

*Using Static Transfer Switches to Enhance Data Center
Availability and Maintainability*

Introduction

Data center servers were traditionally powered by a single cord attached to a single power supply within the server. More recently, to reduce single-points-of-failure through redundancy, most manufacturers now provide servers with two power cords—allowing power delivery from two separate sources. However, the presence of two cords does not necessarily mean there are two power supplies present in the server.

While most servers in the market today have dual power supplies that can power the server independently or share the load equally, there are a number of legacy servers still in operation that actually have single power supplies with a transfer switch between cords. These power supplies do not share the load equally, and may “go to sleep,” reduce processing or shut down if power is disrupted to one of the power feeds.

One way to assure a higher level of availability with these single-cord loads is to implement Static Transfer Switches (STS), which allow the single-cord loads to be powered at all times—even if the primary bus fails or is shut down for maintenance.

Data Center Tier Levels

When it comes to these single-cord loads, data center operators have developed various power distribution architectures to ensure power is reliably delivered to their servers and that power to the power supplies is not disrupted at the same time. The power distribution architectures vary based on the desired “Tier” structure.

Data Center Tiers originally were defined by the Uptime Institute and have been generally accepted within the marketplace for a number of years. The reliability of the tiers and the additional power distribution architectures establish the overall availability of the data center. The Tiers and their definitions are shown in Figure 1.

Basic Definitions of Tier 0 - Tier 4

Tier Level	Definition
Tier 0	Power conditioning and generator back-up power. No UPS. Requires off-line maintenance.
Tier 1	Basic UPS system with one path for power delivery and no redundancy. Requires off-line maintenance for many components.
Tier 2	Basic UPS system with one path for power delivery and some redundant components. Requires off-line maintenance for some components.
Tier 3	Single UPS system with redundancy and dual/multiple active power delivery paths. Concurrent maintenance possible with critical operations on generator or alternate path.
Tier 4	Fully redundant UPS system with dual / multiple redundant active power delivery paths for fault tolerance. Concurrent maintenance possible with critical operations on the redundant UPS system.

Figure 1. The four tier levels designated by the Uptime Institute

Based on the general definition of the availability tier and the reliability of the associated equipment, the Nines of availability of the system can be calculated. Availability is defined as:

$$\text{Availability} = \text{MTBF} / (\text{MTBF} + \text{MTTR})$$

Where:

- MTBF (Mean Time Between Failures) = Increased Reliability
- MTTR (Mean Time To Repair) = Fast Recovery
- Or essentially ...Uptime / (UpTime + DownTime)

In this equation, it is preferred to have a high MTBF (>100,000 hours) and a low MTTR (typically 4-24 hours). The ultimate availability is to have the highest MTBF and the lowest possible MTTR.

The calculated availability for the various tiers, based on the tier definition and the equipment reliability, is shown in Figure 2.

Tier Level	9's of Availability	Downtime	User Value
Tier 0	99.9%	8.77 hours	Protect hardware
Tier 1	99.99%	53 minutes	Backup power/ basic site infrastructure
Tier 2	99.999%	5.3 min - 31.6 seconds	Preserve data integrity – some business interruption
Tier 3	99.99999%	31.6 sec - 3 seconds	Increased uptime – business continuity
Tier 4	99.999999%	3 sec - .3 seconds	No downtime

Figure 2. Availability of each tier

Tier 1 and 2 data centers have a single path for power, even if there are dual feeds into the individual server. The power diagram for this type of data center would look similar to the diagram shown in Figure 3.

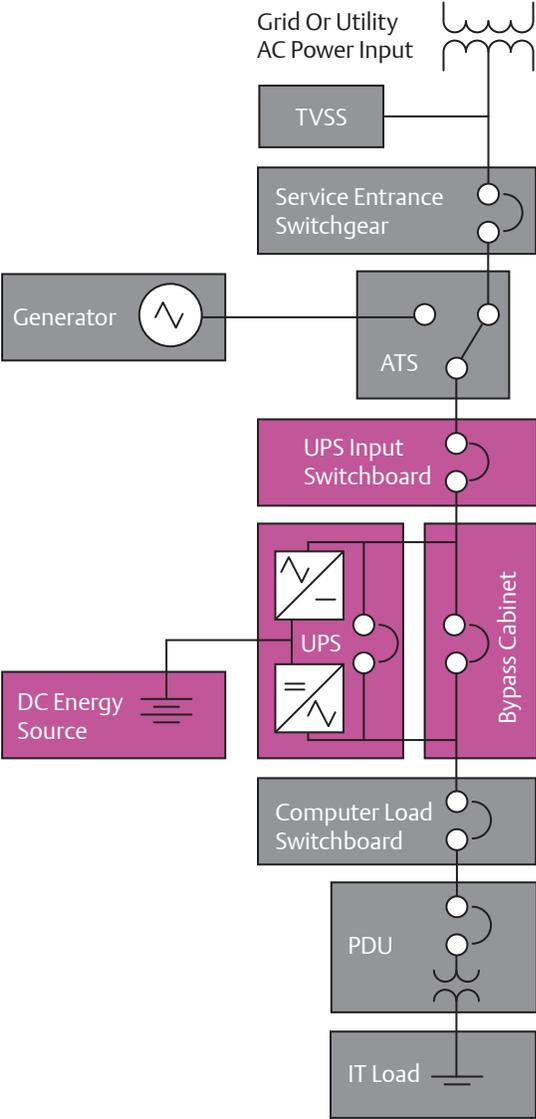
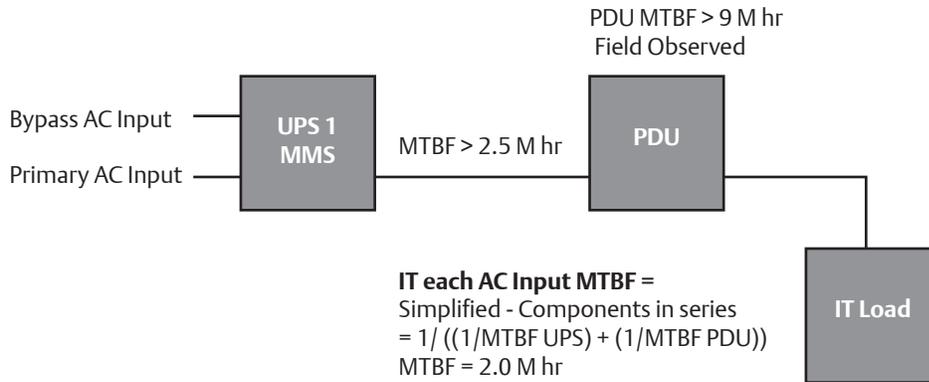


Figure 3. Diagram of a Tier 1 data center infrastructure

Based on the Tier definition and the observed MTBF of the system components, one can calculate the overall power system MTBF of the AC power delivered to the IT loads. A power system with two UPS systems in a redundant multi-module configuration feeding two power supplies has an approximate AC power MTBF into the IT equipment of about 2 million hours (Tier 2). This equates to an availability of 99.998% or almost 5 Nines of power availability (See Figure 4).

MTBF UPS Out= UPS 1 = UPS 2

Primary AC Input MTBF = IF UPS = SMS, then UPS MTBF out = > 1.2M hr MTBF – Field Observed
 Bypass AC Input MTBF = IF UPS = MMS, then UPS MTBF out = > 2.5M hr MTBF – Field Observed
 100 Hr MTBF



Single Input (both A/B inputs fed by single same source)
 MTBF = 2.0 M hrs
 $A = (MTBF) / (MTBF + MTTR)$
 A = 0.9999877335

Figure 4. Diagram of Tier 1 MTBF analysis

A typical Tier 4 data center would have a structure similar to that shown in Figure 5. In this instance, the MTBF is calculated somewhat differently since the IT load is effectively being supplied from two independent sources. In order to properly identify the overall power MTBF, one must use the following formula where MTBF1 and MTBF2 are the Mean Time Between Failure of the two independent AC power systems (similar to the Tier 2 Example):

$$MTBF = MTBF1 + MTBF2 + ((MTBF1 \times MTBF2) / MTTR).$$

$$MTBF = MTBF1 + MTBF2 + ((MTBF1 \times MTBF2) / MTTR)$$

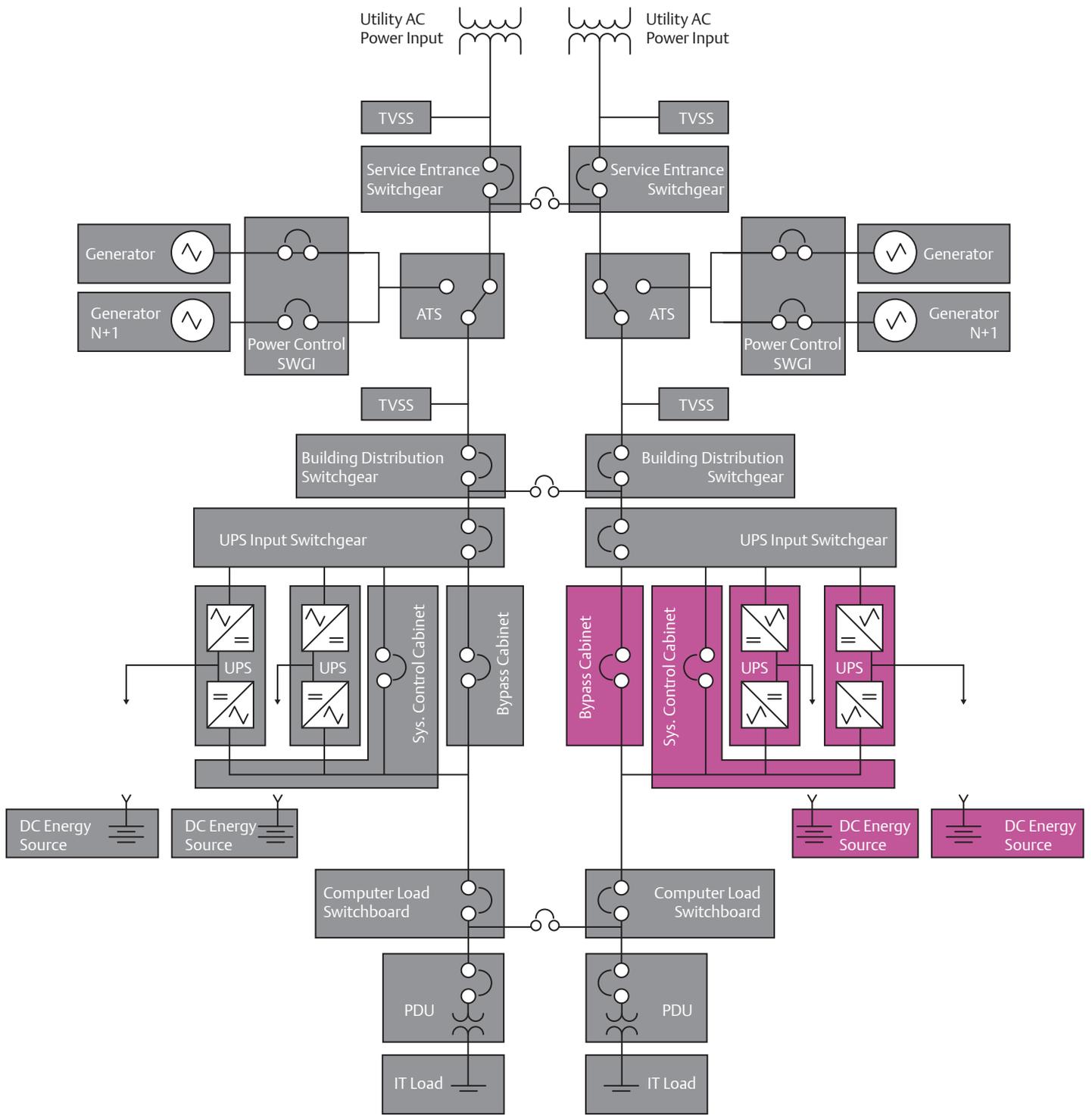


Figure 5. Diagram for a typical Tier 4 data center

For a Tier 4 data center, utilizing two independent power paths with redundant UPS systems on each path, the approximate MTBF of the IT input power is 160 billion hours or 99.999999985% or 9 Nines of availability, as can be seen in the calculations provided in Figure 6.

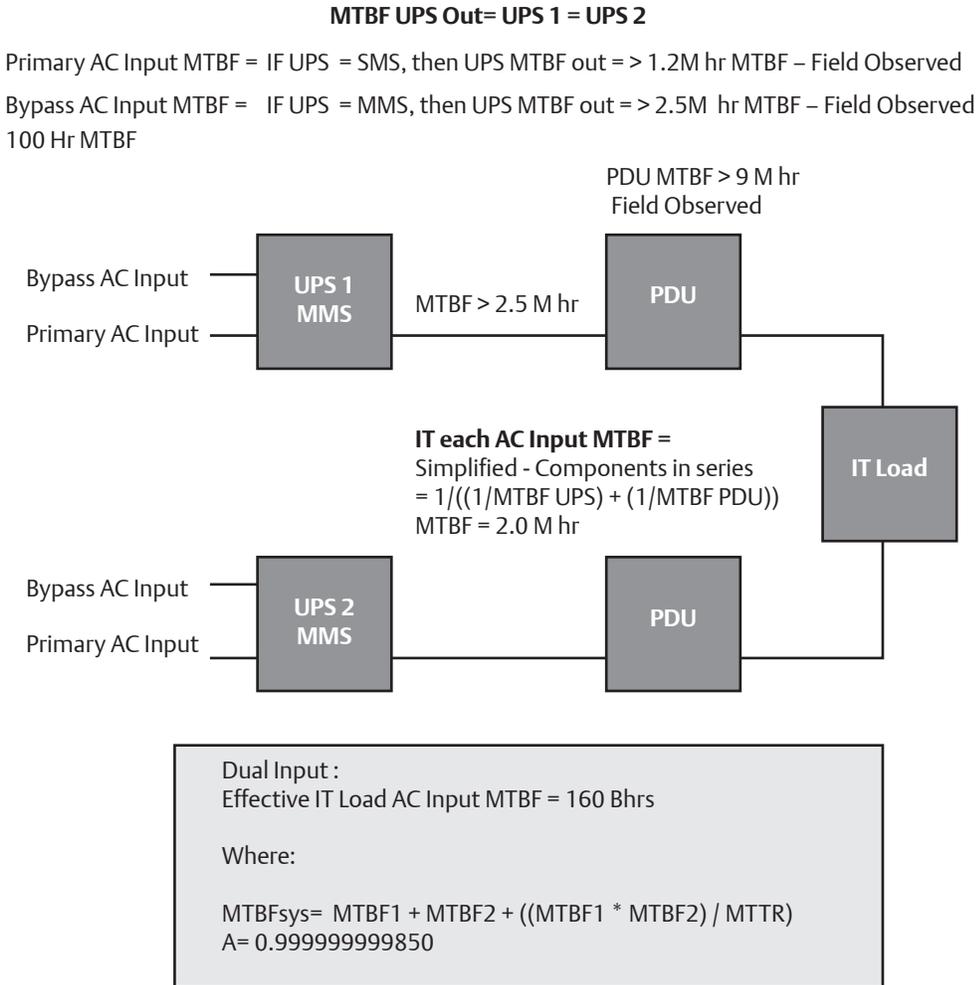


Figure 6. Calculations showing the MTBF for Tier 4 data center utilizing two independent power paths with redundant UPS systems on each path.

Higher Levels of Availability

In recent years, a number of data centers have needed even higher levels of availability. While Tier 3 and 4 systems provide essentially continuous power to the true redundant dual corded loads, they do not provide additional power availability for single cord loads or dual corded loads that require power to both cords to operate properly. In order to provide that additional reliability, static transfer switches (STS) have been implemented to allow the single-cord loads to be powered at all times, even if the primary bus fails or is shut down for maintenance.

Lately, the reliability of large power systems utilizing static transfer switches has been questioned. These system static switches typically are implemented after the computer load switchboard, but before the data center power distribution unit. This power distribution architecture is known as primary side switching (See Figure 7).

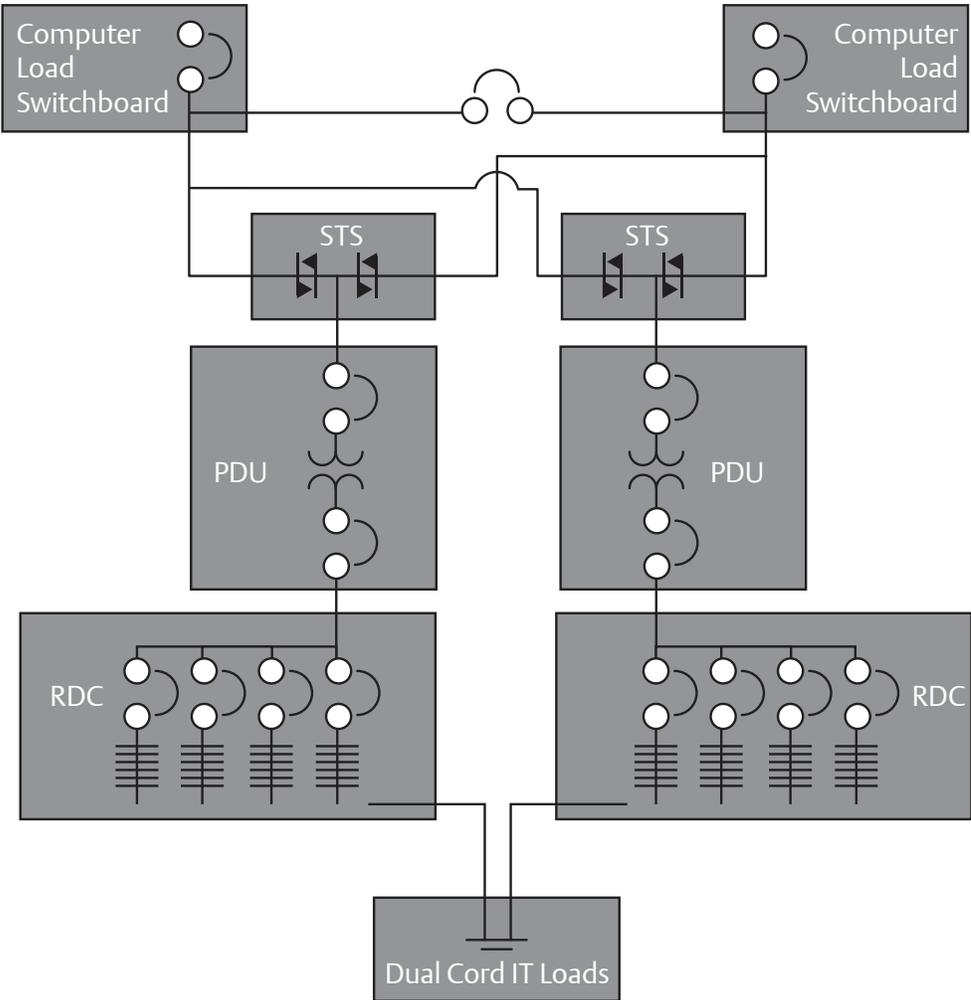


Figure 9. Primary side switching

Under this architecture, if one of the upstream buses fails, the STS will transfer to the remaining bus automatically, keeping power to both PDUs and their respective loads. Since the STS input in this application is at higher voltages (typically 480V or 600V), the STS can be sized at a much lower current rating. This enables lower cost and a smaller footprint. This architecture allows a data center to ensure that the dual bus distribution technique is operational at all times. It also allows for more reliable maintenance to be conducted for the inputs to the power distribution units.

The main concern with this configuration is the effect of transformer re-magnetizing current as a result of the micro-break, which occurs due to the break-before-make switching. The Liebert STS2 static transfer switch has mitigated this issue through its patented Optimized Transfer option, which minimizes voltage disturbances during load switching of magnetics while still maintaining transformer flux balance.

The Tier 4 system MTBF calculation, with the added field observed failure rate of the Liebert STS2 allows us to determine a relative power MTBF of a primary side switched application. Utilizing field observed data Emerson Network Power determined the relative MTBF of power to the IT load for these architectures is 486 billion hours, or an availability of 99.999999951%, or 10 Nines (See Figure 8).

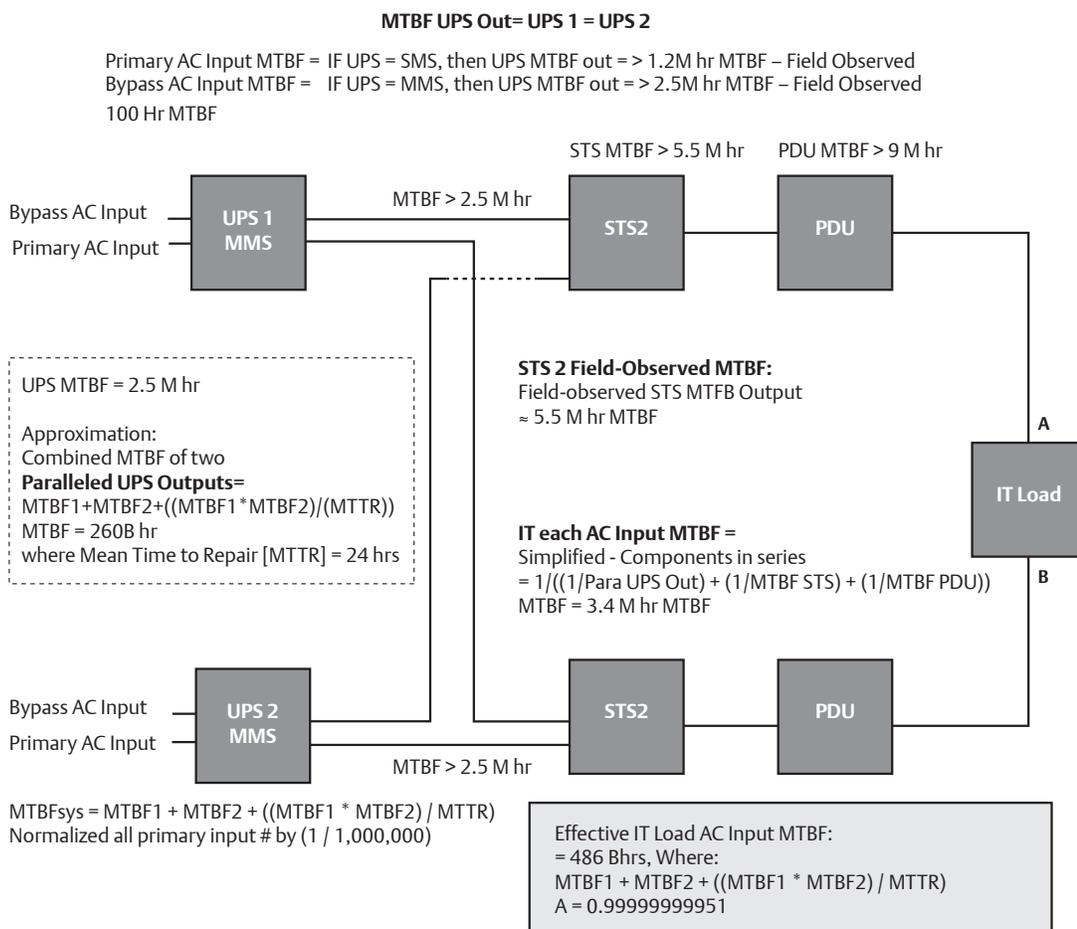


Figure 8. Tier 4 MTBF Analysis with secondary side switching

Another possible configuration that can be used with a static transfer switch is to position the STS on the output (downstream side) of the power distribution unit. This distribution architecture is referred to as secondary side switching. (See Figure 9)

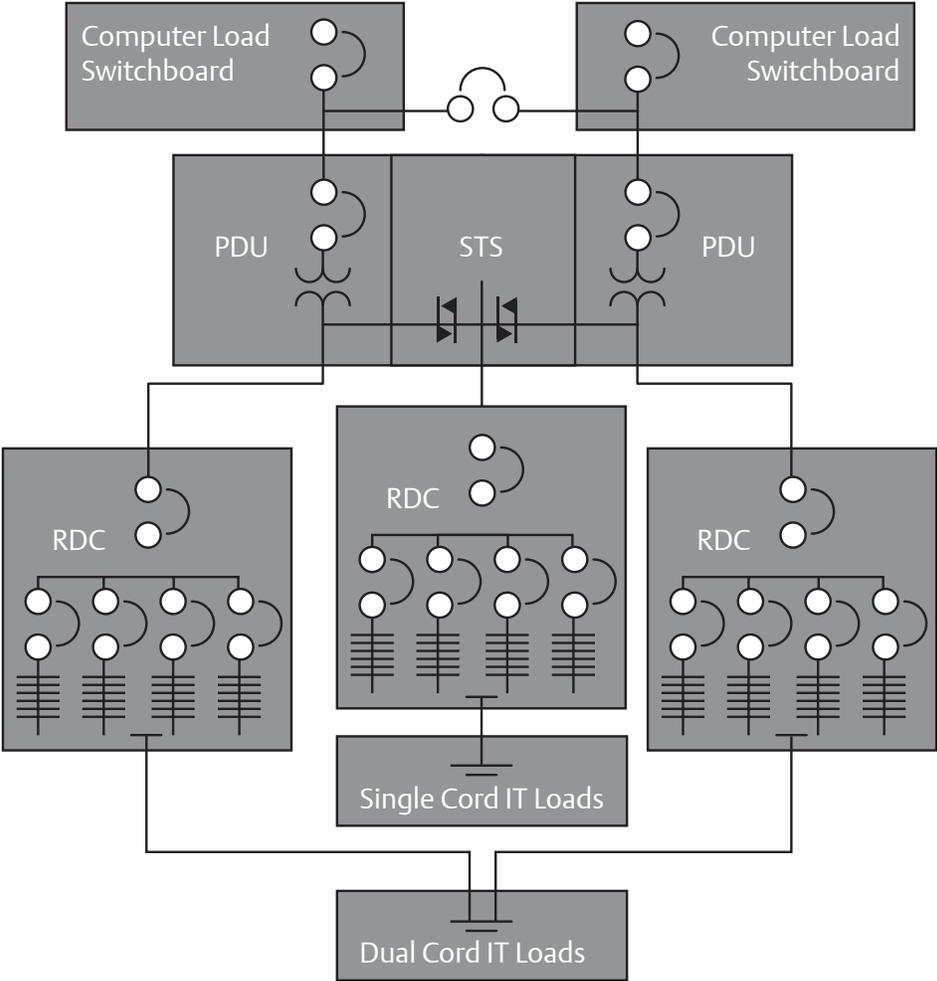


Figure 9. Primary side switching

With secondary-side-switching architecture, if the upstream bus fails, the STS will transfer to the remaining bus automatically to keep power to the loads. Since the STS input in this application is at lower voltage (e.g., 208V), the STS must be sized at a higher current rating, which relates to higher cost and larger footprint. Two advantages of secondary switching are: 1) that it allows for maintaining the power distribution unit transformers without shutting down the data center load; and 2) it also eliminates transformer re-magnetizing current because the transformer stays energized at all times.

Using the Tier 4 system power MTBF calculation, and incorporating the field-observed failure rate of the Liebert STS2, we can calculate a relative MTBF of a secondary-side-switched application. Utilizing the field-observed data, Emerson Network Power determined the relative MTBF of power to the IT load for these architectures to be 1,260 billion hours, or an availability of 99.9999999981% (almost 11 Nines). (See Figure 10)

These simplified examples clearly illustrate that installing static transfer switches on the primary and secondary busses greatly increases the overall system availability.

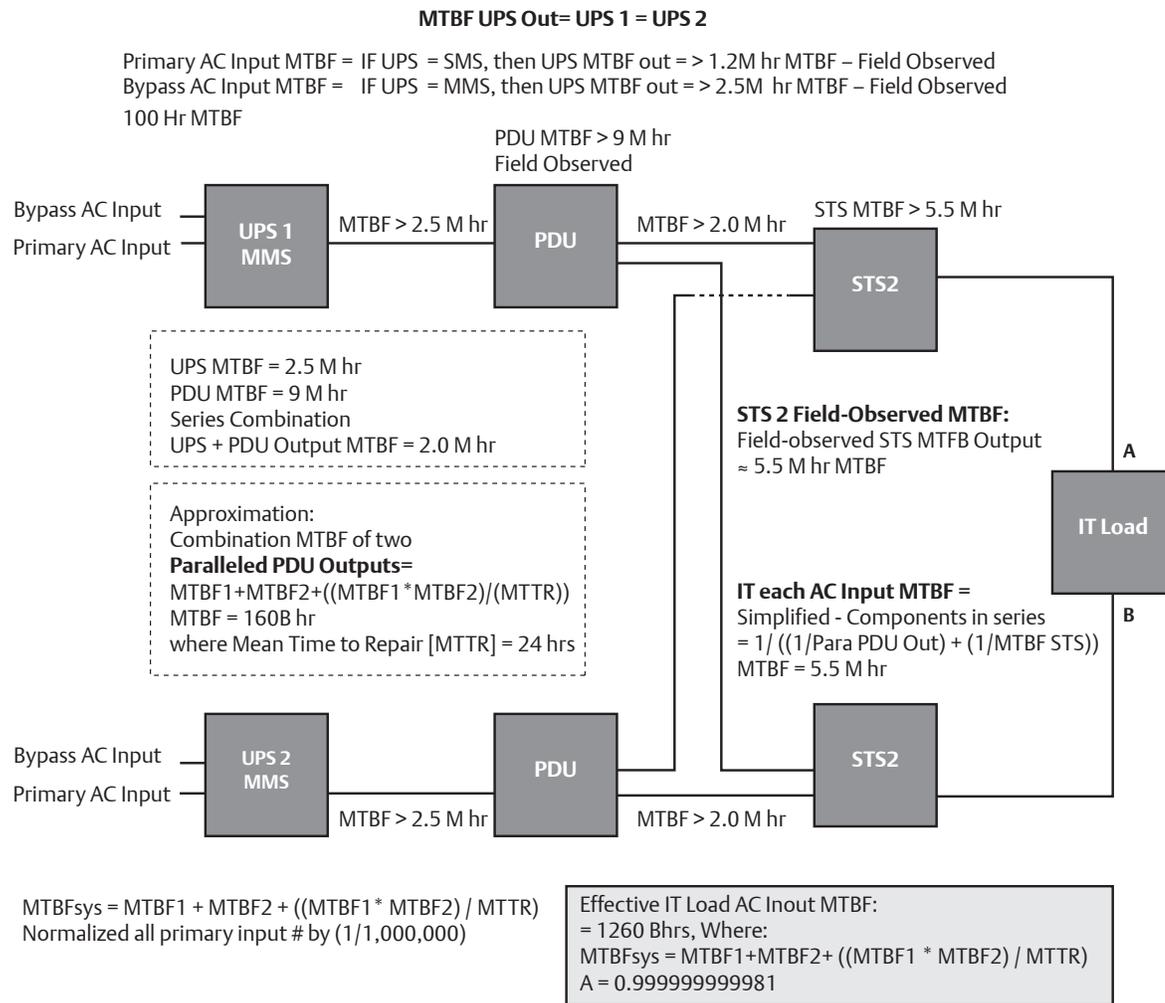


Figure 10. Tier 4 MTBF analysis with secondary side switching

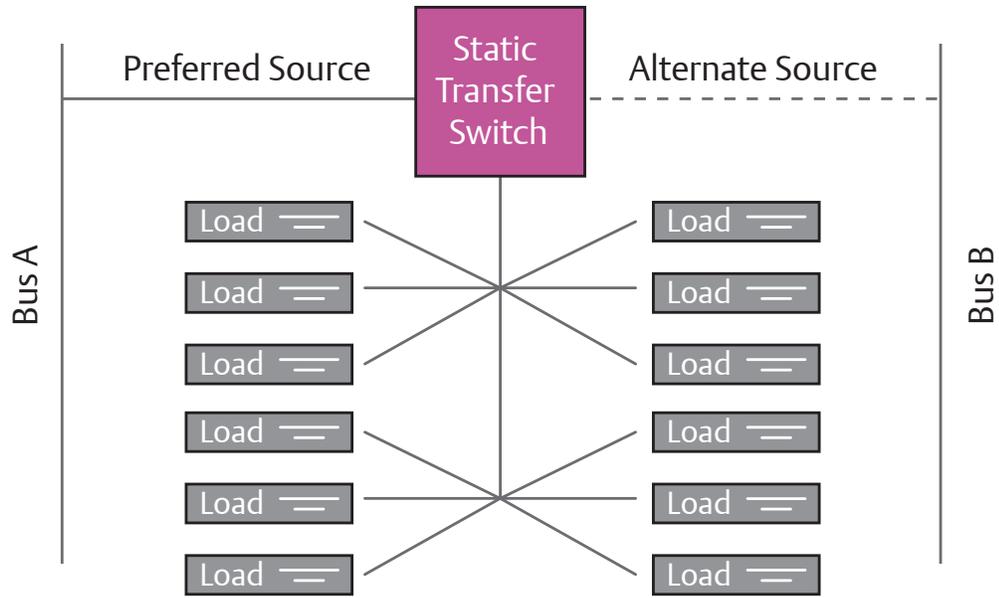
Additional Benefits of Static Switch Use

In addition to providing high levels of power availability, including the static transfer switch also helps to improve system maintainability and fault compartmentalization.

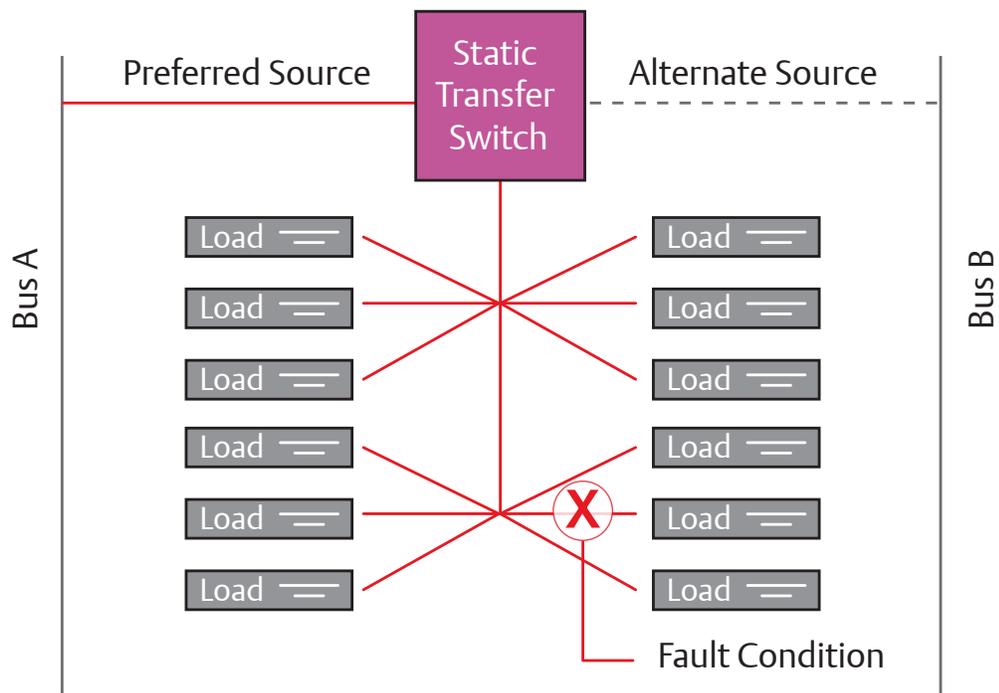
In systems with static switches, when service needs to be done on one side of the system, power can be seamlessly transferred from one bus to the other bus. When the service is completed, the power can be returned seamlessly to the shared status, without experiencing any power outage.

Load faults are another potential source of failures in the data center. If a load fault occurs on a dual bus system it can affect the bus and all the loads, both single- and dual-corded, being power by this bus. If the bus fails before the load breaker opens, all single-corded loads on this bus also will fail. The dual-corded loads, as stated above, also might go offline or stop processing.

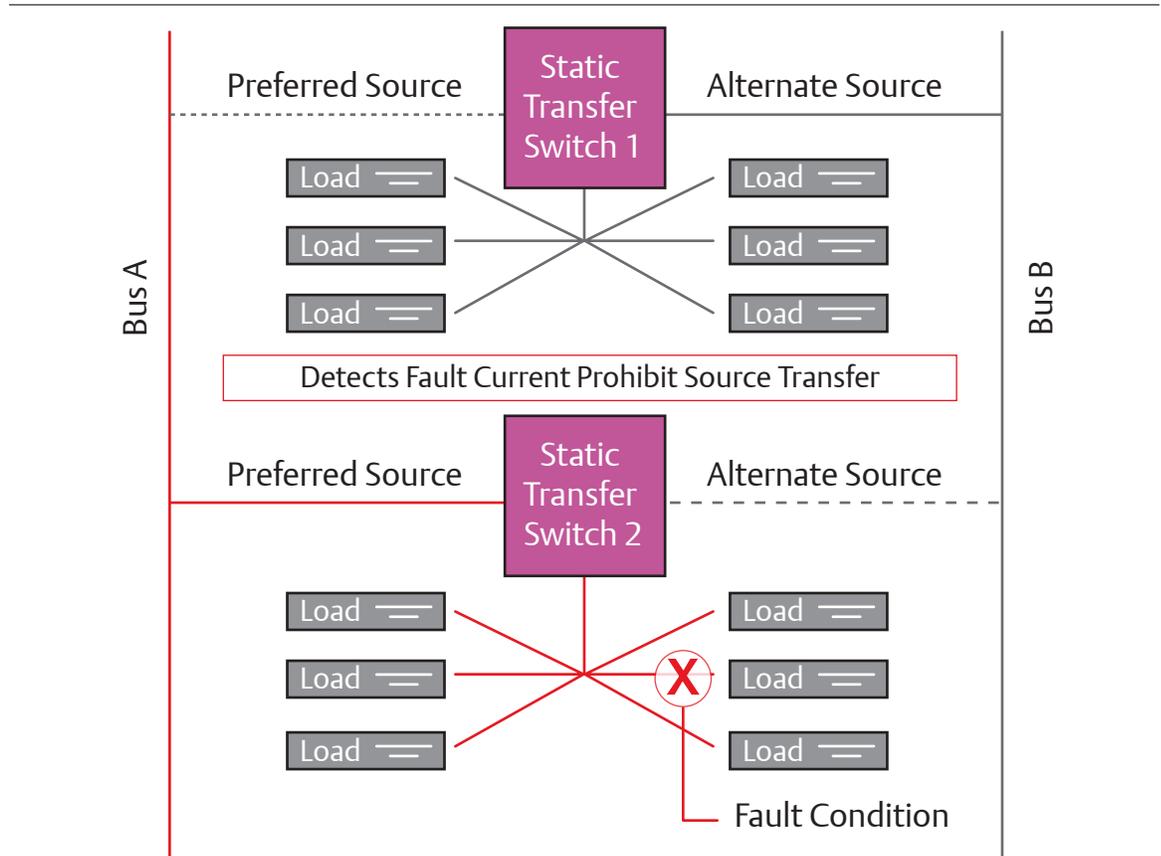
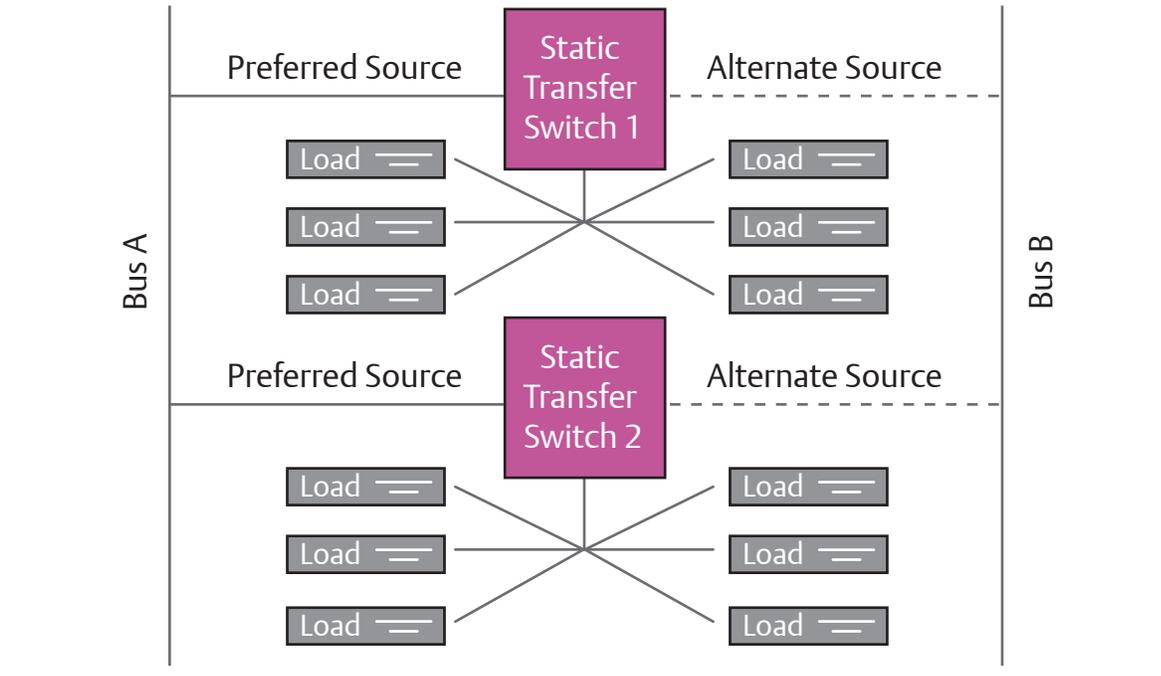
If an STS is being used in a system with a load fault, it remains on that bus and prevents the fault from being transferred to the second bus. Even in this configuration, the results are the same as above—single-corded loads will fail and dual-corded loads may go offline or stop processing.



Detects Fault Current Prohibit Source Transfer



However, there is a solution to this issue. Distributing the loads among multiple STS will minimize the overall affect and reduce the number of loads that might fail.



Conclusion

As data centers increasingly seek higher levels of uptime, the ability to maintain consistent power to the servers is critical. Innovations and advances in server power supplies have allowed for dual bus distribution. Fortunately, when this is designed into the data center through a proper Tier level and power distribution scheme, data centers will be able to take advantage of the reliabilities of dual power supplies.

While dual bus distribution does provide high reliability, Emerson Network Power recommends the use of static transfer switches in either a primary side or secondary side distribution scheme to achieve the additional reliability often demanded by today's data centers. Static transfer switches also provide increased fault isolation, which can protect the data center from internal faults and conditions which often result in significant downtime. Deploying static switches also provides increased protection during service times, ensuring that constant power is delivered to the servers, especially during critical moments when servers are switching from one source to another.

Disclaimer:

For the purposes of illustration, the MTBF calculations for the one-line diagrams illustrated have been significantly simplified, and should be utilized only for relative comparisons. Taking into account all components in the power distribution diagram in a more comprehensive manner will reduce the calculated power MTBF and availability by relatively similar factors.

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