



Advanced Electrical System Design Strategies for Modern Cement Plant

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- 02 Project Cost Optimization (CapEx)**
- 03 System Reliability and Maximise Uptime**
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OBJECTIVE



Modern Cement Plant Projects Are Having Intense Pressure

- To Accelerate Project Timelines
- To Maximize Reliability & Lifecycle Profitability.

This Webinar explains the “Holtec Way” to address these challenges by engineering Design framework, focusing innovation on electrical system design strategies that directly compress project execution schedules, lower initial capital expenditures (CapEx), minimize long-term operational and recurring costs (OpEx) without compromising plant reliability.

MINIMIZING PROJECT TIMELINE & AVOIDING DELAYS

Shorten Project Timeline - “A Key Challenge”

Reduce project timeline without compromising quality shall be achieved by:

- Fast-Track Task
 - Overlap tasks that would normally happen one after other
- Eliminate Bottlenecks
 - Automate recurring manual work
- Reduce The Scope
 - Shift secondary features to second phase
- Crash The Schedule
 - Add extra resources (this increase cost)

MINIMIZING PROTECT TIME-LINE & AVOIDING DELAYS

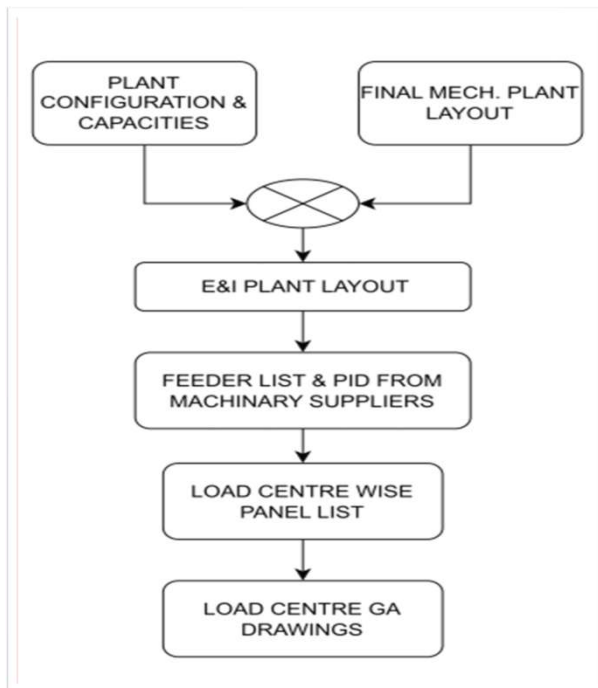
Key Triggers for Project Delays

- Poor Estimation
 - Setting unrealistic deadlines without historical data
- Scope Creep
 - Adding a new features / tasks without adjusting timeline
- Shortage Of Resource
 - Lack of skilled people / equipment during task
- Dependency Bottlenecks
 - Waiting for expert team / input to finish the task
- Communication Gaps
 - Misalignment between stake holders / Project managers
- Unclear Requirements
 - Starting work before a proper understanding
- Slow Approval
 - Delay from Managers / Clients for Approval
- Unexpected Risks
 - Encountering sudden blockade

MINIMIZING PROTECT TIME-LINE & AVOIDING DELAYS

Delays In Main Cable Route & Load Centre Design

Traditional Approach

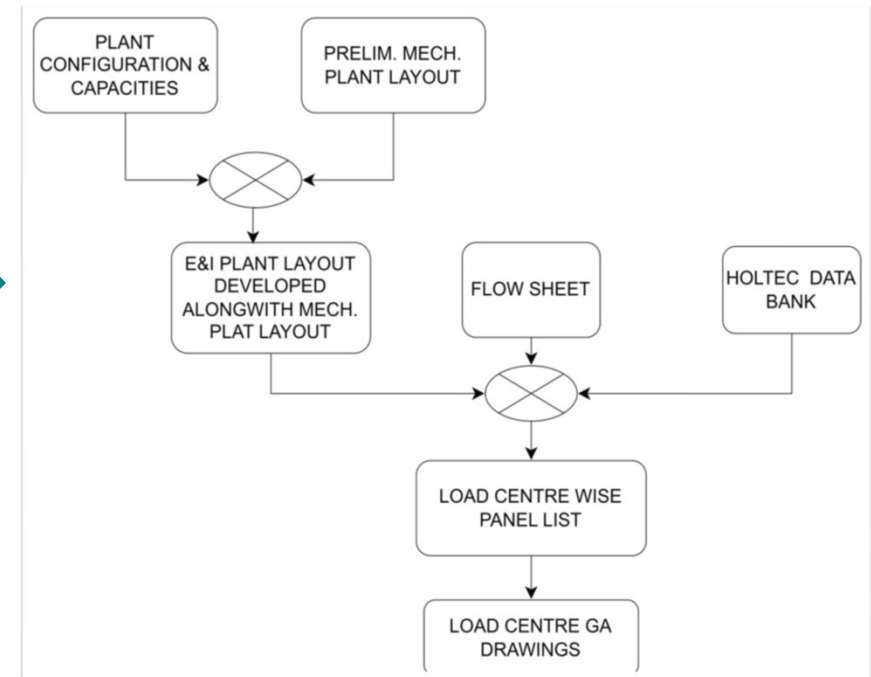


Fast-Track Task →

Notes:

1. Standard depth for MV SWBD, PCC and MCC's and length workout as per panel list with some margin.
2. Standard dimension for other panels taken from data bank.

Progressive Approach



- Early design of sub stations & main cable route.
- Since close coordination with mechanical & civil ensure avoiding issues and execution hindrances.

MINIMIZING PROTECT TIME-LINE & AVOIDING DELAYS



Delay Of Civil Design Due To Delayed Availability Of E&I Engineering Input

Progressive Approach:

1. Identification of Equipment whose data is critical for civil design.
2. If possible, Standardize data for these equipment
 - Like Frame Sizes of LV Motors.
3. If Standardization not possible, fast track their procurement process:
 - Agreement with M/c Supplier for early submission of their specification sheets.
 - Prioritize & Expedite Procurement process
 - Civil Design Data taken from all E&I vendors during ordering and is concurred by Mechanical.
 - Once the ordering concluded, immediately data released for civil design.

Dependency Bottlenecks

MINIMIZING PROTECT TIME-LINE & AVOIDING DELAYS



Delay In E&I Major Equipment Ordering Inputs From Machinery Suppliers

Progressive Approach:

1. Use Holtec Data bank to prepare E&I Ordering inputs in advance and expedite procurement process.
2. Agreement with M/c Supplier for early submission of E&I ordering inputs.
3. Till closure of E&I Ordering 70% firm data shall be available from M/c Supplier. Further addition-deletion clause shall be added to address variations.
4. As applicable ordering initiated on unit rate basis with tentative BOQ and Further addition deletion clause.

- Like Standard LV Motors, etc.

Dependency Bottlenecks

Fast-Track Task

MINIMIZING PROTECT TIME-LINE & AVOIDING DELAYS



Manufacturing Delays

Traditional Approach:

Supplier submit whole engineering drawings/ documents in one lot, and these are with 70% confirm data as given in tender BOQ.

- This led to multiple submission & Delay in approval.

Progressive Approach:

Split Drawing document submission in multiple steps

1. First submit items which has no impact with BOQ variation
 - Like Design Brief, Typical Wiring scheme, Typical SLD, Typical GA etc.
2. Even if 100% BOQ not firm, Drawings/ documents for firm BOQ shall be approved, manufactured and supplied.
3. Balance BOQ shall be approved later and added as add-on panels / vertical .

Dependency Bottlenecks

- Avoid Manufacturing Delays.

Minimizing Protect Time-line & Avoiding Delays

Engineered BOQ Procurement Concerns

Traditional Approach:

1. Ideally, 100% Engineered BOQ shall be prepared before ordering. However, this leads to unavoidable delays in supply causing execution delays.
2. Ordering shall be done based on estimated BOQ. May lead to extra ordinary variation in the range of $\pm 50\%$ for individual items.
 - Excess quantity - Increase in capital cost
 - Shorter quantity – Execution delay

Progressive Approach:

1. Ordering shall be done based on estimated BOQ. However, manufacturing clearance given in phased manner in 2 to 3 phases.
2. In 1st phase, manufacturing clearance shall be issued up to 50-60% Quantity for individual items.
3. When accuracy of 80-90% is achieved, In 2nd Phase, manufacturing clearance released.
4. If required balance quantity shall be cleared in 3rd Phase.

**Shortage of Resources
Dependency Bottlenecks**

- Ensure avoiding any delays.
- Helps in maintaining variation range within 10%.

Project Cost Optimization

Voltage Selection - An Economic Optimisation Tool

Recommended Design Approach

Determine load magnitude and concentration.

Evaluate Candidate voltage levels.

Run ETAP Studies.

Optimize based on TCO
(Capex+Opex+Losses+Maint).

Check Future Expansion

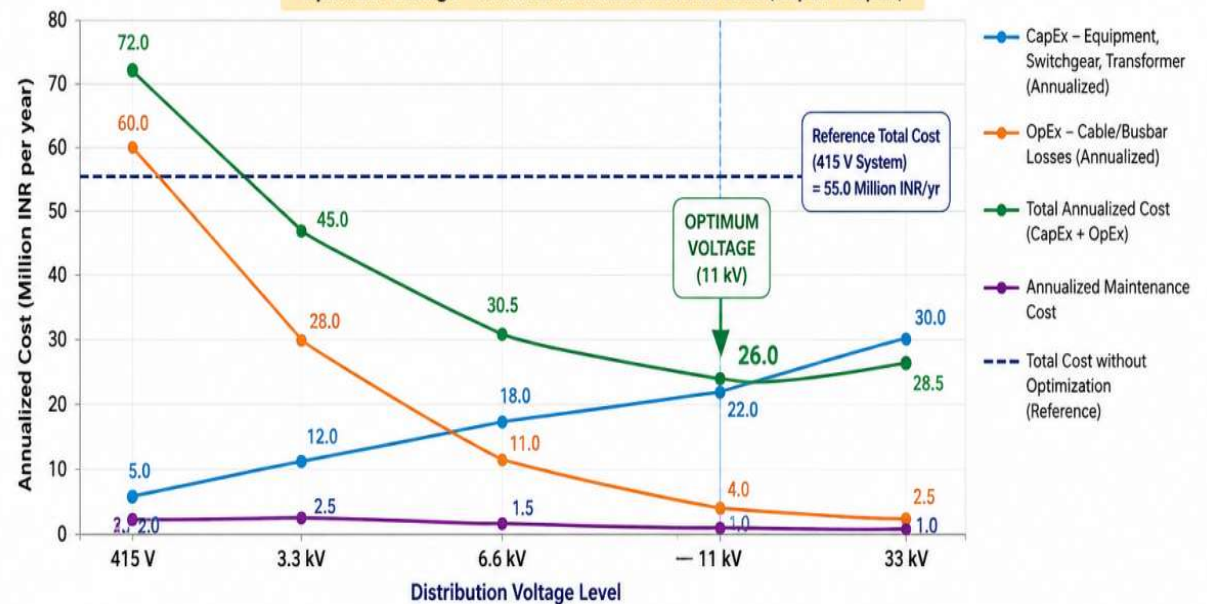
KEY TAKEAWAYS

- CapEx increases with higher voltage due to cost of switchgear, transformers and equipment.
- Cable losses(OpEx) decrease significantly with higher voltage.
- 11 kV provides the minimum annualized total cost for this representative cement plant

VOLTAGE vs ANNUALIZED DISTRIBUTION COST

Trade-off Between Capital Cost (CapEx) and Operating Cost (Losses) – Typical Cement Plant

Optimum Voltage = Minimum Annualized Total Cost (CapEx + OpEx)



PROJECT COST OPTIMIZATION

Voltage Selection - Actual Findings From One Of The Project

CAPEX

MV CABLE COST ESTIMATION FOR 6.6KV AND 11KV POWER DISTRIBUTION OPTIONS					
ITEM DESCRIPTION	UNIT	6.6KV DISTRIBUTION		11KV DISTRIBUTION	
		QTY	TOTAL COST (RS IN LAC)	QTY	TOTAL COST (RS IN LAC)
240SQ MM AL ARMoured 11 KV RATING	KM	0	0	17.92	465.9
630SQ MM AL ARMoured 11 KV RATING	KM	0	0	16.85	313.4
400SQ MM AL ARMoured 6.6 KV RATING	KM	9.19	333.6	0	0.0
630SQ MM AL ARMoured 6.6 KV RATING	KM	54.43	1012.4	0	0.0
30MVA TRANSFORMER	NOS	0	0	1	300.0
CIRCUIT BREAKER	NOS	0	0	6	112.5
TOTAL			1346.0		1191.8
CAPEX SAVING WITH 11KV DISTRIBUTION (RS IN LACS)		154.2			

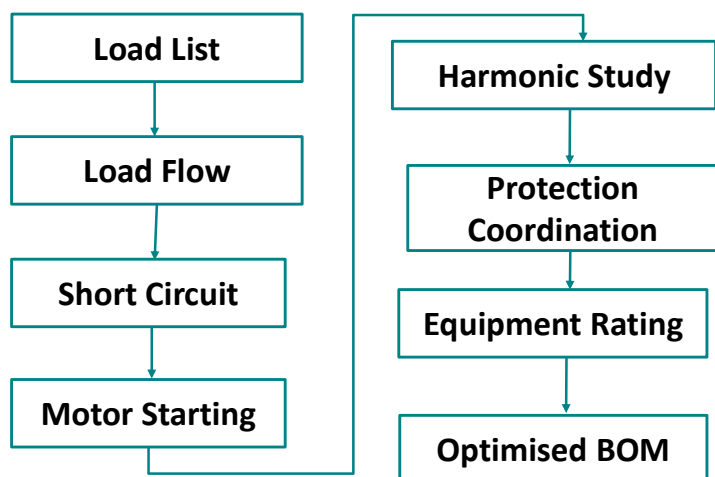
OPEX

LOSSES ESTIMATION FOR 6.6KV AND 11KV POWER DISTRIBUTION OPTIONS		
ITEM DESCRIPTION	LOSSES in KW	
	6.6KV	11KV
PT-1 40 MVA	35.30	32.40
Cable-10	13.00	7.06
Cable-11	0.00	0.00
Cable-13	0.00	0.00
Cable-1	10.70	9.71
Cable-16	8.70	7.90
Cable-18	5.41	4.91
Cable-19	3.44	1.56
Cable-20	2.61	1.18
Cable-17	2.66	1.21
Cable-21	2.18	0.99
Cable-5	41.90	38.20
Cable-6	21.30	19.30
Cable-7	0.35	0.38
Cable-8	18.10	11.00
GT-4 18MVA	44.10	41.00
TOTAL	209.75	176.80
SAVINIG (KW)	32.96	
YEARLY SAVING (KW)	237276.0	
YEARLY SAVING (Rs in Lacs)	17.80	
% SAVING	18.64%	

PROJECT COST OPTIMIZATION

ETAP Driven Right Sizing

Recommended ETAP workflow:



ETAP-Driven Right-Sizing

Design item	Conventional approach	ETAP-driven approach	Benefit
Transformer	Conservative oversizing	Load-flow + diversity + future-load analysis	Lower CapEx & no-load losses
MV/LV cables	Standardised oversizing	Load current + voltage drop + thermal capacity	Lower cable Sizes & quantity + Lower Losses
MV/LV switchgear	Maximum available rating	Short-circuit + load-flow study	Optimum interrupting rating
MV & LV Capacitor	Fixed percentage of load	Reactive-power and harmonic study	Optimum compensation

“Do not size electrical equipment by rule of thumb. Size it from the calculated operating envelope.”

PROJECT COST OPTIMIZATION

CapEx Reduction – Efforts Already Implemented

Efforts Already Implemented				
Category	Area Items	Current Practice	Proposals	% Cost Reduction
Design / Technology	MV VVFD	54 pulse MV VVFD considered with 11kV Motor	30/36 pulse MV VVFD considered with 6.6kV Motor	15-20% of MV VVFD Cost
Design / Technology	LV VFD	AFE to avoid harmonics in LV System	DFE LV VVFD Line-Up with 3-winding Transformer	15-20% LV VFD Cost
Vendor Selection	LVD & MCC	OEM Design	OEM Design Reproduced by System House	30-40% LVD & MCC Cost
Design/ Technology	MCC	Draw-out Design	Fixed Design	20-25% of MCC Cost
Material optimisation	MV Switch Board	Copper Busbar	Aluminium Bus Bar	10-15% MV SWBD Cost
Cable Quantity optimisation	MCC Location	Only 4-6 Load Centres. All LVD and MCC are located in these LC's	MCC to locate in centre of gravity of loads. Maximum distance between MCC and Load shall not be more than 150Mtrs	10-15% of LV Cable Cost
Standardisation	Spare Feeders	Minimum one or 20% for each type / rating	Minimum one or 20% of One type / Group of rating	2-3% of MV & LV feeders Cost

Effort Category

1. Design / Technology selection
2. Vendor Selection
3. Material Optimization
4. Quantity Optimization
5. Standardization

**Start with High-Value Items:
Small Effort = Large Absolute CapEx
Saving**

80% of optimisation effort → High-value packages

“A key lever for electrical CapEx optimization”

PROJECT COST OPTIMIZATION

Caution On Cost Reduction – “Strategic Equipment Selection / Substitution”

Equipment selection should be move from
“lowest purchase price” to **“lowest lifecycle cost”**.
(Technical + Economic + Lifecycle evaluation)

Example		
Parameter	Transformer A	Transformer B
Purchase price	₹10.0 Cr	₹11.0 Cr
Installation	₹0.60 Cr	₹0.60 Cr
Annual energy loss	₹0.80 Cr	₹0.50 Cr
Annual maintenance	₹0.20 Cr	₹0.15 Cr
Expected life	20 years	20 years
Initial CapEx	₹10.60 Cr	₹11.60 Cr

Although **Transformer B** purchase cost is Rs. 1 Cr more, its lower losses and maintenance can potentially **recover the premium within 3 years**.

“The lowest quoted price is not necessarily the lowest project cost. The optimum vendor is the one offering the lowest technically compliant evaluated cost with acceptable reliability, delivery and lifecycle performance.”

PROJECT COST OPTIMIZATION

Optimized Substation Footprint

CIVIL COST ESTIMATION FOR SUBSTATION BUILDINGS

Plant Description	S/S Building	Primary impact	Saving (Rs in Lac)
Grinding Unit	3-5 Nos & Approx 2500-3000sqm/floor	Rs 1375 Lac to Rs 1650 Lac	150
Clinker Unit	6-9 Nos & Approx 6500-7000sqm/floor	Rs 3375 Lac to Rs 4050 Lac	370
Intergraded Unit	10-14 Nos & Approx 8500-9000sqm / Floor	Rs 4375 Lac to Rs 5250 Lac	480
<u>Considerations</u>			
Cost of Building – Rs 0.25 – 0.30 Lacs / Sq Mts / Floor			
Each LC shall have minimum G+1 Configuration			
Saving @ 10% reduction in building size			

ACTION FOR OPTIMIZED LOAD CENTER SIZING

Conventional Approach	Optimised Approach
Over Sized Panel Gaps	Optimisation of Panel Gaps (Front, Rear & Side)
Non – Uniform Panel Depth	Consider Uniform Depth for each type of panels
Uniform Column Width	Adjusting Column Width
Over Sized Margins for future expansion	Space Provision for building expansion in future

SYSTEM RELIABILITY & MAXIMISE UPTIME

ILMS – Intelligent Load Management System

- ILMS shall be designed around load criticality, rather than simply disconnecting loads during an emergency.

During a major electrical disturbance:

Grid disturbance → Detect → Calculate available power → Shed lowest-priority loads →
Stabilise network → Restore loads sequentially

This prevents unnecessary plant-wide trips.

“Prevents Complete system collapse”

SYSTEM RELIABILITY & MAXIMISE UPTIME

Intelligent Diagnostics

Replace:
Periodic inspection → Manual diagnosis → Reactive repair
with:
Continuous monitoring → Automated diagnosis → Predictive intervention

Parameters to monitor:

- Transformer temperature and oil condition
- Partial discharge
- Breaker operation
- Motor vibration / bearing / winding temperature
- Motor current signatures
- Cable and busbar temperature
- VFD health and alarms
- Protection relay event records
- Power-quality events

“Detect degradation before it becomes a production-affecting failure”

SYSTEM RELIABILITY & MAXIMISE UPTIME



Voltage-Dip Ride-Through

Cement plants contain many sensitive loads that can trip during short voltage disturbances, even if the grid disturbance is cleared quickly.

Particularly sensitive systems:

- PLC/DCS
- Control Systems
- VFDs
- Instrumentation
- Contactors
- Critical Auxiliaries

Design philosophy

Voltage dip → Apply controls → Maintain critical drives → Avoid process upset → Automatic recovery

Possible solutions:

UPS + Drive ride-through + DC-link support + Dynamic Voltage Restorer (DVR) + Control-power redundancy

“The correct solution should be selected from a voltage-dip and critical-load study, rather than applying the same solution to every load”

SYSTEM RELIABILITY & MAXIMISE UPTIME

BESS (Battery Energy Storage System) For Reliability

Multiple functions of Battery Energy Storage System`

BESS Function	Reliability Benefit
Fast Progressive power support	Supports critical loads during disturbances
Peak saving	Reduces maximum demand
Load shifting	Optimises energy cost
Backup supply	Supports selected essential loads
Renewable integration	Smooths variable generation
Grid support	Fast active/reactive response
Black-start support	Potential restoration capability

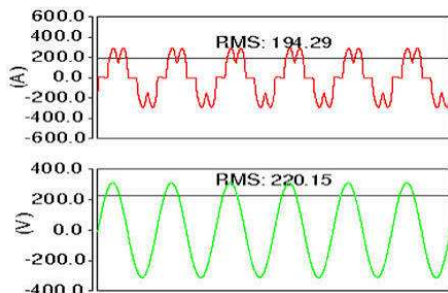
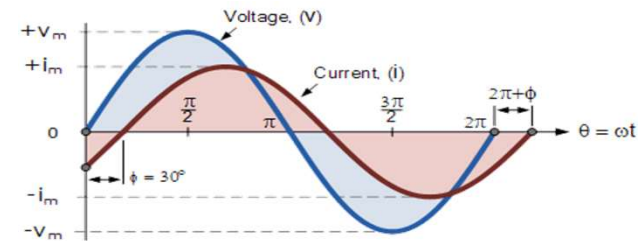
A Battery Energy Storage System can provide multiple functions.

“BESS should be evaluated as a multi-value asset—not solely as a backup battery”

POWER QUALITY & OUTPUT EXCELLENCE

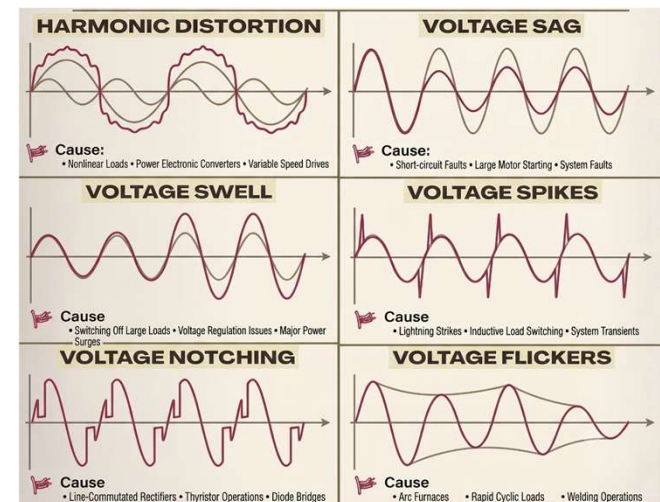
Harmonics

Ideally, Voltage are sinusoidal waveform and resulting load current shall also be sinusoidal.



However, the presence of non-linear loads caused unwanted high frequency wave forms in load current resulting distorted current wave form.

High magnitude of load current distortion results in distortion in voltage wave form. Voltage distortion magnitude depends on Source Strength (I_{SC}/I_L).



“Harmonics are a mathematical way of describing distortion to a voltage or current waveform”

POWER QUALITY & OUTPUT EXCELLENCE

Harmonics

A common term that is used in relation to harmonics –
THD - Total Harmonic Distortion

$$I_{THD} = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + I_5^2 + \dots}}{I_1} \times 100\%$$

Risks Linked to Harmonics

- ❖ Nuisance Tripping
- ❖ Premature Failures
- ❖ Deration in Equipment Rating & Power Losses
- ❖ Poor Power Factor
- ❖ Over Heating – Cables, Transformers, Capacitors, Neutral Conductors etc.
- ❖ Flickering Lights
- ❖ Disturbance in Communication Networks

POWER QUALITY & OUTPUT EXCELLENCE

Standard on Harmonics

IEEE 519 - 2022

Recognizes not only the absolute level of harmonics produced by an individual source, but also their size relative to the supply network.

TDD - Total Demand Distortion

$$I_{TDD} = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + I_5^2 + \dots}}{I_L} \times 100\%$$

Maximum Demand Load Current (IL) is the fundamental-frequency component of the load current calculated as the average of the maximum monthly demand currents over the previous 12 months.

Current Distortion Limits (120 V through 69 kV)

I_{sc} / I_L	$3 \leq h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h < 50$	% TDD
<20	4	2	1.5	0.6	0.3	5
20<50	7	3.5	2.5	1	0.5	8
50<100	10	4.5	4	1.5	0.7	12
100<1000	12	5.5	5	2	1	15
>1000	15	7	6	2.5	1.4	20

All power generation facilities are limited to the <20 row values, regardless of their actual short-circuit ratio (I_{sc}/I_L)

TDD ensures that distortion is evaluated against the actual thermal and physical capacity of the electrical infrastructure.

POWER QUALITY & OUTPUT EXCELLENCE

Standard on Harmonics

IEEE 519 - 2022

Recognizes not only the absolute level of harmonics produced by an individual source, but also their size relative to the supply network.

Current Distortion Limits (69 kV Through 161 kV)

I_{sc} / I_L	$3 \leq h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h < 50$	% TDD
<20	2	1	0.75	0.3	0.15	2.5
20<50	3.5	1.75	1.25	0.5	0.25	4
50<100	5	2.25	2	0.75	0.35	6
100<1000	6	2.75	2.5	1	0.5	7.5
>1000	7.5	3.5	3	1.25	0.7	10

All power generation facilities are limited to the <20 row values, regardless of their actual short-circuit ratio (ISC/IL)

TDD ensures that distortion is evaluated against the actual thermal and physical capacity of the electrical infrastructure.

Current Distortion Limits (Above 161 kV)

I_{sc} / I_L	$3 \leq h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h < 50$	% TDD
<20	1	0.5	0.38	0.15	0.1	1.5
20<50	2	1	0.75	0.3	0.15	2.5
<50	3	1.5	1.15	0.45	0.22	3.75

All power generation facilities are limited to the <20 row values, regardless of their actual short-circuit ratio (ISC/IL)

TDD ensures that distortion is evaluated against the actual thermal and physical capacity of the electrical infrastructure.

POWER QUALITY & OUTPUT EXCELLENCE



Standard on Harmonics

IEEE 519 - 2022

Recognizes not only the absolute level of harmonics produced by an individual source, but also their size relative to the supply network.

Voltage Distortion Limits		
Bus Voltage at PCC (V)	Individual Harmonic Limit (%)	Total Harmonic Distortion VTHD (%)
$V \leq 1.0 \text{ kV}$	5	8
$1.0 \text{ kV} < V \leq 69 \text{ kV}$	3	5
$69 \text{ kV} < V \leq 161 \text{ kV}$	1.5	2.5
$V > 161 \text{ kV}$	1	1.5

POWER QUALITY & OUTPUT EXCELLENCE

❖ Mitigation Measures

It is highly recommended to design power distribution to maintain Harmonic within IEEE 519 limits at The Point of Common Coupling (Every LV / MV / EHV Bus) rather adding harmonic filters for mitigation.

Standard Design Consideration Adopted:

- All distribution transformers shall have Loading of Non-Linear loads as per IEEE519 Guidelines.
- Club 6-pulse LV VFD's (35% ITHD - Predominant 5th & 7th Harmonics) in Line Up to form and fed through 3-winding transformer resulting cancel out 5th & 7th Harmonics.
- Use Line Reactor & DC Choke with LV VFD's.
- Use AFE VFD's.
- Use MV VFD for Higher rating VFD Motors >800KW.
- Use Detuned Series reactor with Capacitors.

“These design consideration are Proven as already implemented in many projects”

POWER QUALITY & OUTPUT EXCELLENCE

❖ Comparison of Mitigation Technology

Solution Type	Typical resulting distortion (THD)	Key Benefits	Primary Trade-offs
DC Choke / Line Reactors	25-50%	Low Cost, Small Foot Print, Basic Circuit Protection	Only attenuate Higher order Harmonics
Passive Filters	15%	Moderately Priced, Effectively targets specific frequency	Risk of Grid Resonance, Lower PF at partial loads
Active Harmonic Filters		Dynamically adopts to changing loads, Cover Wide Frequency Range	High Capital Cost, Must be over sized for PF Correction
AFE	5%	Achieve unity PF, Eliminate starting current surge	High Capital Cost, Complex Setup, Higher Losses compare DFE

POWER QUALITY & OUTPUT EXCELLENCE

❖ Dynamic Reactive PF Compensation

Real-time method of correcting power factor using high-speed power electronics

Reactive PF Compensation Methods:

- Step Detuned Capacitor Banks - Traditional
- Detuned Thyristor Controlled Step Capacitor Banks - Traditional
- Static VAR Generator (SVG) - Low-to-medium voltage inverter generate a current waveform that mimics either a capacitor (leading) or a reactor (lagging)
- Active Harmonic Filter (AHF)/
Active Power Filter (APF) - A dual-purpose tool when struggles with both PF & Harmonics
- STATCOM (Static Synchronous Compensator) - Same as SVG but are scaled to MV/EHV transmission / Grid

POWER QUALITY & OUTPUT EXCELLENCE

❖ Traditional Vs Dynamic

Feature	Detuned Capacitor Banks	Detuned Thyristor Controlled Capacitor Banks	Dynamic Compensation (SVG/AHF)
Response Time	Slow (seconds to minutes)	Moderate (20ms to 100ms)	Ultra-Fast (< 1ms to 5ms)
Control Style	Stepped blocks (e.g., 50kVAR steps)	Stepped blocks	Stepless, Fully linear vector injection
Low-Load Risks	High risk of leading PF / overvoltage	Moderate risk of leading PF	Zero risk, Scales output perfectly down to 0A
Grid Resonance	Mitigated via tuning reactors	Mitigated via tuning reactors	Immune, Acts as a controlled current source
Voltage Sensitivity	Output drops with the square of voltage (V^2)	Output drops with the square of voltage (V^2)	Maintains full current injection capability even during sags

OPTIMIZATION OF RECURRING & OPERATING COST

- ❖ Ultra Efficient Equipment, Minimising Distribution Losses & Sensor based Predictive Maintenance

Major OpEx Reduction Levers		
Area	Strategy	Primary impact
High-efficiency motors	IE4/IE5 motors for suitable duty cycles	↓ Motor losses
Variable-speed drives	Match speed to process demand	↓ Fan/pump/mill auxiliary energy
Transformer efficiency	Low-loss transformers + optimum loading	↓ No-load & load losses
Distribution losses	Optimise voltage, feeder length and conductor size	↓ I^2R losses
Power factor	APFC / SVG / STATCOM	↓ Reactive current & losses
Harmonics	Active filters / AFE drives / appropriate topology	↓ Harmonic losses and equipment heating
Demand management	Peak-load control / ILMS	↓ Maximum-demand charges
Predictive maintenance	Sensors + condition monitoring	↓ Maintenance & failure cost
Energy monitoring	Sub-metering + energy dashboard	Identify losses and abnormal consumption
BESS	Peak shaving / load shifting where economic	↓ Demand cost + improve resilience

CONCLUSION

Advanced electrical design strategies transform the electrical system from a passive utility into a strategic tool for project viability.

Addressing the complete lifecycle—from compressed fast-track execution and minimized CapEx to digitized reliability—ensures modern cement plants remain highly competitive, environmentally compliant, and resilient in an evolving industrial market.

THANK YOU



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