TIME FROM THE GRID

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SUN Time and Star Time, Solar and Sidereal. The first was good enough for primitive man to get up and go to bed by ; the second, the time of the earth's rotation checked against the stars, is precise enough to set the Astronomers wrangling about a small fraction of a second in a year !

They are nature's clocks, and her bountiful gifts cost us nothing. But man is never satisfied, and he proceeded to spend a vast amount of ingenuity on clocks to sub-divide nature's time into smaller periods, each one for himself.

Then came a revolutionary invention, a development of one of the many applications of electricity to the service of man, and this invention, quite unintentionally, gave us clock faces with hands perpetually moving at the right speed as a substitute for our costly and complicated efforts to measure time. And the extraordinary thing was that it provided this as a free service without cost, it being a waste product of a major purpose. That purpose was the generation of electricity for light and power : it happened to carry time with it wherever it went : it didn't want time so it gave it away.

There has been no such example of wholesale generosity since nature gave us sun-rise and sun-set. Soon after the 1914-18 war, Parliament appointed Electrical Commissioners who established The Central Electricity Board with instructions to co-ordinate the nation's electricity undertakings. They evolved the Grid, which came into existence in 1927 and by 1933 had covered the whole country with a series of spider's webs whose centres were linked together—a network of mains carrying alternating current of a uniform period of 50 cycles per second. That contained the gift of time, dispensed at the hands of the engineers of the generating stations. Its accuracy depends upon their skill in keeping their turbo-alternators running steadily at that speed or, if that is not possible, then at a speed which, in its average, is in conformity with Greenwich.

Whilst they watched the speed of their alternations, we of the horological profession have been alternating on our own account, alternating between hope and fear as to the quality of the performance.

Only ten short years ago, when first we approached the engineers, we found them rather Waterbury minded : they thought that a clock which kept time within a minute or two was good enough, and were inclined to rebel against a duty being thrust upon them which they feared would be rewarded more by kicks than by half-pence. But they soon came to a better mind, their courage rose to the occasion and they realised their high destiny as providers of a great national service. They recognised that their misdeeds would in future be counted in seconds and not in minutes.

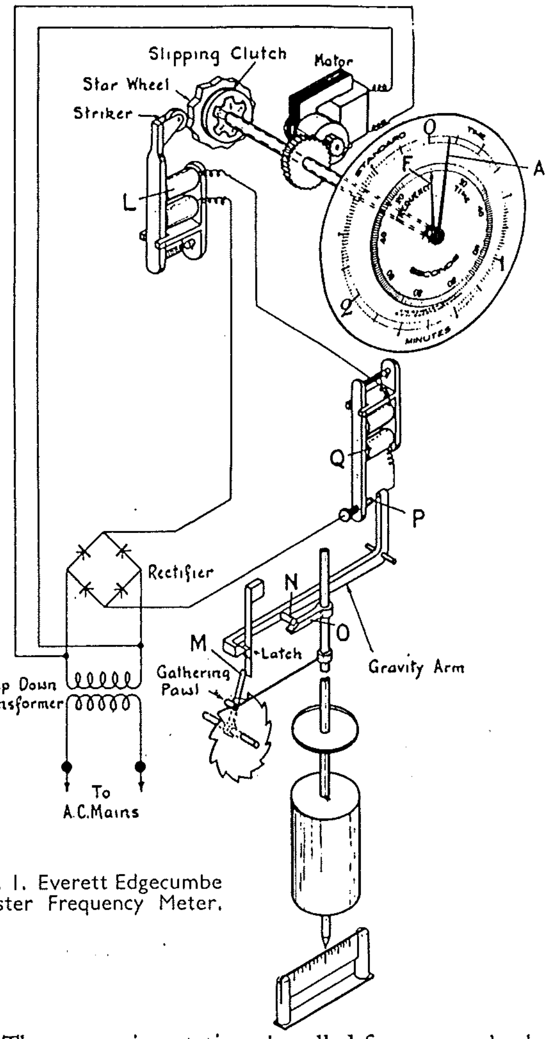


Fig. 1. Everett Edgecumbe Master Frequency Meter.

The generating stations installed frequency checking clocks to assist them to achieve steady running. To compare the engine speed easily and continuously with Greenwich Mean Time two dials are required, one operated by a synchronous motor and therefore representing frequency time or the number of cycles per second, and the other driven by a good clock representing standard time.

Where these dials are placed side by side with prominent centre seconds hands, it is in the nature of a race ; if the motor-driven dial is fast or slow the engineer corrects it by a delicate hand control of the steam valve. That is the method adopted by the Synchronome Company. Alternatively, the lag and lead may be shown by two hands on the same dial, a method favoured by Messrs. Everett Edgecumbe and Company, who were the first to supply the Grid's stations with means for time comparison.

Their double dial is shown in Fig. 1 divided into three minutes only and having a minute hand A driven by the clock, indicating standard time. The central panel of the dial is a rotating disc with a single hand F painted upon it in red and indicating frequency time. This disc is driven by a synchronous motor not shown. The minute hand A is also driven by a synchronous motor but it is corrected every half-minute by a master clock whose well-known Synchronome features will be clearly recognised, viz., the impulse pallet O carried by the pendulum, the gravity lever N which falls upon it, the vane M releasing the gravity lever and the remontoire P and Q which replaces it. The half-minute impulses pass through the synchronising magnet L every half-minute and operate upon a slipping clutch, which corrects the clock motor driving the minute hand.

Continuous motion is a natural feature of a motor clock, consequently its centre panel and hand F moves continuously as if its clock was controlled by a conical pendulum. The object of this rather elaborate design is to retain continuous motion on the standard time second hand A as well.

For ease of comparison, however, many people prefer "jump" seconds. This is the method favoured by the Synchronome Company, who operate a centre-seconds electrical impulse dial direct from the pendulum for standard time and employ a simple trick for making the motor-driven seconds hand jump in seconds also. A further alternative method of time comparison makes use of a "differential" device, and an interesting example of this is shown in Fig. 2 in which the A.C. synchronous motor appears at M on the left, winding the weight W by means of the sprocket wheel A. This weight drives the clock on the right by sprocket (B), but the motor (M) is always lifting it as quickly as it falls, and any difference in their speed is indicated by the pointer (H).

Wireless receiving sets were also used to take the six dot seconds and assist the engineers to keep their clock rated to a high standard of timekeeping. By such means we were cheered by long runs of ± 3 seconds, with only occasional lapses which rarely exceeded 20 seconds fast or slow.

This set many ships sailing. Three or four large manufacturing firms embarked upon extensive programmes of mass production, and the shop windows were soon full of synchronous motor clocks of the domestic type for "plugging in" to the electric light supply.

The idea of using the A.C. electric light supply with timed frequency to operate clocks was proposed so long ago as 1895, but was first introduced in the United States in 1918 by Warren. When he began, the only A.C. motors in common use were quite unsuitable for running small clock dials. He assumed self-starting to be a *sine qua non*, and designed a form of "Ferraris" induction motor whose construction is shown in Fig. 3, sectional drawings at right-angles to each other. The electro-

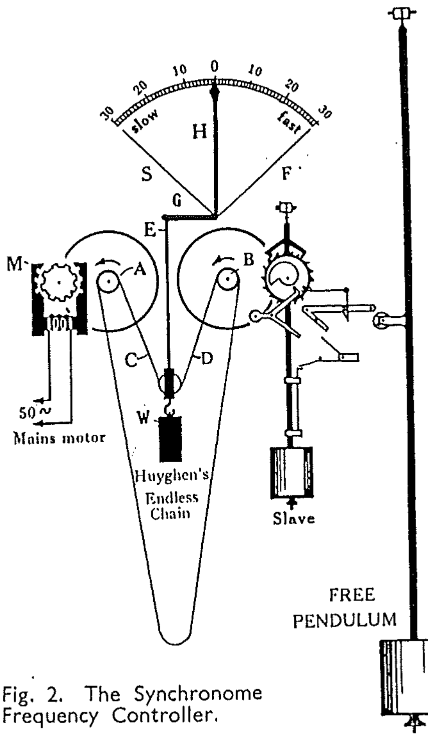


Fig. 2. The Synchronome Frequency Controller.

magnet is provided with copper shading rings which produce a rotating field. The genesis of this rotating field by the alternating current is due to the retardation of the growth of magnetic field in that part of the poles which are enclosed in copper rings. In each 1/1000th part of a second the current gradually rises to a maximum, and the unshaded portion becomes fully magnetised, whereas the growth of the rest in the shaded part is delayed. The rise and decay of the magnetic field in the shaded portion are thus out of phase with the energising impulses.

But we need only concern ourselves with the fact that the armature, consisting of two iron discs, is self-starting and rotates in absolute synchronism with the frequency of the supply. The spindle carrying the disc is geared down so that the main spindle revolves either once a minute or once a second, as desired. All the moving parts are enclosed in a dust-tight housing containing oil in which the working parts are immersed.

The rotor disc of a Warren motor revolves once per cycle, or 3,000 r.p.m., on the English periodicity of fifty cycles per second. This involves reduction

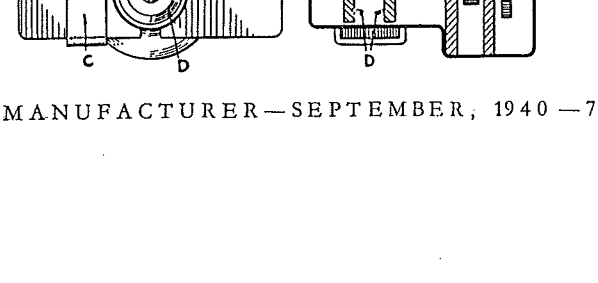


Fig. 3. The Warren Motor.

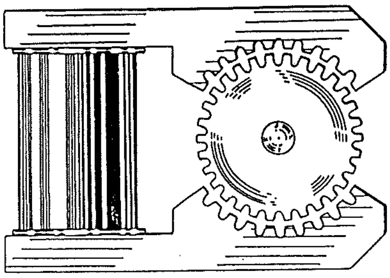


Fig. 4. The Conventional Synchronous Motor.

gear of the ratio of 1/3000 to produce a " seconds " dial revolving once a minute. At that stage one proceeds to make a clock of it by a further reduction of 1/60th for the minute hand and then 1/12th for the hour hand. Although excellent in its design, with its gearing housed in a case no bigger than an egg, and running in oil, it is obviously desirable to reduce the ratio by reducing the r.p.m. of the motor itself, and when manufacturing was begun on a large scale in this country, diligent research was devoted to the subject of slow-speed motors. Inventors vied with each other in " ringing the changes " on the application of the well-known principles underlying hysteresis and induction motors, and expressed them in a variety of ingenious designs.

The construction most commonly adopted utilises a bi-polar stator of horseshoe form with a number of serrations on each pole, and a rotor consisting of a disc with poles for teeth and gaps of the same pitch as those in the stator in Fig. 4. The speed of rotation is reduced as the number of poles in the rotor is increased. Divide the number of current alternations (half-cycles) per minute by the number of teeth in the rotor, and you have its speed in r.p.m. It usually has a rotor with thirty teeth, and runs at 200 r.p.m. on a fifty cycles supply. Motors of this type, but produced in every variety of construction, are in general use to-day, but they are not self-starting.

The new cobalt steel alloys, with their powerful permanent magnetism and their ability to retain it, have been of great value to the designers of this and similar types. Some frankly adopt standard A.C. motor practice in the form of miniature reproductions of single-phase induction motors and obtain synchronisation by combining two motors in one. The main rotor behaves like that of an ordinary squirrel-cage motor, and tries to run at a relatively high speed. On the same spindle is a small polarised piece which forms a synchronous motor, the latter controlling the speed whilst the former develops the torque.

Another type uses a simple polarised rotor with some of its poles displaced with relation to the stator, producing an oscillation which increases until it runs into step with the frequency. This result may be achieved also by introducing on the main rotor a soft iron element in the form of a spider, so arranged that the ends of the legs take up a position between adjacent stator poles when the rotor is at rest. A similar oscillation, increasing in magnitude, occurs until the rotor falls into step. In neither type can the direction of rotation be predetermined by design, for at the instant it reaches synchronous speed it may be rotating clockwise or anti-clockwise, but the latter is prevented by a non-return or " free-wheel " pawl.

The efficiency of all the various types of synchronous clock motors which we have mentioned above is naturally very poor, but since an ordinary twelve-inch clock dial only requires, let us say, 1/20,000,000th of a h.p. to drive its hands, the power of the weakest of them is ample, and the consumption of electricity, although a great deal too high, is not felt in domestic use.

A mouse could easily do the work, and the term " mouse-power " motor is an apt one for domestic clocks. Perhaps the most important consideration uppermost in the minds of all inventors is *silence*, and that is dependent mainly upon lubrication. Self-oiling bearings are a primary necessity, for the clock must run for years without " grumbling."

Some of the synchronous motors we have described are commendably more efficient than others, and considerable improvement is to be expected—in fact is already on the way.

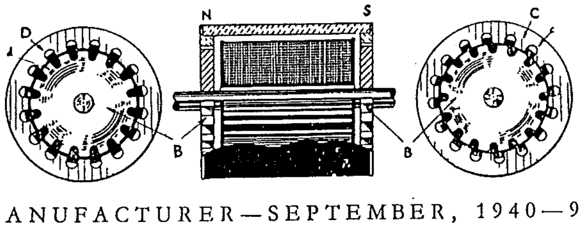
It occurred to the writer that the relatively poor torque was due to the effort of the magnetic impulse resulting from each half-cycle of the supply to move the rotor a distance equivalent to the whole space between two adjacent poles of the stator. And the desire to reduce the space between adjacent poles of opposite polarity often results in the stator being in itself almost a continuously closed magnetic circuit, so that only part of the flux generated is available to act on the rotor.

In Fig. 5 is shown a motor using a polarised method in which the magnetic impulse resulting from each half-cycle of the electrical supply endeavours to move the rotor a distance equivalent to only half the space between two adjacent poles.

It is illustrated in perspective and it will be seen that the stator C.D. is of steel and cylindrical in form. It is magnetised axially, as indicated by the letters N.S., so that its opposite ends (each provided with internally toothed rings) are of opposite polarity. The rotor (B) consists of soft iron in the shape of a bobbin, and has a fixed winding between its cheeks. The polarity of these cheeks (which are fringed with teeth) consequently changes every half-cycle, whilst the stator poles facing them are strongly and permanently magnetised north and south, so that each half-cycle has an effective pull and the movement of the rotor is equivalent to one tooth space distance per complete A.C. cycle instead of half a cycle, with the happy result that its speed is halved.

The use of permanent magnetism and multi-polar construction does nothing to assist self-starting,

Fig. 5. A slow speed motor.



whereas it was inherent in Warren's Ferraris motor, consequently when British practice was in the melting pot, quite a controversy ranged round this question. Taking it for granted, mankind and all his works being human, that even our national Grid system might break down, you must make up your mind whether you would prefer a clock that stops altogether, or whether you would prefer one that having stopped will start up again at a wrong time.

In the case of a non-self-starting clock, the problem is very simple. The provision of a seconds hand leaves no doubt as to whether the clock is running or not, and if it has none one can achieve the same result by attaching a coloured disc to the rotor shaft which can be seen through a little window cut in the dial.

Self-starting clocks, on the other hand, are always made to exhibit the red flag through the window when the current fails, and that danger signal remains even when the clock starts again on the restoration of the supply, as a warning that it is indicating the wrong time.

We have spoken of the difficulty of keeping the great generators in an electric supply station running with that degree of regularity which justifies their acceptance as the time-keepers of the nation, and we have described the frequency checking clock which helped them to do so.

But we ought to know something of what is involved in the regulation of the speed of such heavy machinery.

As its name implies, a turbo-alternator consists of a turbine coupled to an alternating current generator. The turbine is controlled by a governor, which consists of two weights taking up a position dictated by the outward pull of centrifugal force corresponding to the speed, against the inward pull of a spiral spring connected to each, more or less steam being admitted as the load of the generator varies.

The typical Porter-Hartnell type is illustrated in Fig. 6. The basic speed for throttle opening is controlled by an auxiliary governor spring called the synchronising spring. Without it, the governor alone has approximately a 4% drop in speed from no load to full load. The spring is an improvement, but the correction is still rather crude. It requires re-adjustment whenever there is a load change in order to keep the system running at fifty cycles per second, and the speed of the set is influenced by other generators that may be working in parallel with it, feeding into the same network. If a generating station is slightly speeded up it will automatically help itself to more than its share of the work, and will be guilty of "load-snatching" from the "pool." The other stations, being thus deprived of their full share, will automatically speed up also, in order to re-establish an equilibrium. This transference of load is liable to cause an oscillation, or "load-swing" as it is usually called.

To secure even distribution, all generators connected in parallel must be exactly in step; not merely as regards the number of cycles per second, but as regards phase. This latter is achieved by the use of a "synchroscope" when switching in.

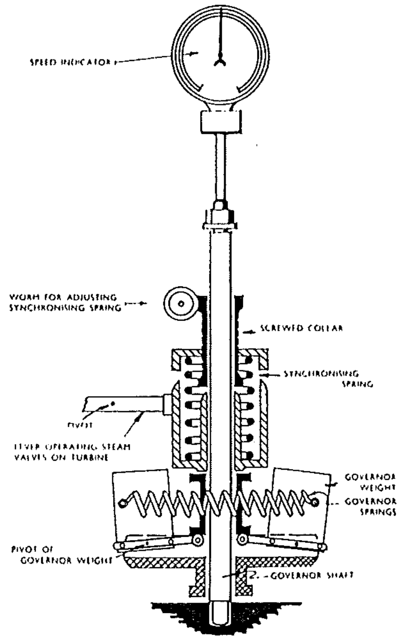


Fig. 6.
Porter-Hartnell Governor.

In 1935, when the Grid was well-established, they began with a series of separate and distinct systems not electrically inter-connected except on rare occasions, and the result was, particularly in South-East England operated from the large Thames-side Stations, the standard of time-keeping was very high and gave ground for the great expectations which we have mentioned. Since then it has been found expedient to adopt much wider inter-communication throughout the country and this, combined with the exigencies of national defence, have militated against precision in time-keeping.

The slow-speed "mouse power" motor is the result of patient research, experiment and development, and it leaves the clockmaker with nothing to do but to provide gearing from 200 r.p.m. to 1 r.p.m. or to 1 r.p.hour.

Much ingenuity has been shown in the design of this gear, and no two of the clocks on pages 20 to 36 are the same. Some of them go in for worm gearing in one or two stages, and some adopt wheels and pinions throughout.

In the lay-out of these gears, the first consideration is economy of space, and that must be obtained without unduly reducing the length of the bearings. Worm gearing is not a space-saver, for although it may save one stage of reduction it must change the direction of rotation and set adjacent arbors at right-angles to one another, but in some designs the lay-out is so neat that the balance of advantage appears to be in its favour.

In every type, some distinctive feature of merit is emphasized and championed, and it would be a pleasure to weigh them up in group and individual comparisons and strike a balance between their competitive merits and the quality of their manufacture, but that would be invidious and we have had to content ourselves with giving our readers information which should enable them to form their own judgment.