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Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

Politecnico di Torino

SAPIENZA UNIVERSITÀ DI ROMA

INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

Missione 4 Istruzione e Ricerca

RISK AND RESILIENCE DAY 2024

Newcastle Upon Tyne (UK)

Andrea MAZZA, Luigi CALCARA

12 March 2024

extrastrong

Resilience Evaluation by **Ex**perimental and **T**heo**r**etical **A**pproache**s** in Elec**tr**ical Distributi**on** Systems with Underg**r**ound Cables

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PARTNERS

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POLITECNICO DI TORINO

- The Electrical Energy (ELEN) research group is the National coordinator of EXTRASTRONG
- It has experience on developing simulation algorithms for network calculation, both in normal and faulted conditions
- It had numerous collaborations with DSOs about reliability aspects, predictive maintenance and resilience
- Main contact: Andrea Mazza (andrea.mazza@polito.it)

Politecnico di Torino
electrical energy

UNIVERSITÀ "LA SAPIENZA" - ROMA

- Sapienza University of Rome (SUR) has collaborated over the years with different Italian DSOs
- Since 2014 it started an experimental acquisition in several sites on underground Medium Voltage (MV) cables and relative joints
- It also developed an instrument able to measure the thermal resistivity of the ground
- Main contact: Luigi Calcara (luigi.calcara@uniroma1.it)

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INRIM - TORINO

- INRiM (Istituto Nazionale di Ricerca Metrologica) is a public scientific research body and is the National Metrology Institute of Italy
- It participates to the project with the INRIM-LATFC Laboratorio Alte Tensioni e Forti Correnti (High Voltage and High Power Lab), which is oriented to the research and calibration of testing measuring systems as well as testing for electrical apparatus
- Main contact: Paolo Roccato (p.roccato@inrim.it)

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OVERVIEW OF THE PROJECT

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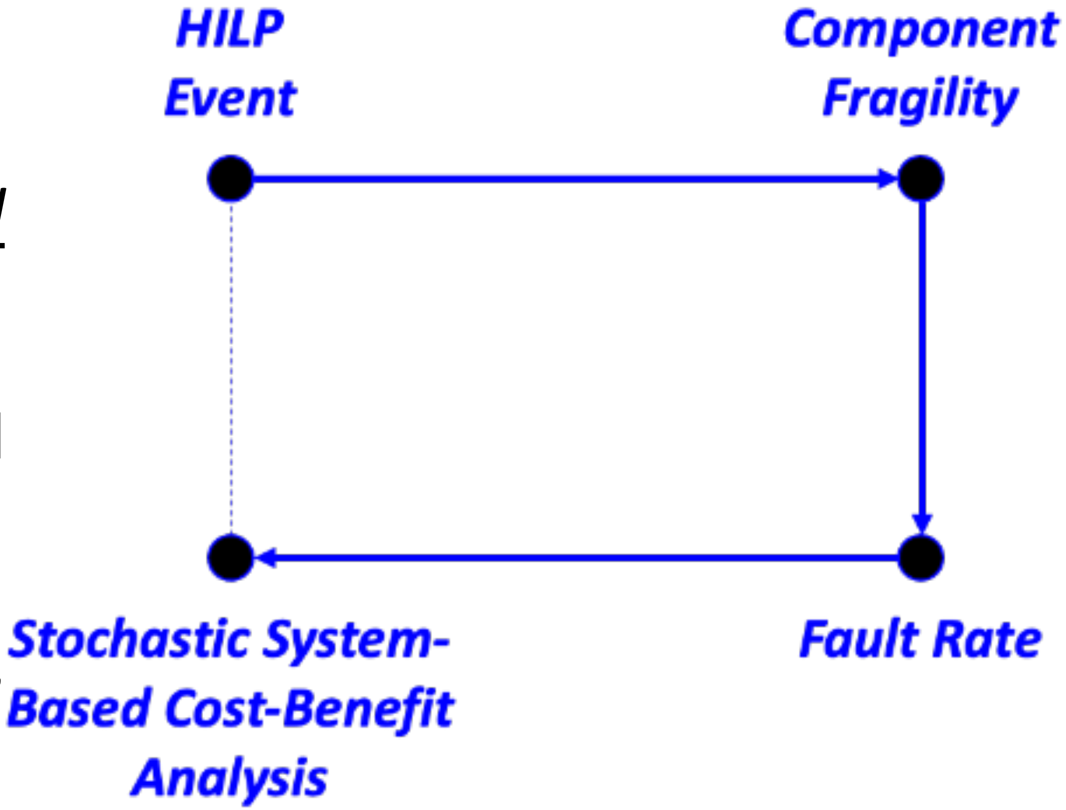
THE "RESILIENCE RECTANGLE"

- First corner → *heat wave*
- Second corner → portion of *underground cables* and joints
- Third corner → *experimental* tests and component *modeling*
- Fourth corner → *system-based studies*, with real-like grids



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SOME HINTS ABOUT THE PROJECT

- Project goals:
  - Proposing a standard measurement system: by installing it, the distribution system operators (DSOs) may check the system conditions and avoid failures due to HWs
  - Proposing standard laboratory test procedures to evaluate the electrical resilience of cables and joints
  - Creating a test bench replicating several load and HW conditions: manufacturers may verify the compliance of the products with the tests specified above
  - Improving the component models including HW effects, insulation degradation and ampacity modification
  - Refining the Statistical-based Cost Benefit Analysis (SCBA)
- Methodology: combined used of 1) field measurements, 2) laboratory experience, 3) simulation activities

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FIELD MEASUREMENTS AND TEST BED CALIBRATION

- Field measurement
  - Needed to have a benchmark on soil moisture, irradiance and heat transfer under defined electrical load and temperature of cables and joints
  - Used to calibrate and set up a test bench installed in the laboratory → replication of the measured irradiance (and therefore heat exchange) conditions.
- Test bench: once calibrated, can be used to replicate the typical irradiance and load conditions that occur during HW → both cables and joints will be studied
- **IMPORTANT**: Both the test bench and the measurement system in the field, will be designed paying attention to apply **metrological accuracy**

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LAB ACTIVITIES AND COMPONENT MODEL REFINING

- Type of tests:
  - Insulation measurements (e.g., capacitance and tg δ)
  - High voltage withstand tests
- These tests will be carried out both on portions of cables and joints subject to replicated HWs and on portions of cable and joints not subject to HWs → effect of the phenomenon
- The results of the tests will be used to refine the cable mathematical model to determine the ampacity → simulation of the internal behavior of cables and joints subject to synthetic HW conditions

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STATISTICAL-BASED COST BENEFIT ANALYSIS (SCBA)

- The behaviors of the components before and after the HW application will be included in a SCBA, aiming at replicating the failures that occur in real-like grids
- This will lead to evaluate the effect of HW and study how the use of different types of cable (e.g., with different insulation levels) or operating methods (e.g., network reconfiguration) can alleviate the HW effects in an economically viable way

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CURRENT ACTIVITIES

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THE NECESSITY OF WEATHER DATA: GLOBAL AND LOCAL SCALES

- Many different datasets, at global or local scale:
  1. Copernicus:
     - Spatial coverage: global
     - Spatial resolution: one point every 0.75° lat and lon
  2. Università di Torino:
     - Spatial coverage: local (Turin)
     - Time coverage: from 2017 to now
  3. Local meteo provider (DanMeteo):
     - Spatial coverage: local (Turin)
     - Time coverage: from 2006 to now

DATABASE INFRASTRUCTURE

- To host all the data a MariaDB database has been set up on a dedicated server
- Data redundancy: HW RAID-5 configuration
- Up to now, more than 1.6 billion records in the DB

extrastrong	145,2 GiB
copernicusGlobRea	145,2 GiB

idx	time	latitude	longitude	slt	sd	tcc	u10	v10	t2m	d2m	lcc	hcc	skt	aerscc	pm10
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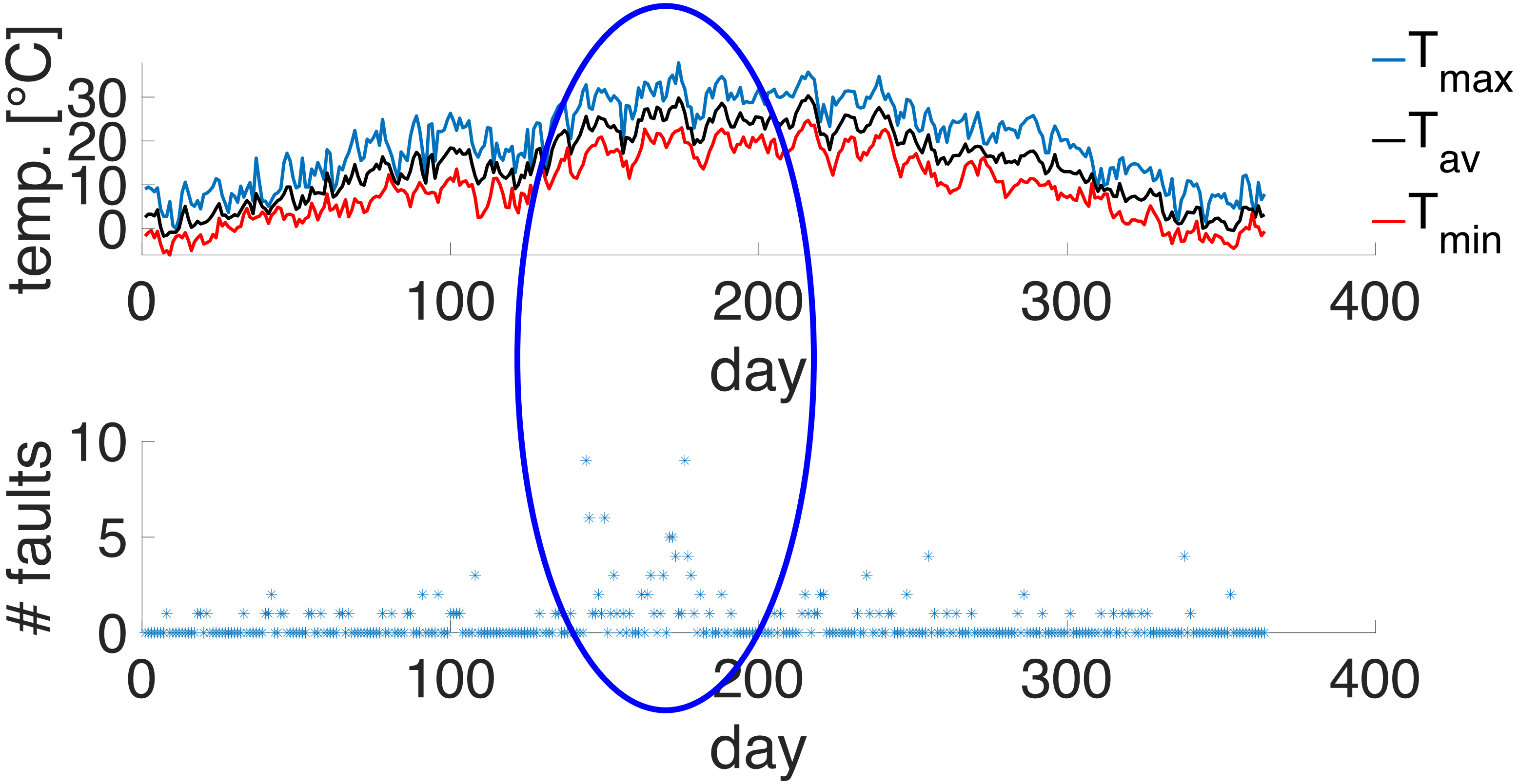
22	2004-01-01 00:00:00	90	15,75	0	0	0,345001	-9,60263	-3,86198	252,606	247,739	0	0,345001	250,936	0	0
23	2004-01-01 00:00:00	90	16,5	0	0	0,345001	-9,60263	-3,86198	252,606	247,739	0	0,345001	250,936	0	0
24	2004-01-01 00:00:00	90	17,25	0	0	0,345001	-9,60263	-3,86198	252,606	247,739	0	0,345001	250,936	0	0
25	2004-01-01 00:00:00	90	18	0	0	0,345001	-9,60263	-3,86198	252,606	247,739	0	0,345001	250,936	0	0
26	2004-01-01 00:00:00	90	18,75	0	0	0,345001	-9,60263	-3,86198	252,606	247,739	0	0,345001	250,936	0	0
27	2004-01-01 00:00:00	90	19,5	0	0	0,345001	-9,60263	-3,86198	252,606	247,739	0	0,345001	250,936	0	0
28	2004-01-01 00:00:00	90	20,25	0	0	0,345001	-9,60263	-3,86198	252,606	247,739	0	0,345001	250,936	0	0
29	2004-01-01 00:00:00	90	21	0	0	0,345001	-9,60263	-3,86198	252,606	247,739	0	0,345001	250,936	0	0
30	2004-01-01 00:00:00	90	21,75	0	0	0,345001	-9,60263	-3,86198	252,606	247,739	0	0,345001	250,936	0	0
31	2004-01-01 00:00:00	90	22,5	0	0	0,345001	-9,60263	-3,86198	252,606	247,739	0	0,345001	250,936	0	0

TEMPERATURE AND FAULTS

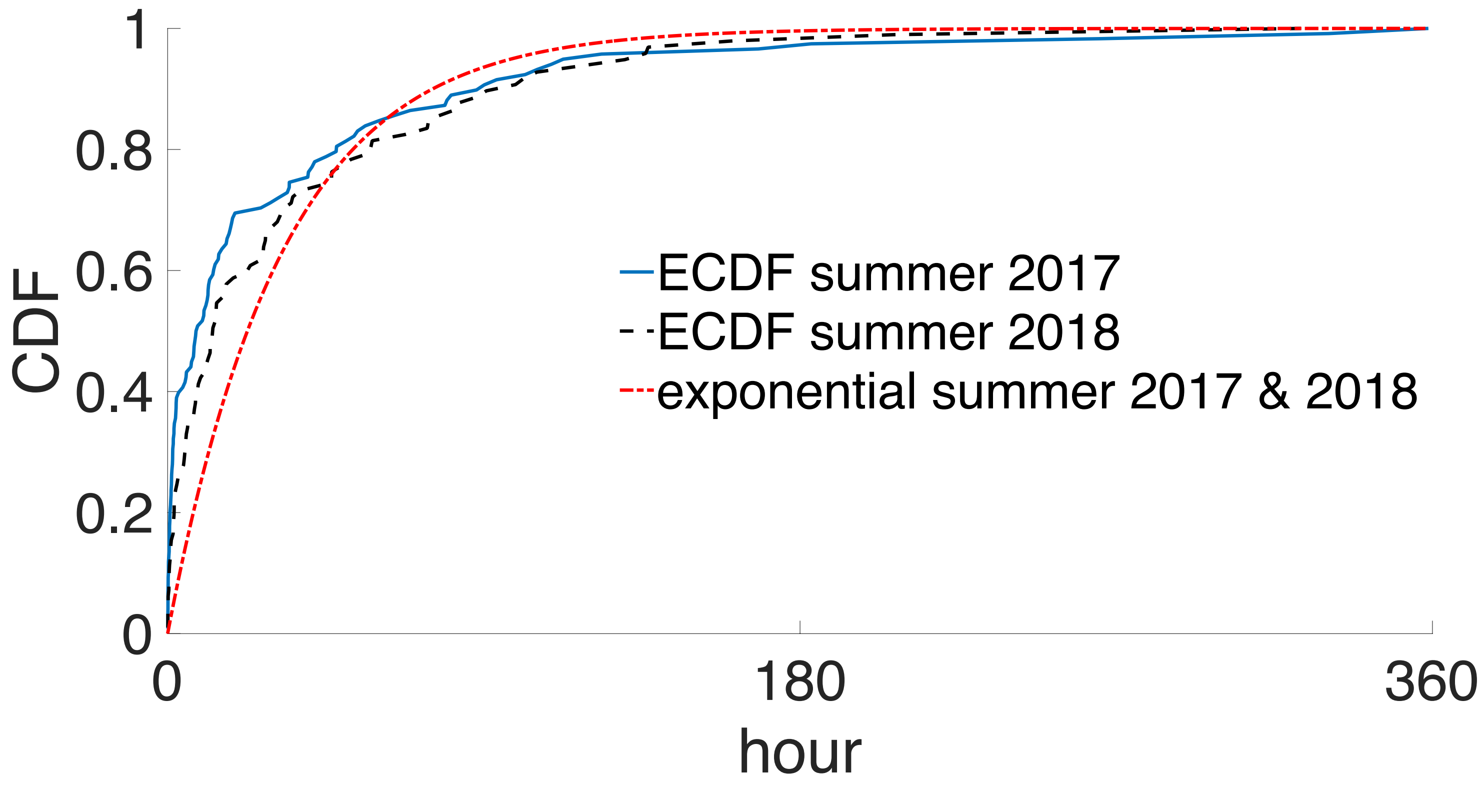
- Some real data from Torino (Italy)



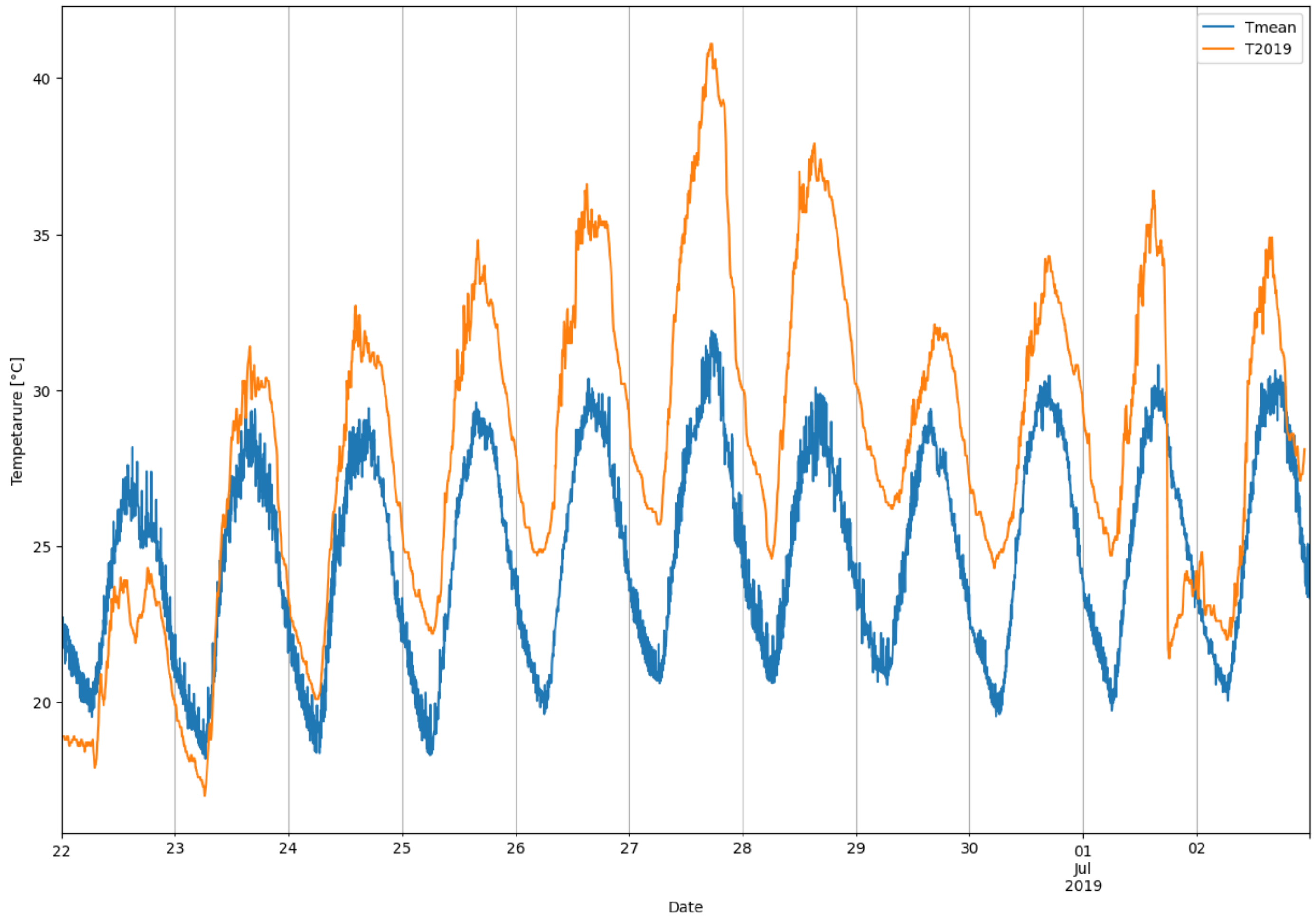
- Daily temperatures
- Fault occurrence during the highest temperature period

CUMULATIVE OF THE FAULTS – SUMMER 2018 AND 2017

- Some real data from Torino (Italy)



- Time between failure (TBF)
- RED: exponential curve (i.e., exponentail curve, for independent faults)
- BLUE and DASHED-BLACK: experimental CDF the TBF for year 2017 and 2018
- 2017 worse than 2018 (more faults with low TBF)



- Example of heat wave in in Torino, in June and July 2019
- Peak 27 June 2019
- Use of a HW indicator called *Excess Heat Factor*

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EXCESS HEAT FACTOR

- For the day *i* defined as follows:

$$EHF_i = max(0, EHI_{sig}) \cdot max(1, EHI_{accl})$$

- With:
  - *N*: number of days beyond *i*
  - T_{95}: 95th percentile of Daily Mean Temperatures (9am to 9am) over 18 years (2006-2023)
  - $EHI_{sig} = \frac{\sum_{f=0}^{N} T_{i+f}}{N+1} - T_{95}$ → *Significance index*: deviation from historical conditions
  - $EHI_{accl} = \frac{\sum_{f=0}^{N} T_{i+f}}{N+1} - \frac{\sum_{p=1}^{30} T_{i-p}}{30}$ → *Acclimatation index*: deviation from short term reference (compareison with the 30-days average daily temperature)

K. Tolika, Assessing Heat Waves over Greece Using the Excess Heat Factor (EHF), Climate, vol.7(9), 2019

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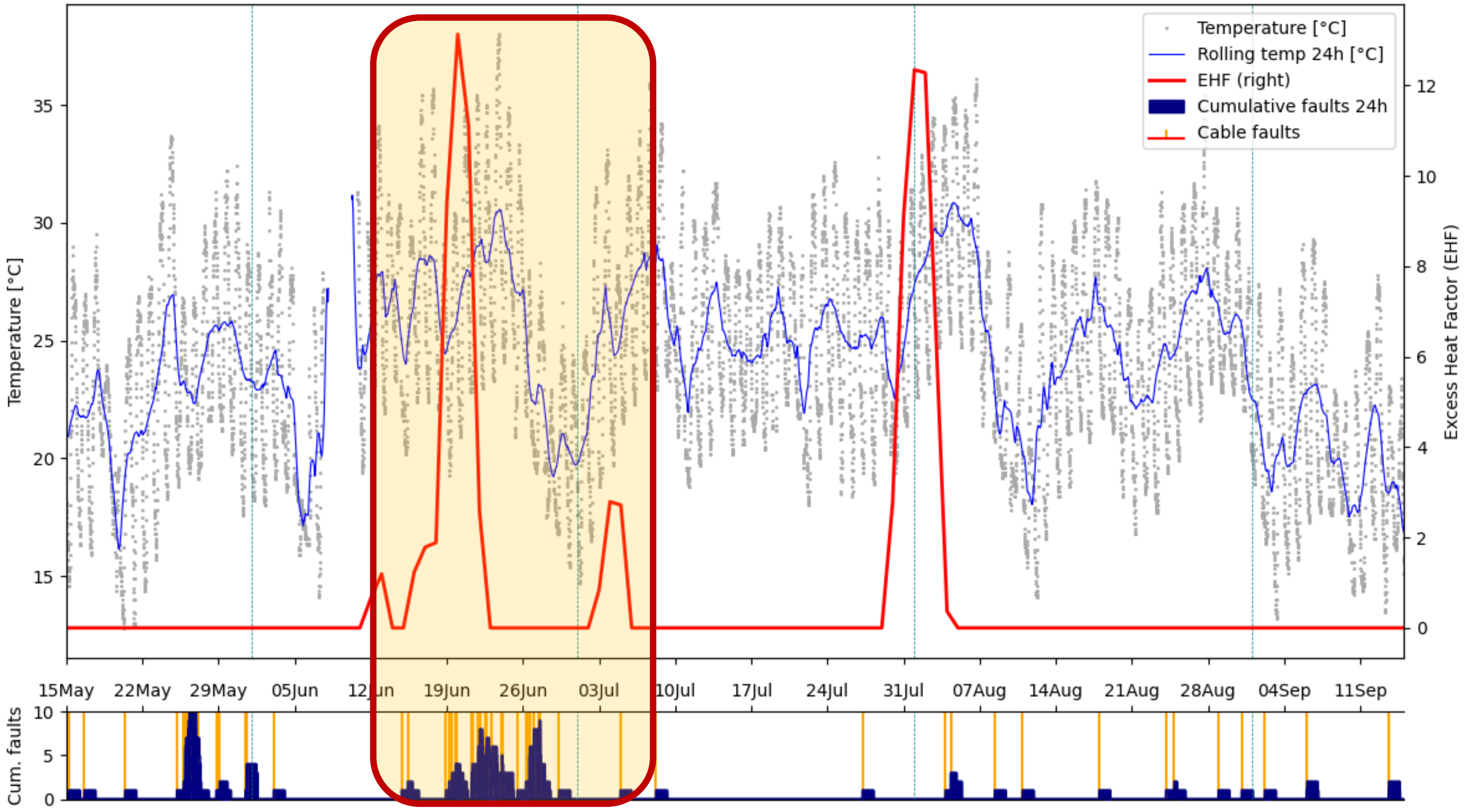

- *EHF* → able to higlight the heat waves
- Faults → also after the heat waves (delay effect), but sometimes not aligned with *EHF*

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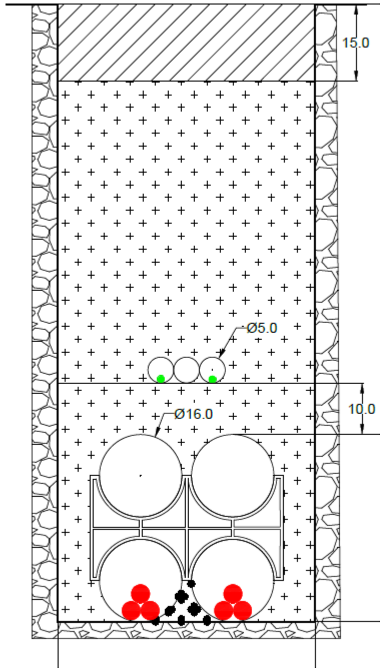
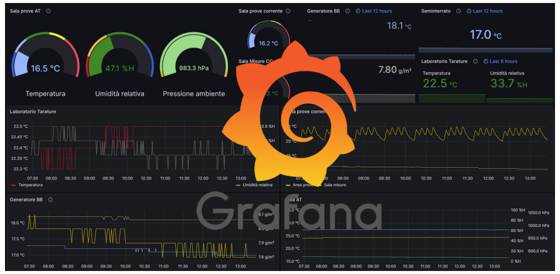
DAQ SYSTEM

- Continue measurements of:
  - Cable / Joint (Tc on external insulation)
  - Filling material (crushed-stone) or cable pipe (Tc)
  - Ground temperature and humidity
  - Weather parameter
  - Pyranometer (near the area, when possible)
- Database of all measure accessible by project partners
- Traceability of measure to National Standards



FTP
(MQTT)

influxdb



NEXT ACTIVITIES

- Refining use of *EHF* on several years
- Analysis of new fault datasets, given by different DSOs in Italy
- Installation of the measurement system on a real underground MV line in Torino
- Starting the installation of the test bench
- Experimental results expected after the summer 2024

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