LEAKAGE CURRENT MITIGATION TECHNIQUE IN SOLAR PV ARRAY USING PASSIVE FILTER

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ABSTRACT

Solar photovoltaic (PV) array systems can suffer from reduced performance due to parasitic capacitances that create a closed-loop path, causing leakage current. This can lead to electromagnetic interference and reduced PV panel lifespan. But there's good news: we've developed a passive filter that effectively suppresses the leakage current without requiring additional semiconductor switches. We've analyzed the system's frequency-domain and optimized the filter parameters to ensure peak performance. Our adaptive controller extracts the fundamental component of the load current for optimal harmonic compensation. Simulation results show that our passive filter is effective in suppressing leakage current within limits based on the DIN and NB/T grid codes. We've even performed comparative analyses to validate the practical feasibility and effectiveness of our system. And with our real-time hardware-in-loop (HIL) performance analysis for multiple operating cases, we've achieved total harmonic distortions (THDs) of the grid current within 5% as per the revised IEEE standard 519 and IEC standard 61727. Say goodbye to leakage current and hello to peak performance with our innovative passive filter design.

INTRODUCTION

Solar electric systems are an excellent choice for those looking to power their homes or businesses with renewable energy. At the core of these systems is the solar panel, also known as a photovoltaic solar panel. These panels come in various types, including monocrystalline, polycrystalline, and thin-film, each with their unique characteristics and specifications. Monocrystalline panels, for example, are made from single-crystal silicon and are known for their high efficiency, while polycrystalline panels are made from multiple silicon crystals and are more affordable. The solar panel itself is made up of an array of series and parallel connected solar cells, which generate a potential difference of about 0.5 volts each. The cells are typically made from silicon, which is a highly

efficient semiconductor material. To charge a standard 12-volt battery, multiple solar cells must be connected in series to achieve the 14 to 18 volts necessary for charging. Solar electric systems offer numerous benefits, including lower energy bills, reduced reliance on nonrenewable energy sources, and a smaller carbon footprint. Additionally, many solar panels come with warranties that can last up to 25 years, ensuring that your investment is protected for years to come. With a solar electric system, you can enjoy the peace of mind that comes with knowing you're doing your part to protect the planet while also saving money on your energy bills.

ADAPTIVE CONTROL

Adaptive control is a control method that adjusts the parameters of a control system in real-time to maintain optimal performance. It is a feedback control system that uses information from the system being controlled to modify the control inputs and ensure that the system operates at peak efficiency. Adaptive control systems are particularly useful in situations where the controlled system is subject to changes in its behavior, such as changes in load or environmental conditions. By constantly adjusting the control parameters, adaptive control systems can maintain optimal control performance even in the face of these changes. Adaptive control is used in a wide range of applications, including robotics, aerospace, and manufacturing. It is a powerful technology that allows control systems to adapt and optimize their performance in real-time, making it an essential tool in modern control engineering.

FILTER DESIGN

This text presents a robust design for a passive filter that will significantly enhance the performance of a grid-tied solar PV array system. By suppressing switching voltage and current harmonics and offering higher impedance at the resonance frequency, this filter will effectively eliminate the resonance component from the grid and suppress leakage current. It is essential to choose the damping ratio appropriately to suppress the resonance frequency effectively. The text provides three cases to illustrate the effect of the damping ratio on the frequency domain plot and impedance offered at high-frequency asymptote. The filter parameters determined for optimal performance are 1.25 kΩ, 8 mH, and 126.65 nF. With this robust filter design, the grid-tied solar PV array system can operate at peak efficiency and deliver optimal performance.

SCHEMATIC DIAGRAM

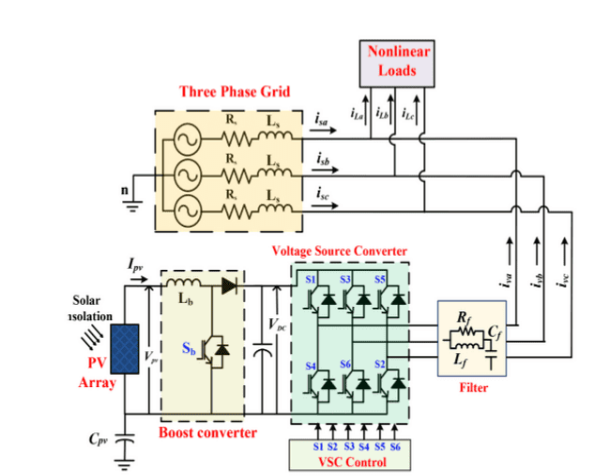


Fig. 1. Schematics of three-phase grid-tied solar energy conversion system.

SYSTEM DESIGN

A MPPT or maximum power point tracker

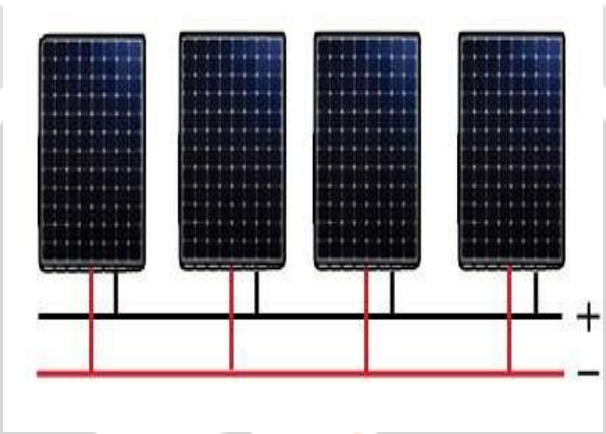
MPPT, which stands for Maximum Power Point Tracking, is an algorithm used in charge controllers to extract the maximum available power from a PV module under certain conditions. The maximum power point, or peak power voltage, is the voltage at which a PV module can produce its maximum power. This value varies depending on solar radiation, ambient temperature, and solar cell temperature. A MPPT, or maximum power point tracker, is an electronic DC to DC converter that optimizes the match between the solar array and the battery bank or utility

grid. In simpler terms, it converts the higher voltage DC output from solar panels (and some wind generators) down to the lower voltage required to charge batteries. MPPTs are sometimes referred to as "power point trackers" for short, not to be confused with "panel trackers," which are a solar panel mount that follows or tracks the sun.

COMPONENTS

Solar Panels

The primary component of a solar electric system is the solar panel, which is also known as a photovoltaic solar panel. There are different types of solar panels available in the market. A solar panel, or solar module, is an array of solar cells connected in series and parallel. Each solar cell generates a potential difference of approximately 0.5 volts. Therefore, to charge a 12-volt battery, the desired number of solar cells must be connected in series to obtain 14 to 18 volts.



Batteries

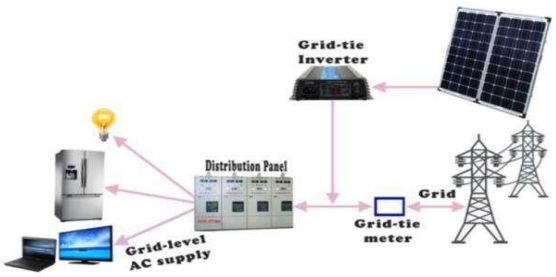
In a grid-tie solar generation system, the solar modules are directly connected to the inverter, not the load. The power collected from solar panels is not constant but varies with the intensity of sunlight. As a result, solar modules cannot directly feed any electrical equipment. Instead, they feed an inverter whose output is synchronized with the external grid supply. In this system, the battery is charged by solar electricity, and then it feeds a load directly or through an inverter. This approach ensures that the variation of power quality due to the variation of sunlight intensity is avoided in the solar power system. As a result, an uninterrupted and uniform power supply is maintained.

Controller

It is not desirable to overcharge or under discharge a lead acid battery, as both these situations can severely damage the battery system. To avoid such scenarios, a controller is required to be attached to the system. The controller helps to maintain the flow of current to and from the batteries, ensuring that overcharging and under discharging do not occur.

Inverter

In a solar power system, the electricity generated by the solar panels is DC, whereas the electricity from the grid supply is AC. To run common equipment from both sources, an inverter is required to convert the DC of the solar system to AC of the same level as the grid supply. In an off-grid system, the inverter is connected across the battery terminals to convert DC into AC. In a grid-tie system, the solar panel is directly connected to the inverter, which feeds the grid with the same voltage and frequency power.

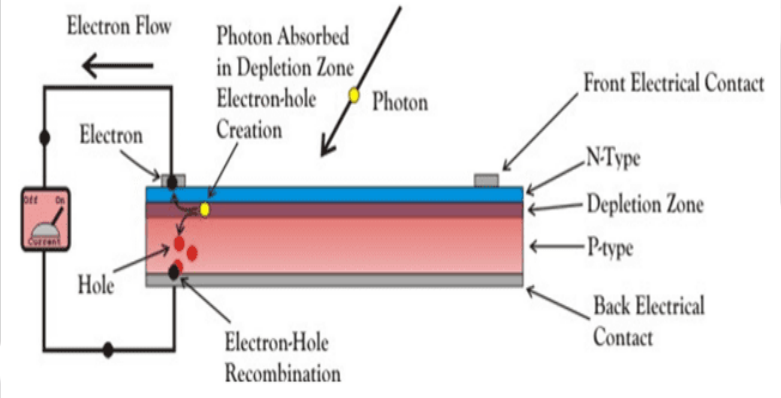


Grid Tie Solar System

Grid-tie solar systems come in two types: with a single macro central inverter and multiple micro inverters. In the former type, the solar panels and grid supply are connected to a common central inverter called a grid-tie inverter. It converts solar panel DC to grid-level AC and feeds it to the grid and consumer's distribution panel. The grid-tie inverter monitors the grid's power supply. During a power cut, it disconnects the solar system to prevent solar electricity from being fed back to the grid. An energy meter records the energy exported to and imported from the grid.

Solar Cell

A solar cell is a plate or cell that converts solar energy into useful electrical energy. The sun is an enormous source of energy that will never run out, making it the primary source of renewable energy. A solar cell is a device made of a p-n junction diode that uses the photovoltaic effect to convert light energy into electrical energy.



ADVANTAGES

- Improved Energy Efficiency
- Enhanced System Reliability
- Reduced Equipment Damage
- Compliance with Safety Standards
- Improved Power Quality

CONCLUSION

The passive filter design is presented for solar PV array systems to alleviate the leakage current enabling power quality improvement features. The novel passive filter design technique is studied and analyzed the dynamics under various operating scenarios. The stability and convergence analysis of the adaptive controller has been demonstrated to evince the robustness property and the boundedness of estimated harmonic components, respectively. Simulation results demonstrate satisfactory performances under various dynamic operating scenarios .Comparative leakage current analysis and THD performance versus the variation in solar power generation have been carried out to ensure the efficacy of the presented work over the state-of-art strategies.

REFERENCES

[1] A. Molina-Garcia, J. Guerrero-Pérez, M. C. Bueso, M. Kessler, and E. Gómez-Lázaro,"A new solar module modelling for PV applications based on a symmetrized and shifted gompertz model," IEEE Trans. Energy Convers., vol. 30, no. 1, pp. 51–59, Mar. 2015.

[2] R. Panigrahi, S. K. Mishra, S. C. Srivastava, A. K. Srivastava, and N. N. Schulz,"Gridintegrationofsmall-scalephotovoltaicsystemsinsecondary distribution network—A review," IEEE Trans. Ind. Appl., vol. 56, no. 3, pp. 3178–3195, May/Jun. 2020.

[3] Power generation systems connected to the low-voltage distribution network—Technical minimum requirements for the connection to and parallel operation with low-voltage distribution networks, VDE-ARN 4105-2011, 2011.

[4] S. Mishra et al., "Enabling cyber-physical demand response in smart gridsviaconjointcommunicationandcontrollerdesign,"IETCyber-Phys. System: Theory Appl., vol. 4, no. 4, pp. 291–303, Dec. 2019.

[5] N.G.Dhere,N.S.Shiradkar,andE.Schneller,"Evolutionofleakagecurrent paths in MC-Si PV modules from leading manufacturers undergoing high-voltage bias testing," IEEE J. Photovolt., vol. 4, no. 2, pp. 654–658, Mar. 2014.

[6] M. Rabiul Islam, A. M. Mahfuz-Ur-Rahman, K. M. Muttaqi, and D. Sutanto, "State-of-the-art of the medium-voltage power converter technologies for grid integration of solar photovoltaic power plants," IEEE Trans. Energy Convers., vol. 34, no. 1, pp. 372–384, Mar. 2019.

[7] A. Ahmed, M. S. Manoharan, and J. Park, "An efficient single-sourced asymmetrical cascaded multilevel inverter with reduced leakage current suitable for single-stage PV systems," IEEE Trans. Energy Convers., vol. 34, no. 1, pp. 211–220, Mar. 2019.

[8] K. S. Kumar, A. Kirubakaran, and N. Subrahmanyam, "Bidirectional clamping-based H5, HERIC, and H6 transformerless inverter topologies with reactive power capability," IEEE Trans. Ind. Appl., vol. 56, no. 5, pp. 5119–5128, Sep./Oct. 2020.

[9] M. N. H. Khan, M. Forouzesh, Y. P. Siwakoti, L. Li, T. Kerekes, and F. Blaabjerg, "Transformerless inverter topologies for single-phase photovoltaic systems: A comparative review," IEEE Trans. Emerg. Sel. Topics Power Electron., vol. 8, no. 1, pp. 805–835, Mar. 2020.

[10] W. Wu, Y. Sun, Z. Lin, T. Tang, F. Blaabjerg, and H. Shu-Hung Chung, "A new LCL-filter with in-series parallel resonant circuit for singlephase grid-tied inverter," IEEE Trans. Ind. Electron., vol. 61, no. 9, pp. 4640–4644, Sep. 2014.

[11] W. Li, Y. Gu, H. Luo, W. Cui, X. He, and C. Xia, "Topology review and derivation methodology of single-phase transformerless photovoltaic inverters for leakage current suppression," IEEE Trans. Ind. Electron., vol. 62, no. 7, pp. 4537–4551, Jul. 2015.

[12] L. Concari, D. Barater, C. Concari, A. Toscani, G. Buticchi, and M. Liserre, "H8 architecture for reduced common-mode voltage threephase PV converters with silicon and SiC power switches," in Proc. 43rd Annu. Conf. IEEE Ind. Electron. Soc., Beijing, China, 2017, pp. 4227–4232.

[13] X. Guo, R. He, J. Jian, Z. Lu, X. Sun, and J. M. Guerrero, "Leakage current elimination of four-leg inverter for transformerless three-phase PVsystems,"IEEETrans.PowerElectron.,vol.31,no.3,pp. 1841–1846, Mar. 2016.

[14] X. Guo, D. Xu, and B. Wu, "Three-phase seven-switch inverter with commonmodevoltagereductionfortransformerlessphotovoltaicsystem," inProc. IEEE IECON 40th Annu.Conf. IEEE Ind . Electron. Soc.,Dallas, TX, USA, 2014, pp. 2279–2284.

[15] R. Rahimi, S. Farhangi, B. Farhangi, G. R. Moradi, E. Afshari, and F. Blaabjerg, "H8 inverter to reduce leakage current in transformerless three-phase grid-connected photovoltaic systems," IEEE Trans. Emerg. Sel. Topics Power Electron., vol. 6, no. 2, pp. 910–918, Jun. 2018.