Research and Developments in the Area of Power System Security

Recherches et Développements dans le Domaine de la Securité des Réseaux Electriques

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Summary

This note gives a survey of some research activities in the Stochastic Methods Group of the University of Liège, "Montefiore" Institute, in the area of power systems security assessment and control, those in which the author is directly involved. Current research activities in the field are conducting through several research projects supported by the European Union and include those within: (a) the **EXaMINE project** in which the group is involved in the research focusing transient stability emergency control, better utilization of phasor measurements for power system control, and application of reinforcement learning to the same problem, and (b) **OMASES project** in which the group is involved in the research focusing on preventive transient stability assessment and control as well as voltage security assessment. A short historical overview of the research activities at the group in the field are introduced then more details are given on the developments achieved within mentioned projects as well as future research directions in the field of transient stability emergency control and application of reinforcement learning methods to power system control.

Introduction

Power system security in general may be defined as the system robustness to operate in an equilibrium state under normal and perturbed conditions. In order to ensure this property power systems are operated within certain limits, commonly referred to as security limits. If such limits depend on steady state feasibility or adequacy criteria, they are called static security limits; otherwise, if such limits depend on transient or long-term stability criteria, these are referred to as dynamic security limits. The research activities in the field of power system security at Institute "Montefiore" were initiated in late sixties with the focus on two aspects of the problem:

1. Transient Stability Assessment and Control,
2. Voltage Stability Assessment and Control.

At the same time the research in application of automatic learning techniques to the two problems, was started. The research efforts resulted in development of comprehensive methodologies able to tackle the problems: SIME (for Single Machine Equivalent), QSS (for Quasi Steady State) approach to voltage stability assessment and control, and a panel of machine learning techniques. The collaboration with industrial partners resulted, since mid nineties, in the application of the developed techniques in real-life power systems: EDF (Electricite de France), Hydro-Quebec, and Electrabel/Elia. The technological advancements have always been followed up by refinement of the developed methodologies. In late 90's the research in the field of reinforcement learning and its application to solve power system control problems, was initiated. Currently, the research activities in the field of power system dynamic security assessment and control are conducted, in part, through two European Union funded projects: the OMASES project and EXaMINE project.

The OMASES project

The acronym OMASES stands for Open Market Access and SEcurity assessment System. It is a partially funded European Union project in which several partners from the industry and the university collaborate in order to implement, and test on-line, new EMS functions to help the operator take decisions. OMASES will enhance the information processed in the current EMS functions with the one provided by new functions like:

- Transient Stability Assessment (TSA)
- Voltage Stability Assessment (VSA)
- Dynamic Dispatcher Training Simulator
- Electric Market Simulator.

These functions are intended to be used in the different modes shortly described below.

- **Real-Time (on-line) mode.** In this mode the DSA tools are going to be used to provide EMS operators alarms about (and countermeasures to) potential dynamic insecurity problems encountered during the changing conditions they meet along the daily operation.
- **Engineering mode (off-line).** In this mode, operation planning engineers will use the TSA and VSA functions in order to perform studies (involving the market or not) for operation planning purposes. The information provided by these functions changes, since in this application context time is not anymore a constraint and more details about system dynamic behavior could be required.
- **Training mode (off-line).** The Dynamic Dispatcher Training Simulator is used in this context for preparing system operators to face unexpected insecurity problems and to improve their abilities to manage them.

OMASES is going to be coupled to existing EMS facilities, using the hardware and software architecture shown in Fig. 1. It is an open architecture so as to facilitate the addition and removal of components having different computing performances.

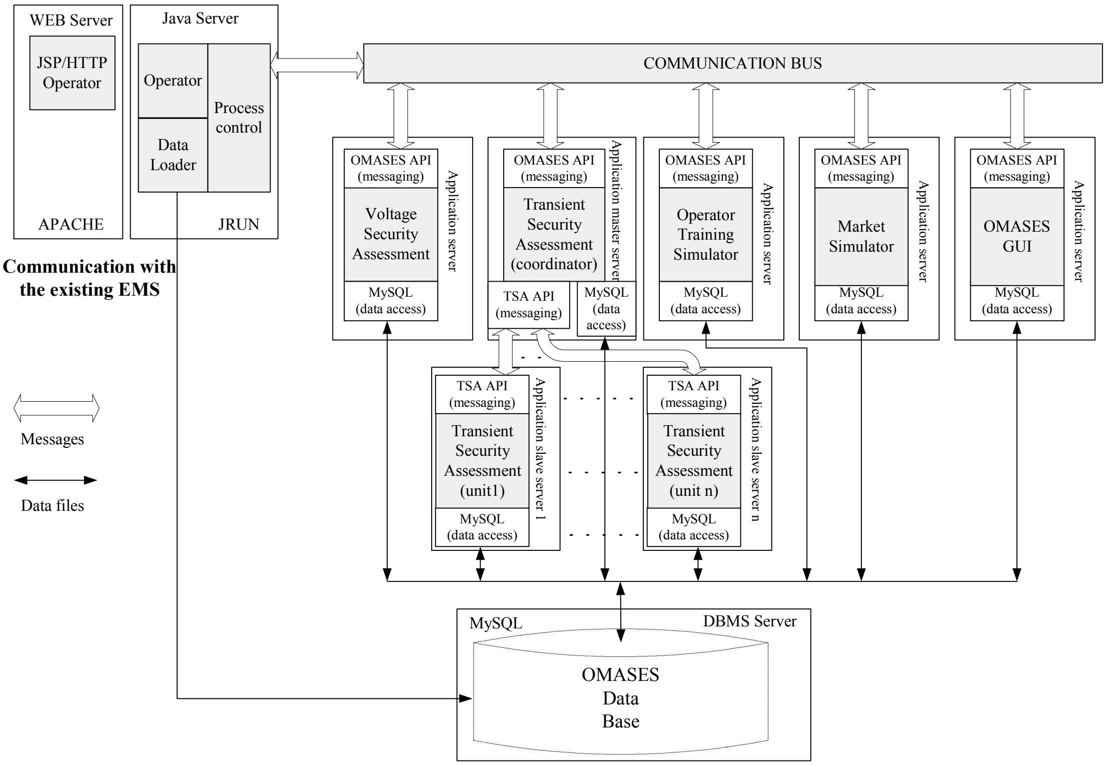

Fig. 1.: Hardware architecture of the OMASES functions.

The EMS at the different experimentation sites (the Hellenic Transmission System Operator in Greece (HTSO) and the *Gestore Rete Trasmissione Nazionale* (GRTN) in Italy) is not modified; it only sends, periodically or on the operator demand, an updated operating condition of the system. OMASES has a general database for storing the system operating condition coming from the EMS, and the corresponding results and data of the different functions. There is a general Graphic User Interface (GUI) for starting the sequence of execution of the different functions and for observing the different results of the new functions.

The EXaMINE project

The acronym EXaMINE stands for EXperimentation of a Monitoring and control system for managing vulnerabilities of the European INfrastructure for Electrical power exchange. It is a fully European Union funded project in which several partners from the industry and the universities collaborate in order to design, prototype and test novel monitoring systems supporting the control centers of the European power system in order to adapt and enhance their security control functions, thus allowing them to collectively meet the challenges of operating the European grid in a safe and reliable fashion, under increased interregional power transfers. The project considers security control in terms of its two complementary modes, namely preventive control and emergency control. Both aspects are tackled by using the latest developments in information technology in order to improve the quality of the information used for security monitoring and control. Field tests with the cooperation of the System Operators (REE – Red Electrica de Espana, and GRTN) that support the project. University of Liege is participating in the project within the context of research, development, and implementation of the emergency control scheme based on Emergency SIME [1] (including better utilization of the observations done on the system by using advanced preprocessing of phasor measurements using artificial neural networks [2]) and reinforcement learning [3,4,5]. Functional architecture of the emergency mode is illustrated in Figure 2.

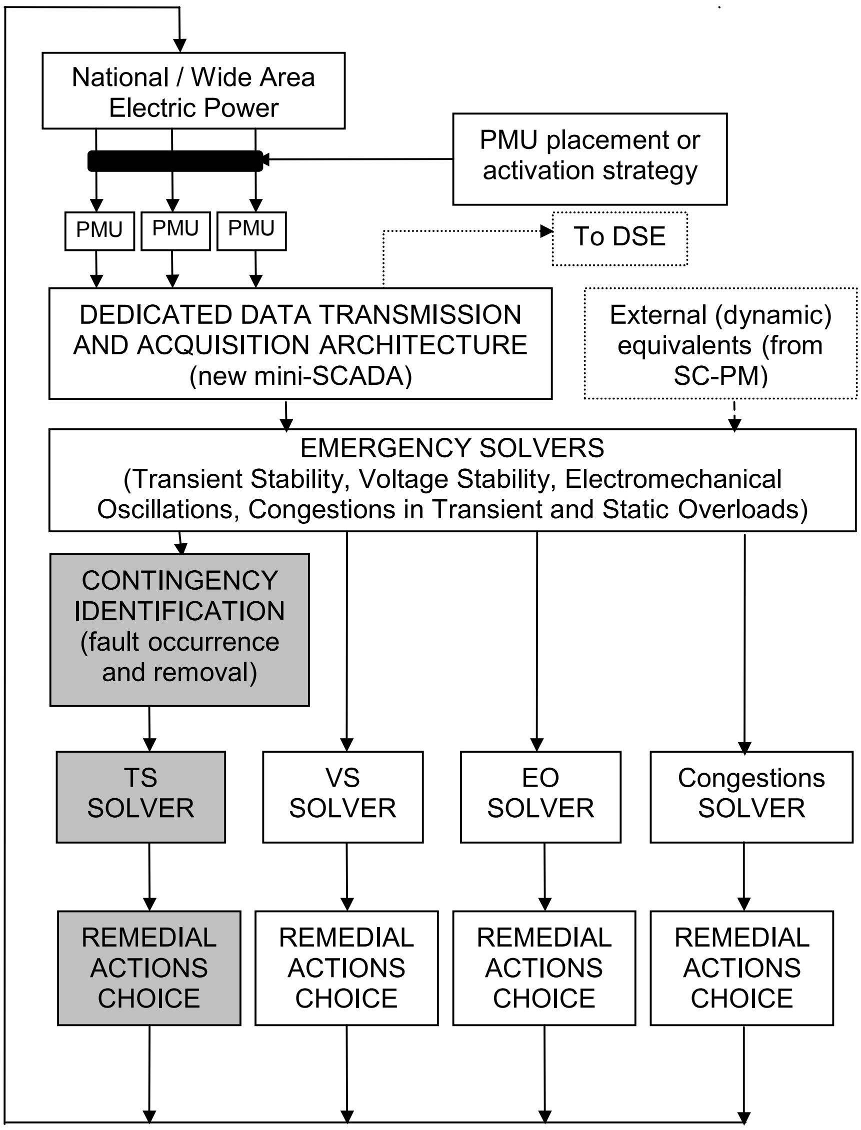

Figure 2. Functional architecture of Security Control – Emergency Mode (shaded blocks identify ULg participation in the project)

EXaMINE Emergency control approach. The emergency part of the EXaMINE project focuses on the use of synchronized phasor measurement units (PMUs) and ultra-fast communication systems in order to achieve the following objectives.

- Complement conventional SCADA with an ultra-fast real-time SCADA system, providing a global picture of the system state with sufficient temporal and spatial resolution so as to allow decision making in the context of fast phenomena such as loss of synchronism and fast cascading line tripping.
- Develop instability detection algorithms working in real-time speed.

- Develop closed-loop measurement based emergency control algorithms, fast enough to avoid loss of synchronism.

Closed loop emergency control. As concerns loss-of-synchronism two approaches are developed and tested in parallel.

E-SIME based generator tripping. The method is explained in detail in [1]. It is essentially a by-product of the E-SIME based instability detection. Indeed, the latter determines the critical group of machines, i.e. those loosing synchronism with respect to the rest of the system. The control module will trip part of these machines in a sequential closed loop fashion. It estimates, on the basis of the real-time single machine equivalent power-angle curves the amount of excess energy and how much of it can be cancelled by tripping each generator. Then the minimal number of generators to trip is determined and a tripping signal is sent to the corresponding power plant(s). The detection module is then called back in order to further monitor the rotor angles after the fact in order to check whether stabilization is successful or not. If not, the control module is called again with the refreshed information in order to decide on a new (additional) control signal to send, and so on.

Reinforcement learning based control. This approach is investigated in the EXaMINE project from a more academic point of view, as a long term, full fledged, solution for emergency control. Reinforcement learning methods provide an automatic way to learn how to control a system (by trial and error) in order to maximize a certain objective function. The method can be coupled either with a real system or with a simulation model of a system. This latter solution allows one to avoid destroying the real system at the early stages of learning, when the algorithm is still ignorant about the correct way to do control. It allows one also to set up appropriate simulation scenarios which are not normally observed on the real system but under which the control algorithm should work. Thus, in the context of electric power systems the learning stage is of course carried out on the basis of simulations. We refer the interested reader to [3,4,5] for a more in depth presentation of reinforcement learning in the context of power system control.

Future research directions

The research activities will particularly be focused on the development of advanced techniques for power system control based on reinforcement learning [5], as well as combining this technique for design of computational autonomous agents with the available control techniques (in particular, the robust control techniques) [3,4,5].

Future research efforts will also include development of system protection schemes based on the SIME principle (both open-loop and close-loop protection schemes, some results in the design of open-loop protections schemes were obtained), QSS approach to voltage security assessment and control (some results were already obtained in this regards, particularly in design of load shedding schemes against voltage instabilities), and further research in improved use of phasor measurements for transient stability assessment and control.

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