

# Distributed Flexible AC Transmission System (D-FACTS)

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**Abstract**— Flexible AC Transmission Devices (FACTS) are used to control real and reactive power in the transmission and distribution system, but widespread use of this technology has been limited due to high cost and reliability concerns. This paper illustrates the concept of distributive approach for realizing the functionality of FACTS devices. Low cost electronic devices, power electronics and communication technologies if distributedly applied, entire transmission and distribution network may be covered more effectively and cost effective power flow control can easily be done by Distributive FACTS (D-FACTS). The line impedance is dynamically changed control power by distributive static series compensator, and improvement of voltage profile of system is done by the use of distributive static shunt compensator (D-STATCOM). On the other hand distributive power flow controller (DPFC) simultaneously adjusts all the parameter of transmission system: Transmission angle, line impedance and bus voltage magnitude. Different topologies of D-FACTS, their range of applications and compensation provided are presented in this paper.

**Keywords**- (D-FACTS), DSSC, D-STATCOM, DPFC, Voltage Source Converters (VSC), Distributed Compensation.

## I. INTRODUCTION

The automation of modern industry has increased the expectation level of reliability and therefore to cater to the needs, power grid is becoming more and more networked in order to fulfil the growing demand of power with acceptable quality and costs. This restructuring of power grid has uncertainties in system operation resulting in various vital issues like uneven line loading, lack of power flow control, voltage stability, and increase in short circuit current etc. In the meshed network, the occurrence of contingency can result the sudden increase/decrease in the power flow. This in turn can result in overloading of the line and increase the risk of cascading outages and blackouts. The problem of active power and reactive power flow control can be effectively solved by introducing the power electronics based power flow controller. To realize a smart and fault tolerant grid Flexible AC transmission system (FACTS) was proposed, which included lumped devices like STATCOM, SSSC and UPFC to improve line capacity, transient stability and angle stability. But wide spread use of this technology is limited due to a number of reasons:-

- High power rating devices are required in high power rating system which resulted in increased installation cost [5].

- Due to the lumped nature of FACTS devices, these are located at specific point (not in wide area) of transmission line. So failure at that point leaves entire system to shut down [5].
- Complex custom engineered system requires on-site maintenance which results increase in operating cost [5].

Recently Distributed Flexible AC transmission system (D-FACTS) has been introduced to overcome most of the problem posed by FACTS devices. D-FACTS devices are power modular, small in size and light in weight. Generally modules are rated about 10 KVA to 15KVA [2]. For instance the series devices may be clamped on the transmission line and can be controlled so as to increase or decrease the line impedance of line, which in turn control active power flow and regulate system voltage.

This paper presents the different topologies and control strategies of D-FACTS devices for instance DSSC, D-STATCOM and DPFC which are used to improve power handling capacity, voltage regulation, system stability and harmonics reduction etc. DSSC is employed to alter line impedance to control the power dynamically. Whereas, D-STATCOM improves the voltage profile of the line acting as current source. On the other hand DPFC has the capability of simultaneously adjusting all the parameters of power system: line impedance, bus voltage magnitude and power angle [4]. This paper presents the operation characteristics and control strategies of different topologies of D-FACTS devices and provides an insight on the subject in a comprehensive way. Based on the characteristics of devices and response of the system the selection of suitable devices has been presented. The paper also presents scope and future of such devices for application to Indian transmission grid, sub transmission network and distribution system.

## II. OVERVIEW OF D-FACTS DEVICES

The concept of D-FACTS originates from the FACTS devices; these are in fact a miniature of FACTS devices, at a lower price, and with a higher capability. The distributed fashion of the D-FACTS contributes more safety and improved controllability of power system [2]. The uniqueness of these devices is that they can be placed into a system at multiple positions suited accordingly. Each D-FACTS on different lines can be used to achieve a control objective by co-ordinating them to work together. The concept of distributive approach

# Distributed Flexible Ac Transmission System D Facts

**BM King**



## **Distributed Flexible AC Transmission System D Facts:**

Power Flow Control with Distributed Flexible AC Transmission System (D-FACTS) Devices David Alan Krieger,2012

Climate change energy crisis and financial crisis are some of the issues that affect the transformation of power and the power industry Distributed FACTS or D FACTS devices are being used today to help correct inefficiencies within the current power grid These devices can help a utility save money by transferring load off a power line near its thermal limits to one that is lightly loaded While using D FACTS devices each MWh of power that does not have to go into power generation with coal can prevent the introduction of approximately 1 ton of pollution into the atmosphere The potential of using Distributed FACTS devices in a power network should bring it into more widespread adoption

An Investigation of the Impact of Distributed Flexible AC Transmission System (D-Facts) Devices on Transmission Line Protection Hussain Beled,2020 This thesis explores the effects of inductive Distributed Flexible AC Transmission System D FACTS device implementations on the performance of different transmission line protection schemes The reliability and sensitivity of the trip decision of the protection elements is crucial for delivering safe and reliable power to customers Furthermore accurate fault location information can help significantly reduce outage duration operating costs and the number of consumer complaints Inductive D FACTS devices offer a distributed solution for managing and relieving the congestion in transmission lines However their interaction with protection and fault location elements may potentially cause unnecessary tripping relay mis operation or misleading fault location information The operation of these devices may also lead to unpredictable changes in transmission line impedance and fault current limitation due to their dynamic behavior before and during the disturbances This work studies these negative aspects of D FACTS devices and proposes solutions and alternatives to mitigate their impact An inductive D FACTS model was developed in the ATP version of the Electromagnetic Transients Program EMTP and then the steady state performance of these devices was validated against the existing D FACTS model in PowerWorld using the IEEE 12 bus test system Once the model was validated a more practical system with D FACTS implementation is simulated using ATP Lastly the generated fault event files are played back into commercial relays and a protective relay software model for evaluation This work examines the influence of two different implementations of inductive D FACTS on the most common protection elements and schemes under different fault scenarios The types of D FACTS devices implementations studied were dispersed distributing the D FACTS along the length of the line and compressed distributing them at specific distances on the line Additionally the impact of placing D FACTS devices on adjacent lines was studied Protection schemes studied in this thesis include distance elements mho or quadrilateral elements communication aided distance schemes permissive overreaching transfer trip POTT and fault location schemes Furthermore the influence of fault resistance and mutual coupling between parallel lines on relay response is studied in the presence of D FACTS devices Dispersed or compressed D FACTS implementation can cause underreaching of distance elements This may lead to a delay in the tripping time or in fact

a failure to trip in a POTT scheme The simulation results show that using dispersed D FACTS implementation can reduce the error compared to the compressed implementation and increase the ability of performing correction for these devices under some operating conditions This work also examined the effect of D FACTS devices on distance elements performance in presence of a fault resistance and mutual coupling between the parallel lines The results illustrated how the direction of the power flow influences the fault resistance coverage of distance elements in the presence of D FACTS devices The D FACTS may help to reduce the distance elements underreach for forward faults and increase the underreach behavior for the reverse fault The results show that mutual coupling influence on distance elements would be not impacted by addition of the D FACTS devices Lastly we investigated how implementing inductive D FACTS devices on the adjacent line affects the dynamic behavior of mho distance elements and the calculated effective impedance tilt of quadrilateral distance elements response Inserting the D FACTS behind the relay can help expand the mho circles for forward faults and contract them for reverse faults As a result fault resistance coverage can be improved On the other hand this may cause underreaching or overreaching of the quadrilateral distance elements response when a fault resistance is present in a ground fault To deal with the challenges in the implementation of D FACTS devices and minimize their influence on transmission line protection system performance this thesis proposes mitigation for creating reliable protection and fault location schemes The work concludes by offering recommendations for D FACTS device implementation and protective relays settings

*Power System Control with Distributed Flexible AC Transmission System Devices* Katherine Rogers,2009 Distributed flexible AC transmission system D FACTS devices offer many potential benefits to power systems This work examines the impact of installing D FACTS devices by studying the sensitivities of power system quantities such as voltage magnitude voltage angle bus power injections line power flows and real power losses with respect to line impedance These sensitivities enable us to identify and develop appropriate applications for the use of D FACTS devices for the enhanced operation and control of the grid Specific applications of D FACTS devices for line flow control real power loss minimization and voltage control are investigated

**Silicon Photonics & High Performance Computing** Anurag Mishra,Anirban Basu,Vipin Tyagi,2017-12-22

This book comprises selected contributions to the Computer Society of India s annual convention Divided into 10 topical volumes the proceedings present papers on state of the art research surveys and succinct reviews covering diverse topics ranging from communications networks to big data analytics and from system architecture to cyber security This volume focuses on silicon photonics high performance computing offering valuable insights for researchers and students alike

**Flexible and Active Distribution Networks** Peng Li,Haoran Ji,Yang Mi,Hao Yu,Yue Zhou,Nian Liu,2021-08-02

*Hosting Capacity Aspects in Distribution Networks Towards Sustainable Energy Systems* Hossam H. H. Mousa,Karar Mahmoud,Matti Lehtonen,2025-04-29 Hosting Capacity Aspects in Distribution Networks Towards Sustainable Energy Systems is a comprehensive guidebook that delves into the critical aspects of power systems It emphasizes the essential

developments necessary to support the transition towards sustainable energy sources The book begins by laying down the fundamental principles of hosting capacity in energy systems highlighting modern challenges in the shift to renewable and distributed energy sources It underscores the pivotal role hosting capacity plays in the planning and operation of successful systems offering readers a solid foundation on which to build their understanding Subsequent chapters are dedicated to providing detailed explanations on various practical hosting capacity calculation methods and enhancement techniques The book also introduces available tools and software solutions to address hosting capacity issues By compiling the latest insights and advancements in this crucial yet under explored area this book serves as an invaluable resource for students researchers and engineers It aids in planning hosting capacity aspects for the successful integration of renewable and sustainable energy systems Outlines the fundamental concepts of hosting capacity and its relation to sustainable energy systems Provides a range of accurate flexible options of tools software calculations and enhancement techniques Supports readers in mastering the latest theoretical and practical developments

*Moving Target Defense in the Smart Grid* Ruilong Deng,Zhenyong Zhang,Mengxiang Liu,Peng Cheng,2025-11-08 Low carbon goals energy crisis and increasing electricity demand lead to the integration of advanced electronic and communication devices into the smart grid to enable environmental friendly real time and economic operation and control However the vulnerabilities exposed in the IP based devices and communication networks make the smart grid prone to cyberattacks For example the false data injection attack is one of the critical cyberattacks that threatens the system operations such as state estimation voltage control economic dispatch and etc Observing that the design of cyberattacks on the smart grid depends on the attacker s knowledge of certain key parameters such as the grid topology and line configurations an innovative defensive mechanism is to proactively perturb these key parameters to prevent the attacker from knowing this related information for constructing cyberattacks This proactive perturbation strategy is termed as moving target defense MTD which mitigates this risk by dynamically altering the power line reactance making it harder for adversaries to construct effective cyberattacks Unlike static countermeasures MTD enhances smart grid cybersecurity by continuously reshaping the attack surface Since MTD increases the system uncertainty and complexity of the smart grid the opportunity for the attacker to successfully launch cyberattacks is reduced This book provides a comprehensive analysis of the theoretical foundations of MTD the optimal deployment of this defense strategy and the deep impact of MTD on the system s operation and control To begin with a thorough literature review is conducted to summarize the cyber physical and cyber physical coordinated MTD approaches Then a detailed theoretical analysis is provided to validate the effectiveness and completeness of MTD in terms of detecting and mitigating cyberattacks Furthermore the hiddenness of MTD is deeply analyzed from the attacker s perspective leading to the development of a coordinated defense framework to enhance the MTD s hiddenness Given the complexity resulted from the nonlinear AC state estimation sensitivity based approximation methods are proposed to quantify the effectiveness and hiddenness of MTD in AC

power systems forming the basis of an optimization framework to balance the MTD s effectiveness between hiddenness Finally considering the proactive activities caused by MTD its impact on the system s operation and control including the operation cost load frequency control and small signal stability is theoretically and numerically analyzed This book concludes by discussing future research directions and practical strategies for deploying MTD The presented MTD design and the corresponding research results covered in this book will provide valuable insights for practical MTD deployment and motivate new ideas for strengthening smart grid cybersecurity This book will be valuable for researchers graduate students and industry professionals seeking a comprehensive understanding of the latest developments in MTD for smart grid cybersecurity Designed for readers with a background in Electrical Computer Engineering Telecommunications Computer Science or related disciplines it provides the necessary foundation to explore advanced defense strategies The primary audiences include college students specializing in smart grid Internet of Things and cybersecurity as well as researchers consultants and executives involved in smart grid cybersecurity and cyber physical systems Additionally the book will be useful for standardization task forces developing advanced defense strategies Beyond individual readers institutions such as power utilities cybersecurity firms universities and research organizations will find it a valuable resource for advancing knowledge and practical applications in smart grid cybersecurity

*Enhancement of Grid-Connected Photovoltaic Systems Using Artificial Intelligence* Amal M. Abd El- Hameid, Adel A. Elbaset, Mohamed Ebeed, Montaser Abdelsattar, 2023-05-11

Enhancement of Grid Connected Photovoltaic Systems Using Artificial Intelligence presents methods for monitoring transmission systems and enhancing distribution system performance using modern optimization techniques considering different multi objective functions such as voltage loss sensitivity indexes reducing total annual cost and voltage deviation The authors offer a comprehensive survey of distributed energy resources DERs explain the backward forward sweep BFS power flow algorithm and present simulation results on the optimal integration of photovoltaic based distributed generators PV DG and distribution static synchronous compensators DSTATCOM in different transmission and distribution systems This book will be a valuable academic and industry resource for electrical engineers students and researchers working on optimization techniques photovoltaic systems energy engineering and artificial intelligence

Smart Grid Communications and Networking Ekram Hossain, Zhu Han, H. Vincent Poor, 2012-05-24 This one stop reference provides the state of the art theory key strategies protocols deployment aspects standardization activities and experimental studies of communication and networking technologies for the smart grid Expert authors provide all the essential information researchers need to progress in the field and to allow power systems engineers to optimize their communication systems

**Electric Distribution Network Planning** Farhad Shahnia, Ali Arefi, Gerard Ledwich, 2018-04-09 This book highlights the latest research advances in the planning and management of electric distribution networks It addresses various aspects of distribution network management including planning operation customer engagement and technology accommodation Given the importance of

electric distribution networks in power delivery systems effectively planning and managing them are vital to satisfying technical economic and customer requirements A new planning and management philosophy techniques and methods are essential to handling uncertainties associated with the integration of renewable based distributed generation demand forecast and customer needs This book covers topics on managing the capacity of distribution networks while also addressing the future needs of electric systems The efficient and economical operation of distribution networks is an essential aspect of ensuring the effective use of resources Accordingly this book addresses operation and control approaches and techniques suitable for future distribution networks

*Service-Oriented Computing* Hakim Hacid,Odej Kao,Massimo Mecella,Naouel Moha,Hye-young Paik,2021-11-17 This book constitutes the proceedings of the 19th International Conference on Service Oriented Computing ICSOC 2020 which is held virtually in November 2021 The 29 full 28 short and 3 vision papers included in this volume were carefully reviewed and selected from 189 submissions They were organized in topical sections named Blockchains and smart contracts Architectures microservices and APIs Applications Internet of Things crowdsourced social and conversational services Service composition and recommendation Cloud computing and Edge computing

*IEEE Transmission and Distribution Conference and Exposition ,2001*

**Handbook of Advanced Electronic and Photonic Materials and Devices: High Tc superconductors and organic conductors** Hari Singh Nalwa,2001 Electronic and photonic materials discussed in this handbook are the key elements of continued scientific and technological advances in the 21st century The electronic and photonic materials comprising this handbook include semiconductors superconductors ferroelectrics liquid crystals conducting polymers organic and superconductors conductors nonlinear optical and optoelectronic materials electrochromic materials laser materials photoconductors photovoltaic and electroluminescent materials dielectric materials nanostructured materials supramolecular and self assemblies silicon and glasses photosynthetic and respiratory proteins etc etc Some of these materials have already been used and will be the most important components of the semiconductor and photonic industries computers internet information processing and storage telecommunications satellite communications integrated circuits photocopiers solar cells batteries light emitting diodes liquid crystal displays magneto optic memories audio and video systems recordable compact discs video cameras X ray technology color imaging printing flat panel displays optical waveguides cable televisions computer chips molecular sized transistors and switches as well as other emerging cutting edge technologies Electronic and photonic materials are expected to grow to a trillion dollar industry in the new millennium and will be the most dominating forces in the emerging new technologies in the fields of science and engineering This handbook is a unique source of the in depth knowledge of synthesis processing fabrication spectroscopy physical properties and applications of electronic and photonic materials covering everything for today s and developing future technologies This handbook consists of over one hundred state of the art review chapters written by more than 200 world leading experts from 25 different countries With more than 23 000 bibliographic citations and several

thousands of figures tables photographs chemical structures and equations this handbook is an invaluable major reference source for scientists and students working in the field of materials science solid state physics chemistry electrical and optical engineering polymer science device engineering and computational engineering photophysics data storage and information technology and technocrats everyone who is involved in science and engineering of electronic and photonic materials

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IEEE/PES Transmission and Distribution Conference and Exhibition 2002: Asia Pacific ,2002      TENCON 2004 ,2004      **Energy Technology Status Report** ,1996      **1994 IEEE International Conference on Systems, Man, and Cybernetics** ,1994      **Flexible AC Transmission Systems (FACTS)** Yong-Hua Song,Allan T. Johns,1999 Provides a comprehensive guide to FACTS covering all the major aspects in research and development of FACTS technology      *Public Utilities Fortnightly* ,2001      Standard Handbook for Electrical Engineers Sixteenth Edition H. Wayne Beaty,Donald Fink,2012-08-30 THE MOST COMPLETE AND CURRENT GUIDE TO ELECTRICAL ENGINEERING For more than a century the Standard Handbook for Electrical Engineers has served as the definitive source for all the pertinent electrical engineering data essential to both engineering students and practicing engineers It offers comprehensive information on the generation transmission distribution control operation and application of electric power Completely revised throughout to address the latest codes and standards the 16th Edition of this renowned reference offers new coverage of green technologies such as smart grids smart meters renewable energy and cogeneration plants Modern computer applications and methods for securing computer network infrastructures that control power grids are also discussed Featuring hundreds of detailed illustrations and contributions from more than 75 global experts this state of the art volume is an essential tool for every electrical engineer Standard Handbook for Electrical Engineers 16th Edition covers Units symbols constants definitions and conversion factors Electric and magnetic circuits Measurements and instruments Properties of materials Generation Prime movers Alternating current generators Direct current generators Hydroelectric power generation Power system components Alternate sources of power Electric power system economics Project economics Transmission systems High voltage direct current power transmission Power system operations Substations Power distribution Wiring design for commercial and industrial buildings Motors and drives Industrial

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