Redundant Supply with Bus Coupler

Automatic switchover of incoming supply with SIPROTEC 7SJ62

1. Introduction

Liberalized energy markets are demanding new solutions for the operation of electrical systems. This publication describes an application in which the availability of power supply of a switchgear or plant can be improved considerably by switching over from a faulty to a redundant incoming supply. The influence of external system faults is minimized decisively by fast disconnection of faulty system parts and switchover from a faulty to a trouble-free infeed. These automation tasks can be accomplished today with modern SIPROTEC protection relays without the need for further equipment.

2. Influential variables of system availability

"Power Quality" covers all the properties of an electrical power supply. Power quality can be further subdivided into "voltage quality and system reliability" as shown in Fig. 2. The latter is closely linked with an "adequate" power supply and the security of the supply. Only the system reliability is looked at in detail below.

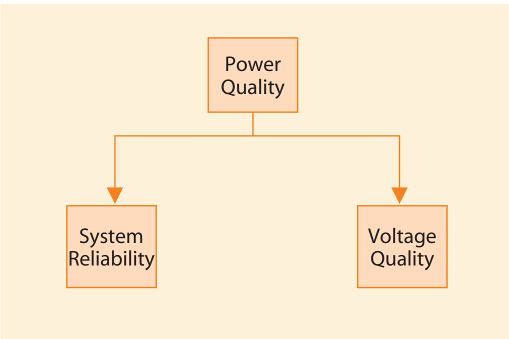

Fig. 2 Subdivision of Power Quality

Fig. 1 SIVACON 400 V, with 7SJ62-protected and controlled circuit-breakers

The reliability of an electrical system is determined by a number of factors. These include the reliability of every single item of equipment, the kind and method of connection of the equipment, i.e. the system topology, the properties of the protection relays, the remote control equipment, the dimensioning of the equipment, the method of operation including troubleshooting, and the system load capacity. The most frequently applied qualitative criterion in power system planning is (n-1), with which a system can be checked for sufficient redundancy.

It requires that the system must be able to survive failure of any item of equipment without impermissible restriction of its function. The (n-1) criterion is a pragmatic and easy-to-handle basis for decision but has the disadvantage that the supply reliability cannot be quantified. Frequency, duration and scope of interruptions in the supply are not measured, with the result that it is not possible (for example) to distinguish between different (n-1)-safe system variants in terms of reliability. Quantitative methods of system reliability analysis allow further evaluation of planning and operating variants supplementary to the qualitative methods. The supply quality is quantified by suitable parameters and thus enables a comparative assessment of different (n-1) reliable planning and operation variants (for example). This allows a specific estimate of the costs and benefits of individual solutions in system planning and operation.

Switchover with redundant incoming feeders means investment. However, by considering the behavior in case of outages of equipment, the system topology, the protection concepts, the system capacity utilization (supply and loads) and the method of operation, even more reliable and safe system operation can be ensured. The aim is overall system reliability, expressed in terms of a high degree of supply availability for special customers with sensitive processes. Closer analyses by way of the load cycle of individual feeders or transformer stations – as well as permanent rationalization measures in operation of the power systems – also call for a higher degree of automation in all power system sections.

2.1 Transient voltage sags and outages

The most frequent cause of system faults and internal voltage sags or outages (total failures) is a lightning strike. As Fig. 3 shows, the system fault may be in the transmission system or in the distribution system.
Usually there is no total blackout but the remaining residual voltage is greater than 70 %.

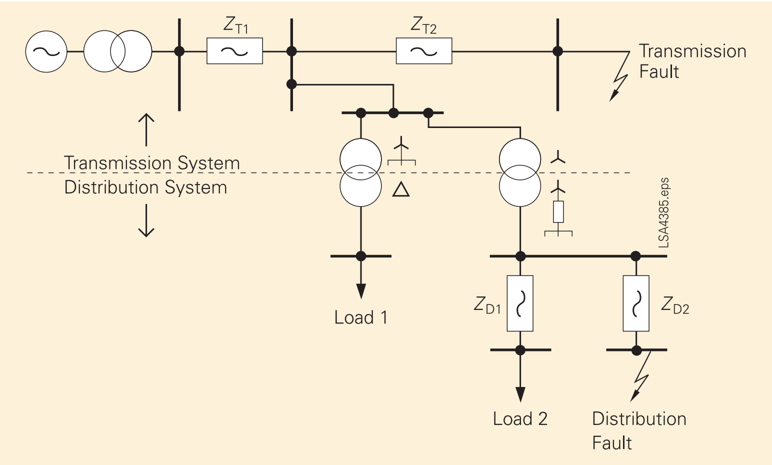

Fig. 3 Possible locations of system faults

The economic damage caused by sags or outages is immense (Fig. 4). The following Fig. 5 shows computer loads can fail already when the system amplitude deviates from its rating for less than one period. This so-called ITI/CBEMA curve is used worldwide as a reference for the sensitivity of other load types too, because the appropriate manufacturer data are often unavailable. The difficulty in protecting a highly automated factory is largely attributable to the large number of loads and the degree of networking of these loads.

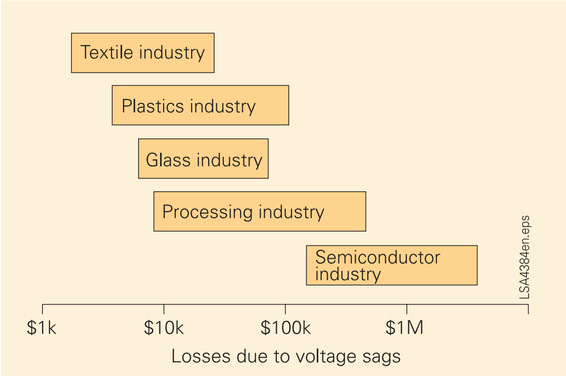

Fig. 4 Typical failure costs per voltage sags

3. Functional principle and aim of automatic switchover

A traditional method for a utility to solve its power quality problems is information from customers about supply limitations suffered. With the multifunction protection relays presented below it is possible to find solutions for protecting whole areas from outages by means of protection relays with integrated automatic functions.

Automatic switchover is suitable for disconnecting an endangered supply and quickly bringing in a redundant, secure supply with the aid of an alternative incoming feeder. A fault is detected by an undervoltage detection function. Using a directional overcurrent detection function, it can be decided whether the fault is external or internal. In the event of an external fault, switchover to the alternative incoming feeder takes place. However, if the fault is internal there is no switchover, with the intention that the fault can be cleared by available circuit-breakers.

Switchover to the alternative incoming feeder or the coupling of separated networks only takes place instantaneously when both separated networks are synchronized. Otherwise it waits until synchro- nicity between the two separated networks is established or the voltage has dropped to such an extent that safe connection is possible. However this is only on condition that the two incoming feeders are not impaired in their voltage quality by the same system fault, such that switchover provides no protection against load shedding.

In the case of rapid system decoupling (opening the circuit-breaker in the faulty incoming feeder) it can be assumed that the fault current has a higher displacement than in normal switching. This should be taken into account in the choice of circuit-breakers. The system configuration and the specific requirements regarding switching time must therefore be analyzed before choosing the suitable rapid switchover.

The following typical applications are particularly conceivable:

1. Switchover from one redundant incoming feeder to the next to protect loads from voltage outages
2. System decoupling in the event of a fault on the load side and therefore prevention of the fault from affecting other loads.

3.1 Practical principle

The SIPROTEC relays attend to full protection of the incoming feeders by means of directional overcurrent-time protection.

Configuration instructions for protection of the incoming feeders are not dealt with in detail here.

Automatic switchover is implemented by at least two autarchic SIPROTEC 4 relays (e.g. 7SJ62) which can be adapted individually to the design and basic conditions applying in a customer specification, in combination with the existing switchgear.

The following switchover possibilities can be distinguished here:

- Overlap switchover
  Both circuit-breakers are actuated almost simultaneously
- Rapid switchover
  Circuit-breaker 1 is opened and circuit-breaker 2 closed as long as the voltage is below ΔU – motor rundown behavior is taken into account
- Slow switchover
  Motors must have run down, or else be switched back on as from a certain residual voltage, the reason being high start-up current of the motor groups; this possibility should be rare.

3.2 Description

The desired configuration can be selected as "normal operation" with the preselector switch S100. The selected circuit-breaker remains defined as "normally OPEN". This open circuit-breaker is considered as a backup in the event of a fault which can then supply the faulty, disconnected busbar section with energy again. Each circuit-breaker operates autarchically and is controlled by one single multifunction relay.

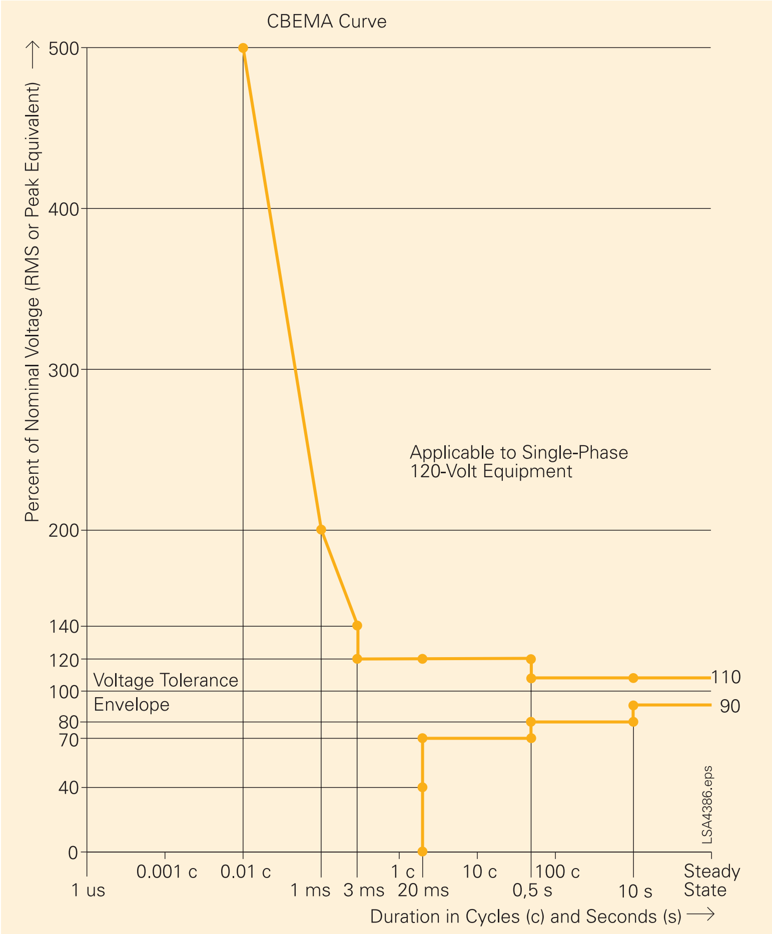

Fig. 5 ITI/CBEMA curve

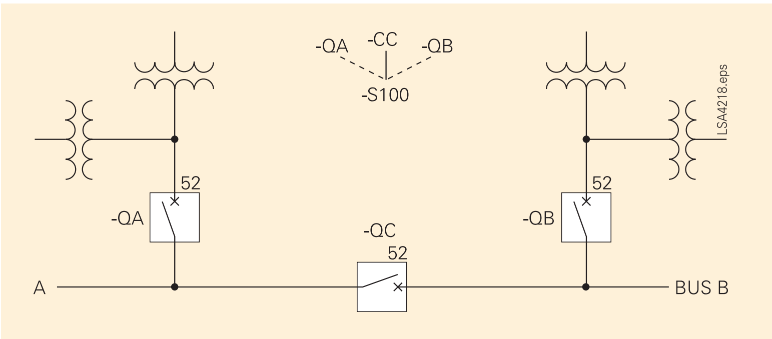

Fig. 6 Bay layout

The relays are interconnected by binary signal communication between the binary inputs and outputs. In this way every relay can communicate with the other two relays and exchange information about circuit-breaker position and protection functions.

Therefore it is possible to create self-controlling automatism also allowing manual control from the outside. When connecting, the synchro-check can be performed by the multifunction relays (7SJ64) themselves or by a separate synchro-check device.

a) In the event of undervoltage and breaker failure from subordinate feeders or from the parallel incoming supply, the circuit-breakers are tripped individually by any protective pickup.

b) If the protection has picked up due to a fault outside the switchgear or plant, or the supply voltage drops although there is no short-circuit/earth fault, the parallel incoming feeder is granted release (release of infeed B) to close.

c) If the disconnector is closed in the trouble-free incoming feeder and the parallel supply is released (2 releases), the circuit-breaker is closed, either at synchronicity or if there is no voltage on the busbar. Disconnection of the faulty incoming feeder and switch-in of the substitute incoming feeder can be coordinated by the timer T1 (overlap time).

   By setting the post-fault time with timer T2, the maximum permissible time interval is specified which may pass between connection and the last satisfied synchronization condition.

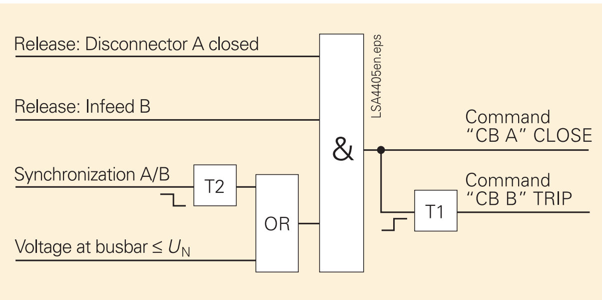

Fig. 7 Logic example for input field A

d) If the circuit-breaker in the faulty incoming feeder has not opened properly, the circuit-breaker in the substitute incoming feeder will be reclosed by the breaker failure protection.

This configuration was installed in the plant of a petrochemical industry customer and has been operating reliably since 2002.

The principle has proven so reliable that it is used in all the busbars there, from the 400 V switchgear through 6.6 kV right up to the 33 kV level.

Fig. 8 Air-insulated switchgear 8BK, 6.6 kV, with 7SJ63-protected and controlled circuit-breakers

4. Summary

Multifunction relays which also assume control and protection duties for the switchgear or plant are highly attractive due to their greater flexibility. There is considerable interest in solutions for protection against outages that would otherwise bring whole factories to a standstill. Therefore this solution has the potential for use in both the low and the medium-voltage sector.

Automatic switchover based exclusively on SIPROTEC 4 relays represents an attractive alternative to existing products in terms of both investment volume and engineering effort. The necessary functions are available. The integrated logic can be used to great advantage for the parameterization (by means of a CFC logic editor) of automatic switchover in the relays.