



# Energy Storage System : Enabler for High-Quality Power Systems

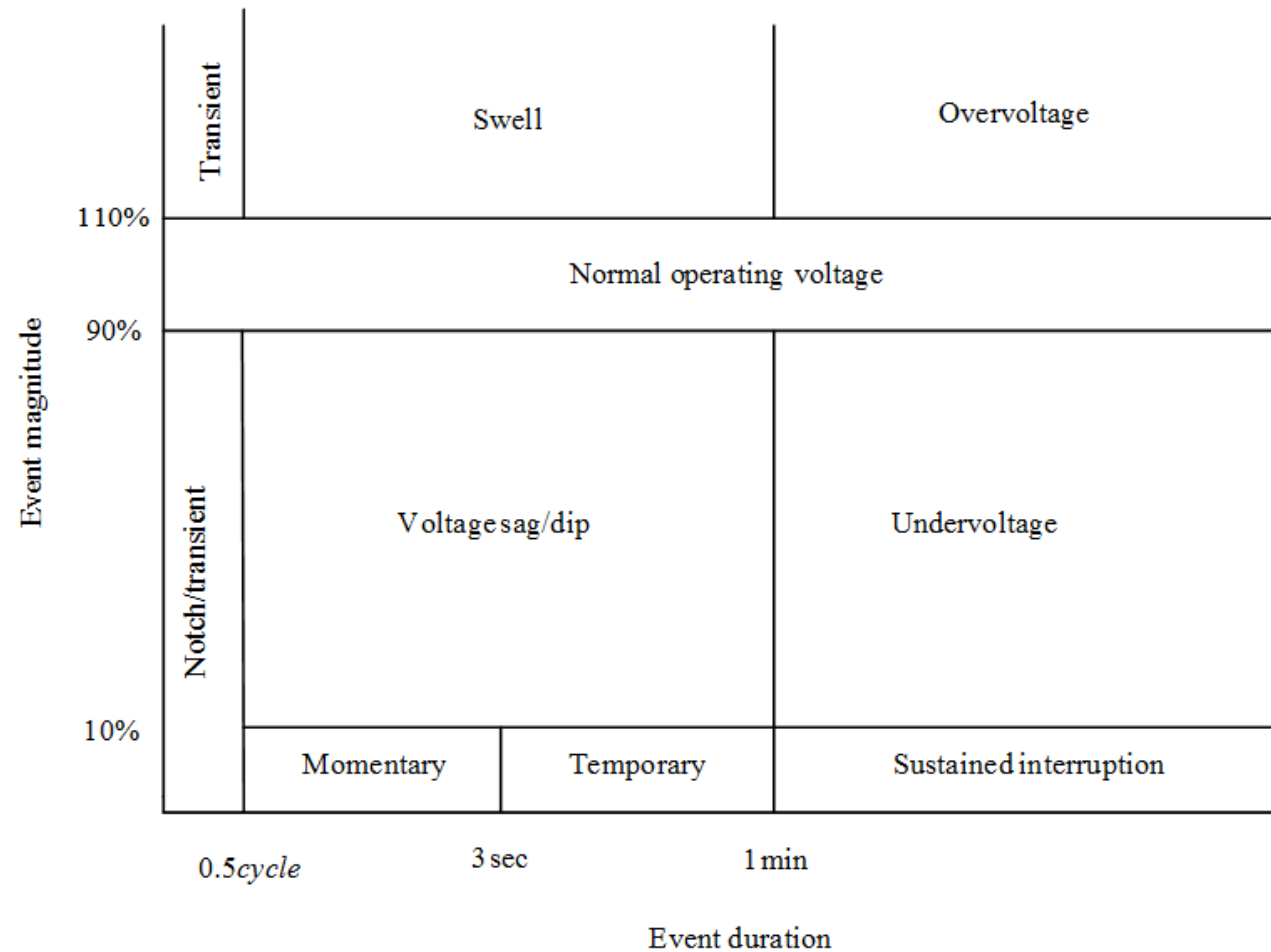
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# Power Quality Definitions

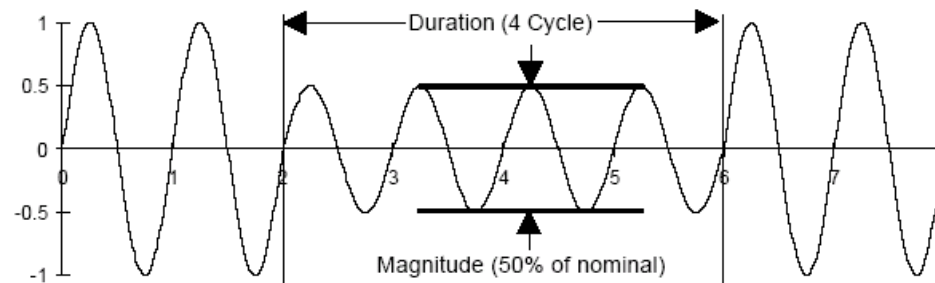
- *IEEE* : The concept of powering and grounding sensitive equipment in a manner that is suitable to the operation of that equipment.
- IEC : Characteristics of the electricity at a given point on an electrical system, evaluated against a set of reference technical parameters

# Voltage Deviation vs Duration



# Voltage Dips

- Reduction in the ac voltage, at the power frequency, for durations from a half-cycle to a few seconds.
- Magnitude between 90% and 10%
- Voltage Dip is Characterized by two parameters – Magnitude and Duration
- Power Electronics Loads are Sensitive to Voltage Dips
- Impacts Industrial Customers 7 to 8 Times More Likely Than Outages



# What Causes Voltage Dips?

- Short Circuit Faults
- Motor starting
- Transformer Energization

# Category of Equipment Sensitivity

- Equipment sensitive to only the magnitude of a voltage sag.
- Equipment sensitive to both the magnitude and duration of a voltage sag.
- Equipment sensitive to characteristics other than magnitude and duration.

# DOE Study

## ➤ Voltage Sags

- \$377,000 per year / large industrial customer.
- National Cost: \$114 B

## ➤ Interruptions

- \$132,000 per year / large industrial customer
- National cost: \$39 B

# Estimating Voltage Dip Performance

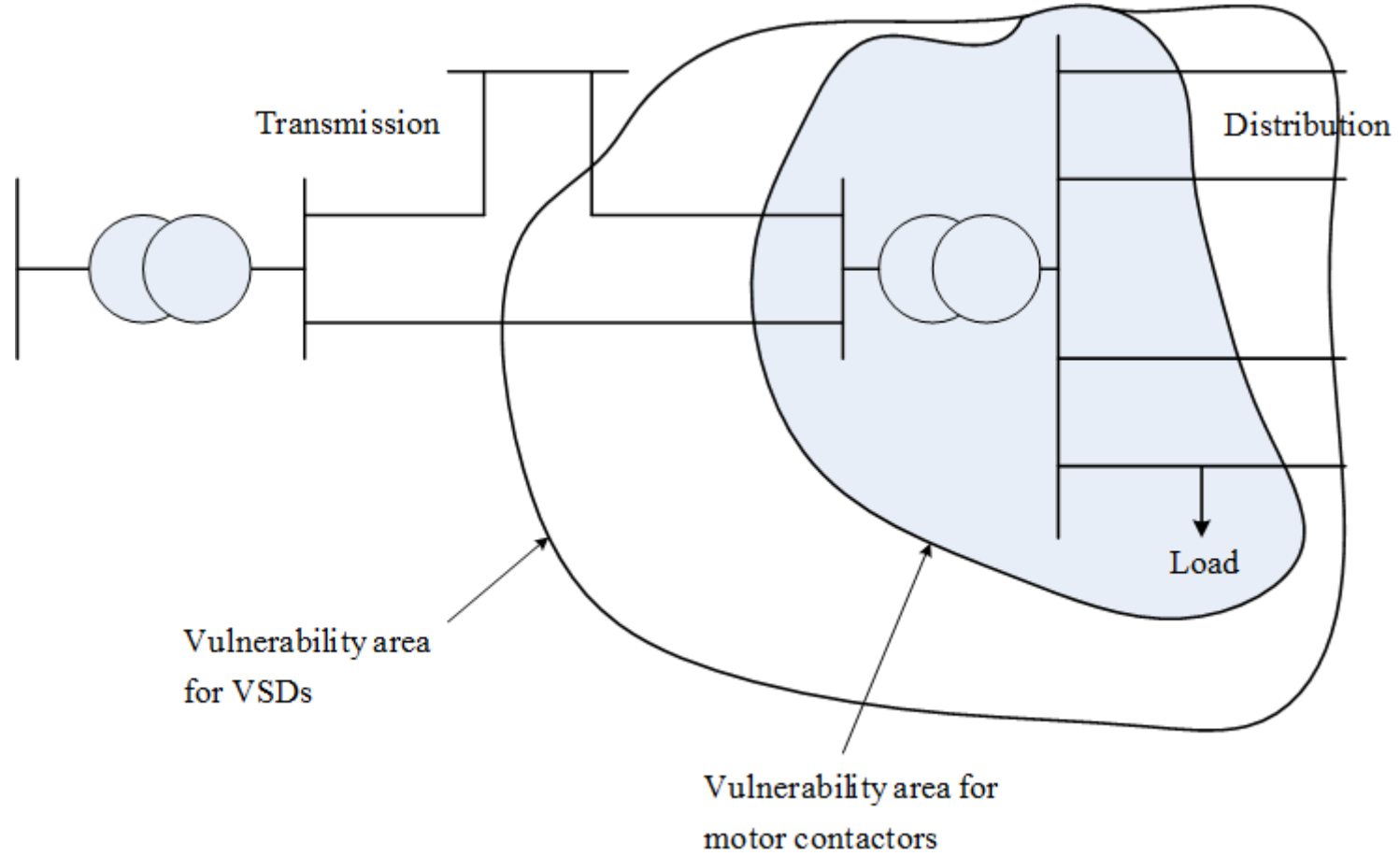
- Determine the number and characteristics of voltage dips that result from transmission system faults.
- Determine the number and characteristics of voltage dips that result from distribution system faults.
- Determine the equipment sensitivity to voltage dips.
- Evaluate the economics of different solutions that could improve the performance.



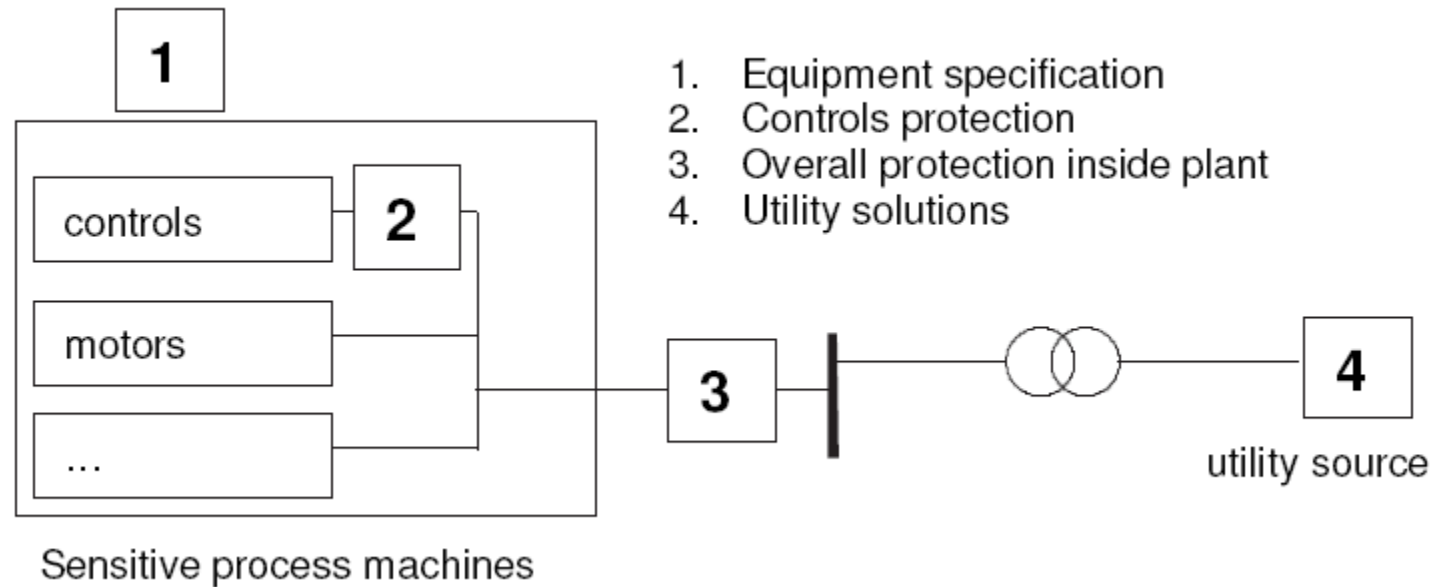
# Voltage Dip Evaluation of Power Distribution System

- Number of feeders supplied by the substation
- Average feeder length
- Average feeder reactance
- Short-circuit capacity at the substation
- Feeder reactors, if any
- Average feeder fault performance

# Vulnerability Area

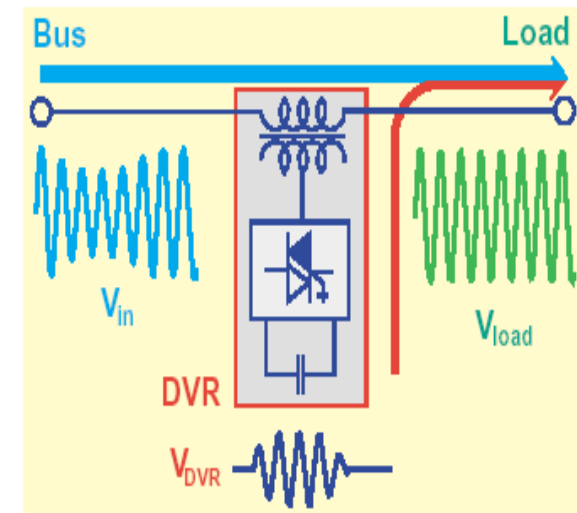


# Voltage Dip Mitigation



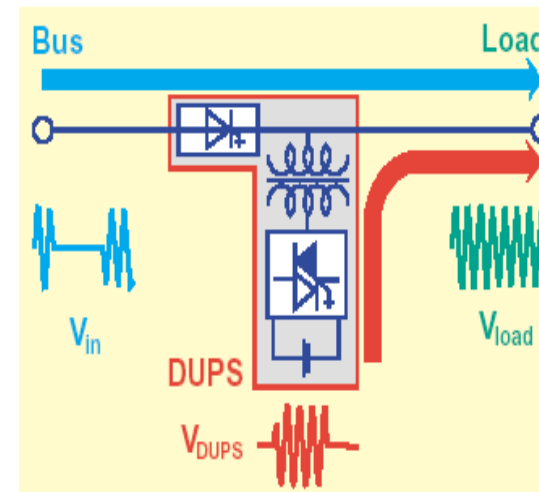
# Dynamic Voltage Restorer

- **Energy storage - DC capacitors**
- **Inverter changes the DC back to AC**
- **AC output waveform is controllable**
- **Adds' its output to the utility waveform through the use of a series transformer**
- **1 to 4 ms response time**
- **Practical boost to about 50%**

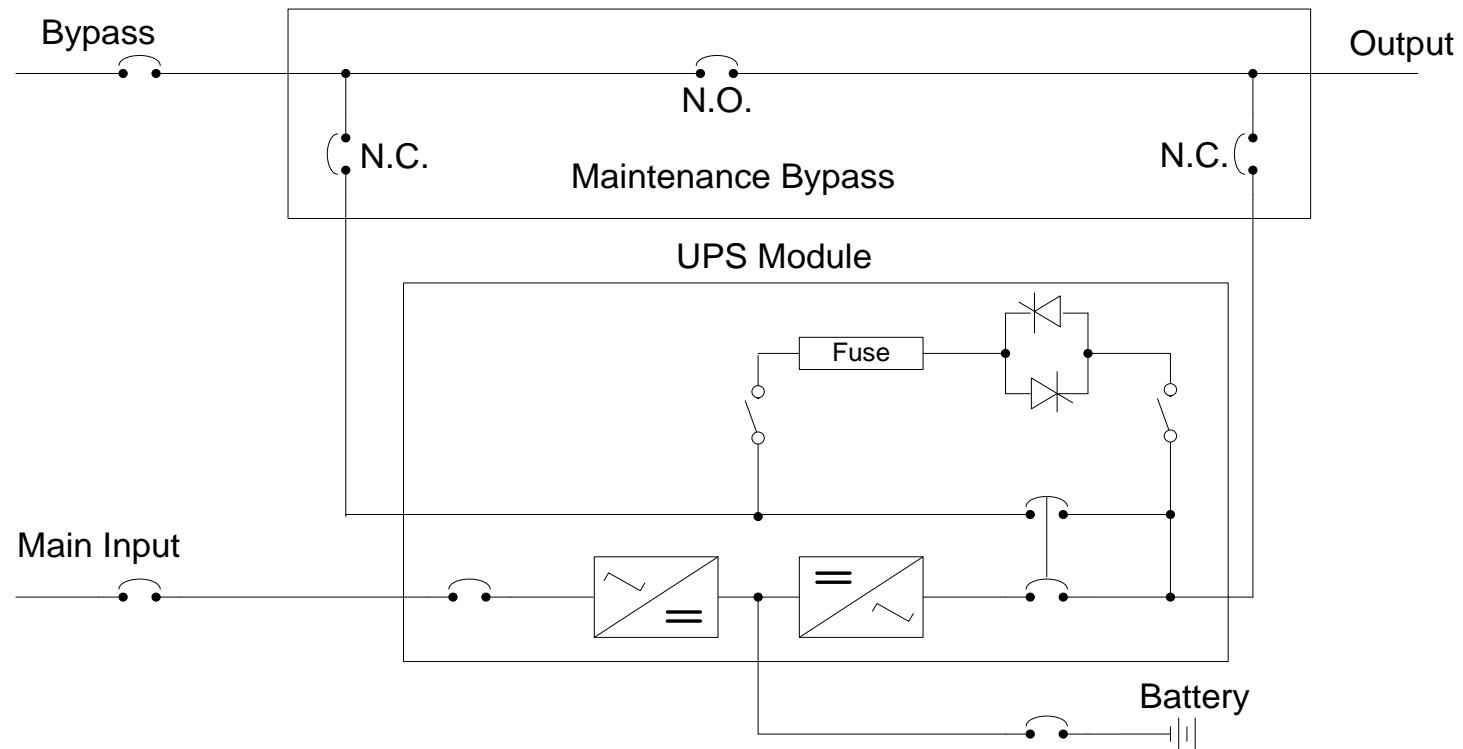


# Dynamic UPS

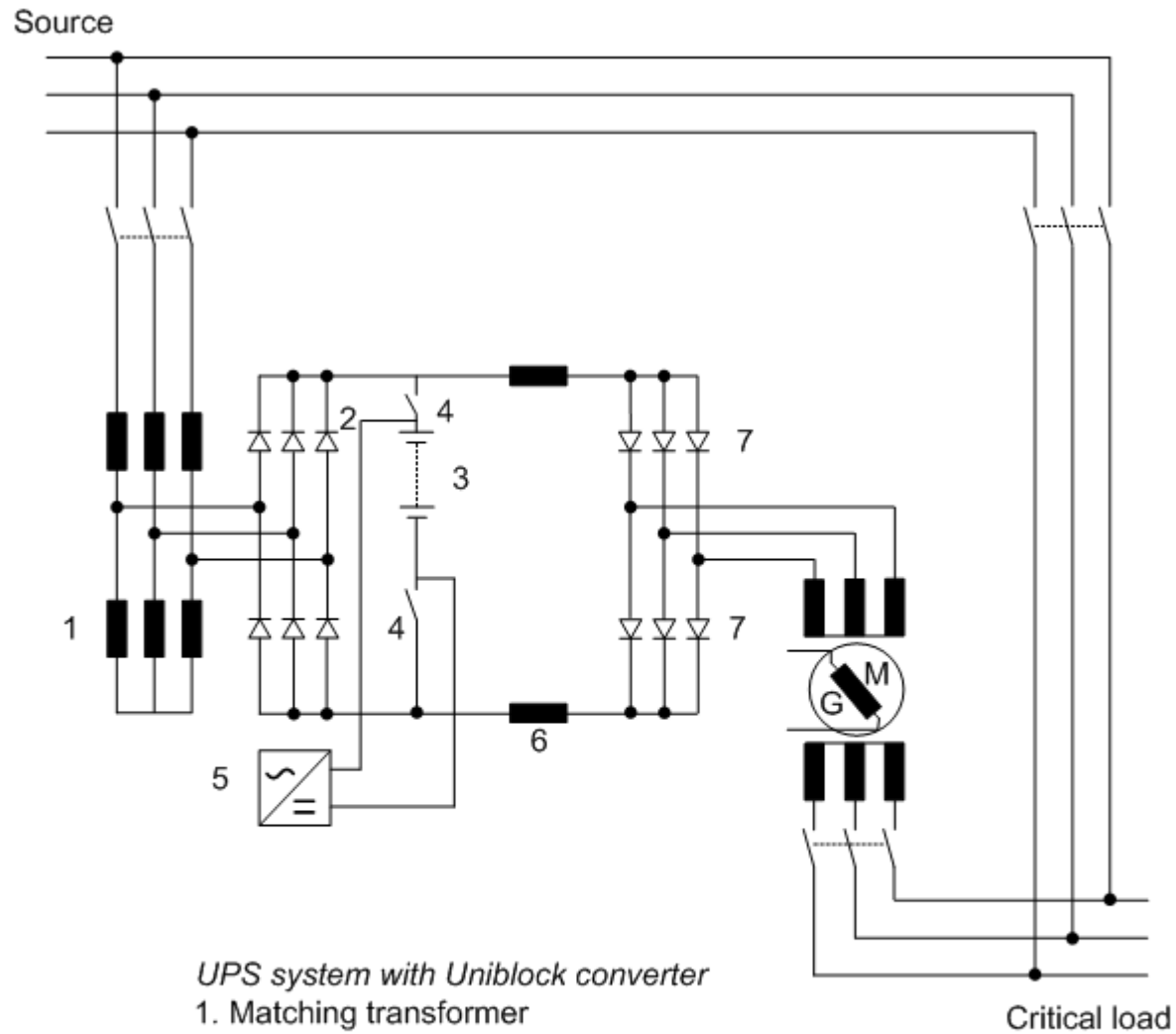
- Energy storage is a high energy cranking battery.
- Mitigates sags and outages, providing 100% voltage compensation
- During a sag or outage the system disconnects from the utility.
- Standby system
- 4 ms response or less



# Complete Scheme of UPS



# Hybrid UPS

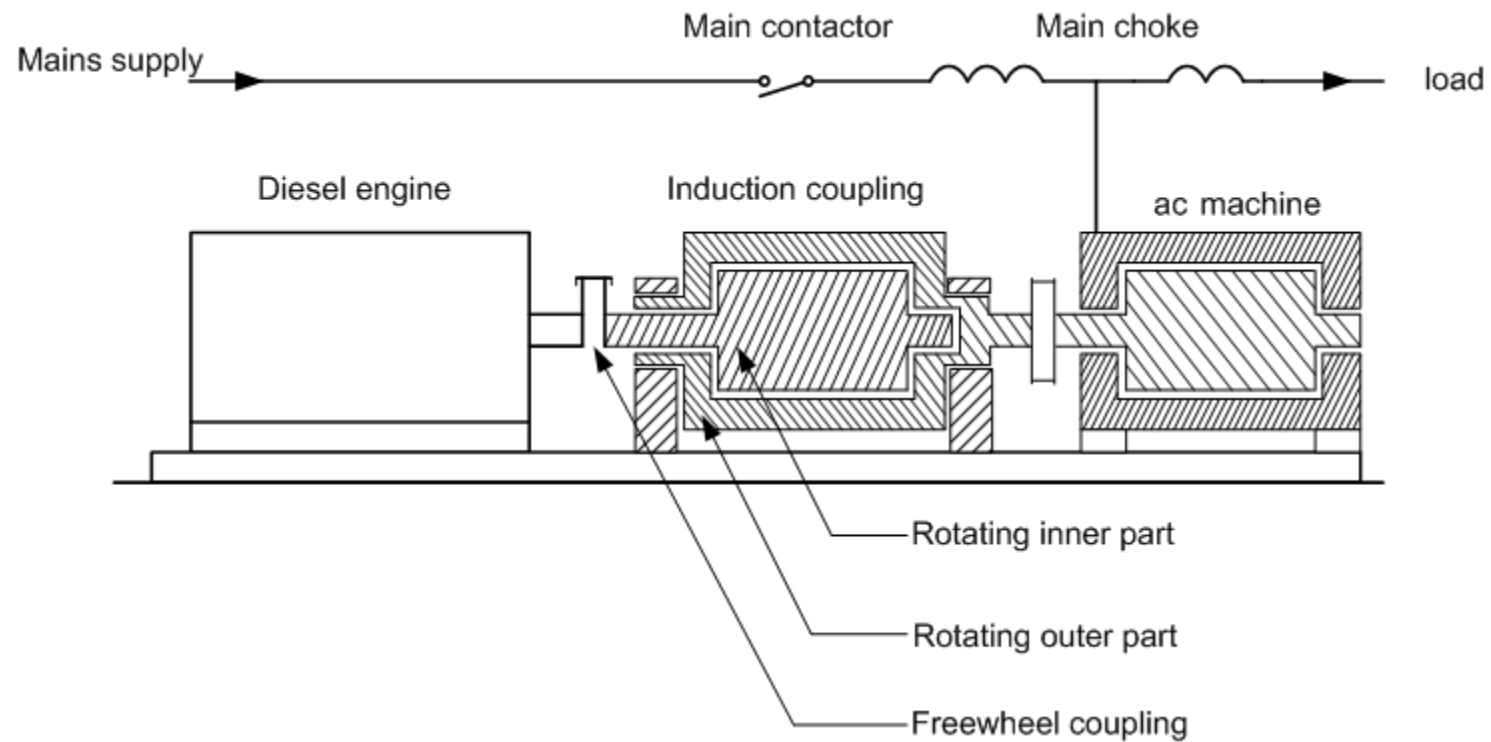


*UPS system with Uniblock converter*

- 1. Matching transformer
- 2. Mains rectifier
- 3. Battery
- 4. Battery switch
- 5. Charger
- 6. Smoothing choke
- 7. Inverter

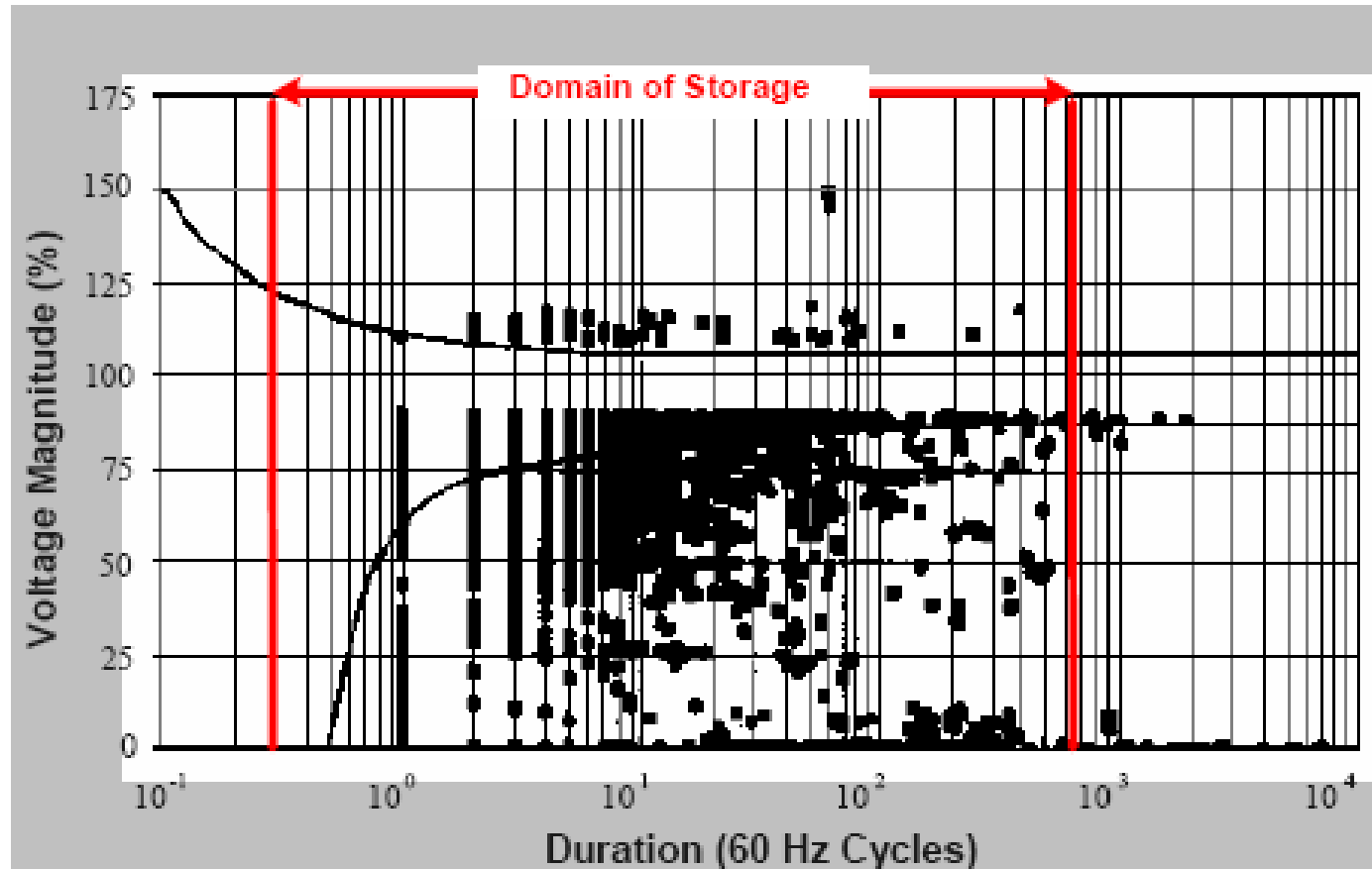
Jakarta, 10 July 2019

# Flywheel Diesel Genset



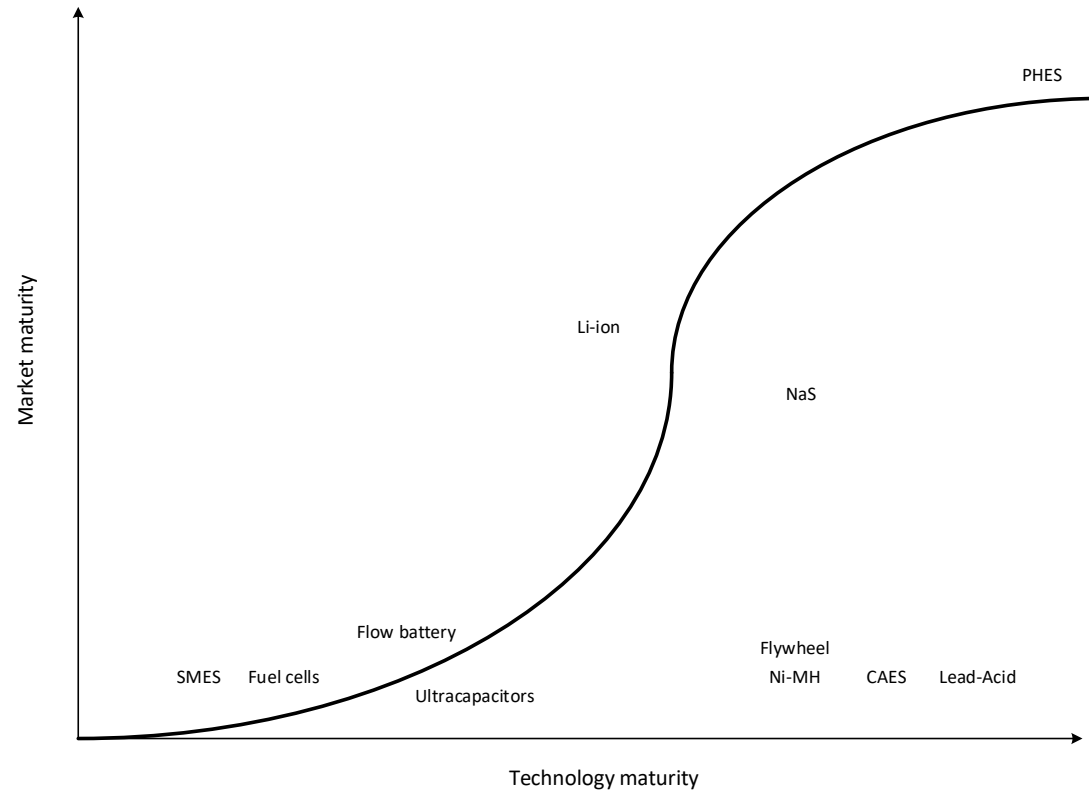


# Power Quality Problems that Could be Addressed by Energy Storage



# Possible Energy Storage Systems

- Pumped Hydro
- Battery
- Ultracapacitor
- Flywheel



# Applications on Transmission Grid Side

- Improving utilization
- Improving spinning reserve
- Solving congestion
- Improving stability
- Voltage support
- Regulating frequency
- Reducing losses
- Postponing the need of new transmission lines

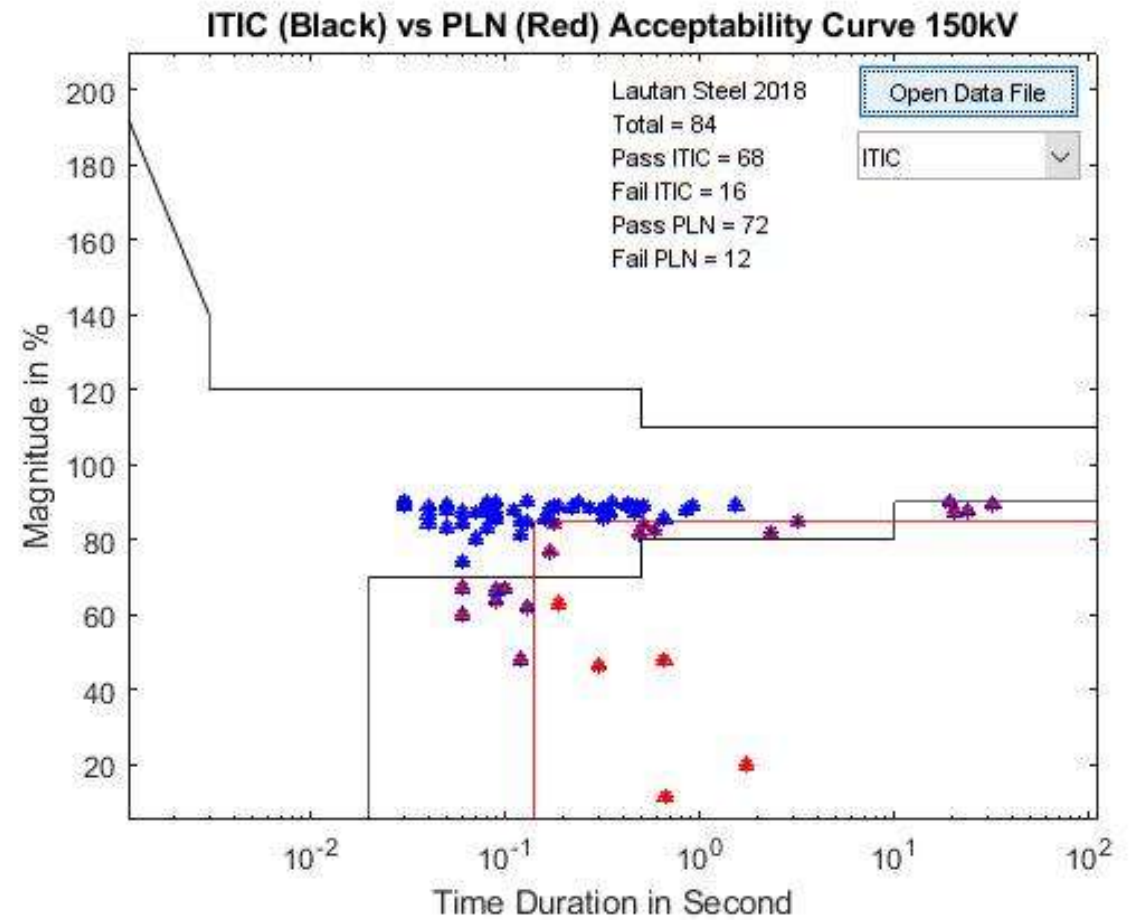
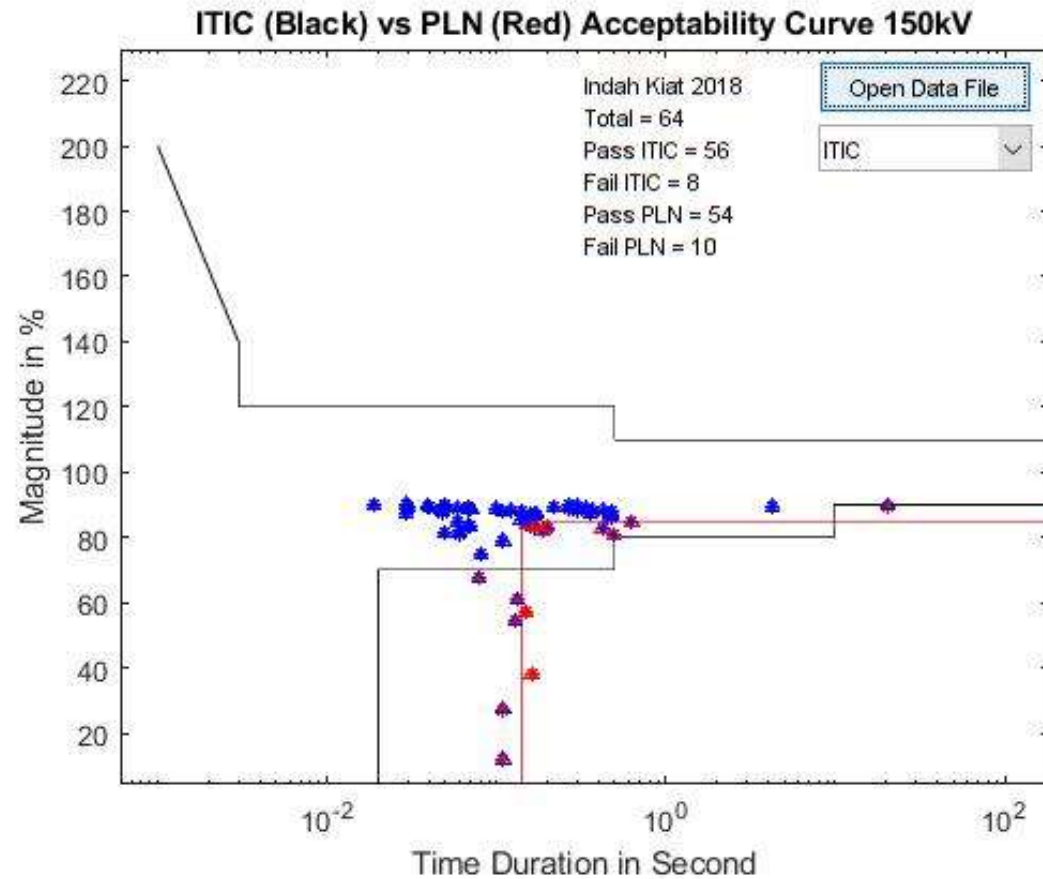
# Applications on Distribution Side

- Improving reliability
- Improving power quality
- Improving utilization of distribution lines
- Increasing the penetration of distributed generation
- Reducing losses

# Applications on Customer Side

- Peak shaving
- Improving reliability
- Improving power quality
- Time shifting

# Survey Results



# Survey Results

- The reliability of the supply is getting better but the power quality is reduced
- Many industrial loads suffered from power quality problems
- Financial loss due power quality is huge
- Many industries eager to pay premium quality
- Many captive loads can be supplied by the utility if the quality can be ensured.
- Many power quality problems can be solved by energy storage.

Thank You