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Digital processing of partial discharge signals

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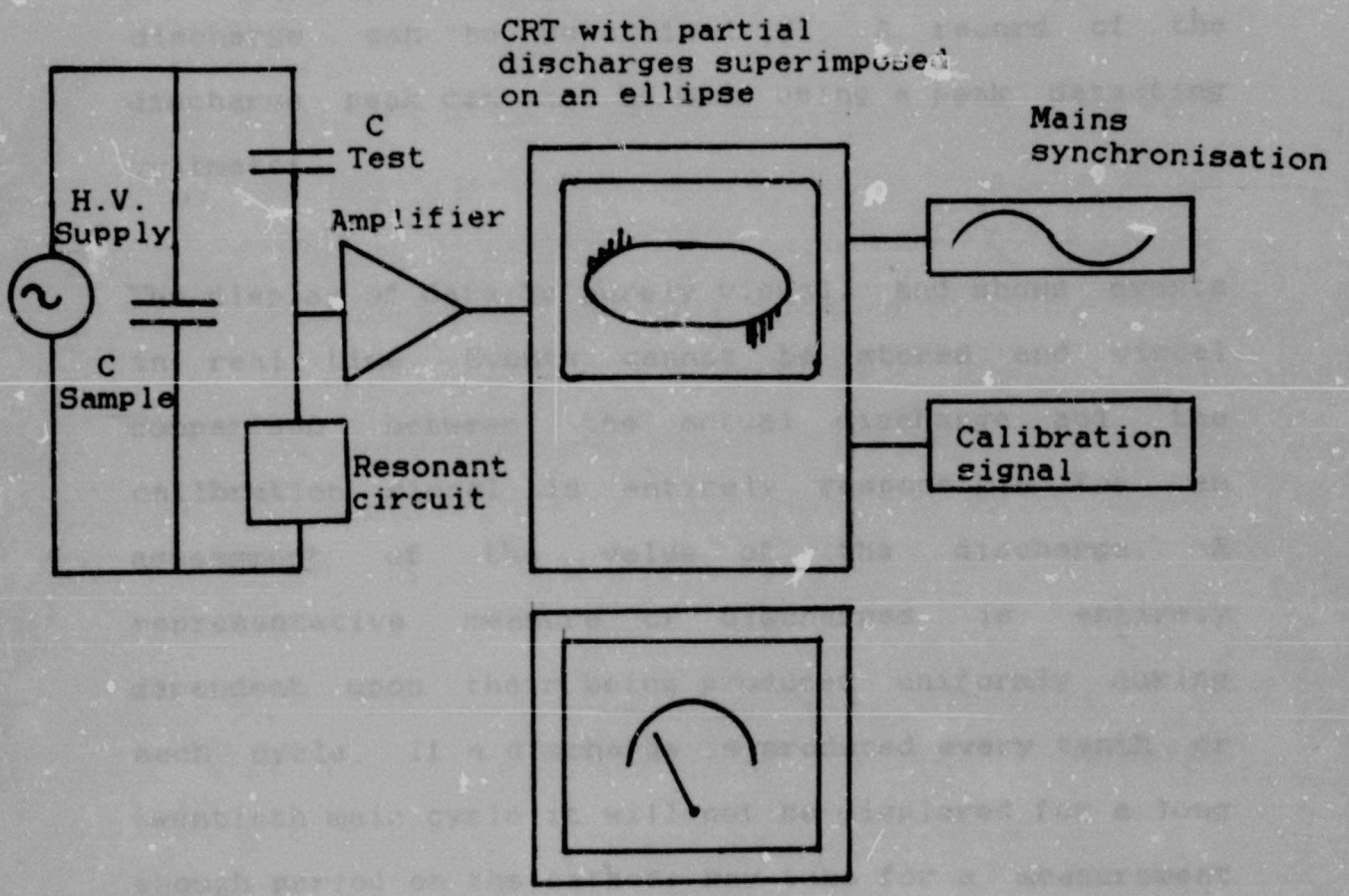


Figure 2.1 Block diagram of analogue partial discharge detector

discharge is sensed by a resonant circuit, the output of which is fed to an amplifier. This amplifies the output of the resonant circuit and displays it on a cathode ray tube superimposed on a 50 Hertz power frequency ellipse. A calibration discharge is then injected onto the main cycle and by adjusting this and comparing it to the displayed value the magnitude of the discharge can be determined.(3) A record of the discharge peak can also be made using a peak detecting voltmeter.

The display of data is purely visual, and shows events in real time. Events cannot be stored and visual comparison between the actual discharge and the calibration signal is entirely responsible for an assessment of the value of the discharge. A representative measure of discharges is entirely dependent upon their being produced uniformly during each cycle. If a discharge is produced every tenth or twentieth main cycle it will not be displayed for a long enough period on the cathode ray tube for a measurement to be made.

3 Design criteria

The object of the present project was to produce an instrument able to capture partial discharge activity in the range 1pC to 10000pC's within 25 micro seconds. The

reason for the 25 micro second limitation was based on the fact that present analogue instruments have a resolution of this order of magnitude. For example, the ERA discharge detector has a claimed 20 micro second resolution. All present analogue detectors have a resolution of this order, but they suffer from the following shortcomings:

a. Since the information is displayed on a cathode ray tube, visual storage is short term, and it is difficult to determine the magnitude of discharges at inception. A possible solution to this problem would be the use of a storage tube, however, once the signal has been stored it becomes impossible to compare it with a reference signal of known magnitude.

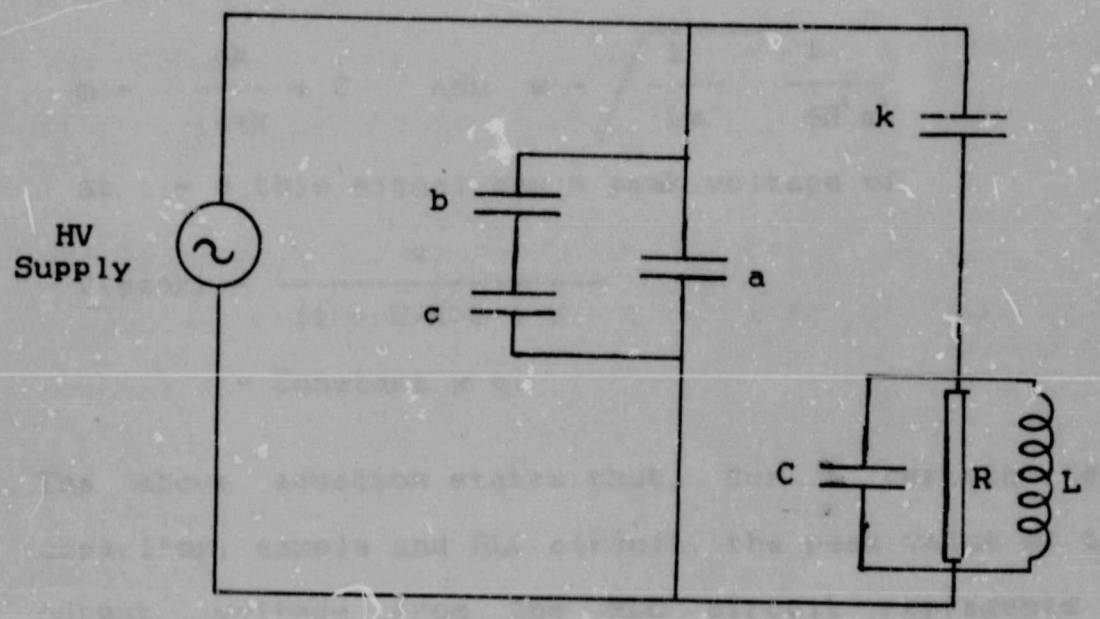
b. If there are a large number of discharges it is difficult to distinguish between individual discharges.

c. The total charge-per-cycle cannot be calculated by an analogue device such as that described above. Bridging techniques have been used but these are not able to distinguish efficiently between dielectric and discharge loss for low levels of discharge loss.

The digital discharge detector's ability to resolve individual discharges means that both the widely spaced discharges at the inception of breakdown and those closely spaced discharges from areas of high discharge activity can be stored and retrieved. The total charge-per-cycle can be calculated from the data stored in memory since all discharges occurring during the cycle have been stored in memory. The instrument has been designed to detect discharges produced by power signals with frequencies as low as 0.1 Hz. This fact, together with the 25 micro second resolution, make the instrument ideal for use with non-standard test signals such as a very low frequency signal. Further the peak value and time of occurrence of the discharge can be stored readily in some form of long term storage medium.

3.1 Determination of the peak value of the signal

The circuit shown in Figure 3.1 is the basic diagram for a discharge detector. A high voltage power frequency signal is applied to a sample of capacitance `a'. If there is a cavity in the sample, then there are considered to be two capacitances in series, `b' and `c'; the capacitance `c' being the capacitance of the cavity and the capacitance `b' being the capacitance of the rest of the conductor. For a test capacitance `k'



k is a coupling capacitor

a is the sample capacitance

c is the cavity capacitance

b is the capacitance of the rest of the dielectric

RLC is the resonant circuit

Figure 3.1 Partial discharge detection circuit

and RLC test circuit connected as shown in Figure 3.1, a partial discharge of charge q occurring across a cavity of capacitance c gives the following output voltage across the terminals of the parallel RLC circuit (2):

$$V = \frac{q}{(1 + C/K)a + C} \exp(-t/2Rm) \cos wt$$

where

$$m = \frac{ak}{a+k} + C \quad \text{AND} \quad w = \sqrt{\frac{1}{Lm} - \frac{1}{4R^2 m^2}}$$

at t = 0 this signal has a peak voltage of

$$V(peak) = \frac{q}{(1 + C/K)a + c}$$

$$= \text{Constant} \times q.$$

The above equation states that, for a certain test capacitor, sample and RLC circuit, the peak value of the output voltage from the RLC circuit represents a constant multiplied by the charge produced by the partial discharge. Hence, if the peak value of the output from RLC circuit can be captured, the amount of charge produced by the partial discharge can be calculated.

3.2 Time and polarity information

It is not enough to know that there is partial discharge activity, if the location of the partial discharge with respect to the mains waveform cannot be determined. This

information gives an indication of the type of discharge that is being produced, for example where the insulation of a polyethelene insulated cable does not adhere to the conductor properly,the discharge is distinguished by a large number of small discharges in the positive half cycle and a smaller number of larger discharges in the negative half cycle (7). It is therefore essential that the time of occurrence of the discharge be localised with respect to the mains waveform.

The polarity information is important because this determines whether it is an earth side or line side partial discharge.

4 Previous work

The ERA model 3 is a good example of an existing analogue discharge detector (7). It is designed to display individual discharges in the specimen under test on the screen of a cathode ray tube. The shape of the response appearing on the screen is determined by the discharge detector, and not by the shape of the discharge transient; which may be taken to be a vertical step waveform.

The discharges are displayed on the screen of a cathode ray tube superimposed on an elliptical timebase derived

from the mains. The discharge may be measured by comparison with a step wave of known magnitude, generated internally. The test voltage is monitored by an internal voltmeter which also provides test voltage zero markers. The resolution of the device is claimed to be 20 micro seconds.

I. A. Black (1) describes the use of pulse discrimination techniques to distinguish the signal from the noise. The system uses a logic system to monitor the polarities of concurrent pulses produced by two measuring units, and this system distinguishes between internal discharges and external noise. The output of the device is analogue in nature, and only the pulse discrimination system is digital. The noise discrimination is therefore the only processing carried by switching techniques.

Austin and James (6) describe how they modified an analogue discharge detecting system so as to convert the output to digital form. This paper dates from 1976 and the digital hardware used is a PDP 8E minicomputer with 12k of core memory, an analogue-to-digital converter with conversion time of 29 micro seconds and tape storage with a transfer time of 100 micro seconds. All this equipment is now outdated and the whole process can now be carried out on equipment that is cheaper, smaller and more efficient.

Hart, Yializis and Donahue (10) describe a technique whereby a data logger and pulse height analyser are controlled by a microprocessor to store data associated with the peak of the discharge.

The GPIB is used to transfer data between the pulse height analyser and the long term storage of the controlling microprocessor. The GPIB is a standard instrumentation control bus, which is slow; firstly because it uses the handshake technique of data transfer, and secondly because it is usually controlled by a high level language. This will limit the speed at which data can be accumulated and hence places a limitation on the discrimination between discharges.

In a paper published in 1976 Karkkainen (11) describes the use of a multichannel pulse analyser for the measurement of partial discharge signals. This system is then interfaced with a computer but no details are given of this computer interface. The multichannel analyser is either capable of converting a signal, or resolving the time of occurrence of 512 pulses; but not both at the same time. Also the time to determine the value of the pulse height is proportional to the height of the pulses, and it varies between 13 and 64 micro seconds.

5 Technique used to store the partial discharge

If the waveform is known, the peak magnitude time of occurrence and polarity specify it completely. This raises the question of how to store the data associated with the discharge. Two alternatives present themselves: To convert the entire signal or to store only the peak magnitude, time of occurrence and polarity.

The conversion of the entire signal could be carried out by either purchasing a system designed to convert entire waveforms or building an instrument for the purpose.

Signal digitisers and storage oscilloscopes are instruments suitable for converting the entire waveform. and those devices produced by both Nicolet (8) and Tektronix (9) were considered. The following drawbacks were found to these devices:

a. Few of the devices could be triggered on both the positive and negative slopes.

The signals to be detected have both positive and negative slopes and hence two storage oscilloscopes or digitisers must be used to store both positive and negative signals. However, some of the more expensive devices have triggering on both positive and negative edges.

b. The internal storage of signals is limited.

The number of successive pulses which can be stored is small (Ranging from 2 to 52 for the devices considered) and this severely limits the amount of data that can be stored.

c. Data transfer between the device and long term storage is slow.

All devices considered transfer data via the GPIB which transfers data using a relatively slow handshake process. This transfer is further slowed by the fact that the device controlling the bus uses a high level language (such as BASIC) to administer control. As a result the transfer of data takes longer than the 20 micro seconds resolution time of present state of the art analogue discharge detection devices. Devices such as the digital storage oscilloscope and signal digitiser, are designed to capture a single or small number of waveforms, store the data in the instrument memory and then pass the data to the controlling computer where further analysis can be carried out. It is clear that these devices are not suitable for fast data transfer applications.

d. These devices are expensive. For example, the instruments investigated cost in the range of R30 000 to over R100 000.

The second solution would be to build an instrument for the purpose of an entire conversion. Such an instrument would work in the following way:

The discharge would be sensed by a resonant circuit, amplified and continuously sampled by an analogue-to-digital converter. The output of the analogue-to-digital converter is then written to memory directly. Such an instrument has the following disadvantages:

a. A fast analogue-to-digital converter and sample-and-hold must be used.

Even though the signal has been slowed down substantially by the RLC circuit it still has a very fast rising edge which must be captured. This means that a sampling frequency of approximately 20MHz should be used. The conversion hardware to carry this out is extremely expensive, elaborate, and sophisticated.

b. Large amounts of memory are required.

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