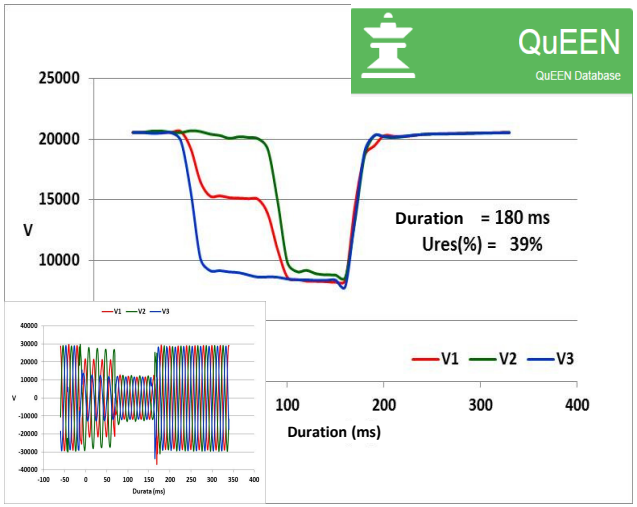
IT4PQ 2nd Stakeholder Virtual Workshop
February 9th, 2022



Power Quality Monitoring in the Italian Medium Voltage Distribution Network

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RSE – Ricerca sul Sistema Energetico

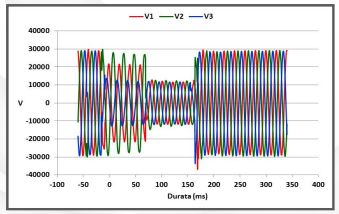
Summary

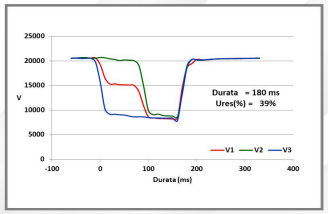
- The QuEEN Monitoring System
- Why worry about voltage dips (VDs)?
- Research provided/provides additional information on VDs
- From QuEEN to MonNaLiSA
- Open Issues
- How Deep Learning and Machine Learning can help
- Conclusions

The QuEEN Monitoring System

PQ monitoring system of the Italian MV distribution grid implemented & managed by RSE since 2006 (Funded by RdS and supported by ARERA):

- 400 Measurement Units (MUs) in the HV/MV substations connected to the MV busbars (~10% of the total number of busbars)
- MUs perform PQ measurements according to IEC 61000-4-30
- Waveforms and RMS voltage sequences recorded during VDs





http://queen.rse-web.it/eng/home.aspx

Why Power Quality Monitoring?

- to provide a sound knowledge of MV networks performance in terms of PQ parameters (CEI - EN 50160) and support Standardization/Regulation

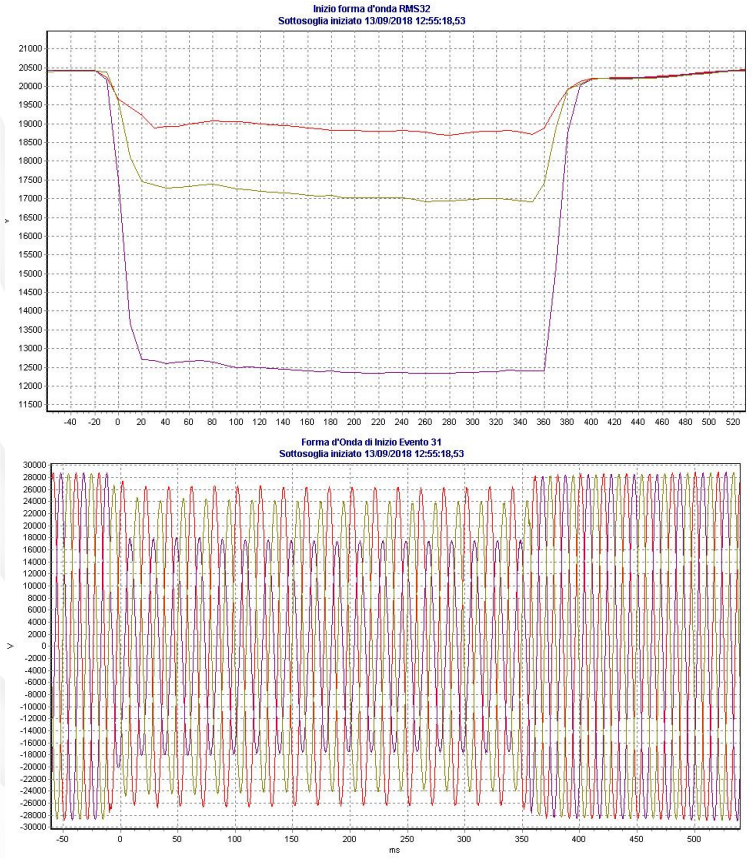
voltage dips
voltage swells
interruptions

voltage variations
rapid voltage variations
unbalances, flicker
voltage harmonics, THD

- VDs classified on the base of duration and depth (or residual voltage)

- gray cells: a zone of Non-immunity for the equipment connected to the MV grid

Avg. number of MV dips for equivalent point of measure within the selected interval (EN50160)						
		Dips duration				
		20-200 ms	200-500 ms	500-1000 ms	1-5 s	5-60 s
Residual V. [%]	80...90	34.9	7.5	2.0	0.6	0.0
	70...80	17.1	5.3	0.6	0.2	0.0
	40...70	28.2	5.3	0.6	0.1	0.0
	5...40	9.9	1.7	0.2	0.0	0.0
	1...5	0.2	0.0	0.0	0.0	0.0



Why worry about voltage dips in MV networks?

Impact on equipment connected to the network

- Voltage dips or micro-interruptions:

  momentary decrease or stop of the flow of energy to the equipment

Direct Effects: degradation of performance depending on the equipment

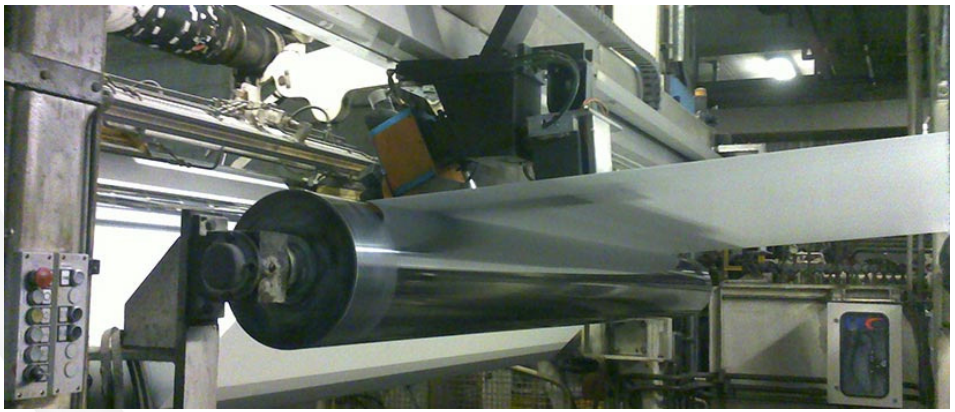
Indirect Effects: related to the criticality of the function performed by the equipment in a process

- Relays and contactors
- Electronic converters
- IT process control equipment
- Synchronous motors
- Lighting
- Asynchronous motors

Impact on complex continuous industrial processes

➢ Type of customers participating in the initial QuEEN project (73)

PAPER INDUSTRY 24%



PLASTIC PACKAGING INDUSTRY 12%

MILLS AND PASTRIES 11%

- ✓ Food (mineral waters, dairy products, ..)
- ✓ Ceramics and Bricks
- ✓ Electrical, electronics (PCB, batteries, ...)
- ✓ Services
- ✓ Mechanics (die casting, molds)
- ✓ ...

Research provided/provides additional information on VDs

Further VDs classifications, beyond the standard, are needed referring to their:

- Validity
- Origin

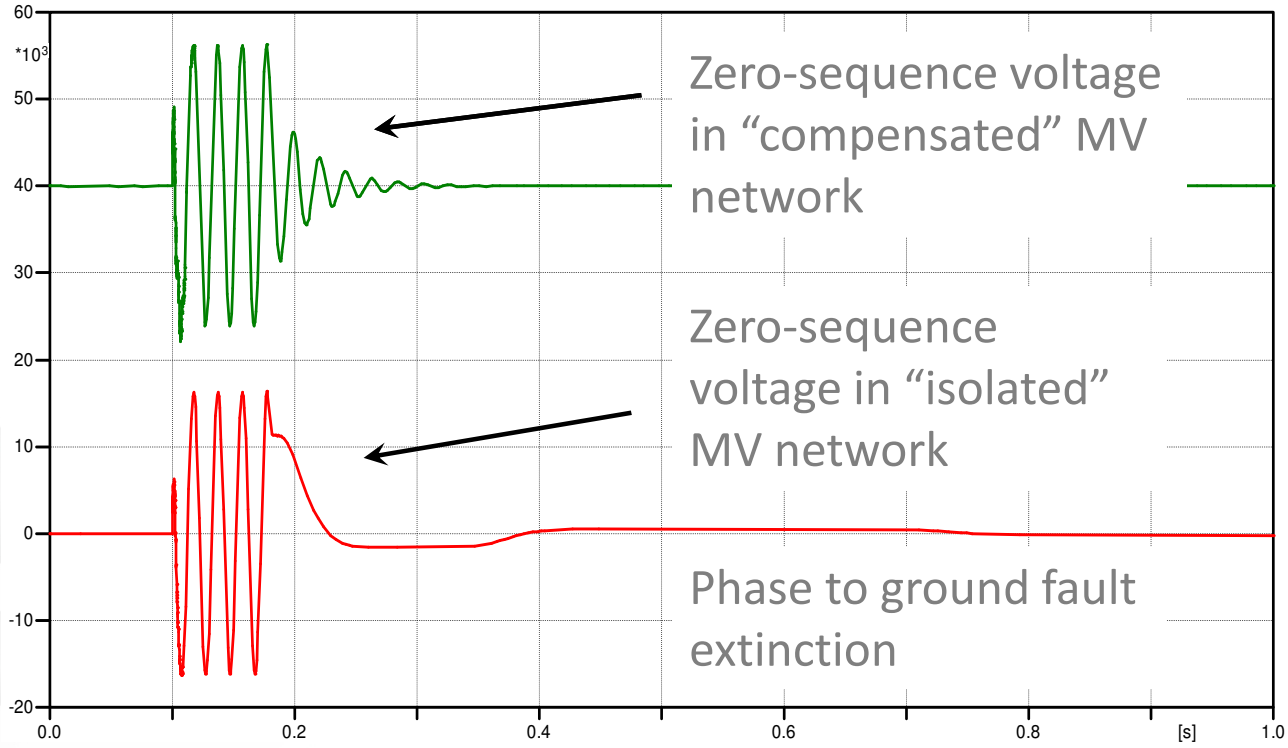
Validity of events in monitoring systems

- MUs are connected to the LV side of voltage transformers (VT)

  (primary windings connected between phase and ground. Line-to-line voltages monitored)

- A single line-to-ground fault may cause VT saturation, during which, a sinusoidal zero-sequence voltage is generated in MV network involving ground

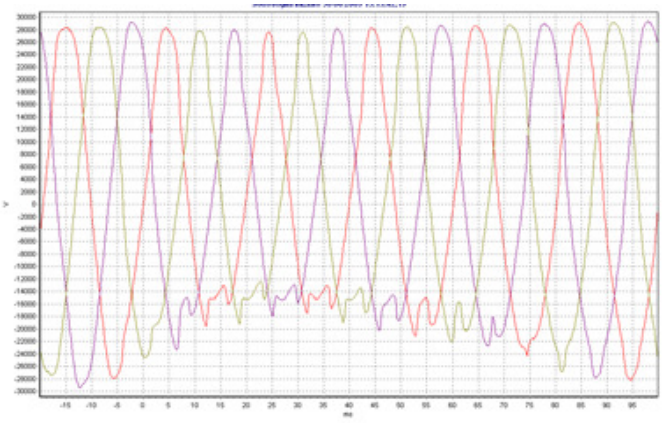
- After the fault is extinguished, this component decays in a different way depending on the neutral connection



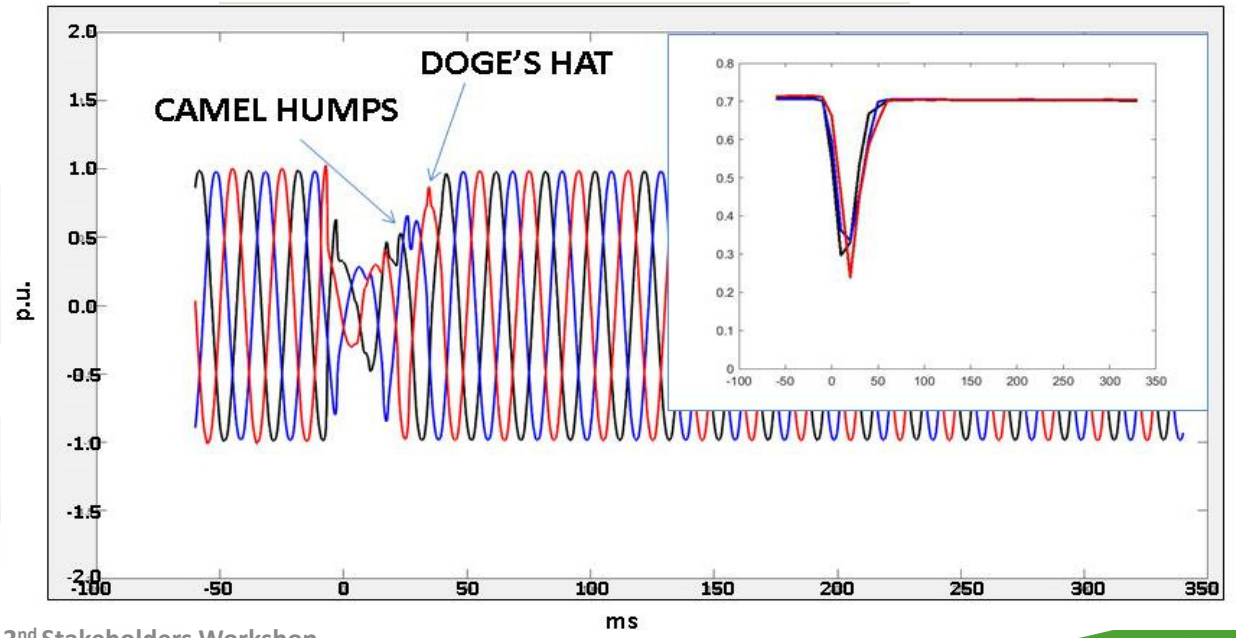
Validity of events in monitoring systems

- In isolated neutral network saturation effects can give origin, at the extinction of the fault, to “false” events for the network, only due to the measurement chain

  (isolated neutral networks are still 25%)



- Their waveforms show some typical deformations: Camel humps and Doge’s hat



- VDs statistics must be cleared of such events (False events)

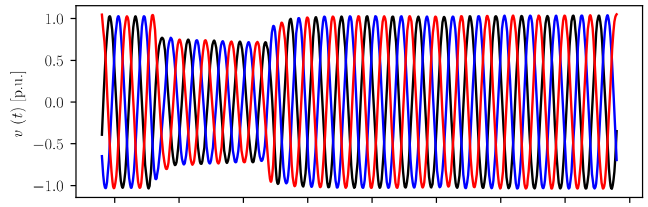
2 °harmonic component detection in measured line to line voltages

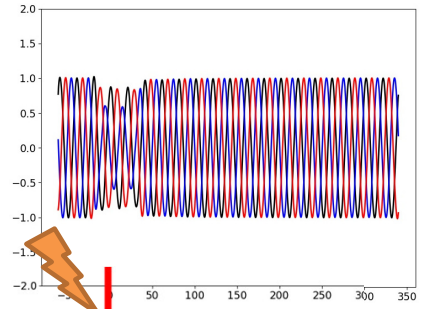
Classification of VD in term of origins

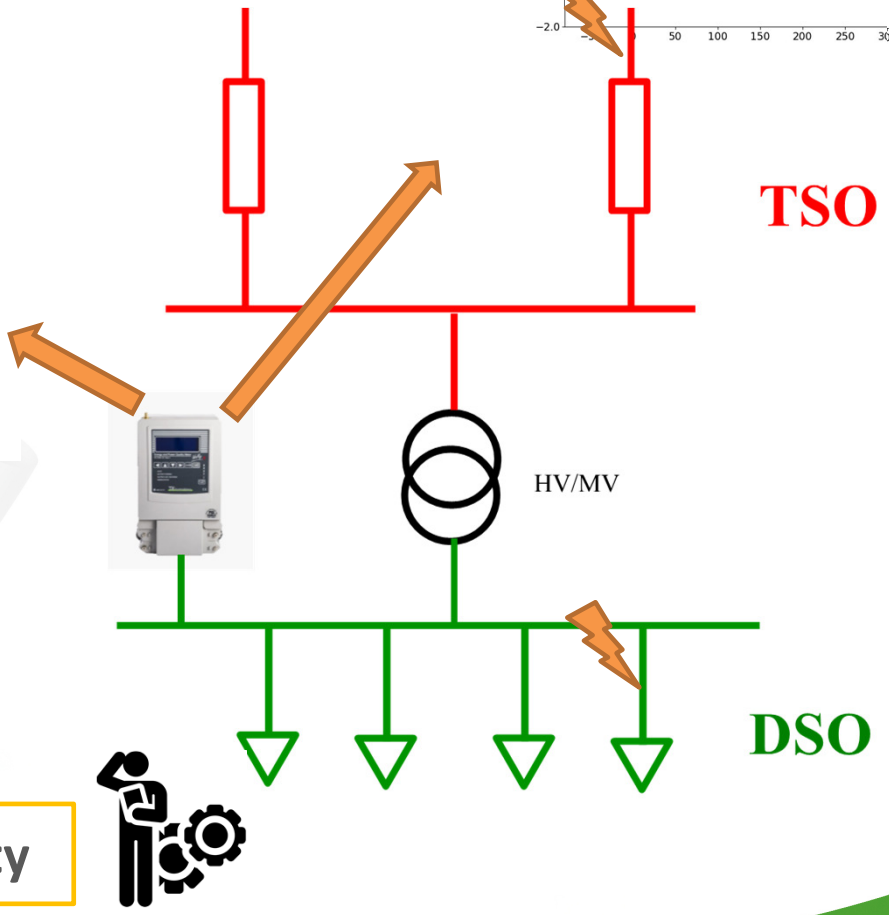
- Voltage dips recorded at MV busbars in HV/MV Substation

Origin:

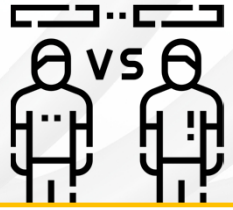
- Upstream/Downstream ?







DSO



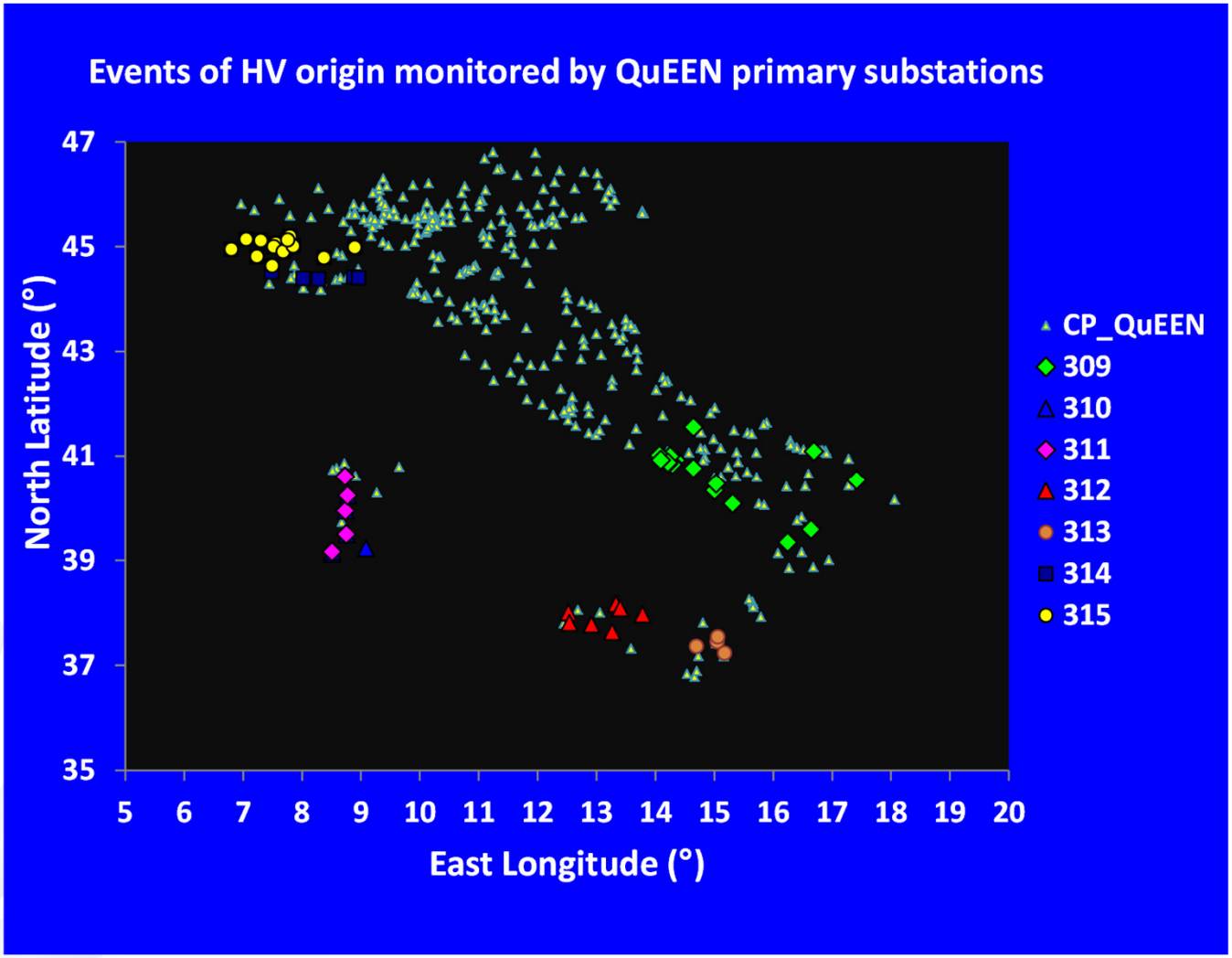
TSO

Position with respect to DSO or TSO responsibility

The Global Method

The percentage of voltage dips of HV origin is evaluated as:

- N° of events monitored contemporaneously at MV level at nearby HV/MV stations underlying a common HV grid
- N° of events correlated to signals coming from HV line distance protections



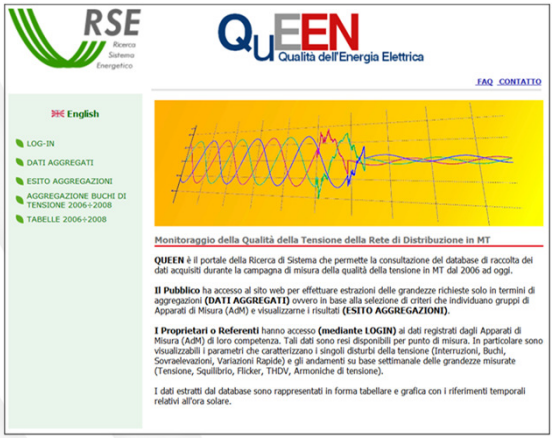
AT: ~ 41%

MT: ~ 59% *

* Average value in the period 2016÷2020

From QuEEN to MonNaLiSA

Starting from QuEEN experience the DSO were asked to monitor all the MV busbars of their HV/MV stations (~4200) by ARERA
…. That's MonNaLiSA



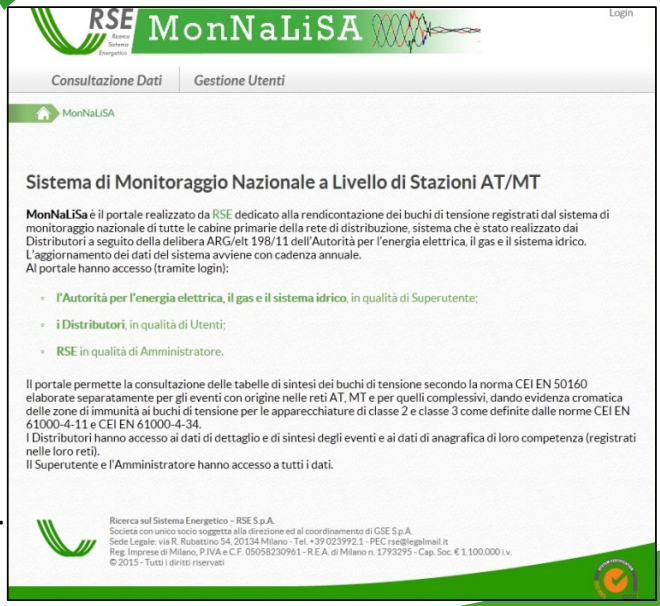
http://queen.rse-web.it

QuEEN VD VALIDITY:

2nd harmonic criterion transferred to MonNaLiSA

VD ORIGIN:

QuEEN Global Method inspired the Local Method adopted in MonNaLiSA



Monitoraggio ***Na***zionale a ***Li***vello di ***S***tazioni ***A***T/MT

Open Issues

2° Harmonic Criterion

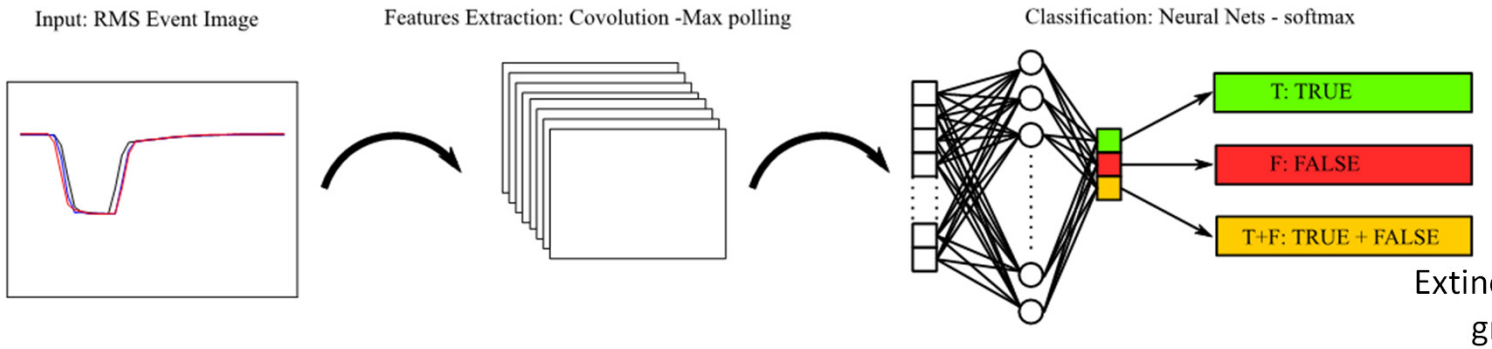
- significant effectiveness (>80%) BUT
- does not give a Boolean response (True/False)
- **12,6%* of Undefined Cases (it is not able to give answer)**

Global and Local Criteria

- **require extensive monitoring, topological information from TSO**
- Local Criterion effectiveness (~89%)

* Average value in the period 2010÷2021

How Deep Learning and Machine Learning can help



TRUE+FALSE
Extinction of polyphase grounded faults

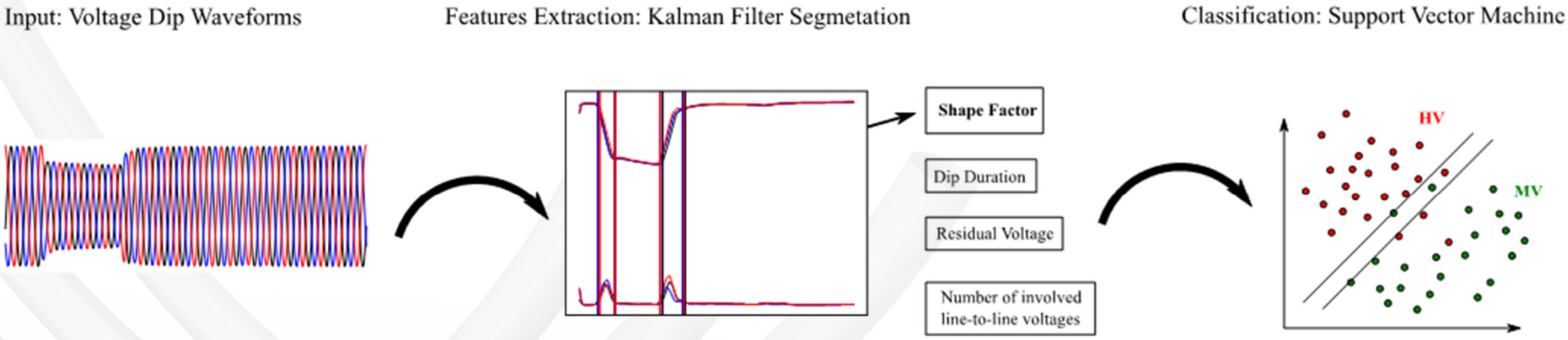
DELFI - DEep Learning for False events Identification

Input:	jpg images of RMS sequence
Model:	1 layer CNN network
Optimization:	Bayesian
Classifier:	SOFTMAX algorithm
Training:	80%10%10% training /development/test set

How Deep Learning and Machine Learning can help

FExWaveS Application

Features Extraction from Waveform Segmentation



Conclusions

- The availability of data from a long-term monitoring is the prerequisite for any Power Quality improvement strategy
- QuEEN has provided a wealth of data/experiences useful for the design of the National Monitoring System
- VDs besides their duration and depth must be characterized by their “validity” (true events, due to actual faults in the network, or false events, caused by VT saturation) and “origin” (upstream or downstream from the point of measurement)

Conclusions

- Proper procedures and algorithms have been implemented: 2° harmonic criterion (Validity assessment) and "Global Method" (Origin assessment)
- These "current solutions" have reached good performances but there are still some open issues that require an additional research effort
- DL and ML can help in this case: the DELFI classifier for false voltage dips identification while, as regards their origin, the FExWaveS + SVM classifier
- The "new criteria" implementation in QuEEN web site, to test them on a larger amount of data, will allow a constant comparison with the performance of the "current" methods

ACKNOWLEDGMENT:

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Thanks for the attention!!!