IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified
Vol. 6, Issue 1, January 2017

Effect of Distributed Elements Filters on Transmission Lines

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Abstract: Electrical Energy is the life stream of progress for any nation and it is all the more vital in a developing country like India. The energy in electrical form is most widely used since it can be converted into any other form efficiently. A power System Network consists of variety of apparatus for generation, transmission and distribution spread over a large area serving to number of Industrial & Commercial consumers. When the power system is polluted with harmonics due to non linear load, unbalance prevailing between phases and bad voltage profile the quality of power supply becomes very inferior which hampers the power apparatus of both the utilities and the customers. Filters have gained a great attention owing to their applications as a solution to above issues. To make it distortion and ripple free filters are used at receiving end. These filtered signals may be used for further processing. This work is an attempt to simulate various filters such as Butterworth and Chebyshev Type I and Type II using MATLAB/SIMULINK. For flat band response Butterworth filter is used. Error probability will be less in Chebyshev filter.

Keywords: Filters, transmission lines, ripple, Butterworth filter, and Chebyshev filter.

I. INTRODUCTION

Transmission lines are used to transmit electric energy and signals from one point to another especially from source to load or from transmitter to receiver. Transmission lines are commonly used in power distribution at low frequencies and in communication at high frequencies. Some day to day life examples of this phenomenon are connections between computers in a network, power station to substation or from substation to other substation etc. One thing which is common in these examples is that they are separated by distances on order of wavelength [1].

When distances are sufficiently large between source and the receiver, time delay effects become appreciable i.e. we deal with wave phenomenon on transmission lines. To reduce the distortion or error in the signals filters are used at the receiver end. Generally passive filters are used in the network.

II. TRANSMISSION LINE PARAMETERS

It is necessary to define transmission line in terms of its line parameters. There are four parameters distributed all along the length of the line which are resistance per unit length R, inductance per unit length L, capacitance per unit length C, conductance per unit length G [2].

a) The line parameters R, L, C, and G are not lumped or discrete but distributed as shown in Fig.1 which means the parameters are uniformly distributed along the entire length of the line [2].

b) For each line, the parameters are given as [2]:-

$$LC = \mu\varepsilon \quad (1)$$

$$\frac{G}{C} = \frac{\sigma}{\varepsilon} \quad (2)$$

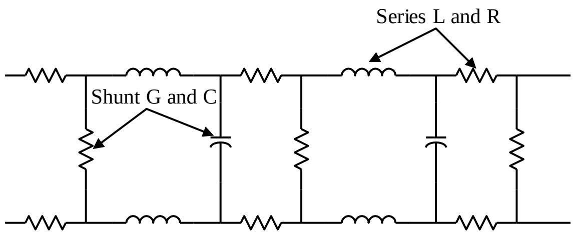

Fig.1: Distributed parameters of a two-conductor transmission lines

General wave equations for the transmission lines are as follows [3]

$$\frac{\partial^2 V}{\partial z^2} = LC\frac{\partial^2 V}{\partial t^2} + (LG + RC)\frac{\partial V}{\partial t} + RGV \quad (3)$$

$$\frac{\partial^2 I}{\partial z^2} = LC\frac{\partial^2 I}{\partial t^2} + (LG + RC)\frac{\partial I}{\partial t} + RGI \quad (4)$$

III. FILTERS

A filter is an electrical network that alters the phase and / or amplitude characteristics of a signal with respect to frequency. Filters are often used in electronic system to emphasize signal in certain frequency range and reject signal in other frequency range. Filters response is defined in frequency domain. This behaviour is defined mathematically by the transfer function H(s).

$$H(s) = \frac{V_{out}(s)}{V_{in}(s)} \quad (5)$$

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The order of the filter is defined by the highest power of the variable in H(s). Usually the total numbers of capacitors and the inductors tells about the order of the filter.

A. Types of Filters
There are three types of filters as per the components used. They are active filters, passive filters and hybrid filters. Passive filter configuration consists of passive components such as inductor, capacitor, resistor or diodes. Active filter combination consist of transistors, common mode transformer etc. Hybrid filter is combination of active and passive filter and use both active and passive components.

a. Active Filters
An active filter mostly uses amplifying elements such as op-amp, transistor, etc with resistors and capacitors in the feedback circuit. They work independently of the systems impedance characteristics. They may have high input impedance and low output impedance. They are expensive than passive filters.

Fig. 2 shows the basic circuit of active filter.

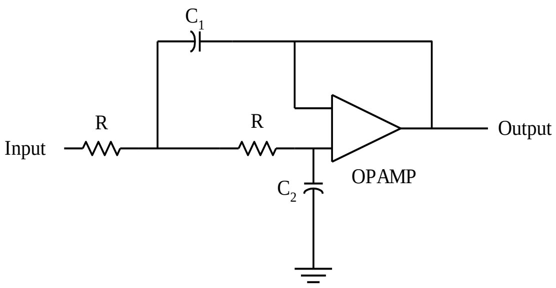

Fig.2: Basic circuit of active filter

b. Passive Filters
The filters which are designed with the passive elements such as resistor, inductor and capacitor are called as passive filters. These filters do not require power supply. Performance of the filter mainly depends upon source impedance. They can work at high frequencies since there is no constrain of bandwidth. Fig.3 shows the basic circuit of passive filter.

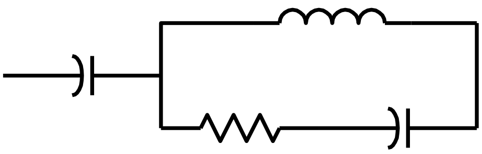
Fig.3: Basic circuit of passive filter

c. Hybrid Filters
High rating and very high switching frequency of PWM (Pulse Width Modulator) converters of the Active power filters (APFs) topologies are not cost-effective for the application of high power. The performance of LC Passive power filters (PPFs) are affected due to the varying impedance of the system. Hence HAPF provides the advantages of APF and PPF by eliminating their disadvantages. These filters are cost effective solutions for the high-power quality problems with well filtering performance [5].

B. Basic Types of Filters
There are mainly four types of filters according to range of operating frequency. They are low-pass, high-pass, band-pass and band-reject filters.

a. Low-pass Filters
A filter which allows the signal to pass through an inductor provides less attenuation to low frequency signals than high frequency signals is called as low- pass filter shown in Fig. 4

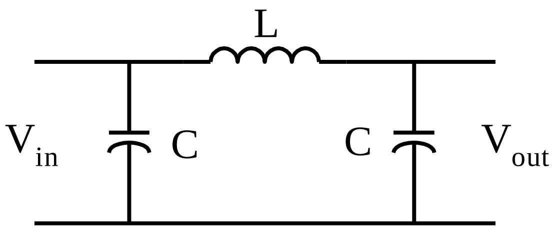

Fig.4: Low-pass π filter

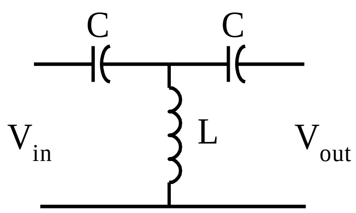

Fig.5: High-pass T filter

b. High-pass Filters
A filter which allows the signal to pass through a capacitor provides less attenuation to high frequency signals than low frequency signals is called as high- pass filter shown in Fig.5.

c. Band-pass Filters
The filter which passes the particular band of the frequencies called as band-pass filter as shown in Fig.6.

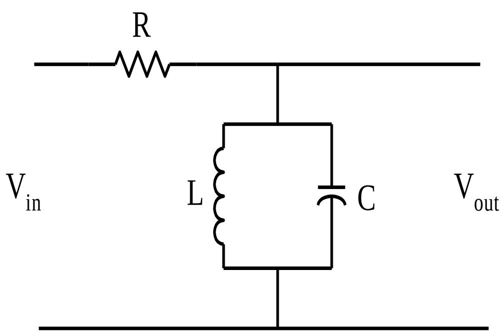

Fig.6: band pass filter

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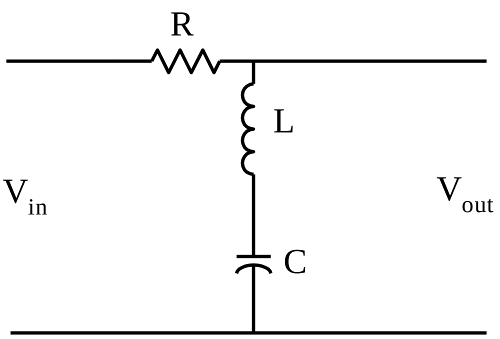

Fig.7: Band reject filter

d. Band Reject / Notch Filters

The filter which rejects the particular band of frequencies is called as band reject or notch filter as shown in Fig.7.This filter is also known as band stop filter. Fig.8 shows the response of the signal which when passed through the various types of the filter proving different output response for the same input response.

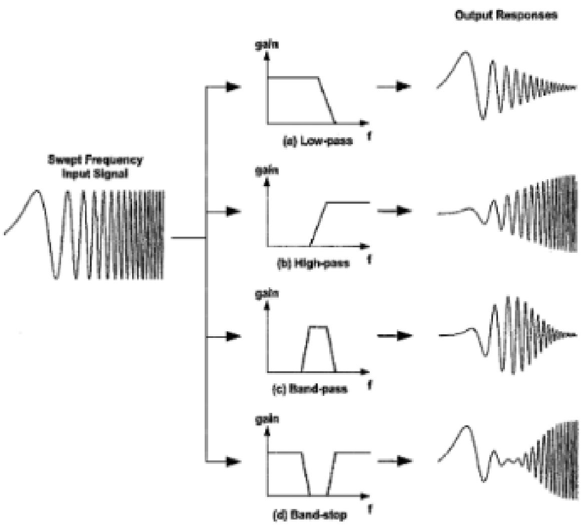

Fig.8: shows different signal response

IV. FILTER APPROXIMATION METHODS

Since transmission lines are running at long distances the signal which is being transmitted suffers from harmonics and/or distortions. To eliminate or reduce this distortion we use various types of filter designed from different approximation methods according to the application. The different types of filter approximation methods such as Butterworth, Chebyshev type -I, Chebyshev type -II, Bessel, Elliptic, etc.

A. Butterworth Filters

This is the best known filter approximation method also known as maximally flat response. It has flat pass band with no ripple. Calculations are simpler than other types because of which it calculate and plot the frequency response. The general magnitude response of Butterworth filter is

$$H(\omega)^2 = \frac{1}{1+\left(\frac{\omega}{\omega_0}\right)^{2N}} \quad (6)$$

Where N is the order of the filter ranging from (1, 2, 3.....) and ω is −3dB cutoff frequency of the filter. The function is monotonically decreasing where the maximum response is utility at $\omega = 0$ [4].

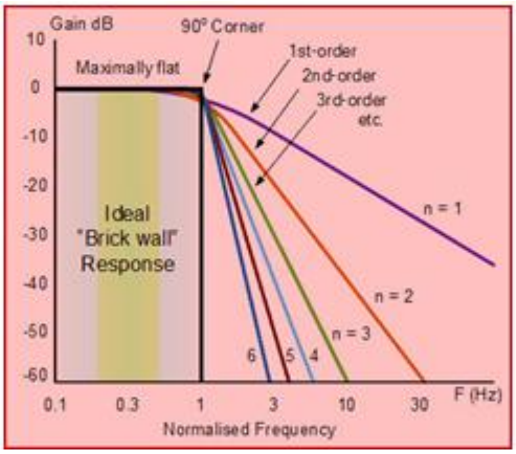

Fig.9: Ideal magnitude and phase response of butterworth filter for different N values

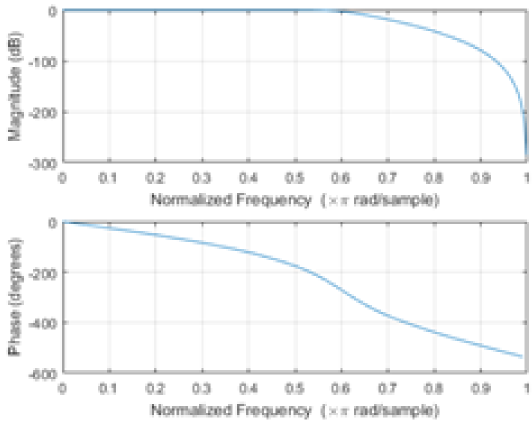

Fig.10 (a) Response of low pass filter

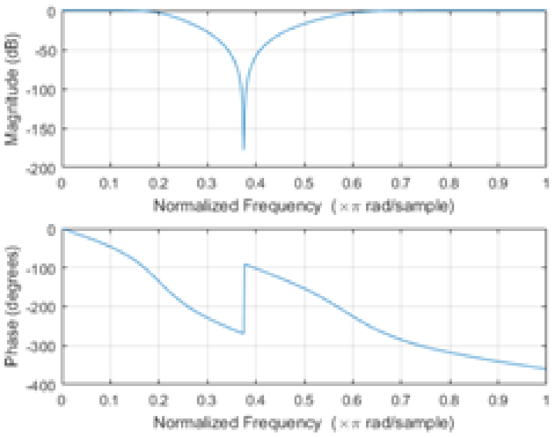

Fig.10 (b) Response of band pass filter

Fig.10: Practical magnitude and phase response of different basic filters

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B. Chebyshev Filters

Chebyshev filters are used where the frequency content of the signal is more important than having constant amplitude. They have steeper roll off.

Type-I filter has more pass band ripple and flat stop band and Type-II filter has more stop band ripple and flat pass band. They are used for distinct frequencies of band from one to another also has steeper roll-off. The main feature is they have good speed [6].

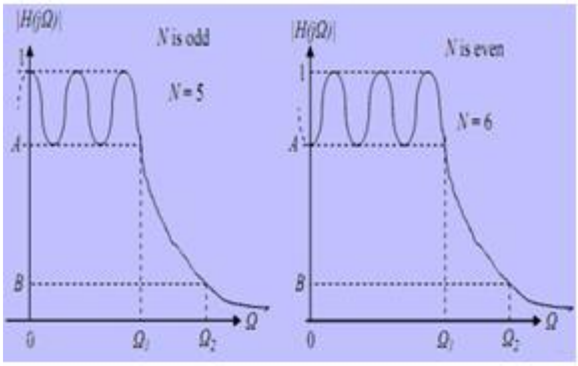


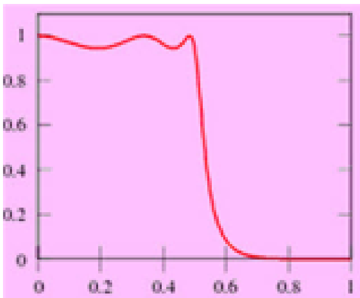
Fig.11: Response of Chebyshev filter when the order of the filter is odd and even [4]

$$H(\omega)^2 = \frac{1}{1+\left\{\varepsilon^2 C_N^2\left(\frac{\omega}{\omega_0}\right)\right\}} \quad (7)$$

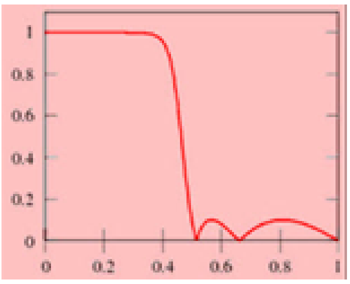
Magnitude response of N[th] order type II filter is

$$H(\omega)^2 = \frac{1}{1+\left\{\frac{1}{\varepsilon^2 C_N^2\left(\frac{\omega_0}{\omega}\right)}\right\}} \quad (8)$$

Where, C_N is chebyshev polynomial, ε is ripple factor, ω_0 is cutoff frequency and N is the order of the filter.



(a) Chebyshev Type - I filter

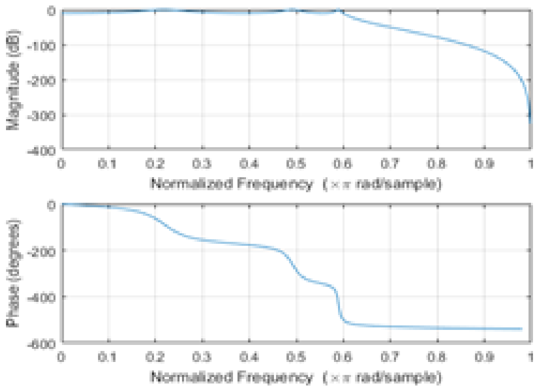


(b) Chebyshev Type - II filter

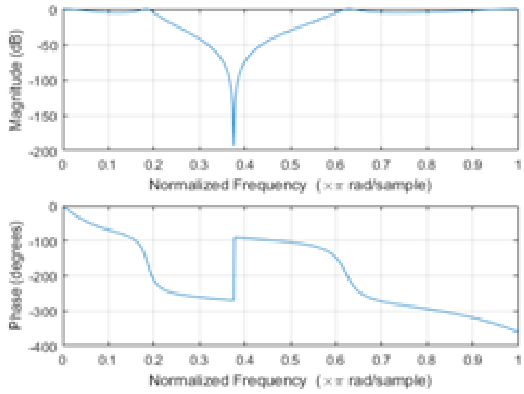
Fig. 12: Response of Chebyshev Type - I and Type - II filter.

Fig.12 (a) and Fig.12 (b) shows the ideal response of Chebyshev Type I and Type II filter.

Fig.13 shows simulated result of Chebyshev filter Type I using MATLAB. Fig.13 (a) shows the response of low pass filter and Fig.13 (b) shows the response of band pass filter.



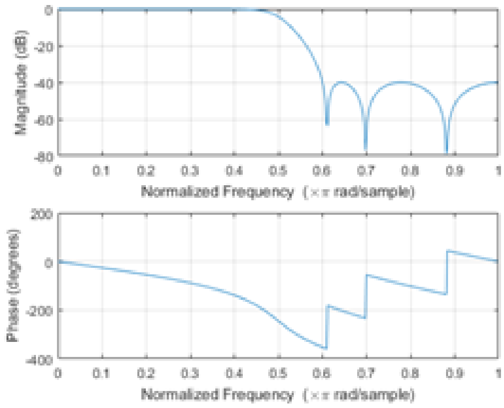
(a) Low pass filter



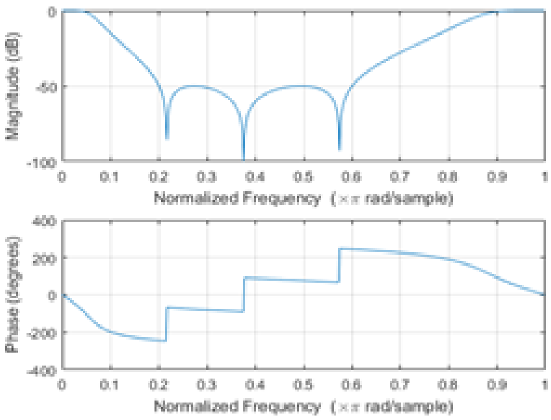
(b) High pass filter

Fig.13: Simulated result of Chebyshev Type - I filter

Fig.14 shows simulated result of Chebyshev filter Type II using MATLAB. Fig.14 (a) shows the response of low pass filter and Fig.14 (b) shows the response of band pass filter.



(a) Low pass filter



(b) High pass filter

Fig.14: Simulated result of Chebyshev Type - II filter

V. CONCLUSION

Theoretical and simulated results of filters tallied with one another. From these results following conclusions can be drawn -

- Distributed element filters are constructed with any band forms like low-pass, band-pass etc. with lumped elements.
- Butterworth, Chebyshev etc filters can be implemented using distributed element approach.
- For frequencies in the range of 30-300 MHz distributed element filters are mostly convenient.
- Magnitude response of Butterworth filter decreases with the increase in frequency and Chebyshev filter response shows ripple in pass-band/stop-band depending upon its types.
- Width of the transition band is more in Butterworth filter than in Chebyshev filter. Butterworth filters have slower roll-off as compared with Chebyshev Type I and Type II.
- Pass-band of Butterworth filter has more linear response compared to Chebyshev filter.
- Chebyshev filter reduces the error between idealized and actual characteristics.
- The order of Butterworth filters is more for same specification as compared to Chebyshev filter.

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