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Ac to Dc Conversion Using Active PFC

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ABSTRACT: *In the modern power distribution system, majority of loads draw reactive power and/or harmonic currents from ac source along with main active power currents. These non-unity powerfactor linear and non-linear loads cause low efficiency of supply system, poor power-factor, destruction of other equipments due to excessive stresses and EMI problems. Active filters have been considered an effective solution to reduce these problems. This paper presents an Active Power Filter (APF) based on simple control technique to provide reactive power and harmonics compensation or non-linear single-phase loads. A voltage source inverter with carrierless hysteresis PWM current control is used to form an APF. A simple P-I (proportional-integral) dc bus voltage controller with reduced energy storage capacitor is employed in the APF.A diode rectifier fed capacitive load and ac voltage regulator fed inductive load as the non-linear loads are taken on ac mains to demonstrate the effectivenessof the proposed APF for reactive power and harmonic compensation. The operation, and simulation results of the proposed scheme are presented.*

Keywords: *Active, power-factor correction,ac/dc converters, sinusoidal line current.*

I. INTRODUCTION

With the development in advanced power semiconductor devices, more and more switch-mode power supplies (SMPS's) and other power switching circuits are used in modern power system. Due to the nonlinear behavior of power switched circuits, distorted currents are normally drawn from the line, resulting in lowpower factor (usually less than 0.67) [1]and high total harmonic distortion (THD). The equation relating the pf and THD is:

$$\mathrm{PF} = \frac{1}{\sqrt{1+\mathrm{THD}^2}} \times \cos\phi.$$

Traditionally, to improve power factor of a given power electronic system, normally a power factor correction (PFC) circuit is designed and placed in front end of the system, which in turn interfaced with the load. This PFC circuit may be an independent unit followed by a dc–dc converter, or an inseparable part of circuit incorporated into the power supply of the load, namely two-stage PFC to perform the input current shaping[2-3] and single-stage PFC power supply, respectively. Because the line voltage is normally not distorted (near sinusoidal), the basic idea of PFC is design circuits with certain means to force the line current to follow the waveform of the line voltage.

Because of the nature of PFC, there exists an unbalance of instantaneous power between the input power, which is an alternative quantity with two times the line frequency, and its dc output power. Therefore, power factor correction involves processing the input power in certain way that it stores the excessive input energy when the input power is larger than the dc output power, and releases the stored energy when the input power is less than the dc output power. To accomplish the above task, at least one energy storage element must be included in the PFC circuit.

In most PFC circuits[4-7], normally an input inductor is used in series with line bridge rectifier in order to smooth the line current.The input inductor can operate in either continuous conduction mode (CCM) or discontinuous conduction mode (DCM).In DCM, the input inductor is no longer a state variable since its state in a given switching cycle is independent on the value in the previous switching cycle . The input inductor operating in DCM cannot hold the excessive input energy because it must release all its stored energy before the end of each switching cycle.

In addition, if discontinuous conduction mode is applied, the input current is normally a train of triangle pulses with nearly constant duty ratio. In this case, an input filter is necessary for smoothing the pulsating input current.The DCM input circuit can be one of the basic dc–dc converter topologies.

In recent years, many switching circuits like the flyback and the boost using DCM input technique were reported. Several single-stage single-switch (S^4) PFC circuits[8-10] have been reported . These circuits are especially attractive in low power applications with increased efficiency and reduced cost.

II. SOLUTIONS FOR PFC

The solutions for PFC can be divided into two groups, according to the input current shape: sinusoidal or nonsinusoidal.

A. Sinusoidal Line Current

For comparison, we have selected as a reference the afore mentioned cascade association of converters . All of them as shown in Fig 1, except passive filters, involve the use of two converters (PFP plus dc-dc) with their respective control loops.

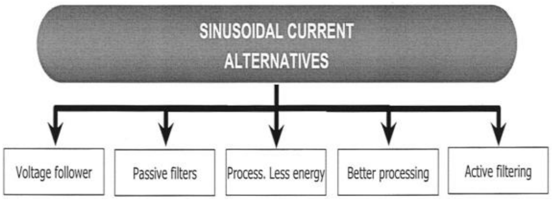

fig.1. Alternatives to the two stage approach.

B. Nonsinusoidal Line Current

Since Regulations allow harmonic currents, designers may take advantage of that, simplifying the circuitry and using new topologies as shown in Fig 2 , mainly in low power applications.

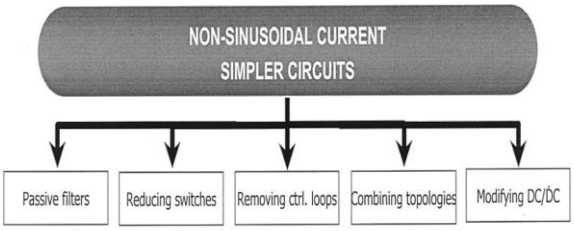

fig.2. Alternatives to the two stage approach for non sinusoidal line current.

III. PROPOSED CONVERTER CIRCUIT AND ITS OPERATION

Different circuits as shown in FIG 3 are proposed for power factor correction in AC to DC convertion process.

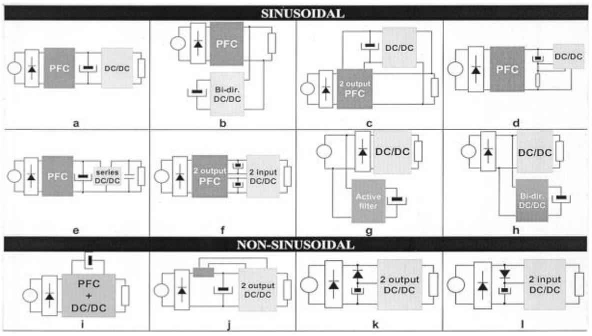

fig.3 Proposed circuits for PFC.

A new technique of active PFC as shown in Fig 4. is proposed.

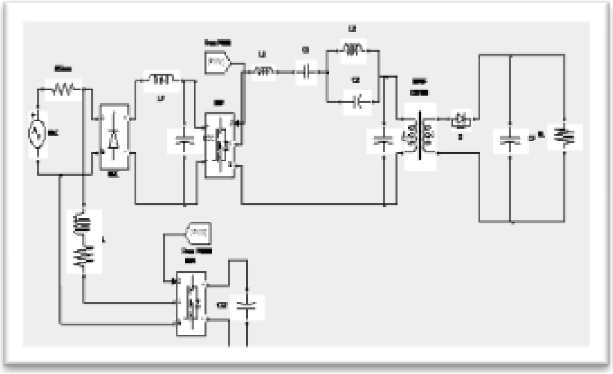

fig.4 Proposed Active PFC circuit.

3.1 PRINCIPLE OF OPERATION

The sinusoidal mains voltage is rectified through the front end bridge diode rectifier. A voltage from the auxiliary winding which is rectified using half bridge diode rectifier is added to the rectified voltage. This forces the input current to follow a sinusoida1 shape and flow in discontinuous manner.

The full bridge PI controlled PWM converter topology provides a good choice to control the converter. Four MOSFET switches (QI - Q4) and a high fiequency power transformer are used to form the full bridge. The capacitor Cb is used to block any net dc voltage Eom appearing across the transformer primary and saturating it. The gate conducting,positive voltage is applied to the primary and when Q2, Q4 are conducting, negative voltage is applied to it. During other periods the primary voltage is zero and energy stored in the output filter capacitor freee-wheels through the secondary.

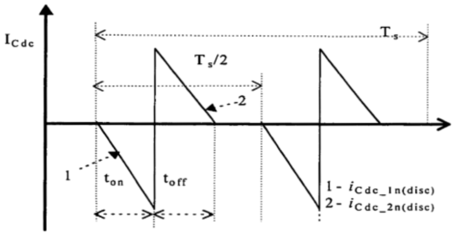

fig.5 Current through filter capacitor on secondary.

3.2 ACTIVE FILTERING

The use of active filters with the parallel configuration is very common in high power installations (from tens of kW).The two quadrant active filter is in charge to obtain a sinusoidal line current even when the load is nonlinear.

The shunt connected single phase active power filter is based on the principle of injection of harmonic currents into the ac system of the same amplitude but opposite in phase to that of the load harmonic currents.

The detailed block diagram in Fig. 5 displays the proposed circuit.

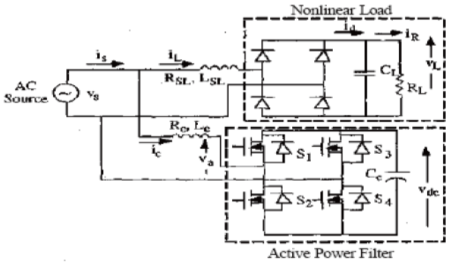

fig.6 Basic Circuit of Single Phase APF

Fig. 5 shows the basic circuit of APF Including inverter having an energy storage capacitor on dc side. Pulse width modulation (PWM) is employed to generate gating Pulses to the switches of APF. The dc based load fed from diode bridge rectifier with a capacitor is a non-linear load on the ac mains. The proposed APF is to eliminate harmonics and to improve the power factor of supply. The major parts constituting APF are described in brief:

3.2.1 INTERFACE FILTER

The filter provides smoothing and isolation for high frequency components. Control of the injected current waveshape is limited by the switching frequency of the inverter and the available driving voltage across the interfacing inductance. The driving voltage across the interfacing inductance determines the maximum di/dt that can be achieved by the filter. This is important because high values of di/dt may be needed to cancel higher order harmonic components. A large value of interfacing inductance is better for isolation but it limits the ability of an active filter to cancel higher order harmonics.

3.2.2 PWM CONTROLLER

A simplified P-I (Proportional-Integral) control of the dc capacitor average voltage is used to generate reference source current in phase with ac source voltage to result inunity power factor of the source current. The pulse width modulation (PWM) is employed to generate gating signal for MOSFETSs to control the phase and magnitude of the inverter output.

3.2.3 ACTIVE SHUNT FILTER

The current drawn by the load is non-sinusoidal and have all odd harmonics.

The load current is expressed as:

$$i = i_1 + i\,h\,1 \text{ ………………….(1)}$$

Where, i_1 is the fundamental component of the load current and i_h is the harmonic current.

Now active filter current is given by:

$$i\,af\,h = i_h \text{ ……………………… (2)}$$

Supply current is given by applying KCL at PCC:

$$i\,s = i - i\,af \text{ ……………… …… (3)}$$

Combining equations *(1), (2) and (3):*

$$i\,s = i1 \text{ ……………………….(4)}$$

Equation *(4)* theoretically shows that with SPAPF the supply current harmonics can be compensated completely.

3.3 FLYBACK TRANSFORMER / LINE OUTPUT TRANSFORMER

Unlike mains transformers and audio transformers, a LOPT is designed not just to transfer energy, but also to store it for a significant fraction of the switching period. This is achieved by winding the coils on a ferrite core with an air gap. The air gap increases the reluctance of the magnetic circuit and therefore its ability to store energy.The current does not flow simultaneously in primary and secondary (output) windings. Because of this the flyback transformer is really a loosely coupled inductor rather than classical transformer, in which currents do flow simultaneously in all magnetically coupled windings.

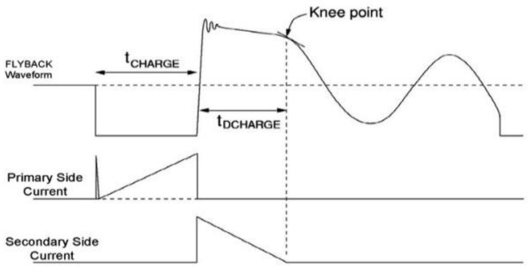

Fig.7 Waveforms of Flyback transformer.

The primary winding of the flyback transformer is driven by a switch from a DC supply. When the switch is switched on, the primary inductance causes the current to build up in a ramp.

When the switch is turned off, the current in the primary winding collapses leaving the energy stored in magnetic core. The voltage in the output winding rises very quickly (usually less than a microsecond) until it is limited by the load conditions. Once the voltage reaches such level as to allow the secondary current to flow, then the current in the secondary winding begins to flow in a form of a descending ramp.

The cycle then can be repeated. If the secondary current is allowed to discharge completely to zero (no energy stored in the core) then it is said that the transformer works in discontinuous mode.

IV. SIMULATION DIAGRAM

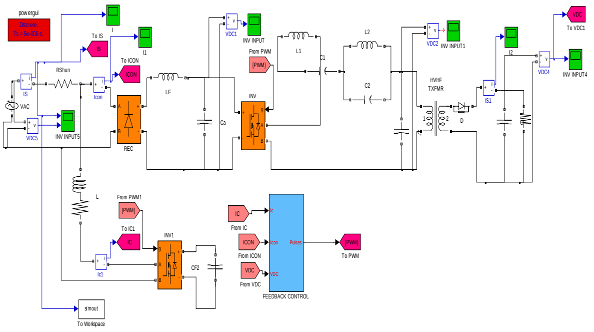

fig.8 MATLAB Simulation diagram of Active PFC

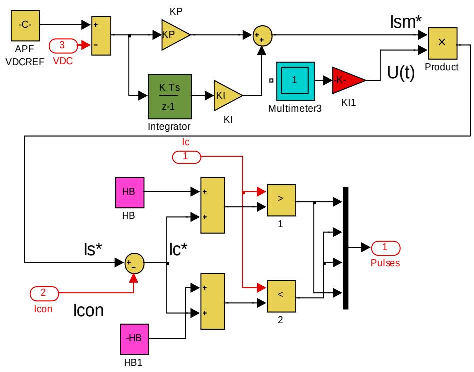

fig.9 MATLAB Simulation diagram of PI control.

V. SIMULATION RESULTS:

5.1 DC-DC LINK OUTPUT VOLTAGE

The resultant voltage across the dc-dc link capacitor placed in the secondary of the flyback transformer:

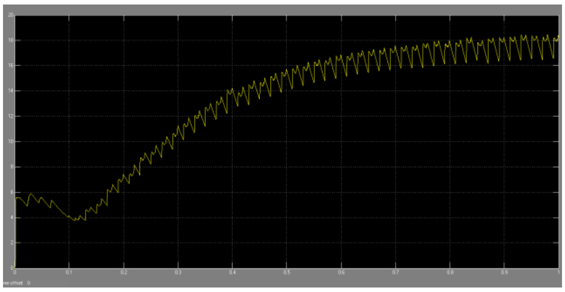

fig.10 Resultant voltage across dc-dc link.

5.2 FLYBACKCONVERTERINPUT

The required high frequency pulsating source required to drive the dc-dc link:

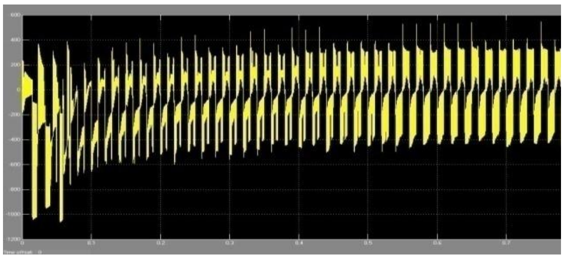

fig.11 High frequency pulsating source.

5.3 INPUT CURRENT HARMONICS

The PFC properties of a active flyback converter can be estimated from the given plots:

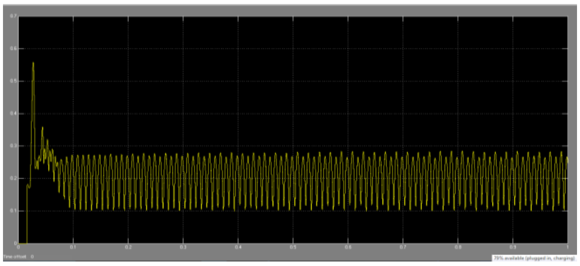

fig.12 Harmonic spectrum of supply current.

5.4 OUTPUT CURRENT HARMONICS

Harmonic content of the current waveform obtained from a rectifier circuit

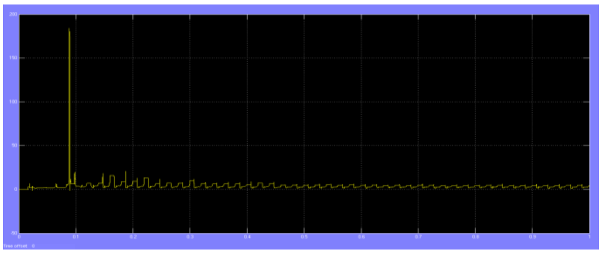

fig.13 Harmonic spectrum of output current.

Harmonic content of the current waveform of a active PFC converter

As can be clearly seen, the higher order harmonics are considerably reduced in the line current by using a active PFC.

VI. CONCLUSION

In this paper, a new ac/dc converter based on a active PFC scheme has been presented. The proposed method produces a current with low harmonic content to meet the standard specifications as well as high efficiency. This circuit is based on adding an a active shunt filter using voltage source inverter. The input inductor can operate in DCM to achieve lower THD and high power factor. By properly designing the converter components, a tradeoff between efficiency and harmonic content can be established to obtain compliance with the regulation and efficiency as high as possible.

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