Static Frequency Converters for Track Circuits

C AHLBERG, L M ERICSSONS SIGNALAKTIEBOLAG, STOCKHOLM

U.D.C. 621.314.26:656.259.12

To meet the need for A.C. sources for feeding track circuits on electrified railways with 16 2/3-cycle traction current L M Ericsson's Signalaktiebolag has designed special frequency converters without moving parts which convert 50-cycle energy into 75- or 125-cycles. The frequency converters designed for this purpose are described in the following article.

On electrified railways the rails are used as common conductors both for the signalling current and the traction current. The signal-receiving relay, which is known as the track relay, must be constructed or connected in such a way that it is not actuated by the traction current but by the signalling current only. Apart from bridge couplings by means of impedance bonds which afford adequate reliability in certain cases, this can be achieved with frequency-selective relays. The frequency of the signalling current is then so selected that it does not conflict with the frequency of the traction current or of its harmonics.

If the traction current consists of alternating current of 16²/₃ cycles, odd, and in certain cases also even harmonics are set up on the voltage drop in the rails. The third and fifth harmonics are specially pronounced, and if the rails are magnetized or have recently been magnetized with direct current the fourth and sixth harmonics are sufficiently marked to exert a disturbing effect. Direct current magnetization of this kind may occur in the event of earth magnetic disturbances.

When direct current is employed for traction purposes the choice or frequency for the signalling current is not so restricted as in the case of alternating current, but the risk of stray 50-cycle currents from power nets cannot be neglected, and a frequency of 50-cycles for the signalling current should consequently be avoided.

Since track circuits, as a rule, are continuously under current, very exacting demands are made as regards the durability of their current sources. Rotary converters meet these demands but they require a certain supervision and instrumentation, on which account they are not very suitable for installation in relay cabinets along the line. They are therefore placed in the stations and the track circuits are supplied through special feeders. A more satisfactory solution is provided by a static converter which when connected to the power network converts current of the power frequency to current of the signalling frequency. Thus, in 1945 the Signalbolaget took up the development of static converters which have now been employed in service for some years with excellent results.

Let us first review the development of static frequency converters which have been known from the infancy of radio-telegraphy. Prior to the introduction of the vacuum tube these converters were employed for the conversion of low-frequency energy generated by rotary machines to high frequency energy which was supplied to the antenna. The raising of the frequency was carried out as a multiplication of the basic frequency by a whole number. At a much later date it was discoverd that it was possible to obtain a division of frequency by means of static elements. It appears that the first patent for a frequency divider of this kind was applied for in France in 1926 by *Fallou* who stated that he had succeeded in effecting a frequency division by three, four and nine. After Fallou had demonstrated

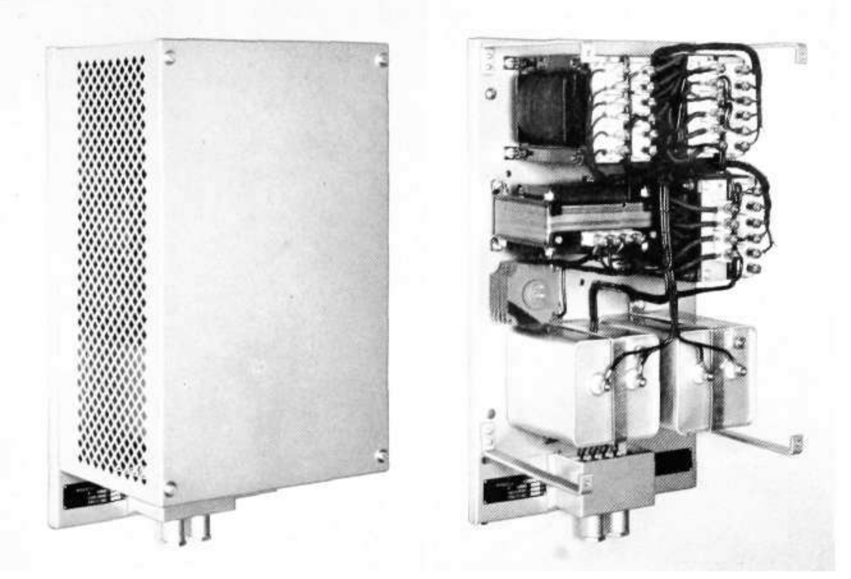

Fig. 1 X 6721

Frequency converter JLM 1102
right: with the casing removed

the possibility of frequency division, several devices were designed and patents applied for. In the United States in particular a »subcycle ringing converter» on Fallou's principle has been in use for many years as a source of ringing current in telephone exchanges. Since then static »frequency reducers» which provide several frequencies simultaneously for party-line ringing have also been introduced.

An undesirable form of frequency division to which attention has been drawn in power engineering during recent years is found in the subharmonics set up in »capacitor transformers» and in big power lines provided with series capacitors. These subharmonics may give rise to overloads with resultant cut-outs which interrupt the service and measures have therefore been taken to prevent such phenomena.

Principles

The frequencies of the harmonics in a $16^2/_3$-cycle traction current referred to in the introductory part are spaced at a mutual distance of $16^2/_3$-cycles. Thus, it is quite natural to place the signalling frequencies exactly in the middle between the harmonics. The latter are $33^1/_3$, 50, $66^2/_3$, $83^1/_3$, 100, $116^2/_3$, $133^1/_3$, 150 cycles, etc. or in other words, $^{50}/_3$-times 2, 3, etc. The frequencies in the middle between them are $^{50}/_3$-times $2^1/_2$, $3^1/_2$, etc, or after the positions of the denominators have been changed, $^{50}/_2$-times $^5/_3$, $^7/_3$, $^9/_3$, $^{11}/_3$, $^{13}/_3$, $^{15}/_3$, $^{17}/_3$, $^{19}/_3$, $^{21}/_3$, etc. As will be seen, amongst the frequencies that can be employed $^{50}/_2 \times 3$, $^{50}/_2 \times 5$, $^{50}/_2 \times 7$, etc, occur, that is to say, when the standardized power frequency of 50-cycles is halved and then multiplied by an odd number in a static device, such a device could be used for the purpose in question.

In previously known methods of static conversion the frequency could be either multiplied or divided. It seemed that a combination of the two methods would be possible, and this was confirmed by preliminary experiments. The experiments were primarily directed towards the halving of the 50-cycle current which was found to be possible with a capacitive impedance connected in the low-frequency secondary circuit. As anticipated, the secondary current was found to have numerous harmonics, particularly odd, and consequently it became possible with the help of a simple filter circuit to emphasize the desired harmonic and in that way effect the multiplication.

The static frequency converter possesses very marked advantages, first and foremost in the absence of moving parts, in addition to others. The voltage obtained is unexpectedly stable under fluctuations both of the primary voltage and secondary load. When the latter rises above the full-load value the voltage collapses to zero so that no damage can occur due to overloading.

The necessary components in this converter, as in all other static frequency converters, are transformers or reactors with saturable iron cores. Consequently the converters absorb a considerable amount of material and are heavy in relation to rotary converters. This is accompanied by the fact that the efficiency is relatively low and the converters take a comparatively heavy reactive (inductive) power from the feeding net.

In track circuits where the selective relay is of the two-phase type with one phase fed locally and the other phase fed through the rails it is often desirable that the voltage vectors of sources of supply for the local phase and the track phase should have a mutual phase displacement of 90°. This can easily be effected by means of two converters connected to the same supply. When starting the converters, the voltage vectors may at random assume one of four positions, namely, at 0, 90, 180 and 270 degrees from one another and it is only necessary to confirm by means of a phase-shifting network between the converters that the angle is the one required. If this is not the case a relay automatically picks up and interrupts the current to one converter or both of them. They start again when the relay drops. If necessary this is repeated a number of times until the desired phase relationship appears and the relay is no longer actuated.

Design

The frequency transformers placed on the market by the Signalbolaget are all designed for wall mounting. The component parts, transformers, reactors, capacitors and in certain cases rectifiers, are mounted on a supporting baseplate and covered with a perforated, aluminium-lacquered sheet metal casing. The connecting terminals are placed under a separate cover so that connection can be effected without removing the casing.

The frequency converters thus far designed are made in four geometrical sizes designated *JLM 10*, *JLM 11*, *JLM 12*, and *JLM 13*. Variants are available in each main type for different outputs and frequencies. All variants are designed for a 220 V primary voltage and a 110/220 V secondary voltage.

A list of the frequency converters available at the present time is given in the following table. It should be noted that a frequency doubler is included in the list. It has a higher efficiency than the other converters but is not self-protecting against overloads.

Frequency converters for 220 V, 50 c/s

Article No.	Freq./sec. c/s	Sec. voltage V	Sec. output VA	Dimensions length mm	Dimensions width mm	Dimensions depth mm	Weight approx. kgs
JLM 1001	75	110/220	20	265	250	170	10
JLM 1002	125	110/220	15	265	250	170	10
JLM 1003	100	110/220	30	265	250	170	10
JLM 1101	75	110/220	70	270	465	205	30
JLM 1102	125	110/220	80	270	465	205	30
JLM 1201	75	110/220	180	450	503	232	60
JLM 1202	125	110/220	140	450	503	232	60
JLM 1301	75	110/220	300	450	720	260	100
JLM 1302*	75	110/220	300	450	720	260	100
JLM 1303	125	110/220	240	450	720	260	100
JLM 1304*	125	110/220	240	450	720	260	100

* JLM 1302 and JLM 1304 are provided with phase-compensating capacitors on the primary side.

The operating temperature of the frequency transformers is 55° C above that of the ambient air, irrespective of whether the transformer is running on no-load or fully loaded.