Modelling at different abstraction levels: the CRUTIAL experience

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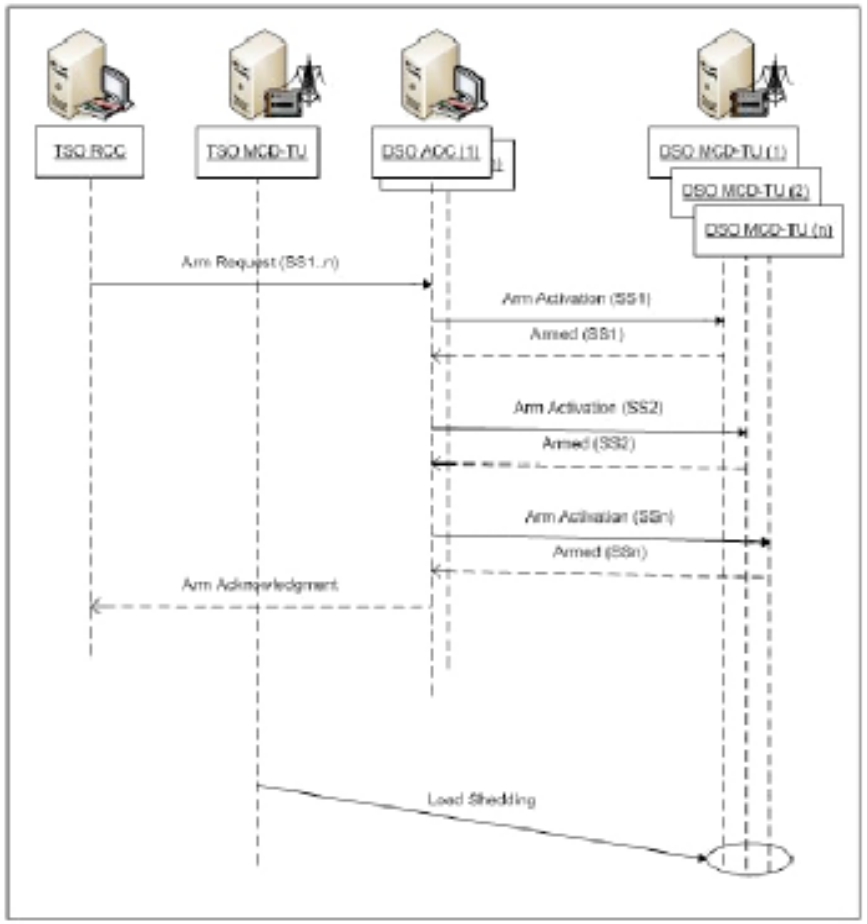
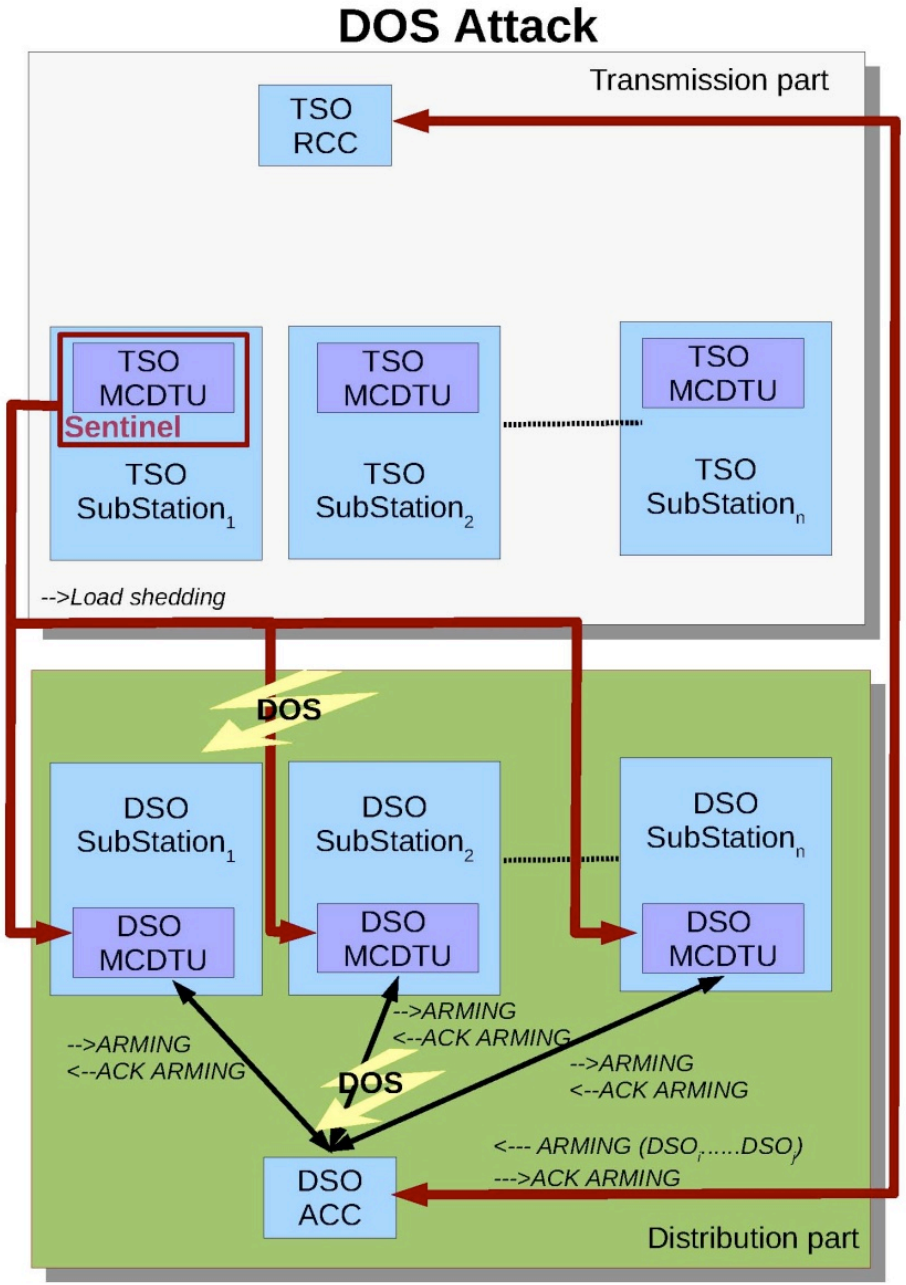
Objective

- Model the interdependencies between Electrical Infrastructure (EI) and information Infrastructure (II)
- Apply the model(s) to a set of scenarios in which the II is used to control the EI: what are the consequences of a II failure over the EI?
- Here we consider a specific scenario: the iteraction between the transmission system operator (TSO) control and the distribution system operator (DSO) control to realize a load shedding


TSO RCC
TSO MCD-TU
DSO ACC (1)
DSO MCD-TU (1)
DSO MCD-TU (2)
DSO MCD-TU (n)
Arm Request (SS1..n)
Arm Activation (SS1)
Armed (SS1)
Arm Activation (SS2)
Armed (SS2)
Arm Activation (SSn)
Armed (SSn)
Arm Acknowledgment
Load Shedding

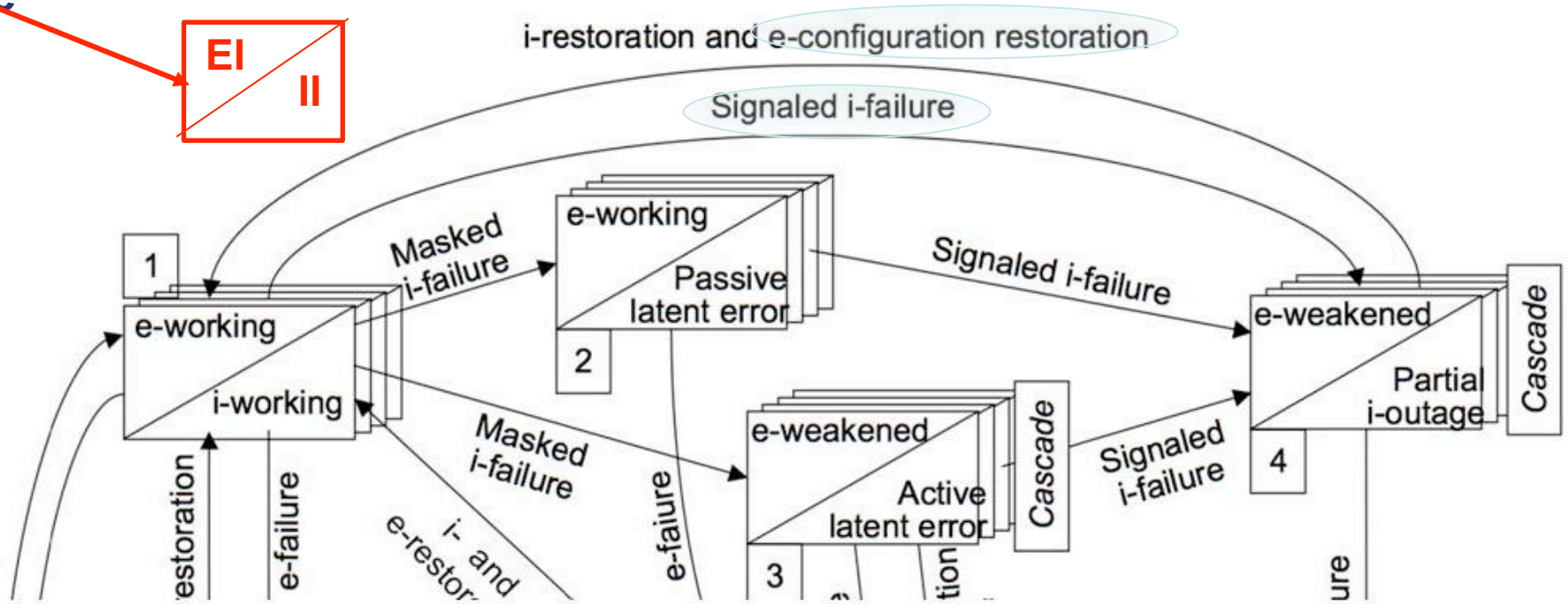

DOS Attack
Transmission part
TSO RCC
TSO MCDTU
Sentinel
TSO SubStation1
TSO MCDTU
TSO SubStation2
TSO MCDTU
TSO SubStationn
-->Load shedding
DOS
DSO SubStation1
DSO MCDTU
DSO SubStation2
DSO MCDTU
DSO SubStationn
DSO MCDTU
-->ARMING
<--ACK ARMING
DOS
-->ARMING
<--ACK ARMING
-->ARMING
<--ACK ARMING
<--- ARMING (DSO1.....DSOj)
--->ACK ARMING
DSO ACC
Distribution part

Outline

- Qualitative model –finite state machine model
- Quantitative model – mainly II – use SWN
- Quantitative model – mainly EI – use SAN

Qualitative

composed state



Qualitative model of the scenario

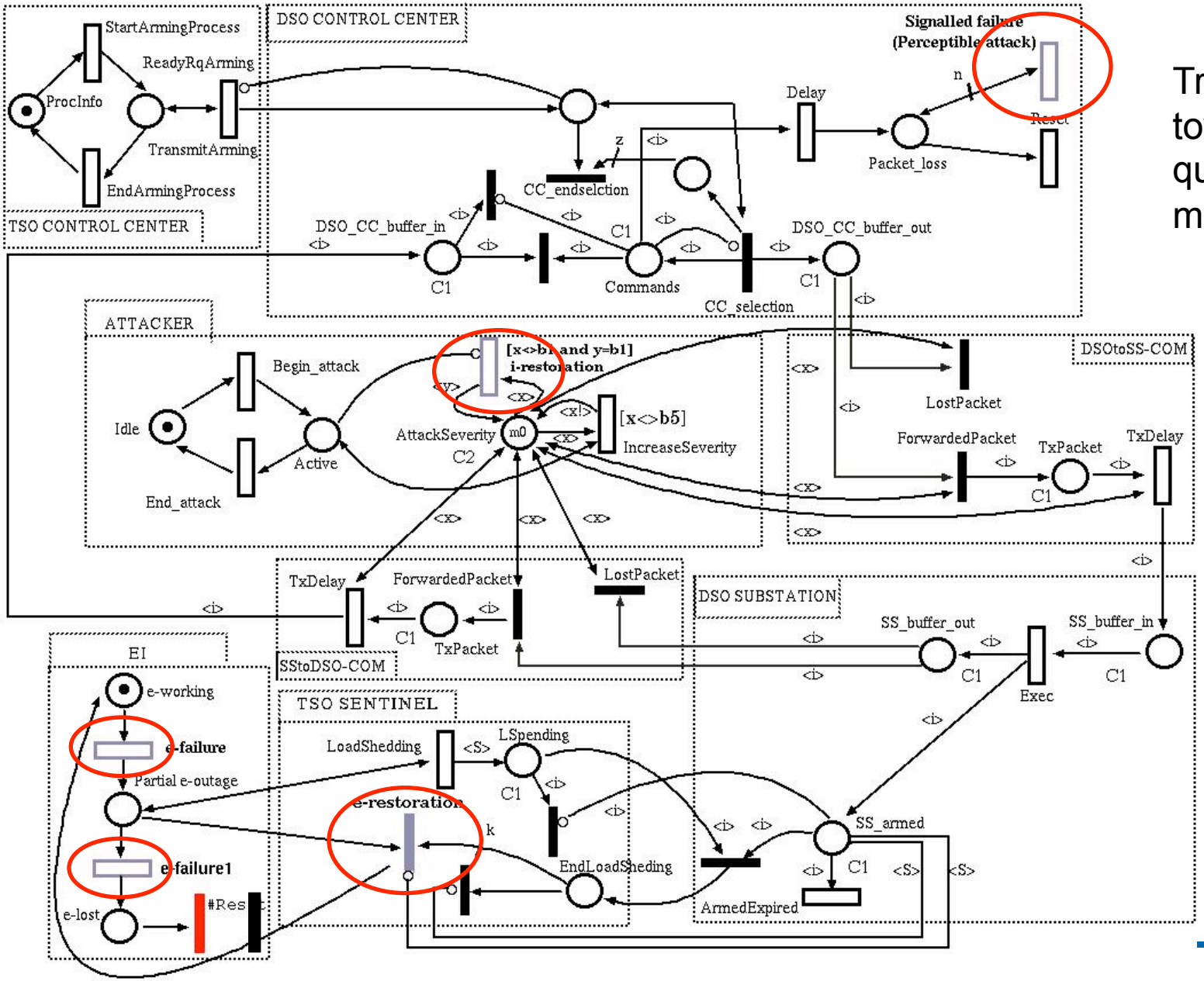
- DoS as a (signalled) i-failure
- Load shedding activity as a e-restoration (if successful)
- Does not capture the scenario complexity

SWN model

Quantitative model – SWN:

- details the arming/disarming protocol, the TSO/DSO and sentinel role – parametric model
- models a communication facility with load dependent behaviour
- Specific trasitions are devoted to the integration between models

SWN model



Transitions towards qualitative model

SAN model

- How to determine the e-failure rate? If we want to study dependencies we need to reflect in the model the consequences of a delayed or missed arming of a substation in the power domain.
- Need a model that is detailed enough in electrical terms to assess the electrical consequences of a wrong control
- SAN model:
  - models a power GRID (lines and substation) in a parametric manner
  - the control system is implemented by three functions that change the ***electrical portion*** of the state (in zero time or after some delay) upon a change (e-failure) of an electrical component
  - One of the three functions requires the network (modelled as on/off)

SAN model

More precisely……

- Discrete and hybrid state representation
- Combination of analytical and simulation solution techniques
- Information Infrastructure components
  - Regional Telecontrol System (RTS)
  - Local Control System (LCS) associated to each substation
  - TSO Communication Network
- Electrical Infrastructure components
  - Nodes (Generator, substation, load)
  - Power Lines
  - Breakers (including protections), transformers,…

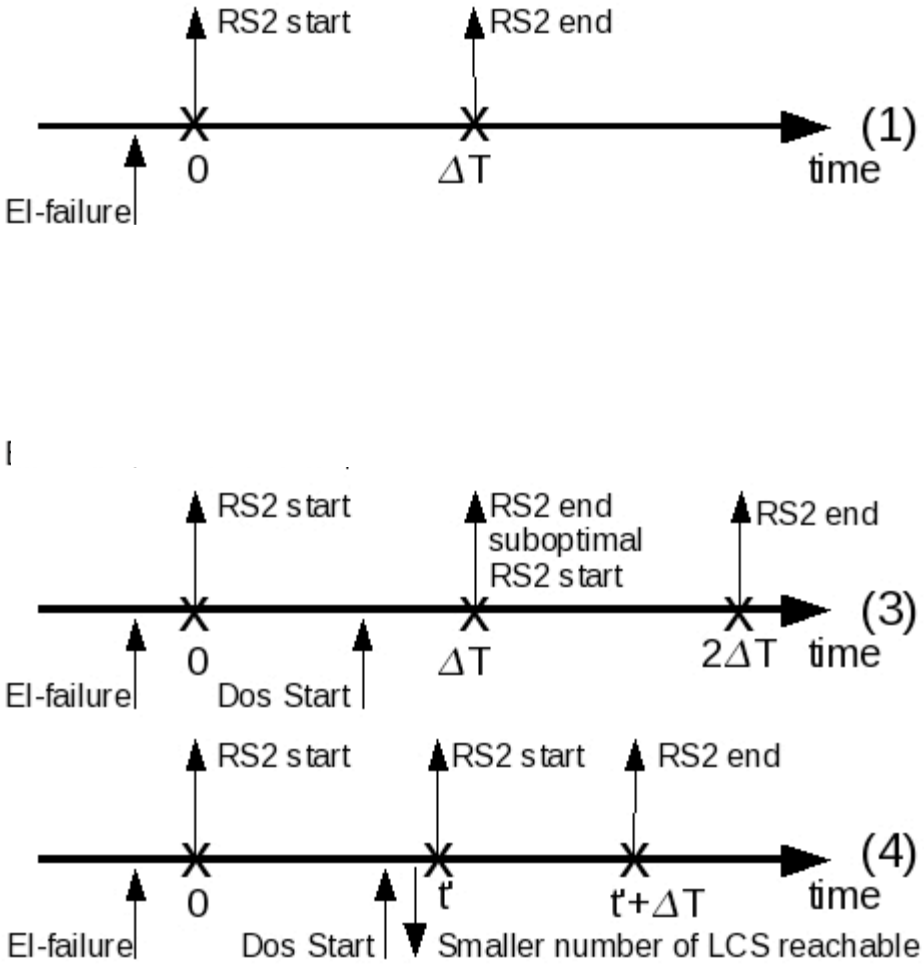
Linking the two models

- SWN have no possibility of modelling the power variables

- The SAN does not have the protocol complexity in it

- Integration?

- SWN computes the distribution of “number of armed substations at a time t”, for a set of discrete values of time



Conclusion

- Three different “view points” on the same system
- Models are meant for different purposes
- Each model can play an active role in the understanding and quantification of our scenario(s)