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Variable Hysteresis Band Current Controller for Power Harmonics Compensation

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***Abstract*— Hysteresis band current controller is proposed for active power filter (APF) to compensate power system harmonics. This control strategy is effective to make supply current sinusoidal. Shunt active power filter plays very vital role in harmonic elimination, which produces due to increase in non linear and unbalanced load, at a point of common coupling. Sensing load currents, dc bus voltage and source voltages controller calculates the reference currents, and compensating currents. Compensating Currents are produced by APF, which are exactly equal and opposite of those harmonic currents in supply by means of a signal provided by hysteresis band current controller.**

MATLAB/Simulink power system tool box is used to simulate the proposed system. The simulation results found quiet satisfactory to compensate the harmonics under different load conditions.

***Keywords*— Shunt active power filter, hysteresis band current controller, Harmonic Distortion**

I. INTRODUCTION

The wide spread demand of power electronics equipment and solid state power conversion equipments causing utilities to become more concern about power quality. The power semiconductors used in all such equipments have nonlinear characteristics which causes serious harmonics and reactive power unbalance in power system[1]. Passive power filters (PPF) are used as traditional way for harmonic suppression which has made up of basic components like power capacitor, power inductance and resistance. But there are so many disadvantages existing in PPF like, 1) It cannot filter the non-characteristic harmonics. 2)The impedance characteristic is deteriorated with frequency reduce below the lowest resonance frequency [2, 3, 4]. The active power filter works on principal by detecting harmonic current to calculate the amount of the compensating current needed for feeding back to the power system in the opposite direction of the harmonic current. There are so many current control methods for such active power filter configurations, but for quick current control and easy implementation hysteresis band current control method has the highest rate among other current control methods such as sinusoidal PWM.

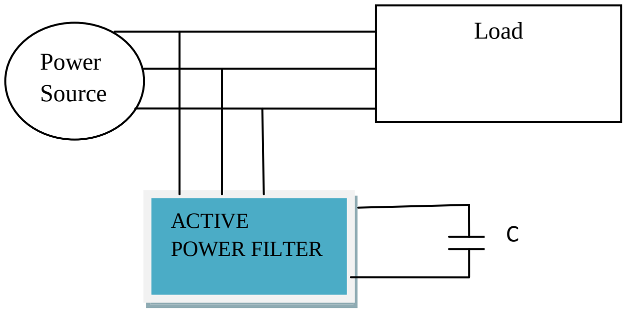


Fig.1: Block Diagram of Shunt Active Power Filter

The aim of this study is to investigate the effect of changing a type of load and change in the bandwidth of hysteresis band current controller to THD of supply current. In this paper Instantaneous power theory is explained initially and later the design of hysteresis band current controller is given. Finally the two cases of different non linear loads are taken and their harmonics content with and without APF are compared.

II. SHUNT ACTIVE POWER FILTER

Shunt active power filter is a device which connects in parallel with non linear load to cancel the reactive and harmonic currents from a non linear load. Thus the resulting total current drawn from the AC main is sinusoidal. Here APF needs these compensating currents to compensate the non linear loads in the system.

In an APF in fig. 1 a current controlled voltage source inverter is used to generate the compensating current(i_c) and is injected into the utility power source grid. This affects the harmonic components get cancelled drawn by the non linear load and keeps the utility line current (is) pure original format i.e. sinusoidal form. In this paper Instantaneous power theory is used for instantaneous current harmonics detection in active power filter (APF).

III. INSTANTANEOUS POWER THEORY

In three-phase circuits, instantaneous currents and voltages are converted to instantaneous space vectors. In instantaneous power theory, the instantaneous three-phase currents and voltages are calculated as following equations. These space vectors are easily converted into the α–β orthogonal coordinates.

$$\begin{bmatrix} v\alpha \\ v\beta \end{bmatrix} = \sqrt{(2/3)} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} va \\ vb \\ vc \end{bmatrix} \qquad (1)$$

$$\begin{bmatrix} i\alpha \\ i\beta \end{bmatrix} = \sqrt{(2/3)} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} ia \\ ib \\ ic \end{bmatrix} \qquad (2)$$

Considering only the three-phase three-wire system, the three-phase currents can be expressed in terms of harmonic positive, negative and zero sequence currents. In Equations (1) and (2), α and β are orthogonal coordinates. Vα and iα are On α axis, vβ and iβ are on β axis. In three-phase conventional instantaneous power is calculated as follows:

$$P = v_\alpha i_\alpha + v_\beta i_\beta \qquad (3)$$

In fact, instantaneous real power (p) is equal to following equation:

$$P = v_a i_a + v_b i_b + v_c i_c \qquad (4)$$

Instantaneous real and imaginary powers are calculated as Equations(5):

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v\alpha & v\beta \\ -v\beta & v\alpha \end{bmatrix} \begin{bmatrix} i\alpha \\ i\beta \end{bmatrix} \qquad (5)$$

In Equation (5),vα iα and vβ iβ are instantaneous real (p) and imaginary (q) powers. Since these equations are products of instantaneous currents and voltages in the same axis. In three-phase circuits, instantaneous real power is p and its unit is watt. In contrast vα iβ and vβ iα are not instantaneous powers. Since these are products of instantaneous current and voltages in two orthogonal axes,qis not conventional electric unit like W or Var.qis instantaneous imaginary power and its unit is Imaginer Volt Ampere (IVA) . These power quantities given above for an electrical system represented in a–b–c coordinates and have the following physical meaning.

$\bar{p}$, the mean value of the instantaneous real power corresponds to the energy per time unity which is transferred from the power supply to the load, through a–b–c coordinates, in a balanced way.

$\tilde{p}$, alternated value of the instantaneous real power—it is the energy per time unity that is exchanged between the power supply and the load through a–b–c coordinates.

$\bar{q}$, instantaneous imaginary power—corresponds to the power that is exchanged between the phases of the load. This component does not imply any exchange of energy between the power supply and the load, but is responsible for the existence of undesirable currents, which circulate between the system phases.

$\tilde{q}$, the mean value of the instantaneous imaginary power that is equal to the conventional reactive power. The instantaneous active and reactive power includes ac and dc values and can be expressed as follows:

$$p = \bar{p} + \tilde{p}$$

$$q = \bar{q} + \tilde{q} \qquad (6)$$

dc values of the p and q (¯ p,¯ q) are created from positive-sequence component of the load current. ac values of the p and q (˜p,˜ q) are produced from harmonic components of the load current. Equation(5)can be written as Equation(7):

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix}^{-1} \begin{bmatrix} p \\ q \end{bmatrix} \qquad (7)$$

From Equation(7), in order to compensate harmonics and reactive power instantaneous compensating currents (icα and icβ) on α and β coordinates are calculated by using $\tilde{p}$ and $\bar{q}$ as given below

$$\begin{bmatrix} i_{c\alpha} \\ i_{c\beta} \end{bmatrix} = \begin{bmatrix} v\alpha & v\beta \\ -v\beta & v\alpha \end{bmatrix}^{-1} \begin{bmatrix} -\tilde{p} \\ -q \end{bmatrix} \qquad (8)$$

In order to obtain the reference compensation currents in the a–b–c coordinates the inverse of the transformation given in expression (9)is applied:

$$\begin{bmatrix} i *_{ca} \\ i *_{cb} \\ i *_{cc} \end{bmatrix} = \sqrt{(2/3)} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_{c\alpha} \\ i_{c\beta} \end{bmatrix} \qquad (9)$$

IV. HYSTERESIS BAND CURRENT CONTROLLER

The actual active power filter line currents are monitored instantaneously, and then compared to the reference currents generated by the control algorithm.

In order to get precise instantaneous current control, the current control method must supply quick current controllability, thus quick response. For this reason, hysteresis band current control for active power filter line currents can be implemented to generate the switch-ing pattern the inverter. There are various current control methods proposed for such active power filter configurations, but in terms of quick current controllability and easy implementation hysteresis band current control method has the highest rate among other current control methods such as sinusoidal PWM. Hysteresis band current control is the fastest control with minimum hardware and software but even switching frequency is its main drawback. The hysteresis band current control scheme, used for the control of active power filter line current, is shown in Fig. 2, composed of a hysteresis around the reference line current.

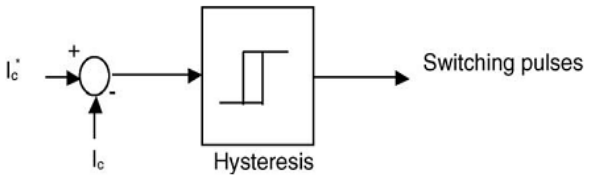


Fig 2:Hysteresis band current controller block diagram.

The reference line current of the active power filter is referred to as ic* and actual line current of the active power filter is referred to as ic. The hysteresis band current controller decides the switching pattern of active power filter. The switching logic is formulated as follows:

Ifica<(i∗ca−HB) upper switch is OFF and lower switch is ON for leg “a” (SA = 1).

Ifica>(i∗ca+ HB) upper switch is ON and lower switch is OFF for leg “a” (SA = 0).

The switching functions SB and SC for phases “b” and “c” are determined similarly, using corresponding reference and measured currents and hysteresis bandwidth (HB).

V. THE PROPOSED METHOD

Simulation is performed on 2 types of Three phase Balanced Non –Linear Load as follows:

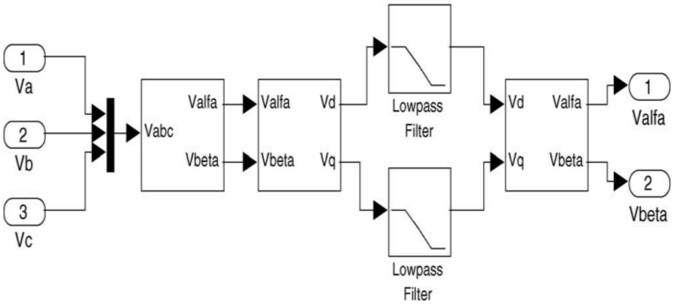


Fig 3 : p-q theory based control block diagram of three-phase shunt APF

A . system Specification of the design:

TABLE I
SYSTEM PARAMETERS

Source Voltage	Vsa, Vsb, Vsc	220v
System Frequency	f	50 Hz

B. APF Specifications

TABLE II
SPECIFICATIONS OF APF

AC side inductance	L Lac	1 mH
AC side resistance	R Lac	0.01 Ω
DC side Resistance	R Ldc	18 Ω
DC side Inductance	L Ldc	85mH

Load 1: Thyristor Rectifier (of rating 4 KVA)supplying to DC motor equivalent of 2.5KW

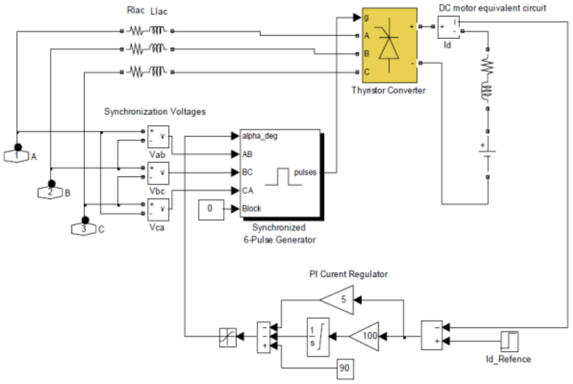


Fig 4: Block Diagram for Thyristor Converter controlled DC motor

Using PI controller DC motor current value is maintained at 20 Amps. PI controller varies alpha of thyristor until motor current matches reference current. Pulse width is takes as .

Load 2: Diode Rectifier supplying to pure resistive load.

A pure resistive load is taken in order to APF performance. As in this load phase current varies in abrupt manner on the contrary to RL load where load phase current is smooth varying curve.

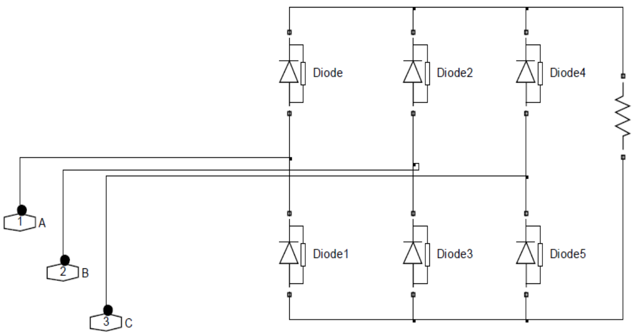
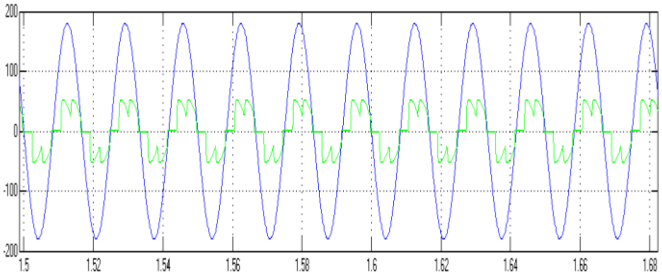
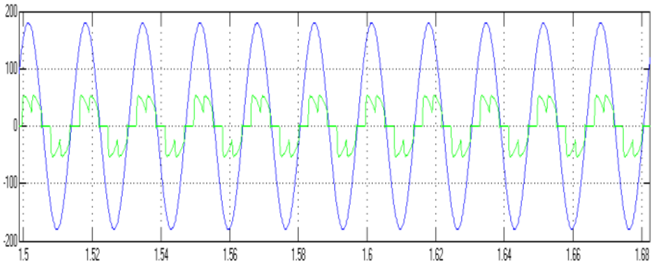


Fig 5: Block diagram for Diode rectifier supplying to pure Resistive Load.

VI. SIMULATION RESULTS

A. Case 1: Thyristor converter supplying to DC motor Equivalent(R-L Type Load)





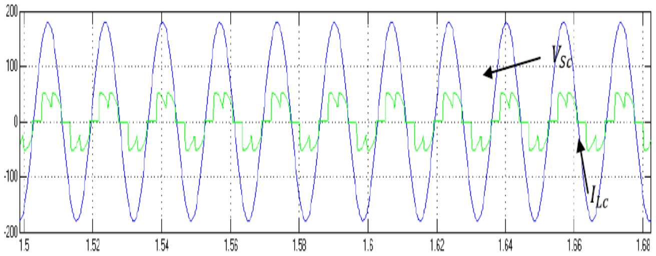


Fig 6: Source Voltages and Load Currents with APF (Case 1)

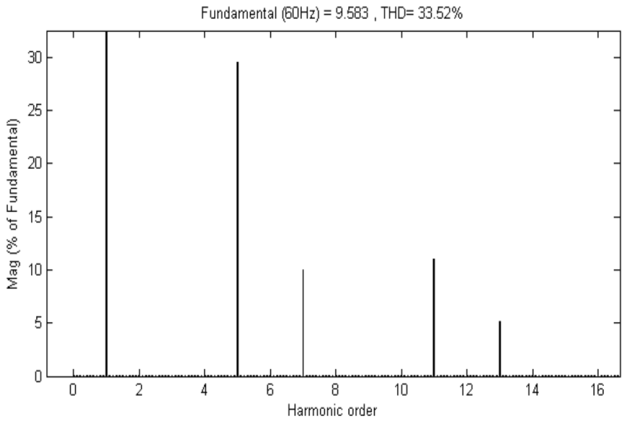


Fig 7 Harmonic Analysis of Load Current with APF (Case 1)

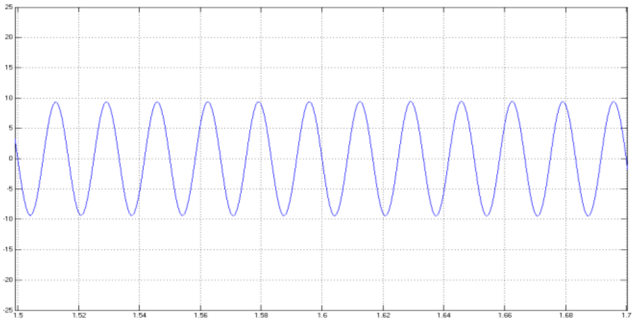


Fig:8 Reference Current (Case 1)

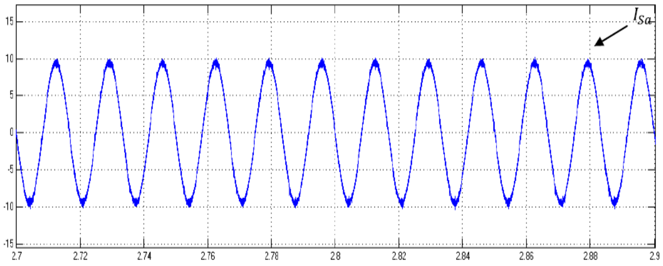


Fig 9: Source Current with APF(Case 1)

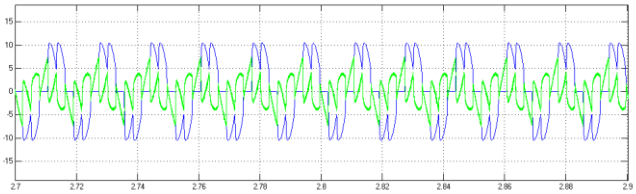


Fig 10: Compensating Current and Load Current(Case 1)

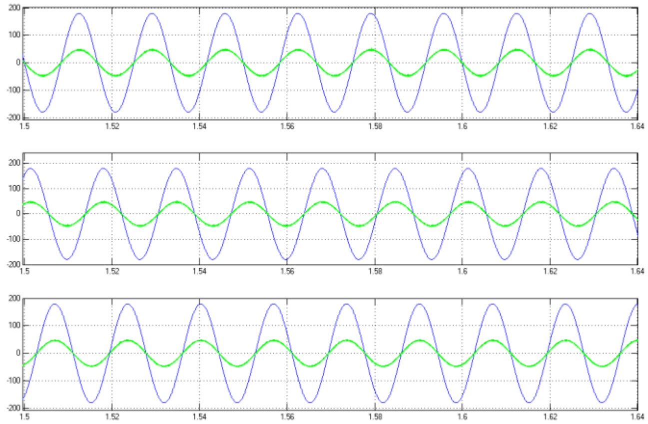


Fig 11: Source Voltage and Source Current with APF(Case 1)

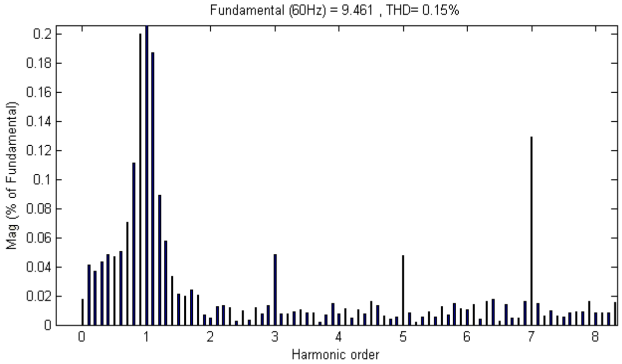


Fig 12: Harmonic Analysis of Source Current (Case 1)

B. Case:2 Diode Rectifier supplying to pure resistive

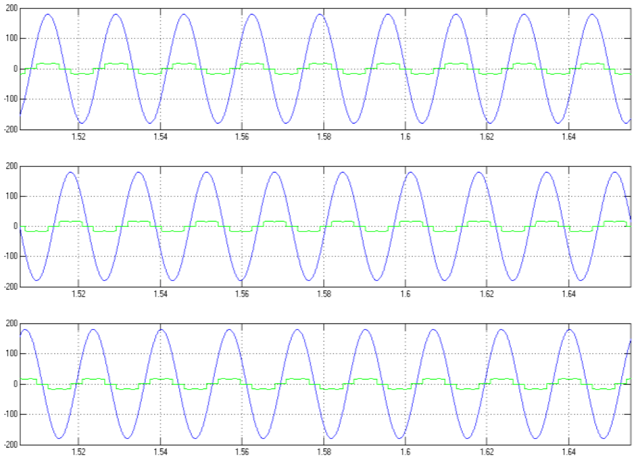


Fig 13: load Source Voltage & Load Current with APF

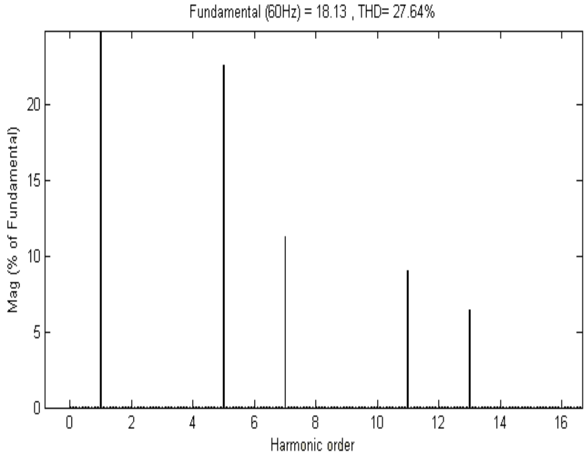


Fig 14: Harmonic Analysis of Load Current

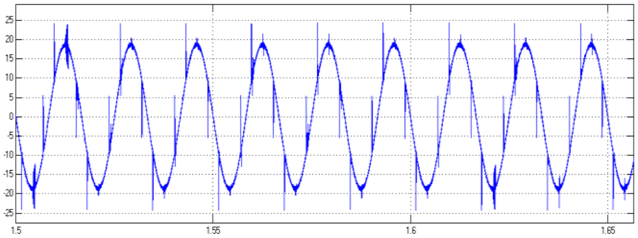


Fig 15: Source Current after Compensation(Case 2)

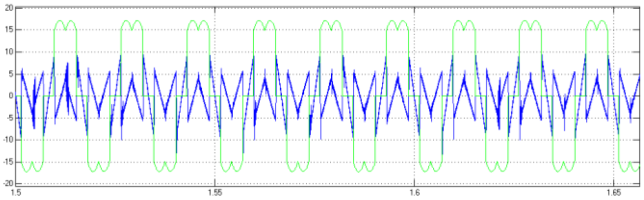


Fig 16: Compensating Current and Load Current(Case 2)

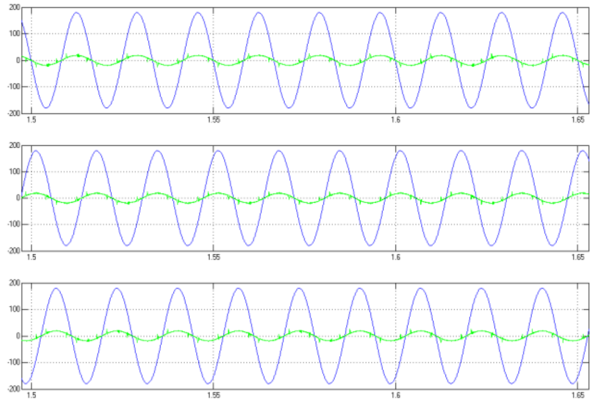


Fig 17: Source Voltages and Source Current(Case 2)

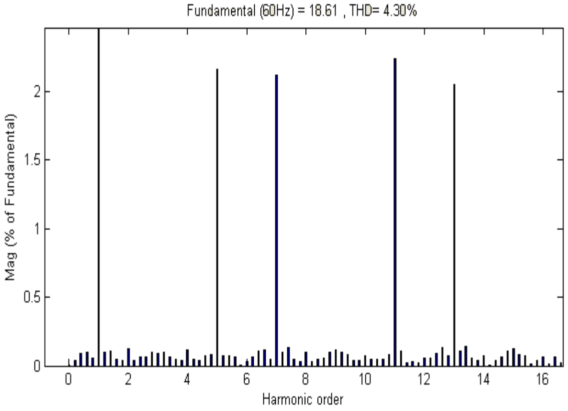


Fig 18: Harmonic analysis of Source Current(Case 2)

VII. CONCLUSION

In this paper new control approach of APF has been proposed for better results of APF. The MATLAB simulation results verified the effectiveness of the proposed control scheme. Active power filter based on hysteresis band current controller gives satisfactory operation even when the system phase voltages are unsymmetrical and distorted, as there is no distortion observed in the line currents.

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