MICROPROCESSOR - CONTROLLED DIFFERENTIAL PROTECTION OF A POWER TRANSFORMER

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LIST OF SYMBOLS :

$h(t)$: A continuous function of time (t) .
$H(\frac{n}{NT})$: The discrete Four-ier transform (DFT) of a sampled function .
N : Number of samples .
n : The order of the harmonic .
T : Sampling interval .
K : An integer number .
$h(KT)$: A sample magnitude of the k th sample .
$\hat{C}_n$: Acosine term of the n th harmonic of the expanded (DFT) .
$\hat{S}_n$: A sine term of the n th harmonic of the expanded (DFT) .
j : $\sqrt{-1}$
e : 2.71828

ABSTRACT :

The paper presents a developed algorithm or a digital filter for the fast computation of the fundamental and higher harmonics of the differential current of a differential protected power transformer. The derived algorithm is based upon the discrete Fou rier transform (DFT). An estimation technique is used in the algorithm to compare the magnitude of the second-harmonic of the differential current with its fundamental content. Then a microprocessor trip command is given or blockad depending on the result of comparison .

The proposed computation algorithm has been coded on a microprocessor unit. Necessary prephirals have been built to link the microprocessor to a complete differential protection scheme on a single-phase power transformer. The whole protective set-up is put into working order for test .

Laboratory experimental investigations of performance of the protective scheme showed accurate discriminative operation of the relaying circuit for different abnormal conditions. The algorithm is simple, fast and highly discriminative and can be implemented in power system protection .

1. INTRODUCTION :

One of the major problems of power transformer differential protection is the magnetizing inrush current. For correct fault discrimination, the effect of the inrush current should be eliminated. Harmonic analysis of the inrush current has shown that the inrush current contains large even harmonics of which the second one is predominant. Thus, in a digital power transformer protective scheme, the main objective is to detect that the system is dealing with an inrush or not .

Fast and accurate algorithmsfor the digital differential protection of power transformere have been the subject of many projects in recent years (1 - 3). The paper presents the theoretical basis and the practical investigation of a developed microprocessor - controlled differential protective system on a single - phase power transformer .

2. THEORETICAL BASIS OF THE PROTECTIVE ALGORITHM

The theoretical basis of the protective algorithm used depende on digital fitering of the differential current. The digital filtering is achieved using the discrete Fourier transform (DFT) of a continuous function h(t) which is given as (4) ;

$$H\left(\frac{n}{NT}\right) = \frac{1}{N}\sum_{K=0}^{N-1} h(kT) \; e^{-j2\pi kn/N} \qquad \ldots\ldots\ldots\ldots\ldots (1)$$

Expanding the exponential function of Eq. (1) into cosine and sine terms and designating them with the following expressions :

$$\hat{C}_n = \sum_{k=0}^{N-1} h(KT)\cos(2\pi kn/N)$$

$$\hat{S}_n = \sum_{k=0}^{N-1} h(KT)\sin(2\pi kn/N)$$

These general terms enable to put Eq. (1) in the form of ;

$$H\left(\frac{n}{NT}\right) = \frac{1}{N}(\hat{C}_n - j\hat{S}_n) \qquad \ldots\ldots\ldots\ldots\ldots (2)$$

Thus the magnitude of any desired harmonic can be computed as :

$$H\left(\frac{n}{NT}\right) = \frac{1}{N}(\hat{C}_n^2 + \hat{S}_n^2)^{1/2} \qquad \ldots\ldots\ldots\ldots\ldots (3)$$

Off - line harmonic analysis carried out on transient current of the power transformer has shown that the second harmonic has a discriminative value during inrush while it approximately vanishes in the fault current. Hence, the amount of the second harmonic available in the differential current is used as a base to discriminate between transient inrush and internal fault carrents of the power transformer.

Accordingly, the magnitudes of the fundamental and the second harmonics of the differential current are estimated and compared to detect whether the transformer is dealing with inrush or not.

3. MICROPROCESSING OF FUNDAMENTAL AND SECOND HARMONICS OF THE SAMPLED DIFFERENTIAL CURRENT:

Since the cosine and sine terms ($\hat{C}_n$, $\hat{S}_n$) are dependent on the sequence andnumber of samples (which are constants) , integers representing these values are stored in an unbroken sequence of RAM-locations within the microprocessor to achieve high computing speed. This has been done for 400-Hz sampling frequency , where N = 8 samples per cycle.

For getting the samples of the differential current (ID) , the microprocessor has been suitably programmed to convert the analog differential voltage (VD) illustrated in Fig. (1) to digital values at equidistant intervals at a sampling frequency of 400 Hz.

After getting the samples of the differential current., the microprocessor is instructed.to compute the fundamental ($\hat{C}$, $\hat{S}$) - and the second ($\hat{C}$, $\hat{S}$)-harmonics magnitudes.

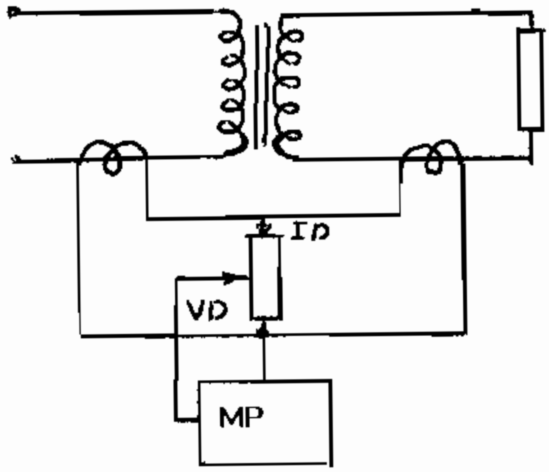

Fig. (1) : Sampling Process

4. PROPOSED PROTECTION ALGORITHM:

The proposed protection algorithm has been designed to perform the following operations:

1. Sense the transformer abnormal operation.
2. Estimate the fundamental and second harmonics of the sampled differential current.
3. Divide the estimated values of ($\hat{C}_1$, $\hat{S}_1$) by four.
4. Isolate the transfermer from the power supply, when the division result of step (3) is less than a specified value (E_o) , otherwise go back.to step (1).

Sensation of transformer abnormal operation is determined as follows:

(a) The differential signal VD is sampled continu a ly.

(b) The digital value of each sample is compared with a threshold value VD_o, where VD_o is the maximum digital value of the differential signal VD for normal operation.

(c) When the digital value of the samole under consideration is greater than VD_0, the transformer is in an abnormal operating condition and a trip decision has to be settled depending on the result of estimated-values comparison (step 3) .

Fig. (2) shows a flowchart of the sensation procedure, whereas Fig. (3) shows a flowchart of the proposed protective algorithm. The trip command is given by the microprocessor relay in the form of a train of pulses.

5. THE DEVELOPED PROTECTION SYSTEM ON A SINGLE-PHASE TRANSFORMER:

The proposed protective algorithm has been implemented within a complete protection system on a one-KVA single-phase transformer using the micropro-cesser application trainer MAT-385 which is available in the laboratory. The schematic diagram of the complete protection system is shown in Fig. (4).

A necessary prephiral of an isolating amplifier as shown in Fig. (4) has to be designed to link the microprocessor to the circuit-breaker driving thyr-istors. The microprocessor trip command is given in the form of a train of pulses. The trip command pulses are fed to the thyristors-gates via the isolating current amplifier. The thyristors control the operation of the circuit breaker used to isolate the transformer in case of a fault occurance.

6. EXPERIMENTAL INVESTIGATION AND TESTING OF THE DEVELOPED PROTECTION SYSTEM:

The software programs necessary to implement the proposed protective algorithm within the complete protection system , have been prepared in the assembly and machine languages of the microprocessor.

Tests have been carried out to investigate the performance of the devel-oped protection system for the following abnormal transformer-operating conditions:

1. Switching-on the transformer at no-load.
2. Switching-on the transformer at full-load.
3. Switching-on the transformer eith a fault on the secondary side within the protected zone.
4. Through-fault during normal operation of the transformer.

The complete protection system has responded well for all cases and the trip command has been blocked for the cases where there is no fault, whereas a trip command has been given by the microprocessor in case of fault existence.

The maximum time required by the microprocessor MAT-385 to give a trip command is about 23 ms after the initiation of the fault. This time results in with a sampling frequency of 400 Hz. This time could largely be reduced, if the microprocessor used contained a multiplication module and the time-window has been reduced.

7. CONCLUSION:

Conclusively, the discrete Fourrier transform (DFT) provides a fast digital filtering technique for continuous functionS. Implementation of the discrete Fourrier transform within protective algorithms operated on microprocessors provides accurate, and fast discriminative operation of the relaying circuits used in power systems.

In the present work, the discrete Fourrier transform has been successfully applied in a protective algorithm which has been used in a microprocessor controlled differential protection of a power transformer. The necessary prephirals have been built to link the microprocessor to a complete protection system. The complete protection system is simple, fast and highly discriminative and could be used even for overcurrent protection.

REFRENCES:

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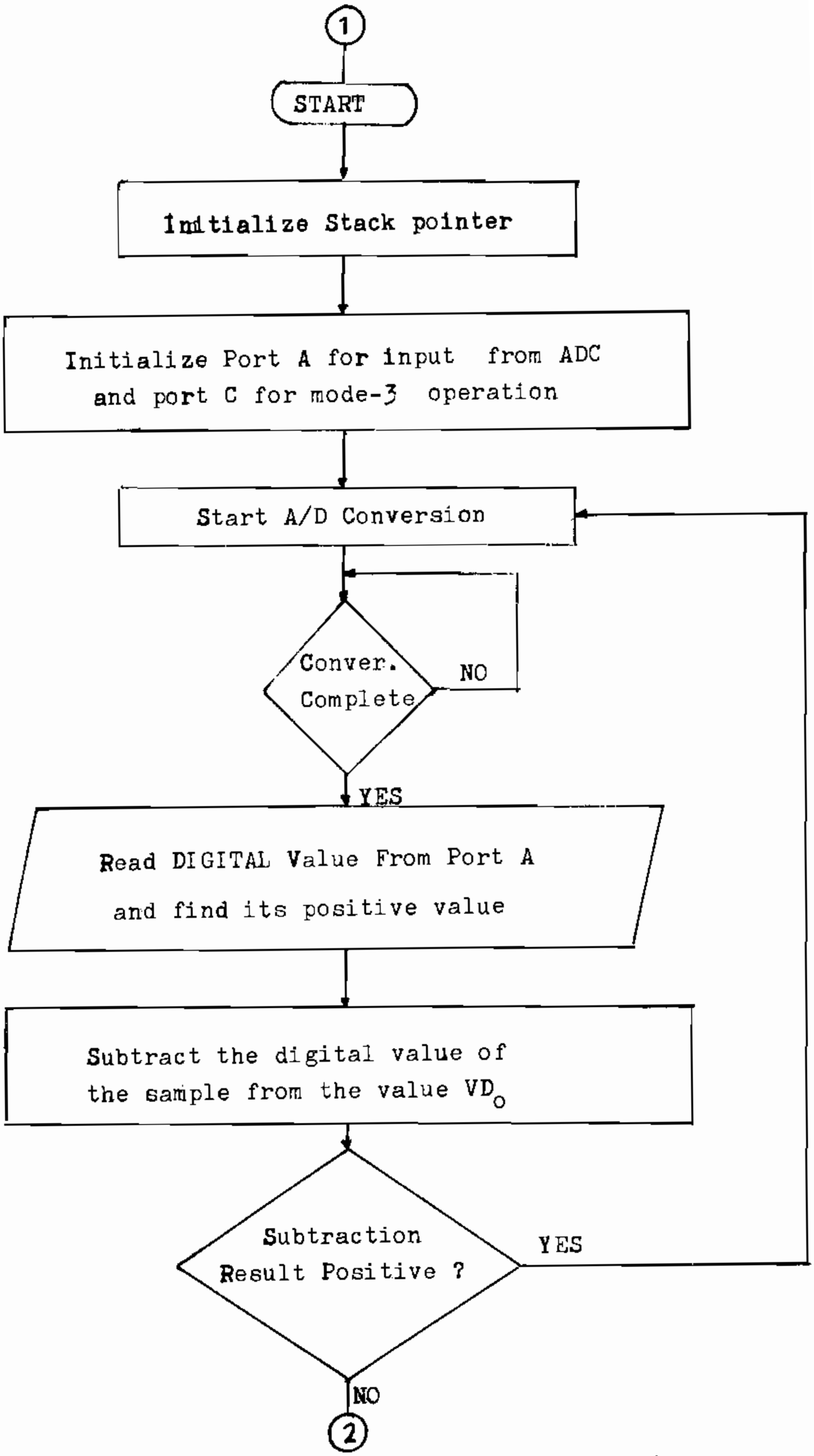

Fig. (2): Flowchart of Sensing the abnormal operation.

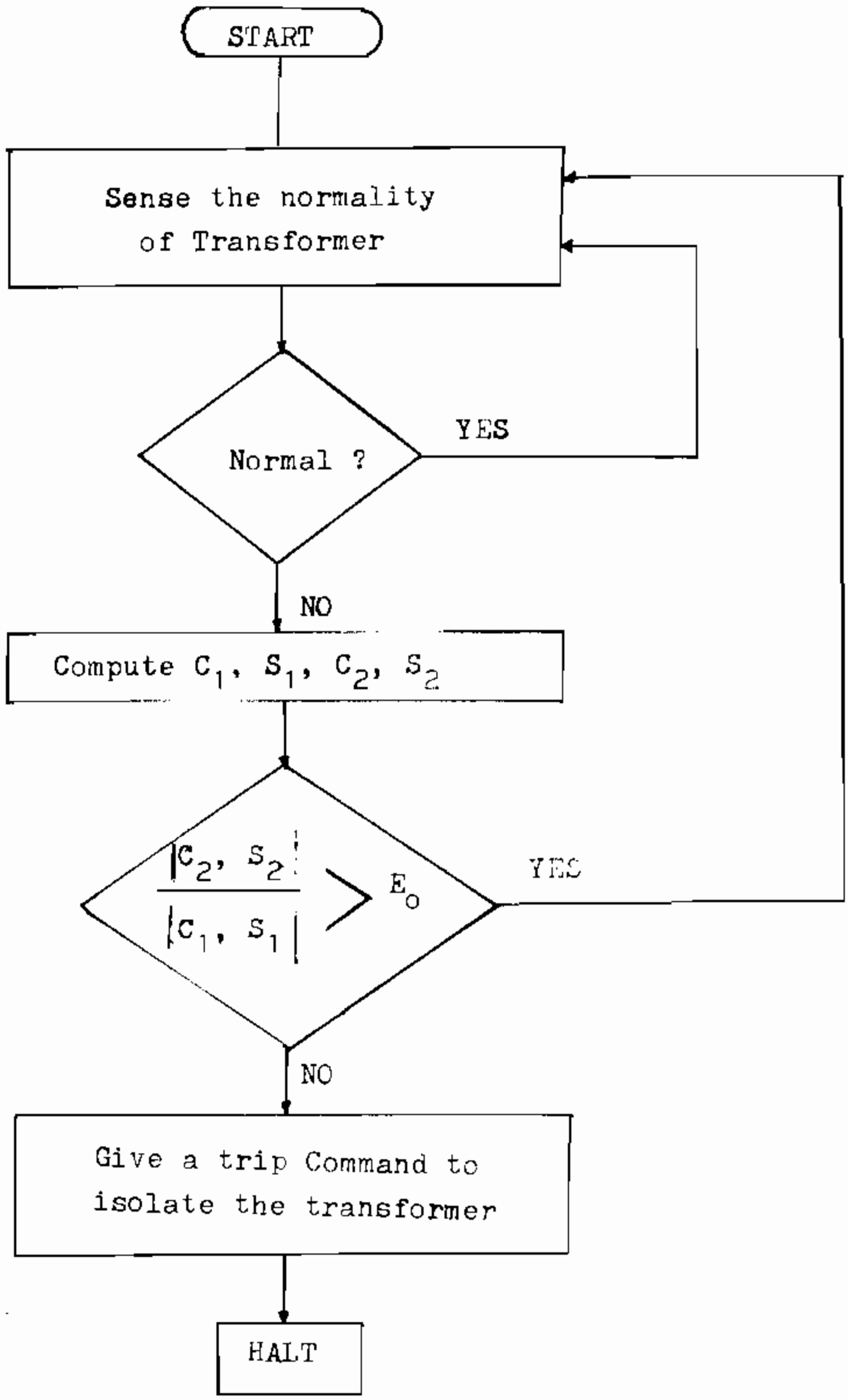

Fig. (3): A Flowchart of the proposed protective Algorithm

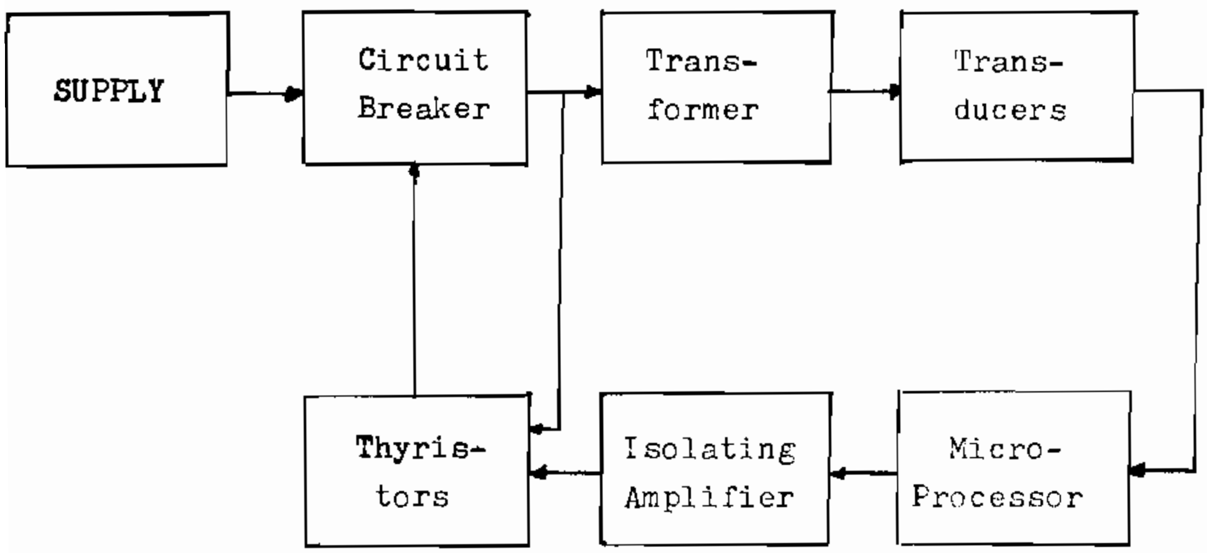

Fig. (4): A Schematic diagram of the developed protection system