Simulation of Shunt Active Filter using Multilevel Inverter

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Abstract---Active Shunt filter is use to eliminate harmonics of the system produced by nonlinear load. Active shunt filter consist mainly two blocks: PWM Converter and Active Filter Controller. In this paper cascaded H bridge type multilevel inverter is use to implement PWM converter. There are three methods to implement Active filter controller. Constant power Control Strategy, Sinusoidal Current Control Strategy and Fryze Current Control Strategy. In this paper Generalized Fryze Current Control Strategy is used for active filter controller.

I. INTRODUCTION

Active filters have being developed since 1983, when one of the first prototypes based on instantaneous power theory was reported. The major oppositions in accepting the active filter controllers based on the pq theory are firmed on the following arguments.

– Controller based on pq theory need low pass filters to separate the instantaneous real and imaginary power into average and oscillating parts, which introduces time delay that degenerate the active filter performance. This is not only pq theory problem but synchronous reference based controller also need low pass filter.
– Controller based on the pq demands more calculations, since it needs clark transformation but without use of clark transformation it is impossible to compensate the positive sequence component, include real and imaginary power.
– Under distorted or unbalance system voltage shunt active filter does not compensate properly the load current.

So, under non sinusoidal or unbalanced system voltage, it is not possible to implement a shunt active filter. The proposed controller forces shunt active filter to compensate load current and from the network sinusoidal balanced even under distorted or balanced condition.

II. PRINCIPLE OF SHUNT ACTIVE FILTER

Figure shows the basic principle of Shunt Active Filter. A nonlinear load is connected to the AC supply system.

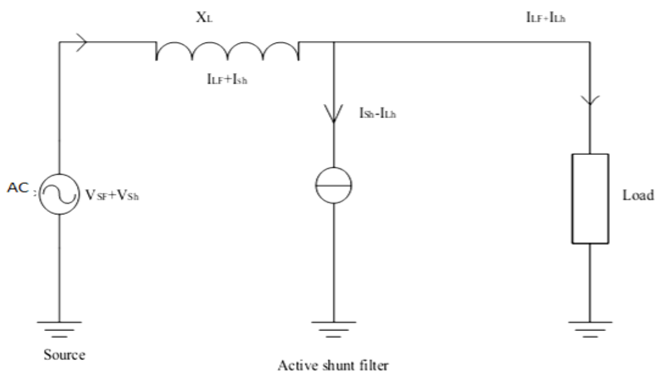

Fig.1: Principle of Shunt Active Filter

It draws the Fundamental load current I_{LF} and Harmonic current I_{Lh} from the supply system. Harmonic current I_{sh} is generated by the source and harmonic current I_{Lh} generated by the load. Shunt Active filter is connected in shunt of the line and it compensates the both harmonic current I_{sh} and I_{Lh}. If the load Harmonic current passes to the power system it generate additional harmonic voltage drop which is $V_T = X_L * I_{Lh}$. This is the shunt compensation principle.

The Shunt active filter generally consists of two main blocks.

1. The PWM Converter
2. The active filter controller

The PWM converter is responsible for power processing and the Active filter controller is responsible for signal processing. The PWM converter operates at high switching frequency. The DC link capacitor and IGBT with anti parallel diode form the voltage source inverter. The firing pulses of VSI are generated from PWM control. The Active shunt filter continuously sense the load current I_L, and calculate the instantaneous current I_c. So it acts as a close loop.

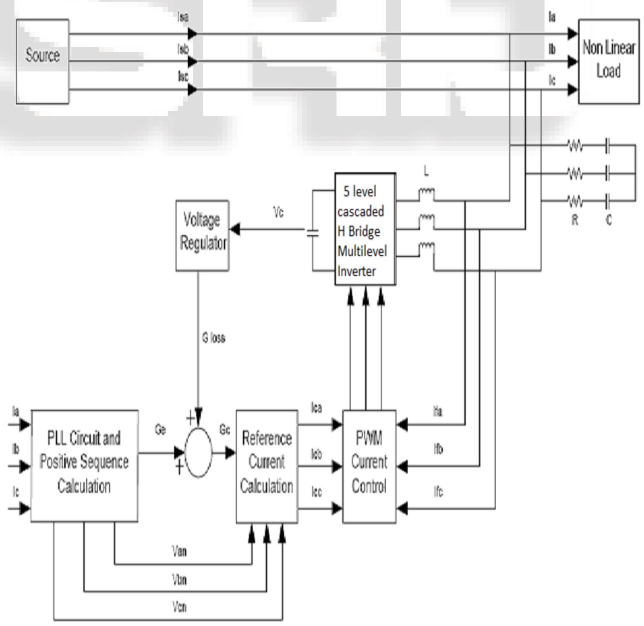

Fig. 2: Block diagram of shunt active filter

In the block diagram L is the commutation inductance and RC are the passive filter. At normal condition it is not connected but if the Harmonics of the Multilevel Inverter becomes higher than the nonlinear load at that time it is use to reduce the harmonics.

III. SYSTEM CONFIGURATION

Figure shows the Shunt Active Filter. For simplicity three phase three wire system is considered so there is no zero sequence component. The shunt active filter generates the compensating currents i_{ca}, i_{cb}, i_{cc} to compensate the load current i_a, i_b, i_c in order to guarantee sinusoidal, balanced, compensated currents i_{sa}, i_{sb} and i_{sc} drawn from the network. This goal is achieved even under non-sinusoidal system voltages.

Note that the active filter controller does not need any information about the system voltage and they are not measured. The control algorithm needs the information about load current.

IV. ACTIVE FILTER CONTROLLER

There are three methods for implementing shunt Active filter current control. Constant Instantaneous Power control strategy, Sinusoidal current control strategy, generalized fryze current control strategy.

Out of all three methods in fryze current control strategy the calculation becomes less as Clark transformation reduces. As it does not use any reference frame transformation, the number of equations and the number of measurements is reduced.

V. DC VOLTAGE REGULATOR

The upper portion of the fryze current calculation is DC Voltage regulator. The DC Voltage regulator generates Gloss. In this the inverter voltage Vdc is compare with some reference value Vref and then pass it to the low pass filter and PI controller. PI controller consist G(s) = Kp + Ki/s.

VI. PHASE LOCKED LOOP (PLL) CIRCUIT

The function of PLL circuit is to track the fundamental frequency continuously at distorted or unbalance condition. For that the load current ia, ib and ic are sense from the load side. Now, $i_{ab} = i_a - i_b$ and $i_{cb} = i_c - i_b$

From the algorithm three phase power,

$P_{3ph} = v_a{*}i_a + v_b{*}i_b + v_c{*}i_c$

$P_{3ph} = v_a{*}i_a - v_a{*}i_b - v_c{*}i_b + v_c{*}i_c$

$P_{3ph} = v_a{*}i_{ab} + v_c{*}i_{cb}$

Note: $v_a + v_b + v_c = 0$

P_{3ph} is passing through PI controller and get ω and for getting ωt integrate ω by 1/S. $v_{a(\omega t)} = \sin(\omega t)$, $v_{c(\omega t)} = \sin(\omega t + 2\pi/3)$

At ω equals to system frequency, a stable point of operation is found. The feedback signal $v_{a(\omega t)}$ becomes orthogonal to the fundamental positive sequence component of measured current Ia. The displacement angle between i_a and $v_{a(\omega t)}$ is cosØ. If the $v_{a(\omega t)}$ leads 90 degree the fundamental positive sequence component of source current then, $v_{an(\omega t)} = \sin(\omega t - \pi/2)$ must be in phase with I+1. Signals v_{an}, v_{bn} and v_{cn} are sinusoidal time function with fundamental positive sequence component of source current.

VII. CALCULATION OF COMPENSATING CURRENT

The Active filter fryze current control strategy has objective to compensate load current. This objective can be easily realized if the fundamental positive sequence component of load current is accurately calculated. Instantaneous value of fundamental positive sequence component of load current can be determine by multiplying voltages Van, Vbn and Vcn generated from PLL signal with $\underline{G_e}$.

$I_{pa} = \underline{G_c} \cdot Van$

$I_{pb} = \underline{G_c} \cdot Vbn$

$I_{pc} = \underline{G_c} \cdot Vcn$

Dynamic G_e is added to Gloss to form total positive sequence amplitude and compensating conductance.

$G_c = G_e + G_{loss}$

$G_e = (2/3)\,(Van\, I_a + Vbn\, I_b + Vcn\, I_c)$

Compensating current is the difference between positive sequence current and load current.

$I_{ca} = I_{pa} - I_a$; $I_{cb} = I_{pb} - I_b$; $I_{cc} = I_{pc} - I_c$

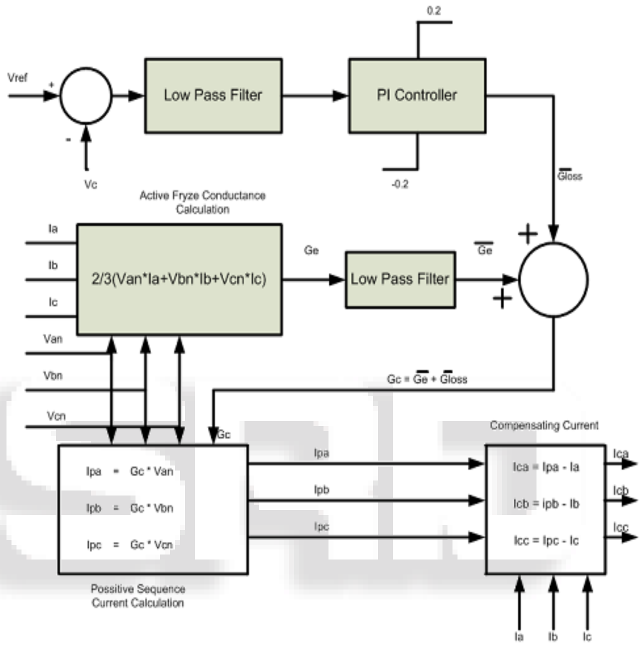

Fig. 3: Generalize Fryze current control strategy

VIII. MULTILEVEL INVERTER

Multilevel inverter are classify into three categories. Cascaded H Bridge Multilevel Inverter, Neutral point Clamped Multilevel Inverter, Flying Capacitor type Multilevel Inverter.

Out of this three in this paper 5 level cascaded H bridge Multilevel Inverter is use. The advantage of cascaded H Bridge Inverter is that, It does not require any Clamping Diode, Flying Capacitors, controlling is simple, it uses less component compare and Voltage across each switches are same so switching loss are reduces and switching stress are also reduce.

IX. NONLINEAR LOAD

An electrical load that draws currents discontinuously or whose impedance varies during each cycle of the input AC voltage wave-form is called Nonlinear Load. The Majority Nonlinear load produces Harmonics that is ODD multiple of fundamental frequency. Some examples of nonlinear loads are adjustable speed drives, fluorescent lighting, rectifier banks, computer and data-processing loads, arc furnaces, etc. From all these load the Three phase rectifier is use here as a nonlinear load for production of Harmonics in the system.

X. RESULTS

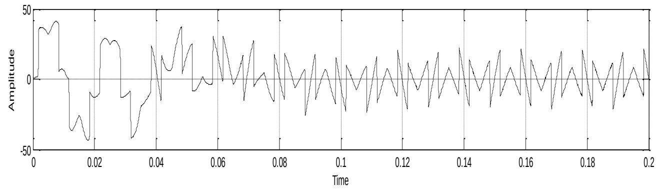

Fig. 4(a): Compensating Current Waveform

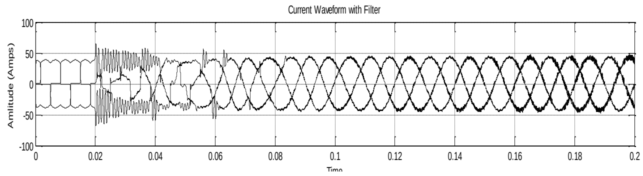

Fig 4 (b): Current Waveform With filter

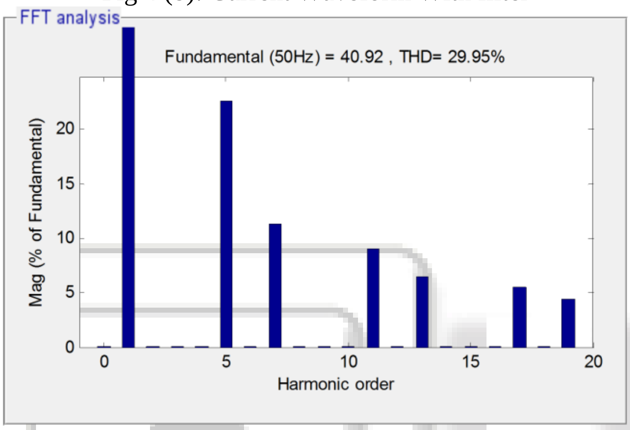

Fig. 5: FFT Analysis of Load Current Without Filter

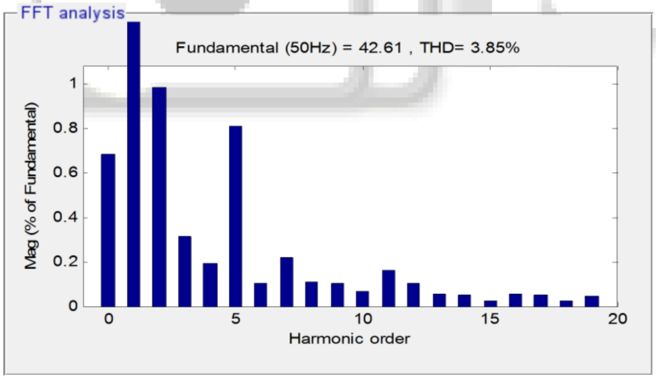

Fig 6: FFT Analysis of load current with Filter

XI. CONCLUSIONS

- From this thesis we conclude the behavior of Total Harmonic distortion without Active filter and with active filter. So with the use of active shunt filter we can reduce the harmonics from the system.
- The Fryze Currents Control strategy is used out of three current control strategies which minimize method equations, together with the synchronizing circuit (PLL circuit). The number of equations is reduced, since it does not use any reference frame transformation and the number of measurements is also reduced, ultimately we can compensate harmonics with less computational effort.
- Performance of Shunt active filter for different types of nonlinear loads is shown in table.

Nonlinear Load		**% THD With Filter**	**% THD Without Filter**
Diode based Rectifier		3.85	29.95
Thyristor Based Rectifier	Firing angle		
	0	3.75	30.40
	15	4.10	30.30
	30	4.46	30.47
	45	5.40	31.49
	60	5.81	34.58
UPS (Uninterrupted Power Supply)		2.48	12.96

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