An Efficient Microgrid Management System for Rural Area using Arduino

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Abstract*—An embedded system is characterized by real-time and multi-rate operations define the ways in which the system works, reacts to events and interrupts and schedules the system's functioning in real time. Typically, the end user does not develop new software for the embedded device. With advances in VLSI technology, embedded systems have become so inexpensive that they are found in most of today's electronic devices. An implementation of a multi-agent system (MAS) for a rural Indian micro grid (MG) using Arduino has been explained in this paper. The focus is on the DG agents- the distributed energy resources (DERs), load, storage and the grid agents - and the Mu agent which acts as the communication channel between the DG agents to the higher level agents such as he control agent. The design philosophy incorporates the core features of an MAS that are required to monitor and control a rural Indian microgrid. The system has been compacted and design simplified, since only relevant parameters from a rural Indian MG are considered. The Arduino system obtains the inputs from the various DG agents which are then channeled to the D agent after appropriate processing. The implementation of the system has been done using an Arduino controller.*

Keywords *- Arduino, ZigBee, Communication, Control, Microgrid, Multi-Agent System(MAS), Distributed Energy Resources(DER).*

I. INTRODUCTION

Renewable energy has been estimated to become cheaper than fossil fuels in the near future which are consolidated by the continuing increase in the number of renewable energy power plants around the world. In 2012, the net renewable energy installed capacities around the globe touched the 500 GW mark with a growth rate of 19% for wind and 42% for solar PV. As a positive outcome of these developments in the field, in countries like India, the numbers of Microgrid installations are on the rise. The emergences of low cost smart microgrids are seen as a need and not as a luxury in a country like India. With the declaration of the Restructured- Accelerated Power Development and Reform Program (RARDP), the need for microgrid designs to concentrate on information and communication technology to improve the control and coordination is paramount. This would also lead to the development of microgrid clusters in the future. This further indicates the need for an effective system to enable communication for implementing periodic control of the various components of the microgrid. Present multi-agent systems studied in the United States of America for military and urban applications utilize sophisticated infrastructure. Hence, a framework based around the rural microgrid and in specific, for the Indian context needs to be developed. A multi-agent system (MAS) for a rural Indian microgrid (MG) using Arduino has been explained in this paper. The focus is on the DG agents – the distributed energy resources (DERs), load, storage and the grid agents - and the Mu agent which acts as the communication channel between the DG agents to the1 higher level agents such as the control agent. The design philosophy incorporates the core features of an MAS that are required to monitor and control arural Indian microgrid. The system has been compacted and design simplified, since only relevant parameters from a rural Indian MG are considered.

II. PROBLEM STATEMENT

Emergence of microgrids has made electrification of rural India possible where the challenge of energy access persists. The ever declining price and hence the usage of distributed renewable sources has paved a way for these systems to operate independently or augment an otherwise unreliable grid supply. To enhance the performance and operation of these microgrids, a proper control and communication strategy has to be adopted. One such commonly used strategy is the Multi Agent System (MAS) model. The current microgrids implementation in India are typically designed such that an average end user has a fixed load of 30-50 W and the size of the microgrids are approximately 15 KW. Me1tering solutions are void due to unaffordability and the assumption of fixed loads and duration of operation for an average customer whose cost of consumption is $ 2.2 per month. In this scenario, it becomes extremely challenging to implement a MAS system using the conventional methods such as JADE and Zeus which is used predominantly in military and urban microgrids in developed countries. Hence, the need

to design an extremely low cost and efficient system capable of handling such a simple rural microgrid in India, yet at the same time being flexible to provide some of the commonly used features in a MAS system is imperative.

1) METHODOLOGY

In general, microgrids encompass of DERs, grid supply, storage system and the loads which are planned to be serviced. For an efficient and. economic operation, the working of these systems needs to be accurately monitored, controlled and co-or1dinated using apposite strategies

A. *Multi-Agent Modelling of Microgrids*

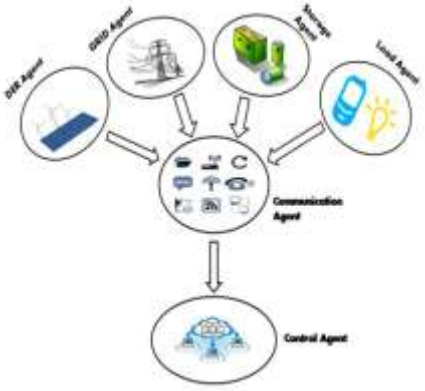

Fig 1. Multi-Agent Collaboration Schematic

Among the various control strategies that are available,the one that is most effectual and frequently used is the MAS model. An ideal agent is defined to be a reactive, pro active and flexible software and/or hardware. Typically, the components of a microgrid are hierarchically grouped into three classes of agents: DG agents, µ agents and D agent. Allthe DERs, grid supply, storage and loads are individual DGagents and the computations required for control and coordinationare carried out by the D-agent which is normally acloud or a computer. The µ agent channels the data from the DG agents to the D agent and vice versa thus acting as the communication link in an MAS. The above mentioned system of agents is depicted in figure 1.

B. MODELING AND SIMULATION OF A DISTRIBUTED GENERATION INTEGRATED INTELLIGENT MICROGRID

At present, there is a need to design a distributed and autonomous subset of a larger grid or a microgrid to increase the security and reliability of electricity supply. The objective of this work was to model and simulate a specialized microgrid called an Intelligent Distributed Autonomous Power Systems (IDAPS), which play a crucial role in building a scalable power grid that facilitates the use of renewable energy technologies. Microgrid device models, including distributed energy sources and loads, as well as their control algorithms, were developed. Several case studies were simulated to evaluate the operation of the IDAPS microgrid during parallel and islanded operation modes. Simulation results indicated that the proposed IDAPS control model was able to: (i) perform demand management during normal operating condition; (ii) island the microgrid from the main grid once an upstream fault is detected; (iii) secure critical loads and shed non-critical loads according to the given priority list during emergencies; and (iv) resynchronize the microgrid to the main grid after an upstream fault is cleared. In response to the DoD's statement of need, this work was the proof-of-concept effort to study the microgrid operation in both islanded and grid-connected modes. This effort resulted in the intelligent distributed autonomous power grid that could facilitate the use of renewable energy technologies, thereby minimizing reliance on external energy resources and reducing fossil fuel consumption.

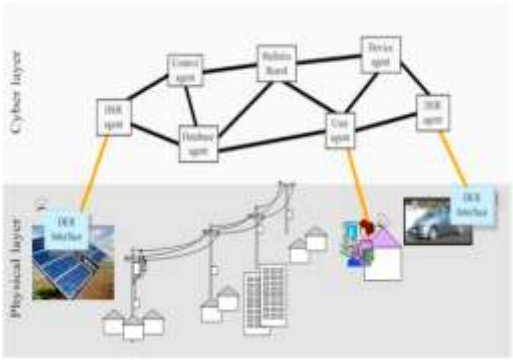

Fig.2 IDAPS Cyber-Physical System

C. MULTI-AGENT SYSTEMS IN MICROGRIDS: DESIGN AND IMPLEMENTATION

The security and resiliency of electric power supply to serve critical facilities are of high importance in today's world. Instead of building large electric power grids and high capacity transmission lines, an intelligent microgrid (or smart grid) can be considered as a promising power supply alternative. In recent years, multi-agent systems have been proposed to provide intelligent energy control and management systems in microgrids. Multi-agent systems offer their inherent benefits of flexibility, extensibility, autonomy, reduced maintenance and more. The implementation of a control network based on multi-agent systems that is capable of making intelligent decisions on behalf of the user has become an area of intense research. Many previous works have proposed multi-agent system architectures that deal with buying and selling of energy within a microgrid and algorithms for auction systems. The others proposed frameworks

for multi-agent systems that could be further developed for real life control of microgrid systems. However, most proposed methods ignore the process of sharing energy resources among multiple distinct sets of prioritized loads. It is important to study a scenario that emphasizes on supporting critical loads during outages based on the user's preferences and limited capacity. The situation becomes further appealing when an excess DER capacity after supplying critical loads is allocated to support non-critical loads that belong to multiple users. The previous works also ignore the study of dynamic interactions between the agents and the physical systems. It is important to study the interaction and time delay when an agent issues a control signal to control a physical device in a microgrid and when the command is executed. Agents must be able to respond to the information sensed from the external environment quickly enough to manage the microgrid in a timely fashion. The ability of agents to disconnect the microgrid during emergencies should also be studied. These issues are identified as knowledge gaps that are of focus in this thesis. In this scenario, it becomes extremely challenging to implement a MAS system using the conventional methods such as JADE and Zeus which is used predominantly in military and urban microgrids in developed countries. The Arduino system obtains the inputs from the various DG agents which are then channeled to the D agent after appropriate processing. The implementation of the system has been done using an Arduino microcontroller. The objective of this research is to design, develop and implement a multi-agent system that enables real-time management of a microgrid.

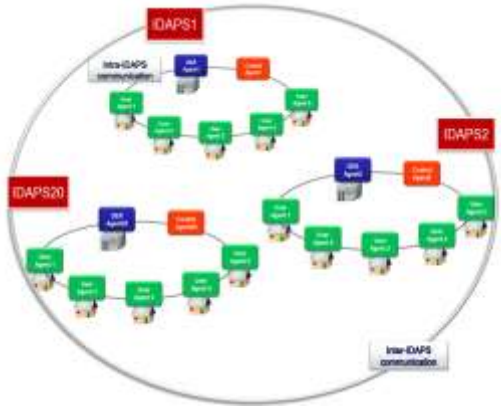

Fig.3 IDAPS Multi-Agent System Architecture

The implementation of multi-agent system was completed by identifying Roles (Role Modeling) and Responsibilities (Social and Domain Responsibilities) of agents in the system, and modeling the Knowledge (Facts), rules and ontology for the agents. Agent-based software engineering is a relatively new field and can be thought of as a evolution of object-oriented programming. Though agent technology provides a means to effectively solve problems in certain application areas, where other techniques may be deemed lacking or cumbersome, there is a current lack of mature agent-based software development methodologies. Finally, both microgrid simulation and multi-agent system are connected together via TCP/IP using external java programming and a third party TCP server in the Matlab/Simulink environment. Microgrids (MG) are expected to contribute to an improved energy efficiency and power supply reliability as well as an increase in the use of renewable energy, thanks to the role of Renewable Energy Sources (RES)and power electronic in supplying clean electric energy.

III.THE PROPOSED AGENT-BASED SOLUTION

An embedded system is characterized by real-time and multi-rate operations define the ways in which the system works, reacts to events and interrupts and schedules the system's functioning in real time. It does so by following a plan to control latencies and to meet deadlines. The different operations may take place at distinct rates. The user of an embedded device is often not even aware that a computer is present in the device. The computer is used primarily to provide flexibility and to simplify the system design. Unlike a PC, program, it does so following a plan to control latencies and to meet deadlines. The different operation may take place at distinct rates. The user of an embedded device is often not even aware that a computer is present in the device. The computer is used primarily to provide flexibility and to simplify the system design. Unlike a PC, program code is usually stored in ROM and not a hard disk drive. Typically, the end user does not develop new software for the embedded device. With advances in VLSI technology, embedded systems have become so inexpensive that they are found in most of today's electronic devices. Multi agent system (MAS) is one of the most dominant research wings which consist of several agents who interact with each other to achieve a common objective. MAS has been developed for a wide range of applications in power systems. Power system restoration is a main application of that. Researchers present several architectures for fault identification, isolation and restoration of the power system. This paper presents a complete literature review on available architectures for power distribution restoration and future trends in MAS based power system restoration.

A conventional distribution network transmits electricity from a central power sources to consumers, and the power dispatch is centrally controlled.The focus is on the DG agents the distributed energy resources(DER) , load, storage and grid agents and the Mu agent which acts as the

communication channel between the DG agents to the higher level agents such as the control agent. A microgrid is an eco-friendly power system because renewable sources such as solar and wind power are used as the main power sources. Operation is one of the important research topics for microgrids.The system has been compacted and design simplified, since only relevant parameters from arural Indian microgrid. The system has been compacted and design simplified, since only relevant parameters considered. The arduino system obtains the inputs from the various DG agents which are then channeled to the D agent after appropriate processing. The implementation of the system has been done using an Arduino controller

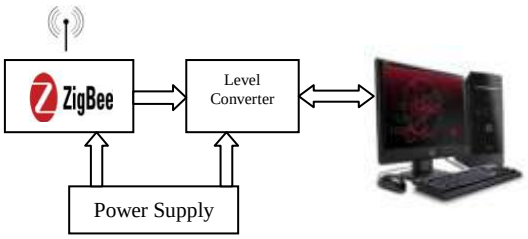

Fig.4 Control & Monitoring Section

Microgrid Section:

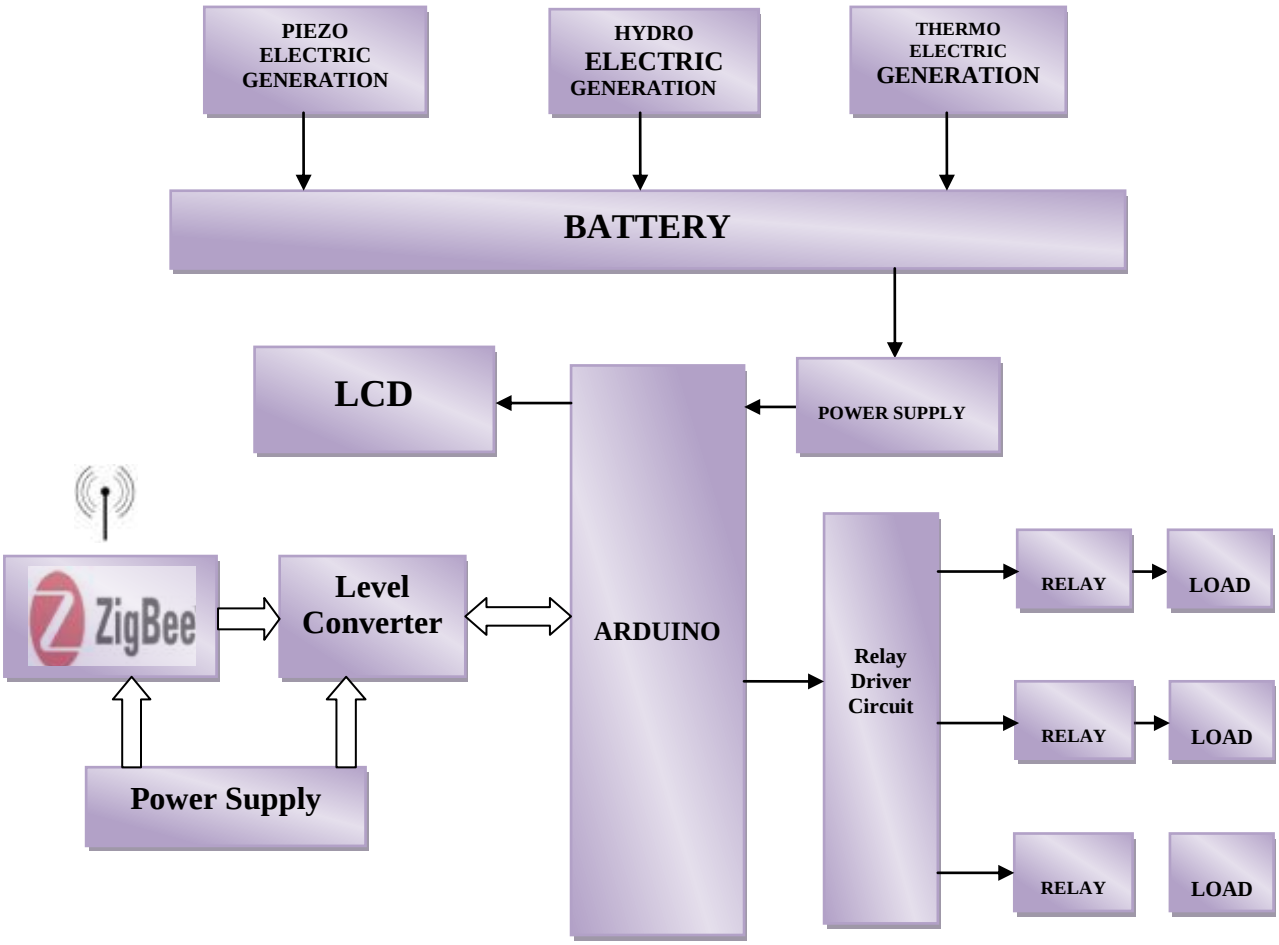

Fig.5 Block Diagram

In general, microgrids encompass of DERs, grid supply, storage system and the loads which are planned to be serviced. For an efficient and economic operation, the working of these systems needs to be accurately monitored, controlled and co-ordinated using apposite strategies. Among the various control strategies that are available, the one that is most effectual and frequently used is the MAS model. An ideal agent is defined to be a reactive, proactive and flexible software and/or hardware. Typically, the components of a microgrid are hierarchically grouped into three classes of agents: DG agents, µ agents and D agent. All the DERs, grid supply, storage and loads are individual DG agents and the computations required for control and coordination are carried out by the D-agent which is normally a cloud or a computer. The µ agent channels the data from the DG agents to the D agent and vice versa thus acting as the communication link in an MAS. There are several existing multi agent- modelling software's available both as open-source and proprietary tools, with a majority of them based on the Java platform. It is evident that an attempt to develop an open-source microcontroller based multi-agent system coded using Embedded C for microgrid control and communication applications, is near to none. The reason for simplification lies in the fact systems need to be easily configured for usage in rural areas and the number of functions required are far lesser compared to those required by an urban microgrid. Several standards have been established by the Foundation of Intelligent Physical Agents (FIPA). Some of the modern data standards such as the Common Information Model for Energy Management Systems are designated for complex power systems which would otherwise be not required here. The system described the design of agent systems using the Java based JADE platform.This platform is used to realize multifarious agent architectures.

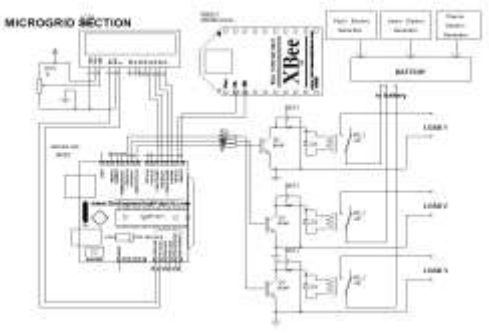

Fig 6 Circuit Diagram of Proposed System

Arduino is a open source electronics prototyping platform based on flexible, Easy - to-use hardware and Software. In addition to the specific functions listed below, the digital pins on an Arduino board can be used for general purpose input and output via the pin Mode(), digital Read(), and digital Write() commands. ZigBee is the product of the ZigBee Alliance, an organization of manufacturers dedicated to developing a new networking technology for small, ISM-band radios that could welcome even the simplest industrial and home end devices into wireless connectivity. Multiplexing is the generic term used to describe the operation of sending one or more analogue or digital signals over a common transmission line at different times or speeds and as such, the device we use to do just that is called a Multiplexer.

IV. SIMULATION SETUP AND RESULTS

In general, microgrids encompass of DERs, grid supply, storage system and the loads which are planned to be serviced. For an efficient and economic operation, the working of these systems needs to be accurately monitored, controlled and co-ordinated using apposite strategies. Among the various control strategies that are available, the one that is most effectual and frequently used is the MAS model. An ideal agent is defined to be a reactive, proactive and flexible software and/or hardware. Typically, the components of microgrids are hierarchically grouped into three classes of agents: DG agents, µ agents and D agent. All the DERs, grid supply, storage and loads are individual DG agents and the computations required for control and coordination are carried out by the D-agent which is normally a computer by using zigbee interface with Arduino based multi agent control system. Control center must consider this variability and uncertainty to dispatch economically. Fortunately, there will be many electric vehicles in smart grid. With the popularization of electric vehicles, charging stations and electric vehicle battery swap stations will be increasing rapidly. Because of its highest production cost, the power amount selected from AgMGOCC using the merit order is different according to the power balance of each interval. In the case of supply surplus, the amount of power it supplies to the microgrid is decreased. Battery swap stations can be regarded as energy storage power stations, which can be used to stabilize the wind power output variability and uncertainty. the simulation has shown how the system privileges the absorption of energy from renewable sources compared to the PG, and how it can perform.

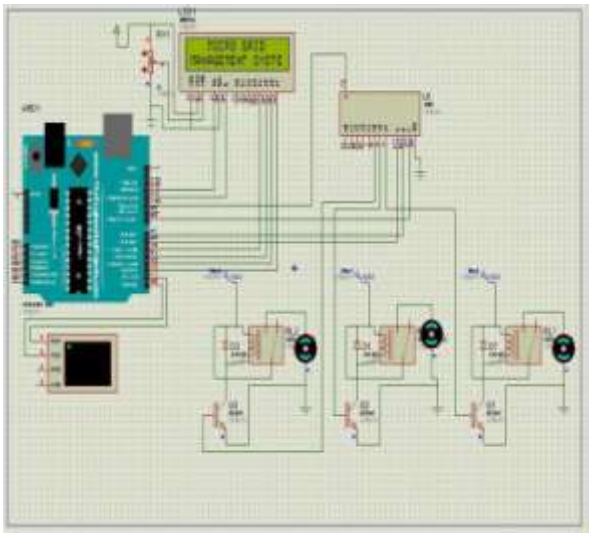

Fig.7 Simulation Output Diagram

I am using Proteus 7 Professional(ISIS) for simulation , considered to the three types of load connected to the figure 7. given input, connect the the circuit diagram in ZigBee at virtual terminal put in the input , and the LED display shows LOAD ON. The output load is time frequently changed in continuously. The implementation of a control network based on multi-agent systems that is capable of making intelligent decisions on behalf of the user has become an area of intense research. Many previous works have proposed multi-agent system architectures that deal with buying and selling of energy within a microgrid and algorithms for auction systems.

V. CONCLUSION

Multi agent system(MAS)is one of the most dominantion search wings which consist of several agents who interact with each other to achieve a common objective. MAS have been developed for a wide range of applications in power systems. Power system restoration is a main application of that.Research present several architectures for isolation and restoration of the power system.agents are connected to the network and focus on capacity discovery within the microgrids system. In our model, we look at implementing a multi-agent based control using an Arduino board capable of taking input parameters from the sensors. This enables the Implementation of a low-cost and application-specific architecture. The use of Arduino microcontroller provides ease of operation and maintenance. The number of input parameters processed by the system is extendable owing to the modularity introduced into the system by the use of multiplexers.

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