Degradation indicators for power electronic converters

Indicadores de degradación para convertidores electrónicos de potencia

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Keywords

Fault; power converter; indicator; capacitor; switching transistor.

Abstract

Power electronic converters are an important element in the interaction between source and load. In fact, failures in this system often lead to bigger problems. Therefore, it is necessary to monitor the converter components that have the most failures. In this work, we present the estimation of three parameters, which are, in turn, degradation indicators of components in the power electronic converters: equivalent series resistance, capacitance and on-state resistance. Using current and voltage measurements of the Boost converter.

Palabras clave

Falla; convertidor de potencia; indicador; capacitor; transistor de conmutación.

Resumen

Los convertidores electrónicos de potencia son un elemento importante en la interacción entre la fuente y la carga. De hecho, los fallos en estos sistemas a menudo conducen a problemas mayores. Por lo tanto, es necesario monitorear los componentes del convertidor que tienen más fallas. En este trabajo presentamos la estimación de tres parámetros, que son a su vez indicadores de degradación de componentes en los convertidores electrónicos de potencia: resistencia equivalente serie, capacitancia y resistencia de encendido; usando medidas de corriente y voltaje del convertidor Boost.

Introduction

Given the importance of continuous and correct operation of power electronic converters (PECs), which are an essential part of more complex systems [1] In fact, PECs have the function of direct interaction between generation and load, besides, the control strategies or maximum power point tracking (MPPT), as with microgrids or PV systems [2].

According to [3], static PECs have component failures of 60% in capacitors, 30% in switching transistor, and 10% in inductors and diodes. Therefore, it is necessary to know the state-of-health (SOH) of the PEC main components for the correct operation of the system. Indeed, some component parameters, such as capacitance (C), equivalent series resistance (ESR) of a capacitor, and on-state resistance ($R_{ds,on}$) in MOSFETs, are indicators of degradation. This article seeks to contribute to establishing the main degradation indicators of electrolytic capacitor and switching transistor in a PEC. In section II, electronic component parameters that can be used as indicators of degradation are shown. Estimation of degradation indicators of the PECs is presented in section III. Finally, the expected results are shown.

Indicators of degradation

Since the capacitor and switching transistor of static PECs have the highest failure rate, some degradation indicators used will be shown. Electrical parameters, such as C, ESR, and physical parameters, such as volume, can show degradation [4]. In the case of MOSFETs, ($R_{ds,on}$), drain-source voltage ($V_{ds,on}$), and junction temperature are some indicators of degradation

[5]. However, the measurement of electrical parameters has the advantage of using sensors already available in the systems. Table 1 summary shows some degradation fault limits for the electrolytic capacitor and MOSFET.

Table 1 Degradation fault limits.

Parameter	Limit
ESR	*Increase of twice the nominal value*
C	Decrease to 80% the nominal value
$R_{ds,on}$	Increase to 25% of the nominal value

Estimation of degradation indicators of the PECs

To establish the degradation indicators of *ESR, C*, and $R_{ds,on}$, a Boost converter is used, as shown in Figure 1.

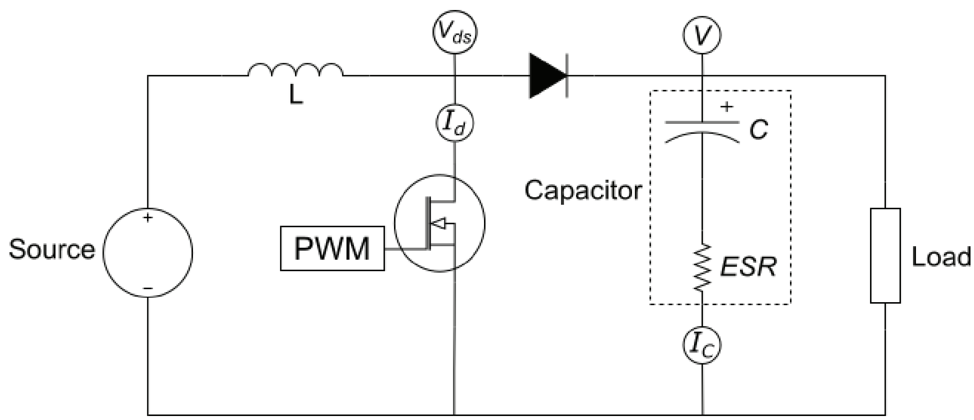

Figure 1. Boost converter.

Table 2 lists Boost converter parameters [6], which corresponds to the experimental setup available in the test microgrid developed at *Laboratorio de Accionamientos Eléctricos y Electrónica de Potencia at Universidad del Valle-Colombia.*

Table 2 Boost converter parameters.

Parameter	Variable	Value	Units
Switching frequency of Boost	F_{SW}	*20*	*kHz*
Inductor	*L*	5	*mH*
Output capacitor	*C*	2200	*mF*
Equivalent series resistance	*ESR*	114.5	*mΩ*
On-state Resistance	$R_{ds,on}$	70	*mΩ*

Capacitor

There are two classical representations of capacitor degradation estimation using *ESR* in PECs: ohmic frequency range and power losses of the capacitor.

The first technique, developed by [7], evaluates voltage/current signals within the ohmic frequency range of capacitors. It requires a band-pass filter (see Figure 2). Where V and I_C are capacitor voltage and current values (RMS), respectively. It is also necessary to adjust the gain for the input signal range in the processor that is calculating the *ESR*.

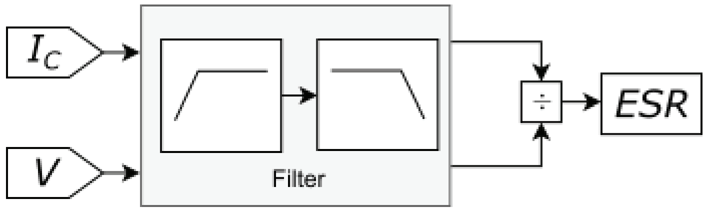

Figure 2. Technique of ohmic frequency range.

The second technique is proposed by [8], which avoids extensive filtering by calculating the AC power losses of the capacitor. Therefore, the *ESR* can be estimated as shown in the Figure 3. It also used the Rogowski coil to measure the capacitor current.

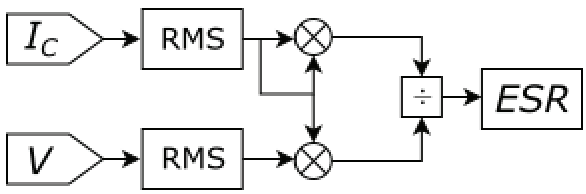

Figure 3. Technique for AC power losses.

However, it is necessary the estimation of both parameters of the capacitor for establishing its degradation. For example, in previous work [2], a grid-connected photovoltaic system, both parameters, *C* and *ESR*, of a DC-link capacitor were estimated using an electrochemical impedance spectroscopy (EIS) method.

Estimation errors in Matlab/Simulink using three techniques present, are 0.087%, 0.026% only ESR. In addition, the last technique for the parameters *ESR* and *C* are 0.53% and 0.37%, respectively.

Switching transistor: MOSFET

In this approach, it needs to measure the drain-source voltage ($V_{ds,PWM\text{-}on}$) and drain current ($I_{d,PWM\text{-}on}$), then $R_{ds,on}$ is calculated, as shown in Figure 4, However, a disadvantage of this method is that it requires high sampling, since the measurement values of interest are when the MOSFET is active. Estimation error of $R_{ds,on}$ in Matlab/Simulink using the procedure shown above, is 4.28%.

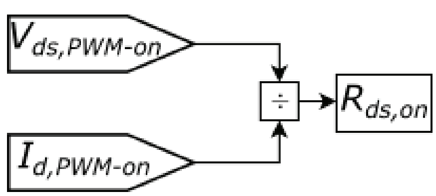

Figure 4. Estimation of on-state resistance of the switching transistor.

The next steps for this research are described below. Initially, in the setup experimental, measure the capacitor current and output voltage to get and compare the *ESR* with the methods presented. Likewise, a control strategy will be implemented. Then, the estimated values will be used in fault diagnosis. With MOSFETs, other degradation indicators will be evaluated using available measurements in the PECs.

Conclusions

This study shows some different methods to establish PEC parameters, which in turn are indicators of degradation. For *ESR* and *C*, the estimation errors are less than 1%, and for $R_{ds,on}$ the estimation is less than 5%. Besides, this research seeks faults-diagnosis in PECs through measure-based techniques of voltage and current for capacitors, and MOSFET. In addition, fault detection and diagnosis methods for PEC must be able to operate in real conditions, i.e., with regulation control or even maximum power point tracking (MPPT) function in photovoltaic systems.

Acknowledgement

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Estimation of degradation indicators

To establish the degradation indicators of ESR, C, and $R_{ds,on}$, a Boost converter is used, as shown in Fig. 1,

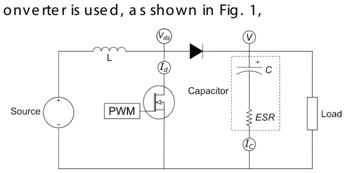

Fig.1 Boost converter

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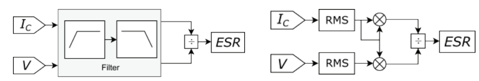

Fig. 2. a) Technique of ohmic frequency range b)Technique for AC power losses

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