

GUIDE FOR ASSESSING THE NETWORK HARMONIC IMPEDANCE

A. Robert¹, T. Defflandre, Joint CIGRE / CTRSD Working Group CC02²

1 INTRODUCTION

WG CC02 (CIGRE 36.05/ CTRSD 2) has published recommendations for the connection of harmonic producing loads in MV and HV power systems which have been an important input for the new EMC Technical Report 1000-3-C "Assessment of emission limits for disturbing loads in MV and HV power systems" (1996). The aim of this Basic EMC Publication is to limit the harmonic currents and voltages in the network to avoid disturbances to sensitive equipment.

Non-linear loads are generally characterized by harmonic currents, and therefore, it is often preferred to express the emission limits in terms of currents rather than voltages. In order to translate the injected harmonic currents into harmonic voltages though, one needs to know the harmonic impedance of the system.

However, assessing the network harmonic impedance is a very complex and difficult task. There is no inexpensive, simple and universal measurement or computational method available, powerful computer programs may be used, but a full knowledge of the network characteristics is lacking. Moreover, the impedance is continuously changing with loads, network elements and system conditions.

The objective of this report is to provide practical guidance for assessing the system harmonic impedance, taking into account the considered network (L.V., MV or HV), the disturbing load importance (small or great contribution to the network pollution), the analytical and computational tools available.

Due to space limitations, we only present an extensive summary of the paper here. The full paper, with all references and appendices, may be obtained on request at the CTRSD Secretariat³. It may also be found in ELECTRA, No. 167, August 1996, 96-111.

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2 CHOICE OF REPRESENTATIVE NETWORK CONDITIONS

For most studies, it will be sufficient to consider normal operating conditions.

However, in particular cases, e.g. when studying the connection of a big disturbing load bringing some risk that the resulting total harmonic voltages could exceed the planning limits, also reasonable emergency conditions (i.e. a N-1 configuration) should be considered.

In both cases, at least heavy- and light-load conditions should be taken into account.

3 MEASUREMENT METHODS

3.1 General principles

The basic principle is to make use of (inter)harmonic currents I_h injected at the point where the (inter)harmonic impedance Z_h is to be measured, then using Ohm's law,

$$Z_h = \frac{U_h}{I_h} \quad (1)$$

assuming that no (inter)harmonic voltage was present in the network prior to the current injection (Fig. 1). In cases where this assumption is not valid, U_h and I_h should be replaced by ΔU_h and ΔI_h .



Fig. 1: Basic principle of measurement methods

N.B. Z_h , U_h and I_h are obviously complex quantities but, in order to simplify the notation, the symbols have not been underlined.

In practice however, the power system is 3-phase and is not symmetrical. Furthermore, in most cases, the injected harmonic currents are far from symmetrical. Thus, even if we assume the system is symmetrical (more correct in MV than in LHV), we have to study the practicability of

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J.P. Barret, P. Bornard, B. Meyer



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Understanding Harmonic Propagation in Meshed Transmission Power Systems with a Large Number of Underground Cables Bjarne Søndergaard Bukh, 2025-07-02 This outstanding PhD thesis reports on new analytical methods developed to analyse harmonic propagation in large transmission systems The focus is on understanding the physical relationships between harmonic propagation phenomena in the passive grid caused by grid expansions or changes to existing transmission lines Principal component analysis and partial least squares regression have been used as tools to investigate statistical correlations between harmonic distortion levels at substations and a harmonic propagation model based on standing wave phenomena and techniques known from radio and microwave theory has been developed Knowledge of the propagation phenomena has also been used to develop a new method for determining appropriate locations for harmonic mitigating equipment in a grid Finally the methods have been validated through both simulation models and harmonic voltage measurements obtained from the Danish transmission grid Overall this thesis reports new insights into harmonic propagation in power systems as the use of underground cables increases and offers new tools for analysing such phenomena No previous examples of data driven analyses of measurement data from a power system in the form presented here could be found in existing literature thus paving a way to new possibilities for this emerging field

Power System Harmonics Jos Arrillaga, Neville R. Watson, 2004-06-25 Harmonic distortion problems include equipment overheating motor failures capacitor failure and inaccurate power metering The topic of power system harmonics was covered for the first time 20 years ago and the first edition has become a standard reference work in this area Unprecedented developments in power electronic devices and their integration at all levels in the power system require a new look at the causes and effects of these problems and the state of hardware and software available for harmonic assessment Following the successful first edition this second edition of Power System Harmonics maintains the practical approach to the subject and discusses the impact of advanced power electronic technology on instrumentation simulation standards and active harmonic elimination techniques Features include A new chapter on modern digital instrumentation techniques Added sections on active filters and modern distorting devices such as FACTS devices multilevel conversion current source voltage source inverters and turn OFF related power electronic devices References to international standards for harmonics and inter harmonics Numerical examples of technique application Offering a comprehensive understanding of power systems this book is an asset to power engineers involved in the planning design and operation of power system generation transmission and distribution Researchers and postgraduate students in the field will also benefit from this useful reference

Power Quality Indices in Liberalized Markets Pierluigi Caramia, Guido Carpinelli, Paola Verde, 2009-08-06 Power Quality PQ indices are a powerful tool for quickly quantifying PQ disturbances They also serve as the basis for illustrating the negative impact of electrical disturbances on components and for assessing compliance with the required standards and recommendations within a regulating framework

Within these pages lies a comprehensive overview of both the traditional PQ indices in use today and new indices likely to be used in the future. Key features of this book include a special focus on the metrics for quantifying PQ disturbances, a complete review of methods and indices for assessing disturbance responsibilities between customers and utilities, a survey on PQ objectives around the world with highlights on the economic aspects of PQ disturbances. Inside you will find a thorough and well-balanced treatment on theoretical concepts and practical applications enhanced by examples and exercises of PQ indices computation and use. This is an important resource for academics, students of power quality, reliability and electrical power systems courses, and also for practicing engineers involved in solving PQ problems in the new structures of liberalised energy markets.

Guide for Limiting Current Harmonics, 1999 With reference to India **Power Quality** Gregorio Romero, Luisa Martinez, 2011-11-23 Nowadays the increasing use of power electronics equipment originates important distortions. The perfect AC power systems are a pure sinusoidal wave both voltage and current, but the ever-increasing existence of non-linear loads modifies the characteristics of voltage and current from the ideal sinusoidal wave. This deviation from the ideal wave is reflected by the harmonics, and although its effects vary depending on the type of load, it affects the efficiency of an electrical system and can cause considerable damage to the systems and infrastructures. Ensuring optimal power quality after a good design and devices means productivity, efficiency, competitiveness and profitability. Nevertheless, nobody can assure the optimal power quality when there is a good design if the correct testing and working process from the obtained data is not properly assured at every instant; this entails processing the real data correctly. In this book, the reader will be introduced to the harmonics analysis from the real measurement data and to the study of different industrial environments and electronic devices. **Green Energy and Networking** João L. Afonso, Vítor Monteiro, José Gabriel

Pinto, 2019-02-05 This book constitutes the refereed post-conference proceedings of the 5th EAI International Conference on Green Energy and Networking (GreeNets 2018) held in Guimarães, Portugal, in November 2018. The 15 full papers were selected from 26 submissions and cover a wide spectrum of ideas to reduce the impact of climate change while maintaining social prosperity. In this context, growing global concern leads to the adoption of the new technological paradigms, especially for the operation of future smart cities. **Real-Time Simulation and Hardware-in-the-Loop Testing**

Using Typhoon HIL Saurabh Mani Tripathi, Francisco M. Gonzalez-Longatt, 2023-05-16 This book is an edited collection that explores the fundamental concepts of real-time simulation hardware in the loop testing using Typhoon HIL for complex electrical systems. Typhoon HIL has recently emerged as a powerful tool in the rapidly growing field of ultra-high-fidelity controller hardware in the loop (C-HIL) simulations for power electronics, microgrids and distribution networks. The book integrates the coverage of underlying theory and acclaimed methodological approaches and high-value applications of real-time simulation and hardware in the loop testing, all from the perspectives of eminent researchers around the globe utilizing Typhoon HIL. This book serves as a valuable resource for engineers, academicians, researchers, experienced professionals and

research scholars engaged in becoming familiarized with the real time simulation of complex electrical systems using Typhoon HIL with a specific focus on hardware in the loop testing *Power System Simulation* J.P. Barret,P. Bornard,B. Meyer,1996-12-31 The authors writing with the experience and technological background of Electricite de France an organisation at the forefront of simulation methods provide a comprehensive and comprehensible treatment of the modelling and simulation techniques currently in use The text emphasises model design applied to power plants producing energy generators and motors carrying out energy transformations and networks transmitting energy The systems are analysed considering each process from steady state to fast transients with detailed explanation of the problem to be solved the choice of models and methods for optimising efficiency Many examples and references are provided The book is essential reading for anyone involved in power system engineering from practising design and development engineers to researchers and postgraduate and advanced graduate students *Trends in Renewable Energy and Power Quality* Manuel Pérez-Donsión,Gianpaolo Vitale,2024-03-19 This book addresses and updates the trends surrounding the potential advantages of renewable energy sources distributed generation energy storage and other factors relevant to smart systems In addition to well consolidated topics such as photovoltaic and wind generation new issues and solutions regarding smart grids power electronics converters energy management storage systems and innovative renewable sources exploitation techniques have been considered **CIREN, 14th International Conference and Exhibition on Electricity Distribution: Contributions. (7 v.)**,1997 **CIREN**,1997 **CIREN, 14th International Conference and Exhibition on Electricity Distribution**,1997 **Report (technical)**. India. Central Board of Irrigation and Power,1999 **12th International Conference on Electricity Distribution: Contributions (7 v.)**,1993 **Transmission and Distribution Electrical Engineering** Colin Bayliss,Brian Hardy,2011-11-29 This market leading classic is a true comprehensive on the job reference covering all aspects of getting electricity from the source to user via the power grid Electric power transmission and distribution is a huge sector and engineers require the real world guidance of this book in order to upgrade networks to handle smart and renewable sources of power This new edition covers renewable and distributed energy developments international regulatory compliance issues with coverage of IEC standards and new key conversions to US based standards and terminologies Utilising examples from real life systems and challenges this book clearly and succinctly outlines fundamental knowledge requirements for working in this area Written by engineers for engineers theory is tied to current best practice and new chapters cover hot topics including DC Transmission Smart Networks and bringing renewable sources into the grid Particularly useful for power engineers starting out on their career this new edition ensures Bayliss remains an essential tool of the trade for all engineers technicians managers and planners involved in electricity supply and industrial electricity usage Updated to ensure that the book continues to deliver all the fundamental knowledge requirements of practicing power engineers in a single volume High profile authors with extensive career long knowledge of the industry

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Table of Contents Guide For Assessing The Network Harmonic Impedance

1. Understanding the eBook Guide For Assessing The Network Harmonic Impedance
 - The Rise of Digital Reading Guide For Assessing The Network Harmonic Impedance
 - Advantages of eBooks Over Traditional Books
2. Identifying Guide For Assessing The Network Harmonic Impedance
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Guide For Assessing The Network Harmonic Impedance
 - User-Friendly Interface
4. Exploring eBook Recommendations from Guide For Assessing The Network Harmonic Impedance
 - Personalized Recommendations
 - Guide For Assessing The Network Harmonic Impedance User Reviews and Ratings
 - Guide For Assessing The Network Harmonic Impedance and Bestseller Lists
5. Accessing Guide For Assessing The Network Harmonic Impedance Free and Paid eBooks
 - Guide For Assessing The Network Harmonic Impedance Public Domain eBooks
 - Guide For Assessing The Network Harmonic Impedance eBook Subscription Services
 - Guide For Assessing The Network Harmonic Impedance Budget-Friendly Options

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 - ePub, PDF, MOBI, and More
 - Guide For Assessing The Network Harmonic Impedance Compatibility with Devices
 - Guide For Assessing The Network Harmonic Impedance Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Guide For Assessing The Network Harmonic Impedance
 - Highlighting and Note-Taking Guide For Assessing The Network Harmonic Impedance
 - Interactive Elements Guide For Assessing The Network Harmonic Impedance
8. Staying Engaged with Guide For Assessing The Network Harmonic Impedance
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Guide For Assessing The Network Harmonic Impedance
9. Balancing eBooks and Physical Books Guide For Assessing The Network Harmonic Impedance
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Guide For Assessing The Network Harmonic Impedance
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Guide For Assessing The Network Harmonic Impedance
 - Setting Reading Goals Guide For Assessing The Network Harmonic Impedance
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Guide For Assessing The Network Harmonic Impedance
 - Fact-Checking eBook Content of Guide For Assessing The Network Harmonic Impedance
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
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