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DYNAMIC DC BUS VOLTAGE CONTROL USING THREE PHASE HIGH POWER SHUNT ACTIVE FILTER

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***Abstract:** Shunt Active Power Filters (SAPF) has been proved to be an effective approach to eliminate harmonic current in power grids. The DC voltage control during dynamic processes is critical for the safe and performance of the SAPF. Soft start-up and impact suppression techniques are proposed to guarantee no voltage overshoots or sags in DC bus during start-up and other dynamic processes. Subsequently, a novel controller for DC bus voltage regulation is put forward according to the small signal model based on the instantaneous power balance in AC and DC sides of three-phase SAPF. With good compensation effects, the shunt active power filter has improved dynamic performances greatly compared with traditional PI controllers as loads change. By using shunt active power filter we can eliminate the harmonics and control voltage sag/swell to improve the power quality. DC bus voltage can be maintaining constant using shunt active power filter with different control strategies.*

***Keywords-** Shunt active power filter, LCL filter, PWM generator, PLL synchronism, DC bus voltage control,*

I. INTRODUCTION

The present power distribution system is usually configured as a three-phase three-wire or four-wire structure featuring a power-limit voltage source with significant source impedance, and an /aggregation of various types of loads. Ideally, the system should provide a balanced and pure sinusoidal three-phase voltage of constant amplitude to the loads; and the loads should draw a current from the line with unity power factor, zero harmonics, and balanced phases. To four-wire systems, no excessive neutral current should exist. As a result, the maximum power capacity and efficiency of the energy delivery are achieved, minimum perturbation to other appliances is ensured, and safe operation is warranted. However, with a fast increasing number of applications of industry electronics connected to the distribution systems today, including nonlinear loads, switching, rectifiers, single-phase and unbalanced three-phase loads, a complex problem of power quality evolved characterized by the voltage and current harmonics, voltage-sag, voltage-swell, unbalances, low Power Factor (PF) etc. The performance and dynamic characteristics of three phase active power filter operating with fixed switching frequency is presented. it can compensate reactive power and the current harmonics component of the non linear load reactive power compensation is achieved without sensing and computing reactive component of the load current. Non-linear load such as static power converters and arc furnaces result in variety of undesirable phenomenon in operation of power system the most important among this are harmonics disturbance, increased reactive power demand and power system voltage fluctuation. Harmonics contamination has become a major concern for power system specialist due to its effect on sensitive load and on the power system distribution system. Harmonics current component increase power losses cause excessive heating in rotating machinery and voltage fluctuation.

A. Power Quality Problem

With the ever-increasing use of sophisticated controls and equipment in industrial, commercial, institutional, and governmental facilities, the continuity, reliability, and quality of electrical service has become extremely crucial to many power users. Electrical systems are subject to a wide variety of power quality problems which can interrupt production processes, affect sensitive equipment, and cause downtime, scrap, and capacity losses. Momentary voltage fluctuations can disastrously impact production. Extended outages have a greater impact. In recent years active methods for power quality control have become more attractive compared with passive ones due to their fast response, smaller size, and higher performance.

B. Why Active Filters are used?

- Passive filters have been used as a solution to solve harmonic current problems, but passive filters having many disadvantages, namely
- They can filter only the frequencies they were previously tuned for;
- Their operation cannot be limited to a certain load;
- Resonances can occur because of the interaction between the passive filters and other loads, with unpredictable results.

To come out of these disadvantages, recent efforts are concentrated in the development of active filters. Different control strategies for implementing active filters have been developed.

II. SHUNT ACTIVE POWER FILTERS

Non-linear load such as static power converters and arc furnaces result in variety of undesirable phenomenon in operation of power system the most important among this are harmonics disturbance, increased reactive power demand and power system voltage fluctuation. Harmonics contamination has become a major concern for power system specialist due to its effect on sensitive load and on the power system distribution system harmonics current Component increase power losses cause excessive heating in rotating machinery and voltage fluctuation. By using shunt active power filter we can eliminate the harmonics and control voltage sag/swell to improve the power quality. By using shunt active power filter we can reduce the voltage overshoot and impact so that constant dc bus voltage can be maintain. In practical application, the DC voltage control is important for voltage source SAPF whether it operates at start up or steady-state process. On one hand, there will be unexpected great DC capacitor voltage overshoots or sags and impulse current as a result of small filter inductance in high power SAPF during the start-up transient process. On the other hand, when under normal operation, it will cause DC link voltage to raise, fall and fluctuate in a wide range due to the active power exchange between the AC and DC side. Consequently, soft start up techniques and regulation control strategies are necessary to control the DC link voltage. Passive filters have been used as a solution to solve harmonic current problems, but passive filters having many disadvantages, namely: they can filter only the frequencies they were previously tuned for; their operation cannot be limited to a certain load; resonances can occur because of the interaction between the passive filters and other loads, with unpredictable results. To come out of these disadvantages, recent efforts are concentrated in the development of active filters. Different control strategies for implementing active filters have been developed over the years.

A. LCL filter used with shunt active power filter

The DC voltage control during dynamic processes is critical for the safe and performance of the SAPF. Soft start up and impact suppression techniques are proposed to guarantee no voltage overshoots or sags in DC bus during start-up and other dynamic processes. Compared with L or LC filter, LCL filter ensures a better smoothing output current from APF. As a result, decreasing the inductance is easy to achieve, which guarantees the dynamic performance of APF. Despite increasing the complexity, LCL filter has been widely used in medium and high power applications. Meanwhile, the design of LCL filter is a complicated procedure and attracts much research attentions. Most of literature on LCL designing is aimed at applications in grid-connected PWM rectifiers or inverters. Little literature research design methods in APF applications. Despite some algorithms can be references, to design LCL filters for APF is much more difficult due to the high bandwidth of output current. In ref, a set of methods on design, control, and implementation of LCL-filter-based SAPF are presented. Unfortunately, the part of design methods for LCL filter is not detailed. SAPF has been used extensively for harmonic suppression, reactive power compensation and grid current equilibrium in the distribution system. However, switching ripples produced by APF inject to the grid and result in a considerable harm. For example, capacitor loads will increase their losses and reduce service lives; moreover, high frequency noise existing in the common voltage will disturb the sensitive equipment. To address this problem, switching noise filter is indispensable for APF. With the rapid development of power electronics, a variety of power electronic devices and nonlinear loads have been widely used. Numerous problems associated with reactive power and harmonic pollution has emerged in power systems. Harmonic suppression and reactive power compensation have become popular issues in current research. Traditional passive power filters are gradually being replaced by active power filters (APFs). A novel APF with an LCL filter can minimize the amount of distortion current in the utility grid and achieve a fast dynamic response with small inductors and filter capacitors.

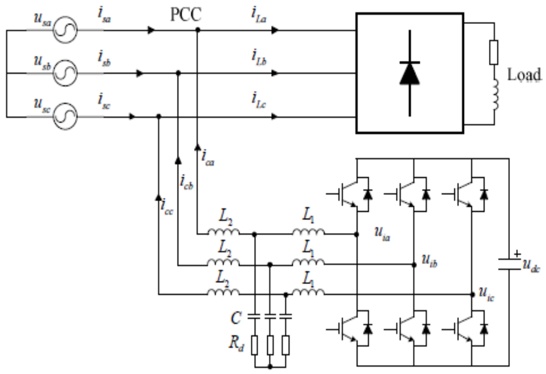

Fig 1. basic diagram of shunt active power filter with LCL filter

A key point in the proper implementation of APF is compensation current tracking. Various methods have been proposed in literature to improve APF current tracking performance. Hysteresis control and proportional-integral (PI) control are conventional methods commonly employed in industrial APF applications although new control methods have also been proposed, such as fuzzy control, sliding mode variable structure control, and adaptive control. Hysteresis control systems are robust although their switch frequency is uncertain; such uncertainty produces harmonics with a continuous spectrum and increases the difficulty of designing an appropriate output filter. PI control has a fast dynamic response and good tracking capability for DC signals. Increasing the PI controller gain helps improve AC signal tracking performance; however, a large controller gain often causes a resonance problem in the LCL filter. The proportion resonance (PR) control method can eliminate the tracking error of regulation sinusoidal signals. However, to compensate for harmonics in this method, each harmonic frequency must correspond to its specific regulator. Therefore, designing a multi-resonant controller for all harmonic components requires a large amount of resources and is thus unsuitable for practical systems. LCL filter-based shunt APF is proposed in this study. The controller is implemented in a positive-rotating synchronous frame where all the ($6n\pm1, n = 0, 1, 2...$) harmonics can be well eliminated. The maximum repetitive control delay time is reduced to one-sixth of the fundamental period; therefore, the dynamic response is significantly improved without sacrificing steady-state performance. The PI regulator is also combined with a fast-transient repetitive controller to compensate for even harmonics under unbalanced conditions. Theoretical analysis and deduction of the proposed method are also demonstrated. The design process of the corrector in the proposed fast-transient repetitive controller is presented in detail. The LCL filter resonance problem is avoided by using an appropriately designed corrector that increases the margin of system stability and maintains the original compensation current tracking accuracy. The feasibility of the hybrid current controller is validated by the experimental results.

III. BASIC CONTROL SCHEME OF SHUNT ACTIVE POWER FILTER

A DC voltage regulator is adopted to maintain DC bus voltage stability. The compensation reference currents are obtained by adding the output current reference of the DC voltage regulator and the harmonic components in the load current. The compensation current controller generates a reference voltage to allow the compensation current to track the reference current accurately. Therefore, the compensation current can offset the harmonic components in the load currents, and the harmonics in the point of common coupling (PCC) current are also eliminated.

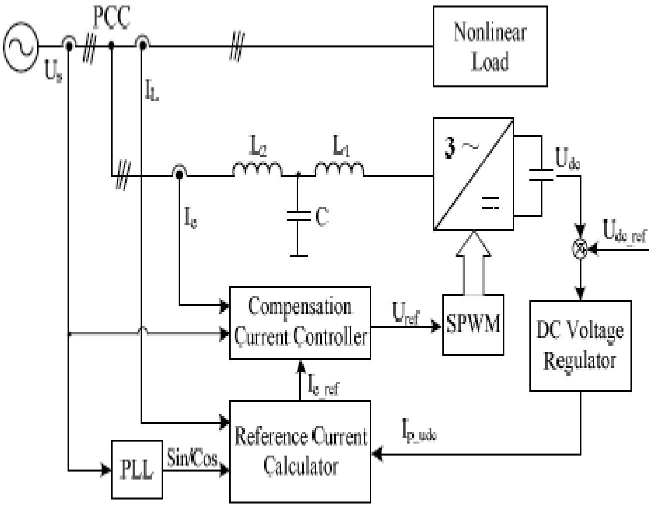

Fig 2. Basic control scheme of shunt active power filter

A large portion of the total electrical energy produced in the world supplies different types of nonlinear loads, such as variable-frequency drives and electronic ballasts. These loads are typically composed of odd harmonic currents, which are multiples of the fundamental frequency. The harmonic currents cannot contribute to active power and need to be eliminated to enhance power quality. Active power filters (APFs) are designed for this purpose. APFs in three-phase three-wire systems can be based on several control methods. Typically, current control is per- formed either by pulse width modulation (PWM), or by direct current control. For detection of undesired harmonic currents, closed-loop synchronous-frame regulators or integrating oscillators can be implemented. However, these methods result in phase shifts, which reduce the filtering performance. A better approach is to use Fourier transformation to determine individual harmonics that need to be eliminated. The APF control proposed in this paper is based on the Fourier transformation approach.

IV. PWM GENERATOR

A. PULSE-WIDTH MODULATION

In PWM pulses representing, successive sample values of s (t) have constant amplitudes but varies in time duration in direct proportion to the sample value. The pulse duration can be changed Relative to fix leading or trailing time edges or a fixed pulse converter. To allow for time-division multiplexing, the maximum pulse duration may be limited to a fraction of the time between samples.

B. SINGLE PULSE WIDTH MODULATION

In this control, there's only one pulse per half cycle and the width of the pulse is varied to control the inverter output. The gating signals are generated by comparing a rectangular reference signal of the amplitude Ar with triangular carrier wave of amplitude Ac, the frequency of the carrier wave determines the fundamental frequency of output voltage. By varying Ar, from 0 to Ac, the pulse width can be varied from 0 to 100 percent. The ratio of Ar to Ac is the control variable and defined as the modulation index.

C. MULTIPLE PULSE WIDTH MODULATION

The harmonic content can be reduced by using several pulses in each half cycle of output voltage, the generation of gating signals for turning ON and OFF transistors by comparing a reference signal with a triangular carrier wave. The frequency Fc, determines the number of pulses per half cycle. The modulation index controls the output voltage. This type of modulation is also known as uniform pulse width modulation (UPWM).

D. WHY PULSE WIDTH MODULATION?

Pulse-width modulation (PWM) of a signal or power source involves the modulation of its duty cycle, to either convey information over a communications channel or control the amount of power sent to a load.

E. Carrier based pulse width modulation

As mentioned earlier, it is desired that the ac output voltage follow a given waveform (e.g., sinusoidal) on a continuous basis by properly switching the power valves. The carrier-based PWM technique fulfils such a requirement as it defines the on and off states of the switches of one leg of a VSI by comparing a modulating signal Vc(desired ac output voltage) and a triangular waveform vΔ (carrier signal).

Modulation index = $\frac{Vc}{V\Delta}$

F. Space vector pulse width modulation

Space Vector Pulse width Modulation (SVPWM) generates the appropriate gate drive wave form for each PWM cycle. The SVPWM provides unique switching time calculations for each of these states.

G. Pulse Width Modulation

PWM is a modulation technique used in communications systems to encode the amplitude of a signal into the width of the pulse (duration) of another signal. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads. The average value of voltage and current fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load. The PWM switching frequency has to be much higher than what would affect the load (the device that uses the power), which is to say that the resultant waveform perceived by the load must be as smooth as possible. The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on. The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle. PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications channel. Pulse-width modulation uses rectangular pulse wave whose pulse width is modulated resulting the variation of the average value of the waveform.

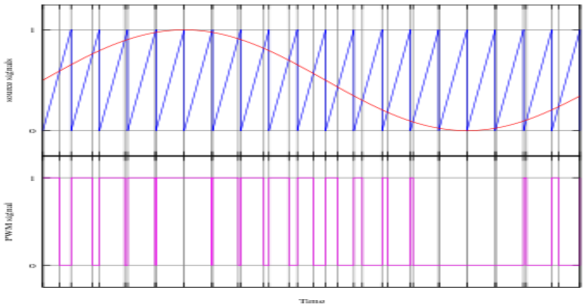

Fig 3. PWM generation

V. DESIGN AND CONTROL CIRCUIT:

A. Control Circuit

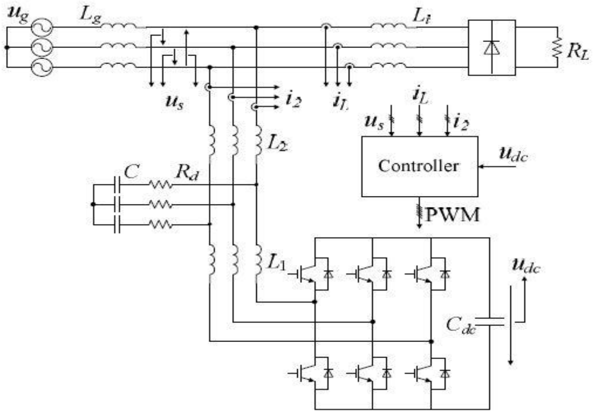

Fig 4.: Configuration of shunt active power filter with LCL filter.

VI. SOFT START UP TECHNIQUE WITH LCL FILTER

Before the normal operation of SAPF, soft start-up in DC link is necessary to avoid high impulse current in DC capacitors which may damage devices. The soft start-up is mainly composed by pre-charging and chopping boost process.

A. Pre-charging Process: (with LCL filter)

Pre-charge in the DC link can be realized by the anti- parallel diodes of the main switches with the grid voltage. To limit the surge current, a proper resistor Rs in series with the grid side inductance L2 is required. Since the current flowing across L1 is very small, the value of DC voltage is determined by the voltage across filter capacitor in the second-order circuit composed by Rs, L2, Rd and C. The DC voltage can be given approximately as

$$V_{d=} \frac{V_c}{\sqrt{X_c^2+R_S^2}} V_g$$

B. Impact Suppression Technique

After the soft start-up of DC link voltage, the system will enter into normal operation. However, impact occurs the very moment the main circuit output compensation current.

In high power SAPF application, the total inductance L in LCL filters is very small to acquire high bandwidth .It can be seen that the larger the inductance, the lower di/dt and tracking ability in the system under the condition that DC link and grid voltage is constant.

On the contrary, the small inductance is conducive to fast dynamic response while it will result in not only high impulse current at AC side but also voltage sag or overshoot at DC link during the transient process. In addition, the last equation indicates that the DC voltage impact is directly related with the three phase output compensation current in AC side. Consequently, some measures must be taken to suppress great DC voltage fluctuation during the starting transient process. In order to solve these problems, soft start up techniques and a novel controller for DC link voltage regulation are proposed according to the small signal model based on the instantaneous power equilibrium of three-phase three-wire SAPF.

Simulation and experimental results demonstrate that these techniques have guaranteed the DC voltage rising to the expected value smoothly and the new controller has obtained excellent steady-state and dynamic performances. The LCL filters give advantages in costs and dynamic performance since smaller inductors can be used compared to L-filter in order to achieve the necessary damping of the switching harmonics. However, LCL-filter design is complex and needs to consider many constraints, such as the current ripple through inductors, total impedance of the filter, resonance phenomenon, reactive power absorbed by filter capacitors, etc

VII. MATLAB SIMULATION

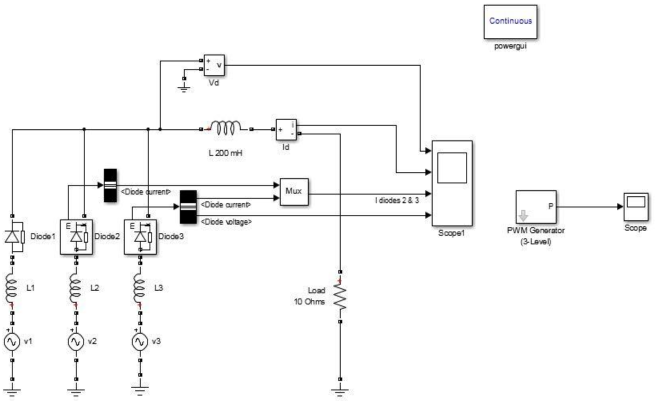

Fig 5: Simulation block diagram

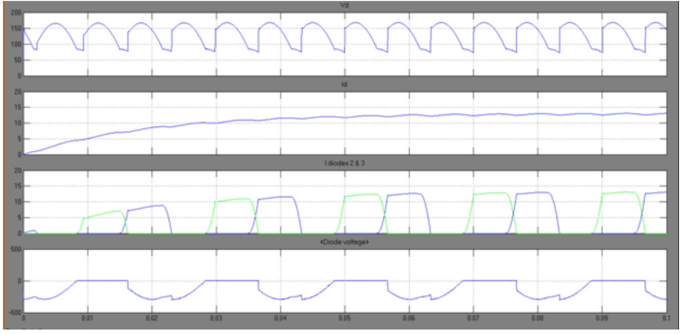

Fig 6: Output waveform

VIII. CONCLUSION

Soft start-up technique is use for shunt active filter with LCL filter to suppress voltage overshoots or sags in DC bus during start-up dynamic processes and a novel controller for DC bus voltage regulation. This paper presents the overview of shunt active power filter and normally the start-up technique which is used to control the DC bus voltage during the dynamic process and the DC voltage maintain constant at load ends. The simulation results show only the distorted output waveform without shunt active power filter.

IX. FUTURE WORK

The three phase high power shunt active power filter with PLL synchronism will obtain constant DC bus voltage at the output of load end and better dynamic performances compared with traditional PI controllers for DC bus voltage control.

REFERENCES

[1] Akagi.H, "New trends in active filters for power conditioning, " IEEE Transactions on Industry Application, vol. 32, no. 6, pp. 1312-1322, 1996.

[2] Chen Guozhu, Lü Zhengyu, Qian Zhaoming, "The general principle of active filter and its application," Proceedings of the CSEE, vol. 20, no. 9, pp. 17-21, 2000.

[3] He Na,WuJian, Xu Dianguo, "Fuzzy soft-startup controller of active power filter," Transactions of China Electrotechnical Society, vol. 20, no. 9, pp. 115-120, 2000.

[4] Akagi. H, Kanazawa.Y, Nabae.A, "Instantaneous reactive power compensators comprising switching devices without energy storage components, " IEEE Transactions on Industry Application, vol. 20, no. 3, pp. 625-630, 1984

[5] Juan Dixon, Jose Contardo, Luis Moran, "DC link fuzzy control for an active power filter, sensing the line current only," in IEEE 1997 Power Electronics Specialists Conference, 1997, pp. 1109-1114.

[6] Abedini.A, Nasiri.A, "An improved adaptive filter for voltage and current reference extraction," in IEEE 2006 Power Electronics and Motion Control Conference, 2006, pp. 1-5.

[7] WenjieGuo, Fei Lin, Trillion Zheng, "Nonlinear PI control for three- phase PWM AC-DC converter," in IEEE 2006 Annual Conference of the IEEE Industrial Electronics Society, 2006, pp. 1093-1097.

[8] Aurelio GarcíaCerrada, Omar PinzónArdila, Vicente FeliuBatll, Pedro Roncero Sánchez, and Pablo García-González, "Application of a repetitive controller for a three-phase active power filter," IEEE Transactions on Power Electronics, vol. 22, no. 1, pp. 237-246, 2007.

[9] R. Griñó, R. Cardoner, R. Costa-Castelló, and E. Fossa, "Digital repetitive control of a three-phase four-wire shunt active filter," IEEE Transactions on Industrial Electronics, vol. 54, no. 3, pp. 1495-1503, 2007.

[10] LuoShiguo, "Optimal design of DC voltage close loop control for an active power filter," in IEEE 1995 Power Electronics and Drive Systems, 1995, pp. 565-570.

[11] Bhim Singh, Kamal Al-Haddad, Senior Member, IEEE, and Ambrish Chandra, Member, IEEE

[12] V.Bhavaraju and P. N. Enjeti, "Analysis and design of an active power filter for balancing unbalanced loads," IEEE Trans. Power Electron., vol. 8, pp. 640–647, Oct. 1993.

[13] S. Saetieo, R. Devaraj, and D. A. Torrey, "The design and implementation of a three-phase active power filter based on sliding mode control," IEEE Trans. Ind. Applicat., vol. 31, pp. 993–1000, Sept./Oct. 1995.

[14] B. Singh, K. Al-Haddad, and A. Chandra, "Active power filter with sliding mode control," in Proc. Inst. Elect. Eng., Generation, Transm. Distrib., vol. 144, Nov. 1997, pp. 564–568.