

# A Three-Phase Inverter with Reactive Power Control

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**Abstract**—A new type of self-commutated inverter for fixed or moderately variable frequency has been developed. The inverter is characterized by an extremely uncomplicated main circuit. In its basic form the inverter contains two converter circuits: a principal converter circuit and an auxiliary converter circuit. The principal converter circuit transfers power from the input dc side to the output ac side, and the auxiliary converter circuit generates an inductive current to balance the reactive current of a three-phase capacitor on the ac side. This capacitor has the combined function of a phase compensator, a filter capacitor, and is also the source of the commutating voltage. Both converter circuits are of the line-commutated type, meaning that at power frequencies normal converter thyristors can be employed. This makes it possible to build high-power inverters without series or parallel connected thyristors. All filter reactors are smoothing reactors placed on the dc side of the converter circuits. Thus the inverter has a very good efficiency even at the higher frequencies. The ability of a converter circuit to generate a negative sequence current when unsymmetrically controlled makes the inverter insensitive to unbalanced loads. The transient behavior of the inverter is similar to that obtained from a conventional self-commutated inverter with an output filter.

## I. INTRODUCTION

A CONVENTIONAL self-commutated inverter has a rather complicated main circuit when compared with an externally commutated converter. It may contain a number of auxiliary components intended to assist in the process of commutation which are not found in the externally commutated converters, i.e., commutating capacitors, inductances, regenerating transformers, etc. Furthermore, the thyristors must be of the "inverter" type to comply with the special requirements of the circuit, i.e., the turn-off time must be short, the  $di/dt$  and/or the  $dv/dt$  capabilities high, etc. These auxiliary components and thyristor requirements make self-commutated inverters expensive when compared with the inverter being introduced in this paper.

This paper deals with a new type of inverter which is a further development of the well-known single-phase load commutated inverter which has been primarily used as a power source for induction heating and melting equipments. Only three-phase inverters are described as these, just as three-phase rectifiers, are superior to the single phase ones in many respects, especially in the high-power field.

The inverter described here basically consists of two converter circuits of the line-commutated type with smoothing reactors, a three-phase capacitor, and an output transformer.

The type and nature of the load determines if the output transformer is required.

No auxiliary components of the aforementioned types are included, and for power frequencies, the thyristors used may be of the ordinary "converter" type. This technique offers an economical way of building simple and robust high-power inverters using sections of standard line-commutated converters.

The aforementioned types of converters are shown in Figs. 1-3. Fig. 1 shows a load commutated inverter; Fig. 2 shows an example of a conventional three-phase inverter with a filtered, uncontrolled output voltage; and Fig. 3 shows an inverter of the new type.

## II. LOAD COMMUTATED INVERTER

The new type of three-phase inverter which is described here is a further development of the single-phase load commutated inverter as shown in Fig. 1.

The load  $Z$ , e.g., an induction furnace with its phase compensating capacitor, is represented by a parallel connection of a capacitor  $C$ , an inductance  $L$ , and a resistance  $R$ .  $L$  and  $C$  oscillate at a frequency near resonance, and the alternating voltage is approximately sinusoidal. The active load current (through  $R$ ) is supplied by the converter circuit 3 which works as an inverter. The current from the direct supply voltage 1 is smoothed by a reactor 2. The converter circuit contains four elements in a bridge, and elements belonging to the same diagonal are fired simultaneously. It works as a line commutated inverter, only here the "line" is a resonant circuit, and the commutating voltage is supplied by the capacitor. The alternating voltage can be controlled by varying the firing angle of the inverter. If the load, especially one of its reactive components, varies, the frequency will also vary. For induction heating and melting purposes a considerable frequency variation may be tolerated, but for a general purpose fixed frequency inverter a variation of 1 percent or less might be desirable, and the inverter could be required to operate anywhere from no load to full load at varying power factors.

This could be achieved with an inverter as shown in Fig. 4. The capacitor and the inductance of the load in Fig. 1 are here regarded as a part of the inverter, and the inductance has been made variable. A new load represented by a resistance and a reactor has been added. In this inverter the active power is supplied from the dc source via the principal converter circuit and the reactive power from the capacitor. The balance between the capacitor current and the reactive components of the load current, the principal converter circuit and the inductance is achieved by varying the latter. This can be illustrated by means of the phasor diagram of Fig. 5, which is valid for the fundamental components of voltage and current.

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**Fekik, Arezki, Benamrouche,  
Nacereddine**



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distribution as well as for human and economic concerns such as pricing consumption and demand management A tutorial exposition is provided in each chapter describing the opportunities and challenges that lie ahead Topics in these chapters include wide area control issues of estimation and integration at the transmission distribution consumers and demand management and cyber physical security for smart grid control systems The contributors describe the problems involved with each topic and what impact these problems would have if not solved The tutorial components and the opportunities and challenges detailed make this book ideal for anyone interested in new paradigms for modernized smart power grids and anyone in a field where control is applied More specifically it is a valuable resource for students studying smart grid control and for researchers and academics wishing to extend their knowledge of the topic

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brings the reader current on the newly emerging fields that play an important role in the power infrastructure Microgrids Design Challenges and Prospects provides knowledge on decision making for newly evolving trends in microgrid design It discusses techniques on how to improve the existing power quality and reduce load shedding and power imbalances The book presents the emerging fields such as data science machine learning AI and IT that now play an important role in microgrid design The readership includes researchers academia practicing engineers consumers power companies and policy makers located across the globe **The Internet of Energy** Sheila Mahapatra,Mohan Krishna S.,B. Chandra

Sekhar,Saurav Raj,2024-02-20 Providing innovative efficient clean and safe solutions and research for interfacing internet technology with energy power grids for smart cities and smart transportation this new volume discusses the use and automation of electricity infrastructures for energy producers and manufacturers integrating the implementation of the Internet of Things IoT technology for distributed energy systems in order to optimize energy efficiency and wastage This volume offers a wide range of research on using IoT for energy solutions such as algorithms for the design and control of energy grids investigations of thermal efficiency from solar grids energy for smart buildings using IoT deep learning for electrical load forecasting hybrid ultracapacitors in solar microgrids induction motor driven electric vehicles power loss reduction and voltage improvement and much more Low-Carbon Oriented Market Mechanism and Reliability

Improvement of Multi-energy Systems Minglei Bao,Sheng Wang,Liang Du,Zhengmao Li ,Weiqi Hua,2024-12-17 The energy crisis has brought great challenges to the low carbon and economic development of the energy system To achieve net zero emissions energy systems can have an increasing penetration of renewable energy and a deep coupling of multiple energy sectors i e electricity gas and heat To deal with the increasing fluctuations of renewable energy in multi energy systems the market mechanism is an effective solution for the optimal allocation of resources An optimal market design could stimulate different resources to actively assist the carbon reduction and reliability improvement of multi energy systems Therefore research on low carbon oriented market design and optimal operation is expected to improve the reliability and sustainability of multi energy systems The objective of this Research Topic is to explore the latest advances in market design and reliability improvement technologies of multi energy systems with a focus on low carbon reliability and resilience We have the following research goals 1 Effective market mechanisms and interaction frameworks to support the operation of energy systems 2 Advanced operation and control methods for flexible resources such as traditional units energy storage electric vehicles electric hydrogen production etc 3 Advanced planning strategies and portfolio management for flexible resources in multi energy systems 4 Advanced evaluation methods for flexibility resilience and carbon emissions of energy systems 5 Effective applications of integrated demand response in energy systems with new technical and economic models Original research and review articles in theoretical methodological or practical focuses such as models policies algorithms and applications are all welcome Research areas may include but are not limited to the following Low carbon oriented market mechanism

Interaction framework designs for flexible resources Modeling and optimization technologies for multi energy systems Evaluation methods for the system resilience flexibility and carbon emissions Operation control and planning methods of multi energy systems Applications of artificial intelligence technology in reliability improvement Renewable energy prediction and integration

*Model Predictive Control of Wind Energy Conversion Systems* Venkata Yaramasu,Bin Wu,2016-12-19 Model Predictive Control of Wind Energy Conversion Systems addresses the predictive control strategy that has emerged as a promising digital control tool within the field of power electronics variable speed motor drives and energy conversion systems The authors provide a comprehensive analysis on the model predictive control of power converters employed in a wide variety of variable speed wind energy conversion systems WECS The contents of this book includes an overview of wind energy system configurations power converters for variable speed WECS digital control techniques MPC modeling of power converters and wind generators for MPC design Other topics include the mapping of continuous time models to discrete time models by various exact approximate and quasi exact discretization methods modeling and control of wind turbine grid side two level and multilevel voltage source converters The authors also focus on the MPC of several power converter configurations for full variable speed permanent magnet synchronous generator based WECS squirrel cage induction generator based WECS and semi variable speed doubly fed induction generator based WECS Furthermore this book Analyzes a wide variety of practical WECS illustrating important concepts with case studies simulations and experimental results Provides a step by step design procedure for the development of predictive control schemes for various WECS configurations Describes continuous and discrete time modeling of wind generators and power converters weighting factor selection discretization methods and extrapolation techniques Presents useful material for other power electronic applications such as variable speed motor drives power quality conditioners electric vehicles photovoltaic energy systems distributed generation and high voltage direct current transmission Explores S Function Builder programming in MATLAB environment to implement various MPC strategies through the companion website Reflecting the latest technologies in the field Model Predictive Control of Wind Energy Conversion Systems is a valuable reference for academic researchers practicing engineers and other professionals It can also be used as a textbook for graduate level and advanced undergraduate courses

**Advanced Control Engineering Methods in Electrical Engineering Systems** Mohammed Chadli,Sofiane Bououden,Salim Ziani,Ivan Zelinka,2018-09-10 This book presents the proceedings of the Third International Conference on Electrical Engineering and Control ICEECA2017 It covers new control system models and troubleshooting tips and also addresses complex system requirements such as increased speed precision and remote capabilities bridging the gap between the complex math heavy controls theory taught in formal courses and the efficient implementation required in real world industry settings Further it considers both the engineering aspects of signal processing and the practical issues in the broad field of information transmission and novel technologies for communication networks and modern antenna design This

book is intended for researchers engineers and advanced postgraduate students in control and electrical engineering computer science signal processing as well as mechanical and chemical engineering Dynamics and Control of Electric Transmission and Microgrids K. R. Padiyar, Anil M. Kulkarni, 2019-02-04 A guide to the latest developments in grid dynamics and control and highlights the role of transmission and distribution grids Dynamics and Control of Electric Transmission and Microgrids offers a concise and comprehensive review of the most recent developments and research in grid dynamics and control In addition the authors present a new style of presentation that highlights the role of transmission and distribution grids that ensure the reliability and quality of electric power supply The authors noted experts in the field offer an introduction to the topic and explore the basic characteristics and operations of the grid The text also reviews a wealth of vital topics such as FACTS and HVDC Converter controllers the stability and security issues of the bulk power system loads which can be viewed as negative generation the power limits and energy availability when distributed storage is used and much more This important resource Puts the focus on the role of transmission and distribution grids that ensure the reliability and quality of electric power supply Includes modeling and control of wind and solar energy generation for secure energy transfer Presents timely coverage of on line detection of loss of synchronism wide area measurements and applications wide area feedback control systems for power swing damping and microgrids operation and control Written for students of power system dynamics and control electrical power industry professionals Dynamics and Control of Electric Transmission and Microgrids is a comprehensive guide to the recent developments in grid dynamics and control and highlights the role of transmission and distribution grids that ensure the reliability and quality of electric power supply

*Distributed Energy Resources and Electric Vehicle* Aijaz Ahmad, Kushal Jagtap, Keerti Rawal, 2024-02-29 Explore the prospective developments in energy systems and transportation through an in depth examination of Distributed Energy Resources and Electric Vehicle Analysis and Optimisation of Network Operations This innovative publication explores the realm of renewable energy electric vehicles and their influence on network operations offering valuable perspectives for readers from diverse disciplines This extensive publication delves into the complex interplay between distributed energy resources DERs and electric vehicles EVs as well as their incorporation into established power grids The subject matter encompasses a diverse array of topics encompassing the attributes and advantages of distributed energy resources DERs and electric vehicles EVs obstacles related to grid integration efficient allocation of resources and strategies pertaining to demand response The book offers a comprehensive exploration of system analysis and optimisation techniques emphasising the effective utilisation of distributed energy resources DERs and electric vehicles EVs in energy networks It aims to equip readers with a robust comprehension of strategies to optimise the performance and potential of DERs and EVs in this context The book focuses on pioneering research and innovative solutions that are at the forefront of enhancing network operations The authors demonstrate the novelty and applicability of their findings through the examination of real world case studies

and the utilisation of sophisticated mathematical models This book serves as a highly valuable resource for individuals engaged in research engineering policy making and industry related activities who are interested in effectively navigating the dynamic realm of energy systems and transportation It equips them with the necessary knowledge and insights to make well informed decisions that contribute to the attainment of a sustainable future *Canadian Journal of Electrical and*

*Computer Engineering* ,1997 *Powers and Compensation in Circuits with Nonsinusoidal Current* Leszek

Czarnecki,2025-07-10 Powers and compensation in circuits with nonsinusoidal currents discusses one of the most controversial problems in electrical engineering the definitions of electrical powers and compensation Many approaches to explain the power properties of electrical circuits and their compensation has occurred over a vast number of publications and referred to as the schools of power theory PT These debates have caused substantial confusion in the electrical engineering community The development of the Current s Physical Components CPC based power theory by the author of this book was a major contribution to the debate on powers and compensation This book explains all the power related physical phenomena in electrical circuits and creates fundamentals for compensation in circuits of any complexity with linear and nonlinear loads in single and three phase circuits using reactance switching and hybrid compensators in terms of CPC power based theory It also discusses some common misinterpretations of power related phenomena This book was written as a by product of more than 30 years of teaching at Louisiana State University of undergraduate and graduate courses on powers and compensation and supervising the development of graduate Msc theses and Ph D dissertations Therefore this book can serve as a major reference for teaching power courses and for those involved in studies on powers and compensation in circuits with nonsinusoidal currents **Energy Research Abstracts** ,1989 **Smart Microgrids** Shahab

Bahrami,Ali Mohammadi,2019-01-17 In this book the authors first provide a comprehensive survey on the available studies on control management and optimization strategies in AC and DC microgrids The authors then provide the design of a laboratory scale microgrid system Finally a real world implementation of the deigned framework is provided This book paves the way for researchers working on the smart microgrids spread over the fields of electrical engineering power systems and smart infrastructures Furthermore it provides the readers with a comprehensive insight to understand an in depth big picture of smart microgrids as well as an all inclusive framework for laboratory scale implementation of a microgrid It is suitable for senior undergraduate students graduate students who are interested in research in areas related to future smart grids and microgrids and the researchers working in the related areas This book also can be used as a reference book for researchers who want to develop laboratories on smart microgrids for future research Power Plants and Power Systems Control 2003 Kwang Y Lee,Myong-Chul Shin,2004-04 Approx 422 pages



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