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# How to maximize reliability using an alternative distribution system for critical loads

## Executive summary

The electric power industry has several different distribution topologies that are typically considered during design of a new power distribution system. Topologies used today from least reliable to most reliable are as follows:

- Simple radial—typically used for servicing small residential or commercial loads
- Primary auto loop—typically two radial feeds tied together at an open switch point
- Underground Residential Distribution (URD)—typically adopted for servicing residential subdivisions or commercial loads
- Primary selective—typically used for larger loads requiring automatic primary side switching
- Secondary selective—typically found in industrial applications used with coordinated secondary side switching schemes, i.e. main-tie-main switchgear
- MV/LV spot network—uses multiple feeders in parallel except typically dedicated to a single customer, outstanding reliability second only to LV grid networks
- Distributed LV grid network—similar to spot networks but typically found in major metropolitan areas servicing many customers (city block). Uses multiple feeders operating in parallel, the most reliable distribution system available

Network systems are the most reliable distribution system available; however, not many understand its benefits or applications. Secondary low-voltage (LV) grid networks operate at 120/208 V and spot networks operate at 240/480 V (some 600 V). The purpose of this white paper is to discuss the functionality of a traditional low-voltage spot network, but designed for medium-voltage, 4160 V loads. Many networked utilities are taking advantage of the LV network reliability and are applying them at a medium-voltage level.

A spot network is a distribution system in which paralleled loads are powered by multiple paralleled sources. The sources can be powered from a single substation, or from multiple high-voltage substations that will always be synchronized. The key feature of a spot network is the relay protection associated with the power sources that isolates individual faulted sources without disconnecting the other sources, providing continuity of service to the loads. Additionally, a network system design has isolation capability so the equipment can be isolated for service or maintenance without causing any interruption to the power supply. This can provide a significant cost benefit by permitting outages for normal maintenance, or system repairs to be carried out during normal working hours. This automatic function is provided by a special network relay, which is designed to open on reverse magnetizing current whenever the primary feeder breaker is opened. It will automatically reconnect the transformer to the network bus when this relay senses that the transformer voltage is higher than the network.

Topics to be discussed include protection functions, how the fault ratings of breakers used in a spot network affect ultimate loading capacity, and then the effects of different loading schemes on capacity and system cost. A comparison to a traditional distribution design is also included.

## Introduction

The advantage of a medium-voltage (MV) spot network with multiple parallel power sources is the opportunity to provide enhanced continuity of service to loads compared to traditional power distribution system designs. With an individual power source serving a load sized for the power source, the loss of the power source results in the shutdown of the load. However, with paralleled loads and sources in an MV spot network, the loss of an individual power source does not interrupt power to the loads if isolation of the faulted source is successful. A typical MV 2-spot network is shown in **Figure 1**.

The performance of an MV spot network is affected by decisions in both the power system and the selection of loads. The performance of the power source equipment improves as the number of power sources, N, increases, with each source becoming smaller. There is a lower percentage loss of total power supply capacity when a single source is lost—the N-1 condition.

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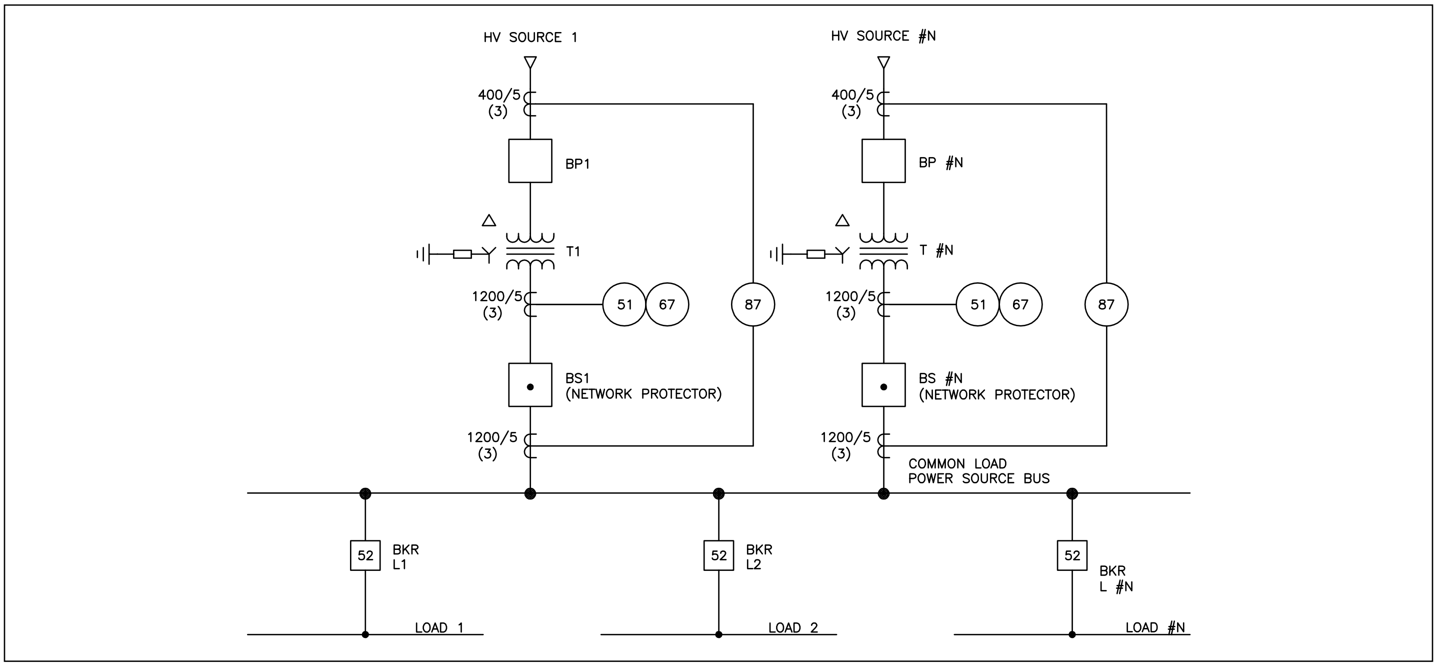


**Figure 1. Typical MV spot network template**

Load size selection relative to power equipment size also affects performance. If success is defined by avoiding the loss of loads when a power source is lost, loads must be limited to the capacity of N-1 transformers. The use of base kVA or fan-cooled kVA ratings for transformers when in the N-1 condition must also be decided. If load shedding in an N-1 condition is allowable, more load can be served in the normal N transformer operation periods, and the cost of the power system on a $/kVA can be lowered. In general, increasing the load in the N condition reduces the advantages available in the N-1 condition, and successful operation of an MV spot network is based on successfully satisfying the needs of a specific load.

## Circuit protection in an MV spot network

Relay protective features that are unique to MV spot networks are phase and ground fault functions related to the isolation of an individual power source from the network for a fault in the power source or upstream of the power source. The intent of traditional protection schemes is the clearing of faults downstream of the transformer before taking the transformer out of service and shutting down the entire load if necessary. A fault in a transformer, or loss of upstream power, results in a shutdown of the load on the transformer in a traditional radial system. However, with an MV spot network, a faulted transformer (or dead power source) can be isolated from the paralleled system through the use of a network protector. Service to the load is maintained because other sources remain in service connected to the loads in parallel.

Circuit protective functions that are needed to isolate a faulted transformer in an MV spot network scheme include differential, 87, and directional current, 67, trips. A fault between the primary and secondary side breakers of a power source will be detected instantly by the differential function, resulting in isolation of a fault in a time of one to two cycles for relay operation time and the time for the secondary side breaker to operate and clear. Until the breaker clears the fault there will be a depression of voltage on the load bus(es), but most loads should remain in service, riding through the disturbance. Faults upstream of the transformer in the power source result in a far less severe disturbance in the network loads and should be detected by directional current or power relaying after several seconds, depending on the severity of the fault.

Ground fault protection in an MV spot network is associated with the connection to the power sources and with the distribution system downstream of the power sources. The ability to remove a power source with an internal ground fault is an advantage of an MV spot network compared to traditional distribution systems. Relaying for ground faults in the MV load circuits fed by an MV spot network will be similar to ground relaying in traditional MV distribution systems. All options available in designing ground fault protection schemes in a simple radial MV system are available when designing the distribution system fed by an MV spot network.

Multifunction numeric relays that will provide all required network protection functions are available from Eaton. Other functions such as high winding temperature, loss of control voltages, and even the detection of doors being open in electrical rooms (triggering arc flash reduction settings for example) can also be added if desired when using modern multifunction relays with multiple settings.

## MV spot network design considerations

The design and load capacity of an MV spot network are based on many specification/loading decisions and considerations. These include the following:

- Transformer size and impedance
- Transformer ratings to be used in the N and N-1 conditions
- Fault ratings of secondary switchgear
- Level of load to be supported by the network

It is assumed in this paper that motor/load control equipment will have fault ratings similar to the standard distribution breakers.

The first devices to be found in an MV spot network are the breakers on the source side of the transformers. The fault duty imposed on these breakers is determined mainly by the details of the upstream power system. Design and determination of ratings for these breakers are outside of the scope of this paper. It will be assumed that all transformer primary side sources are independent, and that the fault current and MVA levels will be 100% additive on the secondary sides of the transformers.

The fault current ratings of the transformer main secondary breakers (network protector) and the load distribution system breakers are determined by the sizes and impedances of the transformers to be used in the network. Because of the paralleling of transformers, the fault current levels experienced by the feeder system breakers will most likely be higher than seen in normal single transformer radial applications. Load breakers will have to be able to interrupt the fault current from all of the transformers, N, plus the fault contribution from all loads other than loads fed by the individual breaker.

Transformer main secondary breakers, for a fault between the network protector and the transformer, must be able to interrupt the fault current from N-1 transformers plus the contributions from all loads. The fault duty requirement for the load feeder breakers will always be higher than the required fault duty for the transformer main secondary network protector. It is recommended that the ratings of all breakers be similar for simplicity of system design. A fault study should be used to verify the fault duty requirements of all breakers as soon as the design of an MV spot network is proposed.

In this paper, three transformer sizes and three switchgear fault ratings are initially analyzed. The transformer sizes are 5000 kVA, 3000 kVA, and 2000 kVA. Three levels of fault duty are considered in the switchgear, 25 kA, 40 kA, and 50 kA. The first step in the selection of MV spot network designs to be analyzed in detail is to determine the number of transformers that can be used with each class of switchgear.

The impedances of transformers used in the examples in this paper are guaranteed minimum values after manufacturing tolerance. During the design of an actual system, lower impedances may be found to be useable. Reductions in manufacturing tolerance in impedance may also be able to be negotiated with the transformer manufacturers. The fault currents from the transformers were also calculated using a 400 MVA high side fault availability.

The contribution from loads to the fault current available in the system will be a function of amount of load, types of loads, and distributions of the loads. It is not feasible to determine a best or worst case of load for analysis in this paper, so the contribution from loads is approximated by adding 25% to the fault contribution from transformers. Further, because distribution of loads is not known, the loads downstream of each breaker will not be deducted in the calculation of fault duty on each load breaker.

Another simplifying assumption used in this paper is that the fault current that is calculated from base current divided by impedance will be used to approximate the value to be compared with the symmetrical interrupting rating of the breakers. **Table 1** shows the fault current available from each size transformer, and the fault current including an extra 25% to simulate load contributions to fault current.

The fault current data above is then used to determine the maximum number of the three sizes of transformers that can be used in a network with the various sizes of switchgear breakers.

In this paper, examples of MV spot networks are developed for the cases of two 5000 kVA transformers and three 3000 kVA transformers using 25 kA rated 5 kV breakers, and three 5000 kVA transformers and five 3000 kVA transformers using 40 kA, 5 kV breakers.

In this paper, the load of an MV spot network is one switchgear bus that feeds all of the loads of a system. The main load switchgear cannot be sectionalized. Traditional distribution systems often include power sources paralleled together through sectionalizing breakers on the secondary side of the power sources. Normally closed sectionalizing breakers can be added to the secondary collector bus of the distribution switchgear in an MV spot network if there is an advantage to being able to operate portions of the load with other portions being de-energized. The MV spot network design described in this paper provides operational advantages for a load that has to operate as a complete system with power requirements larger than can be supported by a single transformer. Sectionalizing breakers would add additional costs to the MV spot network without providing additional operational benefits, and therefore have not been included in the MV spot network design or cost estimate.

**Table 1. Transformer ratings and current values**

| Transformer rating | Secondary voltage | Transformer % impedance | 400 MVA fault availability primary HV side | Secondary side current | | |
|---|---|---|---|---|---|---|
| | | | | Base current | Fault current | Fault current + 25% LC |
| Base kVA | V | %Z | %Z | A | A | A |
| 5000 | 4160 | 7 | 0.013 | 694 | 9896 | 12370 |
| 3000 | 4160 | 7 | 0.008 | 416 | 5942 | 7427 |
| 2000 | 4160 | 7 | 0.005 | 278 | 3962 | 4953 |

**Table 2. Maximum number of transformers per MV spot network**

| Spot network sizes based on Table 1 and standard switchgear ratings | | | |
|---|---|---|---|
| Transformer base rating kVA | Number of parallel transformers | | |
| | 25 kA switchgear | 40 kA switchgear | 50 kA switchgear |
| 5000 | 2.0 | 3.2 (3.0) | 4.0 |
| 3000 | 3.4 (3.0) | 5.4 (5.0) | 6.7 (6.0) |
| 2000 | 5.0 | 8.1 (8.0) | 10.1 (10.0) |

## Transformer loading schemes

Transformers have base, fan, and increased temperature load ratings. The load losses in a transformer increase as the square of the ratio of load to base load, so long-term loading above base rating is normally avoided. The additional load capacity made available by purchasing fans is often used for short time emergency loading. Dry-type transformers are considered in this paper, and the additional kVA load capacity typically available with dry-type transformers with a fan-cooling stage is 33%.

One possible loading scheme involves the use on only base ratings of transformers, without load shedding. In the cases following this rule, the maximum loading of each transformer will be the kVA load equal to the sum of the base kVA ratings of the transformers left in operation after one is lost—N-1 transformers. A tabulation of loading limits for installations following this loading rule is shown in **Table 3**. In these cases, the full kVA capacity of the transformers would not be used.

Another possible loading scheme is to allow loading to equal the sum of the fan ratings of N-1 transformers. However, with low numbers of transformers, the full kVA capacity of the transformers still would not be used. The full base rated capacity of the installed transformers would be used in the case of five 3000 kVA transformers with 40 kA secondary switchgear. A tabulation of loading limits for installations following this loading rule is shown in **Table 4**.

The networks could be loaded to higher levels if load shedding upon the loss of one source is allowed. In this scheme, the network could be loaded to the full base rating of the transformers when all transformers are in service. Upon the loss of a transformer, the load can be reduced to the sum of the fan ratings of the remaining transformers. In the network with five 3000 kVA transformers, load shedding is not required because the total fan kVA with N-1 transformers is higher than the total base kVA with N transformers. Loadings using this scheme are shown in **Table 5**. Load kVA to be shed upon loss of a transformer is shown in the column named "load shed".

**Table 3. System loading limits—N-1 with no stage cooling or load shedding**

| Load considerations based on transformer base ratings | | | | | | |
|---|---|---|---|---|---|---|
| **Spot network size** | **Transformer rating** | **Total transformer** | **Switchgear ratings** | **N-1 contingency** | **Total** | **Per transformer** |
| **"N"** | **Base kVA** | **Installed base kVA** | **kA** | **Base load kVA** | **Design load kVA** | **Nominal load kVA** |
| 2 | 5000 | 10000 | 25 | 5000 | 5000 | 2500 |
| 3 | 5000 | 15000 | 40 | 10000 | 10000 | 3333 |
| 3 | 3000 | 9000 | 25 | 6000 | 6000 | 2000 |
| 5 | 3000 | 15000 | 40 | 12000 | 12000 | 2400 |

**Table 4. System loading limits—N-1 with stage cooling and no load shedding**

| Load considerations based on transformer base ratings with single stage cooling | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Spot network size** | **Transformer rating** | **Transformer rating** | **Total transformer** | **Switchgear ratings** | **N-1 contingency** | **Total** | **Per transformer** |
| **"N"** | **Base kVA** | **Stage fans kVA (x33%)** | **Installed SF kVA (x33%)** | **kA** | **Stage fans kVA (x33%)** | **Design load kVA** | **Nominal load kVA** |
| 2 | 5000 | 6650 | 13300 | 25 | 6650 | 6650 | 3325 |
| 3 | 5000 | 6650 | 19950 | 40 | 13300 | 13300 | 4433 |
| 3 | 3000 | 3990 | 11970 | 25 | 7980 | 7980 | 2660 |
| 5 | 3000 | 3990 | 19950 | 40 | 15960 | 15000 | 3000 (3192) ① |

① Ratings exceed base kVA of transformers, therefore, total design load reduced to 15000 kVA.

**Table 5. System loading limits—N-1 with single stage cooling and load shedding**

| Load considerations based on transformer base ratings with single stage cooling and load shedding | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Spot network size** | **Transformer rating** | **Transformer rating** | **Total transformer** | **Total transformer** | **Switchgear ratings** | **N-1 contingency** | **Total load shed** | **Total** | **Per transformer** |
| **"N"** | **Base kVA** | **Stage fans kVA (x33%)** | **Installed base kVA** | **Installed SF kVA (x33%)** | **kA** | **Stage fans kVA (x33%)** | **Shed to SF kVA rating** | **Design load kVA** | **Nominal load kVA** |
| 2 | 5000 | 6650 | 10000 | 13300 | 25 | 6650 | 3350 | 10000 | 5000 |
| 3 | 5000 | 6650 | 15000 | 19950 | 40 | 13300 | 1700 | 15000 | 5000 |
| 3 | 3000 | 3990 | 9000 | 11970 | 25 | 7980 | 1020 | 9000 | 3000 |
| 5 | 3000 | 3990 | 15000 | 19950 | 40 | 15000 ① | 0 | 15000 | 3000 |

① Rating exceeds base kVA of transformers, therefore, total design load reduced to 15000 kVA.

## Traditional distribution system

A traditional distribution system design that provides improved reliability is the secondary selective dual transformer installation using secondary switchgear on each transformer connected by a tie breaker. The secondary main breakers and tie breaker are programmed to transfer power from one transformer to the load switchgear of the other in case of a loss of power on the second unit. This is known as a main-tie-main (MTM) system. An MTM system is similar to an MV spot network, except that it is limited to only two transformers and the tie breaker is normally open. When similar loading rules are followed, the long-term effect of the loss of one of two transformers in an MTM system is worse than the effect of the loss of one of three or more transformers in an MV spot network with similar total transformer kVA capacity. If the loss of a power source, either from a fault between the transformer primary and secondary breakers, or the loss of the source to a transformer, is more likely than a fault in the secondary switchgear, then better reliability will be provided by an MV spot network than an MTM system.

If there is a failure in the secondary switchgear, the control scheme of an MTM system will prevent the faulted switchgear from being re-energized, possibly shutting down both sets of secondary switchgear. In this case, an MTM system will be able to keep one-half of the supported load energized while a transformer is repaired.

If secondary switchgear is considered to have a higher level of reliability than a transformer or high-voltage power source, then an MV spot network design with more than two transformers should provide better continuity of service than an MTM system, and subject the supported system to lower level of power loss while one transformer is out of service. An analysis of the sensitivity of the supported load to power reduction will determine if an MTM system or an MV spot network will be a better power delivery system for an individual application. A typical MV MTM arrangement is shown in **Figure 2**.

## Cost comparisons between systems

Cost estimates were developed for each of the MV spot network noted configurations and for the traditional MTM system. The estimates are based on equipment takeoffs and on assumptions made when constructing layout drawings for each case.

The different networks and systems are difficult to compare on a total cost basis because the total load capabilities are different. **Table 6** shows the total cost of each different network or system, and also a cost based on kVA of load capacity. There are three sections in the cost table because three levels of loading were explored in the paper. The systems with higher loading capacity cost more, but then cost less on a cost-per-kVA basis.

The estimates for the MV spot network cases are all based on transformers cabled to separately installed switchgear. The MTM traditional system was estimated based on a system with transformers close coupled to the secondary switchgear, which gives the MTM traditional system a cost advantage because the cable and tray costs necessary for the MV spot networks are not needed. However, even with the reduction of equipment cost, the difference in cost between the MTM system and the MV spot network with two 5000 kVA transformers and 25 kA switchgear is not significant. The effect on a life cost of the systems has not been included in this analysis, and even with lower first cost, the MTM system may be more expensive than the highest cost MV spot network due to the cost of downtime.

**Table 6** lists the five networks that were analyzed and estimated three times, for each of the loading levels as shown in **Table 3**, **Table 4**, and **Table 5**. The final cost per kVA column is based on normal loading when all transformers are in service.

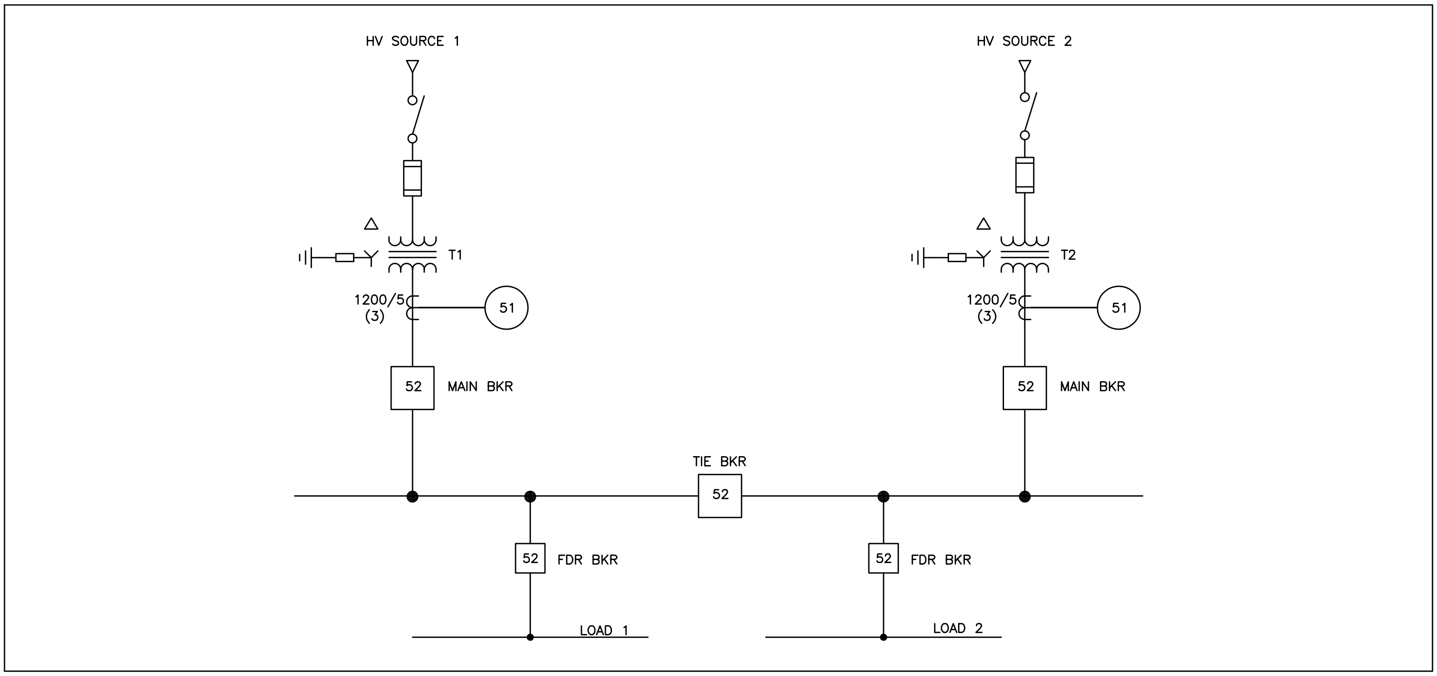


**Figure 2. Typical MV MTM arrangement**

**Table 6. Cost per kVA compared to conventional main-tie-main**

| Table comparisons—cost per kVA | | | | | |
|---|---|---|---|---|---|
| **Options** | **Reference table** | **General arrangement** | **Total estimated cost** | **Total design load kVA** | **$ per kVA** |
| 1A | Load rule from Table 3 | 2-Spot, 5000 kVA transformer, 25 kA | $738,447 | 5000 | $148.00 |
| 1B | Load rule from Table 3 | 3-Spot, 3000 kVA transformer, 25 kA | $917,546 | 6000 | $153.00 |
| 2A | Load rule from Table 3 | 3-Spot, 5000 kVA transformer, 40 kA | $1,186,747 | 10000 | $119.00 |
| 2B | Load rule from Table 3 | 5-Spot, 3000 kVA transformer, 40 kA | $1,747,128 | 12000 | $146.00 |
| 3 | — | Two—5000 kVA transformer, 25 kA MTM | $668,223 | 5000 | $134.00 |
| 1A | Load rule from Table 4 | 2-Spot, 5000 kVA transformer, 25 kA | $738,447 | 6650 | $111.00 |
| 1B | Load rule from Table 4 | 3-Spot, 3000 kVA transformer, 25 kA | $917,546 | 7980 | $115.00 |
| 2A | Load rule from Table 4 | 3-Spot, 5000 kVA transformer, 40 kA | $1,186,747 | 13300 | $89.00 |
| 2B | Load rule from Table 4 | 5-Spot, 3000 kVA transformer, 40 kA | $1,747,128 | 15000 | $116.00 |
| 3 | — | Two—5000 kVA transformer, 25 kA MTM | $668,223 | 6650 | $100.00 |
| 1A | Load rule from Table 5 | 2-Spot, 5000 kVA transformer, 25 kA | $738,447 | 10000 | $74.00 |
| 1B | Load rule from Table 5 | 3-Spot, 3000 kVA transformer, 25 kA | $917,546 | 9000 | $102.00 |
| 2A | Load rule from Table 5 | 3-Spot, 5000 kVA transformer, 40 kA | $1,186,747 | 15000 | $79.00 |
| 2B | Load rule from Table 5 | 5-Spot, 3000 kVA transformer, 40 kA | $1,747,128 | 15000 | $116.00 |
| 3 | — | Two—5000 kVA transformer, 25 kA MTM | $668,223 | 10000 | $67.00 |

The cost of MV spot networks and traditional networks on a cost per kVA of load basis as shown in the preceding tables includes the assumption that the load is an optimal total for the transformers selected. The optimal selection of transformer size will actually be driven by the load to be served. The main conclusions to be inferred from the results of the system cost estimate tables is that all of the distribution schemes for a particular loading rule are similar in cost, and that the cost per kVA served can be lowered if higher loading is allowed. It can also be seen that the use of an MV spot network may even reduce the cost of the supply system due to the omission of tie breakers. The benefit of the simplicity of an MV spot network compared to the best alternative, an MTM network, was not considered in the cost estimates, but typically results in lower operational costs during the life of the system.

## Conclusion

A medium-voltage spot network can be used to provide an enhanced level of continuity of service in supplying power to 4160 V system loads compared to traditional power supply designs. By paralleling transformers, the load can be protected against the loss of an individual transformer. Relaying is available to detect and then isolate transformers for both phase and ground faults. Other advantages of an MV spot network with paralleled transformers are improved voltage regulation, better starting performance in large motors, the capability to perform maintenance on transformers without a shutdown of loads, the ability to use power from isolated sources, flexibility to use different loading schemes, and little cost impact compared to traditional power distribution schemes.

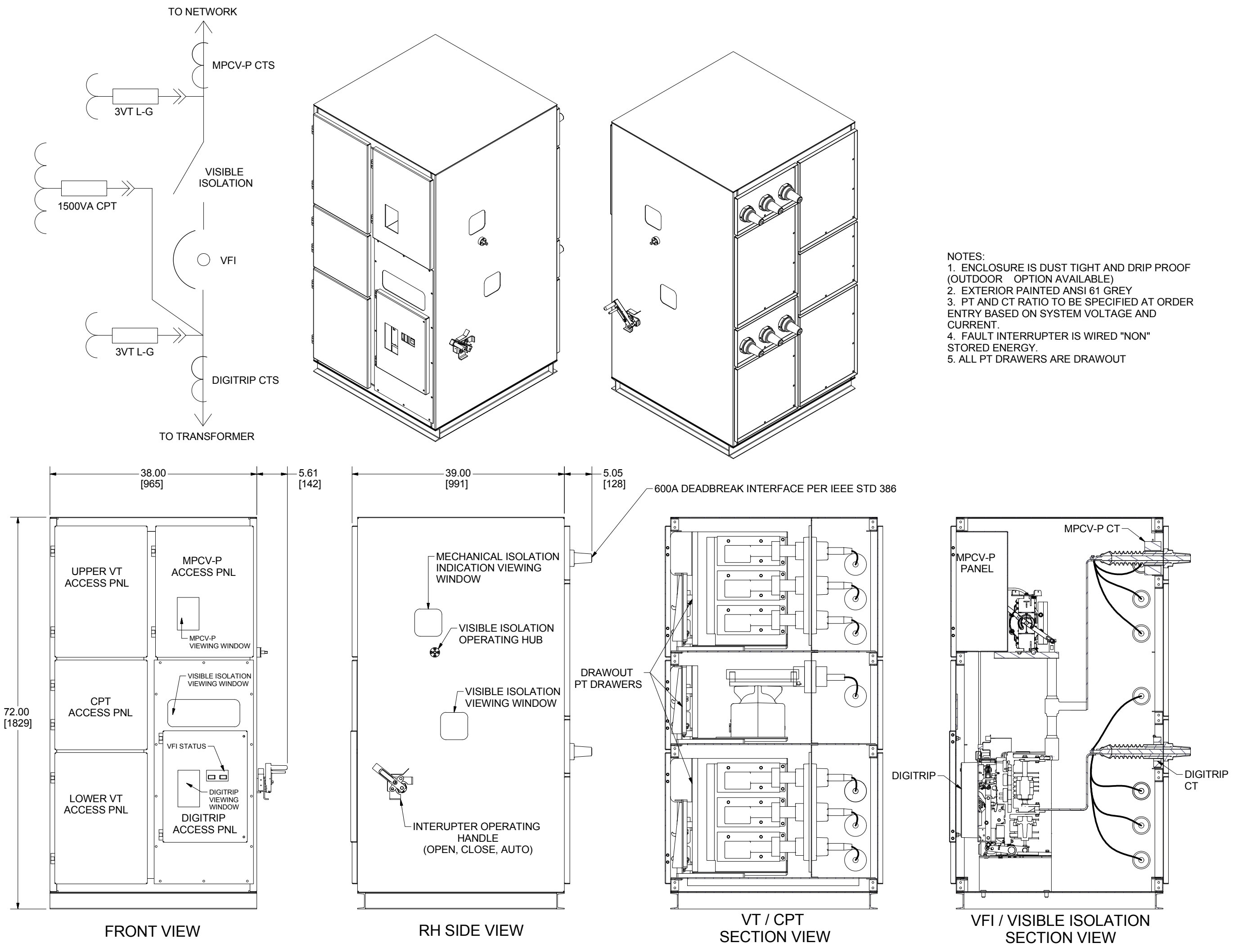
The MV spot network has advantages over a traditional MTM arrangement for industries that have processes that require a high degree of reliability and that have a large quantity of MV motors (typically in excess of 250 hp). Heavy industries such as pulp and paper, metals manufacturing, chemical processing, and polymer processing all have opportunities where an MV spot network may be beneficial and useful.

Additional industries that may see a benefit for an MV or LV spot network are customers who require ultimate reliability such as theme parks, casinos, hospitals, or data center applications. Projects that include any of these processes should give spot networks consideration, especially where loss of production or service is a great concern or any voltage disturbance cannot be tolerated.

## Appendix A—additional information

### Medium-voltage VisoVac network protector

- Eaton VisoVac MV network protector layout
  4.16 kV nominal to 17.5 kV maximum
  900 A maximum continuous current rating
  25 kA symmetrical interrupting, 65 kA asymmetrical peak withstand
  40 kA with 104 kA asymmetrical peak withstand available



NOTES:
1. ENCLOSURE IS DUST TIGHT AND DRIP PROOF (OUTDOOR OPTION AVAILABLE)
2. EXTERIOR PAINTED ANSI 61 GREY
3. PT AND CT RATIO TO BE SPECIFIED AT ORDER ENTRY BASED ON SYSTEM VOLTAGE AND CURRENT.
4. FAULT INTERRUPTER IS WIRED "NON" STORED ENERGY.
5. ALL PT DRAWERS ARE DRAWOUT

Figure 3. Medium-voltage VisoVac network protector

## Option 1A—2-spot 13.8 kV/4.16 kV MV network with 5.0 MVA transformers

- Electrical general arrangement
  Two—5.0 MVA transformers
  4.16 kV, 25 kA breakers, option 1A
- 13.8 kV/4.16 kV network single-line diagram
  Two—5.0 MVA transformers
  4.16 kV, 25 kA breakers, option 1A

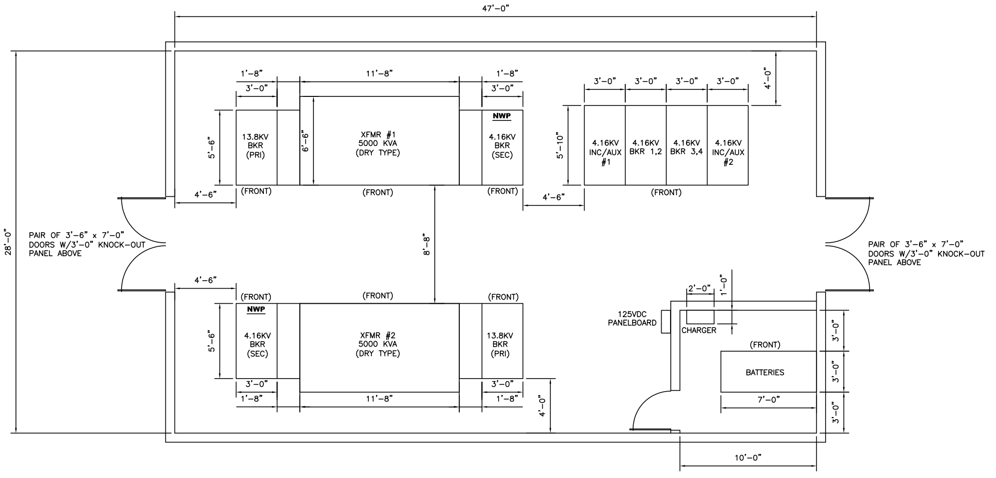


**Figure 4. Option 1A—electrical general arrangement**

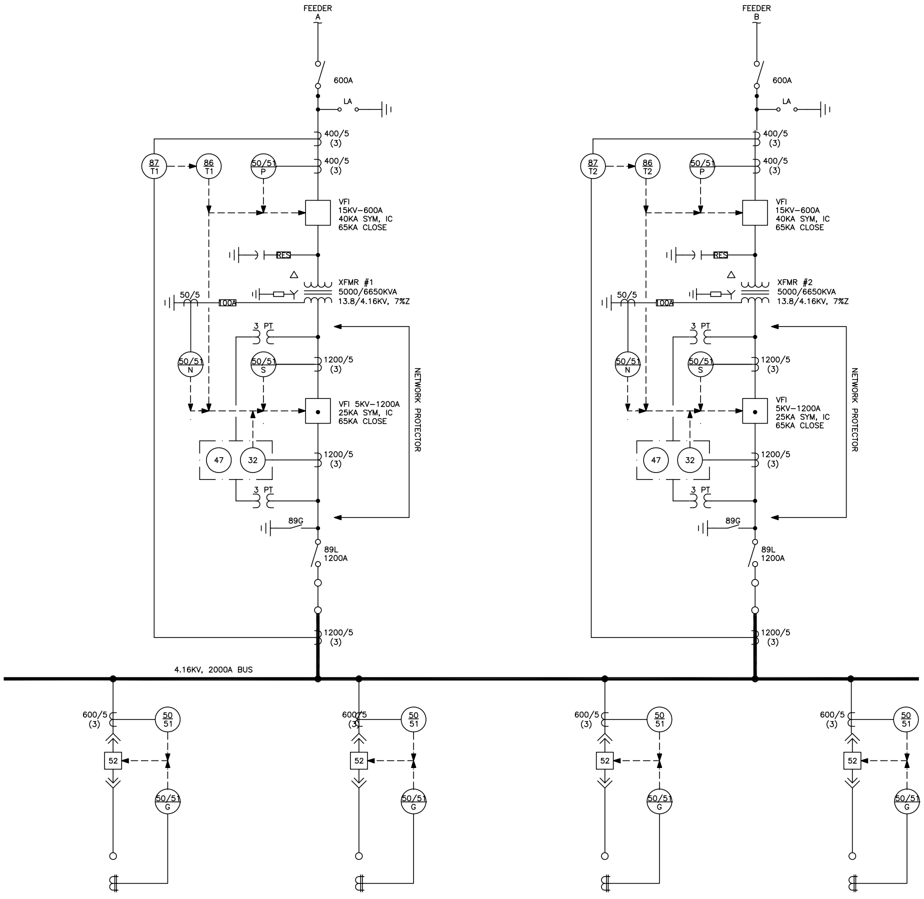


**Figure 5. Option 1A—network single-line diagram**

### Option 1B—3-spot 13.8 kV/4.16 kV MV network with 3.0 MVA transformers

- Electrical general arrangement
  Three—3.0 MVA transformers
  4.16 kV, 25 kA breakers, option 1B
- 13.8 kV/4.16 kV network single-line diagram
  Three—3.0 MVA transformers
  4.16 kV, 25 kA breakers, option 1B

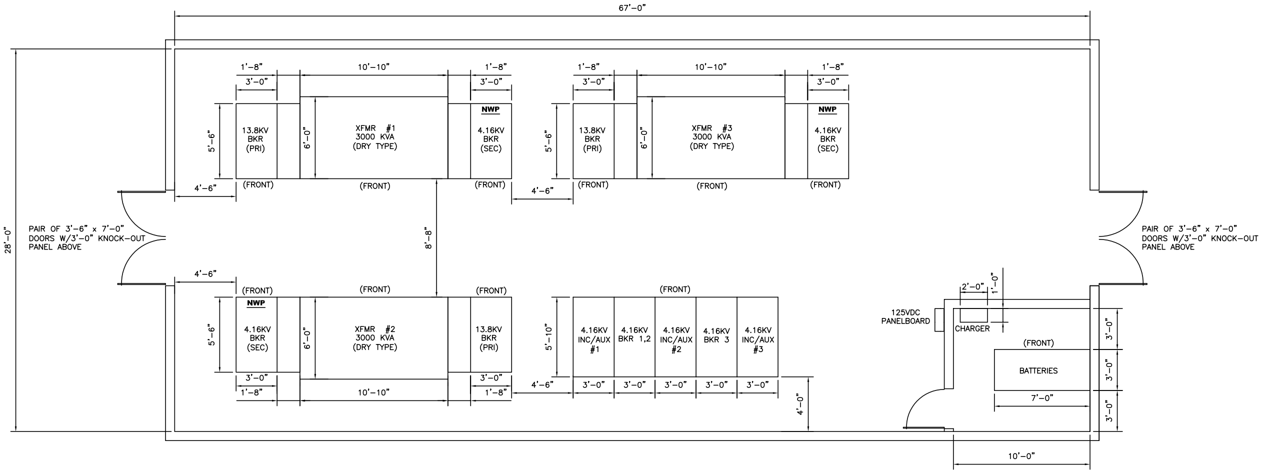


Figure 6. Option 1B—electrical general arrangement

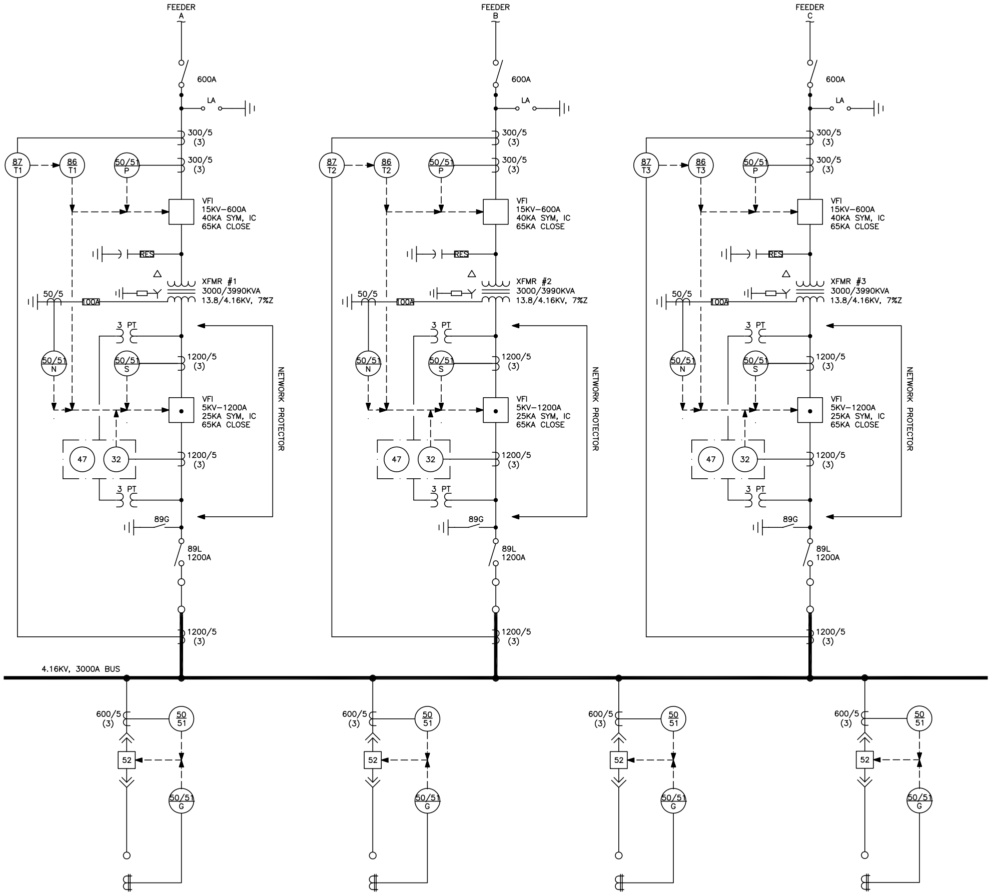


Figure 7. Option 1B—network single-line diagram

## Option 2A—3-spot 13.8 kV/4.16 kV MV network with 5.0 MVA transformers

- Electrical general arrangement
  Three—5.0 MVA transformers
  4.16 kV, 40 kA breakers, option 2A
- 13.8 kV/4.16 kV network single-line diagram
  Three—5.0 MVA transformers
  4.16 kV, 40 kA breakers, option 2A

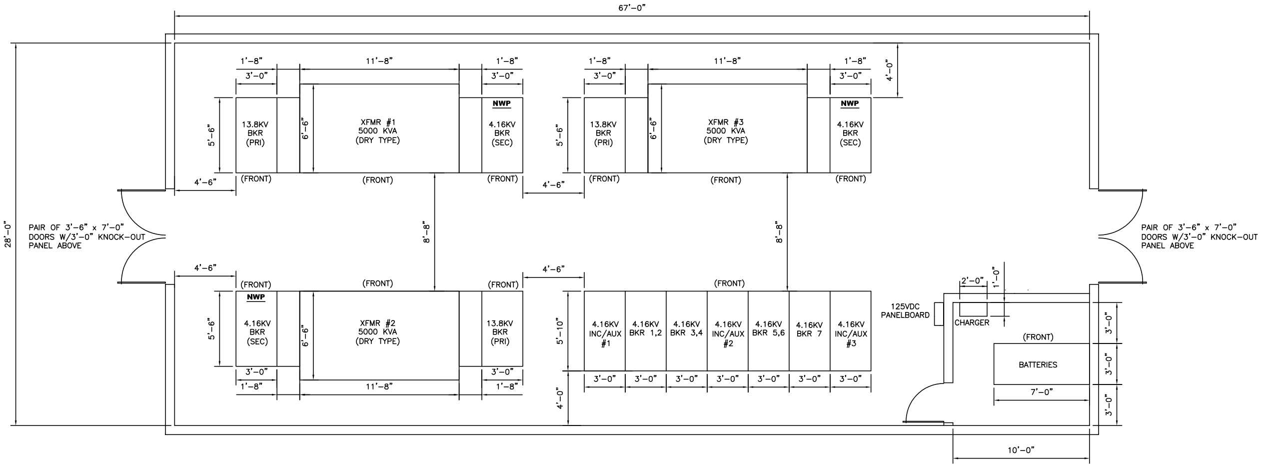


**Figure 8. Option 2A—electrical general arrangement**

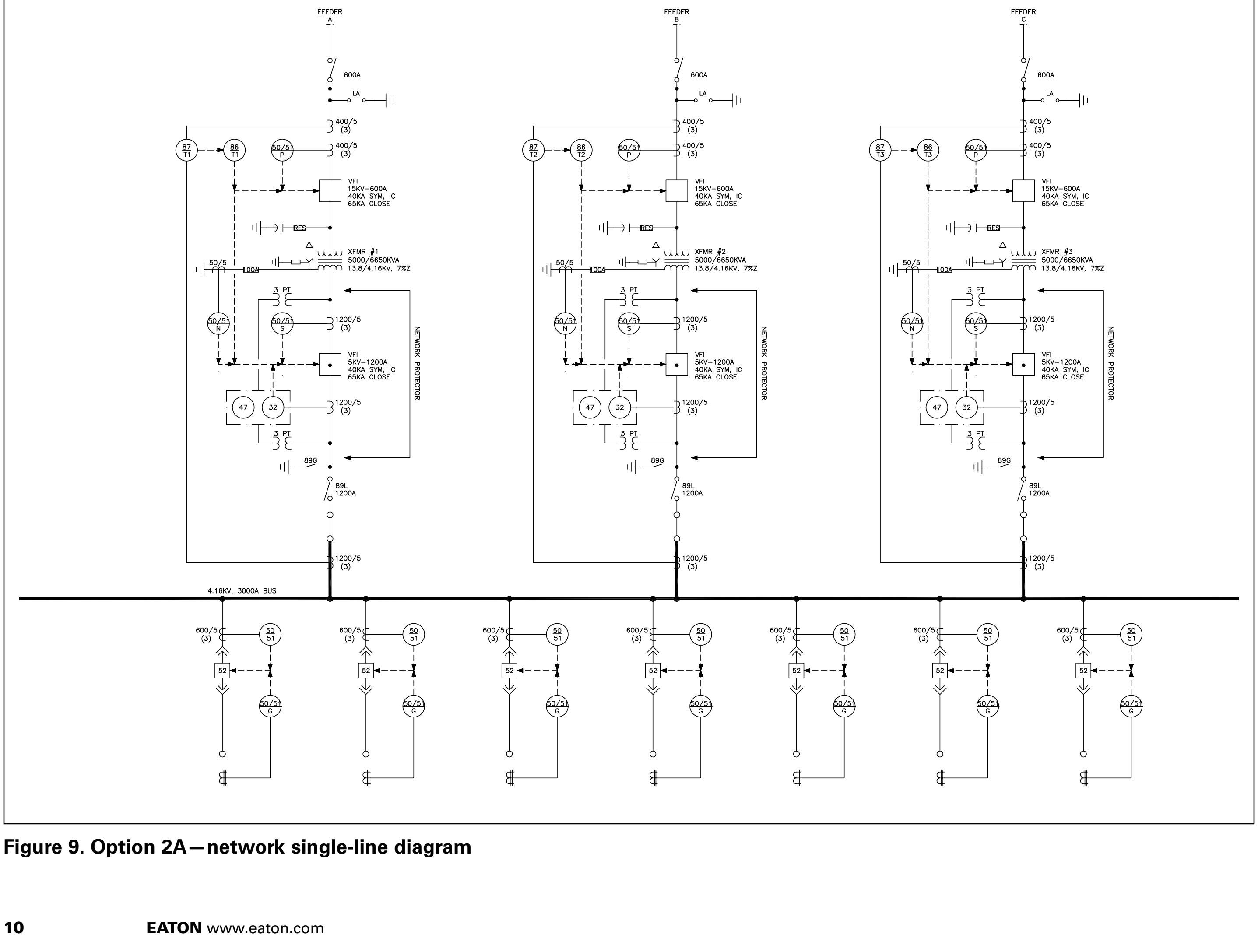


**Figure 9. Option 2A—network single-line diagram**

### Option 2B—5-spot 13.8 kV/4.16 kV MV network with 3.0 MVA transformers

- Electrical general arrangement
  Five—3.0 MVA transformers
  4.16 kV, 40 kA breakers, option 2B
- 13.8 kV/4.16 kV network single-line diagram
  Five—3.0 MVA transformers
  4.16 kV, 40 kA breakers, option 2B

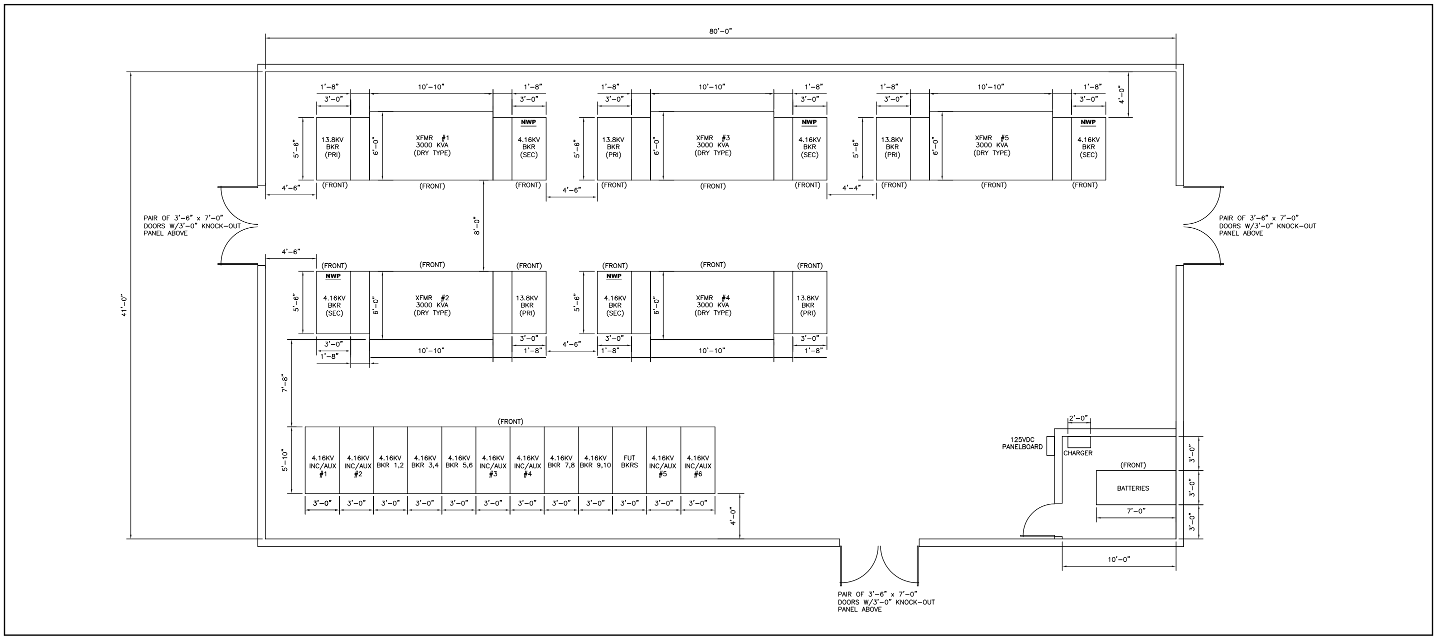


**Figure 10. Option 2B—electrical general arrangement**

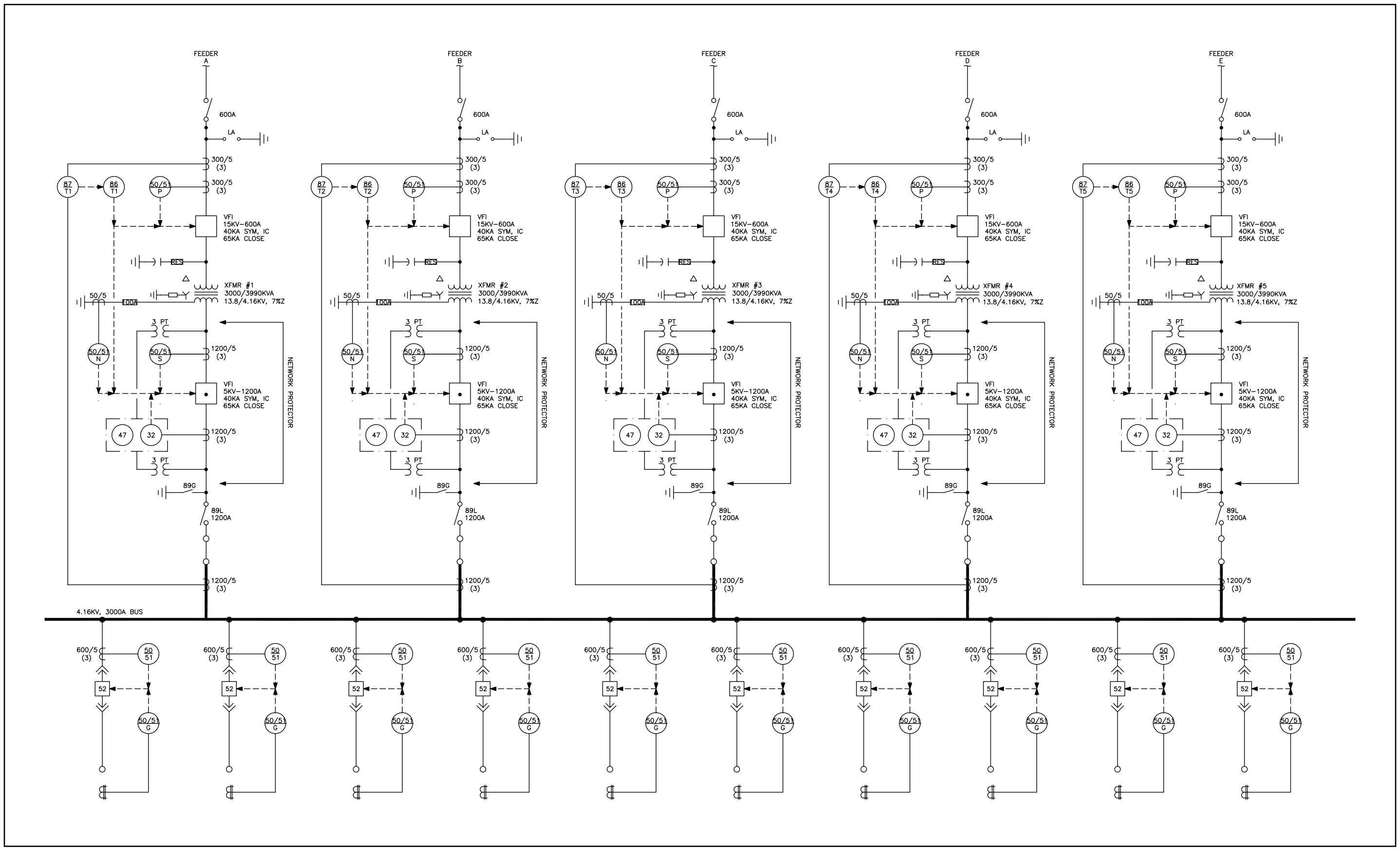


**Figure 11. Option 2B—network single-line diagram**

## Option 3—13.8 kV/4.16 kV main-tie-main with 5.0 MVA transformers

- Conventional MTM general arrangement
  Two—5.0 MVA transformers
  4.16 kV, 25 kA breakers, option 3
- 13.8 kV/4.16 kV MTM single-line diagram
  Two—5.0 MVA transformers
  4.16 kV, 40 kA breakers, option 2B

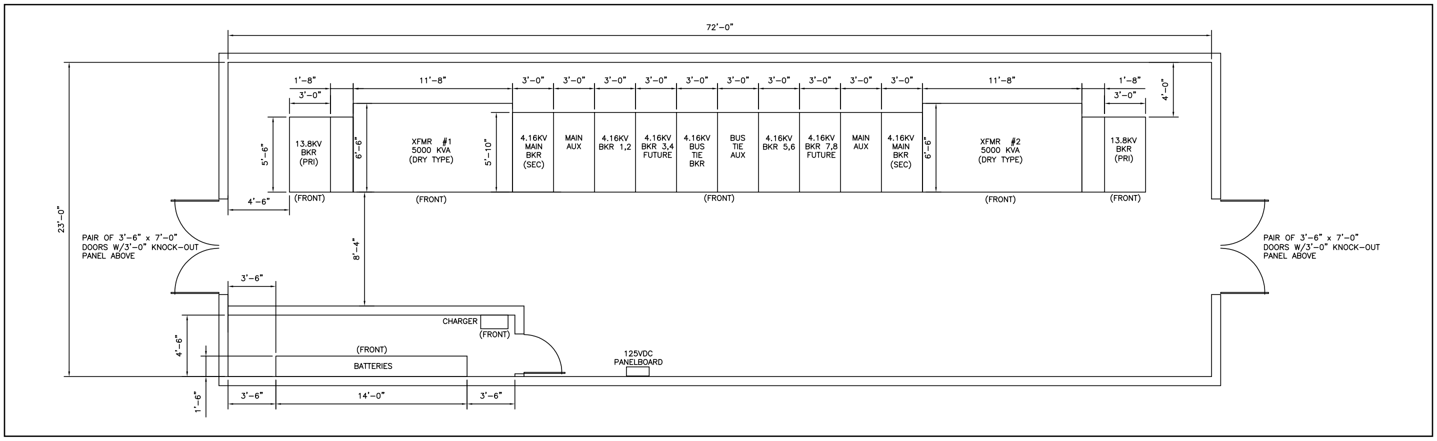


**Figure 12. Option 3—electrical general arrangement**

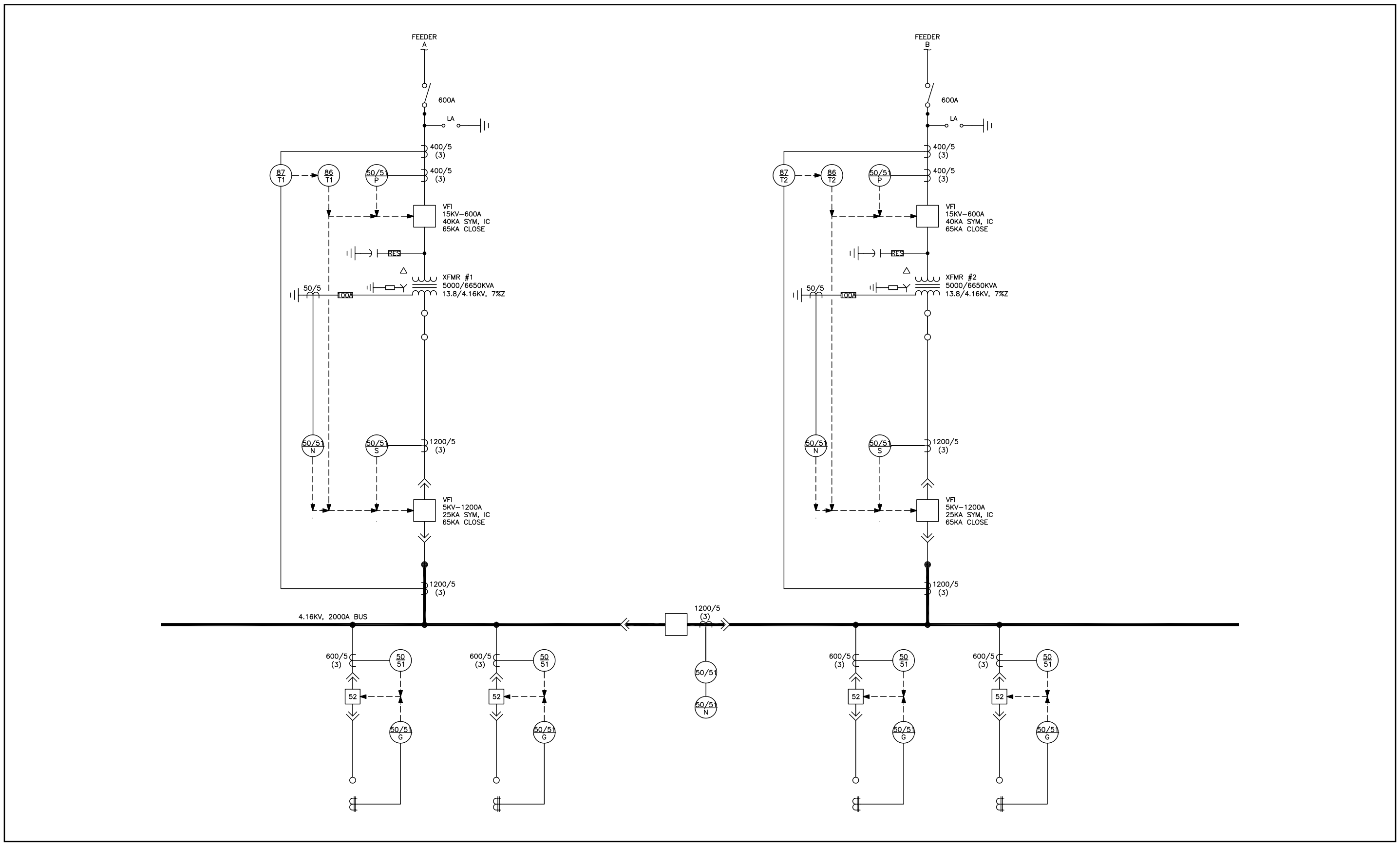


**Figure 13. Option 3—main-tie-main single-line diagram**

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