Auto-reclose Scheme

ZULKARNAIN BIN ISHAK

TECHNICAL EXPERT

ENGINEERING DEPARTMENT

TNB TRANSMISSION

1.0 Auto-reclose

Benefits of Auto-Reclosing

Fault Types

Auto-Reclose Terminology

Single Shot or Multi-Shot?

System Stability

3ph or 1ph A/R

Choice of Scheme

Synchronizing Check

Autoreclose

AUTO-RECLOSING

- DISTRIBUTION
  - Generally <66kV
  - Mainly Applied on Radial Systems
  - Continuity of Supply
- TRANSMISSION
  - Interconnected Supply Sources
  - Stability
  - System Synchronism

Benefits of Auto-Reclosing

- **Improved continuity of supply**
  - **Supply restoration is automatic (does not require human intervention)**
  - **Shorter duration interruptions**
  - **Less hours lost to consumer**
- **Less frequent visits to substations**
  - **More unmanned substations**
  - **Reduced operating costs**

Fault Types

- ***Permanent Faults l***
- ***Self Clearing Faults***
  - **Semi-Permanent Fault**
  - **Transient Faults**

Permanent Faults

Affected part of system that cannot be successfully re-energised until fault has been rectified and damage equipments has been repaired.

Transformers

Machines

Cables (Underground)

Overhead Lines

Most faults are permanent

Broken Conductors

Broken Insulators

Self Clearing Faults

No permanent damage to system.

Once cleared, the affected part of power system can be safely re-energised.

Transient Faults

Cleared by immediate isolation of fault by circuit breaker.

- **Insulator flashover due to transient overvoltage**
  - **Switching**
  - **Lightning**
- **Conductor clashing**

Semi-Permanent Fault

Cleared within a few seconds of fault current interruption.

- **Tree branches blown onto O/H Line**

Fault Occurrence

Auto-reclose is confined to overhead lines and feeders.

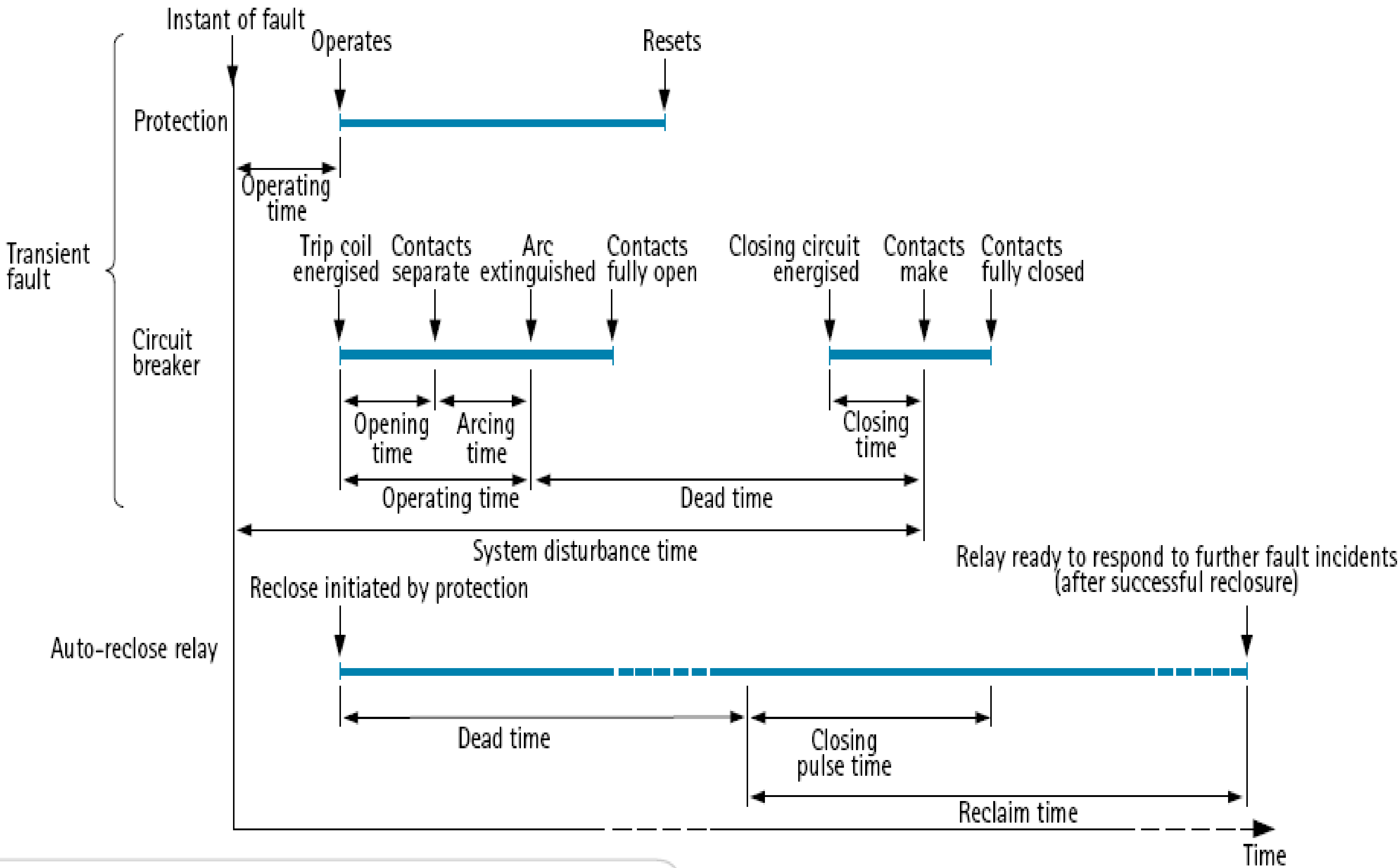
Transient faults	**80 to 85%**
Semi-permanent faults	**5 to 10%**
Permanent	**10%**

Transient faults :-	**E.H.V. > H.V.**
Semi-Permanent faults :-	**E.H.V. < H.V.**

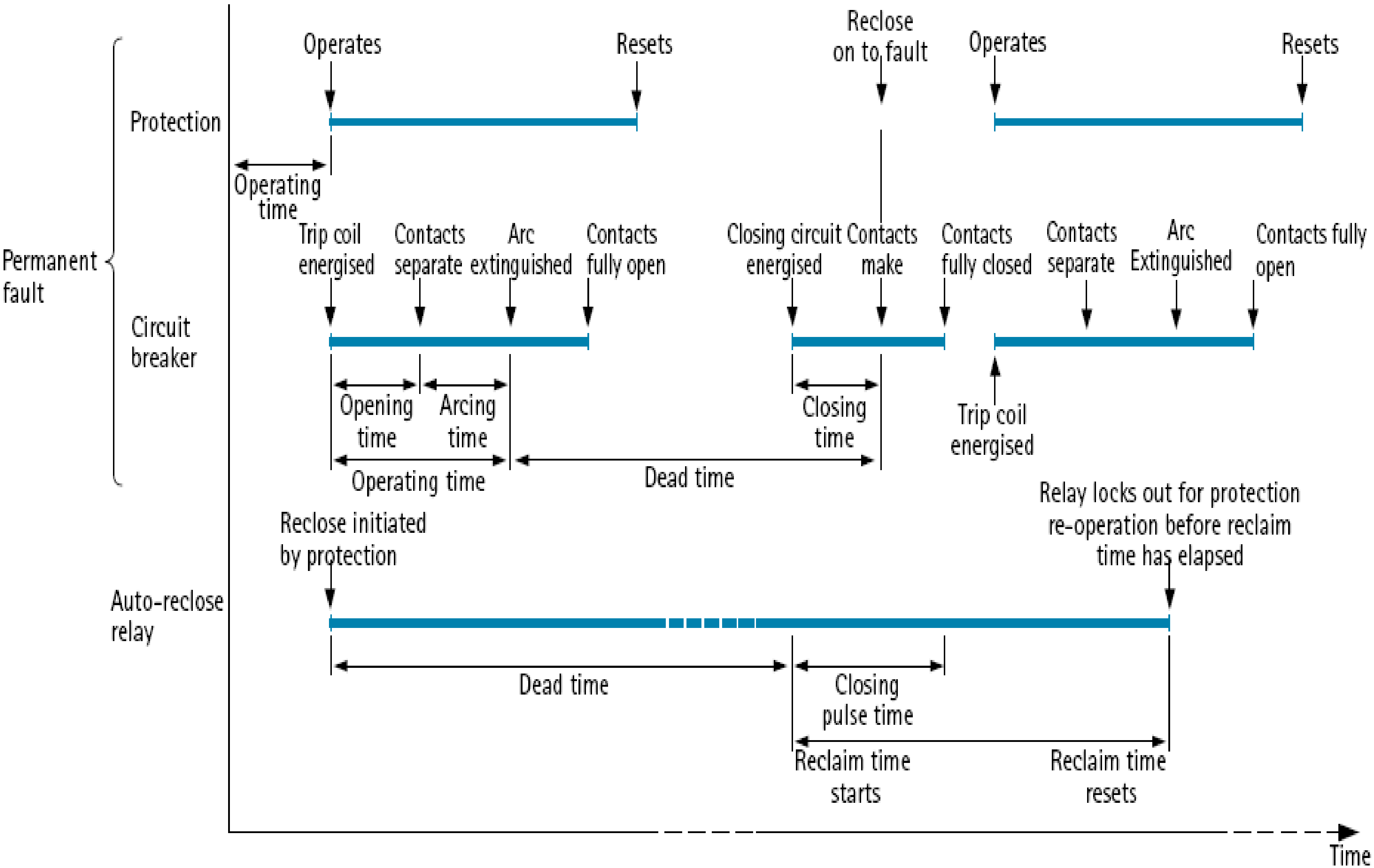
Auto-Reclose Terminology

High speed -	**C.B. reclose in less than 1 sec.**
Low speed (delayed) -	**Reclose after more than 1 sec.**
Repetitive scheme -	**Resets automatically after successful A/R**
Non-repetitive -	**Requires manual reset.**
Single shot -	**Only 1 reclose attempt / fault incidence**
Multi shot -	**2 or more reclose attempts**

Single-shot Auto-reclose Scheme Operation For A Transient Fault



Single-shot Auto-reclose Scheme Operation For A Permement Fault



Choice of Scheme

Need to consider :

- **Dead Time**
- **Reclaim Time**
- **Number of Shots**

Dead Time

Need to consider :

- **Load**
- **Circuit Breaker**
- **Protection Reset Time**
- **Fault De-ionization Time**
- **System Stability**
- **System Synchronism**

Dead Time – Circuit Breaker

- **Minimum dead time = mechanism reset + closing time**

  May be as high as 0.5 secs.

  Only significant for High Speed Auto-Reclose.

Dead Time - Load

Dead time has to be long enough to allow motor circuits to trip out on lost of supply.

Motors
- **Sync: Minimum 0.3 secs.**
- **Induction: not greater than 0.5 sec.**

Usually **3 - 10 secs. (to allow all motors to be disconnected)**

Street Lighting : **1 - 2 secs.**

Domestic : **10 secs - 3 minutes**

Dead Time – Protection Reset

- **Protection must fully reset during dead time.**
- **For high speed A/R :- Instantaneous reset required.**

Dead Time – Fault De-ionization

- Time for ionised air to disperse imposes minimum system dead time.

- Time required depends on :-
  - System voltage
  - Cause and nature of fault
  - Weather conditions
  - Fault clearance time

- Difficult to calculate accurately

  Approximately :-

De-ionising time	=	(10.5 + KV/34.5) cycles
For 66kV	=	0.25 secs. (50Hz)
	=	0.21 secs. (60Hz)
For 132kV	=	0.29 secs. (50Hz)
	=	0.24 secs. (60Hz)

- On distribution systems effect generally less important than C.B. operating times.

Fault Clearance Time

Minimised by :- **(i) Fast protection (< 30msec)**

eg. Distance
Pilot Wire

(ii) Fast circuit breakers

<50msec

Fast fault clearance reduces required fault arc de-ionising time

Reclaim Time

Requirement:- A/R relay should not reset before protection has had time to operate. (Following reclosure for a permanent fault).

Considerations:-

- Supply continuity
- Fault incidence / past experience
- Switchgear duty (rating)
- Switchgear maintenance

Reclaim Time for use with High Speed Protection

When high speed protection is used to clear all faults :

Reclaim Time < 1 sec adequate

but, rarely used in practice, to relieve the duty on the circuit breaker.

Reclaim Time < 5 secs
To relieve circuit breaker duty

Number of Shots (1)

Note:-   Shots = reclose attempts

Usually :-

Transmission	**1 shot**

Additional shots not justified due to :-

- **Maintenance**
- **System Disturbance**
- **Damage**

Sub-Transmission	**1 or 2 shots** **(2 or 3 if radial circuits)**
Distribution	**1, 2, 3 or 4 shots**

Single Shot or Multi-Shot?

One Shot Scheme

- Relatively provides greatest improvement in supply continuity.
- ~ 80% of faults are transient.
- Minimum trip duty on circuit breakers.
- Important when high frequency of circuit breaker maintenance required, eg. Oil C.B.

Circuit breaker duty cycle may prevent > 1 reclose attempt.

Multi-Shot Schemes

- **Improved supply continuity.**
  -- > justified for distribution A/R.

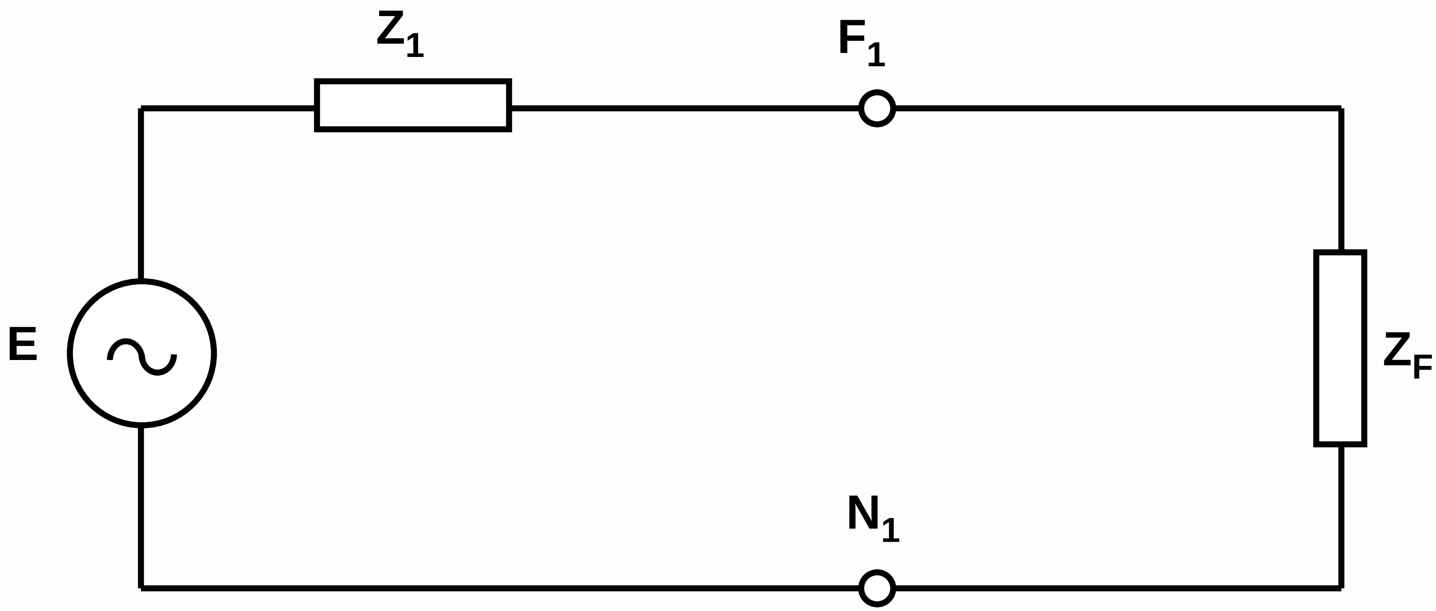
- **Helps prevent lockout due to successive flashovers during severe thunderstorms.**

Systems having relatively high levels of semi-permanent faults.

Inst Trip		
First shot A/R	**-**	**Unsuccessful**
IDMT trip	**-**	**Fault Burns Clear**
Second shot A/R	**-**	**Successful**

System Stability

Fault Shunts (1)



Z_F = Fault shunt

= Combined Impedance of -ve and zero sequence network impedances for particular fault.

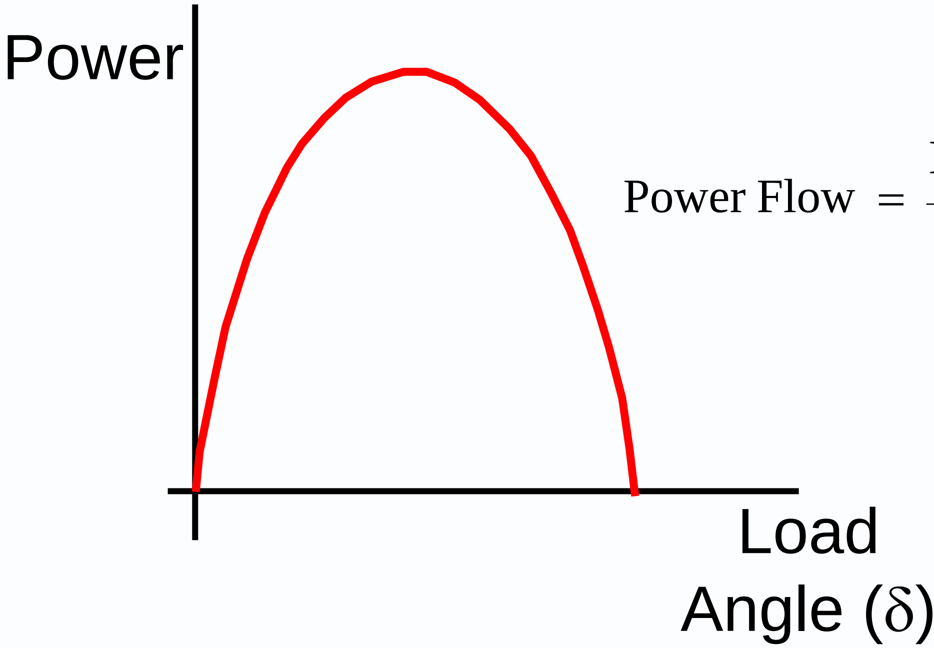
Fault Shunts (2)

Ø / E	$Z_F = Z_2 + Z_0$
Ø / Ø	$Z_F = Z_2$
Ø / Ø / E	$Z_F = \dfrac{Z_2 \cdot Z_0}{Z_2 + Z_0}$
3Ø	$Z_F = 0$ **(short circuit)**
Healthy	$Z_F = \propto$ **(open circuit)**

Power Angle Curves

A graph of P against δ, plotted from the above expression is known as a Power / Angle curve.

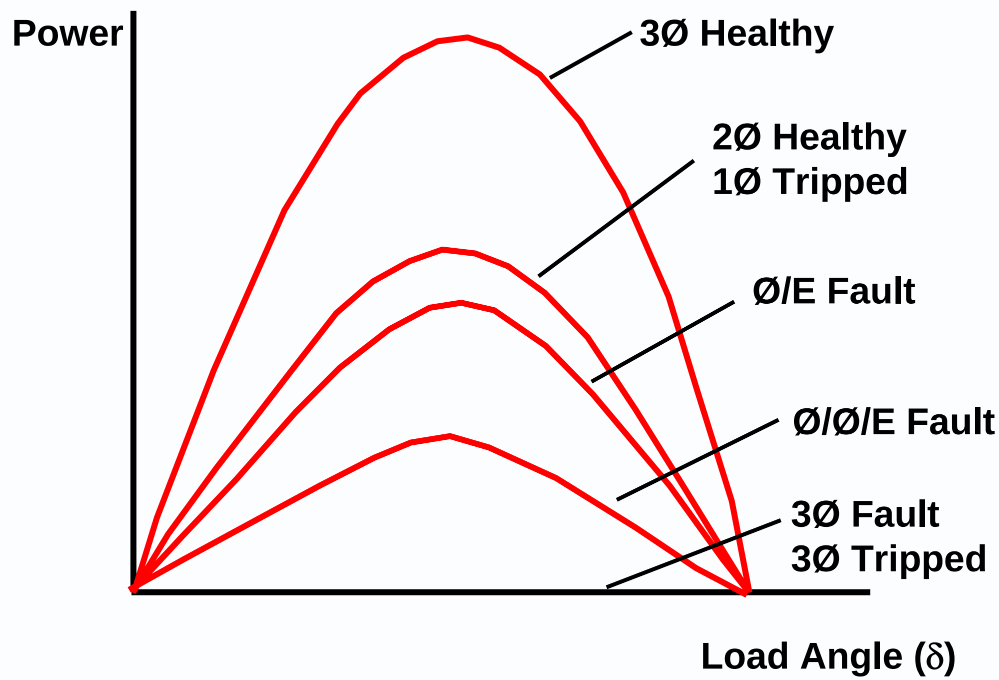
Its amplitude is inversely proportional to the transfer reactance, which in turn depends on system conditions.



$$\text{Power Flow} = \frac{E_1 E_2 \sin\delta}{X}$$

Comparative Power Angle Curves

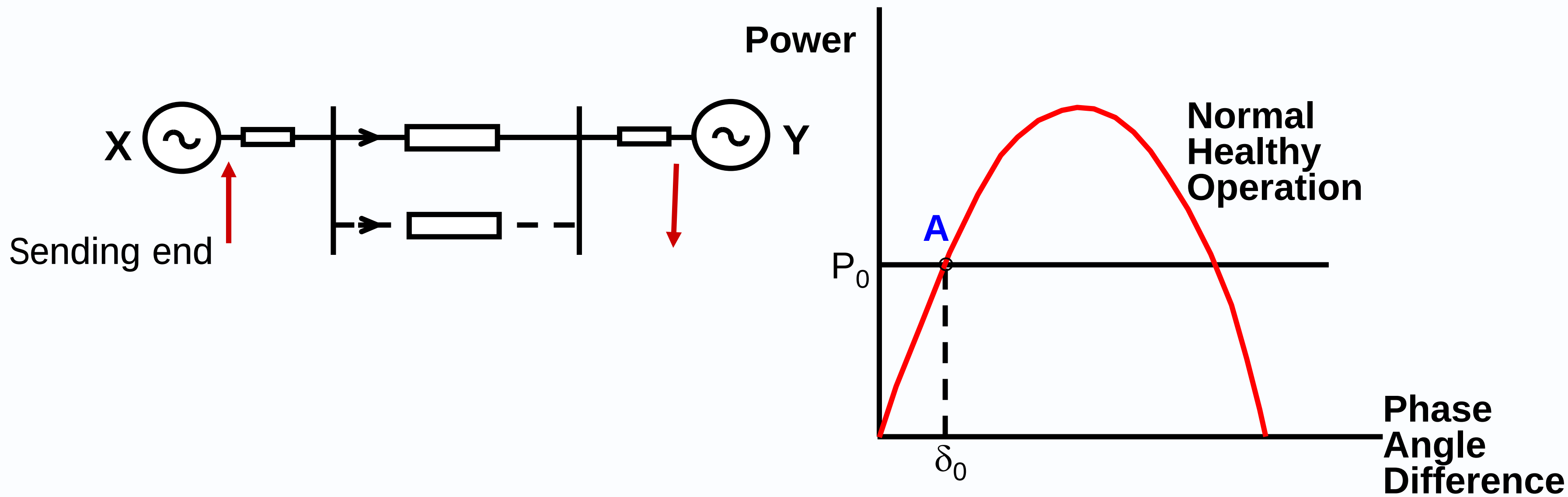
The effect of various system conditions, including different types of fault, can be estimated using the concept of interconnected positive, negative and zero sequence networks.



Steady State

Initial operating conditions are at point A on curve.

P_o represents the surplus of locally generated power at the sending end, and the corresponding deficit at the receiving end.

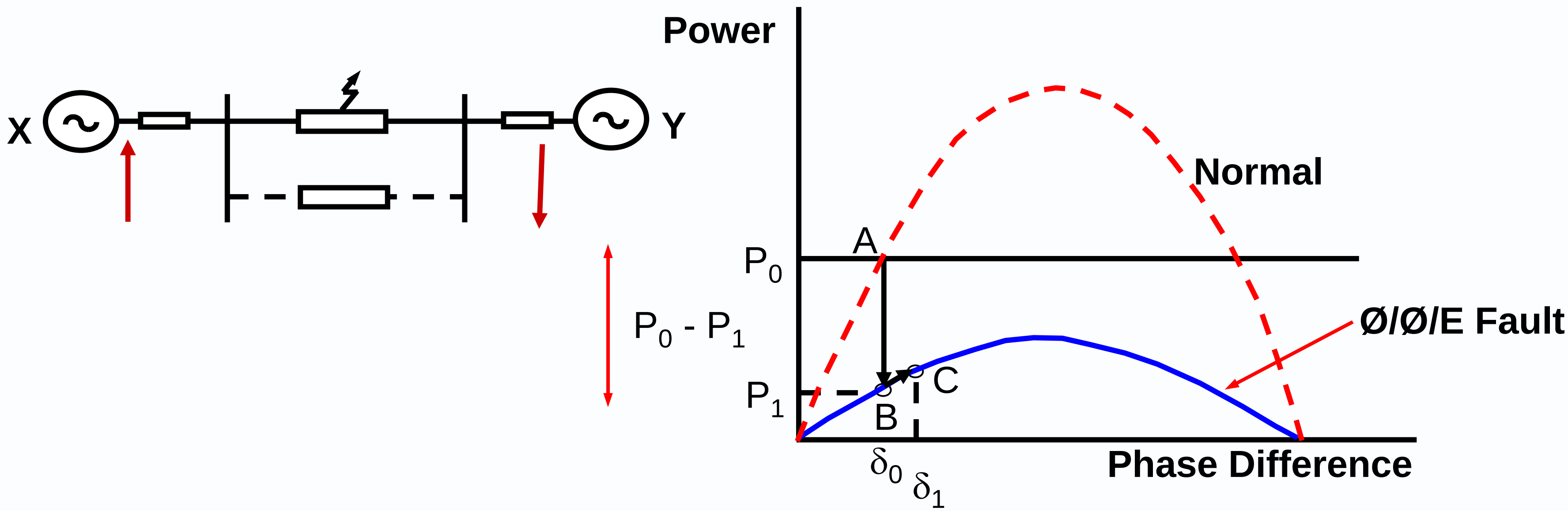


During Fault

If a fault occurs, curve 2 applies, the operating point moves to B, with a lower power transfer level P1.

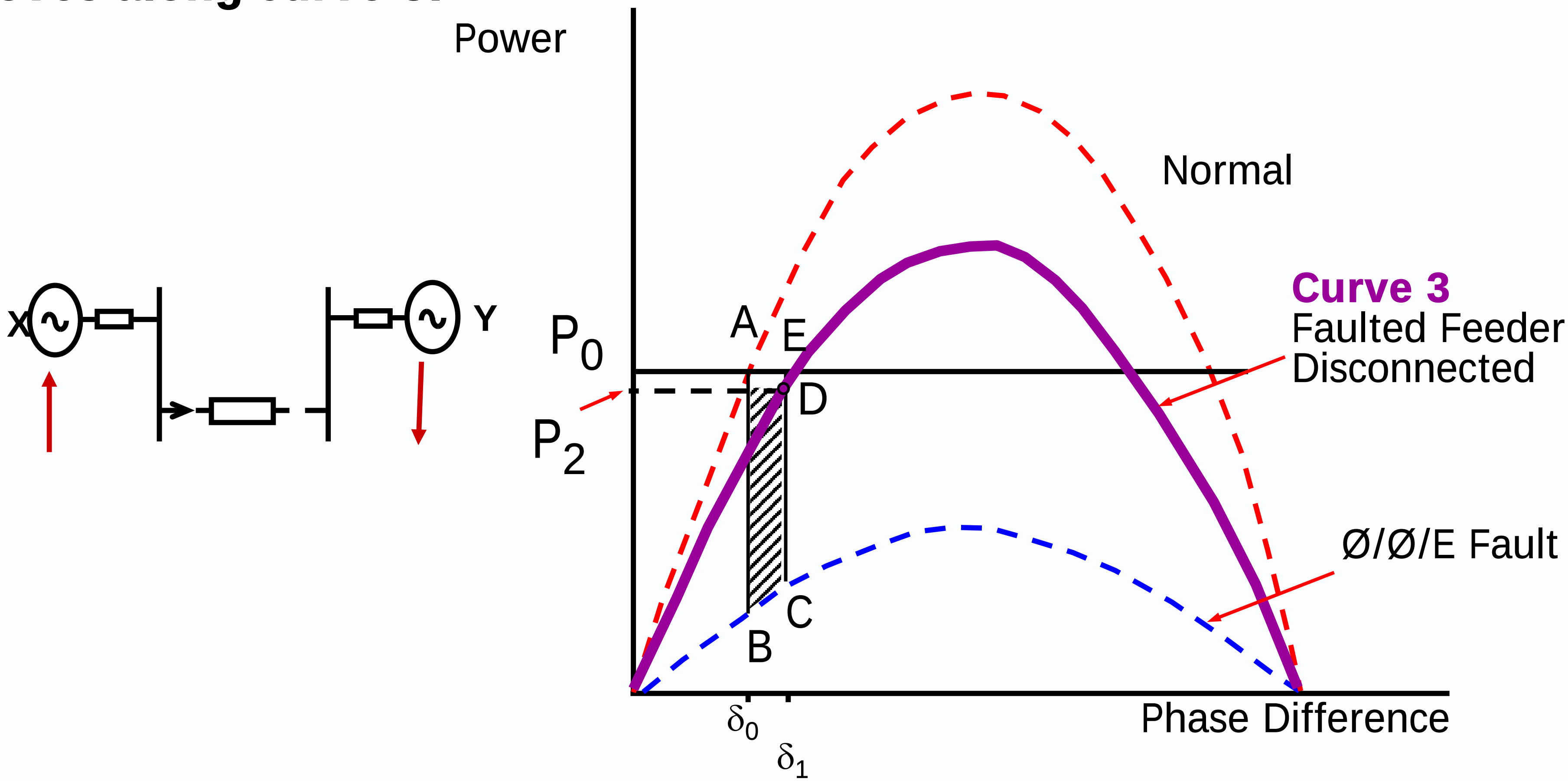
Therefore a surplus of power P0-P1 at the sending end, and a corresponding deficit at the receiving end.

The sending end machines start to speed up, and the receiving end machines start to slow down, so phase angle δ increases, and the operating point moves along curve 2 until the fault is cleared, when the phase angle is δ1.



Increased Power Level

The operating point now moves to point D on curve 3. There is still a power surplus at the sending end, and deficit at the receiving end, so the machines continue to drift apart and the operating point moves along curve 3.

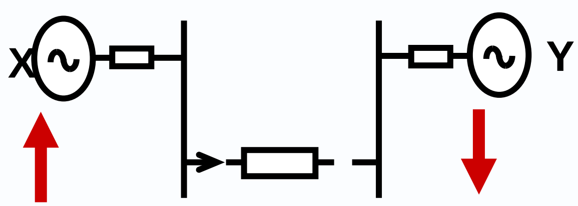


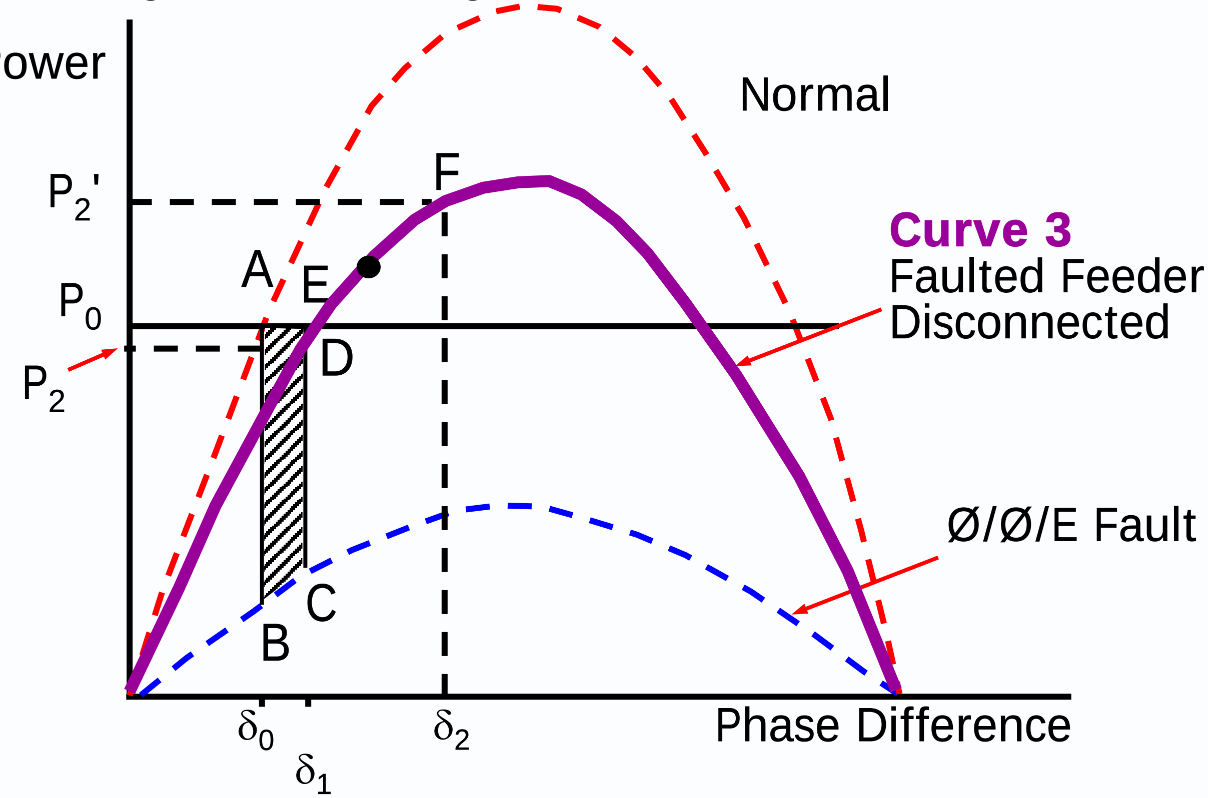
Increased Power Level

When operating point passes E, the transmitted power is more than generated sending end, so there is a nett deficit at the sending end and a nett surplus at the receiving end.

The sending end machines start to slow down and the receiving end machines start to speed up.

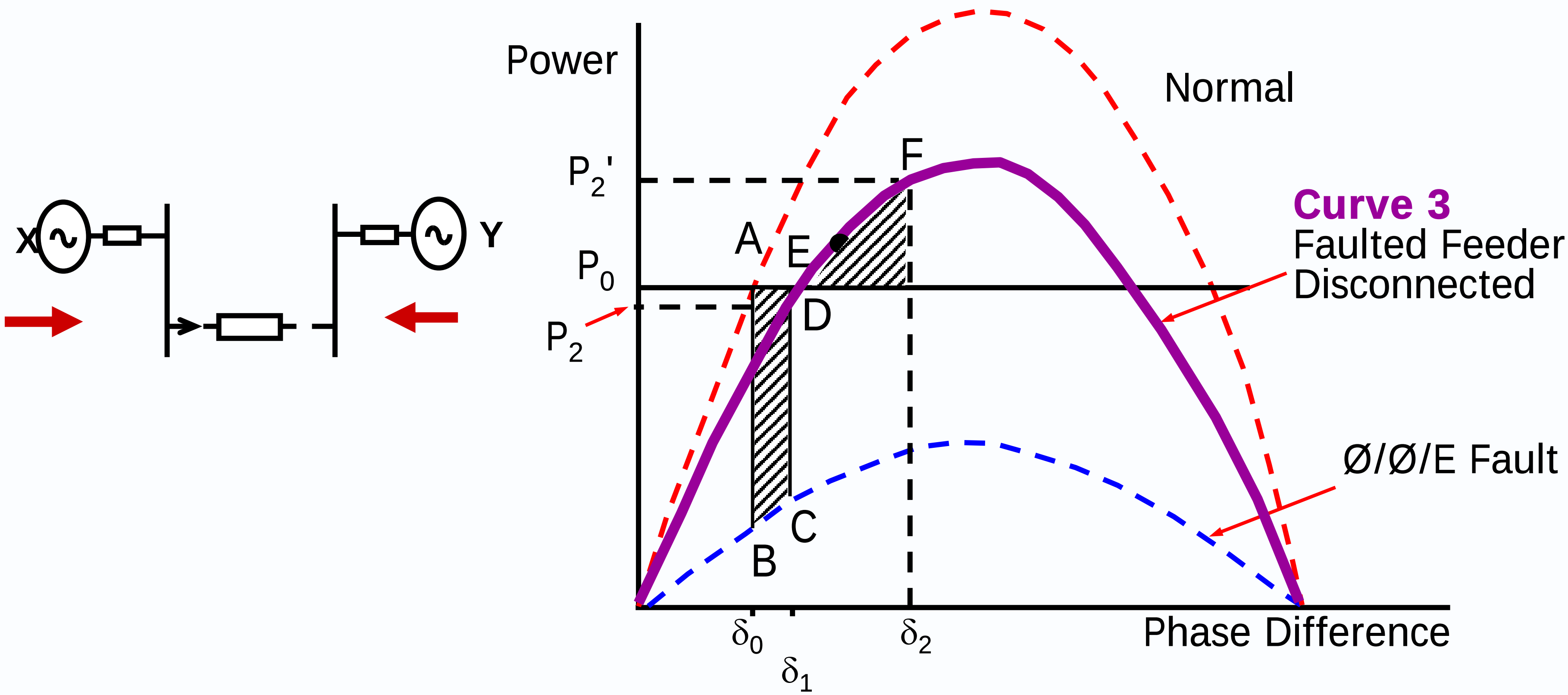
However, the sending end machines are still running faster than the receiving end, so the phase angle continues to increase, though at a decreasing rate.





Increased Power Level

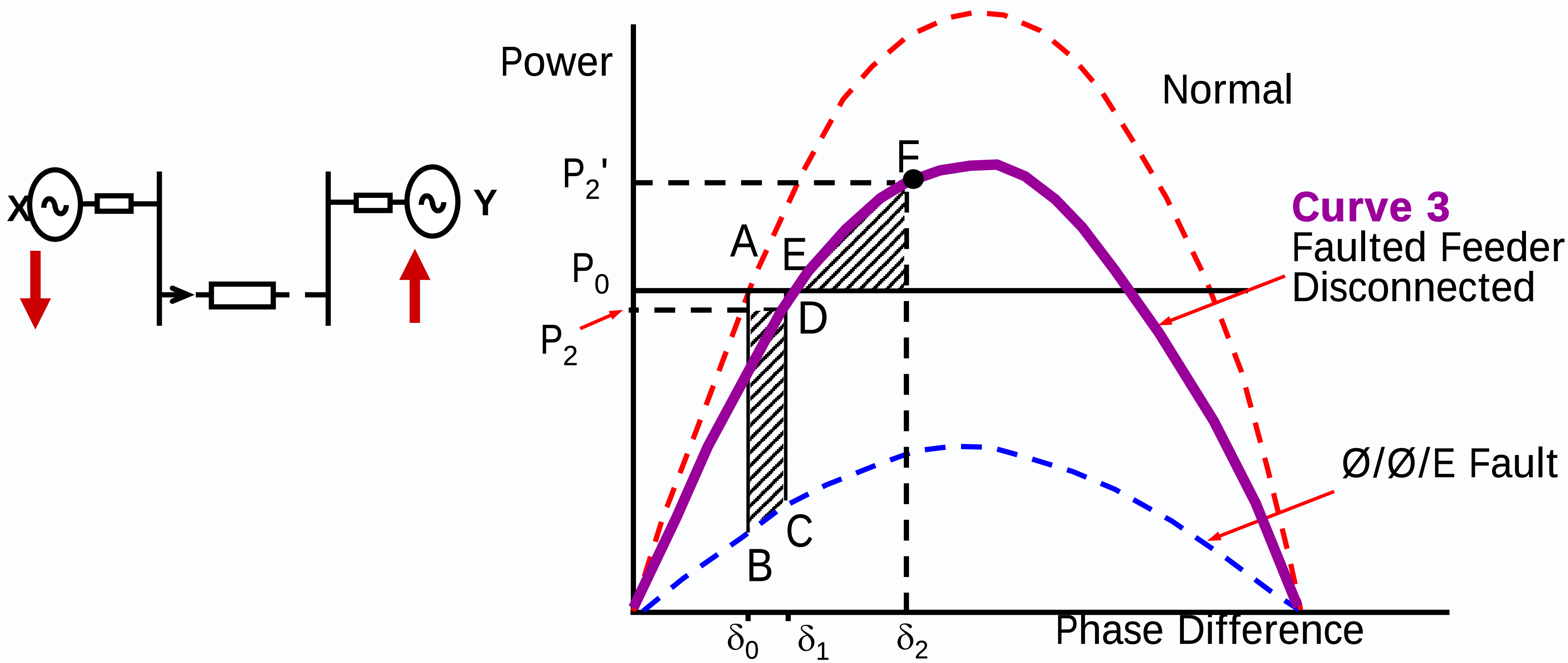
Eventually, at point F, the machines are again rotating at the same speed, so the phase angle stops increasing. According to the "Equal Area Criterion", this occurs when area 2 is equal to area 1.



Increased Power Level

At F there is still a nett sending end power deficit and receiving end power surplus, so the sending end machines continue to slow down, and the receiving end machines continue to speed up.

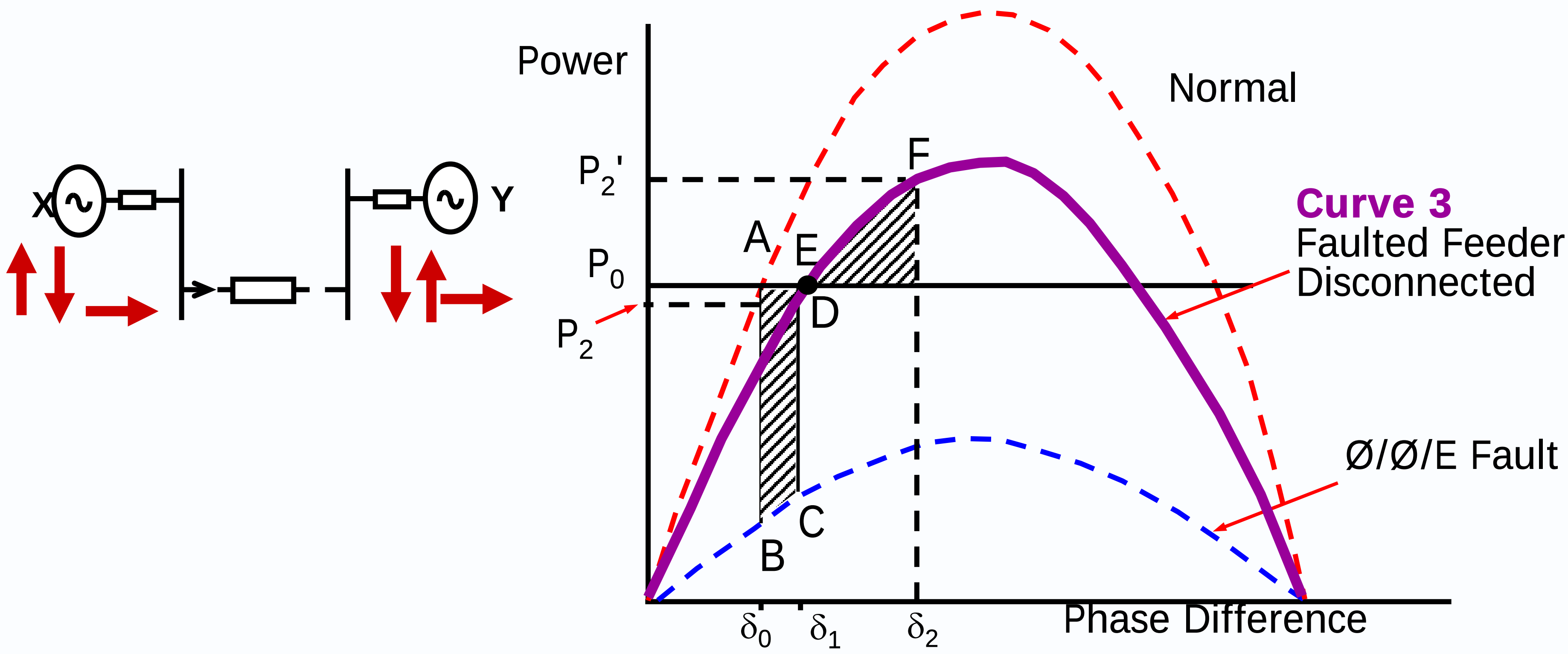
Phase angle starts to decrease, and the operating point moves back towards E.



Increased Power Level

As the operating point passes E, the nett sending end deficit again becomes a surplus, and the receiving end surplus becomes a deficit, so the sending end machines begin to speed up and the receiving end machines begin to slow down.

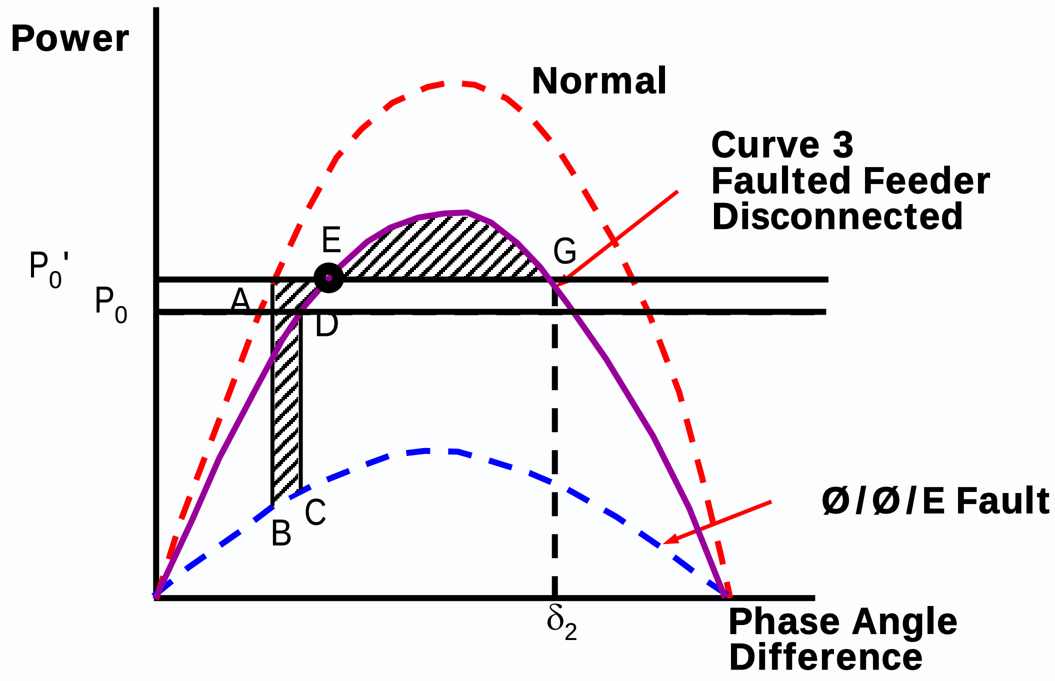
After some time, due to losses the oscillation is damped, and the system eventually settles at operating point E. The system is therefore stable



Equal Area Criteria

With higher initial power transfer level Po' at such a value that the area enclosed by curve 3 above the Po' line is only just greater than the area enclosed by the locus of the operating point below the Po' line.

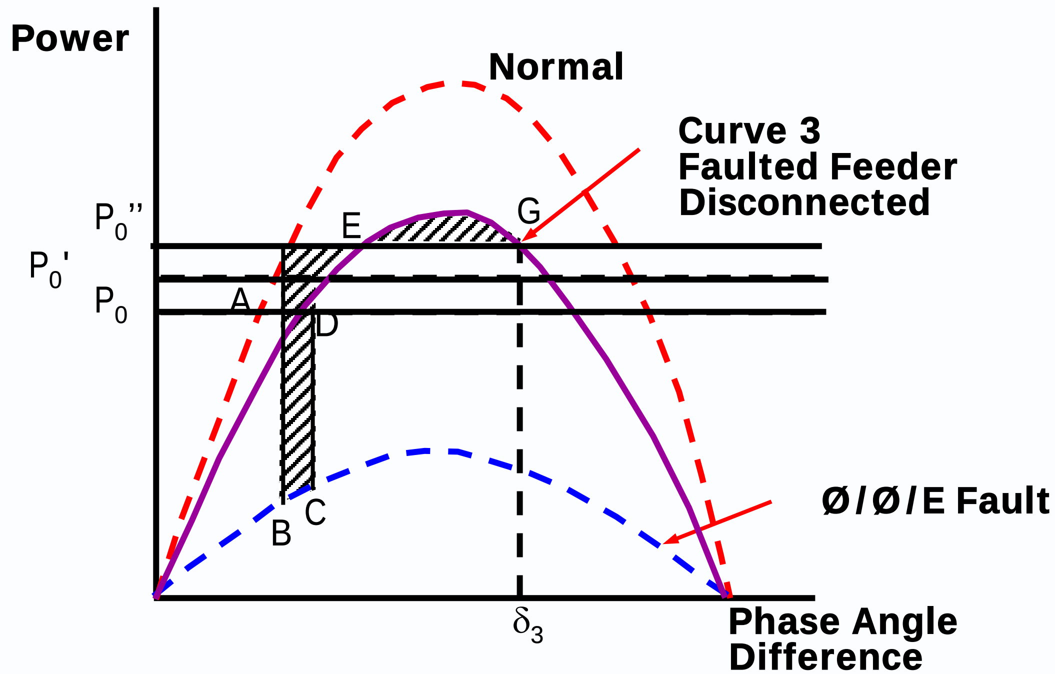
In this case, the two sets of machines have the same speed just before the operating point reaches G, and the operating point then starts to return along curve 3, with the system eventually settling to stable synchronous operation at point E.



Equal Area Criteria

If the initial power transfer level is above Po', the area enclosed by curve 3 above the Po'' line is less than the area enclosed by the locus of the operating point below the Po'' line, so when the operating point passes G, the phase angle difference is still increasing.

The local sending end power deficit becomes a surplus, causing the machines to speed up, and the local receiving end power surplus becomes a deficit, causing the machines to slow down; therefore the two sets of machines continue to drift out of synchronism and the system has become unstable.

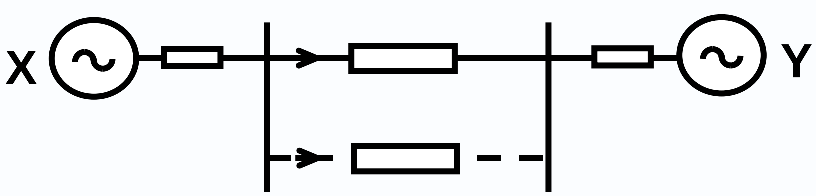


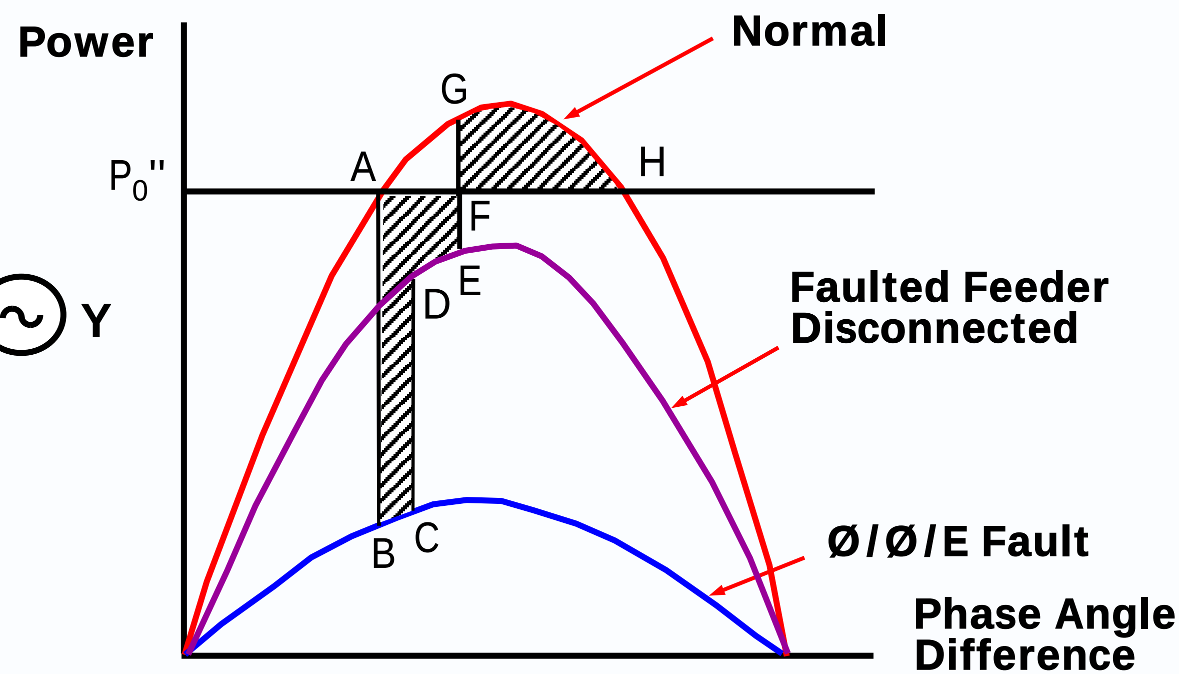
Transient Fault – Successful A/R

At higher power transfer level, it is assumed that after a certain time following fault clearance, the faulted feeder is successfully reclosed, restoring the system to its original healthy state, so curve 1 applies and the operating point moves from E to G.

The maximum level of Po'' for the system to have transient stability, is that value which will make area 2 on Figure 5 just greater than area 1.

it is clear that the application of high speed auto-reclosing enables the system to operate at a higher power level while retaining transient stability.



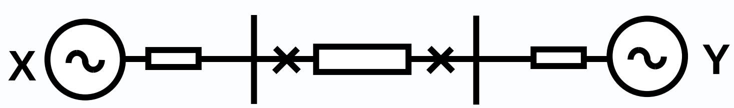


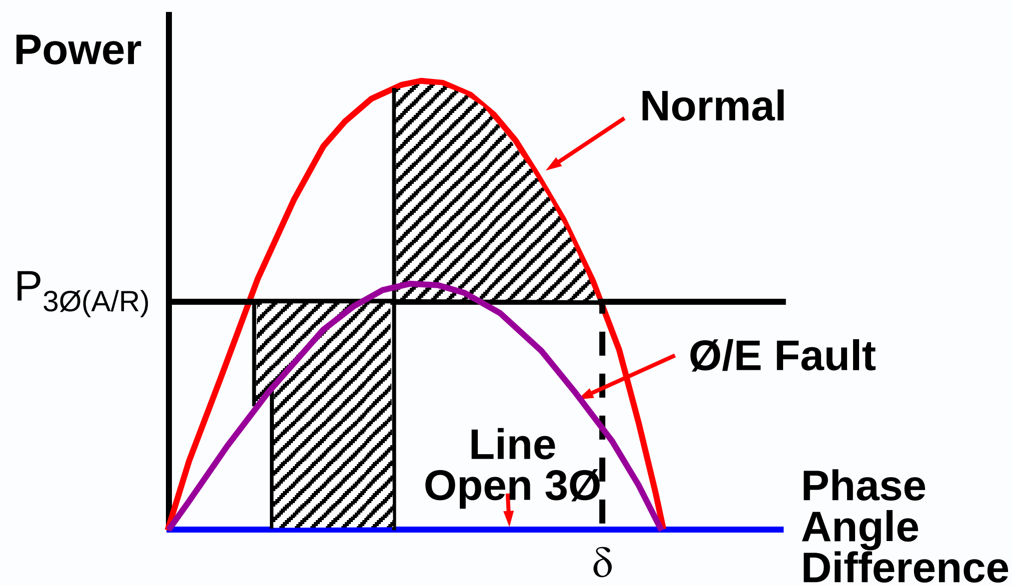
3ph or 1ph A/R

Single Feeder – 3ph A/R

For single circuit interconnector, the power transfer level is zero while the feeder is open, i.e. curve 3 lies along the 'δ' axis, and the limiting power transfer level for transient stability is zero if auto-reclosing is not applied.

The maximum limiting power transfer for transient stability for a particular fault will be obtained when the area enclosed by the locus of the operating point below the power transfer line is as small as possible. This may be achieved by clearing the fault as quickly as possible, and reclosing the circuit in a short a time as possible

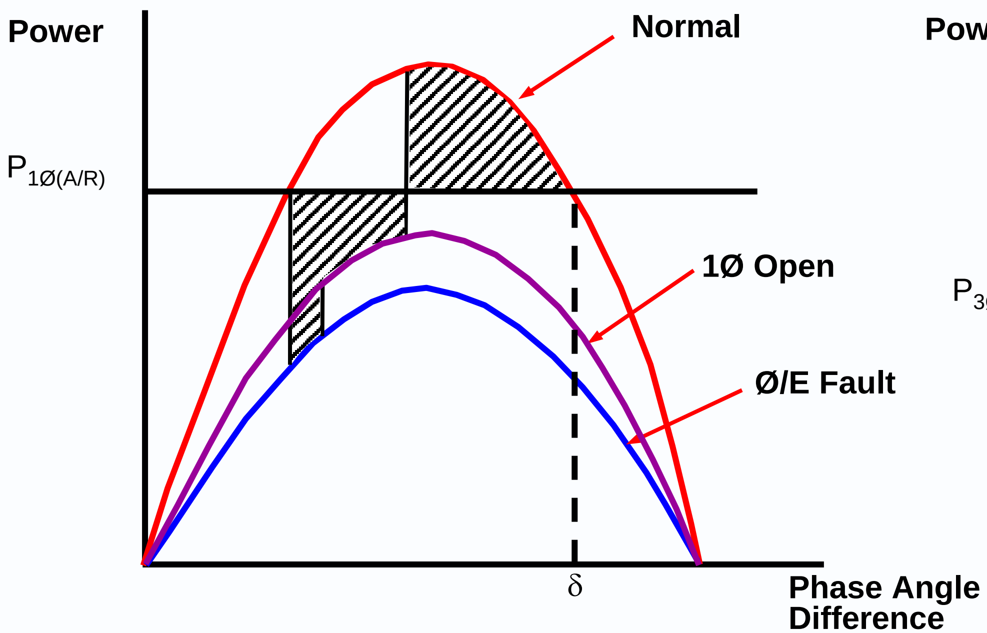




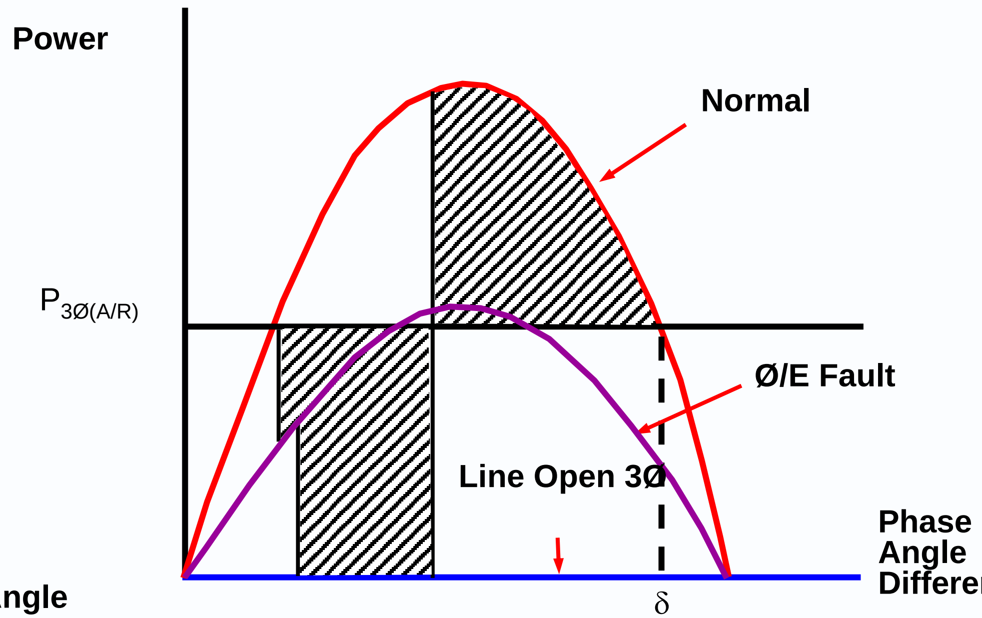
High Speed 1Ø A/R Single Interconnector

Power transfer is zero when all three poles of a single circuit interconnector are open. Fast three-pole tripping and auto-reclosing allows a substantial power transfer limit, while retaining transient stability for single phase to ground faults, which are the most common type of fault on overhead transmission circuits.

However, if only the faulted pole is tripped and then reclosed, a higher power transfer limit can be obtained, due to the power transfer through the two healthy poles. This is illustrated in Figures below.



Power transfer limit for stability following successful high speed 1Ø auto-reclose.



Power transfer limit for stability following successful 3Ø auto-reclose.

1Ø Auto-Reclose Advantages (over 3Ø A/R)

1. **Higher power transfer limit.**

2. **Reduced power swing amplitude.**

3. **Reduced switching overvoltages due to reclosing.**

4. **Reduced shock to generators.**
   Sudden changes in mechanical output are less

Choice of Scheme

Choice of Scheme (1)

High Speed Auto-Reclose

1. Single transmission links.

2. 3Ø A/R.

3. 1Ø A/R for 1Ø-E/Fs
   3Ø A/R for multiphase faults.

4. 1Ø A/R for 1Ø-E/Fs
   Lockout for multiphase faults.

Choice of Scheme (2)

Delayed 3Ø Auto-Reclose

1. Densely interconnected systems.

   ↓

   Minimal power transfer level reduction during dead time

2. Allow power swings due to fault and tripping to decay

   ↓

   Less shock to system than with high speed A/R

1Ø Auto-Reclose Factors Requiring Consideration

1. Separate control of circuit breaker poles.

2. Protection must provide phase selection.

3. Mutual coupling can prolong arcing and require de-ionising time.

4. Unbalance during dead time
   (i) Interference with communications
   (ii) Parallel feeder protection may maloperate

5. More complex and expensive than 3Ø A/R

High Speed Auto-Reclose (H.S.A.R.) (1)

Protection

High speed < 2 cycles

Fast clearance at each line end.

- Current Differential
- Distance schemes with signalling
- Direct intertrip

Phase selection required for 1Ø A/R – important of Fault Detector / Phase Selector element if using Distance Protection.

High Speed Auto-Reclose (H.S.A.R.) (2)

Dead Time (short as possible)

Circuit breaker minimum 'open - close' time

~ 200 - 300 msecs.

Same dead time at each line end.

De-ionising time

1Ø A/R longer → special steps

Delayed Auto-Reclosing (D.A.R.) (1)

Protection

High speed not critical for system stability

↓

desirable to limit fault damage

↓

improves probability of successful A/R

Dead Time

Allow for power swings and rotor oscillations to die down.

Different settings for opposite feeder ends.

Typically 5 to 60 secs.

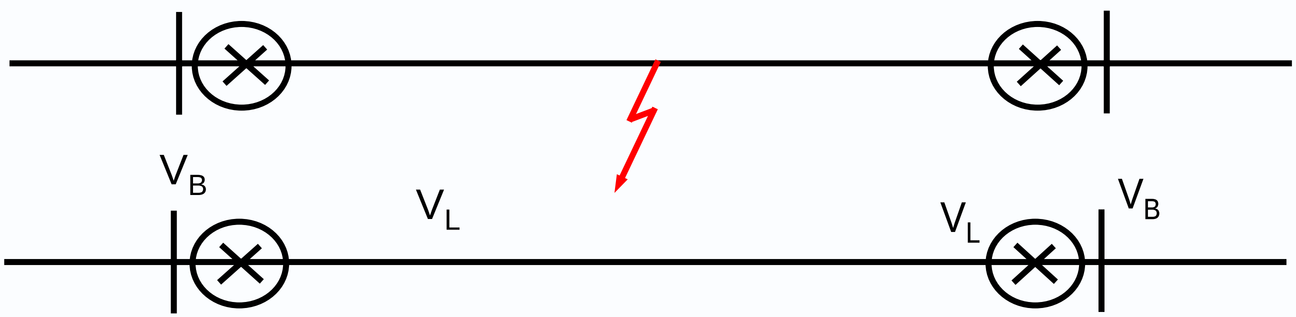
Synchronizing Check

Synchronism & Voltage Check

Radial single feeder, 3Ø tripping caused lost interconnection between both line ends. Re-closing require voltage check on the least dead time end and synchro check on the other end.

On interconnected systems - little chance of complete loss of synchronism after fault and disconnection of a single feeder.

Phase angle difference may change to cause unacceptable shock to system when line ends are re-connected.



VL = 0 | **Dead time = 3.0 sec.** | **Dead time = 3.5 sec.** | **VL = live**

VB = live | **VB = live**

∴ Dead Line Charge | **∴ Synch Check**

Check Synchronising

Used when system is non radial.

Check synch relay usually checks 3 things:

1) **Phase angle difference**
2) **Voltage**
3) **Frequency difference**