DC Power Supply System by using Inductive Filtering Method for Industrial Application

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ABSTRACT

This paper describes the effects of Harmonics in the Power System and steps to reduce the effects of Harmonics. This paper will also explain how Harmonic distortion is one of the most important problems associated with power quality and creates several disturbances to the Power System. It includes the Harmonic reduction techniques to improve the power quality and it also includes the simulation for the same. The operating mechanism of the new inductive filtering method is analyzed, and then, the harmonic model and the equivalent model are established. The research results show that the inductive filtering method not only greatly reduces the harmonic magnetic flux in the rectifier transformer but also prevents harmonic currents from flowing into the primary (grid) winding of the rectifier transformer. It presents good filtering and reactive power compensating performances to public networks and also increases the operating efficiency of the industrial dc power supply system itself.

KEY WORDS: inductive filtering method, harmonic, rectifier, transformer, Direct current (dc) power supply system

1. INTRODUCTION

The term harmonics referred to Power quality in ideal world would mean how pure the voltage is, how pure the current waveform is in its sinusoidal form. Power quality is very important to commercial and industrial power system designs. Ideally, the electrical supply should be a perfect sinusoidal waveform without any kind of distortion. If the current or voltage waveforms are distorted from its ideal form it will be termed as harmonic distortion. This harmonic distortion could result because of many reasons. In today’s world, prime importance is given by the engineers to derive a method to reduce the harmonic distortion. Harmonic distortion was very less in the past when the designs of power systems were very simple and conservative. But, nowadays with the use of complex designs in the industry harmonic distortion has increased as well.

This paper explains the effects of Harmonics in the Power System and steps to reduce the effects of Harmonics. This project will also explain how Harmonic distortion is one of the most important problems associated with power quality and creates several disturbances to the Power System. It includes the Harmonic reduction techniques to improve the power quality and it also include the simulation for the same. This paper also explains different types of inverters that are used in the Power System. During the transformation from DC to AC, harmonics affect the power quality a lot. How harmonic reduction will improve the power quality will be explained in detail.

2. CAUSE OF POWER QUALITY DETERIORATION

As always, the main objective of the power system would be generation of electrical energy to the end user. Also, associated with power system generation is the term power quality. So much emphasis has been given to power quality that it is considered as a separate area of power engineering. There are many reasons for the importance given to the power quality. One of the main reasons is, the consumers are well informed about the power quality issues like interruptions, sagging and switching transients. Also, many power systems are internally connected into a network. Due to this integration if a failure exists in any one of the internal network it would result into unfavorable consequences to the whole power system. In addition to all this, with the microprocessor based controls, protective devices become more sensitive towards power quality variation than were the past generation protective devices.

Following are some of the disturbances which are common in affecting the power system.

- Transients
- Sagging
- Variations in voltage
- Harmonics
2.1. Transients:
In terms of power system, the transients can be defined as an action or a situation in power system with variations in power system and which is not desirable in nature. A general understanding of transient is considered to be an oscillatory transient who is damped due to the RLC network. A person who is new to the power system also uses the term “surge” to define transient. A surge may be analyzed as a transient who is resulting from the stroke of lightening where protection is done by using a surge arrester. A person who is more groomed in the field of power engineering would avoid to use the term “surge” unless it is specified as to what exactly the term “surge” refers to. Transient can be divided into two categories i.e. the oscillatory transient and the impulsive transient.

2.1.1 Oscillatory Transient:
A voltage or a current whose values change polarity rapidly are part of oscillatory transient. In case of a steady state of voltage and current when there is a sudden non-power frequency change or when there is a non-power frequency change in positive and negative polarity values, such a change is termed as an oscillatory transient.

2.1.2 Impulsive Transient:
Impulsive transients are mostly caused due to lightning. Unlike the oscillatory transient, the impulsive transient is such a condition when there is sudden change of non-power frequency in a steady state condition of voltages and currents that is unidirectional in polarity. Impulsive transients also have the ability to produce oscillatory transients by exciting the natural frequency of a power system.

2.2. Variations in Voltage:
There are two types of variations in the voltages.
- Short duration voltage variations
- Long duration voltage variations.

2.2.1 Short Duration Voltage Variations:
Short duration voltage variations are usually caused by faults in the power system. Short duration voltage variations consist of sags which are caused depending on the system conditions and faults that are caused in the power system. It really depends on what kind of fault is caused in the power system under what condition which may lead to voltage drops, voltage rise and even interruptions in certain conditions. When such faults take place, protective devices are used in order to clear the fault. But, the impact of voltage during such faulty conditions is of short-duration variation.

Interruptions:
When there are reductions in the voltage or current supply interruptions take place. Interruptions may occur due to various reasons, some of them being faults in the power system, failures in the equipment, etc.

2.2.2 Long Duration Voltage Variations:
Long duration voltage variations are comprised of over voltages as well as under voltages conditions. These under voltage and over voltage conditions are caused by variations in the power system and not necessarily due to the faults in the system. The long duration voltage variations refer to the steady state condition of the rms voltage of the power system. The long duration voltage variations are further divided into three different categories i.e. interruptions, over voltage and under voltage.

Under Voltage:
There are many reasons for the under voltage conditions in the power system. When there is a decrease in the rms ac voltage to less than 90% of a power system for some amount of time then under voltage condition exists. Load switching on or switching off of a capacitor bank can also cause under voltage condition. Also, when a power system is overloaded it may result into under voltage condition.

Over Voltage:
Compared to the under voltage condition, over voltage is an increase in the rms ac voltage to greater than 110% of the power system for some amount of time. Unlike under voltage condition, load switching off or capacitor bank getting energized are main reasons for the over voltage conditions.

2.3. Sagging:
A short duration voltage variation is often referred to as sagging. When there is a decrease between 0.1 to 0.9pu in rms voltage sagging takes place. There are many ways to obtain the magnitude of sagging from the rms voltages. Most of the times lowest value obtained during the event is considered. Sagging normally has constant rms value during the deep part of the sag. Thus, lowest value is an acceptable approximate value.

2.4 Harmonics:
Harmonics are one of the major concerns in a power system. Harmonics cause distortion in current and voltage waveforms resulting into deterioration of the power system. The first step for harmonic analysis is the harmonics from non-linear loads. The results of such analysis are complex. Over many years, much importance is given to the methods of analysis and control of harmonics. Harmonics present in power system also has non-integer multiples of the fundamental frequency and have aperiodic waveform. The harmonics are generated in a power system from two distinct types of loads.
First category of loads is described as linear loads. The linear time-invariant loads are characterized such that application of sinusoidal voltage results in sinusoidal flow of current. A constant steady-impedance is displayed from these loads during the applied sinusoidal voltage. As the voltage and current are directly proportional to each other, if voltage is increased it will also result into increase in the current. An example of such a load is incandescent lighting. Even if the flux wave in air gap of rotating machine is not sinusoidal, under normal loading conditions transformers and rotation machines pretty much meet this definition. Also, in a transformer the current contains odd and even harmonics including a dc component. More and more use of magnetic circuits over a period of time may get saturated and result into generation of harmonics. In power systems, synchronous generators produce sinusoidal voltages and the loads draw sinusoidal currents. In this case, the harmonic distortion is produced because of the linear load types for sinusoidal voltage is small. Non-linear loads are considered as the second category of loads. The application of sinusoidal voltage does not result in a sinusoidal flow applied sinusoidal voltage for non-linear devices. The non-linear loads draw a current that may be discontinuous. Harmonic current is isolated by using harmonic filters in order to protect the electrical equipment from getting damaged due to harmonic voltage distortion. They can also be used to improve the power factor. The harmful and damaging effects of harmonic distortion can be evident in many different ways such as electronics miss-timings, increased heating effect in electrical equipments, capacitor overloads, etc. There can be two types of filters that are used in order to reduce the harmonic distortion i.e. the active filters and the passive filters. Active harmonic filters are electronic devices that eliminate the undesirable harmonics on the network by inserting negative harmonics into the network. The active filters are normally available for low voltage networks. The active filters consist of active components such as IGBT-transistors and eliminate many different harmonic frequencies. The signal types can be single phase AC, three phases AC. On the other hand, passive harmonic filters consist of passive components such as resistors, inductors and capacitors. Unlike the active filters which are used only for low voltages, the passive filters are commonly used and are available for different voltage levels.

2.4.1 Active Harmonic Filter:
As explained earlier, the active harmonic filters are used for low voltages where reactive power requirement is low. The way this filter works is, the output load with the voltage waveform is obtained by boosting the voltage throughout each half cycle by the filter. The voltage which is thus produced tends to rectifiers in the power supply to gain current. The duty cycle and power factor are thus improved. Depending on the active harmonic filter used, the output distortion is reduced. Also, current that is produced due to load is monitored by the harmonic filter and generates a waveform which coincides with the exact shape of the nonlinear portion of the load current.

2.4.2 Passive Harmonic Filter:
As shown before, the passive harmonic filters are such that they are used for different voltage levels. In case of passive harmonic filters, the harmonics are reduced by using series or parallel resonant filters. The way these passive harmonic filters works is, a filter connected in parallel with the load and in series with inductance and capacitance is a current acceptor. A current acceptor is a parallel filter which is in parallel with the load and is in series with the inductance and capacitance. The filter which is near the resonant frequency of the parallel array provides maximum attenuation. The filter passes as much current as the harmonic voltage nears the filter resonant point. The passive filters thus eliminate the harmonics. If the individual load requirement is more than that of the input load, the harmonic current should be eliminated. A capacitor in series with an inductance is a passive filter. The reduced harmonic frequency must be equal to the resonant frequency of the circuit. The impedance of the network and the low impedance of the filter thus eliminate the harmonic current.

3.  MAIN-CIRCUIT TOPOLOGY
Fig. 1 shows the main-circuit topology of the industrial dc power supply system with three parallel rectifier units, where Unit 1 adopts the new dc supply system and Units 2 and 3 adopt the traditional dc supply system. It is worth noting that this system is the first practical application of the proposed new inductive-filtering-based dc supply system in the industrial custom power fields. With such a system, it is useful to perform the comparative study on the traditional and new dc supply systems. As Fig. 1 shows, in the traditional dc supply system (see Units 2 and 3), the secondary (valve) winding of the traditional rectifier transformer adopts a double-inverse star wiring scheme, the rectifier circuit adopts a diode-based rectifier bridge, and there is a saturable reactor between the rectifier transformer and the rectifier bridge. In addition, the separate on-load tap changer (OLTC) is included in the traditional dc supply system, and the dc-side current can be adjusted by both the OLTC and the saturable reactor. For the new dc supply system (see Unit 1), the new rectifier transformer essentially contains two parts, i.e., the OLTC part linked to the grid winding and the rectifier part with the special inductive filtering winding. Fig. 2 shows the more detailed wiring scheme.
Fig. 1: Main-circuit topology of the practical industrial dc power supply system with one new dc supply unit and two traditional dc supply units.

Fig. 2: Principal wiring scheme of the new rectifier transformer.

In addition, the rectifier circuit adopts the thyristor-based rectifier bridge, as shown in Fig. 3, and the dc-side current can be adjusted by both the OLTC winding and the firing-angle control on the rectifier bridge. The fully tuned circuit adopts a similar structure to the single-tuned passive filters. However, unlike the traditional passive filters, the fully tuned circuit is mainly used to lay the foundation for the implementation of the inductive filtering method, which will be discussed in the following section.

4. INDUCTIVE FILTERING METHOD

4.1. Operating Mechanism of the Inductive Filtering Method

Fig. 3: Circuit structure of the rectifier bridge and the fully tuned circuit
Fig. 4. Influence of inductive filtering on the flow path of the harmonic magnetic flux in the rectifier transformer. (a) Without inductive filtering. (b) With inductive filtering.

Fig. 4 shows the influence of the inductive filtering implementation on the flow path of the harmonic magnetic flux the rectifier transformer. From Fig. 4(a), it can be seen that, when the fully tuned circuit is open, all the harmonic currents generated by the rectifier valves are completely inducted into the primary (grid) winding from the secondary (valve) winding; thus, all harmonic currents inevitably flow free in the windings of the rectifier transformer. For the hth-order harmonic frequency, the harmonic magnetic potential balance equation on the transformer windings shown in Fig. 4(a) can be expressed as

\[ N_2 I_h + N_1 I_{1h} = 0 \]  

Where \( I_h \) is the hth-order harmonic current generated by the rectifier valves, which is also the hth-order harmonic current.

In the secondary winding of the rectifier transformer, \( I_{1h} \) is the inducted hth-order harmonic in the primary winding of the rectifier transformer, and \( N_1 \) and \( N_2 \) are the numbers of turns of the primary and secondary windings, respectively.

When implementing the inductive filtering method, as Fig. 4(b) shows, the hth-order harmonic magnetic flux \( \Phi_{2h} \) inducts the corresponding harmonic voltage \( e_{3h0} \) in the third (filtering) winding, i.e.,

\[ e_{3h0} = -N_3 \frac{d\Phi_{2h}}{dt} = -\frac{d\varphi_{2h}}{dt} \]  

Due to the action of the closed-loop circuit consisting of the filtering winding and the fully tuned circuit shown in Fig. 4(b), such voltage \( e_{3h0} \) induces the corresponding harmonic current \( I_{3h} \), and this harmonic current \( I_{3h} \) further inducts the corresponding harmonic voltage \( e_{3h} \), i.e.,

\[ e_{3h} = -N_3 \frac{d\varphi_{3h}}{dt} = -\frac{d\varphi_{3h}}{dt} \]  

where \( N_3 \) is the number of turns of the filtering winding of the rectifier transformer.

For the hth-order harmonic frequency, if the harmonic equivalent impedance \( Z_{th} \) of the fully tuned circuit is approximately equal to zero and the harmonic equivalent impedance \( Z_{3h} \) of the filtering winding is also approximately equal to zero, then the closed-loop circuit consisting of the fully tuned circuit and the filtering winding can be similarly regarded as the short-circuit loop, which satisfies the constant linkage theorem [26], i.e.,

\[ \sum e = e_{3h0} + e_{3h} = \frac{d\varphi_{2h}}{dt} - \frac{d\varphi_{3h}}{dt} = \frac{d}{dt}(\varphi_{2h} + \varphi_{3h}) = 0 \]  

According to (4), we can further obtain the following

\[ \varphi_{2h} + \varphi_{3h} = C \]  

where C is a constant.

According to the aforementioned analysis, it can be found that, in the case of the specific harmonic frequency, as long as the total harmonic equivalent impedance of the closed-loop circuit, which consists of the filtering winding and the fully tuned circuit, is approximately equal to zero, that is to say, the conditions of the constant linkage theorem are created, then the harmonic magnetic flux at the filtering winding side can balance out the
harmonic magnetic flux at the valve winding side and the harmonic magnetic potential balance equation holds as

\[ N_2 I_{h2} + N_3 I_{h3} = 0. \] (6)

Therefore, the harmonic current cannot be inducted into the grid winding of the rectifier transformer, i.e., the harmonic current is suppressed in the valve and filtering windings. It prevents the harmonic current from flowing into the grid winding and the public network. Moreover, the fully tuned circuit can also partly compensate reactive power near the rectifier bridge.

4.2. Implementation Conditions

From the aforementioned principle analysis, it can be seen that the implementation of the inductive filtering method satisfies the conditions of the constant linkage theorem, which is similar to the damping winding of the synchronous machine [26]. For the new industrial dc power supply system, the closed-loop circuit, which consists of the harmonic equivalent impedances of the filtering winding and the fully tuned circuit, creates exactly such conditions. In order to guarantee the inductive filtering performance, the closed-loop circuit should satisfy the following conditions.

- At the specific harmonic frequencies, the fully tuned circuit should reach resonance state, and its quality factor (Q) should be as high as possible, which means a higher power-loss saving for the fully tuned circuit.
- The equivalent reactance of the filtering winding of the new rectifier transformer should be equal or approximately equal to zero, and the equivalent resistance of the filtering winding should be as small as possible, which also means a higher power-loss saving for the new rectifier transformer.

At present, in the practical project, it could be impossible to implement the complete zero-impedance design for the total equivalent impedance of the closed-loop circuit. However, as long as the values of both equivalent impedances of the fully tuned circuit and the filtering winding are controlled within the acceptable range, a good inductive filtering performance can be achieved.

5. HARMONIC MODEL AND RELATED EQUIVALENT DECOUPLING CIRCUIT MODEL

Fig. 5: New rectifier transformer and the related fully tuned circuit. (a) Harmonic model. (b) Equivalent decoupling circuit model.

The harmonic equivalent impedance of the grid, valve, and filtering windings of the new rectifier transformer can be expressed as

\[
\begin{align*}
Z_{1h} &= \frac{1}{3} \left( Z_{h12} + Z_{h13} - Z_{h23} \right) \\
Z_{2h} &= \frac{1}{3} \left( Z_{h21} + Z_{h23} - Z_{h13} \right) \\
Z_{3h} &= \frac{1}{3} \left( Z_{h31} + Z_{h32} - Z_{h12} \right)
\end{align*}
\] (7)

where \( Z_{h12}, Z_{h13}, \) and \( Z_{h23} \) are the h-th-order harmonic short-circuit impedances between the grid and valve windings, between the grid and filtering windings, and between the valve and filtering windings, respectively, which...
can be obtained from the practical short-circuit test on the new rectifier transformer.

According to the flow path of the hth-order harmonic current shown in Fig. 5(b), the following equations can be obtained:

\[
\begin{align*}
I_{Sh} &= I_{1h} \\
I_{2h} &= I_{Lh} \\
I_{3h} &= -I_{f3h}
\end{align*}
\]

(8)

Fig. 5 shows the harmonic model and the equivalent decoupling circuit model of the new rectifier transformer and the related fully tuned circuit. In these models, the rectifier valves are equivalent to the harmonic current resource \(I_{Lh}\) and considering the possible harmonic voltage from the public network, where \(I_{1h}, I_{2h}, \) and \(I_{3h}\) are the hth-order harmonic currents in the grid, valve, and filtering windings of the new rectifier transformer, respectively, and \(I_{Sh}, I_{Lh}, \) and \(I_{f3h}\) are the hth-order harmonic currents at the grid, load, and filtering sides, respectively.

Also, the equations concerning the hth-order harmonic voltage can be expressed as

\[
\begin{align*}
V_{1h} &= V_{Sh} - Z_{Sh} I_{Sh} \\
V_{2h} &= V_{f3h} \\
V_{f3h} &= Z_{f3h} I_{f3h}
\end{align*}
\]

Where \(V_{1h}\) and \(V_{3h}\) are the hth-order harmonic voltages of the grid and filtering windings of the new rectifier transformer and \(V_{0h}\) is the hth-order harmonic voltage of the fully tuned circuit.

According to the transformer magnetic potential balance principle, the hth-order harmonic magnetic potential balance equation can be obtained as follows:

\[
I_{2h} + \frac{N_1}{N_2} I_{1h} + \frac{N_3}{N_2} I_{Sh} = 0.
\]

(10)

According to the multiwinding transformer theory, the hth-order harmonic voltage transfer equations can be obtained as follows:

\[
\begin{align*}
V_{2h} - \frac{N_3}{N_2} U_{1h} &= -Z_{1h} N_1 I_{1h} - Z_{2h} N_2 I_{2h} - Z_{3h} N_3 I_{3h} \\
V_{f3h} - \frac{N_3}{N_2} U_{3h} &= -Z_{1h} N_1 I_{1h} - Z_{2h} N_2 I_{2h} - Z_{3h} N_3 I_{3h}
\end{align*}
\]

where \(V_{2h}\) is the hth-order harmonic voltage of the valve winding of the new rectifier transformer.

Equations (7)–(11) construct the basic mathematical model of the new rectifier transformer and the fully tuned circuit. This model expresses the constraints among the harmonic voltage, the harmonic current, and the harmonic impedance. Such a mathematical model is useful for technical characteristic study on the inductive-filtering-based industrial dc power supply system, which contains the new rectifier transformer and the fully tuned circuit.

According to the established mathematical model, we can further obtain the equation that expresses the influence of the load side’s harmonic current resource \(I_{Lh}\) and the grid side’s harmonic voltage resource \(V_{Sh}\) on the harmonic current \(I_{Sh}\) in the grid winding and at the grid side, i.e.,

\[
I_{Sh} = \left\{ \frac{(Z_{2h} + Z_{f3h}) N_2 N_1}{(Z_{2h} + Z_{f3h}) N_2^2 + (Z_{1h} - Z_{Sh}) N_3^2} I_{1h} \right. \\
- \frac{N_2^2 V_{2h}}{(Z_{2h} + Z_{f3h}) N_2^2 + (Z_{1h} - Z_{Sh}) N_3^2} \right\}.
\]

(12)

Moreover, we can also obtain the equation that expresses the influence of the load side’s harmonic current resource \(I_{Lh}\) and the grid side’s harmonic voltage resource \(V_{Sh}\) on the harmonic current \(I_{3h}\) in the filtering winding of the new rectifier transformer, i.e.,

\[
I_{3h} = \left\{ \frac{(Z_{2h} - Z_{Sh}) N_3 N_2}{(Z_{2h} + Z_{f3h}) N_2^2 + (Z_{1h} - Z_{Sh}) N_3^2} I_{2h} \right. \\
+ \frac{N_2 N_1 V_{f3h}}{(Z_{2h} + Z_{f3h}) N_2^2 + (Z_{1h} - Z_{Sh}) N_3^2} \right\}.
\]

(13)

Equations (12) and (13) reveal the effect of the equivalent impedances of the new rectifier transformer and the fully tuned circuit on the inductive filtering performance. Looking at the analysis results in Section III-B, we know that \(Z_{Sh} \approx 0\) and based controlled rectifier. \(Z_{Sh} = 0\). Assuming the ideal condition, that is to say, there is no
or few harmonic voltage in the public network \( V_{h0} \approx 0 \), then, from (12), we can obtain \( I_{h0} \approx 0 \), which means that there is no or few \( h \)th-order harmonic current in the grid winding of the rectifier transformer.

To get such good inductive filtering performance for both the ac grid and the grid (primary) winding of the rectifier transformer, aside from the special impedance design of the new transformer mentioned in Section III-B, the capacitance and the reactance of the fully tuned circuit can be designed as follows:

\[
\begin{align*}
\frac{1}{j\omega_1 L_{h}} &= \frac{1}{j\omega_1 C_{h}} = 0 \\
C_{h} &= \frac{Q_{\text{cap}}(h^2-1)}{(V_{h})^2 h^2} \\
L_{h} &= \frac{1}{h^2 \omega_1^2 C_{h}} \\
I_{2h} &= \frac{N_2}{N_3} I_{2h}.
\end{align*}
\]  

From this, it can be clearly seen that (15), obtained from the equivalent circuit model, is the same as (6) obtained from the constant linkage theorem, which verifies the correctness of both the theoretical analysis and the established mathematical model. Moreover, the inductive filtering mechanism, which (6) and (15) reveal, can be physically described as follows: When the harmonic current flows into the valve winding of the new rectifier transformer from the harmonic resource, the filtering winding inducts the corresponding harmonic current to counteract it, and thus, there is no inducted harmonic current in the grid winding and at the grid side.

6. SIMULATION RESULTS

The simulation is used to reveal the distribution of harmonic current in the windings of the new rectifier transformer and validate the theoretical analysis mentioned previously.

Fig. 7 shows the simulation results about the current in different windings of the new rectifier transformer. (a) In the valve winding. (b) In the filtering winding. (c) In the grid winding.

Fig. 7 shows the simulation results about the current in different windings of the new rectifier transformer. Because the transformer is connected to the nonlinear power converter, there are a large number of harmonic currents in the valve winding, as shown in Fig. 7(a). However, the implementation of the inductive filtering method makes the filtering winding induct the corresponding harmonic currents to eliminate them [see Fig.
Thus, most of harmonic currents cannot induct into the grid winding, as shown in Fig. 7(c). Fig. 8 shows that the Total Harmonic Distortion of the grid side current waveforms while using inductive filtering method. Table I shows that comparative analysis, it can be also seen that the inductive filtering method can greatly reduce the harmonic content in the grid winding and at the grid side and the current’s total harmonic distortion (THD), which can be seen from the fast Fourier transform (FFT) results.

![Fig.8: Harmonic distortion percentage of grid current.](image)

**Table I: HARMONIC CONTENT AND THD OF THE CURRENT IN THE GRID WINDING OF THE NEW RECTIFIE TRANSFORMER WITH OR WITHOUT INDUCTIVE FILTERING METHOD (UNIT: PERCENT)**

<table>
<thead>
<tr>
<th>Harmonic order</th>
<th>At 35kv bus side of rectifier unit 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without inductive filtering</td>
</tr>
<tr>
<td>3</td>
<td>7.56</td>
</tr>
<tr>
<td>5</td>
<td>4.55</td>
</tr>
<tr>
<td>7</td>
<td>3.22</td>
</tr>
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<td>11</td>
<td>2.07</td>
</tr>
<tr>
<td>13</td>
<td>1.75</td>
</tr>
<tr>
<td>THD</td>
<td>17.99</td>
</tr>
</tbody>
</table>

7. ADVANTAGES AND APPLICATIONS

7.1. Advantages
- Interference suppression
- Reduce harmonics
- Decreases voltage distortion
- Power factor correction

7.2. Applications
- The inductive filtering method applies in an alternate configuration for the design of band pass filters using transversal methods. This method is used to implement transmission zeros for maximum selectivity.
- The inductive filters are used in the chemical electrolysis process. Filtration is commonly the mechanical or physical operation which is used for the separation of solids from fluids by interposing a medium through which only fluids can pass.
- In textile industries, the inductive filters are used to reduce harmonics, increase efficiency to improve electric power quality and reduce energy consumption.
- The inductive filters use in power systems to reduce the harmonic currents which generates at the dc link to the line currents.
- International wire netting industries.
- In large business environments where the reliability of power is necessary.
- Chemical industries.
- Electrical traction purpose.
- Automobile industries.

CONCLUSIONS
The entire proposed model is designed in MATLAB/SIMULINK software. The simulation results show that the inductive-filtering-based industrial dc power supply system not only can improve the filtering performance but also can greatly reduce the effects of harmonic on the dc power supply system itself and also shows that the percentage of harmonic distortion of grid current reduced to 0.79% from 17.99% by using the inductive filter which increases the operating efficiency of the rectifier transformer in power supply system.

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AUTHORS’ BIOGRAPHY
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