LOAD DISAGGREGATION SMART METERS BY NON-INTRUSIVE LOAD MONITORING USING EVOLUTIONARY ALGORITHMS

By

Moataz Mohsen Gendy Hady

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
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in
ELECTRICAL POWER AND MACHINES ENGINEERING

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Title of Thesis:

LOAD DISAGGREGATION SMART METERS BY NON-INTRUSIVE LOAD MONITORING USING EVOLUTIONARY ALGORITHMS.

Key Words:
Non-intrusive load monitoring; Load disaggregation; Smart meter application; Energy Saving; Load Monitoring.

Summary:
This thesis presents non-intrusive load monitoring to achieve load disaggregation strategy as it considered one of the most important smart meter application. Load disaggregation is considered one of energy saving strategies.
We suggested an optimization evolutionary algorithm to estimate the status of household devices which can be described by binary status, on and off, devices for different time duration. We evaluate our suggestion of evolutionary optimization algorithms, Genetic Algorithm & Biogeography Based Optimization Algorithm, by Matlab simulation then compared the output results as well as the performance of both algorithms.

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Nomenclature

NIST	National Institute of Standard and Technology
GPRS	General Packet Radio System
ISO	Independent System Operators
LM	Load Monitoring
ILM	Intrusive Load Monitoring
NILM	Non-Intrusive Load Monitoring
NILMS	Non-Intrusive Load Monitoring System
MATLAB	Matrix Laboratory Software
GA	Genetic Algorithm
BBO	Biogeography Based Optimization
n	Knapsack Items number
d	Knapsack Profit Value
x	Knapsack Problem Solution
W	Knapsack Weight Value
C	Knapsack Capacity Value
KP	Knapsack Problem
BKP	Bounded Knapsack Problem
UKP	Unbounded Knapsack Problem
FKP	Fractional Knapsack Problem
B[n_w]	Maximum Profit Value in dynamic programming
P	Active Power (Watt)
Q	Reactive Power (VAR)
EPRI	Electric Power Research Institute
AC	Alternating Current
ID	Identification
HVAC	Heating, Ventilating and Air-Conditioning
VSD	Variable Speed Drive
$P(t)$	Power as a function of time
$e(t)$	Error as a function of time
F_s	Genetic Algorithm Fitness Function
db	Number of Appliances in Database
PSO	Particle Swarm Optimization
HSI	Habitat Suitability Index
SIV	Suitability Index Variable
λ	Immigration Rate
μ	Emigration Rate
VA	Volt Ampere (Apparent Power Unit)
ME	Mean Error
S	Number of Algorithm Simulation Run
T	Time (minutes)

k	Number of Appliances in Database (MATLAB Code)

Abstract

Non-intrusive load monitoring (NILM) method is essential for customer energy management solutions which can help to obtain energy consumption statistics for appliances. This information can be further used for load scheduling strategies for optimal energy saving. We suggested an optimization evolutionary algorithm to estimate the status of household devices which can be described by binary status, on and off, devices for different time duration. We evaluate our suggestion of evolutionary optimization algorithms, Genetic Algorithm & Biogeography Based Optimization Algorithm, by Matlab simulation then compared the output results as well as the performance of both algorithms.

Keywords: Non-intrusive load monitoring; Load Disaggregation; Smart meter application; Energy Saving; Smart Grid.

Chapter 1: Introduction

1.1. Motivation

The whole world interests in smart meters that measure the residential energy consumption and also real-time feedback information is being provided to the utility to improve energy consumption, improve maintenance mission and improve electrical power system design based on real electrical consumption database. Although the demand loads are increasing directly with population growth, there is no Investment in this field to be able to achieve maximum reliability of power flow. Consequently, the customers have only access to the total energy consumption. However, detailed information about individual consumption of household is not available.

A considerable reduction in Energy Saving Process can be achieved through monitoring of individual power consumption and transmit monitoring information to customer and utilities. Also, the recent smart meter installed at the power entry of the house is only providing a data of total power consumption and doesn't provide information about operated devices duration and their energy consumption for each device [1].

The traditional power grid as shown in the Fig. (1.1) consists of markets and operation for generation power plant, the generation station, transmission zone, distribution zone and finally the consumption zone. The main characteristic of traditional power grid is the one way flow of electricity and there is neither feedback of data nor real time information for the status of the grid.

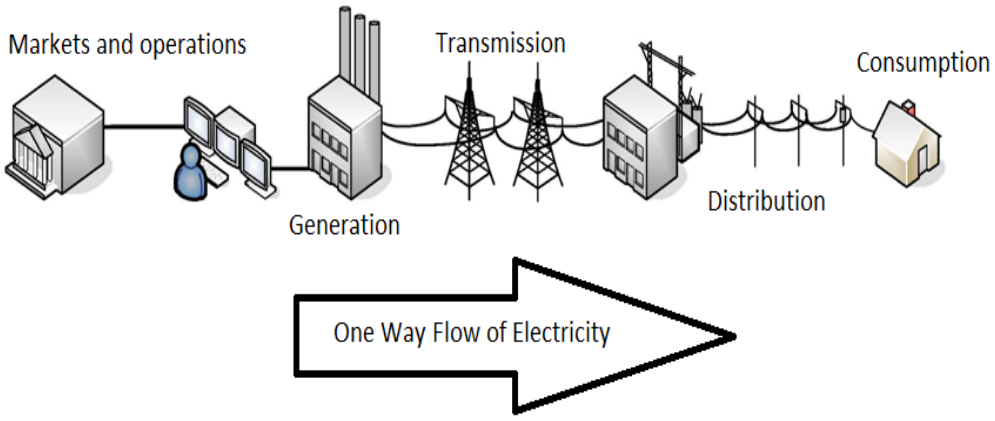

Figure 1. 1: Traditional Power Grid

In another hand, Smart Grid overview as shown in Fig. (1.2) illustrates the main component and philosophy of the smart grid system. "Smart grid" generally refers to a class of technologies that people are using to bring utility electricity delivery system into the 21st century, using computer-based remote control and automation. These systems are made possible by two-way digital communications technologies and computer processing that has

been used for decades in other industries.

They are beginning to be used on electricity networks, from the power plants and wind farms all the way to the consumers of electricity in homes and businesses. They offer many benefits to utilities and consumers - mostly seen in big improvements in energy efficiency and reliability on the electricity grid and energy users' homes and offices. Currently, the customers have only access to the total energy consumption; detailed information about individual consumption of household is not available [2].

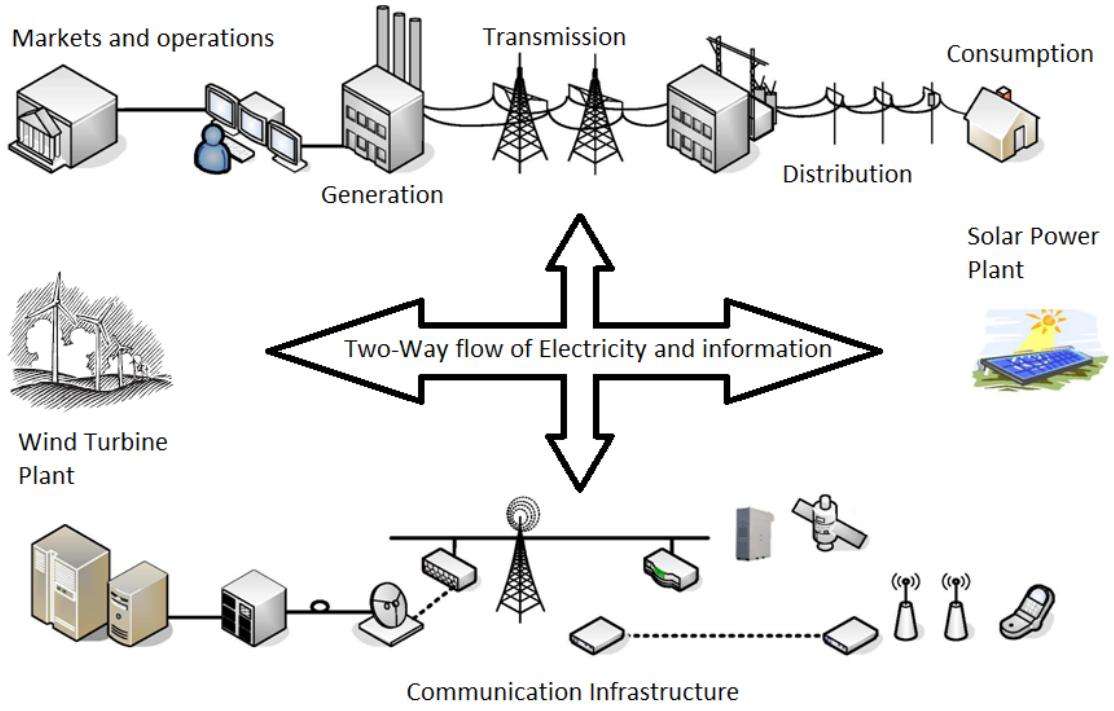

Figure 1. 2: Two Way Smart Grid

1.2 Smart Grid Preference

The smart grid has a preference advantages which are unavailable in the traditional grid. 1st it improves power reliability as the system provide better monitoring using sensors distributed in the network and the communication for data transmitted from the sensors, Although it provides balancing of supply and demand faster.

2nd Smart grid minimizes demand of backup power plant construction as it provides advanced metering infrastructure as well as demand side management.

3rd Smart grid enhances the efficiency and the capacity after integration with existing power grid, thanks to sensors distributed in network and communication which provide real-time resource management and better control.

4th Smart grid improves the ability to resist the disturbance in the network as well as providing self-recovery.

5th Smart grid provides renewable energy implementation although manage the integration