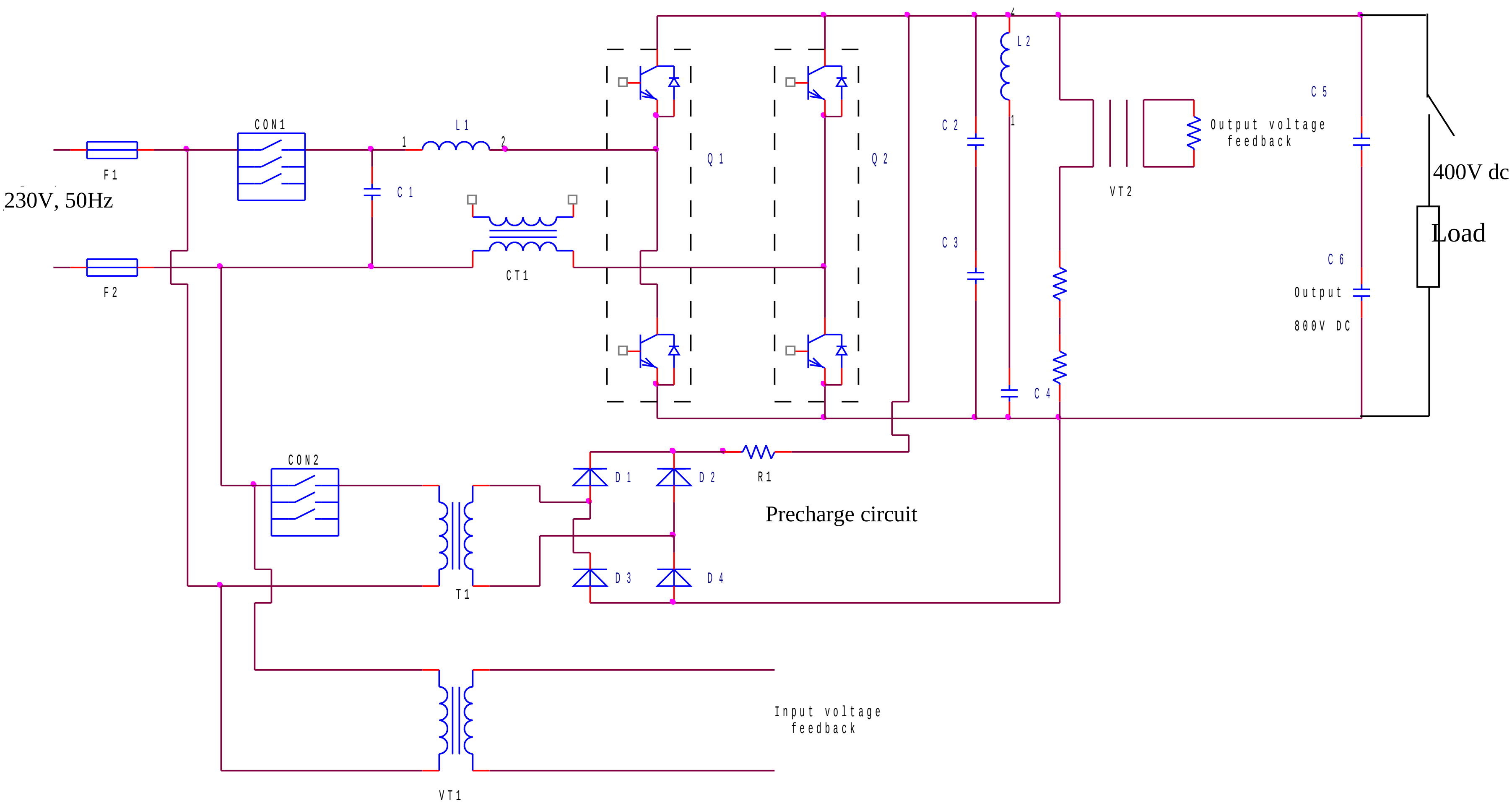
Experiment No. 11: Study of passive (diode) and active ac to dc converter



Circuit Diagram

SINGLE PHASE FRONT-END CONVERTER

1.1 INTRODUCTION:-

A front end converter is an AC-to-DC converter. But it has several advantages over the conventional phase controlled rectifier. The conventional phase controlled rectifier has some serious disadvantages. Firstly, with the dc bus polarity remaining constant, power flow can be in one direction only. Secondly, it draws reactive power from the line, which is a substantial at large firing angle. Lastly, the current drawn from the mains is far from sinusoidal.

Where as the front end converter can be controlled to enable power flow in both the direction and as well as maintaining the DC bus voltage to a good regulation. This single phase front end converter employs a single phase inverter topology. It can be operated at any desired power factor, and hence, can even act as a reactive power source as far as the grid is concerned. The converter is operated as a PWM voltage source inverter in the current-controlled mode; so, the harmonics in the line current waveform are substantially reduced. The converter will be controlled in such a way that it will draw current from grid at unity power factor and as well as it will maintain the dc bus voltage to the desired label.

1.2 SYSTEM DESCRIPTION:

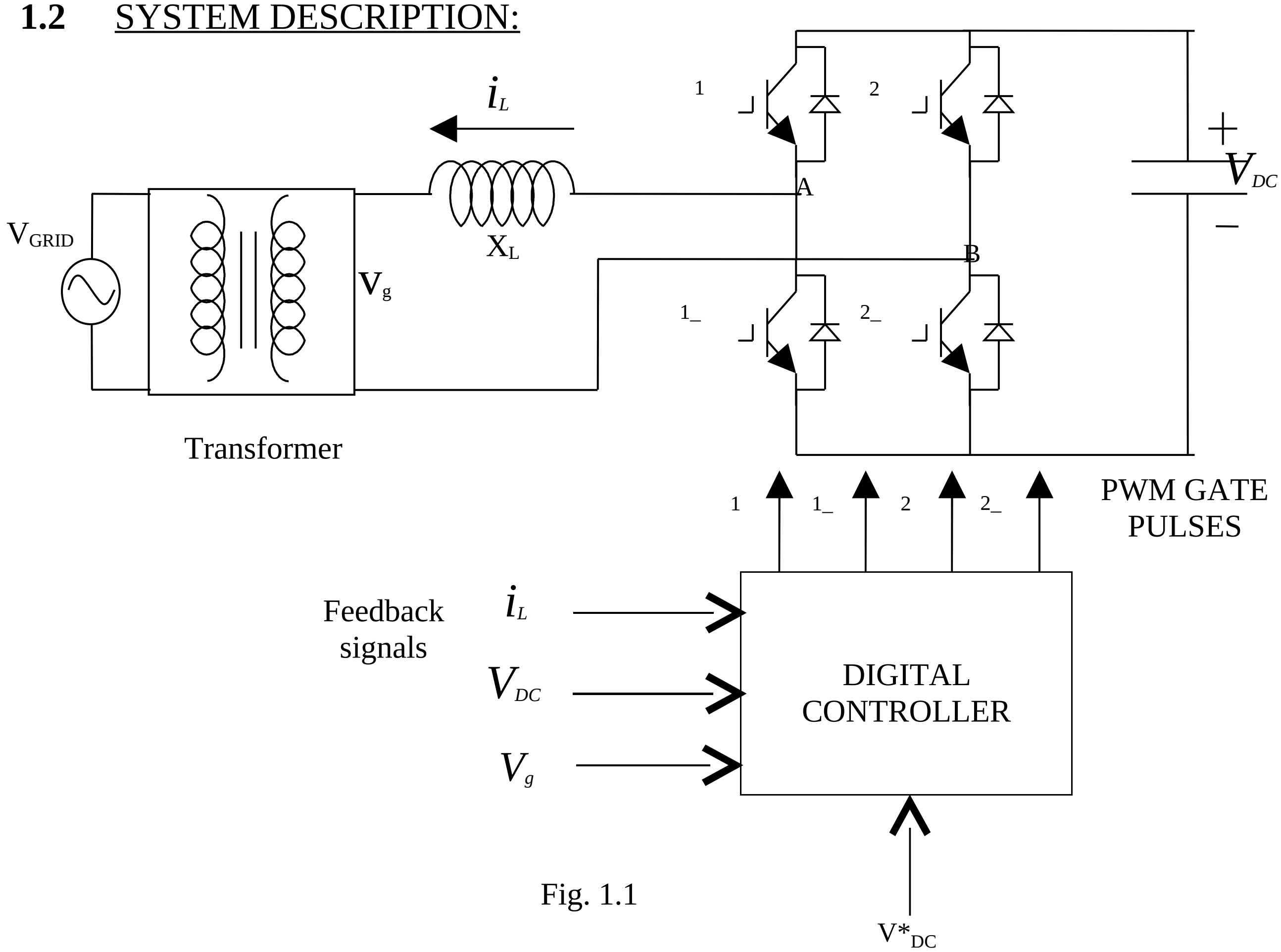


Fig. 1.1

The schematic diagram of the single phase front-end converter is shown in the Fig. 1.1. The transformer in the input side is used to match the voltage levels between the dc bus and the ac side.

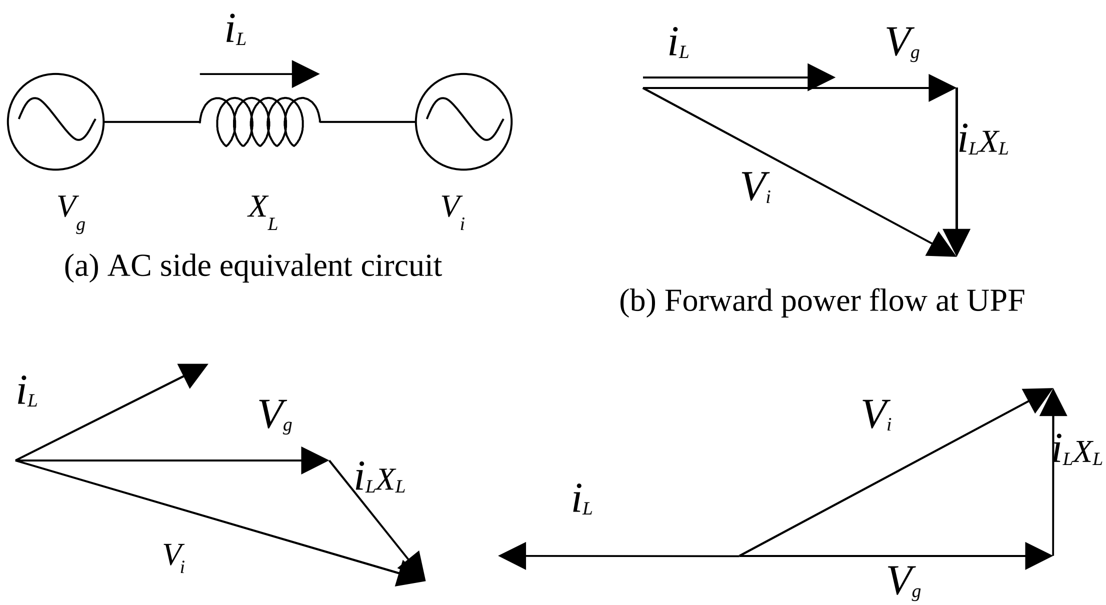
The PWM switching converter is connected to the secondary side of the transformer through series chokes. These inductors act as buffers between the two voltage sources. The choice of the values for these inductors depends on the switching frequency, allowable harmonics in the input current waveform and the reactive power requirement.

The objectives for the control of the converter are,

i) Voltage regulation of the dc bus,
ii) Bi-directional power flow,
iii) Operation at any unity power factor, and
iv) Low current harmonics.

1.3 PRINCIPLE OF OPEARATION:

The front end converter requires closed-loop control to meet the stated objectives. The basic strategy for control and resulting circuit behaviour can be explained easily by means of the phasor diagrams given in Fig. 1.2.



(a) AC side equivalent circuit

(b) Forward power flow at UPF

(c) Forward power flow at leading power factor

(d) Reverse power flow at UPF

Fig. 1.2

Where V_g = grid voltage, i_L= line current, X_L= impedance of the choke, V_i= inverter voltage

The primary objective of control is to regulate the dc bus voltage. A change in the dc bus voltage can be attributed to an imbalance between the active powers between the ac and dc sides. (The effect of reactive power on the dc bus is to produce ripples in the voltage even though the average value remains the same.) Hence, the voltage error in the dc side is an indication of the active power demand in the ac side. If the demand is positive more active power should be drawn from the grid.

If the demand is negative then power should be feed back to the grid. Since the converter has bidirectional switches, current flow can be in either direction and it is possible to source or sink active power in the ac side.

Fig 1.2 (a) shows the equivalent circuit of the ac side of the converter. If the load in the dc side is known then the current drawn from the grid at any power factor can be calculated by applying power balance between ac side and dc side. Consequently, subtracting the reactive drop from the source voltage, the magnitude and phase of the inverter terminal voltage with respect to the source can be computed. Therefore, here inverter acts as a fixed frequency source with controllable phase and magnitude. Fig. 1.2(b) , Fig. 1.2(d) shows the steady state phasor diagrams at unity power factor when power flows from ac side to dc and vice versa respectively. Fig. 1.2(c) shows the steady state phasor diagram at leading power factor when power flows from ac side to dc side. It is observed that the magnitude of the inverter terminal voltage increases in this case. The amount of reactive power that can be injected into the grid depends on the available dc bus voltage and the value of per unit inductance in the ac side. The terminal voltage of the inverter will also contain switching harmonics apart from the fundamental. As far as the harmonics are concerned the ac source acts as a short-circuit and the effective impedance to the harmonic current is nX_L. If the switching frequency is sufficiently high, i.e. more than 1 kHz, then the harmonic content present in the current will be very low resulting in low THD in the current wave form.

I. **Steps:**

1. Activate the 230V, 50Hz control supply line.
2. Turn on the control supply switch.
3. Wait till precharge is over and main contactor is closed. You will hear the closing sound.
4. Activate the 230V, 50Hz power supply line
5. Study the unit as a 3-phase diode rectifier.
6. Now, release the IGBT gate pulses.
7. Study the unit as a 3-phase active rectifier.

II. **Readings:**

Diode rectifier:

Sl. No.	Grid voltage V_g		Grid current (I_g)							DC bus voltage V_{dc} *(volt)*	Load current I_{dc} *(A)*
	RMS value *(volt)*	THD (%)	$I_{g_{rms}}$ *(A)*	$I_{g1_{rms}}$ *(A)*	THD (%) $I_{g1_{rms}}$ as100%	I_{g3} (%) $I_{g1_{rms}}$ as100%	I_{g5} (%) $I_{g1_{rms}}$ as100%	I_{g7} (%) $I_{g1_{rms}}$ as100%	I_{g11} (%) $I_{g1_{rms}}$ as100%		

Sl. No.	Grid side *kVA*	Grid side active power P_g *(kW)*	Grid side reactive power Q_g *(kVAr)*	Grid side displacement factor	Grid side power factor	DC bus power P_{dc} *(kW)*	Converter efficiency η *(%)*

Front-end rectifier:

Sl. No.	Grid voltage V_g		Grid current (I_g)							DC bus voltage V_{dc} *(volt)*	Load current I_{dc} *(A)*
	RMS value *(volt)*	THD (%)	$I_{g_{rms}}$ *(A)*	$I_{g1_{rms}}$ *(A)*	THD (%) $I_{g1_{rms}}$ as100%	I_{g3} (%) $I_{g1_{rms}}$ as100%	I_{g5} (%) $I_{g1_{rms}}$ as100%	I_{g7} (%) $I_{g1_{rms}}$ as100%	I_{g11} (%) $I_{g1_{rms}}$ as100%		

Sl. No.	Grid side *kVA*	Grid side active power P_g *(kW)*	Grid side reactive power Q_g *(kVAr)*	Grid side displacement factor	Grid side power factor	DC bus power P_{dc} *(kW)*	Converter efficiency η *(%)*