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Single phase half controlled rectifier

Performance of Single-phase, half-wave controlled rectifiers with pure resistive load (For α=π/2) Half Controlled Rectifier with R Load Figure a. SCR supplying a passive load. b. Voltage and current waveforms. Here, we have assumed delay angle (α) of 90 deg. The fundamental component of input current lags behind the input voltage, both P and Q flow from AC side to load or DC side. The displacement PF decreases as we delay the triggering pulse. If SCR is triggered ar 0 deg, no Q is absorbed. Half Controlled Rectifier with RL Load Average Load/Output Voltage Average Load/Output Current Single-phase, half-wave controlled rectifiers with Inductive load Role of free-wheeling diode To avoid negative voltage when inductive load involved. area A = area B During α < ωt < π: vL + vR = vo During π < wt < 2π+α: vL + vR = 0 i ≥ 0 (exp decay) i(t) is expressed in two separate equations. Single-phase, half-wave controlled rectifiers with Internal DC Voltage Thyristor based Rectifiers and Inverters (1-phase) Fig a. SCR supplying an active load. b. Voltage and current waveforms. Fig a. Line commutated inverter. b. Voltage and current waveforms. previous Performance Parameters of Rectifiers (Input AC side) next Full Controlled Rectifier In this article, we will see the analysis of Single Phase Half Wave Controlled Rectifier with Resistive (R) Load as shown in Figure 1. Vs is supply and 'is' is the source current. VT and 'iT' is the SCR voltage and current respectively. Vo and 'io' is the load voltage and current respectively. Vs = Vmsin(ωt) Fig. 1 Step-1: Write KVL in the given circuit vs − vT − vo = 0 vab = vs = vT + vo vab = vs = Vmsin(ωt) vba = − vab = − Vmsin(ωt) Step-2: Device working status In the positive half cycle, SCR is forward biased and is turned ON at ωt = α by giving a firing pulse (triggering pulse). The angle α is called delay angle or firing angle. It is measured from the instant the SCR has become forward biased. At ωt = π, the current through the SCR falls to zero i.e. below zero and simultaneously a reverse voltage appears across SCR and it turns OFF. Since the line voltage is used for commutation, it is also known as line commutation converter. Fig. 2 1). 0 < ωt < α SCR is in forward blocking mode and SCR is OFF. io = is = iT = 0 Amp vo = 0 V vT = vab = Vmsin(ωt) 2). α < ωt < π SCR is in forward conduction mode and SCR is ON. vT = 0 V io = is = iT = (Vmsin(ωt))/R vo = vab = Vmsin(ωt) 3). π < ωt < 2π SCR is in forward blocking mode and SCR is OFF. io = is = iT = 0 Amp vo = 0 V vT = vab = Vmsin(ωt) 4). 2π + α < ωt < 3π SCR is in forward conduction mode and SCR is ON. vT = 0 V io = is = iT = (Vmsin(ωt))/R vo = vab = Vmsin(ωt) The waveforms for load voltage(vo), and current(io), SCR voltage(vT) is shown in figure 2. The waveforms of supply current and SCR current is same as load current. Note: For a resistive load, vo and io waveform will be same in nature except in magnitude. Step-3: 1). Firing angle (α) = α 2). Extinction angle (β) = π 3). Conduction angle (γ) = β − α = π − α 4). Conduction time (tc) = γ/ω = (π − α)/ω 5). Circuit turn off time (tckt-off) = (2π − π)/ω = π/ω 6). Peak Inverse voltage (PIV) = Vm Step-4: Average Values The average output voltage Vo(avg) across load R is given by The average output current Io(avg) through the load R is given by RMS values Three phase half controlled bridge converters & fully controlled bridge converters are used extensively in industrial applications up to about 15kW of output power. The Three phase controlled rectifiers provide a maximum dc output of vdc(max)=2vm / ∏ The output ripple frequency is equal to the twice the ac supply frequency. The single phase full wave controlled rectifiers provide two output pulses during every input supply cycle and hence are referred to as two pulse converters. Three phase converters are 3-phase controlled rectifiers which are used to convert ac input power supply into dc output power across the load. Features of 3-phase controlled rectifiers are Operate from 3 phase ac supply voltage.They provide higher dc output voltage and higher dc output power.Higher output voltage ripple frequency.Filtering requirements are simplified for smoothing out load voltage and load current Three phase controlled rectifiers are extensively used in high power variable speed industrial dc drives. 3-phase half wave converter Three single phase half-wave converters are connected together to form a three phase half-wave converter as shown in the figure. THREE PHASE SUPPLY VOLTAGE EQUATIONS We define three line neutral voltages (3 phase voltages) as follows The 3-PHASE HALF WAVE CONVERTER combines three single phase half wave controlled rectifiers in one single circuit feeding a common load. The thyristor T1 in series with one of the supply phase windings 'a-n' acts as one half wave controlled rectifier. The second thyristor T2 in series with the supply phase winding 'b-n' acts as the second half wave controlled rectifier. The third thyristor T3 in series with the supply phase winding acts as the third half wave controlled rectifier. The 3-phase input supply is applied through the star connected supply transformer as shown in the figure. The common neutral point of the supply is connected to one end of the load while the other end of the load connected to the common cathode point. When the thyristor T1 is triggered at ωt=(∏/6 + α)=(30° + α) , the phase voltage Van appears across the load when T1 conducts. The load current flows through the supply phase winding 'a-n' and through thyristor T1 as long as T1 conducts. When thyristor T2 is triggered at ωt=(5∏/6α), T1 becomes reverse biased and turns-off. The load current flows through the thyristor and through the supply phase winding 'b-n' . When T2 conducts the phase voltage vbn appears across the load until the thyristor T3 is triggered . When the thyristor T3 is triggered at ωt=(3∏/2 + α)=(270°+α) , T2 is reversed biased and hence T2 turns-off. The phase voltage Van appears across the load when T3 conducts. When T1 is triggered again at the beginning of the next input cycle the thyristor T3 turns off as it is reverse biased naturally as soon as T1 is triggered. The figure shows the 3-phase input supply voltages, the output voltage which appears across the load, and the load current assuming a constant and ripple free load current for a highly inductive load and the current through the thyristor T1. For a purely resistive load where the load inductance 'L = 0' and the trigger angle α >(∏/6) , the load current appears as discontinuous load current and each thyristor is naturally commutated when the polarity of the corresponding phase supply voltage reverses. The frequency of output ripple frequency for a 3-PHASE HALF WAVE CONVERTER is fs, where fs is the input supply frequency. 3 The 3-PHASE HALF WAVE CONVERTER is not normally used in practical converter systems because of the disadvantage that the supply current waveforms contain dc components (i.e., the supply current waveforms have an average or dc value). TO DERIVE AN EXPRESSION FOR THE AVERAGE OUTPUT VOLTAGE OF A 3-PHASE HALF WAVE CONVERTER FOR CONTINUOUS LOAD CURRENT The reference phase voltage is vRN=van=Vmsinωt. The trigger angle is measured from the cross over points of the 3-phase supply voltage waveforms. When the phase supply voltage Van begins its positive half cycle at ωt=0 , the first cross over point appears at ωt=(∏/6)radians 30°. The trigger angle α for the thyristor T1 is measured from the cross over point at . The thyristor T1 is forward biased during the period ωt=30° to 150° , when the phase supply voltage van has higher amplitude than the other phase supply voltages. Hence T1 can be triggered between 30° to 150°. When the thyristor T1 is triggered at a trigger angle α, the average or dc output voltage for continuous load current is calculated using the equation Note from the trigonometric relationship The maximum average or dc output voltage is obtained at a delay angle α = 0 and is given by Vdx(max>=vdm=3√3Vm/2∏ Vm Is the peak phase voltage. And the normalized average output voltage is TO DERIVE AN EXPRESSION FOR THE RMS VALUE OF THE OUTPUT VOLTAGE OF A 3-PHASE HALF WAVE CONVERTER FOR CONTINUOUS LOAD CURRENT The rms value of output voltage is found by using the equation Three phase half wave controlled rectifier output voltage waveforms for different trigger angles with RL load Three phase half wave controlled rectifier output voltage waveforms for different trigger angles with R load TO DERIVE AN EXPRESSION FOR THE AVERAGE OR DC OUTPUT VOLTAGE OF A 3 PHASE HALF WAVE CONVERTER WITH RESISTIVE LOAD OR RL LOAD WITH FWD. In the case of a three-phase half wave controlled rectifier with resistive load, the thyristor T1 is triggered at ωt=(30°+α) and T1 conducts up to ωt=180°=&pron; radians. When the phase supply voltage decreases to zero at , the load current falls to zero and the thyristor T1 turns off. Thus T1 conducts from ωt=(30° + α) to (180°). Hence the average dc output voltage for a 3-pulse converter (3-phase half wave controlled rectifier) is calculated by using the equation three phase full converter three phase full converter is a fully controlled bridge controlled rectifier using six thyristors connected in the form of a full wave bridge configuration. All the six thyristors are controlled switches which are turned on at a appropriate times by applying suitable gate trigger signals. Thethree phase full converter is extensively used in industrial power applications upto about 120kW output power level, where two quadrant operations is required. The figure shows a three phase full converter with highly inductive load. This circuit is also known as three phase full wave bridge or as a six pulse converter. The thyristors are triggered at an interval of (∏/3) radians (i.e. at an interval of 30°). The frequency of output ripple voltage is 6fs and the filtering requirement is less than that of three phase semi and half wave converters. At ωt=(∏/6 +α) , thyristor is already conducting when the thyristor is turned on by applying the gating signal to the gate of . During the time period ωt=(∏/6 +α) to (∏/2 +α), thyristors and conduct together and the line to line supply voltage appears across the load. At ωt=(∏/2 +α), the thyristor T2 is triggered and T6 is reverse biased immediately and T6 turns off due to natural commutation. During the time period ωt=(∏/ +α) to (5∏/6 +α), thyristor T1 and T2 conduct together and the line to line supply voltage appears across the load. The thyristors are numbered in the circuit diagram corresponding to the order in which they are triggered. The trigger sequence (firing sequence) of the thyristors is 12, 23, 34, 45, 56, 61, 12, 23, and so on. The figure shows the waveforms of three phase input supply voltages, output voltage, the thyristor current through T1 and T4, the supply current through the line 'a'. We define three line neutral voltages (3 phase voltages) as follows To derive an expression for the average output voltage of three phase full converter with highly inductive load assuming continuous and constant load current The output load voltage consists of 6 voltage pulses over a period of 2∏ radians, hence the average output voltage is calculated as Something went wrong. Wait a moment and try again. Jean Pollefliet, in Power Electronics, 2018These controlled rectifiers are in fact line-frequency phase-controlled rectifiers. We study in this chapter half-wave single-phase controlled rectifiers (E1), full wave single-phase controlled rectifiers (B2) and fully controlled three-phase rectifiers (B6).For each of this types we study voltage form, current flow and the expressions for the average output voltage. Again and again we study both cases of load (resistive and resistive-inductive). Current harmonics at the input and voltage harmonics at the output are calculated.Denis Fewson, in Introduction to Power Electronics, 1998Full-wave controlled rectifiers with resistive loads, or with inductive loads with free-wheel diodes, act in what is known as the first quadrant. This means that load voltage and current act in the positive direction only. Figure 3.10 shows how the four quadrants are defined.One-quadrant operation is typical of the circuits in Figs 3.5, 3.6, and 3.9. Two-quadrant operation is possible with the circuits in Figs 3.7 and 3.8, if the load is inductive or contains a d.c. motor. In the second quadrant, the load voltage reverses and energy can flow from the load to the source, with the system inverting.Four-quadrant operation is possible using two full-wave fully controlled bridges connected in inverse parallel, or back-to-back. This type of operation occurs in a separately excited d.c. motor drive providing forward and reverse, speed and braking control.Gating, or firing, of the switches requires the gate pulses to be synchronized to the a.c. mains voltage with a controllable delay on voltage zero. A simple circuit is the R–C– Diac combination, but this has a limited range of firing angle delay. Where a wide range of delay is required, a commercially produced module, such as the TDA2086A, can be used. In the case of the full-wave fully controlled bridge in Fig. 3.8, isolation is required of the gate drive circuits of at least two of the thyristors. This can be achieved using pulse transformers, or optical isolators.José Rodríguez Ph.D., ... Alejandro Weinstein, in Power Electronics Handbook (Third Edition), 2011Important application areas of controlled rectifiers include uninterruptible power supplies (UPS), for feeding critical loads. Figure 11.12 shows a simplified diagram of a single-phase UPS configuration, typically rated for