International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

IJIEMR Transactions, online available on 4th Sept 2019. Link :http://www.ijiemr.org/downloads.php?vol=Volume-08&issue=ISSUE-09

Title **3-STAGE SHUNT ACTIVE POWER FILTER**

Volume 08, Issue 09, Pages: 435–447.

Paper Authors

K SUMA,G SAI HARINI,G PHANITHA KRISHNA

Anu Bose Institute of Technology K.S.P Road, New paloncha, Bhadradri Kothagudem, Telangana, India

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

3-STAGE SHUNT ACTIVE POWER FILTER

K SUMA[1],G SAI HARINI[2],G PHANITHA KRISHNA[3]
[1,2,3]UG Students, Dept. of Electrical and Electronics Engineering Anu Bose Institute of Technology
KSPRoad, Newpaloncha, Bhadradri Kothagudem, Telangana, India.
mallesham2070@gmail.com[1], g.harini002@gmail.com[2], gphanitha123@gmail.com[3]

Abstract:- Shunt dynamic powerfilters(SAPF) are utilized to improve control qualityby infusing remunerating consonant current. The secluded SAPFoffers numerous new abilities that are generally inaccessible bythe ordinary SAPF, for example, high peak factor remunerating present and quick powerful reaction. In any case, there are still difficulties that are should have been tended to, for example, reverberation and strength issues related with the particular SAPF. To research these issues, this work first shows a numerical modelfor customary measured SAPF framework. In light of the scientific investigation, another mixture three-level secluded SAPF is introduced that is made out oftwo kinds of modules, each with various current conveying limits, LCL channel parametersand exchanging frequencies. Theproposed half and half framework gives a more extensive current following data transmission and quick unique reaction when contrasted with the present measured SAPF. An epic self-versatile, dynamic damping technique is suggested that successfully stifles reverberation andcoupling betweenmodules. Scientific examination and trial resultshavebeen utilized to check theproposed framework.

Index Terms:-SAPF, Modeling, HybridModular, Three-level

I. INTRODUCTION

WITHan expansion in infiltration of nonlinearloads all through thepower conveyance framework, current symphonious contamination atthe matrix sideis developing. The expanding number ofhigher request music causesa progression of issues, including voltageand current burdens, electro-attractive obstruction (EMI), and power transmission misfortunes [1], [2]. In like manner, inactive and dynamic symphonious relief procedures have been a noteworthy focal point of research as of late [3], [4]. ShuntActive PowerFilters(SAPF) are usedto alleviate sounds at the heap end by infusing a remunerating symphonious current equivalent in extent and inverse in stage to thatbeing drawn bynonlinear burdens connected [5]–[9].Essentially, theSAPF carries on as a network tiedinverter however supplies higher request music currentwith highercurrent peak factorand higher current slewrate[10].The measured orparallel SAPF examined inisan improvement overthe customary SAPF. Givenhigh peak factor andslew pace of the remunerating current itcan deliver, the measured SAPF apparently gives themore compelling answer for symphonious contortion rather than the regular brought together SAPF structure. Improved performancecan be watched particularly as far as following accuracy and

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

dynamic reaction, since the repaying current equitably disseminated between different modules. Notwithstanding, itwillbe later shown through numerical displaying in segment II, that itis hard forthe regular structure of secluded or parallelSAPF to arrives an ideal harmony between quick unique reaction andstable control performance. The particular SAPFstructure is fundamentally the same as that of parallel inverters. Thecoupling and reverberation betweeninverters are significant territories of researchthat havebeen very much tended to for parallelinverters[16]–[22]. Displaying of parallelinverters, hypothetical examination of reverberation and communications betweenparallel inverters has been talked about in. Itis reasoned thatthe reverberation between inverters is enormously affected by yield channel inductanceand lattice impedance. In this manner, expectedly, the reverberation is stifled by theLCL channel inductance guideline orstructure plan as those in . Lately, dynamic damping hasbeen widely explored toimprove the change proficiency andcurrent following accuracy. J. He, et al.have exhibited dynamic reverberation stifling systems by managing the control laws and applying framework the reverberation concealment and control soundness are themost significant issues withSAPF. Two basic reverberation concealment plans are recommended in the main technique diminishes dull control force at the expense of diminished remuneration exactness, while the subsequent strategy intends to reinforce inactive dampingapproach through expansion ofa damping resistor atthe expense ofa higherpower misfortune. Comparable issues havebeen tended to in for parallelSAPF which demonstrates that expanding theinductance and diminishing the relative addition in PRcontrollers is compelling stifling reverberation conditions. The equipment basic highlights & dynamic reaction capacities ofSAPF are not completely talked about inwhich secluded or parallelSAPFs havebeen basically treatedas parallel sinewave inverters. The reverberation concealment strategies produced for SAPF are constrained to latent damping plans. In any case, it ought to be noticed that symphonious repaying current blunder following of SAPF contrasts eminently from the yield mistake following of customary sine wave inverters, particularly as far as solidness anddynamic reaction. The nearness ofhigher request music uptothe 50th request inSAPF yield converts intoa higher peak factorin current. Consequently, theSAPF requires quicker unique reaction and more noteworthy control data transfer capacity. Because of the previously mentioned issuesthe channel inductance forSAPF is typically intended to be substantially less thanthat of a regular sine wave inverter. Thelower channel inductance represents a more serious danger of the reverberation conditionbetween parallel SAPFmodules while likewise lessening edge for reverberation concealment dynamic and inactive methods. Giventheir central contrasts from the progressively hard to touch base at a tradeoffbetween reverberation concealment anddynamic reaction capacity in secluded SAPF. In this manner, neitherofthe dynamic or inactive reverberation concealment strategies can be legitimately used from traditional inverters as indicated in. This paperpresents abilities toaddress previously mentioned issues related with measured SAPF. Initial, an improved numerical modelfor a summed up three-level secluded SAPFthat incorporates a present controller, framework impedance, and dynamic

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

damping plans is created. In view of the numerical investigation, we furtherpropose a half breed three-level secluded SAPF framework thatis made out of two sorts modules with limits of 100A and 50A, individually. The 50A module has lower LCL channel parameters&higher changing recurrence to remunerate sounds of requests higher than thirteenth, and the 100A module has bigger LCL parameters and lower changing recurrence to address the music of lower request. Last, anovel self-versatile dynamic technique is proposed and actualized forthe secluded SAPFto smother reverberation current betweenmodules. The scientific examination andtest outcomes exhibit that the proposed reverberation control system canimprove the repaying data transfer capacity and solidness alongside quick and exact sounds following capacity.

II. MODELING OF THREE-LEVEL MODULAR SAPF

A. Modeling of a single three-level SAPF

SAPF is basically a controlled current source with yield current criticism control. Each SAPF module is associated with the network through a LCL channel as appeared in Fig.1. L1, L2, C, and Lg speak to SAPF side inductor, matrix side inductor, channel capacitor, and framework impedance, individually.

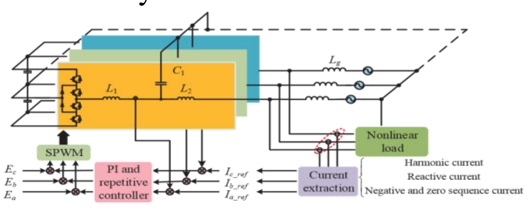


Fig. 1. General structure of three-level SAPF

The control plan of a solitary SAPF is appeared in Fig.2. Despite the fact that the reference current can be contributed by symphonious flows, responsive power, and unbalance (negative and zero succession parts) in the heap, this paper essentially centers around consonant flows remuneration. Sounds are gotten by the specific symphonious identification calculation dependent on Discrete Fourier Transform (DFT). Iref speaks to the reference current, ug(s) is the lattice voltage and E(s) is the feed-forword estimation of ug(s). The criticism control of the present circle is acknowledged in A-B-C pivot by a redundant controller in parallel with a PI controller.

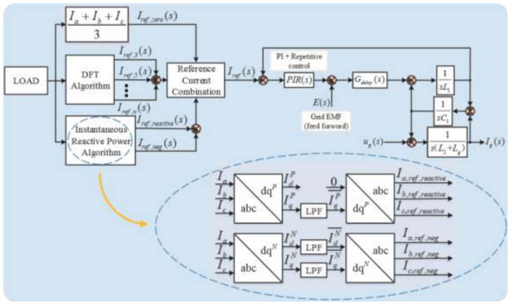


Fig. 2. Control diagram of modular SAPF

According to the control diagram in Fig.2, the transfer function of the output current to the reference current reads.

$$I_g(s) = \{PIR(s)G_{delay}(s)I_{ref}(s) - [s^2L_1C_1 + sC_1PIR(s)G_{delay}(s) - G_{delay}(s) + 1]E(s)\} / [s^2C_1(L_2+L_g)PIR(s)G_{delay}(s) + s(L_1+L_2+L_g) - sL_gG_{delay}(s) + PIR(s)G_{delay}(s) + s^3L_1C_1(L_2+L_g)] \quad (1)$$

where Ig(s) speaks to yield current, PIR(s) is the exchange capacity of the PI and the monotonous controller utilized, and Gdelay speaks to the deferral because of framework examining, count and transmission [23].Fig.3 demonstrates the disentangled, single three-level SAPF model proposed in this paper used to build the secluded framework. The impedance averaging model and little sign linearization methods have been utilized considering the distinction of SAPF from the sine wave inverter models as exhibited in [24], [25]. The proposed model can be isolated into two sections: the present source inverter and the lattice. The present source inverter is

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

made out of the reference current Iref(s), channel impedance ZF(s) and parallel yield impedance ZI(s) presented through input control. The lattice is portrayed by framework EMF E(s), and matrix impedance Zg(s).

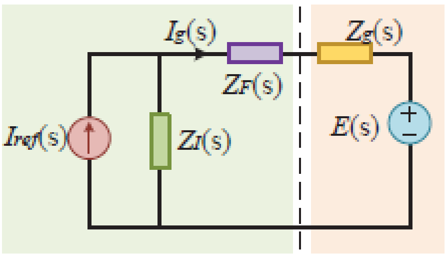


Fig. 3. The proposed single SAPF model in this paper

In light of the comparable model and the superposition hypothesis, the yield current Ig(s) of a solitary SAPF can be composed.

$$I_g(s) = \frac{Z_I(s)I_{ref}(s) - E(s)}{Z_I(s) + Z_F(s) + Z_g(s)} \quad (2)$$

ZI(s) and ZF(s) can be gotten by illuminating Eqs (1) and (2)

$$Z_I(s) = \frac{PIR(s)G_{delay}(s)}{s^2L_1C_1 + sC_1PIR(s)G_{delay}(s) - G_{delay}(s) + 1} \quad (3)$$

$$Z_F(s) = \frac{s^3L_1C_1L_2 + s(L_1 + L_2) + s^2C_1L_2PIR(s)G_{delay}(s)}{s^2L_1C_1 + sC_1PIR(s)G_{delay}(s) - G_{delay}(s) + 1} \quad (4)$$

B. Modeling of parallel three-level SAPF system

In light of the model determined for a solitary three-level SAPF, the structure and model of the measured SAPF framework can be gotten as appeared in Fig.4. Each SAPF module has an autonomous controller, DC transport, and LCL yield channel. For instance, the exchange capacity of SAPF #1 can be gotten utilizing Kirchhoff's present law and the superposition hypothesis as appeared in Eq.(5).

$$I_{g\_1}(s) = G_P(s)I_{ref\_1}(s) + \sum_{n=2}^{N} G_N(s)I_{ref\_n}(s) + G_E(s)E(s) \quad (5)$$

where N is the quantity of parallel units. There are three segments in Eq.(5) meaning three animating sources from the particular framework, which are: current reference of SAPF #1 spoken to by Iref 1, current references of other parallel SAPF spoken to by Iref n, and matrix voltage speak to by E(s). GP(s), GN(s) and GE(s) speak to move elements of these three invigorating sources to Ig 1(s), separately.

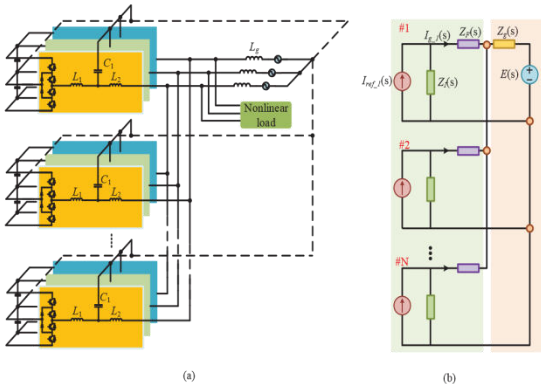


Fig. 4. Parallel structure of modular three-level SAPF

Fig.5 demonstrates the comparable circuits when SAPF 1# is energized by the three distinct sources referenced. As indicated by the superposition hypothesis, these three can be dealt with independently as appeared in Fig.5 (a), (b), and (c). Fig.5(a) is the proportionate circuit model energized by Iref 1. The remaining (N−1) SAPFs are treated as (N −1) impedances in parallel: ZF(s)/(N −1) and ZI(s)/(N − 1). Fig.5(b) demonstrates the proportionate circuit model energized by E(s), wherein, all SAPF are viewed as impedances. Finally, Fig.5(c) demonstrates the equal model energized by Iref N. The impedance of residual (N − 2) parallel inverters is ZF(s)/(N − 2) and ZI(s)/(N − 2).

From the proportionate circuits appeared in Fig.5, GP(s), GN(s) and GE(s) are inferred as following:

$$G_P(s) = \frac{Z_I(s)[Z_I(s) + Z_F(s) + (N-1)Z_g(s)]}{[Z_I(s) + Z_F(s)][Z_I(s) + Z_F(s) + NZ_g(s)]} \quad (6)$$

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

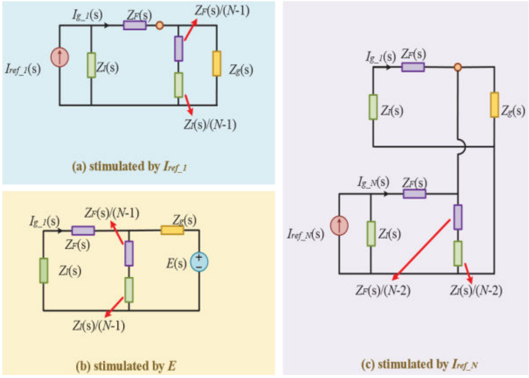


Fig. 5. SAPF #1 stimulated by three sources

$$G_N(s) = \frac{-Z_I(s)Z_g(s)}{[Z_I(s)+Z_F(s)][Z_I(s)+Z_F(s)+NZ_g(s)]} \quad (7)$$

$$G_E(s) = \frac{-1}{Z_I(s)+Z_F(s)+NZ_g(s)} \quad (8)$$

If each SAPF has the same output current, we obtain

$$I_{ref\_1}(s) = I_{ref\_2}(s) = \cdots = I_{ref\_n}(s) \quad (9)$$

$$\begin{aligned} I_{g\_1}(s) &= \\ G_P(s)I_{ref\_1}(s) &+ (N-1)G_N(s)I_{ref\_n}(s) + G_E(s)E(s) \\ &= \frac{Z_I(s)I_{ref\_1}(s) - E(s)}{Z_I(s)+Z_F(s)+NZ_g(s)} \end{aligned} \quad (10)$$

Contrasting Eq.(10) against Eq.(2), it very well may be discovered that for a particular SAPF, for example, previously mentioned SAPF #1, the expansion in the quantity of SAPF associated in parallel makes the proportionate network impedance increment by N times. This can be affirmed promptly by the displaying circuit in Fig.6. Given same parameters for LCL channel and control calculation, the yield impedance ZF(s) of each SAPF module is the equivalent. Each SAPF module is associated at the purpose of basic coupling(PCC) with matrix impedance Zg(s). As appeared in Fig.6(b), Zg(s) can be treated as N divisions of N • Zg(s) in parallel. Since yield current of each SAPF is the equivalent, PCC can be moved to one side as appeared in Fig.6(c). ZF(s) and N • Zg(s) are then associated in arrangement as appeared in Fig.6(c). In this manner, it very well may be unmistakably demonstrated that the proportionate lattice impedance of N parallel SAPF frameworks is expanded by N times.Given the exchange above it is express to comprehend that the full pinnacle of the exchange capacity of a SAPF module shifts towards left when the quantity of paralleled SAPF increments as appeared by the Bode plot in Fig.7. The stage plot in Fig.7 demonstrates that framework strength edge diminishes with expanded N, which represents a more prominent test to the control data transmission edge and reverberation concealment of ordinary measured SAPF.Unlike sine wave matrix tied inverters, SAPF infuses high recurrence consonant current running from 150Hz to 1500Hz as appeared by the concealed region in Fig.7, as opposed to the principal

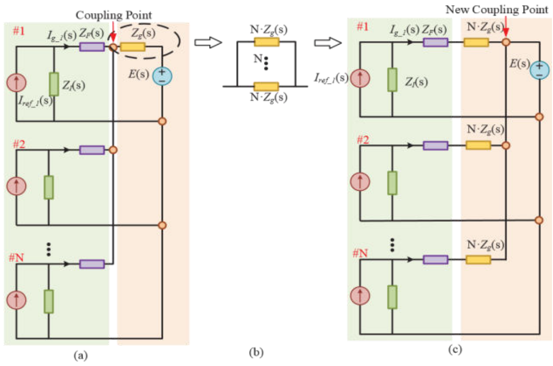


Fig. 6. Modeling of modular SAPF

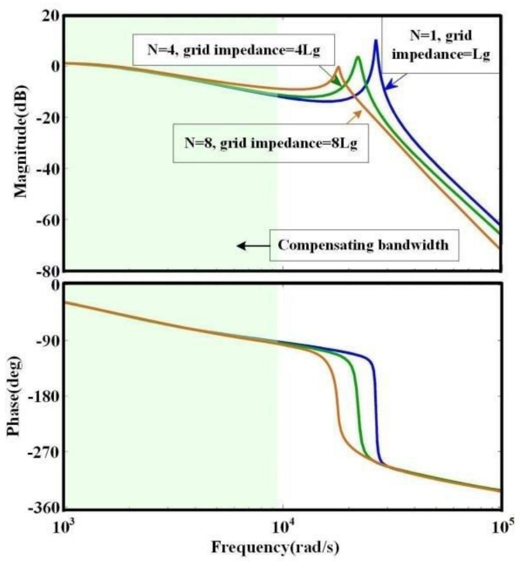


Fig. 7. Bode diagram of $I_g(s)/I_{ref}(s)$ with different grid impedance

sine wave part. For the traditional secluded SAPF, as the recurrence of thunderous pinnacle diminishes while the quantity of modules N builds, the recurrence band of remunerating current will come near the full pinnacle. The steadiness edge likewise drops and reverberation will in general happen. Besides, it can likewise be seen from Fig.7 that the control transmission capacity is never again adequate for high request music remuneration for an expanded N. At long last, in the customary particular SAPF with a similar channel inductance and control parameters, a tradeoff between the dynamic reaction and the steadiness control is hard to get either by aloof segments plan or by dynamic damping control. This is the test that the present exertion plans to in a general sense address.

III. Lcl Filter Design, Resonance Analysis And Self-Adaptive Active Damping For Hybrid Modular Three-Level Sapf

In light of the summed up displaying of secluded SAPF and comprehension of their impediments, a novel cross breed particular three-level SAPF is proposed in this paper. The half and half framework consolidates bigger limit modules and littler modules. Bigger limit modules have higher LCL channel esteems and lower exchanging recurrence while littler limit modules have lower LCL channel esteems and higher exchanging recurrence. The plan intends to remunerate the lower request sounds and higher request music separately. In the proposed crossover framework, the traditional SAPF remunerating band as appeared in Fig.7 is separated into high and low request groups. Such a structure utilizing diverse LCL channel parameters for two remunerating groups enables more space to accomplish tradeoff between the dynamic reaction and the framework soundness control. Next amodular SAPF LCL channel plan technique and a secluded framework reverberation examination will be exhibited, trailed by a novel selfadaptive dynamic damping procedure for crossover measured SAPF.

A. LCL design of modular SAPF

Given the particular SAPF capacities and confinements uncovered in area II, a plan technique for the SAPF latent channel must be created. A well ordered methodology to plan the LCL channel for a particular SAPF is proposed as pursues:

- First the inverter side inductance L1 is planned so as to restrict the present swell created by the SAPF inside 10% evaluated remunerating current [26], [27];
- The worthy degree of the responsive capacity to be consumed by the channel capacitor under evaluated conditions is chosen, and this decides the capacitor esteem [26];
- The by and large inductance of inductors introduced ought to be constrained to well beneath the 10% of the base impedance;
- As appeared from the demonstrating investigation in area II, the identical matrix side inductance changes with the parallel number of modules;
- Minimize the channel volume by utilizing lower inductances and higher capacitances. This is because of the way that SAPF repaying current causes higher voltage drop than the framework tied inverter;
- The reverberation point ought to be higher than that for the sine wave lattice tied inverters in light of the fact that SAPF's repaying band is more extensive;
- Last the present variety rate produced by the SAPF ought to be more prominent than the normal current. This can be communicated by:

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

$$L < \frac{U_{dc} - 1.1U_g}{I_c} \qquad (11)$$

where Udc and Ic are the SAPF dc connect voltage and remunerating current, separately, which forces another restriction to the converter side inductance

B. Resonance and stability analysis of hybrid modular three level SAPF

To research the following and reverberation issues among modules of various limits, rearranged comparable circuit models can be gotten from Fig.5. Fig.8(a) demonstrates a streamlined model for the bigger SAPF module #1 and Fig.8(c) indicates rearranged model for the littler SAPF module #2.In Fig.8(a) and (c), X speaks to the quantity of bigger limit modules and Y speaks to the quantity of littler limit modules. The #1 and #2 converters represent one bigger and one littler limit modules, separately. The other (X −1) bigger limit modules and (Y −1) littler limit modules can be disentangled as impedances. In view of this disentanglement, we can get the bode graph of Ig L(s)/Iref L(s) appeared in Fig.8(b), where (X − 1) bigger limit module impedance, Y littler limit module impedance and framework impedance are plotted. The repaying current of #1 SAPF with a data transmission running from 150Hz to 650Hz, is separated by the impedance of the network, (X−1) SAPF with bigger limit and Y SAPF with lower limit. It tends to be seen that inside the repaying band under thirteenth request, matrix impedance is a lot littler than the impedance of (X − 1) SAPF and Y SAPF. The remunerating current is chiefly infused into the network. It is unmistakably demonstrated that the repaying current band of SAPF #1 is a long way from the reverberation top and gives adequate control transmission capacity. In this manner, it enables more space to tradeoff between the remunerating dynamic reaction and steadiness control.

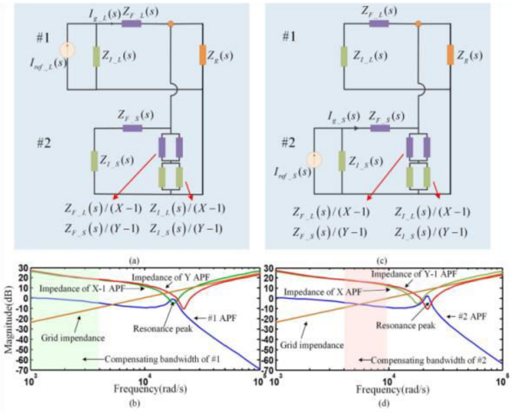


Fig. 8. Equivalent circuit and bode diagram of the hybrid parallel SAPF

For SAPF #2, the littler limit module infuses remunerating sounds higher than the thirteenth request, i.e., from 650Hz onwards. As appeared in Fig.8(d), the Bode outline of Ig S(s)/Iref S(s) demonstrates that littler LCL parameters configuration push the resounding pinnacle higher and makes adequate control transmission capacity for high request remunerating current. As opposed to the regular particular SAPF in Fig.7, Fig.8(d) demonstrates that the secluded SAPF empowers more prominent edge and data transmission to tradeoff between powerful reaction and solidness control. In addition, the higher exchanging recurrence and low inductance further improve the present following reaction capacity. As indicated by the repaying band for SAPF #2, the framework impedance is moderately enormous, yet X SAPF is structured with higher LCL parameters. Accordingly, lattice impedance is still a lot littler than the impedance of X SAPF. Further, the higher request consonant parts are normally littler in extent, and thus, less lower limit modules, conceivably a couple, is required. In short it tends to be inferred that the repaying current essentially streams

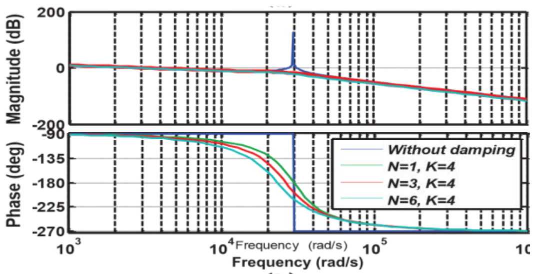
International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

into the grid.It ought to be noticed that in the half breed framework proposed in this paper, the dynamic reaction and the security control are adjusted by latent channel configuration as well as constrained by dynamic damping. Along these lines, the reverberation shouldn't be smothered further by the controller increase guideline as that in [14], [15] which bargain current following exactness.

In this paper, to accomplish quick current unique reaction and remarkable steadiness control, a novel self-versatile reverberation smothering procedure is then proposed for the half breed paralleled framework.

C. Limitations analysis of conventional resonance damping methods and the novel self-adaptive active damping for hybrid modular three-level SAPF

In spite of the fact that LCL channels can more readily fulfill matrix interconnection guidelines with fundamentally littler size and cost, they additionally trigger reverberation between the inverter and the lattice. A functioning or a detached damping measure is typically embraced to smother potential resonances. If there should be an occurrence of secluded SAPFs, a functioning damping strategy creates better results.The dynamic damping technique proposed in [27] is generally utilized in the network tied inverter, which presents the capacitor branch present as the input amount to improve the damping impact of the framework. Be that as it may, in the strategy portrayed in [27], the damping input control coefficient K is fixed ignoring the lattice side impedance, and the converter side inductance may fluctuate. Consider the model where the converter side inductance differs, if K is constantly fixed when the inductance brings due down to the adjustment in burden current, the framework steadiness edge contracts as appeared in Fig.9(a). As appeared in Fig.9(b), with an expanded number of modules N in parallel, lattice impedance develops to N • Lg. The resounding recurrence of the SAPF framework shifts towards the left and the solidness edge of the SAPF framework decreases.As appeared from the measured SAPF displaying, the equal network impedance differs generally because of the quantity of modules associated. Besides, the converter side inductance likewise changes significantly because of the high peak factor of repaying current as opposed to customary sine wave inverter. Hence, the strategy in [27] can't be legitimately utilized. Rather, we proposes a novel self-versatile dynamic damping for the cross breed SAPF. In this technique, K isn't fixed yet got through enhancement on the modules number, and all the more significantly, the moment inductance dictated by the remunerating current.The epic self-versatile dynamic damping strategy dependent on capacitor branch current criticism for the crossover particular three level SAPF is appeared in Fig.10. The new technique includes a variable dynamic damping coefficient K0for various estimations of N and various benefits of remunerating current. Its comparing control outline is appeared in Fig.11.In this paper, just the inductor current following reference is examined, E(s) speaking to the lattice voltage carries on as an unsettling influence and is viewed as zero when investigating the reverberation and soundness of half and half secluded three-level SAPF.



(b)

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

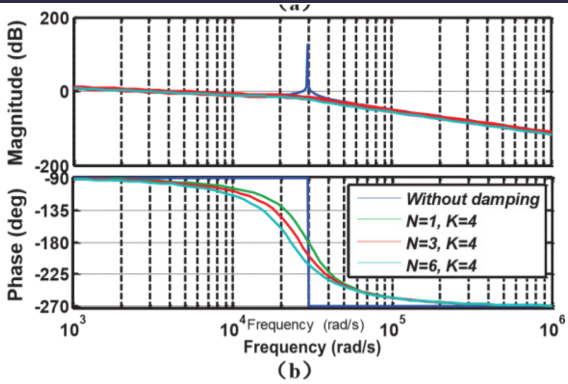


Fig.9.(a)Frequencycharacteristicswith differentoutputcurrent(b)Frequency characteristicswithdifferent numberof parallelunits

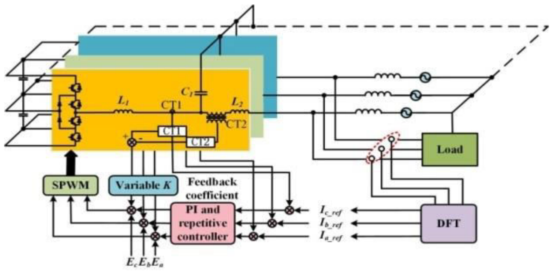


Fig. 10. Controllerdesign withproposed self-adaptiveactivedamping

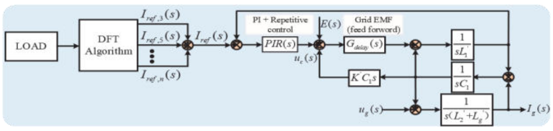


Fig. 11. Novelself-adaptiveactivedampingstrategy

Inthis manner ignoring E(s) andthe impact of Gdelay(s), theopen circle move capacity of the framework can be given by.

$$G_{gc}(s) = \frac{I_g(s)}{u_c(s)} = \frac{1}{L_1'(L_2'+L_g')C_1 s^3 + K'(L_2'+L_g')C_1 s^2 + (L_1'+L_2'+L_g')s} \quad (12)$$

where K0 is the variable criticism coefficient, arethe genuine inductanceas an element of the yield currentand L0g is the comparable matrix impedance ofoneSAPF in the half breed parallelSAPF, and canbe determined bythe cross breed identical circuitin Fig.8.

To improve the dialog, Ggc(s) canbe re-composed asthe result ofan essential circle andasecond request wavering circle:

$$G_{gc}(s) = \frac{1}{L_1'(L_2'+L_g')C_1 s}\frac{1}{s^2 + K's/L_1' + \omega_{res}^2} \quad (13)$$

where ω_{res} is theresonance frequency ofthe secondorder oscillation loop.

$$\omega_{res}^2 = \frac{L_1'+L_2'+L_g'}{L_1'(L_2'+L_g')C_1} \quad (14)$$

Accordingtothe definition of dampingratio ξ inthe second orderoscillation loop, itcan be givenas:

$$\xi = \frac{K'}{2L_1'\omega_{res}} \quad (15)$$

In the under damped secondorder oscillation loop, givena decrease in ξ, the overshoot increases andthe response timedecreases. On the otherside, with the increaseof ξ, the overshootdecreases, but the system response slowsdown. According to the control theory, whendamping ratio equals to 0.707, the system overshoot is moderate and the regulation time is short, where the system is at the best damping condition. In SAPF applications, at the point of ξ = 0.707, the hybrid SAPF system can reach an optimal tradeoff between resonance suppression and time response. Therefore, the optimum damping ratio of the second order oscillation loop is choosen as ξ = 0.707.

Take ξ = 0.707 and substitute Eq.(14) into Eq.(15), we can attain the expression of the optimized feedback coefficient K^0.

$$K' = \sqrt{\frac{2L_1'(L_1'+L_2'+L_g')}{(L_2'+L_g')C_1}} \quad (16)$$

Further examination of Fig.11 demonstrates that the framework solidness is essentially controlled bythe criticism coefficient K0. Fig.12 demonstrates summed up root locus of (12) with various K0. The steady scope of K0 is from0.714to11. In this way, in our framework, to guarantee K0 determined by (16)isin a sensible range, we oblige the criticism coefficientK0 as pursues

$$K' = \begin{cases} 0.714 & K' < 0.714 \\ \sqrt{\frac{2L_1'(L_1'+L_2'+L_g')}{(L_2'+L_g')C_1}} & 0.714 < K' < 11 \\ 11 & 11 < K' \end{cases} \quad (17)$$

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

The proposednovel self-versatile dynamic dampingcontrol technique forthe half and half secluded three level SAPF can be utilized

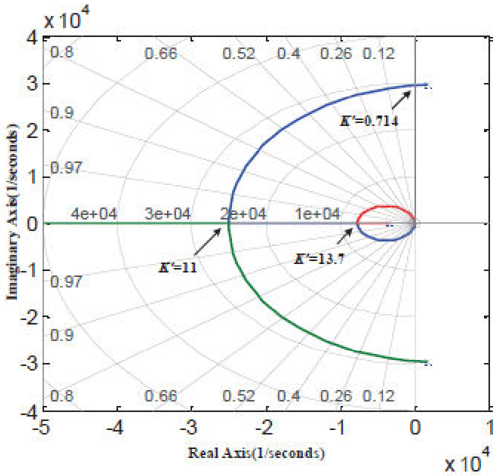


Fig. 12. The generalizedrootlocusof (12) withdifferentK^0

not just in mechanical applications where variable burdens are associated with the framework, yet in addition, the situations where there is communication of various SAPF frameworks associated with a frail power matrix, and an expanded steadiness edge isrequired forthe security of SAPF framework.

IV. SIMULATION AND EXPERIMENTAL RESULTS

A. Simulation results

Impact ofthe inductance and the adjustment inthemodule number on the framework soundness edge is delineated inFig.9with a consistent damping input coefficientK. So as to decipher it unequivocally, we do two reproductions in MATLAB/Simulink. Fig.13 demonstrates the reenactment results for threeSAPFs in parallel activity withthe heap current significantly increased at t = 0.16s. The channel inductance is balanced by the difference in the yield current at t = 0.16s, whilethe input coefficient K of dynamic dampingiskept steady. We can see from the outcomes thatbeforet=0.16s, the half and half SAPF framework with two bigger units andone littler units repays the sounds well. The heap currentand yield flows significantly increased at t = 0.16s, and thusly the inductance diminishes. Be that as it may, because of the unaltered criticism coefficient K, reverberation happens in the framework. This is as per the decline in dependability edge inFig.9(a).

InFig.14,the working conditionis equivalent to depicted in Fig.13 before t = 0.16s with the exception of thatthe inductance issetas a steady worth. After t = 0.16s, loadcurrent duplicates and we turn onanother three SAPFunits, which implies thatthe parallel unitsnumber N increments from 3 to 6. Framework reverberation happens comparably on account of the unaltered K. The recreation results again coordinate the ends got from Fig.9(b).

B. Experimental results

The crossoverSAPF framework as appeared inFig.15is likewise actualized to confirm theproposed plan andresonance suppression system.

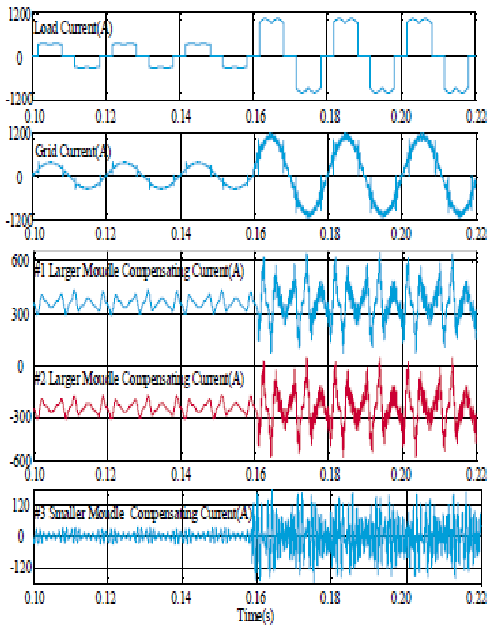


Fig. 13. Simulation results of output current increase with three SAPF in parallel operation

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

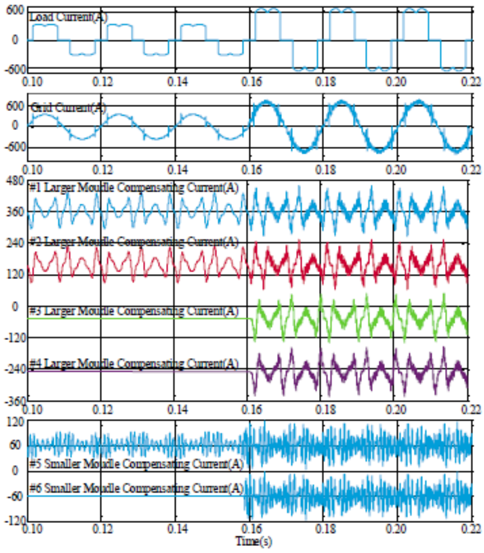


Fig. 14. Simulation results of parallel units increase with six SAPF in parallel operation

The bigger modulepower ratingis fixedat 100A intending to remunerate the low request sounds under thirteenth request, and the littler 50A module repaying the high request music higher than thirteenth request. The fundamental parametersare recorded in Tab. I.

The principle circuitsare appeared in Fig.16. 100 An Infineon threelevelpower module F3L100R07W is picked for 50A littler module. Two F3L100R07W are associated in parallelto fill in as the 100 A bigger powermoduleas appeared inFig.16(b).

Fig.17&Fig.18 demonstrate the self-versatile damping test

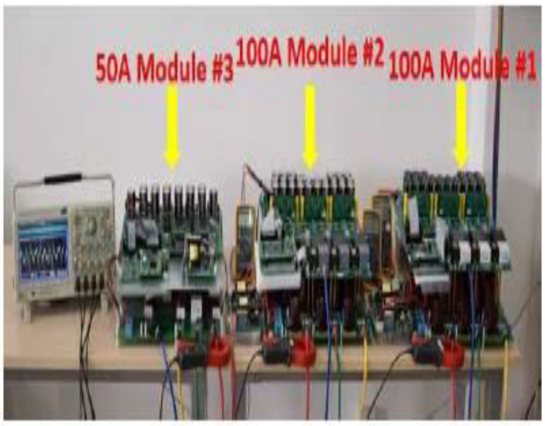


Fig. 15. Hybridmodular three-levelSAPFprototype

TABLE I
PROTOTYPE AND THE EXPERIMENTAL PARAMETERS

Item	Value
Grid frequency	$50Hz$
Switching frequency(100A,50A)	$20kHz$, $40kHz$
Phase voltage(RMS)	$230V$
DC voltage	$800V$
100A module LCL	$800/4\mu H$, $20\mu F$, $75\mu H$
50A module LCL	$200/2\mu H$, $10\mu F$, $50\mu H$
IGBT module	F3L100R07W2E3

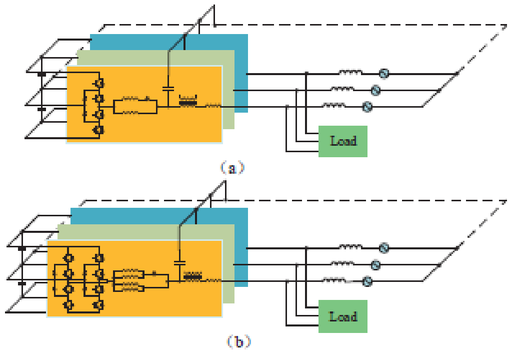


Fig. 16. (a)50A moduletopology(b)100A moduletopology

Results. InFig.17, Channel 1and5 are burden currentand lattice current, individually. Beforet= 32ms, #2SAPF (100A) and #3SAPF (50A) areinstable activity utilizing conventional dynamic damping technique as appeared by Channel 2,3and4. Att= 32ms, #1 SAPF (100A) begins its activity as appeared by Channel 2 utilizing customary dynamic damping strategy. It tends to be seen fromthe waveforms that the conventional dynamic damping strategy withafixed damping criticism coefficient neglects to viably stifle reverberation on the grounds that the quantity of parallel modulesNchanges. Aftert = 64ms, the measured framework begins to work with theproposed self-versatile dynamic damping strategy, andthe reverberation is all around stifled. Fig.18 demonstrates thetest resultswith an adjustment in burden current. Channel 2, 3 and4 demonstrate the remunerating flows of #1SAPF(100A), #2SAPF(100A), #3 SAPF(50A), whichare steady beforet = 32msusing conventional dynamic damping. Nonetheless, with burden

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

multiplied at t = 32ms, reverberation begins to show up in measured framework. At t = 64ms, the proposed selfadaptive dynamic damping is connected to the framework and reverberation vanishes. This is on the grounds that the criticism coefficient presently differs withchangein burden current. Subsequently, the reverberation stifled, renderingthe frameworkstable.

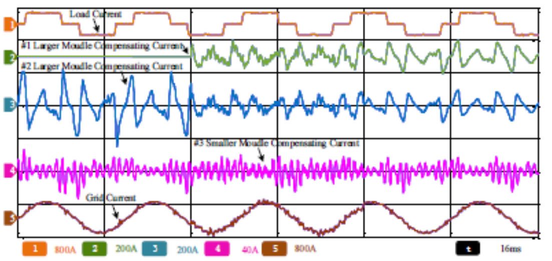


Fig. 17. Compensatingcurrent ofhybrid moduleswith differentdampingmethods

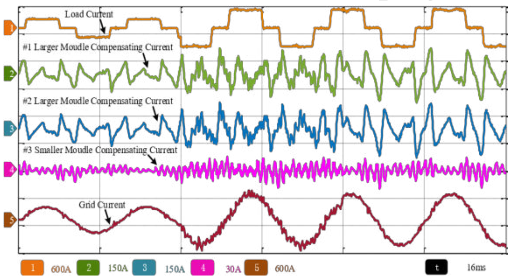


Fig. 18. Compensatingcurrent ofhybrid moduleswithloadchange

It very well may be finished up from Fig.17 and Fig.18 thatwith afixed input coefficientK, reverberation happens when inductanceorparallel number Nchange. These trial resultsare steady withthe examination in Fig.9 and the recreation resultsin Fig.13 and Fig.14.Fig.19 demonstrates the remunerating flows of 50A module and 100A modulesinparallel utilizing the self-versatile damping procedure togetherwith the range ofnetwork current when pay. From Channel 1 to Channel 5 are: I) the heap current; ii) modules #1 and #2 (100A) repaying current; iii) module #3 (50A) remunerating current, and iv) the network current after pay. This outcome demonstrates that the 50A module has quick powerful reaction sinceithas lower LCL parametersandhigher exchanging recurrence. TheTHD of matix current is 27.13% before the remunration and 4.89% after.

V. CONCLUSION

Thispaper enhances customary particular SAPF numerical modelsto research tradeoffsbetween unique reaction and dependabilitycontrol. As indicated by the investigation results got fromthemodel, a novel half breed secluded threelevelSAPF structure isproposed. Rather than past techniques, the proposed framework is made out of twomodules, eachwith various current conveying limits, LCL channel parametersand exchanging frequencies. At last, anovelself versatile reverberation concealment procedure is proposed to consider the varieties in the quantity of modules and burden current.

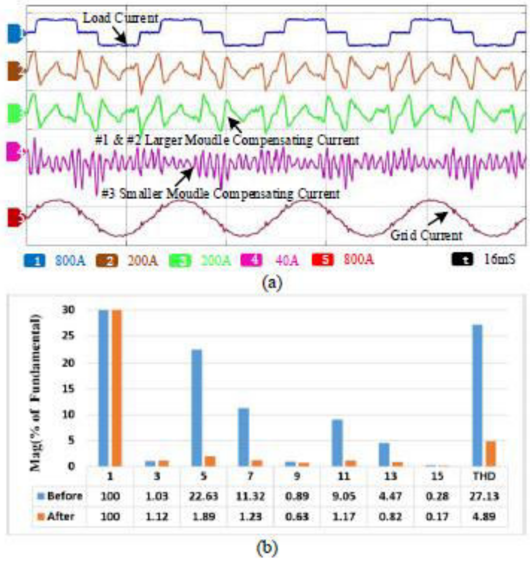


Fig. 19. (a)Experimentalresults ofthree SAPFinparallel (b) THDof gridcurrent

Hypothetical examination and exploratory outcomes affirm that the half breed particular SAPF and its self-versatile reverberation concealment procedure can accomplish a superior tradeoff between unique reaction and security control as contrasted and the regular measured SAPF.

Theproposed framework might beutilized in modern applications, specifically for powerquality improvementin feeble power matrices.

REFERENCES

1. JTooth,GXiao,X.Yang,andY.Tang, "Parameter plan of a novel arrangement parallel-thunderous lcl channel for single-stage half-connect dynamic power channels," IEEE Transactions on PowerElectronics, vol. 32, no. 1, pp. 200–217, Jan 2017.
2. JCAlfonso-Gil,EPerez,CArino,H. Beltran, "Advancement' calculation for particular remuneration in a shunt dynamic power channel," IEEE Transactions onIndustrialElectronics, vol.62,no.6,pp.3351–3361,2015.
3. M.Angulo,D.A.Ruiz-Caballero,J.Lago, M.L.Heldwein,andS.A.Mussa, "Dynamic power channel control system with understood shut circle current control and thunderous controller," IEEE Transactions onIndustrial Electronics,vol.60,no.7,pp.2721–2730,2013.
4. JHe,YWLiand FBlaabjerg, "Adaptable microgrid control quality upgrade utilizing versatile mixture voltage and current controller," IEEE Transactionson Industrial Electronics, vol. 61, no. 6, pp. 2784–2794, 2014.
5. PAcuna,LMoran,MRivera,JDixon, and J.Rodriguez, "Improved' dynamic power channel execution for inexhaustible power age frameworks," IEEE exchanges onpower gadgets, vol.29no.2, pp687–694,2014.
6. HYi,F Zhuo,YZhang,YLi,W.Zhan, W.Chen, J.Liu, "A source-current-recognized shunt dynamic power channel control plan dependent on vector resounding controller," IEEETransactions on Industry Applications, vol. 50, no. 3, pp. 1953–1965, 2014.
7. R.Dian,W.Xu,andC.Mu,"Improved negative grouping current identification and control procedure for h-connect three-level dynamic power channel," IEEETransactionsonAppliedSuper conductivity, vol.26,no.7,pp. 1–5, 2016.
8. S.Rahmani,N.Mendalek,andK.Al-Haddad, "Exploratory structure of a nonlinear control strategy for three-stage shunt dynamic power channel," IEEE Transactions on Industrial Electronics, vol. 57, no. 10, pp. 3364–3375, 2010.
9. Z.Wang,C.Xie,C.He,G.Chen, "A waveform control procedure for high power shunt dynamic power channel dependent on redundant control calculation," inApplied Power Electronics Conferenceand Exposition (APEC), 2010 TwentyFifthAnnual IEEE. IEEE, 2010, pp. 361–366.
10. Y.Tang,P.C.Loh,P.Wang, F.H.Choo, F.Gao,F.Blaabjerg,"Summed up structure of elite shunt dynamic power channel with yield lcl channel," IEEE Transactions onIndustrial Electronics, vol59, no3, pp1443–1452, 2012.