EXECUTIVE RESEARCH SUMMARY

Introduction

The Power generation, conversion and storage are the three important pillars of future sustainable energy systems.

1. The power delivered by PV systems is dependent on irradiance, temperature, and the current drawn from the PV cells. The maximum power point tracking is used to obtain maximum power from these systems. The maximum power extraction is the important area where maximum available power is drawn from the resources under varying environmental conditions.
2. The power delivered by all renewable energy resources/energy storage systems illustrates unstable, unregulated and substantial voltage drops. A suitable power converter and its controller are necessary to achieve efficient and reliable power transfer from energy resources/storage systems to various loads.
3. Battery is prominently used as an energy source. The monitoring and analyzing various battery parameters is important to optimize battery, ensure reliable operation and provide basis safety to the operator. So, the Battery Management System (BMS) is important to estimate the battery indicators.

Any development in above mentioned areas would eventually boost overall efficiency of sustainable energy systems. We are extensively carrying out research in the fields mentioned above to propose innovative solutions that would tackle real-world challenges.

Research progression

Research domain/area

- Analysis and modeling of nonlinear systems which includes dc-dc converters, EV cell / batteries and photovoltaic systems.
- Validation of developed model in time / frequency domain using simulation software.
- Identification and estimation of system parameters, their uncertainties and external disturbances, if any.
- Design and development of control strategies for above mentioned systems.
- Hardware realization of developed control strategies on digital platform like dSPACE MicroLabBox and Texas Instrument TMS320DSP.

Research accomplishments

- Mathematical models of dc-dc converters, EV cell and PV system have been developed and validated using simulation software.
- Four external disturbances and uncertainty estimation methods were developed for dc-dc converters and PV system.
- Two sensor less techniques developed to reduce sensor requirement and associated hardware complexity.
- Seven nonlinear control strategies were developed to regulate dc-dc converter and PV systems.
- All developed control strategies and estimation methods were validated using various digital platform.

Solutions/Contributions we can offer

1. Accurate mathematical model of high order dc-dc converters and various batteries used in EVs.
2. Estimation algorithms to estimate the system states, parameter uncertainties, and external disturbances in order to reduce the sensor requirements and associated hardware complexity.
3. Algorithms for estimating battery state indicators as well as extracting maximum power from PV systems.
4. Robust control algorithms to ensure that the entire system performs as expected even in the presence of disturbances.
5. Open loop and close loop model in the Loop simulations (MIL) to evaluate the performance of developed mathematical model, estimation, and control algorithms.
6. Hardware implementation of developed control schemes on various digital platforms.
7. Hardware in the loop simulations (HIL) to validate the performance of the developed control algorithms as well as the entire system.

Selected publications

1. S. K. Pandey, S. L. Patil, U. M. Chaskar and S. B. Phadke, "**State and Disturbance Observer-Based Integral Sliding Mode Controlled Boost DC–DC Converters**," in *IEEE Transactions on Circuits and Systems II: Express Briefs*, vol. 66, no. 9, pp. 1567-1571, Sept. 2019.
2. S. K. Pandey, S. L. Patil and S. B. Phadke, "**Regulation of Nonminimum Phase DC–DC Converters Using Integral Sliding Mode Control Combined With a Disturbance Observer**," in IEEE Transactions on Circuits and Systems II: Express Briefs, vol. 65, no. 11, pp. 1649-1653, Nov. 2018.
3. S. K. Pandey, S. L. Patil, Praveen V. Pol & S. B. Phadke, "**A new controller for boost DC-DC converters based on a novel sliding surface**", in International Journal of Electronics, 107:10, 1682-1703, 2020.
4. S. K. Pandey, S. L. Patil and S. B. Phadke, "**Comment on "PWM-Based Adaptive Sliding-Mode Control for Boost DC–DC Converters" [Aug 13 3291-3294]**," in IEEE Transactions on Industrial Electronics, vol. 65, no. 6, pp. 5078-5080, June 2018, doi: 10.1109/TIE.2017.2764872.
5. A.S. Deshpande, S.L. Patil., "**Robust Observer-Based Sliding Mode Control for Maximum Power Point Tracking**", Jour. Control Autom Electr Syst 31, 1210–1220 (2020)
6. A. S. Deshpande, S. L. Patil, & S. K. Pandey, "**Maximum Power Point Tracking Using Disturbance Observer-Based Sliding Mode Control for Estimation of Solar Array Voltage**", Electric Power Components and Systems, 48:1-2, 148-161, (2020)
7. A. S. Deshpande, S. L. Patil, "**Maximum Power Point Tracking Using a Hybrid Fuzzy Logic Control**". In: Kolhe M., Tiwari S., Trivedi M., Mishra K. (eds) Advances in Data and Information Sciences. Lecture Notes in Networks and Systems, vol 94. Springer, Singapore.
8. S.H. Chincholkar, S.V. Malge, S.L. Patil, **"Design and Analysis of a Voltage-Mode Non-Linear Control of a Non-Minimum Phase Positive Output Elementary Luo Converter"**. Electronics 2022, 11, 207.
9. S. K. Pandey, S. L. Patil, P. V. Pol & S. B. Phadke, "**A new controller for boost dc–dc converters based on a novel sliding surface**", International Journal of Electronics, 107:10, 1682-1703, 2020.
10. C. -Y. Chan, S. Chincholkar and W. Jiang, "**A Modified Fixed Current-Mode Controller for Improved Performance in Quadratic Boost Converters**," in IEEE Transactions on Circuits and Systems II: Express Briefs, vol. 67, no. 10, pp. 2014-2018, Oct. 2020, doi: 10.1109/TCSII.2019.2942057.

Resources available

Hardware / Software

- dSPACE microLabBox, dSPACE 1104
- TMS320F28069M Launchpad
- STM32F Nucleo-144 Arm Cortex-M7 processor
- Xilinx Vertex board, Zed board
- Programmable power supply
- Electronic Load
- Digital oscilloscopes
- Arbitrary waveform generator

Team

- Prof. S. L. Patil, *Ph.D.* ***IIT Delhi, India***
  Experties: Power electronics, power converter control, motor control, Battery management system
- Prof. A. S. Deshpande, ***Ph.D. COEP, Pune, India***
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- Prof. S. H. Chincholkar, ***Ph.D. NTU, Singapore***
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