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# Robotic Expert System for Energy Management in Distributed Grid Ecosystem

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## ABSTRACT

A robotic expert system (RES) for energy management (EM) in community-based micro-grids is developed using a fuzzy computational scheme. Within the micro-grid multi-dimensional space, embedded algorithms for residential homes, sectors and central controller units are introduced to perform EM in a collaborative manner. Demand response and load shedding are carried out within the community micro-grid to ascertain the behavioral responses based on changes in power demand levels. Various tests are carried out with an observable low error margin. It was observed that the system reduced the total power demand on the micro-grid by 20% of the total distributed power. Micro-grid RES, neuro-fuzzy control (NFC), and support vector regression (SVR) evaluations are compared considering the home units at 40kW of the generated capacity. The results gave a 35.79%, 31.58% and 32.63% energy demand, respectively. Consequently, RES provides a grid look-ahead prediction, annotated-self healing, and stability restoration.

## KEYWORDS

Artificial Intelligence, Cyber Physical Systems, Distributed Grid, Energy Management, Robotic Expert System

## 1. INTRODUCTION

### 1.1. Background of Study

The traditional centralized form of energy generation in Africa has been found to be inadequate to meet today's energy demands. In locations that have sufficient energy, it usually appears erratic and thus unreliable. Again, certain communities are located far away from the utility grid. This makes their connection to the grid rather expensive considering the cost of transmission equipment. These factors have inspired energy consumers within the region to generate their electricity. The consequence is found in enormous energy wastages as most individuals generate more or less than their energy demands. There is no framework/design for sharing energy among the several consumers since the present configuration does not allow for scalability. This necessitates a shift towards distributed generation (DG) which involves several micro-grids isolated or non-isolated from the utility grid in form of Smart-grid (Makdisie, Badia, & Alhelou, 2018). DG comes with several issues like power quality (from the several generating stations), energy management/control within the micro-grid (balancing energy demand and supply), security, smart metering for tariff management. For instance, efforts on smart metering were discussed by (Tonyali, Akkaya, Saputro, Uluagac, & Nojoumian, 2018), focusing on privacy-preserving protocols for secure and reliable data aggregation in Internet

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of Things (IoT)-enabled smart metering systems. (Manzoor, Javaid, Ullah, Abdul, Almogren, & Alamri, 2017) focused on an intelligent hybrid heuristic scheme for smart metering based on demand side management in smart homes. Non-intrusive load monitoring in power grids has been proposed by (Chui, Lytras, & Visvizi, 2018) and (Tabatabaei, Dick, & Xu, 2017). Most solutions are found in Cyber-physical systems (Okafor, 2019)

The challenge is to develop an architectural model for managing energy resources for the community based micro-grid system. This involves sharing energy among members of an 'energy community'. For instance, the grid-networks by (Alhelou, Hamedani, & Askari-Marnani, 2018) offered the use of robust sensors for fault detection as well as isolation in modern smart power systems. Such future smart micro-grids (Alhelou, Golshan, & Masoud, 2015; Alhelou, & Golshan, 2016) could explore multi-agent controls in energy systems. However, achieving a lower computational EMS requires the use of an intelligent scheme for system efficiency.

In this paper, an automated system (RES) is proposed to optimally coordinate the several aspects of the community based micro-grid network. This provides proper operation and reliability for sub-Saharan African communities. An important aspect of the problem is to find an optimal configuration for sharing energy resources among members of the proposed community. The proposed system supports grid annotated-self healing and stability restoration in a production environment.

### 1.2. Robotic Expert System and Energy Management System

RES describes a model that surpasses decision-making of a human expert. This type of system is constructed to address complexity of reasoning in cases like "if-then-rule", instead of the traditional procedural method. This is where artificial intelligence (AI) drives the basic logic engines viz: the inference engine (deduction from rules to established facts) and the knowledge-base (rules and facts), (Jiaying, Xiangjie, Feng, Xiaomei, Lei, Qing, & Ivan, 2018). Expert systems have recently found applications in power (Li, Meng, & Bin,, 2017), health (Zang, Zhang, Di, & Zhu, 2015), enterprise software applications (Niu, & Wang, 2014), (Buyya, Yeo, & Venugopal, 2008), IoTs (Wei, Fan, Xiaofei, William, Chao, Jie, & Xinyu, 2018), as well as other disruptive computing domains. Also, it has been applied to areas such as agriculture, chemistry, computer science, engineering, medicine, etc.

Expert systems (ES) as branch of AI models the knowledge of humans in a particular field, both in terms of content and structure. In such system, reasoning is modeled by using procedures and control structures which process knowledge in a way that is similar to the human expert. ESs incorporates intelligent database management systems, real-time control/monitoring and intelligent statistical analysis in order to process and present energy information to users. This is very useful in energy management systems (EMS) which requires intelligent computation. A major tool used in developing such expert systems is the fuzzy logic inference system (FLIS). This is found very useful in robotic embedded design for EMS.

Obviously, energy management (EM) has become a very important topic in the modern times and is mostly technology driven (Johansson, 2015). While energy resources are abundant in nature, it has various forms and have been, successfully harnessed in most cases. Unfortunately, the generated energy is limited and therefore not usually enough to balance the demand for energy. This makes the subject of AI driven energy management very important. Hence, an efficient EMS seeks to make optimal use of available energy generated at all times. There exists several aspects and levels of EM which correspond to the different stages of energy production, from power generation to distribution. At the consumer level, energy can be managed by controlling the use of appliances using certain criteria (e.g. when the appliances are needed). In fact, at a higher level, EM involves a lot more than energy consumption control. It also involves generation control, distribution, security, tariff and metering, among others.

According to (Karekezi, &Kithyoma, 2002), the Sub-Saharan Africa have significant abundance of renewable energy resources (such as solar, hydro, biomass, wind, among others), that are yet to be fully harnessed. However, these resources, (where they have been harnessed), have not been