Intelligent Agent Based Auction by Economic Generation Scheduling for Microgrid Operation

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Introduction

- Microgrid-integrating distributed energy resources into main grid.
- Transition from centralized power production to distributed production.
- Different DG unit owners – decisions taken locally
- Controllers intelligent enough to make decisions- coordinate actions of other DG units
- Distributed control and autonomous operation

Energy Market in a Smart Grid

- The first reason given for introducing competitive electricity markets - Reducing the price paid by consumers for electricity
- Smart grid operates in a local market and usually cater to the customers of medium sizes (such as, commercial complex, small industries etc.) and residential.
- These customers do not have the financial incentives and the expertise required to contribute effectively in the price matter to such a complex local market.
- Possibly as a consequence of this lack of representation, most electricity markets do not treat consumers as a genuine demand side capable of making rational decisions, but simply as a load that needs to be served under all conditions.
- This research work focuses on considering generators and loads as bidders in an auction process.

Multi Agent Systems

Agent

- is a physical entity that acts in the environment or a virtual one without physical existence.
- can make decisions without the direct intervention of humans or others
- are able to exhibit goal-directed behavior by *taking the initiative.*
- have the ability to engage in social activities (such as cooperative problem solving or negotiation) in order to achieve their goals

Multi Agent Systems (MAS) used for simulating an energy market environment in the microgrid where each agent acts as a trader (buyer/seller of energy)

Past Research

- MAS for centralized control of microgrid

  - difficult as decisions cannot be made locally by each DG owner.

- MAS for microgrid control

  - Optimum usage of DG production was not accomplished.

Proposed Method

MAS is used in conjunction with an optimization technique viz., Artificial Immune System to optimize the cost of operation of the microgrid and to aid the auction process.

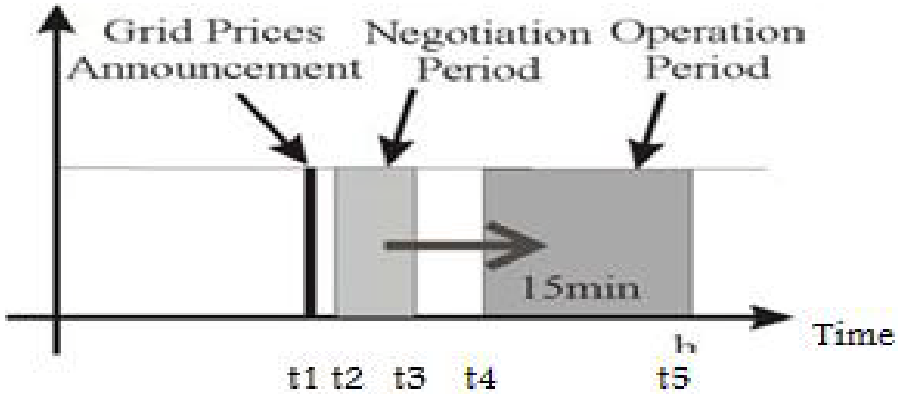
Artificial Immune System-AIS

- Works on the principles of pattern recognition (distinguishing antibody and antigen) and clonal selection principle, implemented to accomplish learning and memory acquisition tasks.
- receptors present on the antibodies -responsible for antibody–antigen interaction - different antibodies have different affinity towards an antigen - binding strength is directly proportional to this affinity
- effectively exploits these interactions - maps the affinity to fitness (objective function) evaluation and constraint satisfaction.
- harnessed into learning, memory and associative retrieval to solve the optimization problems.

Market Operation in a Microgrid

The overall procedure is as follows

- The grid operator announces the prices for selling or buying energy to the microgrid at time t1 as shown in Fig.1.



- The local loads announce their demand at time t1+ for the next 15 minutes. (t_4-t_5)
- The generation units run an optimization routine (AIS) to minimize the cost of generation and to determine the individual generations. The generator bids for DG sources during a particular time period are calculated by taking into account of energy prices in the open market and the generating units operating cost

Market Operation of a Microgrid

- The generator units bids and negotiates for a pre specified time of 3 minutes (t_2-t_3). This means that the generators decrease their offer as long as the generator bid reaches the break even point.
- After the end of the negotiation period, all the units know their generation prices. If there is no generation unit of the microgrid to satisfy the load demand, the power is bought from the grid. Furthermore, if the generator bids are lower than the buying price suggested by the grid, the generator units starts selling power to the network.

Problem Formulation

The objective function can be mathematically formulated as

Minimize {Cost} where

Cost= $\sum_{i=1}^{N} activebid(x_i) + AX$

Subject to the constraint

where activebid(x_i) is the bid from the i^{th} DG source,

x_i is the active power production of the i^{th} DG source

X is the active power bought from the grid,

N is the number of DG sources that offer bids for power production and

A is the open market active power price

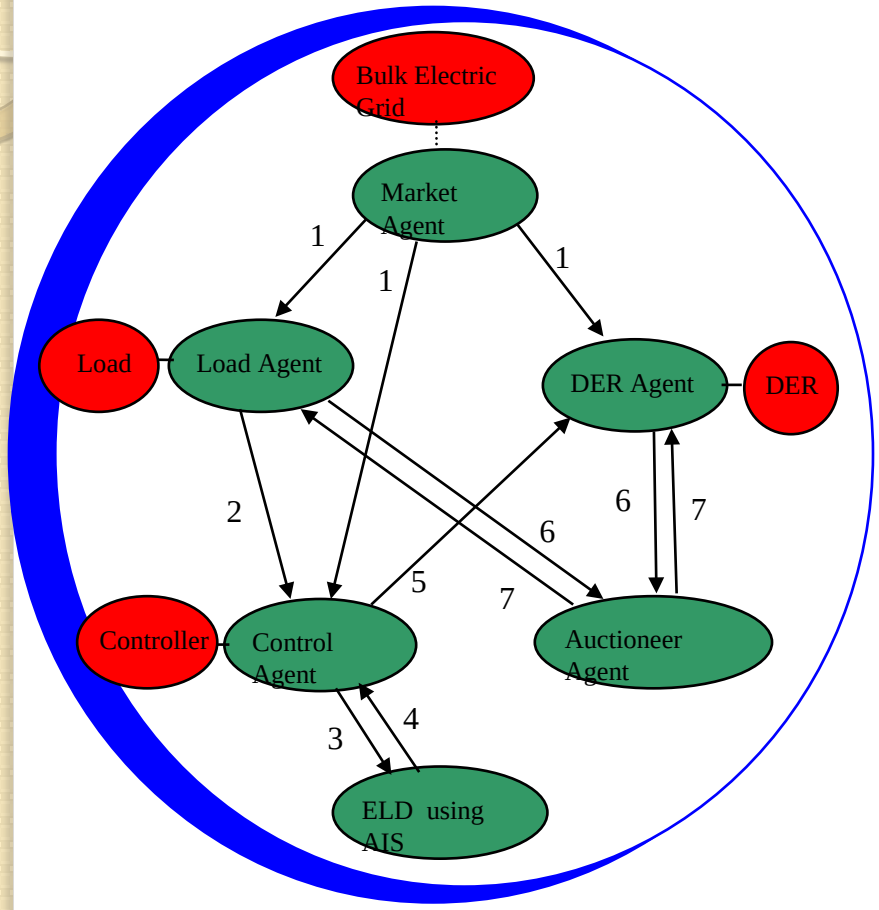
Implementation of MAS for Microgrid Management

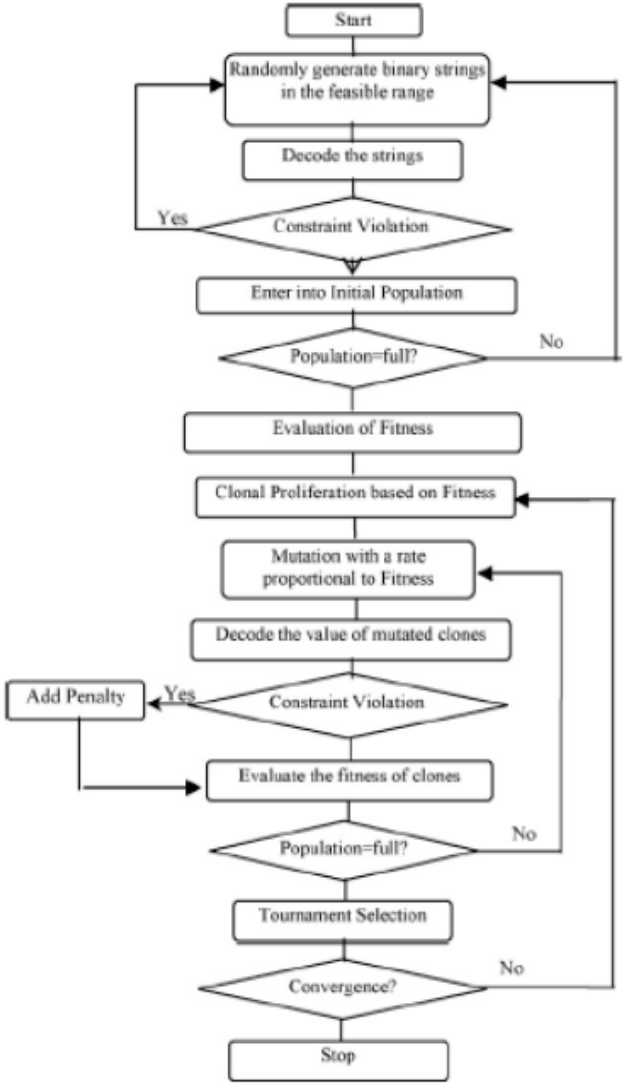
- JADE (Java Agent Development framework) -software development framework for developing MAS and applications conforming to FIPA (Foundation for Intelligent Physical Agents) standards for intelligent agents.

Five kinds of agents are developed:

- Main Grid: The main grid agent announces the buying and selling price to all the participants.
- Load agent: This agent knows the current demand and estimates the energy demand for the next 15 minutes.
- Control agent: The production settings of the regulated DGs and power exchange with the grid are determined using Economic Dispatch (ED). In the proposed work, ED is solved using an Artificial Immune System (AIS) based approach that uses clonal selection principle and evolutionary approach.
- Generator agent: This agent adjusts the power flow depending on the market prices and on the outcome of the optimization routine. Every 15 minutes, he bids to the auctioneer in order to cover the estimated needs.
- Auctioneer: This agent has to coordinate, announce the beginning and end of a negotiation for a specific period and record final power exchanges between agents in every period

MAS +AIS architecture





Auction Process

- Limit price set at generator agents and load agents
- Generators and loads bidding in parallel
- Generator bids > selling price of grid

  Load supplied from the main grid

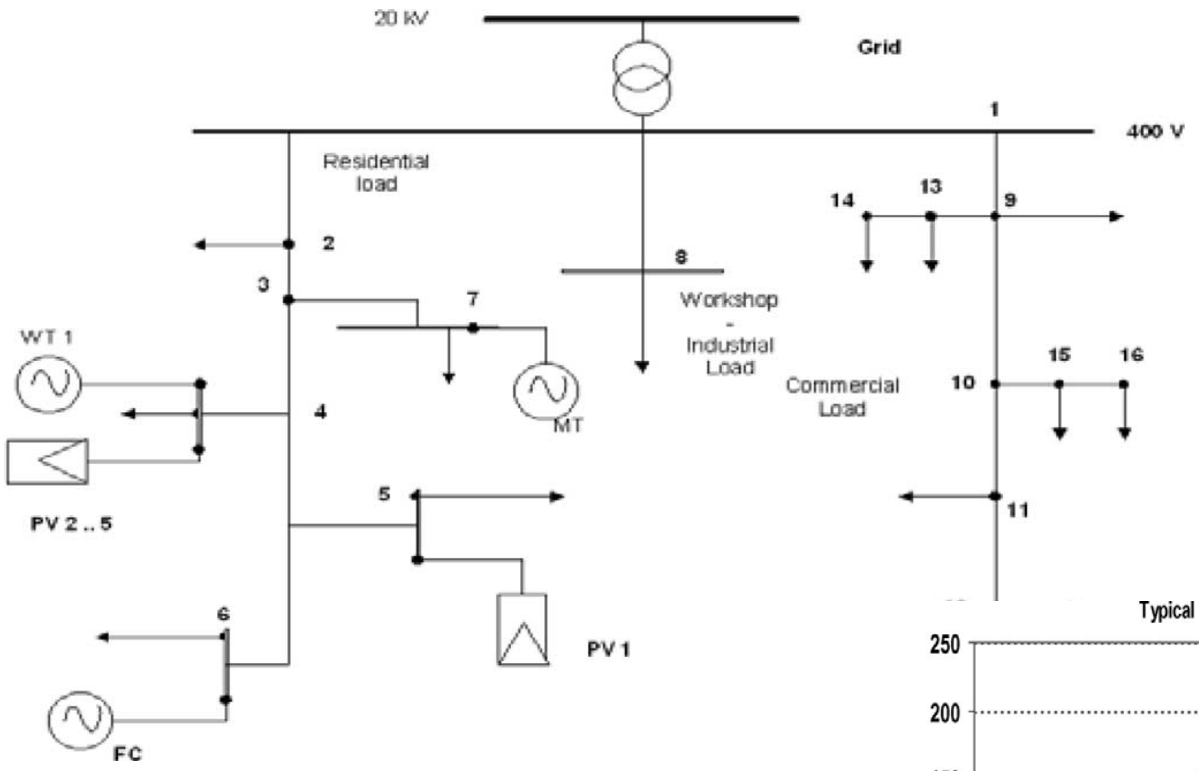
  Generator bids < selling price of grid

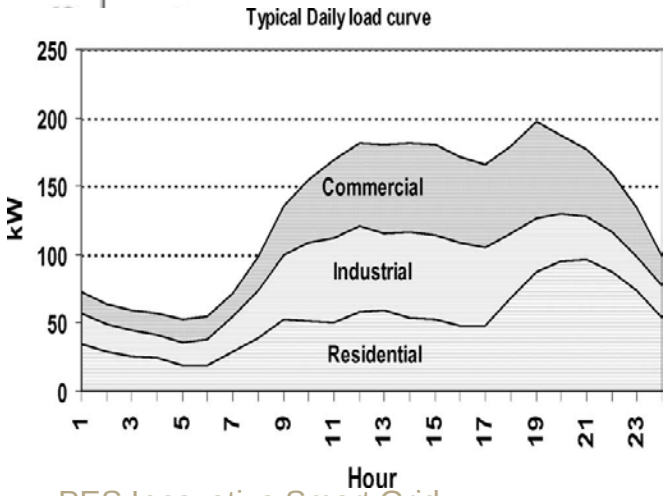
  Load supplied by DGs

  Generator bids < buying price of grid

  DGs export power to the grid

Test Case System

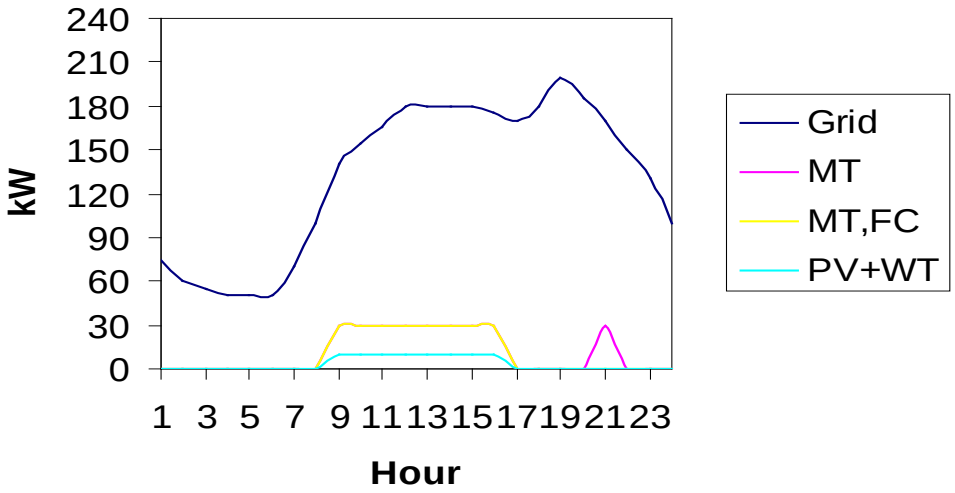




Results

Results of MAS Application to Microgrid

Cost (Euro)	Difference with base case	Average price (Ect/kWh)
368.42	21.92%	11.28



Load sharing of DG sources and Grid

Observations

- between 9.00 and 16.00 and during 21.00, the proposed methodology favors local DG production. During the rest of the time, DG bids are higher than the market prices, and thus the auctioneer buys active power from the grid.
- auctioneer is responsible for monitoring the microgrid and coordinating the remaining agents.
- intelligent agents have to interact with each other and negotiate in order to decide which DG sources are to be committed to deliver a load demand.
- auctioneer optimizes the microgrid operation according to the open market prices, the bids sent by the DG sources and the forecasted loads and sends signals to the generator agent informing the level of their production.

Conclusions

- A new method for agent based optimum market operation of a microgrid using MAS with Artificial Immune System.
- AIS is for determination of economic operating schedule of DG sources in a microgrid.
- The agents participate in a real time market according to a market policy. Bids coming from the various DG sources are considered in comparison with actual market prices.
- Typical load profile is chosen for a day. It is proven that under the test conditions simulated, it is economically beneficial to operate the microgrid leading to reduced energy prices for the consumers.
- Adopting a decentralized approach allows every manufacturer of the DG unit to embed a programmable agent in the controller of his equipment. This would provide the required 'plug and play' capability of future DG units and loads. On the contrary, in a centralized system, the installation of any new component would require extra programming of the central controller.
- A decentralized approach is superior in terms of providing optimal coordination of the production of DG sources.

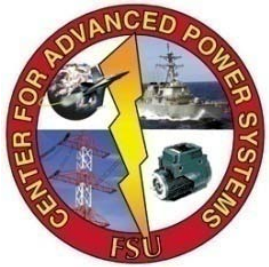
Acknowledgments

FESC Florida Energy Systems Consortium

Universities Addressing Florida's Energy Needs

- FESC: Florida Energy Systems Consortium

- IESES: Institute for Energy Systems, Economics and Sustainability



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Thank you