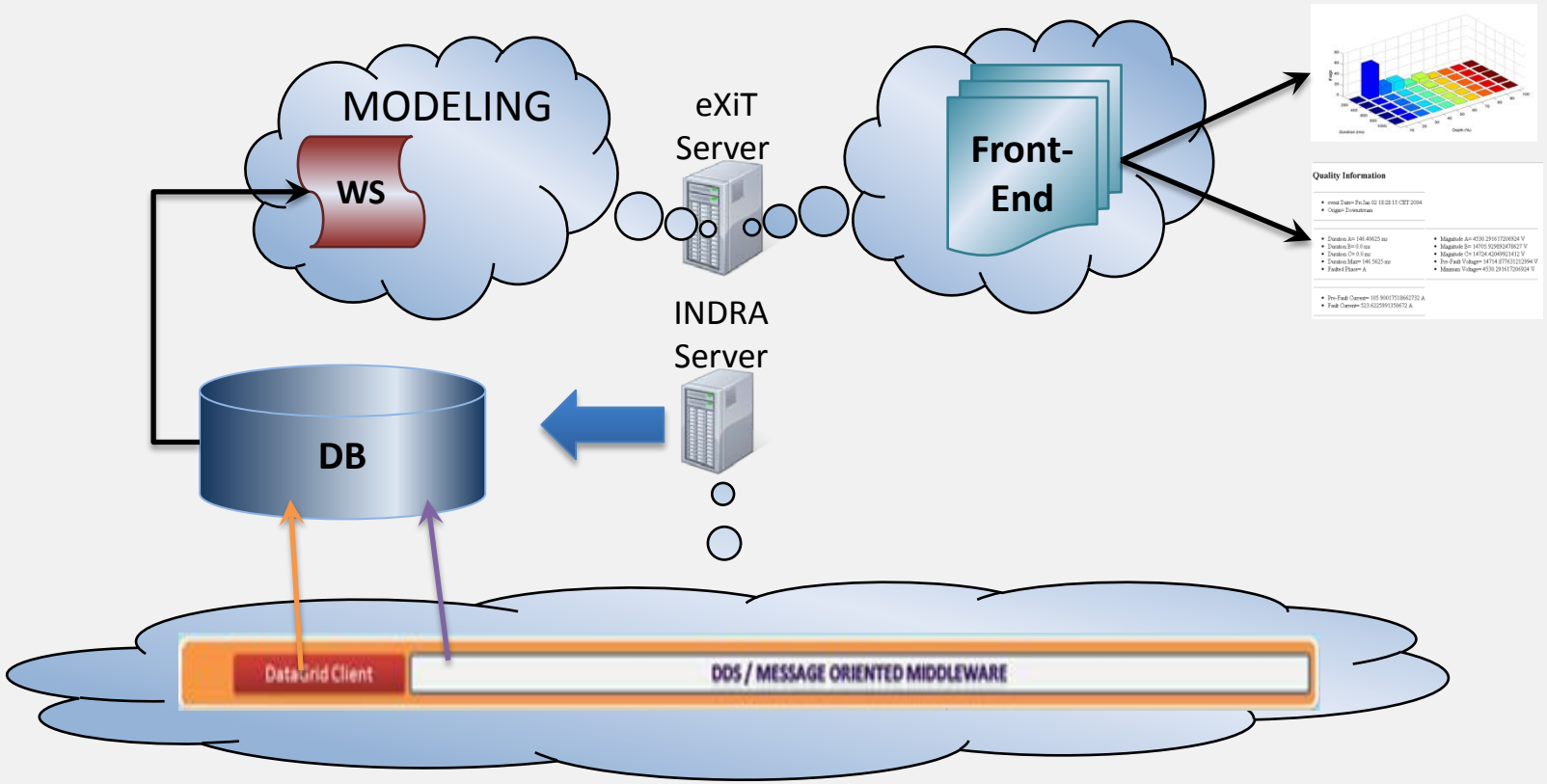
- Raw messages:
  - Information/measurements from the power meters
  - Include basic information of the meters and the disturbance
- Verified messages:
  - Processed information, with values for all the attributes characterizing a disturbance

- Creation and use of an Adapter Service
  - Reactive actor/service that interact with DDS
  - On-line performance invokes WS methods whenever a PQE is received



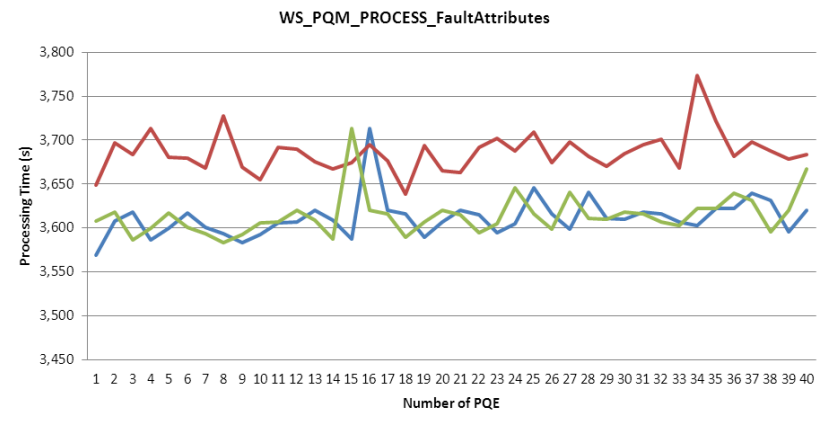


- Creation and use of a Front-End
  - Web services invoked from Front-End.
  - Off-line performance invokes WS methods from historical information

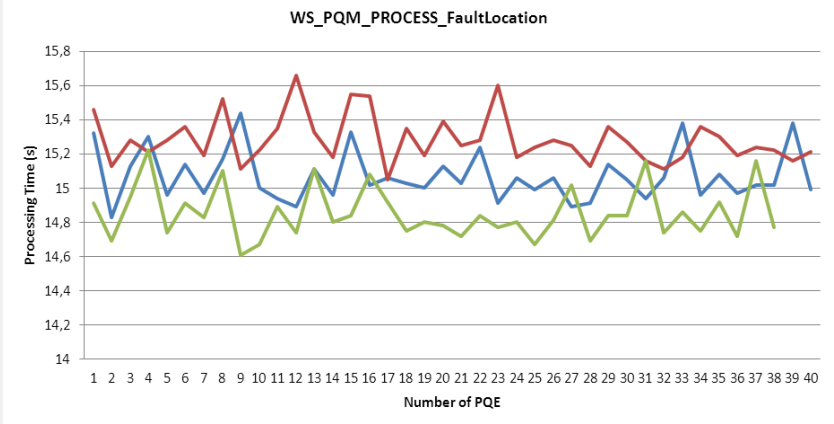


- Performance of PROCESSING Web Services
  - Evaluation of the processing time for computing disturbance features
  - Optimize the global time performance
    - Receive message
    - Process information
    - Send message

- WS_PQM_PROCESS_PQEvent



- WS_PQM_PROCESS_FaultLocation



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Conclusions and Future Work

- Implementation of Web Services for analysis of power disturbances and their evaluation
  - Definition of data structure for power disturbances
- Integration of Web Services into Smart Grid, for Power Quality
  - Software for utilities and costumers power monitoring
- Good on-line performance of the analysis of power disturbances
  - Computation time not critical in real environments

Conclusions and Future Work

- Implement WS for other type of power quality methodology
  - Analysis other type of power disturbances
    - Swells
    - Noise
    - Waveform unbalance
    - Harmonics
  - Extend the data structure to include other attributes

- Security closed related with smart grid architecture
  - Improve WS security with login system

Thank you!

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