IMPLEMENTATION OF A ROBUST HYBRID SERIES ACTIVE POWER FILTER TO IMPROVE POWER QUALITY

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Abstract— The debasement in power quality causes unfavorable temperate effect on the utilities and clients. Harmonics in current and voltage are a standout amongst the most regularly known power quality issues and are unraveled by the utilization of a half breed arrangement dynamic power channel (HSAPF). In this paper, another controller configuration utilizing sliding-mode controller-2 is proposed to make the HSAPF more hearty and stable. An exact arrived at the midpoint of model of a three-stage HSAPF is likewise inferred in this paper. The outline idea of the powerful HSAPF has been confirmed through reproduction and test thinks about, and the outcomes acquired are examined.

I. INTRODUCTION

In the course of recent years, the enormous increase in the use of nonlinear loads raises numerous power quality issues, such as high current harmonics, voltage distortion, and low power factor, on electrical lattice [1]. Consequently, the multiplication of nonlinear load in the system generates symphonious currents infusing into the air conditioner power lines. This distorted supply voltage and current causes breakdown of some security devices, consuming of transformers and motors, and overheating of cables. Subsequently, it is most vital to install compensating devices for the compensation of consonant currents and voltages created because of nonlinear load. Generally, passive power filters (PPFs) have been used as a compensating gadget to compensate distortion created by constant nonlinear loads. These filters [2] are designed to give a low-impedance way to harmonics and keep up great power quality with a simplest design and ease. In any case, passive filters have some disadvantages such as mistuning, resonance, reliance on the conditions of the power supply system, and vast values of passive components that prompt cumbersome implementations. For better power quality prerequisite, diverse topologies of active power filters (series active filters and shunt active filters) are associated with the nonlinear load. These filters are the most generally used solution, as they productively dispense with current distortion and the reactive power delivered by nonlinear loads.

In any case, they are by and large expensive and have high working losses [3],[4]. From now on, to defeat these drawbacks and to enhance the compensation execution with decreased cost of the APFs, a novel HAPF topology-III is presented by Peng et al. in 1988 [5], in which the APF is associated in series with the source as well as nonlinear load, and the PPF associated in parallel with the heap, which behaves as a power factor adjustment capacitor, is proposed. This topology [6] attracts substantially more regard for persevere through high-stack currents and works as a consonant isolator between the source and nonlinear load.

II.LITERATURE REVIEW

The control strategy is imperative to improve the execution of a hybrid series active power filter (HSAPF). Truly, numerous papers for a hybrid power filter have just proposed propelled techniques to lessen current harmonics made by these nonlinear loads. In [7], a direct input feed-forward controller is designed for a hybrid power filter. Be that as it may, this controller is difficult for getting both steady-state and transient-state performances with the direct control strategy because the dynamic model of the HSAPF system contains increase terms of control inputs and state variables. Because of the nonlinear characteristics of the HSAPF, a sliding-mode controller is presented in[8]. The sliding-mode control is known as a suitable control strategy for controlling nonlinear systems with indeterminate dynamics and disturbances because of its request decrease property and low sensitivity to disturbances and plant parameter variations, which reduces the weight of the prerequisite of correct demonstrating.

III.EXISTING SYSTEM

Besides, this sliding-mode control also diminishes the complicacy of the criticism control design by means of decoupling the system into singular subsystems of lower dimension. Because of these given properties, the usage of the slidingmode control can be found in the areas of power electronic switching devices. The rule of the sliding-mode control is characterized as to uphold the sliding-mode movement in the predefined switching surfaces of the system state space using discontinuous control. The switching surfaces should be selected in such a way that sliding movement would keep up desired dynamics of movement as indicated by a specific execution basis. The customary control methods, such as linear– quadratic controller [9] or linear–quadratic Gaussian servo controller [10] for direct systems, are required to choose legitimate switching surfaces. At that point, the discontinuous control needs to be chosen such that any states outside of the discontinuity surface are authorized to achieve the surface at limited time. As needs be, sliding mode occurs along the surface, and the system follows the desired system dynamics. The primary trouble of equipment usage of a classical sliding-mode control technique is chattering. Chattering is only an undesirable marvel of oscillation with limited recurrence and sufficiency. The chattering is dangerous because the system lags control precision, high wear of moving mechanical parts, and high warmth losses happen in electrical power circuits. Chattering occurs because of unmodeled dynamics. These unmodeled dynamics are made from servomechanisms, sensors, and information processors with smaller time constants. In the sliding-mode control, the switching recurrence should be considerably sufficiently high to make the controller more robust, stable, and no chattering because chattering reduces if switching recurrence of the system increases. In the use of sliding mode controller in power converter system, the chattering issue can be lessened in the normal route by increasing switching recurrence. Be that as it may, it is impractical on account of power converters because of specific limitations in switching recurrence for losses in power converters, for which it results in chattering. In this manner, this chattering issue can't accuse sliding-mode execution, since it is mainly caused by switching limitations

IV.PROPOSED SYSTEM:

In [11], it is shown that the chattering exponentially tends to zero if the relative level of the system with actuators or sensors is 2. The relative level of the HSAPF system is 2. Because of this relative level of the HSAPF system and furthermore for these obstacles in a classical sliding-mode controller, this paper proposes another controller, i.e., sliding-mode controller-2 (SMC-2). This proposed controller suppresses chattering and enhances the execution of the HSAPF. This controller is totally new for this topology of the HSAPF system. An ongoing research paper [12] focuses on carrier-based pulse width modulation (CBPWM) for the HSAPF topology. However, in some cases, the CBPWM-based HSAPF may not be totally measurable in most of this present reality situations. On account of CBPWM, power system perturbations have not been mulled over, and furthermore, the presence of a period delay at the reference following point gives rise to a slow response of the general system. Thus, following mistake is not diminished viably, and the stability of the system is negligibly made strides. To beat this, SMC-2 is proposed for a voltage-source converter. The thought behind this controller is to accomplish pick up stability, idealize following, and without distortion current and load voltage. In perspective of the previously mentioned issues, we give more emphasis on the advancement of the robust controller with a faster reference following methodology in the HSAPF, which permits all perturbations such as load voltage distortion, parametric variety of load, source current distortion, and supply voltage unbalance so that compensation capability of the HSAPF system can be enhanced.

A. AVERAGED MODELING OF THE HSAPF

Fig. 2 shows the schematic graph of the control and power circuit of the three-phase HSAPF. The

SAPF consists of a VSI associated with the lattice through a LC filter and a three-phase direct transformer. The series resistance of the inductors is ignored. ua , ub , and uc are the obligation cycles of the inverter legs in a switching period, whereas Vca , Vcb , and Vcc are the yield voltages of the series active filter for three phases shown in Fig. 2 and Ica , Icb , and Icc are known as the three-phase currents of the active filter; VaN , VbN , and VcN are the phase voltages for three phases; Isa , Isb , and Isc are known as the three-phase source currents; and VnN is the nonpartisan voltage. By averaging the inverter legs in the circuit chart, the entire arrived at the midpoint of model [13] of the inverter in three phases is acquired as shown in Fig. 3.

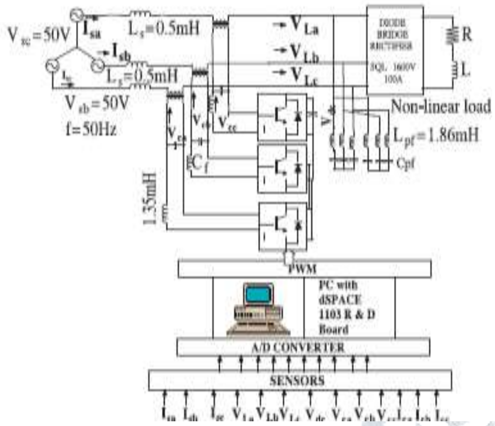

Fig. 2. Schematic diagram of the control and power circuit of the HSAPF.

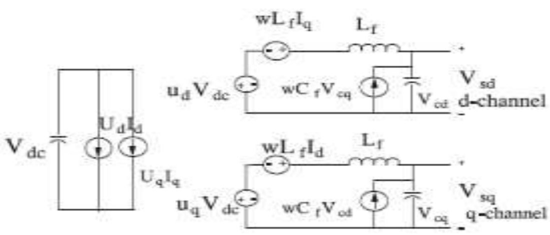

Fig. 3. Averaged equivalent circuit in a three-phase stationary frame of the HSAPF.

To facilitate the controller design, the HSAPF system model can be defined as follows:

$$\begin{cases} \dot{x} = f(x) + g(x)u \\ y = h(x) \end{cases} \qquad ....(1)$$

where x = [icd , icq , Vcd , Vcq , Vdc]

T is defined as the state vector, vector u = [ud , uq] T stands for system control variables, and vector y = [y1 , y2] T = [Vcd , Vcq] T presents the system outputs. It must be noticed that the achieved multi-input multi-output system is nonlinear because of the existence of multiplication terms of the state variables and control variables. And the state variables are intensely combined with each other. These two difficulties can be accurately controlled by the design of the sliding-mode controller, which openly examine the link between the control variables and the system outputs.

B. Development Of The Control System

i. Reference Voltage Generation Scheme (Hybrid Control Approach-Based Synchronous Reference Frame Method, HSRF)

The reference compensation voltage of the HSAPF system adopting hybrid control approach-based synchronous reference frame method is expressed as

$$V_c^* = KI_{sh} - V_{Lh}. \qquad ....(2)$$

This hybrid control approach simultaneously detects both source current Is as well as load voltage VL to obtain their harmonic components. The generation of the reference compensating signal V ∗ c using the combined load voltage and source current detection scheme together with an adopting hybrid control approach-based synchronous reference frame method for the HSAPF system can be obtained as (8) and (9). The realization circuit for generating V ∗ c is shown in Fig. 4

$$U_d = KI_d - V_d \qquad ....(3)$$

$$U_q = KI_q - V_q. \qquad ....(4)$$

The generation of reference compensating signal using the joined load voltage and source current discovery scheme[14] shown in Fig. 4. Fig. 4 shows that the blunder between the reference and the genuine dc-connect voltage of the dc-interface capacitor of the three-phase PWM inverter nourished from the air conditioner system is first passed through a PI controller, and afterward, it is subtracted from the oscillatory segment in the d-axis. Additional major components (i.e. ΔVcaf, ΔVcbf and ΔVccf) are added to the harmonics components in each phase. Thus, the reference compensating voltages can be expressed as

$$\left.\begin{aligned} V_{ca}^{*} &= KI_{sah} - V_{Lah} + \Delta V_{caf} \\ V_{cb}^{*} &= KI_{sbh} - V_{Lbh} + \Delta V_{cbf} \\ V_{cc}^{*} &= KI_{sch} - V_{Lch} + \Delta V_{ccf} \end{aligned}\right\} \quad \text{...........(5)}$$

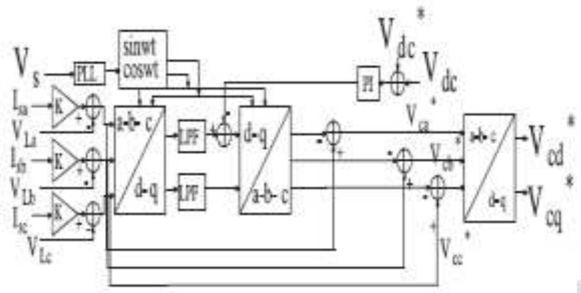

Fig. 4. Reference generation scheme (HSRF).

ii. Proposed Sliding-Mode Controller Design for the HSAPF

This section describes the synthesis of the sliding-mode controller based on the arrived at the midpoint of model of the HSAPF system. Based on the system model (6), we separate the compensating voltage with respect to time until the control variables ud and uq show up unequivocally.

To synthesize a robust HSAPF system, a sliding-mode controller is designed based on the linearized model (6). The control target of the HSAPF system is to drive the compensating voltages Vcd and Vcq ; the scientific expressions of sliding surface are as follows:

$$\overline{S} = \begin{bmatrix} \overline{S}_d \\ \overline{S}_q \end{bmatrix} \quad \text{..............(6)}$$

$$\overline{S} = S + \alpha \dot{S} \quad \text{..............(7)}$$

$$\overline{S}_d = S_d + \dot{S}_d \quad \text{...............(8)}$$

$$\overline{S}_q = S_q + \dot{S}_q \quad \text{..............(9)}$$

putting the values of Vcd and Vcq

$$\overline{S}_d = (V_{cd} - V_{cd}^{*}) + \alpha_1 \left(\dot{V}_{cd} - \dot{V}_{cd}^{*}\right) \quad \text{....(10)}$$

$$\dot{\overline{S}}_d = \left(\dot{V}_{cd} - \dot{V}_{cd}^{*}\right) + \alpha_1 \left(\ddot{V}_{cd} - \ddot{V}_{cd}^{*}\right) \quad \text{....(11)}$$

$$\overline{S}_q = (V_{cq} - V_{cq}^{*}) + \alpha_2 \left(\dot{V}_{cq} - \dot{V}_{cq}^{*}\right) \quad \text{.....(12)}$$

$$\dot{S}_q = \left(\dot{V}_{cq} - \dot{V}_{cq}^{*}\right) + \alpha_2 \left(\dot{V}_{cq} - \dot{V}_{cq}^{*}\right) \quad \text{....(13)}$$

where α is a positive constant. The design procedure of the sliding-mode controller is depicted as

$$\dot{\overline{S}} = 0$$

$$\dot{\overline{S}}_d = 0.$$

The control block diagram of the proposed control strategy has been illustrated in Fig. 5.

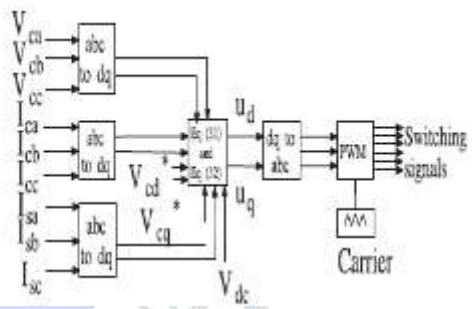

Fig. 5. Proposed sliding-mode control structure for the HSAPF.

The nonlinear control law has been directly derived by putting the values of Udeqv. and Uqeqv ,we get

$$U_q = -\left(\dot{V}_{cq}^{*} + \alpha \ddot{V}_{cq}^{*}\right) + \frac{L_f}{V_{dc}}\left(C_f w V_{cd} - i_{cq} + i_{sq}\right) + \frac{\alpha L_f}{V_{dc}}\left(-C_f w^2 V_{cq} - w i_{cd} + w i_{sd} - \frac{V_{cq}}{L_f} - w \dot{i}_{cd} + \dot{i}_{sq}\right) - K_{21}\text{sign}(S_q) - K_{22}\text{sign}\left(\dot{S}_q\right).$$

..............(14)

$$U_q = -\left(\dot{V}_{cq}^{*} + \alpha \ddot{V}_{cq}^{*}\right) + \frac{L_f}{V_{dc}}\left(C_f w V_{cd} - i_{cq} + i_{sq}\right) + \frac{\alpha L_f}{V_{dc}}\left(-C_f w^2 V_{cq} - w i_{cd} + w i_{sd} - \frac{V_{cq}}{L_f} - w \dot{i}_{cd} + \dot{i}_{sq}\right) - K_{21}\text{sign}(S_q) - K_{22}\text{sign}\left(\dot{S}_q\right).$$

..............(15)

V. RESULTS AND DISCUSSIONS

The reference generation approach (the HSRF technique) with the switching design generation scheme (i.e., SMC-2) of the HSAPF system given in Fig. 2 is tested using MATLAB/Simulink software. A three-phase source voltage is connected to a consonant voltage delivering nonlinear load. This voltage creating nonlinear load comprises of a three-phase diode connect rectifier sustaining a RL load. Because of this kind of nonlinear load, a consonant distortion occurs in both source current and load voltage. This symphonious defilement is the reason of power quality disturbances. So, power quality disturbances can be annihilated by means of the HSAPF.

One reference generation system and one modulation strategy, i.e., hybrid control approach-based SRF technique (HSRF) and sliding-mode-controller-based HSAPF, are checked and investigated using the accompanying MATLAB simulation results. The objective of simulation is to lessen the aggregate consonant distortion (THD) response of the sliding-mode-controller-based HSAPF beneath 5%. What's more, a HSRF joined with the sliding-mode controller strategy utilizes dc-connect voltage appropriately for comparable control law generation. MATLAB simulation results for source voltage Vs , load current IL , source current Is , dc voltage Vdc for steady state, and the dynamic state of load under the existing strategy have been presented in FigThe idea of the source current without a filter is precisely similar to load current.

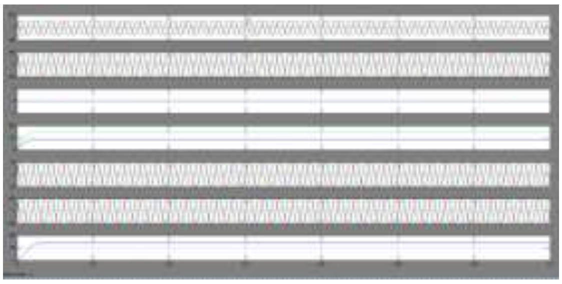

Fig 6.normal mode

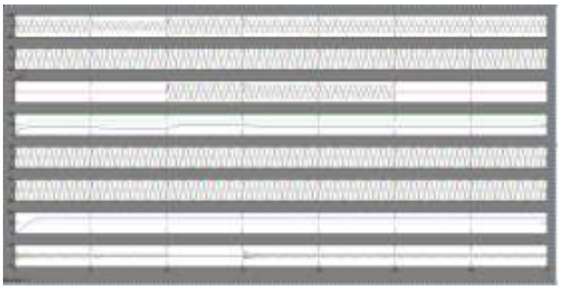

Fig 7. sag-swell mode

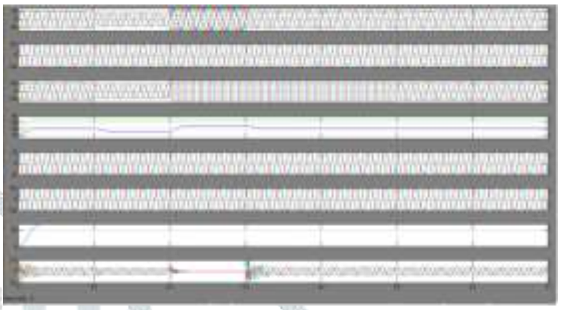

Fig 8. sag- swell hormonics mode

VI. CONCLUSION

In this paper, another robust controller design for the HSAPF has been presented. The control design is established by SMC-2 that derives the proportional control law. This control law is particularly useful for switching design generation. The robustness of the proposed controller has been confirmed by examining the execution under steady-state and transient conditions of the power system. With the utilization of this strategy, the functionalities of the HSAPF are improved. From the got simulations as well as exploratory results, the proposed HSAPF has been observed to give effective current as well as voltage symphonious alleviation, reference voltage following conduct, and reactive power compensation with powerfully changing load conditions. In the presence of an added substance background noise, losses and distortion in both the source current and the load voltage, the SRF technique is observed to be the best one for reference generation. Moreover, the primary component of SMC-2 is the variable structure control technique, which reduces following mistake distortion, suppress chattering, and noise, and consequently, an immaculate pick up stability of the HSAPF system has been accomplished. The proposed filter can compensate source currents and furthermore adjust itself to compensate for variations in nonlinear load currents, keep up dc-interface voltage at steady state, and help in the rectification of the power factor of the supply side neighboring solidarity.

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