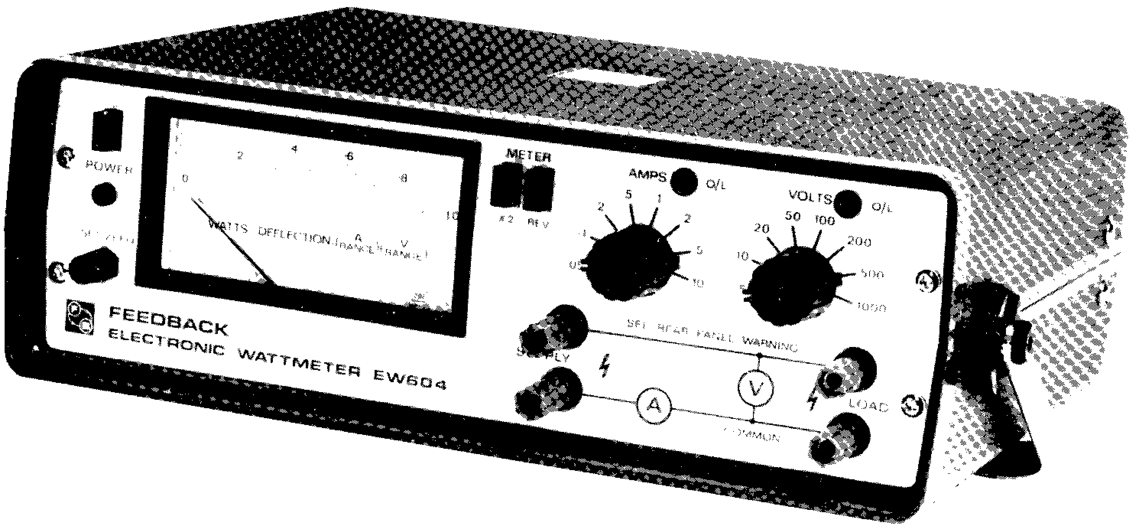
Appendix 10

Electronic Wattmeter EW604



FEEDBACK

DESCRIPTION

1.1 Introduction

The Feedback EW604 electronic wattmeter is based on an analogue multiplying circuit using the logarithmic voltage-to-current transistor characteristic. The inputs to this multiplying circuit are currents that are derived via range-scaling resistors from the input voltage terminals and the input current terminals. The output is displayed on the front panel moving-coil meter calibrated in watts.

The wattmeter terminals are arranged as two pairs marked 'supply' and 'load' to facilitate correct connection.

Separate warning lights are provided on the voltage input and current input to indicate when an overload might affect the reading accuracy. Additional precautions are taken to prevent damage to the instrument in the event of gross overload of current or voltage.

Pushbuttons enable the meter deflection to be reversed to measure reverse power flows and also to increase the meter sensitivity by X2 to improve readability of small deflections.

The wattmeter contains its own partly-regulated power supply for operation on normal line voltages.

The value of the wattage is displayed on the front panel meter which responds to the true wattage or potential heating ability of the current in the associated load. In a resistive load this corresponds to:

$$(I_{rms})^2 \ R \quad \text{or} \quad \frac{(V_{rms})^2}{R} \quad \text{irrespective of the waveform*}$$

and to: $(I_{rms})\ (V_{rms})\ \cos\phi$, in a reactive circuit with sinusoidal excitation

and in general to:

$$\text{Limit}_{T\to\infty} \ \frac{1}{T}\int_0^T v \, . \, i \, . \, dt.$$

1.2 Mechanical

The EW604 is housed in an ABS plastic case made in two halves, each secured by two screws on each side The case provides the main structural strength of the instrument. Removal of the case gives access to all components. Without the cover the EW604 consists of a horizontal PWB fixed by small plastic brackets to the

*High crest values applied to EW604 will illuminate the O/L lamp(s) if they are of such a value as to cause limiting in the circuit and thus errors.

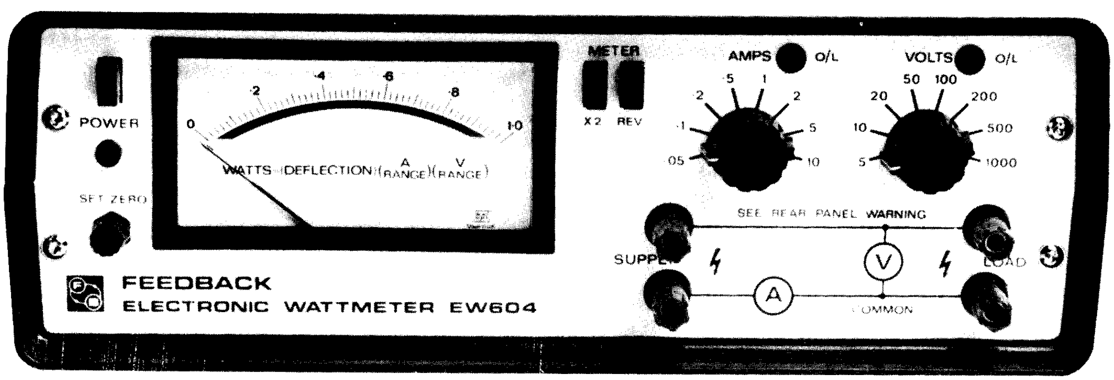


Fig 1.1

front and rear panels, providing a structure strong enough for normal handling and maintenance. The low-power dissipation of the EW604 obviates the need for ventilation holes.

The controls, situated on the front panel (see fig 1.1), are:

Power	Green pushbutton power switch Separate green power ON indicator
Current	Eight-position rotary range selector
Voltage	Eight-position rotary range selector
Terminals	Four 4mm red socket binding posts (two for connection to supply and two for connection to the load) with mimic showing metering circuits.
Meter	Mirror-scale moving-coil meter calibrated in watts. Zero — separate knob for electrical meter zero. X2 — Pushbutton to increase sensitivity. Rev — Pushbutton to reverse deflection

On the rear panel are:
Current circuit-protection fuse holder with spare fuses.

1.3 Specification

'Three-terminal wattmeter' (1 terminal common to voltage and current ranges) connected to four front-panel binding posts so that two are for connection to the 'supply' and two for connection to the 'load'.

Power range

250mW to 10kW fsd.

Voltage ranges

Nominal 5, 10, 20, 50, 100, 200, 500 and 1000 volts.

No more than 1.5kV peak should be applied between the upper pair of terminals and either ground or the lower terminals. The latter must not exceed 400V peak to ground.

Current ranges

Nominal 50, 100, 200, 500mA, 1, 2, 5 and 10A

Overload Indication Input peaks of voltage or current in excess of 1.5X the nominal range can cause overload which is clearly indicated by the appropriate voltage or current overload lamp.

Overload Protection All current circuits are protected by a 10A slow-blow ¼" x 1¼" fuse mounted on the rear panel. The circuit is designed to withstand the transient associated with normal rupturing of this fuse on all current ranges. The voltage circuit will withstand the nominal 250V a.c supply indefinitely on any range.

Frequency range

DC to 20kHz.

Burden

All voltage ranges; 5kΩ/Volt

All current ranges; less than 60mΩ

Meter

3¼" mirror scale graduated 0 to 1.0 in 50 divisions

Reading given by Watts = (meter deflection) x (Voltage range) x (Current range)

Pushbutton to give X2 scale expansion and pushbutton meter reversal.

Accuracy

Many factors control the final indication on any wattmeter. They include voltage, current and power ranges, power factor, temperature and frequency.

The possible permutations of these are so numerous that it is impracticable to specify or to test instruments under all likely operating conditions. The figures below should be interpreted in the light of these comments.

All figures are at 50Hz, unity power factor, 25°C.

Scale Accuracy

Typically better than 1.5% of fsd measured on 100V and 0.5A range at 20, 40, 60, 80 and 100% of fsd with a 200 ohm load (guaranteed better than 2.5% of fsd).

Also typically better than 2% of fsd for all combinations of 0.25A, 0.5V, 0.75A and 1A with 25V, 50V, 75V and 100V applied to the 1A and 100V ranges.

Range-to-range Accuracy

Errors in the current and voltage range multipliers contribute a combined error to power indication that is typically less than 1% of reading (guaranteed less than 2.3% of reading).

Reference power point

This is at full-scale on the 100V and 0.5A range and is set to within 0.3% of 50W.

NB i) In general, scale errors are not affected by choice of range

ii) Typical figures are determined from measurements made on a single batch of instruments.

iii) Guaranteed figures are from measurements made on every instrument.

Fig 1.2 shows the area of operation within which the EW604 may be expected to give results accurate to better than ±5% of fsd and should be interpreted in conjunction with the accuracy figures given for the calibration frequency of 50Hz.

Carrying Handle

A dual purpose handle is fitted for use in carrying the instrument or serving as a stable stand to present the instrument panel at a convenient working angle.

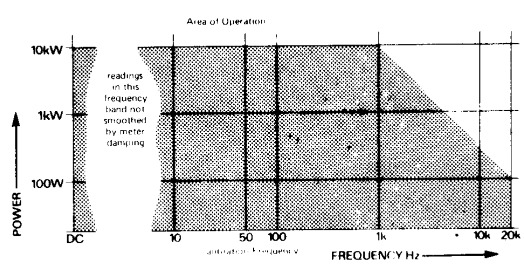


Fig 1.2

Power requirements

Line voltage

200/250V or 100/125V rms 50 or 60Hz

Consumption 4 V.A.

Fuse

315mA slow blow (20mm x 5mm) Littelfuse style 213 Beswick TTC123, Buss GMA.

Dimensions and weight

Width	300mm (12in)
Depth	225mm (9in)
Height (with feet)	115mm (4½in)
Weight	1.9kg (4.3 lb)

OPERATION

SECTION 2

2.1 Installation of EW604

The wattmeter is packed in inserts of expanded polystyrene to prevent damage in transit. On opening the end of the corrugated cardboard container, the inserts together with the EW604 should be smoothly withdrawn from the container. Take care that the inserts and EW604 are held together during this time.

Inspect the EW604 and if any damage is evident, immediately notify the carriers.

2.2 Power Supply Voltage Selection

Ensure that the instrument is set to the appropriate voltage supply either by inspecting the tag (if fitted) on the power cable or by removing the top cover of the instrument. See section 4.1.

Before removing the covers, however, ensure that the mains plug is disconnected.

The voltage selection is accomplished by a slide switch on the printed circuit board. Set the switch to '115' for operation from 100 to 125V and to '230' for 200 to 250V, 50/60Hz AC.

2.3 Wire connections

The colour code of the power supply cable is

Brown Live; Blue Neutral; Green/Yellow Ground

The ground wire is connected to the graphite screening of the case but is isolated from the front panel 'common' terminal.

2.4 Range selection

The current and voltage ranges should be selected to suit the current and voltage present in the circuit under test. This is conveniently done by progressively increasing the sensitivity by means of the appropriate range switch until the corresponding overload indicator lights, and then switching back one range. This should be done with both the current ranges and voltage ranges.

The table in fig 2.1 lists the full-scale power for the various current and voltage range combinations.

	Power for a given Voltage Range (Watts)							
Current Range	5	10	20	50	100	200	500	1000
0.05	0.25	0.5	1.0	2.5	5	10	25	50
0.1	0.5	1.0	2	5	10	20	50	100
0.2	1.0	2	4	10	20	40	100	200
0.5	2.5	5	10	25	50	100	250	500
1	5	10	20	50	100	200	500	1k
2	10	20	40	100	200	400	1k	2k
5	25	50	100	250	500	1k	2.5k	5k
10	50	100	200	500	1k	2k	5k	10k

Fig 2.1

Working voltage limits

It is recommended that the lower front panel terminals are operated at 'neutral' potential and in no case at a potential exceeding 400V d.c or pk, and the upper terminals at no more than 1500V d.c or pk, with respect to the normal supply ground (green/yellow wire in the supply cable to the rear of the EW604).

2.5 Connection of EW604 to circuit under test

The EW604 terminals are arranged so that two terminals can be connected to the supply and a separate two to the load as in fig 2.2.

The current-sensing circuit is in the lower line and should be connected in the neutral line. (This is good practice since it keeps low the operating potential of the wattmeter common connection). However, if necessary, it is possible to operate with the upper line at neutral. (This situation may occur where it is not possible to break the neutral line or where a dangerous situation would be created if the 10A overload protective fuse in series with the current-sensing circuit were ruptured). The live voltage must not then exceed 280V with respect to ground.

With conventional dynamometer wattmeters a decision has to be made before connection whether to include the internally consumed watts of the current coils or the voltage coils in the power supply measured.

With the EW604 connected as in fig 2.3(a) the power consumed by the voltage circuit at (5000 ohms/V) is so

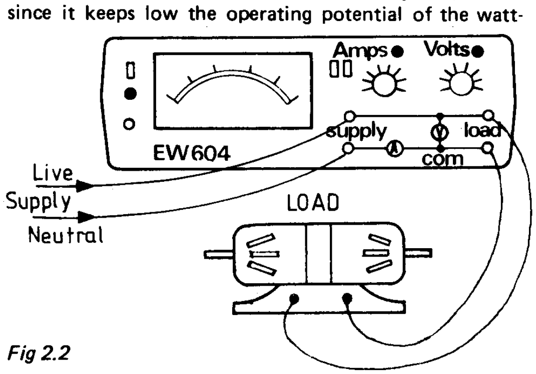


Fig 2.2

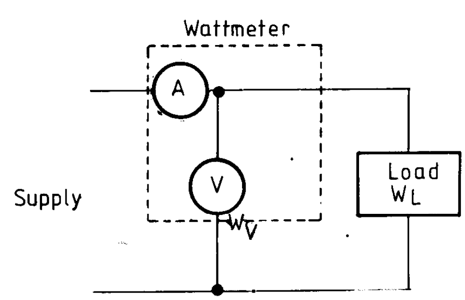


Fig 2.3(a) Indication gives $W_L + W_V$

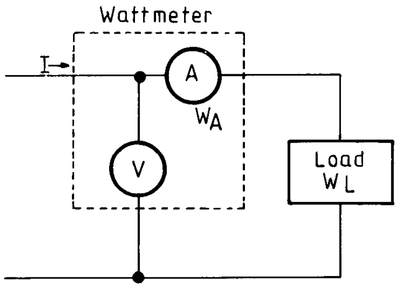


Fig 2.3(b) Indication gives $W_L + W_A$.

small that it is insignificant compared with load power. This enables the prearranged connections as shown on the front panel legend to be used without need for correction.

However the EW604 may, if desired, be connected as in fig 2.3(b). This introduces a small voltage drop (about 60mV/A) in the current sensing circuit. The reading can be corrected if necessary by subtracting the I^2R loss from the EW604 reading.

Warning

As with any electrical measuring instrument care must be taken to avoid contact with supply voltages associated with the test circuit. Switch off the supply voltage before making connections to the wattmeter terminals and avoid contact with these terminals during the test.

2.6 Measuring power in a three-phase system

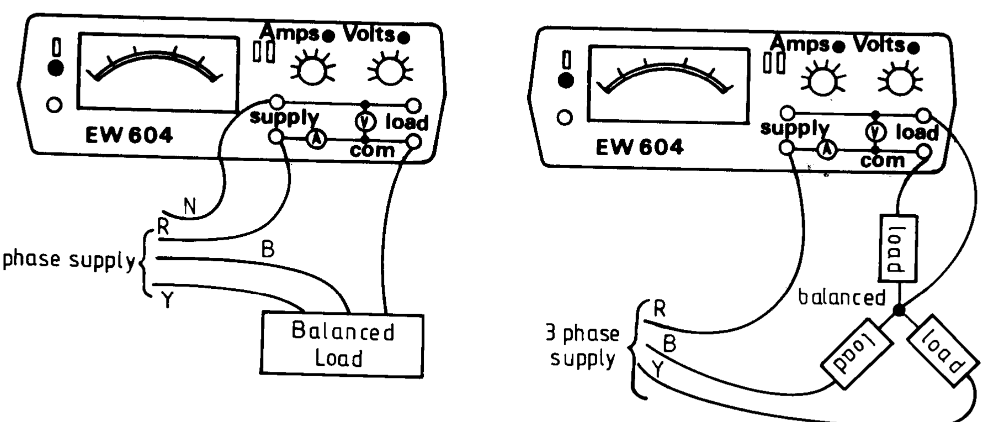
Polyphase measurements invariably require connection of the common terminal of the EW604 to at least one live line. The line voltage must then not significantly exceed 280V. For three-phase systems this implies a maximum line voltage of 490V.

Balanced system

If both the supply and the load are balanced and either a neutral is available on the supply or a star point on the load, the power can be measured by connecting as in fig 2.4 and multiplying the reading obtained by three.

If the supply and load are balanced, both the power and the power factor can be obtained from two readings using the connections of fig 2.5. Two readings P_1 and P_2 are taken using the two positions of the switch. The power is then given by $P_1 + P_2$, and the power factor is

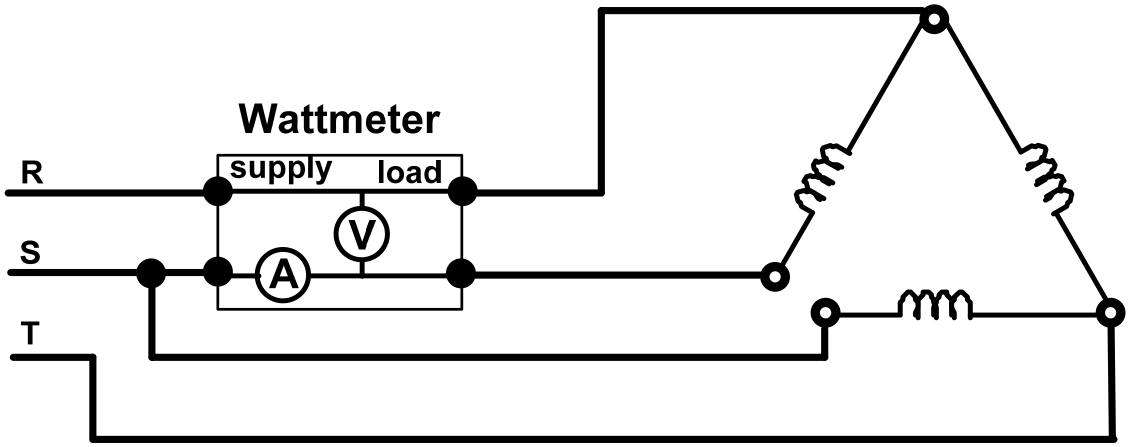
$$\frac{1}{\sqrt{1 + 3\left(\frac{1 - P_1/P_2}{1 + P_1/P_2}\right)^2}}$$



a. Supply neutral available

b. Star point of load available

Fig 2.4 Finding the power in a balanced load system.



Finding the power in balanced 3-angle

Unbalanced system

If either the load or the supply is unbalanced (or both) it is necessary to obtain the power as the sum of readings, taken with the current terminals connected in series with each line turn, except one, and the other voltage connection is taken to that one in each case. Connections are shown in fig 2.6 for three-wire and four-wire three-phase systems. If only one wattmeter is available it may be connected in each of the positions shown in turn. The power is the sum of all the readings. (This scheme of connections can be extended to any number of wires, taking n-1 readings in the n-wire case. Also it is not in principle restricted to any particular current or voltage waveforms).

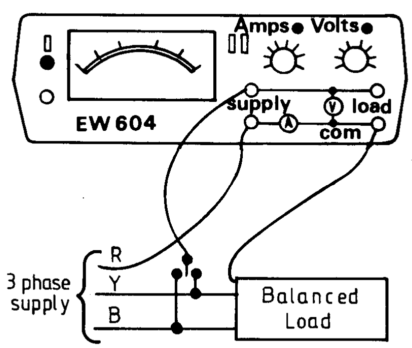


Fig 2.5 Power and power factor in balanced load system.

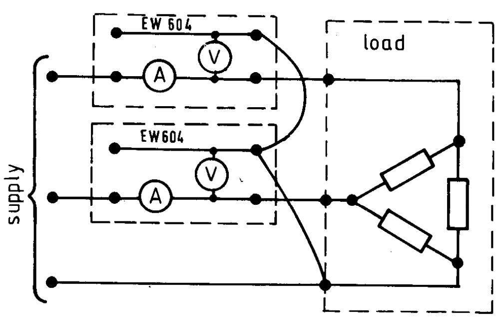


Fig 2.6a Measuring power in a three-terminal load

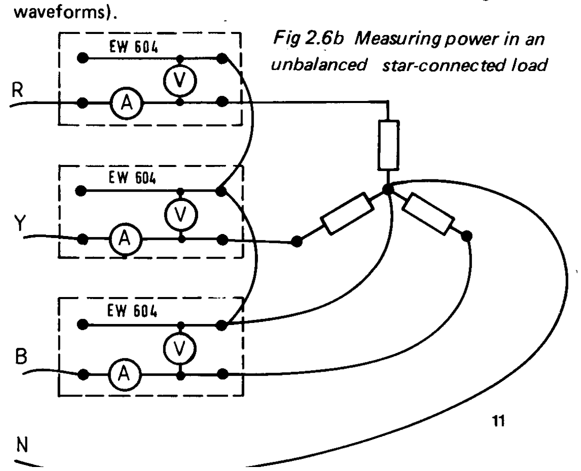


Fig 2.6b Measuring power in an unbalanced star-connected load