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A Novel Fuzzy Approachof Combining Shunt Hybrid Power Filterand TCR for Power Quality

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ABSTRACT: In Recent scenarios in the distribution system is harmonics created by nonlinear load and unbalance current. It affects not only the working of adjacent loads but also shorten the life of power equipment by creating excessive losses. In this paper, a fuzzy controlled shunt active power filter with TCR is described to maintain the (Total Harmonic Distortion) THD within the allowable limits defined to reduce reactive power and improve power factor. This Filter draws the opposite harmonics containing current from the load so that source current remain sinusoidal and undistorted. Fuzzy logic controller is used to control the shunt active power filter and the performance of the shunt active filtercontrol strategies has been evaluated in terms of harmonic mitigation and DC link voltage regulation. A fully functional MATLAB based Simulink model of Shunt ActivePower Filter for different types of load (nonlinear, unbalance, both). The results of simulation comply with all the features described by the theory; justifying employment of TCR based Shunt Active Power Filter (SAPF) in the industry.

KEYWORDS:Total Harmonic Distortion, Shunt Active Power Filter,Simulink, Nonlinear load, unbalance current

INTRODUCTION:Power supply system suffers from serious problems of significant harmonics currents with poor input power factor caused by nonlinear loads. The line current harmonics cause increase in losses, instability, and also voltage distortion. Traditionally, both passive and active filters have been used near harmonic producing loads or at the point of common coupling to block current harmonics. Shunt filters still dominate the harmonic compensation at medium/high voltage level, whereas active filters have been proclaimed for low/medium voltage ratings. Passive filtering has been preferred for harmonic compensation in distribution systems due to low cost, simplicity, reliability, and control less operation. Passive filters are found suitable with diverse applications involving reactive power together with harmonic compensation by thyristor switched filters (TSF) which contains many passive filters and the variation of load power can be adjusted [1]-[2]. The problems of passive filters can be mitigated by active filters have a good performance and more effective in harmonic compensation but for large scale system the active filter cost is high [3]-[11]. Hybrid filters soften effectively the problems of passive filter and an active filter solution and provide convenient harmonic compensation, particularly for high power linear loads [12]. Many techniques such as instant reactive power theory, synchronous rotating reference controller chassis, sliding mode, techniques of neural networks, nonlinear control, pre-control, Lyapunov function- based control ,etc., have been used to improve the Performance Filters and hybrids. Different topologies filter to compensate harmonics and reactive power has been reported in the literature .an air conditioner consists of an active topology multi-converter by operating in parallel with a hybrid conditioner has conditioner It has been proposed. The hybrid air conditioner is constituted by one or more passive filters in series with a filter for rated active power low (APF). Conditioner compensates harmonic distortion, unbalance, and reactive power in three-phase four-wire systems. This topology provides a solution high-power level, which is convenient because of kilovolt ampere Rating Reduction inverters

POWER QUALITY:

Power quality is the set of limits of electrical properties that allows electrical systems to function in their intended manner without significant loss of performance or life. The term is used to describe electric power that drives an electrical load and the load's ability to function properly with that electric power. Without the proper power, an electrical device (or load) may malfunction, fail prematurely or not operate at all. There are many ways in which electric power can be of poor quality and many more causes of such poor quality power.

SYSTEM CONFIGURATION OF SHPF-TCR COMPENSATOR:

Figure shows the topology of the proposed combined SHPF and TCR. The SHPF consists of a small-rating APF connected in series with a fifth-tuned LC passive filter. The APF consists of a three-phase full-bridge voltage-source pulse width modulation (PWM) inverter with an input boost inductor and a dc bus capacitor .The APF sustains very low fundamental voltages and currents of the power grid, and thus, its rated capacity is greatly reduced. Because of these merits, the presented combined topology is very appropriate in compensating reactive power and eliminating harmonic currents in power system. The tuned passive filter in parallel with TCR forms a shunt passive filter (SPF). This latter is mainly for fifth harmonic compensation and PF correction. The smallrating APF is used to filter harmonics generated by the load and the TCR by enhancing the compensation characteristics of the SPF aside from eliminating the risk of resonance between the grid and the SPF. The TCR goal is to obtain a regulation of reactive power. The set of the load is a combination of a three phase diode rectifier and a threephase star-connected resistive inductive linear load.

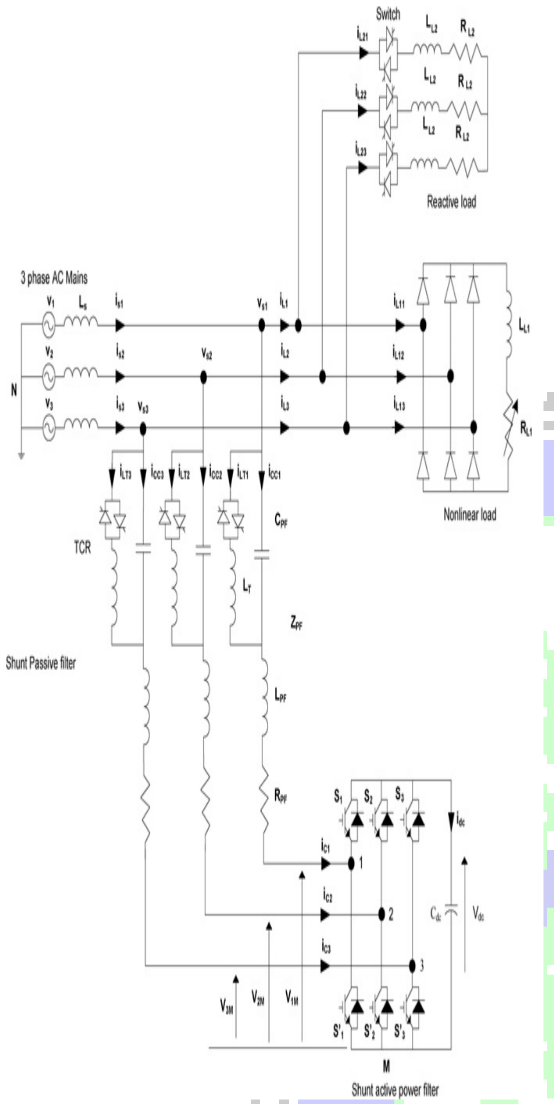

FIG.1 Basic circuit of the SHPF-TCR compensator

SVC USING A TCR AND TSC:

This compensator overcomes two major shortcomings of the earlier compensators by reducing losses under operating conditions and better performance under large system disturbances. In view of the smaller rating of each capacitor bank, the rating of the reactor bank will be 1/n times the maximum output of the SVC, thus reducing the harmonics generated by the reactor. In those situations where harmonics have to be reduced further, a small amount of FCs tuned as filters may be connected in parallel with the TCR.

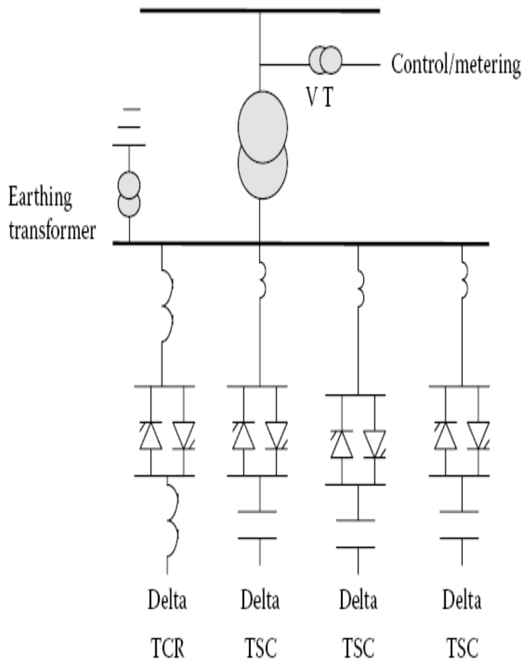

FIG.2 SVC USING TCR AND TSC

SVC OF COMBINED TSC AND TCR TYPE

When large disturbances occur in a power system due to load rejection, there is a possibility for large voltage transients because of oscillatory interaction between system and the SVC capacitor bank or the parallel. The LC circuit of the SVC in the FC compensator. In the TSC–TCR scheme, due to the flexibility of rapid switching of capacitor banks without appreciable disturbance to the power system, oscillations can be avoided, and hence the transients in the system can also be avoided. The capital cost of this SVC is higher than that of the earlier one due to the increased number of capacitor switches and increased control complexity.

STATCOM:

In 1999 the first SVC with Voltage Source Converter called STATCOM (Static Compensator) went into operation. The STATCOM has a characteristic similar to the synchronous condenser, but as an electronic device it has no inertia and is superior to the synchronous condenser in several ways, such as better dynamics, a lower investment cost and lower operating and maintenance costs. A STATCOM is build with Thyristors with turn-off capability like GTO or today IGCT or with more and more IGBTs. The static line between the current limitations has a certain steepness determining the control characteristic for the voltage. The advantage of a STATCOM is that the reactive power provision is independent from the actual voltage on the connection point. This can be seen in the diagram for the maximum currents being independent of the voltage in comparison to the SVC. This means, that even during most severe contingencies, the STATCOM keeps its full capability.

ACTIVE POWER FILTER

The main objective of the APF is to compensate the harmonic currents due to the non linear load. These filters are generally designed around a PWM bridge converter having a capacitor on the dc side. Fig. 1 shows the shunt APF configuration with a proportional-integral (PI) controller. The switching frequency of the bridge determines the frequency range of harmonic currents that are generated by APF. It is expected to correct up to or . The aim now is to control this switching so that the voltage source lines, the nonlinear load, and the filter work together. This leads to designing the control algorithm which is best suited to compensate the harmonic and reactive currents. In the following sections, we have presented the study using some intelligent algorithms, such as fuzzy logic, neuro fuzzy, and fuzzy genetic, which take into account the uncertainty due to the dynamics in load.

A. PI ALGORITHM

The PI control scheme involves regulation of the dc bus to set the amplitude of reference current for harmonic and reactive power compensation [4], [5]. Assuming no power losses in the compensator, the dc-link voltage remains constant if no real power is drawn from it. However, practically, there are switching losses in the APF that increase with the increase in the reactive power demand of the load. These losses are supplied by the capacitor, and its voltage drops. The capacitor also has to supply active power during transient states when the real-power demand of the load increases. Thus, in either case, the capacitor voltage drops. Similarly, the capacitor voltage will increase if the reactive/real power demand of the load decreases. Hence, by monitoring the capacitor voltage, the real power supplied by the APF can be estimated and the amplitude of the fundamental active component of the supply current was estimated indirectly using the real-power balance theory. The control is on the supply current directly. Only one sensor is required to sense the supply current and there is no delay in the compensation process. A PI control algorithm is used to regulate the dc link voltage of the shunt APF. This method is preferred because the reference current is generated without calculating either the load current harmonics or the load reactive power. This results in an instantaneous compensation process and the associated hardware is simple to implement, thereby increasing system reliability. The block diagram of the overall control scheme is shown in Fig. 1. The control variables used by the PI control algorithm are the dc bus voltage, supply current, and supply voltage. In the control scheme investigated here, a sample-and-hold circuit is used to take capacitor voltage samples at every 10 ms for a supply frequency of 50 Hz. The error input to the PI controller and the amplitude of the supply current provided by the controller are thus made available at zero crossing only and the supply current is maintained constant for the entire period of one cycle. Hence, the correction action is achieved every half cycle. The ripple in the capacitor is eliminated with this technique and there is no need to use a lowpass filter. The dc capacitor voltage has to be maintained at more than twice the peak supply voltage for proper operation of the shunt APF system. This is taken as the reference dc-link voltage and compared with the actual voltage of the capacitor .The resulting error at the th sample instant is expressed as

$$V_e(n) = V_{ref}(n) - V_{dc}(n). \quad (1)$$

The compared result is fed to a PI controller and the output of the PI controller is given by

$$V_0(n) = V_0(n-1) + K_p\{V_e(n) - V_e(n-1)\} + K_i V_e(n) \quad (2)$$

where and are proportional and integral gain constants of the voltage regulator. and are the output of the controller and voltage error at the th sampling instant. This output of the controller is limited to a safe permissible value depending on the rating of the APF switches, and the resulting limited output is taken as the peak value of the reference supply current for harmonic and reactive power compensation. The phase information is obtained by a unit amplitude sine wave derived from the mains voltage. The reference current so obtained is compared with the actual supply current and fixed frequency PWM is used to generate the switching signals for the APF converter. The switch control applies or on the ac side, forcing the compensation current to track the reference current. From Fig. 1 of the APF, the following equations can be written

$$i_s = i_l + i_f \tag{3}$$

$$\frac{di_f}{dt} = \frac{v_s - v_f - R_s i_f}{L_f}. \tag{4}$$

The filter output voltage can be controlled only by the duty cycle of the bridge. Therefore, we obtain

$$v_f = u_f \cdot V_{dc}. \tag{5}$$

The problem of a soft computing control algorithm is, therefore, to determine the duty cycle in such a way that remains as constant as possible and produces the right harmonic-compensated current.

FUZZY CONTROL ALGORITHM

Fuzzy logic is a multilevel logic system in which the fuzzy logic set has a degree of membership associated with each variable. Basically, a fuzzy set has three principal components: 1) a degree of membership measured along the vertical axis; 2) the possible domain values for the set along the horizontal axis; and 3) the set membership function (a continuous curve that connects the domain values to the degree of membership in the set). A large class of fuzzy sets represents approximate members of one type or other. Some of these fuzzy sets are explicitly fuzzified numbers whereas others simply represent the fuzzy numeric interval over the domain of a particular variable.

Fuzzy numbers hence can take many shapes triangular, trapezoidal, sigmoid, and bell shape, etc. The fuzzy set principally attributes two fuzzy numbers: a center value and a degree of spread. The degree of spread is also called the expectancy of the fuzzy number; when the fuzzy number is a single point, it is called single tone. As the expectancy increases, the number becomes fuzzier. This results in an increase in information and entropy. The triangular fuzzy membership shape is commonly employed in control applications due to primarily low computational costs of creating and integrating triangular fuzzy sets. However, they are less robust. The sigmoid function and bell-shaped fuzzy numbers are better in robustness since their center value is not a single point. The trapezoidal number is slightly different from the triangular and sigmoid number shapes because the set does not pivot around a single central number. Conventionally, only standard triangular MFs are used in fuzzy control and the suitability of other membership functions is not investigated. In the present study, the fuzzy-logic control system was designed with five functional definitions of MFs viz; triangular, trapezoidal, p Sigmoid, Gaussian and Gaussian Bell MFs. After a comparative study in terms of harmonic compensation achieved under steady-state and transient load conditions, it was observed that the Gaussian MFs gave the best results. Fig. 4 shows the structure of the fuzzy controller for APF.

A.FUZZY CONTROL SCHEME FOR APF:

In order to develop the fuzzy-logic control algorithm for APF, two inputs: 1) the voltage error (reference voltage minus actual capacitive voltage, e), 2) the change of capacitive voltage (previous error minus current error; ce) were considered over one sample period. The two inputs were represented by sets of seven membership functions and expressed in linguistic values as negative big (NB), negative medium (NM), negative small (NS), zero (ZE), positive small (PS), positive medium (PM), and positive big (PB). The range for the “error” input was set as[-30 30] and that for “change of error” was set as [-10 10]. A limiting block was introduced before the fuzzy block in order to truncate values beyond these ranges before supplying them to the fuzzy-logic controller. The shape of these membership functions was varied and the effect on the system was studied. The input to the defuzzification process is a fuzzy set (the aggregate output fuzzy set) and the output is a single nonfuzzy number, obtained by the center-of-gravity (COG) method of defuzzification. The output (magnitude of reference supply currentis represented by a set of nine membership functions (MFs) (NVB to PVB) whose shape was taken to be similar to the shape of the input MFs. The range for the output was set as]. The output of the fuzzy-logic controller was multiplied by a unit sine wave in order to bring it in phase with the supply current before comparison. The AND method used during interpretation of the IF-THEN rules was “min” and the OR method used was “max.” Also, “min” was used as the implication method whereas the “max” method was used for aggregation.

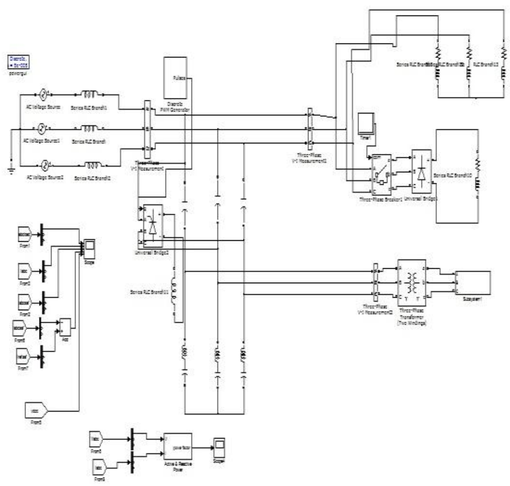

Fig.3.simulation diagram for the SHPF-TCR compensator using fuzzy controller

RESULT:

Simulink results for proposed scheme

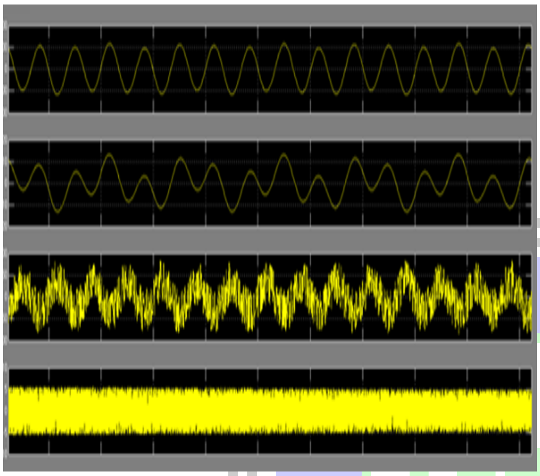

Fig.4 Steady state response of SHPF-TCR compensator a)supply voltage of SHPF-TCR compensator using fuzzy controller b)supply current of SHPF-TCR compensator using fuzzy controller c)load current of SHPF-TCR compensator using fuzzy controller d)SHPF-TCR current in phase 1.

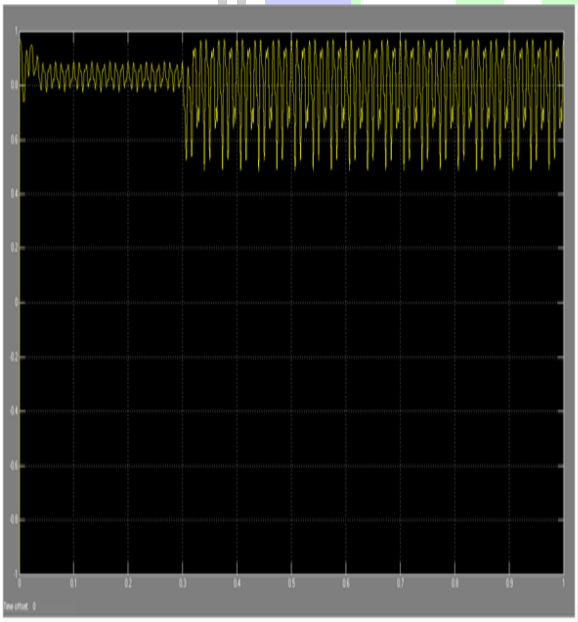

Fig 5.simulink results for active and reactive power measurement

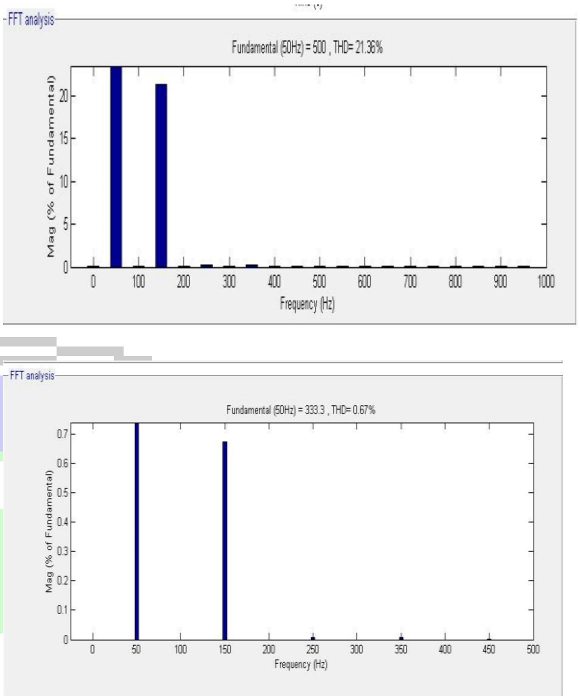

Fig 6.Harmonic spectrum a) before compensation b)after compensation

CONCLUSION:

In this project a SHPF-TCR compensator of a TCR and a SHPF has been proposed to achieve harmonic elimination and reactive power compensation. A proposed nonlinear control scheme of a SHPF-TCR compensator has been established, simulated, using Fuzzy controller. The shunt active filter and SPF have improved the performance of filtering and to reduce the power rating requirements of an active filter. It has been found that the SHPF-TCR compensator can effectively eliminate current harmonic and reactive power compensation of loads using fuzzy control.

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