SHUNT ACTIVE POWER FILTER BASED ON CASCADED TRANSFORMERS COUPLED WITH 3-PHASE BRIDGE CONVERTERS

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Abstract: This paper proposes a multilevel shunt active power filter (SAPF) to deal with either harmonic currents compensation or reactive power compensation. Such a device can reduce the harmonic distortion at the grid currents provided by non-linear loads located in stiff systems. The proposed SAPF is based on three-phase bridge (TPB) converters connected to cascaded single-phase transformers. The transformers arrangement permits the compensator to use a single dc-link unit which simplifies the control strategy and number of sensors. The multilevel waveforms are generated by using a suitable PWM strategy associated with the transformers turns ratio. Modularity and simple maintenance make the proposed SAPF an attractive solution compared to some conventional configurations. The model, PWM technique and control strategy, are presented as well as studies considering harmonic distortion and semiconductor losses estimation.

Keywords: SAPF, bridge converters, PWM technique

I. INTRODUCTION

In the traditional approach, in order to suppress harmonics in power systems, passive power factor correction techniques with line chokes and bulk capacitors are used but they are neither convenient nor economical; they need bulky components and are not adaptive to changing needs. However, the remarkable progress made in the field of the power electronic devices made the systems design for harmonics compensator, named as Active Power Filters (APFs) is a reality. These APFs eliminate the components of power that do not contribute to the net transfer of energy from the source to the load. New systems and appliances can be built with the unity power factor and low current harmonics front end rectifiers but large number of systems that are already in operation need a special attention. Active power filters can be divided in two classes: series type and shunt type active filters, as defined in [31], from the system point of view. The combination usage of shunt active and passive filters has already been in use to compensate large-rated loads input current harmonics. Active Power Filters also help in meeting the IEEE 519-92, IEC-555 and European EN 61000-3-2/IEC 61000-3-4 standards for allowable harmonic contents of mains. To prevail over the above drawbacks of the large number of systems that are already in the field and in operation, power quality improvement filters are included as an inherent part of the total power network system that produces high efficiency, reduced size and regulated output.

The problems with EV chargers are generally associated with multiple stages of power conversion; circulating currents in topologies with high-frequency transformers; losses in the switches; reverse recovery losses in the diodes; or the losses in the snubber circuits associated with the topologies. The reduction in the conduction losses is limited by the availability of the devices with low on-state voltage drop (or low RDSON in MOSFETS)

II. LITERATURE SURVEY

The amount of levels created at the voltage vrj for the proposed setup is progressively conspicuous when appeared differently in relation to the standard one, considering a comparable number of power switches. In any case, to facilitate a comparable number of semiconductors hardships, the topologies need to work with different number of stages (i.e., unmistakable amounts of transformers). From now on, the proposed course of action will require one additional scaled-transformer for each stage. Coincidentally, such an additional transformer must have cut down assessments in examination with the transformers used for the past stage. The outcomes have exhibited its comprehension with the speculative strategies. Ordered examinations taking a gander at the transformer assessments will be investigated for a general cost estimation between the proposed and normal game plans. [1]

This paper displays a shunt dynamic power channel reliant on open-end winding (OEW) transformer for three-arrange three-wire systems. The proposed plan is included two converters, with three legs in each one, course of action related all through a three-organize OEW transformer.

Show, beat width change (PWM) approach, and control plan are shown as well. The rule favored point of view of the proposed system lies on the stunned waveform age, which grants decline of either consonant mutilations or trading mishaps. This proposed topology is sensible for medium-voltage transport systems. Amusement and test outcomes affirm the theoretical examination. [2]

This paper proposes a stunned course of action compensator (MSC) to oversee voltage hangs/swells, symphonious pay, or responsive power compensation. Such a device can be considered as a dynamic voltage restorer or a game plan dynamic power channel (Series-APF). The MSC can upgrade the power idea of weights arranged in firm structures. The course of action relies upon three-organize interface (TPB) converters related by techniques for fell single-arrange transformers. This arrangement permits the use of a singular dc-interface. A theory for K - arranges in which K - transformers are joined with K-TPB converters is shown. The topology awards delivering a high number of levels in the voltage waveforms with a low number of force switches in connection with an excellent topology. The stunned waveforms are delivered by the converters through a fitting pulsewidth control (PWM) strategy that contemplates the transformer turns extents. Estimated quality and direct help make the proposed MSC an engaging plan differentiated and some standard structures. Illustrate, PWM framework, and when all is said in done control are discussed in this paper. Reenactment and exploratory results are shown as well. [3]

In this paper, pay of the dc-side voltage music of a medium-voltage (MV) 12-beat cooling/dc converter is practiced using a course of action dynamic power channel (APF). The yield voltage music are liable to the converter ending put off focuses and, in this manner, on the specific power locus sought after by the climate control system/dc converter. This power locus ensures slightest fifth and seventh sounds (indicate rms) in the data current which gives minimum data current total consonant twisting when the responsive power is under 0.5 p.u. The course of action APF is related between the stack and the converter yield by methods for an alluring enhancer to get rid of the dc current from the APF inverter, as such diminishing inverter adversities. Voltage consonant compensation using a course of action APF, with and without an appealing speaker, is examined with both resistive and inductive weights. The reenactment results for reimbursing a 3.3-kV MV 12-beat converter structure are likely affirmed using a scaled model 12-beat converter with a game plan APF. [4]

This paper shows a revised control procedure for a twofold three-arrange topology of a bound together power quality conditioner-iUPQC. The iUPQC is made out of two unique channels, a course of action dynamic channel and a shunt dynamic channel (parallel powerful channel), used to take out sounds and unbalances. Not exactly equivalent to a conventional UPQC, the iUPQC has the course of action channel controlled as a sinusoidal current source and the shunt channel controlled as a sinusoidal voltage source. Thusly, the beat width change (PWM) controls of the iUPQC deal with an outstanding repeat go, since it is controlled using voltage and current sinusoidal references, not equivalent to the standard UPQC that is controlled using nonsinusoidal references. In this paper, the proposed structure control, control stream examination, and preliminary delayed consequences of the made model are shown. [5]

Dynamic power channels make sideband sounds over a wide repeat stretch out around the distinctive carrier repeat music, and these can encroach into the low repeat run. This issue is particularly essential when low transporter key repeat extents are used, for instance, in aeronautics applications, where high focal frequencies exist. A three-arrange amazed powerful shunt channel with a low trading repeat is proposed to mitigate the most decreased demand transporter repeat terms. In any case, low transporter frequencies incite reference voltage arrange delay and debilitating and can show important baseband music. These effects can't be concealed by using distinctive modulator converters. In watching out for these issues, an improved change approach is proposed in this work licenses commitment cycle invigorating (N - 1) times per trading period for each H-framework of one time of the N - level converter [rather than only more than once as in the as often as possible tried heartbeat width balance (PWM)]. The proposed parity approach is then joined with farsighted current control with the true objective to redesign the structure execution. The control circle execution appeared differently in relation to as often as possible inspected PWM is checked through generations and likely by using a three-arrange five-level powerful shunt control directs in a 400-Hz control compose. [6]

DC-associate capacitors are a basic part in the bigger piece of power electronic converters which add to cost, size and dissatisfaction rate on a huge scale. From capacitor customers' point of view, this paper shows a review on the improvement of resolute nature of dc interface in power electronic converters from two perspectives: 1) reliability orchestrated dc-associate arrangement plans; 2) shaping checking of dc-interface capacitors in the midst of action. Frustration frameworks, dissatisfaction modes and lifetime models of capacitors proper for the applications are similarly inspected as a start to understand the material exploration of-disillusionment. This review serves to give a sensible picture of the best in class examine here and to recognize the relating troubles and future research direction for capacitors and their dc-interface applications. [7]

Another time of force devices was made with the development of the thyristor in 1957. Starting now and into the foreseeable future, the advancement of present day control devices has seen its most extreme limit and is quickly developing in the usages of age, transmission, dispersal, and end-customer use of electrical power. The execution of force electronic systems, especially to the extent capability and power thickness, has been incessantly upgraded by the heightened research and types of progress in circuit topologies, control designs, semiconductors, latent sections, mechanized banner processors, and structure blend developments. [8]

In this paper, a novel arrangement for the estimation of the equivalent game plan impediment (ESR) of the dc-associate electrolytic capacitor in three-organize cooling/dc beat width-converters is proposed for condition checking. Beginning, a controlled cooling current part is mixed into the information. By then, it prompts cooling voltage swells on the dc yield. By controlling these forced air system voltage and current parts with cutting edge channels, the estimation of the ESR can be processed, where the recursive scarcest squares count is used for reliable estimation results. Similarly, the estimation of the ESR is modified by considering the temperature affect, for which a clear temperature-identifying circuit has been arranged. The reenactment and preliminary outcomes show that the estimation slip-up of the ESR is inside a sensible range, thusly engaging the confirmation of the fitting time for the substitution of the capacitor. [9]

Stunned converters have been under imaginative work for more than three decades and have found productive mechanical application. Regardless, this is so far a development a work in advancement, and various new responsibilities and new attachment topologies have been represented over the latest couple of years. The purpose of this paper is to social event and studies these on-going responsibilities, with the true objective to develop the present bleeding edge and examples of the advancement, to give perusers an intensive and snappy review of where amazed converter advancement stands and is going. This paper initially presents a succinct audit of settled in amazed converters solidly arranged to their present state in current applications to then concentrate the trade on the new converters that have progressed into the business. Moreover, new reassuring topologies are inspected. Progressing propels made in change and control of amazed converters is moreover tended to. A unimaginable bit of this paper is committed to show non-customary applications controlled by stunned converters and how amazed converters are transforming into an engaging development in various mechanical parts. Finally, some future examples and challenges in the further enhancement of this advancement are discussed to motivate future responsibilities that address open issues and examine new possible results. [10]

III. SYSTEM ARCHITECTURES

In this paper, a SAPF based on cascaded transformers coupled with three-phase-bridge (TPB) converters is proposed. Such a structure is generalized for K-stages in which K three-phase transformers are coupled with KTPB converters. Equivalent multilevel operation is achieved with reduced number of semiconductors devices if compared to conventional HB one. The multilevel waveforms are generated by TPB converters by using suitable PWM strategy associated with the transformers turns ratio. The modularity and simple maintenance makes proposed SAPF an attractive solution in comparison with some conventional configurations.

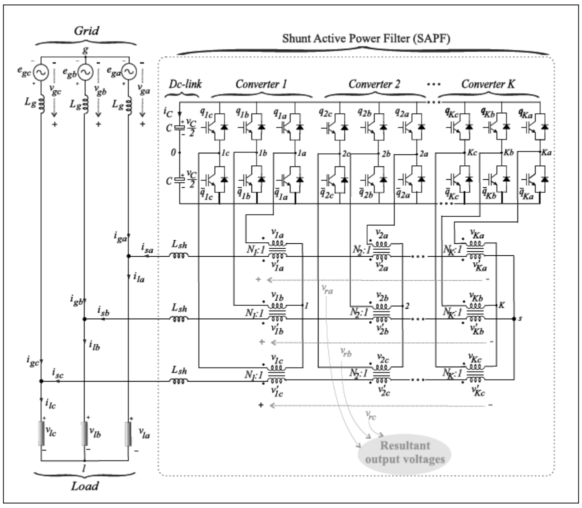

Fig Proposed SAPF generalized with K-cascaded transformers per phase wye-connected with K-three-phase-bridge converters.

The configuration depicted in Fig. 1 is generalized for K-stages (i.e., K tree-phase-transformers and K-three-phase bridge converters). The converter legs are represented by 2K-power switches per phase and 6K per stage (i.e., q1j and q1j for first stage, q2j and q2j for second stage, ..., qKj and qKj for K-stage) in which the subscript j is related to each phase (e.g., j = a; b; c). The conduction state of all power switches is represented by an homonymous binary variable, where q = 1 indicates a closed switch and q = 0 an open one. In addition, power switches q and q are complementary to each other.

The converter pole voltages (v1j0, v2j0,..., vKj0), can be expressed as

$$v_{kj0} = (2q_{kj} - 1)\frac{v_C}{2} \quad \text{.......} (1)$$

Where k corresponds to each stage (i.e., k = 1; 2; 3; K), j is related to each phase (j = a; b; c) and vC is the dc-linkvoltage. A previous work in which the converter was considered as a series compensator. Since the converter equations are similar to those presented before, some of them are not detailed in this paper. Taking into consideration the leakage inductance of a transformer and external interfacing shunt inductance represented by lsh and the load dependent loss of a transformer denoted by rsh, a differential equation for shunt active power filter can be written as

$$v_{rj} - v_{gs} = l_{sh}\frac{di_{sj}}{dt} + r_{sh}i_{sj} - l_g\frac{di_{gj}}{dt} - r_g i_{gj} + e_{gj}$$

…. (2)

Where vrj are the resultant voltages of the converter related to the secondary voltages of the scaled transformers and vgs is voltage between the neutral point's g and s.

From the current node it can be written

$$i_{sj} = i_{lj} - i_{gj} \qquad \text{…… (3)}$$

Where the load currents i_{lj} are given by the load model, replacing (3) in (2) will give

$$v_{rj} - v_{gs} = \overbrace{-(l_g + l_{sh})\frac{di_{gj}}{dt} - (r_g + r_{sh})i_{gj}}^{\text{1st term}} \underbrace{+ l_{sh}\frac{di_{lj}}{dt} + r_{sh}i_{lj} + e_{gj}}_{\text{2nd term}}.$$

From the standpoint of control, the 2nd term in (4) represents perturbations which must be compensated by the controller. The voltages at the secondary side of each transformer (v01j, v02j, ..., v0Kj) are associated with v_{rj} such that

$$v_{rj} = \grave{v}_{1j} + \grave{v}_{2j} + \cdots. + \grave{v}_{Kj} \quad \text{….. (5)}$$

Where v0

1j = N1 (v1j0-v10), v0

2j = N2 (v2j0 - v20)... v0

K j = NK (vKj0 - vK0), in which N1, N2, ..., NK are the transformers turns ratios associated with converters 1, 2,..., K, respectively.

Considering a perfect isolation from primary to secondary side of the transformers (i.e., ideal transformers), the output voltages (vrj) of the resultant converter can be expressed as

$$v_{rj} = v_{rj0} - v_{r0} \quad \text{….. (6)}$$

$$v_{rj0} = N_1 v_{1j0} + N_2 v_{2j0} + \cdots + N_K v_{Kj0} \quad \text{…. (7)}$$

$$v_{r0} = N_1 v_{10} + N_2 v_{20} + \cdots + N_K v_{K0} \quad \text{…… (8)}$$

Since the system is assumed to be a balanced three-phase three-wire system (i.e., vka+vkb+vkc = 0 and ika+ikb+ikc =0) the voltage vro is given by

$$v_{r0} = \frac{N_1}{3}\sum_{j=a}^{c} v_{1j0} + \frac{N_2}{3}\sum_{j=a}^{c} v_{2j0} + \cdots + \frac{N_K}{3}\sum_{j=a}^{c} v_{Kj0} \quad \text{…. (9)}$$

Substituting (9) in (6) will give

$$v_{rj} = v_{rj0} - \frac{N_1}{3}\sum_{j=a}^{c} v_{1j0} - \cdots - \frac{N_K}{3}\sum_{j=a}^{c} v_{Kj0}$$

It should be noted that the voltages vrj can have a maximized number of levels if the voltages vrjo assume a suitable sequence of the switching states. This is achieved by setting transformers turns ratios (N1, N2, ..., NK) properly. A particular case, with 3 transformers per phase and 3 TPB converters has been described for series compensation application. It has shown that voltages vrj can reach 8 different levels per phase according to the switching states. In this case, the converter must operate with different transformer turns ratios (i.e., Nk = 2(k-1)). The one-dimension region of output voltage vrj for each phase (i.e., j = a; b; c) associated with switching states [q1j , q2j and q3j] was described. Such a representation permits to easily synthesize the reference output voltage by using always the nearest switching states to the reference output voltage. This approach has the advantage of reducing the harmonic distortion of the power converter topology. No redundant levels are provided if the transformer turns ratios are considered to have the maximized number of different levels (i.e., 2K). The redundancy levels (with more than one switching states giving the same voltage level) can be obtained by choosing some equal transformer turns ratios. For instance, for 2 stages operation the redundancy is achieved by using N1 = N2 = 1. The redundancy property can be used in order to improve other features associated to the power converters operation, such as the number of commutations or dc-link voltage balancing, which has considered cascaded H-Bridge converters applied with one-dimension modulation approach .

IV. CONCLUSION

A shunt active power filter (SAPF) was studied in this paper. The configuration is based on cascaded transformers coupled with three-phase bridge (TPB) converters. The proposed SAPF has presented lower harmonic distortion content in comparison with the conventional one. Such a reduced harmonic distortion has led to compare the semiconductor losses by fixing the same WTHD value for proposed and conventional configurations. In this way, the proposed configuration could have its switching frequency decreased to match the same WTHD value obtained with the conventional one. Conventional topology has also isolation transformers, a semiconductor losses reduction close to 82% was observed in comparison with the conventional topology. A generalization for K-cascaded TPB converters and K transformers was presented. Such a generalization was validated experimentally for 1, 2 and 3 stages. The proposed SAPF has presented advantages because it provides the improvement of the quality at the signals generated by the PWM converter, by maintaining its modularity features and using simple dc-link control strategy since it need just a single dc-link unity.

V. FUTURE SCOPE

The number of levels generated at the voltage vrj for the proposed configuration is greater when compared to the conventional one, considering the same number of power switches. However, to match the same number of semiconductors losses, the topologies have to operate with different number of stages (i.e., different numbers of transformers). Hence, the proposed configuration will need one additional scaled-transformer for each phase. Nevertheless, such an additional transformer must have lower ratings in comparison with the transformers used for the previous stage

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