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# Study On Power Supply Redundancy Planning To Improve Data Canter Reliability

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***Abstract***

*The data center is a critical infrastructure that demands high reliability of power supply. Electrical system failures, including those caused by human error such as the incident in July 2024, can result in significant financial and reputational losses. This study aims to analyze and compare three redundancy configurations of data center electrical systems—N, N+1, and 2N—in order to enhance the operational reliability of the JTT Pasiranji Data Center. The research method was conducted through planning studies, dual-bus electrical system design analysis, and validation via a series of staged commissioning tests (CX 1 to CX 5), which included insulation testing, UPS and ATS switching time testing, generator performance testing, and failover tests under three failure scenarios. The results show that the 2N configuration provides an availability level of 99.982%, equivalent to the Uptime Institute Tier III standard, significantly surpassing N+1 (99.741%) and N (99.671%). Switching time tests confirmed that the double-conversion online UPS operates without switching gap (0 ms), ATS performs automatic transfer in an average of 8.2–8.5 seconds, and generators reach full load readiness within 11.3–11.8 seconds. Failover tests across all three failure scenarios verified that the 2N configuration maintained 100% server uptime without service interruption. This study also found that system reliability is not solely determined by technical design superiority, but is also influenced by human error, adherence to commissioning procedures, real-time monitoring, and preventive maintenance.*

Keywords: ***Data Center; Electrical Redundancy; 2N Configuration; N+1 Configuration; Reliability; UPS; Generator; Commissioning; Failover Test***

## INTRODUCTION

Data center is a server or computer room where multiple company servers are housed (Bullock, M., 2009). It serves as a storage facility for data and also focuses on delivering network and internet information services (Ye, H.; Song, Z.; Sun, Q, 2014). Today, data centers are a branch of IT widely utilized by institutions and/or companies such as government agencies, educational institutions, banks, and large corporations, with the aim of improving services and competitiveness in serving stakeholders. The ultimate goal is to enhance the effectiveness of the business processes of these institutions or companies (Andi Rosano; Djadjat Sudaradjat. 2021).

In managing a data center, security and reliability are two fundamental pillars that cannot be overlooked. Data center reliability refers to the ability of the facility to operate without disruption during unexpected events. Such events may include network and cooling system failures, natural disasters, power outages, human errors, and cyberattacks.

Two years ago, in July 2024, a member of the operations team made a critical mistake. A power source that was supposed to back up a network was incorrectly connected to two power supplies due to insufficient knowledge of redundancy systems. This resulted in a major power supply failure, significantly impacting the company operating the data center.

This incident serves as an important lesson that neglecting redundancy aspects can lead to severe financial and reputational losses. Data centers mitigate downtime by building redundancy into their infrastructure. Redundancy planning involves duplicating critical components—such as UPS systems, cooling systems, and backup generators—to ensure continuous operation even if one component fails .

Technically, electrical redundancy systems in data centers are implemented through several common architectures—such as N, N+1, 2N, and 2N+1—which differ in the level of duplication of critical components (UPS, dual distribution paths, generators, switchgear) (TIA 942).

## RESEARCH METHODS

This study employs a design research approach to investigate the planning of a redundant power supply system for data centers. The research is conducted through several stages, namely literature review, data collection planning, data collection, system design, testing, data analysis, and finally drawing conclusions and providing recommendations. This systematic approach is expected to produce a reliable and efficient redundancy design that meets the operational requirements of modern data centers.

After conducting the literature review, the next stage is planning the data collection process. At this stage, the types of data required for the design process are determined, including data center load capacity, single-line diagrams, electrical system configurations, equipment specifications, and the redundancy standards to be implemented. These data are obtained through document studies, technical references, and other relevant secondary data sources.

The subsequent stage is data collection, which serves as the basis for both the design and testing processes. The collected data are then classified into two categories: design data and testing data. Design data are used to determine the redundancy configuration, equipment capacity, and power distribution paths to be implemented in the system. Meanwhile, testing data are utilized to evaluate the performance of the designed system through simulations and analyses under both normal operating conditions and failure scenarios.

Based on these data, the redundant power supply system for the data center is designed by considering aspects such as reliability, power availability, and the system's capability to maintain operational continuity in the event of a failure of one of the power sources or electrical components. The design results are then analyzed to evaluate the system reliability, the effectiveness of the implemented redundancy configuration, and the suitability of the design with the operational requirements of the data center.

## RESULTS AND DISCUSSION

### Comparison of Power Supply Redundancy Designs

This heading works well as a section title in your report or thesis. It sets the stage for presenting the differences between configurations such as N, N+1, 2N, and 2N+1, along with their impact on reliability, availability, and failover performance.
Would you like me to help draft a comparative table in English that contrasts these redundancy designs (N, N+1, 2N, 2N+1) with their definitions, advantages, and limitations? That way, your section will look complete and professional.

### Design Configuration N (Without Redundancy)

The N configuration is the basic setup that only meets the minimum power capacity requirements without providing any backup (redundant) components. In this configuration, each electrical component—from the PLN source, generator, UPS, MSB, to the PDU exists as a single unit. If any one component fails, the entire power supply to the servers will be disrupted or halted. In the context of the JTT Pasiranji Data Center, the N configuration is equivalent to a condition where only Path A is active without Path B as backup. This condition has never been implemented in the data center, as redundancy architecture was incorporated from the initial planning stage. The N configuration is studied as a baseline comparison to understand the extent of reliability improvement provided by redundancy implementation.

### Design Configuration N+1 (Partial Redundancy)

The N+1 configuration provides one additional unit or path beyond the minimum required. If one unit fails, the backup unit automatically takes over the load, ensuring uninterrupted operations. This configuration is equivalent to the Tier II standard according to the Uptime Institute.

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At the JTT Pasiranji Data Center, the N+1 configuration is applied partially to the UPS system, where the two installed UPS units back up each other. However, the distribution path from the MSB to the PDU in this configuration remains a single path, meaning that a failure in the distribution line can still cause service disruption.

**Design Configuration 2N (Full Redundancy / Fully Redundant)**

The 2N configuration provides two complete sets of components and two fully independent distribution paths. Each path is capable of carrying 100% of the load on its own. This is the configuration implemented at the JTT Pasiranji Data Center as the design target, where Path A and Path B are designed identically and operate simultaneously. Servers equipped with dual power supplies receive input from two different sources, ensuring that a full failure of one path does not affect service continuity.

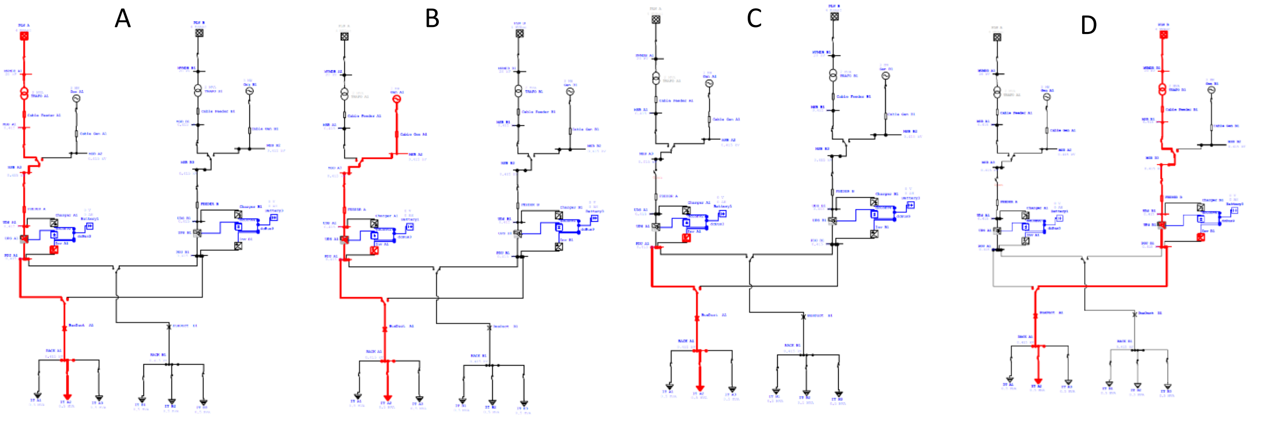


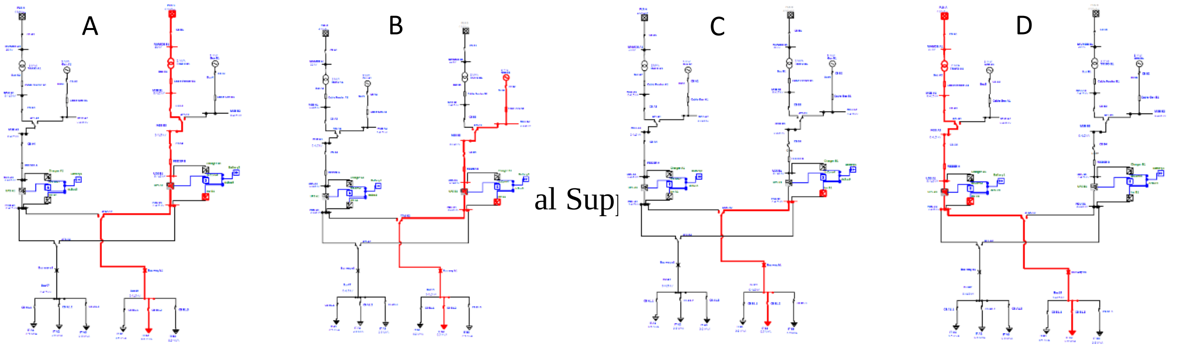

**Figure1. Electrical Supply from Source A**

Normal Condition of Feeder A The electrical power originates from PLN A and flows through Transformer A1 → MDB A → Feeder A → UPS A1 → PDU A1 → Busduct A1 → Rack A1 → IT Load A2. Path A serves as the primary source supplying all IT loads, while Path B remains in standby condition.

PLN A Failure – Generator A Active When the supply from PLN A is interrupted, Generator A1 automatically takes over as the power source. The power flow changes to Generator A1 → MDB A → Feeder A → UPS A1 → PDU A1 → Busduct A1 → Rack A1 → IT Load A2. The UPS ensures power continuity during the transition from PLN to the generator.

Path A Distribution Active with Backup Power from UPS In this condition, the power supply continues to originate from Path A and is delivered through UPS A1 and PDU A1 to Busduct A1, supplying the IT load. The system remains in normal operation despite configuration changes on the source or distribution side.

PLN B Supplying Load Through Redundant Path When Path A experiences a disturbance, the power supply is switched to PLN B. The electricity flows through Transformer B1 → MDB B → Feeder B → UPS B1 → PDU B1, then continues via the interconnection path to Busduct A1 and Rack A1. With this redundancy configuration, IT loads continue to receive uninterrupted power supply without downtime.

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Normal Condition of Feeder B The power supply originates from PLN B and flows through Transformer B1, ATS B1, Feeder B, UPS B1, and PDU B1. The electricity is then delivered via ATS B2 to Busway B1, supplying IT Load B2. Path A remains in standby condition, so all loads are served by Path B.

Generator B as Backup When a disturbance occurs in the PLN B supply, Generator B1 activates as the backup source. The power flow changes to Generator B1 → ATS B1 → Feeder B → UPS B1 → PDU B1 → ATS B2 → Busway B1 → IT Load B2. The UPS ensures power continuity during the transition from PLN to the generator.

Path B Distribution Active with Backup Power from UPS In this condition, the distribution path from UPS B1 through PDU B1 and Busway B1 remains active to supply the IT load. Even if a disturbance occurs upstream in the system, the load continues to receive power through the available redundant path.

PLN A Supplying Load Through Redundant Path In this condition, the power supply originates from PLN A and flows through Transformer A1, Feeder A, UPS A1, and PDU A1. The electricity is then delivered via ATS B2 to Busway B1, supplying IT Load B2. This condition demonstrates that Path A can take over the load supply when Path B experiences a disturbance.

**Failure Scenario Simulation**

The failover test was carried out as part of stage CX 5 to validate the overall capability of the redundancy system. Three failure scenarios were simulated to cover conditions ranging from power source failure, UPS component failure, to distribution path failure.

**Scenario 1**, Total Failure of PLN A the PLN A source was suddenly disconnected to simulate a total blackout condition on Path A. The active load at the time of testing was 70% of capacity.

**Scenario 2**, Failure of One UPS Unit (N+1 Configuration**)** UPS A was suddenly shut down to simulate a UPS module failure. The system was in a normal active PLN condition, with the load distributed between UPS A and UPS B.

**Scenario 3,** Full Failure of Path A (2N Configuration Validation) The entire Path A (PLN A, Generator A, UPS A, MSB A, PDU A) was simultaneously disconnected to simulate a total failure of one path in the 2N configuration. Server racks equipped with dual power supplies (PSU A connected to Path A, PSU B connected to Path B) were observed for their ability to sustain operation on a single source. Scenario 3 confirmed the superiority of the 2N configuration. All servers (100%) successfully maintained operations without service interruption despite the complete failure of Path A. Servers with dual PSUs instantly switched to PSU-B (0 ms) since both PSUs were operating simultaneously. This finding qualitatively demonstrates that the implemented 2N redundancy design has successfully achieved its planning objectives.

Design Compliance with Test Results, The results of all tests conducted from CX 1 through CX 5 indicate that the electrical system of the JTT Pasiranji Data Center generally operates in accordance with the established design specifications. The following table summarizes the comparison between the design values and the actual test results for critical parameters:

**Tabel 1 Summary of Design Data vs Actual Test Data Comparison**

| Critical Parameter | Design Value | Test Result* | Compliance |
|---|---|---|---|
| Switching time UPS (PLN → UPS) | 0 Mili Second (VFI) | 0 Mili Second | Compliant |
| Switching time UPS (ke static bypass) | < 4 Mili Second | 2,3 Mili second | Compliant |
| Switching time ATS (PLN → Genset) | < 10 Second | 8,2 – 8,5 second | Compliant |
| Cold start Genset A & B | < 10 second | 6,8 – 7,1 second | Compliant |
| Idle Time for Generator Run | < 15 second | 11,3 – 11,8 second | Compliant |

| Critical Parameter | Design Value | Test Result* | Compliance |
|---|---|---|---|
| Battery runtime UPS (Full Load) | ≥ 10 minutes | 12,5 – 13,0 minutes | Compliant |
| Efficiency UPS double conversion | ≥ 96% | 96,4% | Compliant |
| Failover 2N: server normal active | 100% | 100% | Compliant |
| Insulation resistance UPS result test CX2 | ≥ 10 MΩ | 15,2 MΩ | Compliant |
| Voltage dip load acceptance Categories | < 10% | 7,5 – 8% | Compliant |

## CONCLUSION

The study of the electrical power supply redundancy system at the JTT Pasiranji Data Center demonstrates that relying solely on the main PLN source without redundancy (N configuration) results in low reliability, with availability of only 99.671% or about 28.8 hours of downtime per year. In contrast, the 2N configuration proves to be the most optimal solution, achieving 99.982% availability (about 1.6 hours downtime per year) and meeting Tier III Uptime Institute standards by eliminating single points of failure. Failover tests across multiple scenarios confirmed that the dual-bus architecture (Path A and Path B) maintained uninterrupted service for all servers. Commissioning tests (CX 1–CX 5) validated that all critical parameters passed within design tolerances, with UPS operating at zero switching gap, ATS transferring in around 8.2–8.5 seconds, and generators reaching full load readiness in 11.3–11.8 seconds.

## REFERENCES

Andi Rosano; Djadjat Sudaradjat. (2021). Perancangan Ruang Data Center Bank XYZ Menggunakan Standar ANSI/BICSI 002 dan Metode PPDIOO.

Bullock, M. (2009). Data Center Definition and Solutions.

CX Pro 8.30 Commisioning Plan

Jeckson Sidabutar; Nia Yulianti. (2022). Design Perangkat Aktif Berdasarkan Standard TIA 942 Tingkat 3.

Kristopel Tulus Pandapotan Shimamora. (2024). Back Up Sistem Kelistrikan Utama pada Gedung INFINITY Kemang Village.

Ni Made Vifiana Anggi Suryanti; I Nengah Suweden; I Wayan Arta Wijaya. (2023). Rancangan Sistem Kelistrikan Data Center Berstandar Tier 3 Pada Perbankan.

Nathanael Dimas Chritiyadi. (2025). Perawatan Preventif High Speed Circuit Breaker sebagai Penunjang Tegangan Listrik pada LRT Jabodetabek Traction Power Substation Cawang-Herjamukti.

Shrestha, B. R. et al. (2018). *Efficiency and Reliability Analyses of AC and 380V DC Distribution in Data Centers*, IEEE Access.

Syarifah Fahira Sulaiman; Adhitia Hadi Priambodo. (2024). *Downtime Data Center* : Memahami Penyebab ,Dampak dan Solusi Efektif.

TIA 942 Data Center Infrastructure Standard

Ye, H.; Song, Z.; Sun, Q. (2014). Design of green data center deployment model based on cloud computing and TIA942 heat dissipation standard.

Yuli Akbar. (2023). Distribusi Daya Listrik Data Center MMR 1-3 Back up Power Supply UPS & Genset Kota Delta Mas Cikarang Pusat.