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Network Licensees must publish the required Project Progress information on the Smarter Networks Portal by 31st July 2014 and each year thereafter. The Network Licensee(s) must publish Project Progress information for each NIA Project that has developed new learning in the preceding relevant year.

NIA Project Close Down Report Document

Date of Submission

Jul 2022

Project Reference Number

NIA_NGSO0036

Project Progress

Project Title

Probabilistic planning for stability constraints

Project Reference Number

NIA_NGSO0036

Funding Licensee(s)

NG ESO - National Grid ESO

Project Start Date

June 2020

Project Duration

1 year and 7 months

Nominated Project Contact(s)

Sami Abdelrahman

Scope

There is increasing uncertainty (e.g. load composition, line flows through interconnectors) and variability (e.g. wind speed) in power system operating conditions and parameters. The changes in the system operating conditions are happening faster, are more complex and are occurring in places where previously there were no issues. There is an expectation of more angular stability issues in the future due to reduction in synchronous generation and system inertia (e.g. as reported in the FES).

Lack of automation in the assessment of stability means that the ESO has to prioritise boundary calculation due to computation time – analysis can be very time consuming and so is focussed on specific areas of the transmission network. For long term planning, power system analysis is currently carried out using deterministic approaches (e.g. selected background studies such as Winter Average Cold Spell – ACS demand or summer minimum demand). These technical studies do not consider all the variability and uncertainty associated with future energy scenarios which could have a significant impact on stability. In the future, this might lead to under- or over-estimated transfer capabilities and sub-optimal techno-economic solutions.

In this project, we will explore, develop and test cutting-edge automated and probabilistic approaches for modelling of angular stability. This will enable year-round boundary capability calculation for stability accounting for a number of sources of variability and uncertainty and enabling ESO to consider the possible issues across the system. This work will be completed across four work packages:

WP1: In this initiation work package, we will review academic literature, review the overlap and available learning from existing and ongoing work, and identify any policy and practical barriers that could affect possible implementation. In this work package TNEI will engage closely with ESO during the annual ETYS/NOA cycle to understand how new angular stability modelling methods will fit into the process and ensure the development of fit for purpose tools.

WP2: In the development work package, we will trial the most promising methods on published test networks or reduced GB networks, to explore how different approaches perform in terms of e.g. accuracy, computation time. This will include methods for (i) screening the network to identify previously unforeseen stability issues, (ii) automated probabilistic evaluation of stability issues, (iii) quantify the uncertainty within the model and key model parameters, and (iv) development of a probabilistic model that captures correlations between demand and renewable generation.

WP3: In the trialling work package, we will engage with the Network Development teams during the 2021/22 Electricity Ten Year Statement (ETYS) and Network Operability Assessment (NOA) planning cycle, testing the most promising methods on the full GB electricity transmission system models. The learnings, where applicable, will also be shared with other relevant ESO teams like the Operability teams.

WP4: In the final work package, we will produce a plan for later implementing the tools into business-as-usual, and produce a roadmap for possible future changes (e.g. in regulation or planning standards) that could help deliver further value for GB energy consumers.

Deliverables: These will include (i) innovative automated tools to possibly be used in the ETYS and NOA, to carry out automated probabilistic stability analysis for stability evaluation processes (e.g. probabilistic demand and renewable generation conditions model, method to screen networks for stability issues, probabilistic tool that supports automated power system analysis using Powerfactory) (ii) reports detailing the development and demonstration of these methods (iii) results from the models that are suitable for sharing with third parties (i.e. in NOA and ETYS publications), and (iv) a roadmap and evidence for further future development.

Objectives

The objectives of this project are to explore the use of cutting-edge techniques (combining traditional power systems stability analysis and statistical modelling), and whether these allow the ESO to better understand the risk and uncertainty associated with angular stability on the GB electricity system. The result of this will be to produce automated tools to allow efficient stability evaluation for more snapshots and locations in the system.

This could help the ESO to make more optimal economic decisions with respect to secure and stable operation of the system.

Success Criteria

The project will be a success if the developed tools will provide the ESO the capacity to accurately and efficiently evaluate stability constraints for more regions and more snapshots, with a Roadmap to integrate the tools within the ESO existing tools for the planning cycle of 2022/23.

Performance Compared to the Original Project Aims, Objectives and Success Criteria

Project Overview

The objective of this NIA project is to explore the potential use of cutting-edge techniques, combining traditional power systems stability analysis with statistical modelling and automation, to allow the NGESO to better understand the risk and uncertainty associated with angular stability on the GB electricity system. Outputs will be automated tools that allow stability to be evaluated and visualized efficiently, accounting for a broader range of conditions and uncertainties at more locations/boundaries in the system.

This will enable year-round boundary capability calculation for stability accounting for several sources of variability and uncertainty and enabling NGESO to identify possible stability constraints across the system. It will enable analysis of the current power system, but also future system models, as represented by the Future Energy Scenarios (FES), making a valuable enhancement to the Networks Options Assessment (NOA).

Project Plan

An initial 18-month project was developed and defined so that the project was to deliver 4 work packages (WPs) delivering 5 main deliverables.

WP1 which involved project initiation with the first deliverable WP1 report (Initiation and Literature review) was delivered in December 2020.

WP2 was a deliverable to develop and test different screening and probabilistic evaluation methods in a reduced network. The WP2 interim report was issued in March 2021 and the WP2 final report and selected methods was delivered in June 2021.

WP3 focused on rescaling the selected methods and demonstrating them in the full GB network. The WP3 deliverable resulted in a developed tool which was demonstrated on a selected case study. Various challenges were experienced whilst developing and testing the tool on the GB network planning ETYS model which caused a delays; primarily data quality issues with NGESO network planning models, which proved not to be fit for the purpose of performing long term stability analysis. These challenges were overcome; however, the testing plan was reduced to a single network planning model case than all five network planning model cases used for our planning analysis. Therefore, WP3 delivered a tool that was developed and tested on a single network planning model which reduced the opportunity for catching and debugging as many bugs as possible to a commercial standard package. The challenges experienced are further discussed in the lessons learned section.

WP4 foccussed on the implementation plan. The deliverables were achieved in June 2022

Project Activities

<u>WP1:</u> Comprehensive engagement between TNEI and the relevant ESO teams was carried out. Several meetings and discussions were organised with the Stability Pathfinder team, Network Development, Network Operability and Network Access Planning teams to achieve a better understanding of the current stability issues and the ongoing internal work of probabilistic modelling. Based on these discussions the overall problem statement and project objectives were captured in WP1 report, in addition to the literature review. A WP1 workshop was delivered by TNEI internally in the ESO to discuss the findings and obtain feedback as input to WP2.

<u>WP2:</u> A Python based Stability Analysis Automation Tool was developed to automate almost all the activities in the NOA (Network Options Assessment) transient stability analysis using a 36-zone reduced GB model. Python tools were also developed and evaluated to explore different machine learning algorithms to predict the outcome of stability analysis. An active learning algorithm was explored to improve the machine learning classifier performance by running more detailed stability analysis for the snapshots where the confidence on the labelled snapshot is not higher than a predefined threshold. The proof-of-concept tools were validated using the reduced GB network model and utilizing historical renewables and demand data extracted from Elexon and projected over a selected scenario from the 2019 FES data. The tools were found to significantly improve the efficiency of the stability analysis as they enable around 2000 scenarios to be run in less than one hour.

<u>WP3:</u> A full network model was shared with TNEI to rescale the tools and demonstrate performance on the full-scale GB network model. However, applying the tool to a real GB network meant overcoming the following challenges:

- The hourly generation dispatch input data to the tool is produced by the NGESO market simulator which uses a linearised (DC) load flow solution, providing a simplified representation of the network. For a year-round stability analysis, the first step is to ensure that the AC load flow converges for all hours. This is not a trivial task for a national electricity transmission system (NETS) due to the model complexity and can be realistically achieved only through an automated process as a manual approach is not feasible.
- Load flow convergence is a necessary but not a sufficient condition. Since, the NGESO market simulator does not consider reactive power dispatch, a load flow convergence does not ensure that the substation voltages across the network are within the steady state Security and Quality of Supply (SQSS) limits. This requires a voltage profiling exercise which ensures that the right number of shunt compensation devices are online, and the synchronous generators are working in over-excitation mode or as close as possible to the unity power factor.
- Due to the size of the NETS and the presence of several dynamic models (e.g., AVRs, governors, detailed wind farm models, HVDC controllers etc) with small time constants, the computational time for a single snapshot of dynamic study is quite high. This becomes impractical in the context of a probabilistic study which can require a very large number of repeated simulations.
- Several competing statistical and machine learning methods were found in the literature which performed very well on standard test networks with certain assumptions about the demand and generation distributions. However, as the number of uncertain parameters

increases in a real network, the validity of the methods decreases.

- It is well established in academic literatures that valid statistical models can be fitted to represent wind and solar resource availabilities for a single region or zone. However, these availability data are usually correlated across different regions which means we must represent the uncertainties using a model of the joint distribution which will capture the statistical dependency structures between the individual marginal distributions. By querying this distribution several samples can be generated very easily. However, options for simple, parametric representations of the joint distribution of all input variables in a real network would likely require unacceptable levels of simplification and, due to the very high number of variables, it would have a very large number of dimensions which would make reliable inference very difficult. Simple models would fail to represent the highly complex and nonlinear dependency structures that could exist between the marginals. As an example, applying this method to the GB network would mean developing a joint distribution of more than a hundred dimensions.
- The performance of Machine Learning (ML) algorithms depends on several factors which are heuristic in nature (e.g., hyperparameters, feature engineering). For a best-fit model, it is important to get the right combination of these factors. For a highly non-linear problem like transient stability, the feature engineering stage of the process is very important to make sure the dataset has the right amount information for training a ML model.

Addressing the challenges discussed above led to extending the project by a further 6 months and reducing the number of tests of the stability tool, as well as limiting the input of the number of results into the ML tool. However, the stability tool developed in this project provides a strong framework to integrate other existing tools such as the probabilistic voltage stability analysis tool and any future tools developed as part of the boundary capability analysis process.

The key outputs of the project have been a pair of prototype analysis tools:

- Stability Automation Tool (SAT): includes a suite of modules to read in NGESO market dispatch data and set up appropriate scenarios in DIgSILENT, PowerFactory to run steady state and dynamic studies. The tool includes an automated stability identification module to check for system stability using time domain results without the need for any manual intervention. The output from the tool provides an understanding of the long-term capability of a boundary considering rotor angle stability as the constraint.

SAT is a powerful tool as it provides an integrated framework to study several boundaries with minimal intervention from planning engineers. It includes a stability identification algorithm (based on signal processing techniques) which helps to automatically categorise studied scenarios into stable-unstable cases, thereby saving valuable time of engineers. All results from load flow and RMS studies and stable-unstable categorisation can be visualised in the plotting window of the user interface thus providing a simple yet powerful way of scanning the horizon in terms of boundary transfer capability.

The input to the tool includes scenario and network data. The scenario data corresponds to the dispatch of the generators in the network which partake in the Balancing Mechanism Unit (BMU) and the aggregate demand data at the Bulk Supply Points (BSP). These inputs are expected from the NGESO tool, POUYA (POwer system Uncertainty Year-round Analyser) market dispatch simulator, although any other market dispatch tool would suffice as long as the demand and generator customers correspond to the modelled connections in the ETYS dynamic network for a particular year i.e., year 1, year 5 etc.

The network data, on the other hand, does not depend on POUYA. There are five files a user would need to provide each focusing on a particular aspect of the boundary such as the outages to study, the flop zones surrounding a boundary etc.

- Stability Classification Tool (SCT): a machine learning model which accepts data from SAT to train a classifier based on random forest algorithm. Several steps are necessary to process the output from SAT to create a final dataset which is suitable for training and testing of the machine learning model. These steps are handled by the tool and does not require manual intervention. Once the model is trained, it can be used for horizon scanning for stable/unstable scenarios without needing any resource intensive RMS studies.

The classification tool is an advanced option to quickly scan a high number of dispatch scenarios for unstable operating points in terms of generator rotor angle stability. The SCT relies on learning the underlying function relating demand and dispatch values with the response of the generators to critical contingencies. Once this function is learnt, SCT does not require any further powerfactory RMS runs thus providing a massive advantage in terms of computational time.

For studying a few scenarios (say 100 sample points from a 10-year dataset) the SAT is sufficient to provide answers and users will not require to use the SCT. However, for a probabilistic outlook of the boundary transfer capability a vast number of samples (> 10k) need to be studied where the capability of SCT can be utilised.

The inputs to the model depend on the purpose of the study. If the purpose is to train the machine learning (ML) classifier, then the required inputs will be different than using a pre-trained ML model for classification only. However, the user does not need to take any actions to assign the correct data, it is handled by the tool itself based on the configuration setting selected in the User Interface (UI).

For training the ML model, tagged scenarios from the SAT (labelled data) i.e., the actual output data (absolute truth based on RMS runs) are required as inputs. For each of these labelled scenarios, there will be several network variables, termed as Features, which are included in the master dataset for training the model. The features could be anything ranging from the demand and generation data to topology specific inputs such as busbar voltages, angles, and line flows. The selection of the features is one of the most important steps in any ML classification problem. This has been discussed in detail in work package reports.

For using a pre-trained model (specific to a boundary), the labelled data are no longer required. Generation and demand data from the market dispatch simulator and load flow results from SAT runs (RMS simulation not required) are the required inputs. To get the load flow results, users would need to run the scenarios in powerfactory. The load flow results are important as it provides the topology information to the ML model.

These two tools are packaged together in a single platform called Stability Tool which can be accessed through a web-browser based user interface.

Required Modifications to the Planned Approach During the Course of the Project

Changes to plan and approach

Due to the challenges earlier mentioned the project ran behind schedule. To minimize the delay the project was descoped as follows:

- For majority of the probabilistic samples, it was observed that some machines operated with high under-excited condition i.e., absorbing a very high amount of reactive power. This unusual and unexpected behavior was suspected to occur due to the nature of NGESO POUYA based dispatches across the network which causes excessive line charging vars in pockets of the network causing the nearby generators to operate in under- excitation mode. This situation, coupled with the salient pole representation of all synchronous machines in the GB network, means that a large percentage of machines are operating close to their steady state stability limits. Therefore, even a small disturbance would lead to unstable behavior of the system.

Therefore, an added deliverable was to add a module to perform **voltage profiling** across the network and thereby managing the reactive power dispatch of the generators. This ensured that the simulated operating point of the scenario did not cause unnecessary voltage and stability issues under intact operation, not to mention problems of non-convergence. However, the number of scenarios to be processed became large and thus was minimized. Later, this report discusses a future need to develop a voltage profiler that can account for a large number of scenarios, because unless every scenario is profiled to an acceptable dispatch level, simulation results from contingency analysis will not be able to identify the full set of problems in the network.

- Further to the earlier point, the tool was amended to consider a single contingency specified by the user through an input file. Moving forward, it might be beneficial to include multiple contingency analyses for horizon scanning exercises and include post fault actions are used to alleviate stability constraints and increase the net boundary flow capability. However, due to the challenges with scenario profiling it was subsequently excluded from the scope.
- The tool was meant to be tested against the five planning models that NGESO uses in its ETYS and NOA studies. However, due to the limited generator dynamic data needed to perform stability simulations in the NGESO model coupled with the voltage profiler problem earlier mentioned, the testing was limited to a single NGESO planning model.

Changes to cost

No expected change in cost.

Changes to programme

The overall program was extended by 6 months and closed in June 2022.

Lessons Learnt for Future Projects

Review of benefits case

The developed tools have proved the concept of the practicality of doing probabilistic stability analysis by utilising automation and Machine Learning techniques. This is a step forward towards the capability of running year-round stability analysis and to be able to run for more boundaries and contingencies in the network.

As with any new tool, the stability tool has constantly evolved throughout the project, as more features have been added to it and other application areas explored. Therefore, rather than viewing the tools developed in this project as the final, one-off delivery of a piece of software, NGESO could continue to further develop these to include new functionality and to accommodate new applications as and when required by the business. This has been made possible through the use of Github version control system which keeps a track of the development and any changes made by a contributor. This will allow NGESO to tap into a larger pool of developers to work in parallel, as well as implement an automated testing framework to identify any bugs in the source code due to periodic developmental changes.

The stability tool has been developed to streamline the long-term boundary capability assessment study which considers rotor angle stability as a constraint. The tool has automated several processes which are otherwise done manually at present, and which require significant time and effort. The tool has introduced several new methods, both in terms of analysis approach and managing large amount of data produced from the studies. These methods are new to the power industry and therefore, require extensive testing and validation as well as some possible changes to the NGESO IT systems.

During the development of the tool, we identified several challenges which are discussed in detail in this report. All these challenges have already been addressed in the project except one on scenario profiling.

Next steps

A fundamental limitation of year-round dispatch for the ETYS model from existing market dispatch simulators is the power factor set point of the generators. Market dispatch simulators are usually based on a linearised DC load flow, which naturally means that the dispatch decision is primarily guided by the market dynamics and the active power operational limits of the machines. There is no mechanism to guide the reactive power dispatch of the generators. This means that even if a dispatch is valid with respect to the operational MW rating of a machine, the operating point can nevertheless end up being at either of the extremes of a machine's capability curve.

For most of the studied dispatch scenarios, it is observed that some machines are operating at highly under-excited condition i.e., absorbing a very high amount of reactive power. We suspect that this is a result of applying the dispatch from a linearised load flow to the dynamic AC simulations within the ETYS model. This dispatch leads to excessive line charging vars (capacitive reactive power flow from long circuits) in pockets of the network causing nearby generators to operate in under-excitation mode. This situation, coupled with the salient pole representation of all synchronous machines in the GB network, means that a large percentage of machines are operating close to their steady state stability limits. Therefore, even a small disturbance can lead to unstable behavior of the system.

Without managing the reactive power dispatch of the generators, the studied scenarios from POUYA will cause unnecessary voltage and stability issues under intact operation, not to mention problems of non-convergence. Unless every scenario is profiled to an acceptable dispatch level under intact operation, simulation results from contingency analysis will not be able to identify actual problems in the network.

Proposed solution for scenario profiling

The first step to reduce voltage issues would be to include power factor as a constraint in the optimal power flow (OPF) solution in POUYA. This will ensure the reactive power dispatch from generators are within the machine capability limits. This however means that the current implementation of OPF will need to be changed to a non-linear formulation. This will prevent synchronous generators from operating close to their stability limit. However, this does not guarantee acceptable voltage profile across the network and a separate profiling exercise will still need to be carried out.

Another approach could be to take actions after the dispatch data have been generated. This can be achieved by profiling voltage across different substations ensuring that shunt compensation devices are the first choice to provide reactive power support while synchronous generators are the last option and only provide the remaining amount and stay close to their nominal operating point.

This has been used in the past within NGESO for profiling winter peak scenario. Since then, it has been developed further in this project for use with year-round scenarios by profiling in parallel the substations which are electricity far apart. This has significantly improved the time taken to profile individual scenarios. In addition, after successfully profiling a scenario the state variables of the network are saved in a file so that successive scenarios can utilise this information. However, even after implementing these changes, a major limitation of this approach is the amount of time taken to profile a scenario which has very different demand and generation dispatch characteristics than already profiled ones.

A potential solution to this problem could be a clustering approach. To utilise the network state information more efficiently and improve on the time taken to profile a scenario, it could be useful to segregate the scenarios first based on certain network features which are important with respect to the purpose of the study. As an example, for stability studies the effective inertia of the network is an important consideration. Based on BMU dispatches and inertia information of individual units in a BMU, zonal inertia factors can be calculated, and these can serve as a feature to create clusters from the year-round data. Additional features can be included such as demand levels in individual zones and so on.

This approach can be included within the stability tool, or it can be implemented as a separate process and only profiled scenarios can be exchanged with all multi-scenario tools used within NGESO.

Dissemination

An abstract with the interim findings was accepted for paper submission in a Cigre Paris 2022 session, taking place from 28 August to 02 September 2022

Note: The following sections are only required for those projects which have been completed since 1st April 2013, or since the previous Project Progress information was reported.

The Outcomes of the Project

In addition to work package (WP) reports, the key outputs of the project have been a pair of prototype analysis tools:

- Stability Automation Tool (SAT): includes a suite of modules to read in market dispatch data and set up appropriate scenarios in DIgSILENT to run steady state and dynamic studies. The tool includes an automated stability identification module to check for system stability using time domain results without the need for any manual intervention. The output from the tool provides an understanding of the long-term capability of a boundary considering rotor angle stability as the constraint.
- Stability Classification Tool (SCT): a machine learning model which accepts data from SAT to train a classifier based on random forest algorithm. Several steps are necessary to process the output from SAT to create a final dataset which is suitable for training and testing of the machine learning model. These steps are handled by the tool and do not require manual intervention. Once the model is trained, it can be used for horizon scanning for stable/unstable scenarios without needing any resource intensive RMS studies.

These two tools are packaged together in a single platform called Stability Tool which can be accessed through a web-browser based user interface.

Data Access

Details on how network or consumption data arising in the course of a NIC or NIA funded project can be requested by interested parties, and the terms on which such data will be made available by National Grid can be found in our publicly available "Data sharing policy related to NIC/NIA projects" and www.nationalgrideso.com/innovation.

National Grid Electricity System Operator already publishes much of the data arising from our NIC/NIA projects at www.smarternetworks.org. You may wish to check this website before making an application under this policy, in case the data which you are seeking has already been published.

Foreground IPR

The foreground IPR generated from this this project are the Stability tools developed - Stability Automation Tool and the Stability Classification Tool (SCT)

Planned Implementation

Planned Implementation

The stability tool is developed to streamline the long-term boundary capability assessment study considering rotor angle stability as a constraint. The SAT has automated several processes which are otherwise done manually at present requiring significant time and effort. The overall Stability Tool has introduced several new methods, both in terms of analysis approach and managing large amount of data produced from the studies. These methods are fairly new to the power industry and therefore, require extensive testing and validation as well as some changes to the ESO IT systems.

Next Steps

As with any new tool, the stability tool is constantly evolving as more features are added to it and other application areas are explored. Therefore, rather than a one-off piece of software this tool can be developed further to include new areas of application as and when required by the business. During the development of the tool, we identified several challenges which have been earlier discussed. The next steps will involve extensive testing of the tool and to explore voltage profiling techniques that can yield maximum benefit for the usability of the tool in the NOA studies.

Recommendations

- Future developments

The stability tool framework has been developed with a modular approach making it easy to include additional features. Improvements will further reduce the total time taken to study a boundary by eliminating the need for manual intervention.

Currently, the critical contingencies are identified for every boundary based on a few different scenarios such as winter peak, summer minimum etc. However, these contingencies may not coincide with the potential critical contingency from year-round scenarios. To achieve this, a critical contingency identification and ranking module needs to be implemented which will scan for the worst possible contingency from all scenarios studied.

The second improvement could be to introduce the capability of studying multiple contingencies. At present, the tool considers a single contingency specified by the user through an input file. Moving forward, it might be beneficial to include multiple contingency analyses for horizon scanning exercises.

Post fault actions are used to alleviate stability constraints and increase the net boundary flow capability. This feature was part of the original scope of the project. However, due to the challenges with scenario profiling (Section Error! Reference source not found.), it was subsequently excluded from the scope. A future revision of the tool should consider this feature as post fault actions are an important element of the long-term boundary capability assessment process.

The project has explored several dimensionality reduction techniques as a means of simplifying the complex relationship between several correlated uncertain variables in the network. The approach adopted in the current version of the tool was found to be adequate. However, there is scope for further improving the method. For example, this could include non-linear dimensionality reduction techniques can be explored such as Manifold learning. This is an active area of research and several works in academia are looking to address this challenge of high dimensionality in practical network analysis.

- Other application areas

The existing capability of the tool covers year-round analysis using DC load flow, AC load flow and RMS studies considering rotor angle stability as a constraint. The analysis can be done with the ETYS model or a reduced equivalent dynamic model. The signal processing approach adopted in the tool to identify stable/unstable scenarios can be easily used for voltage stability constraint as well. Users would simply need to select generator terminal voltage and/or substation voltage measurements as signals to use for the identification process.

Additional application areas of the tool which can be achieved by introducing simple extensions. Frequency stability and inertia are important considerations in a weak network. The tool does not explicitly consider these factors for scenario classification, but the check stable module of the tool can be extended to include these factors as constraints for stable/unstable tagging of scenarios.

Short circuit level is another important parameter and in a weak network it can have a significant impact on the performance of Inverter Based Resources (IBR). The stability classification tool currently does not include short circuit as a feature for the machine learning model. However, this should be considered for future networks where the proportion of IBR is expected to be significantly higher than it is now.

Converter driven instability is a product of the evolving generation mix in the system and a complex interaction between different technology types. A vast majority of the fast interactions will require electromagnetic transient type simulations to study the phenomenon. However, RMS type simulations, such as the stability tool, can be used to capture slower interactions depending on the level of detail included in the proprietary models of wind farm, solar PV farms etc.

Reactive power needs of the future system will be very different from now and dynamic voltage support from devices like SVC, STATCOM etc will be more common. The stability tool can be extended to identify areas of the network having voltage instability issues and potential dynamic voltage support requirements.

Other Comments

Standards Documents

Not applicable.