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Dynamic characteristics of inverter-based resources in bulk power systems – Part 1: Interconnecting inverter-based resources to low short circuit ratio AC networks

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Part 1: Interconnecting inverter-based resources to low short circuit ratio AC networks

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The text of this Technical Report is based on the following documents:

Draft TR	Report on voting
8A/109/DTR	8A/113/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 63401 series, published under the general title *Dynamic characteristics of inverter-based resources in bulk power systems*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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- withdrawn,
- replaced by a revised edition, or
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INTRODUCTION

As the penetration of inverter-based energy generating resources increases, huge challenges to all sections of the power system including planning, operation, control, etc. have been created. The impact on the power grid extends from local to the whole power system. New technical solutions are needed to address the different challenges. The solutions will include the new technologies, methods and practices, to provide more flexibility and improve the efficiency of power systems, constantly balancing generation and load.

The purpose of this document (TR) is to specifically focus on information collection from regulatory agencies, including specifying low short circuit ratio AC networks and the challenges they pose for inverter-based resources, and methods, indexes, and characteristics of low short circuit ratio AC networks. This TR addresses renewable energy (RE) integration in low short circuit ratio AC networks, mainly focusing on the technology development trends, best practices of RE grid integration, and future standardization activities.

The aim of this TR is to create a strategic, technically oriented and referenced document, which presents the core and key issues of interconnecting inverter-based resources to low short circuit ratio AC networks. Renewable energy station developers and owners, transmission systems operators need to have a common understanding of the key issues based on practices and challenges between inverter-based resources and AC networks.

DYNAMIC CHARACTERISTICS OF INVERTER-BASED RESOURCES IN BULK POWER SYSTEMS –

Part 1: Interconnecting inverter-based resources to low short circuit ratio AC networks

1 Scope

As the use of inverter-based RE power generation resources increases, the use of low short circuit ratio AC networks is becoming more common. Considering the advantages of short circuit ratio in stability analysis, the low short circuit ratio is an important indication for describing weak AC networks. This document focuses on technologies and standardization aspects of interconnecting inverter-based resources to low short circuit ratio AC networks. A clear definition of low short circuit ratio AC networks with or without a high proportion of inverter-based resources and the calculation method is described. The adaptability of traditional modelling and analytical method for low short circuit ratio AC networks are discussed. Some new characteristics and challenges will be re-examined, and some adapted control strategies will be studied. This document covers the following major aspects.

In terms of defining a weak AC network, for example the (X/R) ratio, voltage sensitivity, system inertia and the short circuit ratio (SCR) are important characteristics. The definition of low short circuit ratio AC networks in IEEE Std 1204TM-1997 [1][1] and in CIGRE B4.62 TB671 [2] is used. Some stability challenges for inverter-based resources in a low short circuit ratio AC network (SCR AC) will be analyzed. There are stability challenges in a low short circuit ratio (SCR) AC network, typically complex static voltage control, risk of failure in fault ride-through situations, strong control interactions and instability.

In terms of identification of low short circuit ratio (SCR) AC networks, some short circuit ratio -like index for various applications is introduced. A wind power plant (WPP) is a power station consisting of a batch of wind turbines or groups of wind turbines, collection lines, main step-up transformers and other equipment. For a single grid-connected WPP system, a fault current based calculation method and an equivalent circuit based calculation method are introduced to make an SCR calculation possible for any given WPP and network topology. For multi grid-connected WPP systems, eigenvalue decomposition based generalized short circuit ratio (gSCR) is then proposed and compared against other approaches referred to as equivalent short circuit ratio (ESCR), composite short circuit ratio (CSCR), and weighted short circuit ratio (WSCR).

In terms of large scale inverter-based resources integration, the steady-state stability analysis methods, including the P-V curve, Q-V curve, and voltage sensitivity analysis, are illustrated. The conventional control strategies of the renewable energy sources are explained. An adaptive controller designed for the photovoltaic (PV) panels, which can maximize the power output capability of PV stations under weak-grid conditions, is presented. Finally, the steady-state voltage stability problem in China that happened recently is illustrated.

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[1] Numbers in square brackets refer to the Bibliography.

In terms of the transient state stability issue for low short circuit ratio AC networks after large scale inverter-based resources integration, related issues and phenomena that occur need to be discussed. Undervoltage ride-through (UVRT), overvoltage ride-through (OVRT) and multiple fault ride-through occur easily in a low SCR AC network, which bring risk of failure to fault ride-through. Electromagnetic transient simulations to supplement positive sequence root-mean-square (RMS) simulations are described, and shortfalls of the RMS models and how to identify them in simulations are considered.

In terms of the oscillatory stability issue for low short circuit ratio AC networks after large scale inverter-based resources integration, the impedance-based method is used to analyze the system stability. For the inverter modelling, three typical inverter models are established, including: a) only considering the current controller (CC); b) considering CC and phase-locked loop (PLL); c) considering CC, PLL and voltage controller (VC). Relying on the impedance analysis method, the effect of PLL, CC, number of inverters, SCR of AC grid is discussed. Finally, the additional active damping control method is proposed for suppressing the oscillation phenomenon.

This document discusses the challenges of connecting inverter-based resources to low short circuit ratio AC networks, key technical issues and emerging technologies. There are the steady-state stability issue, transient state stability issue, and oscillatory stability issue, which are the most distinct differences compared to inverter-based resources or traditional generators, and accordingly brings new challenges to operation, control, protection, etc. Therefore, technical solutions are needed. The potential solutions will include new technologies, methods and practices, in order to provide more flexibility and improve the efficiency of power systems. It is expected that this document can also provide guidance for further standardization on relevant issues.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62934, *Grid integration of renewable energy generation – Terms and definitions*