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Improving Power Quality by Using Hybrid Active Filters with Novel Fuzzy Controller

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ABSTRACT

In this project an electric power system with linear and non-linear load is considered and the application of filter devices to reduce the harmonics that occurs during the non-linear loads and bringing the power quality. In this project, I proposed hybrid active filter is operated as variable harmonic conductance according to the voltage total harmonic distortion. Therefore, harmonic distortion can be reduced to an acceptable level in response to load change or parameter variation of the power system. In addition, I implement the novel fuzzy controller instead of using PI controller for getting fast response in power system. It can be clearly understand by observing FFT analysis. To verify the effectiveness of the proposed HAFU, simulations based on MATLAB software have been carried out.

INTRODUCTION

Harmonic pollution is becoming increasingly serious due to extensive use of nonlinear loads, such as adjustable speed drives, uninterruptible power supply systems, battery charging system, etc. This equipment usually uses diode or thyristor rectifiers to realize power conversion because of lower component cost and less control complexity. However, the rectifiers will contribute a large amount of harmonic current flowing into the power system, and the resulting harmonic distortion may give rise to malfunction of sensitive equipment or interfering with communication systems in the vicinity of the harmonic sources. Normally, tuned passive filters are deployed at the secondary side of the distribution transformer to provide low impedance for dominant harmonic current and correct power factor for inductive loads [1], [2]. However, due to parameter variations of passive filters, unintentional series and/or parallel resonances may occur between the passive filter and line inductance. The functionality of the passive filter may deteriorate, and excessive harmonic amplification may result [3], [4]. Thus, extra calibrating work must be consumed to maintain the filtering capability.

Recently, a transformerless hybrid active filter was presented to compensate harmonic current and/or fundamental reactive current. Design consideration of the hybrid filter for current compensation has been extensively studied. A hybrid active filter with damping conductance was proposed to suppress harmonic voltage propagation in distribution power systems [2]. Nevertheless, this method did not consider the resonance between the passive filter and the line inductance. The fixed conductance may deteriorate the damping performances. An antiresonance hybrid filter for delta-connected capacitor bank of power-factor-correction applications was presented [1]. This circuit was limited to three single-phase inverters, and the filtering performance was not considered. In addition, the hybrid active filter was proposed for the unified power quality (PQ) conditioner to address PQ issues in the power distribution system [2]. Several case studies of the hybrid active filter considering optimal voltage or current distortion were conducted in [3].

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In previous work, the authors have presented a transformerless hybrid active filter to suppress harmonic resonances in the industrial power system [4], [5]. The hybrid filter is constructed by a seventh-tuned passive filter and an active filter in series connection. It operates as a variable conductance at harmonic frequencies according to the voltage THD, so that harmonic distortion can be reduced to an acceptable level in response to load change and power system variation. Since the series capacitor is responsible for sustaining the fundamental component of the grid voltage, the active filter is able to operate with a very low dc bus voltage, compared with the pure shunt active filter [4] . Hence, both the rated kVA capacity and the switching ripples are reduced accordingly. Moreover, the proposed harmonic conductance is able to avoid overcurrent of the passive filter in the case of mistuning parameters. These features will benefit practical applications.

OPERATION PRINCIPLE

Fig. 1(a) shows a simplified circuit diagram considered in this paper, where *Ls*represented the line inductance plus the leakage inductance of the transformer. The hybrid active filter unit (HAFU) is constructed by a seventh-tuned passive filter and a three-phase voltage source inverter in series connection. The passive filter $Lf - Cf$is intended for compensating harmonic current and reactive power. The inverter is designed to suppress harmonic resonances and improve the filtering performances of the passive filter. Fig. 1(b) shows the overall control block diagram of the HAFU, including harmonic loop, fundamental loop, current regulator, and conductance control. A detailed principle will be presented as follows.

ANALYSIS OF FILTERING PERFORMANCE

The filtering performance of the HAFU has been addressed in [25] by developing equivalent circuit models, in which both harmonic impedance and harmonic amplification are considered. The frequency characteristic of the passive filter is changed by the proposed harmonic conductance to avoid unintentional resonances. Here, we will concentrate on the damping performance with variation of line impedance *Ls*, line resistance *Rs*, and THD$*$. Voltage unbalance and filter capacitors in the power system are also considered.

A. Ls on Damping Performances

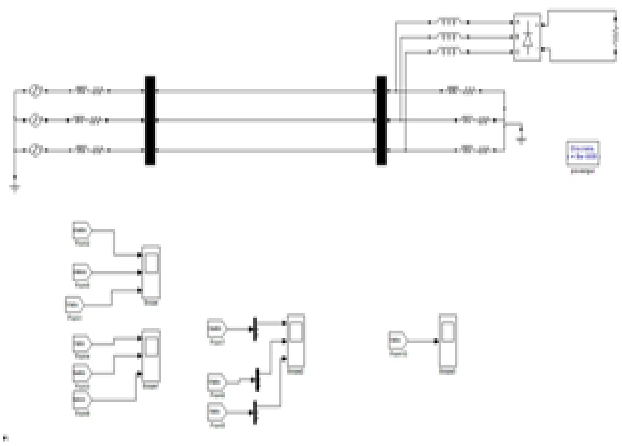
Voltage THD for various values of *Ls*. The fifth harmonic voltage is severely amplified at *Ls*= 0.3 mH (2.3%), This resonance is alleviated if *Ls*is not equal to 2.3%. However, voltage distortion is still significant due to harmonic voltage drop on *Ls*. After the HAFU is started, voltage distortion is maintained at 2% by increasing $G*$, as shown in Fig. 4(c). It is worth noting that the HAFU is operated at antiresonance mode, i.e., $G* = 0$, if *Ls*is less than 2.3% for NL1. This means that the voltage distortion is less than 2%. At that time, a lower THD$*$command is needed to further reduce the current distortion of *is*.

B. Rs on Damping Performances

In the low-voltage system, the *X/R* ratio becomes lower, and line resistance on damping performances must be taken into consideration. voltage distortion with varying *Rs*for NL2. Since increasing *Rs*could help in reducing voltage distortion, the required conductance to maintain voltage distortion at 2% is accordingly reduced, From this observation, the HAFU could provide effective dampingcapability, although *Rs*is as large as 10%.

RESULTS & OUTPUTS

A power system having linear and non-linear loads setup was built and tested as shown.



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FFT ANALYSIS OFHARMONICS:

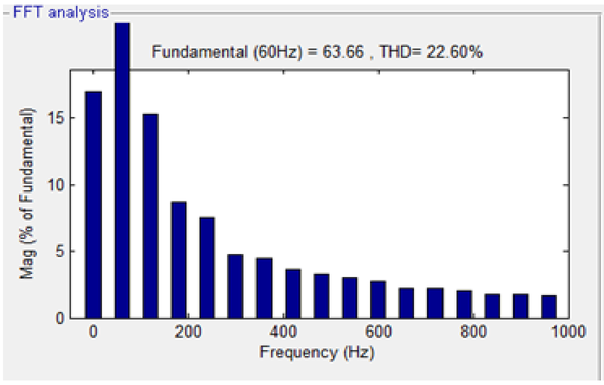
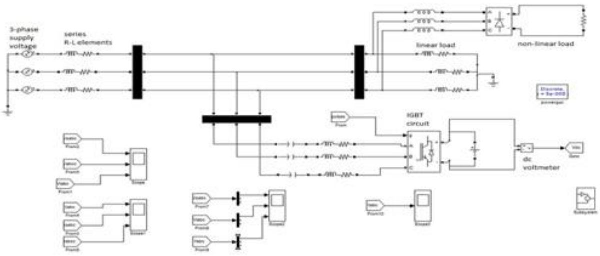


Fig: FFT analysis of harmonics in a power system

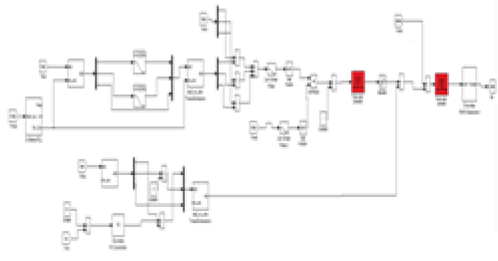
HAFU POWER SYSTEMMODEL:



Experimental results verify the effectiveness of the proposed method. Extended discussions are summarized as follows.

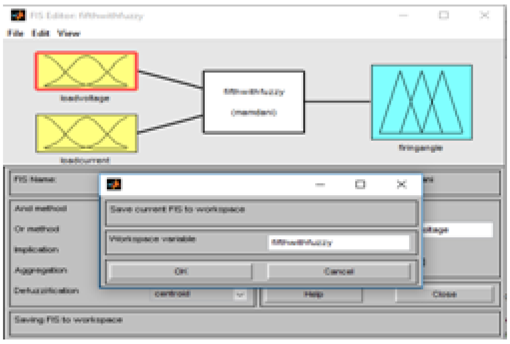
- Large line inductance and large nonlinear load may result in severe voltage distortion. The conductance is increased to maintain distortion to an acceptable level.
- Line resistance may help reduce voltage distortion. The conductance is decreased accordingly.
- For low line impedance, THD*should be reduced to enhance filtering performances. In this situation, measuring voltage distortion becomes a challenging issue.
- High-frequency resonances resulting from capacitive filters is possible to be suppressed by the proposed method.
- In case of unbalanced voltage, a band-rejected filter is needed to filter out second-order harmonics if the SRF is realized to extract voltage harmonics.

SIMULINK DIAGRAM OF HAFU FUZZY SUBSYSTEM:

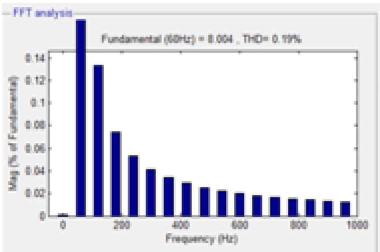


Simulink diagram of HAFU fuzzy subsystem

ADDING FUZZY INTO WORKSPACE:

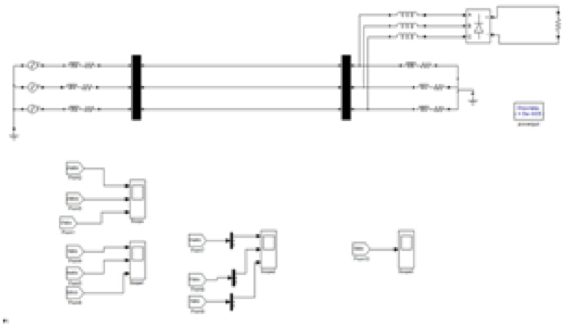


FFT ANALYSIS OF HAFU HAVING FUZZY:



SIMULATIONRESULTS

SIMULINK MODEL OF POWER SYSTEM WITHOUTHAFU:



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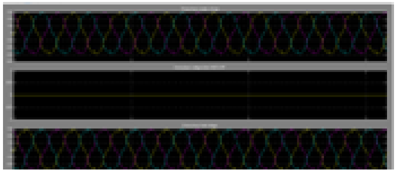
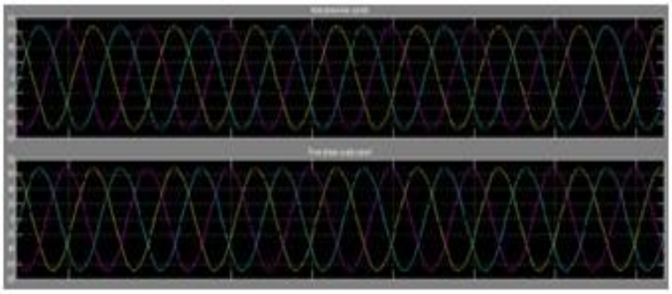
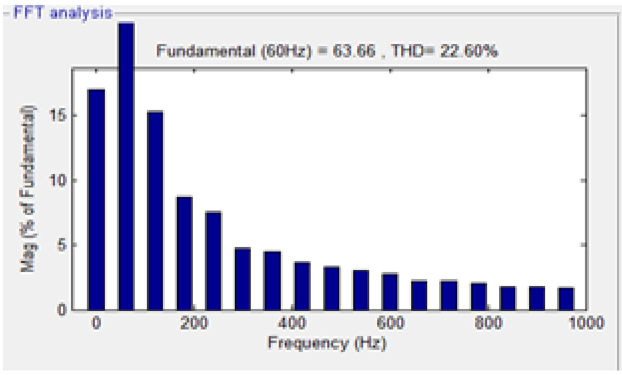
SIMULATION RESULTS WITHOUTHAFU:



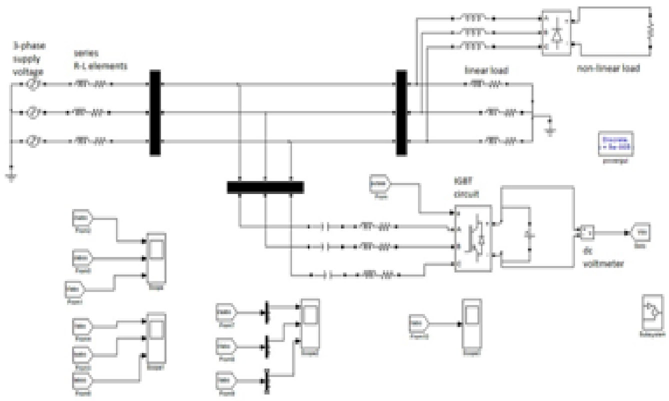
SIMULATION RESULTS OF POWER SYSTEM WITHOUTHAFU



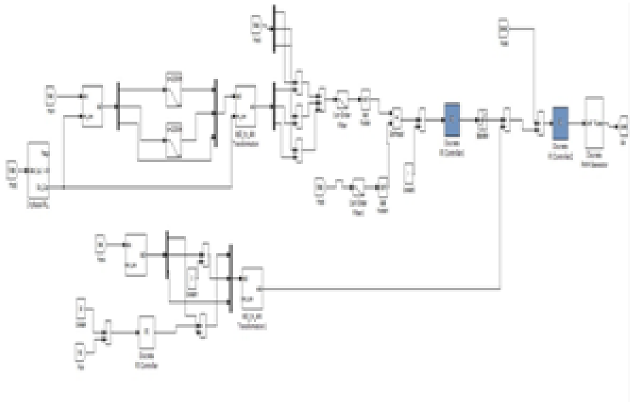
FFT ANALYSIS OF POWER SYSTEM WITHOUTHAFU:



SIMULINK MODEL OF POWER SYSTEM WITHHAFU:

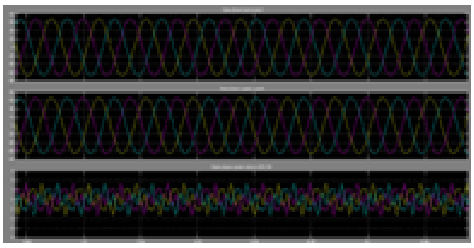


SIMULINK MODEL OF PULSESSUB-SYSTEM:



SIMULATIONOFVOLTAGERESULTSINAPOWERSYSTEMSWITHHAFU:

SIMULATIONOFCURRENTRESULTSINAPOWERSYSTEMSWITHHAFU



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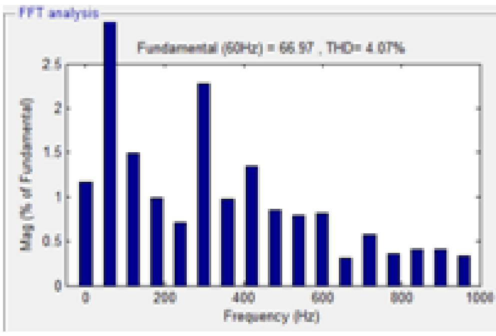

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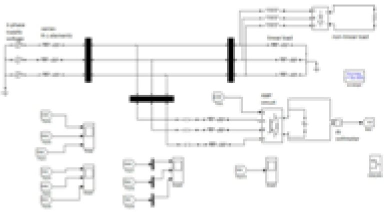
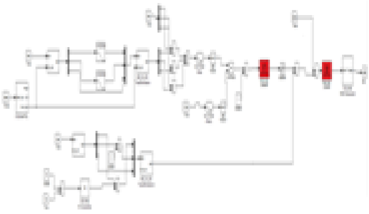
SIMULINK MODEL OF A POWER SYSTEM HAVING WITH HAFUFUZZY:

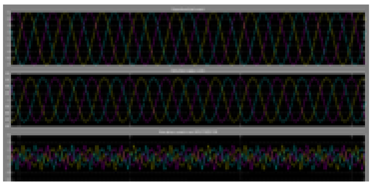


SIMULINK MODEL OF PULSES SUB-SYSTEM HAVING WITH HAFU FUZZY:

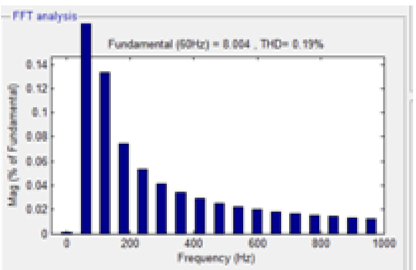


SIMULATION VOLTAGE RESULTS OF POWER SYSTEM WITH HAFU FUZZY:

SIMULATION CURRENT RESULTS OF POWER SYSTEM WITH HAFU FUZZY:



FFT ANALYSIS OF A POWER SYSTEM WITH HAFUFUZZY:



THD PERCENTAGECOMPARISON:

Here the comparison of THD percentage of three stages are as shown in the following table.

S.NO	WITHOUT HAFU	HAFU ON	HAFU WITH FUZZY ON
1	THD = 22.60%	THD = 4.07%	THD = 0.19%

- By comparing all three conditions the THD level is better at the power system which is having HAFU FUZZY for pulsesproduction.
- At first stage the THD percentage is 22.60%, but at second stage the THD percentage is reduced more i.e.,4.07% and finally at last stage, the replacement of novel fuzzy block instead of PI controller in pulses formation gives best results. That is, best reduction of THD i.e.,0.19%

CONCLUSION

A hybrid active filter to suppress harmonic resonances in industrial power systems. The proposed hybrid filter is composed of a seventh harmonic-tuned passive filter and an active filter in series connection at the secondary side of the distribution transformer. With the active filter part operating a variable harmonic conductance, the filtering performances of the passive filter can be significantly improved.

Accordingly,theharmonicresonancescanbeavoided,andtheharmonicdistortioncan be maintained inside an acceptable level in case of load changes and variations of line impedance of the power system. Experimental results verify the effectiveness of the proposed method. Extended discussions are summarized as follows.

- Large line inductance and large nonlinear load may result in severe voltage distortion. The conductance is increased to maintain distortion to an acceptablelevel.
- Line resistance may help reduce voltage distortion. The conductance is decreased accordingly.
- For low line impedance, THD* should be reduced to enhance filtering performances. In

this situation, measuring voltage distortion becomes a challengingissue.

- High-frequency resonances resulting from capacitive filters is possible to be suppressed by the proposedmethod.
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