Newton Method Based Harmonics Estimation and Elimination Using LCL Filters

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Abstract— The main aim of this paper is to maintain the power quality parameters such as harmonics using LCL filter method after duly estimating the harmonics using newton raphson method. Harmonics are frequencies higher than the fundamental. There are two types of harmonics: even harmonics and odd harmonic. Fourier analysis could be used for decomposition of both types of harmonics. In this paper, a selective harmonic compensation scheme using the anti-harmonic injection and FFT is presented both for voltage and current. This method compensates for the preexisting grid background harmonics using the line current and voltage measurement and provides superior harmonic performance. In addition to the harmonics removal, power factor improvement is also carried out. The proposed method requires measuring the angle of the grid voltage harmonics. This PWM control scheme and further quality parameters have been verified by MATLAB models under version 2018 with power systems and power electronics tool boxes.

Keywords: DC Source, Microgrid, Inverter, Matlab/Simulink Software, Various Loads

I. INTRODUCTION

A harmonic of a wave is a component frequency of the signal that is an integer multiple of the fundamental frequency, i.e. if the fundamental frequency is f, the harmonics have frequencies 2f, 3f, 4f, . . . etc. The harmonics have the property that they are all periodic at the fundamental frequency; therefore the sum of harmonics is also periodic at that frequency. Harmonic frequencies are equally spaced by the width of the fundamental frequency and can be found by repeatedly adding that frequency. For example, if the fundamental frequency (first harmonic) is 25 Hz, the frequencies of the next harmonics are: 50 Hz (2nd harmonic), 75 Hz (3rd harmonic), 100 Hz (4th harmonic) etc. It is well known that voltage or current harmonics generated by power converters can cause various problems to other equipment connected to the common ac lines. In a high-power drive system, a grid side (front end) pulse width-modulated (PWM) rectifier usually uses selective harmonic elimination (SHE) PWM to eliminate certain low-order harmonics in the PWM pattern to avoid causing excessive distortions in the line current. Research interests on the SHEPWM so far are mainly on the algorithms of switching angles solutions, the combination of SHE PWM with other modulation schemes in drive systems and the improvement of system dynamic response with SHE scheme. However, the grid background harmonics are not considered in the traditional SHE PWM. In a current source rectifier (CSR) system, due to the use of an input LC filter, the grid background voltage harmonics (such as fifth or seventh harmonic) could be amplified by the filter, which results in a high distortion of the line current, although the grid voltage harmonics are low. To compensate the grid background harmonics and to avoid the amplification of certain harmonics in the line current, passive filters can be used, which certainly increases the cost, size, and weight of a system. Another way to compensate the grid harmonics is to actively control the grid-interfacing converter systems to produce the compensating current or voltage. In this case, the grid-interfacing converter operates as an active power filter at the harmonic frequencies, while controlling the real power flow (with dc or ac voltage/current control) at the fundamental frequency. However, this harmonic compensation requires a relatively high converter switching frequency of at least a few thousands hertz. A newly developed method for accomplishing this harmonic compensation is the selective harmonic compensation (SHC) PWM. It has been experimentally implemented and proven that based on the transfer functions derived from the CSR system equivalent circuit, the obtained grid voltage harmonic information can be used to generate the relevant harmonic reference current in the PWM process, which would in turn improve the line current.

II. EXISTING SYSTEM

The harmonic stability problem is not new, and it was earlier reported in the commissioning stage of the High Voltage Direct Current (HVDC) Cross-Channel link in 1961. That HVDC system was based on the Line-Commutated Converters (LCCs), where the voltage distortion caused by a high grid impedance, i.e., a low Short-Circuit Ratio (SCR) grid, leads to asymmetric firing angles for the LCC, which consequently distorts the grid current with the unexpected harmonics, and forms a positive feedback loop with the grid impedance. The harmonic instability of LCC-HVDC system can be exaggerated by the core saturation of the converter transformer. A second-order harmonic instability resulting from the transformer core saturation has been well discussed.

It is worth mentioning that the characteristic of the ac system impedance is important for the harmonic stability of the LCC-HVDC systems. The system is more prone to the harmonic instability in the high-impedance (the low SCR) grid, where the high voltage harmonics are introduced at the input of the firing-angle control system, and the frequency coupling nature of the firing angle control distinguishes the harmonic instability from the instability of low-frequency control loops. Moreover, the frequency transformation of ac-dc converters translates the oscillation component (fdc) at the dc-side into two components of the frequencies f1 ±fdc at the ac-side, where f1 is the grid fundamental frequency. These two components can be seen as the sideband components of the fundamental frequency, which can also cause the harmonic instability when interacting with the ac system impedance.

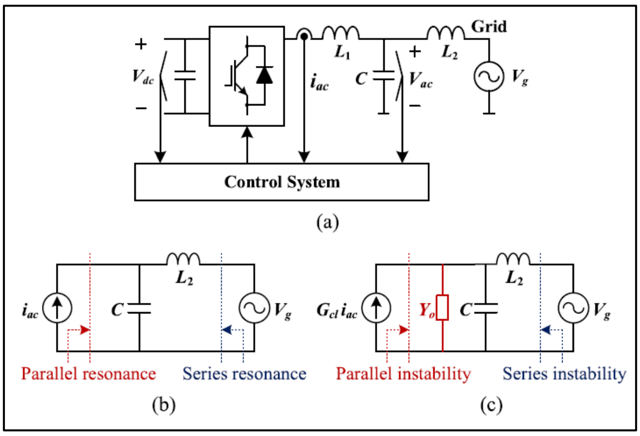

Fig. 1: General diagram of grid connected VSC and its equivalent circuit

III. OVERVIEW OF PROPOSED SYSTEM

The proposed VI-SHC scheme compensates the system background harmonics using the line current measurement instead of the source voltage in the SHC scheme. Therefore the VI-SHC PWM is more practical in the real applications, since the voltage distortion is usually very subtle for accurate measurement. As the PWM output in a CSR system is directly related to the line current, the VI-SHC method is essentially a closed-loop compensation scheme by feeding back the line current harmonics. Therefore, it does not require the detailed and precise system parameters for the derivation of the system transfer functions.

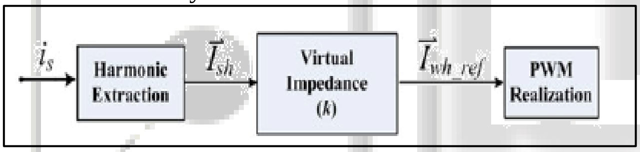

Fig. 2: Schematic layout of proposed system

Here all blocks are connected as per the desired block diagram with the rated parameters, which is shown below in fig 3. Here Both virtual impedance and FFT based analysis is done and both are compared. This is a new method to detect and eliminate both voltage and current harmonics.

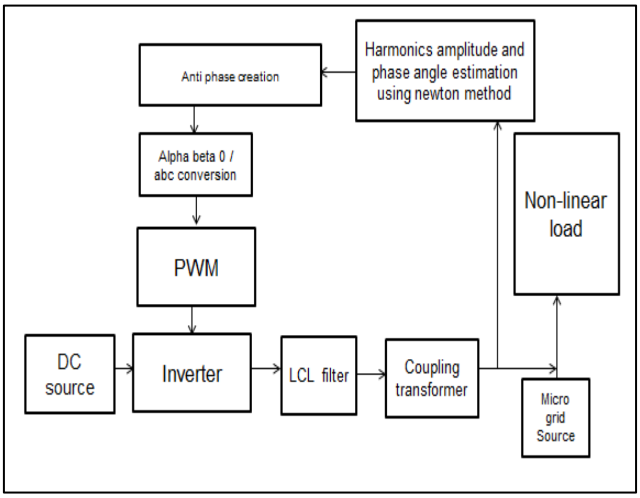

Fig. 3: Block diagram of harmonic elimination method

IV. ANALYSIS OF SIMULINK MODEL

The below figure 4 shows the Simulink model of the proposed system with harmonics reduction as a major task. The Simulink had been built with the power electronics tool box available in Simulink library. Drag and drop operation has made the design easy and measurement devices helps us to measure the THD values at any point of interest in the Simulink model. 'Goto' Tags helps the user to place the oscilloscope anywhere in the Simulink model window without using confusing wiring in between the components. It could be seen that equivalent impedance is place in the input circuitry of the Simulink model.

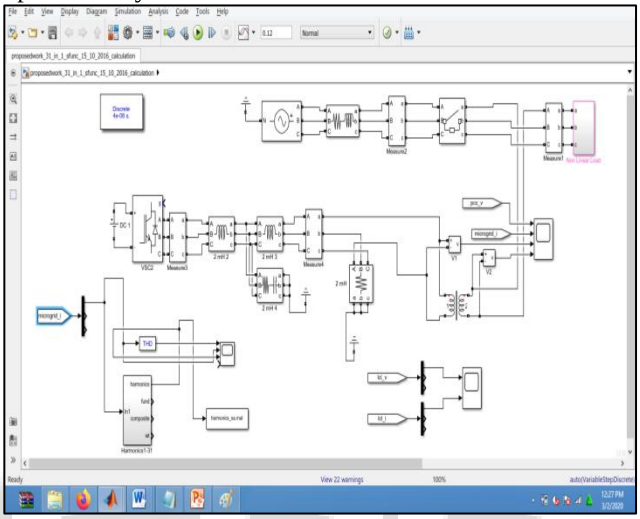
Fig. 4: Simulink model of single phase with harmonics

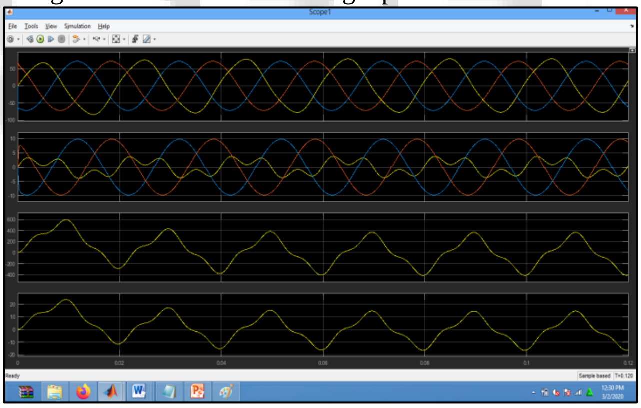
Fig. 5: output of single phase with harmonics

The simulation model shown below in fig 6 is related to the reduction of the harmonics introduced into the microgrid due to the presence of non-linear loads. The concept relies on injecting a reasonable inverted voltage of the harmonics detected in the line. The harmonics are detected based on newton method which gives the amplitude and phase angle of a particular order of the harmonic. This is duly inverted and injected into the line using a single phase transformer. Due to this injection the harmonics which exists in the load does not affect the micro grid and does not harm other loads.

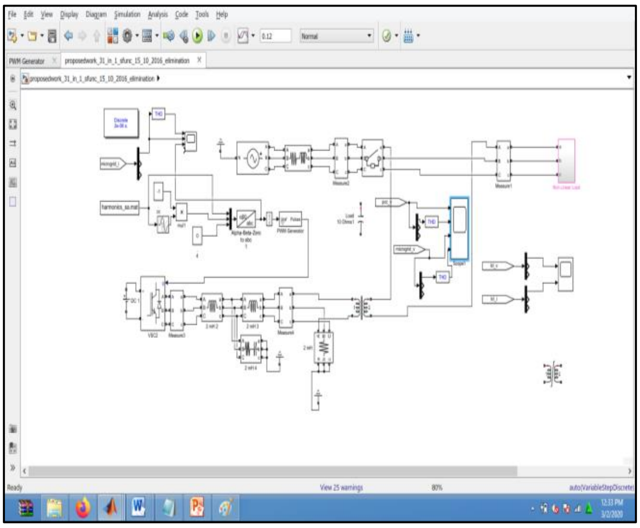

Fig. 6: Simulink model of single phase harmonics elimination

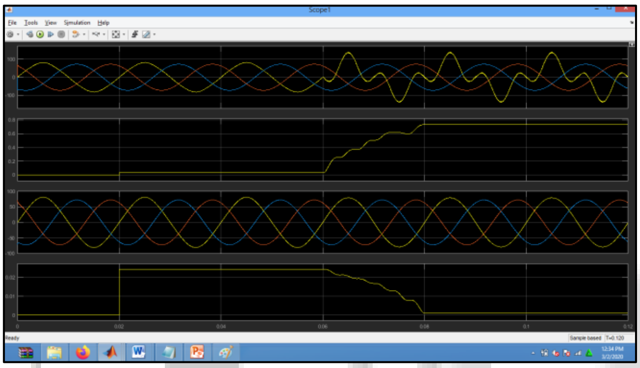

Fig. 7: output of single phase harmonics elimination

The below figure 8 shows the Simulink model of the proposed system with harmonics calculation as a major task of three phase. The calculation part of the method is written as a similar with single phase model. The Simulink had been built with the power electronics tool box available in Simulink library. Drag and drop operation has made the design easy and measurement devices helps us to measure the THD values at any point of interest in the Simulink model. 'Goto' Tags helps the user to place the oscilloscope anywhere in the Simulink model window without using confusing wiring in between the components. It could be seen that equivalent impedance is place in the input circuitry of the simulink model.

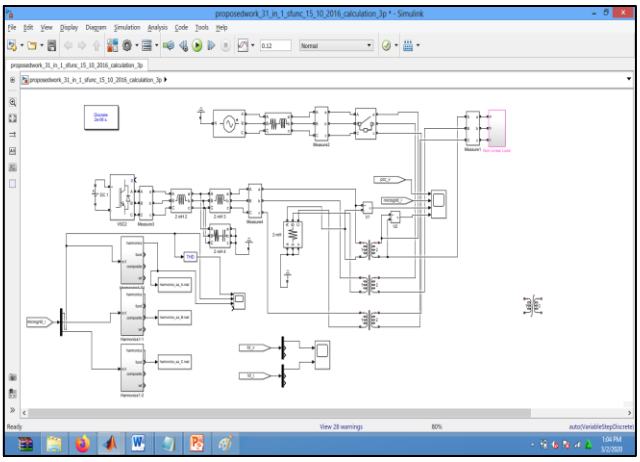

Fig. 8: Simulink model of three phases with harmonics

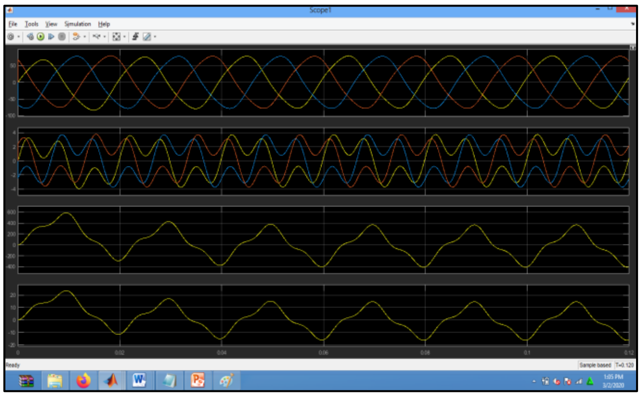

Fig. 9: output of three phases with harmonics

The simulation model presented below in fig 10 is related to the reduction of the harmonics in a three phase system which was introduced into the microgrid due to the presence of non-linear loads. The concept relies on injecting a reasonable inverted voltage of the harmonics detected in the line. The harmonics are detected based on newton method which gives the amplitude and phase angle of a particular order of the harmonic. This is duly inverted and injected into the line using three single phase transformers. Due to this injection the harmonics which exists in the load does not affect the micro grid and does not harm other loads.

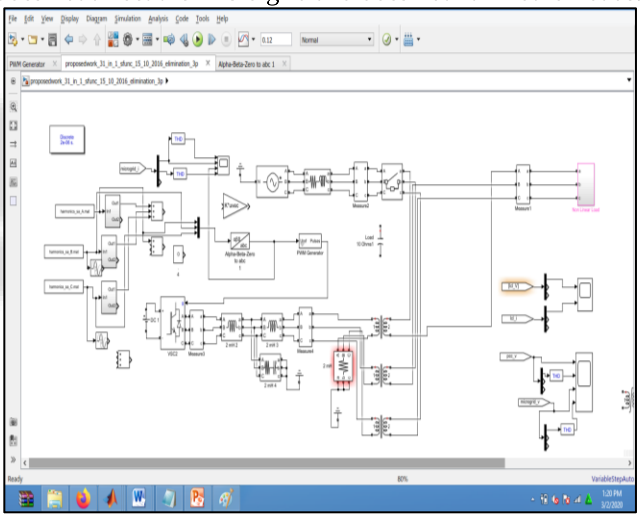

Fig. 10: Simulink model of three phase harmonics elimination

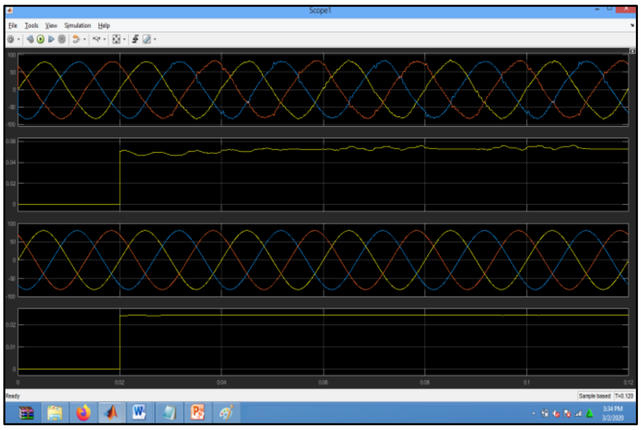

Fig. 11: output of three phases harmonics elimination

V. CONCLUSION

It is well seen that the estimation of harmonics prior to reducing it gives a good and acceptable performance based on the lowest THD. The main problem in injecting the anti-harmonic content is its phase angle. Predicting the phase angle of the harmonics yields a better rejection and also the task is done instantaneously within two cycles. The THD achieved in this project is less than 4%. This task is accomplished using LCL filter method after duly estimating the harmonics using newton raphson method. In this project, a selective harmonic compensation scheme using the anti-harmonic injection for all the harmonics in the range of 3 to 31 excluding the even harmonics which is not harmful to the grid systems. This method compensates for the preexisting grid background harmonics using the line current and voltage measurement and provides superior harmonic performance. In addition to the harmonics removal, power factor improvement is also carried out. The proposed method requires measuring the angle of the grid voltage harmonics. This PWM control scheme and further quality parameters had been verified by MATLAB models under version 2018.

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