Impacts on Power Factor of AC Voltage Controllers Under Non-Sinusoidal Conditions

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ABSTRACT

AC-AC conversion is obtained with the help of Cyclo-converters, DC Link converters and AC Voltage Controllers. AC voltage controllers are also referred to as voltage regulators. Main issue concerned to these converters is that they generate harmonics due to periodic variable structure system. The generated harmonics create disturbances and degrade the performance of converter. The power factor of supply side is affected due to these harmonics.

This paper focuses on source side power factor of ac voltage controllers under nonsinusoidal conditions. In order to observe the power factor, measurement tool of power factor and simulation model of ac voltage controller is also developed in MATLAB software.

Key Words: AC Voltage Controllers, Bidirectional, Harmonics, Power Factor under Nonsinusoidal Conditions.

1. INTRODUCTION

Power electronic converters are widely used in various industrial applications. The development of new power electronic devices such as GTOs, IGCTs, MCTs, MOSFETs, IGBTs etc. further widen the application of these converters.

Nowadays, power electronic converter based loads such as energy savers, uninterruptible power supplies, light dimmers, fluorescent lamps, induction heating equipment, arc furnaces, etc. utilized by the power system network consumers. [1-3]. Due to switching operations of power electronic converters they contain nonlinearities and generate harmonics. The generation of harmonics not only affects the performance of converters but the quality of power system is badly affected when these converters are connected with electrical networks. The most common effects of harmonics include overloading of neutral conductor, transformers and power factor improving capacitors, distortion in supply voltage, supply side power factor, and errors in energy meters. [1-2,4]. To minimize these effects, power electronic researchers are devoting in the further improvement of converter topologies. In this work, source side power factor of bidirectional ac voltage controller under nonsinusoidal conditions has been analyzed through simulation.

2. THE BIDIRECTIONAL AC VOLTAGE CONTROLLER

AC voltage controllers have found various applications due to their advantages such as, simplicity, low cost and high efficiency. These controllers are commonly used in light dimmer circuits, industrial heating, speed control of ac motors, etc. The fixed supply voltage of ac voltage regulators is varied by using On-Off control, PWM (Pulse Width Modulation) and PAC (Phase Angle Control) methods.

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The circuit diagram of bidirectional ac voltage controller is shown in Fig. 1. It consists two anti-parallel thyristors TH_1 and TH_2, load and ac source Vs.

3. SIMULATION MODEL OF BIDIRECTIONAL AC VOLTAGE CONTROLLER

The controller is designed and simulated using SIMULINK and SIM Power Systems tool boxes of MATLAB software. MATLAB has a strong capability to model, simulate, and analyze linear and nonlinear systems. SIMULINK has complete library and user can access of linear and nonlinear blocks, sink and source components, and various connectors. The users can also design and simulate the models of power systems by using libraries of SIM Power System Blockset. This library includes ac and dc machines, solid state components, dc and ac power sources FACTS (Flexible AC Transmission Systems) devices and measuring tools.

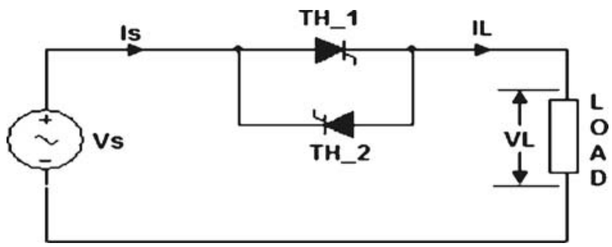

FIG. 1.CIRCUIT DIAGRAM OF BIDIRECTIONAL AC VOLTAGE CONTROLLER

The simulation model of bidirectional ac voltage controller consists of two anti-parallel thyristors as shown in Fig. 2. The output voltage is controlled by varying triggering angle of two anti-parallel thyristors by using pulse generator Blocks (1 and 2). THD (Total Harmonic Distortion) to signal block is used for the measurement of THD in source current. For the measurement of power factor, a power and power factor model is also developed which is under masked in the simulation model. The simulation model was triggered at various firing angles in order to get the values of THD and power factor.

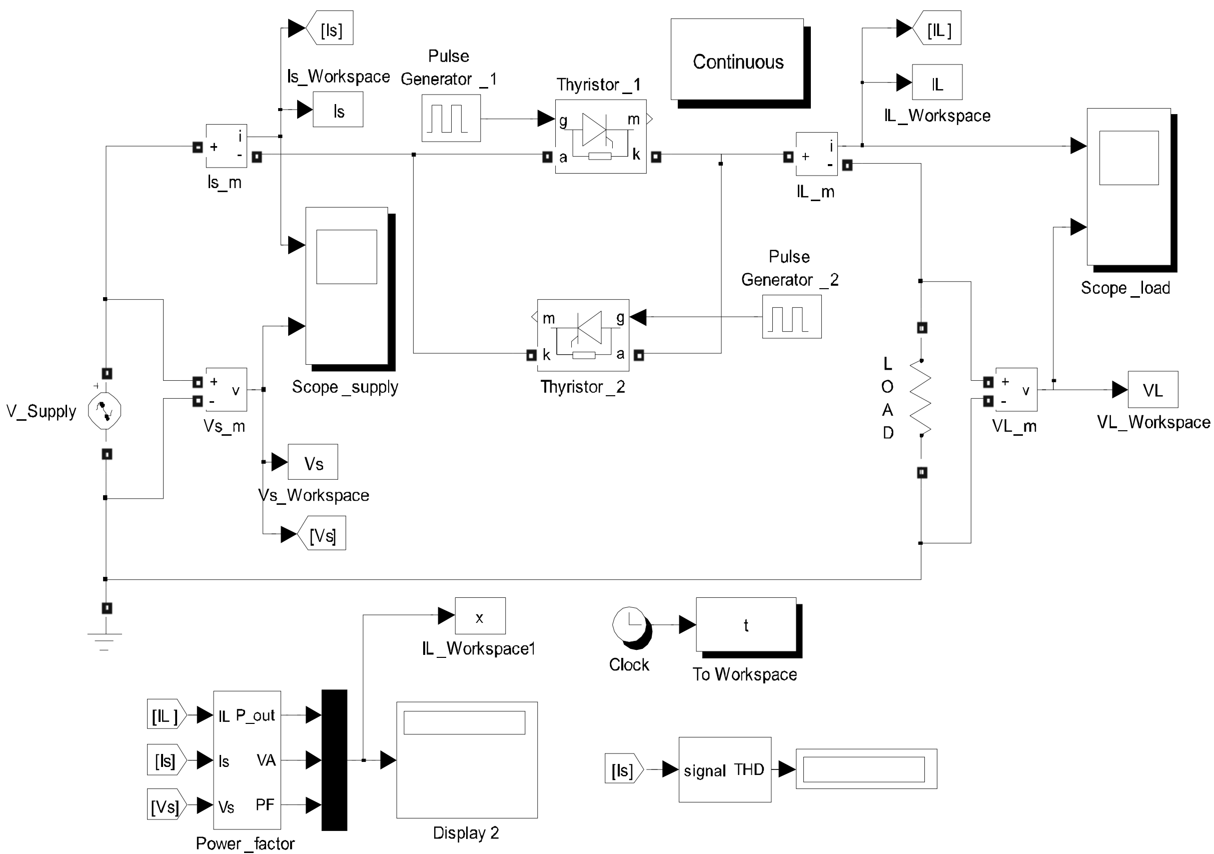

FIG. 2. SIMULATION MODEL OF BIDIRECTIONAL AC VOLTAGE CONTROLLER CONSISTS WITH TWO ANTI-PARALLEL THYRISTORS

The current and voltage waveforms of simulated model at resistive load are illustrated in Figs. 3-4. It is seen from Figs.3-4 that the supply and load currents and load voltage becomes non-sinusoidal due to harmonics. The different values of THD plotted against firing angles at different loads are shown in Fig. 5.

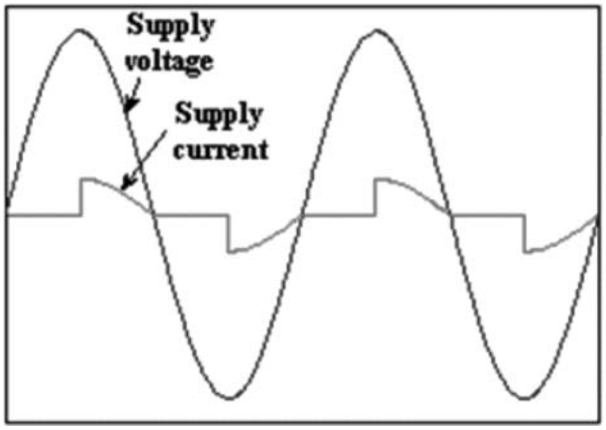

FIG. 3. WAVEFORMS OF SUPPLY CURRENT & VOLTAGE

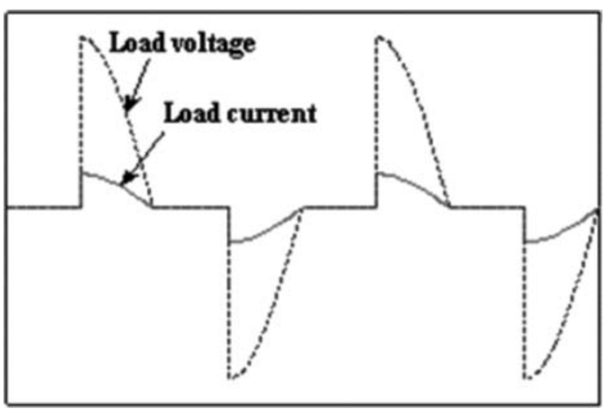

FIG. 4. LOAD CURRENT AND VOLTAGE WAVEFORMS

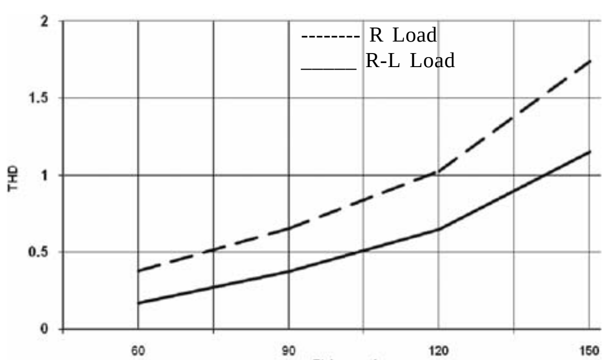

FIG. 5. THD AGAINST FIRING ANGLE AT DIFFERENT LOADS OF SUPPLY CURRENT

4. POWER FACTOR ANALYSIS OF AC VOLTAGE CONTROLLERS

AC voltage controllers with phase control techniques are extensively used in many ac power control applications. These converters are variable structure systems and contain nonlinearities which generate harmonic currents [1,2,5-9]. The power factor of supply side is affected due to these harmonics.

4.1 Power Factor of Sinusoidal Circuits

Power Factor of Sinusoidal Circuits is as follows:

Power Factor PF = P/S (1)

Where P is $V_sI_s \cos\phi$, S is V_sI_s V_s is rms input voltage, and I_s is rms input current.

If sinusoidal current and voltage has phase difference of angle ϕ then power factor is also equal to $\cos\phi$. Power factor is always equal to or less than unity. Power factor of sinusoidal circuits can be made unity by connecting energy storage compensator such as capacitor [5-6].

4.2 Power Factor Measurement of AC Voltage Controller under Non-Sinusoidal Conditions

The non sinusoidal situation in a circuit can occur when [5,7-8]:

(i) Linear circuit consists of non-sinusoidal supply voltage.

(ii) Circuit consists of nonlinear impedance but supply voltage is sinusoidal.

(iii) Circuit consists of nonlinear impedance but supply voltage is non-sinusoidal.

The power factor of bidirectional ac voltage controller was analyzed by using developed power factor measurement tool of simulation model as shown in Fig. 2. The simulation model is supplied from sinusoidal voltage at its input but its supply current is non-sinusoidal (Fig. 3). Therefore, power factor of the supply side is the product of displacement factor and current ratio which is given by Equation (2)

Power Factor, $P_F = \cos\phi_1 x (I_F / I_L)$ (2)

Where ϕ_1 is angle between current and voltage of fundamental component (supply), I_F is Current of fundamental component in rms, and I_L is total load current (fundamental + harmonics) in rms

Fig. 6 illustrates the power factor variation of supply side against firing angles at resistive and RL loads. At resistive load, the power factor is less than unity when firing angle is other than zero. This is because of harmonics in supply current. This low power factor increases the KVA loading on the source. Furthermore, the current in electrical networks is increased. As a result the losses are increased which limit the capacity of electrical networks. Furthermore, if ac voltage controllers are connected at the premises of industrial consumers, they are charged with low power factor penalty if the harmonics are not controlled. By using capacitors, the overall power factor of non-sinusoidal circuits can not be compensated but only displacement factor, cos ϕ_1 can be made unity.

5. CONCLUSIONS

In this work, source side power factor of bidirectional ac voltage controller under nonsinusoidal conditions has been analyzed through simulation. The simulation model of such converter is successfully developed in MATLAB/ Simulink.

From the results obtained from the simulation model it is concluded that at pure resistive load, the power factor is less than unity when firing angle is other than zero. This is because of harmonics in the supply current. By using only capacitors, the overall power factor of non-sinusoidal circuits can not be compensated but only displacement factor, Cosϕ_1 can be made unity.

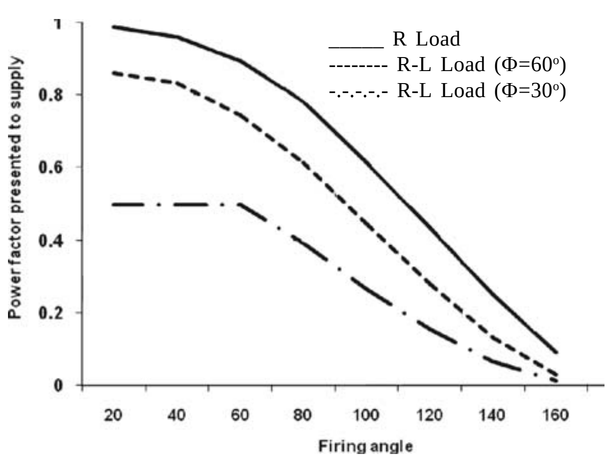

FIG. 6. POWER FACTOR VARIATION OF SUPPLY SIDE AGAINST FIRING ANGLE AT DIFFERENT LOADS

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