CIGRE PARIS 2022

GROUP REF. : B4
COUNTRY : Australia PREF. SUBJECT : PS1
REGISTRATION NUMBER : DLG1383 QUESTION N° : 1.2

This presentation discusses modelling tools and model validation practices for power systems with a high-share of inverter-based resources. It is primarily based on lessons learned and issues encountered in Australia's National Electricity Market (NEM), but also consolidates author's experience in assisting some of the European system operators and network owners (TSOs/ISOs). Furthermore, this presentation accounts for author's experience in leading CIGRE WG C4.56 which has recently been complete.

Power systems around the world are transitioning to significantly higher shares of inverter-based resources (IBR) with fewer synchronous generators remaining online. IBR and synchronous generators have fundamentally different dynamic performance characteristics. System dynamics and technical needs are therefore vastly different between synchronous and IBR dominated power systems, and these differences will become greater as IBR uptake increases in the power system. Changes in system characteristics have caused new and emerging power system phenomena. These phenomena either did not previously exist or when they did, they manifested themselves on a limited scale and only in a small part of the power system.

Worldwide experiences indicate that conventional power system stability analysis tools, referred to as phasor-domain simulation (PDT) tools or more commonly as root mean square (RMS) tools, have often not been able to predict these phenomena due to the simplifications inherent in these tools. The consequence of this inability to predict the problems early enough is that problems might be first experienced during actual power system operation, at which point it is more difficult to address and more disruptive and costly to the connecting party; i.e. if the system operator or network owner needs to invoke a constraint to pre-empt the impact on power system stability or nearby network users. The particular area where PDT models and tools fall short is assessing the potential for adverse control system interactions between several nearby IBRs. Furthermore, it is this author's experience that PDT models for grid-forming inverters do not sometimes have the same level of maturity and readiness compared to respective electromagnetic transient (EMT) models.

Detailed whole-system modelling based on EMT simulation has been increasingly used in recent times in particular in countries/regions such as Australia with higher IBR penetration to address the problems discussed above. This will facilitate accurate long-term power system planning allowing the identification and resolution of new and emerging phenomena before they manifest in real power system operation. It will also permit a more accurate albeit more involved assessment of the impact of connecting new IBR such as battery energy storage systems, hydrogen electrolyser, solar and wind generation on power system planning and operation. This detailed modelling will also facilitate better understanding of the performance of emerging technologies such as grid-forming inverters and how best they can be designed to meet emerging power system needs and technical requirements in power systems with significantly higher IBR penetration.

However, it is noted that access to the EMT models and in particular wide-area EMT models has not been straightforward. System operators and network owners generally have access to the wide-area EMT models, however, with limited access to inside the black-box model or expertise to perform coordinated control system tuning. OEMs have intimate knowledge of their control system design and tuning, however, often not have access to the wider system models and cannot therefore make meaningful changes to their model to rectify an adverse interaction identified by TSO/ISO studies.

Slides 3 shows an end-to-end connection process in Australia's NEM including how individual power system models are tested and validated. The intent of model acceptance testing is to make sure that EMT and PDT models are fit for purpose and do not exhibit any unexpected responses before they are integrated into the wide-area models. Having sufficient confidence in early stages of grid connection process, would assist in having a smoother process for technical performance assessment. These studies are generally conducted by the developer/OEM and their consultants, and submitted for due diligence studies by TSO/ISO. The only exception is wide-area EMT studies which is currently possible for TSO/ISO only due to the confidentiality of black-box EMT models. Once all the necessary EMT and PDT studies are complete and if satisfactory performances can be achieved in various aspects of the performance including steady-state and dynamic performance, the IBR is then permitted to physically connect to the power system. Commissioning and compliance testing involving the application of small changes in voltage, frequency, active and reactive power are typically conducted. Subsequently, measured and simulated response are compared against model accuracy requirements set out in Power System Model Guidelines. Models considered validated if they can meet model accuracy requirements. However, such an approach does not permit validation against the fault ride-through response of the IBR. As such, the use of high-speed data obtained from natural or staged system disturbances has been a common practice to validate individual IBR models as well as the overall power system response to those events.