**SUPPORT LETTER AUTHOR INFORMATION**

**(For Internal Use Only)**

*Please complete one form for each support letter author.*

1. Name of author: Prof. Bikash Pal
2. Author’s e-mail address: linglingfan@usf.edu
3. **Attach author’s CV and/or biography to this worksheet.** We need the information contained in these documents to write a letter that is sufficiently detailed and tailored to the author.

Have you attached the author’s CV and/or biography?  Yes  No

*If yes, continue onto part 3.*

*If no, please obtain these documents. If you are unable to provide copies at this time, please explain:*

1. List author’s current position and research focus. If the author’s research focus is different from your own, please explain how the two areas are related.

Current position: ­­­­­­­­­­­­­­Associate Professor at the Department of Electrical Engineering of the University of South Florida, Tampa, Florida

Research focus: Dr. Fan's research area covers power systems, power electronics, and electric machines. Her focus area include dynamic systems and optimization. In dynamic systems area, her research covers modeling, analysis, estimation and control with applications in wind energy grid integration, microgrids, high-voltage direct current (HVDC) systems, energy storage systems, phasor-measurements units (PMU). In optimization area, her research focuses on implementing optimzation in smart building operation, energy storage operation, and power electronic converter controls.

Dr. Fan is an active member of the IEEE Power and Energy Society (PES). She is an editor of IEEE Transactions on Sustainable Energy. She is serving as the Technical Committee Program Chair (TCPC) for Power System Dynamic Performance (PSDP) subcommittee, Secretary of IEEE PES Power Engineering Education Committee Research Subcommittee. She is a senior member of IEEE.

Dr. Fan is a leading expert on the stability issues encountered by renewable energy systems, particularly wind and PV based power generation resources. She has written highly cited papers and books on these subjects. Her paper "Modeling of DFIG-based wind farms for SSR analysis" published in the IEEE Transactions on Power Delivery in 2010 was one of first papers that described the subsynchronous resonance (SSR) problem faced by a particular type of wind power plant and it has been cited for more than 380 times. Since then the problem has received much attention, particularly because of several regular incidences in wind power plants in the state of Texas. Dr. Fan has also writen a widely referred book on the modeling and control design of wind turbines. Dr. Fan and Dr. Shah conduct research in the same field focusing on different aspects of stability problems in renewable energy systems.

1. Describe ***in detail*** how the author knows about ***your*** work (***5-7 sentence minimum***). Explain how the author first came to know of your work and explain the continuing nature of your professional relationship. Include the following:
2. If you worked together, explain where and when you worked together and explain the type of work/research you did together.
3. If you know each other from conferences, please list the conferences and discuss what it was that brought the two of you to each other’s attention.
4. If you have never met and the author is familiar with your work simply through your reputation or publications, please list how the author first learned about your work, the extent of his or her knowledge of your work, and why he or she is interested in your work.

Dr. Fan first learned about Dr. Shah's work on impedance methods for evaluating stability of wind and PV renewable energy system through Dr. Shah's papers he published between 2015-2017 during his Ph.D. studies at the Rensselaer Polytechnic Institute (RPI). Dr. Fan also works on this new and emerging area and follows an approach of using impedance defined in a rotating reference frames. Certain research groups use stationary reference frame for defining impedance and performing impedance-based stability analysis. There has been an on going debate in the community about which approach is superior and if they are related. Dr. Shah in a series of papers he published in 2016-2017 showed that the impedance of three-phase electrical systems in stationary frame when defined properly is mathematically equivalent to the impedance defined in the rotating reference frame. Dr. Shah's papers summarily settled the long standing debate on which approach is superior by discovering the relationship between the two. Dr. Fan has used in her research the relationship between the impedance in rotating and stationary reference frames that was discovered by Dr. Shah. Following paper from Dr. Fan's research group at the University of South Florida has cited Dr. Shah's papers showing the relationship between impedances in two reference frames: L. Fan and Z. Miao, "A modular small-signal analysis framework for inverter penetrated power grids: measurement, assembling, and stability assessment," (preprint available on arXiv). After learning about the expertise of Dr. Shah in impedance-based stability analysis methods in particular and power system dyanmics in general, Dr. Fan has regularly invited Dr. Shah to review journal articles submitted for review to the IEEE Transactions on Sustainable Energy and IEEE Transactions on Energy Conversion.

Dr. Fan has closely followed research activities of Dr. Shah following his graduation from RPI with the Ph.D. degree. After joining NREL, Dr. Shah expanded his research on impedance methods for evaluating stability problems in wind and PV power plants by looking at practical aspects of impedance measurement of very large utility scale wind turbines and PV inverters. He led the development of first-ever impedance measurement system of wind turbines using a multimegawatt grid simulator at NREL. Impedance measurement of wind turbines are critical for understanding how they will operate under different conditions of the power system grid and if they will encounter any stability problems. However, impedance responses of wind turbines are generally obtained from their simulation models instead of actual measurements because of the complexities involved in characterizing the impedance of a real wind turbine. Dr. Fan identified the value of conducting impedance measurement of large-scale wind turbines and PV inverters using the system developed by Dr. Shah at NREL. She had invited him to discuss the impedance measurement system at a meeting organized by the IEEE Power and Energy Society (PES) Task Force on Subsyncornous oscillations (SSO) in wind energy interconected system (IEEE Wind SSO TF). The meeting was held alongside the IEEE Power and Energy Society General Meeting Conference in Atlanta, GA in July 2019. Dr. Fan is the chair of this task force, which focuses on the problem of subsynchronous oscillations in wind power plants. The objective of the task force is to identify best industry practices for evaluating the risks of SSO problems in wind power plants and disseminating advanced research results on the subject. The members of the task force are represented from all over the world and they come from power system utility companies, research and consulting firms, wind turbine manufacturers, and premier academic institutions. Dr. Shah's presentation at the Task Force meeting on the impedance measurement system was very well appreciated. In addition to impedance measurement system, Dr. Shah also presented the large-signal impedance theory he developed for predicting the severity of stability problems in renewable energy systems.

Subsequent to Dr. Shah's presentation at the Task Force meeting in 2019, Dr. Fan invited Dr. Shah to contribute a chapter on impedance measurement of utility-scale wind turbines in the IEEE Wind SSO Task Force report. The report presents real-world wind SSO events and lessons learned, modeling and simulation techniques for the evaluation of wind SSO events, state-of-the-art wind SSO study and screening methologies suitable for very large power system grids, and wind SSO detection and mitigation methods. The report is being finalized and is scheduled for release before the end of this year.

Dr. Fan also invited Dr. Shah to present practical issues in impedance characterization of commercial wind turbine at a panel session on subsynchronous oscillations problems in wind power plants. The pantel session was organized by the Wind SSO Task Force as a part of the IEEE Power and Energy Society General Meeting.

Because of the overlapping research interests and to leverage the impedance measurement system Dr. Shah has developed at NREL, Dr. Fan invited Dr. Shah to partner on a research project led by the University of South Florida. The project is supported by the Solar Energy Technologies Office (SETO) of the U.S. Department of Energy (DOE) by providing funcing of two million U.S. dollars. The project is titled "Modeling and Control of Solar PVs for Large Grid Disturbances and Weak grids"; it focuses on the development of high-fidelity models of PV inverters to understand their behavior during transient and fault events in the power system. The high-fidelity models of PV inverters that will be developed through this project will explain the behavior of PV inverters during grid events to avoid sudden loss of very large amounts of solar generation and reduced reliability of U.S. electric grids. The U.S. DOE awarded this project to avoid events such as the one that happened in the state of California in 2016; the California power grid lost around 700 MW of PV generation following a transmission line fault, which was resulted from a Blue Cut forest fire event. The impedance measurement system developed by Dr. Shah at NREL plays a key role in this project by servind as a validation platform for the models developed by the USF team. Impedance measurements of utility-scale inverter excite the inverter dynamics at different frequencies and serve as an ideal platform for high-fidelity model validation.

1. Provide a technical description of what the author knows about ***your*** research/work (***5-7 sentence minimum***). This information enables us to focus on the area of your work with which the author is most familiar.

Dr. Fan understands the seminal work of Dr. Shah that discovered the relationship between the impedance of three-phase systems such as wind turbines and PV inverters in the stationary reference frame and rotating reference frame. Dr. Fan is also very familiar with the work Dr. Shah conducted at NREL for establishing the impedance measurement system at NREL. Dr. Shah recently developed a graphical tool to organize and simplify the modeling of complex power electronics systems. This tool is called "harmonic signal0flow graphs" and it was published by Dr. Shah in a journal article titled "Harmonic Signal-Flow Graphs for the Modeling and Design of Phase-Locked Loops" in IEEE Transactions on Energy Conversion in June 2020. Dr. Fan is aware of this work.