# TRANSIENTS OF MAGNETOGRAPHS AND INSTANTANEOUS VALUES FROM RECORDINGS

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In a previous note (Malurkar, 1953), the transients that are recorded in a magnetograph were briefly referred to. It is, however, necessary to work out the pattern in a few cases which would be of interest. Among them is, for example, that of an impulse in a sudden commencement storm or sometimes even without a storm. These impulses can be isolated from the disturbance and may be amenable for theoretical study much easier than the complete disturbance. It is worth recalling a few of the stages from the last communication.

The value of the 'impulse is derived by measuring the sudden displacement in terms of the scale value. The scale value is determined by superposing a known magnetic variation near the magnetographs' (by placing subsidiary magnets) 'allowing the magnets' of the photographic instruments 'to become steady and measuring the resultant displacements. The magnification is a *static* determination.'

The need for the investigation arose due to the fact that from Jan. 1949, the Watson Magnetographs at Alibag were on some selected occasions used with an open time scale (nearly 12 times the ordinary one). With a small time scale, many of the doubts remain in the background. 'While tabulating the equivalent magnetic variations, a doubt arose whether the displacements as instantaneously recorded represented genuine variations in the magnetic field... Would one be justified in using the static values when the magnetographs were moving rapidly ?'

Changing the magnetic field by electric currents was unsatisfactory as the transients due to electric currents would complicate the problem. The changes in the magnetic field were brought about by suddenly changing the position of the permanent subsidiary magnets, referred to above, from a horizontal position to a vertical one and vice versa. By this method the magnetic field changes unidirectionally from one value to another.

During the above period the recorders were put on quick-run to clearly observe the transients.

The traces for $V$ and $H$ are reproduced in Fig. (see Malurkar, 1953).

When the field changed, no lag in recording was noticed. The initial displacement was greater than that expected from the scale value. The trace is a damped harmonic one, and it ultimately settles down to a constant value.

The equation for the deflection angle $\theta$ can be written as:

$$\ddot{\theta}+2k\dot{\theta}+(k^2+n^2)\theta = A(k^2+n^2)\,F$$

where $k$ is the damping factor,

$2\pi/n = T$—period of oscillation of the inst.,
$A$—a constant,
$F$—change in the magnetic field and

$\theta$ and $\ddot{\theta}$ are the time differentials of $\theta$.

The general form of the solution is

$$\theta = \frac{\sin nt}{n} \epsilon^{-kt} \int A\,(k^2+n^2)\,F\epsilon^{kt} \cos nt\,dt - \frac{\cos nt}{n} \epsilon^{-kt} \int A\,(k^2+n^2)\,F\epsilon^{kt} \sin nt\,dt.$$

In particular cases, the solutions can be got by other methods (e.g. Heaviside operators).

(1) Change from one constant magnetic field to another constant one. The change in magnetic field at time $t = 0$ takes place suddenly and $F$ is a constant. Taking $p$ as the usual Heaviside operator $\theta$ can be expressed as

$$\frac{1}{p^2+2kp+k^2+n^2} \cdot A(k^2+n^2)\,F = AF\left\{1-\epsilon^{-kt}\left(\cos nt+\frac{k}{n}\sin nt\right)\right\}$$

$\dot{\theta} = 0$ if $\sin nt = 0$, i.e. $nt = \pi$; $t = \pi/n = T/2$ for the first deflection. Hence the ratio of the first deflection to the static value is $(1+\epsilon^{-kT/2}) : 1$

In most instruments, this ratio is appreciably greater than 1. By increasing the value of the damping factor, the defect may be diminished. The optimum value of the factors would be when the damping is so adjusted that it is *critical*. In the above notation then $n = 0$.

(2) Critical damping. $n = 0$.

The solution is $\theta = \dfrac{1}{p^2+2kp+k^2} \cdot Ak^2 F$

$$\text{i.e.} = AF\{1-\epsilon^{-kt}(1+kt)\};$$

$$\theta/\theta' = 1-(1+kt)\epsilon^{-kt}$$

where $\theta'$ is the limiting or terminal value.

It may also be put in a different way. If $\delta$ is a small fraction, the time required by the magnetograph speck to reach a value just a fraction $\delta$ short of the true value is given by

$$\delta = (1+kt)\epsilon^{-kt}; \quad \theta/\theta' = 1-\delta$$

or

$$t = \frac{1}{k}\log_e \frac{1}{\delta} + \frac{1}{k}\log_e (1+kt).$$

In a critically damped magnetograph (with quick run), the values registered would remain short of the true value.

(3) The next case when $F = \alpha t$, the magnetogram has a sharp bend. Then

$$\theta = A\alpha\left\{t - \frac{2k}{k^2+n^2}(1-\epsilon^{-kt}\cos nt) + \frac{1}{n}\epsilon^{-kt}\sin nt\right\}$$

which shows a superposition of some extraneous terms. The damped harmonic terms have the free periods of the recording instrument.

So long as the time co-ordinate or scale is small, the period of vibration of the instrument occupies a very small length. Hence vibrations of that order of period can hardly be noticed. But when an open time scale is used and attempts are made to estimate points to an accuracy of a few seconds, i.e. the same order as the periods of vibration of the recording instruments, it would not be possible to neglect the superposed effects. As it appears, the accuracy of timing any particular effect is subject to an error of an order comparable to the period of vibration of the instrument.

The effect of resonance of a periodic magnetic field whose period is near about that of the recording instrument has been discussed by Vestine *et al.* (1947). When more than one recording instrument is used at a place, and the free periods of the recording instruments are different, those micropulsations which have common periods in all the instrumental records are likely to be genuine, i.e. when the free periods of the horizontal and vertical component magnetographs have different free periods, those pulsations which have been recorded in both the instruments with the same interval of time as period are genuine.

In large magnetic disturbances, the records at many stations consist of rapidly changing traces and sometimes consist of only disjointed specks at the extremities which will need to be connected up. Even if quick-run be used, it is quite likely that rapid variations will be found in many instances. Then the application of the static magnification value would need modification. This would particularly be true if one wished to find the equivalent currents by using magnetic displacements as *recorded* at various observatories with different types of instruments. The constants of the individual magnetometers would be needed. Similarly if detailed correlation of individual peaks in the magnetograms are to be made with ionospheric records, where the free period of the recording system is extremely small or negligible, it will be necessary to bear in mind the transients recorded in the magnetograms.

Leaving off the finer details, the general character of a magnetic storm disturbance has till now been tabulated at intervals of time large compared with the free periods of the instrument. In fact most of the analysis has been from the slow-run records where it is almost impossible to tabulate at intervals of time of the order of the free period of the instruments. The broad feature of the superposed magnetic field has no period as considered comparable to those of the instruments. Hence in these instances it is possible to ignore the time differentials of the deflection and the static magnification is the result. The general character of the disturbance curves as calculated by Moos (1910), Chapman (1936), Chapman and Bartels (1940) will be essentially maintained.

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