

# **Electrolux Energy Management System**

**Normalized Database Schema**

**BCNF Compliant - 16 Tables**

Database Systems Project  
FAST NUCES Karachi | Fall 2024

# Schema Overview

This document provides detailed specifications for all 16 tables in the Electrolux Energy Management System database. Each table is documented with complete attribute definitions, data types, constraints, and descriptions. The schema is normalized to Boyce-Codd Normal Form (BCNF) ensuring data integrity and minimal redundancy.

**Notation:** Primary keys are shown in **bold**, foreign keys are prefixed with \*asterisk.

## Category 1: Authentication & User Management

### 1. users

Attribute	Type	Constraint	Description
<b>id</b>	INT	PRIMARY KEY, AUTO_INCREMENT	User ID
email	VARCHAR(255)	NOT NULL, UNIQUE	Login email
password	VARCHAR(255)	NOT NULL	Bcrypt hashed password
user_type	ENUM	NOT NULL	admin/employee/customer
name	VARCHAR(255)	NOT NULL	Full name
phone	VARCHAR(20)	NULL	Contact phone
is_active	INT	DEFAULT 1	Active status (1=active, 0=inactive)
requires_password_change	INT	DEFAULT 0	Force password change flag
created_at	TIMESTAMP	DEFAULT NOW()	Record creation timestamp
updated_at	TIMESTAMP	ON UPDATE NOW()	Record update timestamp

**Candidate Keys:** id, email

### 2. password\_reset\_requests

Attribute	Type	Constraint	Description
<b>id</b>	INT	PRIMARY KEY, AUTO_INCREMENT	Request ID
request_number	VARCHAR(50)	NOT NULL, UNIQUE	PWRST-2025-XXXXX
*user_id	INT	FK → users(id), CASCADE	User reference
email	VARCHAR(255)	NOT NULL	User email
account_number	VARCHAR(50)	NULL	Customer account number
user_type	ENUM	NOT NULL	employee/customer
status	ENUM	DEFAULT 'pending'	pending/approved/rejected/completed
*processed_by	INT	FK → users(id)	Admin who processed
created_at	TIMESTAMP	DEFAULT NOW()	Record creation

**Candidate Keys:** id, request\_number

## Category 2: Customer Management

### 3. customers

Attribute	Type	Constraint	Description
<b>id</b>	INT	PRIMARY KEY, AUTO_INCREMENT	Customer ID
*user_id	INT	FK → users(id), UNIQUE, CASCADE	User account reference
account_number	VARCHAR(50)	NOT NULL, UNIQUE	ELX-2024-XXXXXX
meter_number	VARCHAR(50)	UNIQUE	MTR-XXX-XXXXXX
full_name	VARCHAR(255)	NOT NULL	Customer full name
email	VARCHAR(255)	NOT NULL	Contact email
phone	VARCHAR(20)	NOT NULL	Contact phone
address	VARCHAR(500)	NOT NULL	Full address
city	VARCHAR(100)	NOT NULL	City
state	VARCHAR(100)	NOT NULL	State/Province
pincode	VARCHAR(10)	NOT NULL	Postal code
zone	VARCHAR(50)	NULL	Load shedding zone (A-E)
connection_type	ENUM	NOT NULL	Residential/Commercial/Industrial/Agricultural
status	ENUM	DEFAULT 'active'	active/suspended/inactive/pending_installation
connection_date	DATE	NOT NULL	Service activation date
outstanding_balance	DECIMAL(10,2)	DEFAULT 0.00	Denormalized for performance
payment_status	ENUM	DEFAULT 'paid'	paid/pending/overdue
created_at	TIMESTAMP	DEFAULT NOW()	Record creation
updated_at	TIMESTAMP	ON UPDATE NOW()	Record update

**Candidate Keys:** id, user\_id, account\_number, meter\_number

## Category 3: Employee Management

### 4. employees

Attribute	Type	Constraint	Description
<b>id</b>	INT	PRIMARY KEY, AUTO_INCREMENT	Employee ID
employee_number	VARCHAR(20)	UNIQUE	EMP-001, EMP-002...
*user_id	INT	FK → users(id), UNIQUE, CASCADE	User account reference

Attribute	Type	Constraint	Description
employee_name	VARCHAR(255)	NOT NULL	Employee full name
email	VARCHAR(255)	NOT NULL	Work email
phone	VARCHAR(20)	NOT NULL	Work phone
designation	VARCHAR(100)	NOT NULL	Job title (e.g., Meter Reader)
department	VARCHAR(100)	NOT NULL	Department (e.g., Operations)
assigned_zone	VARCHAR(100)	NULL	Service area assigned
status	ENUM	DEFAULT 'active'	active/inactive
hire_date	DATE	NOT NULL	Employment start date
created_at	TIMESTAMP	DEFAULT NOW()	Record creation

**Candidate Keys:** id, employee\_number, user\_id

## Category 4: Billing & Tariffs

### 5. tariffs

Attribute	Type	Constraint	Description
id	INT	PRIMARY KEY, AUTO_INCREMENT	Tariff ID
category	ENUM	NOT NULL	Residential/Commercial/Industrial/Agricultural
fixed_charge	DECIMAL(10,2)	NOT NULL	Monthly fixed fee
time_of_use_peak_rate	DECIMAL(10,2)	NULL	Peak hours rate (optional)
time_of_use_normal_rate	DECIMAL(10,2)	NULL	Normal hours rate (optional)
time_of_use_offpeak_rate	DECIMAL(10,2)	NULL	Off-peak hours rate (optional)
electricity_duty_percentage	DECIMAL(5,2)	DEFAULT 0.00	Electricity duty percentage
gst_percent	DECIMAL(5,2)	DEFAULT 18.00	GST percentage
effective_date	DATE	NOT NULL	Rate effective from
valid_until	DATE	NULL	Rate valid until
created_at	TIMESTAMP	DEFAULT NOW()	Record creation

**Candidate Keys:** id

## 6. tariff\_slabs

Attribute	Type	Constraint	Description
<b>id</b>	INT	PRIMARY KEY, AUTO_INCREMENT	Slab ID
*tariff_id	INT	FK → tariffs(id), CASCADE	Parent tariff reference
slab_order	INT	NOT NULL	Slab sequence (1, 2, 3...)
start_units	INT	NOT NULL	Minimum kWh for this slab
end_units	INT	NULL	Maximum kWh (NULL = unlimited)
rate_per_unit	DECIMAL(10,2)	NOT NULL	Rate per kWh
created_at	TIMESTAMP	DEFAULT NOW()	Record creation

*Note: Extracted from tariffs table to eliminate repeating groups (1NF → BCNF)*

## 7. meter\_readings

Attribute	Type	Constraint	Description
<b>id</b>	INT	PRIMARY KEY, AUTO_INCREMENT	Reading ID
*customer_id	INT	FK → customers(id), CASCADE	Customer reference
meter_number	VARCHAR(50)	NOT NULL	Meter serial number
current_reading	DECIMAL(10,2)	NOT NULL	Current meter value (kWh)
previous_reading	DECIMAL(10,2)	NOT NULL	Previous meter value (kWh)
units_consumed	DECIMAL(10,2)	NOT NULL	Consumption (current - previous)
reading_date	DATE	NOT NULL	Reading date
reading_time	TIMESTAMP	NOT NULL	Reading timestamp
meter_condition	ENUM	DEFAULT 'good'	good/fair/poor/damaged
accessibility	ENUM	DEFAULT 'accessible'	accessible/partially_accessible/inaccessible
*employee_id	INT	FK → employees(id)	Employee who recorded reading
photo_path	VARCHAR(500)	NULL	Meter photo path
notes	TEXT	NULL	Additional notes
created_at	TIMESTAMP	DEFAULT NOW()	Record creation

**Candidate Keys:** id

## 8. bills

Attribute	Type	Constraint	Description
<b>id</b>	INT	PRIMARY KEY, AUTO_INCREMENT	Bill ID
*customer_id	INT	FK → customers(id), CASCADE	Customer reference
bill_number	VARCHAR(50)	NOT NULL, UNIQUE	BILL-2024-XXXXXX
billing_month	DATE	NOT NULL	Billing period (YYYY-MM-01)
issue_date	DATE	NOT NULL	Bill issue date
due_date	DATE	NOT NULL	Payment due date
units_consumed	DECIMAL(10,2)	NOT NULL	Total kWh consumed
*meter_reading_id	INT	FK → meter_readings(id)	Source reading reference
base_amount	DECIMAL(10,2)	NOT NULL	Units × tariff rate
fixed_charges	DECIMAL(10,2)	NOT NULL	Monthly fixed fee
electricity_duty	DECIMAL(10,2)	DEFAULT 0.00	Electricity duty amount
gst_amount	DECIMAL(10,2)	DEFAULT 0.00	GST amount
total_amount	DECIMAL(10,2)	NOT NULL	Total payable amount
status	ENUM	DEFAULT 'generated'	generated/issued/paid/overdue /cancelled
*tariff_id	INT	FK → tariffs(id)	Tariff used for calculation
created_at	TIMESTAMP	DEFAULT NOW()	Record creation

**Candidate Keys:** id, bill\_number

## 9. payments

Attribute	Type	Constraint	Description
<b>id</b>	INT	PRIMARY KEY, AUTO_INCREMENT	Payment ID
*customer_id	INT	FK → customers(id), CASCADE	Customer reference
*bill_id	INT	FK → bills(id)	Related bill reference
payment_amount	DECIMAL(10,2)	NOT NULL	Amount paid
payment_method	ENUM	NOT NULL	credit_card/debit_card/bank_tr ansfer/cash/cheque/upi/wallet
payment_date	DATE	NOT NULL	Payment date
transaction_id	VARCHAR(100)	UNIQUE	External transaction reference
receipt_number	VARCHAR(50)	UNIQUE	Receipt number
status	ENUM	DEFAULT 'completed'	pending/completed/failed/refun ded

Attribute	Type	Constraint	Description
created_at	TIMESTAMP	DEFAULT NOW()	Record creation

Candidate Keys: id, transaction\_id, receipt\_number

## Category 5: Service Management

### 10. complaints

Attribute	Type	Constraint	Description
id	INT	PRIMARY KEY, AUTO_INCREMENT	Complaint ID
*customer_id	INT	FK → customers(id), CASCADE	Customer who filed complaint
*employee_id	INT	FK → employees(id)	Assigned employee
category	ENUM	NOT NULL	power_outage/billing/service/meter_issue/connection/other
title	VARCHAR(255)	NOT NULL	Brief complaint title
description	TEXT	NOT NULL	Detailed description
status	ENUM	DEFAULT 'submitted'	submitted/under_review/assigned/in_progress/resolved/closed
priority	ENUM	DEFAULT 'medium'	low/medium/high/urgent
submitted_at	TIMESTAMP	DEFAULT NOW()	Submission timestamp
resolved_at	TIMESTAMP	NULL	Resolution timestamp
created_at	TIMESTAMP	DEFAULT NOW()	Record creation

Candidate Keys: id

### 11. work\_orders

Attribute	Type	Constraint	Description
id	INT	PRIMARY KEY, AUTO_INCREMENT	Work Order ID
*employee_id	INT	FK → employees(id)	Assigned employee
*customer_id	INT	FK → customers(id)	Related customer
work_type	ENUM	NOT NULL	meter_reading/maintenance/complaint_resolution/new_connection/disconnection/reconnection
title	VARCHAR(255)	NOT NULL	Work order title
description	TEXT	NULL	Task description
status	ENUM	DEFAULT 'assigned'	assigned/in_progress/complete/d onCancelled
priority	ENUM	DEFAULT 'medium'	low/medium/high/urgent

Attribute	Type	Constraint	Description
assigned_date	DATE	NOT NULL	Assignment date
due_date	DATE	NOT NULL	Due date
completion_date	DATE	NULL	Actual completion date
created_at	TIMESTAMP	DEFAULT NOW()	Record creation

Candidate Keys: id

## Category 6: Infrastructure

### 12. outages

Attribute	Type	Constraint	Description
id	INT	PRIMARY KEY, AUTO_INCREMENT	Outage ID
area_name	VARCHAR(255)	NOT NULL	Affected area name
zone	VARCHAR(50)	NOT NULL	Affected zone (A-E)
outage_type	ENUM	NOT NULL	planned/unplanned
severity	ENUM	NOT NULL	low/medium/high/critical
scheduled_start_time	DATETIME	NULL	Planned start time
scheduled_end_time	DATETIME	NULL	Planned end time
status	ENUM	NOT NULL	scheduled/ongoing/restored/cancelled
*created_by	INT	FK → users(id)	Admin who created
created_at	TIMESTAMP	DEFAULT NOW()	Record creation

Candidate Keys: id

### 13. notifications

Attribute	Type	Constraint	Description
id	INT	PRIMARY KEY, AUTO_INCREMENT	Notification ID
*user_id	INT	FK → users(id), CASCADE	Target user
notification_type	ENUM	NOT NULL	billing/payment/usage/outage/service/reminder/system/maintenance/alert/info/work_order
title	VARCHAR(255)	NOT NULL	Notification title
message	TEXT	NOT NULL	Notification message
priority	ENUM	DEFAULT 'normal'	low/normal/medium/high
is_read	INT	DEFAULT 0	Read status (0=unread, 1=read)

Attribute	Type	Constraint	Description
created_at	TIMESTAMP	DEFAULT NOW()	Record creation

Candidate Keys: id

## Category 7: Workflows & Requests

### 14. connection\_requests

Attribute	Type	Constraint	Description
<b>id</b>	INT	PRIMARY KEY, AUTO_INCREMENT	Request ID
application_number	VARCHAR(50)	NOT NULL, UNIQUE	Unique application number
applicant_name	VARCHAR(255)	NOT NULL	Applicant full name
email	VARCHAR(255)	NOT NULL	Contact email
phone	VARCHAR(20)	NOT NULL	Contact phone
id_type	ENUM	NOT NULL	passport/drivers_license/national_id/voter_id/aadhaar
id_number	VARCHAR(100)	NOT NULL	ID document number
property_type	ENUM	NOT NULL	Residential/Commercial/Industrial/Agricultural
connection_type	ENUM	NOT NULL	single-phase/three-phase/industrial
property_address	VARCHAR(500)	NOT NULL	Installation address
city	VARCHAR(100)	NOT NULL	City
zone	VARCHAR(50)	NULL	Assigned zone
status	ENUM	DEFAULT 'pending'	pending/under_review/approved/rejected/connected
application_date	DATE	NOT NULL	Application submission date
account_number	VARCHAR(50)	NULL	Generated account (after approval)
temporary_password	VARCHAR(255)	NULL	Initial login password
created_at	TIMESTAMP	DEFAULT NOW()	Record creation

Candidate Keys: id, application\_number

### 15. bill\_requests

Attribute	Type	Constraint	Description
<b>id</b>	INT	PRIMARY KEY, AUTO_INCREMENT	Request ID
request_id	VARCHAR(50)	NOT NULL, UNIQUE	Request identifier
*customer_id	INT	FK → customers(id), CASCADE	Customer reference

Attribute	Type	Constraint	Description
billing_month	DATE	NOT NULL	Requested billing month
priority	ENUM	DEFAULT 'medium'	low/medium/high
status	ENUM	DEFAULT 'pending'	pending/processing/completed/rejected
request_date	DATE	NOT NULL	Request date
*created_by	INT	FK → users(id)	User who created request
created_at	TIMESTAMP	DEFAULT NOW()	Record creation

**Candidate Keys:** id, request\_id

## 16. reading\_requests

Attribute	Type	Constraint	Description
<b>id</b>	INT	PRIMARY KEY, AUTO_INCREMENT	Request ID
request_number	VARCHAR(50)	NOT NULL, UNIQUE	Request number
*customer_id	INT	FK → customers(id), CASCADE	Customer reference
request_date	TIMESTAMP	DEFAULT NOW()	Request submission date
priority	ENUM	DEFAULT 'normal'	normal/urgent
status	ENUM	DEFAULT 'pending'	pending/assigned/completed/cancelled
*work_order_id	INT	FK → work_orders(id)	Related work order
assigned_date	TIMESTAMP	NULL	Assignment timestamp
completed_date	TIMESTAMP	NULL	Completion timestamp
created_at	TIMESTAMP	DEFAULT NOW()	Record creation

**Candidate Keys:** id, request\_number

## Normalization Compliance

All 16 tables in the Electrolux EMS database schema satisfy Boyce-Codd Normal Form (BCNF) requirements, ensuring data integrity and minimal redundancy.

### Normal Forms Satisfied

#### First Normal Form (1NF):

All attributes contain atomic values with no repeating groups. For example, the tariff\_slabs table was extracted from the tariffs table to eliminate repeating slab columns (slab1\_rate, slab2\_rate, etc.), converting them into individual rows.

#### Second Normal Form (2NF):

No partial dependencies exist. All non-key attributes fully depend on the entire primary key. In composite key scenarios, every non-key attribute depends on the complete primary key, not just part of it.

#### Third Normal Form (3NF):

No transitive dependencies exist. Non-key attributes depend only on primary keys, not on other non-key attributes. Each table represents a single entity with attributes directly related to that entity's primary key.

### **Boyce-Codd Normal Form (BCNF):**

For every functional dependency  $X \rightarrow Y$  in any table, X is a superkey. This ensures that every determinant is a candidate key, eliminating all anomalies related to functional dependencies.

## **Strategic Denormalization**

The *outstanding\_balance* attribute in the *customers* table represents a controlled denormalization implemented for performance optimization. While this value could be calculated by aggregating bill and payment data, storing it directly in the customers table enables:

- Faster dashboard queries without complex joins
- Improved performance for customer lists and reports
- Simplified payment status checks

Data consistency is maintained through ACID-compliant transactions that update the *outstanding\_balance* atomically whenever payments are processed or bills are generated, ensuring the denormalized value always reflects the current state.

## **Referential Integrity**

The schema maintains 25 foreign key relationships with appropriate cascade rules (CASCADE, SET NULL, RESTRICT) to ensure referential integrity across all tables. Each foreign key enforces parent-child relationships, preventing orphaned records and maintaining data consistency throughout the database lifecycle.