Real-Time Detection of the Risk of Blackout

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Abstract -- **This paper addresses the problem of quantifying the risk of blackout and the need to do it fast, in real-time and for multiple off-line simulations. Two key issues are addressed: *computational speed*, required for on-line decision-making, and *ease of interpretation of the results*, i.e., the ability to *see* how far is the blackout without having to interpret large amounts of information and to perform complex data analysis chores. Theoretical aspects are analyzed, and a two-step stability limit evaluation paradigm is formulated. Practical aspects are also reviewed and illustrated with actual case studies taken directly from SCADA/EMS installations where the method is currently being used both in real-time and in study-mode. The approach presented herein can help system dispatchers and reliability engineers foresee whether the transmission loading progresses, or is projected to progress, beyond the operating reliability limit.**

Index Terms -- **open access transmission, maximum loadability, energy management systems, independent system operators.**

I. INTRODUCTION

THIS presentation describes an approach to the real-time detection of system conditions that may hide an approaching blackout. This is particularly relevant in the aftermath of the wave of blackouts that affected utilities in US, UK and mainland Europe in 2003.

Deregulation, restructuring and unbundling were said to have been the main contributing factors, followed by lack of coordination between neighboring ISOs and/or TSOs.

The need to immediately reinforce the transmission and communications infrastructure was also invoked – yet no flags were raised by the inability of the existing, and truly advanced, network analysis systems and dynamic security assessment tools to detect and alarm system conditions that subsequently developed into blackouts due to instability.

II. DISTANCE TO INSTABILITY

Is there a way to measure and to visualize the *distance to instability*? Can such an index be computed within split seconds and displayed automatically, after each state estimate or power-flow calculation?

Is there such a technology available and, if there is, should it be used in addition to, or, rather, instead of, extensive dynamic security assessment calculations?

To begin with the last question, the approach presented herein has been available for quite some time [2], [3], [4] and was implemented, off-line and in real-time, *in addition to*, rather than instead of, detailed stability simulations. The concept is simple and is reminiscent of classic contingency evaluation.

First, the *stability reserve*, defined as the distance between the current system loading and the system state corresponding to steady-state instability, is computed. If the system state is far from instability, no further action is needed. Otherwise, detailed stability simulations may be run to refine the analysis or, if time is of essence, which is typically the case in real-time, remedial action must performed.

In order to better understand the concept of *stability reserve*, we need to step back and take another look at some indices introduced by NERC [5] in 1996: Available Transfer Capability (ATC), Total Transfer Capability (TTC), and Transmission Reliability Margin (TRM). TTC corresponds to a state where there are no thermal, voltage and stability limit violations.

The stability limit, or *stability envelope*, is the minimum of Steady-State Stability Limit (SSSL), Voltage Stability Limit (VSL) and Transient Stability Limit (TSL). TSL is the most restrictive and can be perceived as a stability envelope. States outside the stability envelope are dangerous, and become critical near SSSL, which is the point of blackout.

Detecting thermal and voltage violations in real-time is straightforward and is a common routine in modern SCADA/EMS. The computation of the stability envelope is a different story altogether. Detailed stability assessment procedures entail heavy computations, use large amounts of data, may not converge near instability, and require significant expertise to interpret the results.

The alternate is the two-step approach mentioned earlier: begin with a fast approximation of the SSSL and the stability envelope then, if needed, perform detailed stability calculations, e.g., small-signal and transient stability analysis or dynamic security assessment.

III. APPROACH

A fast and sound method for approximating the steady-state stability limit was described in [3] and [4], with detailed equations and validation results fully documented in [2]. The most significant feature of the method is *speed*. A 1300 bus steady-state stability case is solved in 1 second on a 1 GHz Celeron laptop. Because of this computational speed, the technique was implemented in real-time as part of the real-time network analysis sequence for automatic execution after each state-estimate. The other unique aspect of the method is *how* the information is presented. The computations, which

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are quite complex, generate a large amount of data, but only the essential results needed to convey the concept of stability reserve are extracted and displayed, in addition to other relevant information, in a format that's simple and easy to interpret.

In this author's opinion, real-time stability assessment could easily be implemented in most of the existing SCADA/EMS installations if the two-step approach described in this presentation were implemented. First, a quick check of the stability reserve should be performed after each state estimate, power-flow solution and N-1 contingency evaluation. Then, if needed, detailed and extensive stability computations might be triggered to refine the initial results.

IV. References

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