Scopus

Documents

Beroual, S., Hrairi, M., Yatim, N.M., Dawood, M.S.I.S.

Solar cell micro crack detection technique using electromechanical impedance and finite element analysis
(2023) *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, .

DOI: 10.1177/09544062231198776

Department of Mechanical and Aerospace Engineering, Faculty of Engineering, International Islamic University Malaysia, Kuala Lumpur, Malaysia

Abstract
Electromechanical impedance (EMI) is one of the modern techniques employed in the field of structural health monitoring (SHM) and has witnessed a great expansion in many domains due to its ability to ensure continuous monitoring and high reliability with a lower cost. Hence, the purpose of this study is to investigate the effectiveness of EMI in monitoring and detecting pre-existing cracks in the silicon layer of the photovoltaic (PV) solar cells. Indeed, a detailed finite element analysis (FEA) on the effect of piezoelectric lead zirconate titanate (PZT) patch shape on the EMI of crystalline-silicon (c-Si) layer of the PV solar cells were performed. The typical structure (c-Si + PZT) of different scenarios were stimulated by giving a lower voltage and high frequency as input data to extract the EMI signature as an explainable output result. Different models were investigated based on PZT patch types and crack position in the silicon layer. The results indicate that the EMI technique is effective in detecting crack, even in its incipient stage. The analysis suggests using a higher frequency range (350–650 kHz) for characterizing damage with an invisible depth due to the higher sensitivity of the EMI technique in this specific frequency.

Author Keywords
electromechanical impedance; finite element analysis; microcracks; piezoelectric patch; silicon layer; Solar cells

References

- Xu, Y., Li, J., Tan, Q.
  Global status of recycling waste solar panels: a review
  (2018) *Waste Manage*, 75, pp. 450-458.
- Chowdhury, M.S., Rahman, K.S., Chowdhury, T.
  An overview of solar photovoltaic panels' end-of-life material recycling
  (2020) *Energy Strategy Rev*, 27, p. 100431.
- Pei, T., Hao, X.
  A fault detection method for photovoltaic systems based on voltage and current observation and evaluation
  (2019) *Energies*, 12 (9), p. 1712.
- Rendler, L.C., Romer, P., Beinert, A.J.
  Thermomechanical stress in solar cells: contact pad modeling and reliability analysis
  (2019) *Sol Energy Mater Sol Cells*, 196, pp. 167-177.
- Gou, X., Li, X., Wang, S.
  The effect of microcrack length in silicon cells on the potential induced degradation behavior
  (2018) *Int J Photoenergy*, 2018, p. 4381579.
- Papargyri, L., Theristis, M., Kubicek, B.
  Modelling and experimental investigations of microcracks in crystalline silicon photovoltaics: a review
  (2020) *Renew Energy*, 145, pp. 2387-2408.
- Monastyrskyi, A., Ostapenko, S., Polupan, O.
  Resonance Ultrasonic Vibrations for in-line crack detection in silicon wafers and solar

cells, pp. 1-6.
Proceedings of the 33rd IEEE phototaic specialists conference, San Diego, CA, 11–16 May 2008, New York, IEEE, In

- Liu, Z., Peters, M., Shanmugam, V.
Luminescence imaging analysis of light harvesting from inactive areas in crystalline silicon PV modules
(2016) *Sol Energy Mater Sol Cells*, 144, pp. 523-531.

- Dhimish, M., Holmes, V., Mather, P.
Novel hot spot mitigation technique to enhance photovoltaic solar panels output power performance
(2018) *Sol Energy Mater Sol Cells*, 179, pp. 72-79.

- Dhimish, M., Holmes, V., Mehrdadi, B.
The impact of cracks on photovoltaic power performance
(2017) *J Sci Adv Mater Devices*, 2, pp. 199-209.

- Pramana, P.A.A., Dalimi, R.
Hotspot detection method in large capacity photovoltaic (PV) farm
(2020) *IOP Conf Ser Mater Sci Eng*, 982, p. 012019.

- Liang, C., Sun, F.P., Rogers, C.A.
Electromechanical impedance modeling of active material systems, pp. 232-253.
North American conference on smart structures and materials 1994. international society for optics and photonics, Orlando, FL, USA, May 1994, Bellingham, WA, SPIE, In

- Li, H., Wang, X., Chen, J.
Nonlinear electro-mechanical coupling vibration of corrugated graphene/piezoelectric laminated structures
(2019) *Int J Mech Sci*, 150, pp. 705-714.

- Lim, Y.Y., Soh, C.K.
Fatigue life estimation of a 1D aluminum beam under mode-I loading using the electromechanical impedance technique
(2011) *Smart Mater Struct*, 20, p. 125001.

- Yang, Y., Lim, Y.Y., Soh, C.K.
Practical issues related to the application of the electromechanical impedance technique in the structural health monitoring of civil structures: II. Numerical verification
(2008) *Smart Mater Struct*, 17, p. 035009.

- Hamzeloo, S.R., Shamshirsaz, M., Rezaei, S.M.
Damage detection on hollow cylinders by electro-mechanical impedance method: experiments and finite element modeling
(2012) *C R Méc*, 340, pp. 668-677.

- Rugina, C., Toader, A., Giurgiutiu, V.
The electromechanical impedance method for structural health monitoring of thin circular plates
(2014) *Proc Rom Acad Seri A Math Phys Tech Sci Inf Sci*, 15, pp. 272-282.

- Djemana, M., Hrairi, M., Al Jeroudi, Y.
Using electromechanical impedance and extreme learning machine to detect and locate damage in structures
(2017) *J Nondestruct Eval*, 36, p. 39.

- Zhu, J., Wang, Y., Qing, X.
Modified electromechanical impedance-based disbond monitoring for honeycomb

sandwich composite structure
(2019) *Compos Struct*, 217, pp. 175-185.

- (2017) *ANSYS element reference guide*, 18.
Canonsburg, PA, ANSYS Inc, Rev

- Li, W., Liu, T., Zou, D.
PZT based smart corrosion coupon using electromechanical impedance
(2019) *Mech Syst Signal Process*, 129, pp. 455-469.

- Ai, D., Zhu, H., Luo, H.
Mechanical impedance based embedded piezoelectric transducer for reinforced concrete structural impact damage detection: a comparative study
(2018) *Constr Build Mater*, 165, pp. 472-483.

- Na, W., Baek, J.
A review of the piezoelectric electromechanical impedance based structural health monitoring technique for engineering structures
(2018) *Sensors*, 18 (5), p. 1307.

- Bhalla, S., Soh, C.K.
Structural health monitoring by piezo-impedance transducers. I: modeling
(2004) *J Aerosp Eng*, 17 (4), pp. 154-165.

- Fan, S., Zhao, S., Qi, B.
Damage evaluation of concrete column under impact load using a piezoelectric-based EMI technique
(2018) *Sensors*, 18 (5), p. 1591.

- Liang, C., Sun, F.P., Rogers, C.A.
Coupled electro-mechanical analysis of adaptive material systems—determination of the actuator power consumption and system energy transfer
(1994) *J Intell Mater Syst Struct*, 5, pp. 12-20.

- Park, G., Farrar, C.R., di Scalea, F.L.
Performance assessment and validation of piezoelectric active-sensors in structural health monitoring
(2006) *Smart Mater Struct*, 15, p. 1673.

- Nguyen, K.-D., Kim, J.-T.
Smart PZT-interface for wireless impedance-based prestress-loss monitoring in tendon-anchorage connection
(2012) *Smart Struct Syst*, 9, pp. 489-504.

- (2020) *Significance of increasing size of mono-crystalline wafers in modules*,
(, accessed 27 September 2021

- Liu, W., Giurgiutiu, V.
(2007) *Finite element simulation of piezoelectric wafer active sensors for structural health monitoring with coupled-filed elements*, 6529.
SPIE smart structures and materials + nondestructive evaluation and health monitoring, Bellingham, WA: SPIE, In:, San Diego, CA, 18-22 March

- Djemana, M., Hrairi, M.
Modelling and simulation of impedance-based damage monitoring of structures
(2016) *Int J Simul Model*, 15 (3), pp. 295-408.

- Park, G., Kabeya, K., Cudney, H.H.
Impedance-based structural health monitoring for temperature varying applications
(1999) *JSME Int J Ser A*, 42 (2), pp. 249-258.

- Antunes, R.A., Cortez, N.E., Gianesini, B.M.
Modeling, simulation, experimentation, and compensation of temperature effect in impedance-based SHM systems applied to steel pipes
(2019) *Sensors*, 19, p. 2802.

- Ai, D., Lin, C., Zhu, H.
Embedded piezoelectric transducers based early-age hydration monitoring of cement concrete added with accelerator/retarder admixtures
(2020) *J Intell Mater Syst Struct*, 32 (8), pp. 847-866.

- Sepehry, N., Shamshirsaz, M., Bastani, A.
Experimental and theoretical analysis in impedance-based structural health monitoring with varying temperature
(2011) *Struct Health Monit*, 10 (6), pp. 573-585.

- Djemana, M., Hrairi, M., Yatim, N.H.M.
Improving electromechanical impedance damage detection under varying temperature
(2022) *J Adv Res Fluid Mech Therm Sci*, 92 (1), pp. 123-133.

Correspondence Address
Hrairi M.; Department of Mechanical and Aerospace Engineering, Malaysia; email: meftah@iium.edu.my

Publisher: SAGE Publications Ltd

ISSN: 09544062
CODEN: PMCSE
Language of Original Document: English
Abbreviated Source Title: Proc. Inst. Mech. Eng. Part C J. Mech. Eng. Sci.
2-s2.0-85174493808
Document Type: Article
Publication Stage: Article in Press
Source: Scopus