the phase and amplitude of the signal if the vehicle moves over a distance.

The performance of both SPMC, FIFO, and No priority schemes are compared using a Ricean fading channels in case σ equal 4dB using the system illustrated in Fig. 3. In the first set of experiments the system performance is tested against the call arrival rate for the different call classes using the three handoff schemes. Figs. 7(a ,b, c) and Figs. 7(d, e, f) show, the results including the new call blocking probability p_b and the handoff call dropping probability p_d of three service classes versus different offered load, respectively. Note that handoff dropping probability p_d and the new call blocking probability p_b in case of Ricean fading are increasing about 3% - 4% and about 2% - 2.5% as compared to p_d and p_b respectively in case of Shadow fading channels for three handoff schemes. The SPMC method reduces handoff call dropping probability for every multimedia service class in the presence of fading as the same as the absent fading, and the SPMC is effective in reducing class3's handoff call dropping probability about 4% - 14% more than other classes specially class1's, because class3's have a highest handoff priority and longest connection mean duration time.

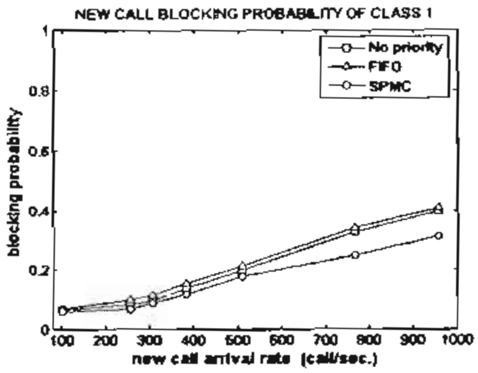

Fig.(7-a)

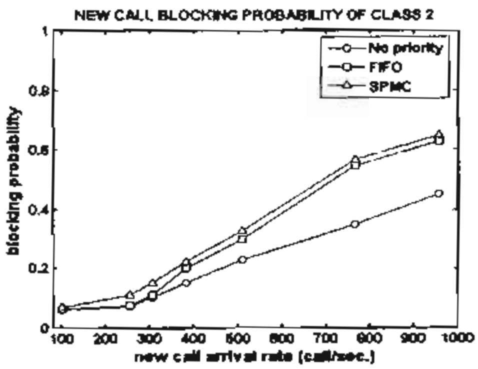

Fig.(7-b)

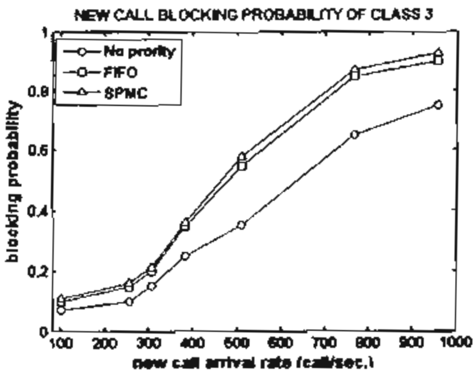

Fig.(7-c)

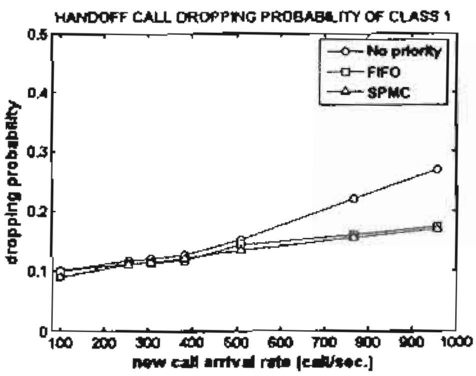

Fig.(7-d)

Harmonic Elimination using Discrete Wavelet Transform

التخلص من التوافقيات باستخدام DWT

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ملخص: يقدم هذا البحث دراسة عن كيفية عزل محتوى التوافقيات المتواجدة على موجات الجهد والتيار والتى تم تسجيلها فعليا فى المغذيات الخارجة من محطة محولات غرب طلخابالشبكة الموحدة المصرية (٦٦|١١ ك ف). وفى هذا الخصوص تم استخدام طريقة DWT لعمل تحليل لمحتوى موجات الجهد والتيار من التوافقيات. وفى البداية تم عمل محاكاة لمحطة المحولات باستخدام صندوق المعدات فى برنامج "ماتلاب" وذلك فى حالة تواجد مجموعة المكثفات أو عدم تواجدها. وفى هذا المجال تم عمل مقارنة بين موجات الجهد والتيار الناتجة من هذه المحاكاة وبين نظيرتها الفعلية المسجلة فى الموقع. كما تم استخدام النموذج المقترح لدراسة تأثير استبدال مجموعة المكثفات بدائرة توالف لمرشح توازى غير فعال . كما تم تحليل محتوى موجات الجهد والتيار الناتجة باستخدام طريقة DWT المقترحة. و قد أوضحت النتائج تحسن كل من THD لكل من موجات الجهد والتيار وكذلك معامل القدرة .

Abstract: The objective of this paper is to present an approach for isolating the harmonic contents in both voltage and current waveforms at the outage feeder of Gharb Talkha substation (66/11 kV). A novel technique using Discrete Wavelet transform (DWT) for the analysis of the waveforms harmonics content. At the beginning the substation is simulated using Simulink toolbox in Matlab program with and without the presence of capacitor bank. The obtained voltage and current waveforms are compared to the actual data. The proposed model is used to study the effect of replacing the capacitor bank with single tuned parallel passive filter. The resulting current and voltage waveforms are analyzed using the proposed DWT technique. The analysis showed that the Total Harmonic Distortion (THD) of both voltage and current waveforms is improved as well as the power factor.

Keywords: Discrete Wavelet transform (DWT), Harmonic Elimination, Total Harmonic Distortion (THD), and distribution power system.

INTRODUCTION

One of the most important issues for the power system is the reduction of current and voltage harmonics created by non linear loads. Oversizing and derating of the installation is one of the solutions to decrease the effect of harmonics only[1]. Specially connected transformers (star/delta connection) and Zig-Zag transformer are used to isolate triplen harmonics [2].Passive filters series, shunt and series shunt are usually used to filter harmonic current and for reactive power compensation[3,4,5]. The common types of passive filters include single tuned and double tuned resonant filters, but because single tuned resonant filter comprises lC components, it has low investment cost and power loss so it is widely used [6].

Previously, harmonic analysis was done using Fourier transform but recently, Discrete Wavelet Transform (DWT)is utilized. DWT is a mathematical tool to decompose a given signal into different scales at different levels of resolutions [7-9].

In this paper the actual voltage and current waveforms of Gharb Talkha Substation transformer are analyzed using (DWT). This analysis is done with and without the presence of capacitor bank. The substation is then simulated using Simulink Toolbox of Matlab and comparison between actual and simulated voltage and current waveforms is illustrated for both with and without capacitor bank. The proposed model is

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used to detect the effect of replacement of capacitor bank by single tuned parallel passive filter on both the harmonic contents and the power factor.
The following sections presents the problem then the (DWT) technique used for the waveforms after that the simulation and analysis of the results will follow.

Problem Formulation:

The system under study is selected from one of the Egyptian network system. One of the transformers of Gharb Talkha substation (66/11 kV) as a model for studying the harmonics traveling through the system. The transformer is 25 kVA, 66/11 kV, 10 % impedance. In order to improve the power factor from 0.826 to 0.996 at the outer feeder of the substation a capacitor bank of 5.4 Mvar is placed at the low voltage side. The presence of this capacitor bank will cause increase in the Total Harmonic Distortion (THD) of both voltage and current waveforms. The THD of the current waveform is (1.55-5.36 %) without capacitor bank and (3.89-17.48 %) with the presence of capacitor bank while the THD of voltage waveform is (0.85-1.80 %) without capacitor bank and (2.21-4.2 %) with capacitor bank, while the p.f. is improved from (0.826-0.897 lag) to (0.985-0.993 lag).

In order to eliminate such harmonics a single tuned parallel passive filter is connected.

For the design of the filter it is known that the filter impedance is

$$Z_{Fi} = j(X_{Li} - X_{Ci}) \qquad (1)$$

At tuning frequency

$$\frac{X_{Ci}}{n_i} = n_i X_{Li} \qquad (2)$$

Where n is the filter resonant point

$$\therefore X_c = n_i^2 X_L \qquad (3)$$

$$X_{Li} = \frac{1}{n_i^2} X_{ci} \qquad (4)$$

$$Z_{Fi} = \frac{X_{Ci}}{a_i} \qquad (5)$$

Where $$a_i = \frac{n_i^2}{n_i^2 - 1} \qquad (6)$$

Knowing that

$$Z_{Fi} = \frac{1}{S_{Fi}} \qquad (7)$$

$$S_{Fi} = \frac{Q_{Fi}}{S_b} \qquad (8)$$

$$\therefore X_{Ci} = \frac{S_B * a_i}{Q_{F13}} \qquad (9)$$

Where;

Q_{Fi} = the filter reactive capacity

S_b = the base capacity

So the capacitance (C) and inductance (L) for the filter can be expressed as a function of the reactive power compensation (Q_{Fi}) for the filter and the resonant point n_i of each filter.

$$C_i = \frac{Q_{Fi}}{S_B * \omega * a_i} \qquad (10)$$

$$L_i = \frac{S_B * a_i}{Q_{Fi} * \omega * n_i^2} \qquad (11)$$

Discrete Wavelet Transform:

The instantaneous current signal, can be represented by the wavelet transform as follows:

$$i(t) = \sum_k c_{j_o,k} \phi_{j_o,k}(t) + \sum_{j \geq j_o} \sum_k d_{j,k} \psi_{j,k}(t) \qquad (12)$$

Where;

$c_{j_o,k} = \langle i(t), \phi_{j_o,k} \rangle$ and $d_{j_o,k} = \langle i(t), \psi_{j_o,k} \rangle$

j_o: Scaling level for the lowest band
j: wavelet frequency scales for higher frequency
k: wavelet time scale
c and d: wavelet coefficients
the RMS value for the current I could be obtained as follows:

$$I = \sqrt{\frac{1}{T}\int_0^T i^2(t)dt} =$$

$$\sqrt{\frac{1}{T}\sum_k c_{j_o,k}^2 + \frac{1}{T}\sum_{j\geq j_o}\sum_k d_{j,k}^2}$$

$$I = \sqrt{I_{j_o}^2 + \sum_{j\geq j_o} I_j^2} \qquad (13)$$

Where I_{jo} is the rms value of the current of the lowest frequency j_o also called *fundamental current* (I_{fun}). $\{I_j\}$ is the set of rms value of the current of each frequency or wavelet-level higher than or equal to the scale level j_o, and are called *harmonic current* (I_h). By the same way the voltage waveform could be analyzed so both voltage and current are

$$V_h = \sqrt{\sum_j V_j^2} \text{ and } I_h = \sqrt{\sum_j I_j^2} \qquad (14)$$

The equivalent total harmonic distortion of voltage THD_V and the equivalent total harmonic distortion of current THD_I can be computed from :

$$THD_V = \frac{V_h}{V_{fun}} \qquad (15)$$

$$THD_I = \frac{I_h}{I_{fun}} \qquad (16)$$

The DWT can used to isolate the frequency band for every signal $S(t)$ having the fundamental frequency f depending on two factors. The first factor is the sample per second of the original signal f_s, while the second factor is the approximation level a_0 and wavelet level d_j where the j is the wavelet level. If the original signal $S(t)$ have the fundamental frequency f = 1 Hz, the decomposition level j = 6 level, and the sample per second f_s = 128 s/s. Each frequency band could be obtained dividing the sampling frequency by two (128/2=64). Table (2) shows the approximation, details, and frequency band for the signal $S(t)$. A_5 is the approximation containing the DC component, fundamental, and second harmonic. The level D_5 to D_1 is the detailed components for the signal at each frequency as in table (1).

Table (1) Wavelet level and frequency bands for sampling (128 S/S)

$F_s = (2^7 * 1) = 128$ sample / second			
Levels		Frequency bands	Odd harmonics
j_o	A_5	(0-2)	DC + Fundamental + second harmonic
j	D_5	(2-4)	(2^{nd} to 4^{th})harmonic
	D_4	(4-8)	(4^{th} o 8^{th}) harmonics
	D_3	(8-16)	(8^{th} to 16^{th})harmonics
	D_2	(16-32)	(16^{th} to 32^{nd}) harmonics
	D_1	(32-64)	(32^{nd} to 64^{th}) harmonics

When using different sampling frequencies 2^8*f, $3*2^7*f$, 2^9*f where f is the fundamental frequency, the different harmonics could be calculated as follows:

$$S_1 = A_{5(128)} \qquad (17)$$

$$S_3 = \sqrt{A_{5(256)}^2 - A_{5(128)}^2} \qquad (18)$$

$$S_5 = \sqrt{A_{5(384)}^2 - A_{5(256)}^2} \qquad (19)$$

$$S_7 = \sqrt{A_{5(512)}^2 - A_{5(384)}^2} \qquad (20)$$

$$S_9 = \sqrt{A^2_{5(640)} - A^2_{5(512)}} \quad (21)$$

$$S_{11} = \sqrt{A^2_{5(768)} - A^2_{5(640)}} \quad (22)$$

$$S_{13} = \sqrt{A^2_{5(896)} - A^2_{5(768)}} \quad (23)$$

Where $A_{m(n)}$ is the m approximation when the sampling frequency is n times the fundamental frequency.

Simulation and Analysis of Results:

In order to study the effect of filter placement on both voltage and current waveforms, simulation of Gharb Talkha substation is carried on using Simulink toolbox of Matlab. The output of the simulation could be seen in comparison with the actual data in Figures 3,4.

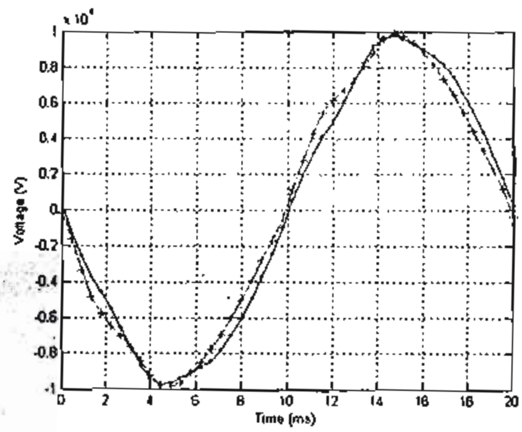

Figure (3) Actual(+) and Simulated (-) voltage waveform

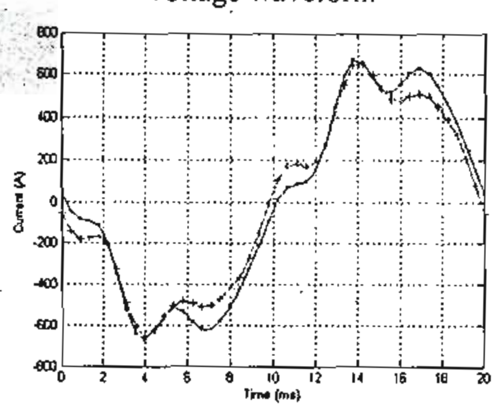

Figure (4) Actual(+) and Simulated (-) current waveform

It could be seen that there is almost no difference between actual and simulated output waveforms.

The single tuned parallel passive filter is designed according to equations (1-16) and the data is seen in Table (2)

Table (2) Filter parameters.

	Filter (5)	Filter (7)
Harmonic number (h)	5th	7th
Line voltage V_L (kV)	11.4	11.4
Resonance point n_h	h_5 = 4.6	h_7= 6.44
Q_{1h} (MVar)	Q_{15}=3.27	Q_{17}= 2.13
R_h (Ω)	0.0906	0.097
C_h (μ F)	76.3067	50.912
L_h (mH)	6.275	4.7985

When these filters are connected at the bus bar substation as shown in Figure (5), the result of DWT for current using 128*50 sampling rate is shown in Figure (6).

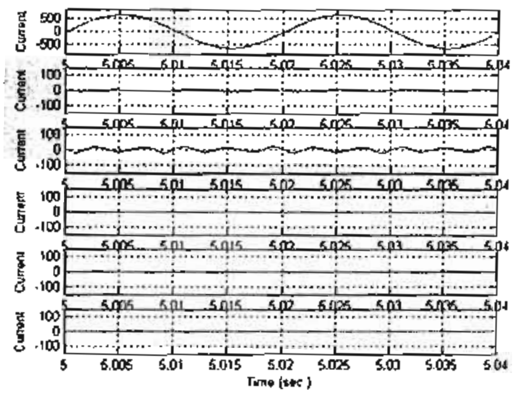

Figure (6) Detailed and pproximation of current waveform with 128*50 sampling frequency.

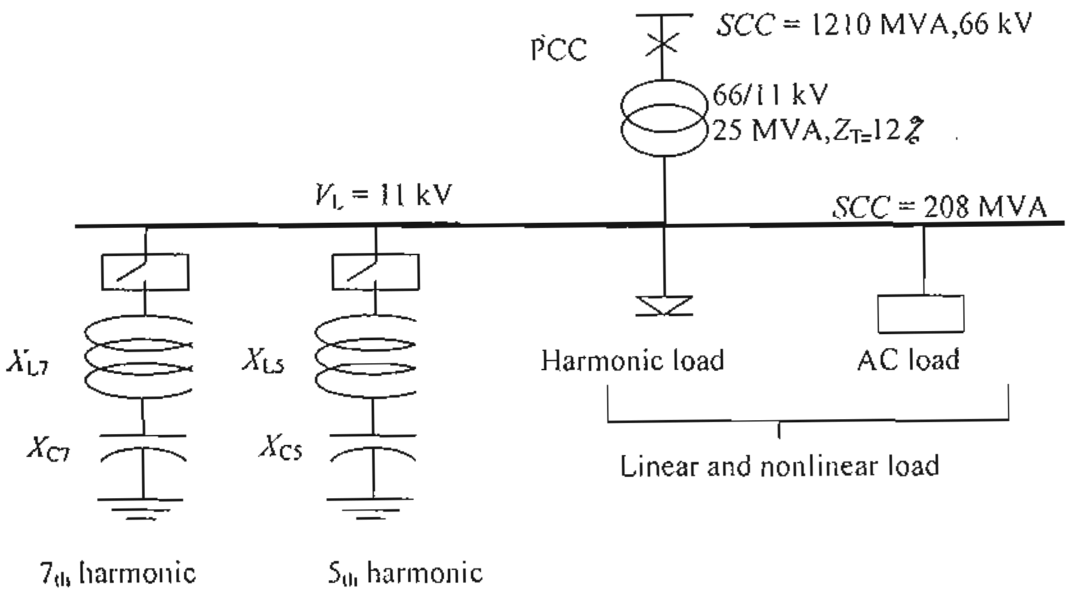

Figure (5) The substation with the filters connected to it.

Using equations (17-23) for the analysis of the waveforms revealed the results shown in Tables (3,4) for both voltage and current.

Table (3) Current signal analysis using DWT

I_1	446.15	A	I_7	3.2	A
I_3	3.63	A	I_{total}	446.3	A
I_5	11.8	A	THD_I	2.9	%

Table (4)Voltage signal analysis using DWT

V_1	6737.75	V	V_7	12.25	V
V_3	6.2	V	V_{total}	6738	V
V_5	34.18	V	THD_v	0.56	%

It could be seen from the above results that the THD for the current decreased from (3.89-17.48 %) with the presence of capacitor to about 2.9 % and for the voltage the THD decreased from (2.21-4.2%) with the capacitor to about 0.56 % with the filter presence. Also it should be noted that the p.f. reached a value of with the presence of the filter 0.994.

Conclusion:

A novel technique for isolation of different types of harmonics using DWT with different sampling rate is implemented. Parallel passive single tuned filters of fifth and seventh order are used to eliminate the harmonics and improve the p.f. as well. The suggested DWT is used to analyze the voltage and current waveforms of Gharb Talkha substation. The results showed that the THD for both voltage and current waveforms is decreased and the power factor is improved.