Backup To Busbar Protection With Numerical Distance Protection

Shashank Jewalikar; Dy.E.E, MSETCL
email id: shashank.jewalikar@gmail.com

Abstract— An application idea for applying distance protection to backup the busbar protection is presented here. The proposed scheme is applicable to substations with following bus configurations.
1) 2 Main + 1 transfer bus with bus coupler.
2) 1 Main + 1 Transfer bus with bus sectionalizer breaker
3) 1 Main bus with sectionalizer breaker.
The proposed scheme envisages use of reverse zone of existing numerical distance protection relays in a different way than conventionally used in utilities.

Index Terms— Busbar protection, Numerical distance protection, backup to busbar protection, reverse zone

I. INTRODUCTION
A bus differential protection is applied for protection of busbar against bus faults. Looking at the various reports of past occurrences in our network; there are many occurrences involving non operation of bus bar protection schemes. Any case of such non operation,
1. Always results into loss of complete bus as no selective tripping are possible in present scheme.
2. Delays the fault clearance as the fault in such cases will be cleared by remote Zone 2, Zone 3, T/F or generator backup protections as the case may be.
3. Increases the spread of occurrence.
4. Many times results into a wide spread system disturbance. This can lead to a cascade tripping condition.

Practices for enhancing reliability of Busbar protection:
For enhancing the reliability of busbar protection; following practices are adopted.
1. Main and check zones in busbar protection.
2. Replicated DR with check zone in RADSS
3. Main 1 and Main2 busbar protection schemes in 1 out of 2 or 2 out of two trip logic.
4. Distance protection reverse zone is also said to act as a back up for busbar protection.
First three of these practices are basically busbar replication schemes with same differential operating principle.

Present practice for reverse Zone as back up to busbar:
1. The reverse zone of numerical line distance protection is adopted to cover the bus at many places. The reverse zone is generally set to cover 10% of the line impedance.
2. This is said to be a back up to the busbar protection.
3. The time setting adopted in these cases is generally more than Zone 3 time.
4. This makes the operating possibility of reverse zone virtually remote. The bus fault, in case of non operation of busbar protection is cleared from remote end Z2 & Z3 as the case may be. The purpose of reverse zone backing up bus bar protection is defeated. In a way the reverse zone in this case is acting as a backup to remote Zone 3 for the local bus coverage area.

The gravity of this situation can be reduced to a large extent if bus coupler / bus sectionalizer breaker can be opened before any Zone 2 operation takes place. This can be achieved by use of reverse zone available with numerical distance protection relays. The necessary configuration & settings are discussed here. The suggested scheme is applicable to following bus configurations.
1. 2 Main + 1 Aux. bus with bus coupler breaker.
2. 1 Main + 1 Aux. bus with Main bus divided in two sections with sectionalizer breaker.
3. 1 Main bus with sectionalizer breaker.
   By way of opening the bus coupler before any Zone 2 operation; the bus fault will be limited the faulty bus section. This fault will be eventually cleared by the remote Zone 2
protections of the lines; transformer / generator backup protections connected to that bus section only. (Ref. Fig 3)

![Figure 3: Reverse zone suggested usage](image)

**Requirements of the scheme:**

1. **Time:**
   1. Bus coupler breaker should open before any remote Zone 2 operation.
   2. Bus coupler trip should not be initiated before Zone 1 fault clearance time.
   3. The bus coupler trip should not initiate the LBB (50Z) of line protected by the distance protection from which the bus coupler trip is obtained.

2. **Impedance:**
   1. The reverse zone always must cover the local bus completely.
   2. The reverse zone should never encroach into Zone 2 of any of the lines connected to the bus.
   3. The reverse zone can be set to cover 10% of protected line impedance.
   4. A setting of 20% of shortest line impedance can be used for all lines where a short and a long line are connected to the same bus.

Considering these requirements a two stage configuration of reverse zone is suggested.

**Two stage reverse zone**

1. Numerical distance relays are having separately settable impedance zones for reach as well as direction.
2. The reverse zone impedance to be set to cover the bus fault. The impedance setting to be adopted as per the requirements discussed above. A fixed impedance so as to cover the bus can also be thought over in this case for all the lines connected to the bus.
3. A two stage trip is to be obtained from this reverse zone element.
4. **Stage 1:** The reverse zone stage 1 will be obtained as below.

The reverse zone start signal will be used to start an internal timer. The timer will be set to less than Zone2 time setting of remote end protections and more than Zone1 fault clearance time of local end. Considering currently adopted time setting on 400 kV level (T Z2 =300 mS & T Z1 =0 so Z1 fault clearance = 100 mS), a time of 200 mS can be set for the timer. An output contact will pick up on operation of timer with presence of reverse zone start continued. (Refer figure 4 & 5)

![Figure 4: Reverse zone 2 stage operation logic.](image)

The reverse zone stage1 operation logic is like creating a new zone of operation inside the relay.

![Figure 5: Reverse zone 2 stage trip logic](image)

**Logic Verification & testing:**

The suggested scheme logic is verified on Micom P442 relay (ref fig.6). The logic testing was carried by using the automatic relay testing kit Omicron CMC 256-6. The method
The possibility of having similar configuration with REL 521 relay is also verified.

**Implementation:** The possibilities of configuration and checks required are discussed in view of present protection practice of 400 kV & 220 kV lines.

**Case 1: 400 kV Substation where two distance protections (Main1 & Main2) are provided on all lines.**

Following situations are considered for this case.

1. Both numerical protections on line: Following possibilities exist in this case.
   a. The reverse zone stage 1 and stage 2 tripping can be separately obtained from each of the relays. It is essential in this case that the reverse zone stage 1 trip should not initiate the LBB protection.
   b. Only one of the protections can be used for a two stage reverse zone.
   c. A series combination of stage1 reverse zone from both is also possible.

2. One numerical and one static distance protection:
   a. Only numerical protection will be used for two stage reverse zone.

3. Suggested timings for 400 kV
   a. Present Zone timings
      i. Zone 1 = 0 mS
      ii. Zone 2 = 300 mS
      iii. Zone 3 = 500 mS to 1 S
   b. Reverse Zone timings suggested
      i. Stage 1 = 200 mS
      ii. Stage 2 = 400 mS

**Case 2: 220 kV substations where the main protection is distance and back up is IDMT O/C & E/F**

In such condition the scheme can be applied safely as far as all of the distance protection relays connected to the concerned bus is in service and functioning correctly. The scheme can also be safely applied when the Zone1 fault clearance time on the overlapping area of reverse zones and Zone1 with only back up protection operation can be coordinated with the reverse zone stage1 operating time. As the Zone 2 operating time for 220 kV lines is 400 mS, the stage 1 reverse Zone time can be taken to 300 mS for tripping of bus couplers in this case.

1. Suggested timings for 220 kV
   a. Present Zone timings
      i. Zone1 = 0 mS
   ii. Zone 2 = 400 mS
   iii. Zone 3 = 700 mS to 1 S
   b. Reverse Zone timings suggested
      i. Stage 1 = 250/300 mS
      ii. Stage 2 = 500/600 mS

**Check:** For a Zone 1 fault in 30% of line section the fault clearance time with only back up protection in service should be less than the stage1 trip time of reverse zone used to trip the bus coupler.

**Configuration possibilities and LBB:**

The numerical relays are providing lot of flexibility for their configuration. Different logical formations can be possibly configured in the relay to achieve the same functional behavior. The functional behavior of the numerical relays is always a combination of its logic configuration and settings adopted.

Some possibilities while configuring & setting the relay for adoption of this busbar backup scheme are discussed below. In this the logical formation shown in the logic diagram (Fig.4 & 5) above to initiate the stage 1 is referred as ‘new zone’ and reverse zone of the relay is referred as ‘reverse zone’.

1. **New Zone = Stage 1 & Reverse Zone = Stage 2**
   a. This is as shown in the logic diagram (Fig.4 & 5) and described already. This is the recommended configuration.

2. **New Zone = Stage 2 & Reverse Zone = Stage 1**
   In this case following precautions are essential.
   a. The stage 1 trip needs to be disconnected from all general trip conditions inside the relay.
   b. The stage 1 trip should not initiate the internal or external LBB of the feeder. The external LBB initiation can be avoided in wiring. In cases where internal LBB is used; a configuration change becomes essential. A check should be made with the relay logic for possibility of separation of such initiation condition.
   c. The stage 2 here needs to be connected to the general trip conditions initiated from the relay. The stage2 will initiate the LBB of the feeder.

3. **Reverse Zone = Stage 1 and No stage 2**
   a. If any of the relay is not providing facility for creation of new zones this configuration can be used.
   b. The stage 1 trip needs to be disconnected from all general trip conditions inside the relay.
   c. Here also the stage 1 trip should not initiate the internal or external LBB of the feeder. The necessary care as discussed in 2 above is applicable here.

4. **Rev Zone of Main1 = Stage 1 and Rev Zone of Main2 = Stage 2**
   a. When both main1 and main2 both numerical distance relays are provided; it is possible to configure the reverse zones of one for stage1 and the other for stage2.
   b. The stage1 trip needs to be disconnected from all general trip conditions.
   c. Here also the stage 1 trip should not initiate the internal or external LBB of the feeder. The necessary care as discussed in 2 above is applicable here.
   d. The stage 2 here needs to be connected to the general trip conditions initiated from the relay. The stage2 will initiate the LBB of the feeder.

![Figure 6: Reverse Zone stage 1 logic as implemented in Micom P442](image)
5. **Use of multiple reverse zones from one relay.**
   a. Some of the numerical relays are providing facility to have more than one reverse zone from one relay.
   b. In such cases a possibility of configuring one for stage1 and the other for stage2 comes up. This may not be used unless it is possible to configure the relay for continued measurement by other zones even after tripping is issued by one of them.
   c. If such configuration becomes possible; the zone configured for stage1 should never initiate LBB of feeder and be separated from the general trip conditions.

**Extending the idea:**

The idea can be extended. Following variations can be considered.

1) The scheme can be used to isolate the auxiliary bus faults (i.e. by tripping the TBC breaker only) before stage2 trip by some logic and timing modifications.
2) A definite time check zone in combination with distance reverse zone can be considered for increasing the stability of scheme.

**Conclusion:**

Non operation of busbar protection always increases the spread of the disturbance. Applying relaying with different operating principle to backup the busbar protection will be a good practice. The present practice of utilizing reverse zone with operating time more than Zone3 as busbar backup serves no purpose. The suggested usage of distance protection reverse zone to trip the bus coupler / sectionalizer breaker will serve this purpose and limit the spread of the disturbance.

Shashank Jewalikar  
400 kV Testing Unit  
MSETCL  
Girwali -431 519

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