

Essential supplies: replacing the weak link .

Jeff Rodbard.

In this article the author describes a proven high reliability system for operating the changeover from mains to generator power.

Time is money. This truism is particularly significant in the case of financial organisations. For these businesses, a failure of electrical power can create a nightmare scenario where literally millions of pounds can be lost in a matter of seconds. It is for this reason that the essential computer equipment used by financial institutions is run from UPS power, avoiding any immediate disaster if a mains failure occurs. However, the power input to the UPS units must be reinstated from an alternative source well within the discharge time of the batteries. Although more than one generator may be installed to increase reliability of the alternative supply, the availability of this power then hinges on the correct operation of the change-over switch system. A chain is only as strong as its weakest link, and in the standard type of circuit used at present, the failure of one device,

been installed retrospectively in a large City building, housing both management and dealer floors of a major bank, together with other high-level businesses. Not only is the system operating fully to specification, but it was installed without disruption or complaint from any of these tenants.

The problem

Where UPS systems are provided to maintain essential supplies such as computer facilities for dealer floors, there are limitations on the space available to store battery power, particularly in a high-rent city area. In most cases the UPS batteries cannot support the load unaided for more than an hour at best, so if the mains fail and any generator supply problem arises, dealers must commence shutting down to avoid a financial calamity.

Where two or more generators are installed in a bid to ensure that at least some generator power is available, two problems still remain:

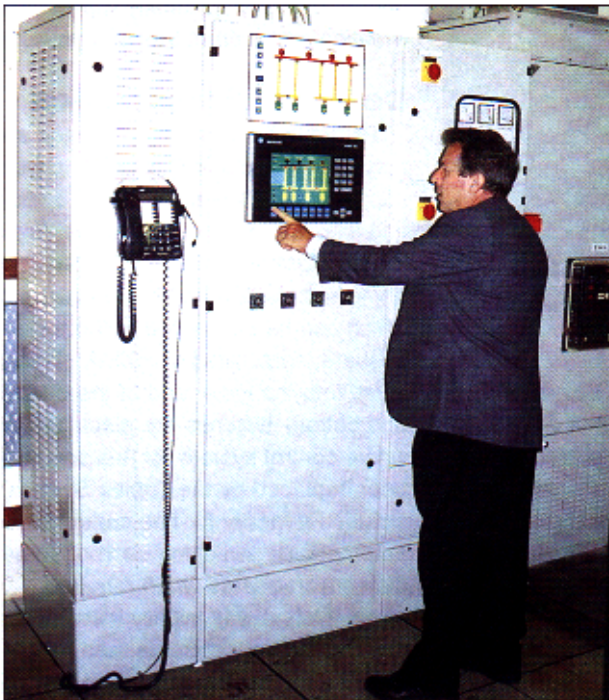
- i) Should the change-over circuit fail in any way, generator power cannot be used, however many generators are installed.
- ii) Where one generator of a pair or more fails when in use, some pre-determined amount of load must be shed reliably and quickly; any problem here can cause loss of the remaining generator power due to overload.

In either event, the chances of being able to successfully diagnose the problem, then correct the fault or replace the faulty component, all within the life of the UPS batteries, are very low. Indeed, in the centre of a major city, it is unlikely that a specialist with sufficient knowledge of the system could even reach the building within that time.

In addition, for many existing buildings, undervoltage interlocks are used to ensure that mains and generator inputs cannot be closed together, and here a fault in this circuit alone can prevent use of even the mains supply, should it return meanwhile.

Once a 'dead building' scenario exists, rectification of the problem is even more difficult and protracted, during which time not only is there a very serious loss of facilities for tenants, but major fire and safety issues are also raised. Types of fault that can cause the events described, even with a simple system, are:

- Faults on Phase Failure Relays
- Loss of supply to the control circuit
- Earth or short circuit fault on the control circuit
- Failure of a relay or timer.



building status

a bad connection, or just the blowing of one small fuse, can cause total loss of supply to the entire building and the consequent financial disaster.

To preclude this situation, Triplex Power Control (TPC) has designed and developed an alternative system, similar in many ways to that used in aircraft, where the occurrence of any one fault has no effect on the correct operation of the circuit overall. This TPC system has

Eliminating the problem

Triplex Power Control (TPC) is a company whose sole activity is to design and install high reliability systems to control alternative building supplies, which still operate correctly even if one of the above faults should occur. This is achieved by the use of triplicated circuitry that produces a "two-out-of-three" priority system, such that any one fault on a power supply, any component, or one part of the wiring, has no effect at all on the correct operation of the circuit. This fundamental approach has been used on aircraft since the mid sixties, but is



Main Triplex panel at lower level; 3DC supplies on right hand side, battery section on the left.

adapted by TPC, and in many ways simplified to suit the present application.

It follows that any single first fault must be made clearly apparent by other means, although it does not affect correct operation overall, because a second fault in the same area would of course cause a problem. The TPC fault diagnostics system is generally a dedicated PLC, wherein all inputs used are of high impedance, and routed via resistors so that the PLC system can never affect the main circuits. Any fault within the diagnostics system itself will also indicate a fault. Any first fault detected can be readily verified and located, and then corrected at a convenient time to reinstate the full Triplex integrity of the system. For this fault diagnosis and its subsequent correction, the main differences, apart from the level of complication, between a building triplex system and normal aircraft triplex systems are:

- Aircraft systems must deal with analogue signals, e.g. control surface movements, altitude etc.,

whereas switching systems in buildings are digital, i.e. power on or off, or a value above or below a pre-set threshold.

- Aircraft systems are designed for correction of faults after landing, during non-active operation, whereas TPC designs the circuit and layout to enable most fault corrections to be possible without shutdown.

The TPC control system in practice

The TPC control circuits consist of conventional hard-wired relays, timers, and phase failure relays, but triplicated, and powered by three separate DC supplies. This does not necessarily mean an increase in components; careful design on the large building referred to later in this article produced a lower (Triplex) component count after conversion than for the original single-wired circuits. The fault diagnostic system monitors each of the three "channels" of the system at various points, looking for any differences that may be present at one point compared with the two similar points of the other channels, and also monitors the control circuit supplies. If an operating fault is detected by the system, it then operates an alarm, and indicates the type of fault and the area wherein it is located. This information, together with the status of all power supplies in the building, is graphically displayed on screens in any locations required. The fault can be corrected when it is convenient to do so, and without the supply being affected at any time. Moreover, if a low voltage DC is used for the control circuits, components can be replaced without danger whilst the supply is operational, and generally without the need for isolation and a permit-to-work system.

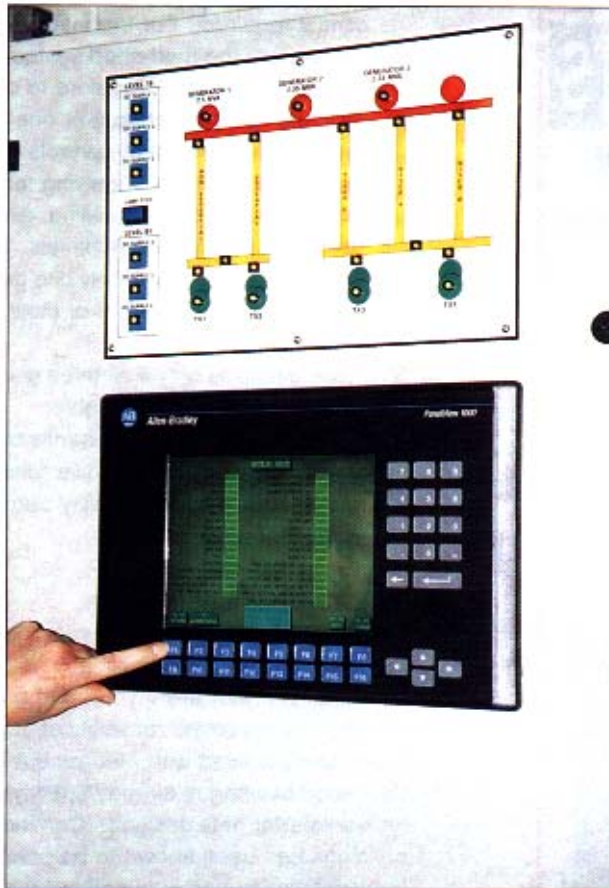
Design and installation

TPC have successfully designed and installed such a system in a major City building with a total available supply of 8MVA, and occupied by companies with financial operations, including a major dealer facility of Chase Manhattan Bank. This building has one 2.5 MVA and two 2.35 MVA generators at high level, which can be connected to the top of five rising busbars, each rated at 3000A. Normal mains supply is fed into the lower end of the busbars, and the top and bottom switches are electrically interlocked. The whole control system for this arrangement has now been replaced by the Triplex System, which also includes a facility for fine control of load shedding by automatically switching each of some 47 floor distribution boards when required.

This system was initially installed without connection to the main switchboards, and before any change or interruption was made to the LV supply. After testing and proving of the new boards and wiring, final active conversion to the new circuitry was achieved over just one weekend.

This is possible for any building by splitting the conversion into the following stages:

- a) Design study and load analysis.



Hard-wired Mimic (top) and fault diagnostic screen (lower)

dummy ACBs. These units are specially designed and constructed by TPC, and use the same operating coils as the real ACBs in the building. Although small and portable, they can be shown to operate mechanically and electrically in the same way as the actual units, although the main contacts are represented on each unit by a simple microswitch.

c) The model is used to check that the circuit operates correctly when one of the three power supplies is failed, and also when any one component of the entire circuit is failed in various ways. This can be demonstrated to all interested parties.

d) The model is used to demonstrate and prove that replacement of components is possible without problems when operating normally.

e) Construction and installation of control panels and interwiring is then carried out. In the case of the building mentioned, the cables were split into three groups, each routed differently. Since the routes from basement switchboards to generator boards on level 18 were close to 100 metres long, this was a difficult task, involving removal and replacement of both ceiling components and fire barriers, and often following awkward routes. Using highly experienced contractors, this was achieved without complaint from any occupant. The reason for using three different routes is that if any one group of cables is damaged, or completely severed, by fire or other damage, the system can be made to operate simply by isolating that group of cables.

Although the Triplex reliability would not be regained until the affected wiring is replaced, normal operation could be available meanwhile.

f) The entire installed Triplex system is then tested and proven, by using hand-operated switches to represent Phase-failure relays and generator running signals, connected to the new building wiring and panels. The dummy ACBs are still used, this time mounting them in front of the existing mains switchboards, each dummy ACB mounted directly in front of the actual ACB it represents. By this means all new wiring, components and connections can be verified as correct and ready for the building conversion, without any disturbance to power supplies.

g) For the final conversion over one weekend, the main transformers are shut off, the existing ACB control wiring disconnected, and the new wiring moved from the dummies to the actual ACBs. The PFRs on the mains and generator supplies are connected, and mains restored using the new system. The old wiring can be removed during a future shutdown.

h) If a closely controlled load shed system is included, this can be made active over subsequent weekends, according to the type of control required. For the building previously mentioned, the load-shed system is also fully Triplex, and is able therefore to operate correctly with one component fault or one total power failure. This load shed system controls the 47 floor distribution cubicles supplying tenants' power to different areas of the building, allowing each to be set to one of four priority levels. These are:

- 1) Power delivered even if only one generator available
- 2) Power delivered only if two or more generators available
- 3) Power delivered only if all three generators available
- 4) No generator power available.

The priority level of each tenant's board is set by the Landlord, according to the power distribution survey, and the level of electrical facility purchased by the individual tenant.

Conclusion

Although the electrical requirements of each building are different, the basic approach described can be adapted to almost any layout, and gives an enormously improved reliability of supply. The major consultant involved with TPC on the installation of the described building is already specifying Triplex techniques for new designs. Conversion of existing buildings has been shown to be practical as regards both installation and conversion, without undue disruption or inconvenience to occupiers.

The author is a Director of Triplex Power Control Ltd.