DECLARATION OF JUNE ANN MUNFORD

I. QUALIFICATIONS

1. My name is June Ann Munford. I am over the age of 18, have personal knowledge of the facts set forth herein, and am competent to testify to the same.

2. I earned a Master of Library and Information Science (MLIS) from the University of Wisconsin-Milwaukee in 2009. I have over ten years of experience in the library/information science field. Beginning in 2004, I have served in various positions in the public library sector including Assistant Librarian, Youth Services Librarian and Library Director. I have attached my Curriculum Vitae as Appendix CV.

3. During my career in the library profession, I have been responsible for materials acquisition for multiple libraries. In that position, I have cataloged, purchased and processed incoming library works. That includes purchasing materials directly from vendors, recording publishing data from the material in question, creating detailed material records for library catalogs and physically preparing that material for circulation. In addition to my experience in acquisitions, I was also responsible for analyzing large collections of library materials, tailoring library records for optimal catalog search performance and creating lending agreements between libraries during my time as a Library Director.

4. I am fully familiar with the catalog record creation process in the library sector. In preparing a material for public availability, a library catalog record

describing that material would be created. These records are typically written in Machine Readable Catalog (herein referred to as "MARC") code and contain information such as a physical description of the material, metadata from the material's publisher, and date of library acquisition. In particular, the 008 field of the MARC record is reserved for denoting the date of creation of the library record itself. As this typically occurs during the process of preparing materials for public access, it is my experience that an item's MARC record indicates the date of an item's public availability.

5. Typically, in creating a MARC record, a librarian would gather various bits of metadata such as title, publisher and subject headings among others and assign each value to a relevant numerical field. For example, a publication's physical description is tracked in field 300 while title/attribution is tracked in field 245. The 008 field of the MARC record is reserved for denoting the creation of the library record itself. As this is the only date reflecting the inclusion of said materials within the library's collection, it is my experience that an item's 008 field accurately indicates the date of an item's public availability.

6. The MARC record serves several purposes vital for library catalogs to function. Although most library users will not directly interface with a MARC record, the MARC record is used to generate individual web pages for library catalog materials and serves as the basis for library catalog searches. When visiting a library

catalog web page describing a single item, that page would typically display select fields such as title, author and publisher from the corresponding MARC field. For instance, a library user may discover a single item record for a given library material and see the contents of that item's 245 field displayed as 'Title: [245 field contents]' on the item record. These fields are similarly mapped to the functions of the library catalog search engine. A library user searching for a given publication's title will be provided results based on the 245 field contents of each MARC present in that collection.

7. The 008 field represents the first date of record creation, signifying that the library has purchased the material being indexed and intends to integrate that item into the library's collection. Materials are frequently purchased prior to their formal publication date from library vendors, booksellers and publishers, then made available to the public upon the material arriving at the library. Once the material arrives at the library, the catalog record is examined for accuracy and modified if necessary. The material is then prepared for the shelf by adding elements such as date stamps, RFID tags, barcode stickers and protective covering. As it is not possible to ascertain how long this process requires for any one item based on the MARC record, my determinations of availability assume an average preparation time. Based on my own experiences acquiring and cataloging library materials, the

majority of library materials are made available to the public within 2 – 12 weeks of the material's initial acquisition.

8. To illustrate the various services and functions of the standard library catalog, the next section of this declaration will discuss the Penn State University Library catalog as an example.

9. Attached hereto as Appendix PSU01 is a screen capture of the Internet Archive Wayback Machine entry for http://www.lias.psu.edu/lcsdesc/descript.htm. I secured these screen captures myself from https://web.archive.org/web/19961018145356/http://www.lias.psu.edu/lcsdesc/descript.htm. This record was captured as of October 18, 1996.

10. Appendix PSU01 is an Internet Archive capture of a web page entitled LIAS as hosted on the Penn State University Library Computing Services website. This page describes various digital services available via the Penn State University Library's online resources as of 1996. This list of services includes an online catalog, indexing and abstracting databases sorted by subject, electronic journals and the collections of other research libraries. This page indicates that library users could expect to perform complex search inquiries via the library catalog and the library's indexing service.

11. Attached hereto as Appendix PSU02 is a screen capture of the Internet Archive Wayback Machine entry for http://www.lias.psu.edu/lcshelp/hist80.htm. I

secured these screen captures myself from https://web.archive.org/web/19961018150838/http://www.lias.psu.edu/lcshelp/hist80.htm. This record was captured as of October 18, 1996.

12. Appendix PSU02 is an Internet Archive capture of a web page entitled LIAS History - The 1980's as hosted on the Penn State University Library Computing Services website. This web page provides a detailed history of the Penn State University Library's online services program from 1981 – 1989. This history indicates the adoption of an OPAC (Online Public Access Catalog) in 1983, catalog terminals installed in the library for public use in 1983 and online dial-up service made available in 1984. This history indicates the standard practice of adopting library catalogs as a public access point has a history dating back to the early 1980's.

13. Attached hereto as Appendix PSU03 is a screen capture of the Internet Archive Wayback Machine entry for http://www.libraries.psu.edu/instruction/CAT_guide/catguide.pdf. I secured these screen captures myself from https://web.archive.org/web/20060104035934/http://www.libraries.psu.edu/instruction/CAT_guide/catguide.pdf. This record was captured as of January 4, 2006.

14. Appendix PSU03 is an Internet Archive capture of a file entitled Quick Guide to Searching The CAT as hosted on the Penn State University Library website. This document details the search features of the library catalog as of 2006. This

document indicates users of the Penn State University Library catalog were capable of searching the catalog by keyword, title, author, subject, journal title, series, LC subject heading or medical subject heading. Search results can be filtered by location, with individual catalog records including fields for library campus, call number and location-specific locations such as 'Second Floor' or 'Stacks 4'. Search queries can also include Boolean language such as 'and', 'or' and 'not'.

15. Appendix PSU03's description of the catalog search features indicates users of the Penn State University Library were capable of performing advanced search queries to explore the library's catalog and discover specific printed publications. In my experience, these search options are typical of library catalog software in 2006. For each type of search query performed, the typical library catalog will search a collection of thousands of MARC records making up the library's catalog entries. The type of search query will determine which results are displayed. To include some common examples: searching for title will provide results derived from the 245 field among others, searching for author will provide results derived from the 245 field among others and searching for a subject will provide results from the 650 field among others. This relationship between the search query and the MARC record powers the search functions of the library catalog, enabling library users to search thousands of publications with a single complex query and discover the specific physical location of a given publication within the library's facilities.

16. Attached hereto as Appendix PSU04 is a screen capture of the Internet Archive Wayback Machine entry for http://www.libraries.psu.edu/psul/lionsearch.html. I secured these screen captures myself from https://web.archive.org/web/20120824204323/http://www.libraries.psu.edu/psul/lionsearch.html. This record was captured as of August 24, 2012.

17. Appendix PSU04 is an Internet Archive capture of a web page entitled LionSearch Help (FAQ) as hosted on the Penn State University Library website. This document details the search features of the library catalog as of 2012. This document indicates users of the Penn State University Library catalog were capable of searching the catalog by title, subject, author, publisher, publication title, volume, issue, language, notes, ISBN, ISSN, DOI number and call number. This document also explains that library users can search using Boolean language, refining their queries further. Comparing Appendix PSU03 and PSU04 indicates library industry standards for search engine capabilities were largely unchanged from 2006 to 2012 aside from the addition of search refinement features.

18. Appendices PSU03 and PSU04 each indicate users of the Penn State University Library's public catalog were able to search by call number, a proprietary number assigned to a given library material in Dewey or LC format. Call numbers are assigned to a given publication by matching the alphanumerical formatting

standards to the subjects assigned to the publication in the MARC record. Library materials are shelved by this call number, ensuring that publications discussing similar topics are located next to each other on library shelves. Library catalogs frequently provide users the ability to search by call number, ensuring search results include publications with similar topics. As a standard library practice, call numbers have been used to organize collections prior to the adoption of MARC records in the 1970s.

II. PUBLICATIONS

A. LOPES

19. I have reviewed Exhibit EX1011, "Defining Control Strategies for MicroGrids Islanded Operation" by J.A. Peças Lopes, et al as published in IEEE Transactions on Power Systems May 2006.

20. Attached hereto as Appendix LOPES01 is a true and correct copy of the MARC record for IEEE Transactions on Power Systems as held by the Penn State University Library. I secured this record myself from the library's public catalog. The MARC record contained within Appendix LOPES01 accurately describes the title, publisher and ISSN number of IEEE Transactions on Power Systems. The 050 field of Appendix LOPES01 indicates this journal was assigned a call number of TK1005.I35. The Showing Results field present on page 3 of this record indicates the library's collection includes the May 2006 issue of IEEE

Transactions on Power Systems containing "Defining Control Strategies for MicroGrids Islanded Operation". Based upon the indexed data present in Appendix LOPES01, it is my determination this publication could be found in the Penn State University Library catalog via a keyword search or title search at the time of acquisition.

21. Attached hereto as Appendix LOPES02 is a true and correct copy of "Defining Control Strategies for MicroGrids Islanded Operation" as published in IEEE Transactions on Power Systems as held by the Penn State University Library. These scans were secured from the library's collection. In comparing Exhibit EX1011 to Appendix LOPES02, it is my determination that Exhibit EX1011 is a true and correct copy of "Defining Control Strategies for MicroGrids Islanded Operation" by J.A. Peças Lopes, et al as published in IEEE Transactions on Power Systems.

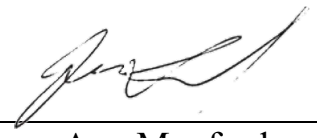
22. The 008 field of the MARC record in Appendix LOPES01 indicates the date of record creation. The 008 field of Appendix LOPES01 indicates the Penn State University Library first acquired IEEE Transactions on Power Systems as of June 15, 2005 and held the journal in perpetuity until the publication of "Defining Control Strategies for MicroGrids Islanded Operation". Considering this information, it is my determination that IEEE Transactions on Power Systems May

2006 and therefore "Defining Control Strategies for MicroGrids Islanded Operation" was made available to the public shortly after its initial publication in May 2006.

23. I have been retained on behalf of the Petitioner to provide assistance in the above-illustrated matter in establishing the authenticity and public availability of the documents discussed in this declaration. I am being compensated for my services in this matter at the rate of $200.00 per hour plus reasonable expenses. My statements are objective, and my compensation does not depend on the outcome of this matter.

24. I declare under penalty of perjury that the foregoing is true and correct. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Dated: October 8, 2025



June Ann Munford

APPENDIX CV

June A. Munford
Curriculum Vitae

Education

University of Wisconsin-Milwaukee - MS, Library & Information Science, 2009
Milwaukee, WI

- Coursework included cataloging, metadata, data analysis, library systems, management strategies and collection development.
- Specialized in library advocacy, cataloging and public administration.

Grand Valley State University - BA, English Language & Literature, 2008
Allendale, MI

- Coursework included linguistics, documentation and literary analysis.
- Minor in political science with a focus in local-level economics and government.

Professional Experience

Researcher / Expert Witness, October 2017 – present
Freelance ● Pittsburgh, Pennsylvania & Grand Rapids, Michigan

- Material authentication and public accessibility determination. Declarations of authenticity and/or public accessibility provided upon research completion. Experienced with appeals and deposition process.

- Research provided on topics of public library operations, material publication history, digital database services and legacy web resources.

- Past clients include Alston & Bird, Arnold & Porter, Baker Botts, Fish & Richardson, Erise IP, Irell & Manella, O'Melveny & Myers, Perkins-Coie, Pillsbury Winthrop Shaw Pittman and Slayden Grubert Beard.

Library Director, February 2013 - March 2015
Dowagiac District Library ● Dowagiac, Michigan

- Executive administrator of the Dowagiac District Library. Located in Southwest Michigan, this library has a service area of 13,000, an annual operating budget of over $400,000 and total assets of approximately $1,300,000.

● Developed careful budgeting guidelines to produce a 15% surplus during the 2013-2014 & 2014-2015 fiscal years while being audited.

● Using this budget surplus, oversaw significant library investments including the purchase of property for a future building site, demolition of existing buildings and building renovation projects on the current facility.

● Led the organization and digitization of the library's archival records.

● Served as the public representative for the library, developing business relationships with local school, museum and tribal government entities.

● Developed an objective-based analysis system for measuring library services - including a full collection analysis of the library's 50,000+ circulating items and their records.

November 2010 - January 2013
Librarian & Branch Manager, Anchorage Public Library ● Anchorage, Alaska

● Headed the 2013 Anchorage Reads community reading campaign including event planning, staging public performances and creating marketing materials for mass distribution.

● Co-led the social media department of the library's marketing team, drafting social media guidelines, creating original content and instituting long-term planning via content calendars.

● Developed business relationships with The Boys & Girls Club, Anchorage School District and the US Army to establish summer reading programs for children.

June 2004 - September 2005, September 2006 - October 2013
Library Assistant, Hart Area Public Library
Hart, MI

● Responsible for verifying imported MARC records and original MARC cataloging for the local-level collection as well as the Michigan Electronic Library.

● Handled OCLC Worldcat interlibrary loan requests & fulfillment via ongoing communication with lending libraries.

Professional Involvement

Alaska Library Association - Anchorage Chapter

- Treasurer, 2012

Library Of Michigan
- Level VII Certification, 2008
- Level II Certification, 2013

Michigan Library Association Annual Conference 2014
- New Directors Conference Panel Member

Southwest Michigan Library Cooperative
- Represented the Dowagiac District Library, 2013-2015

Professional Development

Library Of Michigan Beginning Workshop, May 2008
Petoskey, MI
- Received training in cataloging, local history, collection management, children's literacy and reference service.

Public Library Association Intensive Library Management Training, October 2011
Nashville, TN
- Attended a five-day workshop focused on strategic planning, staff management, statistical analysis, collections and cataloging theory.

Alaska Library Association Annual Conference 2012 - Fairbanks, February 2012
Fairbanks, AK
- Attended seminars on EBSCO advanced search methods, budgeting, cataloging, database usage and marketing.

Depositions

2019 ● Fish & Richardson

Apple v. Qualcomm (Case No. IPR2018-001281, 39521-00421IP, IPR2018-01282 and 39521-00421IP2)

2019 ● Erise IP

Implicit, LLC v. Netscout Systems, Inc (Case No. 2:18-cv-53-JRG)

2019 ● Perkins-Coie

Adobe Inc. v. RAH Color Technologies LLC (Case No. IPR2019-00627, IPR2019-00628, IPR2019-00629 and IPR2019-00646)

2020 ● O'Melveny & Myers

Maxell, Ltd. v. Apple Inc. (Case No. 5:19-cv-00036-RWS)

2021 ● Pillsbury Winthrop Shaw Pittman LLP

Intel v. SRC (Case No. IPR2020-1449)

2022 ● Perkins-Coie

Realtek v. Future Link (Case No. IPR2021-01182)

2023 ● Fish & Richardson

Neuroderm Ltd. v. Abbvie, Inc (Case No. PGR2022-00040)

2023 ● Fish & Richardson

Nearmap US Inc. v. Pictometry International Corp. (Case No. IPR2022-00735)

2023 ● Fish & Richardson

Samsung Electronics v. MemoryWeb LLC (Case No. 39843-0136PS1)

2023 ● Pillsbury Winthrop Shaw Whitman LLP

Gravel Rating Systems v. Costco Wholesale Corp. (Case No. 4:21-cv-149-ALM)

2024 ● Willkie-Farr

Netflix, Inc. v. VideoLabs. Inc. (Case No. IPR2023-00628)

2024 ● Quinn Emanuel Urquhart & Sullivan

Purdue University v. Wolfspeed (Case No. 1:21-CV-840)

2024 ● Fish & Richardson

Dish Network v. Entropic Communications (Case No. IPR2024-00393)

2025 ● Perkins Coie

Amazon.com, Inc. v. Nokia Technologies Oy (Case No. IPR2024-00572)

2025 ● Fish & Richardson

Dish Network v. Entropic Communications (Case No. IPR2024-00373)

Limited Case and Clientele History

Alston & Bird

- Ericsson

  v. Collision Communications (Case No. IPR2022-01233)

- Nokia

  v. Neptune Subsea, Xtera (Case No. 1:17-cv-01876)

- Universal Electronics Inc

  v. Roku Inc (Case No. IPR2022-00818)

Alavi & Anaipakos PLLC

- Stingray Group Inc. and Stingray Music USA, Inc.

  v. Edwin A. Hernandez-Mondragon and Egla Corp. (Case No. 1:24-cv-21226-RAR)

Arnold & Porter

- Ivantis

  v. Glaukos (Case No. 8:18-cv-00620)

- Samsung

  v. Jawbone (Case No. 2:21-cv-00186)

Benesch Friedlander Coplan & Aronoff

- Voyis

  v. Cathx (Case No. 5:21-cv-00077-RWS)

Buchanan, Ingersoll & Rooney PC

- Google LLC, AT&T Service Inc., T Mobile USA Inc., Cellco Partnership, Ericsson Inc. & Nokia of America Corp.

  v. KT Corp & Pegasus Wireless Innovation LLC (Case No. IPR2025-00293)

Deschert LLP

- Smaxtec Animal Care

  v. ST Reproductive Technologies, LLC (Case No. IPR2024-00885)

Duane Morris

- Kangxi Communication Technologies

  v. Skyworks Solutions Inc. (Case No. IPR2025-00373)

- Microsoft

  v. Edge Networking Systems LLC (Case No. 1:24-cv-00215)

Erise I.P.

- Apple

  v. Ericsson Inc. (Case No. IPR2022-00715)

  v. Future Link Systems (Case No. IPRs 6317804, 6622108, 6807505, and 7917680)

  v. INVT (Case No. 20-1881)

  v. Navblazer LLC (Case No. IPR2020-01253)

  v. Qualcomm (Case No. IPR2018-001281, 39521-00421IP, IPR2018-01282, 39521-00421IP2)

v. Quest Nettech Corp (Case No. 2:19-cv-00118-JRG)

v. Telefonaktiebolaget LM Ericsson (Case No. IPR2022-00275)

v. Theta IP, LLC (Case No. IPR2024-00818)

v. THL Holding Company LLC (Case No. 1:23-cv-00548)

- Fanduel

  v. CGT (Case No. 19-1393)

- Garmin

  v. Phillips North America LLC (Case No. 2:19-cv-6301-AB-KS)

- Netscout

  v. Longhorn HD LLC (Case No. 2:20-cv-00349)

  v. Implicit, LLC (Case No. 2:18-cv-53-JRG)

- Sony Interactive Entertainment LLC

  v. Bot M8 LLC (Case No. IPR2020-01288)

  v. Infernal Technology LLC (Case No. 2:19-CV-00248-JRG)

- Tesla

  v. Charge Fusion Technologies LLC (Case No. IPR2025-00032)

- Unified Patents

  v. GE Video Compression (Case No. 2:19-cv-248)

Fish & Richardson

- Apple

  v. AliveCor (Case No. 3:21-cv-03958)

  v. LBS Innovations (Case No. 2:19-cv-00119-JRG-RSP)

  v. Koss Corporation (Case No. IPR2021-00305)

v. Masimo (Case No. IPR 50095-0012IP1, 50095-0012IP2, 50095-0013IP1, 50095-0013IP2, 50095-0006IP1, 50095-0135IP1)

v. Neonode (Case No. 21-cv-08872-EMC)

v. Qualcomm (Case No. IPR2018-001281, 39521-00421IP, IPR2018-01282, 39521-00421IP2)

v. Resonant Sys. (Case No. 7:23-cv-00077-ADA)

- AsusTek Computer Inc.
  v. Videolabs, Inc. (Case No. 22-CV-00720-ADA)

- Dell
  v. Neo Wireless (Case No. IPR2022-00616)

- Dish Network

  v. Entropic Communications, LLC (Case No. 2:2023-CV-01043)

  v. Entropic Communications LLC (Case No. IPR2024-00393)

  v. Realtime Adaptive Streaming (Case No. 1:17-CV-02097-RBJ)

  v. TQ Delta LLC (Case No. 18-1798)

- Evapco Dry Cooling

  v. SPG Dry Cooling (Case No. IPR2021-00688)

- Genetec

  v. Sensormatic Electronics (Case No. 1:20-CV-00760)

- Huawei

  v. Bell Northern Research LLC (Case No. IPR2019-01174)

- Kianxis

  v. Blue Yonder (Case No. 3:20-cv-03636)

- LG Electronics

  v. Bell Northern Research LLC (Case No. 3:18-cv-2864-CAB-BLM)

- MediaTek

  v. MOSAID (Case No. IPR2024-00718)

- Metaswitch

  v. Sonus Networks (Case No. IPR2018-01719)

- Microsoft

  v. Throughputer Inc (Case No. IPR2022-00757)

- Mom Enterprises

  v. Ddrops Company (Case No. 1:22-cv-00332)

- MLC Intellectual Property

  v. MicronTech (Case No. 3:14-cv-03657-SI)

- Nearmap Inc

  v. EagleView Technologies (Case No. IPR2022-01009)

- Neuroderm Ltd.

  v. Abbvie, Inc (Case No. PGR2022-00040)

- Posco Co Ltd.

  v. Pascal Drillet et al. (Case No. IPR2025-00370)

- Realtek Semiconductor

  v. Future Link (Case No. IPR2021-01182)

- Quectel
  - v. Koninklijke Philips (Case No. 1:20-cv-01710)

- Samsung
  - v. Aire Technology (Case No. IPR2022-00877)
  - v. Bell Northern Research (Case No. 2:19-cv-00286-JRG)
  - v. Communication Technologies Inc (Case No. IPR2022-01221)
  - v. Jawbone Innovations (Case No. IPR2022-00865)
  - v. MemoryWeb LLC (Case No. IPR2022-00885)
  - v. Dodots Licensing Solutions (Case No. IPR2023-00701)
  - v. Telefonaktiebolaget LM Ericsson (Case No. IPR2021-00615)

- Texas Instruments
  - v. Vantage Micro LLC (Case No. IPR2020-01261)

- Xilinx
  - v. Sentient Sensors LCC (Case No. 1:22-cv-00173)

Goodwin Proctor

- Intel
  - v. Proxense, LLC (Case No. 6:24-cv-00283)

- Samsung Electronics
  - v. Mobile Data Technologies (Case No. 2:24-cv-00435)

- Taiwan Semiconductor Manufacturing Company Ltd.
  - v. Advanced Integrated Circuit Process LLC (Case No. 2:24-cv-00623)

Groombridge Wu

- Nearmap

  v. Eagle View Technologies Inc. and Pictometry International Corp. (Case No. 2:21-cv-00283-TS-DAO)

Irell & Manella

- Curium

Latham & Watkins LLP

- Apple

  v. Advanced Coding Research LLC

Leydig, Voit & Mayer, Ltd.

- Public Availability Consultancy

O'Melveny & Myers

- Apple

  v. Maxell (Case No. 5:19-cv-00036-RWS)

- Disney Media & Entertainment Distribution LLC

  v. Digital Media Technology Holdings, LLC (Case No. 2:22-cv-01642)

- Micron Technology Inc.

  v. Besang Inc (Case No. IPR2023-00900)

- Samsung

  v. Daedalus Prime LLC (1335 Investigation)

Perkins-Coie

- Amazon
  - v. Nokia (Case No. IPR2024-00847 and IPR2024-00848)
  - v. Nokia Technologies Oy (Case No. IPR2024-00572)
- Heru Industries
  - v. The UAB Research Foundation (Case No. IPR2022-01148)
- Intel Corporation
  - v. BeSang Inc. (Case No. IPR2023-00991)
  - v. BitMICRO (Case No. 5:23-cv-00625)
  - v. Telefonaktiebolaget L M Ericsson (Case No. IPR2024-00610)
- Realtek Semiconductor
  - v. Future Link (Case No. IPR2021-01182)
- r-pac
  - v. Adasa, Inc. (Case No. 1:2024cv06102)
- Twitter Inc
  - v. VOIP-Pal.com (Case No. 3:20-cv-02397-JD)
- TCL Industries
  - v. Koninklijke Philips NV (Case No. IPR2021-00495, IPR2021-00496 and IPR2021-00497)
- VusionGroup
  - v. Hanshow (Case No. IPR2024-00857)

Pillsbury Winthrop Shaw Pittman

- Intel

  v. FG SRC LLC (Case No. 6:20-cv-00315)

- Gravel Rating Systems

  v. Costco (Case No. 4:21-cv-149)
  v. Lowe's Home Centers (Case No. 4:21-cv-150)
  v. T-Mobile USA (Case No. 4:21-cv-152)
  v. Kohl's Inc. (Case No. 4:21-cv-258)
  v. Under Armor (Case No. 4:21-cv-356)

Quinn Emanuel

- Exact Sciences Corporation

  v. Geneoscopy, Inc. (Case No. IPR2024-00459 and IPR2024-1330)

- ServiceNow, Inc.

  v. InQuisient, Inc. (Case No. 22-900-CJB)

- Wolfspeed

  v. The Trustees of Purdue University (Case No. 1:2021-cv-00840)

Sheppard, Mullin, Richter & Hampton LLP

- Advanced Micro Devices, Inc and Pensando Systems, Inc.

  v. Concurrent Ventures LLC and Xtreamedge, Inc. (Case No. IPR2025-00478)

- Cadence Design Systems Inc.

  v. Semiconductor Design Technologies (Case No. 3:23-cv-01001)

Shook, Hardy & Bacon LLP

- HP Inc.

  v. Universal Connectivity Technologies (Case No. 1:23-cv-01177)

Stern, Kessler, Goldstein & Fox

- Preliminary Research

Wilmer, Cutler, Pickering, Hale and Dorr

- Apple

  v. Shunock (Case No. 1:23-cv-08598)

- Quest Diagnostics Inc., Haystack Oncology Inc. and Haystack Oncology GmbH

  v. Natera, Inc. (Case No. 1:23-cv-08598)

- Roche Diabetes, Inc.

  v. Trividia Health, Inc. (Case No. 1:24-cv-00668)

Willkie, Farr & Gallagher LLP

- Lenovo, Dell, HP

  v. Universal Connectivity Technologies Inc. (Case No. 2:2023cv00449)

- Neurent

  v. The Foundry, LLC (Case No. IPR2024-00669)

- Netflix, Inc.

  v. VideoLabs, Inc. (Case No. IPR2023-00628)

APPENDIX PSU01

https://web.archive.org/web/19960901000000*/http://www.lias.psu.edu/lcsdesc/descript.htm September 24, 2025

INTERNET ARCHIVE WEB TEXTS VIDEO AUDIO SOFTWARE IMAGES SIGN UP | LOG IN UPLOAD Search

ABOUT BLOG PROJECTS HELP DONATE CONTACT JOBS VOLUNTEER PEOPLE

DONATE

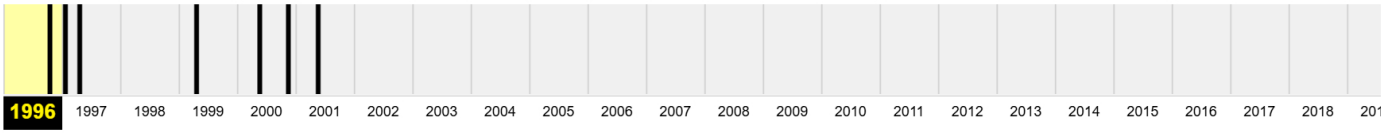
INTERNET ARCHIVE WayBackMachine

Explore more than 946 billion web pages saved over time

http://www.lias.psu.edu/lcsdesc/descript.htm

Calendar · Collections · Changes · Summary · Site Map · URLs

Saved **7 times** between October 18, 1996 and May 3, 2001.



JAN

	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

FEB

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Note

This calendar view maps the number of times **http://www.lias.psu.edu/lcsdesc/descript.htm** was crawled by the Wayback Machine, *not* how many times the site was actually updated. More info in the FAQ.

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https://web.archive.org/web/19961018145356/http://www.lias.psu.edu/lcsdesc/descript.htm September 24, 2025
INTERNET ARCHIVE WayBack Machine http://www.lias.psu.edu/lcsdesc/descript.htm Go SEP OCT JAN
7 captures 18 Oct 1996 - 3 May 2001 1995 18 1996 1999 About this capture

C&IS Library Computing Services

Library Computing Services (LCS), a division of Computer & Information Systems, provides a wide range of electronic information resources to Penn State's students, faculty and staff through LIAS, the Library Information Access System. LCS also provides computing support for the University Libraries programs and services, and supplies computing cycles and operations support for the office of Continuing and Distance Education. In addition, LCS plays a leadership role in the development of new electronic information resources, services and technologies.

LIAS

LIAS, the Library Information Access System, is the most visible LCS application. Developed by LCS, LIAS provides access to Penn State's online catalog "The CAT", indexing and abstracting databases covering a wide range of subject areas, CD-ROM networks, electronic journals, collections of other research libraries, the Internet, and many other electronic resources.

- Connect to LIAS
- Learn More About LIAS
- LIAS Through the Years
- Z39.50 Server Description

Project Status

LCS continually strives to provide better and faster access to information resources, including full text, image, graphics and digital spatial databases. Projects that LCS is currently working on, (or just thinking about!) include ...

- Software Projects
- Workstation Projects
- Network Projects
- Other Projects
- Completed Projects

Who's Responsible?

LCS consists of twenty design, development, systems, network, operations and support staff who are responsible for LIAS and other LCS projects.

- Alphabetical List
- Organization Chart

How Are We Doing?

- Annual Report, July 1995 - June 1996
- Semi-Annual Report, July - December 1995
- Annual Report, July 1994 - June 1995

Back to: LIAS Home Page

Updated: 3/26/96

APPENDIX PSU02

https://web.archive.org/web/19961001000000*/http://www.lias.psu.edu/lcshelp/hist80.htm September 24, 2025

INTERNET ARCHIVE WEB TEXTS VIDEO AUDIO SOFTWARE IMAGES SIGN UP | LOG IN UPLOAD Search

ABOUT BLOG PROJECTS HELP DONATE CONTACT JOBS VOLUNTEER PEOPLE

DONATE

INTERNET ARCHIVE WayBackMachine

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http://www.lias.psu.edu/lcshelp/hist80.htm

Calendar · Collections · Changes · Summary · Site Map · URLs

Saved **2 times** between October 18, 1996 and January 10, 1997.

1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 201

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Note

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INTERNET ARCHIVE WayBackMachine http://www.lias.psu.edu/lcshelp/hist80.htm Go SEP OCT JAN
2 captures 18 Oct 1996 - 10 Jan 1997 1995 18 1996 1997 About this capture

LIAS History -- The 1980's

January 1981	Card catalog closed. Online current cataloging begins. COM catalog used as interim catalog.
January 1981	Conversion to Honeywell CP-6.
Spring 1982	Staff-mediated public access at a limited number of UP terminal locations.
August 1983	OPAC brought up: 40 at University Park; 40 at campuses. A total of 160 terminals in use university-wide.
August 26, 1983	Preview of LIAS.
Sept. 29, 1983	16 terminals placed in Catalog Room.
December 16, 1983	LIAS brought to first campus (York, King of Prussia, Allentown).
Spring 1984	Dial-up service to LIAS made available.
July 1, 1985	First demo of MicroLIAS.
December 1985	Asbestos removal in Computer Room.
January 17, 1986	MicroLIAS made available.
July 1, 1988	Library Computer Operations changes to Library Computing Services.
December 1988 - January 1989	Penn State sends initial load of tapes containing 1,289,451 LIAS records to RLIN.
November 29, 1989	DEC announced grants to PSU and University of California to support linking of these library systems at these institutions via Z39.50.
January, 1989	CBRST (Computer-Based Resources and Services Team) moves into LCS quarters.
July 1, 1989	Eric Ferrin appointed Director.
September 22, 1989	LIAS migration to VAX 9000-420 begins. Digital Equipment provides $2.5 million in grants to enable PSU to purchase VAX.

1970's | 1990's

Back to: LIAS Home Page | LIAS FAQ | LIAS History

Updated: 12/4/95

APPENDIX PSU03

https://web.archive.org/web/20060615000000*/http://www.libraries.psu.edu/instruction/CAT_guide/catguide.pdf September 24, 2025

INTERNET ARCHIVE WEB TEXTS VIDEO AUDIO SOFTWARE IMAGES SIGN UP | LOG IN UPLOAD Search

ABOUT BLOG PROJECTS HELP DONATE CONTACT JOBS VOLUNTEER PEOPLE

DONATE

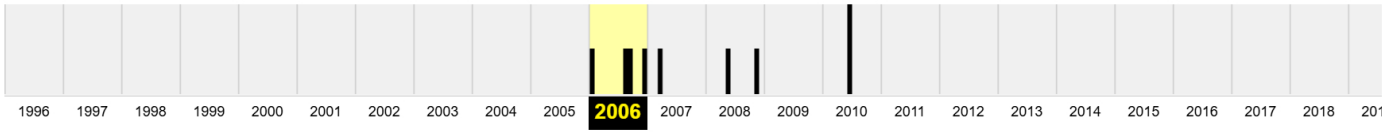
INTERNET ARCHIVE WaybackMachine

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http://www.libraries.psu.edu/instruction/CAT_guide/catguide.pdf

Calendar · Collections · Changes · Summary · Site Map · URLs

Saved **9 times** between January 4, 2006 and June 16, 2010.



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Note

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INTERNET ARCHIVE WayBackMachine http://www.libraries.psu.edu/instruction/CAT_guide/catguide.pdf Go DEC JAN AUG
9 captures 4 Jan 2006 - 16 Jun 2010 2005 04 2006 2007 About this capture



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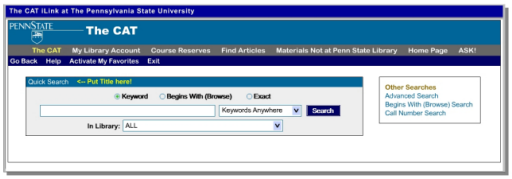


Quick Guide to Searching The CAT

Penn State University Libraries



To get to The CAT, visit the University Libraries' home page (www.libraries.psu.edu) and click on the link marked "The CAT."

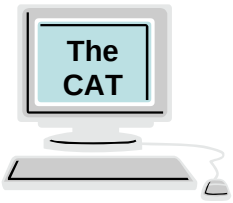


What?
The new Quick Search screen allows you to select from a powerful array of searches. From one screen it is possible to perform any of the main search types: keyword, browse, or exact search. This enables you to easily select the search most appropriate to your needs.

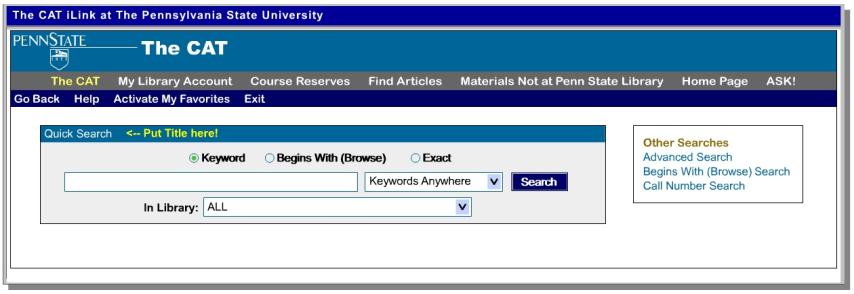


Quick Guide to Searching The CAT

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What?

The new Quick Search screen allows you to select from a powerful array of searches. From one screen it is possible to perform any of the main search types: keyword, browse, or exact search. This enables you to easily select the search most appropriate to your needs.

When?

Use **Quick Search** when you have a basic topic in mind, and want to get results quickly. **Advanced Search** should be used for more complex searches. Quick Search performs three types of searches: **Keyword**, **Browse** and **Exact**.

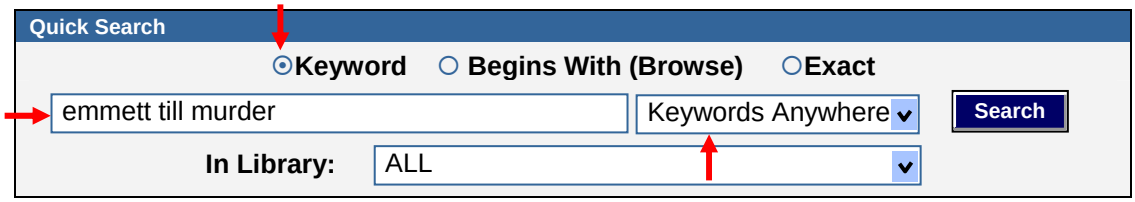
- Choose **Keyword** to find a word or phrase anywhere.
- Choose **Begins with (Browse)** to search a series of words sequentially.
- Choose **Exact** to search an exact title, author, or subject.

How?

To begin a **quick search** . . .

1. **Type the word(s) or phrase** you're looking for in the box provided. **Note:** You can use Connectors (**AND, OR, NOT**) by typing them directly into your search box.
2. **Select the type of search** that you want to do: **Keyword**, **Browse** or **Exact**.
3. From the dropdown menu, **select the kind of search you want to do**: Keywords Anywhere (Searches the entire record); Topic: Title + Subject; Author; Title; Journal Title; Series; LC Subject Heading or Medical Subject Heading.
4. **Select a Library** to limit your search to a specific library location, if you desire. "All" will search the entire PSU Libraries collections at all locations.
5. **Press the Search button** to begin your search.

Sample Quick Search:



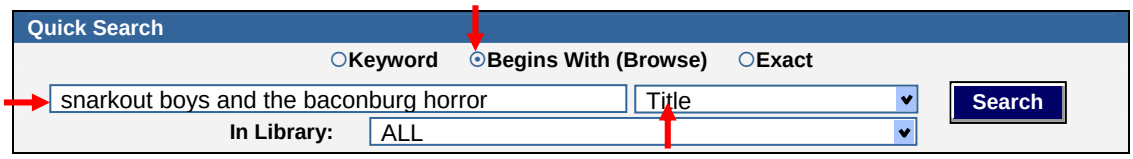
If you have additional questions about using the new CAT, see "The CAT Help" pages at
http://cat.libraries.psu.edu/iBistro_helps/English/alsitemap.html

* Please visit the CAT tutorial at: http://www.libraries.psu.edu/instruction/cat_tutorial/index.html

How Do I Search for Books?

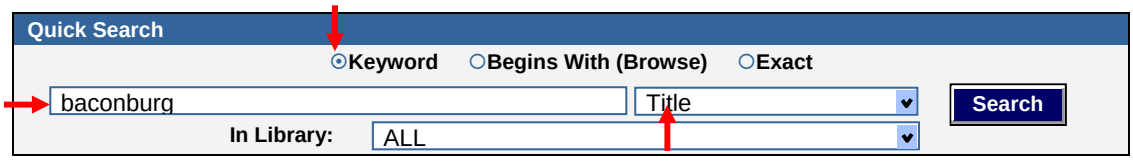
Do you know the Title of the book?

On the **Quick Search** screen, select "**Title**" from the drop down menu located next to the search box. Enter the title of the book in the search box. Click on the radio button marked "**Begins with (Browse)**" above the search box. (See example below.)



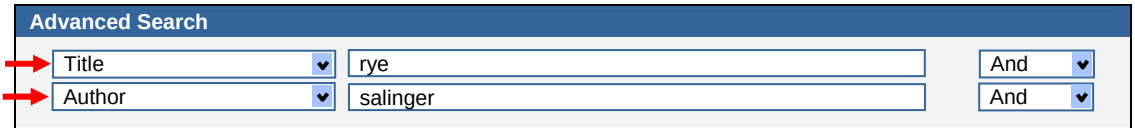
Are you unsure of the exact title?

On the **Quick Search** screen, select "**Title**" from the drop down menu located next to the search box. Enter the title word(s) that you know for the item in the search box. Click on the radio button marked "**Keyword**" above the search box. (See example below.)



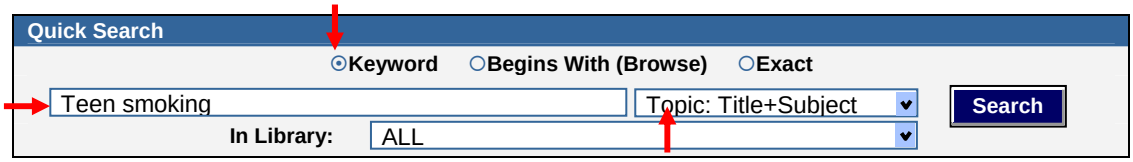
Do you know an Author and part of the Title?

Go to **Advanced Search**. (The advanced search link is located on the right side of the main search page in The CAT.) Enter the **title word**(s) in the first box. Select "**Title**" from the drop-down menu next to the search box. Enter the **author's last name** in the next box down. Select "**Author**" from the drop-down menu next to the search box. Click "Search." (See example below.)



Are you looking for books on a Topic?

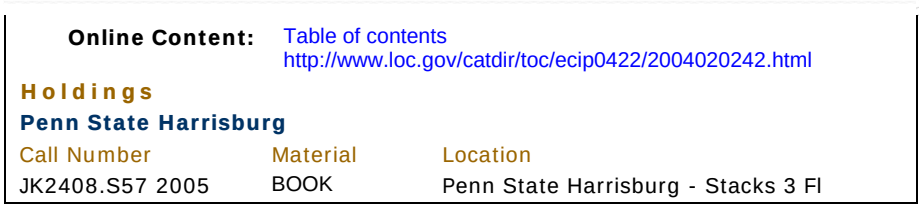
On the Quick Search screen, select "Topic: Title & Subject" from the drop down menu located next to the search box. Enter your topic word(s) in the search box. Click on the radio button marked "Keyword" above the search box. (See example below.)



How can I tell if the item is on the shelf?

If your search has found two or more items: Click on the **Details** button beside a record that you are interested in to see more information about the item.

On the "Details" page for the specific item, look at the bottom of the record to see whether the item is **available** or is **checked out**. Unless the item has a due date listed, it should be on the shelf at the location indicated. (See example below.)



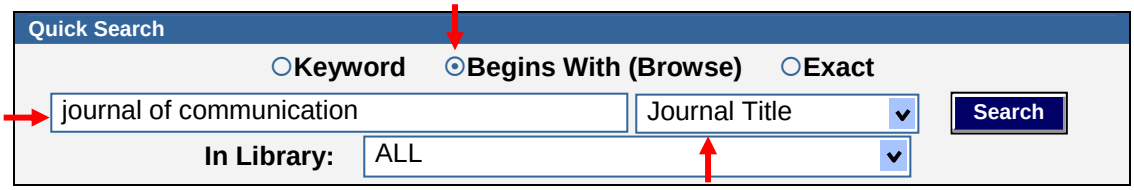
If the item is available, you will want to note the call number and location. If the item is not available or is held at another location, click on the **I Want It** button on the left side of the screen to place a hold on the item or to have it sent from another campus.

How do I search for journals?

Do you know the NAME of the journal?

The CAT indexes journals but it does not provide access to the individual articles published within journals. **If you are searching for journal articles on a specific topic**, use the Libraries' **Find Articles** (http://www.libraries.psu.edu/articles.html) page. To browse article databases by subject, use **Find Articles by Subject** (http://www.lias.psu.edu/gensubjlist.html).

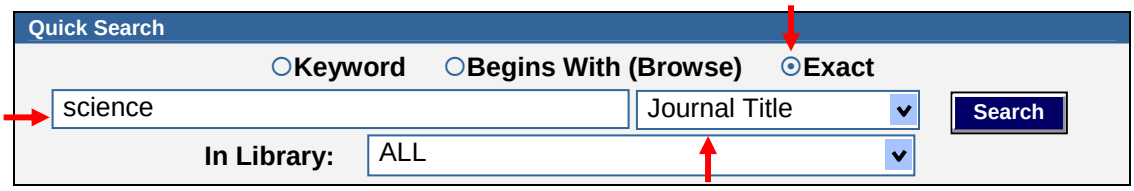
At the **Quick Search** screen, type the **journal name** in the search box, and select "**Journal Title**" from the drop-down menu. Then, click the "**Begins With (Browse)**" radio button. **The CAT** will retrieve journal titles that begin with the words you type.



Exact journal title searching

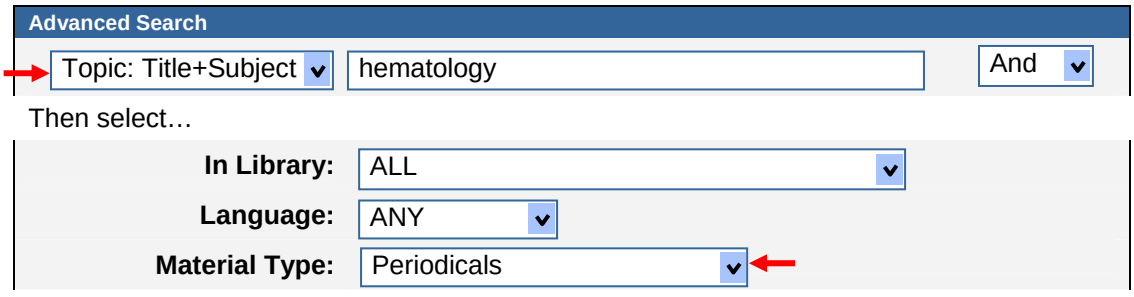
Another option is to select the "Exact" radio button. In **Quick Search**, type the **journal name** in the search box, and select "**Journal Title**" from the drop-down menu. Then, click the "**Exact**" radio button.

One-Word Titles: "Exact" is especially useful if the journal's title consists of one very common word, such as *Science, Cell,* or *Time*. "Exact" allows you to search only for journals that specifically match on the words you type. Keep in mind that you may still have to scroll down through the list of search results to find the specific journal title that you are seeking.



Are you looking for journals on a particular SUBJECT?

First, go to the **Advanced Search** screen. There, type your subject word(s) in the first search box and select "Topic: Title + Subject" from the drop-down menu. Then, select "Periodicals" from the "Material Type" drop-down menu at the bottom of the screen.



Once I find journals in The CAT, how do I access them?

Online Content: If the journal is available electronically, there will often be a direct link, labeled "Online Content." Click this link to go to the database featuring the journal.
Print Format: At the journal's detailed screen, look at the "Locations" area of the record to see where bound and unbound issues of the journal are kept in the library. Note the call number for the bound volume(s).

Are you looking for ONLINE journals?

Other ways to find online journals include:

- Citation Linker (http://getit.libraries.psu.edu:9003/sfx_local/cgi/core/citation-linker.cgi)
- E-Journals and E-Newspapers search page (http://apps.libraries.psu.edu/fasttrack/search.cfm).

Most online resources are available at all locations; however, there are exceptions. If you are having trouble accessing a resource, email er_help@psulias.psu.edu or contact a service desk at your nearest library location.

Use the Advanced Search screen to take advantage of these advanced searching capabilities.

Boolean Searching

BOOLEAN Operators enable you to *narrow* or *expand* your results.

AND *Narrows*: The terms you use must both occur in the same work, although they can occur in different fields (such as in Author and Subject fields).

OR *Expands*: The terms you use can occur in the same or different works. Either term will be retrieved.

NOT *Narrows*: Discards any record containing the word you specify using **NOT**. (e. g. Depression **NOT** economic)

With

With allows you to search for terms in the same sentence of the same ***field*** (e.g. title, series, subject) in the ***record***.

Nesting ( )

Nesting utilizes ***parentheses*** to clarify relationships between search terms. Generally the items in parentheses are linked by ***"OR."***

Use parentheses ( ) to group or nest search terms together.

Example:

Using	**(Iraq or Kuwait) and oil**
will search …	**Iraq or Kuwait** first

Phrase Searching ' '

Phrase Searching will retrieve your search terms in the order you typed them.

Use ***Phrase Searching*** when you are trying to link two or more common words that may have different meanings when separated.

To search for a phrase on the quick search page, enclose the phrase in single quotes.

Example:

Using	**'women engineers'**
will search …	the exact phrase (**women engineers**)

Limit

The ***Limit*** option allows you to restrict your search to particular criteria that you specify – such as date, language, where it is located, or what type of material (book, video, score, juvenile material, etc…) it is.

Use ***Limit*** when you get too many results, or find many of your results to be irrelevant, due to age, language, location or type.

Truncation $

Truncation searches for documents containing variations on a search term. The CAT uses a "$" as the "wildcard" which represents a single character, many characters, or no characters.

Use ***truncation*** when your search yields no or too few results, or if you want to conduct a more comprehensive search.

Example:

Using	**environment$**
will search …	**environment, environments, environmental,** and **environmentally**

Substitution ?

A ***Question Mark*** substitutes a single character in a keyword search.

Use ***?*** when you are unsure of a spelling or when you want to find two forms of one word.

Example:

Using	**wom?n**
will search …	**woman** and **women**

Publication Date

1980-2005:	for dates between 1980 and 2005
>1980:	for dates after 1980 (retrieves 1981 to present)
<1990:	for dates previous to 1990 (retrieves 1989 and earlier)
<=1900:	for dates published in 1900 and earlier ("less than or equal to" 1900)
>=1900:	for dates published in 1900 and after ("greater than or equal to" 1900)

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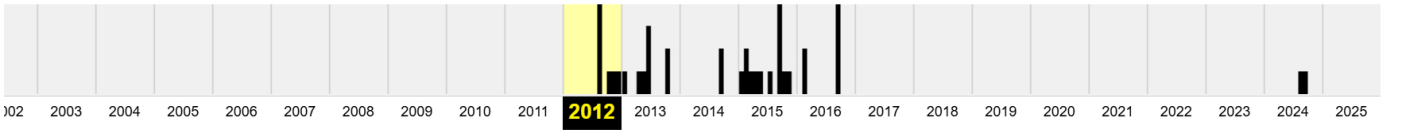
APPENDIX PSU04

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JAN

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Note

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https://web.archive.org/web/20120824204323/http://www.libraries.psu.edu/psul/lionsearch.html September 24, 2025

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General Information | Scope | Searching and Facets | Results | The CAT

Searching Basics | Searching Questions | Facets

Searching Basics

Basic Search guide (PDF)
Advanced Search guide (PDF)

Phrase Searching

Use quotation marks to search for phrases. For example, the query "teacher education" will find results with that phrase.

Searching Specific Fields

The single search box (basic search box or keyword search box in advanced search) will search across many fields automatically. For example, entering an ISBN, ISSN, or Call Number will bring back associated records.

You can explicitly search a field using the syntax: "field:(query)." For example, the search **ISSN:(1234-5678)**, finds records that contain that value in the ISSN field.

Searchable fields:

- Title
- SubjectTerms
- Author
- Publisher
- PublicationTitle
- Volume
- Issue
- Language
- Notes
- ISBN
- ISSN
- DOI
- DEWEY

Boolean Operators

Valid Boolean operations are: OR, NOT and AND. The operators must be written in ALL CAPS.

By default, all terms in a search are combined with the AND operator. To expand the results set, use the OR operator "microcircuits OR nanocircuits" will return items that contain either term.

This can be combined with quoted terms such as "teacher education" OR "educator training".

To exclude items, use the NOT operator or "-" character before a term. When used in the following query "animal NOT dog" the results will not include the term "dog".

Wildcard Use in Summon

Searches can be performed using the wildcards "?" and "*".

The question mark (?) will match any one character and can be used to find "Olsen" or "Olson" by searching for "Ols?n".

The asterisk (*) will match zero or more characters within a word or at the end of a word. A search for "Ch*ter" would match "Charter", "Character", and "Chapter". When used at the end of a word, such as "Temp*", it will match all suffixes "Temptation", "Temple" and "Temporary".

Wildcards cannot be used as the first character of a search.

Searching questions

How does LionSearch work?
LionSearch presents a single search box for entering search terms. The LionSearch engine quickly collects all the relevant material and presents the results sorted by relevance along with a number of facets that may be used to refine the results, such as date, language, and content type.

Does LionSearch work like a "federated search"?
Yes and no. LionSearch is not designed to search a selected group of databases; instead it searches everything and does it much faster than a federated search.Federated searches send the same query to each of the databases and wait for the database to send back some results (seldom complete). LionSearch searches a single index managed by SerialsSolutions. This index is

created by pre-harvesting metadata from the source databases. So you search a single index and get a single result set. On the other hand, the metadata harvested by SerialsSolutions is the same metadata that is searched in the individual databases. Searches in LionSearch are no smarter than federated searches, but they are more comprehensive and much faster.

How extensive is the indexing? Does LionSearch index all of the full text of an article?
It depends on what the publisher allows.

When I enter a search, several suggested options appear in a box underneath. Where is this information coming from? Sometimes the information is truncated and I'd like to get the full text.
LionSearch has an autocomplete feature, which provides users with suggestions as they type in a search box. These suggestions come from a collection of open access sources freely available on the Internet. Major sources include the Library of Congress, Open Library, PubMed Central, and Wikipedia.

When is it more appropriate to use the Advanced Search?
The Advanced Search has multiple pre-set search boxes to facilitate Boolean searching by keyword, authors, title, source and so on. It is most useful if you are looking for a known item or citation since you can limit by volume, issue, and date. It is also possible to limit the search to just items in the CAT using the Advanced Search.

Can you access a database from a LionSearch search?
Yes. To access a particular database via LionSearch, simply search for the database by name then follow the link.

Does LionSearch support non-Roman character searching or sorting? Can we turn on a non-English language interface to LionSearch?
We have not enabled these features at this time.

Can I use LionSearch to find a specific, known title?
Yes. Search for the title of the item using the LionSearch box or use the advance search.

Are there any instances when it is better to NOT use LionSearch? When should I go directly to a database versus use LionSearch?
One circumstance might be if you need to do a specialized search of a particular database. Most databases support more sophisticated searching if you utilize their internal, individual search software. Some offer unique searching features not found in LionSearch, such as cited reference searching. In the case of the CAT, the records themselves are indexed in more detail by the CAT software than that of LionSearch so your search results might yield more results. Also, since LionSearch only supports one Content Type for each record (many items have multiple Content Types, e.g., e-book and government document), its results are very misleading if you are searching for a particular Content Type.

Facets

What are facets and how should I use them to refine my search?
Facets are used to display the results of your search in several pre-determined categories, such as language and date. The facets display on the left side of the results screen. By default, "Any" is checked to show all results. Clicking on one of the categories will keep the results that fall into that category, while eliminating everything else. For instance, clicking on the Language "English" will limit results to items in that language. For more precise control, click on "more options" at the bottom of the list of categories; you can "include" or "exclude" each category separately. To remove the limits, click on "Any" to see the full list of results. Within the "more options" link, the sorting order can be changed from a frequency sort to an alphabetic sort, if desired. Each of these facets work independently; in other words, you can choose categories within different facets in order to refine your search.

What facets are available to refine search results?
LionSearch includes the following facets:

"Refine your search": a few very general limits, such as "items with full text online"
Content Type: resource categories such as "Book" or "Journal Article"
Author
Subject Terms (collated from the subject terms in the search results)
Publication Date
Library Location
Language

Why don't the content type facets yield better results? Sometimes they just seem wrong!
LionSearch assigns a single Content Type to each record no matter how many different content types the item may actually have (e.g., government document *and* book). Also, we have no control over what content types the various database producers assign to their records. For our library's catalog records, the Content Type mapping of records from The CAT is based on the Item Type element. We developed a hierarchy of Item Types to map our records into the LionSearch Content Types (see below). Since a record could only be assigned one Content Type the results are not ideal. For example, we have many records that have both print and microform Item Types, such as theses, dissertations, and journals. Since the microform Item Type was near the bottom of our hierarchy, it gets assigned only if no other Item Type applies to the record. This means that our microform collections are under-represented as a category because the Content Type "microform" is never assigned when the same record has print holdings.

Hierarchy of Item Types used when assigning Content Types:

1. Thesis/dissertation
2. E-book
3. E-journal
4. Web resource
5. Journal
6. Archival material
7. Map
8. Music score
9. Newspaper
10. Audio recording
11. Video recording
12. Electronic resource (e.g., CD-ROM)
13. Kit
14. Book
15. Pamphlet
16. Microform
17. Equipment

How can I use facets to refine my search?
The left column of the LionSearch results display provides a number of facets listing categories which can be used to refine a

search. By default, "Any" is checked to show all results. Clicking on one of the categories will keep the results that fall into that category, while eliminating everything else. For instance, clicking on the Content Type "Book" will eliminate everything that is not a book from the results list. For more precise control, click on "more options" at the bottom of the list of categories; you can "include" or "exclude" each category separately. To remove the limits, click on "Any" to see the full list of results.

I wanted to restrict my search to materials in the Arts & Humanities Library but I don't see that as an option on the Libraries Location list. Why not?
Given the way call numbers are assigned to materials in the Pattee and Paterno Libraries, Summon had difficulty separating materials accurately by floor/subject library. For LionSearch, we decided to treat all libraries within the Pattee and Paterno Libraries as one location. If you want to search for materials specifically in one of the subject libraries in Pattee or Paterno, you should use the interface in the CAT, which allows much more granular searching by location.

Why don't the results retrieved under the content type facets add up to the same number of total records?
A few of our resources did not match any of the Content Types allowed by Summon. Rather than map these resources to the wrong type, we chose to not map them to any particular type instead. An example would be various types of equipment, such as laptops.

Return to LionSearch

Scope | Results

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APPENDIX LOPES01

MARC View

LEADER 02745nas a22005177a 4500

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003			SIRSI
005			20250914090050.0
006			m o d
007			cr n
008			050615c19869999nyuqr pss 0 a0eng c
010			a| 2005212474
016	7		a| 2034320-6 2| DE-600
016	7		a| 012433313 2| Uk
019			a| DO NOT EDIT this 360 MARC RECORD
022			a| 1558-0679 l| 0885-8950 y| 0885-8950
035			a| (WaSeSS)ssj0006679
037			b| IEEE Computer Society, 10662 Los Vaqueros Circle, PO Box 3014, Los Alamitos, CA 90720-1314 USA
040			a| OCLCS b| eng e| pn c| OCLCS d| NSD d| MUQ d| DLC d| OCLCQ d| HEBIS d| OCLCQ d| BUF d| OCLCF d| OCLCO d| OCLCQ d| OCLCA d| AU@ d| UKMGB d| NJT d| OCLCO d| OCLCQ d| UAB d| DLC d| OCLCL d| WaSeSS
042			a| nsdp a| pcc
050		4	a| TK1005 b| .I35
082	1	0	a| 621 2| 13 1| https://id.oclc.org/worldcat/ddc/E4djYmFy7KK4mwFQy33t3Tt7kT
130	0		a| IEEE transactions on power systems (Online)
210	0		a| IEEE trans. power syst. b| (Online)
222		0	a| IEEE transactions on power systems b| (Online)
245	1	0	a| IEEE transactions on power systems h| [electronic resource] : b| a publication of the Power Engineering Society.
246	3		a| Institute of Electrical and Electronics Engineers transactions on power systems
246	3	0	a| Transactions on power systems
246	1		i| Some providers use title: a| Power systems, IEEE transaction on
260			a| [New York, NY] : b| [Institute of Electrical and Electronics Engineers], c| 1986-
310			a| Quarterly
362	1		a| Began with v. PWRS-1, no. 1 (Feb. 1986).
538			a| Mode of access: World Wide Web.
580			a| Indexed by: Combined index for IEEE transactions on power delivery, IEEE transactions on power systems, IEEE transactions on energy conversion.
588			a| Description based on print version record.
588			a| Latest issue consulted: Vol. 28, no. 4 (Nov. 2013) (IEEE Xplore, viewed Oct. 30, 2013).
650		0	a| Electric power systems v| Periodicals.
655		0	a| Electronic journals.
710	2		a| IEEE Power Engineering Society.
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776	0	8	i| Print version: t| IEEE transactions on power systems x| 0885-8950 w| (DLC) 88659376 w| (OCoLC)12760783
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856	4	0	u| http://SK8ES4MC2L.search.serialssolutions.com/?V=1.0&L=SK8ES4MC2L&S=JCs&C=IEEETRANONPO&T=marc
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Additional Titles	IEEE trans. power syst. (Online), Institute of Electrical and Electronics Engineers transactions on power systems, Transactions on power systems, and Some providers use title: Power systems, IEEE transaction on
Published	[New York, NY] : [Institute of Electrical and Electronics Engineers], 1986-
Additional Creators	IEEE Power Engineering Society and Institute of Electrical and Electronics Engineers

Access Online

serialssolutions.com

Continues in Part

IEEE transactions on power apparatus and systems

Dates of Publication and/or Sequential Designation

Began with v. PWRS-1, no. 1 (Feb. 1986).

Subject(s)

Electric power systems—Periodicals

Genre(s)

Electronic journals

ISSN

1558-0679

Publication Frequency

Quarterly

Technical Details

Mode of access: World Wide Web.

Complexity Note

Indexed by: Combined index for IEEE transactions on power delivery, IEEE transactions on power systems, IEEE transactions on energy conversion.

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IEEE transactions on power systems

ISSN: 0885-8950

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APPENDIX LOPES02

Defining Control Strategies for MicroGrids Islanded Operation

J. A. Peças Lopes, *Senior Member, IEEE*, C. L. Moreira, and A. G. Madureira

***Abstract*—This paper describes and evaluates the feasibility of control strategies to be adopted for the operation of a microgrid when it becomes isolated. Normally, the microgrid operates in interconnected mode with the medium voltage network; however, scheduled or forced isolation can take place. In such conditions, the microgrid must have the ability to operate stably and autonomously. An evaluation of the need of storage devices and load shedding strategies is included in this paper.**

***Index Terms*—Dynamic response, energy storage, frequency control, microgrid, power system dynamic stability, voltage control.**

I. Introduction

THE need of reducing CO_2 emissions in the electricity generation field, recent technological developments in the microgeneration domain, and electricity business restructuring are the main factors responsible for the growing interest in the use of microgeneration [1], [2]. In fact, the connection of small generation units—the microsources (MS), with power ratings less than a few tens of kilowatts—to low voltage (LV) networks potentially increases reliability to final consumers and brings additional benefits for global system operation and planning, namely, regarding investment reduction for future grid reinforcement and expansion.

In this context, a MicroGrid (MG) can be defined as an LV network (e.g., a small urban area, a shopping center, or an industrial park) plus its loads and several small modular generation systems connected to it, providing both power and heat to local loads [combined heat and power (CHP)]. The Consortium for Electric Reliability Technology Solutions (CERTS) initiated the research on the impact of connecting large amounts of distributed energy resources (DER) to LV networks in order to enhance the reliability of the electric power system and developed the MG concept [1]. The MG is intended to operate in the following two different operating conditions.

- *Normal Interconnected Mode*—the MG is connected to a main MV network, either being supplied by it or injecting some amount of power into the main system.
- *Emergency Mode*—the MG operates autonomously, in a similar way to physical islands, when the disconnection from the upstream MV network occurs.

A. General Overview

It will not be common to find fully controllable synchronous generators in an MG, which are normally responsible for voltage and frequency control in conventional power systems. Most MS technologies that can be installed in an MG are not suitable for direct connection to the electrical network due to the characteristics of the energy produced. Therefore, power electronic interfaces (dc/ac or ac/dc/ac) are required. Inverter control is thus the main concern in MG operation. In [3] and [4], a control scheme based on droop concepts to operate inverters feeding a standalone ac system is presented. This concept was further developed in this research (using two different inverter control schemes) to allow for MG islanded operation. The feasibility of this operational concept has been preliminarily described by the authors in [5].

Fault events that may lead to islanding of a distribution system are discussed in [6] assuming, however, that the MG (related in this case to an MV distribution system) comprises synchronous generators and grid power electronic interfaced generation units. In [7] and [8], the behavior of DER connected to distribution networks has also been addressed. However, the dynamics of the primary energy sources has not been considered, not allowing to obtain the full picture of the MG long-term dynamic behavior, which is largely influenced by the MS dynamics.

The feasibility of the MG islanding mode concept was laboratory tested in a prototype installed in the National Technical University of Athens (NTUA), which comprises a photovoltaic (PV) generator, battery energy storage, loads, and a controlled interconnection to an LV grid [9]. The converters used to couple the PV and the battery storage to the LV grid allow MG operation either in an LV grid interconnected mode or under islanded conditions. Also, experimental tests for islanding and synchronization were presented in [9].

The work described in this paper regards the evaluation, through numerical simulation, of the inverter-fed MG dynamic behavior under islanded operation for different load conditions and using two different control strategies. The impact of considering the primary energy source dynamics and the inverters contributions to faults are issues addressed in this paper. The robustness of the tested control strategies was evaluated for large disturbances taking place in the MV network, followed by a forced islanding of the MG. Since there is little inertia in the MG, and MS have small time constants, a combination of

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The authors are with the INESC Porto—Instituto de Engenharia de Sistemas e Computadores do Porto and FEUP—Faculdade de Engenharia da Universidade do Porto, Porto, Portugal (e-mail: jpl@fe.up.pt; cmoreira@inescporto.pt; agm@inescporto.pt).

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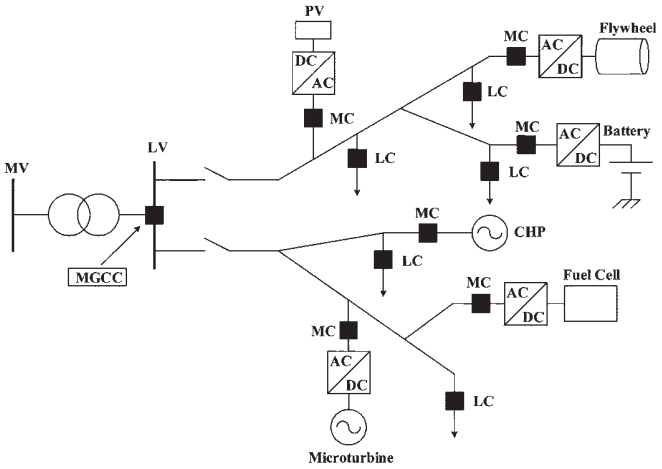


Fig. 1. MG architecture, comprising MS, loads, and control devices.

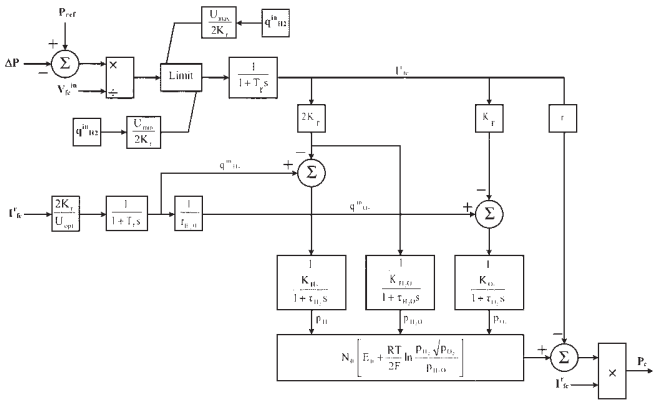


Fig. 2. SOFC block diagram model.

load shedding strategies and the use of storage devices were investigated in order to avoid large frequency and voltage excursions during the operating emergency mode conditions.

MatLab Simulink and its libraries (mainly the *SimPowerSystems* toolbox) were employed in order to develop a simulation platform suitable for identifying MG control requirements and evaluating MG dynamic behavior under several operating conditions. Different MS technologies were modeled and are considered to operate together in the simulation platform.

II. MG Architecture

The MG concept adopted in this research involves an operational architecture, developed within the EU R&D Microgrids project [2], [10], which is presented in Fig. 1. It comprises an LV network, loads (some of them interruptible), both controllable and noncontrollable MS, storage devices, and a hierarchical-type management and control scheme supported by a communication infrastructure used to monitor and control MS and loads.

The MG is centrally controlled and managed by a MicroGrid Central Controller (MGCC) installed at the MV/LV substation. The MGCC includes several key functions (such as economic managing functions and control functionalities) and heads the hierarchical control system. At a second hierarchical control level, controllers located at loads or at groups of loads [load controller (LC)] and controllers located at MS [microsource controller (MC)] exchange information with the MGCC that manages MG operation by providing set-points to both LC and MC. LC serve as interfaces to control loads through the application of an interruptibility concept that includes local load shedding schemes in emergency situations; MC control active and reactive power production levels at each MS.

The amount of data to be exchanged between network controllers is small, since it includes mainly messages containing set-points to LC and MC, information requests sent by the MGCC to LC and MC about active and reactive powers, and voltage levels and messages to control MG switches. Also, the short geographical span of the MG may aid establishing a communication infrastructure using low-cost communications. The adoption of standard protocols and open technologies allows designing and developing modular solutions using off-the-shelf, low-cost, widely available, and fully supported hardware and software components. These solutions provide flexibility and scalability for future low-cost implementations.

III. Dynamic Modeling of Components

A set of models capable of simulating the response of the MG under several conditions was developed in order to analyze MG dynamic behavior.

A. Microsource Modeling

Several MS models, able to describe their dynamic behavior, have been developed from available literature, which include fuel-cells, microturbines, wind generators, and photovoltaic arrays.

For illustration purposes, some details on the dynamic model developed for the solid oxide fuel-cell (SOFC) are given next. The fuel-cell includes a fuel processor that converts the used fuel in hydrogen, a power section, where chemical reactions take place, and a power conditioner that converts dc to ac power. The SOFC model adopted assumes several simplifications, such as fuel gases are considered to be ideal, it is sufficient to define only one single pressure value in the interior of the electrodes, the temperature in the fuel-cell is presumed to be always stable, only ohmic losses are considered, assuming that the working conditions are far away from the upper and lower extreme values of current, and the Nernst equation is assumed to be applicable. The complete model can be seen in the block diagram in Fig. 2. A complete description on the SOFC dynamic model and its parameters can be found in [11] and [12].

The GAST dynamic model [11] was adopted for the primary unit of microturbines, since these units are small simple-cycle gas turbines. Both high-speed single-shaft units (with a synchronous machine) and split-shaft units (using a power turbine rotating at 3000 rpm and a conventional induction generator connected via a gearbox) were modeled. The single-shaft microturbine (SSMT) requires an ac/dc/ac converter for grid connection.

A wind generator was also included in the library of MS using for that purpose an induction generator directly connected to the network and represented by a fifth-order model, available in *MatLab Simulink* toolboxes.

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Concerning the PV generator, it was assumed that the array is always working at its maximum power level for a given temperature and irradiance. Basically, it is an empirical model based on experimental results as described in [13], where a detailed description on MS modeling adopted in the MG project can also be found.

B. Storage Devices Modeling

Due to the large time constants of the responses of some MS, such as fuel-cells and microturbines, storage devices must be able to provide the amount of power required to balance the system following disturbances and/or significant load changes.

Considering the time period of interest for analyzing MG dynamic behavior, storage devices, such as flywheels and batteries, are modeled as constant dc voltage sources using power electronic interfaces to be coupled with the electrical network (ac/dc/ac converters for flywheels and dc/ac inverters for batteries). These devices act as controllable ac voltage sources (with very fast output characteristics) to face sudden system changes such as in load-following situations. In spite of acting as voltage sources, these devices have physical limitations and thus a finite capacity for storing energy. The active power needed to balance generation and consumption inside the MG is injected into the LV grid using a proportional to frequency deviation control approach (with a specified droop characteristic).

C. Inverter Modeling

Two kinds of control strategies may be used to operate an inverter. The inverter model is derived according to the following control strategies.

- *PQ inverter control:* the inverter is used to supply a given active and reactive power set-point.
- *Voltage source inverter (VSI) control:* the inverter is controlled to "feed" the load with pre-defined values for voltage and frequency. Depending on the load, the VSI real and reactive power output is defined.

In [14], more details on these control strategies can be found. It must be highlighted that, when analyzing the dynamic behavior of the MG, inverters are modeled based only on their control functions so that fast switching transients, harmonics, and inverter losses are neglected. This is the general procedure adopted, as described in [3], [6]–[8], [14], and [15].

1) PQ Inverter Control: The PQ controlled inverter operates by injecting into the grid the power available at its input. The reactive power injected corresponds to a pre-specified value, defined locally (using a local control loop) or centrally from the MGCC.

The PQ inverter control is implemented as a current-controlled voltage source, as shown in Fig. 3. Current components in phase ($i_{\rm act}$) and quadrature ($i_{\rm react}$) with the inverter terminal voltage are computed based on a method presented in [9] for power calculation in single-phase inverters. Power variations in the MS induce a dc-link voltage error, which is corrected via the PI-1 regulator by adjusting the magnitude of the active current output delivered to the grid. The reactive power output is controlled via the PI-2 regulator by adjusting the magnitude of the inverter reactive current output. This inverter can be operated with a unit power factor or receive a set-point (locally or from the MGCC) for the output reactive power.

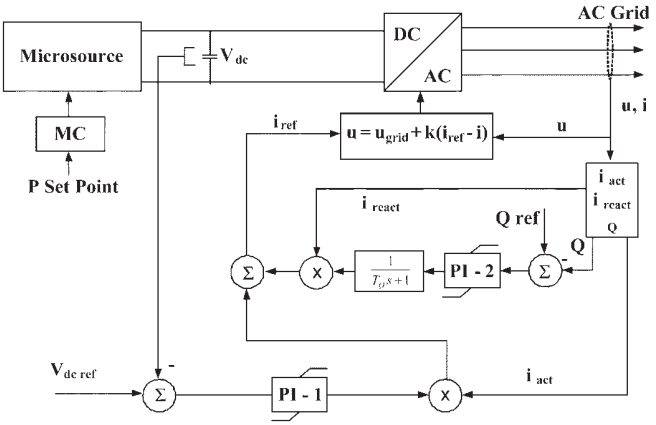


Fig. 3. PQ inverter control system.

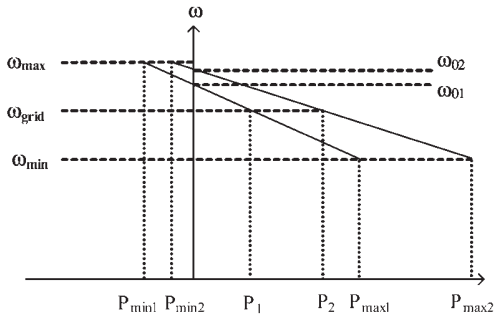


Fig. 4. Frequency versus active power droops.

2) VSI Control: The VSI emulates the behavior of a synchronous machine, thus controlling voltage and frequency on the ac system [3], [4], [9]. The VSI acts as a voltage source, with the magnitude and frequency of the output voltage controlled through droops, as described in the following equations:

$$w = w_0 - k_P \times P$$
$$V = V_0 - k_Q \times Q \tag{1}$$

where P and Q are the inverter active and reactive power outputs, k_P and k_Q are the droop slopes (positive quantities), and ω_0 and V_0 are the idle values of the angular frequency and voltage (values of the inverter angular frequency and terminal voltage at no load conditions).

When a VSI is interconnected with a stiff ac system, characterized by an angular frequency $\omega_{\rm grid}$ and terminal voltage $V_{\rm grid}$, the voltage and frequency references are externally imposed [9]. In this case, the desired output powers P_1 and Q_1 can be obtained in the VSI output by adjusting the idle values of the angular frequency and voltage as follows (see Fig. 4):

$$w_{01} = w_{\rm grid} + k_P \times P_1$$
$$V_{01} = V_{\rm grid} + k_Q \times Q_1. \tag{2}$$

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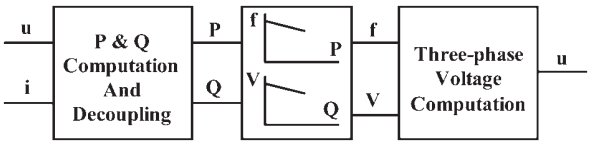


Fig. 5. VSI model.

If a cluster of VSI operates in a standalone ac system, frequency variation leads automatically to power sharing, such that for a system with n VSI, the following equality stands:

$$\Delta P = \sum_{i=1}^{n} \Delta P_i \tag{3}$$

with ΔP_i being the power variation in the ith VSI. The frequency variation can be computed as

$$\begin{aligned} \Delta w &= w_{0i} - k_{Pi} \times P_i - [w_{0i} - k_{Pi} \times (P_i + \Delta Pi)] \\ &= k_{Pi} \times \Delta Pi. \end{aligned} \tag{4}$$

Similar considerations can be made for the voltage/reactive power VSI control mode based on droops [3], [4]. However, as voltage has local characteristics, network cable impedances do not allow a precise sharing of reactive power among VSI.

A three-phase balanced model of a VSI implementing the described droop concepts was derived from a single-phase version presented in [16] and shown in Fig. 5. A complete description on VSI modeling can be found in [16] and [17]. The VSI terminal voltage and current are measured in order to compute active and reactive powers. This measuring stage introduces a delay for decoupling purposes. The output voltages are the reference signals that control the VSI switching sequence using a PWM modulation technique.

In terms of standalone ac system operation, this control principle allows the VSI to react to system disturbances (for example, load or generation changes) based on information available at its terminals [4]. In this way, the operation of a standalone ac system like an MG does not rely on fast communications between MS controllers, which could be impractical [3]. However, a communication infrastructure will be available in the MG, with the purpose of allowing an optimal management, not requiring fast communication capabilities.

3) Inverter Control During Transient Overloads and Short Circuits: Inverter overcurrents can be caused by transient overloads (due to the connection of a large amount of load in islanded mode) or by short circuits.

When moving to islanded operation or when a large load is connected during islanded operation, the initial high imbalance between local load and generation may lead to large frequency deviations and transient overload of the VSI, since this unit has a fast response to this type of situations. In order to overcome this problem, the following two solutions were adopted.

- Allow a temporary disconnection of less important loads (load shedding activated by under-frequency relays);
- Up-rate the VSI, allowing an overload situation during a certain time interval (at least greater than the one required for load shedding activation).

Due to the nature of the control of PQ inverters, they are not significantly affected by transient phenomena like load changes or power variations in renewable DER.

Conventional power plants comprising synchronous generators directly connected to the network provide large short-circuit currents, which are very helpful for fast and efficient fault detection and elimination. However, in an MG where generation units are mainly connected to the grid through power electronic interfaces, it is difficult to obtain high fault currents. Solid state switching devices used in inverters are selected based on voltage, current carrying capability (under certain cooling conditions for a defined switching frequency) and safe operating areas. The islanded system can ride through short-circuits if there is sufficient oversizing of power electronic interfaces, since they have no thermal short-term overcurrent capabilities, in contrast to synchronous generators. At the same time, a novel protection scheme for the MG must be developed using different types of relays and section breakers instead of conventional fuses. Accordingly, the following considerations are in order.

- The VSI was selected to be up-rated in order to provide a significant contribution to short-circuit currents (ranging from 3–5 p.u.) due to conventional overcurrent protection devices.
- PQ inverters can provide only a small amount of short circuit current (1.5–2 p.u.).

After a short-circuit, the time interval in which large current outputs are absorbed from the VSI is dependent on the impact caused by the dynamics of induction machines (operating as motors or generators). Induction machines can recover from short-circuits if the stability limit is not over-passed and enough reactive power is provided by external sources. In this case, the VSI will provide reactive power within the specified current limits and this behavior will be sustained until the induction machines recover. Thus, it is also important that the VSI are able to sustain overcurrents for a time interval larger than the one required for fault clearance.

The PQ inverter control scheme allows a simple control over the output inverter current during short-circuit conditions by limiting the total gain of the PI controllers shown in Fig. 2. Acting as a voltage source, the output current of a VSI tends to be very high (similarly to what happens in a conventional synchronous machine). In order to limit its output current, a control technique such as the one presented in Fig. 2 is used. The main difference is that in this case, the current reference has a maximum peak value dependent on the characteristics of the solid-state switches, and its frequency is imposed by inverter frequency/active power droop.

D. Network and Load Modeling

In this paper, the evaluation of the feasibility of MG islanded operation was performed through the analysis of the LV network dynamic behavior considering only three-phase balanced operation, despite the fact that this is not the most common situation in LV distribution networks. Two load types were considered: constant impedance loads (dependent on frequency and voltage) and motor loads (induction motor with nominal power ranging

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between 3 and 10 kW). Electrical parameters of motor loads are typical values available in *MatLab Simulink SimPowerSystems* toolbox. As will be shown, load characteristics greatly influence the dynamic behavior of the MG, mainly under short-circuit conditions.

Controllable loads in the MG, available for load shedding purposes, have also been modeled. The amount of load to be shed is defined based on the amplitude of frequency deviation. In this study, motor loads have not been considered as sheddable loads.

IV. MG Control for Islanded Operation

Islanding of the MG can take place by unplanned events like faults in the MV network or by planned actions like maintenance requirements. In this case, the local generation profile of the MG can be modified in order to reduce the imbalance between local load and generation and reduce the disconnection transient [6]. In the presence of unplanned events like faults, MG separation from the MV network must occur as fast as possible. However, the switching transient will have great impact on MG dynamics.

If there are no synchronous machines to balance demand and supply, through its frequency control scheme, the inverters should also be responsible for frequency control during islanded operation. In addition, a voltage regulation strategy is required; otherwise, the MG might experience voltage and/or reactive power oscillations [18]. If a cluster of MS is operated within an MG and the main power supply (the MV network) is available, all the inverters can be operated in PQ mode, because there are voltage and frequency references. In this case, a sudden disconnection of the main power supply would lead to the loss of the MG, since there would be no possibility for load/generation balancing and therefore for frequency and voltage control. However, by using a VSI to provide a reference for voltage and frequency, it is thus possible to operate the MG in islanded mode, and a smooth moving to islanded operation can be performed without changing the control mode of any inverter [9]. As previously described, the VSI can react to network disturbances based only on information available at its terminals. This working principle of a VSI provides a primary voltage and frequency regulation in the islanded MG. After identifying the key solution for MG islanded operation, two main control strategies are possible: a) single master operation (SMO) or b) multi master operation (MMO). In both cases, a convenient secondary load-frequency control during islanded operation must be considered to be installed in controllable MS.

A. Single Master Operation

A general overview of an SMO is shown in Fig. 6. In this case, a VSI—acting as master—can be used as voltage reference when the main power supply is lost being that all the other inverters operated in PQ mode (slaves). Local MS controllers can receive information from the MGCC about the generation profile and control accordingly the corresponding MS.

B. Multi Master Operation

As described in Fig. 7, in a multi master approach, several inverters are operating as VSI with pre-defined frequency/active power and voltage/reactive power characteristics. The VSI can

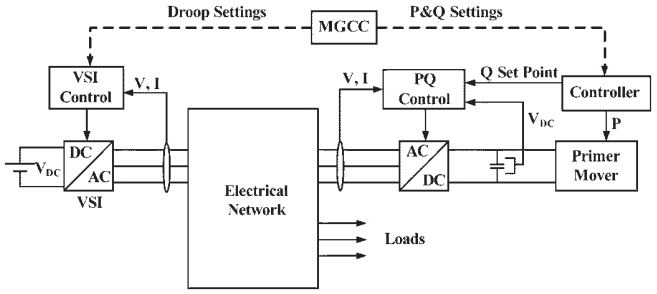


Fig. 6. Control scheme for SMO.

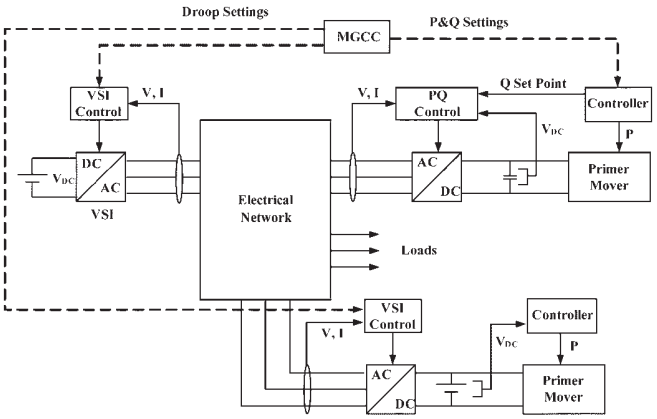


Fig. 7. Control scheme for MMO.

be coupled to storage devices (batteries or flywheels) or to MS with storage devices in the dc-link (batteries, super capacitors), which are continuously charged by the primary energy source. Eventually, other PQ-controlled inverters may also coexist. The MGCC can modify the generation profile by changing the idle frequency of VSI and/or by defining new set points for controllable MS connected to the grid through PQ-controlled inverters.

C. Secondary Load-Frequency Control

Equation (4) shows that the VSI active power output is proportional to the MG frequency deviation. If the MG frequency stabilizes in a value different from the nominal one (due to the use of only proportional droop controls), storage devices would keep on injecting or absorbing active power whenever the frequency deviation differs from zero. This should be only admissible during transient situations, where storage devices are responsible for the primary load-frequency control. Storage devices (batteries or flywheels with high capabilities for injecting power during small time intervals) have a finite storage capacity and can be loaded mainly by absorbing power from the LV grid. Therefore, correcting permanent frequency deviations during any islanded operating conditions should then be considered as one of the key objectives for any control strategy.

In order to promote adequate secondary control aiming to restore frequency to the nominal value after a disturbance, two main strategies can be followed: local secondary control, by using a PI controller at each controllable MS (Fig. 8) or centralized secondary control mastered by the MGCC. In both cases, target values for active power outputs of the primary energy sources are defined based on the frequency deviation error [19].

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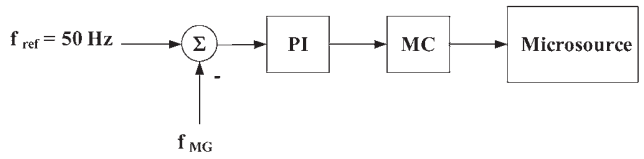


Fig. 8. Local secondary load-frequency control for controllable microsources.

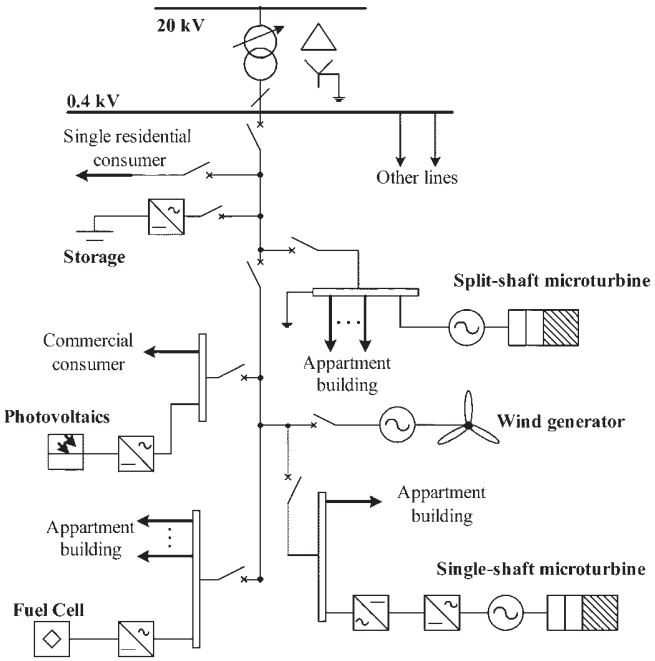


Fig. 9. LV test network.

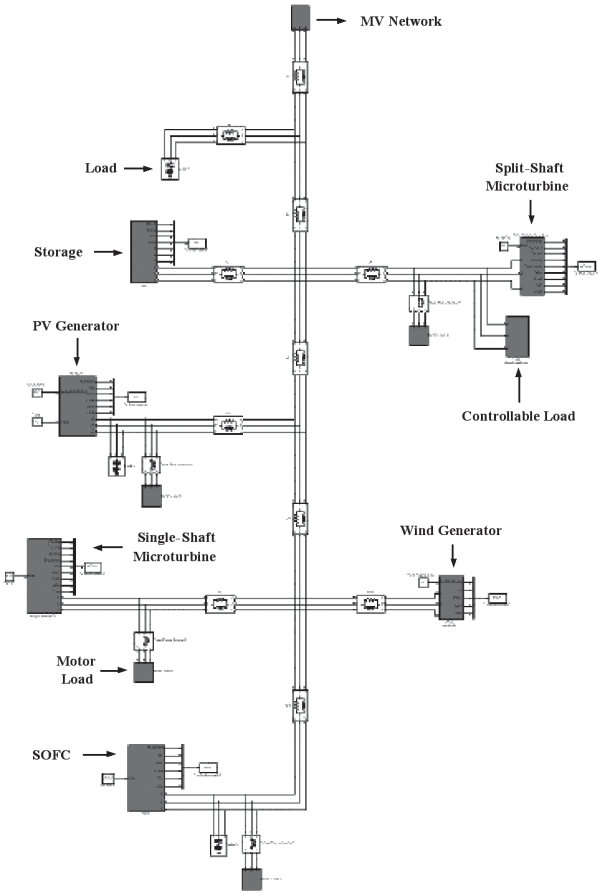


Fig. 10. LV network for the *Matlab Simulink* simulation platform.

For SMO, the target value is directly an active power set-point sent to the prime mover of a controllable MS (see Fig. 2), while for MMO, the target value can be both an active power set-point for a controllable MS connected to a PQ inverter or a new value for the idle frequency of a VSI.

V. Simulation Platform

A simulation platform under the *MatLab Simulink* environment was developed in order to evaluate the dynamic behavior of the MG. An LV test network was built based on a system defined by NTUA and used to test both presented control strategies (SMO and MMO). A detailed description of the test system and its electrical parameters can be found in [20]. Fig. 9 shows the MG single-line diagram. The implementation of the LV test network under the *MatLab Simulink* environment is shown in Fig. 10.

VI. Results and Discussion

Disconnection from the upstream MV network and load-following in islanded operation was simulated in order to understand the dynamic behavior of the MG and to evaluate the effectiveness of the developed control approaches. MG islanding can occur in two different situations (scheduled islanding and forced islanding) with possible faults taking place in the MV or LV grids. Due to space limitations, only results from forced islanding, due to faults in the MV grid, are described next. In this scenario, the SOFC and the SSMT are supposed to be the controllable MS used for the secondary load-frequency control using the scheme depicted in Fig. 8. Two load/generation scenarios using the single master operation strategy with a VSI and MMO were tested, with the corresponding results described next.

A. Single Master Operation

The scenario is characterized by a local load of 80 kW (65% of impedance type and 35% of induction motor type) and a local generation of 50 kW (high load scenario). A fault in the MV side occurred at $t = 10$ s followed by MG islanding 100 ms after.

Due to the large initial frequency deviation, a certain amount of load is automatically shed through the activation of under-frequency load shedding relays in order to aid frequency restoration. This load is later reconnected in small load steps, to avoid load disconnection by activating the under-frequency load shedding relays. Load reconnection in small steps allows the evaluation of the MG behavior under load-following conditions (see Fig. 11).

The principles described for current limitation in inverters can also be observed in Fig. 12 for the VSI for a PQ-controlled inverter (SOFC inverter).

The reacceleration of motor loads leads to a relatively slow ramping up of the voltage after fault clearing. Motor loads and asynchronous generators absorb high currents after disturbance

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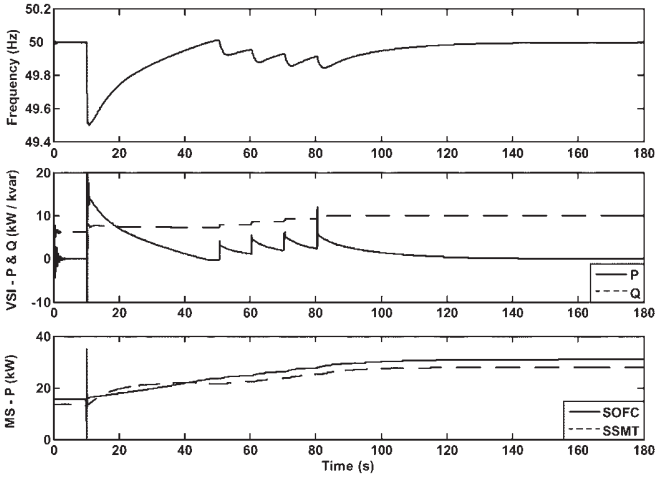


Fig. 11. MG frequency, VSI active and reactive power, and SOFC and SSMT active power (high load scenario).

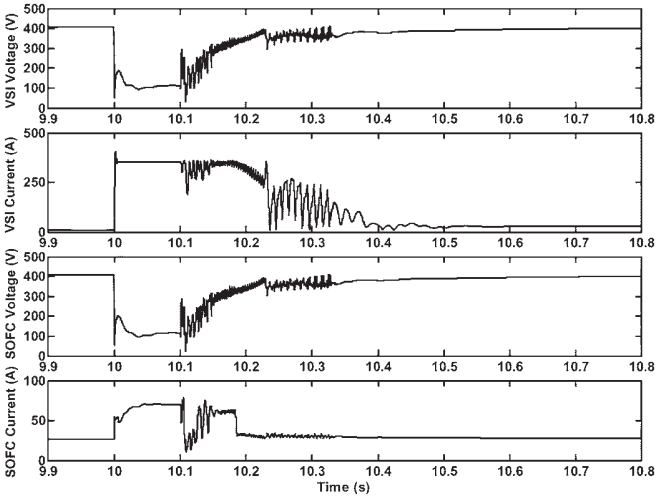


Fig. 12. Detail of the VSI and SOFC terminal voltages and currents during and subsequent to the MV fault and islanding procedure (high load scenario).

elimination, which lead to the activation of the short-circuit current limitation function in the VSI, as depicted in Fig. 12. After fault elimination, there is a transient period for restoring normal operation of asynchronous generators, which also contributes to the impact on inverter current and voltage, as it can be observed in Fig. 12 after $t = 10.1$ s. Thus, a slower restoration of the MG voltage is observed. In this case, no motor loads were disconnected because all of them were able to successfully reaccelerate after fault elimination. Asynchronous generators (the split-shaft microturbine and the wind generator) were not disconnected in order not to lose generation.

In Fig. 13 are shown the time evolution of the terminal voltages in the VSI and SOFC and the generated reactive power in the SOFC and SSMT. The voltage/reactive power droop is the only mean used for voltage control during islanded operation. Thus, it is responsible for compensating reactive load transients as can be observed in Fig. 11. Reactive power in PQ-controlled inverters is kept constant (reactive power support) due to the control scheme described in Fig. 3.

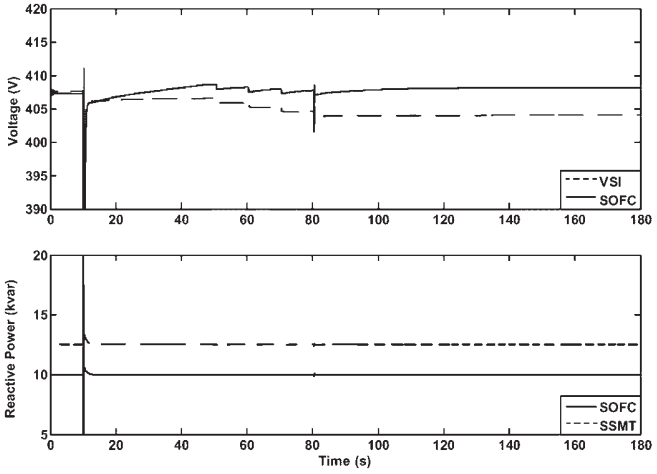


Fig. 13. Voltages and reactive powers (high load scenario).

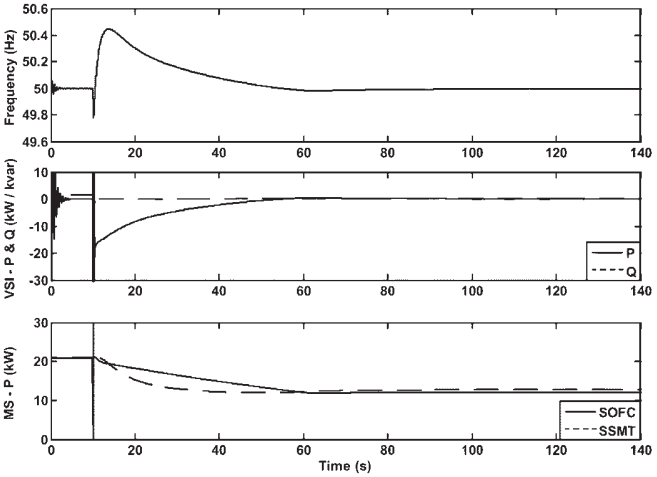


Fig. 14. MG frequency, VSI active and reactive power, and SOFC and SSMT active power (low load scenario).

A low load scenario with power being exported to the MV network was also tested. The scenario is characterized by a local load of 56 kW (70% of impedance type and 30% of induction motor type) and a local generation of 73 kW. Fault conditions are those previously described.

The MG control strategies applied are valid for any operating conditions. The key issue for successful MG islanded operation is the management of load shedding and the state of charge of the storage devices. In this case, the MGCC should manage the state of charge of the storage so that it absorbs the power generation surplus after an unpredicted system islanding, as can be observed in Fig. 14. In both scenarios (high and low load conditions), a slow frequency restoration process that results from the large MS time constants can be observed. During this phenomenon, the VSI is responsible for a continuous matching between load and generation.

B. Multi Master Operation

In order to analyze the initial dynamic behavior of an MG under a multi master approach, the dynamics of the primary energy sources can be neglected due to the high storage capacity

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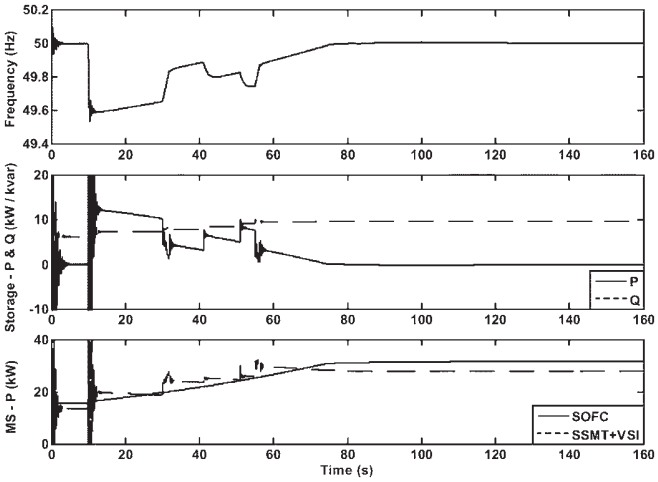


Fig. 15. MG frequency, VSI active and reactive power, and SOFC and SSMT active power (high load scenario).

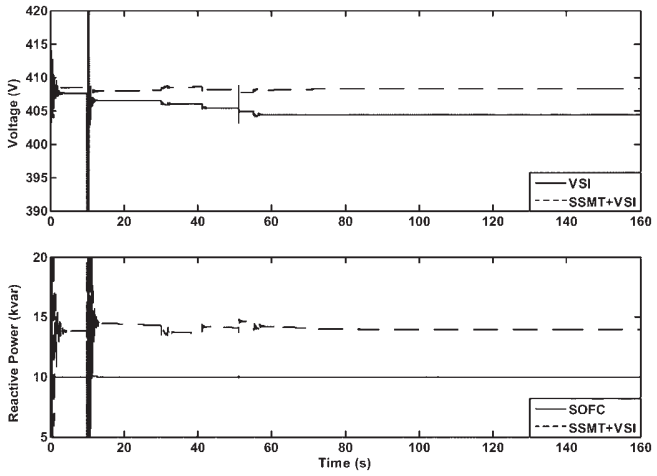


Fig. 16. Voltages and reactive powers.

assumed to be installed at their dc link [13]. Some microturbine manufactures install batteries on its dc link in order to provide black start capability and allow operation under islanded conditions [21]. In this case, it was assumed that the SSMT has a storage device installed on its dc link, and in this way, the inverter used to connect it to the LV grid can be operated as a VSI. In the high load scenario described for the single master, operation was used in this simulation.

Due to the existence of a higher storage capacity, system frequency is restored faster to its nominal value. The SSMT with storage devices in its dc link increases its output power in three steps: the first one corresponds to the contribution after MG islanding, which occurs due to the control scheme used in the VSI. The second and the third ones occur at $t = 30\,\mathrm{s}$ and at $t = 55\,\mathrm{s}$, respectively, as can be observed in Fig. 15. They were defined in advance based on the information about the load and generation imbalance with the MG before islanding takes place. The SOFC power output was controlled as depicted in Fig. 5 in order to restore MG frequency to the nominal value.

In this case, MG voltage support is assured by the voltage/reactive power droop controllers installed in the two VSI. As it can be observed in Figs. 15 and 16, there are no reactive power oscillations among MS, and MG stability is maintained. Proportional voltage control through droops is sufficient to maintain voltage levels within acceptable limits. However, reactive power sharing is not performed according to droops (similarly to what happens with active power) due to cable impedances.

VII. Conclusion

This paper describes and evaluates the feasibility of the control strategies needed for MG islanded operation, where no directly grid-connected synchronous generators are used. From the analysis performed, the following main conclusions can be derived.

- Simulation results indicate that the forced islanding of the MG can be performed safely under several different power importing and exporting conditions.
- A fast elimination of a fault in the MV network is required; otherwise, motor loads may compromise the transition to islanded operation. Undervoltage load-shedding of large motor loads and induction generators could be an interesting possibility.
- Simulation results also indicate that both control strategies tested—SMO and MMO—are effective and ensure efficient and stable MG operation.
- The results obtained suggest that the management of storage devices are absolutely essential to implement successful control strategies for MG operation in islanded mode with the load shedding procedure assuming also very high importance to avoid fast and long frequency deviations.

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