Cost Effective Protection Scheme For Single Breaker Substations

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Background

In the de-regulated and competitive environment, the utilities are trying to find cost effective method of engineering problems. They are cutting the cost by innovation by applying new technologies. They are trying to utilize their system and equipment to its maximum capacity . The sectionalizing of the transmission line by single breaker station used to be called a cheap method of reliability improvement, but it is not true any more. It is common practice in the utility industry to install single breaker for sectionalizing the transmission lines for reliability improvement. A typically a single breaker is normally protected by two sets (four relays) of multifunction distance relays primary and backup on each side of breaker. In this paper it was suggested to use just two relay (one each side of breaker) to protect the transmission line on each side of the breaker. These two relays will provide the primary and backup protection at the half (50%) of the cost of a typical scheme.

Introduction

Thanks for the new microprocessor based relays, since they have provided tremendous flexibility to protection at lower cost. The modern microprocessor based distance relays have four (4) or five (5) zones of phase and/or ground distance elements. And it is also possible that any of those zones can be reversible. In the new scheme as shown in figure-1 the Zone#1 & Zone#2 provide forward protection and Zone#3 & Zone#4 provide reverse direction protection. Both of these relays can be assigned reclosing (79) functions and breaker failure (BF) functions. In the example shown figure-1, relay R#1 and relay R#2 are both designated to provide reclosing function. Also the relay R#2 provides breaker failure (BF) function, The ground overcurrent relays are non-directional, instantaneous ground elements are directional in this example, but they can be made non directional. In case of failure or maintenance of any one of the relay, the other relay will act as a full backup relay.

Single Breaker Installation

The single breaker can be installed at any following two line configuration;

1-Two Terminal Line
2- Three Terminal Line

Two Terminal Line:

In two terminal line the two breaker at remote ends and single installed at appropriate location on the line. In order to improve the reliability of Distribution Substations a breaker at Dist. Sub. "C" is installed as shown in Fig-1. In this example the Sub-C is a single breaker Substation. The fault any where on line without single breaker (between Sub-A and Sub-B) will trip all three Distribution Subs. But, the fault on the line in after single breaker installation will one or two rather than three Distribution Substation and approximately improve the reliability by 33% (based on assumption that fault frequency is uniform between the Substations)

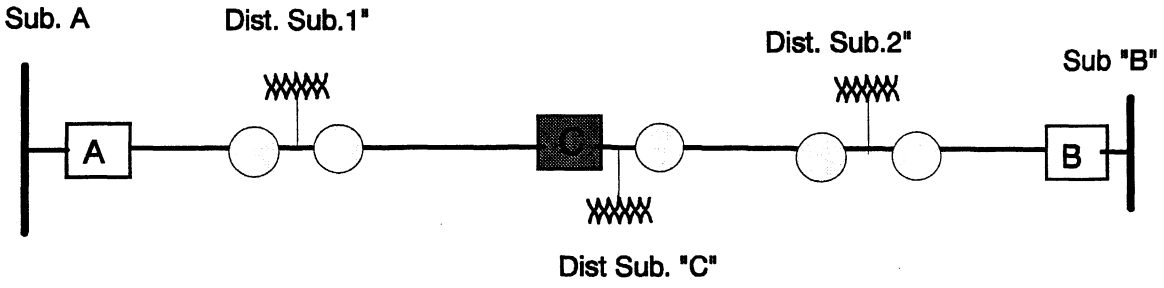


Figure 1

Three Terminal Line

Adding a single breaker for three terminal line also improves the reliability of distribution Substations. In fig. 2 fault on anywhere on tree terminal line will trip all four distribution Substations. If breaker at Sub. C is added as shown in fig-2, the faults on line will trip two distribution Substation instead of four. In the example the reliability will improve by 50% assuming the uniform fault exposure either side of single breaker Substation.

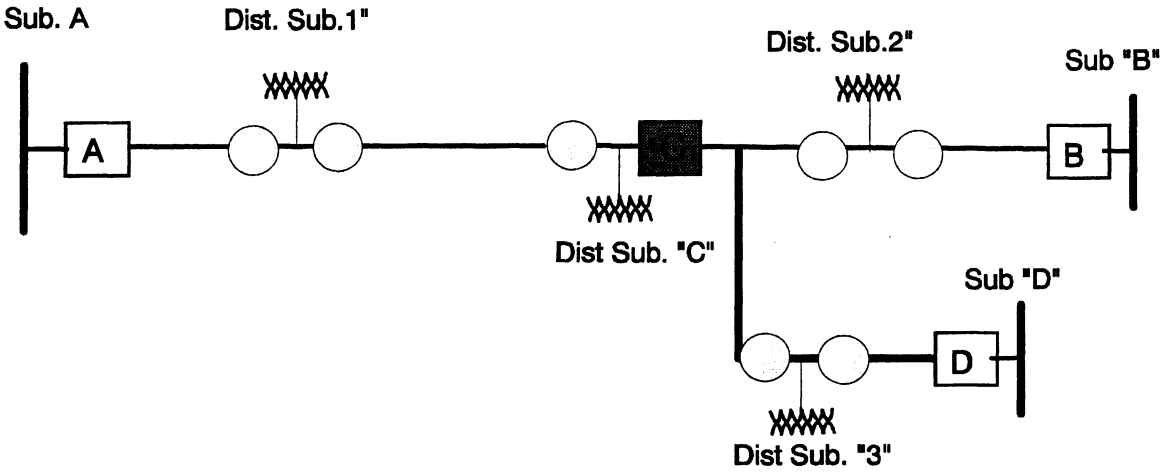


Figure 2

Existing Protection Philosophy

- Four (4) microprocessor based distance relays with ground overcurrent and negative sequence elements. The line on each side of breaker is protected by two relays as shown in figure-3. In this diagram R1, R2, R3 and R4 provides at least three zone of distance protection and ground overcurrent protection.

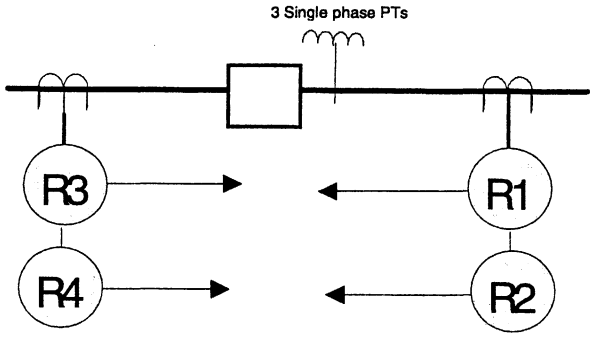


Figure 3

- Six (6) electromechanical distance relays three on side of breaker and two (2) ground directional overcurrent relays one on each side of breaker as shown in figure-4. In this diagram Z1, Z2,Z3 are the first, second and third zone of protection. The relay 67N provides ground directional overcurrent protection, but in some cases if coordination permits the 50/51N non-directional ground overcurrent relays can be utilized

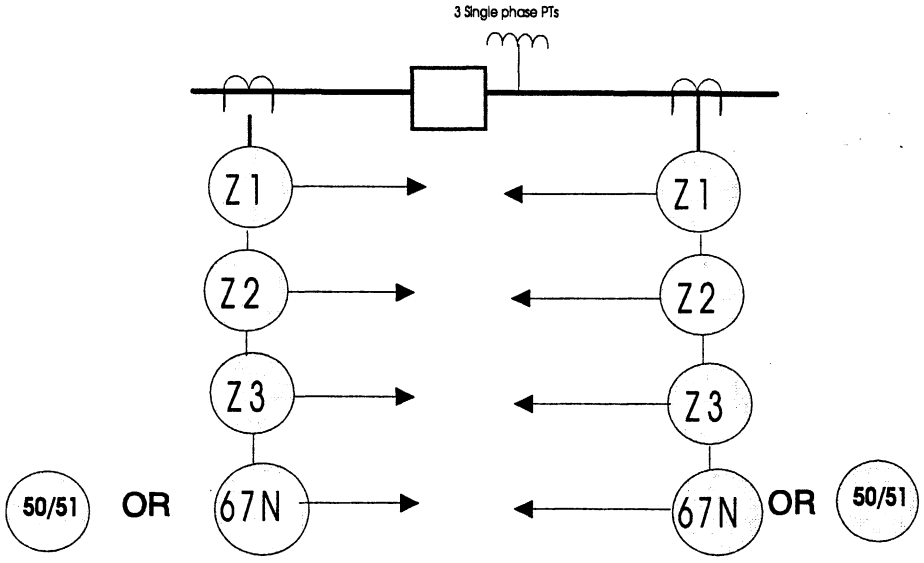


Figure 4

Proposed Protection Scheme:

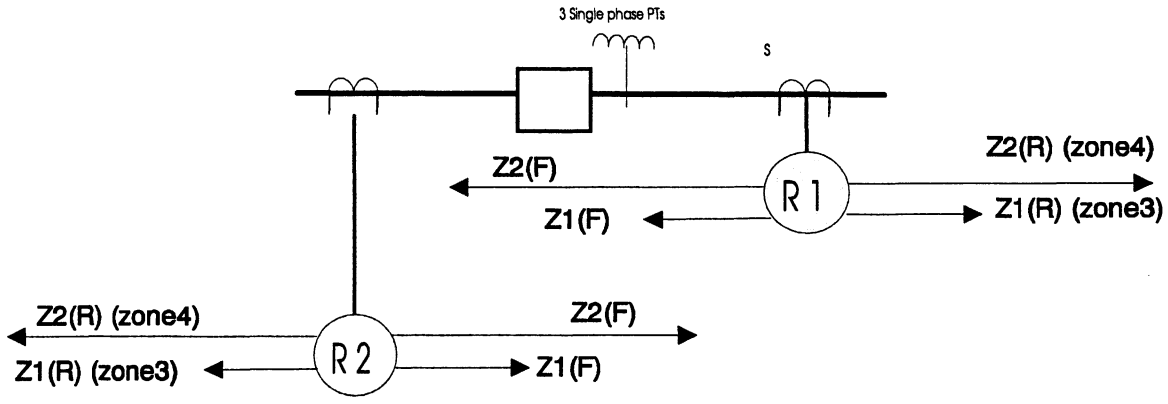
Two microprocessor based relays R1 & R2 as shown figure-5 (with four zones (4)) provides following protection;

Relay (R1)

- Two zones of phase distance protection forward direction
- Two zones of phase distance protection in reverse direction
- Two zones of ground distance protection in forward direction
- Two zones of ground distance protection in reverse direction
- Ground overcurrent either direction or non directional.
- Reclosing
- Breaker Failure

Relay (R2)

- Two zones of phase distance protection forward direction
- Two zones of phase distance protection in reverse direction
- Two zones of ground distance protection in forward direction
- Two zones of ground distance protection in reverse direction
- Ground overcurrent either direction or non directional.
- Reclosing
- Breaker Failure



Z1(F) = Forward direction zone-1
Z2(F) = Forward direction zone-2
Z1(R) = Reverse direction zone-1
Z2(R) = Reverse direction zone-2

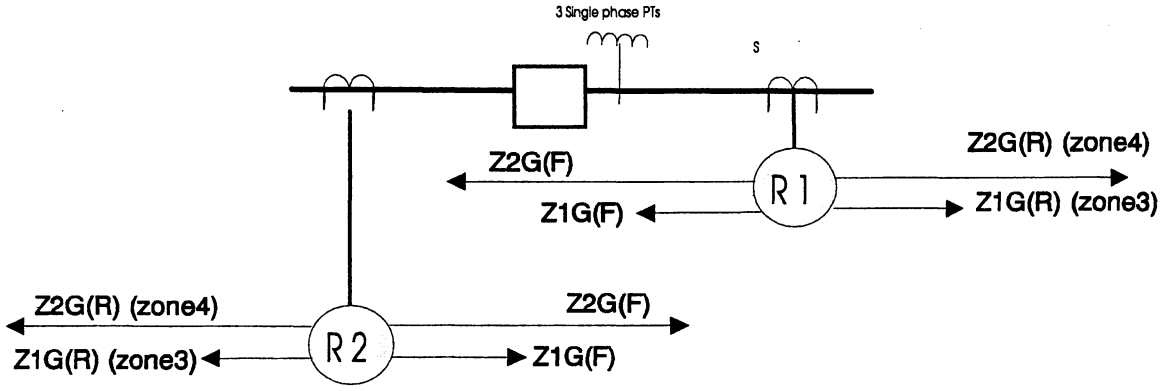
Figure 5

1- Phase Distance Protection:

In the proposed scheme only two (2) relays one on each side of breaker are used. Each relay will provide Z1(F) and Z2(F) protection in forward direction as shown in figure-6. The Zone-3 & Zone-4 of the each relay are set in reverse direction Z1(R) and Z2(R) and provide the phase protection of the line in the reverse direction.

2- Ground Distance Protection:

The ground distance elements of the R1 & R2 are set in forward and reverse direction as phase distance elements. Ground distance Zone-1 (ZIG) and Ground distance Zone-2 (Z2G) are set in forward direction. The zon3G and zone4G of each relay is set to provide reverse direction zon1G and zone2G, to provide the protection for the line in reverse direction.



Z1G(F) = Forward direction zone-1
Z2G(F) = Forward direction zone-2
Z1G(R) = Reverse direction zone-1
Z2G(R) = Reverse direction zone-2

Figure 6

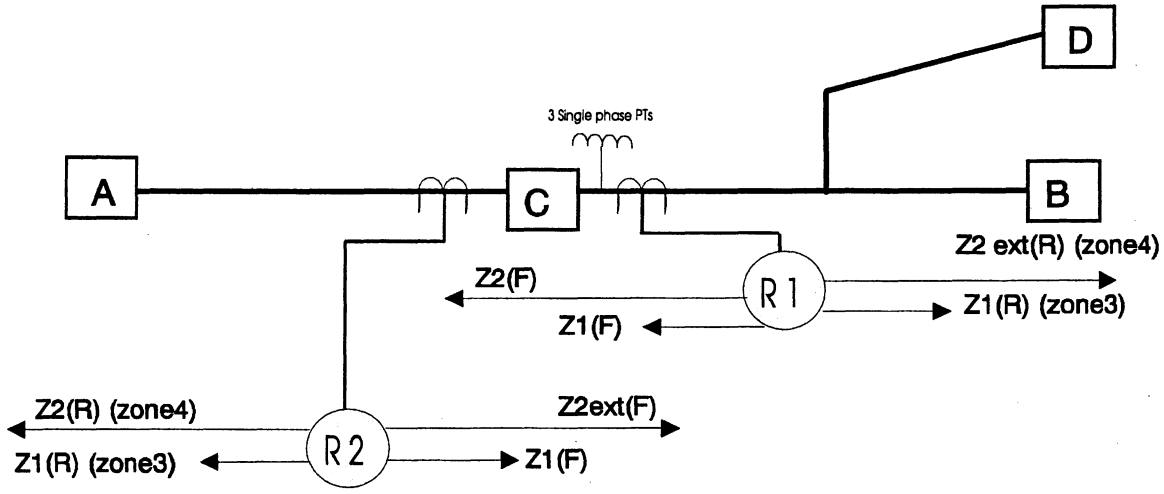
A single breaker at three terminal line as shown in previous figure-7 the above zone selection criteria may not work because of the infeed, consequently the zone-2 reach may not adequate to protect the full length of transmission line. In that case the zone 2 of relays (R1) is set as an extended zone-2, that include the apparent impedance due to the infeed 15-20%with some time delay and Zone 4 for relay (R2)

Z2ext(F) = (Z (infeed)x M
Zone-4 of Relay (R2) Z2ext(R) = Z2ext(F)

Where;

Z2ext (F) is extended forward Zone-2 of Relay (R1)
Z2ext (R) is extended forward Zone-4 of Relay (R2)

"M" is margin can be set 110% or more depending on remote relay zone-1 and Zone-2 reach.



Relay-R1

Z1(F) = Forward direction zone-1
Z2(F) = Forward direction zone-2
Z1(R) = Reverse direction zone-1
Z2ext (R) = Reverse direction extended zone-2

Relay-R2

Z1(F) = Forward direction zone-1
Z2 ext(F) = Forward direction extended zone-2
Z1(R) = Reverse direction zone-1
Z2 (R) = Reverse direction zone-2

Figure-7

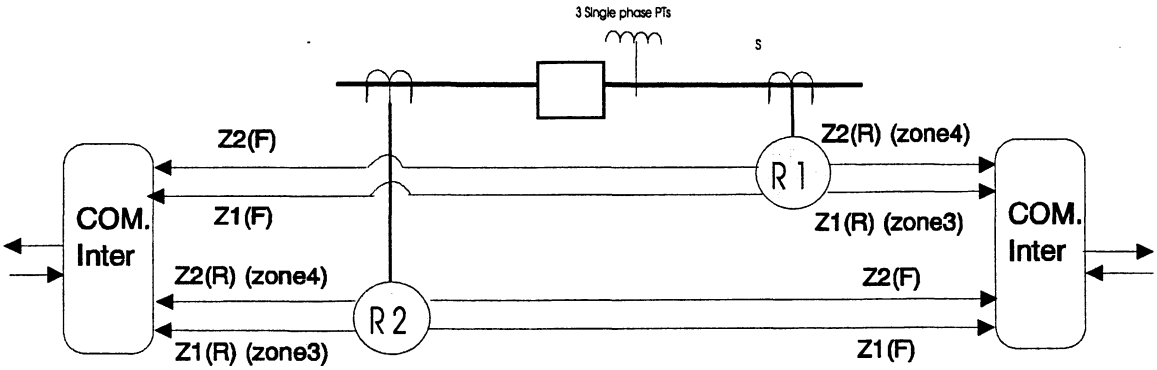
3- **Ground Overcurrent Protection;**

The relay R1 and R2 provide the ground protection for transmission line on either side of breaker. The ground elements can be selected as a directional or no-directional elements depending on the system and relay coordination. If there is no coordination problem than the non-directional ground option is more preferable, since it provides ground overcurrent backup in case the one relay is out of service.

4- Communication Assisted Protection Scheme:

The above proposed schemes are also applicable to Short line protection scheme In the example shown in figure-8, the required output and input contacts from both R1 and R2 relays are provided to the Communication Interface box. But, in some new microprocessor based distance or overcurrent relays there is no need for communication interface since the local relays can communicate (send and receive transfer trip signal) directly to remote end relay.

Communication Assisted Phase Distance Protection Scheme



Z1(F) = Forward direction zone-1
Z2(F) = Forward direction zone-2
Z1(R) = Reverse direction zone-1
Z2(R) = Reverse direction zone-2
COM. = Communication interface.

Figure 8

5- Reclosing:

In the proposed scheme, each relay provides reclosing function and there is no need to install a separate reclosing relay. If any of these (R1 or R2) relay trip the breaker it will also send the a reclose initiate to other relay in order to perform reclosing. The number of reclose and reclosing time delays of one relay (R1) are set independent to the other relay as shown in figure-9 The R1 and R2 relays both provide input contacts to each other for the forward and reverse direction fault in order enable or block the reclosing scheme.

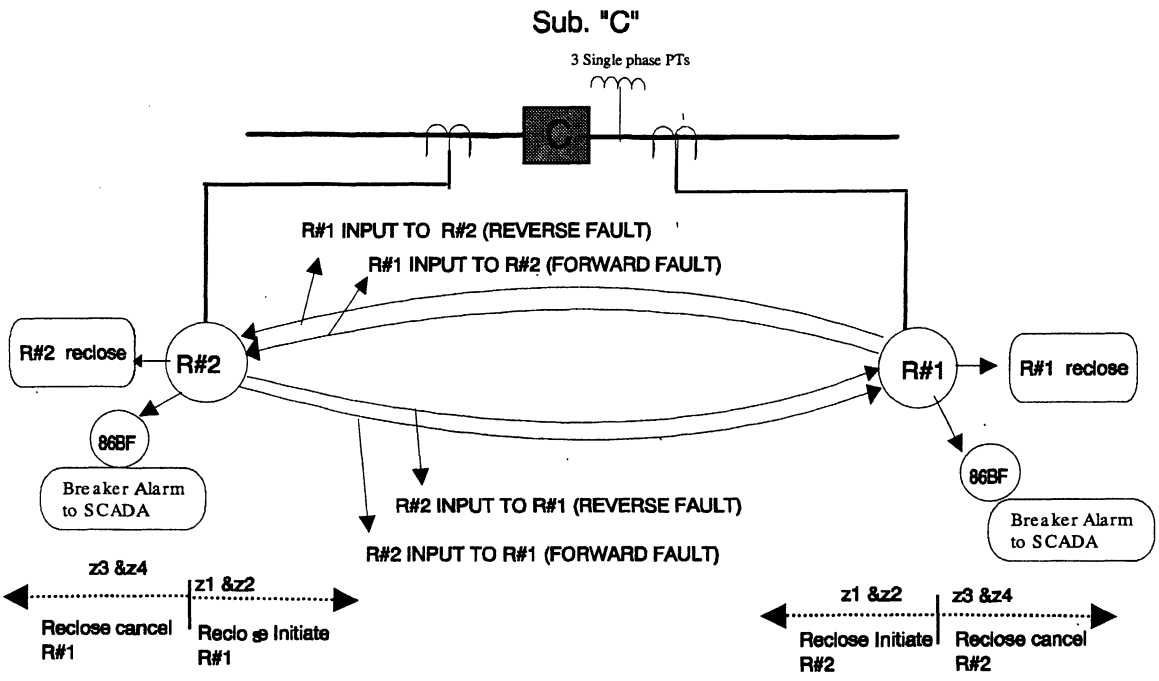


Figure 9

6- **Breaker Failure**

In the single breaker Substation the breaker failure scheme provides following functions;

If there is communication channel available the relay will send a trip signal to the relay at remote backup breaker. In absence of communication channel the relay will send alarm to system operators for appropriate action.

In our scheme we utilize one relay to provide breaker failure function, because of relay timer limitations. The relay (R1) provides breaker inputs to relay (R2) during breaker failure conditions. The relay (R2) provides SCADA alarm to system operators for breaker failure condition through lockout relay.

Conclusion:

The main objective of this paper was to share our experiences and also like to encourage other to utilize the full benefits of microprocessor based relays. We obtain following main benefits by utilizing this scheme.

1- Since each relay can perform full reclosing functions, so there is no need to install separate reclosing relay

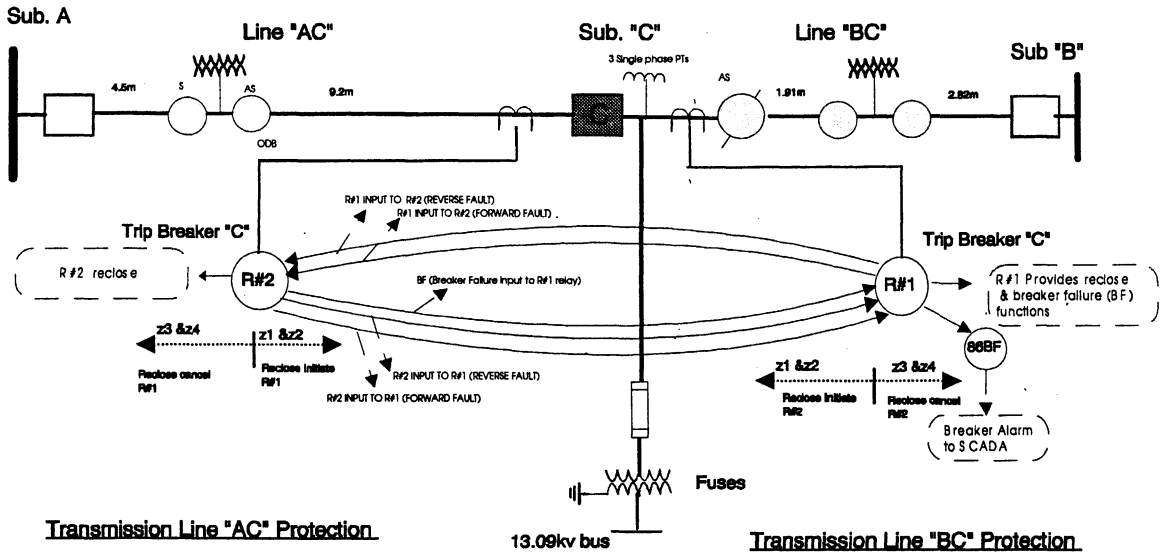
2- No need to install separate breaker failure relay .

3- This scheme utilize less panel space, and it will require smaller station battery, since DC battery power consumption is lower. So, far we have six such a installations and have a plan to install more schemes in near future. By the application of this scheme we approximately saved $20,000 per single breaker installation ($120,000 for six installation in two years).

Future Improvements:

We hope the relay manufacturing industry will produce distance relays with six zones (reversible) of protection that will enables us the full three zones of protection at either side of single breaker Substation. Also this scheme can be further improved if additional timer are available breaker operation.

Single Breaker Substation
Protection Scheme



Transmission Line "AC" Protection

1- Relay R#1 provides Zone1 & Zone 2

2- Z3 & Z4 of relay R#2 are set in reverse direction and provide Zone 1 & Zone 3 protection.

3- Relay R#2 recloses for the faults on "BC" line

Transmission Line "BC" Protection

1- Relay R#2 provides Zone1 & Zone 2

2- Z3 & Z4 of relay R#1 are set in reverse direction and they provide Zone 1 & Zone 3 protection

3- Relay R#1 recloses for the faults on "AC" line