SPOT NETWORK SYSTEMS

INTRODUCTION

If a highly reliable electrical distribution system is needed, traditional design practice recommends a low voltage, double ended substation. This provides reliable, robust electrical distribution for applications in critical facilities such as hospitals. However, there is a more reliable and cost effective alternative to the tradition double-ended substation by using low voltage network protectors.

DOUBLE-ENDED SUBSTATIONS

Figure 1 is a one-line diagram of a double-ended substation. The line-up includes two transformers, each sized to carry the load of the entire line-up. Should one transformer fail, the remaining transformer will carry the full load. This provides continuity of service in the event of a transformer failure.

Further, the substation has two utility feeds. Should a utility cable fail, the tie breaker is closed and service is quickly restored.

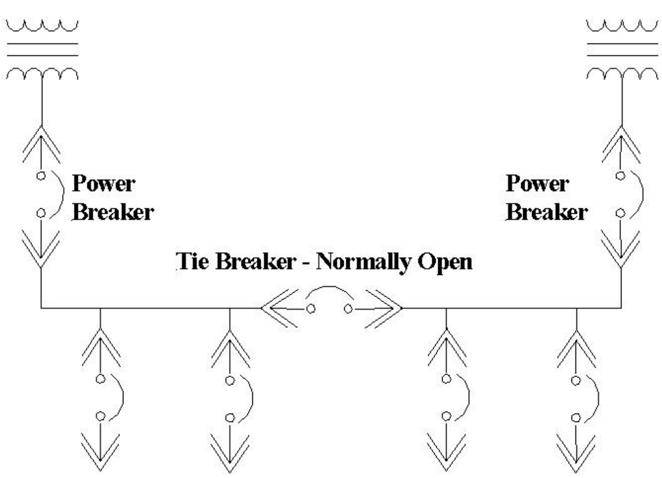

FIGURE 1 - Double - Ended Substation

The draw-back to double-ended substations is size and cost. Because of transformer redundancy, two transformers are furnished making the physical size of the substations large. Cost also increases as transformers construction is nearly all metal (copper or aluminum, steel) and the price of these raw materials has sky rocketed over the past year. These prices are not expected is significantly drop.

Another characteristic of a traditional double-ended substation is the MAIN-TIE-MAIN arrangement. In normal operation, the substation functions as two separate line-ups each with an independent main breaker and transformers. Should power be lost on one side of the line-up, the tie-breaker is closed allowing the power to be restored by the opposite side.

The opening of the affected main-breaker and closing the tie-breaker can be either an automatic operation or manual operation. The automatic control uses voltage sensing to first initiate the opening of the main breaker and then close the tie-breaker. Manual operation requires a person to physically operate and sequence the breakers. Usually, the breakers are electrically interlocked and mechanically interlocked, using a series of keys, to prevent the breakers from being closed out of sequence.

One disadvantage of the automatic transfer main-tie-main with an open tie breaker is that a momentary interruption of power will occur. This system reacts to correct a power interruption by switching to the alternate source to power the system. However, the power first is lost initiate closure of the tie-breaker, and the power serving the loads is interrupted for a short time before restoration.

This issue can be fixed by making the tie-breaker normally closed rather than normally open. However, there are issues with this arrangement. In the event of the loss of only

CONSIDER a SPOT NETWORK SYSTEM OVER MAIN-TIE-MAIN SUBSTATION SYSTEM

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one utility line, the associated main breaker remains closed, electric power continues to flow into the line-up, and power will flow through the closed breaker and back feed the utility service. This can result in electric power from the unaffected utility feed pouring power into a fault condition. Power breakers do not open on a reverse power condition.

NETWORK PROTECTOR

What is a network protector? It is a specialized power circuit breaker that monitors the voltage as well as the current through the closed contacts. Further, a network protector is designed to operate for a minimum of 10,000 mechanical operations and has a withstand duty cycle rating of 60 cycles. In contrast, a standard power breaker has a withstand rating of 30 cycles.

The withstand rating, or short time rating, is defined as "the maximum current that an unprotected electrical component can sustain for a specified period of time without the occurrence of extensive damage to that component". Meaning, the short time rating is how much current over a time period a breaker will hold closed before opening. The instantaneous rating is not time dependant. As the name implies, the breaker opens immediately if the current is above instantaneous trip setting

What does this mean for coordination? The withstand rating allows the instantaneous trip function of the power breaker to be disabled. This provides the downstream breakers with the opportunity to clear a fault without the main breaker tripping.

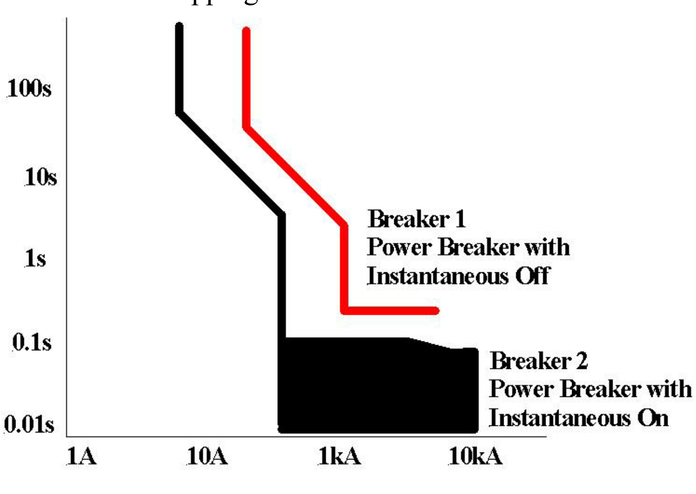

FIGURE 2 - Typical Power Breaker Time/Current Curves

Figure 2 is a time-current coordination curve with two devices. The main device is a power circuit breaker with the instantaneous overcurrent trip setting turned off. As shown, the breaker downstream of the main breaker has an instantaneous trip setting. Therefore, the downstream devices will trip first.

The network protector has three special functions that are performed by the network protective relay. These functions are:

1. Open the breaker on primary feed failure by sensing reverse power flow
2. Automatically reclose the breaker on sensing correct power flow
3. Open the breaker on an overcurrent condition or if the main substation breaker opens (if a main substation breaker is used).

The ability to sense reverse power flow and take corrective action is what differs a network protector from a standard power circuit breaker. Because spot network systems include multiple power sources into a common distribution bus, the loss of an incoming feed requires a network protector to open preventing power from the bus to back feed the deenergized source. Failure to isolate this feed can result in further damage to an already damaged incoming feed and overload the remaining live feeds causing an overcurrent condition. The ability of the network protector to sense reverse power makes this substation configuration systems possible.

NETWORK SUBSTATIONS

In the two previous sections, double ended substations and network protectors were discussed. By integrating a network protector into a substation, improved reliability is gained.

Figure 3 is a one-line diagram of a low voltage substation incorporating two network protectors. Comparing this to the traditional substation as shown in Figure 1, the two main breakers have been replaced by two network protectors. The network protectors include instantaneous overcurrent (device 50) and time overcurrent (device 51) relay protection, this same protection furnished by the main breakers in Figure 1. In addition, the network protector opens within 7 cycles on sensing reverse power flow.

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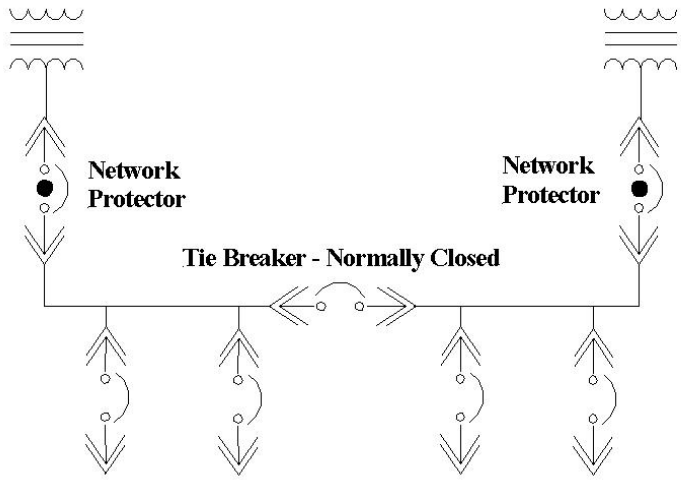

FIGURE 3 - Spot Network Substation

A second difference between the main-tie-main substation and the network substation is the tie breaker is now normally closed. The network substation continuously feeds the entire switchgear bus from two or more sources. In the event of a lost utility feed, the remaining feed keeps the bus energized without any interruption of power to the loads. This is possible because the tie breaker is closed.

In contrast, the main-tie-main configuration includes a normally ***open*** tie breaker. Using an automatic transfer scheme, the loss of a utility feed opens the associated main breaker then the tie breaker is closed. Although this transfer is fast, a short interruption of power to the loads will last a minimum of several cycles. This is enough time where the possibility of dropping out motor starters, resetting medical equipment and instrumentation, and losing computer data exists

The National Electric Code article 517.17 requires ground fault protection on 480/277 volt systems above 1000 Amps. Because both network protectors are closed to a common switchgear bus and supply electric power, coordination is needed to prevent both network protectors from opening in the event of a ground fault condition.

A single point protection ground fault scheme cannot determine which specific network protector is effected and may open both network protectors. A proper ground fault protection scheme is needed to preserve the enhanced reliability of the network substation.

The breaker located closest to the ground fault event needs to open for isolation of the fault, rather than opening a breaker unable to isolate the fault. The tie breaker and network protector ground fault relays are set slightly higher and have a longer delay than the feeder breakers.

An insulated switchgear ground bus with only one point of connection to the ground is required. Three ground fault relays are used to isolate a ground fault internal to the switchgear or an incoming cable fault. The operation is as follows: when the ground fault is detected, the tie breaker is opened. This isolates both main buses from each other. With the tie breaker open, the location of the ground fault (either right side bus or left side bus) is known and the associated network protector is opened to isolate the line to ground fault.

COMPARISON of RELIABILITY

Three systems are compared for reliability: simple radial, main-tie-main, and spot network. Unlike both the main-tie-main and network configurations, the radial system does not include transformer redundancy.

Before presenting the reliabilities, several metrics are defined.

- **Number of Outages per Year** – These are unplanned outages lasting 5 minutes or longer
- **Average Duration of Outage** – The average time (in minutes) of an outage
- **Momentary Interruptions per Year** - These are unplanned outages lasting less than 5 minutes

As Table 1 on the following page proves, the spot network system has far fewer outages and interruptions through a typical year when compared to a simple radial system or a main-tie-main system. Statistically, the spot network has an outage once every 10 to 50 years.

However the **Average Duration of Outage,** as shown in Table 1, proves that both the radial system and the main-tie-main system, when compared to the network system, have less down-time. One may conclude that network system is more difficult to repair in the event of an outage.

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	Simple Radial	Main-Tie-Main	Spot Network
Number of Outages per Year	**.3 to 1.3 (Once every 9 months to 3 years)**	**.1 to .5 (Once every 2 years to 10 years)**	**.02 to .1 (Once every 10 years to 50 years)**
Average Duration of Outage	**90 Minutes**	**180 Minutes**	**180 Minutes**
Momentary Interruptions per Year	**5 to 10**	**2 to 4**	**0 to 1**

TABLE 1 - Reliability Comparison (Data from Consolidated Edison Company)

This is miss-leading.

Why? Because of the high reliability of a network system, the cause of a network substation outage most often is a major, catastrophic event. Remember, the bus is energized from two sources and some repairs/maintenance can be performed without deenergizing the entire system. Catastrophic type events will result in long outages regardless of the power distribution system (radial / main-tie-main / network). Further, the radial and main-tie-main systems need outages for certain repairs and maintenance where a network system may not require an outage.

NETWORK SYSTEM ADVANTAGES

A Spot Network system offers advantages over a main-tie-main substation with little additional cost. As described above, the network system configuration is the same as a main-tie-main substation. The difference lies in substituting the main breakers with network protectors equipped with overcurrent protection.

- ✓ **Reliability** – The spot network bus is continuously energized from two or more sources. Should one power source be lost, the remaining sources carry the load without any interruption.

- ✓ **Automatic Operation** – The network protectors are fully automatic. When a primary line source is lost, the network protector automatically opens and then recloses on the return of power. Manual operation is not needed.

- ✓ **Voltage Regulation** – Because the bus is fed from transformers connected in parallel, the systems are very stiff. Therefore, voltage dips cause by sudden changes in load (such as motor starting) causes less of a disturbance when compared to other systems.

- ✓ **Isolation Capability** – Opening one network protector allows maintenance and repair of the primary distribution without interrupting service. Therefore, maintenance can be performed during normal hours without an outage.