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LIFETIME PREDICTION OF SINGLE-STAGE LED DRIVER CIRCUIT USING BAYESIAN BELIEF NETWORK

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Keywords: Light-emitting diode (LED); Single-ended primary inductor converter; Parallel ripple cancellation circuit; Bayesian belief network (BBN); Electrolytic capacitor (EC); Mean time to failure (MTF).

In light-emitting diode (LED) lighting, the driver commands the lifetime and the LED bulb. It is essential to predict the driver's lifetime during its design stage. This paper proposes a viable method to predict the lifetime of the LED driver based on its failure rate. A novel single-ended primary inductor converter (SEPIC) integrated parallel ripple cancellation circuit (PRC) topology of 30 W is considered to estimate the lifetime of the driver circuit. The failure rate model is regarded as a base to predict the lifetime of LED drivers using Bayesian belief network (BBN) analysis. The weakest links are the prime components to estimate the lifetime, and they are active devices and capacitors employed in the driver circuit. The output capacitor is considered a degree of importance as per the existing literature, and the proposed course has been designed without using any electrolytic capacitor (EC) to enhance the reliability of the driver circuit. This approach ensures an effective way to access the mean time to failure (MTTF) or the lifetime of the LED driver in a lucrative manner.

1. INTRODUCTION

LED luminaire generally consists of a light module, a driver embedded with a control circuit, and a heat-dissipating enclosure [1]. Typical LED light has a lifetime of approximately 50,000 h [2], but the converter lifespan to drive the LED is commonly less, especially when EC is employed [3]. The failure of an LED driver depends on its associated critical components under running conditions, such as capacitors, power diodes, and switches [4]. The Mean time to failure (MTTF) determines the luminaire's lifetime. The difference between LED lifetime and the driver MTTF is to be lesser. It may result in a complete make-off. Several topological studies have been carried out to enhance the lifetime of LED drivers, focused mainly on electrolytic capacitor (EC) less drivers [5–7]. However, the trade-off between the driver's lifetime and efficiency is still an unsolved issue in the lighting industry. In real-time, the status of an LED lamp does not depend on a single component. It depends on its components like LED lamps, driver or power supply with control, reflectors, and diffuser. Among all the subsystems, the LED driver failure mechanism is the weakest component in the entire system, constituting 50 % of the failure [8].

Several LED reliability and lifetime prediction methods, such as lifetime prediction based on field data, are traditionally presented in the literature. The major drawback of this approach is the non-availability of the field data. In the current situation, there are more suitable approaches to predict a driver's lifetime. Another way to predict the reliability is based on the data obtained from the testing process [9]. Although a non-accelerated test performs at the nominal loaded condition, it isn't easy to arrange the test environment as the real functional environment. It is only sometimes known, and the execution will take a long time. Alternatively, accelerated life tests (ALT) [10] are progressing to determine the lifetime of components like LEDs and Batteries. However, it takes more time to get enough data on time to fail and is found to be costly. In [11], the authors suggested the accelerated life test method for the electrolytic capacitors employed in the driver.

Output current ripple is considered the prime factor of failure. Based on the rate of change in output, the current ripple useful life of the driver is determined. However, the other critical components in the circuit are not considered to estimate the lifetime of the driver circuit. In addition, the probability of failure is presented in [12] using the Monte Carlo simulation approach; however, the author mainly focused on EC degradation, neglecting other critical components. In the case of an EC-free flyback converter with an LC filter [13], a fault tree approach (FTA) is employed to predict the failure rate of the critical components in the driver circuit. However, the critical components in the proposed design are limited to a single switch and a power diode. The process could be clearer and more accurate in the case of advanced LED drivers [14] with more critical components.

Another approach of combining the failure rate statistical data from the handbook and the Weibull model for flyback LED driver [15] is suggested. Though it does not require any testing, the lifetime prediction is inaccurate. The Pseudo Black Box testing method is suggested in [16] to project the degradation of the LED driver with a factor *di*/*dv* at different stages of driver operation. To assess the lifetime and reliability of LED light modules, several degradation data approaches, such as the gamma process [17], the Wiener process [18], and the Levy process [19], are presented in the literature. These methods concentrate mainly on the lifetime of the LED module, and the rest of the key weak components should be addressed.

Despite the significant advancements in engineering design and development, it created difficulties in evaluating system-level reliability due to unanticipated failures in complex systems. Fault tree analysis (FTA) is the graphical approach to identifying the different sets of node failures that could cause the emergence of particular "unwanted events" in the process. Though several research reports on FTA for LED drivers are presented [20], it is difficult to embed the unknown variables and dependent states. Regardless of the shortcomings of conventional methods, the Bayesian belief network (BBN) [21] is another suitable approach to estimate the reliability of the complex network dealing with correlations, ambiguities, and the dependent interaction between the critical components in the system. It is a widely used approach in intelligent systems and reliability prediction in many complex process systems [22].

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Hence, BBN is crucial to integrate operation data from the various parts of a complicated process or system. While the system has insufficient test data to estimate the lifetime of all the critical components in the LED driver with less time and in an economical method, the BBN approach is much desired. A novel single-stage SEPIC integrated PRC converter is considered an LED driver. The failure rate of the critical components in the proposed converter is obtained from the MIL-HDBK-217F handbook [23], and based on the conditional probabilities, the life span of the LED driver is estimated.

The paper is structured as follows. Section 2 presents the proposed topology with critical components; section 3 explains lifetime evaluation and methodology. Section 4 projects on the theory and implementation of BBN to estimate LED lifetime. Results are presented in section 5, and section 6 ends with a conclusion.

2. TOPOLOGY OVERVIEW

The circuit diagram of the SEPIC with a PRC converter is shown in Fig. 1. Inductors (L_1 L_2), switch (Q_1), capacitor (C_1), and diode (D) form SEPIC. Switches (Q_{BDC}, $Q^{|}_{BDC}$), inductor (L_{BDC}), and capacitor (C_{BDC}) form the PRC circuit. The front-end SEPIC converter acts as a power factor correction (PFC) converter with discontinuous conduction operation. The bi-directional buck-boost converter acts as PRC shunted with the SEPIC converter to reduce the ac ripple; a high value of EC will be employed, degrading the driver's lifetime. The inductor (L_o) allows higher switching harmonics than the second harmonic. The PRC converter assists in bypassing the double-line frequency current from the front-end SEPIC PFC.

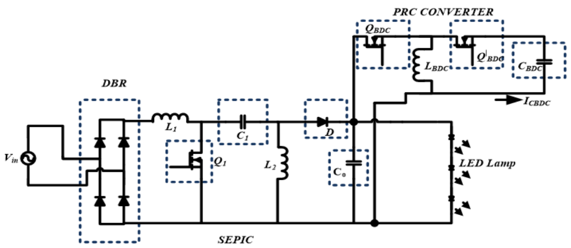

Fig. 1 – SEPIC integrated PRC LED driver.

A single-stage SEPIC PFC with a ripple minimization circuit is employed for ripple-free LED application. The front-end PFC converter is a SEPIC converter [24] with an inherent PFC. But to achieve the desired standards for the LED driver, an individual PFC converter deserves a larger output capacitance value to nullify the flicker. As a result, a parallel ripple cancellation (PRC) circuit coupled with PFC is offered to reduce output capacitance without sacrificing flicker.

The Buck-Boost converter acts as a PRC circuit, allowing ripple-free DC to the LED. Proper PRC switching permits bidirectional current flow and the passage of a second harmonic current. The selection of switching frequencies is independent of each other in this solution. This topology employs film capacitor design, which extends the lifespan of an LED driver circuit. The detailed design and the modes of operation are presented in [25], as this article mainly focuses on the lifetime estimation process of the presented topology, which is mainly concentrated in this article. The basic operation of the circuit model discussed in this section is divided into four modes based on the switching state of the switching devices in PFC and PRC circuits. Initially, switches Q_1 and Q_{BDC} are in conduction based on the switching pulse.

Mode-1's inductors (L_1, L_2) store energy to the input voltage value. QBDC bypasses the ripple current at the output to the inductor. At the end of this mode, Q turns OFF. In mode-2, Q is in the OFF state: the stored inductor energy forward biases the output diode, and the PRC switch is still in conduction. Low-frequency ripple is bypassed through the PRC circuit. At the end of this mode, the PFC output diode (D) and Q are in the OFF state. In mode-3, Q_{BDC} alone is in conduction to allow the ripple content. The energy in the output capacitor delivers energy to the LED. The operation of PRC switches is complementary to each other. In mode-4, $Q^{|}_{BDC}$ allows the stored inductor energy of L_{BDC}. The stored energy in the inductor is delivered to the capacitor through $Q^{|}_{BDC}$.

The critical components in the LED driver circuit are identified initially based on performance metrics such as current and temperature across the devices. The critical components highlighted in Fig. 1 are the weakest links in the driver circuit. The capacitors employed in both SEPIC and PRC converters are non-electrolytic, and the active devices such as MOSFET and diodes have been given the highest priority while evaluating the reliability of the driver circuit.

3. LIFETIME EVALUATION- METHODOLOGY

This section discusses the proposed LED driver topology reliability approach in detail. Initially, the empirical failure rate of the system-level critical components is obtained from the part stress analysis (PSA). Based on this data and to obtain a more accurate failure rate, the data sheets of several components are also considered to obtain accurate empirical failure rates. Later, the obtained failure rates are applied to the Bayesian network to determine the life of the LED driver. Failure of a component or device is the instant of the end of its life. It is represented by a failure rate 'λ', which indicates the number of failures in time. The failure of an LED driver depends on the weakest links or components in the driver circuit. Failure of a component is not instantaneous; it progresses or deteriorates with time based on its characteristic behavior. It is represented by the reliability curve, as shown in Fig. 2.

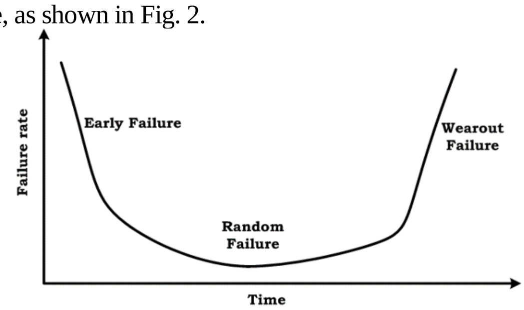

Fig. 2 – Reliability curve.

It indicates the random, early failure and wears out as time progresses. Initially, the failure rate is very high and remains constant during its operating period after replacing the defective products. Later, the component enters the wear-out region, and the failure rate increases as the lifespan of the component or device ends. The lifespan of an LED driver depends on the useful life of critical components in the driver circuit. Hence, the LED driver's lifetime is the maximum operating time under defined conditions. Often, authors need clarification on reliability and the lifetime. Reliability is the probability of failure or pass of the component or device within a given period at a given failure rate. However, it can be measured using failure rate, mean time to failure (MTTF), and mean time between the failure (MTBF) based on the suitable selection of distribution function. A basic theoretical approach is initially chosen to estimate the failure rate of the driver's critical components.

3.1. PART STRESS ANALYSIS

The idea to obtain the failure rate of the proposed LED driver using the PSA method is to obtain the failure rate of the individual critical components in the driver circuit, and the algebraic sum of individual failure rates can be considered as the failure rate of the LED driver. The overall failure rate of the LED driver is represented by λ using eq. (1) and obtained using MIL-HDBK-217F handbook.

$$\lambda_{driver}=\Sigma\lambda_j=\lambda_{DBR}+\lambda_{Q_1}+\lambda_{C_1}+\lambda_D+\lambda_{C_o}+\lambda_{Q_{BDC}}+\lambda_{Q^{|}_{BDC}}+\lambda_{C_{BDC}}. \quad (1)$$

Where j is the individual critical components in the driver circuit, the critical components in the proposed converter are the diode bridge rectifier (DBR) at the front end, SEPIC switch (Q_1), the non-electrolytic SEPIC capacitor (C_1), D, and output film capacitor (C_o), in addition to Q_{BDC}, $Q^{|}_{BDC}$ and capacitor (C_{BDC}) are considered critical components, and their respective failure rates are represented in eq. (1). The component failure rate depends on temperature, environmental, and stress factors. These factors vary for different types of components. In the current application, the temperature and power rating of the component are considered to estimate the base failure of the critical component. Using PSA, the failure rate is obtained from eq. (1) and the MTTF is obtained by eq. (2).

$$\text{MTTF}=\frac{1}{\lambda_{driver}}. \quad (2)$$

Therefore, the failure rate of critical components in the proposed converter is tabulated in Table 1. Based on the constant failure rate, the MTTF of the proposed LED driver is estimated using eq. (2) obtained as 36,734 hours. Among all the components, power switches have the highest failure rate. The proposed converter has no electrolytic capacitor during its implementation; hence, a higher lifetime can be guaranteed. Based on the constant failure rate, the MTTF of the proposed LED driver is estimated using eq. (2) obtained as 36,734 hours. Among all the components, power switches have the highest failure rate. The proposed converter has no electrolytic capacitor during its implementation; hence, a higher lifetime can be guaranteed.

Table 1

Failure rates of critical components in the proposed converter

Critical Components	Failure rate (hours)
Diode Bridge rectifier	$0.0363\cdot10^{-6}$
MOSFET (Q_1)	$9.768\cdot10^{-6}$
Capacitor (C_1)	$0.0266\cdot10^{-6}$
Diode (D)	$3.0096\cdot10^{-6}$
Output Film Capacitor (C_o)	$0.0308\cdot10^{-6}$
PRC converter MOSFET1 (Q_{BDC})	$9.768\cdot10^{-6}$
PRC converter MOSFET2 ($Q^{|}_{BDC}$)	$7.128\cdot10^{-6}$
PRC Capacitor (C_{BDC})	$0.462\cdot10^{-6}$

4. LIFETIME EVALUATION USING BBN APPROACH

The BBN or Bayes nets approach for lifetime evaluation is a powerful tool in a real-time application, especially during a lack of test data and uncertainties. BBN is a little graphic depiction with a collection of nodes that stand in for random variables, and these nodes or variables are linked using arcs. This complete structure can form a directed acyclic graph (DAG). The probability of failure occurrence at each node depends on the prior probabilities of the parent node and the conditional dependence of each node. The conditional probabilistic dependencies influence the correlation between the nodes in BBN. To understand the BBN, it is essential to understand the terms root node and leaf node. The root node is the node that does not have a parent node, and the leaf node is the node that does not have a child. These are used to represent the input and output in the network. Based on the network conditional probabilities at each node, a joint probabilistic function is obtained for a given parent node. The detailed analysis of the BBN concept is reported in [26]; hence, the approach to estimating the lifetime of the LED driver is explained in detail.

4.1. BAYESIAN NETWORK MODEL FOR THE PROPOSED CONVERTER

The flow of BBN for lifetime evaluation is determined systematically. Initially, the structure model that represents the DAG with nodes and arc of the network is to be determined. A conditional probability table is formed during parameter modeling by assigning the prior and posterior probabilities. Bayesian inference is to update the new observations in the network, and the simulation tool GenIe is employed. Finally, the network verification can be done using sensitivity analysis BN to ensure accurate operation and validation based on the data obtained from the handbook. The flow of BBN is shown in Fig. 3.

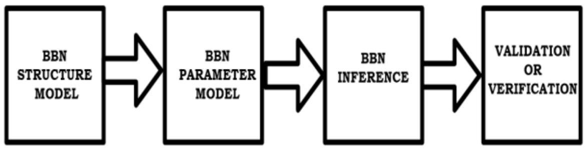

Fig. 3 – Flow of Bayesian network model.

4.2. BBN STRUCTURE MODEL

Primarily, it is essential to identify the nodes or variables on the proposed converter. The root nodes of the BN structure are the diode bridge rectifier and SEPIC components, *i.e.*, MOSFET (Q_1) capacitor (C_1), diode (D), and output capacitor (C_o). In addition, the PRC components MOSFETs (Q_{BDC} & $Q^{|}_{BDC}$) and capacitor (C_{BDC}) are the critical components considered as nodes or variables of the network form a cyclic graph. The leaf node of the network is the SEPIC-integrated PRC LED driver. Each network node operates in two states, *i.e.*, the working state (T) and the failure state (F). The failure rate of the critical components based on the handbook data is fed to the variables as failure state.

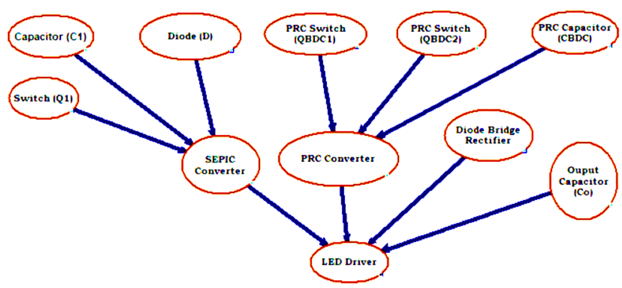

Fig. 4 – DAG representation of Bayesian structure for proposed LED driver.

4.3. BBN PARAMETER MODEL

This section tabulates the probability of the critical components' healthy and failure states. The root nodes consist of two probabilistic states, *i.e.*, the working state (T)

and the failure state (F). The failure of SEPIC in Fig. 4 fails if any of its parent nodes fails, and similarly in the case of the PRC converter. Failure of any parent node of the PRC converter leads to failure of the PRC converter. Based on the conditional probability of SEPIC, PRC converter, diode bridge rectifier, and output capacitor, the failure rate of the LED driver is predicted using BBN. The corresponding probabilistic table of the root node is shown in Table 2. A conditional probability table (CPT) includes each node's set of parents. The failure state of the SEPIC and PRC converter is considered as if any of its parent nodes fails.

The CPT for the SEPIC node and PRC converter nodes are represented in Tables 3 and 4, respectively. The failure probability of the SEPIC and PRC converter can be predicted using eq. (3) to (6). The failure probability rate of the SEPIC is obtained from eq. (4).

$$P(SEPIC=T)=P(Q_1,C_1,D)=P(SEPIC|Q_1,C_1,D)* *P(Q_1)*P(C_1)*P(D), \quad (3)$$

$$P(SEPIC=F)=1-P(SEPIC=T). \quad (4)$$

Similarly, the failure probability rate of the PRC converter node can be obtained from eq. (6)

$$P(PRC=T)=P(Q_{BDC},Q^{|}_{BDC},C_{BDC})= \quad (5)$$

$$=P(PRC|Q_{BDC},Q_{BDC},C_{BDC})*P(Q_{BDC})*P(Q^{|}_{BDC})*P(C_{BDC}),$$

$$P(PRC=F)=1-P(PRC=T). \quad (6)$$

From eq. (4) and eq. (6) the failure rate of SEPIC and PRC converter can be obtained.

Table 2

Probabilistic table for root nodes of SEPIC PRC converter

	$P(DBR)$		$P(Q_1)$		$P(C_1)$
T F	0.999999963 $0.0363*10^{-6}$	T F	0.999990232 $9.768*10^{-6}$	T F	0.999999973 $0.0266*10^{-6}$
	$P(D)$		$P(C_o)$		$P(Q_{BDC})$
T F	0.99999699 $3.0096*10^{-9}$	T F	0.999999969 $0.0308*10^{-6}$	T F	0.999990232 $9.768*10^{-6}$
	$P(Q_{BDC}^{|})$				$P(C_{BDC})$
T F	0.999990232 $7.128*10^{-6}$			T F	0.999999538 $0.462*10^{-6}$

Table 3

Conditional Probabilistic table of SEPIC node

Q_1	C_1	D	$P(SEPIC=T)$	$P(SEPIC=F)$
F	F	F	0	1
F	F	T	0	1
F	T	F	0	1
F	T	T	0	1
T	F	F	0	1
T	F	T	0	1
T	T	F	0	1
T	T	T	1	0

From Table 4, the probability of LED driver in working state (T) can obtained from two different instincts. When all the parent nodes of the LED driver are 'T', the probability of the LED driver is considered as '1', *i.e.*, the driver operated effectively without the occurrence of any fault.

Table 4

Conditional Probabilistic table of PRC converter node

Q_{BDC}	$Q_{BDC}^{|}$	C_{BDC}	$P(PRC=T)$	$P(PRC=F)$
F	F	F	0	1
F	F	T	0	1
F	T	F	0	1
F	T	T	0	1
T	F	F	0	1
T	F	T	0	1
T	T	F	0	1
T	T	T	1	0

According to the operation of the proposed converter without PRC converter, the driver delivers the partial output, and this case is considered as 30 percent of the desired output. To determine the failure rate of the proposed LED driver, the joint probability of the driver is obtained from eq. (7) and (8).

$$P(DRIVER=T)=P(SEPIC,PRC,DBR,C_O)=$$
$$[P(DRIVER|SEPIC,PRC,DBR,C_o)*P(SEPIC)*P(PRC)*P(DBR)*P(C_o)]+[P(DRIVER|SEPIC,\sim PRC,DBR,C_o)*P(SEPIC)*P(\sim PRC)*P(DBR)*P(C_o)], \quad (7)$$

$$P(DRIVER=F)=1-P(DRIVER=T). \quad (8)$$

Substituting the values obtained from eq. (3) to (6) and the probability of the root nodes from Table 1, the failure rate of the proposed LED driver can be obtained theoretically. Therefore, prior and conditional probabilities are obtained for the variable in the Bayesian network in this section.

4.4. BBN INFERENCE

The inference in this context is executed using an exact inference algorithm. GenIe software and its default exact algorithm, *i.e.*, clustering algorithm, is employed to update the beliefs. This algorithm compiles the network into a junction tree and updates the probabilities. This algorithm generates the marginal probability over the network nodes, similar to other algorithms. In addition, the joint probabilities of the nodes in the same clique can be generated.

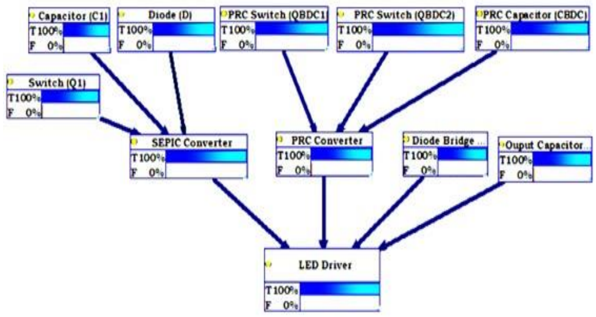

Fig. 5 – Working state of the LED driver.

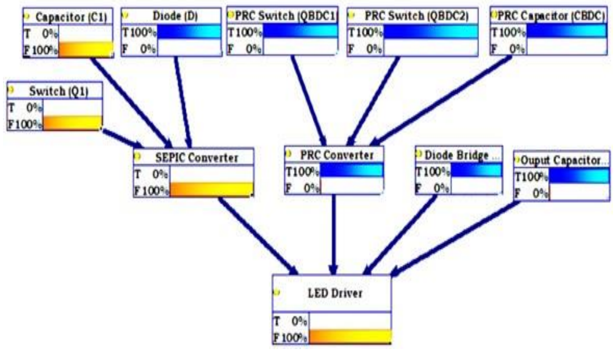

Fig. 6 – SEPIC Converter failure state.

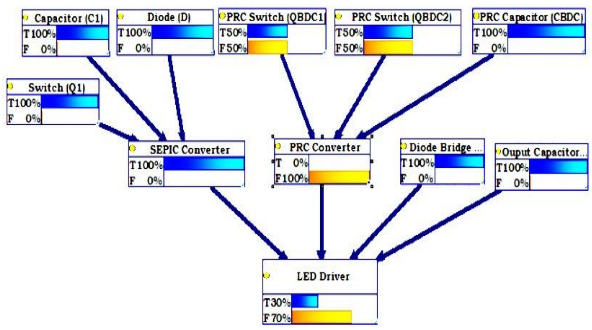

Fig. 7 – PRC Converter failure state.

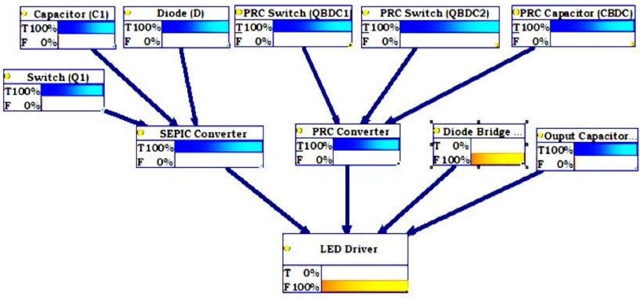

Fig. 8 – Diode bridge rectifier failure state.

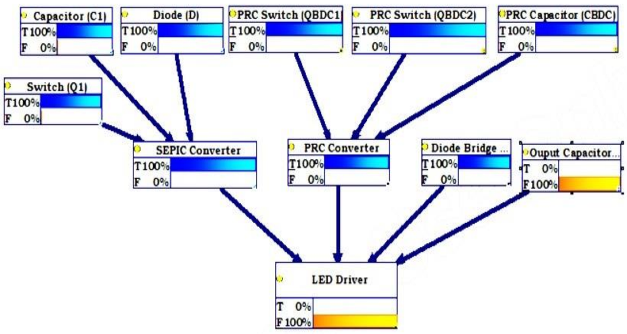

Fig. 9 – Output capacitor failure state.

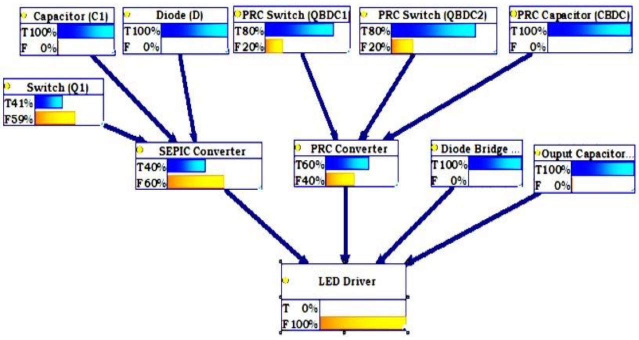

Fig. 10 – Possible failure state of LED driver.

Figure 5 represents the working state of the LED driver where all the critical components are in healthy condition. However, the failure of the driver depends on the failure of any of the parent nodes of the LED driver. Hence, in Fig. 6, the failure state of the SEPIC converter is mainly dominated by the failure of the SEPIC switch (Q_1). Based on the inference, the failure probability of the SEPIC converter is obtained as $9.7976093 \cdot 10^{-6}$.

Figure 7 represents the failure of the LED driver due to PRC converter failure. The PRC switches dominate the failure in the PRC converter (Q_{BDC} & $Q^{|}_{BDC}$). Though the PRC converter fails, the proposed converter delivers 30% of the desired output to drive the LED. The failure probability of the PRC converter is obtained as $1.7357923 \cdot 10^{-5}$. Though the capacitor employed in the PRC converter is a film capacitor, the failure rate is much dominated by the power switches rather than the capacitor in the ripple cancellation circuit. The failure state of the diode bridge rectifier and the output capacitor are shown in Fig. 8 and 9, respectively. These are the root nodes of the LED driver. The failure of root nodes leads to the failure of the LED driver. Though the output capacitor is a more critical element in the driver circuit, the proposed converter is implemented with a non-electrolytic output capacitor to enhance the life span of the LED driver. Figure 10 shows the possible failure state of the LED driver; power switches in the proposed converter have the highest possible failure compared to the other critical components, leading to the complete failure of the driver circuit.

4.4 VERIFICATION OR VALIDATION OF BN MODEL

The verification or validation of network model is essential to provide reasonable assurance to judge the outcomes or results. The network model's accuracy is evaluated during validation. Uses genuine data, mirrors reality, and is realizable. The verification of the network is done using sensitivity analysis. Under all the critical components of the driver circuit are in working condition (T), the failure rate of the LED driver is obtained as $2.20151 \cdot 10^{-5}$, as shown in Fig. 11. Validation is done with the handbook approach and the fault tree analysis. Using a Bayesian network, the LED driver's failure rate is lesser than other methods due to the consideration of partial output during PRC failure.

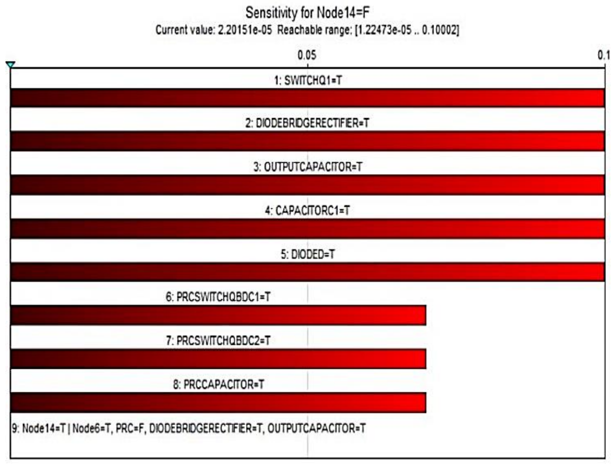

Fig. 11 – Sensitivity of LED driver using tornado diagram.

Table 5

The failure rate of critical components

Critical Components	MIL-HDBK-217F Handbook	Fault tree Analysis	Bayesian Belief Network
Diode Bridge Rectifier	$0.0363 \cdot 10^{-6}$	$0.0363 \cdot 10^{-6}$	$0.0363 \cdot 10^{-6}$
Output Capacitor	$0.0308 \cdot 10^{-6}$	$0.0308 \cdot 10^{-6}$	$0.0308 \cdot 10^{-6}$
SEPIC Converter	-	-	$9.7976093 \cdot 10^{-6}$
PRC Converter	-	-	$1.7357923 \cdot 10^{-5}$
Proposed LED Driver	$2.7222709 \cdot 10^{-5}$	$2.7222709 \cdot 10^{-5}$	$2.2015135 \cdot 10^{-5}$

Table 6

Lifetime of Proposed LED driver

	MIL-HDBK-217F Handbook	Fault tree Analysis	Bayesian Belief Network
Lifetime of the Driver	36,734 hours	36,734 hours	45,423 hours

5. RESULTS AND DISCUSSION

The current study proposed the evaluation of the lifetime of SEPIC-integrated PRC circuits using BBN. The critical components are identified initially, and the Bayesian network is formed. Based on the proposed converter's operation and the critical components' failure rate based on the handbook data, the failure state of each node is updated. Failure of any parent node (DBR, C_o, SEPIC, and PRC converters) of the LED driver leads to failure of the entire system. The failure rates of individual components are identified based on the operation and the effect of temperature on the critical components. Conditional probabilities are obtained based on the operation of the driver circuit. The PRC is used as a ripple cancellation circuit in the proposed converter without employing any EC. Among all the critical components, power switches have a higher failure rate than the capacitors employed in the circuit. The proposed converter is designed to operate with non-EC to enhance the lifetime of the driver circuit. The failure rates of the critical components in the driver are tabulated in Table 6 compared with handbook data and FTA. The lifetime of the proposed LED driver using BBN and its comparison is shown in Table 7. Using BBN, the proposed converter lifetime is estimated to be 45,423 hours, on par with the lifetime of the LED lamp.

6. CONCLUSION

This paper proposes the lifetime evaluation of a single-stage SEPIC integrated PRC converter as an LED driver to drive a 30 W LED bulb. Here, the front-end discontinuous SEPIC acts as Power factor correction and PRC converter as ripple cancellation without employing any EC. The output capacitor employed in the circuit is non-EC, which can enhance the life span of the driver circuit and is estimated using the Bayesian approach. The basic critical components in the proposed converter are identified based on the failure rate of each critical component in the converter. The failure rate of each component is identified using the MIL-HDBK-217F handbook. Based on the failure rate, the PFC switch in the solution presented is more critical than the other components. The selection of Bayesian Belief Network in this paper is mainly selected due to the need for test data to estimate the lifetime of the LED driver. In this approach, each critical component is considered the root node of the Bayesian network. The failure rate of the critical components based on the handbook data is fed to the variables as failure state. In this configuration, the failure state of the PRC converter and SEPIC is regarded as if any of its parent nodes fails. Based on the conditional probability, the failure rate of the SEPIC and PRC converter is obtained theoretically. Under healthy conditions, the lifetime of the proposed converter is predicted to be 45,423 hours of operation based on the Bayesian belief network.

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