Multi-Agent Systems (MAS) controlled Smart Grid – A Review

Mahesh S Narkhede
Research Scholar, Electrical Engineering Department
NITTTR
Chandigarh, India

S.Chatterji, Ph.D.
Prof. and Head Electrical Engineering Department
NITTTR
Chandigarh, India

Smarajit Ghosh, Ph.D.
Prof. and Head Electrical And Instrumentation Engg.
Thapar University
Patiala, India

ABSTRACT
An attempt has been made in this paper to reveal the latest applications of Multi-Agent Systems(MAS) in operation and control of Smart Grid. Major applications available in literature are elaborated and at the end, based on the inference of article future scope in applications of MAS in Smart Grid is discussed.

General Terms
Smart Grid (SG), Microgrid (MG),Economic Dispatch (ED)

Keywords
Multi-Agent System(MAS), Demand Response (DR), Service Restoration (SR),VPP (Virtual Power Plant)

1. INTRODUCTION
Multi-agent systems (MAS), are presently playing an important role in software development at industrial level. MAS consists of numerous interacting computing elements, known as agents. Agents are nothing but computer systems with two important capabilities. Firstly , up to some extents , they are capable of autonomous action – of deciding for themselves what they need to do in order to satisfy their design objectives. Secondly, they are able to interact with other agents – not simply by exchanging data, but by engaging in activities: cooperation, coordination, negotiation, and the like [1].

Agents concept in Multi-agent systems and Objects concept in Object Oriented Programming (OOPs) are two distinct notions - each having its own particular place in software development. The agent based system development is quite different from the object-oriented way[2]. In the wider context, software agents represent an area of Artificial Intelligence (AI) combined to computer science . Distributed Artificial Intelligence (DAI) a subfield of AI is concerned with solving problems in distributed manner. Agent based computing is one of its prime and important research area.

MAS has been so far applied in Computer Games (Star craft, Age of Empires, Half Life 2, Splinter Cell), Supply Chain Management, B2B, Logistics, Air Traffic Control, Industry (Car Assembly, Factory Management, Task Assignment, Container Terminal Management), Urban Search and Rescue (Unmanned vehicles, First Responder management, decentralized sensing, coalition formation, path planning), Space (Space missions with multiple rovers, space ship repair, Earth Orbiters etc) [3]. Recently MAS technology is finding greater applications in Power system that too in Smart Grid.

After introducing a basic concept of MAS in section – 1, a brief overview of Smart Grid is presented in section – 2. The most recent trends in applications of MAS in Smart Grid are presented in section– 3. Section – 4 discusses the future scope in developing an enhanced agent based framework in Smart Grid. Finally section – 5 concludes the article.

2 SMART GRID
Much of today's power grid is based on Nikola Tesla's assumptions like centralized power generation, demand responsive control and unidirectional transmission of electricity and communication. Due to depleting fossil fuels , increasing exponential demand of electricity and liberalization of energy market has given birth to Smart Grid concept. Smart Grid is the amalgam of electrical transmission , Information and Communication technology (ICT) in five spheres : smart geographical areas, smart renewables generation services, smart electricity services, smart distribution and transmission and smart power grid [4]. It is also defined as broad range of solutions and application of Technologies that optimize the energy value chain. It is evolving in nature.

Smart Grid has below mentioned enormous potential benefits:

i) It optimizes the value of existing production and transmission capacity
ii) It incorporates more renewable energy
iii) It enables broader penetration of DERs and use of energy storage options
iv) It reduces Carbon foot prints.
v) It improves power quality
vi) It improves power reliability, operational performance, asset management and overall productivity of utilities.
vii) It enables two way communication with consumers by enabling them to manage their energy usage

The traditional or classical system dispatch focused mainly on:

- Unit commitment scheduling
- Economic dispatch
- Automatic generation control
- Grid security
- Local dispatch with some regional implications.

The market-based system dispatch in a Smart Grid has additional sophisticated focus areas including:

- Formal day-ahead and real-time tasks
- Unit commitment and economic dispatch with more explicit transmission security constraints
- Checks and balances to ensure transparency and consistency
- Large-scale system dispatch that is regional and multiregional in scope.
- Integration of distributed energy resources and demand response resources.
- Shifting loads to more efficient generation using demand response and distributed generation and

storage with the aim of saving energy and reducing carbon emissions.
- Integrating technological advances in transmission to control power flows (FACTS,SVC, etc.).

3. TRENDS IN APPICATIONS OF MAS IN SG

This section deals with the applications of MAS in Smart Grid.

Stephen D. J. McArthur et al in [5] examined the potential value of MAS technology to the power industry The authors further described fundamental concepts and approaches within the field of Multi-Agent Systems that are appropriate to power engineering applications. Further the authors presented a comprehensive review of the meaningful power engineering applications for which MAS are being investigated. They further defined the technical issues which must be addressed in order to accelerate and facilitate the uptake of the technology within the power and energy sector.

H. J. Zhou et al in [6] analyzed advantages of the Multi-Agent systems and Software Oriented Architecture (MAS-SOA) design consideration and architecture in integration for intelligent distribution network. The authors realized the specific service by encapsulating agent, which interacted with other agent services through the Enterprize Service Bus (ESB). The authors designed Web Service-Agent Adapter as the standard interface between agent and the other services.

After a critical analysis of application of MAS in Smart Grid. It is observed that MAS technology has been applied to following application areas in Smart Grid.

1) Demand Response
2) Microgrid – Operation and Control
3) Service Restoration
4) Smart Grid control
5) Spot Market Mechanism
6) VPP control
7) Economic Disptach

3.1 DEMAND RESPONSE

Rehan Fazal et al in [7], proposed a combined dynamic demand response and DG management optimization system using multi-agents for a smart microgrid. With dynamic DR, The authors considered impact of Critical Peak Pricing rates with the penetration of PHEVs for smart microgrid. The authors further proved that by using Multi-agent System and controlled charging system overloading can be avoided. Also, the proposed system reduced overall cost of electricity by shifting loads to off peak hours. The PHEVs in this scheme were charged depending on their battery state of charge (BSOC). PHEVs with less BSOC were charged on priority. From the results the authors further proved that by controlling the charging of PHEVs along with the load shaping, the grid resources can be efficiently utilized to overcome the real time demand keeping in view the unpredictable nature of wind source.

3.2 MICROGRID MANAGEMENT

Mingzhu Lu et al in [8] proposed the multiagent based distributed energy system, incorporating traditional central power plant and different DER by using Multi-agent system (MAS) technology. The authors designed a new three layered MAS architecture with good generality useable in small, medium and large scale multi-agent based distributed energy system (MAS-DES). The authors presented the novel architecture for single agent system with learning ability. The authors further claimed that proposed MAS-DES uses the traditional and renewable resources in a more reasonable way and provides a better solution for the power supply considering the cost, pollution index and reliability.

A. Dimeas et al in [9]-[13] explained the capabilities offered by MultiAgent System technology in the operation of a Microgrid. The authors developed MAS based on Java Agent Development Framework (JADE) and tested it on the Microgrid in a Lab.. The authors further introduced a novel approach called multiagent reinforcement learning in order to increase the intelligence and the efficiency of the Microgrid.

J. Oyarzabal et al in [14], reported a Micro Grid Management system based on intelligent software agent technologies and its application to the effective management of generation & storage devices connected to a LV network forming a microgrid. The software modular architecture developed by authors enabled additional services for advanced control, such as the deployed Generation secondary control system. The effectiveness and applicability of the introduced software was evaluated in a laboratory environment where real generation, storage and load devices were being monitored and controlled. The authors further also assessed performance and scalability issues related to the agent framework.

Zhenhua Jiang in [15], presented an agent-based control framework for distributed energy resources microgrids. To demonstrate the effectiveness of the proposed agent-based control framework, the authors performed simulation studies on a dc distributed energy system that can be used in a microgrid as a modular power generation unit. Simulation studies demonstrated that the control agents manage the power of each energy source properly and the microgrid works reliably.

S. J. Chatzivasiliadis et al in [16], contributed to the investigation of the benefits that distributed control can offer to future electricity grids. The authors described the first field test of a Multi-Agent System in a Microgrid. They proposed a possible low-cost approach for the maximization of the use of Renewable Energy Sources and environmental friendly technologies in an electricity power supply grid.

T. Logenthiran et al in [17], outlined an application of MAS for distributed energy resource (DER) management in a MicroGrid. With the help of software simulation the authors demonstrated that it is possible to apply a distributed coordination approach to coordinating distributed energy systems at the strategic level.

Zhang Jian et al in [18], discussed the framework of MAS and presented an agent control model aiming at maximizing efficiency of Microgrid based on the idea of hierarchical coordinated control. The authors discussed the coordination control strategies of MAS. With the help of simulation an example of a particular Microgrid was performed to demonstrate the fact that the efficiency and reliability of Microgrid can be improved by using MAS.

Wen-Di Zheng et al in [19], presented a multi-agent system approach for distributed energy resources control in microgrid. The authors established two-layer control strategies, both in the

grid-connected mode and the island mode. In the primary control, autonomy of each agent was maximized to control the DERs without any communications based on certain levels of learning process.

Tinghua Li et al in [20] , designed a simpler IP and multi-agent technologies-based microgrid monitor and control system using the platforms of MATLAB and ZEUS, and discussed its implementation. With the help of simulations , the authors proved the feasibility of microgrid scheduling under the control of MAS.

T. Logenthiran, et al in [21]-[22] presented a MultiAgent System (MAS) for generation scheduling of a microgrid. The MAS architecture proposed by authors had different types of agents such as micro source controller agent, load controller agent, storage agent, and microgrid controller agent. Micro source controller agent that modeled corresponding distributed energy sources such as photovoltaic, wind turbine. The distributed generators, maximized their power production subject to production cost and unit's constraints. Load controller agent representing corresponding controllable load in the system, was capable to do demand side management techniques. The MAS was successfully developed in JADE,a FIPA compliant open source multiagent platform.

H. N. Aung et al in [23], developed a Multi Agent System (MAS) in JADE platform and implemented the microgrid in Real Time Digital Simulator (RTDS). The control system included an algorithm for the management of the microgrid operation in both grid connected and islanded modes, functionality of power management, load sharing, isolating microgrid and securing critical loads during the power outage. A real-time communication interface between MAS and RTDS was presented via TCP/IP. The simulation results of the study carried by authors indicated the effectiveness of proposed agent-based control system in coordinating the distributed energy resources in real-time for operation of both islanded and grid connected modes.

C.M. Colson et al in [24], presented a a distributed agent based microgrid control architecture capable of coordinating and cooperatively achieving user-defined objectives. The authors also presented key attributes of centralized versus decentralized agent-based control.

Niannian Cai et al in [25], presented a hierarchical control scheme using a multi-agent system for black start operation of a microgrid with power electronic interfaces. The authors proposed five types of agents, namely Grid Agent, Central Agent, Generation Agent, Load Agent and Breaker Agent. The authors showed that with the help of proposed architecture, the multi-agent system is able to coordinate distributed generators (DG) and loads to maintain steady state operation of the microgrid either in grid-connected mode or islanded mode; it can also perform a black start if a seamless transition to the islanded mode fails or if a black start becomes necessary for any other reason.

Mao Meiqin et al in [26], presented a novel platform for the study of EMS-MG based on MAS and used a structure of Client- Server to implement it. With the help of simulations the authors showed that a generation coordination control method is valid in operating the Microgrid in islanding mode or gridconnected mode.

Massimo Cossentino et al in [27], proposed a MAS-based approach for the solution of the energy transportation problem providing a system that is able to react to feeders overloading and failures by redirecting the energy flow and protecting itself.

A.L. Kulasekera et al in [28], reviewed current research on the application of multi-agent systems in microgrid schemes. The authors mainly focused on recent developments of multi-agent systems in different aspects of microgrids such as control, market modeling, optimization and power restoration. The future directions of multi-agent systems in microgrid applications were also discussed briefly.

H. S. V. S. Kumar Nunna et al in [29], proposed a two level architecture for distributed energy resource management for multiple microgrids using multi agent systems (MAS). At the end authors presented two case studies with two and four interconnected microgrids participating in market.

Thillainathan Logenthiran et al in [30], presented a multiagent system for real-time operation of a residential microgrid in both grid-connected and islanded modes with a RTDS. The multiagent system was developed in an open source IEEE FIPA compliant platform, and a two-stage operational strategy was implemented on the multiagent system. The simulations results from authors demonstrated the effectiveness of the proposed control and management technique, and showed the possibility of autonomous built-in operation of a microgrid with a multiagent system.

3.3 SERVICE RESTORATION

X. D. Li et al in [31], proposed a model based on multi-agent immune (MIA) algorithm to solve the service restoration problem in the event of a large-scale blackout in a power distribution network with DGs. The authors used "random tree" method to code the antibody which avoids lots of unfeasible solutions. The authors manifested the feasibility and high speed of MIA in DSR problem considering DGs.

Peng Li et al in [32], build up a multi-agent system (MAS) for service restoration of microgrid. The authors also discussed , the special functions and control strategies of each agent in detail. With the help of simulations the authors demonstrated that the efficiency and reliability of the microgrid can be improved by using MAS.

Yinliang Xu et al in [33], proposed a stable MAS based load restoration algorithm for microgrids based on the Average Consensus Theorem. The proposed algorithm has the advantages such as guaranteed stability of the algorithm , generalized nature of the algorithm suitable for power systems of any configurations and sizes. With the help of simulations the authors demonstrated the effectiveness of the proposed algorithm.

Seetaram Alwala et in in [34], proposed a Multi Agent System (MAS) based on sequence current magnitudes and current direction, for fault location and isolation in a smart microgrid system. The authors used a hierarchical model in which fault detection is done at the top level while the fault location is done at the zonal level.. Authors tested the MAS on modified IEEE37 bus system. Different fault types like Single line to ground, Line to Line and Three Phase to ground faults were successfully located by this agent system.

3.4 SMART GRID CONTROL

M. Pipattanasomporn et al in [35], discussed the design and implementation of the multi-agent system for use in an Intelligent Distributed Autonomous Power Systems (IDAPS) microgrid. The authors considered members of MAS as a control agent, a DER agent, a user agent and a database agent. Agents exchanged their messages via a TCP/IP protocol based on the IEEE FIPA standard to ensure the system interoperability.

T. Logenthiran et al in [36], presented a Multi-Agent System (MAS) for Demand Side Management (DSM) in smart grid which used an energy market for resource allocation. The multi-agent system contained Load Agents, Generator Agents and DSM Agent, which provided an electronic auction platform. The agents were able to shift energy demand within certain boundaries from peak hours to off peak hours to minimize the operational cost of the system.

3.5 SPOT MARKET MECHANISM

T. Funabashi et al in [37], proposed a multi-agent approach to Microgrid power system operation. The proposed method consisted of several Loads Agents (LAGs) , Generator Agents (GAGs) and a single Microgrid Control Agent (MAG). The authors targeted to maximize revenue from the microgrid. To demonstrate its capability, the proposed electricity trading algorithm was applied to a model system. The simulation results showed that the proposed multi-agent approach was promising.

Rui Duan et al in [38]-[39], introduced the architecture of future electricity infrastructure based on microgrids for high RES penetration. Moreover, the authors briefed and elaborated the MAS mechanisms of a prevailing electricity market, for economical incentives of RES accommodation. The authors also proposed a retailing spot market of electric energy in Smart grid.

3.6 VPP CONTROL

A. L. Dimeas et al in [40], presented a new interesting concept where Microgrids and other production or consumption units form a Virtual Power Plant. The authors through examples and case studies presented how the local intelligence and the social ability of the agents may provide solutions in the optimal and effective control of a Virtual Power Plant.

Isabel Praça et al in [41], proposed the MASCEM – Multi-Agent Simulator of Competitive Electricity Markets , a multi-agent simulation tool to study negotiations in electricity spot markets based on different market mechanisms and behavior strategies, in order to take account of decentralized players such as VPP.

M. Pipattanasomporn et al in [42], discussed a multi-agent application development that involves agent specification, application analysis, application design and application realization. The authors demonstrated the use of multi-agent systems to control a distributed smart grid in a simulated environment. The simulation results indicated that the proposed multi-agent system can facilitate the seamless transition from grid connected to an island mode when upstream outages are detected. This denoted the capability of a multi-agent system as a technology for managing the microgrid operation.

3.7 ECONOMIC DISPATCH

Niannian Cai et al in [43] , discussed a potential solution for distributed economic dispatch realization in a decentralized multi-agent platform. The authors proposed a decent communication algorithm based on the consensus theorem. Authors further proved that the agents are able to compete and corporate with each other to achieve a global minimal operational cost for microgrids. The authors with the help of simulations also proved the effectiveness of the proposed algorithm

4 FUTURE SCOPE

As seen from the trends in applications of MAS to Smart Grid, the use of MAS for simulation, operation , control of Microgrid , Demand Response , Service restoration, Smart grid control, has been observed.

Smart Grid consists of numerous technologies. Apart from previously discussed techniques some of the major technologies used in Smart Grid can be enumerated as: Reliability, Smart Meters ,Smart Sensors, Smart Appliances, Real Time pricing, Automatic Meter Reading (AMR), Outage Management System (OMS), Plug in Hybrid Electric Vehicles(PHEV), Vehicle to Grid Technology(V2G), Home and Building Automation, Substation Automation ,Feeder Automation / Reconfiguration ,Intelligent Electronic Devices(IED) & their applications for monitoring & protection , Smart storage (like Battery, SMES, Pumped Hydro, Compressed Air Energy Storage),Wide Area Measurement System(WAMS),Phase Measurement Units (PMU), Load Restoration & Reconfiguration, Information & Communication Technology (ICT) containing Advanced Metering Infrastructure(AMI), Home Area Network(HAN), Neighborhood Area Network (NAN), Wide Area Network (WAN), Bluetooth, ZigBee, GPS, Wi-Fi, Wi-Max based communication, Cloud Computing, Cyber Security, Broadband over power line (BPL) along with Smart Micro Grid and Virtual Generation Technologies.

So MAS framework has a wide potential base for evaluating above said techniques

5 CONCLUSION

A critical analysis of the literature review undertaken in the present paper finally reveals that Multi- Agent System has a wide scope in operation and control of Smart Grids.

6 ACKNOWLEDGMENTS

The author wishes to thank NITTTR Chandigarh for providing the required resources.

7 REFERENCES

[1] Michael Wooldridge, "An Introduction to Multiagent Systems", John Wiley & Sons Ltd, West Sussex, England, 2002, ISBN 0-471-4969 I-X

[2] James Odell, "Objects and Agents comopared", Journal of Object Technology, Vol. 1, No. 1, May-June 2002 ,pp:41-53

[3] Alexander Kleiner, Bernhard Nebel , " Introduction to Multi – Agent Programming", Lecture notes at http://www.informatik.uni-freiburg.de/~ki/teaching/ws0809 / map/mas_lect11b.pdf

[4] Special report by Zpryme's Smart Grid Insights in July 2011 in South Korea available online.

[5] Stephen D. J. McArthur, Euan M. Davidson, Victoria M. Catterson, Aris L. Dimeas, Nikos D. Hatziargyriou, Ferdinanda Ponci, Toshihisa Funabashi, "Multi-Agent Systems for Power Engineering Applications—Part I: Concepts, Approaches, and Technical Challenges", IEEE Transactions On Power Systems,4 November 2007, Vol. 22, No. 4, pp: 1743-1752

[6] H. J. Zhou, J. Z. Cao, C. X. Guo, J. Qin, "The Architecture of Intelligent Distribution Network based on MAS-SOA", Proceedings of IEEE Power and Energy Society General Meeting, Minneapolis, MN, 25-29 July 2010, pp:1-6

[7] Rehan Fazal, Jignesh Solanki, Sarika Khushalani Solanki, "Demand Response using Multi-agent System", Proceedings of North American Power Symposium (NAPS 2012), Champaign, IL, USA, 9-11 September 2012, pp:1-6

[8] Mingzhu Lu ,C. L. Philip Chen, "The Design of Multi-agent based Distributed Energy System", Proceedings of IEEE International Conference on Systems, Man and Cybernetics, SMC2009, San Antonio, TX, 11-14 October 2009, pp:2001-2006

[9] A. Dimeas, N. Hatziargyriou , "A MultiAgent System for Microgrids", Proceedings of IEEE PES Power Engineering Society General Meeting, 6-10 June 2004, vol-1, pp:55-58

[10]Aris L. Dimeas, Nikos D. Hatziargyriou , "Operation of a Multiagent System for Microgrid Control",IEEE Transactions On Power Systems, August 2005, Vol. 20, No. 3, pp: 1447-1455

[11]A. L. Dimeas, N. D. Hatziargyriou, "A MAS architecture for Microgrids control",Proceedings of the 13th International Conference on Intelligent Systems Application to Power Systems, 2005, Arlington, VA, 6-10 November 2005, pp:402-406

[12]A.L. Dimeas , N.D. Hatziargyriou ," Agent based Control for Microgrids", Proceedings of IEEE PES Power Engineering Society General Meeting, Tampa, Florida, 24-28 June 2007, pp:1-5

[13]A. L. Dimeas, N. D. Hatziargyriou, "Multi-Agent Reinforcement Learning for Microgrids", Proceedings of IEEE Power and Energy Society General Meeting, Minneapolis, MN, 25-29 July 2010, pp:1-8

[14]J. Oyarzabal, J. Jimeno, J. Ruela, A. Engler, C. Hardt, "Agent based Micro Grid Management System",Proceedings of the International Conference on Future Power Systems , 2005, Amsterdam, 18 November 2005, pp:1-6

[15]Zhenhua Jiang, "Agent-Based Control Framework for Distributed Energy Resources Microgrids",Proceedings of the International Conference on Intelligent Agent Technology IAT2006, Hongkong, 18-22 December 2006, pp: 646-652

[16]S. J. Chatzivasiliadis, N. D. Hatziargyriou, A. L. Dimeas," Development of an Agent Based Intelligent Control System for Microgrids",Proceedings of IEEE Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century, Pittsburgh, PA, 20-24 July 2008, pp:1-6

[17]T. Logenthiran, Dipti Srinivasan, David Wong," Multi-Agent Coordination for DER in MicroGrid",Proceedings of IEEE International Conference on Sustainable Energy Technologies, ICSET 2008, Hongkong, 24-27 November. 2008, pp:77-82

[18]Zhang Jian, Ai Qian, Jiang Chuanwen, Wang Xingang, Zheng Zhanghua, Gu Chenghong, "The application of Multi Agent System in Microgrid coordination control", Proceedings of IEEE International Conference on Sustainable Power Generation and Supply, SUPERGEN '09, Nanjing, 6-7 April 2009, pp:1-6

[19]Wen-Di Zheng, Jin-Ding Cai, "A Multi-Agent System for Distributed Energy Resources Control in Microgrid",Proceedings of IEEE Power and Energy Society General Meeting, Minneapolis, MN, 25-29 July 2010, pp:1-6

[20]Tinghua Li , Zhe Xiao, Ming Huang, Jiang Yu, Jingsong Hu ," Control System Simulation of Microgrid Based on IP and Multi-Agent",Proceedings of International Conference on Information Networking and Automation (ICINA 2010), Kunming, 18-19 October 2010, pp: V1-235 - V1-239

[21]T. Logenthiran,, D. Srinivasan, A. M. Khambadkone ,H. N. Aung, "Multi-Agent System (MAS) for Short-Term Generation Scheduling of a Microgrid" , Proceedings of International Conference on Sustainable Energy Technologies (ICSET 2010), Kandy, 6-9 December 2010, pp: 1-6

[22]T. Logenthiran, D. Srinivasan, A. M. Khambadkone, H. N. Aung, "Scalable Multi-Agent System (MAS) for Operation of a Microgrid in Islanded Mode", Proceedings of Joint International Conference on Sustainable Power Electronics, Drives and Energy Systems (PEDES) & Power India, New Delhi, 20-23 December 2010. Pp:1-6

[23]H. N. Aung, A. M. Khambadkone, D. Srinivasan, T. Logenthiran, "Agent-based Intelligent Control for Real-time Operation of a Microgrid", Proceedings of Joint International Conference on Sustainable Power Electronics, Drives and Energy Systems (PEDES) & Power India, New Delhi, 20-23 December 2010. pp:1-6

[24]C.M. Colson, M.H. Nehrir, "Agent-based Power Management of Microgrids including Renewable Energy Power Generation", Proceedings of IEEE Power and Energy Society General Meeting 2011, San Diego, CA, 24-29 July 2011, pp:1-3

[25]Niannian Cai, Xufeng Xu, Joydeep Mitra, "A Hierarchical Multi-agent Control Scheme for a Black Start-Capable Microgrid", Proceedings of IEEE Power and Energy Society General Meeting 2011, San Diego, CA, 24-29 July 2011, pp:1-7

[26]Mao Meiqin, Dong Wei, Liuchen Chang, "Multi-Agent Based Simulation for Microgrid Energy Management", Proceedinigs of 8th IEEE International Conference on Power Electronics and ECCE Asia (ICPE & ECCE 2011),Jeju,30 May – 30 June 2011,pp: 1219 - 1223

[27]Massimo Cossentino, Carmelo Lodato, Salvatore Lopes, Marcello Pucci, Gianpaolo Vitale, Maurizio Cirrincione, "A Multi-Agent Architecture for Simulating and Managing Microgrids", Proceedings of Federated Conference on Computer Science and Information Systems (FedCSIS 2011), Szczecin, Poland, 18-21 September 2011, pp:619-622

[28]A .L. Kulasekera, R.A.R.C. Gopura, K.T.M.U. Hemapala, N.Perera, "A Review on Multi-Agent Systems in Microgrid Applications",Proceedings of IEEE-PES conference on

Innovative Smart Grid Technologies - India (ISGT India), Kollam, Kerala, 1-3 December 2011, pp: 173-177

[29] V. S. Kumar Nunna, Suryanarayana Doolla, "Multi Agent based Distributed Energy Resource Management for Intelligent Microgrids",IEEE Transactions on Industrial Electronics, 06 April2012, Vol:PP, Issue:99, pp: 1-10

[30] Thillainathan Logenthiran, Dipti Srinivasan, Ashwin M. Khambadkone, Htay Nwe Aung, "Multiagent System for Real-Time Operation of a Microgrid in Real-Time Digital Simulator",IEEE Transactions On Smartgrid,June 2012, Vol. 3,No.2, pp: 925-933

[31] X. D. Li, Y. Q.XU, L. Zhang, "Distribution Service Restoration with DGs Based on Multi-agent Immune Algorithm",Proceedings of 31st IEEE International Conference on Telecommunications Energy , INTELEC 2009, Incheon, 18-22 October 2009, pp:1-5

[32] Peng Li, Tiemin Wang, "Multi-agent Approach for Service Restoration of Microgrid" , Proceedings of 5th IEEE conference on Industrial Electronics and Applications (ICIEA 2010), Taichung, 15-17 June 2010, 962-966

[33] Yinliang Xu, Wenxin Liu, "Novel Multiagent Based Load Restoration Algorithm for Microgrids", IEEE Transactions On Smartgrid, March 2011, Vol. 2,No. 1,pp:152-161

[34] Seetaram Alwala, Ali Feliachi, M. A. Choudhry, "Multi Agent System based Fault Location and Isolation in a Smart Microgrid System", Proceedings of IEEE PES conference on Innovative Smart Grid Technologies (ISGT 2012),Washington, DC, 16-20 January 2012, pp:1-4

[35] M. Pipattanasomporn, H. Feroze, S. Rahman, "Multi-Agent Systems in a Distributed Smart Grid: Design and Implementation",Proceedings of IEEE/PES Power Systems Conference and Exposition, PSCE '09, Seattle,WA, 15-18 March 2009, pp:1 – 8

[36] T S. Logenthiran,Dipti Srinivasan,Tan Zong Shun, "Multi-Agent System for Demand Side Management in Smart Grid", Proceedings of 9th IEEE International Conference on Power Electronics and DriveSystems (PEDS 2011), Singapore, 5-8 Dec. 2011, pp: 424 - 429

[37] T. Funabashi, T. Tanabe, T. Nagata, R. Yokoyama, "An Autonomous Agent for Reliable Operation of Power Market and Systems Including Microgrids", Proceedings of Third International Conference on Electric Utility Deregulation and Restructuring and Power Technologies, 2008, Nanjuing, China, 6- 9 April 2008, pp: 173-177

[38] Rui Duan, Geert Deconinck, "Multi-agent Coordination in Market Environment for Future Electricity Infrastructure based on Microgrids", Proceedings of IEEE International Conference on Systems, Man and Cybernetics, SMC2009, San Antonio, TX, 11- 14 October 2009, pp:3959-3964

[39] Rui Duan, Geert Deconinck, "Multi-agent Model and Interoperability of a Market Mechanism of the Smart Grids", Proceedings of IEEE/PES Symposium Workshop on Network Operations and Management (NOMS Wksps2010), Osaka, 19-23 April 2010, pp:312-315

[40] A. L. Dimeas, N. D. Hatziargyriou, "Agent based control of Virtual Power Plants",Proceedings of International Conference on Intelligent Systems Applications to Power Systems, 2007, Toki Messe, Niigata, 5-8 November 2007, pp:1-6

[41] Isabel Praça, Hugo Morais, Carlos Ramos, Zita Vale, Hussein Khodr, "Multi-Agent Electricity Market Simulation with Dynamic Strategies & Virtual Power Producers",Proceedings of IEEE Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century, Pittsburgh, PA, 20-24 July 2008, pp:1-8

[42] M. Pipattanasomporn, H. Feroze, S. Rahman," Multi-Agent Systems in a Distributed Smart Grid: Design and Implementation",Proceedings of IEEE/PES Power Systems Conference and Exposition, PSCE '09, Seattle,WA, 15-18 March 2009, pp:1 – 8

[43] Niannian Cai, , Nguyen Thi Thanh Nga, Joydeep Mitra, "Economic Dispatch in Microgrids, Using Multi-Agent System", Proceedings of North American Power Symposium (NAPS 2012), Champaign, IL, USA, 9-11 September 2012, pp:1-5