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TECHNICAL GUIDES

Plant Electrical Load Management: Cut Peak Demand Charges by ₹3 Lakh/Month with Staggered Crusher Starts

Reduce peak demand charges by ₹3 lakh monthly using staggered crusher starts. Optimize electrical load and utility tariffs.

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Your crushing plant's electricity bill shows ₹12-18 lakhs monthly with demand charges accounting for 40-50% of total cost—₹5-9 lakhs based on your 15-minute peak consumption window. The peak occurs during morning startup when jaw crusher, cone crusher, and conveyors all start simultaneously, drawing 850-1,100 kW for 8-12 minutes. Yet production only requires 600-700 kW average continuous load. That 200-400 kW peak delta, lasting mere minutes monthly, costs you ₹3-5 lakhs every month in demand charges. The solution isn't larger transformer capacity or utility negotiation—it's intelligent load sequencing that staggers equipment starts across 6-10 minutes, cutting peak demand 25-35% without affecting production throughput.

Industrial electricity tariffs in India impose two distinct charges: energy consumption (kWh billing at ₹5-8 per unit) and peak demand (kVA billing at ₹250-450 per kVA per month). While operators focus on minimizing runtime hours to reduce energy consumption, peak demand charges—based on the highest 15-minute average load in

the billing period—receive minimal attention. In crushing plants, simultaneous startup of multiple high-power motors creates artificial peaks 30-45% above normal operating load, inflating demand charges disproportionately to actual production needs.

This guide examines electrical load management strategies for aggregate crushing plants, focusing on staggered startup sequencing, power factor correction, and automation systems that reduce peak demand charges by ₹3-6 lakhs monthly for typical 200-300 TPH operations without capital-intensive equipment replacement.

Understanding Peak Demand Charges and Plant Load Profile

Electricity Tariff Structure

High-Tension (HT) industrial electricity supply in India (11 kV or 33 kV) uses two-part tariffs:

Energy Charges (kWh Component):

- Billed based on actual consumption recorded by kWh meter
- Rate varies by state and time-of-day: ₹5-6.50/kWh off-peak, ₹7-9/kWh peak hours (typically 6-10 AM and 6-10 PM)
- Predictable and directly related to production hours
- 200 TPH plant at 3-3.5 kWh/ton consumption: 600-700 kWh/hour × 10 hours/day × 26 days = 156,000-182,000 kWh monthly
- Energy cost @ ₹6.50/kWh average: ₹10.14-11.83 lakhs monthly

Demand Charges (kVA Component):

- Billed on maximum 15-minute average kVA demand recorded in billing period (monthly)
- Rate: ₹250-450/kVA/month depending on state, voltage level, and contract
- Independent of duration—even single 15-minute peak sets billing for entire month
- Typical plant: 850 kVA recorded peak (simultaneous equipment start) @ ₹350/kVA = ₹2.975 lakhs monthly
- Optimized load: 650 kVA with staggered starting = ₹2.275 lakhs monthly (**₹70,000 monthly saving**)

Power Factor Penalty/Incentive:

- Utilities require minimum 0.90-0.92 power factor (PF) to avoid penalty charges
- Below threshold: Penalty of 0.5-1% per 0.01 PF drop (below 0.85 PF can add 5-15% to total bill)
- Above 0.95 PF: Some utilities offer 1-2% rebate
- Crusher plants with large induction motors typically operate at 0.75-0.85 PF without correction (require capacitor banks)

⚠ **Economic Impact:** For a plant with ₹16 lakhs monthly electricity bill, typical breakdown: ₹10.5 lakhs energy charges (66%), ₹5.5 lakhs demand charges (34%). Reducing peak demand 25% (850 to 638 kVA) saves ₹1.38 lakhs monthly (₹16.5 lakhs annually) with zero impact on production. Over 5-year period, this represents ₹82.5 lakhs in reduced operating costs—often exceeding the total capital cost of automation systems required to achieve this saving.

Crushing Plant Load Profile Analysis

Understanding instantaneous and average power consumption for each equipment component enables load management optimization:

Primary Jaw Crusher (200 TPH Nominal):

- Motor Rating: 110-150 kW (150-200 HP)
- Starting Current: 5-6.5x full-load current for 8-15 seconds (DOL starter)
- Starting kVA: 750-975 kVA peak for 8-15 seconds, dropping to 180-220 kVA running
- Running Load (Under Feed): 140-170 kW (0.82-0.85 PF) = 170-200 kVA
- Running Load (No Feed): 25-35 kW (no-load losses) = 35-45 kVA

Secondary Cone Crusher (200 TPH Nominal):

- Motor Rating: 160-220 kW (200-300 HP)
- Starting kVA: 950-1,300 kVA peak for 8-15 seconds
- Running Load (Under Feed): 180-240 kW (0.80-0.83 PF) = 220-290 kVA
- Running Load (No Feed): 40-55 kW = 50-70 kVA

Vibrating Screens (2-3 Units):

- Motor Rating: 15-30 kW per screen

- Starting kVA: 80-180 kVA combined
- Running Load: 35-70 kW combined = 45-90 kVA

Conveyor Belts (4-6 Units):

- Motor Rating: 11-30 kW per conveyor
- Starting kVA: 50-150 kVA per unit (DOL start)
- Running Load (Under Load): 50-120 kW combined = 65-150 kVA
- Running Load (Empty): 20-40 kW combined = 28-55 kVA

Feeder, Dust Suppression, Auxiliaries:

- Combined Load: 25-50 kW = 35-65 kVA

Simultaneous Start Scenario (Current Practice):

- All equipment starts within 60-90 seconds during morning startup
- Peak 15-minute average demand: 750-950 kVA (includes inrush overlaps)
- Normal running demand: 535-665 kVA (all equipment under production load)
- **Avoidable Peak Delta: 215-285 kVA (28-37% of peak)**

Staggered Startup Sequencing Strategy

Optimal Start Sequence Design

Proper sequencing starts equipment in reverse process flow order (downstream to upstream) with timed delays to avoid inrush current overlap:

Sequence Step 1: Discharge Conveyor (Time 0:00)

- Start final product discharge conveyor (30-45 kW motor)
- Inrush: 150-180 kVA for 8-12 seconds, stabilizes to 40-55 kVA
- Purpose: Establishes material flow path before crushers start producing
- Wait: 30 seconds before next start

Sequence Step 2: Screens and Intermediate Conveyors (Time 0:30)

- Start vibrating screens (2-3 units) and inter-crusher conveyors

- Combined inrush: 180-260 kVA for 10-15 seconds, stabilizes to 110-145 kVA
- Current peak from Step 1 has subsided; total load now 150-200 kVA
- Wait: 45-60 seconds before next major load

Sequence Step 3: Secondary Crusher (Time 1:15)

- Start cone crusher (160-220 kW motor)
- Inrush: 950-1,300 kVA for 8-15 seconds
- During inrush, total load: 1,100-1,500 kVA instantaneous (but less than 8-15 seconds, not captured in 15-min average)
- After stabilization: 330-360 kVA (crusher running empty plus downstream equipment)
- Wait: 90-120 seconds to allow full acceleration and stabilization

Sequence Step 4: Feed Conveyor to Secondary (Time 2:45)

- Start conveyor feeding jaw crusher discharge to cone crusher
- Inrush: 120-160 kVA for 10 seconds
- Total load during inrush: 450-520 kVA (well below simultaneous-start peak)
- Stabilized load: 380-420 kVA
- Wait: 45 seconds

Sequence Step 5: Primary Jaw Crusher (Time 3:30)

- Start jaw crusher (110-150 kW motor)
- Inrush: 750-975 kVA for 8-15 seconds
- Total load during inrush: 1,130-1,395 kVA instantaneous (brief, minimal 15-min average impact)
- Stabilized no-load: 415-465 kVA total plant load
- Wait: 60 seconds for mechanical stabilization

Sequence Step 6: Feeder and Material Flow (Time 4:30)

- Start apron feeder or grizzly feeder to begin material flow
- Inrush: 80-120 kVA, stabilizes to 50-70 kVA
- As material begins processing, crusher loads increase to running values
- Full production load: 535-665 kVA (vs. 750-950 kVA peak in simultaneous start)

Demand Reduction Calculation:

- **Simultaneous Start Peak (15-min average):** 850 kVA typical
- **Staggered Start Peak (15-min average):** 620 kVA (inrush events less than 15 seconds do not significantly affect 15-minute rolling average)
- **Reduction:** 230 kVA (27%)
- **Monthly Saving:** 230 kVA × ₹350/kVA = ₹80,500
- **Annual Saving:** ₹9.66 lakhs

Soft Starter and VFD Considerations

While staggered sequencing reduces peak demand significantly, motor starting method further optimizes inrush characteristics:

Direct-On-Line (DOL) Starting (Current Standard):

- Full voltage applied to motor instantly, causing 5-7x full-load current inrush
- Simple, low-cost (₹8,000-15,000 per starter), highly reliable
- Creates maximum mechanical stress on motor and driven equipment (useful for clearing crusher cavities)
- Suitable for motors under 50 kW or where inrush management handled by sequencing

Soft Starter (Reduced Inrush Option):

- Gradually ramps voltage over 10-30 seconds, reducing inrush to 2.5-4x full-load current
- Reduces starting kVA by 40-60% vs. DOL (jaw crusher: 750 kVA DOL to 300-450 kVA soft start)
- Cost: ₹45,000-85,000 for 150 kW unit, ₹65,000-120,000 for 220 kW unit
- Payback: Debatable unless multiple large motors starting frequently (2-3 plus starts per hour)
- Limitation: Does not reduce energy consumption during running (only affects starting)

Variable Frequency Drive (VFD):

- Provides soft start plus ability to vary motor speed for load optimization

- Inrush: 1.0-1.5x full-load current (minimal impact on peak demand)
- Running Benefit: Can reduce motor speed 10-20% during low-feed conditions, saving 25-45% energy during those periods
- Cost: ₹1.2-2.2 lakhs for 150 kW unit, ₹1.8-3.2 lakhs for 220 kW unit
- Application: Best for conveyors and feeders (variable speed matches material flow), limited benefit for crushers (operate best at design speed)
- Payback: 2-4 years from combined energy and demand savings for feeders or conveyors, over 5 years for crushers (not recommended)

Recommendation for Crushing Plants:

- Continue DOL starting for crushers (benefit of mechanical clearing outweighs inrush cost when combined with sequencing)
- Use soft starters only if plant has frequent start-stop cycles (over 3-4 daily), otherwise sequencing alone sufficient
- Consider VFDs for conveyors over 30 kW to enable speed matching with crusher throughput (saves energy plus improves system efficiency)

Power Factor Correction Implementation

Understanding Power Factor Impact

Induction motors (crushers, screens, conveyors) consume two types of power:

- **Real Power (kW):** Performs useful work (crushing, conveying)
- **Reactive Power (kVAR):** Maintains magnetic fields in motor windings (no useful output, but essential for operation)
- **Apparent Power (kVA):** Vector sum of kW and kVAR, what utility meter measures for demand charges

Power Factor Formula: PF = kW / kVA

Example: 150 kW motor at 0.82 PF draws 183 kVA (150 kW real plus 104 kVAR reactive). Same motor with PF correction to 0.95 draws 158 kVA (150 kW plus 49 kVAR)—**14% reduction in kVA demand.**

Capacitor Bank Sizing and Installation

Plant Power Factor Assessment:

- Measure current PF at main incomer using power quality analyzer (3-phase logging meter)
- Typical crushing plant without correction: 0.78-0.85 PF under full load, 0.65-0.75 at partial load
- Target PF: 0.92-0.95 (balances demand reduction with over-correction risk)

Capacitor Bank Sizing Calculation:

For 200 TPH plant with 600 kW total connected load at 0.82 PF:

- Current kVA demand: 600 kW / 0.82 = 732 kVA
- Current kVAR: square root of (732^2 - 600^2) = 419 kVAR (reactive power consumption)
- Target kVA at 0.95 PF: 600 kW / 0.95 = 632 kVA
- Target kVAR: square root of (632^2 - 600^2) = 197 kVAR
- **Required Capacitor Bank: 419 - 197 = 222 kVAR**

Installation Configuration:

Centralized Capacitor Bank (Recommended for Most Plants):

- Single 200-250 kVAR automatic capacitor bank at main distribution board
- 6-8 step switching (25-40 kVAR per step) via contactors controlled by PF relay
- Automatically adjusts reactive compensation based on load (prevents over-correction at low load)
- Cost: ₹1.8-3.2 lakhs for 225 kVAR automatic panel with harmonic de-tuned reactor (7% reactor prevents harmonic resonance)
- Maintenance: Minimal—annual capacitor insulation testing, contactor inspection

Distributed Correction (For Large Plants over 500 kW):

- Fixed capacitors at each large motor (jaw crusher, cone crusher) sized for 80% of motor kVAR
- Reduces cable losses by compensating reactive current locally

- Requires motor protection coordination (capacitors can cause overvoltage during motor stopping)
- Cost: ₹18,000-35,000 per motor (50-80 kVAR capacitor plus switching contactor)

Power Factor Correction ROI

Scenario: 600 kW Plant, 0.82 to 0.95 PF Correction

Before Correction:

- kVA Demand: 732 kVA @ ₹350/kVA = ₹2.562 lakhs monthly
- Low PF penalty (0.82 vs. 0.90 minimum): 8 × 0.5% = 4% penalty on total bill
- Penalty cost: ₹15 lakhs bill × 4% = ₹60,000 monthly
- **Total PF-Related Cost: ₹3.162 lakhs monthly**

After Correction:

- kVA Demand: 632 kVA @ ₹350/kVA = ₹2.212 lakhs monthly
- PF incentive (0.95 vs. 0.90 minimum): 1-2% rebate in some states (assume 0% conservative)
- **Total Cost: ₹2.212 lakhs monthly**

Monthly Saving: ₹95,000
Annual Saving: ₹11.4 lakhs
Capacitor Bank Investment: ₹2.5 lakhs
Payback Period: 2.6 months

Automation and Control Systems

PLC-Based Sequential Starter System

Manual staggered starting relies on operator discipline and timing accuracy (prone to shortcuts during production pressure). Automated systems ensure consistent peak demand management:

System Components:

Programmable Logic Controller (PLC):

- 6-10 digital outputs controlling motor starter contactors via relay interface
- Timer functions for sequential delays (adjustable 5-120 second range per step)
- Feedback inputs from motor running status (auxiliary contacts on starters)
- Fault logic: Aborts sequence if any motor fails to start or trips on overload
- Cost: ₹45,000-75,000 for compact PLC with 16 I/O sufficient for crushing plant

Human-Machine Interface (HMI):

- 7-10 inch touchscreen for operator control and status display
- Single Start Production button initiates full sequence
- Status indication for each motor (off, starting, running, fault)
- Adjustable delay settings (supervisor access only to prevent tampering)
- Cost: ₹25,000-45,000 for industrial HMI panel

Interlocking and Safety:

- Emergency stop circuit independent of PLC (hardwired safety relay)
- Reverse sequence for shutdown (upstream equipment stops first to clear material)
- Crusher cavity full protection (prevents start if pressure sensors indicate blockage)
- Conveyor pull-cord and belt-slip detection integrated into fault logic

Energy Monitoring Integration:

- Digital power meter with kW, kVA, PF, and current measurement for each feeder
- Data logging to PLC or separate SCADA system for trend analysis
- Real-time peak demand tracking (15-minute rolling average calculation)
- Alarm if approaching historical peak (allows operator intervention before new peak set)
- Cost: ₹8,000-15,000 per feeder for digital multifunction meter

Total Automation System Cost: ₹1.8-3.5 lakhs (PLC, HMI, meters, panel integration, commissioning)

Advanced Demand Management Features

Predictive Peak Demand Control:

- PLC calculates current 15-minute rolling average kVA every 60 seconds
- Compares to historical billing peak (stored setpoint)
- If projection exceeds peak by over 5%, triggers load shedding sequence
- Temporarily stops non-critical loads (dust suppression, office AC) for 5-10 minutes
- Prevents new monthly peak from brief operational anomaly (oversize feed, simultaneous restart after fault)

Time-of-Day Optimization:

- Shifts high-consumption auxiliary processes (compressor charging, water tank filling) to off-peak tariff hours
- Scheduling: Run air compressor 5-6 AM (off-peak rate), rely on receiver tank during peak hours
- Savings: 15-25% energy cost reduction for auxiliary loads (5-8% of plant total)

Implementation Case Study and Results

Baseline Plant Profile

Operation: 250 TPH hard rock crushing, 10 hours per day, 26 days per month

Equipment:

- Jaw crusher: 150 kW
- Cone crusher: 200 kW
- 3 screens: 22 kW each
- 5 conveyors: 11-30 kW (total 95 kW)
- Auxiliaries: 40 kW
- **Total Connected Load: 551 kW**

Pre-Optimization Electrical Costs (Monthly):

- Energy Consumption: 145,000 kWh @ ₹6.80/kWh = ₹9.86 lakhs

- Peak Demand: 895 kVA @ ₹360/kVA = ₹3.222 lakhs
- Low PF Penalty (0.80 PF): 5% = ₹65,500
- **Total: ₹13.147 lakhs monthly**

Optimization Measures Implemented

Phase 1: Staggered Startup Sequencing (Manual Protocol)

- Operator training on 6-step start sequence with timing sheet
- Supervisory oversight for first 2 weeks to ensure compliance
- Investment: ₹0 (training only)
- Result: Peak demand reduced to 720 kVA (175 kVA reduction, 19.6%)
- Savings: 175 × ₹360 = ₹63,000 monthly

Phase 2: Power Factor Correction

- Installed 200 kVAR automatic capacitor bank with 8-step switching
- Investment: ₹2.35 lakhs
- Result: PF improved from 0.80 to 0.94
- kVA Demand: 720 kVA to 620 kVA (additional 100 kVA reduction from PF alone)
- Penalty Eliminated: ₹65,500 monthly saved
- Demand Charge Savings: 100 × ₹360 = ₹36,000 monthly
- **Total Phase 2 Savings: ₹1.015 lakhs monthly**

Phase 3: PLC Automation and Monitoring

- Installed PLC-based sequential starter with HMI and energy monitoring
- Investment: ₹2.85 lakhs
- Result: Consistent execution of start sequence (vs. 60-70% manual compliance)
- Additional 5% peak demand reduction from optimized timing: 620 to 590 kVA
- Savings: 30 × ₹360 = ₹10,800 monthly
- Benefit: Real-time monitoring identified screen motor inefficiency (replaced, saved additional ₹8,500 per month energy)

Final Results

Post-Optimization Electrical Costs (Monthly):

- Energy Consumption: 140,500 kWh @ ₹6.80/kWh = ₹9.554 lakhs (2% reduction from auxiliary optimization)
- Peak Demand: 590 kVA @ ₹360/kVA = ₹2.124 lakhs
- PF Penalty: ₹0 (eliminated)
- **Total: ₹11.678 lakhs monthly**

Total Monthly Savings: ₹1.469 lakhs (11.2% reduction)
Annual Savings: ₹17.63 lakhs
Total Investment: ₹5.20 lakhs
Payback Period: 3.5 months
5-Year NPV @ 12% discount: ₹58.2 lakhs net benefit

Implementation Roadmap

Phase 1: Assessment and Quick Wins (Week 1-2)

- **Electricity Bill Analysis:** Review past 12 months billing to identify peak demand timing and magnitude
- **Load Profiling:** Install temporary power logger on main incomer for 7-10 days to record actual kW, kVA, PF patterns
- **Equipment Audit:** Document all motor ratings, starting methods, and current start sequence timing
- **Manual Sequencing Trial:** Implement operator protocol for staggered startup, monitor demand reduction for 2-3 weeks
- **Cost: ₹15,000-25,000 for power logger rental plus analysis**

Phase 2: Power Factor Correction (Month 1-2)

- **Capacitor Bank Sizing:** Calculate required kVAR based on load profile data
- **Procurement:** Select automatic capacitor panel with harmonic de-tuning reactor (prevents resonance with VFDs if any)

- **Installation:** Mount near main distribution board, connect via circuit breaker and PF controller
- **Commissioning:** Set target PF (0.93-0.96), verify automatic switching operates correctly across load range
- **Timeline: 4-6 weeks from order to commissioning**

Phase 3: Automation System (Month 2-4)

- **Control System Design:** Define start sequence logic, interlock conditions, and HMI screens
- **Panel Fabrication:** Build control panel with PLC, HMI, motor starters (or interface to existing starters)
- **Installation:** Mount panel, run control wiring to motors, integrate sensors
- **Programming and Testing:** Develop PLC logic, test sequence under no-load and production conditions
- **Operator Training:** Train all shifts on HMI operation, fault response, and manual override procedures
- **Timeline: 8-12 weeks from design to full production release**

Phase 4: Continuous Optimization (Ongoing)

- **Monthly Bill Tracking:** Compare actual peak demand to target, investigate any anomalies
- **Quarterly Load Analysis:** Review energy monitoring data to identify inefficient equipment or process changes
- **Annual Energy Audit:** Systematic assessment of all electrical systems for upgrade opportunities (motor efficiency, lighting, HVAC)

Risk Factors and Mitigation

Technical Risks

Capacitor Bank Over-Correction:

- **Issue:** Excessive reactive compensation at light load causes leading PF (PF over 1.0), potential utility penalty or voltage rise
- **Prevention:** Use automatic switching capacitor bank, not fixed capacitor (adjusts to load)
- **Monitoring:** Set PF relay to alarm if PF over 0.98 (indicates over-correction approaching)

Automation System Failure During Production:

- **Issue:** PLC fault prevents equipment start, causing production stoppage
- **Mitigation:** Include manual bypass mode (local start buttons at each motor) for emergency operation
- **Reliability:** Use industrial-grade PLC (MTBF over 150,000 hours), UPS backup for control power

Operational Risks

Operator Resistance to Delayed Startup:

- **Concern:** 4-5 minute sequence delays production start vs. immediate manual starting
- **Response:** Demonstrate that 5-minute startup delay equals less than 1% of 10-hour shift, eliminated by cost savings far exceeding lost production value
- **Engagement:** Share monthly savings results with operations team to build buy-in

✓ **Success Metrics:** Effective electrical load management programs achieve: (1) 20-35% peak demand reduction within 3 months of full implementation, (2) Power factor improvement to 0.92-0.96 range eliminating penalties, (3) 8-12% total electricity cost reduction, (4) under 6 month payback on automation and capacitor investments, and (5) Improved equipment life from reduced starting stress (motors, belts, couplings).

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