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Proactive Management of Micro-Grids for Energy Efficiency in Industrial Sites

Yehya Al-Rifai[1] *, Prof. Ionel Vechiu[1], Dr Adriana Aguilera Gonzalez[1]

[1] *Univ. Bordeaux, ESTIA INSTITUTE OF TECHNOLOGY, F-64210 Bidart, France.*

Micro-grids are receiving more-and-more attention for industrial sites to alleviate energy costs while reducing environmental impact. However, the proliferation of renewable energy sources along with the recovery of wasted energy into this innovative structure imposes new challenges, making energy management more complicated, especially while complying with grid policies. Furthermore, the availability and correct operation of industrial microgrids (IMG), under all circumstances, is a strategic research issue.

Therefore, this doctoral thesis aims to develop a proactive energy management system that ensures high energy efficiency, cost saving while maximizing collective self-consumption (CSC) with the presence of faults. In this context, this thesis proposes an innovative combination of Model Predictive Control's approach with the joint action of an active fault-tolerant strategy. This methodology is performed by two cascading modules based on diagnostic and fault detection methods, and a fault reconfiguration approach. By means of analytical redundancy, the former is derived from model-based state estimation methods to detect, localize, and isolate anomalies as quickly as possible. Once faults are detected, residuals are generated to proceed with mitigation action. The faulty reconfiguration approach will adapt the control laws accordingly and/or even reconfigure the system to mitigate faults effect and preserve the system's required performance.

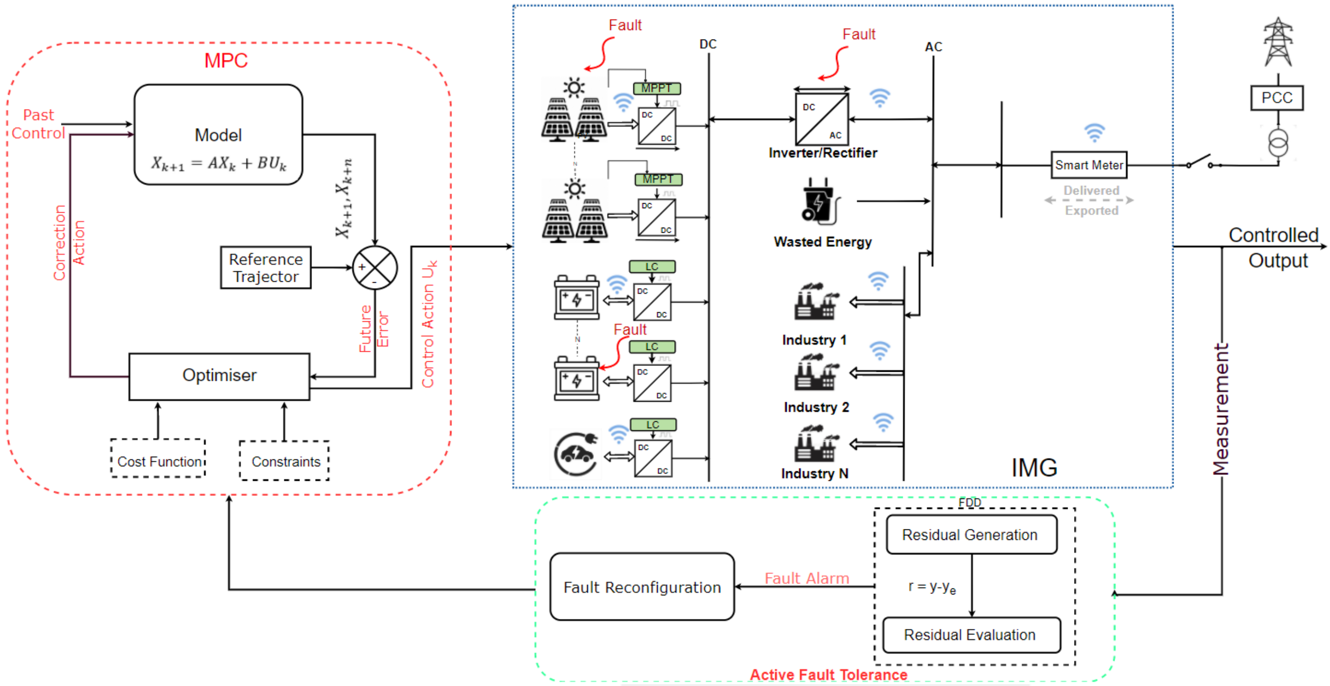

Figure 1: Global overview of proposed control methodology

In this context, a comprehensive review of the different energy storage systems applicable to the IMG is carried out, followed by a critical analysis of the different fault-tolerance and diagnostic approaches. Thus, a techno-economic comparison based on a real IMG is performed to identify the optimal configuration allowing to recover the wasted energy with the least cost, while attaining higher marks of CSC rate. On the other side, a risk analysis is conducted to target the fault effect of key IMG components that significantly influences CSC and reliability. Furthermore, in the current activity, the robustness of the battery's state estimation method based on the Kalman filter is being examined under MATLAB/Simulink®. In conclusion, this novel methodology aims to optimize the power flow of IMGs with respect to strict code constraints considering the fluctuations in the daily electricity market, the unstable load demand, and the stochasticity of renewable energy sources and wasted energy even under fault occurrence.

Keywords: Industrial micro-grid, renewable energy, energy storage system, wasted energy, collective self-consumption, Model Predictive Control, fault tolerance, FDD, fault reconfiguration, KF.