# IMPROVING DISTRIBUTION SYSTEM RELIABILITY USING DISTRIBUTION AUTOMATION BASED ON COORDINATION BETWEEN AUTO-RECLOSER , SECTIONALISER AND LIMIT FUSES

Eng. Mohammed Abd El Aziz Awad
North Delta Electricity Distribution Company - Egypt
Eng_melbayomy@yahoo.com

## *1-ABSTRACT*

*Customers served by modern electric utilities have come to expect highly reliable service due to an increased customer awareness and to the sensitive electric devices utilized in today's technologically advanced society. When the electric service is disrupted, even for a short period of time. The result can be anything from a minor inconvenience to a major economic loss, the high percentage of temporary faults of OHL allows the application of a device with a dual timing characteristic to coordinate with limit fuses and sectionalisers placed on the system. These devices were developed to reduce circuit outages and increase the reliability of distribution systems. The number of reclosing setting, the reclosing interval delays fast and time delay (also referred to as slow) curve selection and minimum trip selection must be chosen to satisfy a number of objectives. The variability in settings, combined with the multiple reclosing events, must be considered when coordinating the reclosers (ACR) with source-side and/or load side fuses, sectionalisers and other auto-reclosers.*

## 2-INTRODUCTION

North Delta Electricity Distribution Company (NDEDC) is responsible for supplying electrical energy for different purposes on both medium and low voltage among three North Delta governorates ( Dakahlia , Kafr Elsheik and damietta) Which represent approximately one / sixth of Egypt's population . Improvements in reliability of NDEDC network do not come easily, It is dramatically difficult to improve distribution system reliability because their design provides an inherent very high level of reliability, faults in distribution systems are the primary factors in determining reliability. Long lines are more exposed to frequent faults and thus lower reliability. Studies of faults to OHL have shown that most are transient and can be cleared without interrupting customer supply. The overhead network represents (60%) of NDEDC network

## 3- LIMIT FUSES & COORDINATION WITH UPSTREAM PROTECTIVE DEVICES

Ideally, the goal of any protection system is to confine the effects of a fault to the smallest possible area by protecting upstream devices using current-limiting fuses. This is normally done through Time Current Characteristic Curve coordination practices and by use of the limits on the $I_{(squ)}t$ let through. Time Current Characteristic Curve coordination is done by simply overlaying the curves and comparing the maximum clearing curve of the protecting Device with the minimum melt curve of the protected fuse. Following typical coordination rules, the maximum clearing curve of the current-limiting fuse should be to the left of the upstream device's trip curve. When this is done the current-limiting fuse will clear before the upstream device trip. In very short times, 0.01 seconds or less, the current-limiting fuse clear curve may cross the upstream fuse melt curve. As a result there would be concern that the upstream device would open before it interrupts the current. $I_{(squ)}t$ coordination allows this to be assessed. $I_{(squ)}t$ values provide two factors to consider: minimum melt $I_{(squ)}t$ and maximum let through $I_{(squ)}t$. The minimum melt $I_{(squ)}t$ is the amount of energy necessary to melt a fuse element. The let through $I_{(squ)}t$ is the maximum "energy" the fuse will let through. If the maximum let through $I_{(squ)}t$ of the current-limiting fuse in a transformer is less than the device trip $I_{(squ)}t$ of the protecting upstream recloser, a fault that the transformer fuse operates against will not let enough $I_{(squ)}t$ through to cause the upstream device to operate. This prevents upstream device operations, and allows the rest of the system to remain on-line, serving customers.

### 3.1- Coordinating Reclosers and fuse-links

Reclosers must be coordinated with both source-side and load side fuse links . For proper application of reclosers in distribution systems, the following basic coordination principles must be observed .The load side device must

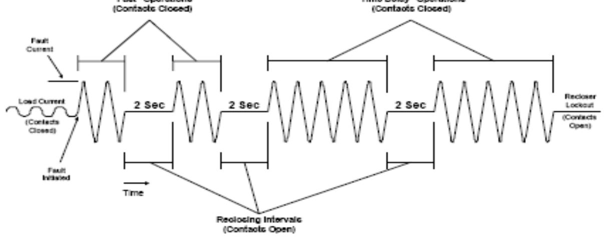



**Fig (1) Limit Fuse Coordination**

clear a permanent or temporary fault before the source side device interrupts the circuit (fuse link) or operates to lockout (Recloser). Outages caused by permanent faults must be restricted to the smallest segment of the system.

### 3.2- Source side Recloser and Load side fuse .

**For temporary fault** coordination, the recloser's fast curve operations should not cause fuse link damage (this includes the cumulative heating effects of multiple fast curve operations with very short reclosing interval).

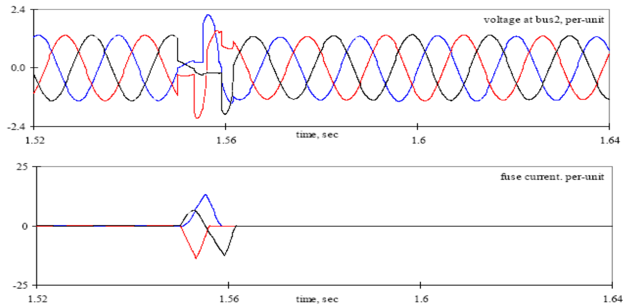



**Fig (2) Transient fault in a system protected by current-limiting fuses.**

**For permanent faults,** the recloser's delayed operations should be slower than the fuse's maximum clear curve. This will ensure that the fuse link melts and clears any permanent faults before the recloser operates on its delay curve. With load-side fuse coordination, the K-factor Is applied to the recloser's fast curve to account for the cumulative heating effects produced by the successive fast operations of the source-side recloser. This ensures that the fuse link Is not damaged during the fast trip operations of the recloser, up to the maximum available fault current.

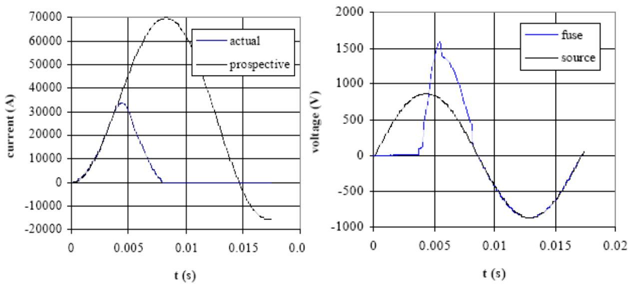



**Fig (3) Waveforms for breaking of an A.C. short-circuit by a current-limiting fuse**

**3.2.1- source-side Recloser and load-side fuse coordination for temporary faults .**

**Phase trip** : coordination check is based on the source side recloser phase fast curve ( K factor applied to the Recloser curve) with the load-side fuse minimum melt curve. **Ground Trip**: Coordination check is based on the source-side Recloser phase-ground composite fast curve (K-factor applied to the Recloser curve) with the load-side fuse minimum melt curve.

**3.2.2- Source-side Recloser and Load-Side Fuse Coordination for Permanent Faults**

**Phase Trip:** Coordination check is based on the source-side Recloser phase time delay, curve (10 percent tolerance applied to Recloser curve) with the load-side fuse maximum curve. **Ground Trip:** Coordination check is based on the source-side recloser phase-ground composite time delay curve ( 10 percent tolerance applied to recloser curve) with the load-side (use maximum clear curve).

### 3.3 - Coordinating Reclosers and Sectionaliser .

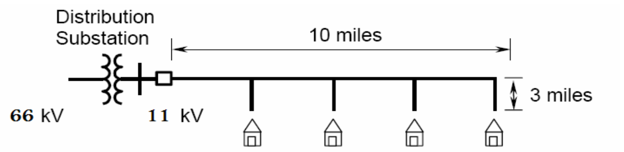
Sectionalisers are installed in branches which are long and have high rate of faults, Sectionalizing depends on the ability of the LBS to count the operations (trips) of an upstream Recloser. An upstream trip at the Recloser is detected by a fault followed by no current and no voltage. This condition is called a Supply Interruption. A supply interruption occurs when the current drops from above the fault threshold to zero within one second and the other phases also reduce to zero current (zero current is defined as all three phase currents less than 2.5 Amp). Interruption of supply is confirmed by ensuring that the source and load side voltages fall below the “Live threshold value”. This causes the Supply Interrupt Count to increment, when the timer expires the supply interrupt count is cleared.

## 4-DISTRIBUTION/FEEDER AUTOMATION

Distribution Automation is the ability to remotely monitor and control the distribution network, collect information, and provide information in a useful manner to the users. Distribution Automation provides a building block for protection, metering, control and monitoring of the distribution system. Distribution Automation products are designed for interoperability and rapid automation implementation. These products provide Supervisory Control and Data Acquisition System (SCADA) interface and enable feeder automation with communications, help to strengthen existing distribution systems and provide a strong foundation for building a fully implemented feeder scheme in the future. Feeder automation products are a powerful tool for improving customer service and reducing operation costs. Solutions not only have to be justified based on hard benefits, which are measurable to the bottom-line (e.g., deferred or eliminated capital expenditures, reduced operating and maintenance costs, increased Kwh sales), they must also satisfy the need of less tangible benefits.

## 5- RELIABILITY INDEX

In today's utility environment, distribution system reliability is becoming more important. There are several indices developed for reliability of service that utilities account for and track. These indices include (SAIFI), (SAIDI), (CAIDI) & (MAIFI). The distribution circuit, shown in Figure (4) , will be used to demonstrate the relative value of reclosing schemes for a suburban/rural system. This system has the following characteristics: 10 miles of line, 8 lateral taps, Laterals are 3 miles long, Total of 1800 customers.




**Fig( 4 ) – Model Distribution System**

**Case ( 1 )**

**Without Auto-Recloser .**

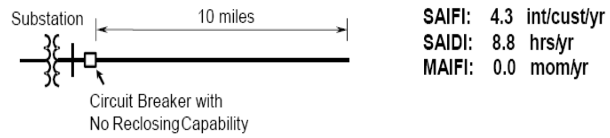



**Fig ( 4-1 )**

**Case ( 2 )**

**With one Auto-Recloser .**

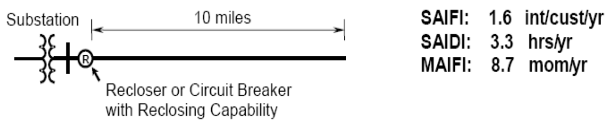



**Fig ( 4-2 )**

Fig ( 4-3 ) shown below, illustrates the value of the line recloser. As can be seen, the use of the line recloser (comparing cases 2 and 4) reduces all the indices approximately 25%.

**Case ( 3 )**

**With mid Auto-Recloser .**

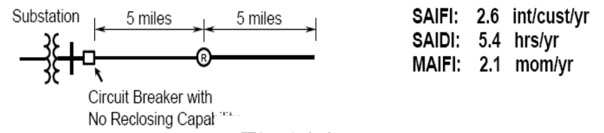



**Fig ( 4-3**

**Case ( 4 )**

**With two Auto-Reclosers .**

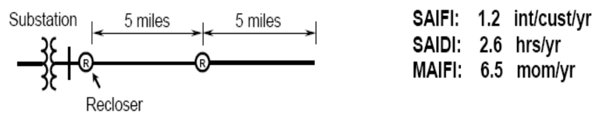



**Fig ( 4-4 )**

Fig ( 4-5 ) (Case 5) shows the effect of using a manual tie and fig(4- 6) (Case 6) shows the value of replacing the manual tie with a recloser and implementing a Loop Scheme restoration system. Adding this automatic tie point and implementing a loop scheme as indicated in this manual provides improvement in the SAIFI and SAIDI.

**Case ( 5 )**

**Loop Configuration with Manual Switch**

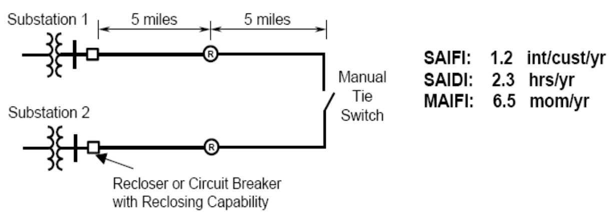



**Fig ( 4-5 )**

**Case ( 6 )**

**3 Automatic Reclosers Loop Scheme**

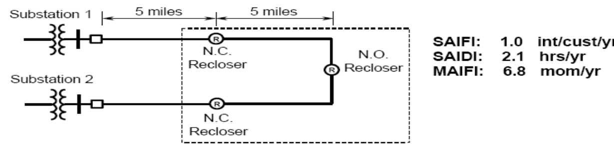



**Fig ( 4-6 )**

A 14% reduction in SAIDI can be obtained using this scheme

**Case ( 7 )**

**5 Reclosers Loop Scheme**

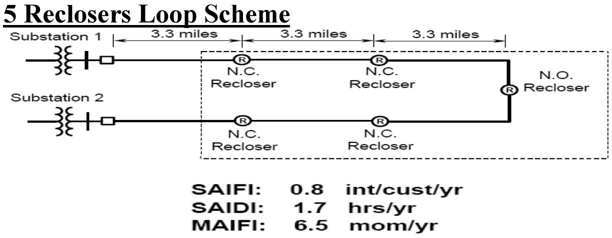



**Fig ( 4-7 )**

A summary of the benefits of reclosing is shown below. As can be seen, protection schemes to improve reliability are clearly a case of diminishing returns but, if a utility requires these different tiers of reliability, reclosers are clearly the way to go.

**Table (1) summary of all cases**

| | Connection | SAIDI | % Improvement |
|---|---|---|---|
| Case 1 | NO Reclosing | 8.8 | **— ( Base )** |
| Case 2 | Substation Reclosing | 3.3 | **63 %** |
| Case 4 | Line Recloser | 2.6 | **70 %** |
| Case 5 | Loop with manual Switch | 2.3 | **74 %** |
| Case 6 | 3 Recloser Automatic Loop Restoration | 2.1 | **76 %** |
| Case 7 | 5 Recloser Automatic Loop Restoration | 1.7 | **81 %** |

## 6- CASE STUDY ( NDEDC PILOT PROJECT )

### 6.1 - Important Goals of NDEDC company are:

**[A]** Ensure the continuity of power supply to customers. **[B]** Decrease the unserved energy. **[C]** Improves quality of power supply in its coverage zone by decreasing time of supply loss. To achieve this, our company decided to install the Auto-recloser system and the Sectionaliser on the medium voltage overhead lines.

**As a Result** On 10/4/2002 our company invited some expert companies which are concerned in this field to install this pilot Project in EGYPT (Auto Recloser & Sectionaliser) on the most faulty lines which enable our company to evaluate the project performance for 6 months from the beginning of operation and make a feasibility study for the project as well as Schneider and ABB companies proposals have met our requirements and technical specifications , our company accepted their offers , These Systems Are installed in

**[ 1 ] -** (Gamasa – Shoman ) OHTL.

**[ 2 ]-** ( Gamalia - Robiha ) OHTL .

## 7- ( NDEDC OHL )

NDEDC choose Shoman & Robiaa overhead lines from Gamasa & Gamalia S/S for the following reasons:- Considered as a relatively long lines approximately 65Km (the main line (20 km) and lateral branches (45km)) , Far from maintenance centers , High rate of faults , High Average fault duration / year , Most part of the lines pass through agriculture areas , Near to bird emigration roads , near to sea , high rate of unserved and unsold energy.

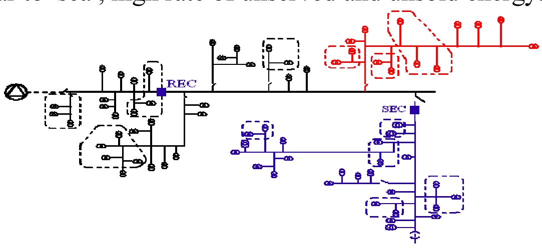



**Fig (5) Gamasa- Shoman OHL**

**( Table 2 ) Coordination for Gamasa shoman Line**

| Type | Substation setting | the Recloser setting for | Sectionaliser |
|---|---|---|---|
| O / C | 480 | 470 Amp | 150 Amp |
| E / F | 180 | 120 Amp | 15 Amp |
| Definite time operation element | 0.45 | 0.25 sec | 0.1 sec |
| Mechanical opening time | 0.05 | 0.04 sec | 1 sec |
| Total clearing time | 0.5 | 0.29 sec | 1.1 sec |
| Time between trip 1 & trip 2 | | 0.5 sec | Count 1 |
| Time between trip 2 & trip 3 | | 10.0 sec | Count 2 |
| Single shot reset time | | 1.00 sec | |
| Sequence reset time | | 30 Sec | |

## 8- THE PERFORMANCE & ECONOMICAL STUDY OF THE PILOT PROJECT

### <u>8.1 - The following table show the operation summary for the Auto-Recloser & Sectionaliser of Gamasa -Shoman line .</u>

**( Table3) Shoman during the period from 4/5/2004 to 1/4/2005**

| Period | Total Faults | Successful operation of The Auto Recloser ( A/R ) | | | | Sectionaliser Operation (83 fault ) 25.6 % | | S/S Tripping |
|---|---|---|---|---|---|---|---|---|
| | | Number | % | Reclosed | Lockout | transitent | Sustained | |
| 4/5/04 to 1/4/2005 | 324 241+83 | 324 | 100 % | 282 ( 87%) | 42 (13%) | 67 (21%) | 16 (5%) | 0 |

The economical study can be evaluated on the following basis [A] Calculation of the unsold energy due to faults (NDEDC).[B] Calculation of the losses in the national income bear due to loss of power supply for customers.

1) In agriculture area ( 2.9$ : 7.7$ per KWH)
2) In Commercial & Industrial Areas ( 3.72 $ : 8.2 $ per KWH ) These values is according to the study of the international Bank to India

## 9 - PROJECT EXTENSION.

After NDEDC Successes in its pilot project they expand their project to include 6 OHL in its three sectors installed in Dec 2005, its selection based on the following information :- Number of faults During a Year , The Average interruption time per fault ,Unserved Energy and unsold Energy due to tripping of the line from the main substation (S/S) , Length of the line / as well as the laterals and nature of its right of way , Weather Condition and Max Short circuit level .

**( Table 4 ) Economical Studies of New Lines**

| NO | OHL Name | No of faults / year | Payback period according to unsold energy " NDEDC" month | Payback period according to National Income DAY |
|---|---|---|---|---|
| 1 | AbuAkhdar | 420 | 29 | 39 |
| 2 | El Mahmodia | 168 | 40 | 53 |
| 3 | El Hafer | 828 | 8 | 11 |
| 4 | El Sakhawy | 216 | 40 | 54 |
| 5 | El Khadmia | 156 | 28 | 38 |
| 6 | Rasheed | 180 | 38 | 51 |

## 10- FUTURE WORK

NDEDC Will install ( 2 Auto-Recloser ) in the main line and activate the function of ACR sequence coordination instead of ( 1 ACR + 1 Sectionaliser ) & also will install limit fuses in its lateral branches . NDEDC will be the first company in Egypt that will use the Technology of Radio fault passage indicator for overhead networks . (FPI) is mandatory to locate faults on Distribution networks based in their operation in Low power license-free wireless transmission to send fault records to Accumulating Unit "RTU" which includes GSM Modem to send these events to Operators Mobiles . The installation must match electrical network characteristics and be very visible in order to help maintenance crew to quickly locate network faults. A FPI must be coordinated with the upstream recloser or circuit breaker and therefore, depending on its location on the MV network.

## 11- BENEFITS OF USING ACR IN NDEDC

**[1]** Continuity of power supply for the consumers resulting in less complaints from citizens. **[2]** Reduce the time of power supply disconnection in cases of transient faults. **[3]** Reduce the unsold energy due to faults. **[4]** Reduce the cost of manpower operating in managing disconnected lines **[5]** Maximum utilization of the network components. **[6]** Raising operators efficiency and using Hi-Tech in networks. **[7]** Ability to connect to SCADA system. **[8]** Event Log and Remote control **[9]** Reduce cost of fault finding **. [10]** Better knowledge of the network

## 12 - CONCLUSION

This paper presents a comparative analysis of distribution reliability improvements that can be achieved by using various outdoor distribution devices. There are two objectives for this paper: First, it is to discuss the application of the most common types of devices, including automatic line reclosers, sectionalisers and Limit fuses . Second, an analysis to quantify the reliability improvements that can be achieved by using each (or a combination) of these devices, as well as a combination of these devices.