ECCE 2017

IEEE ENERGY CONVERSION CONGRESS & EXPO

Cincinnati OHIO October 1–5

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PROCEEDINGS

IEEE ENERGY CONVERSION CONGRESS & EXPOSITION®

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Welcome from General Chair: Andy Knight

It is my pleasure to welcome you to Cincinnati for the 9th Annual IEEE Energy Conversion Congress & Exposition ECCE 2017, sponsored by the IEEE Power Electronics Society (PELS) and the IEEE Industry Applications Society (IAS).

As the world's leading technical conference and exposition for energy conversion solutions, ECCE provides a unique opportunity to engineers, researchers, students, and other professionals from the broad spectrum of energy conversion for the exchange of technical knowledge, networking, and exposure to the latest technology trends. ECCE is unique in our emphasis on integrated systems, presenting the best in contemporary energy conversion research alongside innovations from more traditional component topics.

As we are in Ohio, close to the home of the Wright brothers' pioneering efforts in aviation, ECCE 2017 features an emphasis on the challenges in aerospace electrification. This is highlighted in our plenary keynote speeches from Robert Bayles of UTC Aerospace Systems, Dr. Nateri K. Madavan of NASA and Dr. Huang Hao from GE Aviation Systems. We are extremely fortunate to have these distinguished leaders from industry to share their visions and wisdom with us.

At ECCE 2017, as we build on previous successes in our technical program, we have also made efforts to expand our professional program. This year, the technical program features 864 technical presentations which are selected from over 1500 digests submitted from across the globe. Technical papers are organized in 141 oral sessions across 10 time-slots and 29 poster sessions across 3 poster dialog sessions.

The professional program at ECCE 2017 begins on Sunday, with 11 tutorial sessions that offer an in-depth discussion of important and complex technical topics that combine practical application with theory. After the Monday plenary session, we have expanded our special sessions to offer applied and practical topics throughout the first three days of the conference. Special session topics include: Workforce Development and Careers in Power Electronics from the US Power Electronics Industry Collaborative; a joint session between IAS and KIPE on developments in Energy Conversion in Korea; Advances in Magnetic Materials. Recognizing and taking advantage of our location in Cincinnati, Wednesday features a series of four special sessions on challenges facing aerospace electrification. Wednesday also sees a session on power electronics in low inertia electrical systems, and two joint sessions on the interface between Power Electronics and Power Systems. Smart Grid initiatives are also emphasized by technical tours to the Duke Energy Envision Center. A new focus of the professional program this year is our support of Women in Engineering. There is a WIE function on Monday evening, the traditional PELS WIE breakfast on Wednesday and a family space reserved for any attendees who may be traveling with small children.

We are very pleased to acknowledge the support of Wolong Electric Group Co. and GE Aviation Systems as Platinum Partners for ECCE 2017. Both our PlatinumPartners will join our other exhibitors and partners in the Exhibition Hall on Monday and Tuesday. The exhibitors will showcase their state-of-the-art tech-nologies, products, and solutions, creating a highly interactive networking environment. This year sees the return products and services presentations to theExpo floor, together with the poster sessions and student demonstrations.

For many of our attendees, the ECCE conference is like a homecoming event where you can catch up with old friends and meet new ones. One of the changes that people may see this year is the co-location of the Industry Applications Society Annual Meeting. ECCE and the IAS AM will operate as separate conferences, with their own technical and professional programs. However, IAS AM attendees will join us at our social functions. We look forward to new networking opportunities with our IAS colleagues at the Welcome Reception, Expo Opening Reception, Industry Night Out, and Awards Luncheon. For those new to ECCE, thank you for joining us and we hope you can come to our first timer session just before the Sunday Welcome Reception event.

ECCE 2017 provides two Creative Digressions Lounges, spaces that do not need a reservation and provide a place for colleagues and friends to brainstorm on a few ideas generated during the conference, with paper boards, markers, and of course coffee and refreshments. Additionally, ECCE 2017 has three rooms that may be booked by industry organizations, exhibitors or alumni groups for private meetings.

I would like to express my utmost gratitude to the members of the organizing committee, the technical program committee, the steering committee, and Courtesy Associates / SmithBucklin, who with hard work and selfless dedication have made possible this event. I would like to thank PELS and IAS for their sponsorship and stewardship, and the generous support of all our corporate partners. I would like to thank each and every one of you as a presenter, an attendee, an exhibitor, a volunteer, or any combined role of the above for your contribution and participation.

Once again I welcome you to ECCE 2017,

Andrew M Knight

Andy Knight
General Chair IEEE ECCE 2017

Welcome from Technical Program Chairs

Electrical energy conversion is driving forward not only the industry, but also our society. We transform solar, wind, wave, heat, fuel energy into electrical energy. We can then store this in batteries, or transform it into mechanical energy through motors, or into light energy via lighting systems, or supply power converters. The whole process represents industrial connections and collaboration at its best. Since the start of the ECCE conference series in 2009, there has been a continuous growth in the numbers of technical papers submitted, the topics covered and worldwide attendance representation. We are pleased that you have selected ECCE to be one of the top events and conferences in the world and greatly appreciate your support as an author and/or attendee. In 2017, for the 9th edition of ECCE, there have been submitted 1504 digests – this is in line with the average achieved in the last three years of the event. Following the peer review process, a total of 864 papers have been accepted and scheduled into 16 parallel oral sessions and 3 poster sessions. An acceptance ratio of 57.5% shows that all research topics and results that will be presented at ECCE 2017, have earned the right to publication through a good competition. As a tradition started few years back, there are 10 presentation-only special sessions that are scheduled throughout the week.

Each submitted digest has been peer reviewed by three to five experts in the field. It is here, that we want to express our appreciation and big thanks for all the experts from around the world, who by volunteering to be part of the review process, make this conference a successful event. On average, we had over 4 reviews per digest. The review process was monitored by the Technical Program Committee (TPC), which is formed by Chairs, Vice Chairs, and Topic Chairs. Based on reviewers' comments/observations, the Topic Chairs responsible for that technical sub-track made a proposal for publication to the corresponding Vice Chairs, which proposed a final recommendation to the TPC Chairs. As per the usual procedure, all accepted digests have been discussed in the TPC meeting. As TPC Chairs, we have tried our best to monitor the whole review process, providing guidelines when and if required. Each of the TPC members has his/her responsibilities and a as group we have worked hard to ensure a uniform acceptance standard across all the tracks. The allocation of an accepted digest to a certain topic session and the mode of presentation, i.e. oral or poster, is the result of creating a balanced program. This should allow the audience to attend presentations that are in the same specific field, but spread on several days in oral sessions, or discuss all technical details and meet the authors in poster sessions. All papers presented at ECCE 2017, will be uploaded to IEEE Xplore Digital Library and made available to the world research community. Please reference this official conference policy if your institution requires conference attendance justification. Following ECCE 2017, depending on the topics, all presented papers are eligible for submission to IEEE Transactions on Industry Applications or Power Electronics. Please contact for more details the specific technical committee covering the scope of your paper.

On behalf of the entire Technical Program Committee, we strongly trust that you will consider 2017 to be one of the best ECCE events yet. We look forward to seeing you in Cincinnati. Once again, we want to give our gratitude to all of you who have contributed to ECCE2017 as an author, reviewer, TPC member or attendee.

Sincerely,

Emmanuel Agamloh
Advanced Energy, USA

David Dorrell
University of KwaZulu-Natal, South Africa

Ryan Li
University of Alberta, Canada

Mircea Popescu
Motor Design Ltd, UK

Pat Wheeler
University of Nottingham, UK

ECCE 2016 Technical Program Chairs

Welcome from Society Presidents

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On behalf of the IEEE Power Electronics Society and Industry Applications Society, it gives us immense pleasure to welcome you all to Cincinnati to attend the 9th Annual IEEE Energy Conversion Congress and Exposition (ECCE). Considering the growing importance of electrical energy conversion driven by the urgent need to reduce carbon emissions and save energy, the two Societies came together to establish the first ECCE in 2009. The objective was to provide a forum for the exchange of information among students, researchers and practicing professionals in the energy conversion business. ECCE 2017 organizing committee has worked diligently so we can once again bring together both users and researchers of energy conversion systems and sub systems with an emphasis on the content of technical papers and on the quality of the growing exposition.

Whether you are a first time attendee or regular attendee since 2009 or anything in between, we encourage you to enjoy the ECCE experience, create new networks and get involved in the organization of the future ECCE's. The technical committees of the two Societies work hard in consistently delivering an excellent technical program at ECCE. The committees conduct their meetings at various times during ECCE (Please refer to the meeting calendar in the program booklet) and are open to all Society members. If you are not a Society member, please visit the Society booth at the exposition area and become a member. The Society volunteers will be ready to answer any questions you may have.

Many thanks to our ECCE 2017 General Chair Prof. Andy Knight and his dedicated organizing committee who have developed an excellent program that is rich in its technical content with plenty of socializing opportunities. Please make use of this opportunity to network with other professionals in the energy conversion area. It is our hope that all the interactions and technical programs will give you and your organization the tools to advance the field and address the challenges of the industry.

Again, on behalf of both Societies, we welcome you to Cincinnati and wish you a pleasant and productive conference!

H. Alan Mantooth

Alan Mantooth
President
IEEE Power Electronics Society

Tomy Sebastian

Tomy Sebastian
President
IEEE Industry Applications Society

Schedule-at-a-Glance

Saturday, September 30th

5:00PM – 7:00PM **Registration** . . . . *2nd Floor "V"*

Sunday, October 1st

7:00AM – 7:00PM **Registration** . . . . *2nd Floor "V"*

AM Tutorials • 8:00AM – 12:00PM

262	260/261	236	263	264	237/238
T1-1: High Power Medium Frequency Transformer Design Optimization	**T1-2:** Model Predictive Control of High Power Converters and Industrial Drives	**T1-3:** Modeling and Energy Management of Modern Shipboard Power Systems	**T1-4:** DC Arc Fault Detection and Protection in DC Electric Power Systems	**T1-5:** Practical Considerations for the Application of High Power Si and SiC Modules	**T1-6:** Isolated Bi-directional DC/DC Converter Topologies and Control

12:00PM – 1:00PM **Lunch on Your Own**

PM Tutorials • 1:00PM – 5:00PM

263	236	260/261	264	237/238
T2-1: Using Soft-Switching Technology to Design High-Power, High-Current, Isolated, DC/DC Converters that Achieve Low-Cost, High Reliability, and Electromagnetic Compliance	**T2-2:** SiC Power Device Design and Fabrication, And Insertion In Novel MV Power Conversion Systems	**T2-4:** Electrical Machine Analysis Using Free Software	**T2-5:** EMI Issues and Solutions in PWM Converters	**T2-6:** Wireless Power Transfer for Electric Vehicle and Mobile Applications

5:00PM – 5:45PM **ECCE Newcomers** . . . . *Room: 252*

5:30PM – 7:30PM **Welcome Reception** . . . . *Grand Ballroom Pre-function Lobby*

Monday, October 2nd

7:00AM – 7:00PM **Registration** . . . . *2nd Floor "V"*

8:30AM – 10:20AM **Plenary Session** . . . . *Grand Ballroom AB*

10:20AM – 10:50AM **AM Break** . . . . *Greenhouse Pre-function Lobby & South Concourse Alcove*

Oral Sessions • 10:50AM – 12:30PM

200	201	203	204	205	206	207/208	230/31	232	233	236	237/38	260/61	262	263	264
S9: Modeling and Control of Resonant Converters	**S8:** DC/DC Converters I	**S4:** Applications of MMC	**S7:** Multi-Phase DC/AC Converters I	**S10:** Modeling and Control of Power Factor Correction Converters	**S16:** Magnetics I	**S15:** GaN Switching Performance	**S6:** Single-Phase DC/AC Converters I	**S5:** Inductive Power Transfer for EV Charging	**S3:** Dynamic Performance of Power Converters for Renewable Energy	**S1:** Power Conversion for Solar Photovoltaic Systems I	**S2:** Hybrid AC/DC Microgrids	**S14:** Diagnostics and Fault Tolerant Systems in Drives	**S13:** Control of Electric Drives I	**S12:** Axial Flux Machines	**S11:** Induction Machines I

12:30PM – 2:00PM **Lunch on Your Own**

Oral Sessions • 2:00PM – 4:05PM

200	201	203	204	205	206	207/208	230/31	232	233	236	237/38	260/61	262	263	264
S24: Modeling and Control of Multilevel Converters	**SS1:** Workforce Development and Careers in Power Electronics	**S31:** Wireless Power Transfer I	**S21:** Multi-Phase DC/AC Converters II	**S23:** Power Quality Control	**S29:** Magnetics II	**S30:** SiC Converter Applications	**S22:** Single-Phase DC/AC Converters II	**S20:** Control Aspects of Electified Vehicles	**S18:** Power Converter Topologies for Renewable Energy	**S17:** Power Conversion for Solar Photovoltaic Systems II	**S19:** Renewable Impacts in Industrial Microgrids	**S27:** Medium Voltage Drives and High Power Drives	**S28:** Sensorless Drives I	**S25:** Switched Reluctance Machines	**S26:** Induction Machines II

4:15PM – 7:30PM **Expo Hall Reception** . . . . *Exhibit Hall B*

Poster Session 1 • 5:00PM – 7:30PM

Exhibit Hall B

Energy Storage Systems	AC/AC Converters	Reliability, Diagnostics and Fault Analysis of Power Electronics	AC Electrical Machines: Innovative Design Studies	Axial and Transversal Flux Machines	Utility Converters and Power Electronics Transformers	Motor Drives I	Switching Devices I	Electric Vehicle Energy Management	Sensing and Control for Power Converters	Modelling and Control of MMC	Control in Microgrids

Tuesday, October 3rd

7:00AM– 5:30PM **Registration** . . . . . . *2nd Floor "V"*

Oral Sessions • 8:30AM – 10:10AM

200	201	203	204	205	206	207/208	230/31	232	233	236	237/38	260/61	262	263	264
S40: Modeling and Control of Modular Multilevel Converter	**S37:** DC/DC Converters II	**S33:** Power Converters for HVDC Grids	**S36:** Multi-Phase AC/DC Converters	**S39:** Sensorless Methods and State and Parameter Estimation	**S46:** Wide Band Gap Device Reliability	**S45:** GaN Device and Gate Drive	**S38:** Single-Phase Grid Connected Converters	**SS2:** Industry Activities in Korea, Organized in Collaboration with KIPE	**S32:** Harmonic Compensation Techniques for Microgrids	**S35:** Power Conversion for Solar Photovoltaic Systems III	**S34:** Solid State Transformers	**S43:** Sensorless Drives II	**S44:** PM and IPM Motor Drives I	**S41:** Large Synchronous Machines	**S42:** Synchronous Reluctance Machines I

10:10AM– 10:30AM **AM Break** . . . . . . *Greenhouse Pre-function Lobby & South Concourse Alcove*

Poster Session 2 • 10:30AM – 1:00PM

Exhibit Hall B

Datacenters and Telecommunication Applications	Applications of Electric Traction and Propulsion	Multilevel Converters	DC/AC Converters	DC/DC Converters	PV Applications	EMI in Power Converters	Advances in Special Electrical Machines	Induction and Permanent Magnet AC Machines	Motor Drives II	Switching Devices II	Wireless Power Transfer	DC and Hydrid AC/DC Systems

10:30AM– 5:30PM **Exhibit Hall Open** . . . . . . *Exhibit Hall B*

12:15PM – 2:30PM **Lunch**. . . . . . *Exhibit Hall B*

Poster Session 3 • 2:30PM – 5:00PM

Exhibit Hall B

Applications of MMC	Batteries and Wireless EV Charging	AC/DC Converters	Modeling and Control of Multilevel Converters	Modeling and Control of Grid Connected Converters	Power Quality	Stability of Converter Systems	Other Topics in Control, Modeling and Optimization of Power Converters	Analysis Techniques in Electrical Machines	AC Electrical Machines: Performance Estimation	Component Technologies	Renewable Energy and Grid Integration

Wednesday, October 4th

7:00AM – 5:30PM **Registration** . . . . . . *2nd Floor "V"*

7:30AM – 8:30AM **IEEE PELS Women In Engineering Breakfast (WIPELS)** . . . . . . *Room: 211*

Oral Sessions • 8:30AM – 10:10AM

200	201	203	204	205	206	207/208	230/31	232	233	236	237/38	260/61	262	263	264
S54: Design Optimization of Power Converters	**S51:** DC/DC Converter Topologies	**S60:** LED Drivers	**S50:** Control and Modulation of Multi-Phase AC/DC Converters	**S53:** Reliability, Diagnostic, and Faults Analysis in Power Converters I	**SS7:** Power Electronic Meets Power Utilities & Systems	**S59:** Packaging I	**S52:** AC-AC Converters I	**SS3:** Electrical Power for Aviation Applications	**S48:** Droop Control in Microgrids	**S47:** Wind Energy Systems	**S49:** Grid Connected Converter Stability	**S57:** Energy Efficient Motor Drives	**S58:** Induction Motor Drives	**S55:** Thermal and Faults of Electric Machines	**S56:** PM Machines and Windings

10:10AM– 10:30AM **AM Break** . . . . . . *Greenhouse Pre-function Lobby & South Concourse Alcove*

Oral Sessions • 10:30AM – 12:10PM

200	201	204	205	206	207/208	230/31	232	233	236	237/38	260/61	262	263	264
S73: Wireless Power Transfer II	**S67:** Modulation Techniques I	**S64:** LLC Converters	**S66:** Reliability, Diagnostic, and Faults Analysis in Power Converters II	**SS8:** Power Electronic Meets Power Utilities & Systems	**S72:** Packaging II	**S65:** AC-AC Converters II	**SS4:** IOT and Twin for Aviation	**S62:** Power Sharing Techniques in Microgrids	**S61:** Wind Energy Applications	**S63:** DC Circuit Breaker Design	**S68:** Modeling and Control of Grid Connected Converters I	**S71:** PM and IPM Motor Drives II	**S69:** Synchronous Reluctance Machines II	**S70:** Variable Flux PM Machines

12:10PM– 2:00PM **Lunch on Your Own**

Oral Sessions • 2:00PM – 3:40PM

200	201	204	205	206	207/208	230/31	232	233	236	237/38	260/61	262	263	264
S86: Wireless Power Transfer III	**S80:** Modulation Techniques II	**S77:** Resonant DC/DC Converters	**S79:** Reliability, Diagnostic, and Faults Analysis for Power Devices	**SS9:** Power Electronics and Control for Low-Inertia Electrical Systems	**S85:** High Voltage Devices	**S78:** Modular Multilevel Converters (MMC)	**SS5:** Advanced Aircraft Electrification beyond MEAs	**S75:** Droop Sharing Techniques for Microgrid Operation	**S74:** PV Plants and PV Farms	**S76:** Control in DC Microgrids	**S81:** Modeling and Control of Grid Connected Converters II	**S84:** Drive Applications	**S82:** Linear Machines	**S83:** PM Motor Design, Control and Testing

Schedule-at-a-Glance (continued)

Wednesday, October 4th (continued)

3:40PM– 4:00PM **PM Break** . . . . Greenhouse Pre-function Lobby & South Concourse Alcove

Oral Sessions • 4:00PM – 5:40PM

200	201	204	205	206	207/08	230/31	232	233	236	237/38	260/61	262	263	264
S99: Emerging Applications	**S95:** Model Predictive Control of Power Converters I	**S91:** DAB DC/DC Converters	**S94:** Modeling and Control of AC-DC Converters	**SS10:** Magnetic Materials Standards in the Research Environment	**S89:** Datacenters and Telecommunication Applications	**S92:** MMC Modulation and Control	**SS6:** Wide Band Gap Devices for the Aviation Applications	**S90:** Power Electronics in Electrified Vehicles	**S87:** Solar Photovoltaic Technologies	**S88:** Control and Design Techniques for Microgrids I	**S93:** Control of Grid Connected Converter	**S98:** Control of Electric Drives II	**S96:** Thermal Model of Electric Machines	**S97:** PM Machines, Demagnetization, Eccentricity and Losses

6:30PM– 8:30PM **Industry Night Out** . . . . Grand Ballroom AB

Thursday, October 5th

7:00AM – 12:00PM **Registration** . . . . *2nd Floor "V"*

Oral Sessions • 8:30AM – 10:10AM

200	201	204	205	207/208	230/31	232	233	236	237/38	260/61	262	263	264
S113: New Device, Circuit and Control Strategies	**S107:** Model Predictive Control of Power Converters II	**S104:** Multilevel Converters Applications	**S106:** Modeling and Control of DC-DC Converters I	**S112:** SiC Switching I	**S105:** MMC New Topologies	**S103:** Wireless Charging for EV	**S101:** Power Quality of Grid Connected Converters I	**S100:** Other Topics in Renewable Energy Applications	**S102:** Control and Design Techniques for Microgrids II	**S108:** Stability in Power Converters	**S111:** Electric Drives for Wind and Other Renewable Integration	**S109:** High Torque Machines	**S110:** Small PM Motors

10:10AM – 10:30AM **AM Break** . . . . *Greenhouse Pre-function Lobby & South Concourse Alcove*

Oral Sessions • 10:30AM – 12:10PM

200	201	204	205	207/208	230/31	232	233	236	237/38	260/61	262	263	264
S127: Wireless Power Transfer IV	**S121:** Modeling and Control of DC-AC Converters I	**S118:** Multilevel Converters I	**S120:** Modeling and Control of DC-DC Converters II	**S126:** SiC Switching II	**S119:** PFC Converters	**S117:** Modeling and Monitoring of Batteries I	**S116:** Power Quality of Grid Connected Converters II	**S114:** Energy Storage Systems	**S115:** Power Conversion Systems for AC and DC Grids	**S122:** EMI in Power Converters	**S125:** Electric Drives for Aerospace and Traction Applications	**S123:** High Speed Machines	**S124:** Noise, Vibration, Short Circuit of Electric Machines

12:10PM – 2:00PM **Awards Luncheon** . . . . *Grand Ballroom AB*

Oral Sessions • 2:00PM – 3:40PM

200	201	204	205	207/208	230/31	232	233	236	237/38	260/61	262	263	264
S134: Isolated DC/DC Converters	**S136:** Modeling and Control of DC-AC Converters II	**S133:** Multilevel Converters II	**S135:** Grid Synchronization Techniques	**S141:** Device Self Sensing Techniques	**S132:** Single-Phase AC/DC Converters	**S131:** Modeling and Monitoring of Batteries II	**S130:** Grid Connected Inverters and LCL Filter Design	**S129:** Wave Energy System	**S128:** Hybrid Energy Systems	**S137:** Testing, Measurement, and Validation of Power Converters	**S140:** PM and IPM Motor Drives III	**S139:** General Topics in Electrical Machines	**S138:** Motors for Transportation

Organizing Committee

Technical Program

Technical Program Co-Chairs
Emmanuel Agamloh
Dave Dorrell
Ryan Li
Mircea Popescu
Pat Wheeler

Publication
Xu She

Professional Program

Industry Liaison
Uday Deshpanday

Industry PR
Longya Xu

Expo & Sponsorship
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Tutorials
Julia Zhang

Special, Panel and Plenary Sessions
Pete Wung
Ian Brown

Student Activities
Robert Pilawa - Podgurski

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Giovanna Oriti
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Vanessa Broccoli
Rudy Wang

Local Chairs
Yilmaz Sozer
Mark Scott

Student Awards
Helen Li
Po Tai Cheng

Renewable and Sustainable Energy Applications

Rathore, Akshay (Vice Chair), Concordia University, Canada
Mazumder, Sudip (Vice Chair), University of Illinois, Chicago, USA
Kumar, Dinesh, Danfoss Drives A/S, Denmark
Weise, Nathan, Marquette, University, USA
Mahanty, Ranjit, Indian Institute of Technology (BHU), India
Ma, Ke, Shanghai Jiao Tong University, China
Liu, Liming, ABB Inc, USA
Akin, Bilal, UT Dallas, USA
Doolla, Suryanarayana, Indian Institute of Technology, Bombay, India
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Pan, Xuewei, Harbin Institute of Technology, China
Sarkar, Tirthajyoti, ON Semiconductor, USA
Mishra, Santanu, Indian Institute of Technology, Kanpur, India
Khanna, Raghav, University of Toledo, USA
Gao, Fei, University of Technology of Belfort-Montbeliard (UTBM), France

Smart Grid & Utility Applications

Grainger, Brandon (Vice Chair), University of Pittsburgh, USA
Mirafzal, Behrooz (Vice Chair), Kansas State University, USA
Barater, Davide, University of Parma, Italy
Kish, Gregory, University of Alberta, Canada
Suul, Jon Are, SINTEF Energy Research, Norway
Izadian, Afshin, Purdue School of Engineering and Technology, USA
Bifaretti, Stefano, University of Rome Tor Vergata, Italy
Skorek, Adam, University of Qubec at Trois-Rivieres, Canada
Chen, Nan, ABB Corporate Research, Sweden
Lu, Xiaonan, Argonne National Laboratory, USA
Du, Yu, ABB Inc, USA
Wang, Xiongfei, Aalborg University, Denmark
Vasquez, Juan, Aalborg University, Denmark
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Liang, Hao, University of Alberta, Canada
Lee, Tzung-Lin, National Sun Yat-sen University, Taiwan
Garcia, Jorge, University of Oviedo, Spain
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She, Xu, GE Global Research, USA

Datacenters and Telecommunication Applications

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Tan, Nadia, Universiti Tenaga Nasional, Malaysia

Transportation Electrification Applications

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Krishnamurthy, Mahesh, Illinois Institute of Technology, USA
Ye, Jin, San Francisco State University, USA
Wang, Mengqi, University of Michigan-Dearborn, USA

Power Converter Topologies

Zanchetta, Pericle (Vice Chair), University of Nottingham, UK
Sun, Kai (Vice Chair), Tsinghua University, China
Mishra, Santanu, Indian Institute of Technology, Kanpur, India
Lei, Qin, Arizona State University, USA
G. Lamar, Diego, University of Oviedo, Spain
Lee, Tzung-Lin, National Sun Yat-sen University, Taiwan
Solero, Luca, University of Roma Tre, Italy
Grbovic, Petar, Huawei Technologies, Germany
Petrella, Roberto, University of Udine, Italy
Cao, Dong, North Dakota State University
Pucci, Marcello, ISSIA-CNR, Italy
Formentini, Andrea, University of Nottingham, UK
Lidozzi, Alessandro, University of Roma Tre, Italy
Manjrekar, Madhav, UNC Charlotte, USA
Kshirsagar, Parag, UTRC, USA
Itoh, Junichi, Nagaoka University of Technology, Japan
Zarri, Luca, University of Bologna, Italy
Tang, Yi, Nanyang Technological University, Singapore

Control, Modelling and Optimization of Power Converters

Pitel, Grant (Vice Chair), Magna Power Electronics, USA
Muetze, Annette (Vice Chair), Graz University of Technology, Austria
Preindl, Matthias, Columbia University, USA
Lu, Xiaonan, Argonne National Laboratory, USA
Essakiappan, Somasundaram, UNC Charlotte, USA
Oriti, Giovanna, Naval Postgraduate School, USA
Guerrero, Juan, University of Oviedo
Anglani, Norma, University of Pavia, Italy
Skorek, Adam, University of Qubec at Trois-Rivieres, Canada
Suul, Jon Are, SINTEF Energy Research, Norway
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Current Derivative Estimation by Using AMR Current Sensor and its Application in Sensorless Control of an IPMSM Drive 1901
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Enabling Driving Cycle Loss Reduction in Variable Flux PMSMs via Closed-Loop Magnetization State Control 1932
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Crosstalk Suppression in a 650-V GaN FET Bridge-Leg Converter using 6.7-GHz Active Gate Driver 1955
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Technische Universität Berlin, Germany; Siemens AG, Germany

Short-Circuit Ruggedness Assessment of a 1.2 kV/180 A SiC MOSFET Power Module 1982
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Prognosis of Enhance Mode Gallium Nitride High Electron Mobility Transistors using On-State Resistance as a Fault Precursor 1988
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E-Mode GaN HEMT Short Circuit Robustness and Degradation 1995
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Startup and Control of High Efficiency 48/1V Sigma Converter 2010
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A Hybrid AC and DC Distribution Architecture in Data Centers 2017
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Power Quality Improvement Utilizing Photovoltaic Generation Connected to a Weak Grid

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***Abstract*--Microgrid research and development in the past decades have been one of the most popular topics. Similarly, the photovoltaic generation has been surging among renewable generation in the past few years, thanks to the availability, affordability, technology maturity of the PV panels and the PV inverter in the general market. Unfortunately, quite often, the PV installations are connected to weak grids and may have been considered as the culprit of poor power quality affecting other loads in particular sensitive loads connected to the same point of common coupling (PCC). This paper is intended to demystify the renewable generation, and turns the negative perception into positive revelation of the superiority of PV generation to the power quality improvement in a microgrid system. The main objective of this work is to develop a control method for the PV inverter so that the power quality at the PCC will be improved under various disturbances. The method is to control the reactive current based on utilizing the grid current to counteract the negative impact of the disturbances. The proposed control method is verified in PSIM platform. Promising results have been obtained.**

***Keywords*—Photovoltaic, PV, solar power, power quality, reactive power, unbalance, symmetrical, weak grid.**

I. INTRODUCTION

Nowadays, most of the renewable energy sources such as Photovoltaic (PV) panels are connected to the grid using inverters. They can feed substantial power to the grid. However, high penetration levels of PV panels could bring significant impacts to the power system. A review of some reports and a survey to utility engineers regarding impacts of PV penetration is presented in [1]. Several concerns about high PV penetration include transient condition during cloud passing, voltage rise in steady state and the need to include voltage regulation in PV inverters.

Since the voltage regulation corresponds to reactive power flow in power system, a PV inverter should have an additional capability to control the reactive power flow. Thus, the PV plant would provide voltage support in steady state and transient (fault) condition in order to reduce network losses and improve transmission capacity.

Many studies about reactive power control in a grid-connected PV inverter have been done [2]-[7][9]. Generally, a PV inverter absorbs or injects reactive power or current depending upon its control strategies, such as constant voltage, constant reactive power, or constant power factor type. The control strategy is commonly supported by a PI controller or a V-Q slope characteristic. It is also possible to employ an intelligent controller [7]. Some controllers work in a *dq* reference frame to simplify the control process. Reactive power flow can also be determined by active power flow associated to system impedance (Rs/Xs). For unbalanced system, it is common for PV and other distributed generation inverters to apply a symmetrical component method in the control process [6][9]-[11]. In [6], the controller defines control parameters (k^+ and k^-) to balance the positive- and negative-sequence voltages (voltage equalizing strategy). Moreover, the injected reactive current to the grid is mostly based on the required voltage or power. To convert to the current, the process frequently needs extensive calculation. In this paper, a different approach to the control strategy is based on utilizing the available reactive current flowing in the power system, which corresponds to system voltage. Different from the previous approaches, the strategy is simple, comprehensive and robust, because the reactive current produced by the PV generator just emulates to the reactive current circulating in the grid. Since the main objective of this research is to improve the grid power (voltage) quality, this system is also effective for all conditions especially unsymmetrical faults.

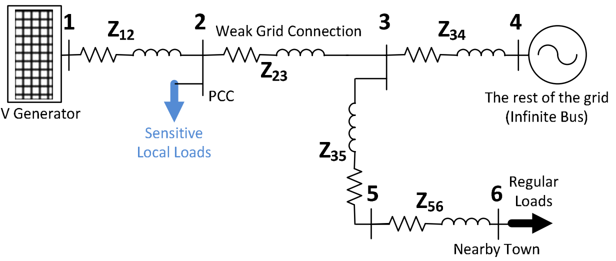

Figure 1. A single line diagram of a typical PV installation.

A typical system of interest is illustrated in the single line diagram in Fig. 1. As shown, a typical PV installation is connected to the main grid via weak lines (weak grid system). On the same site, regular loads and sensitive loads (e.g. medical equipment, computer center, and a radar installation) may be connected to the same bus. The major concern is mostly on the

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power quality of the grid at the installation of the PV inverter, that may affect the performance of the loads connected to the point of common coupling (PCC). This paper intends to reveal the benefit of PV generation and the significance of the proposed control strategy to the power (voltage) quality improvement in a microgrid system.

II. PV INVERTER TO IMPROVE POWER QUALITY

PV panels convert solar energy to electrical energy. They generate active power in a DC quantity. In order to deliver the active power from PV panels to the grid, an inverter along with a MPPT controller is commonly used to interface PV panels to the grid. In addition, the PV inverter will be equipped with a reactive power controller.

A. PV Model

The PV generator consists of PV panels and a PV inverter along with its controller. The DC side of the PV inverter is attached to PV panels, and the AC side of the PV inverter is connected to the grid. PV panels generally operate as a current source. While a grid-connected PV inverter works in a current-controlled mode [6][9][10][12]. The PV inverter and its controller determine the PV output currents sent to the grid, which is usually based on sliding mode control [12]. This paper chooses a three-phase dependent current source as an average model for representing the PV generator. The Norton equivalent circuit of the dependent current source is shown in Fig. 2, where $I_{a\text{-}pv}$, $I_{b\text{-}pv}$ and $I_{c\text{-}pv}$ are connected to a three-phase reference current of the controller ($I_{ref(a,b,c)}$).

B. PV Controller

The PV output currents comprise of the active and reactive current. To produce the PV output currents, the controller has to drive the PV inverter using the three-phase reference current ($I_{ref(a,b,c)}$). The main block diagram of the PV inverter control strategy is shown in Fig. 3.

The quantity of active power sent to the grid is determined by the intensity of sunlight striking on PV panels as well as the environment surrounding the panels. To get maximum active power, the PV inverter is supported by the maximum power point tracking (MPPT) controller, which regulates the DC-bus voltage [12]. Hence, the active power delivered to the grid is relatively independent on the electric power system condition. On the other hand, the active power from PV panels may influence the performance of the power system.

Different from active power flow, the PV generator will contribute reactive currents flowing to the grid. The reference current for reactive currents as well as unbalanced currents will be constructed by utilizing grid currents. According to Watanabe [13], instantaneously, reactive power is being exchanged between phases of the power system. The reactive as well as unbalanced current is flowing in the power system without transferring energy.

Therefore, the controller has to sense the currents flowing in the grid. A current sensor is placed on each phase of the grid to detect three-phase grid currents ($I_{grid} = I_{43}$). Based on the three-phase grid current, the control strategy focuses on developing a three-phase active positive-sequence current ($I_{+active(a,b,c)}$).

From the output signals of grid current sensors, the controller separates the grid currents into positive-sequence, negative-sequence and zero-sequence current components. If the system is balanced, then the grid currents only have positive-sequence currents. To obtain the three-phase positive-sequence current ($I_{+(a,b,c)}$), the three-phase grid/line currents ($I_{grid(a,b,c)}$) are processed with symmetrical component extraction according to equation (1) and (2).

$$\begin{bmatrix} I_+ \\ I_- \\ I_o \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & a & a^2 \\ 1 & a^2 & a \\ 1 & 1 & 1 \end{bmatrix}\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} \tag{1}$$

$$\begin{bmatrix} I_{+a} \\ I_{+b} \\ I_{+c} \end{bmatrix} = \begin{bmatrix} 1 \\ a^2 \\ a \end{bmatrix}[I_+] \tag{2}$$

Where:

I_a, I_b, I_c = line currents

I_+, I_-, I_0 = positive-, negative-, and zero-sequence currents

$a = e^{j120^\circ}$ and, $a^2 = e^{-j120^\circ}$

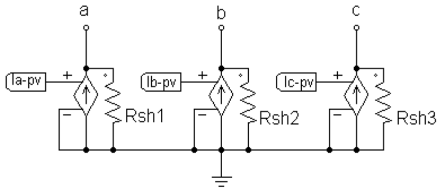

Figure 2. A three-phase PV average model

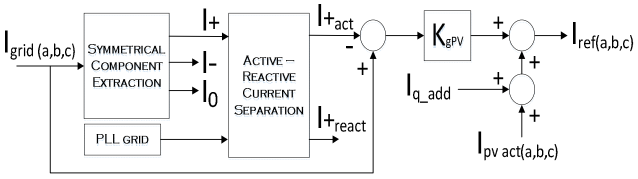

Figure 3. A block diagram of a PV inverter control strategy.

The positive-sequence currents, which are three-phase balanced currents, consist of active and reactive currents. As a consequence, the three-phase positive-sequence currents have to be split into three-phase active and reactive positive-sequence currents. To obtain the active currents, the positive-sequence currents are synchronized to the grid voltages using a phase lock loop (PLL) controller. The active currents are in-phase with the grid voltages, while the reactive currents are perpendicular to the grid voltages. Both the active and reactive positive-sequence currents are three-phase balanced currents.

$$I_{+(a,b,c)} = I_{+\,active(a,b,c)} + I_{+\,reactive(a,b,c)} \tag{3}$$

Finally, the three-phase active positive-sequence current is subtracted from the grid currents. As a result, the controller will automatically produce a three-phase reactive unbalanced current ($I_{r(a,b,c)}$), which consists of reactive currents as well as negative- and zero-sequence currents for unbalanced system.

$$I_{r(a,b,c)} = I_{grid(a,b,c)} - I_{+\,active(a,b,c)} \tag{4}$$

$$I_{r(a,b,c)} = I_{+\,reactive(a,b,c)} + I_{-(a,b,c)} + I_{0(a,b,c)} \tag{5}$$

However, the PV inverter will not employ the entire reactive unbalanced current ($I_{r(a,b,c)}$) component as for supporting the whole power system. The inverter supplies only a fraction of this current (multiplied by a gain, K_{gPV}) for improving the voltage regulation at the PCC bus. The gain K_{gPV} is a constant between 0 and 1, and is associated with the system impedance.

This current combined with the active current ($I_{PV\,active(a,b,c)}$) from PV panels will become the three-phase reference current.

$$I_{ref\,(a,b,c)} = I_{PV\,active(a,b,c)} + K_{gPV}\, I_{r(a,b,c)} \tag{6}$$

If the PV inverter possesses satisfying conversion effect, then the reference current becomes the output currents of the PV inverter (I_{PV})

$$I_{PV(a,b,c)} = I_{PV\,active(a,b,c)} + K_{gPV}\,(I_{+\,reactive(a,b,c)} + I_{-(a,b,c)} + I_{0(a,b,c)}) \tag{7}$$

Thus, the generated current by the PV generator contains the current components that will counteract the load- and disturbance-impact on the PCC voltage. As a result, the voltage at the PCC will be corrected to normal per unit value.

The main control system mentioned above is an open loop. As a result, the PCC voltages may not equal to the reference voltage, and a small voltage gap (ΔV_{PCC}) may occur. To create a close loop system, a simple PI controller will be integrated to the main controller. The PI controller adjusts the reactive current generated by the PV inverter. However, the PI controller cannot operate without the main controller since it is not capable to handle unbalance condition. The block diagram of the PI controller with anti-windup is shown in Fig. 4.

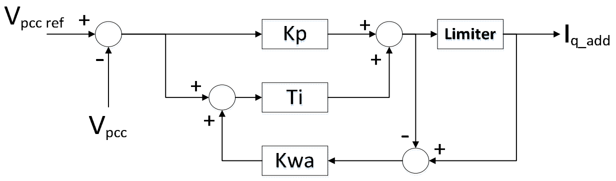

Figure 4. PI controller.

III. MICROGRID SYSTEM INVESTIGATED

A. System under Study

The system under study is depicted in Fig. 1. From the figure, it can be seen that the three-phase dependent current source representing a high power PV plant is connected to the point of common coupling (PCC – bus 2) through a star-star winding connection power transformer (represented by impedance Z_{12}). The PV plant, which is a type of distributed generation (DG), is usually located some distance away from the transmission line. Therefore, the PCC (bus 2) is connected to bus 3 via a weak line. It is considered to be a weak grid connection, which is normally characterized by high impedance ($Z_{23} = Z_{weak}$). The short circuit ratio (SCR) at this point is smaller than 10 [8]. SCR is the ratio of PCC short circuit power to maximum apparent power of generator. Bus 3 is the terminal of a three-phase infinite voltage source/grid with small equivalent impedance (Z_{34}).

To prove the concept proposed above, the system in Fig. 1 is simulated under dynamic conditions and transient faults. In case of the fault occurrence, the PV generator is still connected to the grid (fault ride-through) and supports the voltage level at PCC. The system parameters under study are listed in Table I.

TABLE I
SYSTEM PARAMETER UNDER STUDY

MVA base	10MVA
KV base (L-L)	20kV
Z_{12}	7%
Z_{weak} (Z_{23})	50% (SCR ≈ 2)
Z_{34}	5%
Z_{35}	7%
Load (bus 5)	0.4pu, PF = 0.9 lag
K_{gPV}	0.1
Z_f	1%

B. Dynamic Simulations of a Quasi-Steady-State System

Under normal condition, the voltage and current of the system change dynamically due to predominantly the fluctuation of solar irradiation. In reference to Fig. 1, the voltage equation under normal condition can be presented as follow:

$$V_2 = V_3 + I_{PV} Z_{23} \tag{8}$$

Or in reference to the voltage at bus 4 (V_4), we can also write the equation as follow:

$$V_2 = V_4 - I_{43} Z_{34} + I_{PV} Z_{23} \tag{9}$$

Where

$$I_{43} = I_{35} - I_{PV} \tag{10}$$

1) Night Operation of the PV generation

At night, the PV panels do not generate active power ($P_{PV} = 0$). The PV inverter still works as a reactive power controller and generates small reactive currents. Fig. 5 shows that the load current is supplied mostly by the grid since there is no contribution of active current from PV generator. The system is stable. In this case, the system is open loop. The value of the PCC voltage (phase-neutral) is 0.992p.u.

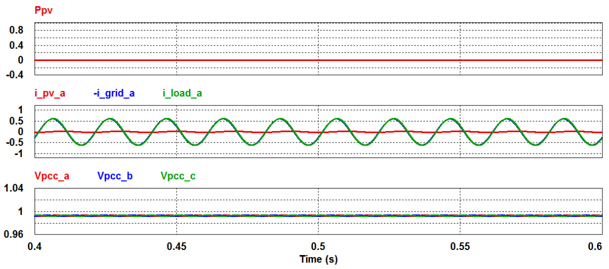

Figure 5. At night ($P_{PV} = 0$), system currents in phase A (middle), PCC voltages (bottom) for an open loop system.

Actually, the PCC voltage gap (ΔV_{PCC}) is small (< 1%). However, if to fill the voltage gap is needed, the PI controller can adjust the reactive power generated by PV inverter. The PI controller output signal (I_{q_add}) will be added to the main controller output as shown in Fig. 3. Fig. 6 (bottom) shows the additional reactive power. The system is close loop and the PCC voltages equal to 1p.u.

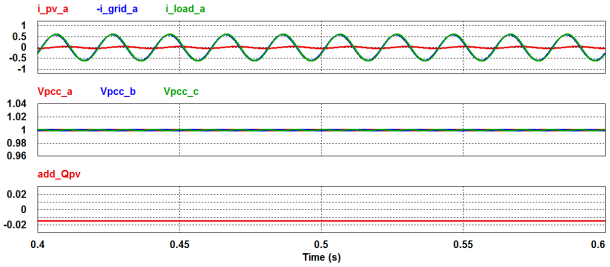

Figure 6. At night ($P_{PV} = 0$), system currents in phase A (top), and PCC voltages (1p.u) (middle), an additional reactive power (bottom) for a close loop system.

2) Power Changes of PV Generation

The fluctuation of solar irradiation due to earth rotation and weather condition as well as temporary cloud passing will vary the active power generated by PV panels. The PV active current will also change following the solar irradiation variation. The PV active current will create a voltage across Z_{23}. As a result, the PCC voltage will fluctuate according to equation (8). However, the reactive power controller will keep the PCC voltage constant at 1p.u by adjusting the reactive current component of I_{PV}.

Figure 7 shows that the active current generated by PV generator is larger than the load current. Part of the PV active current flows to the grid. From Fig. 7, when solar irradiation (PV active power (P_{PV})) fluctuates, the grid current fluctuates following the PV output current because the load current is constant. The fluctuation of solar irradiance has no effect on the system performance and stability. Fig. 8 also shows the same system performance when cloud passing occurs in a short time so that P_{PV} slightly decreases. Active power reduction depends on the cloud condition that obstructs the PV panels from sunlight.

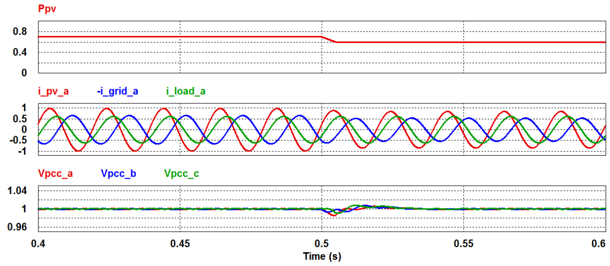

Figure 7. Solar power drops (top), system currents in phase A (middle) and PCC voltages (bottom) when solar irradiation changes

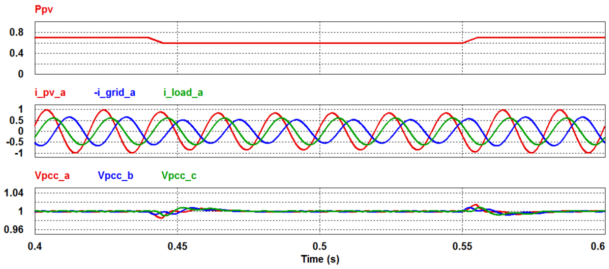

Figure 8. Solar power fluctuation (top), system currents in phase A (middle) and PCC voltages (bottom) when cloud passing

C. Dynamic Simulations under Transient Faults

The system under study experiencing different kinds of fault is depicted in Fig. 9. From this figure, only the main circuit is affected by large fault current. The branch connected to the PV plant is not drawn, because the current source nature of the PV inverter does not contribute to the fault current. The dependent current source basically generates currents according to the reference currents which consists of the active current ($I_{PV\,active}$) from PV panels and the reactive unbalanced current derived from the grid currents. Moreover, as a current source, currents from the grid are prevented flowing into the PV generator.

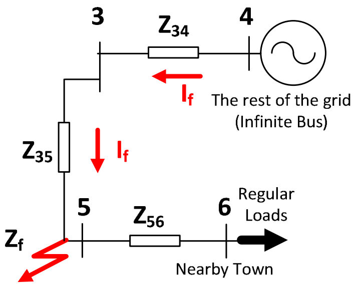

Figure 9. System under fault condition.

During the fault, $I_{35} = I_f$, and, as the amount of the fault current $I_f >> I_{PV}$, the current contributed from the PV plant will not affect significantly the voltage at bus 3.

$$I_{43} = I_f - I_{PV} \approx I_f \tag{11}$$

The voltage at the bus 3 can be expressed as

$$V_3 = \frac{Z_f + Z_{35}}{Z_f + Z_{35} + Z_{34}} V_4 \tag{12}$$

And the voltage at the bus 5 can be expressed as

$$V_5 = \frac{Z_f}{Z_f + Z_{35} + Z_{34}} V_4 \tag{13}$$

Thus, for a solid ground fault, the voltage at bus 5 is theoretically zero. Meanwhile at bus 3 as well as bus 2, there are significant voltage drops depending on the ratio Z_{35} to Z_{34}.

However, I_{PV} can be controlled such that the currents from the PV plant have the ability to improve the voltage at the PCC (bus 2). Thus, it will protect the sensitive local loads connected to bus 2 from experiencing a severe voltage dip.

$$V_2 = V_4 - I_f Z_{34} + I_{PV} Z_{23} \tag{14}$$

Assuming that X/R of the system impedance is high, and the reactive unbalanced currents generated by PV inverter controller significantly support the voltage regulation. If K_{gPV} can be chosen such that

$$K_{gPV} = \frac{Z_{34}}{Z_{23}} \tag{15}$$

Then

$$I_f Z_{34} \approx I_{PV} Z_{23} \tag{16}$$

As a result, the value of bus 2 voltage is close to bus 4 voltage ($V_2 \approx V_4$). Thus, the disturbance effect of the fault is neutralized by the additional reactive power generated by the PV plant and the ratio of the line impedance. The value of K_{gPV} can also be applied to the normal condition.

1) *Fault and breaker logic*

The following figures illustrate the process of the proposed control strategy drawn in Fig. 3. When t < 0.6s, the system is normal and balanced. During 0.6s < t < 0.9s, a disturbance happens. And when t > 0.9s, protection system detects the fault so that breaker is active. So the disturbance is cut off, and the system returns to normal and balance. The system breaker is closed at t = 1.05s assuming that fault has been removed at this point. The system is stable. Detailed fault and breaker logic are presented in Fig. 10.

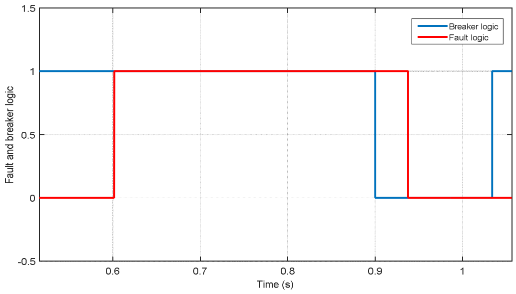

Figure 10. Fault and breaker logic under transient faults

To explain the main-control process, a double-line to ground fault is selected as the demonstration case. When the fault happens at bus 5 (phase A and B), the voltage sag also takes place at the PCC. The large grid currents flow into the faulty bus (Fig. 11 top). The current sensors detect the fault currents. From the current sensor output, the symmetrical component extractor creates a three-phase positive-sequence current as shown in Fig. 11 (bottom). Then, the three-phase positive-sequence current is decomposed into three-phase active and reactive positive-sequence currents. Only the active positive-sequence current (Fig. 12 top) that is in-phase with the grid voltage is needed in the next process. Fig. 12 (bottom) shows the distinction between the positive-sequence current and the active positive-sequence current. Then, the three-phase active positive-sequence current is subtracted from the three-phase grid current in order to generate three-phase reactive unbalanced current ($I_{r(a,b,c)}$) (Fig. 13 top). This current is multiplied by a gain (K_{gPV}) because the inverter supplies only a small quantity (Fig. 13 bottom) to enhance the PCC voltage.

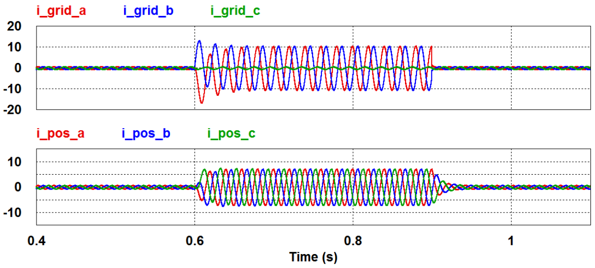

Figure 11. Grid (fault) currents (top), and positive-sequence currents (bottom).

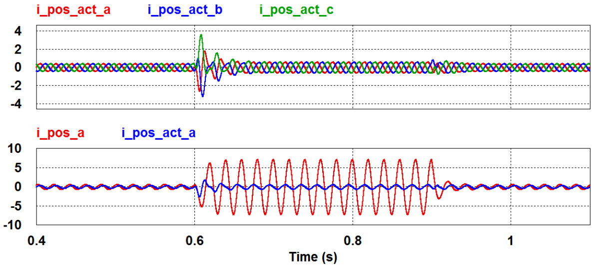

Figure 12. Three-phase active positive-sequence currents (top), and distinction between positive-sequence current and active positive-sequence current – phase A (bottom)

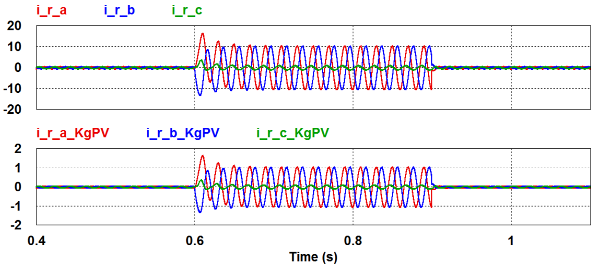

Figure 13. Reactive unbalanced currents: from the grid (top), and after multiplied by K_{gPV} (bottom)

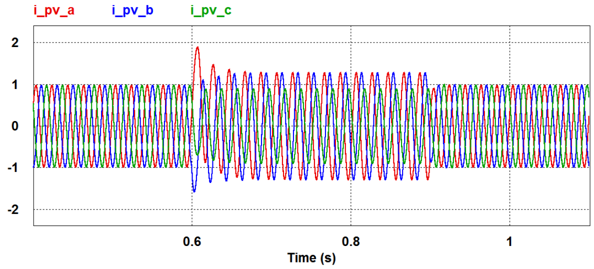

Figure 14. Three-phase reference currents (= PV inverter output currents)

Finally, the large active current ($I_{PV\ active}$ = 0.7p.u) from PV panels is added to create the three-phase reference current as

(Fig. 14). The amount of active power generated from PV panels is not affected by the disturbances. For dependent current source's gain equals one, the PV output currents equal to the reference currents.

2) *Symmetrical faults*

Symmetrical faults happen when there is a three-phase short circuit. In this case, a three-phase to ground fault through Z_f occurs at bus 5. During the fault, the grid fault-current (I_f) rises considerably (Fig. 15 bottom). The fault disturbs the voltage of the adjacent buses including PCC voltage. The three-phase voltage at PCC declines significantly (Fig. 15 top).

The PV inverter senses the three-phase grid fault-current (I_f) and the controller responses quickly by generating reactive currents to counteract the voltage dip at the PCC. For a symmetrical-fault case, there is no unbalanced current. Fig. 16 (top) describes that the PV output current is a summation of the active current (from solar power, $P_{PV} = 0.7$p.u) and the reactive current proportional to the grid fault-current. It can be seen that the system is stable and the PCC voltage is corrected very well to 1p.u, as shown in Fig. 16 (bottom), according to equation (16) and due to the PI controller. The PCC voltage is balanced as well. Hence, the voltage quality is enhanced.

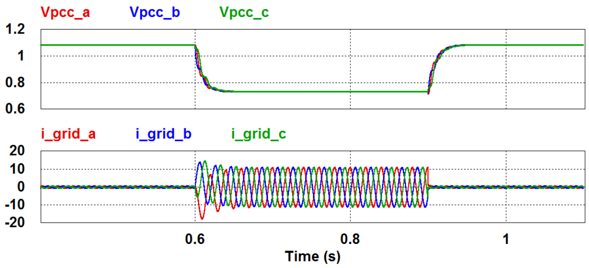

Figure 15. Voltages at PCC (top), and grid currents (bottom) without reactive power control for a three-phase to ground fault (symmetrical fault)

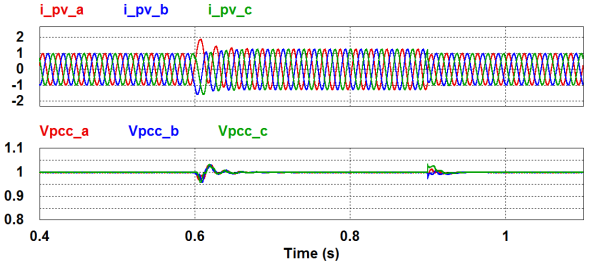

Figure 16. PV output currents (top) and voltages at PCC (bottom) with reactive power control for a three-phase to ground fault (symmetrical fault)

3) *Unsymmetrical faults*

The unsymmetrical faults introduced in this paper includes a single-line to ground fault, a line-to-line fault and a double-line to ground fault. The faults through Z_f create unbalanced voltage and current. Thus, the PV inverter has to produce reactive unbalanced currents to compensate unbalanced disturbances.

a) *Single-Line to Ground Fault*

Fig. 17 illustrates the voltage at the PCC when bus 5 experiences a single-line to ground fault at phase A. The phase-A voltage decreases about 30%, while the other phases stay a slightly higher than the normal voltage. Obviously, the phase-A grid current will rise very high and flow to the faulty bus. The phase-A grid current peak is about 10p.u (Fig. 17 bottom). The grid currents are unbalanced due to the unsymmetrical fault.

Consequently, during the fault the output current of the PV inverter will also be unbalanced, which is similar to the grid currents with a proportional gain K_{gPV}. Since K_{gPV} is selected to be 0.1, the PV reactive unbalanced current peak (phase A) is about 1p.u. From Fig. 18, it can be seen that the PV generator produces reactive unbalanced currents during the fault in addition to the active currents ($P_{PV} = 0.7$p.u) as shown in Fig. 18 (top). The unbalanced voltage drop is compensated very well so that voltage at PCC is three-phase balanced voltage waveform and its magnitude is 1p.u (rms) (Fig. 18 bottom). The system is stable and the voltage quality is enhanced.

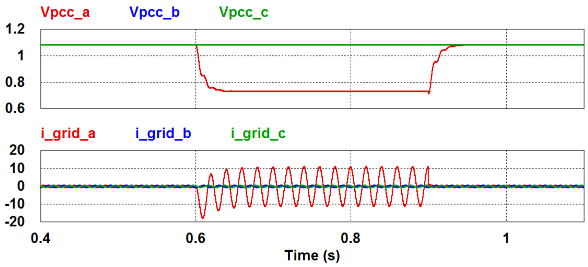

Figure 17. Voltages at PCC (top), and grid currents (bottom) without reactive power control for a single-phase to ground fault (unsymmetrical fault)

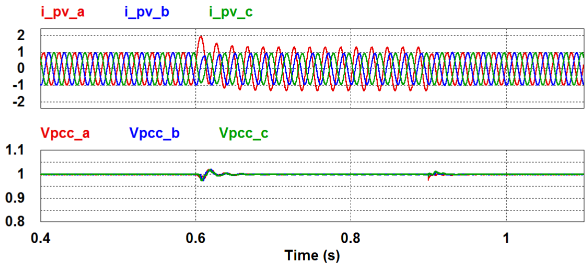

Figure 18. PV output currents (top) and voltages at PCC (bottom) with reactive power control for a single-phase to ground fault

b) *Line-to-Line (double-line) to Ground Fault*

Fig. 19 describes the voltage at the PCC when bus 5 experiences a line-to-line to ground fault at phase A and B. The phase-A and phase-B voltages drop about 30%, while the phase C voltage is still around the normal value. The three-phase unbalanced grid currents flow to the fault. Due to the control strategy proposed in this paper, the PV inverter will generate the active current and the reactive unbalanced current that is similar to the grid currents but with proportional gain K_{gPV}. Fig. 20 shows the PV output currents (top picture), and the PCC balanced voltages which are corrected to 1p.u (rms) during disturbance (bottom picture). The voltage quality is enhanced.

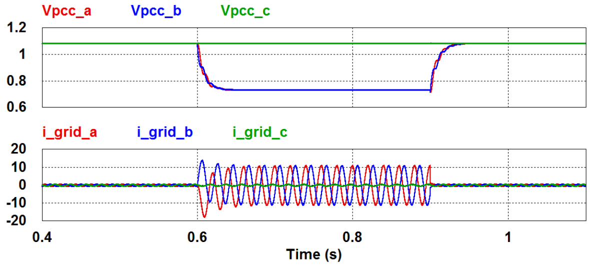

Figure 19. Voltages at PCC (top), and grid currents (bottom) without reactive power control for a line-to-line to ground fault

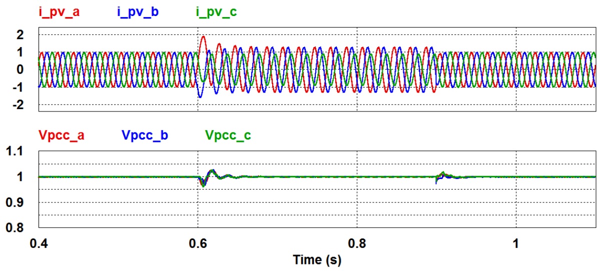

Figure 20. PV output currents (top) and voltages at PCC (bottom) with reactive power control for a line-to-line to ground fault

c) Line-to-Line Fault

Fig. 21 illustrates voltages at the PCC when bus 5 experiences a line-to-line fault between phase A and B. The short circuit between phase-A and phase-B causes voltage drops about 25% at the phase A and about 15% at phase B, while the phase C remains at a normal value. The fault also makes the phase angle of the three-phase PCC voltage unbalanced (Fig. 22). Obviously, phase-A and phase-B grid currents will rise very high and flow to the fault bus.

Similar to the previous unsymmetrical faults, based on the control strategy proposed, the PV inverter output currents will be a summation of the active current ($P_{PV} = 0.7$p.u), the reactive unbalanced current that is similar to the grid current with a proportional gain, and an additional reactive current from the PI controller as demonstrated in Fig. 23 (top picture). The figure also shows that the system is stable, and the voltage drop is recovered significantly. Fig. 24 shows the magnitude and the phase angle of the PCC balanced voltages during disturbance. The voltage quality is enhanced.

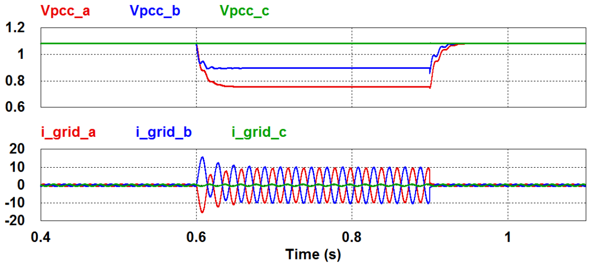

Figure 21. Voltages at PCC magnitude (top), and grid currents (bottom) without reactive power control for a line-to-line fault

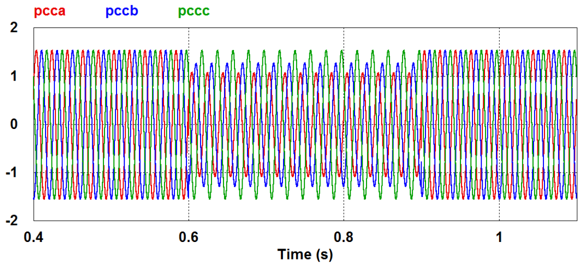

Figure 22. Unbalanced magnitude and phase angle of the PCC voltages without reactive power control for a line-to-line fault

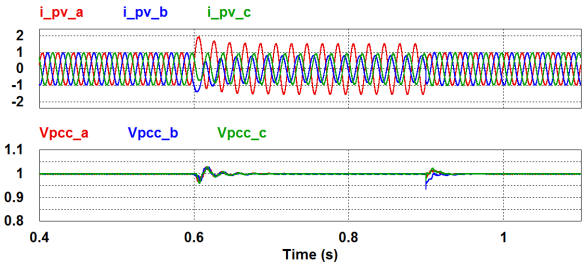

Figure 23. PV output currents (top) and voltages at PCC (bottom) with reactive power control for a line-to-line fault

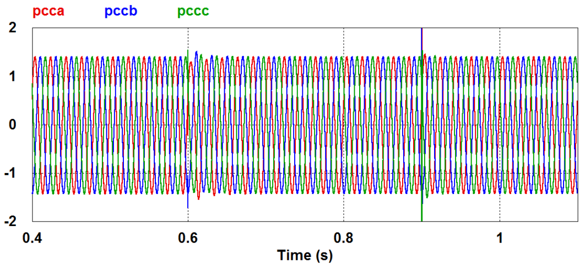

Figure 24. The balanced magnitude and phase angle of the PCC voltages with reactive power control for a line-to-line fault

D. The Effect of K_{gPV} Variation

The effect of K_{gPV} variation on the PCC voltage is described in Figure 25 and Figure 26. K_{gPV} is the impedance ratio that controls the voltage drop across Z_{23}. Without the assistance of K_{gPV}, equation (16) will not be justified. K_{gPV} can be varied corresponding to the variation of grid impedance (Z_{34}).

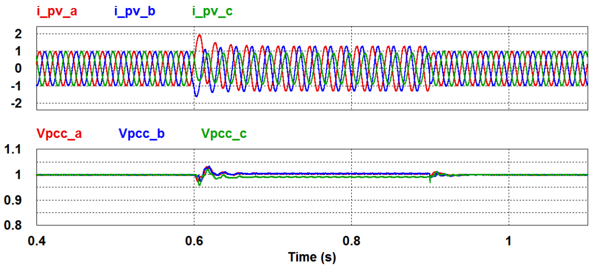

Figure 25. PV output current and PCC voltage when $K_{gPV} = 0.104$

Figure 25 shows the voltage of PCC during a fault (selected case: a double line to ground fault, phase A and B) when K_{gPV} is 0.104. Clearly, the PCC voltage is unbalanced and not equal to 1p.u. The phase-C voltage (< 1p.u) is lower than other two phases (> 1p.u). On the other hand, when K_{gPV} is 0.096 (Fig. 26), the phase-C voltage (> 1p.u) is higher than other two phases (< 1p.u).

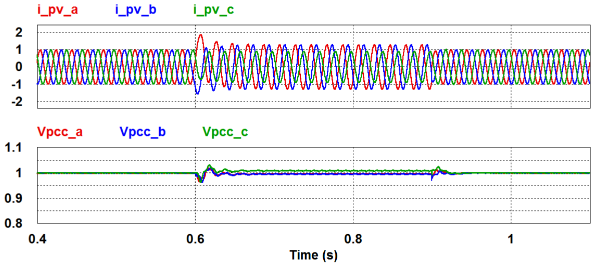

Figure 26. PV output current and PCC voltage when $K_{gPV} = 0.096$

IV. CONCLUSION

This paper presents the performance of the grid-connected PV source to support voltage regulation of microgrid system especially under transient faults. The high-power PV source is connected to the grid through a weak line with high impedance. Since PV panels only generate active power, the PV inverter is equipped with a reactive power controller to improve the power (voltage) quality.

The control strategy is based on utilizing the grid currents so that the PV generator creates a three-phase reactive unbalanced current. However, the inverter supplies only a small amount (multiplied by a gain, K_{gPV}) for improving the voltage at the PCC. The gain K_{gPV} is associated with the system impedance. This open loop strategy succeds to maintain the PCC voltage close to 1p.u. If it is necessary to make the PCC voltage equals to 1p.u value, a simple PI controller is integrated to the main controller. The PI controller adjusts the reactive current generated by the PV inverter. The advantages of this control strategy are simple because of less computation, comprehensive and robust due to emulating the reactive current circulating in the grid

The control method proposed in this paper is simulated in PSIM. Simulation results demonstrate that satisfactory results are obtained and the proposed control strategy is feasible to manage the voltage regulation. Power quality in terms of voltage level is improved under both normal conditions and transient disturbances. The system is stable and voltage dips at the PCC due to both symmetrical and unsymmetrical faults are corrected significantly.

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REFERENCES

[1] M. Ropp, J. Newmiller, C. Whitaker, and B. Norris, "Review of potential problems and utility concerns arising from high penetration levels of photovoltaics in distribution systems," in 2008 *Photovoltaic Specialist Conference, PVSC '08 33rd IEEE*, pp. 1 – 6.

[2] L. Zhou, and Y. Chao, "The research of reactive power control strategy for grid-connected photovoltaics plants," in 2013 *World Congress on Sustainable Technologies*, pp. 12 – 17.

[3] H. Li, et. al., "Real and reactive power control of a three-phase single-stage PV system and PV voltage stability," in 2012 *IEEE Power and Energy Society General Meeting,* pp. 1 – 8.

[4] A. Cagnano, et. al., "Online optimal reactive power control strategy of PV inverters," *IEEE Transactions on Industrial Electronics*, vol. 58, no. 10, 2011, pp. 4549 – 4558.

[5] P. Esslinger, and R. Witzmann, "Evaluation of reactive power control concepts for PV inverter in low-voltage grids," in 2012 *CIRED Workshop*, paper 363.

[6] A. Camacho, et. al., "Flexible voltage support control for three-phase distributed generation inverters under grid fault," *IEEE Transactions on Industrial Electronics*, vol. 60, no. 4, 2013, pp. 1429 – 1441.

[7] Faa-Jen Lin, et. al., "Reactive power control of three-phase grid-connected PV system during grid faults using Takagi-Sugeno-Kang probabilistic fuzzy neural network control," *IEEE Transactions on Industrial Electronics,* vol. 62, no. 9, 2015, pp. 5516 – 55528.

[8] N. P. W. Strachan, and D. Jovcic, "Stability of a variable-speed permanent magnet wind generator with weak ac grids," *IEEE Transactions on Power Delivery*, vol. 25, no. 4, 2010, pp. 2779 – 2788.

[9] P. Rodriguez, et al., "Independent PQ control for distributed power generation systems under grid faults," in IECON 2006, pp 5185 – 5190.

[10] S. Alepuz, et. al., "Control Strategies Based on Symmetrical Components for Grid-Connected Converters Under Voltage Dips," *IEEE Transactions on Industrial Electronics*, vol. 56, no. 6, June 2009, pp. 2162 – 2173

[11] Fei Wang, J. L. Duarte, and M.A. M. Hendrix, "Pliant Active and Reactive Power Control for Grid-Interactive Converters Under Unbalanced Voltage Dips," *IEEE Transactions on Power Electronics*, vol. 26, no. 5, May 2011, pp. 1511 – 1521.

[12] Hanny H. Tumbelaka, M. Miyatake, "Simple Integration of Three-Phase Shunt Active Power Filter and Photovoltaic Generation System with Fibonacci-Search-Based MPPT," in IEEE Symposium on Industrial Electronics and Applications (ISIEA), 2010, pp. 94 – 99.

[13] Edson H. Watanabe, et. al., "New Concepts of Instantaneous Active and Reactive Powers in Electrical Systems with Generic Loads," *IEEE Transactions on Power Delivery*, vol. 8, no. 2, 1993, pp. 697 – 703.