.

**ABSTRACT**

In this paper is presented a new method of AUTOMATED FAULT LOCATION

SYSTEM in PRIMARY DISTRIBUTION NETWORKS based on measurements

provided by intelligent electronic devices (IEDs) with built in oscillography functions,

installed only at the substation level .This system can identify the most probable fault

locations in a fast and accurate way using a database that stores information about the

network topology and its electrical parameters.

The method is based on an algorithm which combines the information about

both the fault type and load rejection for better estimation of fault location .This

algorithm is robust in nature and is also least influenced by errors in load distribution.

This is because of the fact that magnitude of load current is much smaller than that of

the fault current.

This procedure excels the traditional ones which assume that measurements

from local terminals of the faulted distribution lines are available. It is a powerful tool

to operate and maintain the distribution network efficiently and locate the faults ver y

far from the substation.

When the fault resistance is greater, the error in estimation of the fault rises to a

higher level. A part of my contribution : a novel approach is proposed to minimize the

error in such cases. The approach increases the accuracy of estimation and also

improves the stability of the system.

**INTRODUCTION :-**

A Power system is said to be well designed if it gives a good quality and

reliable supply. Good quality means maintaining flat voltage profile. Reliable supply

means having stability. The reliability of a system is affected because of short circuit

fault occurrences which represent one of the most extreme conditions of the power

systems. The causes of the faults must be determined and eliminated. The process can

be expedited only if f ault location can be determined quickly and reliably. Since the

deregulation process has started , most of the research on power distribution systems

is focused on delivering power in an efficient way , i.e. ,in terms of quality , reliability

and end user price.

**PROBLEM DEFINED:-**

An accurate estimation of fault location in power systems presents a

challenging task. Several authors have researched on this topic and have proposed

valuable methods. Most of the proposed methods assume that measurements from the

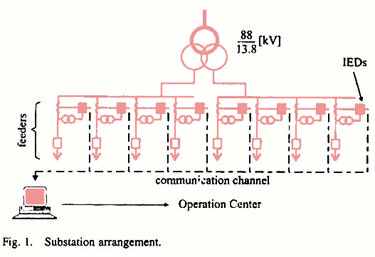
local terminals of faulted line are available. As most of the power systems are

equipped by sparsely located instrumentation, the number of measured quantities is

rather small. The problem is compounded by the presence of measuring noise.

Despite the advances and wide spread use of intelligent electronic devices and

need for performance improvements, the fault location process employed now-a-days



is still based on trouble calls from the affected customers. Besides, when a transient

fault occurs, the operation centre will not receive any phone call and prevention of

these transient faults from becoming permanent ones is difficult.

**FAULT LOCATION ALGORITHMS IN VOGUE :-**

Most of the proposed fault location algorithms were developed for power

transmission systems. A few methods were proposed for distribution networks due to

the following reasons:-

i. Variety of conductors and structures

ii. Lateral branches

iii. Load distributed along the feeder

iv. Modifications in feeder configurations

Most of the proposed algorithms are based on fault detectors installed along the

feeders and can only be applied to balanced networks. As a result, these methods will

estimate a fault location far from the actual one.

**AUTOMATED FAULT LOCATION SYSTEM :-**

The automated fault location system proposed in this paper combines

information provided by IEDs located only at the substations with knowledge of the

distribution system’s topology and its electrical parameters. Whenever an over current

event occurs, the system automatically provides the most probable fault locations to

the operators, at the operation center .

Let us examine the substation ar rangement depicted in fig.1. An IED, connected

to each medium-voltage feeder, is responsible for monitoring voltage and current

signals .It also records transient data whenever an over current event occurs.

A computer, located at the substation, is connected to the array of IEDs and to

the computer at the operation centre via a communication channel such as dial phone

line, dedicated line, radio link, and tie to corporate local area network (LAN).

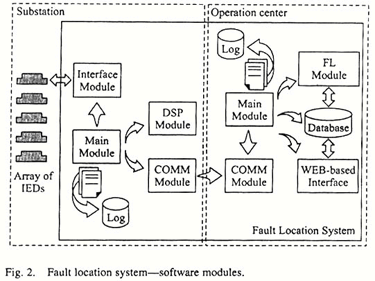
This fault location system consists of eight software modules. These software

modularities enable future software upgrades with out the need for changing the

whole system. A part of these modules is installed at the substations whereas the rest

are installed at the operation centre as illustrated in fig.2. The decision of installing

2



the fault location modules at the substations and at the operation centre was based on

the following reasons.

***D***

***U***

***:***

The fault location system uses information stored in

***ATABASE***

***PDATE***

database, which must be periodically updated in order to reflect possible

modifications in the distribution networks. Therefore, this database and

software modules that have access to it should be located at the operation

centre computers.

***C***

***C***

***O***

***:***

Transferring all transient data

***OMMUNICATION***

***HANNEL***

***VERFLOW***

recorded by the IEDs to operation centre would probably overflow the

communication channel that connects the substations’ computers to the

operation centre computer. Therefore it is convenient to preprocess the

transient data and extract only the information located by the fault location

system, which is transmitted to the operation centre.

***S***

***S***

***M***

***:***

***UBSTATION***

***OFTWARE***

***ODULES***

***M***

***M***

***:***

Responsible for scheduling and storing data acquisition . It

***AIN***

***ODULE***

also coordinates and monitors all data transfers among other modules.

***IED I***

***M***

***:***

Converts the transient data recorded by the IEDs

***NTERFACE***

***ODULE***

into COMTRADE format. This format is desirable to make the fault location

system independent of the recording equipment in such a way that future IEDs

changes will not imply in major software upgrades. The information sets

included in the COMTRADE file are as follows:

**i. Detailed oscillography of the fault:**

phase voltages and line currents;

ii.

**Additional measurements:**

Prefault and post fault measurements (active and

reactive powers, voltages and currents),circuit-breaker operation time, etc.

***D***

***S***

***P***

***(DSP) M***

***:***

Preprocesses the transient

***IGITAL***

***IGNAL***

***ROCESSING***

***ODULE***

data stored in COMTRADE file. This software module performs the tasks

described below and stores the results in an ASCII file, which is less than 1

KB and much smaller than the COMTRADE file.

**Determination of the fault occurrence instant :**

The algorithm

3

developed to perform this task is based on digital signal processing

techniques, which can identif y signal transition instants .

**Estimation of pre-fault and f ault phasor quantities :-**

The DSP

module places two data windows(one at the present fault region and

other at the fault region) after the fault occurrence instant is determined

and estimates the phasor quantities using the discrete fourier transform

method (DFT).

**Fault type and phases involved**

:- The algorithm developed to perform

this task is based on the analysis of the super imposed sequence

components of the currents. The DSP module compares the

magnitudes and phases of the positive, negative and zero sequence

components to determine whether the fault is single line to ground

(AN, BN, or CN), line-line faults (AB, BC, or CA) double line to

ground (ABN, BCN, or CAN), or three phase.

**Estimation of load rejection**

: The DSP module estimates the pre fault

and post fault active power to determine the amount of load rejection.

This information is used to classify the fault.

**Fault classification**

: Using the information about the circuit breaker

status, after the fault clearance , and the amount of load rejection , the

algorithm can classify the fault as :

**Permanent faults isolated by breaker operation**

: When the

circuit breaker remains closed after the over current event

**Permanent faults isolated by the fuse operation:**

When the

circuit breaker remains closed after the overcurrent event and

there is load rejection (the prefault active power is bigger than

the active power measured after the fault clearance).

**Transient faults**

: When the circuit breaker remains closed after

the event and there is no load rejection.

***C***

***(COMM)***

**:**

Responsible for automatically sending

***OMMUNICATION***

***MODULE***

the ASCII file produced by the DSP module to the operation centre.

***O***

***C***

***M***

***:***

***PERATION***

***ENTRE***

***ODULES***

***M***

***:***

Responsible for scheduling and storing data acquisition data

***AIN MODULE***

transfer among the other modules.

***COMM M***

***:***

Responsible for receiving the data sent by the sub station

***ODULE***

computer and scheduling its processing priority.

***WEB B***

***I***

**:**

Provides graphical results of the fault location

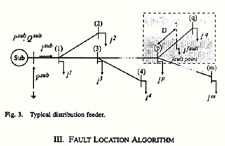
***ASED***

***NTERFACE***

procedure. The decision of using this kind of Interface was based on its

flexibility and widespread use of web based tools. Besides, the results

4



provided by the system can not only be accessed f rom computers connected to

the utility’s intranet, but also from the computers at the operation center.

***Fault location module***

**:**

Performs the fault location procedure, based on the

algorithm detailed in the next item, and provides the results to the web based

interface.

**D**

**ATABASE**

The fault location system has access to the database that stores the information

about the topology and electrical parameters of the feeders. This data base is

obtained and periodically updated from the electricity utility’s corporate database

and contains the following information.

***T***

**:**

The distribution feeders are described using the universal

***OPOLOGY***

transverse mercator coor dinates (UTM) . Therefore, it is possible to integrate

information provided by the fault location system to any geographic

information systems ( GIS) system ;

***E***

*:*

Cable types and feeder geometry such as overhead,

***LECTRICAL PARAMETERS***

spacer, twisted, and underground, are used to calculate the line impedances,

nominal power of the distribution transformers and connection schemes, etc.

**FAULT LOCATION ALGORITHM**

Primary distribution feeders are radial networks with several lateral branches.

This means that faults at different locations may result in the same voltage and current

signals recorded at the substation. Therefore, the algorithm should investigate all line

sections in order to determine the possible fault locations.

Consider the feeder illustrated in figure

3, where a starting and ending node identify

each line section. The procedure adopted to

determine whether the

*k*

th line section,

generically delimited by nodes

*p*

and

*q*

, has a

possible fault location, consists of estimating

the fault distance(D) from node

*p ,*

where a

fault would produce the same voltage and

current signals recorded at the substation. If the estimated distance is less than the

section’s length (

*L*

), the

*k*

th line section has a possible fault location.

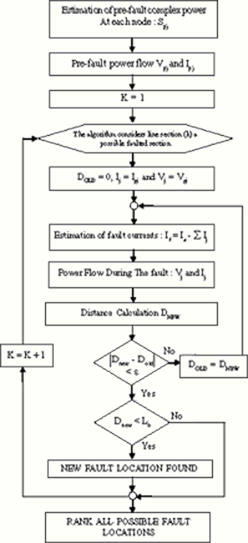
*K*

The methodology used to estimate the fault distance is described later. It is

based on a set of equations that depends on the fault type, and on the following phasor

quantities:

5



*V*

*I*

*p*

*pq*

*a*

*a*

V

=

and I

=

P

pq

(1)

*V*

*I*

*p*

*pq*

*b*

*b*

*V*

*I*

*p*

*pq*

*c*

*c*

V

I

are the phasor quantities at node

*p*

, during the fault, and the

Where

p and

pq

currents at line section

*k*

,during the fault.

Assuming that the fault current (I

fault

) and the load currents during the fault ( I

j

,

j =1 to n) are known, V

and I

can be calculated using a three phase power flow

P

pq

algorithm.

Since it is impossible to correctly calculate the load currents during the fault using

data available only at the substation, a procedure was developed to estimate them.

This procedure consists of estimating the pre-fault complex power at each node , then

using it to calculate the pre-fault voltage and current phasor quantities(using a three

phase power flow algorithm), and finally calculating the complex power at each node

during the fault by means of modeling its behaviour according to the voltage

variation.

**Symbols used in the block diagram**

**and in following equations are:**

‘m’ total number of nodes at the feeder

‘S

’ Prefault complex power at the

ps

sbstn.

‘S

’ Nominal power of transformers

j n

connected to node j

‘S

’ prefault complex power at node j

pj

‘S

’ complex power at node j during

j

the fault

‘V

’ pre-fault voltage at node j

pj

‘V

’ voltage at node j during the fault

j

‘I

’ load current at node j during fault

j

‘V

’ voltage at sbstn. during fault

s

‘I

’ current at sbstn. during fault

s

‘I

’ fault current phasor

m

‘n’ load model used by the algorithm

‘z

’ line and mutual impedances( )

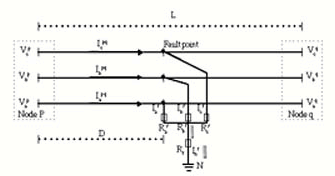
/

*km*

i j

Fault location algorithm logic diagram

6



Fault Types

The fault location algorithm is recursive, which means that a new fault

distance D is calculated at each step .With this distance, the voltage and current

phasor quantities during the fault are recalculated (considering the fault to have

occurred at the new distance). The block diagram depicted in fig.4, presents the

procedure developed to locate the possible fault points.

***E***

***O***

***T***

***P***

***C***

***P***

***STIMATION***

***F***

***HE***

***REFAULT***

***OMPLEX***

***OWER***

The first methodology used to determine the prefault complex power at each

node consists of aggregating the representative load curves of all consumers

connected to each node of the feeder. Preliminary tests indicate that minor errors in

the load estimation have not considerably affected the algorithm’s accuracy and, since

this methodology uses a large amount of data to determine the complex power at each

bus, a simplified methodology was developed.

It consists of assuming that all distribution transformers connected to the

feeder operate proportionally to their nominal apparent power. Consequently, the total

complex power measured at the substation is distributed at each node according to

*S*

their nominal power as in S

= S

x

(2)

*t*

pj

ps

*m*

*S*

*t*

*j*

1

***P***

***P***

***F***

***REFAULT***

***OWER***

***LOW***

The prefault load currents and voltages at each node are estimated using a

three phase power flow .The implemented power flow algorithm explains the fact that

distribution networks are almost always radial .Therefore, it does not use the

admittance matrix.

***I***

***A***

***L***

***S***

***:***

***NVESTIGATION OF***

***LL***

***INE***

***ECTIONS***

After estimating the prefault voltage and current phasor quantities, the

algorithm starts investigating all line sections in order to determine all possible fault

points. First, the algorithm assumes that the load currents and node voltages, during

the fault are equal to the prefault ones, and the f ault distances are zero (i.e., the fault

occurred at the beginning of the investigated line section).

***E***

***STIMATION OF THE FAULT CURRENT***

The fault cur rent is estimated by subtracting the fault current phasor quantities

(measured at the substation) from the load currents at the feeder, during the fault, as in

*m*

I

= I

-

*I*

(3)

f

s

*j*

*j*

1

7

***P***

***OWER FLOW DURING THE FAULT***

In this item the load currents are calculated using the following procedure.

First the complex load power at each node during every fault is calculated assuming

that the loads connected to each node depend on voltage.

*n*

*V*

S

= S

(4)

*j*

j

pj

*V*

*pj*

Then the load currents at each node can be calculated using the complex

power previously calculated, and the voltage phasor quantities at each node are

calculated.

*S*

I

=

(5)

*j*

j

*V*

*j*

*n*

2

*V*

From 4 and 5, I

= (S

) \*

\* V

(6)

*j*

j

pj

j

*n*

*V*

*pj*

Once the load currents during the fault, are known, the voltages at each node

can be calculated.

***D***

***:***

***ISTANCE CALCULATION***

The algorithm presented in this paper is based on solution of (7) that describes

the fault condition.Fig.5 and table 1 illustrate all possible fault types occurring in the

line section delimited by nodes p and q.

**TABLE I**

**RESISTANCE VALUES FOR ALL FAULT TYPES**

**Fault Type R**

**R**

**R**

**R**

**af**

**bf**

**cf**

**f**

AN 0

Unknown

BN

0

Unknown

CN

0 Unknown

AB Unknown Unknown

BC

Unknown Unknown

CA Unknown

Unknown

ABN Unknown Unknown

Unknown

BCN

Unknown Unknown Unknown

CAN Unknown

Unknown Unknown

ABC Unknown Unknown Unknown

ABCN Unknown Unknown Unknown Unknown

*Z*

*Z*

*Z*

*V*

*I*

*R*

*R*

*R*

*R*

*I*

*p*

*pq*

*f*

*f*

+

*aa*

*ab*

*ac*

*a*

*a*

*a*

*f*

*f*

*f*

*a*

= D .

*Z*

*Z*

*Z*

.

x

(7)

*V*

*I*

*R*

*R*

*R*

*R*

*I*

*p*

*pq*

*f*

*f*

*ba*

*bb*

*bc*

*b*

*b*

*f*

*b*

*f*

*f*

*b*

*Z*

*Z*

*Z*

*V*

*I*

*R*

*R*

*R*

*R*

*I*

*p*

*pq*

*f*

*f*

*ca*

*cb*

*cc*

*c*

*c*

*f*

*f*

*c*

*f*

*c*

Based on fault type and phases involved equations are written. Using (7) as

example consider ABN fault now equation (7) can be written resulting in 8 and 9 as

+

+

follows

= D .

*Z*

.

*I*

.

(

+

) (8)

*V*

*pq*

*R*

*I*

*R*

*I*

*I*

*p*

*f*

*f*

*f*

*f*

*ai*

*i*

*a*

*a*

*a*

*f*

*a*

*b*

*i*

*a*

,

*b*

,

*c*

8

+

+

= D .

*Z*

.

*I*

.

(

+

) (9)

*pq*

*V*

*R*

*I*

*R*

*I*

*I*

*p*

*f*

*f*

*f*

*f*

*bi*

*i*

*b*

*b*

*b*

*f*

*a*

*b*

*i*

*a*

,

*b*

,

*c*

The fault distance (D) and fault resistances can be calculated by separating 9

and 8 into real and imaginary parts and then solving the resulting linear system

***R***

***A***

***P***

***F***

***L***

***:***

***ANKING***

***LL***

***OSSIBLE***

***AULT***

***OCATIONS***

The fault location algorithm provides more than one possible fault point. In

order to exactly estimate fault location, the algorithm combines information about the

fault type and load rejection (provided by the DSP module) with the feeder’s topology

and electrical parameter s (stored in data base) to rank them by the most probable

ones. Basically, the algorithm follows the rules described below:

i> When the fault is permanent, isolated by breaker operation, the algorithm

verifies which located points are protected by fuses and ranks them as the less

probable ones.

ii> When the fault is permanent isolated by fuse operation, the algorithm verifies

which located points are not protected by fuses and ranks them as the less probable

ones. Among those who are protected by fuses the algorithm ranks as the most

probable one the point that is protected by a fuse whose opening would cause an

amount of load rejection comparable to the load rejection measured by the IEDs.

**INFLUENCE OF LOAD DISTRIBUTION**

The fault location algorithm estimates the load currents by proportionally

distributing the total apparent power measured at the substation to each node,

according to their nominal apparent power. However, the load distribution may not be

proportional to nominal installed load. The error caused due to this estimation does

not influence significantly the algorithm’s accuracy due to the fact that in most cases

the magnitude of load currents is much smaller than that of the fault current.

**ADDITIONAL SIMPLIFICATION TO THE GIVEN ALGORITHM**

An additional simplification reducing the algorithm’s computational burden

consists of replacing the power –flow algorithm by a simple equation removing the

iterative process. This is done by considering the voltage phasor quantities at each

node, during the fault, equal to the voltage phasor quantities measured at the

substation also during the fault. The error level is based on the fact that, the bigger the

fault resistance becomes, the smaller becomes the magnitude of the fault current.

When the magnitude of fault current is comparable to that of the load current , the

error level increases greatly. However, large fault resistances (>20 ohms) will not

trigger the digital meter oscillography function resulting in large errors while

estimating the fault.

**M**

**C**

**T**

**T**

**P**

**:**

**Y**

**ONTRIBUTION**

**O**

**HE**

**APER**

As mentioned in this presentation, when the fault resistance is greater than 20

ohms, the error in the estimation of fault rises to a greater value. As a part of my

contribution, a novel approach is proposed to minimize the error in such cases.

Considering the operation of the circuit shown in fig. 6, when a fault occurs, the

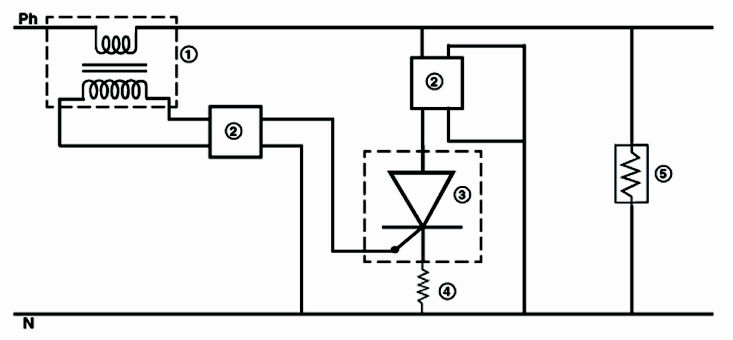
pulse transformer through the rectifiers forces the thyristors to turn ON(due to high

fault cur rents).Therefore, a shunt path across the load with effective resistance (<20

ohms) is obtained. This decreases the error in estimation. As it can be observed, the

circuit is activated only when a fault occurs.

9



(1) Pulse Transformer

(2) Rectifiers with Filters

(3) Thyristor Controller

(4) Shunt Resistance (< 1ohm)

(5) Fault Resistance

Fig. 6

**T**

**A**

**O**

**T**

**A**

**A**

**:-**

**HE**

**DVANTAGES**

**F**

**HIS**

**PPROACH**

**RE**

i. Accurate estimation of fault by considerable minimization of error. This accurate

estimation helps especially in the case of underground cables.

ii. When a fault occurs, a considerable part of the fault current is shunted through the

circuit and hence the effect of fault on other loads is reduced. Consequently, stability

of the system increases.

**CONCLUSION**

The most important benefits provided by the fault location system for primary

distribution networks are as follows:

Downtime reduction: Decrease in time spent by maintenance crews to locate

faults.

Operation costs get reduced.

No. of maintenance crews on standby is reduced.

Higher profits and increase in electricity supply

Consumer satisfaction due to faster system restoration

Identification of, transient faults which do not cause permanent breaker

Operation or fuse blowing.

Identification of areas with high no. of transient f aults resulting in reduced

maintenance.

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