IJEE Volume-6 • Number-1 Jan -June 2014 pp. 47-50 (ISSN: 0973-7383)

Wavelet Transform Based Techniques for Fault Detection of Power Supply Unit

J.A. WAGH[1], S. K. SHINDE[1], S. R. POL[1], R.R. MUDHOLKAR[2], P.P. SHAH[3]
[1]*Department of Electronics, YCIS, Satara, MS, India*
[2]*Department of Electronics, Shivaji University, Kolhapur, MS, India*
[3]*Department of Electronics, Devchand College Arjunnagar, MS, India*
jaw12345@rediffmail.com

ABSTRACT: A wavelet transform method for fault detection of power supply circuit is presented. The wavelet transform is applied to the healthy and faulty circuit under test (CUT) to obtain transform coefficients. Standard deviation (SD) of transform coefficients are extracted to create fault dictionary. The simulation result shows effectiveness of transform based method for fault detection of power supply circuit.

Keywords: Circuit Under Test (CUT), Wavelet Transform (WT), Standard Deviation (SD), Fault detection (FD), Power Supply.

I. INTRODUCTION

Fault diagnosis is a common activity in everyday lives. Fault detection and analysis of analog electronic circuits is still an indispensable part of modern modeling and designing process. Fault is the change in the system that prevents it from operating in the desired manner. Every complex electronic system is liable to faults or failures. The identification of faults in any analog circuit is highly obligatory to ensure the reliability of the circuit.

The fault diagnosis in analog electronic circuit is more complicated than digital circuits due to nonlinear effects, poor fault models, component tolerance and diverse design styles [1, 2]. Fault diagnosis approaches are of many types,such as the parameter identification approach, the fault verification approach, the approximation approach, fault dictionary approach, the artificial intelligence technique and so on [3]. In general, the fault diagnosis approaches of analog circuit can be categorized as *Simulation-Before-Test* (SBT) and *Simulation-After-Test* (SAT) [4]. As both are procedural in nature the suspicious knowledge of the functioning of the CUT is not mandatory. The signature can be suitably used to create a fault dictionary, which is the collection of measurement of network under different faults [5, 6]. Early detection of faults can possibly avoid the damage borne out of the fault. The faults can be either short circuit faults or open circuit faults [7].

Power supply plays a vital role in all electronic systems. Fault detection in power supply circuit is fundamental to avoid catastrophic conditions. Early detection of faults in power supply can greatly assist in maintenance of any faulty circuits to avoid catastrophic problems due to fault occurred in power supply and its variations.

The bridge rectifier is chosen as CUT and it is modeled and simulated in Simscape toolbox, output is analyzed in wavelet toolbox of MATLAB. The standard deviation (SD) of transform coefficients are used to form fault dictionary designed significantly to identify the fault type.

A. WAVELET TRANSFORM

Wavelet mean 'small wave'. Its nomenclature as a wave can be assigned to its oscillatory nature. The wavelet analysis involves analyzing a signal with short duration finite energy functions. Thus the signal under investigation is being transformed into another representation of more useful format. This signal transformation is called Wavelet Transform. Wavelet can be manipulated in two ways, translation and scaling [8]. Mathematically, a wavelet can be denoted as

$$\psi_{a,b}(x)=\frac{1}{\sqrt{a}}+\Psi\left(\frac{(x-b)}{a}\right),$$

Where,
b = Location parameter
a = Scaling parameter

Generally, wavelet transform is used as a tool to decompose functions or operators into diverse frequency components. The transform is computed generally at various locations of the signal and for various scales of the wavelet, thus filling up the transform plane. If the process is done in a smooth and continuous fashion, then the transform is called Continuous Wavelet Transform (CWT). If the scale and position are changed in discrete steps, the transform is called Discrete Wavelet Transform (DWT). Continuous wavelet transform is defined by the inner product of the function and basis wavelet:

$$CWT_f(a,b)=\frac{1}{\sqrt{a}}\int\int_{-\infty}^{\infty} f(x)\,\psi\,\frac{x-b}{a}\,dx \qquad \text{---- (1)}$$

According to this equation (1) for every (a, b), we have a wavelet transform coefficient, representing how much the scaled wavelet is similar to the function at location x = (b/a). The practical application of CWT is limited by the redundant and non-finite nature of the coefficients. These coefficients are obtained by the correlation of the function and the wavelet performed during the continuous translation and scaling of the wavelet. The generation of fast algorithms calls for the development of discrete wavelets, which are usually part by part continuous functions [9].

I. METHODOLOGY

The fault diagnosis methodology can be divided into the following distinct steps [7]:

A. Formulation of a model of CUT, which is a bridge rectifier circuit.

B. Applications of the wavelet transform for the fault free as well as various fault condition.

C. Building a fault dictionary by extracting the standard deviation of transform coefficients.

A. CIRCUIT UNDER TEST

A bridge rectifier as power supply shown in Fig.1 forms the circuit under test (CUT). It consists of four diodes D1, D2, D3 and D4. A capacitor of 1000µf, inductor of1mH and 1000Ω load resistor was used in the construction of model [9].The CUT is simulated in Simscape and analyzed using Wavelet toolbox in MATLAB as shown in Fig.2 for fault free condition.The open circuit faults are simulated by removing component while short circuit fault are introduced by short circuiting the component. These faults are categorized under catastrophic (hard) faults as shown in Fig.3. Parametric (soft) faults are introduced by changing parameters model in CUT as shown in Fig.4.

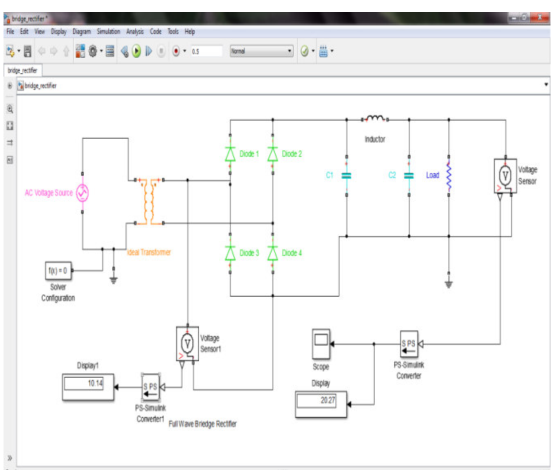

Fig. 1: Power supply circuit

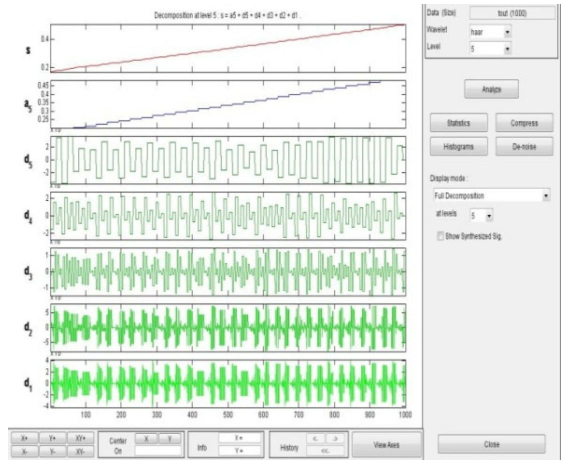

Fig. 2: Wavelet Transform of fault free response

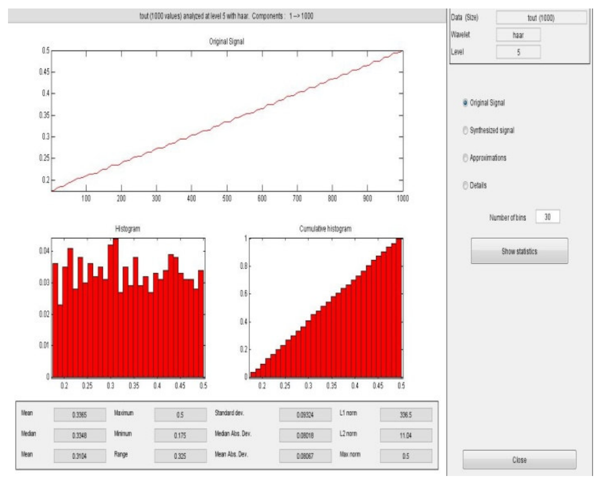

Fig. 4: Wavelet Transform for d1 open

B. SIGNATURE EXTRACTION

The signature for each fault condition as well as for fault free condition has to be extracted to build the fault dictionary. This utilizes the statistical analysis of transform coefficient. The CUT consists of 4 Diodes, 2 Capacitors, single Inductor and load R_L. There are possibility of 7 open and 7 short circuit single faults and 10 multiple (open and short) faults.

The output response is analyzed using Wavelet toolbox in MATLAB. After detailed analysis, the Haar wavelet is used as wavelet of choice. The wavelet was employed at fifth level. The transformation is being followed by statistical analysis. The SD was chosen as the statistical parameter. Thus the fault dictionary is being framed by tabulating the SD extracted and output voltage for all fault conditions. The waveforms shown in Fig.5 through Fig.8 are subjected to the wavelet and statistical analysis.

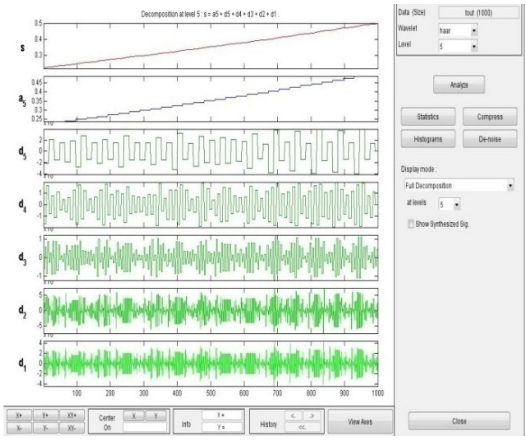

Fig. 5: Wavelet Transform for d1 open

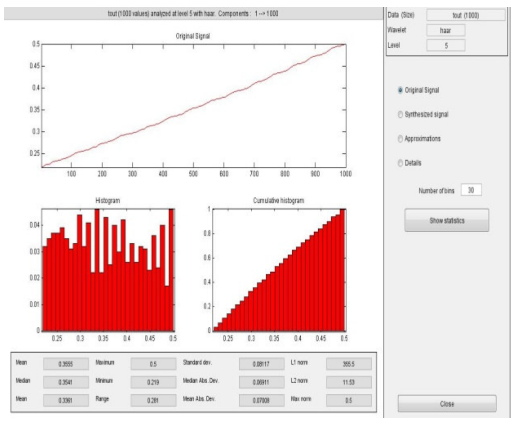

Fig. 6: Statistical analysis of Wavelet Transform for d1 open

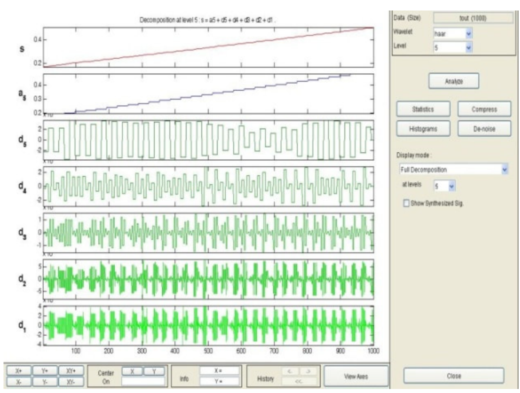

Fig. 7 Wavelet Transform for Parametric (soft fault) at -60^{0}C

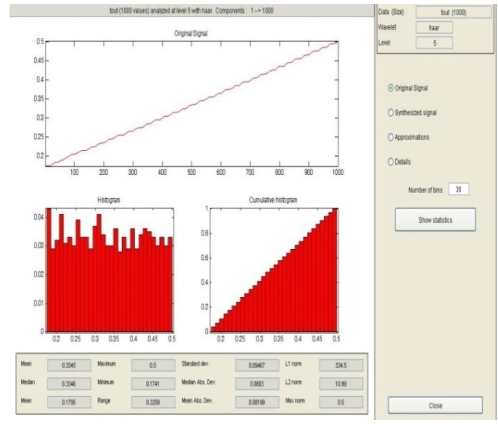

Fig. 8 statistical analysis of Wavelet Transform for Parametric (soft fault) at -60^{0}C

C. FAULT DICTIONARY

The fault dictionary of CUT framed consists of entire database extracted from faults & fault free responses which are simulated. Set of values are unique to each faulty state of the circuittaken up as signature that characterize the respective state.

The SD was chosen as statistical parameter. This is due to fact that SD spans a finite positive spectrum with adequate margin between potential signatures for various faults. The fault dictionary is being framed by tabulating SD, extracted from faults and fault free responses, and output voltages of respective responses are taken.

Table I: Fault dictionary for fault free circuit

Fault ID	**Faulty Component**	**SD for response**	**Output voltage**
FF	Fault Free	0.09324	20.27

Table II: Fault dictionary for single faults (open)

Fault ID	**Faulty Component**	**SD for response**	**Output voltage**
OF1	D1	0.08117	20.19
OF2	D2	0.07845	20.28
OF3	D3	0.08308	20.27
OF4	D4	0.08194	20.12
OF5	L	0.16070	0
OF6	C2	0.0004648	20.26
OF7	RL	0.09569	21.09

Table III: Fault dictionary for single faults (short)

Fault ID	**Faulty Component**	**SD for response**	**Output voltage**
SF1	D1	0.08444	21.35
SF2	D2	0.08501	21.63
SF3	D3	0.08486	21.51
SF4	D4	0.08667	21.44
SF5	L	9.586xe^{-7}	19.91
SF6	C2	0.06965	0
SF7	RL	0.06930	0

Table IV: Fault dictionary for multiple faults (open)

Fault ID	Faulty Component	SD for response	Output voltage
OF9	D2,D3	0.097260	20.3
OF10	D1,D4	0.097930	20.21
OF11	C1,C2	0.0004701	20.47

Table V: Fault dictionary for multiple faults (short)

Fault ID	Faulty Component	SD for response	Output voltage
SF9	D1,L	$4.659xe^{-7}$	20.26
SF10	D2,C2	0.15320	0
SF11	C1,C2	0.1660	0
SF12	D2,D3	$4.653xe^{-7}$	0

Table VI: Fault dictionary for multiple faults (open-short)

Fault ID	Faulty Component	SD for response	Output voltage
OSF1	C1,C2-L	0.16560	20.27
OSF2	D3-D1	0.06339	21.49
OSF4	D3-D4	0.09555	21.16
OSF5	D4-D3	0.09282	21.41

Table VII: Fault dictionary for parametric (soft) fault

Fault ID	Tempe rature	Faulty Compone nt	SD for response	Output voltage
PF1	-60^0C	D1,D2, D3,D4	0.09467	19.88
PF2	25^0C	D1,D2, D3,D4	0.09324	20.27
PF3	75^0C	D1,D2 ,D3,D4	0.09414	20.42

FF- Fault Free,**EF**- Entire Faulty,**OF**- Open Fault,**SF**- Short Fault,**OSF**-Open-Short Fault,**PF**-Parametric Fault.

II. MATERIALS AND METHOD

The model of CUT was formulated using MATLAB 8.1 Simscape. The output of which is subjected to wavelet analysis.

III. RESULT AND CONCLUSION

The CUT is studied for catastrophic and parametric faults and fault free responses in various locations. The analysis of responses is made with wavelet toolbox and the statistical analysis is made to estimate SD of the unique responses. Standard Dictionary of SD andoutput voltage of faults and fault free responses are framed.

Responses of faulty circuit are compared with standard signatures. It provides the kind of fault and fault location in CUT.

IV. CONCLUSION AND FURTHER WORK

The fault dictionary was created with Wavelet transform. The system was capable of analysing the faults. A novel method for fault diagnosis helps ensure the competent performance of the Circuit under Study. The suitability of wavelet analysis for the diagnosis of the fault has been illustrated.The proposed approach is found to be efficient in accurate identification and isolation of faults using fault dictionary, but time taken to complete the process is title more.

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