Research Article

Total Harmonic Reduction in Distribution System Using Discrete Wavelet Transform

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Abstract: The study of a discrete wavelet transform for an adaptive shunt compensator (STATCOM) to minimize THD in a large and small power utility system is presented in this paper. During loading conditions, THD analysis, such as harmonics in output currents, is also performed. This algorithm divides each line's non-sinusoidal output current into different frequency ranges in order to analyze different non-sinusoidal frequency parameters in order to find the ideal KW power component. The error of each sensed output current is used to find the ideal sinusoidal currents for the triggering of a voltage source inverter (VSI) that is acting as a STATCOM. The software validation results of the proposed control algorithm are addressed under various loading conditions. Under different loading conditions, the (THD) Total harmonic distortion in input current is less than 5%, which is appropriate according to IEEE519 and IEC requirements.

Keywords: THD, Voltage Source Inverter, and Wavelet transform

1. Introduction

Electrical power quality plays an important role in manufactures & customers point of view to achieve max. Efficiency. Power Quality means deviation or changes in frequency, Voltage & current phasor from normal waveform. Harmonics is ultimately a customer-operated problem, and the customer's point of reference taken into consideration. Any deviation in voltage, current, or frequency gives results in misbehavior of customer equipment. Therefore, harmonics will affect both input & output system as well. Harmonics is estimated from the analyzing of customer's equipment. If the harmonics are present, then the quality is decreasing. Alternating system is operating at a sinusoidal voltage of a given frequency [typically 50 Hz)] and magnitude. Any major changes in the waveform Magnitude, frequency, or purity is a potential harmonic issue. Since, there is always a strong understanding between voltage and current in any actual power network [1-4]. Due to non-linear loads, there is a necessary to explore the quality of electric supply provided in an all domain that can be analyzed by the Input side operator as well as by output side operators.

Generally the Alternator gives approximately pure sinusoidal wave but passing through impedance will cause some harmonics into the system. But, finally we need to control this harmonic value below predefined level because it gives adverse effect on all system parameters such as input & output parameters. Harmonics will directly affect badly on output equipment. So, we need to provide automatically controlled, low power consumed devices offer more sensible towards change in deviation. The electric suppliers & users is also treating harmonics issue very seriously. While sensing the movements, it is important to capture deviation of the harmonic at the same moment so that issue can be addressed with possible causes [5-7]. Harmonic analyzing is the process of collecting, processing, and analyzing initial measurement data into useful information. The process of collecting data is usually done by continuously measurement of voltage and current for longer duration [8]. The process of processing, and analyzing has been done by manually & with advanced mathematical manipulations, but wavelet transform, Hadoop, machine learning have made it easy to design and implement Artificial intelligent systems to automatically processing and analyze initial data into useful information with less manual interference[8-11]. Harmonic monitoring systems are run by customers to reduce harmonic in the system. Many large and small consumers have instrument that is sensible to harmonics, and therefore, it is most important to understand the supply quality being provided [12-13]. Section 2 describes about proposed system configuration and control algorithm. Section 3 describes results & discussions and section 4 ends with conclusion.

2. Proposed System Configuration

The detailed diagram of suggested control algorithm is drawn in below Fig.1. It Consists of fundamental 3-Phase STATCOM having a VSI (Voltage Source Inverter), associated inductor coil connected in series, Loads and 3-Phase system, 415V, as a 3-Phase Source. The MOSFET of a 3-Phase VSI are managed using the triggering impulse. The triggering impulse is developed from the triggering impulse generator as mentioned in suggested work. The associated inductor coil is placed between the Input supply system and the VSI to avoid the large frequency changing waveform of the reception currents. At the output side is connected with L-R star connected load is analyzed using R & L parameters of the load. A 3-Phase Rectifier Converter Bridge is implemented to understand & capture non-sinusoidal behavior in output current during an L-R loading condition.

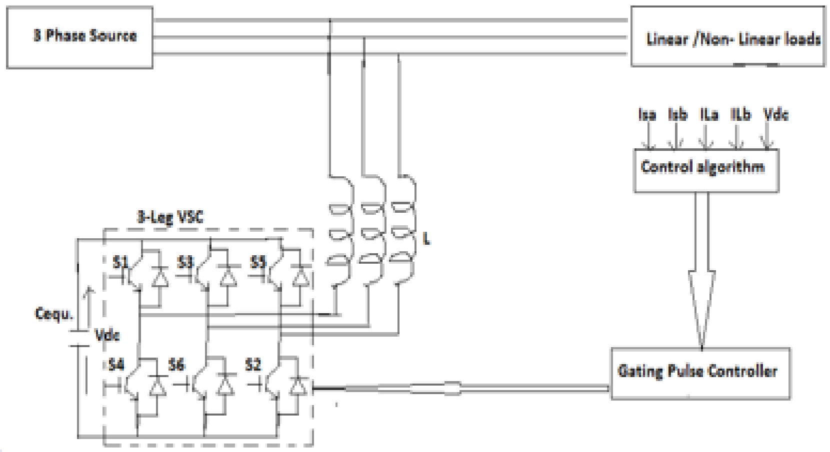

Fig.1 Detailed block diagram

1.1. Control Algorithm

With use of Discrete Wavelet transform technique for harmonic elimination in input as well as output. DWT is mainly implemented for analyzing the Non-sinusoidal like harmonics, swag, swell & any other discontinuity contents available in the waveform etc. DWT is a waveform of effectively for some definite time period & over that time period, the mean value of waveform null. DWT is used to capture disturbed events in waveform i.e.; the frequency domain analysis of waveform changes in Time-Domain. DWT provides adaptive interaction and Waveform is processed & analyzed both in frequency & time domain. This suggested work needs the observing of the Middle point of integration Line Voltages (VL12, VL23), supply currents (IL1, IL2), load currents (Il1, Il2) and the Direct Current link Voltage of VSI (Vlink) during analysis. Middle point of integration Line Voltages (VL12, VL23) are used to find the phase voltages (Vp1, Vp2, Vp3). So, all observed and calculated Middle point of integration Phase Voltages (Vp1,Vp2,Vp3), load currents (IL1,IL2,IL3), supply currents (Is1,Is2,Is3) and Direct Current coupling potential differences of VSI (Vlink) waveforms are trained as per the below process to obtain the triggering impulses of VSI as drawn above in Fig.2.The obtained Reception Currents from VSI are integrated to the Middle point of integration to find a pure standard input current signal on the supply side for the different loading situation. Identification of Middle point of integration voltages namely as (Uap, Ubp,Ucp). The max. Value of Middle point of integration phase voltage (Vsa, Vsb, and Vsc) is estimated as,

$$Vp = \sqrt{\frac{2\,((Vsa)2 + (Vsb)2 + (Vsc)2)}{3}}$$

3.

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The Middle point of integration voltages are calculated below,

$$Uap = \frac{Vsa}{Vp}, \quad Ubp = \frac{Vsb}{Vp}, \quad Ucp = \frac{Vsc}{Vp} \qquad \text{.... (2)}$$

Now, for the determining of Average KW Power of Load Current, load current is observed. The observed load currents (IL1, IL2, and IL3) are processed individually through each DWT for the finding of the corresponding sinusoidal part in waveform. The different level for splitting of load current when sampled at 2.6 kHz. The 4th level coefficients (A4I) of the unreal tree gives the Fourth-Order component (IqLa) of Load current as it is collecting the component of frequency from 0-75 Hz. The specimen frequency of 2.6 KHz is used to decrease the processing burden.

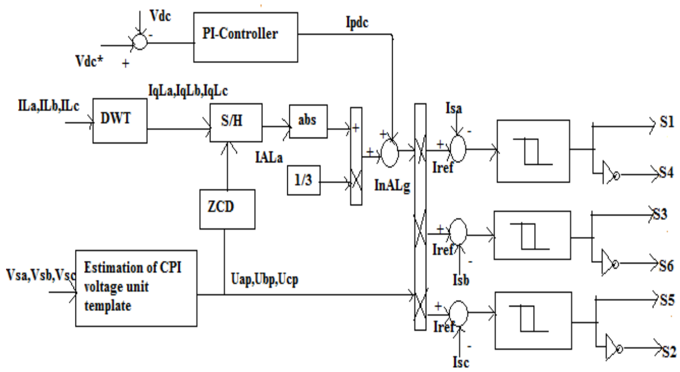

Fig. 2 Simulink model of DWT based control algorithm

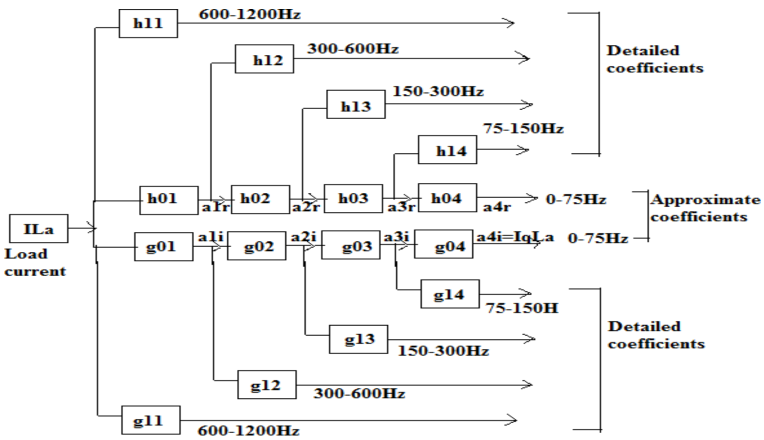

Fig. 3 DWT decomposition of load current in various frequency level to extract quadrature component

Now, Calculated Fourth-Order component of load currents components (IqfLa, IqfLb, IqfLc) is utilized to find out relative KW Power parameter (IAfLa, IAfLb, IAfLc) respectively. These KW power components (IAfLa, IAfLb, IAfLc) are estimated by taking the mean weight of relative calculated parameter (IqfLa, IqfLb, IqfLc) at every null passing of relative voltages (Uap, Ubp, Ucp).

The mean value of KW parameter of load currents (IApLg) find out below,

$$IApLg = \frac{iAfLa + iAfLb + iAfLc}{3} \quad \text{…. (3)}$$

A Proportional-Integral (PI) controller is utilized for maintaining Direct Current junction potential of VSI worked as a STATCOM for the finding of KW parameters of Direct Current tie-up voltage control (IPdc), then these calculated KW parameters of Direct Current tie-up voltage is added with an KW power component of load current to get Final KW power component is given below,

$$InApLg = IApLg + Ipdc \quad \text{…. (4)}$$

Lastly, in order to find out a recommended current the final active supply voltage (I_{ALG}) is cross-multiplied by the Middle point of integration voltages (Uap, Ubp, Ucp) as,

$$\left.\begin{aligned} i_{aref} &= I_{nApLg} u_{ap} \\ i_{bref} &= I_{nApLg} u_{bp} \\ i_{cref} &= I_{nApLg} u_{cp} \end{aligned}\right\} \quad \text{…. (5)}$$

For the Generating of triggering pulses, the observed supply currents (IL1,IL2,IL3) is minus from recommended input currents to estimate the differences (iaref, ibref, icref). For the Generating of triggering pulses, the observed supply currents (IL1,IL2,IL3) is minus from recommended input currents to estimate the differences (iaref, ibref, icref). Then these differences given to (HCC) Hysteresis current controller for finding of the triggering impulses

(S1 to S6) for the MOSFETs of the VSI. The reception currents are find out from VSI is integrated with the input side for reduction in THD (Total Harmonic Distortion) in input current.

3. Results & Discussion

3.1 Before Compensation

In before compensation mode, due to presence of distorted load, harmonics produce in input current .The THD (Total Harmonic Distortion) of distorted input is 31.10% and this showed in below in Fig. 4 & 5respectively. But as per IEEE-519 & IEC standards, THD in current should be less than 5%.

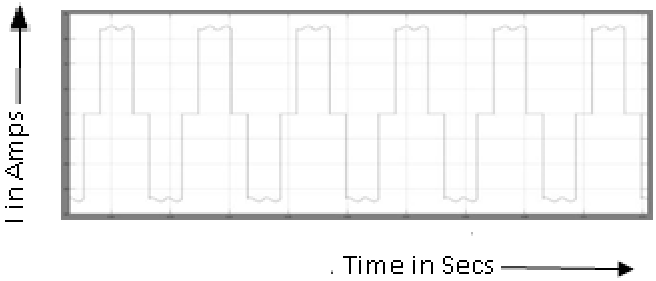

Fig.4 source current before compensation

As we know that, due to presence of harmonics in the system, it will badly affect to system behavior and also affect to system equipment's. Due to presence of harmonics , the equipment's are sensible to any deviation will may possible to misbehave , also the life of instrument will reduce , system efficiency decreases, performance is also reduce and there are many more adverse effect of harmonics in the system and also harmonics are more poisons to system. So, these kinds of harmonics are eliminated by using a discrete wavelet transform technique. The result i.e. sinusoidal input current and THD analysis of Input current after implementing suggested work is elaborated in below Fig.6&7 respectively.

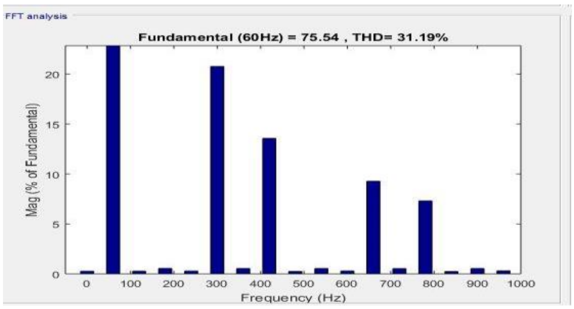

Fig.5 Harmonic analysis of input current before compensation

3.2 After Compensation

By using Discrete wavelet transform technique, for harmonic elimination, the input current become Sinusoidal and reduces THD less than 5% shown in Fig.6 below,

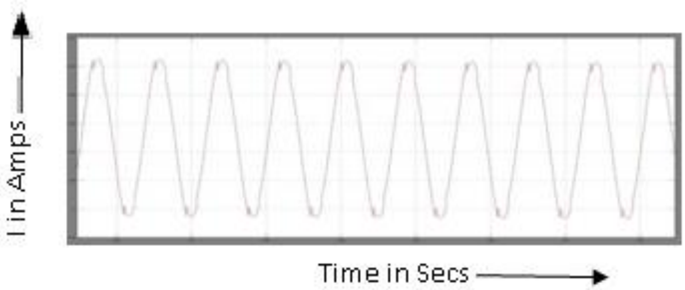

Fig.6 Source current after the compensation

The FFT analysis of the input current after the compensation is elaborated in Fig.7 below,

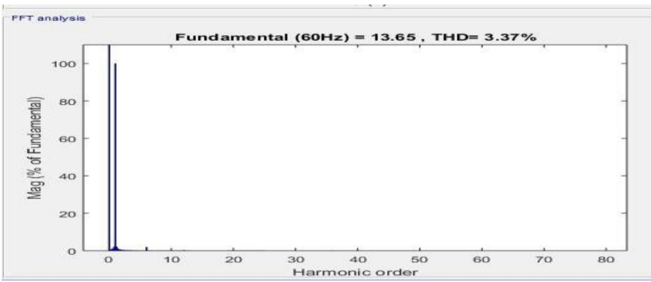

Fig.7 FFT analysis of source current after compensation

Now, effect of power factor angle (Ø) on THD of input current & load current magnitude & distortion in output current is analyzed in table no.1. The relationship between power factor angle and different value of R-L is shown in equation (6) below. From table no.1 we can conclude that as we reduce the value of inductor (L) then more fluctuations in load current magnitude and no effects on THD of source current. Similarly as we increase resistance(R) then THD in source current is reducing and fluctuations in source current is elaborated below in table no.1

$$\tan Ø = XL/R \qquad (6)$$

Table- I: Load, THD & Output Current Magnitude

Load	THD in %			Output current magnitude
	A	B	C	
R=10Ω, L=0.10H, ø=75.14, tan ø =3.7688	4.47	4.32	4.26	66 (No fluctuation)
R=10Ω, L=0.02652H, ø =45, tan ø =1	4.47	4.32	4.26	66 (less fluctuation)
R=10Ω, L=0.01H, ø =20.65, tan ø =0.3768	4.47	4.32	4.26	70 (more fluctuation)
R=50Ω, L=0.01H, ø =4.31, tan ø =0.075	0.99	0.93	0.87	15 (more fluctuation)
R=3.7699Ω, L=0.01H, ø =45, tan ø =1	11.23	10.76	10.76	180 (less fluctuation)
R=3.7699Ω, L=0.026H, ø =68.96, tan ø =2.599	0.99	0.93	0.87	180 (No fluctuation)

4. Conclusion

The suggested algorithm has been successfully executed to reduce harmonics in a large & small system. The suggested algorithm splits the output current into a various different category of frequency ranges for collect the elementary part of non-sinusoidal output current. The estimated elementary part of output parameter is again utilized to find out the recommended stable input currents in this suggested work for the avoiding the distortions, in the large & small system. Software results validations have shown that harmonics reduction under different load situations & as per the guidelines from IEEE-519& IEC for maintaining THD in the input current is below 5%..

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