DIGITAL SIMULATION OF MULTILEVEL INVERTER FED INDUCTION MOTOR DRIVE

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ABSTRACT

This paper extends the knowledge about the simulation of three phase nine level inverter fed induction motor drive through harmonic analysis. Large electric drives and utility applications require advanced power electronic converter to meet high power demands. As a result, multilevel converter has been introduced as an alternative in high power and medium voltage situations. The quality of voltage and current of a conventional inverter fed induction machine is poor due to presence of harmonics and hence there is a significant level of energy losses. The nine level inverter is used to reduce the harmonics. The inverters with a large number of steps can generate high quality of voltage waveforms. The nine levels can follow voltage reference with accuracy and with the advantage to balance the DC capacitor voltages, sine triangle pulse width modulation (SPWM) technique, is applied and suitable for multilevel converter. The digital simulation of multilevel inverter fed induction motor model is done using Simulink.

Keywords: Conventional Inverter, Harmonics, Induction Motor, Multilevel Converter, SPWM

I. INTRODUCTION

Power Electronics is playing an important role in the torque speed control of motor drive. Variable speed AC induction motor drives are replacing the conventional DC drives in industrial drive environment [1]. DC motors have excellent speed and torque response, they have inherent disadvantage of commutator and mechanical brushes, which undergo wear and tear with time. AC induction machines are single excited, mechanically rugged and robust, but speed and torque control of these machines are more complex compared to DC machines. Induction machines have low starting torque and the motors carry large amplitude of starting currents, star delta starting or pole changing methods [2]. The advantage of controlled switches the speed and torque control of induction machines have become relatively easier. A voltage source inverter can run the induction by applying three phase square wave voltages to the motor stator winding [3]. A variable frequency square wave voltage can be applied to the motor by controlling the switches of the power semiconductor switches. The square wave voltage will induce low frequency harmonic torque pulsation in the machine. Also variable voltage control with variable frequencies of operation is not possible with square wave inverters [4]. The recent advancement in power electronics has initiated to improve the level of inverter instead increasing the size of filter. The total harmonic distortion of the classical inverter is very high. The performance of multilevel inverter is better than the classical inverter. In other words the total harmonic distortion for multilevel inverter is low. The total harmonic distortion is analysed between multilevel inverter and other classical inverter [5]. Three different major multilevel converter structures have been applied in industrial applications cascaded H-bridges converter with separate dc sources, diode clamped and flying capacitors. The cascaded multilevel inverter with separate

DC sources is clearly the most feasible topology for use as a power converter for medium and high power applications. A cascaded multilevel inverter is to eliminate the excessively large number of bulky transformers required by conventional multi pulse inverters, clamping diodes required by multilevel diode-clamped inverters and flying capacitors required by multilevel flying-capacitor inverters. The most advantage of using the cascaded inverter it makes induction motor more accessible and open wiring possible for most of an induction motor power system, low voltage switching devices can be used, no EMI problem or common voltage problem exists. The cascaded multilevel inverter packaging layout is much easier because of the simplicity of structure and lower component count. These advantages are our motivation of work on the harmonic analysis of multilevel inverter fed induction motor drive.

II. NINE LEVEL CONVERTER

A nine level inverter consists of a series H-bridge inverter units connected to three phase induction motor. The general function of this multilevel inverter is to synthesize a desired voltage from several dc sources. The AC terminal voltages of each bridge are connected in series. Unlike the diode clamp or flying capacitors inverter, the cascaded inverter does not require any voltage clamping diodes or voltage balancing capacitors [6].This configuration is useful for constant frequency applications such as active front-end rectifiers, active power filters, and reactive power compensation. In this case, the power supply could also be the voltage regulated dc capacitor. One important characteristic of multilevel converters using voltage escalation is that electric power distribution and switching frequency present advantages for the implementation of these topologies. The Fig.1 shows the multilevel inverter topology. This paper makes an overview to find the various induction motor drive configurations used in industry [7]. The various control strategies used to improve drive efficiency and various inverter used to control the motor speed, reduce torque ripple, current ripple and reduce harmonics [8]. Also different topologies and control strategies are useful for different situations. One of the very efficiently used control strategies is the sinusoidal PWM control which can be implemented.

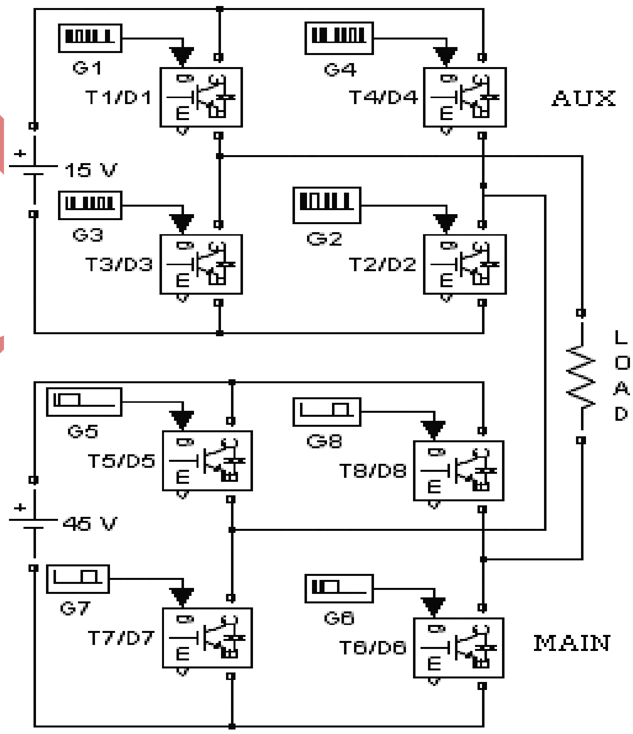


Fig.1 Multilevel

III. INDUCTION MOTOR MODEL

The speed of the synchronously rotating reference frame model is

$$\omega_c = \omega_s = \text{Stator supply angular frequency/rad/sec} \quad (1)$$

In stator reference frame model,

The stator reference frame is also called as stationary reference frame or Stanley reference frame. Using flux linkages as variables, the equations of the induction machine along any reference frame can be developed. Even though the voltages and currents are discontinuous, the flux linkages will always be continuous.

$$\begin{bmatrix} V_{qs} \\ V_{ds} \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} R_s + L_s p & 0 & L_m p & 0 \\ 0 & R_s + L_s p & 0 & L_m p \\ L_m p & -\omega_r L_m & R_r + L_r p & -\omega_r L_r \\ \omega_r L_m & L_m p & \omega_r L_r & R_r + L_r p \end{bmatrix} \begin{bmatrix} i_{qs} \\ i_{ds} \\ i_{qr} \\ i_{dr} \end{bmatrix} \quad (2)$$

Where, $\omega_r = \frac{d\theta}{dt}$ and $p = \frac{d}{dt}$ (3)

The stator and rotor flux linkages in the stationary reference frame are defined by,

$$\varphi_{qs} = L_s i_{qs} + L_m i_{qr} \quad (4)$$

$$\varphi_{ds} = L_s i_{ds} + L_m i_{dr} \quad (5)$$

$$\varphi_{qr} = L_r i_{qr} + L_m i_{qs} \quad (6)$$

$$\varphi_{dr} = L_r i_{dr} + L_m i_{ds} \quad (7)$$

From equation 4 to 7, the d-q stator and rotor voltages can be obtained as,

$$V_{ds} = R_s i_{ds} + \frac{d\varphi_{ds}}{dt} \quad (8)$$

$$V_{qs} = R_s i_{qs} + \frac{d\varphi_{qs}}{dt} \quad (9)$$

$$V_{dr} = R_r i_{dr} + \omega_r \varphi_{qr} \frac{d\varphi_{dr}}{dt} \quad (10)$$

$$V_{qr} = R_r i_{qr} - \omega_r \varphi_{dr} \frac{d\varphi_{qr}}{dt} \quad (11)$$

The equivalent circuits of the dynamic model of the induction motor that satisfies the equations 8 to 11 are shown in Fig. 2(a) & 2(b)

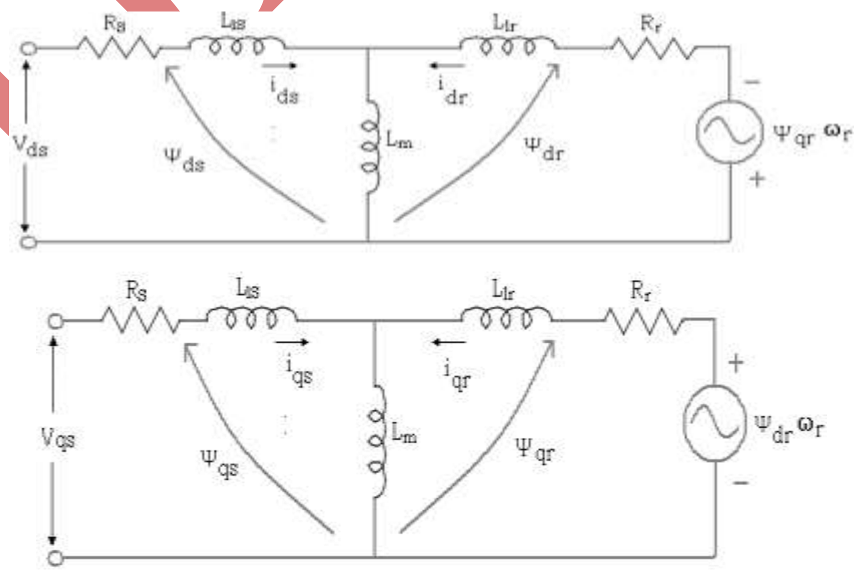


Fig. 2(A) D-Equivalent Circuit (B) Q-Equivalent Circuit

The expression for the electromagnetic torque of an induction machine in the stationary reference frame is given by,

$$T_e = \frac{3}{2}\left(\frac{p}{2}\right)\left(\varphi_{ds} i_{qs} - \varphi_{qs} i_{ds}\right) \qquad (12)$$

The expression for the electromagnetic torque when the load torque T_L and moment of inertia J are considered is given by,

$$T_e = T_L + J\frac{d\omega_m}{dt} = T_L + \frac{2}{p} J \frac{d\omega_r}{dt} \qquad (13)$$

The motor drive power circuit model was developed as shown in the Fig.3 for simulation work using Simulink.

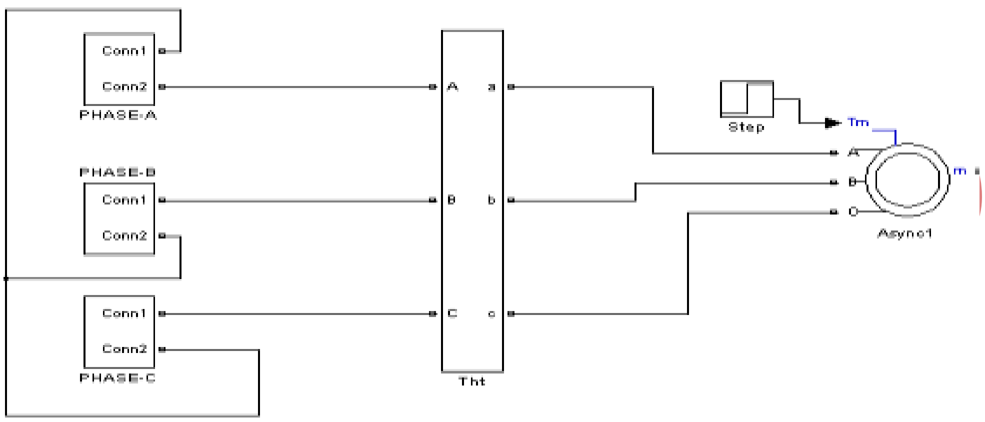


Fig.3 Power Circuit Model of Induction Motor

IV. SIMULINK MODELLING AND SIMULATION RESULTS

In order to verify the proposed cascaded multilevel inverter topology for induction motor drives. The simulation is based on MATLAB/SIMULINK was carried out. The simulation of nine level inverter fed induction motor model was done using Simulink. The simulation results of phase voltage, phase currents, stator currents, motor speed and FFT spectrum were presented. The inverter output voltage is shown in Fig.5 and the current is shown in Fig.6.The motor currents are shown in the Fig.7 and the motor speed and Torque is shown in Fig.8 and Fig.9. The FFT analysis for the motor drive system was also done as shown in Fig.10. It is seen that the percentage of harmonics in the multilevel inverter fed induction motor drive is less compare to classical inverter system.

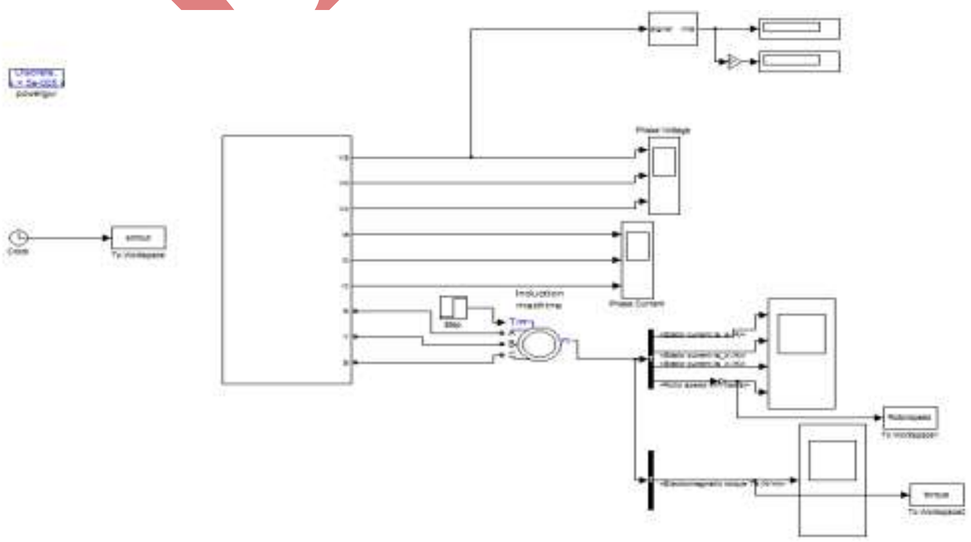


Fig.4 Simulation circuit Model of nine level inverter fed induction motor drive

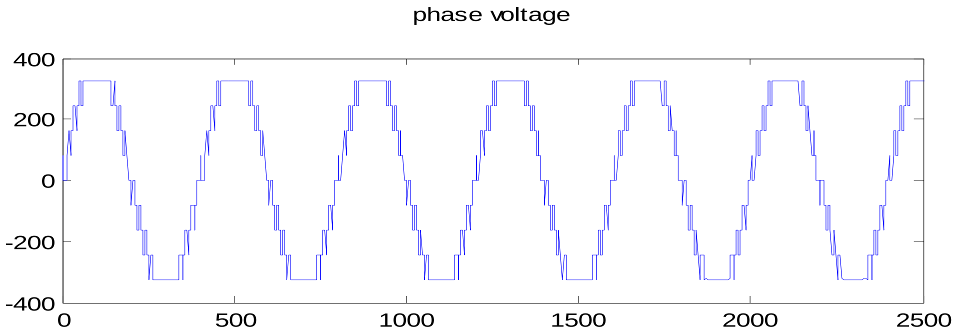


Fig.5 Inverter Output Voltage

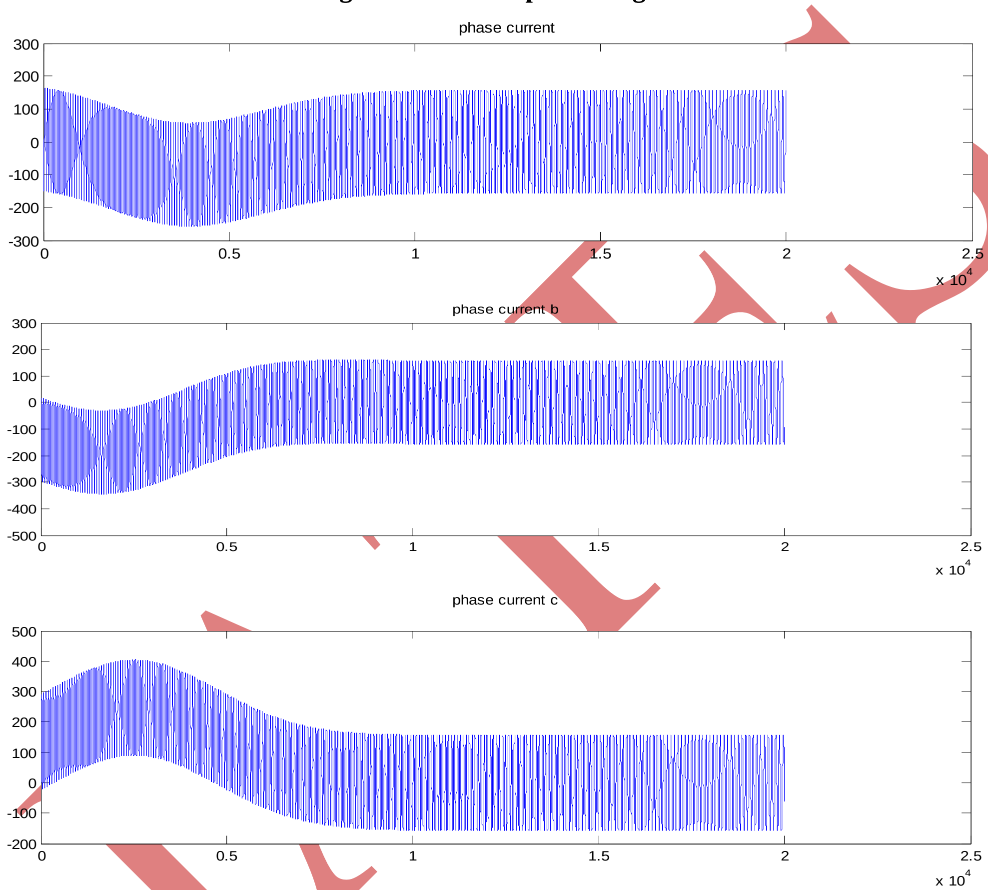
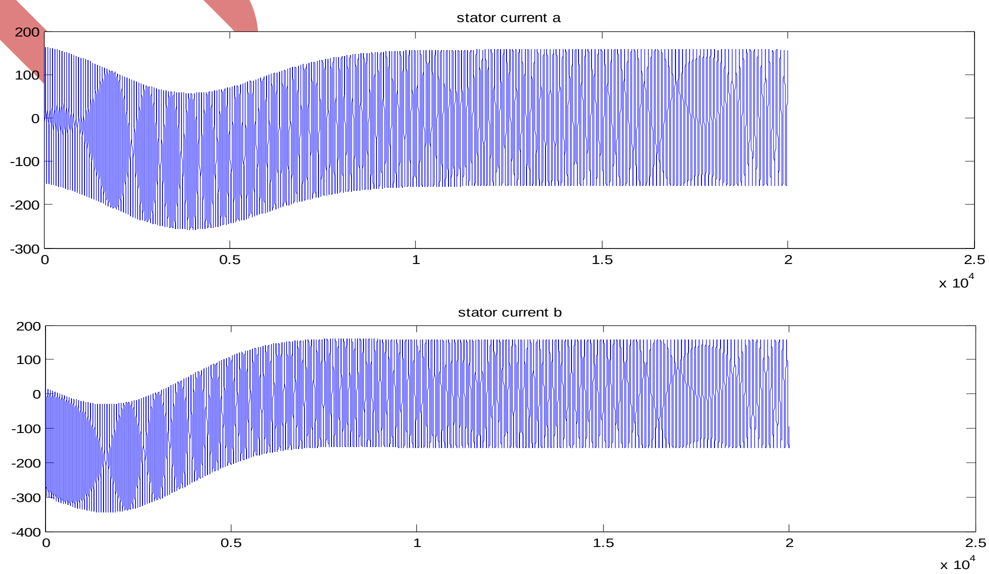


Fig.6 Inverter Output Currents



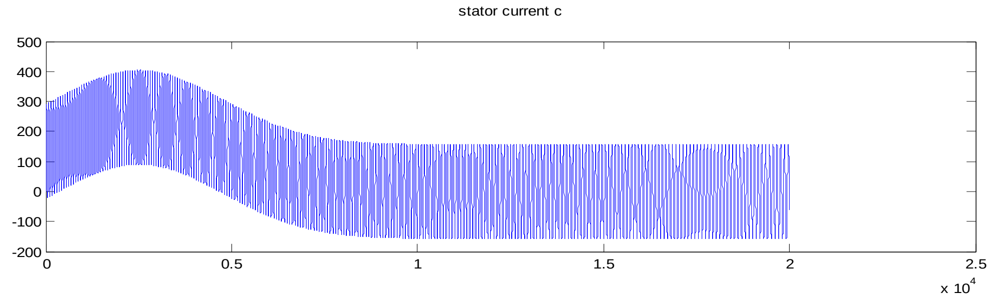


Fig.7 Stator Output Currents

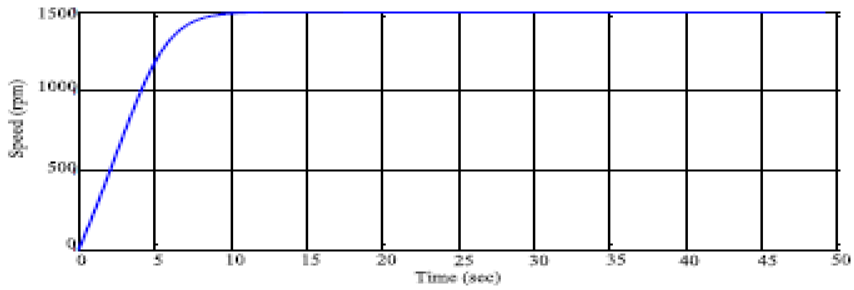


Fig.8 Motor Speed

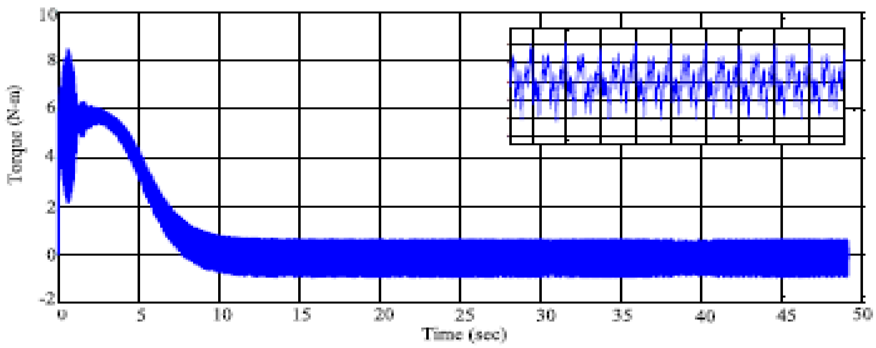


Fig.9 Torque

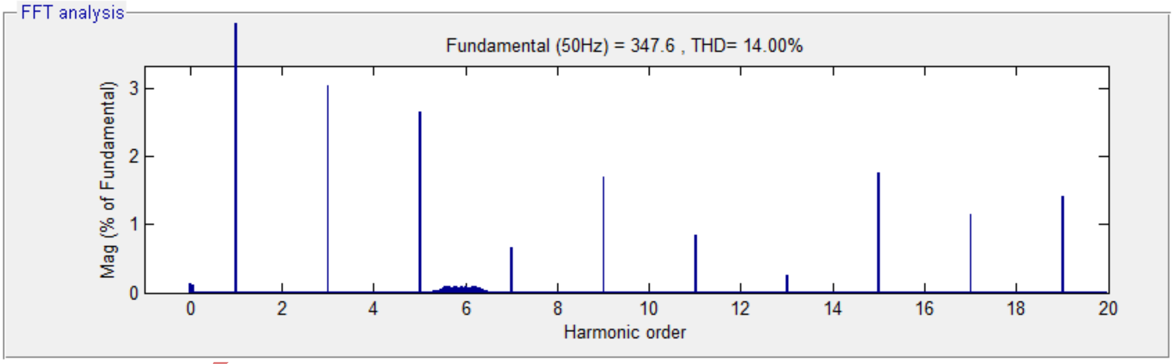


Fig.10 FFT Spectrum

V. CONCLUSION

The modelling of nine level inverter fed induction motor drive was done and simulated using Simulink. The total harmonic distortion is very low compared to that of classical inverter. The simulation result shows that the harmonics have been reduced considerably. The nine level inverter fed induction motor system has been successfully simulated and the results of voltage waveforms, current waveforms, motor speed, torqueand frequency spectrum for the output were obtained. The inverter system can be used for industries where the adjustable speed drives are required and significant amount of energy can be saved as the system has less harmonic losses.

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