See Fig. 2.7 on Page 15

- $\emptyset dc$ is the direction of dc flux
- $\emptyset ac$ is the direction of ac flux
- Idc is the direct injected current
- Iac is the ac current flowing through windings L_2 and L_3 (Fig. 2.3)
- N_b is the number of turns of the dc winding
- N_a is the number of turns of the ac winding

The reactor of Fig. 2.7 consist of two C cores each of which carries a dc control winding with a common ac winding. The direct current is produced by the control circuit (Chap. 4) and the ac current is the current flowing in windings L_2 and L_3 from Fig. 2.3. The positive directions for the alternating fluxes are shown by the arrows. The waveforms of the voltage, flux and current are shown in Fig. 2.8 (23).

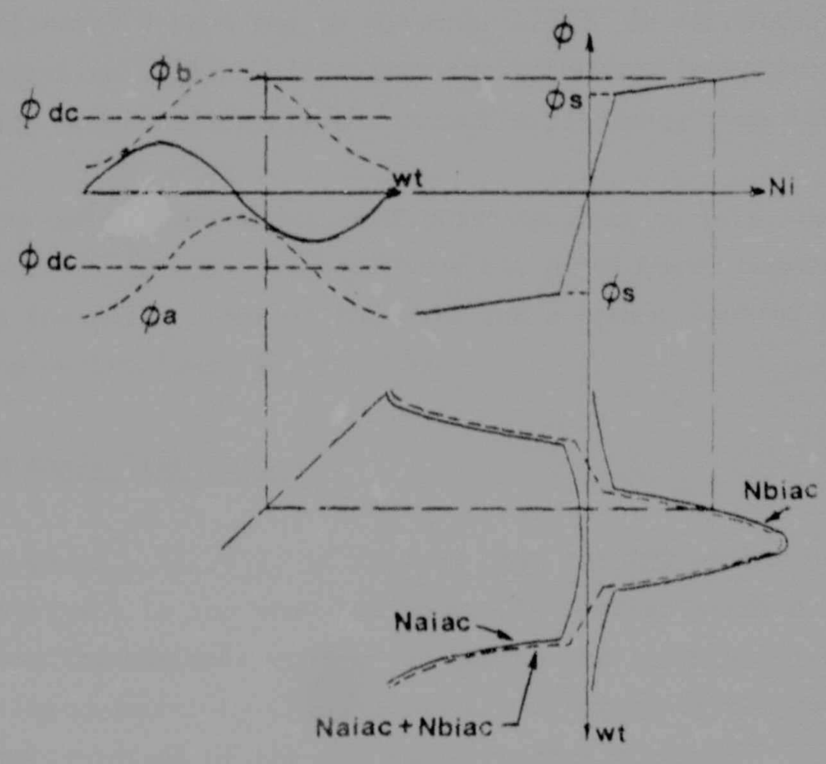

Figure 2.8 Voltage, current and flux waveforms in the core and windings of the saturable reactor.

- $\emptyset a$ is the flux during the positive half cycle
- $\emptyset b$ is the flux during the negative half cycle

See Fig. 2.7 on Page 15

- Ødc is the direction of dc flux
- Øac is the direction of ac flux
- Idc is the direct injected current
- Iac is the ac current flowing through windings L_2 and L_3 (Fig. 2.3)
- N_b is the number of turns of the dc winding
- N_a is the number of turns of the ac winding

The reactor of Fig. 2.7 consist of two C cores each of which carries a dc control winding with a common ac winding. The direct current is produced by the control circuit (Chap. 4) and the ac current is the current flowing in windings L_2 and L_3 from Fig. 2.3. The positive directions for the alternating fluxes are shown by the arrows. The waveforms of the voltage, flux and current are shown in Fig. 2.8 (23)

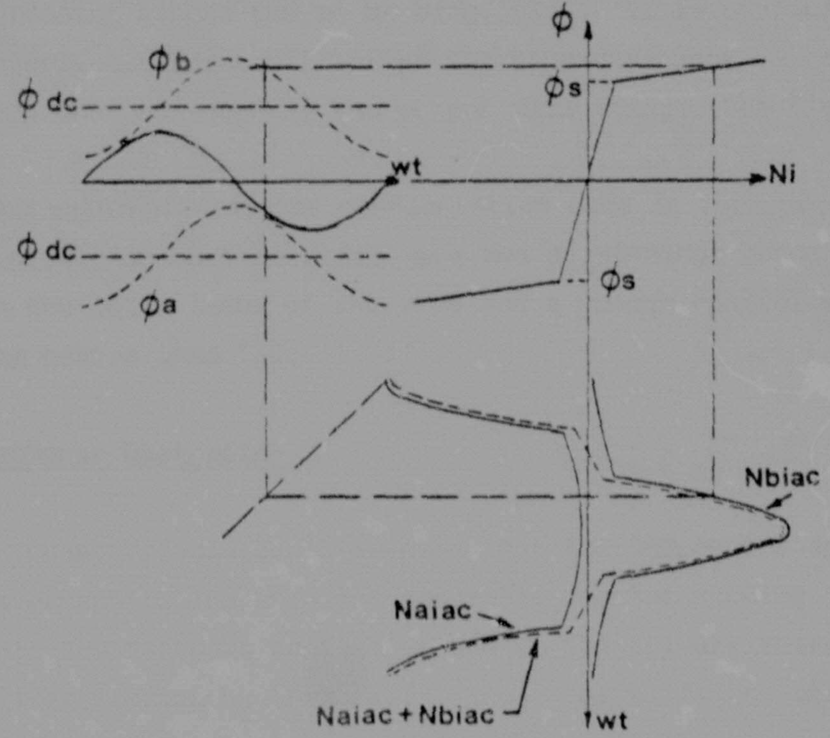

Figure 2.8 Voltage, current and flux waveforms in the core and windings of the saturable reactor.

- Øa is the flux during the positive half cycle
- Øb is the flux during the negative half cycle

A non-sinusoidal voltage is impressed upon the single ac coil in Fig. 2.7. The two fluxes Øa and Øb lag the impressed voltage by 90° if the coil resistance is negligible. The total flux in each core is the sum of the alternating and direct components as indicated and for each value of total flux the corresponding value of core mmf (Naiac and Nbiac) can be found from the magnetising curve. The mmf wave can thus be found graphically as shown in Fig. 2.8. From the conditions of symmetry, Naiac and Nbiac will have identical shapes but are shifted 180° with respect to each other. Each of the mmf waves contain both odd and even harmonics, as well as a dc component. The dc windings are wound in series and in antiphase and no alternating flux is impressed upon the dc windings. The dc fluxes in the centre limb of the core cancel each other out.

The mmf supplied by the ac circuit will be the sum Naiac + Nbiac which contains only the fundamental and odd harmonics. The even harmonics, required for the non-sinusoidal flux, are, therefore, supplied by the control winding. Owing to the fact that the dc fluxes in the centre limb are cancelled, there are no even harmonics across the ac winding. (23) It is obvious that the dc injection current will alter the secondary leakage reactance volt drop and consequently the output will change (See Fig. 2.4 and equ. 2.5).

The saturable reactor configuration used in this project is not typical, as most reactors have two ac windings connected in series on the outer limbs of the core and a common control winding around the centre limb (10, 11, 23).

2.5 Harmonic Distortion

In Chap. 3 Table 2, it is seen that the T.H.D. of the output voltage waveshape is low when the saturable reactor winding is included. This low harmonic content is due to the primary third harmonic filter winding L_6 (Fig. 2.3), the external filter choke and the configuration of the saturable reactor windings.

It has been shown (7) that by reducing the airgap in the single core C_3 and retaining the capacitor voltage, the C.V.T. moves closer to electrical resonance and the output voltage becomes more "square" which is ideal for rectification purposes (7). However, only the ac application is discussed in the text.

2.6 Summary

When using a split C-core geometry on core C_3 and including a saturable reactor type winding arrangement, the ac output voltage was controlled from 213 volts to 232 volts by varying the dc injection current (7). It has already been stated that the output voltage changes when the mains frequency is varied. The saturable reactor winding, when incorporated in a closed loop feedback arrangement will allow the output voltage to be controlled. The system now becomes independent of variations in output voltage for a range of input voltage of -20% to + 10% of rated value as well as for a frequency drift of $\pm$ 4% of rated frequency. A graph showing the effects of frequency changes on the output voltage for the uncontrolled device is given in Chap. 5 Fig. 5.3 (Also see Chap. 3 Table 2).

CHAPTER 3

THE OPERATION OF THE CONSTANT VOLTAGE TRANSFORMER WITH THE SATURABLE REACTOR WINDING

This chapter deals with the operation of the C.V.T. with the control windings and circuitry connected. For comparison between the uncontrolled and the controlled C.V.T., a table of the important circuit parameters has been provided (See Table 2).

3.1 The windings of the complete system

The device from Fig. 2.3 has been modified to enable the saturation of the secondary leakage reactance to be controlled. The C-core C_3 of Fig. 2.3 has been removed and a split C-core C_3 and C_3' have replaced it as the secondary leakage reactance path. In Fig. 3.1 the control windings L_8 and L_9 are incorporated. Winding L_7 provides power to the control circuit. Although winding L_7 is depicted as a single winding in the drawing, it does, in fact consist of three separate windings. Two of these windings supply power to the control circuit electronics to give ± 12 Volts dc and the third supplies power to the transistor current amplifier configuration which drives dc current into the dc windings L_8 and L_9. Windings L_8 and L_9 have an equal number of turns. These windings are connected in series and in antiphase so no ac voltage is produced across the coils which could cause damage to the control circuit.

Windings L_8 and L_9 have 600 turns each. This amount of turns ensures that a large number of ampere turns are available for control purposes. For the operating condition where Vin = 220 Volts, 50 Hz, and for the flux density in cores C_3, C_3' of 1,85T, the ampere turns per metre required for control purposes are approximately 2000 (7). Therefore the number of ampere turns per coil is 2000 times the magnetic path length of the split C-cores (C_3 and C_3' respectively) = $2000 \times 52{,}49 \times 10^{-2}$ = 1050 Ampere turns.

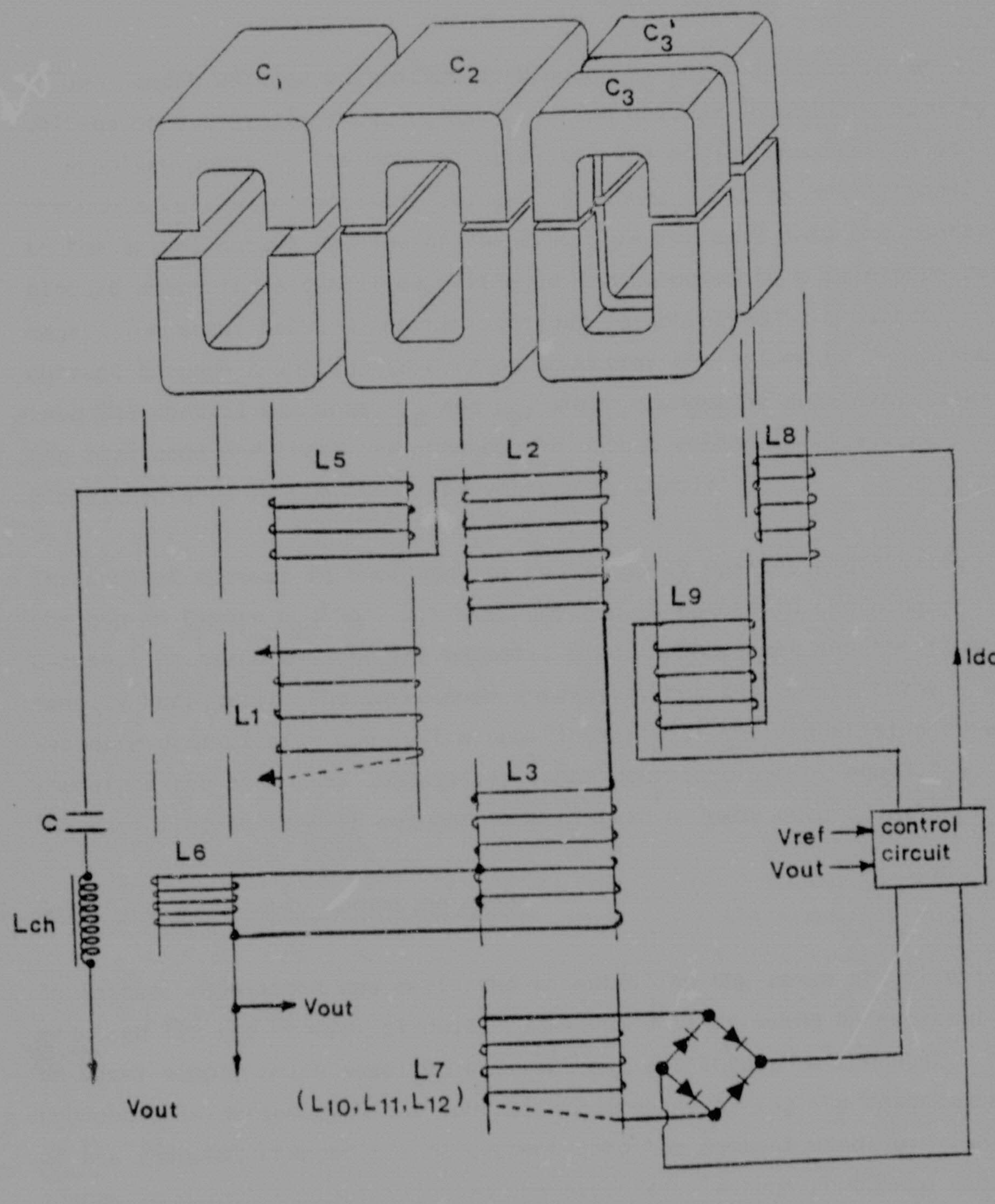

Figure 3.1 Core arrangement and connection diagram for output voltage control via saturable reactor type windings showing the split C-core

An ac input voltage is applied to winding L_1 which induces an ac voltage across windings L_2, L_3 and L_7. The voltage induced in winding L_7 supplies power to the control circuit. The ac is converted to dc through a full-wave rectifier bridge. A signal directly proportional to the actual output voltage of the C.V.T. is fed back into the control circuit where it is rectified, filtered and compared to a reference voltage. The error between the two voltages is converted to a direct current through a voltage to current converter and drives dc current into the control windings, L_8 and L_9, which changes the secondary leakage reactance and therefore changes the output voltage. (i.e. the circuit acts to reduce the error voltage to zero).

The control circuit is analogous to continuously opening and closing the gap in C-core C_3 (Fig. 2.3.) When the gap is opened in the single C-core, the reluctance of the magnetic circuit increases and the flux density decreases. The inductance increases, but the ampere turns decrease dramatically due to the non-linearity of the magnetising curve. Therefore the secondary leakage reactance decreases and by equ. 2.2 the capacitor current is reduced resulting in a lower output voltage.

3.2 Selecting a suitable operating point

An initial experiment was performed to establish the range of variation required for the control circuit. This was done by using an external dc power supply which supplied a direct current through a rheostat connected in series with the control windings. Varying the resistance of the rheostat changed the dc current into the control winding. The change in direct current adjusted the secondary leakage reactance and caused the output voltage to change. (See Chap. 2 Sect. 2.4). Variable frequency was obtained by controlling the field of a dc motor which drove an ac generator (Chap. 5 Sect. 5.1).

The output voltage was controlled for frequency variations from 48Hz to 52 Hz. An operating point was selected at nominal frequency, 50 Hz with an input voltage Vin = 220 Volts at full-load. At 50 Hz for this condition the operating point for the dc injection current is 1,82 Amps. (See Table 1).

TABLE 1 MEASURED DC INJECTION CURRENTS AT NO-LOAD AND FULL-LOAD

INPUT VOLTS	LOAD %	OUTPUT VOLTS	FREQUENCY (Hz) 48	49	50	51	52	
176	0	220	1,63	1,95	2,20	2,42	2,68	DIRECT
220	0	220	1,71	2,20	2,27	2,53	2,81	CURRENT
242	0	220	1,60	2,40	2,30	2,59	2,84	INJECTED
176	100	220	0,84	1,26	1,58	1,87	2,15	(AMPS)
220	100	220	1,11	1,49	1,82	2,09	2,41	
242	100	220	1,14	1,56	1,88	2,20	2,44	

If the frequency falls to 48 Hz on full load, say, less dc current needs to be injected into the circuit. From Table 1 it is seen that for this condition 1,11 Amps dc are needed. The current requirement increases as the frequency increases. Also, the dc control current required at no-load is greater than that at full-load for a particular input voltage and frequency. Referring to Fig. 2.5 and equ. 2.2 it is seen that at no-load there is no volt drop across the secondary leakage reactance but at full-load there is a secondary leakage volt drop. Therefore, the output voltage at no-load is higher than that at full load.

Table 1 shows that high frequencies and input voltages correspond to the highest values of the output voltage, therefore the highest dc injection current is required to bring the output voltage back to 220 volts. For this condition the dc current has to be high to saturate cores C_3 and C_3' thereby reducing the secondary leakage reactance considerably, to counterbalance the otherwise high output voltage.

In selecting an operating point care must be taken to ensure that at the low frequencies control is still available. From Table 1 it is evident that the lowest current needed is 0,84 amps. It may be argued that the smallest current should be near zero. Measurements were taken at 47 Hz and 53 Hz and the results prove that the device is capable of operating at a wider range (Table 6, Sect. 5.7). It is possible to decrease the core area slightly to have a lower operating point. A disadvantage of adding extra windings and circuitry is that the efficiency of the device decreases by approximately 5% for all conditions (See Table 2.).

The gaps in the split C-cores have been set to produce an output of 238 Volts for an input voltage of 220 Volts at 50 Hz, at full-load with no control current. The dc current needed to bring the output voltage down to 220 Volts is 1,82 Amps. The new core geometry gives an output of 230 Volts for an input of 220 Volts at 50 Hz. A point worth noting is that a trade off exists between stability and percent harmonic distortion in the output voltage waveform. The trade off depends on the length of the gap in core C_3 or the split core C_3 and C_3'. If the reactance is increased, the distortion improves, but stability worsens and vice-versa. This is due to an increase in the secondary leakage reactance. A large reactance effectively increases the capacitor current because the volt drop across the secondary leakage reactance is in the same direction as the secondary emf. The core C_2 is driven harder into saturation so the stability improves but the distortion worsens. Therefore, the availability of the control circuit allows the C.V.T. to produce very low harmonic distortion with excellent stability, simply by pre-setting the gap length (to provide low distortion) and selecting an operating point which keeps the output voltage stable.

3.3 Working flux density of the split C-cores

In order to obtain the desired range on the variation of the secondary leakage reactance it was necessary to ensure that the operating point was around the knee of the magnetising curve for the steel used on cores C_3 and C_3'.

The new C.V.T. geometry is designed for a flux density of 1,7T in core C_3. This is on the knee of the magnetising curve. The split C-core, C_3 and C_3' operate at 1,8T which is in the saturated region. At a low frequency, fewer ampere turns are needed to hold the output voltage constant. At high frequencies the non-linear characteristic begins to take effect and more ampere turns are required.

3.4 The performance of the controlled and uncontrolled C.V.T.

Table 2 gives the output voltage, percent harmonic distortion, efficiency, input power factor and stability over the full range of operation for the new C.V.T. and the controlled device. The stability of the controlled device is excellent and the percent total harmonic distortion compares favourably with that of the uncontrolled device. As stated previously by pre-setting the gap length the distortion may be improved to well below the specified 3%. As expected the efficiency of the controlled device is lower under all conditions.

TABLE 2: COMPARISON BETWEEN CONTROLLED AND UNCONTROLLED CVT.

DESCRIPTION OF PARAMETER			UNCONTROLLED			CONTROLLED		
FFREQUENCY (HZ)			48	50	52	48	50	52
	LOAD	INPUT VOLTS						
OUTPUT VOLTS	NO-LOAD	176	223,5	234,5	[illegible]	220	220	220
	NO-LOAD	220	220	232	243	220	219,5	219,5
	NO-LOAD	242	218	230	240	219,5	219,5	219,5
	FULL-LOAD	176	208	229	242	221	220,5	220,5
	FULL-LOAD	220	215	230	242	220,5	220,5	220,5
	FULL-LOAD	242	214	228	241	220,5	220,5	220,5
% TOTAL HARMONIC DISTORTION	NO-LOAD	220	4,86	5,92	6,19	5,02	5,06	5,77
	FULL-LOAD	220	1,84	3,08	4,02	3,42	3,07	3,15
% EFFICIENCY	FULL-LOAD	176	92	89	87	87	84	82
	FULL-LOAD	220	89	88	86	84	82	81
	FULL-LOAD	242	86	86	84	82	81	79
INPUT POWER FACTOR	FULL-LOAD	176	0,97	0,97	0,95	0,97	0.96	0,96
	FULL-LOAD	220	0,80	0.87	0.92	0,80	0.87	0,92
	FULL-LOAD	242	0,63	0,69	0,78	0,63	0,71	0,79
% STABILITY	1/2(V out max- V out min) / 1/2(V out max+ V out min)		3,59	1,41	1,23	0,34	0,23	0,23
% STABILITY OVER COMPLETE RANGE			±8,37			±0,35		

CHAPTER 4

CIRCUIT TO CONTROL THE SECONDARY LEAKAGE REACTANCE

This chapter deals with the details of the continuous control system that was devised in order to implement the variation of the secondary leakage reactance required for control over the range given in Chap.3.

Continuous control has the advantage of producing no switching spikes (See Chap.1) and closed loop feedback is necessary to prevent oscillations which may lead to an unstable system. A requirement of this design is that the control system be independant of external auxilliary power supplies.

4.1 Block diagram of the control circuit

A functional description of the control circuit relating to the C.V.T. is given in this chapter. All circuit diagrams and equations are referred to in the Appendices. A block diagram of the system is given in Fig.4.1.

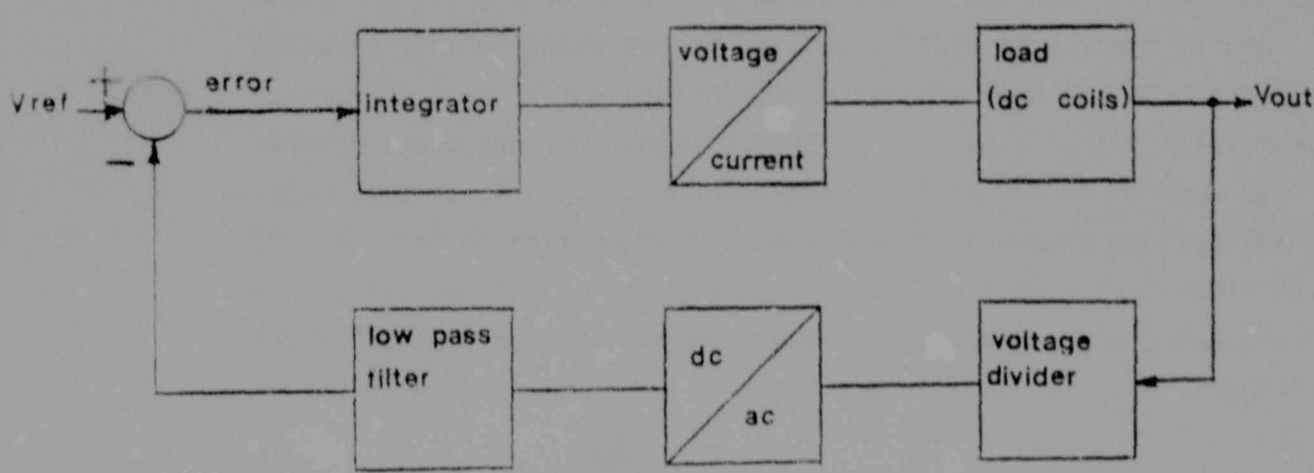

Figure 4.1 Block diagram of the control circuit.

The control circuit is basically a voltage to current converter and the signal operation is as follows: A signal, directly proportional to the ac output voltage of the C.V.T. Vo is obtained via a resistance voltage divider. This reduced output voltage signal is then rectified using a full-wave bridge rectifier. Four diodes configured as a full-wave bridge rectifier may be used, otherwise a full-wave precision rectifier provides excellent rectification. The former requires only diodes whilst the latter consists of diodes, resistors and two operational amplifiers (12,14) (Appendix A).

The rectified signal is then filtered to produce a dc voltage, the magnitude of which is directly proportional to the ac output voltage. A second order, low pass Butterworth filter with a cut-off frequency of less than 5Hz is used. This low cut-off frequency prevents unwanted ripple on the dc signal. A large dc ripple could result in oscillations and instability as explained later in this chapter. The smoothed dc signal is inverted using a unity gain operational amplifier circuit (Appendix B).

The inverted (negative) dc signal is added to a positive reference voltage. The positive reference voltage is obtained using a zener diode in parallel with a potentiometer. (Appendix C). The reference voltage is preset to provide a dc current in the control coils (described later in the chapter). This dc current is the operating point of the control and acts to change the secondary leakage reactance (See Chap. 3 Sect. 3.2). Varying the reference potentiometer of Fig. C1 adjusts the C.V.T.'s output voltage by shifting the operating point. Consequently the user may set the output voltage to his requirements (See Chap.5 Sect. 5.2 Table 3). The difference between the negative dc voltage and the positive reference voltage provides an error signal which is then integrated.

The error signal obtained from the adder circuit is then integrated. The integrated circuit is shown in (Fig. D1 Appendix D). The diode clamps the voltage at zero volts and does not allow for a negative swing. The integrator circuit is necessary for two reasons:-

1. The time constant of the RC circuit is such as to provide a short time delay. This delay allows the C.V.T. to start up under normal operating conditions before the control circuit is activated.

2. The moment that the output voltage deviates from the set point (dependent on the reference voltage), an error signal exists at the input to the integrator. This error signal is integrated and the output voltage from the integrator rises slowly towards the power supply rail voltage. As this voltage rises, more current is injected into the control windings via the voltage to current converter circuit (Appendix E), thereby adjusting the secondary reactance and correcting the output voltage from the C.V.T. When the output voltage is correct, the reference voltage and the varying dc signals are equal and no error signal exists. The integrator's output only changes when there is an error signal. With no error this output voltage remains at the value required to provide the correct injection current to keep the C.V.T.'s output voltage constant at the pre-set point.

It may be argued that an integrator is not necessary and that a circuit with a large gain will suffice. The problem with large gain is explained below. As the output voltage deviates from the required value the varying dc signal becomes larger or smaller than the reference voltage. Again an error is produced, which in this case, is amplified. The circuit acts to correct itself immediately and the injection current is pumped into the control windings causing the C.V.T.'s output voltage to change rapidly. The circuit then sees the change in C.V.T.'s output voltage and tries to correct it again. Thus an oscillation occurs until the error is reduced to zero. If rapid fluctuations of input voltage and/or frequency occurs, instability occurs and the control circuit fails.

If a ripple voltage is present on the varying dc signal, there will be a ripple on the error signal. This error will be integrated and amplified causing an oscillating injection current to flow into the control windings. Consequently, the output voltage from the C.V.T. will oscillate which is an unsatisfactory condition.

The integrated error signal is fed into the voltage to current converter circuit (Appendix E). The current is amplified through a Darlington transistor pair and a power transistor, and flows into the control windings which are wound around the split C-cores C_3 and C_3' respectively. The injection current changes the secondary leakage reactance, which, in turn adjusts the C.V.T.'s output voltage, thus reducing the error to zero.

The complete control system is independent of external power supplies. Three power supply windings are incorporated into the unit. Two of the windings supply power to the operational amplifier circuit via a positive and negative integrated voltage regulator. The third winding supplies current to the transistor amplifier stage that feeds the injection current into the control windings (Appendix F). The disadvantage of the internal power supplies is that the C.V.T.'s efficiency decreases due to the increased power consumption of the complete system. The advantage is that the system is powered by a single power source.

4.2 Summary

The aim of the control circuit is to reduce the error signal to zero, thereby maintaining the output voltage at the pre-set point. If the frequency and/or input voltage increases, the error increases and more dc injection current is required to adjust the secondary leakage reactance. At low frequencies and/or voltages a small error is present so a little dc current is necessary.

The variable reference voltage allows the user to pre-set the operating point of the dc current to a value which maintains the output voltage at a pre-selected level. If it is required to change the output voltage then the potentiometer needs only to be turned (Table 3, Chap. 5).

The integrated error signal is fed into the voltage to current converter circuit (Appendix E). The current is amplified through a Darlington transistor pair and a power transistor, and flows into the control windings which are wound around the split C-cores C_3 and C_3' respectively. The injection current changes the secondary leakage reactance, which, in turn adjusts the C.V.T.'s output voltage, thus reducing the error to zero.

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The variable reference voltage allows the user to pre-set the operating point of the dc current to a value which maintains the output voltage at a pre-selected level. If it is required to change the output voltage then the potentiometer needs only to be turned (Table 3, Chap. 5).

The circuitry used is of very simple design and may easily be upgraded to accomodate C.V.T.'s with a much higher KVA rating. All that needs to be done is to provide more transistor amplifier stages. For larger KVA ratings, where high efficiency is important, the power supply windings may be excluded and external power supplies used instead.

Much greater accuracy may be obtained by increasing the order of the filter to provide an extemely smooth, ripple free dc signal. Also by replacing the zener diode reference with a precision reference integrated circuit, which is temperature compensated greater accuracy may be achieved.

CHAPTER 5

THE PERFORMANCE OF THE CONTROLLED CONSTANT VOLTAGE TRANSFORMER

The measured performance parameters of the controlled and uncontrolled constant voltage transformer are shown graphically. Photographs are provided of the output voltage waveforms and the response times. The harmonic distortion at different frequencies, input voltages and for two load conditions are also given. All voltage and current measurements were taken using the experimental setup described in Section 5.1.

5.1 The Experimental Setup

The variable frequency ac supply was obtained from an ac generator which was driven by a dc machine. The speed of the system was varied by controlling the field of the dc motor. The output voltage of the generator was also controlled to provide 0 to 270 volt ac at a frequency of 47 to 53 Hz. The transformer was loaded with a variable resistance load-box giving a load variation from zero-load to twice full-load.

A storage oscilloscope and a spectrum analyser were used to measure the response times, voltage waveforms and harmonic content of the output voltage waveform. The experimental setup, including the circuit of the C.V.T. and the control windings is shown in Fig. 5.1.

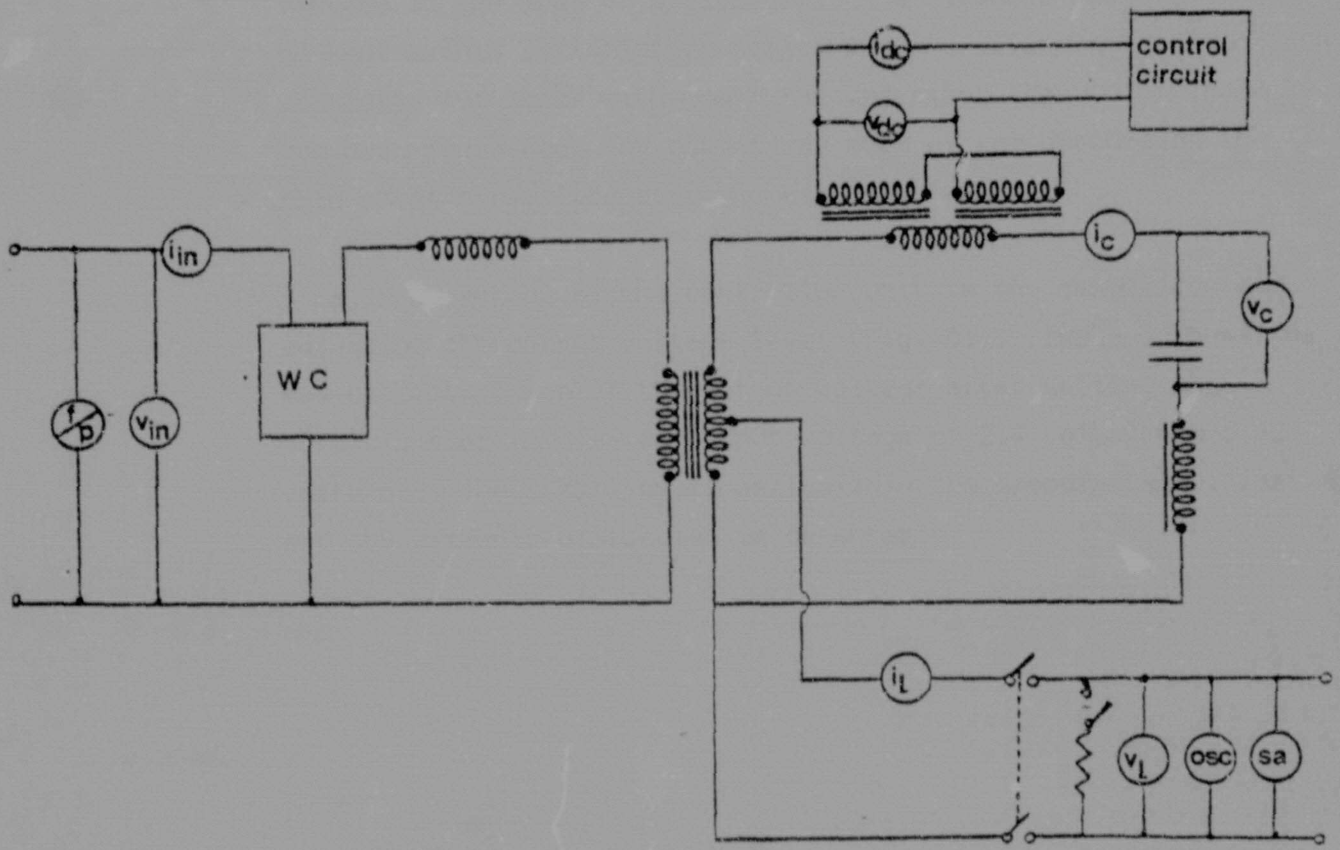

Figure 5.1 Laboratory measuring equipment

f/p is frequency period meter
Vin is the input voltage voltmeter
Iin is the input current ammeter
WC is the input watts, (watt converter)
Ic is the capacitor current ammeter
Vc is the capacitor voltage voltmeter
I_L is the load current ammeter
V_L is the load voltage voltmeter
Osc is the storage oscilloscope
SA is the spectrum analyser
Idc is the control winding dc current ammeter
Vdc is the dc voltage across the coils voltmeter

5.2 Comparison of results

The results of Table 2 in Chap. 3 prove that the control circuit greatly improves the performance of the C.V.T. The only disadvantage is the loss of efficiency. The harmonic distortion may be kept within satisfactory limits and the device should function correctly for loads with power factors other than unity. Table 2 has been reproduced for clarity as much of the discussion in this chapter revolves around these measured results.

A major advantage of the controlled unit is the capability of adjusting the output voltage level (Fig. C1). Table 3 shows the measurements taken of the output voltage after setting the potentiometer to give an output voltage of 214 volts ac and 228 volts ac. The stability is well within the proposed specification and the harmonic distortion is reasonable.

TABLE 2: COMPARISON BETWEEN CONTROLLED AND UNCONTROLLED CVT

DESCRIPTION OF PARAMETER			UNCONTROLLED			CONTROLLED		
FFREQUENCY (HZ)			48	50	52	48	50	52
	LOAD	INPUT VOLTS						
OUTPUT VOLTS	NO-LOAD	176	223,5	234,5	246	220	220	220
	NO-LOAD	220	220	232	243	220	219,5	219,5
	NO-LOAD	242	218	230	240	219,5	219,5	219,5
	FULL-LOAD	176	208	229	242	221	220,5	220,5
	FULL-LOAD	220	215	230	242	220,5	220,5	220,5
	FULL-LOAD	242	214	228	241	220,5	220,5	220,5
% TOTAL HARMONIC DISTORTION	NO-LOAD	220	4,86	5,92	6,19	5,02	5,06	5,77
	FULL-LOAD	220	1,84	3,08	4,02	3,42	3,07	3,15
% EFFICIENCY	FULL-LOAD	176	92	89	87	87	84	82
	FULL-LOAD	220	89	88	86	84	82	81
	FULL-LOAD	242	86	86	84	82	81	79
INPUT POWER FACTOR	FULL-LOAD	176	0,97	0,97	0,95	0,97	0,96	0,96
	FULL-LOAD	220	0,80	0,87	0,92	0,80	0,87	0,92
	FULL-LOAD	242	0,63	0,69	0,78	0,63	0,71	0,79
% STABILITY	1/2(V out max- V out min) / 1/2(V out max+ V out min)		3,59	1,41	1,23	0,34	0,23	0,23
% STABILITY OVER COMPLETE RANGE			±8,37			±0,35		

TABLE 3 MANUAL ADJUSTMENT OF OUTPUT VOLTAGE

		Vout SET AT 228 VOLTS			Vout SET AT 214 VOLTS		
		FREQUENCY (Hz)			FREQUENCY (Hz)		
INPUT VOLTS	LOAD	48	50	52	48	50	52
176	NO-LOAD	227,00	228,00	227,50	214,00	214,50	214,50
220	NO-LOAD	228,00	228,00	228,00	214,00	214,00	214,00
242	NO-LOAD	228,00	227,00	228,00	213,50	213,00	214,00
176	FULL-LOAD	227,00	228,00	227,00	215,00	215,00	215,00
220	FULL-LOAD	227,00	227,00	227,00	215,00	214,50	215,00
242	FULL-LOAD	226,00	228,00	226,00	214,50	214,50	215,00
% STABILITY OVER COMPLETE RANGE		± 0,44%			± 0,47%		

HARMONIC DISTORTION MEASURED AT 50 Hz		
Vout	LOAD	% THD
228	NO-LOAD	5,73
228	FULL-LOAD	3,34
214	NO-LOAD	6,13
214	FULL-LOAD	3,18

Figs. 5.2 a, b and c show the variation of the output voltages when the input voltage is varied from -20% to + 10% of nominal for frequencies of 48 Hz to 52 Hz. These measurements have been taken at no – load and at full-load. The results clearly show the remarkable overall stability achieved by using the control circuit.

The uncontrolled C.V.T. of Fig. 2.3 is set to operate at an output voltage of 230 Volts for Vin = 220 Volts at 50 Hz. The effect of frequency variation is clearly illustrated in Fig. 5.3

TABLE 3 MANUAL ADJUSTMENT OF OUTPUT VOLTAGE

		Vout SET AT 228 VOLTS			Vout SET AT 214 VOLTS		
		FREQUENCY (Hz)			FREQUENCY (Hz)		
INPUT VOLTS	LOAD	48	50	52	48	50	52
176	NO-LOAD	227,00	228,00	227,50	214,00	214,50	214,50
220	NO-LOAD	228,00	228,00	228,00	214,00	214,00	214,00
242	NO-LOAD	228,00	227,00	228,00	213,50	213,00	214,00
176	FULL-LOAD	227,00	228,00	227,00	215,00	215,00	215,00
220	FULL-LOAD	227,00	227,00	227,00	215,00	214,50	215,00
242	FULL-LOAD	226,00	228,00	226,00	214,50	214,50	215,00
% STABILITY OVER COMPLETE RANGE		± 0,44%			± 0,47%		

HARMONIC DISTORTION MEASURED AT 50 Hz		
Vout	LOAD	% THD
228	NO-LOAD	5,73
228	FULL-LOAD	3,34
214	NO-LOAD	6,13
214	FULL-LOAD	3,18

Figs. 5.2 a, b and c show the variation of the output voltages when the input voltage is varied from -20% to + 10% of nominal for frequencies of 48 Hz to 52 Hz. These measurements have been taken at no-load and at full-load. The results clearly show the remarkable overall stability achieved by using the control circuit.

The uncontrolled C.V.T. of Fig. 2.3 is set to operate at an output voltage of 230 Volts for Vin = 220 Volts at 50 Hz. The effect of frequency variation is clearly illustrated in Fig. 5.3

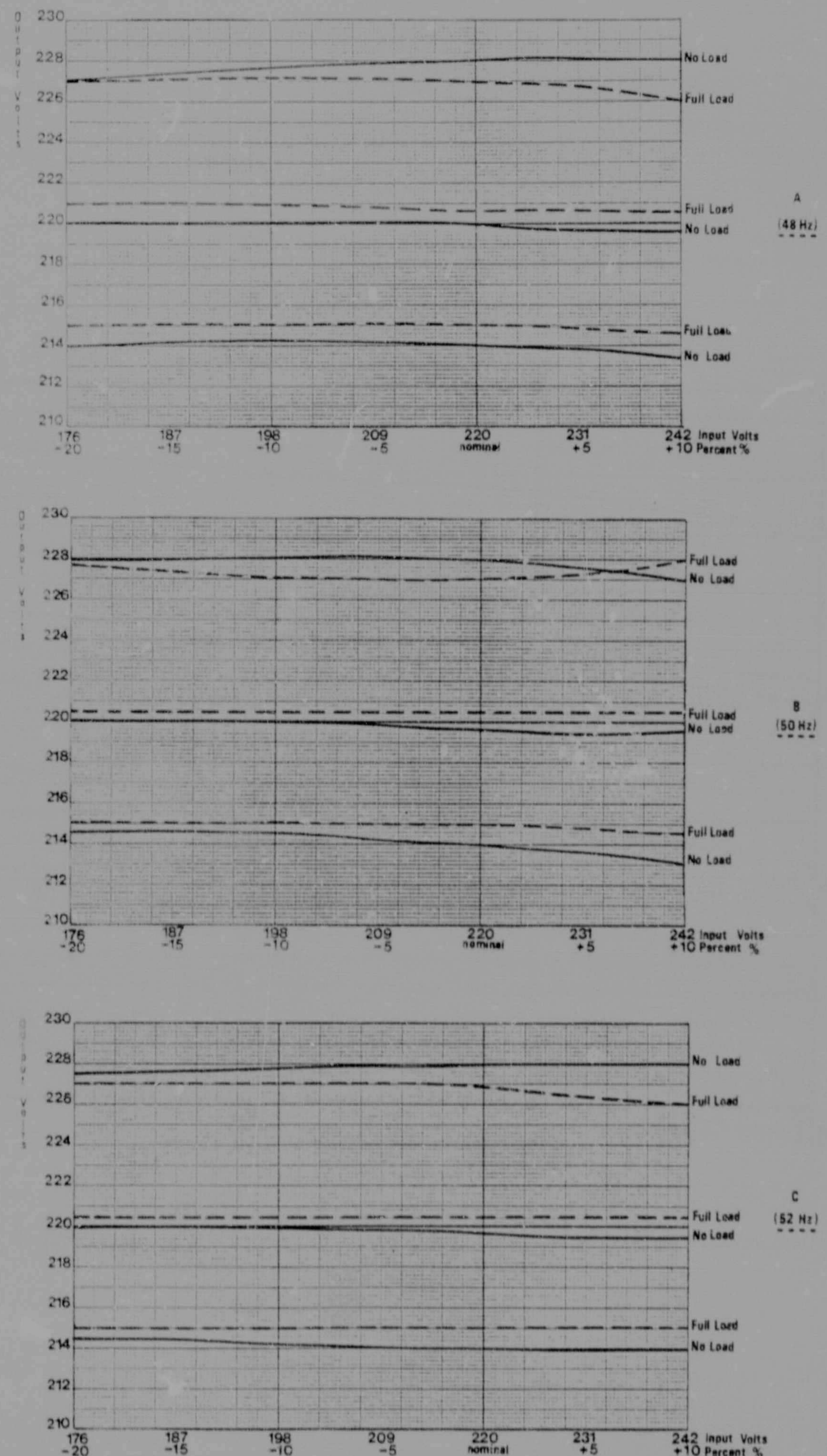

Figure 5.2 Output voltage versus input voltage for output voltages set at 214 V, 220 V and 227 V at frequencies 48,50 and 52 Hz respectively.

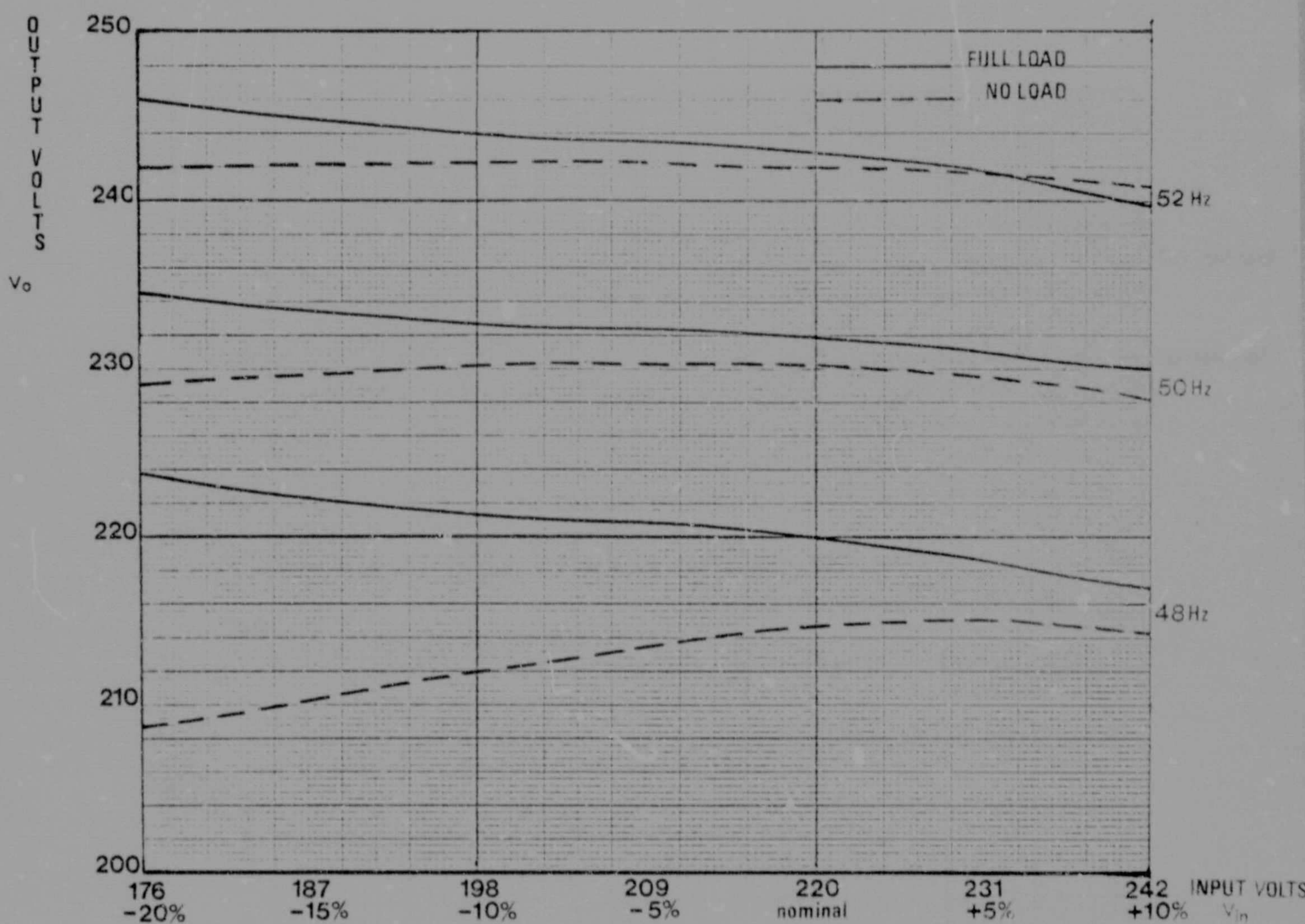

Figure 5.3 Output voltage versus input voltage for 500 VA uncontrolled C.V.T. at 48,50 and 52 Hz.