A Distribution Power System with PI and PR Controller to Suppress Harmonic Resonance

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Abstract-Here a distribution power system with pi &pr controller to suppress harmonic resonance is presented. Here, in the distribution power system a parallel connected filter operates as a harmonic conductance, which can reduce the resonance produced harmonically. Normally filter behaves as admittance instead of conductance because of phase lagging concept in Digital Signal Processing (DSP). As a result an unwanted harmonics may get amplified at some different location while starting the filter. Here, PI and PR controllers are used for the suppression of harmonic resonance. To control the currents of a converters which are connected in a grid way the PI controllers are used. The PR controllers compensate the needed harmonics. At harmonic frequencies to assure that the filter used here functions as conductance, the band pass filters are connected in parallel and tuned to the specific value. By the obtained result it is clear that the presented work provides good damping than other control methods.

Keywords: *Harmonic resonance Active filter, PR controller, resonant current control.*

1. Introduction

Distortions which are caused harmonically are because of variable filters and inductance. To suppress this above problem hybrid active filter is used. In the Distribution power system various concerns are been received regarding distortion in voltage [1]-[6]. Filters are adapted to the issues on the harmonics. Hence, constant calibration is needed to check performance of filtering. To reduce a harmonic resonance a filters connected parallel are controlled as conductance. Thus the admittance worsens the performance of damping of filter [7]. Performance of damping of filters are studied when so many current controls are used and when different loads are utilized. Normally filter behaves as admittance instead of conductance because of phase lagging concept in Digital Signal Processing (DSP). As a result an unwanted harmonics may get amplified at some different location while starting the filter. Here, PI and PR controllers are used for the suppression of harmonic resonance [8]. The PR controller tracks the current introducing an infinite gain at a certain frequency (resonant frequency). To control the currents of a converters which are connected in a grid way the PI controllers are used. The PR controllers compensate the needed harmonics. At harmonic frequencies to assure that the filter used here functions as conductance, the band pass filters are connected in parallel and tuned to the specific value.

2. Operation Principle

Our proposed frame work is shown in figure 1. To diminish the harmonic resonance an Active Filter Unit (AFU) will be integrated close to the radial line end. For different harmonic frequencies the AFU operates as conductance which is given as

$$i_{abc,h}^{*} = \sum_h G_h^{*} . E_{abc,h} \qquad (1)$$

Where, h means order of frequency.

G_h^* is control gain to Voltage $E_{abc,h}$.

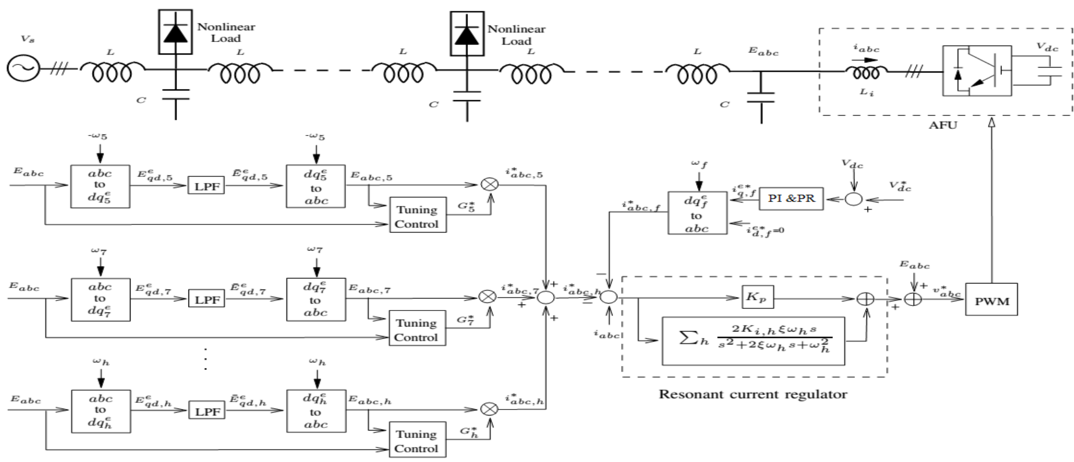


Fig. 1 Filters and its associated controls

A. AFU control

Synchronous Reference Frame (SRF) transformation determines the voltage harmonics of different frequencies.

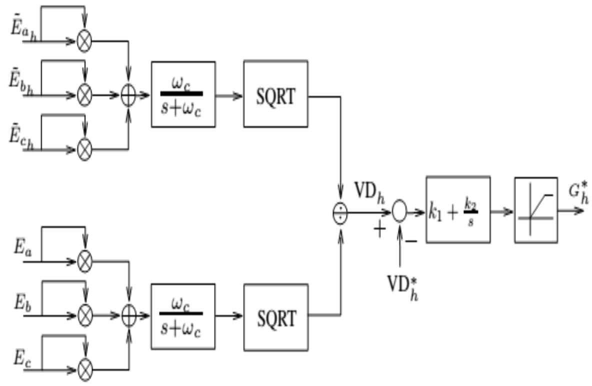


Fig. 2 Variable control of G^*_h

As illustrated, G_h^* is determined on behalf of harmonic voltage distortion VD_h at AFU installation point E_{abc}, in which VD_h is the ratio of harmonic voltage component Eh (rms value) to the voltage E (rms value) by

$$VD_h = \frac{E_{h,RMS}}{E_{RMS}}.100\% \qquad (2)$$

$$E_{h,RMS} = \sqrt{\frac{\int_t^{t+T}(E_{a,h}(t)^2+E_{b,h}(t)^2+E_{a,h}(t)^2)}{T}}dt \qquad (3)$$

$$E_{RMS} = \sqrt{\frac{\int_t^{t+T}(E_{a,h}(t)^2+E_{b,h}(t)^2+E_{a,h}(t)^2)}{T}}dt \qquad (4)$$

B. Modeling of control

Nomenclature used in this section is given as:

$V_{sh}(s)$: voltage harmonic at input point

$E_h(s)$: voltage harmonic of filter at installation location

$I_h(s)$: current harmonic of filter

$I_h^*(s)$: command for current harmonic of active filter.

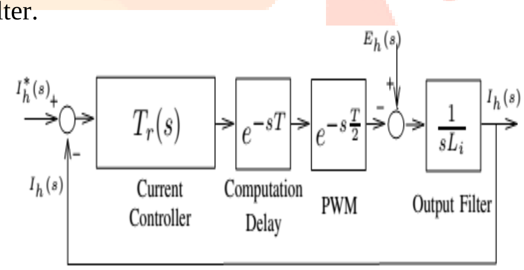


Fig. 3 Block diagram of Current control

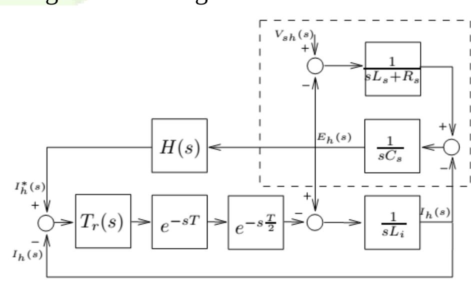


Fig. 4 Block diagram of Voltage control

3. Harmonic Resonance

Here, to calculate the harmonic resonance a distributed parameter model is used. With the admittance Y_h a filter is equipped.

$$Y_h = |Y_h| < \theta_h \qquad (5)$$

The magnification factor is given as

$$M_h(x) = \frac{|v_h(x)|}{|v_{s,h}|} \qquad (6)$$

A. Harmonic conductance

The figure shown below gives the details about magnification factor's of 5^{th} & 7^{th} harmonics for pure conductance i.e., $\theta=0^0$.

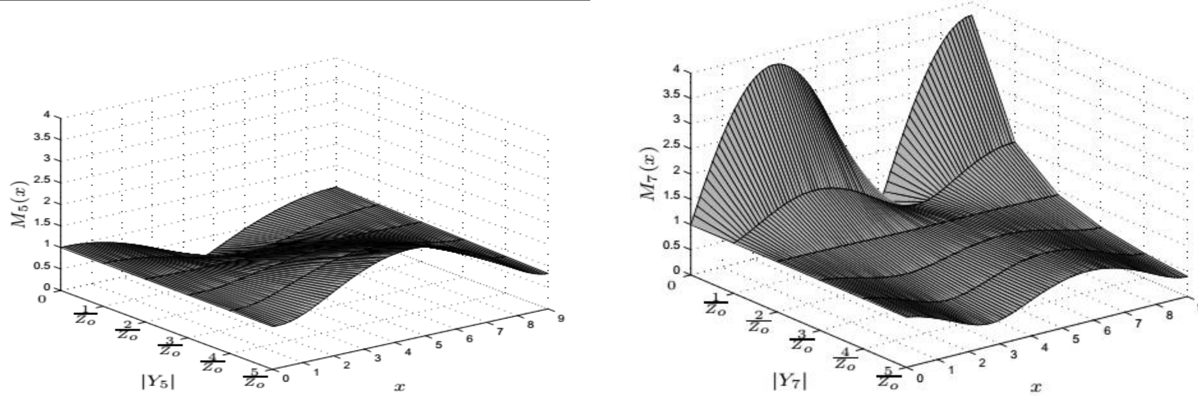


Fig. 5 Magnification factors of 5th &7th harmonics modeled for pure conductance

B. Harmonic admittance

The figure shown below gives the details about magnification factor's of 5th & 7th harmonics modeled at admittance -45⁰

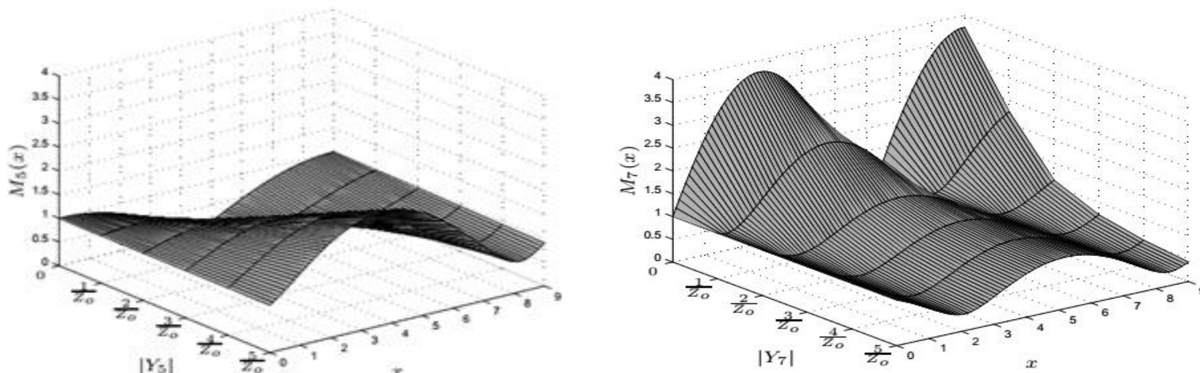


Fig. 6 Magnification factors of 5th &7th harmonics modeled for θ= -45⁰

The figure shown below gives the details about magnification factor's of 5th & 7th harmonics modeled at admittance -90⁰

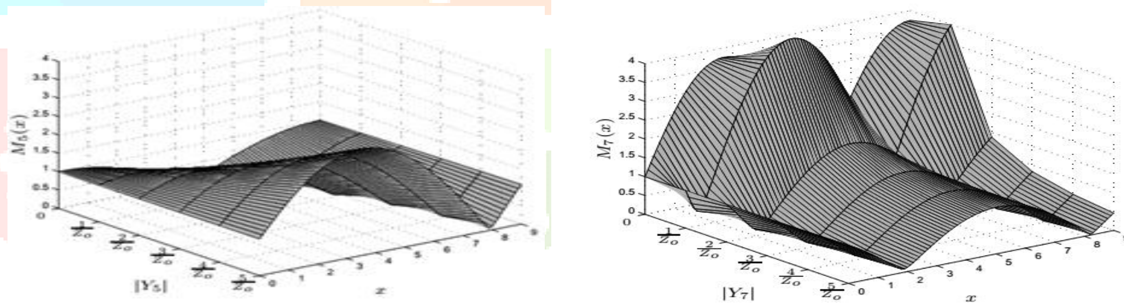


Fig. 7: Magnification factors of 5th &7th harmonics modeled for θ= -90⁰

TABLE I PARAMETERS OF AGIVENPOWERLINE

Line voltage	11.4 kV
Line frequency	60 Hz
Feeder length	9 km
Line inductor	1.55 mH/km(4.5 %)
Line resistor	0.36 Ω/km(1.2 %)
Line capacitor	22.7 μF/km(11.1 %)
Characteristic impedance, Z_o	8.45 Ω
Wavelength of 5^{th} harmonics, λ_5	17.8 km
Wavelength of 7^{th} harmonics, λ_7	12.7 km
	3ϕ 11.4 kV 10 MVA base

4. PR Control

According to the Fig. 8 beneath demonstrates the current system which is PR controlled. Ii is inverter yield value which is utilized as input, I_i^* is current reference & U_i^* is voltage reference.

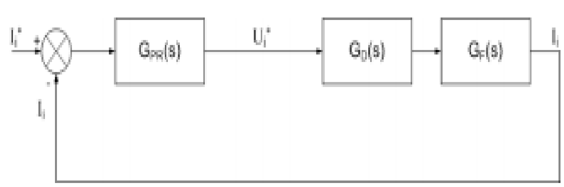


Fig. 8 PR Current Control

In PR current controller $G_{PR}(s)$ which is denoted as:

$$G_{PR}(s) = K_p + K_i \frac{s}{s^2+\omega_0{}^2}$$

Where, K_p is proportionality gain term, K_I is integral gain term & ω_0 is full recurrence. The perfect thunderous term alone in the PR controller gives an endless pick up at the air conditioner recurrence ω0 and no stage move and pick up at alternate frequencies. The K_P expression decides the elements of the framework; transmission capacity, stage and pick up edges [5]. Condition (6) speaks to a perfect PR controller which can give solidness issues on account of the unending addition. To maintain a strategic distance from these issues, the PR controller can be made non-perfect by presenting damping as appeared in (7) underneath.

$$G_{PR}(s) = K_p + K_i \frac{2\omega_c s}{s^2+2\omega_c s+\omega_0{}^2}$$

The gain of controller is presently limited however it is still sufficiently huge to give just a little consistent state mistake. This condition likewise makes the controller all the more effectively feasible in computerized frameworks because of their limited exactness.

5. Results

The Alternative Transient Program is performed to check the performance of harmonic damping.

- Power: 3phase, 220 Volts, 20 kilovolts ampere, 60 Hertz.
- Parameters of line: C= 13.7 percentage, L=3.1 percentage
- Loads: Linear loads are off at starting point and rated with 0.1 to 0.09 power units, where as non linear loads are developed using 3 phase bridge rectifiers and are rated with 0.25 power units.
- To implement an AFU an inverter of 3phase v/g source along with pulse wave modulator of freq. 10kiloHertz is used.

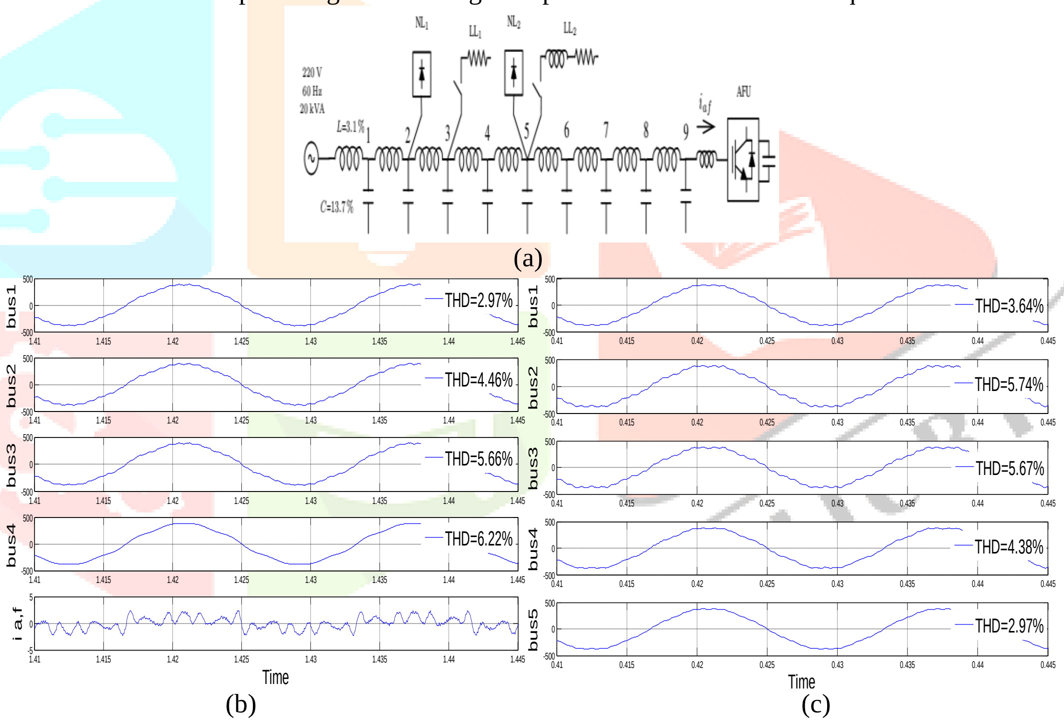


Fig. 9 Circuit design and its steady state results (a) Circuit design (b) AFU is off (c) AFU is on

A. *Results of steady state*

The above figure shows the distortion which can seen clearly at Bus1 & Bus2. It can be explained clearly in the figure given below.

TABLE II BASEVALUES

Voltage base	220 V
Current base	52.5 A
Impedance base	2.42 Ω
Conductance base	0.413 Ω^{-1}

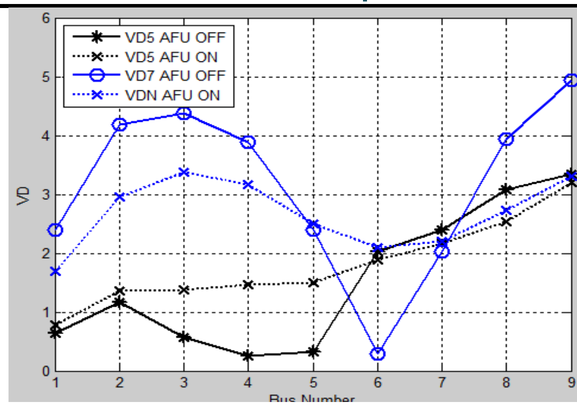
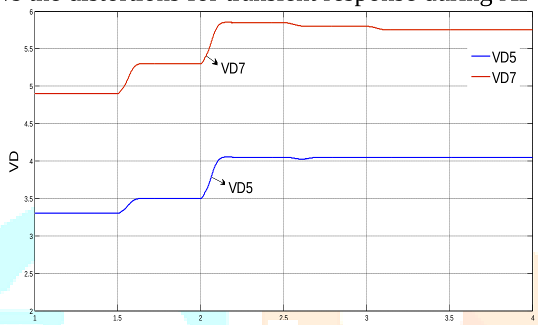


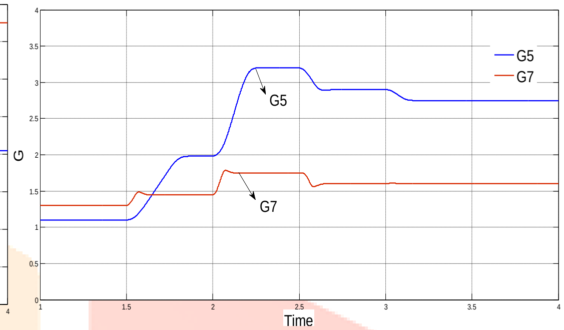
Fig. 10 VD_5 & VD_7 of different busses at AFU

Transient behavior

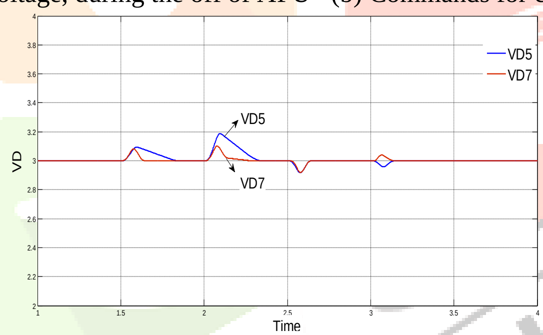
The figure below shows the distortions for transient response during AFU operation



(a) Distortions of voltage, during the off of AFU



(b) Commands for conductance of filter

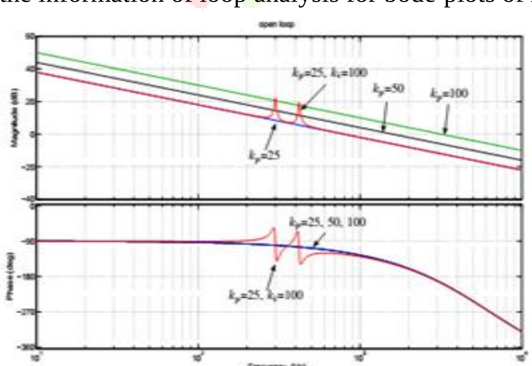


(c) Distortions of voltage when AFU is on

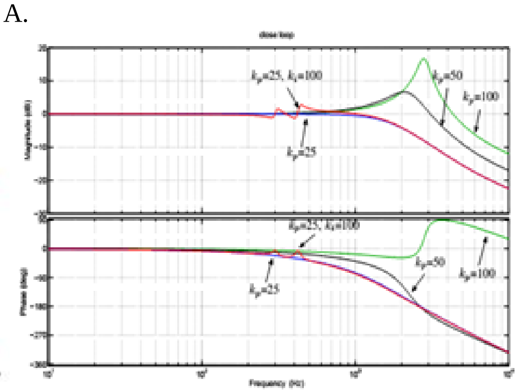
Fig. 11 Transient behavior of AFU

B. loop analysis of Current

The figure below gives the information of loop analysis for bode plots of A.



(a)



(b)

Fig. 12 Current loop analyses for different Bode plots (a) Open-loop gain (b) Closed-loop gain.

The figure below shows the voltage levels for different current controls.

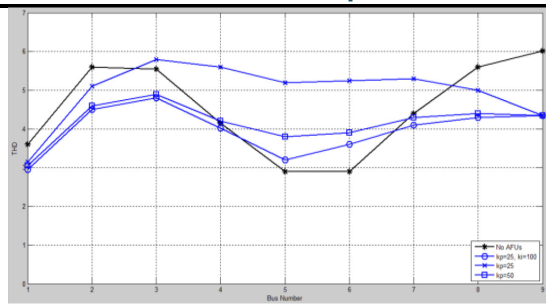


Fig. 13 Voltage level comparison

TABLE III Results for G_5 & G_7

	G_5	G_7	RMS current
k_p=50	1.89 pu	1.04 pu	7.8 %
k_p=25	3.39 pu	0.90 pu	12 %
k_p=25,k_i=100	1.14 pu	1.28 pu	6 %

C. Damping analysis of Voltage

The following figure shows the 7th harmonic voltage is decreased by conductance as AFU is on

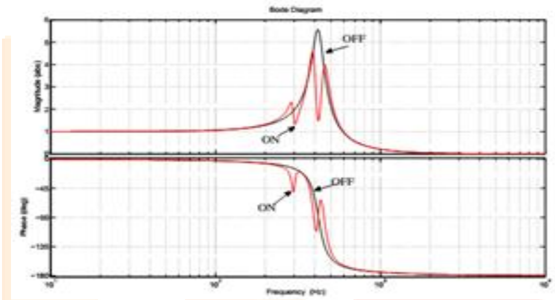
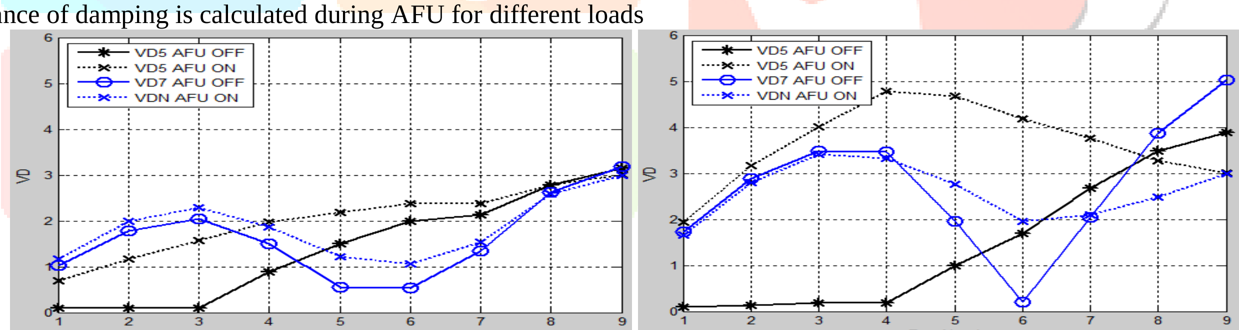


Fig. 14 Characteristics of amplification

D. Loads at different points

Here, performance of damping is calculated during AFU for different loads



(a) (b)

Fig. 15 Damping Performance of loads at different bus (a) Loads at Bus4 &Bus6 (b) Loads at Bus3 & Bus9

TABLE IV Commands for conductance of AFU

	G_5^*	G_7^*
NLs at Bus 2,5	1.14 pu	1.28 pu
NLs at Bus 3,7	1.19 pu	0.32 pu
NLs at Bus 4,6	3.15 pu	1.23 pu

6. Conclusion

According to harmonic distortion technique the filter is operated as harmonic conductance. As a result the distortions are lowered to the accepted value by the proper variations in distribution power system. Here, the resonant current control is utilized along with filter to mitigate the harmonics in resonance. An infinite gain has been introduced by the PR control at the central frequency and therefore can accomplish zero steady-state error. The PR controller tracks the current introducing an infinite gain at a certain frequency (resonant frequency). To control the currents of a converters which are connected in a grid way the PI controllers are used. The PR controllers compensate the needed harmonics. At harmonic frequencies to assure that the filter used here functions as conductance, the band pass filters are connected in parallel and tuned to the specific value. By the obtained result it is clear that the presented work provides good damping than other control methods.

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