

HARMONIC MITIGATION USING MULTILEVEL INVERTER AT DISTRIBUTION SIDE

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ABSTRACT: The proliferation of microelectronics processors in a wide range of equipment in automated industrial assembly lines, has increased the vulnerability of such equipment to power quality problems. These problems include a variety of electrical disturbances, which may originate in several ways and have different effects on various kinds of sensitive loads. Moreover, the proliferation of nonlinear loads with large rated power has increased the contamination level in voltages and currents waveforms, forcing to improve the compensation characteristics required to satisfy more stringent harmonics standard. Between the different technical options available to improve power quality, active power filters have proved to be an important alternative to compensate for current and voltage disturbances in power distribution systems. A flexible and versatile solution to voltage quality problems is offered by active power filters. Currently they are based on PWM converters and connect to low and medium voltage distribution system in shunt. Shunt active power filters are normally implemented with pulse-width modulated voltage source inverters. In this type of applications, the PWM-VSI operates as a current controlled voltage source. Traditionally, 2 level PWM-VSI have been used to implement such system. However, in the past years multilevel PWM voltage source inverters have been proposed to develop active power filters for medium voltage applications. Also, active power filters implemented with multiple VSI connected in parallel to a dc bus. In recent years, there has been an increasing interest in using multilevel inverters for high power energy conversion, especially for drives and reactive power compensation. Multilevel PWM inverters can be connected to high voltage source without a coupling transformer. The use of neutral-point-clamped (NPC) inverters allows equal voltage shearing of the series connected devices in each phase. However, the neutral point potential deviates, resulting in an excess voltage stress to either the upper or lower set of devices.

Key words: Neutral Point Clamped (NPC), Pulse Width Modulation (PWM), Voltage Source Inverter (VSI), Harmonics

I. INTRODUCTION

The proliferation of microelectronics processors in a wide range of equipment in automated industrial assembly lines, has increased the vulnerability of such equipment to power quality problems. These problems include a variety of electrical disturbances, which may originate in several ways and have different effects on various kinds of sensitive loads. Moreover, the proliferation of nonlinear loads with large rated power has increased the contamination level in voltages and currents waveforms, forcing to improve the compensation characteristics required to satisfy more stringent harmonics standard. Between the different technical options available to improve power quality, active power filters have proved to be an important alternative to compensate for current and voltage disturbances in power distribution systems. A flexible and

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II. HARMONICS AT GENERATING STATION

The harmonics studies are being carried out in the load side power quality management only. But the other area which has not been taken into studies lies in power generating stations. The Thermal Power stations are having its own auxiliaries for the main equipment of Boiler, Turbine and Generator to perform process. Thermal Power Station also has field Instruments, Digitally Distributed systems, UPS, Battery Chargers. This aids for the automation of Thermal Power Stations. The Power to cater the need of auxiliaries and its automation electronic gadgets are taken from the Synchronous Generators itself.

A typical Design of Thermal Power stations have Auxiliary Transformers fed from the generator output and the auxiliary transformers forming the Auxiliary Buses A & B meant for the Auxiliaries of fans and pumps for the Boiler and Turbine, The MV bus 6.6 KV also feed the LT transformers Unit service switchgear (USSG) A & B .And from the USSG the other LT equipment and the supply for DDCS, UPS, Battery chargers and Lighting Loads.

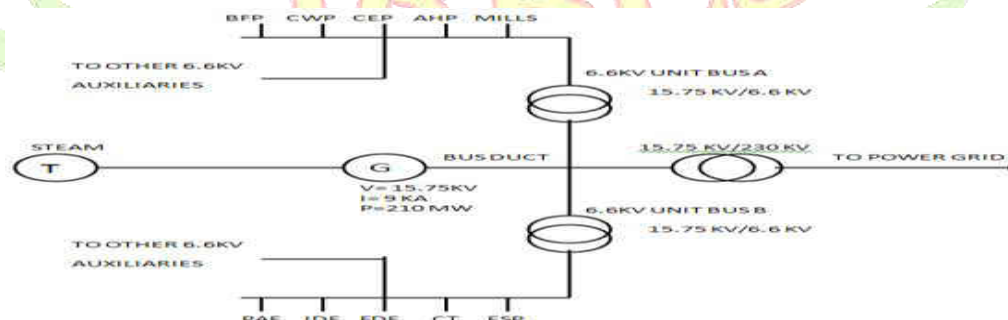


Figure 1: Power Station Power System

The M.V. Bus having the 9 % (C E A “Ministry of Power, Government of India, Data for Power Scenario ,2012) of the total load of generating capacity .The 500 M.W. Generating Thermal unit will consume around 45 M.W (Ministry of Power Govt. of India) and It will be having starting

stopping of large capacity pumps and Fans. The connected Loads on the bus will modulate depending on the command from the Control Loops. The Digitally Distributed control system (DDCS) will be in service all through time when the unit is in service to give the control and Logic commands. The emergency and standby supply for DC equipment will be taken care by the Battery Banks and the Battery inverter will always be in service.

These equipment will produce the harmonics, which will affect the Auxiliary transformers and directly with the Generator. The harmonics has effects on the DDCS and causes spurious trappings in Thermal power Units. So it is imperative to quantify the Harmonics in Thermal Power Stations and find the optimum means to mitigate the problem.

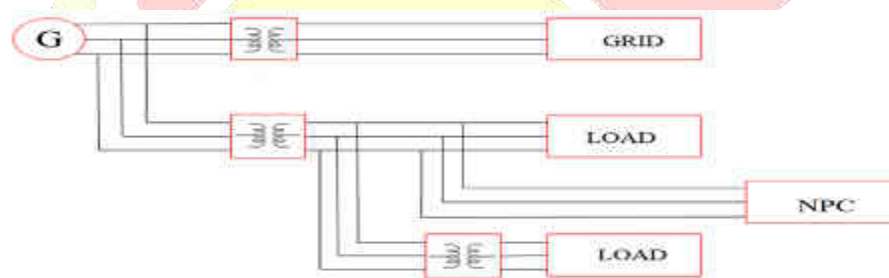


Figure 2: Block Diagram

The Auxiliary bus which feed the loads of the Thermal Power station subjects to various pulses from start and Stop of M.V equipment. As the power is drawn from the Generator through the Auxiliary Transformers, all the grid disturbances which affects the generator will affect the bus and thus the voltage sag swill , frequency dip . It also has the computer network systems for its Digitally Distributed Control systems, UPS and Battery Chargers. All these produce Harmonics in the power system of the Power Station.

III. HARMONICS

Harmonics is a sinusoidal component of a periodic wave or quantity having a frequency that is integral multiple of the fundamental power frequency. Harmonic distortion is a distortion occurring in a sinusoidal voltage or current. When a voltage and/or current waveform is distorted, it causes abnormal operating conditions in a power system.

The equation representing a harmonic frequency (f_h) is given by

$$f_h = f_1 * h \quad (1)$$

Sub-Harmonics :

Sub-Harmonics having frequency below the fundamental frequency which are rare in the power system. When sub- Harmonics are present causes resonance between the harmonic current or voltage with the power system capacitance and inductance. Sub-Harmonic may be generated when a system is highly inductive or if the system contain large capacitor banks for power factor

correction or filtering. This produces slow oscillation that are relatively un damped causing voltage sags and light flicker.

Effect of Harmonics

When a voltage and/or current waveform is distorted, it causes abnormal operating conditions in a power system such as: Voltage Harmonics can cause additional heating in induction and synchronous motors and generators.

- Voltage Harmonics with high peak values can weaken insulation in cables, windings, and capacitors.
- Voltage Harmonics can cause malfunction of different electronic components and circuits that utilize the voltage waveform for synchronization or timing.
- Current Harmonics in motor windings can create Electromagnetic Interference (EMI).
- Current Harmonics flowing through cables can cause higher heating over and above the heating that is created from the fundamental component.
- Current Harmonics flowing through a transformer can cause higher heating over and above the heating that is created by the fundamental component.
- Current Harmonics flowing through circuit breakers and switch-gear can increase their heating losses.
- RESONANT CURRENTS which are created by current harmonics and the different filtering topologies of the power system can cause capacitor failures and/or fuse failures in the capacitor or other electrical equipment.
- False tripping of circuit breakers and protective relays.

IV. HARMONIC MITIGATION TECHNIQUE

Harmonic elimination in a system can be eliminated using multi-level power converters. The term multilevel begun with the three-level converter. Subsequently, several multilevel converter topologies have been developed. However, the elementary concept of a multilevel converter to achieve higher power is to use a series of power semiconductor switches with several lower voltage dc sources to perform the power conversion by synthesizing a staircase voltage waveform. Capacitors, batteries, and renewable energy voltage sources can be used as the multiple dc voltage sources. The commutation of the power switches aggregate these multiple dc sources in order to achieve high voltage at the output; however, the rated voltage of the power semiconductor switches depends only upon the rating of the dc voltage sources to which they are connected.

A multilevel converter has several advantages over a conventional two-level converter that uses high switching frequency pulse width modulation (PWM). The attractive features of a multilevel converter can be briefly summarized as follows.

- Staircase waveform quality: Multilevel converters not only can generate the output voltages with very low distortion, but also can reduce the dv/dt stresses; so electromagnetic compatibility (EMC) problems can be reduced.
- Common-mode (CM) voltage: Multilevel converters produce smaller CM voltage; therefore, the stress in the bearing sofa motor connected to a multilevel motor drive can be reduced. Furthermore, CM voltage can be eliminated by using advanced modulation strategies.
- Input current: Multilevel converters can draw input current with low distortion.
- Switching frequency: Multilevel converters can operate at both fundamental switching frequency and high switching frequency PWM. It should be noted that lower switching frequency usually means lower switching loss and higher efficiency.

Unfortunately, multilevel converters do have some disadvantages. One particular disadvantage is the greater number of power semiconductor switches needed. Although lower Voltage rated switches can be utilized in a multilevel converter, each switch requires a related gate drive circuit. This may cause the overall system to be more expensive and complex.

Multilevel topologies

1. Neutral point clamped (NPC) also called Diode clamped (DC) Topology
2. Capacitor clamped Topology also called Flying capacitor Type
3. Cascaded H bridge topology (CHB)
4. Modular multilevel converter (MMC)

Neutral-point-clamped.

Neutral –point-clamped (NPC) is the three level topology which is multilevel topology system. NPC is based on Pulse Width Modulation (PWM) technique. Selective harmonic elimination can be done with the help of PWM at low switching frequency. Multilevel inverters are used for the high power and medium voltage applications, such as static var compensator, active power filter and motor drives due to their ability to obtain waveforms with better harmonic spectrum and attain higher voltages with a lower maximum device rating. Three-level NPC rectifier are proposed to draw the sinusoidal line current in phase with main voltage. The input power factor is unity. The low cost converter with less power switches and small size are used in industrial application.

Voltage across the switches are only half of the dc-link voltage. This topology can be generalised and the principle used in the basic three level topology can be extended to any number of levels. Voltage harmonics is centred on twice the switching frequency.

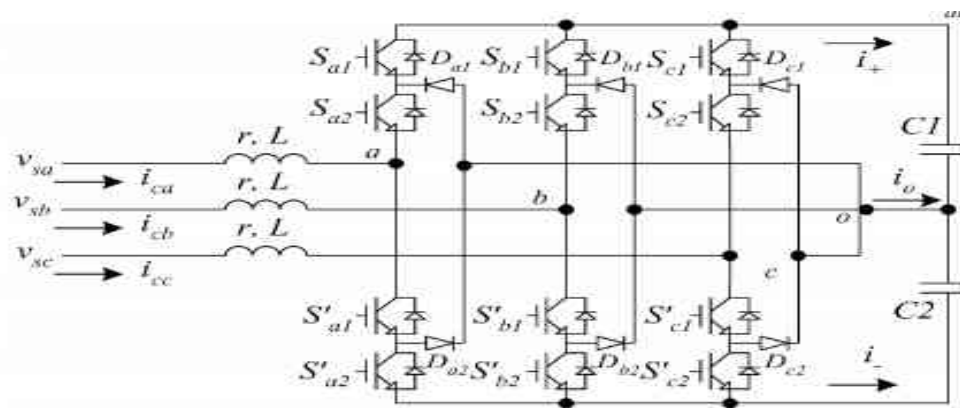


Figure 3: Three level NPC Inverter

Three level NPC inverter is shown in the figure 3.1. IGBT or MOSFET is used as switches. An important issue for multilevel inverter is the neutral point balancing. The dc bus of three level inverter consists of two capacitors. The maintaining the charge balance of the capacitor is still an open issue for NPC topologies with more than three levels. Although the three level are mostly used with higher power factor loads, NPC with more than three level are used for static var compensation circuit. Balancing of capacitor nearest three vector modulation is used which is the modulation scheme for least amount of stress and better spectral performance. For more than three level the clamping diode are subjected to increased voltage stress equal to $V_p n(n-1) / n$. therefore series connection of diode might be required .

Operation of Neutral Point Clamped.

The operation of neutral point clamped can clearly studied by considering one leg of multilevel inverter. The one leg of three level inverter is shown in figure 3.2

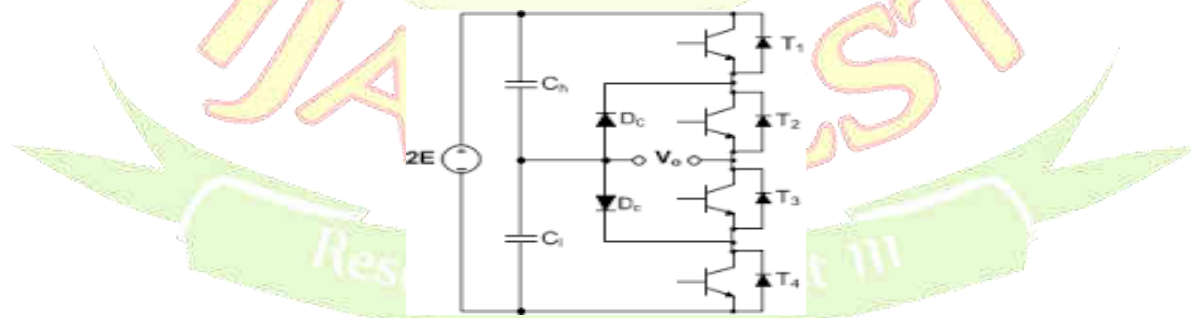


Figure 4: one leg of multilevel inverter.

The operation of multilevel inverter is analyzed through the single pole triple through switch is kept in order to measure $+V_{dc} / 2$ and $-V_{dc} / 2$ with respect to 0. The diode connected in the inverter is a clamping diode. The conduction will be in the both direction. Waveform can be improved by connecting to midpoint of the inverter.

T₁ & T₃ are complementary switch.

T₂ & T₄ are complementary switch.

Considering for R phase, When T_1 and T_2 are ON then T_3 and T_4 will be OFF then R will be connected to $0.5 V_{dc}$.

When T_1 and T_2 are OFF then T_3 and T_4 will be ON then R will be connected to $-0.5 V_{dc}$.

Connecting R to midpoint T_1 and T_4 are OFF then T_3 and T_2 will be ON then $V_{RO} = V_{dc}/2$.

When the upper switch are ON then $+0.5 V_{dc}$.

When the lower switch are ON then $-0.5 V_{dc}$.

T_1	T_2	T_3	T_4	V_{RO}
1	1	0	0	$0.5 V_{dc}$
0	1	1	0	0
0	0	1	1	$-0.5 V_{dc}$
1	0	0	1	Load is open

Table 1 Switching operation is given in the table.

Advantages of NPC

- Reduces harmonics in the system and improve power quality.
- Harmonic can be reduced by increasing to number of levels and filtering requirement is reduced.
- Output voltage and power increases with number of level.
- Allow voltage clamping, and reduces switching losses.

Disadvantages of NPC

- Burden on inverter increases when clamping point gets deviated
- Extra devices are required.

V. RESULTS AND INTERPRETATION

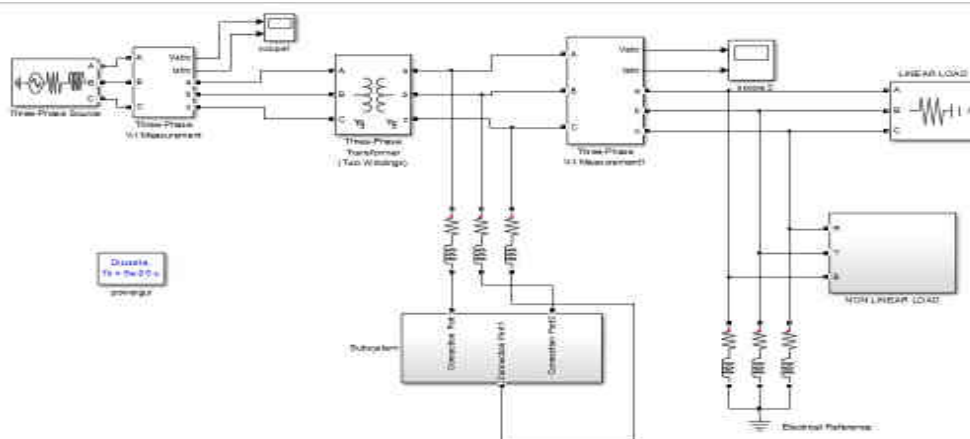


Figure 5. Simulink model of NPC with grid

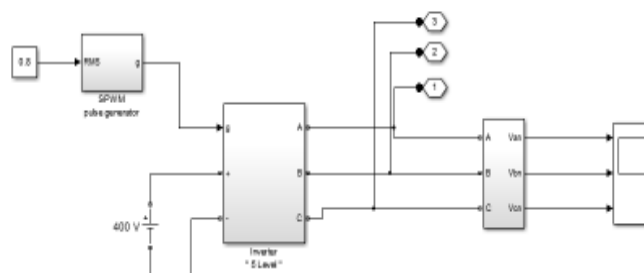


Figure 6. Subsystem of NPC

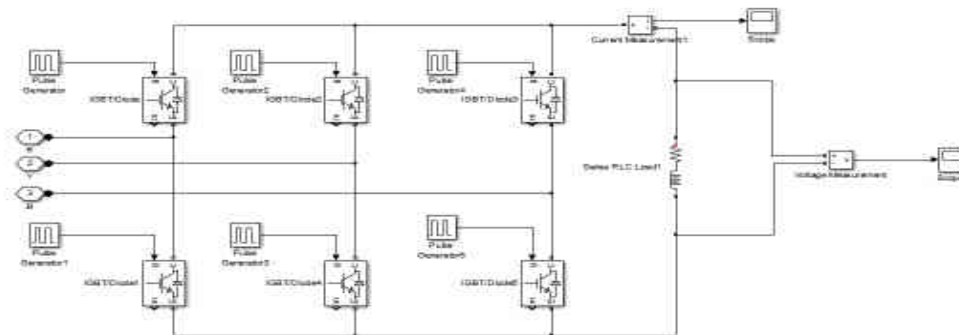


Figure 7. Subsystem of Non-Linear load

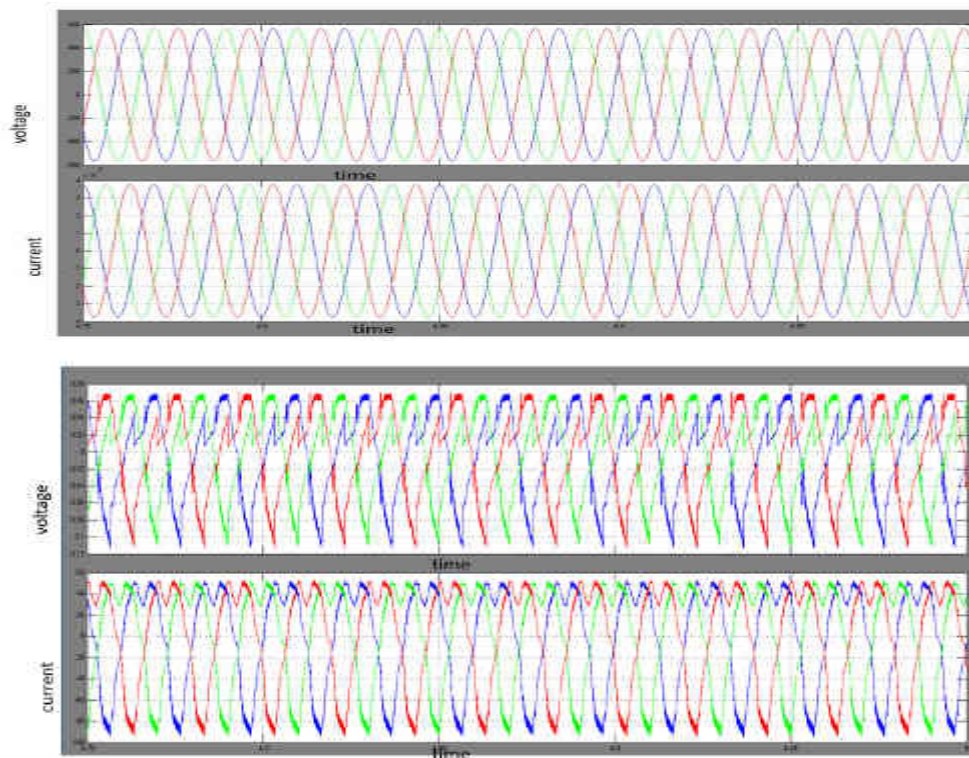


Figure 8. Voltage and current waveforms of NPC

VI. CONCLUSION

In this paper the use and advantages of applying of Multi-level inverter(NPC) to compensate the real and reactive power in the system and to mitigate the harmonics present in the source side due to load. By using multi-level topology %THD considerably reduced using multilevel inverters. Here I'm simulating performance of Neutral point clamped method to eliminate the harmonic content from source to load. The need of eliminating harmonic content to improve power quality. However NPC have some of disadvantages like excessive stress when a neutral point gets deviated.

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