Three-Level Topology for Shunt Active Power Filters

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Abstract. The development in the field of power electronics has led to its optimum and efficient use in domestic and industrial arena especially in control and automation processes. In turn this has created a threat in terms of power quality issues. To some extent solution to power quality issues is obtained again using power electronic devices in the form of active filtering. A shunt active power filter (SAPF) is used for harmonic filtering. The performance of such system is enhanced by using multilevel inverters. A novel three level inverter topology is proposed here. A three phase transformer fed from both ends at its primary terminals with two independent voltage source inverters is used to replace a filter inductance of a conventional system. The benefits of multilevel inverter are utilized in SAPF and also system power factor is kept near unity in all conditions.

Keywords: Active powers filter (APF), current controlled voltage source inverter, dual inverter.

1. Introduction

The rising uncertainties in AC system and increasing dynamics and non-linearity of loads have attracted more attention of engineers/researchers to evolve improved methods. This leads to evolution of universal control technique of compensation having substantially improved transient performance under unbalanced load conditions (Ali, 2011). Here we have used an indirect method of reference current generation as given in (Patidar and Singh, 2010). Section 2 describes the system used in the paper. The indirect control method is explained in section 3. System modeling is covered in section 4 while section 5 covers the results and discussions. A brief conclusion on the work is covered in section 6. (Baiju, M.R., Shivakumar et al., 2002; Somasekhar et al., 2004).

2. System Description

Two DC capacitors are connected at the two inputs of the VSI’s. An elevated stage of manufacturing proficiency must necessities the appropriate analysis of PQ troubles. Moreover, the complexity of PQ analysis is necessities that the professional awareness in several region of electric power, e.g., electric drives, sensors, revolving machines, transformers, and common power systems function etc.. (Manivasagam.R et al. 2020). The observation of utilities, utensils producer, and clients might be entirely dissimilar in endeavor to describe PQ. Utilities observe PQ from the system consistency point of observation. Furthermore, utensils producer deem PQ as being that stage allocate for suitable function of their utensils, but clients deem superior PQ that make sure the constant operation of progression, function, and trade. A PQ trouble could be distinct as some power difficulty evident in voltage, current, or frequency variation that consequence in breakdown or malfunction of client.
utensils.

![Basic shunt compensation principle](image_url)

**Figure 1.** Basic shunt compensation principle

On the other hand, the requirement of electric power contains persistent to produce quickly. Immediate power recompense procedures are employed to maintain the grid presentation at a superior eminence. Distribution system undergoes current with voltage associated PQ troubles, which comprise deprived power feature, imprecise basis current, voltage conflict. The significant PQ troubles are voltage dissimilarity, voltage sag, load derange, harmonic deformation, disruption, voltage swells, and voltage flicker, that can origin disruption in the dispensation plants and economic fatalities. These conflicts can origin troubles, such as overheating, motor breakdown, imprecise metering, and disoperation of defensive utensils. Voltage swell and sag can take place because of lightning, capacitor controlling, motor opening, close to circuit error, or misfortune, and can also direct to power disruption. There are frequent processes to moderate harmonics, swells, voltage sags, and disturb in the power allocation format. Nonetheless, there are abundant methods to diminish the consequence of harmonics unaccompanied in the format.

3. **Control Method**
This method is to employ active power filter that capitulate harmonic current of identical magnitude and contradictory division to that of the harmonic current perverted in the format such that it extract the harmonic current in the format. APF is exploited its remuneration of elevated speed reaction and suppleness in function as it encompass the power electronic devices. Furthermore the identical device is exploited to incorporate the power from the RES to the allocation format. Subsequently the necessity of supplementary utensils is escaped. Thus, the APF substance is the grid interfacing inverter for interfacing RES to the electrical grid devoid of further power stipulation utensils. These active power
filters are habitually exploited to diminish only the THD in load region and source region of some format but not accomplished of explanatory foremost PQ troubles like voltage sag, disturb and voltage swell etc. The convention of a practice power device is considered to be the significant powerful procedure.

4. **SV-PWM For Dual Inverter**

A new multilevel topology is being used to drive induction motor (Baiju et al., 2004). Based on similar lines a dual fed three phase transformer is used here in place of an induction motor (Manivasagam et al 2014,2019). Out of six free terminals of primary winding of this transformer, three ends are fed from VSI-I and other three free ends are fed from VSI-II as shown in figure 4. The state phasor locations from individual inverters are shown in figure 5 (Ragavi et al 2015).

![Figure 4](image-url)  
Figure 4. Open end fed primary winding of transformer
Figure 5. Voltage vector locations for inverter –I and II

![Voltage vector locations for inverter –I and II](image)

Figure 6. Voltage vector positions in three-level inverter.

The control strategy of these two inverters is selected such that three level output voltage is generated across each phase of the transformer primary. The space phasor combinations ($23 \times 23 = 64$) as each inverter is assumed with 8 states independently of each other) from the 2 inverters is shown in figure 6. The resultant space vector combination locations shown in figure 6 are obtained.
In order to have equal switching losses in the two inverters the role of each inverter (clamping or switching) is altered every 600 (D,Aarthi et al 2017).

**Figure. 7.** Switching vector components along d and q axis
5. Results And Discussions

Figure 8. Principle of NSH switching scheme

Figure 9. Dual inverter SVPWM functional diagram
Table 1. Simulation Parameters

| Location   | Parameter          | Value                                                                 |
|------------|--------------------|----------------------------------------------------------------------|
| Supply     | Supply voltage     | (i) 400 V, 3 phase, 50 Hz                                            |
|            |                    | (ii) 400V+5th and 7th harmonic components                            |
| Active     | Filter             | 1. open end 3-phase transformer                                      |
| Power      |                    | 2. DC-bus capacitance 10kVA, 800V/800V, 0.002 pu resistance and 0.045 pu reactance 1000 μF |

Case (a): sinusoidal supply and non-linear load. (Figure 10 (a) to (d)) Here supply voltage is assumed to be balanced sinusoidal voltage. Initially the system runs without SAPF. The source current is equal to the load current. At t=0.1 sec, SAPF is added to the circuit. Now the source current becomes sinusoidal as shown in fig 10(b) and the source current lies in phase with the source voltage as shown in fig 10(c). Fig 10(d) shows the dual inverter phase voltage.

Case (b): sinusoidal voltage and change in load. (Figure 11(a) to (d)) Here too supply voltage is assumed to be balanced sinusoidal voltage. Initially the system runs without SAPF. The source current is equal to the load current. At t=0.1 sec, SAPF is added to the circuit. Now the source current becomes sinusoidal as shown in fig 11(b) and the source current lies in phase with the source voltage as shown in fig 11(c). At t=0.4 sec additional load is connected and the effect is seen in fig 11(b) and (c). Still the system maintains unity pf. Fig 11(d) shows the dual inverter phase voltage.

Figure 10(a). Source phase voltage
Figure 10(b). Source, filter and load current

Figure 10(c). Power factor

Figure 10(d). Dual inverter phase voltage
Figure 11(a). Source phase voltage

Figure 11(b). Source, filter and load current

Figure 11(c). Power factor
Figure. 11.(d). Dual inverter phase voltage

Case (c): non-sinusoidal supply and non-linear load. (Figure 12(a) to (d)). Here supply voltage is distorted with 5th and 7th harmonics of voltages added to the fundamental. Initially the system runs without SAPF. The source current is equal to the load current. At $t=0.1$ sec, SAPF is added to the circuit. Now the source current becomes sinusoidal as shown in fig 12(b) and the source current lies in phase with the source voltage as shown in fig 12(c). Fig 12(d) shows the dual inverter phase voltage.

Figure. 12.(a). Source phase voltage
**Figure 12.(b).** Source, filter and load current

**Figure 12.(c).** Power factor

**Figure 12.(d).** Dual inverter phase voltage

Figures 13(a) and (b) shows the load current and source current THD respectively under balanced supply conditions.

**Figure 13.(a).** Load current THD under balanced supply voltage
6. Conclusion

The system power factor is kept near unity in all conditions. The system performance is also verified for different load conditions to check the dynamic behavior of the system. The implementation through digital controller is simple as SVPWM technique is used to drive the dual inverter.

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**Figure. 13.(b).** Source current THD under balanced supply voltage
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