SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA15127- Resilient Communication Services Protecting End-user Applications from Disaster-based Failures (RECODIS WG3: Technology-related disasters)
STSM title: Modelling approach for resilience of ICT in interconnected systems
STSM start and end date: 25/08/2019 to 31/08/2019
Grantee name: Amit Dilip Patil

PURPOSE OF THE STSM:

Future smart grid systems are likely to be heavily information and communication technology(ICT)-reliant to cover real-time processes, market operation, demand response schemes and so on. However, failures in one subsystem may impact another subsystem through cascading failures and lead to large scale blackouts. One such set of failures are technology based failures. For example, failures in ICT system may propagate to power systems through their interdependencies and lead to technological based disasters such as large scale blackouts. To assess the impact of technology based failures, models that encompass ICT and power systems are required.
We assume high reliance of power grid on ICT systems making power grids vulnerable to ICT related failures. The purpose of the STSM was to:

1) Analyze characteristics of scenarios that include power and ICT systems suitable for modelling purposes.
2) Understand modelling techniques and their suitability to ICT-reliant power grid use cases.
3) Discuss metrics of interest that could be used to measure resilience of system of interest.
4) First approach to model the system of interest.

The STSM fits in the scope of WG3: Technology-related disasters.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

This STSM was implemented at Norwegain University of Science and Technology (NTNU), Trondheim, Norway and was hosted by Prof. Bjarne Helvik.

The issue of ICT resilience has been extensively studied in literature in recent years and is now being considered in context of power grids. Future power grid scenarios include high ICT penetration that allow near complete grid automation. The work carried out in this STSM was related to the modelling of future ICT reliant-power grids for resilience assessment.

This STSM continues the work begun in the previous STSM on the modeling approach for such systems with a focus on resilience. The current state of the modeling approach was discussed. Initially, the model consisted of 6 layers,

Funded by the Horizon 2020 Framework Programme of the European Union

The first task carried out in the STSM was to analyze current state of the art and characteristics of ICT-reliant power grids. A number of scenarios were considered including overloading, underloading, day ahead scheduling that could lead to various different outcomes such as cascading line failures, blackouts, instabilities in failure situations etc and must be handled adequately to avoid failure propagation with disastrous outages as a consequence and simultaneously maintain an acceptable level of power supply. The focus was on failures originating from ICT and propagating into power systems.

Building on the work carried out in the first STSM, a simple system model was analyzed. The system consisted of two low voltage(LV) grids, each with a production(P) and consumption(C) quantities associated with them. The two LV grids were attached to a medium voltage(MV) grid monitored by a substation. An ICT overlay was added to describe ICT connectivity in the system

The modeling process involved describing the system state (also known as global state) using system graph and subsystem graphs representing ICT and power systems individually. The interaction between the subsystem graphs is described by stochastic activity nets (SANs). SANs are preferred to stochastic reward nets as SANs allow the modeling of cascading failures and simultaneous failures in a system, which are the most likely to cause large scale damage in power-ICT systems. Hence, rather than rewards obtained in the interacting rewards nets, the changes in system state are described by the markings in the SANs (which are governed by system parameters such as power generated, consumed, voltage levels, ICT device availability) is depicted in the resilience state space representation. The resilience state space representation is a two-dimensional plot mapping operational state vs system service level. The system state is defined by P and C markings in the activity nets along with switch position and ICT system marking, represented as a vector. The values taken by these parameters determines the movement of the state in the state space diagram. System metrics, such as survivability metrics could be derived from the system state space using ESAIDI metrics. To maintain tractability, a “triggering graph” depicting the sequence of firings taking place in the SANs is constructed.

Concrete use cases were discussed, specifically those which lead to power system instability. Examples are a sudden fall in production of power, sudden rise in demand, switching failures, incorrect sensor data and so on. These use cases are described by SANs in the multi-layered model. Discussions were carried out on whether it is beneficial to model the status of each measure of interest and system component atomically, in which case several atomic models could be combined to form a use case or model an entire use case entirely at once, thereby obtaining one SAN model for each use case. A case study consisting of false information obtained from field sensors by the ICT system, which then makes decisions based on this false information that could lead to grid instability was assessed.

Discussions were conducted to reconcile the use of terminology in modeling and networking disciplines.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

The main results and approaches are described above. In addition, future collaborative work has been discussed.
The resulting model description included a system description layer, a state space representation of the system state layer and interacting SANs layer used to describe the use cases (describing a sequence of events impacting the system). A triggering graph is simultaneously constructed to trace the sequence of events.

The main results of the STSM include:

1. Establishing a concrete system description for a power-ICT system model

a. Including system architecture and properties
b. Defining the system state using power system operational values such as production(P), Consumption(C) and switching states
c. Scrutiny of multi-layered with a focus on system description, state space and interacting SANs for use cases

2. Identification of the topic of planned publication with the hosts
   d. Model to represent ICT-reliant power systems
   e. Using grid instability and its causes as a use case
   f. Focus on interdependencies between power and ICT systems
   g. Derive metrics from the state space description

FUTURE COLLABORATIONS (if applicable)

During the STSM, grounds for continued collaboration with the STSM host were laid in area of *modelling of a resilient ICT-reliant power systems*. Further joint work in the context of RECODIS WG3 are planned with a future publication on modeling of ICT-reliant power systems with grid instability as a use case in the works.