Stochastic Negotiation with Market Utility for Automated Power Restoration on a Smart Grid

Yi-Wei Huang[1], Yi-Chun Chen[2], Wan-Yu Yu[1], Von-Wun Soo[3]

[1]Institute of Information Systems and Applications,
National Tsing Hua University
No.101, section2, Kuang-Fu Road, Hsinchu, Taiwan
30013, R.O.C
{g122y135,csvillea}@gmail.com

[2,3]Department of Computer Science,
National Tsing Hua University
No.101, section2, Kuang-Fu Road, Hsinchu, Taiwan
30013, R.O.C
rimi7609@gmail.com, soo@cs.nthu.edu.tw

ABSTRACT

In this paper, we propose a novel agent-based power restoration system using stochastic negotiation algorithm. We model each power feeder and demand zone on the topology of a smart grid as an agent. Once a power fault occurs, the feeder agents will isolate the region as the target region and coordinate by negotiation to restore the power as soon as possible. The method we proposed is an any-time negotiation algorithm, so it can find a feasible solution at any-time to reduce the damage caused by black-out to society, and can gradually train the solution to approach the optimal one if more time is allowed. Besides, we also consider the market effects on the cost of power generation for different feeders by combining the concept of marginal price to affect agent's negotiation. In the experiment, we show the results by testing the system with different network topologies at different scenarios that can illustrate the performance and reliability, availability of our method. The results demonstrate that the method is much better than the previous method[1].

Categories and Subject Descriptors

I.2.11 **[Artificial Intelligence]**: Distributed Artificial Intelligence-*Coherence and coordination, Intelligent agents, Multiagent Systems*

General Terms

Algorithms, Management, Measurement, Performance, Design, Experimentation, Languages, Theory, Verification.

Keywords

Agent committee problem solving, power distribution service restoration, smart power grids, Supply function equilibrium, locational marginal price and coordination.

1. INTRODUCTION

In recent years, the automated power restoration becomes one of the popular issues in the smart grid. In face of a black-out, power plants must come up with a solution quickly to restore the black-out area in order to minimize the huge loss that might be caused by the event. There have already been many articles discuss about this topic and some algorithms existed or published. But most the existing methods consider only about partial constraints and problems in the power field in practice. So the solutions they provided are still not satisfactorily in the actual problems encountered in practice. We design a multi-agent system to solve the automated power restoration problem using more realistic constraints on a smart grid.

We model two kinds of power agents, feeder agent and zone agent, to construct a power grid. Each feeder agent represents a feeder, which is a supplier of a power delivery system, and each zone agent represents a power demand zone. We also design the detection and isolation mechanisms to auto-detect the black-out region and then isolate this region to be restored. However, we only focus on the restoration part in this paper.

For achieving higher efficiency, enhancing maintenance flexibility and saving cost on hardware, we designed our method under the concept of a fully distributed system in contrast to a centralized system. This feature allows each agent to use less available information and can conduct their tasks simultaneously and locally to speed up the time to come up with a solution. When a power fault occurs, the responsible affected agents will negotiate with each other, exchange information to achieve their own goal, and then generate a feasible solution in a short time. After that, the system will continue searching for a better solution anytime until an optimal one is found.

The method we proposed here combines many concepts to avoid the main problems which may often occur in other algorithm. We adopt the concept of stochastic negotiation to allow agents to negotiate and make decision so that they can have better chance of jumping out of a local optimal solution that might be trapped by a hill-climbing approach of negotiation due to individual rationality of agents. Furthermore, we also apply the market utility concept to vary the utilities of each feeder agent. This will also affect the decision making of feeder agents and make the solution fit in the practical situations.

In the paper, we will describe some related research or works we have done in section 2; illustrate the method we proposed in detail with some decision flow charts of agents in section 3; and show the results of different experiments to demonstrate our performance, reliability and availability in section 4; finally, we will have a brief conclusion of this paper in section 5.

2. RELATE WORK

For describe our methods for this problem clearly, we start with definitions of some notations that combines from different fields [2-10] which are briefly described below.

2.1 Background of Power Restoration

Restoring power to out-of-service zones is called a power restoration problem [11].

There are three primary roles in this domain: feeders, zones, and switches. Zones play the role as consumers. A feeder generates and reserves power, and supplies power according to each zone's demand. Switches are tuned on and off in a way not only to connect the path from a feeder to the zones but also to isolate the zones to prevent them from conflicting with other feeders.

According to the architecture of electrical power grid, we can describe a power restoration problem as follows:

After a fault occurs, abiding by all of basic constraints of power grid, searching for a minimum change of a combination states of switches so that the number of restored zones can reach maximum? To simplify this problem, we consider two main constraints in this paper:

1) Each feeder has limited power to distribute: After a feeder restored a zone, it will consume some power equals to the zone demand. Therefore, it only has the ability to restore limited number of zones.

2) Radial power distribution structure has to be maintained: A zone can connect or disconnect to others via switch operations, that allow the chosen feeders to work together to supply power to satisfy the zones' demands. If there is no path from a feeder a zone, then the zone cannot be restored by the feeder. Besides, each zone can be restored by only one feeder, that may sometimes cause a feeder to block others.

For instance, Figure 1 shows a topology in which a power fault occurs at zone 2 (z2), and then all the downstream regions of z2 as the zones marked in red lines are blackout. Black nodes represent switches which are turned on while white nodes represent switches turned off. The number attached to each zone is the power demand of the zone

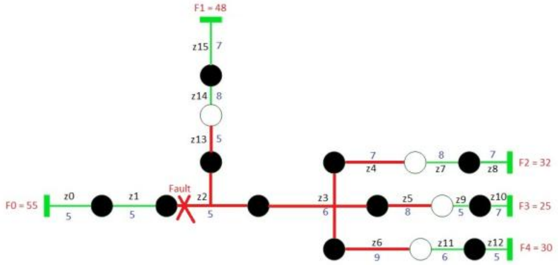

Figure 1. A topology with fault occurring

In Figure 2, it shows one of the solutions generated by the feeder agents after negotiating with each other and making decisions due to their own utilities. Feeder 1 restores z13, z5, z6 and z7; feeder 3 restores z5; and feeder 4 restores the last one, z6.

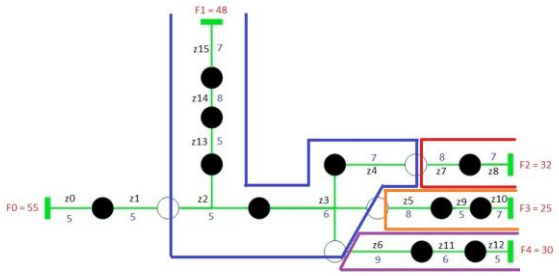

Figure 2. A scenario of restoration

2.2 Power Constraints

In power domain, there are some basic constraints. Those constraints need to be satisfied, thus the solution will be reasonable.

1) A zone cannot be restored by more than one feeder agent at the same time. It can only be restored by one feeder, if a responsible zone of two feeders overlap, it may cause the short circuit problem.

2) Only when the total power supply is no less than the total power demand, can all zones be possibly restored but not necessarily. The same concept can be applied further to that only when the the remaining power of a power supply is no less than the demand of a target zone, can the zone be restored by the supply.

2.3 Market mechanism

Market is defined as an environment in which sellers offer their products or services for money and buyers receiving services and goods by trading with money. In this paper, we concern about free market, which means the market is not interfered with by government. In a free market, property right is exchanged with a price satisfied the seller and buyer. The trade is not affected by any other external force. This kind of competition between sellers or buyers is called “free competition”. Therefore, the price changes according to the relation between demand and supply. We can define this kind of economic phenomenon as market mechanism or free price mechanism. Market mechanism is an invisible but powerful force to affect the condition of market. It is composed by many essential components, such as demand, supply, products and price. Each of them will be affected by each other. For instance, when the demand of a product increased, the price of this product must be raised. On the contrary, when the demand of a product reduced, the price of this product must be decreased. Here we describe some important concepts used in the paper.

1) Demand and Supply: We treat the amount of power provided by a feeder as the supply while the demand as the amount of power demanded by a zone.

2) Cost: Cost means the amount of money paid for getting some items or services. We use this concept to design the formula of power generation cost as the utility comparison value.

3) Marginal cost: In general, it means the increase of total cost when one more unit produced. In this paper, it is defined as the incremental cost of supplying per unit power energy[12][13].

3. ALGORITHM DESIGN

Combining all works in Section 2, we describe our protocol as follows:

3.1 Definition of Elements

Two kinds of agents were defined in our multi-agent system: feeder agents and zone agents. Feeder Agent (FA) and Zone Agent (ZA) play roles as a feeder and a zone in a physical smart grid respectively. Before discussing the stochastic protocol, some notations are described as follows:

3.1.1 Candidate List

Since our power restoration problem is designed as a distributed system, we assume feeders do not need to know the global topology during the restoration procedure. They maintain their own restored zones locally, and get information from those zones. According to the adjacency of zones, each feeder can maintain the zone information by building a candidate list for all zones that are reachable and restorable.

3.1.2 Zone Decision Function (ZDF)

A feeder agent holds its own decision function for making decision and choosing a target zone from its own candidate list. The formula of the decision function will be discussed in section 3.3.

3.1.3 Guest Feeder Agent (Guest FA)

When a feeder agent chooses a zone from its candidate list, and starts to negotiate with the zone and other feeder agents, we call the feeder agent as a "Guest Feeder Agent".

3.1.4 Target Zone Agent (Target ZA)

As a zone will be chosen from the candidate list by a feeder agent, we call it the Target Zone Agent of the feeder agent.

3.1.5 Host Feeder Agent (Host FA)

If a zone chosen by a feeder agent is already being restored, we call the feeder agent who restores the zone as a Host Feeder Agent of the zone.

3.1.6 Proposal Decision Function (PDF)

During negotiation procedure, the host feeder agents use their own Proposal Decision Function (PDF) to make decision whether they should accept other feeder agent's proposal which will be described in detail in section 3.3.3.

3.2 Stochastic decision making

Decision-making for a feeder agent is important to find a good feasible solution to the restoration problem. If the agent [14] has the information about the global environment, then it can possibly make the decision to reach the best solution. Unfortunately, as the network topology becomes larger, utilizing all available information to find the optimal solution tends to become more difficult. This is true because, distributed agents usually work under uncertainty with limited local information. How to make a right and better decision to achieve better global solution based on agents' individual rationality becomes an important issue.

In decision theory, rational agents tend to make a rational decision by maximizing its expected utility[15][16][17]. The basic idea of decision theory is that an agent is individual rational who will choose an action that yield the highest expected utility called maximum expected utility (MEU), and it can be formulated as following two equations (1) and (2).

$$EU\left(A_j \middle| E\right) = \sum_i P(\mathrm{Result}_i(A_j) \,|\, Do(A_j), E)\, U\left(\mathrm{Result}_i(A_j)\right) \qquad (1)$$

A_j denotes an action, and $U(\mathrm{Result}_i(A_j))$ is for the utility of the result after A_j was done. E is agent's available evidence about the world.

We bring in the concept of probability by forming a Probability Maximum Expected Utility as below:

$$MEU = Max(EU(A_j|E)) \qquad (2)$$

(2) is the maximum expected utility estimated using (1). However, MEU principle alone is not sufficient, since if agents always follow the maximum expected utility, after a series of decision-makings they may still trap in some local optimal as most greedy methods do.

Our idea is that even some action that does not maximize the expected utility, it should also have a chance to be chosen. Then, those actions that don't yield the maximum expected utility may have a chance to be chosen.

3.3 PDF & ZDF

In section 3.1, we defined agent decision function as follows:

3.3.1 Generation cost function

A quadratic form of a generation cost function is defined in equation (3).

$$C_i(D_k) = a_i * (D_k)^2 + b_i * D_k \qquad (3)$$

where $C_i(D_k)$ is the cost function of feeder agent i to generate power demand D_k for zone k, and a_i and b_i are parameters of the generation cost function for feeder agent i. Thus we can get the marginal cost of a feeder agent by its partial differentiation of cost with respect to power demand D_k of a specific zone k:

$$MC_i(D_k) = \frac{\partial C_i(D_k)}{\partial D_k} = 2 * a_i * D_k + b_i \qquad (4)$$

3.3.2 Zone Decision Function (ZDF)

When a negotiation begins, a feeder agent uses ZDF to choose a target zone from its candidate list. The decision function is given by the concept of Probability Maximum Expected Utility.

One of the objectives of power restoration is to restore more zones, we use a stochastic function to allow the feeder agent to have a chance to pay attention to those zones that haven't been restored.

$$P_k(A_k) = \frac{1}{NR_k} \bigg/ \sum_{j=1}^{n} \frac{1}{NR_j} \qquad (5)$$

Equation (5) is the probability for decision action A_k to choose zone k. Feeder agent maintains the parameter NR_k which is the number of times that zone k have been chosen from the candidate list with number of zones n. We use the sum of all $1/NR_j$ in the candidate list as the denominator and $1/NR_k$ as numerator. With this probability formula, zones that have not been restored for many times tend to have a larger probability to be chosen.

Using the notion of expected utility, we devise formula (6).

$$ZDF_{i,k} = P_k(A_h) \times (M - MC_i) \times D_k \tag{6}$$

In (6), $ZDF_{i,k}$ is a zone decision function for feeder i to choose zone k with power demand D_k . M is the unit market price of power, MCi is the marginal cost for feeder i and A_h is the decision action for choosing zone k.

The probability for zone k to be chosen as a restoration zone from the candidate list of feeder i is calculated based on its relative expected utility $ZDF_{i,k}$ with respect to the total utility of all zones in the candidate list of feeder i.

3.3.3 Proposal Decision Function (PDF)

The proposal decision function is for a feeder agent to decide whether to accept other feeder agent's proposal. Similar to ZDF, we use stochastic term to allow it to have some tolerance to the greedy bias. This formula was formed as below:

1) In proposal comparison, the more power that a host feeder agent has the lower chance the proposal by other agents will be accepted. Since if one feeder agent has more power, we can regard it as having more potential to restore more zones. However it is not absolute.

2) If the sum of demand about a host feeder agent's candidate list is larger than others', it shall have more chance to accept others' proposal. Since if a host feeder agent can reserve more power, it may have a better chance to restore more out-of -service zones.

3) A host feeder may have already taken care of some zones, once it decided to accept a proposal may affect other restored zone. If the sum of those affected zones is larger, then the acceptance probability will be lower. That is because a host feeder agent have to give up one zone which is the bridge to other zones, it have to give up those zones also that may lead to a lot of loss of utility.

Combining with the above thoughts, we define the acceptance probability for a feeder agent in equation (7) and (8).

$$F_i(accept) = \frac{a}{b} \times (1 - \frac{x}{y})^f \tag{7}$$

$$F_i(reject) = \frac{c}{d} \tag{8}$$

F_i(accept) represents a score function that reflects our intuition, where *a* denotes the sum of demands in the candidate list, *b* is the remaining power of the host feeder agent, x is the total demand in the downstream zones that has to also give up after accepting the proposal of other agents, y is the sum of power consumption for the zones restored by the host feeder agent, f is a flag whose value is 1 if the path to downstream zones needs to pass through the target Zone agent, otherwise is 0. F_i(reject) is similar to F_i(accept), but is for rejection term where c denotes the total demand in the candidate list, d is the remaining power of Feeder Agent i. We therefore combine the formula (7) and (8) to construct the PDF as a probability to decide whether a proposal is to be accepted or not as formula (9).

$$PDF_{i,ac} = \frac{F_i(accept)}{F_i(accept) + F_i(reject)} = \frac{\frac{a}{b} \times \left(1 - \frac{x}{y}\right)^f}{\frac{a}{b} \times \left(1 - \frac{x}{y}\right)^f + \frac{c}{d}} \tag{9}$$

3.4 Objectives

Using local smart agents in combination with the traditional power grid in solving a power restoration problem, it allows pass the local situation information in the grid for intelligent negotiation that possibly gets around the local and global conflicts. Therefore, it can effectively reduce the scaled-up complexity of a centralized system, and can work independently. Furthermore, since each agent only maintain local information and can thus decrease the load of centralized computation.

But for a power restoration system, how to reach the optimal solution using efficient decision making methods that can escape from local optimal solutions is the main concern of the paper. There can be various criteria for an optimal solution. But the simple optimal criterion can be defined as the maximal number of zones to be restored. Therefore our system evaluation is based on the efficiency of the negotiation methods that can find maximal number of restoration zones.

3.5 The Negotiation Protocol

In the negotiation protocol, we wish to find a better solution. We assume that agents are cooperative and honest in the negotiation proposal, thus feeder agents can make decisions based on others' proposals. The protocol is described below.

After black-out, all feeder agents begin to negotiate with each other for power restoration. Here we illustrate in detail the steps of negotiating protocol. As an any-time algorithm, these steps are iterated until the optimal solution is reached if possible.

1) Chooses a target ZA from its candidate list based on its ZDF.

2) There are two kinds of situations:

A. The target zone has not been restored. Since one of our objectives is to restore all out-of-service zones, a feeder agent can restore it directly if the target zone has not been restored. The target zone agent will accept the feeder agent's proposal, then go back to 1).

B. The target zone has already been restored by other feeder agents. Then go to step 3).

3) The target zone has been restored, but we wish to reach a better solution. Get the host feeder agent's information from the zone agent, then enter the negotiation process.

4) A feeder agent sends both its proposal to the host feeder agent.

5) The host feeder agent either accepts or rejects the proposal from the feeder agent according to its PDF, then send the decision to target zone agent.

6) If a feeder agent's proposal is accepted, the target zone agent will send relevant information to the feeder agent, then change the target zone agent's subordinated status. Go back to 1).

Figure 3 shows steps of the negotiation protocol we designed for the two kinds of conditions described above. Figure 3.a is for the condition that a target zone has not been restored. And Figure 3.b is for the condition that a target zone has been restored by another

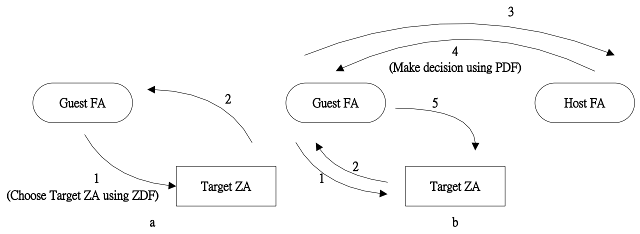

Figure 3 two cases of the negotiation protocol

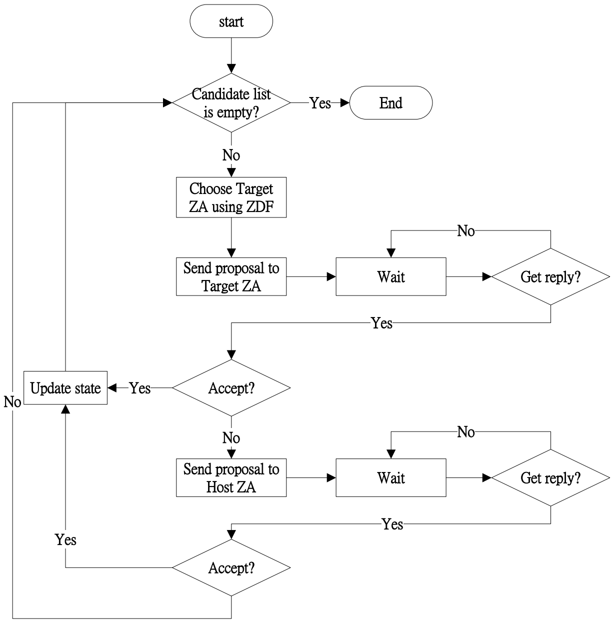

Figure 4 behavior of a feeder agent

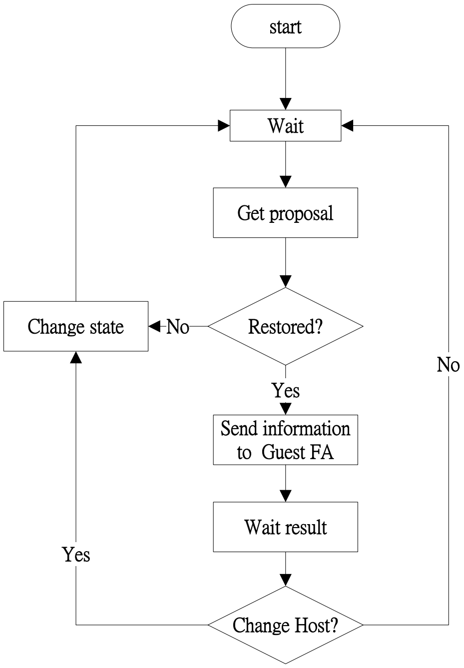

Figure 5 the behavior of a zone agent

feeder agent. Figure 4 and 5 shows the overall decision flow of both feeder agents and zone agents respectively.

4. VERIFICATION OF SYSTEM PERFORMANCE

In this part, we test the agent-based power restoration system with two different power topologies. To illustrate that our system can work in general cases, the topologies we chose for testing are in different sizes for different number of agents. We also compare the results with the committee-based algorithm developed in [18] and another stochastic-based algorithm in [1]. After analysis, we observe the advantages and drawbacks between these methods. The environment we tested in is windows 7 64 bit, AMD phenom(tm) II X4 945 processor (3G Hz) with 4GB of ram.

Case1:

In this case, we use the smallest topology to be our sample as Figure 6 below. There are 19 zone agents and 5 feeder agents here.

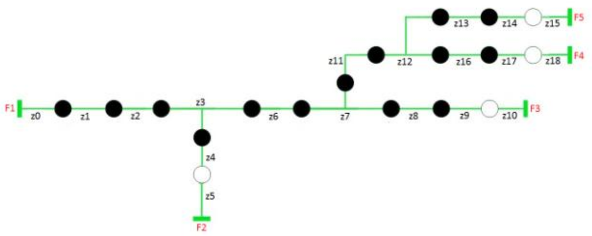

Figure 6 small topology of 19 zone and 5 feeders

We tested two scenarios for a fault occurring in different zones, one is in zone2 and another is in zone7. Once a power fault happens, all the downstream zones of the fault region will be black-out, too. We test each scenario 50 times and calculate the average time. We measure the execution time of each method to find the solution as shown in Table1. (the unit of time is millisecond)

Table 1 Execution time to find a solution with 100 percent restoration at different fault sites

	Fault occurs in zone2	Fault occurs in zone7
Our Method	18	11
Committee-based algorithm in [18]	34	26

Case2:

In this case, we use a larger topology as our sample as shown in figure 7. There are 50 zone agents and 6 feeder agents. To fit the experiment to practical conditions, the network topology used is adopted from a real case. It takes as a part of topology from the power systems in Fongshan city, Taiwan [19].

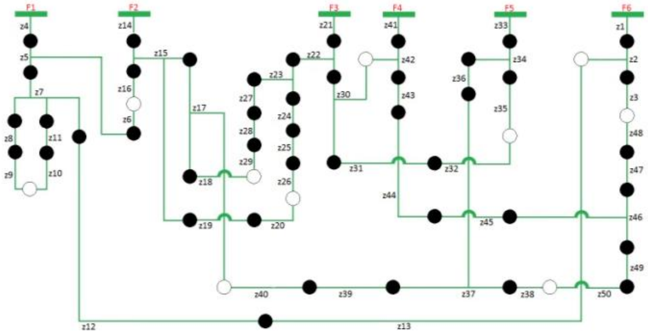

Figure 7 A practical topology with 50 zones and 6 feeders

We also tested two scenarios for a fault occurring in different zones, one is in zone36 and another is in zone15. We tested each scenario 50 times and calculate the average time. We measure the execution time of each method and find the solutions shown in Table 2.

Table.2 Execution time to find a solution with 100 percent restoration at different fault sites for a real case

	Fault occurs in zone36	Fault occurs in zone15
Our Method	11	14
Committee-based algorithm [18]	25	31

We observe clearly that our methods find a solution much faster than previous methods [18]. Here we further test some more complicated cases whose scenarios and results are illustrated in Table 3 and Table 4 respectively with the unit of time expressed in millisecond. The topology used for case 3 and case 4 is the same one and shown in Figure 9 and another topology used for case 5 is shown in Figure 10.

Besides, since the method we proposed is an any-time algorithm, we can generate a feasible solution in a very short time and then gradually improve the solution to a better one or until the optimal one is found. We also test the solution of each case generated at different time points to estimate its performance in terms of the averaged restoration rate which demonstrates the ratio of restoration of total black-out regions of a solution generated at certain time points. We test every case 50 times at different time points to calculate the average value. The result is shown in Figure 8.

Table 3

	Case3	Case4	Case5
Number of black-out zones	19	23	47
Number of feeders affected	3	5	5

Table 4

	Case3	Case4	Case5
Our method	27	31	53
Committee-based algorithm [18]	49	55	134

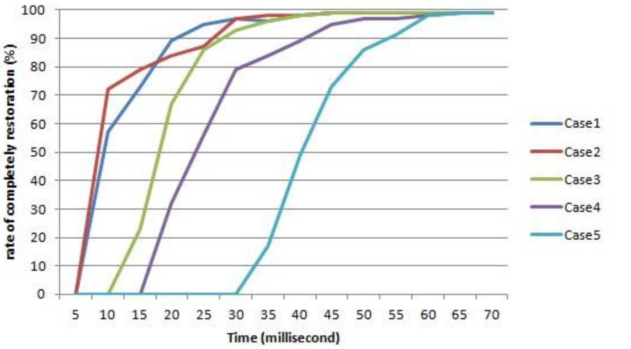

Figure 8

Our proposed method is an any-time algorithm and we compared its difference with a committee-based algorithm. The main objective of the domain problem is to find a solution that can completely restore the black-out areas as soon as possible instead of finding the optimal solution directly that may sometimes takes much longer time. So in practice, the any-time algorithm makes more sense. Although the committee-based algorithm can find out the optimal solution exhaustively, the message passing between the agents can be complicated in scaled-up situations and committee member agents need to spend more time to negotiate with each other. This can slow down the generation of the optimal solution.

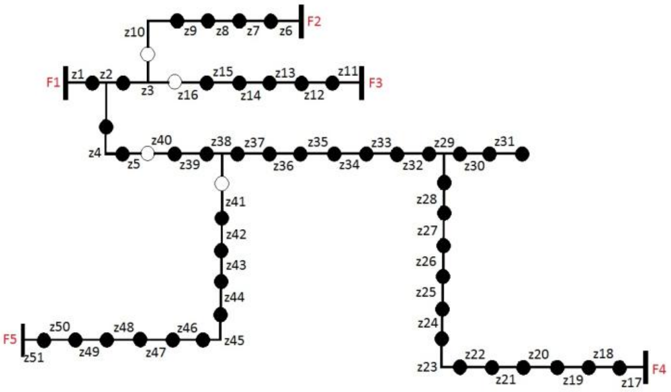

Figure 9 A practical topology with 51 zones and 5 feeders

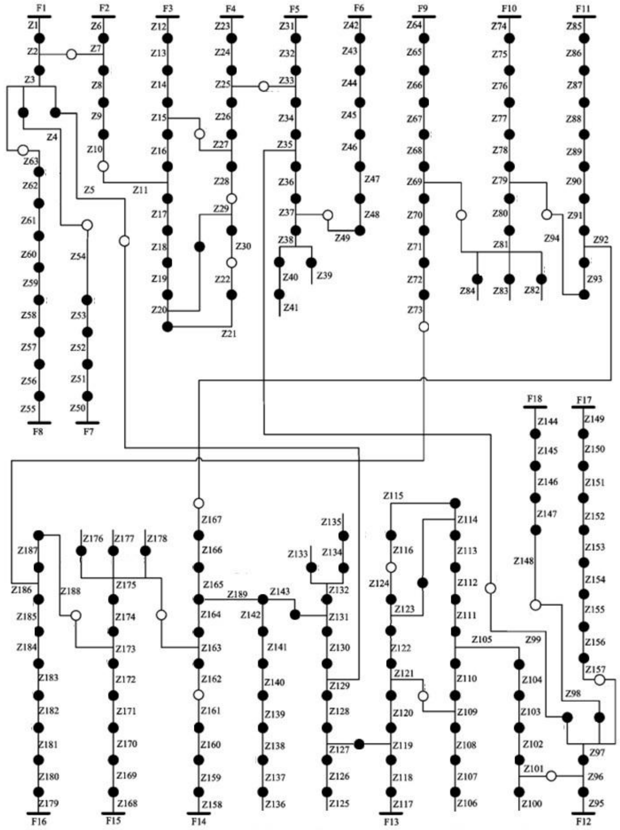

Figure 10 A practical topology with 189 zones and 18 feeders

5. CONCLUSIONS

In this research, we explore a better way to solve the problem of automated power restoration. We use the concept of stochastic and market mechanism to design the rules for agents to make decision. We also consider the marginal price which is different between each feeder due to the variation of market supply and demand. Marginal price is added in to the decision policy as a parameter to measure the utility of each feeder agent, and then influence the behaviors of the agents. This will also make our research much closer to the practical situations in the real power market. Furthermore, the concept of stochastic negotiation allows the agents to have a chance to negotiate with less than optimal case so that it can avoid being trapped in local optimal solution.

Besides, the method we proposed is an any-time algorithm, it indeed can generate solution under various timing constraints so that decision can be made at any critical time imposed by users in dealing with the automated restoration of black-out. In contrast to the committee-based algorithm, the number of messages transferred between agents during the process of negotiation is less in our method. This speeds up the time for solution generation. We have also demonstrated its performance, reliability and availability via the experiments under various conditions.

Although the methods we proposed can greatly solve the problem of power restoration, there are still many aspects we can improve. In the future, we will extend the algorithm by taking more constraints and objectives in the power field into considered. For example, we will consider about the stability problems of voltage and current drop in the solutions as well as the multi-fault problems to make the methods more flexible to be used in real applications in smart grids.

6. ACKNOWLEDGEMENTS

We thank professor Men-Shen Tsai at Institution of electrical engineering, National Taipei University of Technology. Due to his help, we understand the power domain problems and obtain the cases of power network topology and data to test our method. Furthermore, we also thank the partial support from “Low Carbon Energy Research Center” of National Tsing Hua University and National Science Council of Taiwan under the grant NSC-99-2221-E-007-090-MY3.

7. REFERENCES

[1] Von-Wun Soo and Yen-Bo Peng, 2011, A Stochastic Negotiation Approach to Power Restoration Problems in a Smart Grid. PRIMA.

[2] Hsiao, Y.T. and C.Y. Chien, 2000, Enhancement of restoration service in distribution systems using a combination fuzzy-GA method. IEEE Transactions on Power Systems, 15(4): p. 1394-1400.

[3] Lambert-Torres, G., et al., 2009, Particle Swarm Optimization Applied to System Restoration. 2009 IEEE Bucharest Powertech, Vols 1-5, 1992-1997.

[4] Luan, W.P., M.R. Irving, and J.S. Daniel, 2002, Genetic algorithm for supply restoration and optimal load shedding in power system distribution networks. IEE Proceedings-Generation Transmission and Distribution, 149(2): p. 145-151.

[5] Shin, D.J., et al., 2004, Optimal service restoration and reconfiguration of network using Genetic-Tabu algorithm. Electric Power Systems Research, 71(2): p. 145-152.

[6] Li, X.D., Y.Q. Xu, and L. Zhang., 2009, Distribution service restoration with DGs based on multi-agent immune algorithm. In Power Electronics and Intelligent Transportation System (PEITS), 2009 2nd International Conference.

[7] Solanki, J.M., S. Khushalani, and N.N. Schulz, 2007, A multi-agent solution to distribution systems restoration. IEEE Transactions on Power Systems, 2007. 22(3): p. 1026-1034.

[8] Wu, J.S., et al., 2009, An autonomous decision approach for fault allocation and service restoration in electrical distribution systems by multi agent system. In Proceedings of the Ninth International Conference on Hybrid Intelligent Systems, Vol 3, 89-94.

[9] Nagata, T. and H. Sasaki, 2002, A multi-agent approach to power system restoration. IEEE Transactions on Power Systems, 17(2): p. 457-462.

[10] Pipattanasomporn, M., H. Feroze, and S. Rahman, 2009, Multi-Agent systems in a distributed smart grid: design and implementation. IEEE/PES Power Systems Conference and Exposition, Vols 1-3, 1629-1636.

[11] Adibi, M.M. and R.J. Kafka, 1991, Power system restoration issues. Computer Applications in Power, IEEE, 4(2): p. 19-24.

[12] D.W Bunn, 2000, Forecasting loads and prices in competitive power markets. IEEE, 88(2): p. 163-169.

[13] Von-Wun Soo, Yi-Je Tsai, 2011, Finding Optimal Dispatch Schedule of Power Generation Using Locational Marginal Pricing in a Dynamic Market, AAMAS workshop ATES, p. 39-46.

[14] Stuart Russell, P.N., 2003, Artificial Intelligence: A modern approach. seconded.

[15] Sankaran, S. and T. Bui., 2004, A stochastic negotiation model for organizational choice. in System Sciences, 2004. Proceedings of the 37th Annual Hawaii International Conference.

[16] Levy, H. and H.M. Markowitz, 1979, Approximating expected utility by a function of mean and variance. American Economic Review, 69(3): p. 308-317.

[17] Anders Levander, L.N., 2007, A stochastic negotiation model. Gnosie, Stockholm.

[18] Von-Wun Soo, M.-S.T., Wan-Yu Yu, Yen-Bo Peng, 2010, Coordination of a society of agents for automatic distribution system restoration: toward a smart grid. 2010 International Conference on Technologies and Applications of Artificial Intelligence, p. 110-115.

[19] Men-Shen Tsai, 2008, Development of an Object-Oriented Service Restoration Expert System With Load Variations , Power Systems, IEEE Transactions on Volume: 23 , Issue: 1, p. 219 – 225