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Power Factor Correction Using a Series Active Filter

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Abstract: Power factor correction (PFC) for single-phase diode rectifiers utilising a series active filter is demonstrated in this project at a minimal cost.
When compared to the typical PFC, the suggested PFC has reduced power device ratings requirements, which results in cheaper costs and improved efficiency.
It can also eliminate the requirement for a large inductor in the typical PFC, making it more compact.
This study examines the proposed PFC's topology, operating principle, and application concerns.
The control approach and simulation results are presented in detail.
Prototypes of 1-kW are made and the experimental findings are shown to verify the theoretical analysis.
Index Terms: Harmonic resonance, hybrid active filter, industrial power system.

I. INTRODUCTION

Electricity is the most widely used and most efficient source of energy, and modern society is completely reliant on it.
It is impossible to picture a day without power. End-user equipment's performance is directly impacted by the quality of the electricity it receives.One of the most used terms in the energy industry today is "power quality," and it's something that both electric power providers and end customers are concerned about [1]. It is the voltage and frequency range of the power that determine the quality of the power given to users. Quality of electricity delivered is compromised if the voltage and frequency of electric power delivered are different from the standard levels.
Semiconductor devices have improved dramatically throughout the years as a result of advances in technology.
Semiconductor devices have a permanent presence in the power sector because to this progress and the advantages they bring. This helps to make overall system control easier.
In addition, the vast majority of the loads are comprised of semiconductor-based technology.
Non-linear semiconductor devices draw non-linear current from the source, however.
As well as power conversion from one form to another, semiconductor devices also play a role in the process.
There are numerous switching processes in this power conversion, and these might cause current discontinuity.
In the presence of harmonics, which are caused by this non-linearity and discontinuity, the quality of electricity transmitted to end users is compromised.
The harmonics must be filtered away in order to retain the quality of the electricity delivered.
A device called Filter is therefore employed to do this.
Active, passive and hybrid filter topologies are all available in the literature.
When it comes to electric power quality, this study examines the usage of hybrid power filters.

II. LITERATURE SURVEY

Filters are used to reduce harmonic interference.
For this objective, various filter topologies have been described in the literature.
System settings have a significant impact on passive filters at first.
They have resonance issues with the system impedance, but they are good at filtering out specific harmonic frequencies.
Because of this, active filters are utilised instead of passive filters.
Since the 1970s, they have been employed to compensate for reactive power and negative sequence currents.
According to [2,] one way to improve electrical quality is to utilise active power filters.

A review of active filter configurations for improving power quality and control strategies is offered in this work.
It is found that the active filters are facing some drawbacks when employed for power quality improvement. They are-

- ✓ High converter ratings are required
- ✓ Costlier when compared to its counterpart, passive filter
- ✓ Huge size
- ✓ Increased losses

As a result, [3] proposes a hybrid power filter to address these issues. This filter combines active and passive filters.
Using both active and passive filters is a cost-effective method for improving power quality.
The active filter must be correctly regulated in order to improve the passive filter's properties as well as the system as a whole.
There are a variety of methods for accomplishing this goal.
Regardless of the method used, the ultimate goal is to correct for harmonics by injecting a voltage into the system through an active filter.
The active filter's output voltage is held constant at a predetermined reference value in order to achieve this result.
It is more efficient to use instantaneous reactive power theory to control the active filter.
[4] covers the various control algorithms derived from the formulations of instantaneous reactive power theory.
Finally, it finds that vectorial based theory outperforms other techniques when it comes to analysing sinusoidal currents.
Dual instantaneous reactive power vectorial theory is used to regulate series active and shunt passive filters [5].
MATLAB SIMULINK simulations are used to test the given theory in this research work.
For both balanced and unbalanced load scenarios, the proposed control approach is simulated.

III. POWER FACTOR CORRECTION (PFC)

Increasing power quality is one of the goals of power factor correction (PFC).
As a result, the electrical distribution system is less strained and electricity prices are decreased.
As a result, equipment is less likely to become unstable or fail.

A. Power Quality Problems

Any variation in voltage, current, or frequency has an impact on power quality [6]. The common problems that affect the sensitivity of the equipment are-

- ✓ Power Surges
- ✓ Transients
- ✓ Frequency Variation
- ✓ Electrical Line Noise
- ✓ Brownouts or Blackouts
- ✓ Power System Faults
- ✓ Improper grounding affect

The generation of harmonics is the primary effect of these issues.
End user equipment may be damaged as a result of the presence of harmonics.
Heating of underground cables, insulation failure, reduced equipment life-span and increased losses are all a result of harmonics generated by these devices.

B. Solutions to Power Quality Problems

Filtering out harmonics is the most effective way to improve power quality.
According to Fig. 1.1, a filter works by injecting a compensatory current to offset the harmonics of the load current.
There are a variety of filter topologies, including active, passive, and hybrid, in the literature.
Parallel resonance is a difficulty with passive power filters, which are used to filter out a specific harmonic.
The Active Power Filter is another option (APF).
Series APF and shunt APF are two different types of APF.
Shunt APFs are expensive, hence they are not typically utilised in big systems.
Harmonic isolators and voltage dividers are utilised in the series APF to lower the negative-sequence voltage.
The term "Hybrid Filter" refers to a filter architecture that incorporates both a passive filter and an APF.

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C. Block Diagram

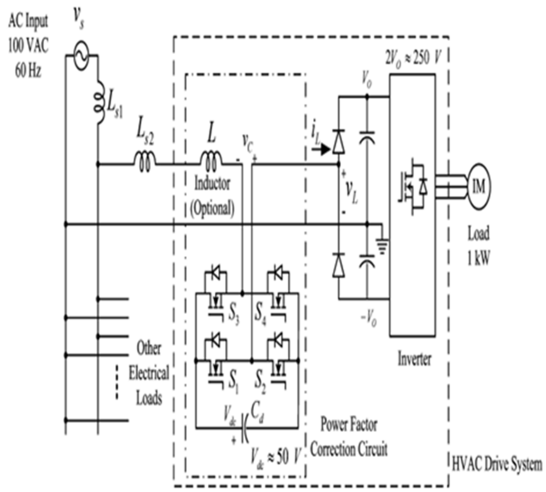


Fig.1: Power factor correction (PFC)

1) Series Active Filter

The primary function of series active filters is to regulate voltage and isolate nonlinear loads from the utility grid.
Voltage imbalances and voltage drops from the AC power supply can be remedied with the use of this type of technique.

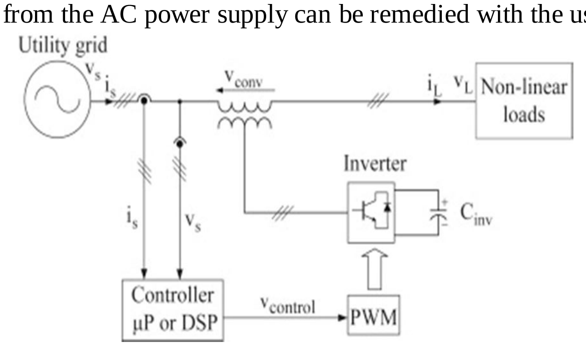


Fig.2: Series Active Filter

2) Inverter

a) Delivering sinusoidal voltage throughout an electric utility's system is critical, but the growing non-linear demands on the system make this problematic.
b) A common coupling point is used to introduce harmonic currents generated by non-linear loads into the system (PCC). System impedance can introduce harmonic voltages that distort the PCC voltage, resulting in current distortion.
c) Harmonics lead to increased eddy current and hysteresis losses in generators, transmission lines, transformers, and load resistances, as well as equipment heating or malfunctioning and incorrect operation of fuses and circuit breakers.

Studies comparing sinusoidal (system with only linear loads) to non-sinusoidal situations show that harmonics have a negative impact on voltage stability (system with linear and non-linear loads).

3) Nonlinear Loads

When a nonlinear load is used, the voltage waveform does not change in accordance with the current waveform.
Non-sinusoidal current waveforms result as a result of this
Large impedance is provided by nonlinear loads at a portion of the voltage waveform.
When the voltage reaches its apex, the impedance drops dramatically.
Low impedance of the load causes a quick increase in current. When the impedance value suddenly rises again, this causes a sudden decrease in current.
Nonlinearity is a term used to describe voltage and current waveforms that are no longer linked.

A few examples of nonlinear loads include laser printers, uninterruptible power supplies, variable-speed drives, and loads with diode-capacitor power sources, among others.
When the line voltage crests, these loads draw short pulse currents.
Unexpected reflected currents are injected back into the power distribution system as a result of these non-sinusoidal current pulses, causing current to operate at frequencies other than the fundamental frequency, or 50 Hz.

4) Applications

a) Loads with a large moment of inertia are driven by slip ring induction motors, which have a substantial rotor energy loss during acceleration.
b) These induction motors are also employed for loads that require a slow buildup of power. Controlling the speed of moving objects is one of its primary functions.
c) Slip ring induction motors are appropriate for loads demanding high beginning torque and low starting current applications.
d) During acceleration, slip ring induction motors lose a lot of energy due to the high inertia of the load.
e) These motors are also used for loads that require a progressive build-up of load. • They are utilised for loads that need speed control.

IV. SIMULATION RESULTS

The power stage shown in Figure 8 was constructed and tested. With Table III as a reference, we can calculate experimental parameters.
There are two voltage distortions in the laboratory that are known as VD5 and VD7: A seventh-order harmonic resonant frequency is achieved by selecting a filter capacitor CF and filter inductor LF to compensate for inductive load.
On the basis of the voltage ripple, the dc link capacitor is selected (5 percent). PLL, synchronous reference frame transformation, LPFs, PI controllers, current regulators, A/D conversion and PWM units were all implemented on the evaluation platform of the TMS320F28335 chip [40].
The inverter's three phases are short-circuited when the series active is in the OFF state, which is equivalent to turning on three upper switches and turning off three lower switches.
In its current state, the HAFU is nothing more than a passive filter.

A. Simulink

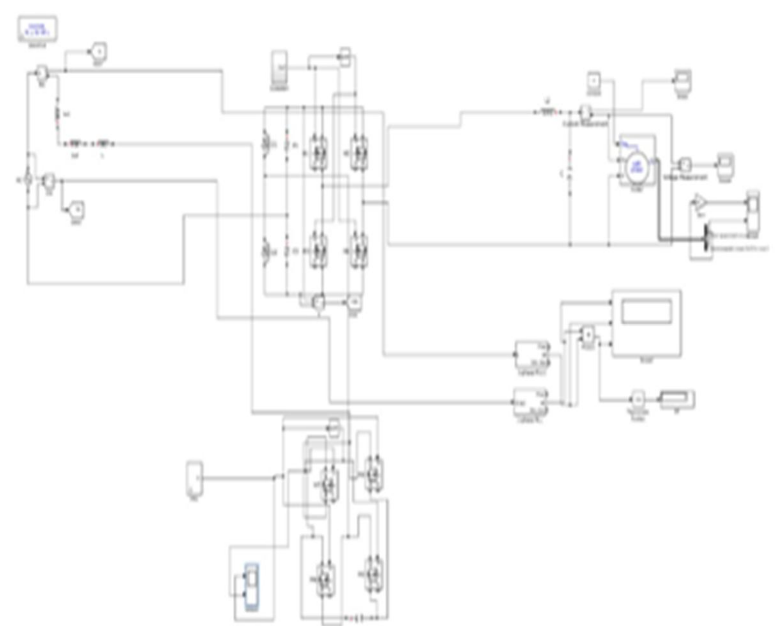
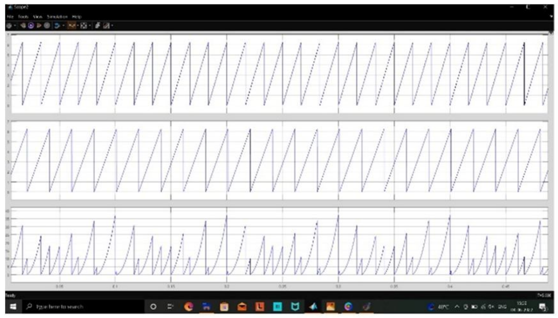


Fig.3: Power Factor Correction (PFC)



PFC Output Ramp Signal

Fig.4: PFC output response

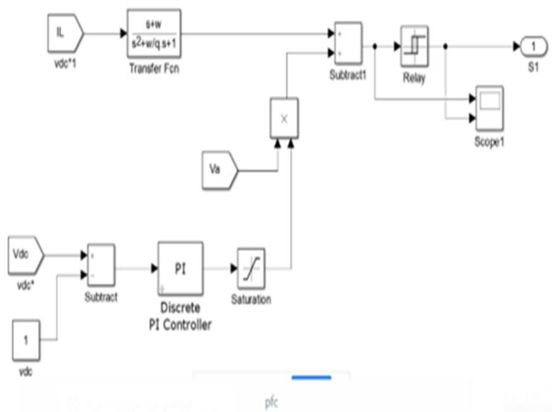
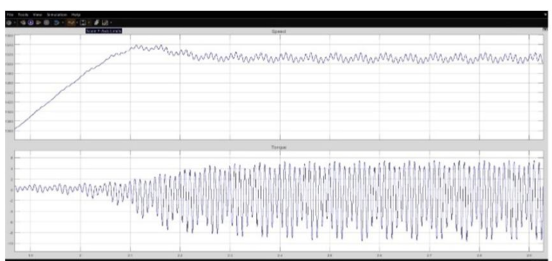


Fig.5: PFC Corrections



Rotor speed and Torque

Fig.6: Rotor speed and torque

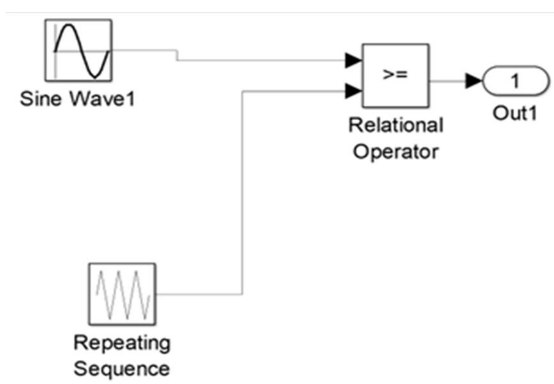


Fig.7: Sine wave comparison

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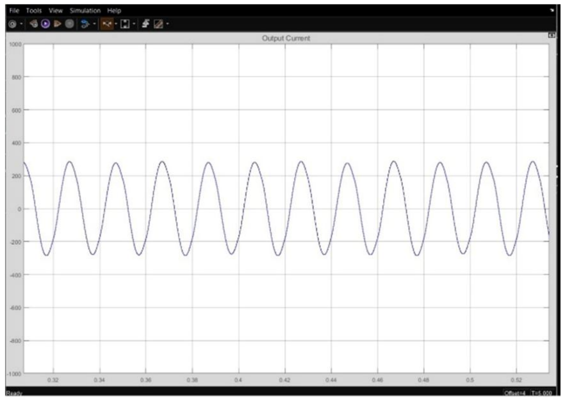

Inverter Output Voltage

Fig.8: Inverter output voltage

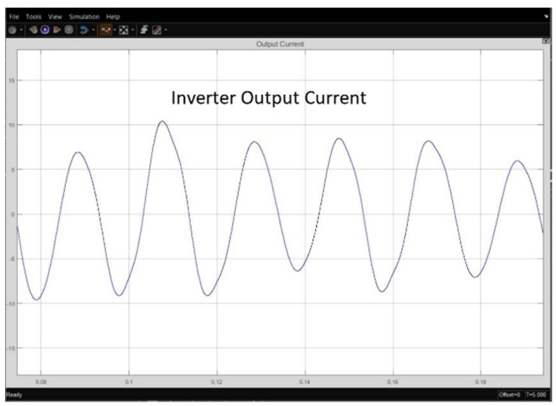

Fig.9: Inverter output current

V. CONCLUSION

In this study, a novel PFC with double hysteresis control has been presented.
The operation principle has been examined in detail.
A 1-kW prototype has been created to verify the analytical and simulation results.
It shows that a high-power factor has been reached.
Compared with the typical PFC, the suggested PFC has the following advantages:

1) Lower devices rating, which reduces cost, EMI, and switching losses.
2) No additional inductor is required, the line impedance is enough for most cases.
3) The proposed double hysteresis control reduces the switching frequency significantly, which leads to higher efficiency.

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