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# Analyzing the Static Security Functions of a Power System Dynamic Security Assessment Toolbox

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ABSTRACT

This paper presents the results from the iTesla offline workflow for a given set of contingencies applied to Nordic 44 power system model and are verified against the results from a similar workflow implemented separately using Python/Matlab that uses PSS/E analysis function. 21 (20 'N-1' and 1 'N-2') contingencies were created on the Nordic 44 power system model and was executed on 2928 snapshots (April to July 2015). This verification is only performed for the (static) steady state stability assessment results of the offline workflow. The generated decision trees (DTs) by the iTesla platform were verified for different network operating conditions. It was observed that the generated DT's are consistent for the given set of operating conditions. It would be beneficial to check how the rules generated from DT's with four months of data (April to July 2015) vary from the rules generated with one year of data (2015). The verification approach adopted provides a useful means to test and verify dynamic security assessment (DSA) tools' with an independent implementation of some of the tools' functions, this can be of value to other DSA tool developers.

## 1. Introduction

### 1.1. Motivation

The deployment of renewable energy sources increases network forecast uncertainty, making it difficult to accurately assess grid security levels during operation. The secure integration of generation from renewable energy sources (RES) into today's power systems requires an appropriate assessment of the security of the system in near real-time. The uncertainty associated with RES makes it unfeasible to tackle this problem via a brute-force approach, i.e. it is impractical to execute detailed static and dynamic simulations for all possible security problems.

An approach is to combine offline and online applications assessing different phenomena (steady-state violations determined by power flow computations or instabilities through dynamic simulations) with uncertainty. This allows bridging the gap between risk-based methods and traditional deterministic approaches, by introducing the concepts of probability and impact associated to the contingencies as well as the uncertainty of the energy consumption forecast and of the power production of RES.

Using this approach, the iTesla[1] project developed a platform for static and dynamic security assessment. The computations are performed with two complementary offline and online workflows. The offline workflow builds security rules and uncertainty models for use in the online workflow. Online, the security rules are applied to plausible grid operation states within the uncertainty margin of the forecasted network state, in order to identify the contingencies for which control actions are needed, while limiting the number of dynamic simulations to be performed online.

### 1.2. Literature review

The tools developed in [1,2] were able to manage several analysis applications within a single environment using a deterministic approach. Research projects have also dealt with the issue of security-assessment tool integration [3]. However, full integration of methods, models, tools, and analytics within a single platform is desirable. Computations based on different models may be inconsistent; the various outputs become fragmented, difficult to interpret and synthesize into a meaningful and actionable form. Therefore, it is becoming crucial to exploit an integrated environment that can manage different tools: static and dynamic analyses, contingency filtering and ranking, margins and control actions computation, and effective synthesis and

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[1] iTESLA (Innovative Tools for Electrical System Security within Large Areas), online: www.itesla-project.eu.

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visualization of results.

The uncertainty of future power systems operating conditions due to RES integration and introduction of the electricity market causes two main effects: on one side, the need for techniques to perform an online dynamic security assessment (DSA) [4], and on the other side, new tools performing a probabilistic assessment of the operational risk are becoming necessary to exploit power systems flexibility [5,6]. The proposed iTesla platform combines traditional deterministic and probabilistic risk-assessment tools effectively and can fulfill the requirements.

### 1.3. Contribution

In this paper, the results from the iTesla offline workflow for a given set of contingencies applied to Nordic 44 power system model [7] are verified with the results from a similar workflow implementation separately using Python/Matlab that uses PSS/E's analysis functions. While this verification is only performed for the (static) steady-state stability assessment results of the offline workflow, to the authors' knowledge, this is the only paper proposing means for cross-validation of iTesla platform functions, or any other DSA's functions. The aim of this paper is also to contribute to the body of knowledge by proposing new means to test and validate DSA tools [8,9], which if imitated by DSA tool providers, can help in gaining confidence and credibility in the tools' functions and results.

## 2. Background

The iTesla platform is an open source and modular software that supports operators in power system security assessment from several hours ahead of operation up to near real time. The platform also determines and quantifies their efficiency when they are needed. The iTesla platform can consider the uncertainties affecting power injections, such as non-dispatchable RES and loads, and the dynamic behavior of the grid, thanks to a filtering approach that takes advantage of machine learning techniques. The computations are performed in two complementary workflows, namely the offline and the online workflows (see Fig. 1). The offline workflow builds (1) security rules and (2) uncertainty models for use in the online workflow: the security rules are applied to plausible states in the "uncertainty domain" of the forecast under analysis, to identify the contingencies for which control actions are needed, while limiting the number of accurate network simulations to be performed online. Both workflows include different computation modules, each fulfilling a specific technical function such as power flow (PF) computation or time-domain (dynamic) simulations.

### 2.1. Offline workflow

The offline workflow builds a database of historical and simulated network conditions that are used to compute security rules, which will

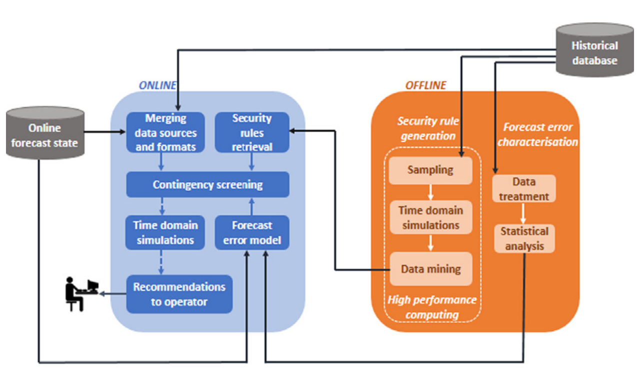


**Fig. 1.** iTesla workflow.

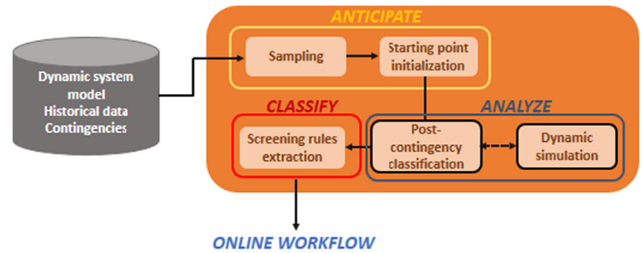


**Fig. 2.** Offline security assessment workflow.

serve to characterize future operating conditions as secure or unsecure. The process follows the triptych anticipate – analyze – classify as shown in Fig. 2.

**Anticipate:** To compliment historical data, a large number of additional plausible network states isbuilt (sampled), using the historical data. Uncertainties such as demand or wind power production are also modeled
**Analyze:** for each sampled network state, dynamic simulations are performed to quantify the impact of various contingencies (overloads, transient instability, etc.).
**Classify:** machine learning algorithms are used to compress the results from the analysis stage into a set of security rules (threshold values) discriminating secure from unsecure network states. These rules are used by the online platform to quickly classify unseen network states as safe/unsafe against a contingency.

### 2.2. Online workflow

During operation, the network forecasts are complimented with an uncertainty margin (loads, RES) and the iTesla online workflow allows to perform a fast security assessment within this margin. First, plausible network states are sampled within the margin of uncertainty of the forecast, and then, the states are checked against the security rules computed offline, characterizing them as secure/unsecure.

For potentially unsecure network conditions, an additional but get limited number of dynamic simulations are performed and analyzed. If needed, curative/remedial actions are generated in order to assist the network operator. Further details about offline and online workflow of iTesla platform can be found in [10] and [11].

## 3. Application of the offline workflow to the Nordic44 power system model

The outputs from the offline workflow of the iTesla platform for a set of contingencies applied to the Nordic 44 power system model are verified against the results obtained from a similar workflow implemented separately using Python.

### 3.1. Nordic44. Power system model

The Nordic-44 Bus test system is an equivalent representation of the Nordic grid (Sweden, Norway and Finland) as shown in Fig. 3. and was originally implemented in PSS/E and Modelica [7,12]. It consists of 44 buses, 61 generators with various control systems (exciter, turbine, governor and stabilizer), 67 transmission lines (420 kV and 300 kV) and 43 loads. The regions shown in this model are defined according to the Nordic electricity market bidding regions. The entire historical market data for 2015 was matched w.r.t the powerflow results for this model and the details can be found in [7]. These snapshots are provided in CIMv14, Modelica and PSS/E (Siemens PTI) files. The software developed to generate these snapshots are also provided in [6].

To perform a meaningful assessment, it was necessary to match and consolidate the historical market data to the physical description of the