

ML-Assistant For Human Operators in Processing Power System Alarm Data

Ricardo Bessa



ricardo.j.bessa@inesctec.pt

Motivation and Challenges

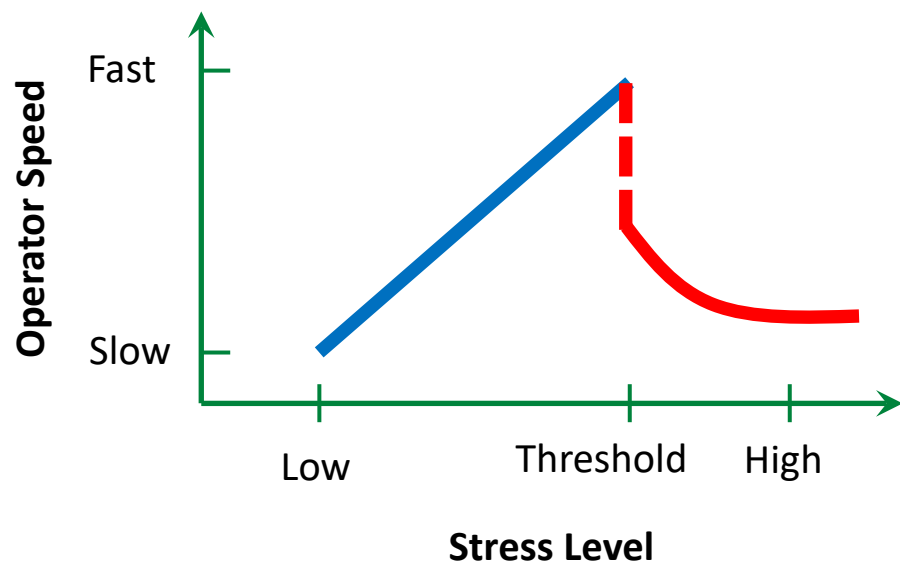


Fig. ref.: Kirschen, D. S., Wollenberg, B. F. (1992). Intelligent alarm processing in power systems. Proceedings of the IEEE, 80(5), 663-672

Challenges

Power system more complex to operate



Operation complexity rising at a fast pace
(e.g., DER, prosumers, grid maintenance)



Decision-making under pressure

Grid monitoring & protection equipment



Large volume of real-time and historical alarms data

High-volume of the information generated during outages



up to 200 alarm messages per minute

High Cognitive Load!

Alarms!



Decisions!

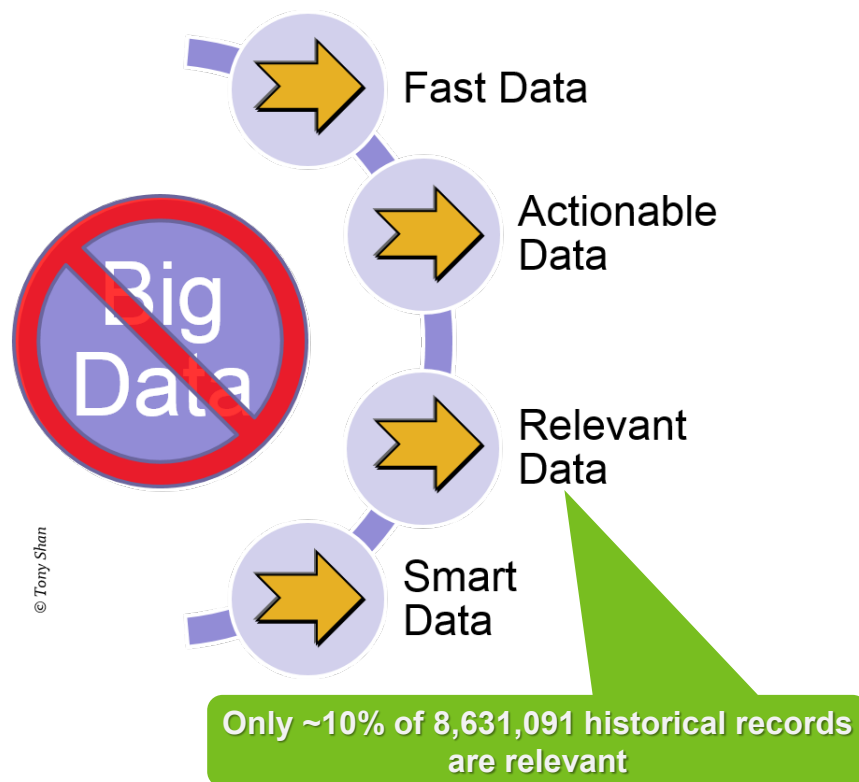


Data!

only for assets in HV and MV grids!

Data Representation

Raw SCADA Data from a DSO



evdate	evdesc				
2014-01-02 06:33:14.000	SE SAO JORGE	P332 SAO MAMEDE	MAX I> INST	ARRANQUE	
2014-01-02 06:33:14.000	SE SAO JORGE	P330 TRANSFORMADOR2	MAX I> INST UP1	ARRANQUE	
2014-01-02 06:33:14.000	SE SAO JORGE	P330 TRANSFORMADOR2	MIN U< INST	ARRANQUE	
2014-01-02 06:33:14.000	SE SAO JORGE	P330 TRANSFORMADOR2	MIN U<< INST	ARRANQUE	
2014-01-02 06:33:14.000	SE SAO JORGE	P502 TRANSFORMADOR2	MAX I> INST UP1	ARRANQUE	
2014-01-02 06:33:13.000	SE SAO JORGE	P502 TRANSFORMADOR2	MAX I> INST UP2 - DIF	ARRANQUE	
2014-01-02 06:33:14.000	SE SAO JORGE	P332 SAO MAMEDE	MAX I>>> INST	ARRANQUE	
2014-01-02 06:33:14.000	SE SAO JORGE	P332 SAO MAMEDE	MAX I>>> TEMP	DISPARO	
2014-01-02 06:33:14.000	SE SAO JORGE	P332 SAO MAMEDE	PROT DEFEITO FASE-FASE	DISPARO	
2014-01-02 06:33:24.000	SE SAO JORGE	P332 SAO MAMEDE	SUPERVISAO CIRCUIT DESL	ALARME	
2014-01-02 06:33:14.000	SE SAO JORGE	P330 TRANSFORMADOR2	NORMALIZACAO TENSÃO+FREQ	INATIVO	
2014-01-02 06:33:14.000	SE SAO JORGE	P332 SAO MAMEDE	DISJUNTOR	DESLIGADO	
2014-01-02 06:33:14.000	SE SAO JORGE	P332 SAO MAMEDE	PROT TERRAS RESIST INST	ARRANQUE	
2014-01-02 06:33:14.000	SE SAO JORGE	P326 MIRA D'AIRE	MAX I>> INST	ARRANQUE	
2014-01-02 06:33:14.000	SE SAO JORGE	P326 MIRA D'AIRE	PROT TERRAS RESIST INST	ARRANQUE	
2014-01-02 06:33:14.000	SE SAO JORGE	P329 TSA+REACTANCIA2	MAX Io> DTR INST	ARRANQUE	
2014-01-02 06:33:14.000	SE SAO JORGE	P329 TSA+REACTANCIA2	MAX Io>>>DTR INST	ARRANQUE	
2014-01-02 06:33:14.000	SE SAO JORGE	P332 SAO MAMEDE	MAX I>>> INST	NORMAL	
2014-01-02 06:33:14.000	SE SAO JORGE	P326 MIRA D'AIRE	MAX I>>> INST	ARRANQUE	
2014-01-02 06:33:14.000	SE SAO JORGE	P326 MIRA D'AIRE	MAX I> INST	ARRANQUE	
2014-01-02 06:33:14.000	SE SAO JORGE	P328 PATAIAS	PROT TERRAS RESIST INST	ARRANQUE	
2014-01-02 06:33:14.000	SE SAO JORGE	P329 TSA+REACTANCIA2	MAX Io>>>INST PHB	ARRANQUE	
2014-01-02 06:33:14.000	SE SAO JORGE	P332 SAO MAMEDE	MAX I> INST	NORMAL	
2014-01-02 06:33:14.000	SE SAO JORGE	P332 SAO MAMEDE	MAX I>> INST	NORMAL	
2014-01-02 06:33:14.000	SE SAO JORGE	P332 SAO MAMEDE	PROT DEFEITO FASE-FASE	NORMAL	
2014-01-02 06:33:14.000	SE SAO JORGE	P332 SAO MAMEDE	PROT TERRAS RESIST INST	NORMAL	
2014-01-02 06:33:14.000	SE SAO JORGE	P332 SAO MAMEDE	MAX I>>> TEMP	NORMAL	
2014-01-02 06:33:14.000	SE SAO JORGE	P328 PATAIAS	PROT TERRAS RESIST INST	NORMAL	
2014-01-02 06:33:14.000	SE SAO JORGE	P326 MIRA D'AIRE	MAX I>>> TEMP	DISPARO	
2014-01-02 06:33:14.000	SE SAO JORGE	P326 MIRA D'AIRE	PROT DEFEITO FASE-FASE	DISPARO	
2014-01-02 06:33:14.000	SE SAO JORGE	P509 BARRAMENTO2	TENSÃO BARR	56.386 KV	Baixo
2014-01-02 06:33:14.000	SE SAO JORGE	P329 TSA+REACTANCIA2	MAX Io>>>INST PHB	NORMAL	
2014-01-02 06:33:14.000	SE SAO JORGE	P326 MIRA D'AIRE	DISJUNTOR	DESLIGADO	

Source: E-REDES SCADA Alarm event log data
(a snapshot for less than a second)

Data Representation

Pros:

- simple approach
- low computational effort

Cons:

- unable to capture relations between sequence tags
- variable output length
- sparse representation (*one-hot encoding*)

JSRAN-3305-PRETA ARRANQUE
JSRAN-3305-PRETA ARRANQUE
JSRAN-3305-PRETD DISPARO
JSRAN-3305-DJDT- DISPARO
JSRAN-3305-DJEST DESLIGADO

Pros:

- simple approach
- low computational effort
- fixed output length

Cons:

- unable to capture relations between sequence tags
- sparse representation of original data

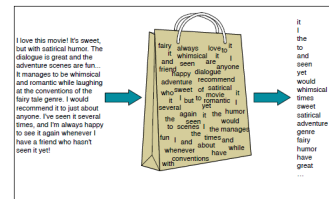
Integer Encoding

JSRAN-3305-PRETA ARRANQUE 1
JSRAN-3305-PRETD DISPARO 2
JSRAN-3305-DJDT- DISPARO 3
JSRAN-3305-DJEST DESLIGADO 4

One-Hot Encoding

Pet	Cat	Dog	Turtle	Fish
Cat	1	0	0	0
Dog	0	1	0	0
Turtle	0	0	1	0
Fish	0	0	0	1
Cat	1	0	0	0

Bag-of-Words



TF-IDF

$$w_{i,j} = tf_{i,j} \times \log \left(\frac{N}{df_i} \right)$$

$tf_{i,j}$ = number of occurrences of i in j
 df_i = number of documents containing i
 N = total number of documents

Transformed Sequence

[1, 1, 2, 3, 4]

(1 row per sequence)

(Max. number = Vocabulary size)

[1, 0, 0, ..., 0]
[1, 0, 0, ..., 0]
[0, 1, 0, ..., 0]
[0, 0, 1, ..., 0]
[0, 0, 0, ..., 1]

(1 row per sequence)

(nr. cols = vocabulary size)

Tag1, Tag2, Tag3, Tag4

[2, 1, 1, 1]

(1 row per sequence)

(nr. cols = vocabulary size)

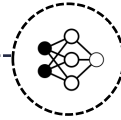
[0.2, 0.1, 0, 0, ..., 0.9, 0.2, 0]

(1 row per sequence)

(nr. elements = vocabulary size)

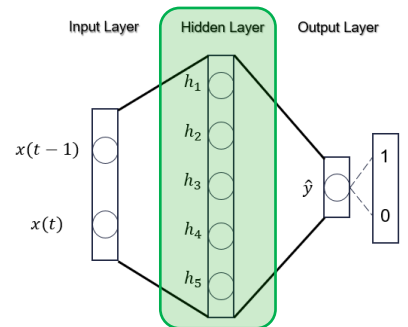
Data Representation

Word2Vec



Input Layer

Tag sequence skip-grams



Output

Probability of being the nearby tag for every tag in vocabulary

Word Embeddings Sequence:

[0.3, 0.2, 0.1, 0.9]	Tag1
[0.8, 0.5, 0.9, 0.3]	Tag2
[0.2, 0.3, 0.3, 0.1]	Tag3
[0.1, 0.7, 0.3, 0.2]	Tag4

$N \times M$ matrix

Where:

N – number of words in sequence

M – embedding layer dimension (n. units)

Pros:

- captures relations between sequence tags

Cons:

- time-consuming (parameter tuning needed)
- high computational effort
- variable output length

Graph-based Representation

Time synchronization
problem
*reclosure cycle event after
circuit breaker closed*

Operator sent
command to close a
circuit breaker after it
was closed already

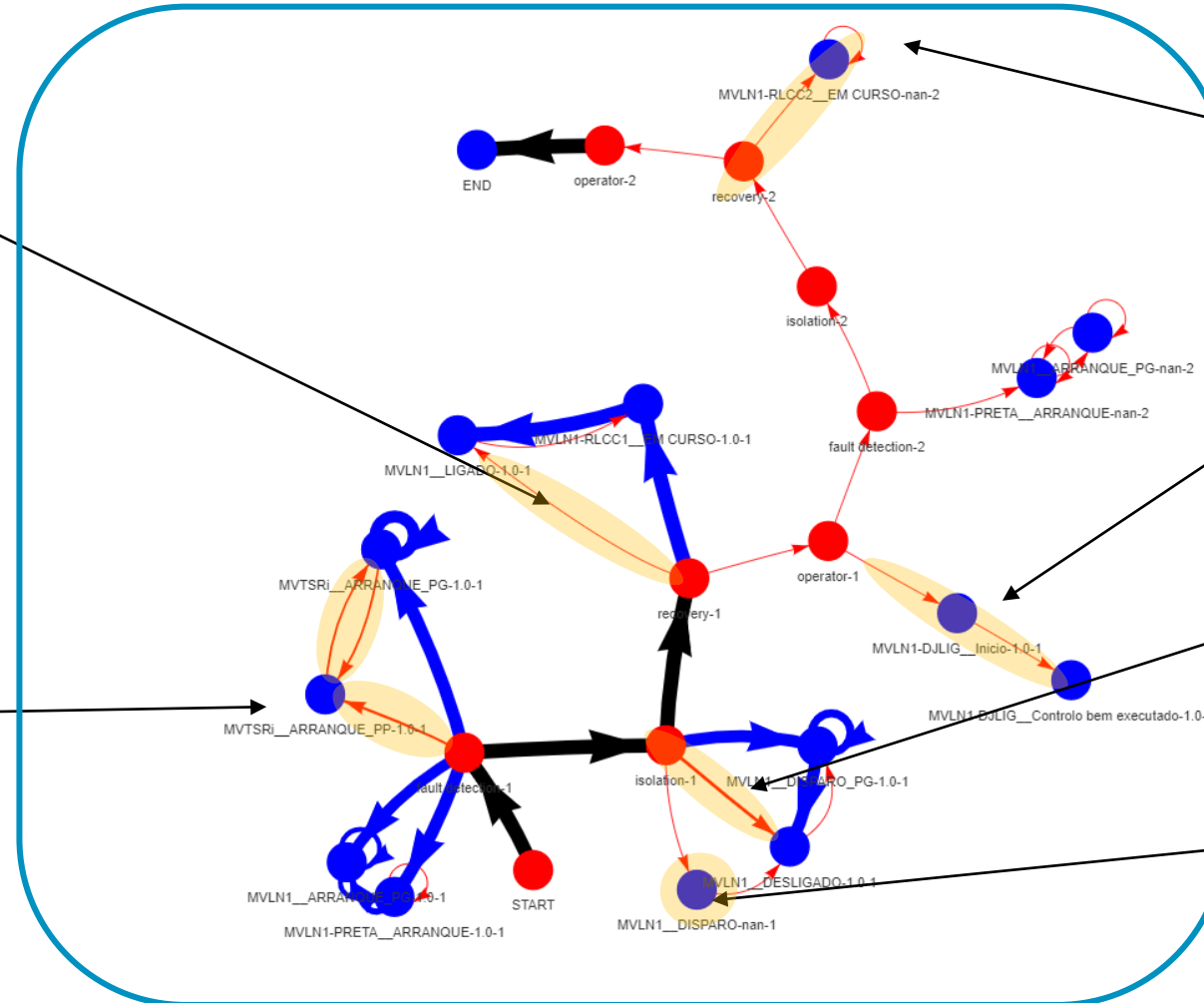
Missing event
*Circuit breaker opens
without a protection
TRIP*

Abnormal pickup
during phase-to-ground
fault

Reported as “Trabalho EDP
Empreiteiro”

“DISJ em REE DISPARO”

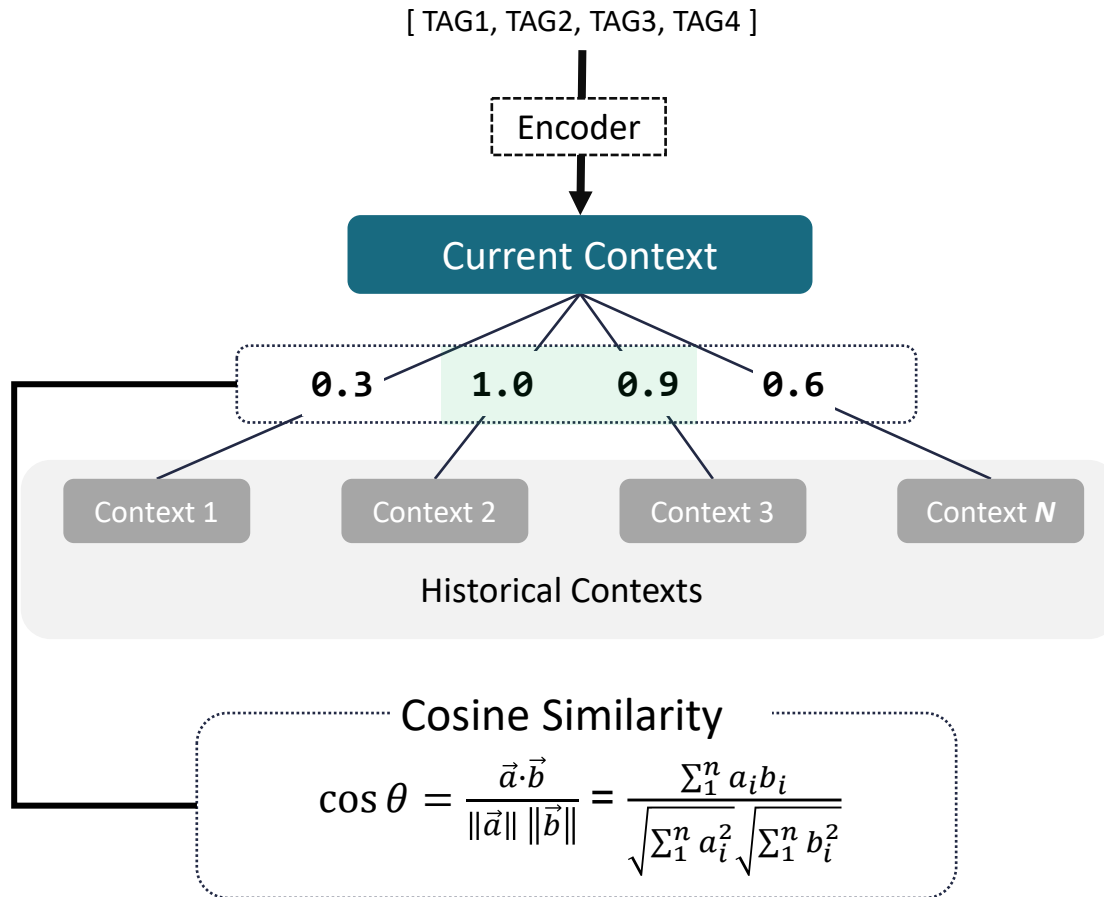
MV Line circuit breaker in
“Special Exploration Regime”
with automated reclosure
cycles deactivated



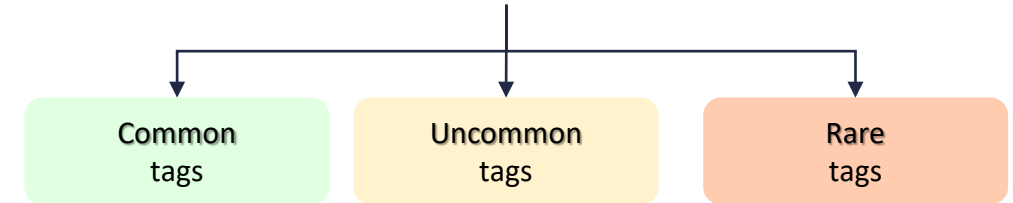
Graph for a collection of short phase-to-ground cases

Example of Use Cases

UC1: Identification of Similar Events / Abnormal Protection Behaviour



Profile the “normal” protection behavior within the subset of contexts for the same fault type using data from all substations



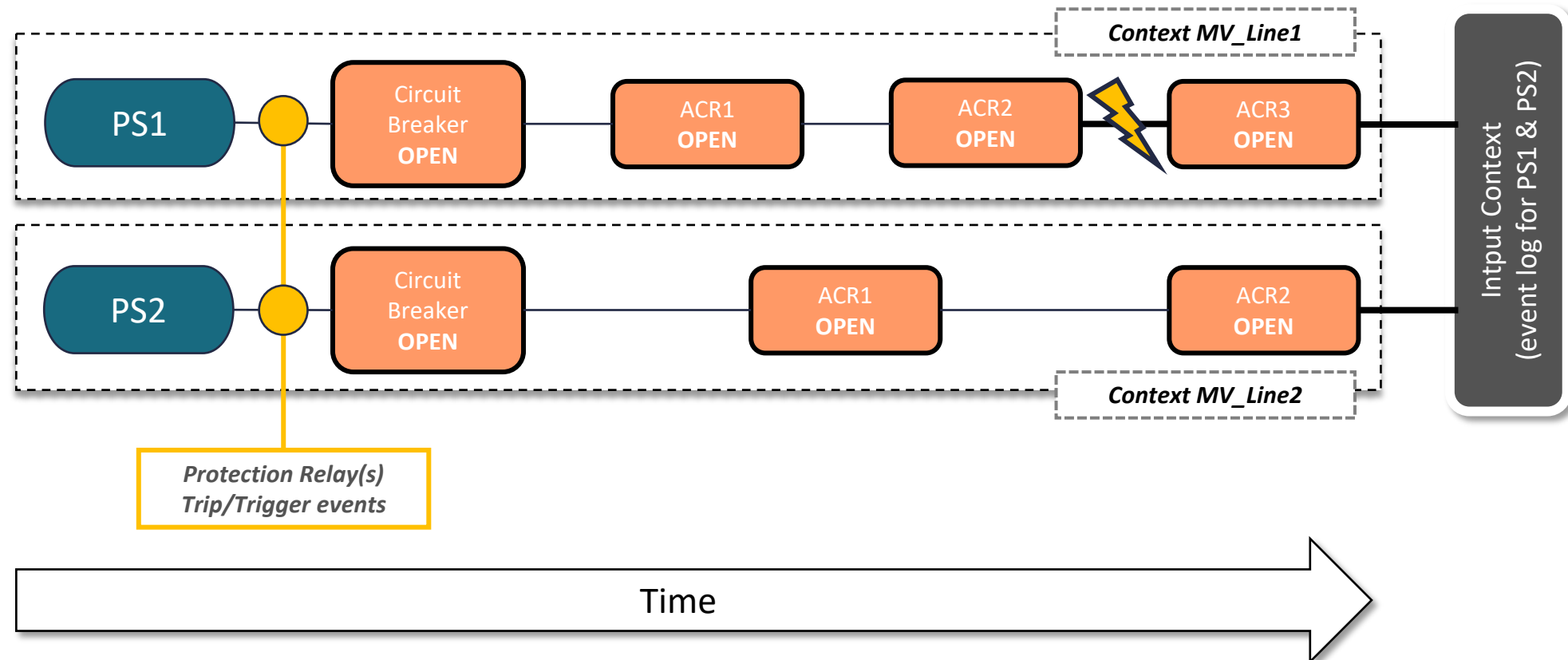
Detect missing “**common**” protection logs
(logs frequent in historical contexts but not present in current context)

Detect “**uncommon**” and “**rare**” protection logs
(logs present in current context and rarely detected in similar historical contexts)

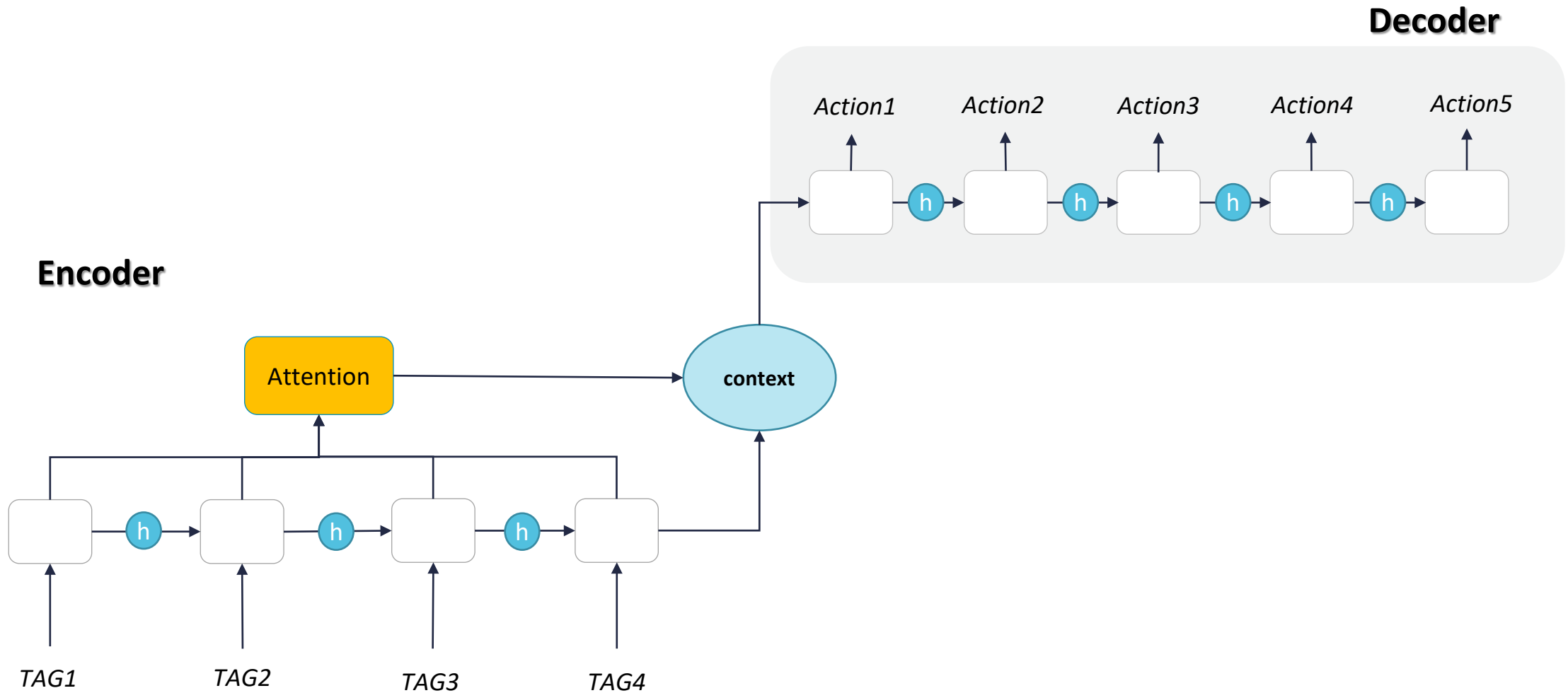
UC2: Inference of the next operator commands

Occurrence

1. Fault in line segment between Automatic Circuit Reclosers (ACR) 2 and 3 protection equipment's
2. Circuit breaker opening for Primary Substation 1 and Primary Substation 2



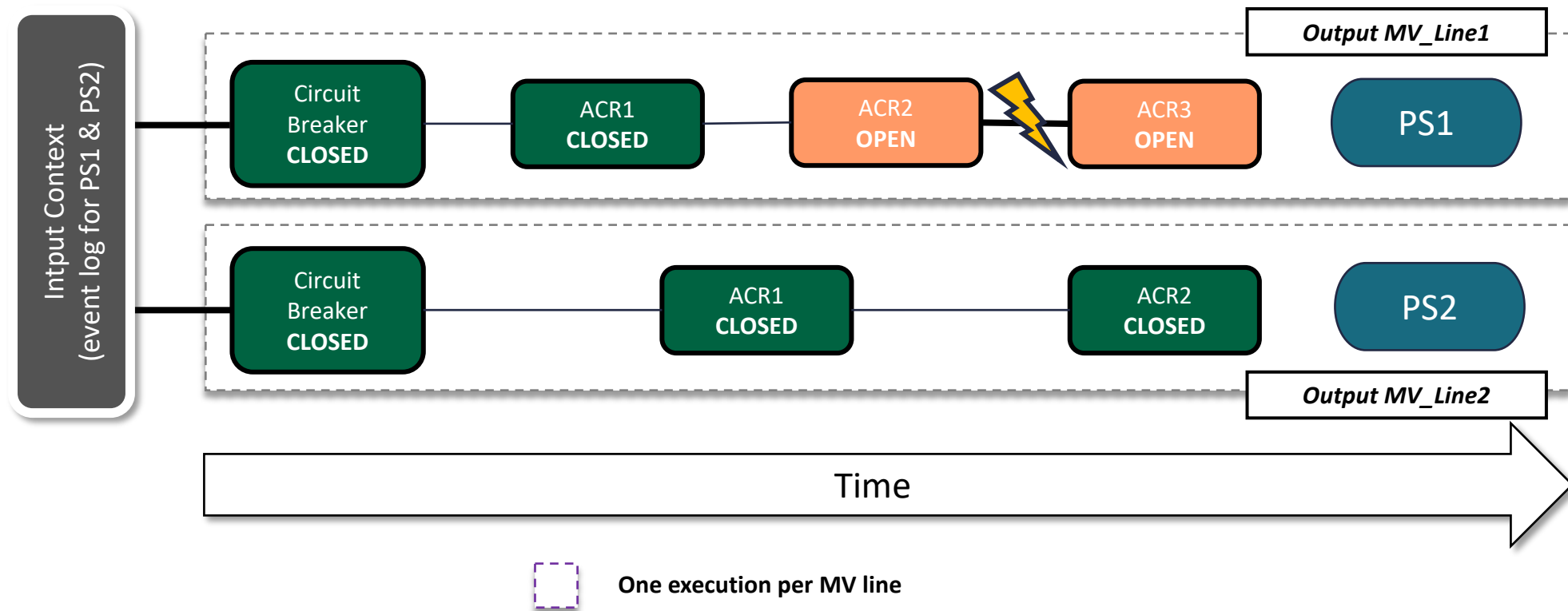
UC2: Inference of the next operator commands



UC2: Inference of the next operator commands

Occurrence

1. Fault in line segment between ACR2 and ACR3 protection equipment's
2. Circuit breaker opening for Primary Substation 1 and Primary Substation 2
3. Isolation of affected segment of MV Line1 by leaving ACR2 and ACR3 in OPEN state
4. Service was completely restored in MV Line2 by closing the circuit breaker and all the ACRs throughout the line



Concluding Remarks

- Alarm data has been undermined...
 - ...in value for system operation and event analysis, but also in human-computer interaction
- Data scarcity is a challenge: poor performance of data-intensive methods (deep learning)
- The potential of use cases for alarm data is high. Other examples explored at INESC TEC:
 - Classify type occurrences (simple ones can be replaced by automation)
 - Event log profiling and segmentation
 - Improve fault cause classification

Acknowledgments

**Ricardo Andrade, Vasco Campos, Olga Klyagina
INESC TEC**