MULTI-FREQUENCY POWER CONVERSION TOPOLOGIES FOR AC-PLUS-DC GRID

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by

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CERTIFICATE

This is to certify that the thesis entitled **"MULTI-FREQUENCY POWER CONVERSION TOPOLOGIES FOR AC-PLUS-DC GRID"** being submitted by **Mr. Varun Chitransh** for the award of degree of **Doctor of Philosophy** is a record of bonafide research work carried out by him in the Department of Electrical Engineering of Indian Institute of Technology, New Delhi.

Mr. Varun Chitransh worked under my guidance and supervision and has fulfilled the requirement for the submission of the thesis, which to my knowledge has reached the required standards. The matter embodied in this thesis has not been submitted to any other University or Institute for the award of any Degree or Diploma.

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ABSTRACT

The multiple-source multiple-load power electronic converter systems are increasingly gaining popularity due to their ability to integrate different power sources, storage elements and diverse loads. Usually, such systems require different power electronic converters for integrating diverse sources and loads (AC or DC), which reduces the flexibility in power management. In this thesis, multi-frequency (MF) based unified power electronic converter systems are presented to simultaneously cater the AC and DC load demand. The proposed MF-based converters minimize the interaction among the sources and effectively supply different frequency components. Thus the complexity in power management is reduced and flexible integration of AC as well as DC loads is achieved.

In this thesis, the concept of transferring average power at multiple frequencies is discussed with the help of the principle of orthogonal power transfer and superposition theorem. Apart from investigating the impacts of transferring power at multiple frequencies, the thesis aims at in bringing out such topologies which are capable of integrating different electrical power sources (AC or DC) irrespective of its frequency of generation, form a MF bus, transfer power over a common line and extract/convert them at the load side. In these topologies, independent operation of sources is achieved by transferring power at multiple frequencies.

It is shown that power transfer at multiple frequencies offers several new possibilities such as source-decoupling, independent operation of sources, selective power transfer among desired terminals and flexibility in power management. Finally, the feasibility of transferring electrical power at multiple frequencies is tested with the help of laboratory-scale prototype systems as proof-of-concept (poc). For this, passive filter based and power electronic converter based systems are presented in the thesis. The simulation and experimental results along with the theoretical analysis validate the effectiveness of the proposed MF based power transfer concept.

सारांश

विभिन्न शक्ति स्रोतों, भंडारण तत्वों और विविध भारों को एकीकृत करने की उनकी क्षमता के कारण बहु-स्रोत बहु-लोड पावर इलेक्ट्रॉनिक कनवर्टर सिस्टम तेजी से लोकप्रियता प्राप्त कर रहे हैं। आमतौर पर, ऐसी प्रणालियों को विविध स्रोतों और भार (एसी या डीसी) को एकीकृत करने के लिए विभिन्न पावर इलेक्ट्रॉनिक कन्वर्टर्स की आवश्यकता होती है, जो बिजली प्रबंधन में लचीलेपन को कम करता है। इस थीसिस में एसी और डीसी लोड की मांग को एक साथ पूरा करने के लिए मल्टी-फ्रीक्वेंसी (एमएफ) आधारित यूनिफाइड पावर इलेक्ट्रॉनिक कन्वर्टर सिस्टम प्रस्तुत किए गए हैं। प्रस्तावित एमएफ-आधारित कन्वर्टर्स स्रोतों के बीच बातचीत को कम करते हैं और विभिन्न आवृत्ति घटकों को प्रभावी ढंग से आपूर्ति करते हैं। इस प्रकार बिजली प्रबंधन में जटिलता कम हो जाती है, और एसी के साथ-साथ डीसी लोड का लचीला एकीकरण हासिल किया जाता है।

इस थीसिस में, कई आवृत्तियों पर औसत शक्ति को स्थानांतरित करने की अवधारणा पर ऑर्थोगोनल पावर ट्रांसफर और सुपरपोजिशन प्रमेय के सिद्धांत की मदद से चर्चा की गई है। कई आवृत्तियों पर बिजली स्थानांतरित करने के प्रभावों की जांच के अलावा, थीसिस का उद्देश्य ऐसी टोपोलॉजी को बाहर लाना है जो विभिन्न विद्युत शक्ति स्रोतों (एसी या डीसी) को एकीकृत करने में सक्षम हैं, चाहे इसकी आवृत्ति कुछ भी हो, एक एमएफ बस बनाएं, बिजली को स्थानांतरित करें एक आम लाइन और उन्हें लोड साइड पर निकालें/रूपांतरित करें। इन टोपोलॉजी में, कई आवृत्तियों पर बिजली स्थानांतरित करके स्रोतों का स्वतंत्र संचालन प्राप्त किया जाता है।

यह दिखाया गया है कि कई आवृत्तियों पर बिजली हस्तांतरण कई नई संभावनाएं प्रदान करता है जैसे स्रोत-डिकॉउलिंग, स्रोतों का स्वतंत्र संचालन, वांछित टर्मिनलों के बीच चयनात्मक बिजली हस्तांतरण और बिजली प्रबंधन में लचीलापन। अंत में, प्रूफ-ऑफ-कॉन्सेप्ट (पीओसी) के रूप में प्रयोगशाला-पैमाने के प्रोटोटाइप सिस्टम की मदद से कई आवृत्तियों पर विद्युत शक्ति को स्थानांतरित करने की व्यवहार्यता का परीक्षण किया जाता है। इसके लिए थीसिस में पैसिव फिल्टर आधारित और पावर इलेक्ट्रॉनिक कन्वर्टर आधारित सिस्टम प्रस्तुत किए गए हैं। सैद्धांतिक विश्लेषण के साथ सिमुलेशन और प्रयोगात्मक परिणाम प्रस्तावित एमएफ आधारित पावर ट्रांसफर अवधारणा की प्रभावशीलता को मान्य करते हैं।

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LIST OF ABBREVIATIONS

BEV	Battery electric vehicles
BPF	Band pass filter
BSF	Band stop filter
CHB	Cascaded H-bridge
DPFC	Distributed power flow controller
FC	Flying capacitor
HEV	Hybrid electric vehicles
LPF	Low pass filter
MF	Multi-frequency
MICs	Multi-input converters
MIMO	Multiple-input multiple-output
MISO	Multiple-input single-output
MMCs	Modular multilevel converters
MPC	Multi-port converter
NPC	Neutral-point clamped
PEI	Power electronic interface
RESs	Renewable energy sources
SIMO	Single-input multiple output
SMs	Sub-modules
TDM	Time division multiplexing
TSTL	Two-source two-load
UACDC	Unified ac-dc