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Importance Measure Evaluation of Level 1 EV Charger Converter Topologies

[1] Abhinav Jindal, [2] G.L. Pahuja

[1] Department of Electrical Engineering, National Institute of Technology, Kurukshetra, Haryana, India
[2] Professor, Department of Electrical Engineering, National Institute of Technology, Kurukshetra, Haryana, India
Corresponding Author Email: [1] abhinav.jindal1234@gmail.com, [2] pahuja.gl@gmail.com

Abstract*— This study evaluates the importance measures of six distinct electric vehicle (EV) charger converter topologies: the Conventional Power Factor Correction (PFC) Boost Converter, Bridgeless PFC Boost Converter, Interleaved Boost PFC Converter, Conventional Flyback Converter, Isolated Half-Bridge. LLC Resonant Converter, and Phase-Shifted Full-Bridge (PSFB) Center-Tapped Converter. Utilizing failure probabilities for each component alongside series reliability models, risk metrics are systematically computed for each design. Five widely recognized importance measures—Birnbaum Importance, Fussell–Vesely (FV), Risk Reduction Worth (RRW), Risk Achievement Worth (RAW), and Criticality Importance (CI)—are employed to quantitatively assess and compare each component's contribution to the overall reliability of the converters across all topologies. The results reveal that electrolytic capacitors represent the most hazardous components in every topology, whereas inductors pose the least hazard. Furthermore, the analysis indicates that the Fussell–Vesely (FV) and Criticality Importance (CI) measures yield identical outcomes, and the Risk Achievement Worth (RAW) remains constant for all components in series-configured systems. These findings offer valuable insights for the optimal design, component selection, and maintenance prioritization of reliable EV charger power converters.

Index Terms*—Electric vehicle chargers, power converter reliability, reliability importance measures, Birnbaum importance, Fussell–Vesely importance, Risk Reduction Worth (RRW), Risk Achievement Worth (RAW), Criticality Importance, reliability assessment, power electronics.

I. INTRODUCTION

Power electronic converters play a crucial role in energy conversion systems and are commonly found in renewable energy, electric vehicles, industrial drives, and consumer electronics. While efficiency, power density, and cost are important considerations, reliability has become equally important as power electronics are becoming more prevalent. It is important to ensure the power electronic converters to function reliably as more than 70% of electrical energy goes through power electronic converters [1]. When converters fail, it can lead to higher maintenance costs, less system availability, and significant economic losses, especially in critical applications.

Recent studies on reliability began to deviate from the traditional predictive techniques and began to emphasize the understanding of the failure mechanisms and incorporating reliability into the design process [1]. Similarly, [2] demonstrated the significant impact of usage, environment, and wear of parts on the lifetime of a converter. The results indicate that, besides modelling failures adequately, it is also necessary to identify the components that introduce the greatest risk to the converter in order to make it more reliable.

Engineers can use measures of component importance to determine relative contribution of each part to system failure. These tools can help identify vulnerabilities, prioritize maintenance activities, optimize resource utilization and enhance reliability. The importance of various parts to the system performance and reliability is not the same, as noted by [3], so determining the importance of parts is crucial to designing reliable systems. Some of the most common measures used to rank how critical components are include Birnbaum Importance, Fussell–Vesely (FV) Importance, Risk Reduction Worth (RRW), Risk Achievement Worth (RAW), and Criticality Importance [4].

These importance measures have been helpful in a number of reliability studies, as indicated by [4] who demonstrated that they provide a structured approach to identifying critical components and for reliability-related decision making. Recent advances in FV analysis also demonstrate its effectiveness in risk prioritization of complex systems [5]. Economic aspects have also been studied by proposing cost-related importance measures [6] and a cost-based version of Birnbaum Importance [7] where the importance of components is being given increasing importance in planning for reliability and maintenance.

While importance measures are commonly used in reliability engineering, little comparisons have been made between the significance of various power electronic converter designs. This paper aims to fill this gap by comparing the reliability importance of six typical converter types: Conventional PFC Boost Converter, Bridgeless PFC Boost Converter, Interleaved PFC Boost Converter, Conventional Flyback Converter, Isolated Half-Bridge LLC Resonant Converter, and Phase-Shifted Full-Bridge Center-Tapped Converter. We use known importance measures to rank and quantify the importance of each component and provide a solid foundation for designing and maintaining

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more reliable converters.

II. RELIABILITY-BASED IMPORTANCE MEASURES

Reliability importance measures are used to determine the contribution of each component to the overall risk of the system and can be used to rank the components by their criticality. These measures are frequently employed in reliability engineering to determine the priority of components, to plan reliability maintenance and to design reliability systems [3], [4], [6], [7].

The converter system is modeled here with a system risk metric Q_{sys}, with a bigger value signifying a larger risk of system failure. Let the mean failure probability for component *i* be denoted by q_i and the system risk be denoted by $Q(q_i = 0)$ when the *i*th component is assumed to be perfectly reliable and by $Q(q_i = 1)$ when the *i*th component is forced to fail.

System Risk Metric shows the overall risk that the converter system might fail. It comes from the reliability model of the converter's design and helps determine how important each component is. If the system risk metric is higher, the chance of failure is greater.

A. Birnbaum Importance (BI)

This shows how sensitive the system risk is to the condition of a specific component. It measures how much the overall converter reliability changes when that component's state changes. Components with higher Birnbaum Importance values have a bigger impact on system failure and are seen as more critical to the converter's reliability performance [4], [7].

B. Fussell–Vesely Importance (FV)

This measure shows how much each component adds to the overall system risk. It reflects how likely a converter failure is linked to a specific component. Components with higher FV values have a bigger impact on system risk and should be prioritized for reliability improvement [5], [6].

C. Risk Reduction Worth (RRW)

This metric shows the potential benefit of making a component more reliable. It measures how much the overall converter risk would drop if the component were perfectly reliable. Components with high RRW values give the best chance to lower system failure risk by improving their reliability [6], [7].

D. Risk Achievement Worth (RAW)

This shows how a component failure affects the overall system risk. It tells us how much the converter risk goes up if a component fails. If the RAW value is high, the converter relies heavily on that component for reliable operation [4], [7].

E. Criticality Importance (CI)

This method considers both how much a component affects system performance and how likely it is to fail. It shows which parts are most important in the converter and most at risk. This helps rank components by their impact on system risk and is useful for setting priorities to improve reliability [5]–[7].

Table I. Reliability-Based Importance Measures

Measure	Definition
System Risk Metric	$Q_{sys} = Q(q_1, q_2, \ldots, q_n)$
BI	$BI_i = Q(q_i = 1) - Q(q_i = 0)$
FV	$FV_i = \frac{Q_{sys} - Q(q_i = 0)}{Q_{sys}}$
RRW	$RRW_i = \frac{Q_{sys}}{Q(q_i = 0)}$
RAW	$RAW_i = \frac{Q(q_i = 1)}{Q_{sys}}$
CI	$CI_i = \frac{[Q(q_i = 1) - Q(q_i = 0)]\, q_i}{Q_{sys}}$

III. CONVERTER TOPOLOGIES AND RELIABILITY MODELING

A. Selected Topologies

Six typical power converter topologies were chosen for reliability analysis. The AC–DC converter group (Figure 1) includes the Conventional PFC Boost Converter, Bridgeless PFC Boost Converter, and Interleaved PFC Boost Converter, all commonly used for power-factor-correction (PFC). The DC–DC converter group (Figure 2) includes the Conventional Flyback Converter, Isolated Half-Bridge (HB) LLC Resonant Converter, and Phase-Shifted Full-Bridge (PSFB) Center-Tapped Converter, which are standard isolated power conversion designs [8]–[13]. For reliability assessment, each topology was shown with its main reliability-critical components in a series reliability structure.

B. Reliability Modelling

To assess the reliability of the chosen converter topologies, we used component failure-rate data from the MIL-HDBK217 reliability prediction method, as reported in [14]. The key components we considered were MOSFETs, diodes, inductors, transformers, electrolytic capacitors, and film capacitors. Table II shows their failure rates and unreliability, given in failures per 10^6 operating hours.

Table II. Component Failure Rates and Unreliability

Component	Failure Rate per 10^6 Hours	Unreliability (q_i)
Diode	0.0357	0.001562
MOSFET	0.0814	0.003558
Film Capacitor	0.3218	0.013995
Electrolytic Capacitor	1.7609	0.074228

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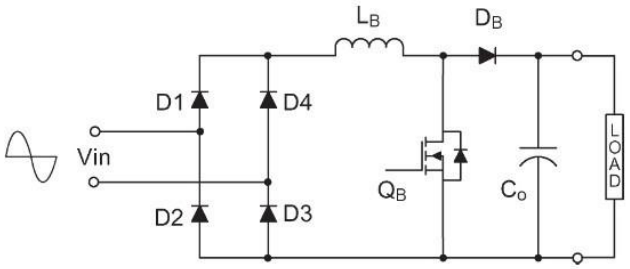
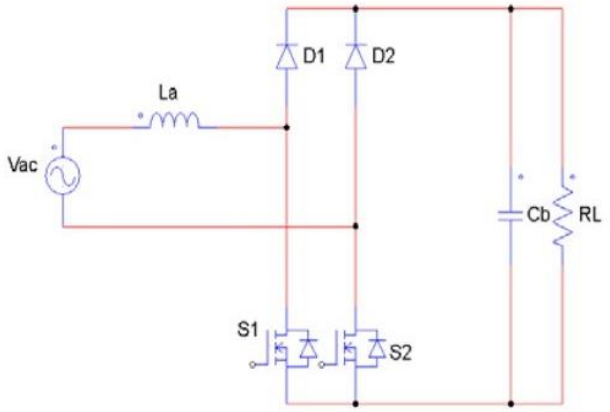
Inductor	0.0001	4.37999×10^{-6}
Transformer	0.0655	0.002864

IV. RESULT

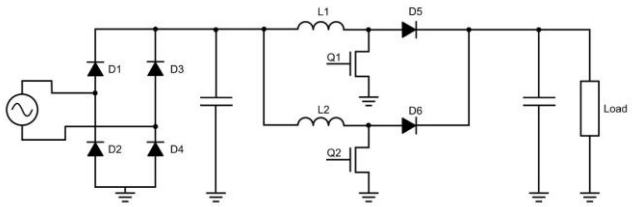
Tables III - VIII show the component importance rankings for the six converter topologies. Although the converters differ in design and number of components, the same pattern appears in each case. The electrolytic capacitor is always the main source of system unreliability, ranking highest every time. In contrast, the inductor consistently has the lowest importance values and adds little to the overall system risk.



(a) Conventional PFC Boost Converter



(b) Bridgeless PFC Boost Converter



(c) Interleaved Boost PFC Converter

Fig. 1. AC–DC Charger Topologies

Table III. Importance Measures: Conventional PFC Boost Converter

Component	BI	FV/CI	RRW
Electrolytic Capacitor	0.988677	0.866329	7.481056
MOSFET	0.918558	0.038591	1.040141
Diode	0.916721	0.016908	1.017199
Inductor	0.915293	0.000047	1.000047

Topology RAW = 11.804842.

Table IV. Importance Measures: Bridgeless PFC Boost Converter

Component	BI	FV/CI	RRW
Electrolytic Capacitor	0.989790	0.877989	8.196009
MOSFET	0.919593	0.039111	1.040703
Diode	0.917754	0.017136	1.017435
Inductor	0.916324	0.000048	1.000048

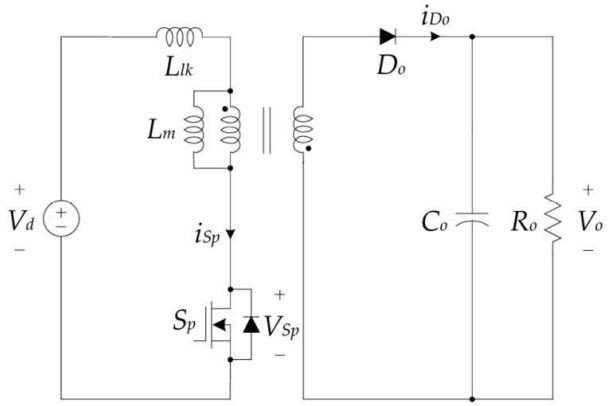
Topology RAW = 11.950270.

Table V. Importance Measures: Interleaved Boost PFC Converter

Component	BI	FV/CI	RRW
Electrolytic Capacitor	0.983614	0.816710	5.455846
MOSFET	0.913855	0.036381	1.037755
Diode	0.912028	0.015940	1.016198
Inductor	0.910607	0.000045	1.000045

Topology RAW = 11.185999.

The Birnbaum Importance results show that the electrolytic capacitor has the biggest impact on system failure probability, meaning the system risk metric is most sensitive to changes in its reliability. The Fussell–Vesely (FV) and Criticality Importance (CI) measures also consistently rank the electrolytic capacitor as the most important part.



(a) Conventional Flyback Converter

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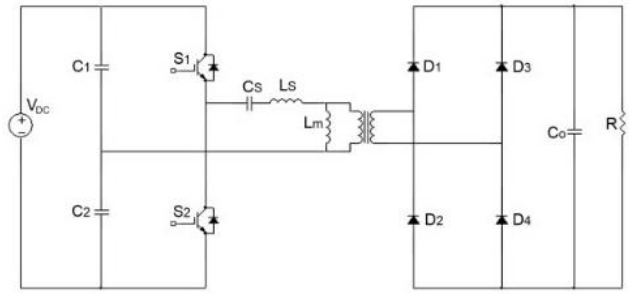
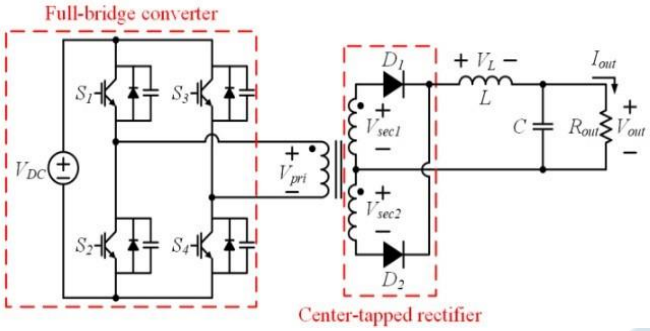


(b) Isolated Half Bridge LLC Resonant Converter



(c) PSFB Center-Tapped Converter

Fig. 2. DC–DC Charger Topologies

The fact that FV and CI are equal in Tables III - VIII comes directly from the series reliability structure used in the converter models. The Risk Reduction Worth (RRW) values also show that improving the reliability of the electrolytic capacitor leads to the largest drop in overall system risk, so it is the best target for reliability improvement.

The Risk Achievement Worth (RAW) values are the same for all components in a given topology. This is because if any required part fails in the series configuration, the whole system fails. As a result, RAW depends only on the system's overall unreliability for that topology, not on the details of each component.

Table VI. Importance Measures: Conventional Flyback Converter

Component	BI	FV/CI	RRW
Electrolytic Capacitor	0.992030	0.902333	10.238829
MOSFET	0.921673	0.040195	1.041879
Transformer	0.921032	0.032333	1.033413
Diode	0.919830	0.017611	1.017927
Inductor	0.918397	0.000049	1.000049

Topology RAW = 12.253878.

The results show that both repeating components and complex topologies affect reliability. In designs with several identical parts, like the diodes and MOSFETs in PFC and LLC converters, each device has the same importance because they contribute equally to system reliability.

Table VII. Importance Measures: Isolated HB LLC Resonant Converter

Component	BI	FV/CI	RRW
Electrolytic Capacitor	0.831426	0.267990	1.366102
Film Capacitor	0.780637	0.047444	1.049807
MOSFET	0.772460	0.011938	1.012082
Transformer	0.771922	0.009603	1.009696
Diode	0.770916	0.005230	1.005258
Inductor	0.769714	0.000015	1.000015

Topology RAW = 4.342372.

Table VIII. Importance Measures: PSFB CT Converter

Component	BI	FV/CI	RRW
Electrolytic Capacitor	0.979942	0.783851	4.626448
MOSFET	0.910443	0.034917	1.036181
Transformer	0.909809	0.028087	1.028899
Diode	0.908622	0.015299	1.015536
Inductor	0.907207	0.000043	1.000043

Topology RAW = 10.776183.

Also, converter topologies that use more components usually have a higher overall system risk, as shown in the rankings in Tables III to VIII.

For design improvements, the results suggest focusing first on electrolytic capacitors. This can be done by using component derating, better thermal management, choosing parts with longer lifespans, or replacing them with more reliable options when possible. Since semiconductor devices like MOSFETs and diodes usually rank in the middle, improving their reliability can offer some extra benefits. On the other hand, making inductors more reliable is likely to have less effect on the overall reliability of the converter.

V. CONCLUSION

Six power converter topologies were evaluated for reliability importance by Birnbaum Importance, Fussell–Vesely (FV), Risk Reduction Worth (RRW), Risk Achievement Worth (RAW) and Criticality Importance (CI) metrics. The use of MIL-HDBK-217 based component failure rates resulted in a calculation for reliability and unreliability. In all topologies, the electrolytic capacitor turned out to be the most critical component, the inductor the least critical. The framework provides a systematic approach to sizing the importance of the components and it can be used as a guide for converter design, component selection and maintenance planning on the basis of reliability. Future research directions will include mission profile-based

reliability assessment, physics-of-failure based modelling, and experimental testing with field data.

REFERENCES

[1] H. Wang, M. Liserre, F. Blaabjerg, P. de Place Rimmen, J. B. Jacobsen, T. Kvisgaard, and J. Landkildehus, "Transitioning to physics-of-failure as a reliability driver in power electronics," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 2, no. 1, pp. 97–114, 2014.

[2] N.-C. Sintamarean, F. Blaabjerg, H. Wang, F. Iannuzzo, and P. de Place Rimmen, "Reliability oriented design tool for the new generation of grid connected pv-inverters," *IEEE Transactions on Power Electronics*, vol. 30, no. 5, pp. 2635–2644, 2015.

[3] K. J. Szajowski and M. 'Srednicka, "Operation comfort vs. the importance of system components," *arXiv preprint arXiv: 2101.08205*, 2021.

[4] W. Ahmad, S. A. Murtza, O. Hasan, and S. Tahar, "On the formalization of importance measures using hol theorem proving," in *Proceedings of the 2019 IEEE/ACM 7th International Conference on Formal Methods in Software Engineering (FormaliSE)*, 2019, pp. 109–118.

[5] X. Xiao and P. Chen, "A hybrid real-time framework for efficient fussellvesely importance evaluation using virtual fault trees and graph neural networks," *arXiv preprint arXiv:2412.10484*, 2024.

[6] M. Xu, W. Zhao, and X. Yang, "Cost-related importance measure," in *Proceedings of the IEEE International Conference on Information and Automation*, Shenzhen, China, 2011, pp. 644–649.

[7] S. Wu and F. P. A. Coolen, "A cost-based importance measure for system components: An extension of the birnbaum importance," *European Journal of Operational Research*, vol. 225, no. 1, pp. 189–195, 2013.

[8] F. Musavi, W. Eberle, and W. G. Dunford, "A high-performance singlephase bridgeless interleaved pfc converter for plug-in hybrid electric vehicle battery chargers," *IEEE Transactions on Industry Applications*, vol. 47, no. 4, pp. 1833–1843, 2011.

[9] A. J. S. Renius and K. V. Kumar, "Analysis of variable speed pfc chopper fed bldc motor drive," *International Journal of Power Electronics and Drive Systems*, vol. 5, pp. 326–335, 2015.

[10] T. Hudson and C. Pineda, "Comparative study of pfc topologies: Interleaved boost vs. totem-pole pfc," 2022, monolithic Power Systems Application Note.

[11] W.-Y. Choi, "A flyback converter with a simple passive circuit for improving power efficiency," *Energies*, vol. 17, no. 18, 2024.

[12] V. V. S. K. Bhajana and P. Drabek, "Development and evaluation of an isolated resonant converter for auxiliary power supply in DC traction," *Engineering, Technology Applied Science Research*, vol. 9, no. 2, pp. 4048–4052, 2019.

[13] Y. J. Lee, Y. Bak, and K.-B. Lee, "Control method for phase-shift full-bridge center-tapped converters using a hybrid fuzzy sliding mode controller," *Electronics*, vol. 8, no. 6, 2019. [Online]. Available: https://www.mdpi.com/2079-9292/8/6/705

[14] M. Ghavami, S. Essakiappan, and C. Singh, "A framework for reliability evaluation of electric vehicle charging stations," in *2016 IEEE Power and Energy Society General Meeting (PESGM)*, 2016, pp. 1–5.