POWER AND COOLING CONSULTANTS MASTER CLASS 2016

HITTING THE GREEN MARK:

BEST PRACTICES IN DATA CENTER OPTIMIZATION

EMERSON
Network Power

High Performance and Optimized Power Architectures with Predictive Infrastructure Management Tool for Future Green Data Centers

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Overview : Data Center Research

5 primary focus areas in the design of green data centers

1. Electrical Systems
2. IT Systems
3. Cooling Systems
4. Infrastructure & Facilities Management
5. Environmental Conditions

System Design

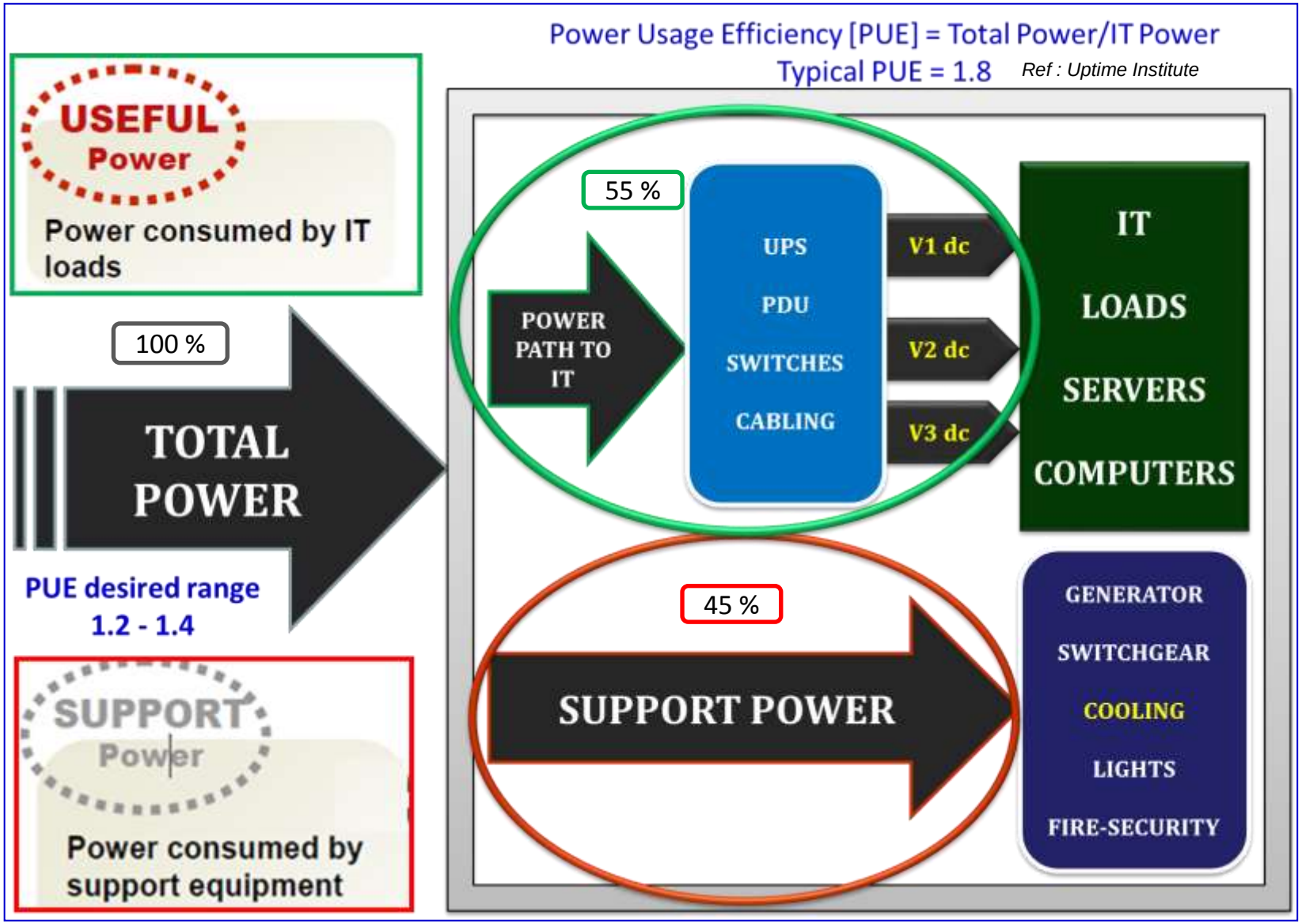
1. Optimized Power Supply Architectures
2. Highly Efficient Power Electronic Converter Systems
3. Novel Control Algorithms & DCIM tools
4. AC vs DC Distribution System Comparison

Challenges

1. Power Quality Problems
2. Efficiency & Cost
3. Facilities & Cooling requirements
4. Performance & Reliability

DCIM : Data Center Infrastructure Management

Typical Power Distribution : Data Center



Data Center Standards



Green Mark Standards : Singapore

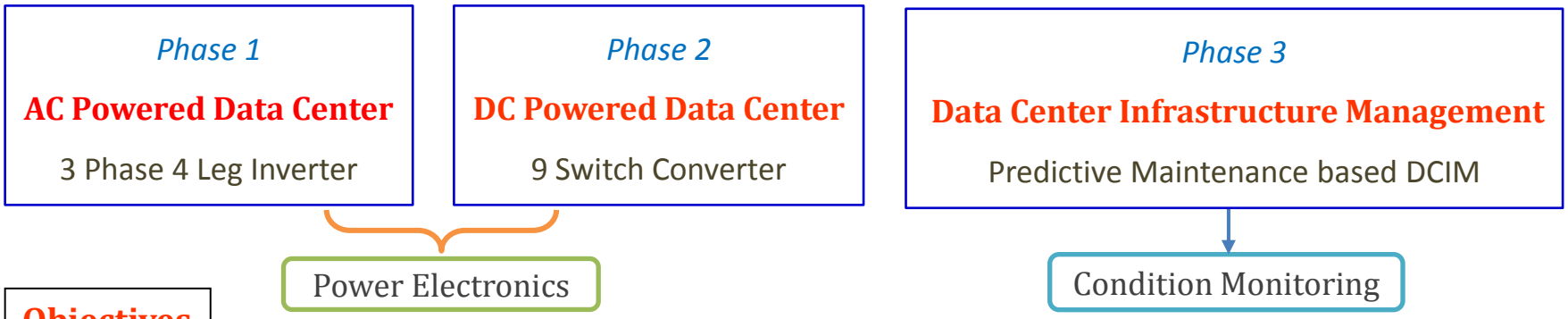
- New "Green Mark" pre-requisite requirements have been released by BCA-IDA for Data Centres in Singapore.
- Out of 125 total green mark score, 83 points are allocated for "Energy Efficiency category". This clearly shows that a high performance power architecture & an intelligent infrastructure management tool will have a huge impact on the overall data centre efficiency.

Green Mark Score	Green Mark Rating
90 and above	Green Mark Platinum
85 to <90	Green Mark GoldPlus
75 to <85	Green Mark Gold
50 to <75	Green Mark Certified

Assessment criteria	Green mark score / points
Part 1 – Energy Efficiency	83
Part 2 - Water Efficiency	12
Part 3 - Sustainable Construction & Management	12
Part 4 - Indoor Environmental Quality	8
Part 5 - Other Green Features & Innovations	10
Total points allocated	125

Green Mark pre-requisite requirements for New Data Centres - BCA-IDA Singapore

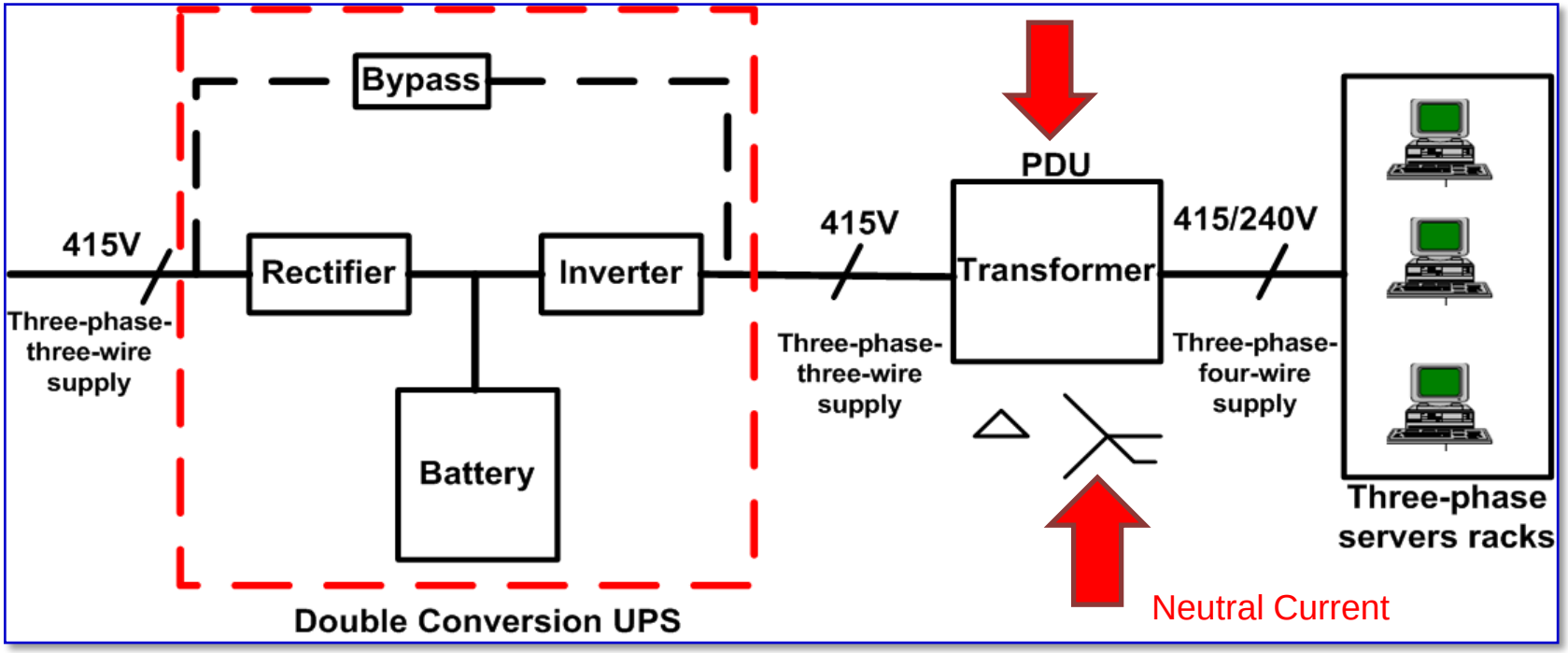
Our Research (Innovation)



Objectives

- ✧ Optimized design & development of High Efficient Power Supply Architectures for green data centers.
- ✧ To reduce the number of power conversion stages and to minimize cooling requirements by reducing heat generation due to electrical losses.
- ✧ To improve Power Usage Efficiency (PUE).
- ✧ Design and validation of high performance controllers for power electronic converters.
- ✧ Penetration of Renewable Energy Sources to reduce energy consumption and thereby the carbon footprint.
- ✧ DCIM, AC and DC power distribution - Detailed implementation.

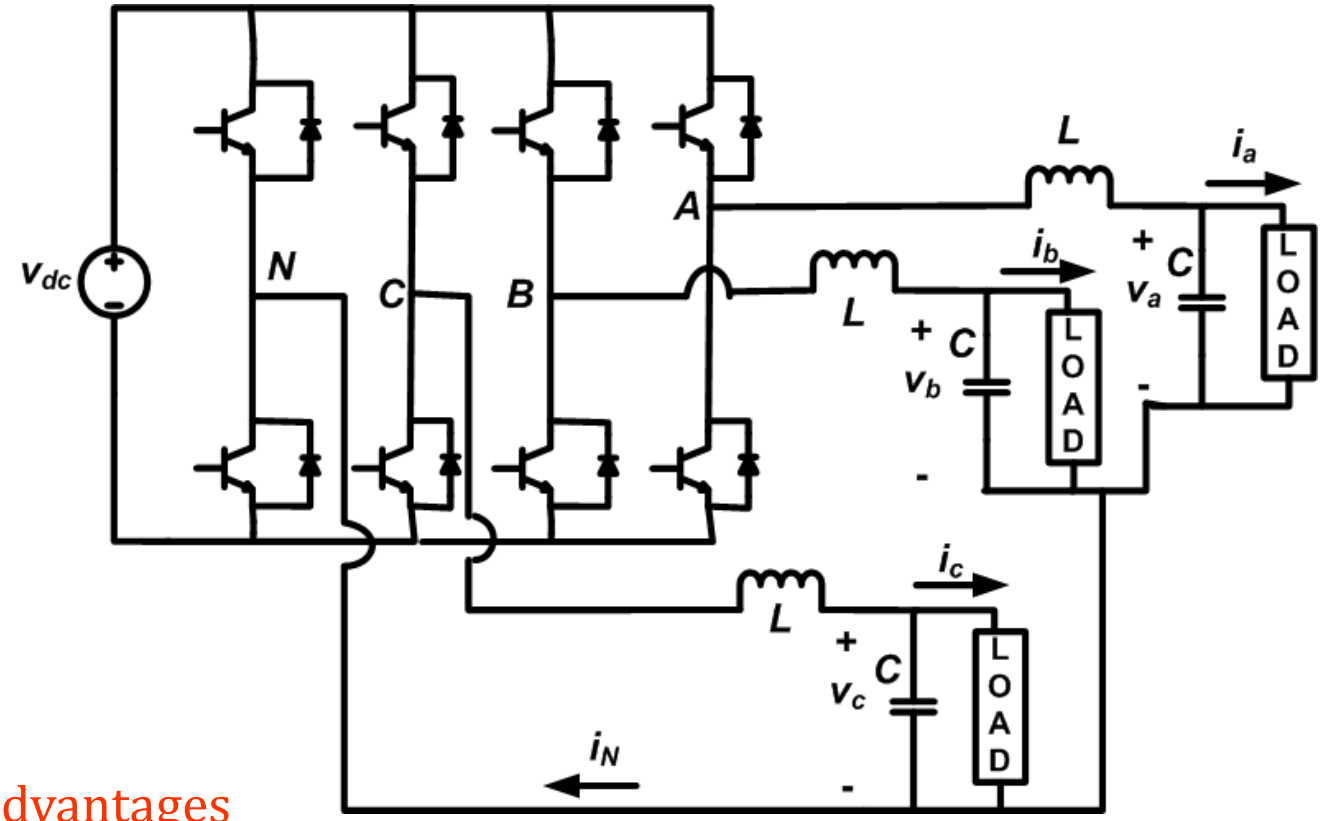
Typical Power Supply Architecture for Conventional AC Data Centers



Disadvantages

- PDU is needed
- Neutral current heating appears in the secondary side of the transformer
- Extra thermal loss in the PDU

Proposed Four-leg UPS Inverter For Three-Phase Asymmetrical Load



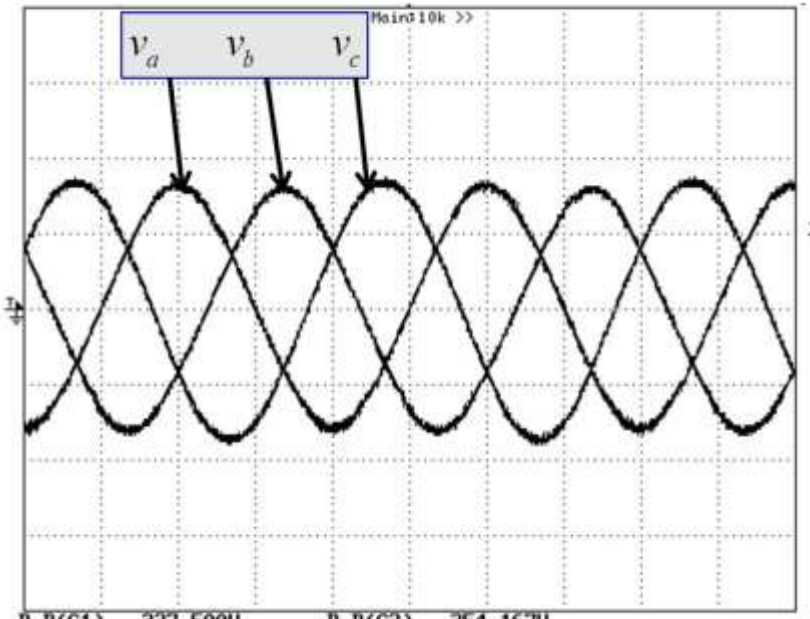
Advantages

1. Elimination of PDU, reduced associated thermal generation
2. Minimization of Neutral Current – Application of high-performance control for providing quality voltage to the servers

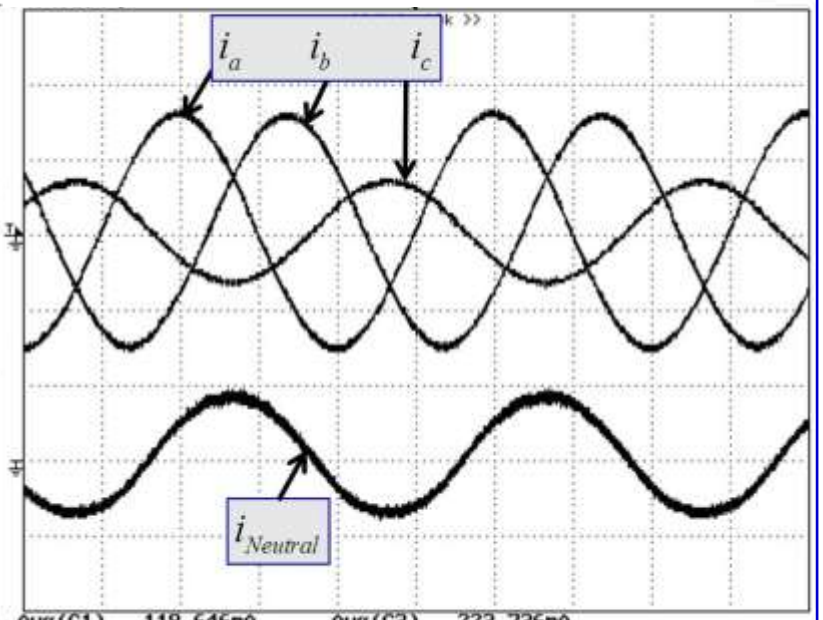
Experimental Results

Large neutral current exists due to the unbalanced loads.
$R_a = 50.7$ ohm, $R_b = 51.3$ ohm, $R_c = 127.8$ ohm.

Three Phase Balanced Voltages



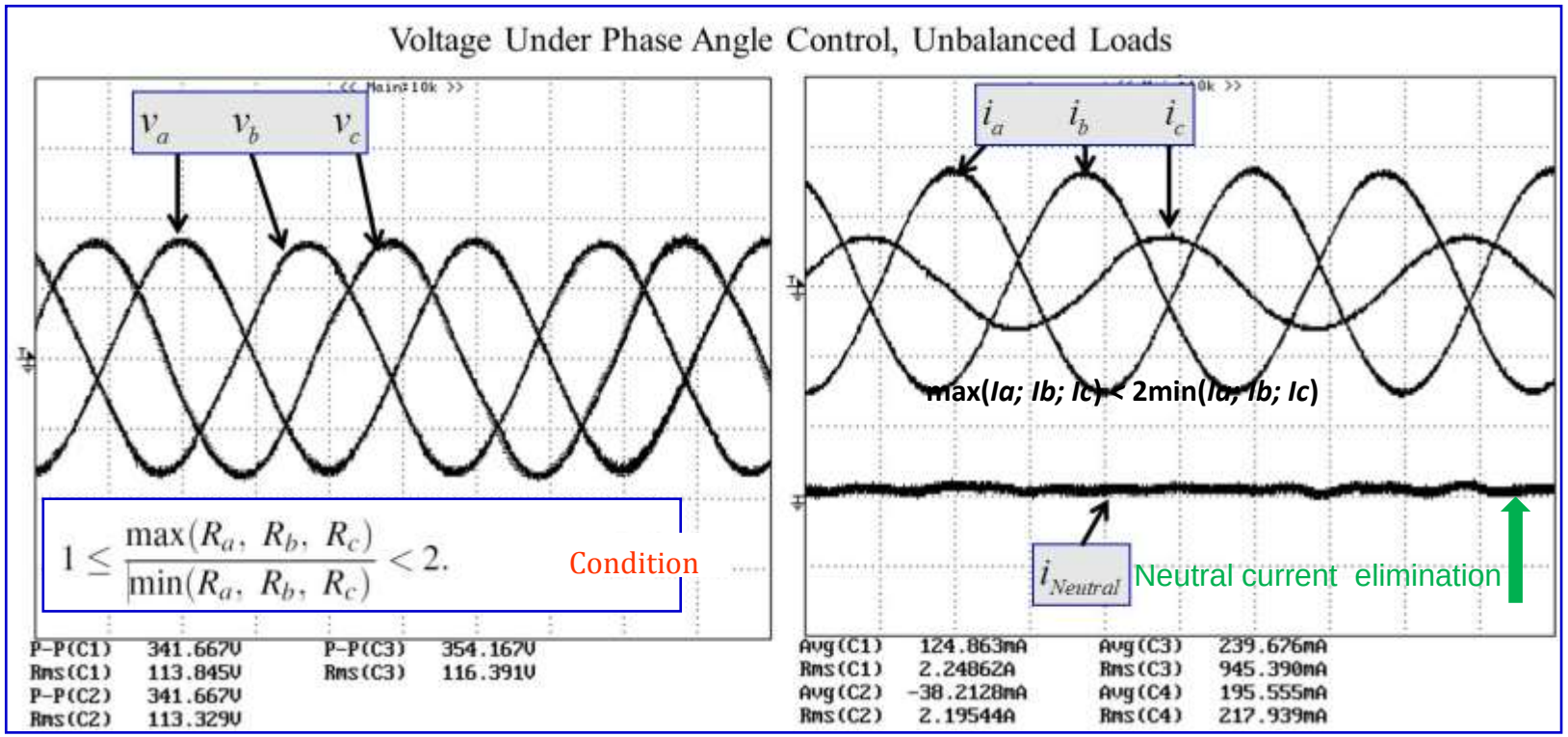
Three Phase Unbalance & Neutral Current



3 Novel Control Strategies are designed to Eliminate the Neutral Current Under Unbalanced Loads by using Four-Leg Three-Phase Inverter Topology

1. Phase Angle Control

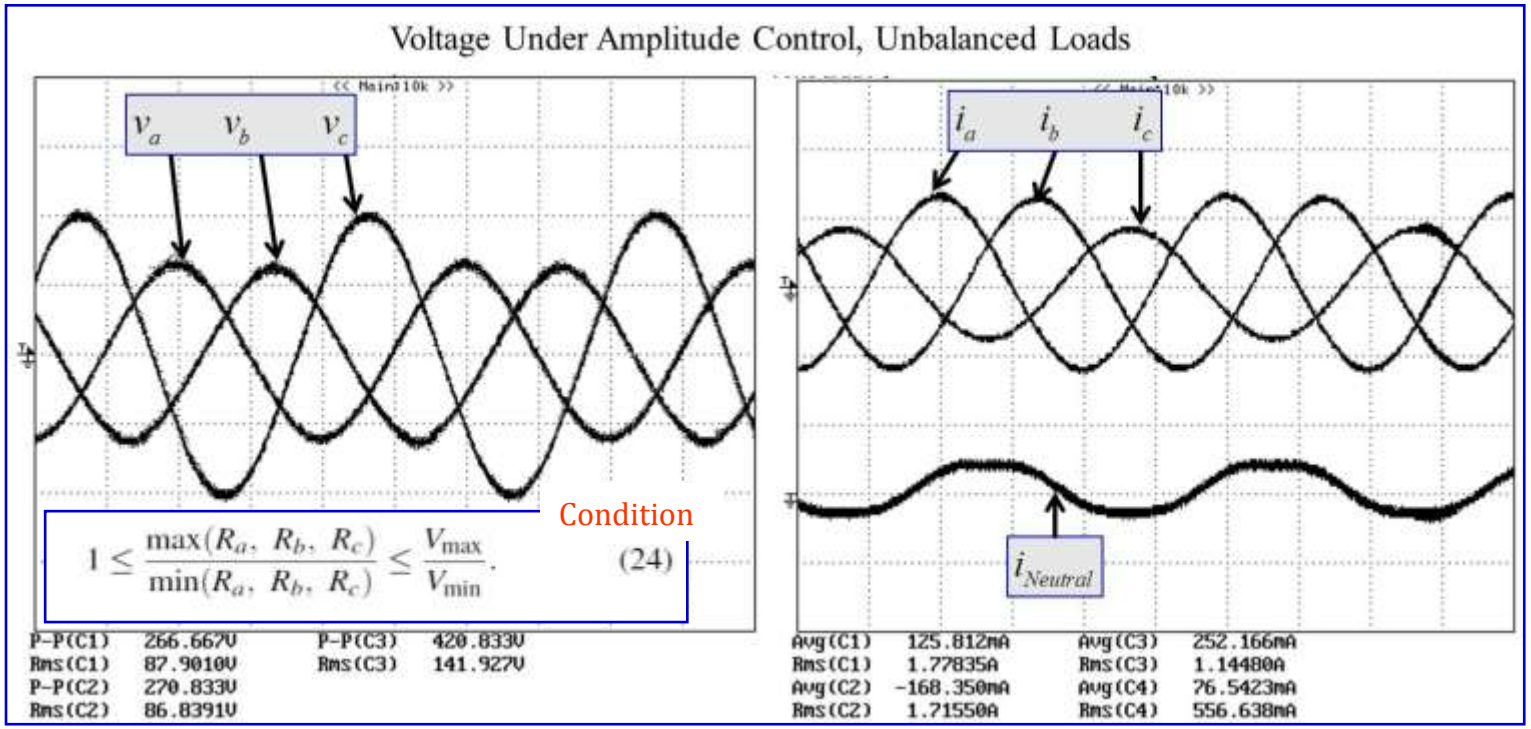
- The amplitudes of the A-B-C phase voltages are the same and fixed
- Phase angle differences are adjusted according to the measured phase currents/calculated loads



By **controlling the Phase Angles** of the inverter output voltages, the neutral current is largely reduced.

2. Amplitude Control

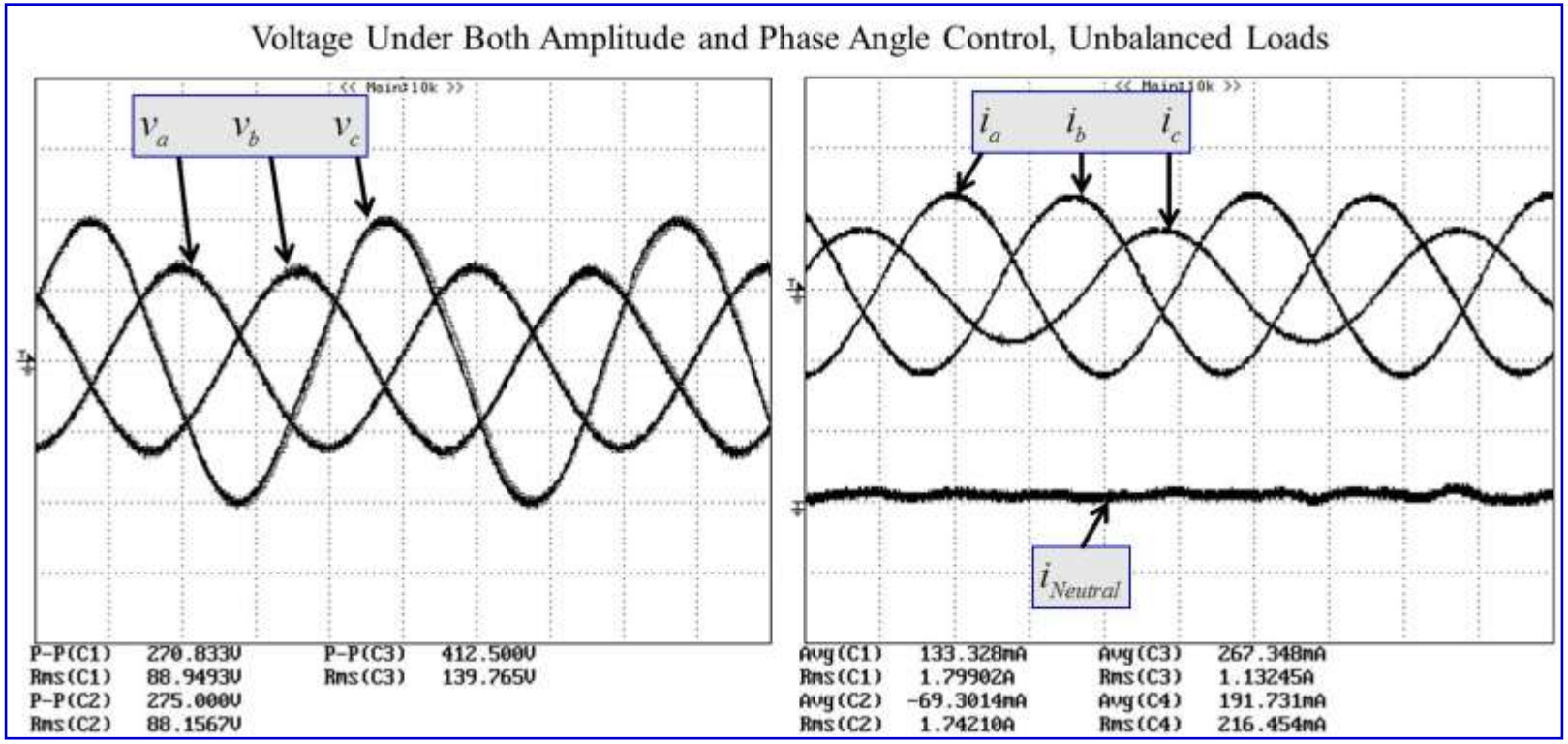
- The A-B-C phases are in positive sequence with fixed phase angle differences (120 degrees)
- Amplitudes of the phase voltages are adjusted according to the measured phase currents / voltages / calculated loads



By **controlling the Amplitudes** of the inverter output voltages in the allowable range (RMS 110 Vac x (1±20%)), the neutral current is reduced to some extent.

3. Amplitude & Phase Angle Control

- The Amplitudes of the A-B-C phase voltages and Phase angle differences are adjusted



Condition

$$\frac{V_{\min}}{\min(R_a,\ R_b,\ R_c)} < \frac{2V_{\max}}{\max(R_a,\ R_b,\ R_c)}, \tag{28}$$

that is

$$1 \le \frac{\max(R_a,\ R_b,\ R_c)}{\min(R_a,\ R_b,\ R_c)} < \frac{2V_{\max}}{V_{\min}}. \tag{29}$$

By controlling **both the amplitudes and phase angles** of the inverter output voltages, the neutral current is largely reduced.

Note : Effective when large load differences exist

Summary : AC Powered Data Center (Phase-1)

Contribution & Impact :

1. The proposed AC UPS power supply architecture enables to power the server with the same 110/240 Vac, 50/60 Hz (optimal efficiency operation of servers) while supplying the data center with 3Ph-3-Wire utility power supply, eliminating the neutral current.
2. Elimination of PDU is assured, thus the thermal losses in the neutral wire and PDU are eliminated resulting in improved overall efficiency.

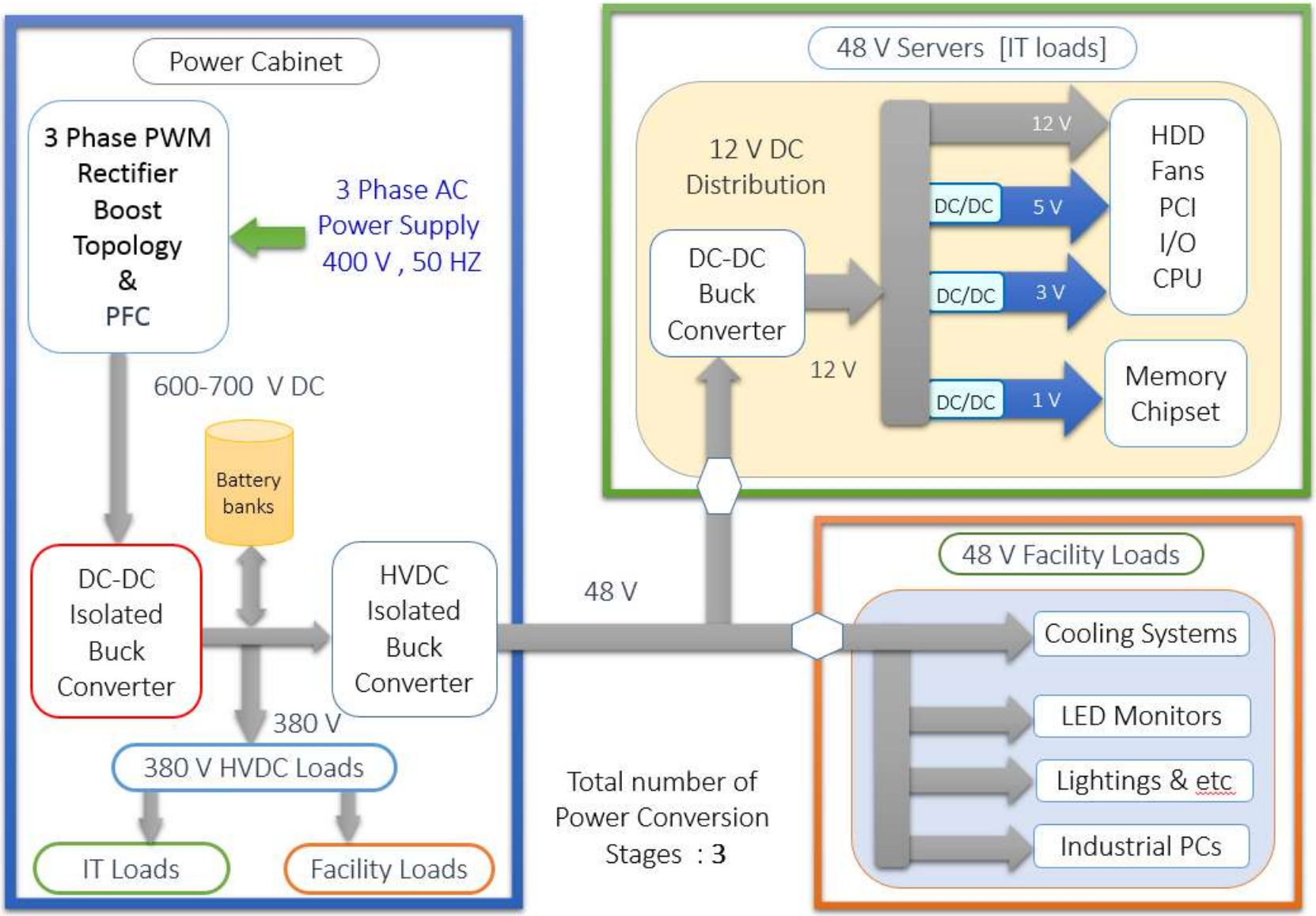
Deliverables Achieved :

1. 3Ph-4-Leg Inverter successfully eliminates the neutral current and the need for PDU.
2. Design and validation of the non-linear controller algorithms is tested and implemented in real time.
3. Small Scale Data Center Development (Servers & IT loads integration) has been implemented.

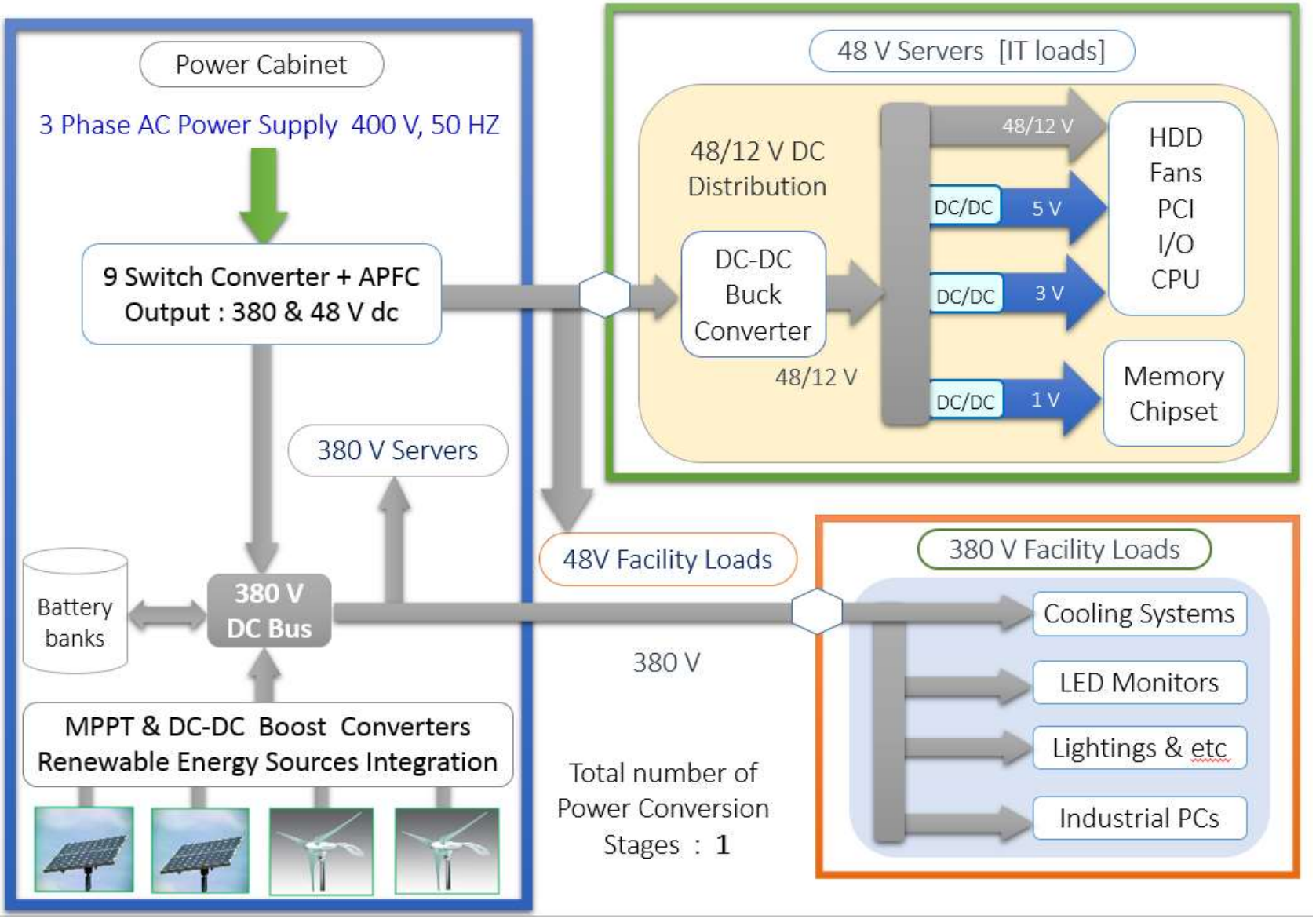
Research Challenges:

1. Development of high performance non-linear control algorithms to take care of grid side current THD and elimination of zero sequence current.
2. Industry has lesser trend to go towards the application of non-linear control algorithm for power electronic converters because of its complexity. Thus, the developed algorithm needs to be simplified to suit the needs of industries.

Typical Power Supply Architecture for Conventional DC Data Centers

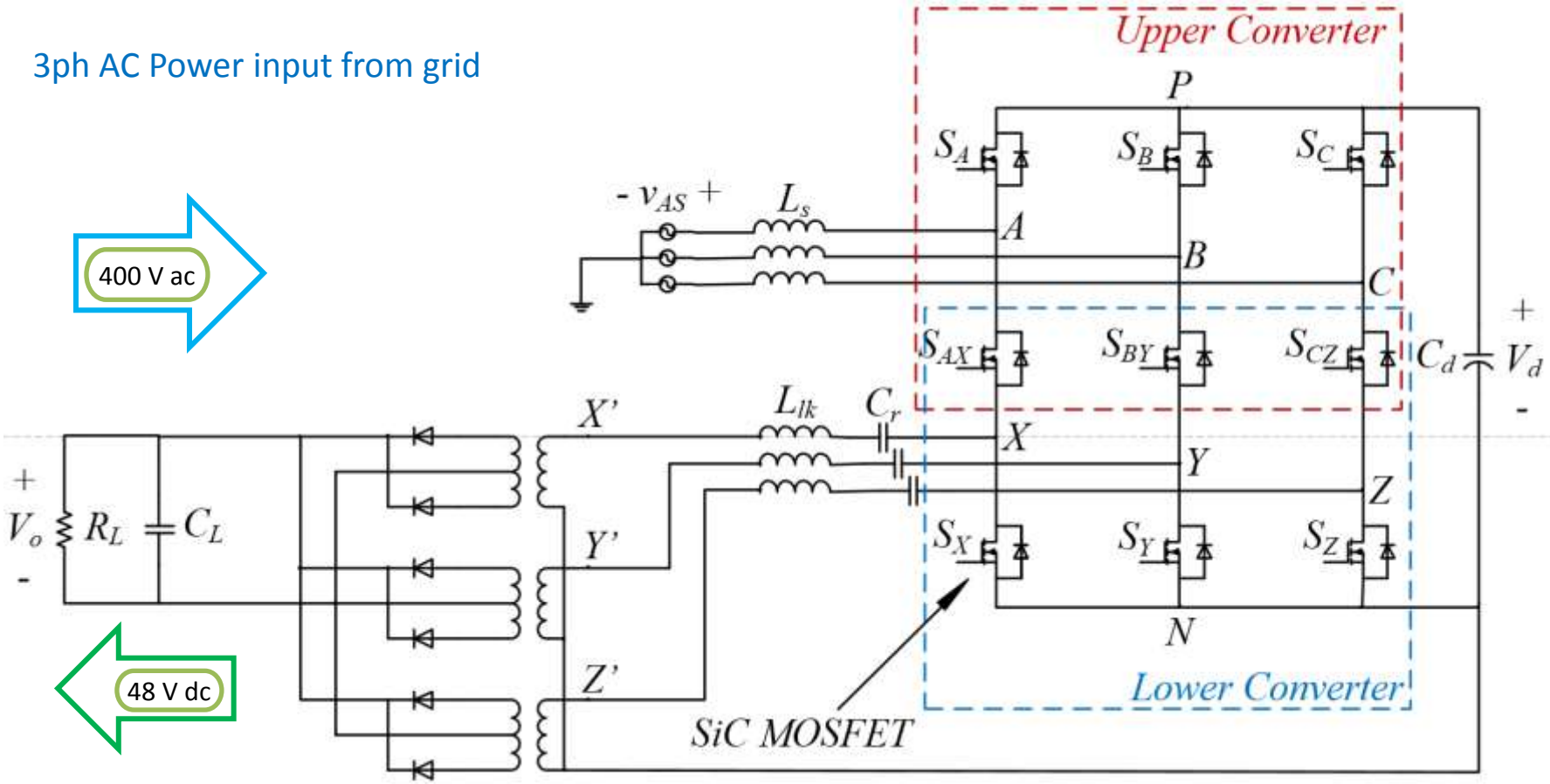


Proposed : Nine Switch Converter Topology

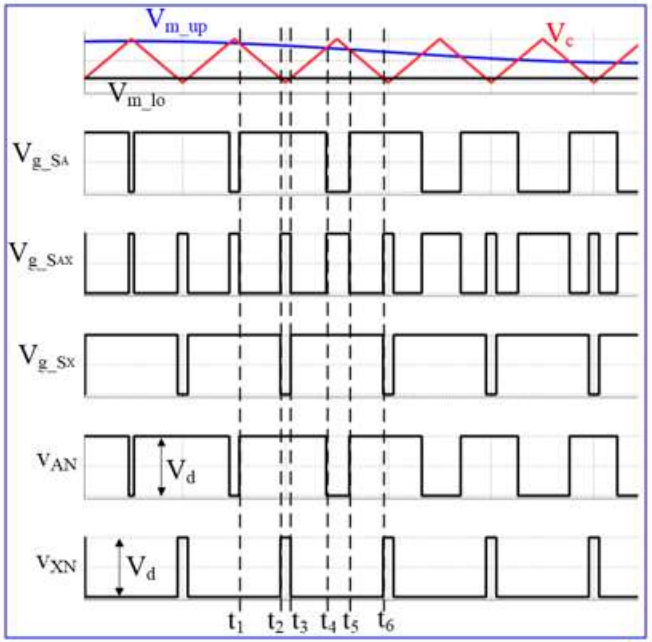


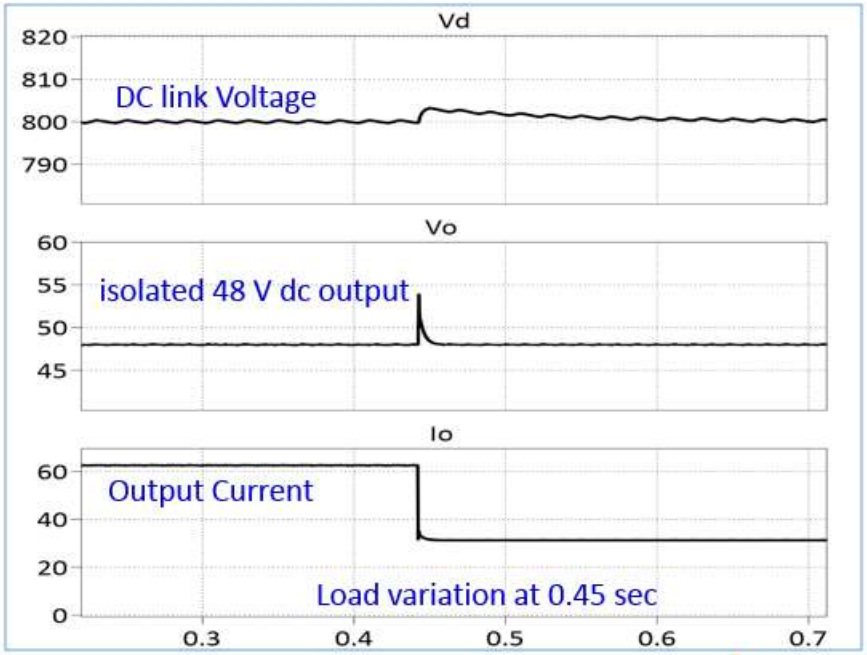
9 Switch Converter : Schematic

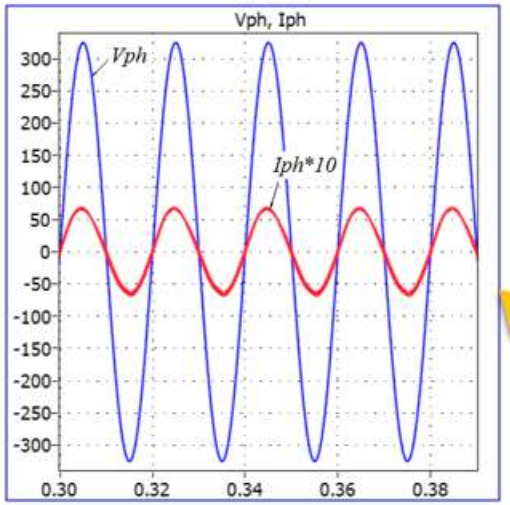
- Single stage conversion : 400 Vac to 380 & 48 Vdc
- Reduction of number of active switches and number of conversion stages



Simulation Results

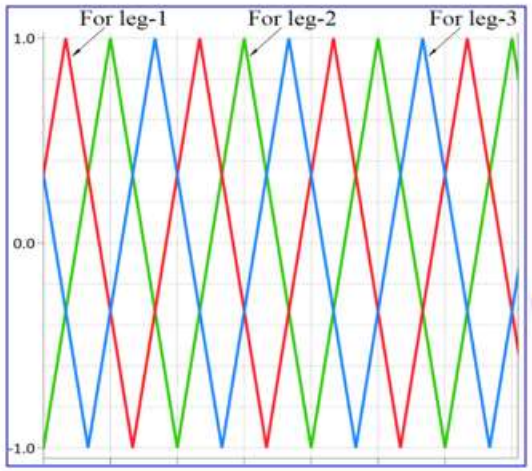






Switching Modulation Scheme

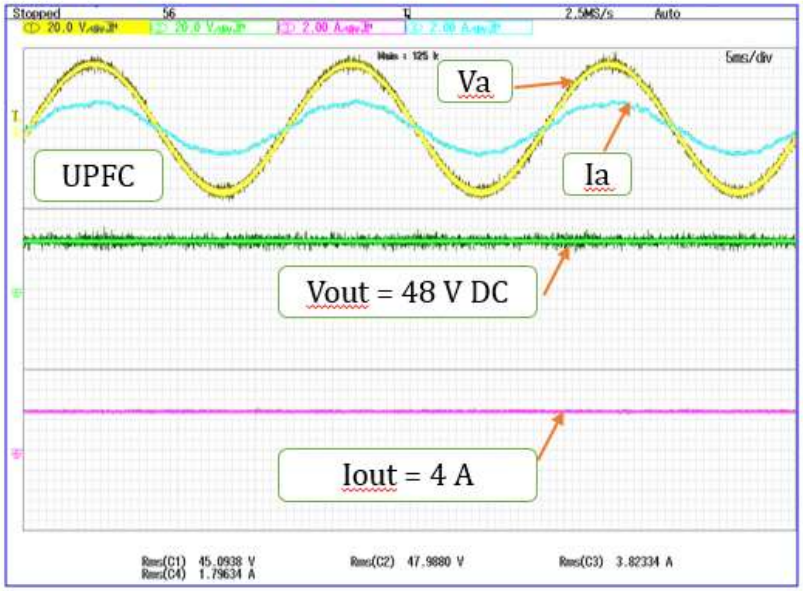
Input side Power Factor Correction

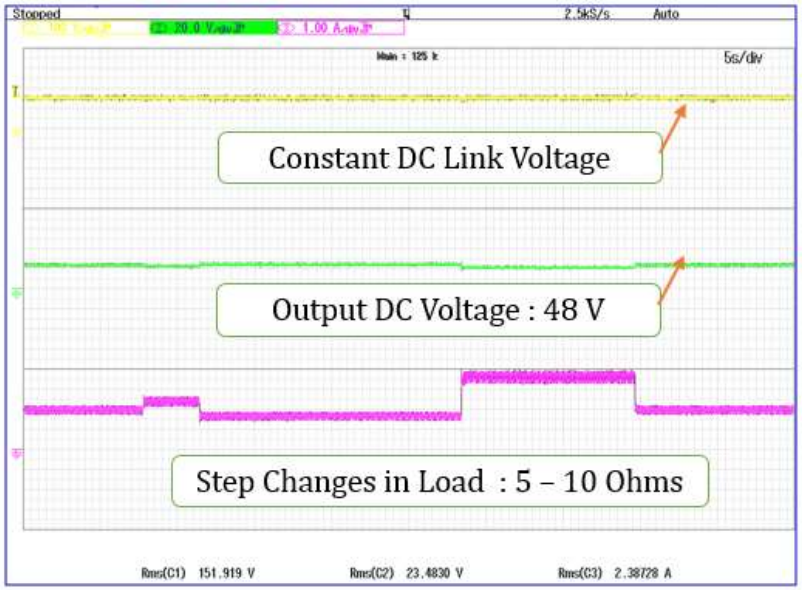


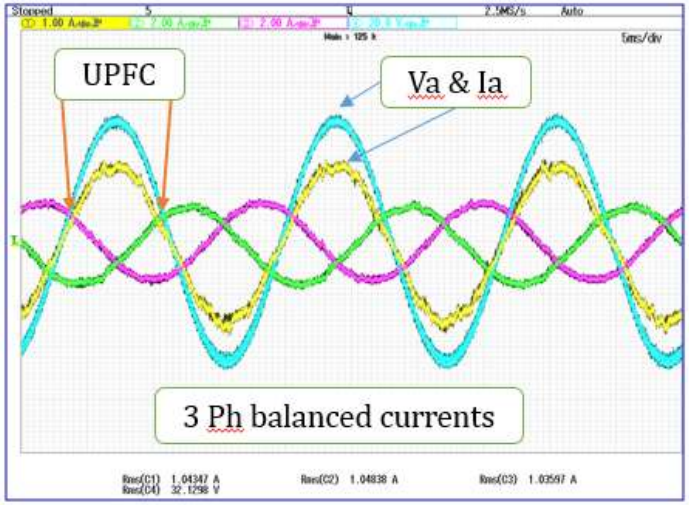
Results

Carriers

Experimental Results : Voltage & Current







Summary : DC Powered Data Center (Phase-2)

Contribution & Impact :

1. The proposed DC power distribution system utilizes renewable energy harvesting and it is designed with less number of power conversion stages (1) compared to the typical (3).
2. Proposed 9 Switch Converter Topology will improve the overall data center efficiency by reducing the transmission, distribution and thermal losses.
3. Single Stage Power Conversion to get both 380 V dc & 48 V dc.

Deliverables Achieved :

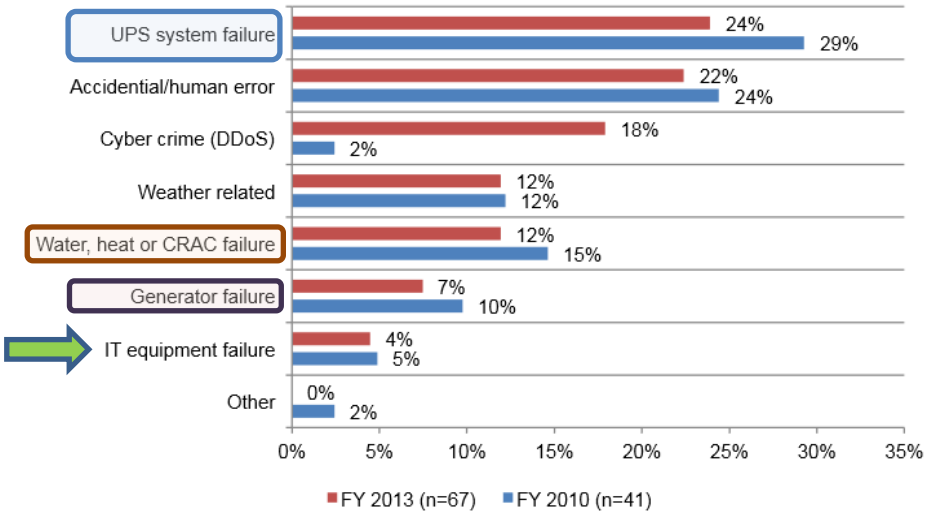
1. DC power distribution architecture with reduced power conversion stages has been designed.
2. 9 Switch Converter has been developed and tested.

Research Challenges:

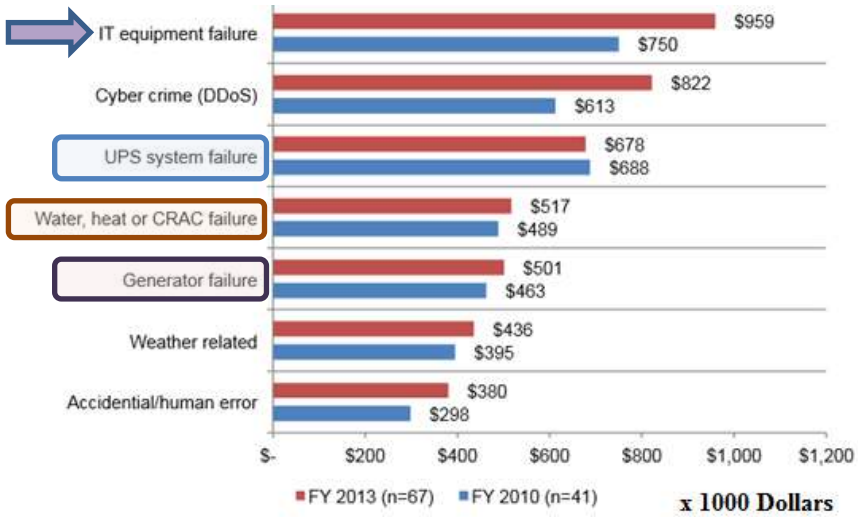
1. Industry is less willing to go towards the application of non-linear control algorithm for power converters because of its complexity. Thus, the developed algorithm needs to be simplified to certain extent to meet industry requirements.
2. Introduction of 400VDC interface brings up some questions about personnel safety and implementation of system grounding. Although DC is considered safer than AC, till now data-com operators have been hesitant to deploy 400VDC because it's not as commonly used and well understood as AC.
3. DC distribution offers the best theoretical efficiency, but not all IT equipment is compatible. i.e, availability of 380 V HVDC & 48 LVDC input servers.
4. Compatibility issues of Server loads with 48 V dc bus (memory chips , processors & hard disk drives).

Typical Data Centre Outages : Cost and Root-causes

- Data Centre outages are expensive
  - $45 to $95 per square foot per outage
  - $690,204 per incident
- Total cost of outages is systematically related to the **duration** of the outage and **size** of the data center
- Certain causes of the outage are more expensive than others:
  - Specifically, IT equipment failure is the most expensive root cause
  - Electrical subsystem failures in power and cooling assemblies also contribute a major share



Root causes of unplanned outages
Comparison of FY 2010 and FY 2013 results

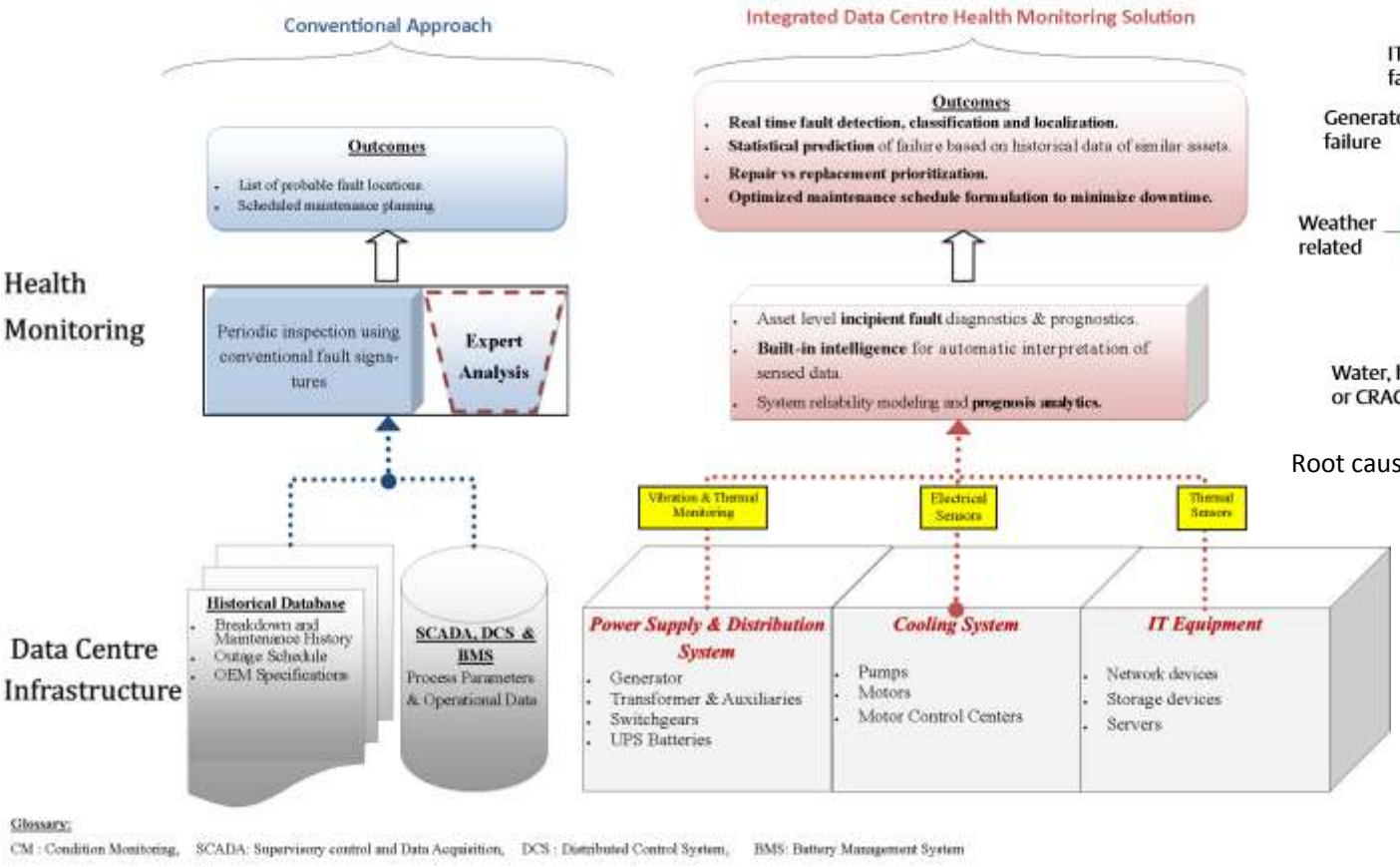


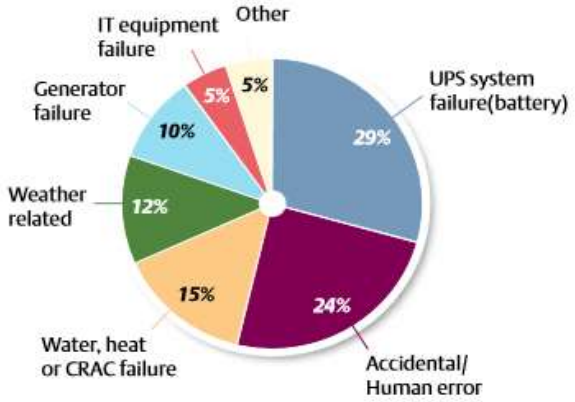
Total cost by primary root causes of unplanned outages
Comparison of FY 2010 and FY 2013 results

Source: 2013 Cost of Data Center Outages, Ponemon Institute, December 2013

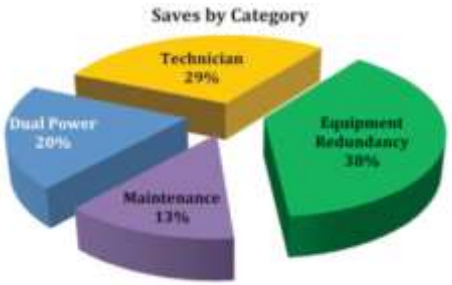
Preventive vs Predictive Maintenance

- 13% reduction in outages can be achieved by Preventive scheduled maintenance.
- Real time health monitoring and predictive maintenance is required to optimize maintenance costs.





Root causes of unplanned data center outages



Summary : Outcomes & Deliverables (Phase-3)

- Provides an intelligent fault diagnosis and prognosis system for critical data centre infrastructure sub-systems such as generators, transformers, battery, motor control centres, switchgears, pumps etc.,
- Centralised solution: Integration and automation of different sub-systems, data-driven fault diagnosis and prognosis will lead to improved availability, efficiency and planning. This integrated health monitoring system will provide improved awareness of the state-of-health of various parts of the data centre and direct recommendations for necessary corrective actions to the operator.
- Reduced Downtime: Early prediction of imminent faults will allow for faster turnaround in case of failures leading to shortened downtime per failure.
- Reduced maintenance cost: Current industrial practices mostly rely on historical failure data for (data driven) short term fault prediction and preventive maintenance. Dynamic load expansions in modern data centres render the past data unreliable. The Data centre operators therefore resort to pessimistic periodic maintenance strategies which in turn increase the operational expenditures.
- Reduced Capital Cost: The resultant system will account not only individual component level anomalies but also interactions between connected components. This will allow a holistic view of interdependent systems. Considerable cost savings can be achieved through reduced redundancy without loss of availability.
- Improved Power Usage Efficiency (PUE).

Thank You

