Reducing Cable Use and Actuator Consumption: A Model-Driven Approach for Smart Building Electrical Systems

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***Abstract*—In recent decades, the electrical systems of buildings have taken on an increasingly important role in carrying out the most varied functions, from lighting to the power supply of air conditioning systems. Furthermore, we are seeing the massive introduction of IoT devices to automate many behaviors and scenarios. This extended abstract reports the design of a framework based on model-driven techniques for the analysis of the electrical systems of a building, evaluating the economic and environmental impacts of the use of cyclic relays both in lighting in place of traditional switches/inverters and the control of loads, to reduce the necessary cables and self-consumption of the actuators when integrated into IoT architectures.**

***Index Terms*—sustainability, environment, IoT, model-driven engineering**

I. INTRODUCTION

Sustainability is becoming a key aspect of most of our daily activities. National governments are defining even more strict policies aiming to reduce human impact both in industrial processes and in everyday life. This work focuses the attention at the end user level, considering two aspects: reducing electrical cables needed in new buildings or those under renovation; and reducing the energy self-consumption of actuators used in home automation systems.

Minimizing cable usage is a key point in other domains, such as automotive [1], where this leads to a standardization in linking different appliances resulting in a lower product final cost. Similarly, optimizing the number and length of cables used for electrical high-voltage transmission lines and city electric power systems lowers the construction and maintenance costs of such infrastructures, as evinced in part of the [2] work. In some cases, can be also convenient to reuse existing cables in infrastructure updates if their performances are satisfying, as evinced in [3] analysis.

However, using or reusing degraded cables could be not convenient due to power loss, as analyzed in [4]. In this situation, initial savings are absorbed and overcome with the use over time, making it convenient to invest more in automatic control systems, such as automatic lighting systems as proposed in [5].

Model-driven engineering (MDE) represents an effective approach in orchestrating various aspects of systems design, allowing automation and standardization of the whole process through models, reducing errors, development effort and refinement time.

We propose a model-based framework to model structural constraints and optimization heuristics altogether, where models describes components and their characteristics, domain-specific relations among them, including regulatory constraints. Such a framework lets the designer focus on a subset of components of interest; the overview of the changes' impacts on the rest of the system allows the designer to analyze and improve each part of the building project synergistically and systematically.

Further, the framework allows to calculate, e.g., estimated savings in terms of energy and material costs in renovating end-user electrical systems, such as lighting systems or load drivers, substituting common switches/inverters with cyclic relays, avoiding self-consumption, especially during long time activation, reducing cables need and being easy incorporated in domotic systems.

II. BACKGROUND CONSTRAINTS

The specific case of study about the electrical system design points to an efficient design that is not only optimized for cost, maintenance and energy sustainability, but also compliant with a set of mandatory regulations, which typically differ from one nation to another. For instance, such regulations (e.g., IEC 60364, CEI 64-8, CENELEC HD) prescribe the admitted cable's characteristics and limit cable locations inside the building's rooms; or, in case of existing buildings, the reuse of cable ducts already in place. These constraints have impacts and may deviate the solution from the real optimum; furthermore their changes and evolution have several impacts that must be reflected properly. Possible scenarios include both the need to explore the implications of regulation's changes to the structural optimum, and the opposite need of examining what modification's boundaries are feasible to the regulation set, given a fixed subset of structural variables.

III. FRAMEWORK ARCHITECTURE

The framework relies on the domain-specific metamodel (Fig. 1) which defines buildings' electrical system, including both physical constraints and economic costs.

A *building* includes a set of *rooms*, each containing a set of *appliances* (i.e., switches, lights, etc.) and *cables* to link them. Physical constraints (e.g., max supported power, cable length, etc.) describe the feasibility of the solution, while economic

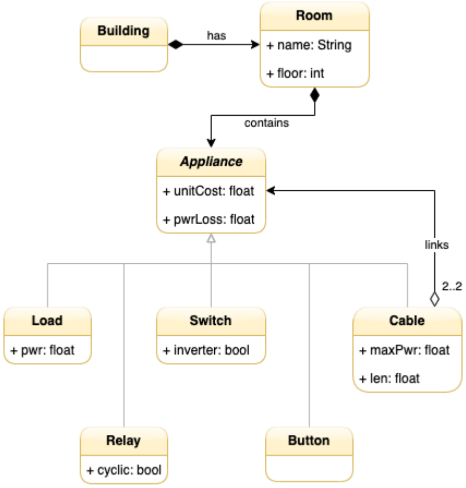


Fig. 1. Simplified version of the framework metamodel

ones (e.g., unitary cost) define the best solution among the feasible ones.

Starting from the designer's proposal, the framework will evaluate the feasibility of the configuration, validate the constraints and analyze the related cost. For instance, the cost may include both the initial costs of needed devices and their runtime costs taking into consideration devices' self-consumption.

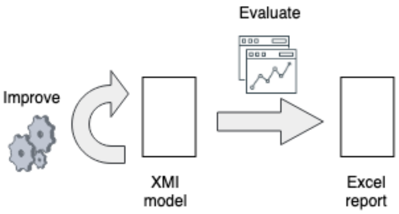
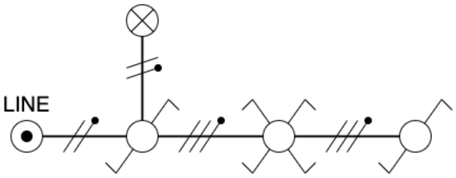


Fig. 2. (Semi)automatic processes enabled by our framework

Having a model-based representation of the appliances' configuration makes it possible to define a set of model-to-model transformations (Fig. 2) which help model improvements relying on the designer's intentions preserving the coherence of information inside the whole model. As an example, the proposed framework exposes functionality to identify traditional switches/inverters light circuits inside a model and substitute them with buttons/relays ones in an automated way, assuring that all recognized patterns will be correctly substituted.

IV. CONCLUSIONS

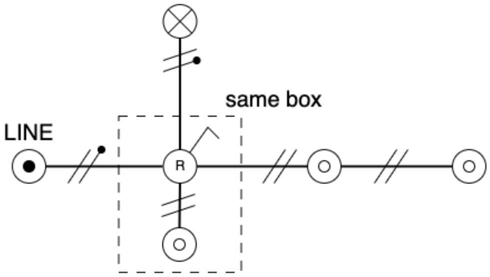
A simple example is presented starting from the evaluation of a traditional switches/inverter light circuit model (Fig. 3), subsequently evolved with MDE transformations, proposing and evaluating an alternative button/relay one (Fig. 4) requiring 3 commands at 2 meters from the roof and 1 light at the center of it, deployed into a building room of 10 x 10 meters in dimensions. In this example material costs were assessed.



Appliance	Q.ty	Unit cost	Total cost
switch	2	6€	12€
inverter	1	6€	6€
light	1	2€	2€
cable (ϕ1.5)	84 mt	0.9€/mt	76€
			96€

Fig. 3. Traditional lighting system evaluation

Comparing results, a solution based on cyclic-relay gives a discharge about of 10€ in a $100m^2$ room, which could be even more for larger rooms or buildings. Moreover, the latter is easily interoperable with domotic systems, also permitting the reduce of power self-consuming during long activation due to the cyclic relay's impulsive native nature.



Appliance	Q.ty	Unit cost	Total cost
pulse button	3	5€	15€
cyclic relay	1	10€	10€
light	1	2€	2€
cable (ϕ1.5)	64 mt	0.9€/mt	58€
			85€

Fig. 4. Cyclic relay based lighting system evaluation

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