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Active Harmonic Filtering Using Multilevel H-Bridge Inverter Based Statcom

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Abstract
To reduce the amount of harmonic components in a transmission network, this paper proposed a three-phase multilevel cascaded H-bridge inverter (MCHI) based active harmonic filtering (AHF) compensator, also known as a static synchronous compensator (STATCOM). A STATCOM is made up of three main components: modulation method, topology of the inverter, and control plan. The synchronous reference frame (SRF) based controller for the pulse width modulation (PWM) module is designed and implemented in this work to produce the desired modulating signals—one for each phase. The three-phase, five-level CHI is driven by the carrier based pulse width modulation (CBPWM) with in phase disposition (IPD) method for simplicity's sake. On the other hand, the proposed AHF's viability is checked out using two three-phase non-linear loading conditions that are based on different transformer winding configurations and power rectifier circuits. Using the MATLAB SIMULINK software package, simulation studies are used to investigate and validate the proposed method's effectiveness as well as theoretical predictions.

1. Introduction

Problems with power quality (PQ) have been the biggest issue for utility companies and industrial customers. For instance, due to the presence of harmonic frequencies and voltage fluctuations [1], low PQ causes low electrical transmission efficiency, which results in high or wasteful expenditures. The increased use of electrical and electronic appliances, particularly non-linear loads like electric arc furnaces, refrigerators, converters, inverter drives, and so on, is to blame for these issues. 2]. However, utilities and other professions can refer to a few international PQ standards on the desired PQ level, such as IEC 61000, EN 50160, and IEEE 519 series [3]. Harmonic is one of the factors that contribute to poor PQ, as was mentioned earlier. The voltage or current at frequencies where the integer multiplies with the fundamental frequency is said to be harmonic. Particularly the negative sequence components (such as: 5th, 11th, 17th, and so on). causes equipment to overheat unnecessarily, reduce its efficiency [2], and shorten its lifespan. Telephone interference, which hinders metering and instrumentation, and capacitor damage are additional effects of the harmonics [4]. The harmonic filter (i.e.:) is used to solve the system's harmonic issue. both passive and active filters) have been installed. Simple and less costly is the passive filter, which provides the path with the lowest impedance for tuning the harmonic frequency.

However, there are some disadvantages to it. It has resonance issues with the L-C filter, can only produce regular compensation, cannot compensate for unbalanced loads, and is large [5]. To address the system's harmonic issue, an active harmonic filter (AHF) is developed due

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to these drawbacks. The series AHF and the shunt AHF are the two distinct types of AHF. While the shunt AHF is typically used to compensate for the current harmonic for non-linear loads, the series AHF is typically used to reduce voltage total harmonic distortion (THD) [6]. In contrast, in order to produce sinusoidal current source curves and compensate for the non-linear load current, the shunt AHF injects harmonic current at the point of common coupling (PCC). Examples of advanced AHF that effectively address PQ issues include flexible alternating current transmission system (FACTS) devices. The static synchronous series compensator (SSSC), STATCOM, static var compensator (SVC), unified power flow controller (UPFC), and other controllers are examples of FACTS devices. By providing the transmission with inductive or capacitive reactive power, the FACTS devices increase the PQ and lower the power cost [7]-[17]. Harmonics caused by incremental non-linear loads are a significant contributor to issues with power quality. This includes waveforms that are getting worse and more distorted and have high THD values. THD means that there is more power lost, less transmission efficiency, and it costs a lot to run. As a result, AHF should be used to reduce harmonics in the power system, which are critical. An AHF-like MCHI-based STATCOM is simulated in this project. The design of an AHF that can simultaneously reduce THD and remove harmonics was demonstrated in this paper. Simulink will be used to implement and model the STATCOM controller, PWM, and multilevel inverter (MLI) that was chosen. Based on the system's current waveform and THD results, the planned model is examined.

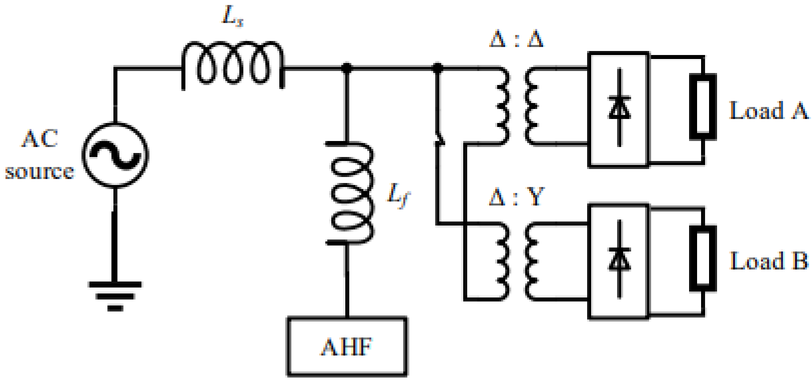

Fig.1 Single Line Diagram

2. Proposed System

The single-line diagram of the proposed three-phase power transmission system with the proposed AHF connected at the PCC is shown in Figure 1. The main transmission line element is shown as an inductor Ls, and its size is estimated to be one percent of the coupling inductor Lf. The non-linear loads are created by two sets of six-pulse diode rectifiers with distinct transformer winding configurations and resistive loading conditions. The AHF is constructed using five-level CHI in this work. When MCHI is compared to the conventional voltage source inverter (VSI), a coupling inductor Lf 2.1 can take the place of a substantial and pricey power transformer. Figure 2 depicts the schematic of a three-phase, five-level CHI. Multilevel cascaded h-bridge inverter In particular, two identical H-bridge inverters need to be stacked in series to form a single phase, five-level CHI. Similar to the conventional H-bridge inverter, the DC-link output voltage of the CHI should be at least

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twice that of the PCC voltage. This is because the two series-connected switching devices that structure each phase-leg cannot be turned on simultaneously. Using (1), you can determine the size of the coupling inductor Lf as follows:
where ic is the maximum current that can flow through Lf in relation to vc and fc is the cut off frequency of the low pass filter, which is twice the fundamental frequency. In contrast, the DC-link capacitor of each H-bridge cell serves as an energy storage component. Its size is determined in (2) by where Vpv and Ipv are the DC source voltage and DC source current of the PV array boost converter, respectively, and Vdc and Idc are the boost converter's output voltage and output current

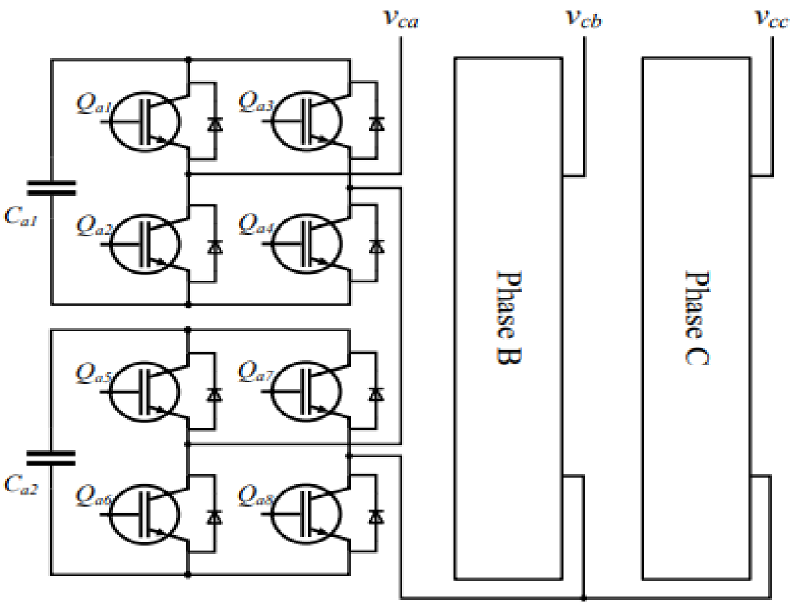

Fig.2 Three Phase Five Level H-Bridge Inverter

3. Result And Analysis

Since P-I controller has no ability to predict the future errors of the system it cannot decrease the rise time and eliminate the oscillations. If applied, any amount of I guarantees set point overshoot.

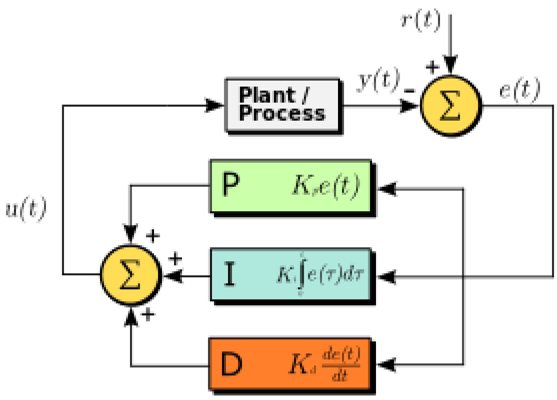

Fig.3: PID controller

A control loop feedback mechanism (controller) known as a proportional–integral–derivative controller (PID controller) is frequently utilized in industrial control systems. An error value

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is the difference between a measured process variable and a desired setpoint that is continuously calculated by a PID controller. Adjusting a control variable, such as the position of a control valve, adamper, or the power supplied to a heating element, to a new value determined by a weighted sum is one way the controller tries to reduce error over time.

$$u(t) = MV(t) = K_p e(t) + K_i \int_0^t e(\tau)\,d\tau + K_d \frac{d}{dt} e(t)$$

Fig. 1 (a) depicts the fundamental circuit diagram of the 3-phase, 4-wire, 4-leg VSC-based AC shunt DSTATCOM. The resistive-inductive (RL) load of three single-phase AC voltage controllers is connected in parallel to the DSTATCOM via a three-phase, four-wire system. The Synchronous Reference Frame (SRF) theory is used to generate the switching signals for the six IGBTs on the three legs of DSTATCOM. The IGBTs on the fourth leg are connected so that the neutral current is zero. As a result, load compensation and neutral current elimination are achieved using this approach. In order to reduce the ripple in the injected current and connect the Voltage source Converter (VSI) to the system, AC inductors are used. To lessen the PCC voltage injection ripple during DSTATCOM switching, RC filters are used in parallel with the load. III. Control Algorithm Fig. 1 (b) depicts the control algorithm's block diagram. The system voltages Va, Vb, and Vc, as well as the load currents ILa, ILb, and ILc, are sensed and utilized for the generation of a reference current. This reference current is then utilized to generate the switching signals for the three legs of DSTATCOM. The following transformation is how three-phase load current is transformed through the Park Transformation into two-phase revolving vector current with direct axis Id, quadratic axis IQ, and zero sequence I0

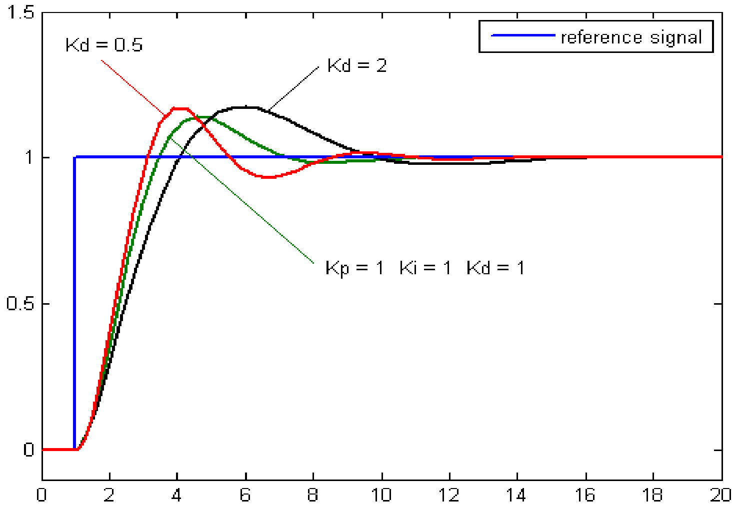

Fig.4 Experimental Result

5.Conclusion

Industries and electric utilities are becoming alarmed by the presence of non-linear loads in high voltage electrical power systems, which is making them a major concern in this day and age. As a result, using the AHF to get rid of harmonics is an important part of every transmission and distribution system. The standard FACTS inverter-based compensator known as STATCOM functions as an AHF to eliminate these undesirable harmonics. The three-phase, five-level CHI inverter topology for STATCOM is selected in this paper. When MCHI is compared to the conventional VSI, a coupling inductor can be used in place of a large and costly power transformer to improve THD from the source side. The MCHI is driven by a controller based on SRF and a CBPWM method. The proposed AHF system's results are checked using the MATLAB/Simulink software. Because the AHF injects the necessary harmonic currents at the PCC to mitigate the harmonics produced by the non-linear loads, the results show that the source current is clearly sinusoidal. Additionally, source current THD values are lower than load curren values.

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