I'm not a bot

A diode rectifier or uncontrolled rectifier is the converter circuit that converts ac signal into (an alternating signal) dc signal (unidirectional signal). Uncontrolled rectifier circuits use diodes to convert ac power to dc power and are divided into two types, single-phase and three-phase. Again singe-phase uncontrolled rectifiers are divided into two types, they are,Half-wave uncontrolled rectifierFull-wave uncontrolled rectifierCenter tapped rectifierBridge rectifierIn a single-phase half-wave uncontrolled rectifier circuit only either the positive or negative half-cycle of the ac input is converted into dc. Whereas a single-phase full-wave uncontrolled rectifier converts both the positive or negative half-cycle of the ac input into dc. In full-wave rectifiers, there are two types of circuit configurations, center-tapped, and bridge-type full-wave rectifiers. A center-tapped rectifier uses a center-tapped transformer and two diodes whereas a bridge rectifier uses four bridges.The performance of both center-tapped and bridge rectifiers is almost identical, except the bridge configuration has the advantages of reduced peak inverse voltage across diodes and improved transformer utilization factor. In this article let us see the circuit diagram and operation of a single-phase full-wave bridge rectifier.Single Phase Full Wave Bridge Rectifier with R-Load :The below figure presents the circuit connection of a single-phase full-wave bridge rectifier loaded with a resistive load. A full-wave bridge rectifier uses four diodes connected in a close-loop configuration which converts alternating current into direct current. The ac input to the uncontrolled full wave rectifier is given through a transformer. When the ac supply source to the rectifier is turned ON, the positive half cycle of ac input starts. During the positive half cycle of ac input, point A in the above circuit is made positive with respect to point B. Due to this, diodes D1 and D2 are forward biased (since their anode terminals are connected to positive with respect to the cathode), and diodes D3 and D4 are reverse biased (since their anode terminals are connected to negative with respect to the cathode).Thus diodes D1 and D2 act as the closed switch and diodes D3 and D4 act as the open switch. Therefore, the current starts flowing from point A, through diode D1, the load resistance R, and diode D2 to point B as shown below in figure A. The load current will continue to flow through D1 and D2 until the positive half-cycle ends. Once the positive half cycle of ac input ends, the negative half cycle starts where the positive and negative terminals of the supply source are reversed. During the negative half cycle, point B is made positive with respect to point A. Due to this, diodes D1 and D2 are reverse-biased, and diodes D3 and D4 are forward-biased.Thus, during the negative half-cycle conduction takes place from point B, through diode D3, the load resistance R, and diode D4, to point A as shown above in figure B. The load current will continue to flow through D3 and D4 until the next positive half-cycle starts. Therefore, two diodes will always be in conduction providing a path for the current to flow in an alternating direction through the supply, but in the same direction through the load, and thus the output voltage developed across the load will be in the same direction throughout the whole input cycle.Hence a dc voltage will appear across the load from an ac source. The below shows the waveforms for output voltage Vo, output current Io, and the voltage drop across diodes. Since the load is of resistive type, the load current will be in phase with the load voltage i.e., the load current will have the same waveform as the load voltage. During the positive half-cycle i.e., from t = 0 to , diodes D1 and D2 conduct, and during the negative half-cycle i.e., from t = to 2, diodes D3 and D4 conduct. The average value of the load voltage Vdc can be calculated as follows,It can be seen that the average output voltage of a full-wave rectifier is twice of a half-wave rectifier. The average value of the output current Idc is, The output dc power is given by, Single Phase Full Wave Bridge Rectifier with RL-Load:In the above circuit, we have seen the full wave bridge rectifier with a resistive load where the output current and voltage will be in phase. However, in practice loads are not purely resistive but contain inductance in combination with the resistance. Let us see the circuit operation of an uncontrolled full wave bridge rectifier with RL-load. For an RL load, the average output voltage of the rectifier will be the same as in the case of resistive load, but the output current waveform changes and it becomes continuous (non-zero) depending upon the value of load inductance and load resistance. For a highly inductive load where L is much greater than R, the load current will be constant. The waveforms for output voltage and current with RL load are shown below.The value of average output voltage and output current with RL load is given by, Advantages of Full Wave Bridge Rectifier:The efficiency of a full-wave bridge rectifier is high.The output dc voltage of a full-wave rectifier is almost equal to the input ac signal, whereas, in a half-wave rectifier, only half the cycle of ac input will reach the load.Ripple factor is less.High transformer utilization factor of source transformer.A bridge rectifier doesnt require any center-tapped transformer.In a bridge rectifier peak inverse voltage of each diode is low.In a center-tapped full-wave rectifier only half of the transformer secondary is used at a time, whereas in a bridge rectifier entire transformer secondary is used. Thus required transformer rating in the bridge rectifier is smaller than the center-tapped rectifier.Disadvantages of Full Wave Bridge Rectifier:Higher voltage drop since two diodes conducts at a time in a bridge rectifier which leads to poor voltage regulation when working with low voltages.In a center-tapped rectifier if one diode fails the circuit still works as a half-wave rectifier, but if one diode fails in a bridge rectifier complete circuit fails. Since a bridge rectifier eliminates most of the drawbacks of the center-tapped rectifier and can supply a large amount of dc power to the load. It is therefore used in most power electronics applications to convert ac power into dc power. 0 ratings0% found this document useful (0 votes)2K views1. The document describes the operation of a single phase half controlled bridge converter with resistive (R) and resistive-inductive (RL) loads. It includes the circuit diagram, waveforms, AI-enhanced title and descriptionSaveSave EXP-4 SEMICONVERTER For Later0%0% found this document useful, undefined Single phase fully controlled bridge converters are two quadrant converters having unidirectional current with both positive and negative voltage polarity. Thus they can be operated either as a controlled rectifier or an inverter. But for some applications that do not utilize the inverter mode operation, a fully controlled converter with four thyristors and their associated control and gate drive circuit makes the system unnecessarily complicated. In such situations, two of the thyristors of a single phase fully controlled converter has to be replaced by diodes. The resulting converters are called single phase semi-converter or single phase half controlled converters. Semi-convertors are single quadrant converters having one polarity of voltage and current at the DC terminals. 1. Single Phase Semi-Converter - R Load Fig. 1 Single Phase Semi-converter with R Load Fig. 2 Waveforms of Single Phase Semi-converter with R Load In the figure, shows the circuit diagram of single phase semiconverter bridge rectifier with R load. In this rectifier two SCRs and two diodes are connected in symmetrical configuration. The operation of this converter mainly consists of three modes: Mode 1: (to) During positive half-cycle of AC input voltage, thyristor T1 diode D1 conduct and thyristor T1 is fired at t = . Therefore the average output voltage is equal to the instantaneous supply voltage and load current flows through T1, R, D1 and back supply again. Mode 2: (to +) At instant t = , the supply goes through zero and after supply voltage reverses its polarity. Due to reverse supply across conducting devices T1 and D1, they turned off at t = and this type of turn-off is called as "natural" or "line commutation". Therefore, the average output voltage is zero and load current is also zero. Mode 3: (+ to 2) At instant t = + , the supply voltage becomes completely negative i.e., during negative half cycle of AC input voltage, thyristor T2 and diode D2 are forward biased, thyristor T2 is fired at t = + . Thus the average output is equal to instantaneous supply voltage because due to conduction of T2 and D2, the load is directly connected to supply. The load current flows through T2, R, D2. Thyristor T2 and diode D2 conduct upto 2, at t = 2 commutation takes place due to natural zero appears across supply. The average and rms value of output voltage and current are, $$V_{o} = \frac {V_{m}}{\pi}(1 + cos\alpha) .....(1)$$ $$I_{o} = \frac {V_{o}}{R} = \frac {V_{m}}{\pi R} (1+ \cos\alpha).....(2)$$ $$V_{o~(rms)} = \frac {V_{m}}{\sqrt {2}} \left[\frac {1}{\pi}\left(\pi - \alpha + \frac {sin 2\alpha}{2}\right) \right]^{\frac {1}{2}}.....(3)$$ $$I_{o ~ rms} = \frac {V_{o ~ rms}}{R} = \frac {V_{m}}{\sqrt {2} R} \left[\frac {1}{\pi}\left(\pi - \alpha + \frac {sin 2\alpha}{2}\right) \right]^{\frac {1}{2}}.....(4)$$ 2. Single Phase Semi-Converter - RL Load with Freewheeling Diode Fig. 3 Single Phase Semi-converter with RL Load and Freewheeling diode Fig. 4 Waveforms of Single Phase Semi-converter with RL Load and Freewheeling diode Due to inductive load, there will be a flow of load current even after phase reversal i.e., after completing each half cycle. This is because, due to the large inductive nature of the load, the load current has a tendency to flow continuously by finding an alternative path through the diode of the same arm of conducting SCR even after phase reversal. Thus, there will be no control over the thyristor once it is triggered as seen in continuous and discontinuous modes. This problem can be overcome by connecting a diode in parallel with the load. This diode is known as a fly-back diode or freewheeling diode. When there is a phase reversal, this diode acts as the short-circuit path for inductive load current rather than passing it through the thyristors. Hence, The thyristor regains its blocking state once there is a phase reversal in the supply. The free-wheeling diode improves the load current waveform and increases the input power factor. It also eliminates the damage of the current components from the formation of voltage spikes during the turn-off period of the thyristors and diodes. In this circuit, at t = , T1 and D1 become reverse biased, whereas the freewheeling diode Df becomes forward biased. Hence, after t = , the load current will be transferred from T1 D1 to Df. Now the current flows through the path Df, R, L and then Df. During this period, the output gets short circulated through Df and the output voltage will be zero as shown in the below waveforms. This process continues from to + . When T2 is triggered at t = + a, D2 and Df get forward biased. Now the load current shifts from Df to T2 D2, and again the load voltage follows the supply voltage till t = 2. At t = 2, T2 and D2 get reverse biased, and Df gets forward biased, and again the above process repeats. We can see that the above load current and load voltage waveforms are similar to the waveforms of the converter without a freewheeling diode. But here load current due to inductive load is transferred back to it through the freewheeling diode Df rather than through the thyristor and diode combination T1 D2 and T2 D1. Hence the freewheeling diode improves the circuit performance and also ensures commutation of thyristors at the end of each half-cycle providing a controlled load current under the triggering circuit. The average and rms of bridge output voltage are, $$V_o = \frac {2}{2\pi} \int_{\alpha}^{\pi} V_{m}sinwt ~ dwt = \frac {2V_m}{2\pi}\big[-cos\omega t \big]_{\alpha}^{\pi} = \frac {V_m}{\pi}(1 + cos\alpha).....(5)$$ $$V_{o~(rms)} = \left[\frac {2}{2\pi} \int_{\alpha}^{\pi} V_{m}^2 ~ sin^2wt ~ dwt \right]^{\frac {1}{2}}.....(6)$$ $$V_{o~(rms)} = \left[\frac {V_{m}^{2}}{2\pi} \int_{\alpha}^{\pi} (1 - cos2\omega t) ~ dwt\right]^{\frac {1}{2}}.....(7)$$ $$V_{o~(rms)} = \frac {V_{m}}{\sqrt {2}} \left[\frac {1}{\pi}\left(\pi - \alpha + \frac {sin 2\alpha}{2}\right) \right]^{\frac {1}{2}}.....(8)$$ 3. Single Phase Semi-converter - RLE Load with Freewheeling Diode Fig. 5 Single Phase Semi-converter with RLE Load and Freewheeling diode Fig. 6 Waveforms of Single Phase Semi-converter with RLE Load and Freewheeling diode The circuit consists of two thyristors, two diodes, and a freewheeling diode across the load. After t = 0, thyristor T1 is forward biased only when source voltage Vm sin t exceeds E. Thus, T1 is triggered at a firing angle delay such that Vmsin > E. With T1 on, load gets connected to source through T1 and D1. For the period t = to , load current io flows through RLE, D1, source and T1 and the load terminal voltage vo is of the same waveshape as the ac source voltage vs. Soon after t = , load voltage vo tends to reverse as the ac source voltage changes polarity. Just as vo tends to reverse, FD is forward biased and starts conducting. The load current io is transferred from T1, D1 to FD. As SCR T1 is reverse biased at t > through FD, therefore load voltage vo is zero during < t < (+). After t = , during the negative half cycle, T2 will be forward biased only when source voltage is more than E. At t = + , source voltage exceeds E, T2 is therefore triggered. Soon after (+), FD is reverse biased and is therefore turned off; load current now shifts from FD to T2, D2. At t = 2, FD is again forward biased and output current io is transferred from T2, D2 to FD as explained before. The average and rms of bridge output voltage are, $$V_o = \frac {2}{2\pi} \int_{\alpha}^{\pi} V_{m} ~ sinwt ~ dwt = \frac {2V_m}{2\pi}\big[-cos\omega t \big]_{\alpha}^{\pi} = \frac {V_m}{\pi}(1 + cos\alpha).....(9)$$ $$V_{o~(rms)} = \left[\frac {2}{2\pi} \int_{\alpha}^{\pi} V_{m}^2 ~ sin^2wt ~ dwt \right]^{\frac {1}{2}}.....(10)$$ $$V_{o~(rms)} = \left[\frac {V_{m}^{2}}{2\pi} \int_{\alpha}^{\pi} (1 - cos2\omega t) ~ dwt\right]^{\frac {1}{2}}.....(11)$$ $$V_{o~(rms)} = \frac {V_{m}}{\sqrt {2}} \left[\frac {1}{\pi}\left(\pi - \alpha + \frac {sin 2\alpha}{2}\right) \right]^{\frac {1}{2}}.....(12)$$ Advantages of Single Phase Semi-converter Single-phase semiconverters have a straightforward design with fewer components compared to three-phase converters. This simplicity makes them cost-effective and easier to implement, particularly for low-power applications. Due to their simpler design, single-phase semiconverters tend to be more compact, making them suitable for space-constrained applications or when a compact form factor is essential. Controlling single-phase semiconverters is less complex compared to three-phase converters. The control circuitry is simpler, leading to reduced development and maintenance costs. Single-phase semiconverters find applications in various industries, including small motor drives, battery chargers, uninterruptible power supplies (UPS), and household appliances like laptops, mobile phone chargers, and small electronic devices. By varying the firing angle of the semiconductor switches (such as thyristors or silicon-controlled rectifiers), the output voltage can be controlled effectively. This feature allows for regulation of the output DC voltage, making it suitable for applications where variable voltage control is required. In regions or applications where only single-phase AC power is available, single-phase semiconverters become the obvious choice for converting AC to DC. Disadvantages of Single Phase Semi-converter Compared to three-phase converters, single-phase semiconverters have relatively lower efficiency due to the pulsating nature of the output current. Three-phase converters offer smoother output and therefore higher efficiency. Single-phase semiconverters are generally limited to lower power applications. For high-power applications, three-phase converters are preferred as they distribute the power more evenly and efficiently. The pulsating nature of the output current in single-phase semiconverters can lead to higher harmonic content in the AC supply, potentially causing issues with power quality and electromagnetic interference. Applications of Single Phase Semi-converter High power converters Main line a.c. traction Electroplating Battery Charging Systems Static VAR systems In order to get a controllable dc output voltage from the rectifier circuit, phase-controlled rectifiers are used. The phase-controlled rectifiers are also known as ac to dc converters. They employ thyristors whose triggering angle is varied to get a controllable dc output voltage.In a semi or half-controlled converter, one quadrant operation is obtained i.e., only positive voltage and current will be obtained at the output. This type of converter circuit uses two thyristors and two diodes for the rectification process. Let us see the operation of a single-phase semi or half-controlled converter with bridge-type circuit configuration connected to an RL load.The use of bridge-type configuration in converter circuits increases the average load voltage and improves the power factor and input current waveform. This type of circuit configuration is best suited to supply current to highly inductive loads and also there is no need for a center-tapped transformer which is needed in mid-point type circuit configuration. Single-Phase Semi Converter With RL-Load :The below shows the circuit diagram of a single-phase semi or half-controlled converter supplying power to an RL load. When a converter delivers power to the RL load, the load current can be of two types. Either the load current can be continuous or it can be discontinuous depending upon the inductance of inductive load.Discontinuous Current Mode of Operation :During the positive half cycle of the supply, thyristor T1 and diode D1 get forward biased, while thyristor T2 and diode D2 get reverse biased. Now, if T1 is triggered at a firing angle it starts conducting. As a result, the load current iL starts flowing through the path VS T1 R L D1 VS. As soon as VS reaches zero, VL also becomes zero.Once VS enters into the negative cycle, T2 and D2 get forward biased and T1 and D1 get reverse biased. But, the load inductance L opposes a sudden change in current and hence releases the energy which is stored in the positive cycle. So, an EMF, e1 is induced in the inductor with opposite polarity. This EMF is responsible for maintaining the load current in the negative cycle before T2 is triggered. Since T1 cannot be turned OFF until iL falls below its holding current value, iL continues to flow through the path L D2 T1 R L. Therefore, VL follows the negative cycle of supply voltage till , where the load current becomes zero.If the load inductance is not large enough to supply load current until T2 is triggered, then discontinuous conduction is obtained. So, iL falls to zero at an extinction angle, where, < < (+). Therefore, from to (+) both VL and iL remain at zero.Once T2 is triggered i.e., at (+), the load current rushes through the path VS T2 R L D2 VS. At the instant 2, the load voltage falls to zero and once again the inductor releases the energy which has been stored in the negative cycle. This freewheel current flows through the path L D1 T2 R L. Hence, VL will be again a small negative value which is equal to the sum of drops across T2 and D1. The entire operation repeats with a period of 2 as depicted by the waveforms shown above, which belongs to the steady-state operation.Continuous Current Mode of Operation :The continuous current mode of operation is obtained when the inductance of the load (shown in the above circuit) is large enough to supply the load current until the next thyristor is triggered.So, in this mode of operation, extinction angle, (+) and therefore the load current never remains at zero. Except for this, the entire operation is similar to the discontinuous current mode of operation. The waveform for this mode is shown below. Need for Freewheeling Diode :In the above two modes, we have seen that, due to inductive load, there will be a flow of load current even after phase reversal i.e., after completing each half cycle. This is because, due to the large inductive nature of the load, the load current has a tendency to flow continuously by finding an alternative path through the diode of the same arm of conducting SCR even after phase reversal. Thus there will be no control over the thyristor once it is triggered as seen in continuous and discontinuous modes.This problem can be overcome by connecting a diode in parallel with the load. This diode is known as a fly-back diode or freewheeling diode. When there is a phase reversal, this diode acts as the short-circuit path for inductive load current rather than passing it through the thyristors. Hence the thyristor regains its blocking state once there is a phase reversal in the supply.The free-wheeling diode improves the load current waveform and increases the input power factor. It also eliminates the damage of the circuit components from the formation of voltage spikes during the turn-OFF period of thyristors and diodes. Single-Phase Semi Converter With RL-Load and Freewheeling Diode :The circuit diagram of a single-phase semi-converter with freewheeling diode connected to RL-load is shown in the below figure. The circuit is similar except for a freewheeling diode Df connected across the RL load.In this circuit, at t = , T1 and D1 become reverse biased, whereas the freewheeling diode Df becomes forward biased. Hence, after t = , the load current will be transferred from T1 D1 to Df. Now the current flows through the path Df R L Df. During this period, the output gets short circulated through Df and the output voltage will be zero as shown in the below waveforms.This process continues from to + . When T2 is triggered at t = + a, D2 and Df get forward biased. Now the load current shifts from Df to T2 D2, and again the load voltage follows the supply voltage till t = 2. At t = 2, T2 and D2 get reverse biased, and Df gets forward biased, and again the above process repeats. We can see that the above load current and load voltage waveforms are similar to the waveforms of the converter without a freewheeling diode. But here load current due to inductive load is transferred back to it through the freewheeling diode Df rather than through the thyristor and diode combination T1 D2 and T2 D1.Hence the freewheeling diode improves the circuit performance and also ensures commutation of thyristors at the end of each half-cycle providing a controlled load current under the triggering circuit.Derivation for Single-Phase Bridge Semi Converter :In both the single-phase semi converter circuits (with and without freewheeling diode) shown above. The source supplies the power to the load from to . From the above waveforms, upon neglecting the drops of diodes and thyristors. The average output voltage can be found from, The RMS value of output voltage is given as, Single Phase Semi Converter provides only a one-quadrant operation. Most commercial applications need only controlled rectification and for this a Single Phase Semi Converter is enough.Types of Single Phase Semi ConverterGenerally, there are two types of configurations of semi-converter.Symmetrical Semi Converter.Asymmetrical Semi Converter.Single Phase Symmetrical Semi Converter with R Load(a) Circuit Diagram. (b) Input, output voltage and current waveformsFig. 1: Single Phase Symmetrical Semi Converter with R LoadIn Fig. 1 (a), shows the circuit diagram of single-phase half-controlled bridge rectifier with R load. In this rectifier two SCRs and two diodes are connected in symmetrical configuration.The operation of this converter mainly consists of three modes:Mode 1 :(to):During positive half-cycle of AC input voltage, thyristor T1 and diode D1 conduct and thyristor T1 is fired at t = . Therefore the average output voltage is equal to the instantaneous supply voltage and load current flows through T1 R D1 and back supply again.Mode 2 : (to +):At instant t = , the supply goes through zero and after supply voltage reverses its polarity. Due to reverse supply across conducting devices T1 and D1, they turned off at t = and this type of turn-off is called as natural or line commutation. Therefore, the average output voltage is zero (i.e. V0 = 0 volt) and load current is also zero.Mode 3: (+ to 2):At instant t = + , the supply voltage becomes completely negative i.e. during negative half cycle of AC input voltage, thyristor T2 and diode D2 are forward biased, thyristor T2 is fired at t = + . Thus the average output is equal to instantaneous supply voltage because due to conduction of T2 and D2, the load is directly connected to supply (i.e. V0 = VS). The load current flows through T2 R D2. Thyristor T2 and diode D2 conduct upto 2 , at t = 2 commutation takes place due to natural zero appears across supply.Advantages of Single Phase Semi ConverterImproved power factor.Cost is reduced as 2 SCRs are replaced by 2 diodes.Reactive input power is reduced.Average output d.c. voltage is higher for same firing angle.Disadvantages of Single Phase Semi ConverterIt can be operated only in rectification mode.Energy feedback from load to source is not possible.Applications of Single Phase Semi ConverterSince it has a higher power factor, it can be used in high power applications. It is also widely used in main line a.c. traction where large d.c. motors are applied from a single-phase a.c. supply.Formulas of Single Phase Semi ConverterAverage value of output voltage (V0)\[{{\text{V}}_{\text{0}}}=\frac{{{\text{V}}_{\text{m}}}}{\text{ }\!\!\pi\!\!\text{ }}\left(1+\cos \alpha \right) \]RMS value of output voltage (Vrms)\[{{\text{V}}_{\text{rms}}}=\frac{{{\text{V}}_{\text{m}}}}{\sqrt{2}}{{\left[\frac{\text{1}}{\text{ }\pi \text{ }}\left(\text{ }\pi \text{ }-\alpha +\text{ }\frac{\text{sin 2}\alpha }{\text{ 2 }}\text{ } \right) \right]}^{\text{1/2}}}\]Single Phase TransformerIn this topic, you study Single Phase Transformer. The transformers are designed to operate either Option 4 : \(\frac{\alpha }{\pi }\) Free 16 Questions 8 Marks 20 Mins Answer:- Fraction of conduction time freewheeling diode conducts = / Concept:- Circuit of single phase halfcontrolledbridge rectifier is supplying on R-L load and Freewheeling diode. The circuit consists of a thyristor T, voltage source Vs , a freewheeling diode across the RL load, an inductive load L and resistive load R. During the positive half cycle of input voltage, the thyristor T is forward biased but it does not conduct until a gate signal is applied to it. When the gate pulse is given to thyristor T, it gets turned on and begins to conduct. When the thyristor is on, the input voltage is applied to the load but due to the inductor present in the load, the current through the load build up slowly. During the negative half cycle, the thyristor T gets reverse biased. At this instant i.e. at \(\omega t = \;\pi \), the load current shift its path from the thyristor to the freewheeling diode. When the current is shifted from thyristor to freewheeling diode, the thyristor turns off.(Fig.2) The current through the inductor slowly decays to zero through the loop R Freewheeling diode L. So here the thyristor will not conduct in the negative half cycle and turns off at \(\alpha \) So the load reverse voltage only during the positive half cycle. The average value of output voltage can be varied by varying the firing angle The waveform of voltage and current. The Advantages of using Freewheeling Diode:- It prevents the output voltage from becoming negative. As the energy stored in the L is transferred to load R through freewheeling diode, the system efficiency is improved. The load current waveform is more smooth. The power factor is improved. The performance of converter is improved with a freewheeling diode. Indias #1 Learning Platform Start Complete Exam Preparation Daily Live MasterClasses Practice Question Bank Mock Tests & Quizzes Trusted by 7.1 Crore+ Students The process of conversion of ac power into dc power is called Rectification. The device used for the rectification process is called Rectifier. In normal rectifiers, which includes P-N junction semiconductor diodes, the output voltage obtained is fixed in amplitude by the amplitude of ac input voltage.So in order to obtain controllable variable dc output, controlled rectifiers are used. Controlled rectifiers incorporate phase-controlled thyristors instead of diodes to obtain the variable output. The controlled rectifiers can be single-phase or three-phase. Based on control over output voltage, there are two types of controlled rectifiers,Half Wave Controlled Rectifier and,Full Wave Controlled Rectifier.In this article, let us learn about half-wave controlled rectifiers. In practice, the performance of controlled rectifiers gets affected by the type of load (resistive or inductive, or capacitive) to which it is supplying power. So, let us see the operation of half-wave controlled rectifiers with various types of loads.Single-phase Half Wave Controlled Rectifier with R Load :The circuit diagram for a single-phase half-wave controlled rectifier with resistive load is shown below. The circuit is energized from transformer secondary and an SCR is included between load and secondary. The ac input is given to the primary of the transformer. In the below circuit load is assumed to be purely resistive. Working of Single-phase Half Wave Controlled Rectifier with R Load :We know that thyristor is a unidirectional device, allowing the flow of current only in one direction. When the thyristor is forward-biased i.e., anode terminal is positive with respect to the cathode terminal, and the gate terminal is not triggered, there will be no conduction due to the reverse biasing of the inner junction of SCR. Hence, the entire supply voltage appears across the SCR.If the gate terminal of SCR is triggered with an adequate duration pulse, then the width of the depletion layer (reverse biased inner junction) starts reducing and finally disappears and SCR starts conducting. As soon as the conduction starts, the voltage across SCR drops to a very small value and the supply voltage appears across the load.The magnitude of the conduction current depends upon the instant when it is triggered i.e., firing angle , and the load resistance R. Since the circuit does not contain any energy storing elements, the load current will be in phase with voltage and becomes zero instantaneously with the voltage at zero crossing (at t = rad/sec). During the negative half cycle of supply voltage, the SCR is reverse-biased, so there will be no conduction even if the gate is triggered. Hence, the entire supply voltage appears across SCR. The waveforms for the above circuit operation with resistive load are illustrated below.In the above waveforms, the load current and voltage are zero from 0 to . When SCR is triggered by giving gate signal at . The entire supply voltage except for drop across SCR will be applied across the load (from t = to t =). At t = , the phase reversal takes place and the negative half-cycle of the input supply will start.Due to the negative half-cycle, the SCR will be reverse biased and will be turned OFF at t = . From t = to t = 2, the load current and voltage will be zero. Again when the positive half cycle starts i.e., from t = 2, SCR will be forward biased but it will not be switched ON until it is triggered i.e. until t = (2 +). Calculation of Average Load Voltage and Current with R load :From the above waveform, the load voltage appears only from to in the period of 2 during the first cycle of the input supply. From this, the average value of load voltage and the load current is derived as,Therefore, from the above equation, the average output voltage across the load can be varied by varying the firing angle . The maximum output voltage across the load is obtained when firing angle = 0.Single-phase Half Wave Controlled Rectifier with RL Load :When the load is complex i.e., when the load contains any energy storage elements like inductor (RL load), the situation becomes different from that of pure resistive load. Here the load current doesnt follow the waveform of the load voltage (load current will be out of phase with load voltage). The below figure illustrates the half-wave rectifier with RL (resistive-inductive) load. Working of Single-phase Half Wave Controlled Rectifier with RL Load :At t = , when SCR is triggered, it starts conducting. Now, the SCR acts as a closed switch due to which the voltage across SCR decreases and becomes equal to ON state drop. The load voltage will now become equal to the supply voltage; whereas, the load current increases at a slow rate because of the presence of an inductor.At t = , the supply voltage becomes zero but the load current will not become zero instantaneously because of the load inductor. The load current after t = slowly decreases due to which the load voltage still follows the supply voltage even in the negative cycle. At some angle t = + (extinction angle), the load current becomes zero and hence the load voltage. The above process repeats even in the next cycle.Calculation of Average Load Voltage and Current with RL load :The average value of load voltage and load current when half-wave controlled rectifier supplying power to an inductive load is derived as, Working of Single-phase Half Wave Controlled Rectifier with Freewheeling Diode :From the above rectifier operation with inductive load. We notice that, the load inductor stores energy in the initial part of the positive half-cycle of the applied voltage and maintains the conduction of current during the negative half-cycle by releasing the stored energy for a substantial period.The time of conduction depends upon the value of load inductance. Thus supply positive voltage appears across the load and thus even negative voltage reaches the load. In order to stop the negative voltage wave to reach the load or to prevent the instantaneous value of the load voltage to become negative. A free-wheeling or flywheel diode (FD) is connected across the load as shown below.By using a free-wheeling diode only positive voltage reaches the load. If the circuit is connected to the ac supply, the diode or power device is likely to damage when the switch is closed and opened due to sparks established. To overcome this situation a freewheel diode must be connected across the load. At t = , the thyristor is triggered and the supply voltage appears across the load from t = to t = . With a freewheeling diode, the thyristor will not be able to conduct beyond . At t = the supply voltage, as well as the load voltage, becomes zero, but the load current does not become zero instantaneously because of the presence of an inductor.At t = the thyristor becomes reverse biased, whereas the freewheeling diode becomes forward biased. Hence after t = , the load current will be transferred from thyristor to the freewheeling diode. During the negative half cycle of supply voltage, the freewheeling diode action takes place and no power will be returned to the source.In practice, half-wave controlled rectifiers are not generally used, since they cannot produce continuous load current and a large ripple will be present in the output voltage. A rectifier circuit that employs only diodes as the switching device is called an Uncontrolled rectifier. In an uncontrolled rectifier, the average output voltage is fixed and cannot be varied for a given load and a given ac supply. Since there is no triggering terminal to a diode, the conduction and commutation of the diode in uncontrolled rectifiers depend upon circuit conditions.Uncontrolled rectifiers are divided into single-phase and three-phase. The single-phase uncontrolled rectifiers are again divided into half-wave and full-wave uncontrolled rectifiers. In a half-wave rectifier only either the positive or negative half-cycle of ac input is rectified, whereas, in a full-wave rectifier, both positive and negative half-cycles are rectified. In this article let us see about a single-phase half-wave uncontrolled rectifier with R and RL load.Single-Phase Half-Wave Uncontrolled Rectifier with R-Load:The circuit diagram for a single-phase half-wave uncontrolled rectifier supplying power to a resistive load is shown below. The circuit is supplied by a single-phase transformer whose secondary represents the rectifiers circuit. A single-phase half-wave uncontrolled rectifier circuit uses only one diode that converts half of the ac input cycle into dc. When the supply source is turned ON, the positive half cycle of ac input starts. During the positive half cycle of the ac input, point A will become positive with respect to point B. Due to this, the diode D1 goes into forward biased condition because the anode terminal of the D1 is made positive and the cathode terminal is made negative.We know that a diode in a forward-biased condition will act as a closed switch i.e., it allows current to flow through it. Thus the resistive load gets connected across the supply and the load current starts flowing in the circuit from point A to B throughout the positive half cycle. Now when the negative half cycle of ac input starts, point B will become positive with respect to point A. In this condition, the diode D1 will be reverse-biased because the anode terminal of the diode is made negative and the cathode terminal is made positive. When a diode is reverse-biased it acts as an open switch and blocks the flow of current through it.Therefore, during the negative half cycle of ac input, the load gets disconnected from the supply. Thus no load current flows except a very small leakage current which can be neglected and no voltage is developed across the load until the next positive half cycle. The waveforms for input voltage VI, output voltage Vo, output current Io, and the voltage across the diode VD1 are shown below. In the above waveforms, we can see that load current Io flows from 0 to i.e., during the positive half cycle, and Io will be zero from to 2 i.e., during the negative half cycle. Since the load is resistive type, the load current or output current Io will be in phase with the output voltage Vo i.e., the current waveform will be a replica of the voltage waveform.The average value of the output voltage of the rectifier can be calculated as follows, Since output voltage and current are in phase due to resistive load. Both output voltage and current are related by I = V/R. Consequently, the average output current is given by, Single-Phase Half-Wave Uncontrolled Rectifier with RL-Load:In the above circuit, we have seen a half-wave uncontrolled rectifier with a resistive load. Now let us see the operation of a half-wave uncontrolled rectifier with RL load (resistive-inductive load). The circuit is similar to a rectifier with an R-load except the load consists inductor (L) in series with the resistor (R) as shown below. Due to the inductive nature of the load, the load current Io will not be in phase with the voltage Vo rather it lags behind the voltage. The waveforms for load voltage and current with RL-load are shown below.It can be seen that, The load current Io rises from zero to peak at t1 which lags the voltage peak due to load inductance. During the time period from 0 to t1 the load inductor stores energy in it.Once the load current reaches its peak value it starts to decay and load voltage Vo becomes negative at t = because the load current Io doesnt reach zero with voltage. Both source and inductor supply energy to R during the time period from t1 to .The load current Io continues to decay and reaches zero at t = (+), Vo remains negative until Io reaches zero. The energy is supplied by the inductor to both source and resistor from to (+).At t = current and voltage reach zero and the diode is reverse-biased disconnecting the load from the supply. The load gets disconnected until the next positive half cycle of ac input.The average value of the output voltage and current with RL-load can be calculated as, From the above equation, the average output voltage Vdc can be increased by making = 0. This can be done by connecting another diode across the load called a freewheeling diode Df as shown in the below figure.The above-modified circuit will transfer current due to inductive load from diode D1 to freewheel diode Df during the period to (+). Due to this a negative voltage doesnt appear across the load. The value of average output voltage and current with a freewheeling diode is given as, Disadvantages of Single-Phase Half-Wave Uncontrolled Rectifier:Since the diode conducts only for a half-cycle the efficiency of the rectifier is less (