Low-cost emergency power generator

220V sine-wave generator using a lawn-mower engine and a scrap car dynamo

by J. M. Caunter

It has long been the dream of the author to become independent of the national grid during what seems to be the annual "silly season" of threatened disruptions in the supply of electricity. Inverters are attractive, being cheaper than petrol generating sets, but still expensive when one considers the batteries needed to run them. Most inverters have square-wave outputs, for optimum efficiency, which are not suitable for central heating pumps, 25% of the power being wasted in harmonics which could overheat the motors. Television sets should have the input taps changed because of the different peak-mean value of square waves. Sine-wave inverters are available at a price, but these are less efficient, and require even bigger batteries.

Alternative methods of generating low-cost power for the home have been investigated. The author's solution costs about £12 and makes use of a petrol mower. A 12V car dynamo rescued from a scrapyard provides an excellent skeleton for an alternator, and a transformer at about £8 saves a tedious winding process. A scrap 12V battery supplies the excitation current, and about £2.50 secures enough components to monitor the frequency of the output voltage and protect the field winding from setting fire to the garden shed when the motor stalls while you are in the bath (metaphorically speaking).

The armature of the dynamo is rewound for a slightly higher voltage which does not cause insulation problems but keeps brush currents down, since the area of contact with the slip rings is less than that with the original commutator. The design to be described is by no means an optimum one and can easily be changed to suit the reader. For example, if the armature was wound for 110V a.c., it would require about 78 conductors of 22swg per slot. However, the insulation would need more careful selection than in this proposed design.

A. mature construction

Remove the armature from the dynamo yoke and dismantle from the drive-end bearing plate. Push out the paper rope filler from the outer edge of each armature slot, and after cutting the wires at the commutator remove the windings.

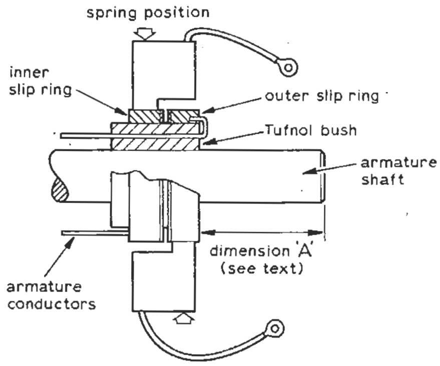

Fig. 1. Sectional view of slip-ring assembly and brushes.

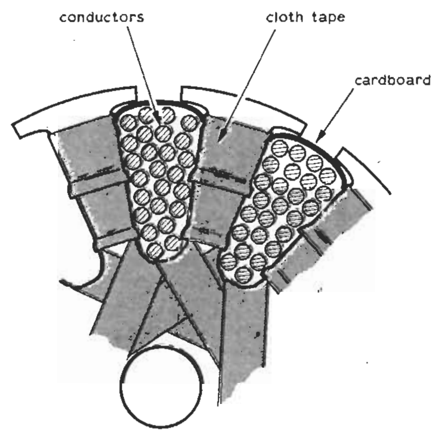

Fig. 2. Armature insulation.

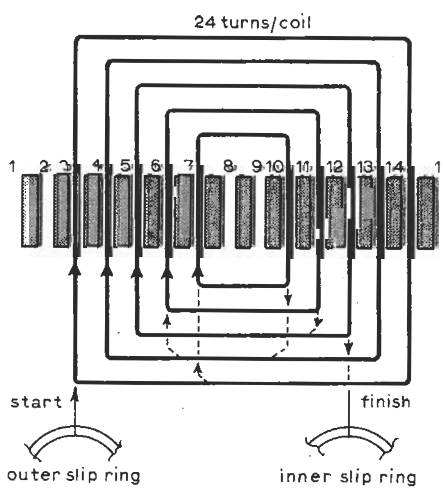

Fig. 3. Developed winding diagram.

Clean the armature core with paraffin and then dry. Before removing the commutator measure its major dimensions and its position relative to the end of the shaft which is shown as dimension A in Fig. 1. Note the width and relative position of the brush marks on its circumference. These dimensions are vital to ensure correct alignment between brushes and slip rings, especially on dynamos without brush inspection windows. With reference to Fig. 1, the author's slip-ring assembly was made to the following dimensions:

overall diameter 37.25mm;
insulating bush bore 15mm;
width of each slip ring 8.5mm;
gap between slip rings 3mm.

The remaining dimensions are less critical and can be varied to suit the reader. The commutator is now pulled off the shaft by brute force or ignorance.

Construction of the slip-ring assembly is shown sectioned in Fig. 1. The copper slip rings are retained on the Tufnol bush by Araldite or Loctite adhesive. When completed, the assembly is pressed or drifted on to the shaft to a position determined by dimension A. The old armature insulation must be removed from the slots and renewed. The most successful method was to wind single layers of black cloth insulation tape between adjacent slots and between diametrically opposite bottoms of the slots as shown in Fig. 2. This has the added advantage of building up a cone-shaped collar where the shaft enters the armature laminations and greatly aids the winding operation. One or two layers of tape are also wound tightly around the armature shaft between this collar and the slip-ring assembly.

Before commencing with the winding, Fig. 3, which shows the armature slots laid out flat for simplification, should be studied. Each pair of slots is wound with 24 turns of 18swg enamelled wire except the two outer pairs which are left empty. The slot nearest the hole through the slip-ring bush is designated slot 3; the remaining slots are numbered clockwise from this, through 14 and back to 2. When one is winding between slots 5 and 12 the coil is divided equally on each side of the armature shaft. Use thin but strong card cut into strips to insulate the open end of the armature slots as shown

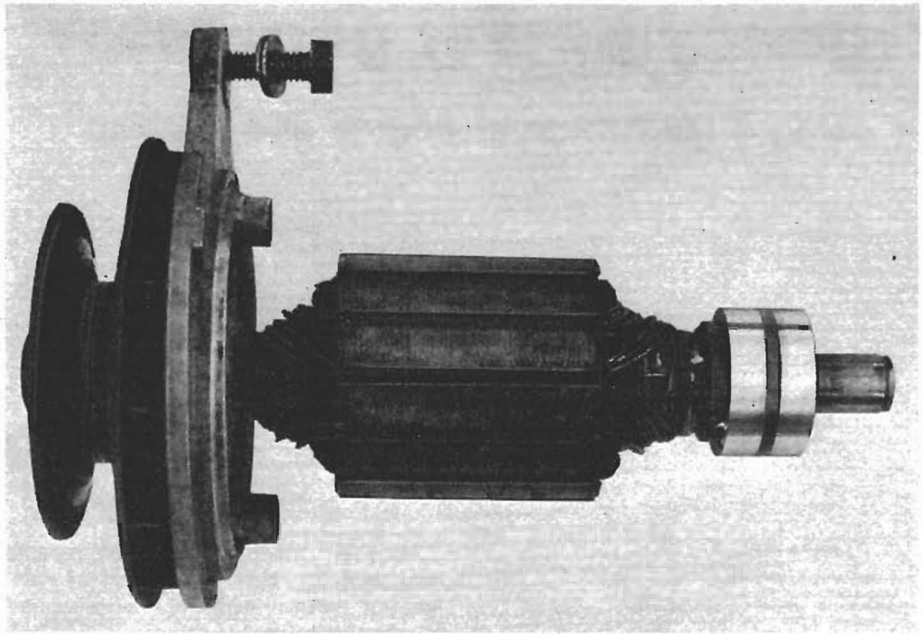

Fig. 4. Completed armature assembly.

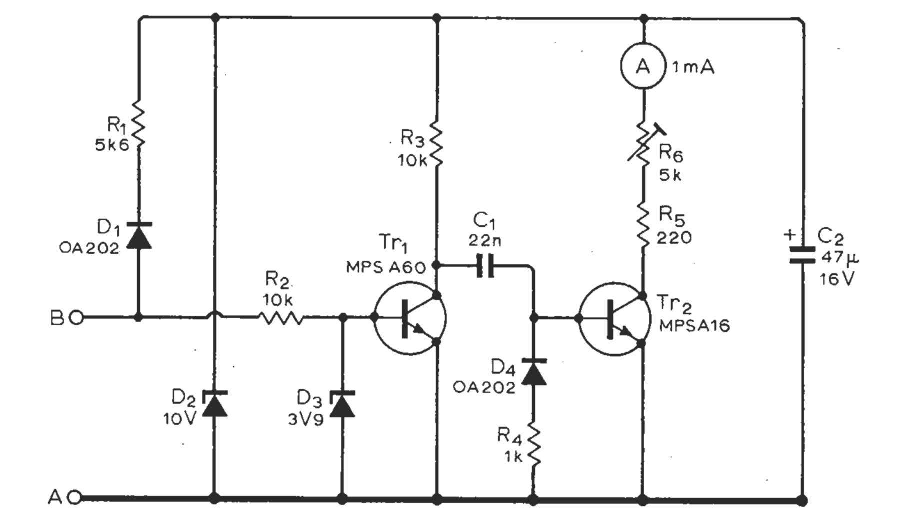

Fig. 5. Frequency-meter circuit diagram.

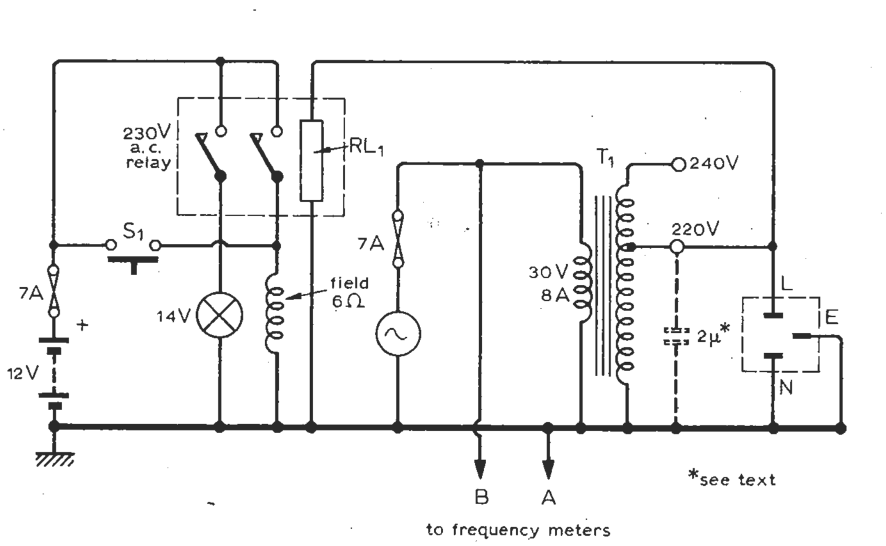

Fig. 6. Cut-out and output circuit.

in Fig. 2. By tapering one end, the cards slide into position fairly easily. Bind the armature shaft with thin string, where the conductors enter the slip-ring bush, and tie securely. Impregnate the whole winding with shellac applied by brush, ensuring that the liquid penetrates the slots. The completed armature is shown in Fig. 4.

The brush gear

The brushes are modified to contact the slip rings as shown in Fig. 1. In the author's model the brushes were filed back to a width of 6.5mm. If new brushes are used it may be necessary to bed them in with the aid of fine-grade carborundum paper wrapped around the slip rings. When finally fitting the brushes to the end plate it is important to position the pressure springs over the contact area as shown. The alternator may now be assembled.

Frequency indicator and control circuit

To ensure that the alternator is driven at the correct speed it is necessary to monitor the frequency of the output voltage. Fig. 5 shows the circuit of a suitable frequency meter. D_1, R_1, D_2 and C_2 provide a stabilized 10V d.c. supply to the circuit, derived from the input. The input voltage is squared by Tr_1 to minimize errors caused by changes in input amplitude. R_2 and D_3 protect Tr_1 from transients and reverse base-emitter potentials. A differentiating circuit—R_3, C_1 and D_4 into Tr_2 is driven by Tr_1 whose collector current is limited by R_4 when discharging C_1. The current pulses developed in the collector circuit of Tr_2 are of constant width and varying repetition rate depending on the input frequency. These pulses are integrated by the inertia of the meter movement and displayed as a steady reading, changing only with input frequency. The linearity of this circuit is dependent on the mark/space ratio of the current pulses at the maximum operating frequency. The values chosen for the differentiator in the author's circuit give a negligible error at the maximum meter reading of 100Hz. The meter scale is calibrated directly from 0 to 100Hz, and R_6 is adjusted to give a reading of 50Hz when the input is fed with 10V–60V a.c. from a mains-connected transformer. Fig. 6 shows the cut-out and output circuitry. The output from the alternator is stepped up to mains voltage by a transformer T_1 which has a rating of 250W. An auto transformer would be ideal for this function on the basis of size and cost. It is important for safety reasons to connect the N and E terminals together on the output socket and return both to the metalwork of the complete unit. The output of the transformer is used to energize a 230V a.c. relay, the contacts of which complete the field circuit with the 12V excitation voltage. A separate set of contacts is used for the indicator lamp to prevent the back e.m.f. from the field winding fusing the bulb when the relay drops out. The lamp is positioned on the control panel to illuminate the frequency meter. The relay

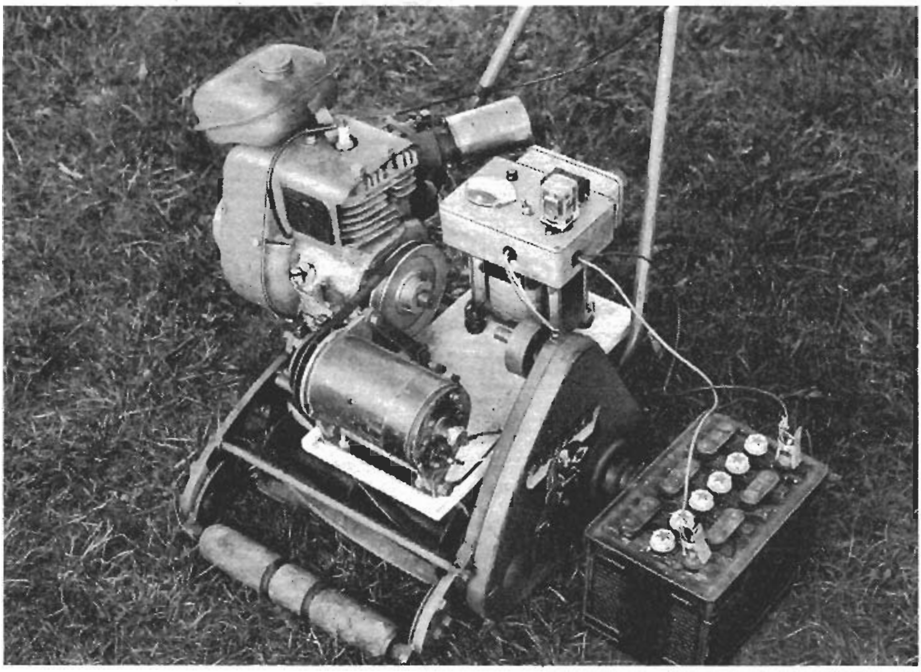

Fig. 7. Complete generator.

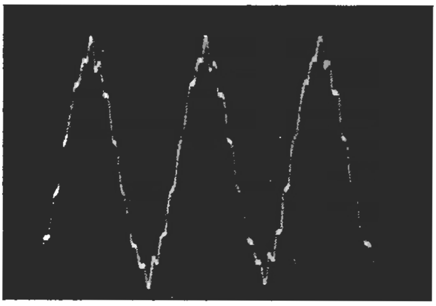

Fig. 8. Output waveform.

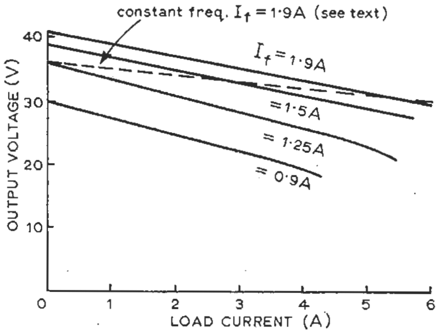

Fig. 9. Load characteristic for alternator.

drops out if, for any reason, the output falls below 150V a.c., e.g. overload or engine failure, the latter causing loss of air cooling to the field coils. To reset the output S_1 is depressed. A battery charger may be connected to the output to maintain battery charge if needed.

Driving the alternator

The unit is shown mounted on a motor mower in Fig. 7. This engine is ideal because it has a governor incorporated at the air intake of the cooling fan which maintains a fairly constant speed during changes in load. The drive pulley is five inches in diameter giving a step-up ratio of about 2:1. This ratio was chosen to give maximum economy with minimum noise. A further reduction in noise was effected by fitting a cocoa tin, suitably perforated and filled with glass wool, over the silencer and held in place by a capacitor clip. The engine, at full load, runs for one hour on one pint of petrol if the carburettor is correctly adjusted.

Performance

The output waveform is shown in Fig. 8. A component at 700Hz is present due to the variation in reluctance of the magnetic circuit as the armature slots rotate. This can be reduced by means of a 2μF 240V a.c. capacitor connected at the output (Fig. 6) but some distortion of the waveform will result due to armature reaction on the field flux.

The open circuit output of the alternator at $I_f = 1.9$A is 0.72V r.m.s./Hz and the load characteristic for varying excitation is shown in Fig. 9. The speed regulation of the engine is such that a load of 180W reduces the output frequency from 56Hz to 50Hz. The load characteristic of Fig. 9 includes the drop in output caused by the change in frequency. The broken line shows the output regulation at $I_f = 1.9$A with the frequency held constant at 50Hz. For a full-load voltage of 200V at 50Hz, the no-load voltage is 265V at 56Hz.

This generating set, while crude in its concept, is quite adequate to supply the demands of a typical central-heating system and has been used to power a monochrome television set with good results. The performance tests have prompted the author to experiment with a higher-power, self-excited version incorporating electronic regulation, using the same alternator and output transformer.