DESCRIPTION

POWER SYSTEM CONTROL SYSTEM AND CONTROL METHOD

TECHNICAL FIELD

[0001] The present invention relates to control system and control method for optimizing the system operation cost and CO2 emission quantity by the use of a multi agent in a power system having distributed power generators.

BACKGROUND ART

[0002] Recently, attempts are being made for utilizing, for an electric power system, a complex distributed generation system including an electric power generation system utilizing natural energy, such as solar power generation and wind power generation, and an output adjustable power generation system capable of adjusting the output, such as micro gas turbine generation, diesel generation, and fuel cell system, and an energy storage device (ECS: Energy Capacity System) composed of electric dual layer capacitors.

[0003] FIG. 17 shows a construction example of a stand-alone 6.6 kV distributed power system. Distributed power sources or distributed generators such as a diesel generation unit 11, a wind power generation unit 12, a solar or photovoltaic power generation unit 13 and an energy storage device (ECS) 14 composed of electric dual layer capacitors are distributed and connected with a distribution line 15. A reference numeral 16 denotes a

fixed load, and a reference numeral 17 denotes a variable load.

[0004] As the output adjustment method for the thus-constructed distributed generator system, there has been proposed technique of automatic generation control (AGC: Automatic Generation System) composed of several computers and a multi-agent system arranged to exchange information on frequency variation and information on output by the use of information transmission through a computer network (cf. a non-patent document 1 and a non-patent document 2, for example).

Non-patent document 1: Publication in Japan, Hidari, Hiyama, and Funabashi, "Application of multi-agent system to automatic generation control in stand alone system", 2002 Annual Conference of Power and Energy Society IEEJ, 2002. 8.7-9, Fukui University.

Non-patent document 2: Publication in Japan, Hiyama, Ezaki, Mori, Ono, and Funabashi, "Experimental Studies on Multi-Agent Based AGC for Isolated Power System including electric power storage system ECS" 2003 IEEJ National Convention, 2003.3.17-19, Tohoku Gakuin University.

DISCLOSURE OF INVENTION

[0005] In a system (distributed generator system) in which a plurality of distributed generators or distributed power sources are disposed, there are components of two types, components on the power supply side and components on the power consumption side. In order to control the system in an optimal manner most suitable for the cost and environment, it is necessary to operate the generators with optimal setting determined in accordance

with information on the generator output, characteristic and load consumption quantity. In this case, the central control is unable to deal properly with dynamic change in the equipment (the need arises for an enormous amount of changes in setting of the system). Therefore, the system adopts the method of using the multi-agent technique, and thereby causing the generators etc. to act autonomously and to cooperate with other components (negotiating a contract between the consuming side and the supplying side).

[0006] A protocol used in the contract is called a contract protocol, and it is possible to request a task to another agent by communication according to a process shown in FIG. 18. First, a contract initiating side or party (initiator) sends, to a responding side or m responding parties (responders)(m is the number of responding parties), the contents of the task to be requested as cfp (call for proposal) message. The responding parties (responders) send a refuse message in the case of rejection, and send a proposal message with an accepting condition (about the cost, for example) in the case of acceptance.

[0007] The contract initiating side (initiator) compares the accepting conditions of j propose messages (j is the number of propose messages) among n propose messages (n is the number of propose messages) which are received by a time limit (deadline), sends an accept-proposal message to the responder which is best among them, and requests the task by so sending the accept-proposal message. To the other responders, the initiator rejects the proposals by sending reject-proposal messages.

[0008] The responder to which the task is entrusted deals with the task, and sends a failure message in case of failure or a message of result (inform-result) or completion (inf or m-done) when the task is finished successfully. Thus, the sequence of operations of the net protocol is finished.

[0009] However, this contract net protocol is applicable only to the situation where the ratio of the contract initiating side and responding side is one-to-many. When the power supplying side and the power consuming side are initiator and responder (or responder and initiator, reversely), and a plurality of entities are involved in each of the power supplying side and consuming side, then a plurality of initiators must repeat the contract net protocol one after another.

[0010] In this case, the process is continued until all the initiators have completed the contract net protocol, and therefore, the process time for the overall optimization is too long. Furthermore, in the case of the contract net protocol between the power supplying side and power consuming side, the increase of the system scale increases the number of entities of the power supplying side and the number of entities of the power consuming side, and hence increases the communication load.

[0011] In consideration of this problem, the applicant of the present application has proposed control system and control method enabling high speed optimization control by reducing the process time of each of the agents, and decreasing the communication load in the distributed generator system using the multi-agent technique.

[0012] In this control, in the case of the general power system shown in FIG. 19, for example, a switch agent disposed in a section switch in the section separated by the section switch is used as an initiator, and agents provided in generator G, load L and downstream switch are used as responders, and the system performs the power supply-demand control of the distributed generator(s) and load(s) in the section and the downstream section by negotiating a contract of the power supply and demand by the use of the contract net protocol among these agents. This supply and demand contract process is as follows:

[0013] (Operation 1) The switch agent communicates with the load agent(s) in the section and the downstream switch agent (of the downstream section which is regarded as one power resource) or downstream switch agents, and receives information on the required power consumption quantity and wanted power purchase const.

[0014] (Operation 2) The switch agent determines the total power consumption quantity and a supply priority order based on the cost, in accordance with the collected information.

[0015] (Operation 3) The switch agent initiates the contract net protocol. The switch agent sends cfp messages to the generator agent(s) in the section and the downstream switch agent(s). The recipient agent(s) entering into the contract sends a table of generation cost, as a propose message, to the switch agent.

[0016] (Operation 4) The switch agent determines the output allotments so as to lower the total cost in accordance with the generation cost table(s) received from the in-section generator and/or other agent.

[0017] (Operation 5) The switch agent sends the generation output in the form of an accept-proposal message to the agent(s) in the section, and the generator agent(s) sets the output of the generator(s). In the case of the downstream switch agent, the message is utilized for optimization in the downstream section.

[0018] In this method, however, the switch agent performs all the major operations such as operations of collecting load information, and calculating generator output allotments. Therefore, the load is concentrated, and it is not possible to decrease the resource in which the switch agent is operated and not possible to perform the operations in parallel.

[0019] Similarly, the microgrid system encounters the same problems in the supply-demand process by the switch agent provided in the connection point switch.

[0020] It is an object of the present invention to provide distributed generator control system and control method for performing the supply and demand control in the power system in which distributed generators are installed, by the multi-agent, for preventing concentration of the major operations such as collection of load information and calculation of generator output allotments, on a specified agent such as a switch agent, for reducing the process time of the supply and demand control and for simplifying the process of each agent.

[0021] To solve the above-mentioned problem, according to the present invention: a section agent grasps a power flow quantity in a section separated by a section switch in a general power system, and requests adjustment for a flow variation quantity to a generator

agent or a downstream section agent; that generator or downstream section agent performs adjustment autonomously and respectively with other generator agent or downstream section agent; and these agents perform the supply and demand control of the distributed generators within the section and the downstream section by repeating a chain of these operations.

[0022] Furthermore, according to the present invention: a microgrid agent grasps a power flow quantity in a unit microgrid in a microgrid system, and requests adjustment for a flow variation quantity to a generator agent or a child microgrid agent; that generator or child microgrid agent performs adjustment autonomously and respectively with other generator agent or child microgrid agent; and these agents control the supply and demand balance in the microgrid and the child microgrid by repeating a chain of these operations.

[0023] Accordingly, the present invention is characterized by the following control system and control method.

[0024] (1) A control system for a power system in which distributed generators are introduced, the control system characterized in that

in a section separated by a section switch in the power system, a section agent disposed in one of a generator(s), a load(s) and a downstream switch(s) is set as an initiator, agents disposed in the generator(s) and load(s) in the section and the downstream switch(s) are set as responders, and a power supply and demand

contract is negotiated by the use of a contract net protocol among these agents,

the above-mentioned section agent is configured to grasp a power flow quantity, and to request adjustment for a flow variation quantity to the generator agent(s) or downstream section agent(s), that generator or downstream section agent performs adjustment autonomously and respectively with other generator agent(s) or downstream section agent(s), and there is provided means for performing a supply and demand control of the distributed generators in the section and downstream section by repeating a chain of these operations.

[0025] (2) A control system for a power system in which distributed generators are introduced, the control system characterized in that

in a unit microgrid in a microgrid, a microgrid agent disposed in one of a generator(s), a load(s) and a downstream switch(s) is set as an initiator, agents disposed in the generator(s) and load(s) in the section microgrid and the downstream switch(s) are set as responders, and a power supply and demand contract is negotiated by the use of a contract net protocol among these agents,

the above-mentioned microgrid agent is configured to grasp a power flow quantity, and to request adjustment for a flow variation quantity to the generator agent(s) or child microgrid agent(s) on the downstream side, that generator or child microgrid agent performs adjustment autonomously and respectively with other generator agent(s) or child microgrid agent(s), and there is

provided means for controlling a supply and demand balance in the microgrid and child microgrid(s) by repeating a chain of these operations.

[0026] (3) The control system is characterized in that

the generator agent is provided for each of the generators, configured so that several other generator and downstream section agents are preliminarily determined for optimizing adjustment, and provided with means for performing one-to-one optimization with each of the preliminarily determined other generator agent(s) or downstream section agent(s) when an optimization request is received from the above-mentioned section agent or microgrid agent; and

the above-mentioned downstream section agent is configured to estimate an electric power characteristic in the whole of the downstream section, and provided with means for performing one-to-one optimization with each of the preliminarily determined other generator agents in the downstream section or downstream section agent(s) when a request of optimization is received from the generator agent in the downstream section.

[0027] (4) The control system is characterized in that

the above-mentioned section agent or downstream section agent in the general power system or the above-mentioned microgrid agent or child microgrid agent in the microgrid system is set as a manager agent;

the above-mentioned generator or load agent is provided with means for serving as a proxy for the manager agent on the occurrence of abnormality of the manager agent; and

other generator or load agent is provided with means for serving as a proxy for the generator or load agent serving as the proxy for the manager agent on the occurrence of abnormality in the generator or load agent serving as the proxy for the manager agent.

[0028] (5) The control system is characterized in that the above-mentioned proxy is requested to the agent having a higher degree of importance in the system.

[0029] (6) A control method for a power system in which distributed generators are introduced, characterized in that:

a section agent or a microgrid agent is disposed in one of a generator, a load and a downstream switch in a section separated by a section switch, and agents are disposed in the generator and load in the section and a downstream switch;

the section agent or microgrid agent has

(S1) a step of determining several generators with which communication is to be performed,

(S2) a step of grasping a power consumption quantity in the section from a power quantity of power flowing through a switch,

(S3) a step of calculating an output adjustment quantity of a generator group,

(S4) a step of allocating the output adjustment quantity to the determined generators with which communication is to be performed, and

(S5) a step of returning to the step (S2) for repetition after waiting for a predetermined time; and

the generator agent has

(S11) a step of determining a number N of other generator agents with which communication is performed,

(S12) a step of waiting until a communication is received from other generator agent,

(S13) a step of sending a characteristic and current (or present) generation quantity of an associate generator which is the generator of the generator agent, to the agent from which a communication is received,

(S14) a step of receiving a set output value of the associate generator calculated by the communication partner,

(S15) a repetition step of returning to the step (S12) and waiting for communication from other agents when there is no change in the set output value,

(S16) a step of setting a communication partner number when there is a change in the set output value,

(S17) a step of receiving a generation characteristic and a current or present output from that communication partner,

(S18) a step of calculating an optimum generation quantity between the associate generator and the generator of the communication partner,

(S19) a step of sending the generation quantity to the communication partner,

(S20) a repetition step of returning to the step (S17) with a variable shift to a next communication partner for repetition until a predetermined last communication partner N is reached,

(S21, S22) a step of setting the generation quantity under charge of the generator agent itself and returning to the step (S12) for repetition when setting of the

generation quantity is finished for all the communication partners.

[0030] (7) The control method is characterized in that

the above-mentioned section agent or downstream section agent in the general power system or the above-mentioned microgrid agent or child microgrid agent in the microgrid system is set as a manager agent,

the above-mentioned load agent has a step (S31) of sending a load demand to the manager agent,

the above-mentioned manager agent has a step (S32) of making a generation request to the generator agent when the load demand is delivered, and a step (S33, S34) of making a proxy request to one generator or load agent having a higher degree of importance if no proxy request is made yet,

the above-mentioned generator agent has a step (S35) of performing an optimization process among the generator agents in response to the generation request, and

the generator agent or load agent has a step (S36) for the generator agent or load agent having received the proxy request, of checking the existence of the manager agent periodically, and a step (S37) of sending, to other agents, a message on assumption on the post of a proxy for the manager agent when the existence of the manager agent cannot be confirmed.

BRIEF DESCRIPTION OF DRAWINGS

[0031] FIG. 1 is a view showing a configuration example of a multi-agent system in a general power system, representing an embodiment of the present invention.

[0032] FIG. 2 is a view showing the environment of an agent.

[0033] FIG. 3 is a view illustrating a process among agents (part 1).

[0034] FIG. 4 is a view illustrating the process among agents (part 2).

[0035] FIG. 5 is a view illustrating the process among agents (part 3).

[0036] FIG. 6 is a view illustrating the process among agents (part 4).

[0037] FIG. 7 is a view showing a process flow of a section agent.

[0038] FIG. 8 is a view showing a process flow of a generator agent.

[0039] FIG. 9 is a view showing an example of a microgrid system.

[0040] FIG. 10 is a view showing an example of agent arrangement in the microgrid system.

[0041] FIG. 11 is a view showing an example of a characteristic of the generation output-the generation cost.

[0042] FIG. 12 is a view showing example of a relationship between the total generation quantity and the output variation.

[0043] FIG. 13 is a view showing an output adjusting operation (part 1) of the generator.

[0044] FIG. 14 is a view showing an output adjusting operation (part 2) of the generator.

[0045] FIG. 15 is a view showing an output adjusting operation (part 3) of the generator.

[0046] FIG. 16 is a view showing an output adjusting operation (part 4) of the generator.

[0047] FIG. 17 is a view showing a construction example of a distributed generator system.

[0048] FIG. 18 is a view showing a contract net protocol.

[0049] FIG. 19 is a view showing an example of agent arrangement in the general power system.

[0050] FIG. 20 is a view showing a process by a manager agent in a normal state.

[0051] FIG. 21 is a view showing a process by the manager agent on the occurrence of an abnormality.

[0052] FIG. 22 is a view showing an overall process flow in the normal state and the abnormal state.

[0053] FIG. 23 is a view showing a process by a load agent on the occurrence of an abnormality.

BEST MODE(S) FOR CARRYING OUT THE INVENTION

[0054] (1) Embodiment applied to general power system

FIG. 1 shows a multi-agent configuration for a general power system, representing this embodiment. In the general power system, there are provided many switches for safeguard against accident, etc. Among the switches, there are section switch(es) for isolating a specified section as shown in FIG. 19. When viewed downstream from a given section in the power system, it is possible to regard a section switch on the downstream side and following components as an electric power resource such as one generator or load. FIG. 1 shows one example in which a focus is on the most upstream section shown in FIG. 19.

[0055] In the multi-agent configuration, a group is formed for each section separated by the section switch(es), and optimization is performed in the section. Agent(s) are disposed in one section as shown in FIG. 1. A

section agent is provided in place of a switch agent shown in FIG. 19. Each of agents 1~4 operates in an environment of a computer as shown in FIG. 2. In this environment, the generator agent 2 is formed in a generator control terminal, and the load agent 3 is formed in a consumption measuring terminal. In the case of the section agent 1, the section agent 1 is arranged to operate somewhere in components in the section, and the location is not determined (somewhere in a power flow measurement terminal of a section switch, or a generator control terminal or a load measurement terminal in the section). The downstream section agent 4 is arranged to operate in one of components in the downstream section.

[0056] Hereinafter, each agent and processing function are explained in detail.

[0057] One section agent 1 is provided in a section, and the section agent has functions of grasping the agents in the section, collecting information on the power flow from load, switch and downstream section agents, and transmitting variation quantity of the power flow to the generator agent to request optimization.

[0058] One generator agent 2 is provided for each of generators and arranged to perform the following functions. Several partners or parties for optimization (generator agent and downstream section agent) are preliminarily determined or selected in advance. When an optimization request is received from the section agent, the generator agent 2 performs a one-to-one optimization with each of the preliminarily determined optimization partners or parties (another generator agent or downstream section agent). In this case, the generator

agent receives the generator characteristic from the partner or other party, and calculates the optimal allotment values only between its own side and the partner. In the case of an operation for optimization requested by another generator agent, the generator agent gives the generator characteristic, and receives the optimal value from the partner.

[0059] Load agent 3 sends power flow information in response to a request of the section agent.

[0060] Downstream section agent 4 estimates an electric power characteristic in the whole of the downstream section. Moreover, downstream section agent 4 performs the optimization in response to a request for optimization from the generator agent in the section. In this case, downstream section agent 4 gives the power characteristic in the whole of the downstream section to the partner or other party and receives the optimal value. Within the downstream section, downstream section agent 4 performs operations similar to the operations of the above-mentioned section agent.

[0061] FIG. 3 shows the agent configuration of FIG. 1 logically. In this configurations, as shown in FIG. 4, the section agent 1 regularly or periodically collects information on the power consumption quantity from the section switch, and the load and downstream section agents, and measures the variation of flow in this section. Normally, the section agent obtains the change or variation quantity of the flow through the section switch. Then, as shown in FIG. 5, the section agent 1 requests adjustment for the variation quantity, to the generator agent group 2. Thereafter, as shown in FIG. 6, the agents

of the generator agent group (and the downstream section agent) 2 perform one-to-one communication and thereby perform the optimization between two agents. Then, the agents further perform one-to-one communication with another agent, and achieve the optimization of the whole by a chain of optimizing operations.

[0062] FIG. 7 shows the process flow in the section agent, and FIG. 8 shows the process flow in generator agent 2.

[0063] In section agent 1, (S1) the number of the generator agents with which communication is to be performed is determined (for example, three generator agents for the first, second and third greatest outputs within the section). (S2) The power quantity (consumption) through the switch is obtained for grasping the in-section power consumption quantity. (S3) Output adjustment quantity of the generator agent group is calculated. (S4) The adjustment quantity is allocated to the preliminarily determined generators of the communication parties or partners. (S5) The section agent returns to the operation of S2 after waiting for a predetermined time or time interval, to repeat the operations.

[0064] In generator agent 2, (S11) several generators with which communication is to be performed are preliminarily determined (for example, three generators having outputs closer to a similar output within the section). The number of generators determined in this way is N. (S12) The generator agent 2 waits until the generator agent 2 receives a communication from another generator agent. (S13) The generator agent 2 sends the

characteristic and current generation quantity of the (associate) generator under its care to the agent from which a communication is received. (S14) Thereafter, the generator agent 2 receives the output set value of the (associate) generator under its care calculated by the communication party. (S15) Then, the generator agent 2 returns to S12 and waits for a communication from another agent in case of no change in the output set value.

[0065] When the generator output set value is varied, (S16) the generator agent 2 sets the variable n indicating the number of the communication party equal to one, n=1. (S17) Then, the generator agent 2 receives the generation characteristic and current output from the n-th communication party. (S18) The generator agent calculates the optimal generation quantity between the (associate) generator under its care and the generator of the communication party. (S19) The generator agent sends the generation quantity to the communication party. Thereafter, (S20) when the communication party is not the last party, that is when n is not equal to N ($n \neq N$), then (S21) the generator agent 2 varies (increments) the variable to the next communication party, and returns to step S17, repeatedly. (S22) When the setting of the generation quantity is finished for all the communication parties, the generator agent 2 sets the generation quantity in its charge. Then, the generator agent 2 returns to step S12, and waits until a next generation quantity variation.

[0066] Therefore, in the section separated by the section switch in the general power system as shown in FIG. 1, the section agent 1 grasps the power flow

quantity, makes an adjustment request for a flow variation quantity or flow increase/decrease quantity, to the generator agent 2 or the downstream section agent 4, and that generator agent 2 or downstream section agent 4 performs adjustment autonomously with another generator agent or downstream section agent. By repeating a sequence of these operations, the system can perform the supply and demand control among the distributed generators and the downstream section.

[0067] In this case, the system can prevent concentration of major processes such as collection of load information and calculation for generator output allotment, to a specified agent, shorten the processing time of the supply and demand control, and simplify the process of each agent.

[0068] (2) Embodiment applied to microgrid system

A microgrid system is connected with a general power system at a single connection point, and operated independently in order to achieve optimal performance in a portion following the connection point. FIG. 9 shows a configuration of the microgrid system which can take a nesting structure. A child microgrid connected with a parent microgrid closer to the power system can be regarded as an electric power resource, and called a child microgrid agent.

[0069] In the multi-agent configuration of the microgrid system, a group is formed for each microgrid unit as in the general power system, and the inside of the microgrid is optimized. In one microgrid, there are disposed the following agents, as shown in FIG. 10.

[0070] One microgrid agent 11 (corresponding to the section agent in the general system) is provided in a microgrid, and arranged to perform the following functions. Microgrid agent 11 grasps the agents in the microgrid, collects information on the power flow from load, connection point switch and child microgrid agents, and requests optimization by transmitting variation quantity of the flow to the generator agent.

[0071] One generator agent 12 is provided for each of generators and arranged to perform the following functions. Several partners or parties for optimization (generator agent and child microgrid agent) are preliminarily determined in advance. When an optimization request is received from the microgrid agent, the generator agent performs a one-to-one optimization with each of the preliminarily determined optimization partners or parties (another-generator agent or child microgrid agent). In this case, the generator agent receives the generator characteristic from the partner or other party, and calculates the optimal allotment values only between its own side and the partner. In the case of an operation for optimization requested by another generator agent, the generator agent gives the generator characteristic, and receives the optimal value from the partner.

[0072] Load agent 13 sends power flow information in response to a request of the microgrid agent.

[0073] Child microgrid agent 14 estimates an electric power characteristic in the whole of the child microgrid. Moreover, child microgrid agent 14 performs the optimization in response to a

request for optimization from a generator agent in the microgrid. In this case, the child microgrid agent 14 gives the power characteristic in the whole of the child microgrid to the partner or other party and receives the optimal value. Within the child microgrid, the child microgrid agent 14 performs operations like the above-mentioned microgrid agent.

[0074] Concrete operations of agents with respect to the microgrid system are the same as the operations explained in the explanation of FIG. 3 to FIG. 8 if the section switch is replaced by the connection point switch, the section agent is replaced by the microgrid agent, and the downstream section agent is replaced by the child microgrid agent.

[0075] Therefore, in the unit microgrid in the microgrid system as shown in FIG. 10, the microgrid agent grasps the power flow quantity, and makes an adjustment request for a flow variation quantity or flow increase/decrease quantity, to the generator agent or the child microgrid agent, and that generator agent or child microgrid agent performs adjustment autonomously with another generator agent or child microgrid agent. By repeating a sequence of these operations, the system can control the supply and demand balance and control the child microgrid.

[0076] In this case, the system can prevent concentration of major processes such as collection of load information and calculation for generator output allotment, to a specified agent, reduce the processing time of the supply and demand control, and simplify the process of each agent.

[0077] (3) Optimizing generation process between two generators (including the downstream section agent or child microgrid agent)

The following explanation is on an optimizing power generation process between two generators. For example, two generators have the following characteristic between the generation output and generation cost shown in Table 1 and FIG. 11.

[0078] [Table 1]

OUTPUT	COST OF GENERATOR A	COST OF GENERATOR B
0.0	0.100	0.300
0.1	0.199	0.325
0.2	0.294	0.360
0.3	0.387	0.405
0.4	0.476	0.460
0.5	0.563	0.525
0.6	0.646	0.600
0.7	0.727	0.685
0.8	0.804	0.780
0.9	0.879	0.885
1.0	0.950	1.000

[0079] From the above-mentioned graph, the outputs vary as shown in FIG. 12 when the total generation quantity of the two generators varies from 0.0 to 2.0. It is possible to determine the respective generator outputs by determining p making a sum f(p)+g(P-p) smallest where the total quantity of generation to be obtained by generator A and generator B is P, the generator characteristic and the generation quantity of one of the

generators A and B are f(x) and p, and the generator characteristic of the other generator is g(x).

[0080] (4) Example of output adjusting operation by multi-agent

[0081] Generators are operated as a whole in the following manner.

[0082] (a) As shown in FIG. 13, there are nine generators, and the generators are operated respectively in the optimal state (so presumed).

[0083] (b) A load consumption quantity is increased, and a section agent or microgrid agent obtains information about this increase of the consumption quantity and requests an appropriated generator agent or generator agents for adjustment to increase the generator output. In FIG. 14, the increase is requested to agents E3 and E7.

[0084] (c) Generator agents

E3 and E7 perform output adjustment with other agents which are contactable (next neighbors in this example). In FIG. 15, E3 adjusts the output with E2, and E7 adjusts the output with E8.

[0085] (d) Communication is further repeated, and overall adjustment is performed. In FIG. 16, the output adjustment is performed between E1 and E2, between E3 and E4, between E6 and E7 and between E8 and E9, and the system can improve the efficiency of the generator operation and reduce the CO2 quantity.

[0086] (5) Countermeasure against failure and stoppage of manager agent

As mentioned before, an autonomous distribution control by multi-agent is performed to the general power system as shown in FIG. 1 or the microgrid system as

shown in FIG. 10. In practice, however, each agent is not always completely autonomous or self-independent, but there is at least one agent (hereinafter referred to as a manager agent) undertaking a role of management. In FIG. 1, the section agent 1 or the downstream section agent 4 serves as the manager agent. In FIG. 10, the microgrid agent 11 or child microgrid agent 14 serves as the manager agent.

[0087] The overall flow of optimizing process of the system operation on the basis of the manager agent is as follows:

[0088] (Step a) In a specified area (an area between section switches or an area between connection point switches), the load agent sends power flow data in response to a request of the manager agent.

[0089] (Step b) In receipt of the flow data of the load, the manager agent makes a generation request to a generator agent.

[0090] (Step c) The requested generator agent performs a one-to-one optimizing calculation with a neighboring generator agent, and allocates optimal values.

[0091] (Step d) The optimizing calculation is further performed with an agent in the neighborhood, and optimal values are allocated.

[0092] (Step e) The operations of steps c and d are repeated until a settlement is reached within a predetermined range.

[0093] (Step f) Steps a~e are repeated in the downstream section or in the child microgrid.

[0094] In this way, the manager agent acts as a mediator between the generator agent and load agent in the

optimization process, and the manager agent can be regarded as a most important agent. Therefore, in case of a failure or stoppage of the manager agent due to some influence, the system becomes unable to carry out the optimization process on the downstream side in the case of the general power system and in the child's side in the case of the microgrid system, so that it becomes difficult to achieve the overall optimization of the entire system.

[0095] This embodiment is arranged to ensure the function of the optimization and guarantees the execution of the optimization even in the case of failure or stoppage of the manager agent. In outline, the function is secured in the following manner. At the time of occurrence of abnormality in the manager agent, a generator agent or load agent in the section or the microgrid acts as a proxy on behalf of the manager agent. If an abnormality occurs in the proxy agent acting on behalf of the manager agent, then still another generator agent or load agent acts as a proxy on behalf of the proxy agent acting as the manager agent. Thus, the system ensures the optimization process in the section.

[0096] In this case, a more important agent in the system is selected as the agent to which a proxy request is made. Namely, when the multi-agent is applied to the power system, it is considered that the importance of the generators is different in dependence on the type of the generator according to the operation mode. When, for example, the entire system is operated in the mode of economic efficiency, the generator which is low in the operating cost and high in generation quantity is used as a leading part for generation, and the generator having an

opposite characteristic is lower in the importance. When the system is operated in the mode placing greater importance on the environmental aspect, a greater weight is placed on the natural energy generation, and the ranking of the importance is determined according to the CO_2 emission or the like so that the generation of a smaller emission is more important. In this embodiment, the role of a proxy agent at the time of abnormality of the manager agent is assigned by utilizing the ranking of the importance of the generator agents or load agents.

[0097] FIG. 20 shows a concrete process flow in a simplified model at the time of execution of optimization process in each agent. This flow is as follows:

[0098] (a) The manager agent 1 receives load demands or load requests from load agents 3A~3C.

[0099] Manager agent 1 requests generation to generator agents 2A~2C. At the same time, manager agent 1 ranks the generator agents 2A~2C according to the generation mode, and sends a request message for proxy at the time of abnormality, to generator agent 2A having a higher priority or higher degree of importance.

[0100] (c) Generator agents 2A~2C perform optimizing process with other generator agents mutually.

[0101] When no message is received from the manager agent 1 during a predetermined time, the generator agent 2A having received the proxy request sends a message for confirming the life of manger agent 1, to the manager agent 1, and checks whether the manager agent is alive or not, by checking a reply from manager agent 1.

[0102] Thus, the generator agent 2A having received the proxy request from manager agent 1 performs the function

of monitoring the life of manager agent 1. In this example, on the assumption that generation requests are received periodically from manager agent 1, a time out value is set and the agent sends a life confirmation message when the time exceeds the time out value, and judges that the manager agent 1 fails or stops, if no reply is received.

[0103] FIG. 21 shows a securement process of the optimizing function on the occurrence of abnormality in the manager agent 1. The securement process is as follows:

[0104] (p) When no reply to the life confirmation message is received from the manager agent 1, the generator agent 2A serving as a proxy of manager agent 1 sends messages on the new post notifying the assumption or undertaking of the post of the manager agent, to the other generator agents 2B and 2C and load agents 3A~3C. At the same time, the generator agent 2A sends a proxy request to the generator agent (2B, for example) having the next priority in the ranking next to the generator agent 2A in preparation for the occurrence of abnormal failure or stoppage or separation from the system, of generator agent 2A itself.

[0105] (q) Generator agent 2A is set in a prepared state capable of receiving load demands from the load agents 3A~3C.

[0106] (r) Generator agent 2A performs an optimization process with other generator agents 2B and 2C when the load demand is received.

[0107] (s) If the generator agent 2A falls in a state incapable of performing the job, the generator agent 2B

having received the proxy request in advance serves as the proxy and takes over the job.

[0108] FIG. 22 shows an overall process flow combining the processes of FIG. 20 and FIG. 21. First, the load agent sends a load demand (S31), and the manager agent makes generation requests to the generator agents in response to this load demand (S32). In this case, if a proxy request is not yet made to the generator agent (S33), then the manager agent delivers a proxy request to one of the generator agents in accordance with the result of the ranking (S34). Then, the optimization is performed among the generator agents (S35). The generator agent having received the proxy request checks the existence of the manager agent by checking whether generation requests are received periodically (S36). When no messages are received, the generator agent sends a message of the assumption or undertaking of the proxy of the manager agent (S37).

[0109] Instead of the proxy of the manager agent by the generator agent, the load agent can serve as the proxy of the manager agent. In this case, the structure and flow of the process are the same as in the case of the generator agent. FIG. 23 shows a simplified model in which the load agent 3A assumes the post of proxy of the manager agent at the time of abnormality of the manager agent 1.

[0110] As explained above, according to this embodiment, the generator agent or load agent takes over (serves as the proxy) the job of the manager agent, and thereby the damage of the execution of the optimization is restrained low.

[0111] Thus, according to the present invention, in the section portioned by the section switch or the unit microgrid, the section agent or microgrid agent grasps the power flow quantity, requests adjustment for the flow variation quantity to the generator agents or downstream section agent, the requested generator agent or downstream section agent performs the adjustment autonomously with the other generator agent or downstream section agent. By repeating this sequence of operations, the system control the supply and demand of the distributed generators in the section and the downstream section. Therefore, the system can perform the supply and demand control of the power system including distributed generators with the multi-agent technique, and prevent concentration of major operations such as load information collection and allocating calculation of generator outputs to a specified agent such as the section agent.

[0112] Specifically, the algorithm of each of the agents is simplified. This leads to improvement in the ease of maintenance of the source code, and reduction of bugs.

[0113] The degree of autonomy of each agent is enhanced, the degree of parallel distributed processing is improved and the waist of the computation resource of each system component is reduced. Moreover, the processing speed is increased.

[0114] Moreover, at the time of occurrence of abnormality of the manager agent, the generator agent or load agent functions as the proxy of the manager agent, and thereby the system can maintain the function of the

optimization on the downstream side or the child's side without loosing the optimizing function in the whole of the system.

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CLAIMS

1. A control system for a power system in which distributed generators are introduced, the control system characterized:

in that, in a section separated by a section switch in the power system, a section agent disposed in one of generator, load and downstream switch is set as an initiator, agents disposed in the generator and load in the section and the downstream switch are set as responders, and a power supply and demand contract is negotiated by the use of a contract net protocol among these agents; and

in that the above-mentioned section agent is configured to grasp a power flow quantity, and to request adjustment for a flow variation quantity to the generator agent or downstream section agent, and the generator or downstream section agent is configured to perform adjustment autonomously with other generator agent or downstream section agent, respectively, and provided with means for performing a supply and demand control of the distributed generators in the section and the downstream section by repeating a chain of operations of the adjustment.

2. A control system for a power system in which distributed generators are introduced, the control system characterized:

in that, in a unit microgrid in a microgrid, a microgrid agent disposed in one of generator, load and downstream switch is set as an initiator, agents disposed in the generator and load in the section microgrid and the downstream switch are set as responders, and a

power supply and demand contract is negotiated by the use of a contract net protocol among these agents; and

in that the above-mentioned microgrid agent is configured to grasp a power flow quantity, and to request adjustment for a flow variation quantity to the generator agent or child microgrid agent on the downstream side, and the generator or child microgrid agent is configured to perform adjustment autonomously with other generator agent or child microgrid agent, respectively, and provided with means for controlling a supply and demand balance in the microgrid and the child microgrid by repeating a chain of these operations of the adjustment.

3. The control system as recited in Claim 1 or 2, characterized:

in that the generator agent is provided for each of the generators, configured so that several other generator and downstream section agents are preliminarily determined for optimizing adjustment, and provided with means for performing one-to-one optimization with each of the preliminarily determined other generator agent or downstream section agent when an optimization request is received from the above-mentioned section agent or microgrid agent; and

the above-mentioned downstream section agent is configured to estimate an electric power characteristic in the whole of the downstream section, and provided with means for performing one-to-one optimization with each of the preliminarily determined generator agents in the downstream section or downstream section agent when a

request of optimization is received from the generator agent in the downstream section.

4. The control system as recited in one of Claims 1~3, characterized in that:

the above-mentioned section agent or downstream section agent in the general power system or the above-mentioned microgrid agent or child microgrid agent in the microgrid system is set as a manager agent;

the above-mentioned generator or load agent is provided with means for serving as a proxy for the manager agent on the occurrence of abnormality of the manager agent; and

other generator or load agent is provided with means for serving as a proxy for the generator or load agent serving as the proxy for the manager agent on the occurrence of abnormality in the generator or load agent serving as the proxy for the manager agent.

5. The control system as recited in Claim 4, characterized in that the above-mentioned proxy is requested to the agent having a higher degree of importance in the system.

6. A control method for a power system in which distributed generators are introduced, the control method characterized:

in that, in a section separated by a section switch, a section agent or a microgrid agent is disposed in one of generator, load and downstream switch, and agents are disposed in the generator and load in the section and the downstream switch, respectively;

in that the section agent or microgrid agent has

(S1) a step of determining several generators with which communication is to be performed,

(S2) a step of grasping a power consumption quantity in the section from a power quantity of power flowing through a switch,

(S3) a step of calculating an output adjustment quantity of a generator group,

(S4) a step of allocating the output adjustment quantity to the determined generators with which communication is to be performed, and

(S5) a repetition step of returning to the step (S2) after waiting for a predetermined time; and

in that the generator agent has

(S11) a step of determining the number N of other generator agents with which communication is to be performed,

(S12) a step of waiting until a communication is received from other generator agent,

(S13) a step of sending a characteristic and current generation quantity of an associate generator which is the generator of the generator agent, to the partner agent from which a communication is received,

(S14) a step of receiving a set output value of the associate generator calculated by the communication partner,

(S15) a repetition step of returning to the step (S12) and waiting for communication from other agents when there is no change in the set output value,

(S16) a step of setting a communication partner number when there is a change in the set output value,

(S17) a step of receiving a generation characteristic and a current output from that communication partner,

(S18) a step of calculating an optimum generation quantity between the associate generator and the generator of the communication partner,

(S19) a step of sending the generation quantity to the communication partner,

(S20) a repetition step of returning to the step (S17) with a variable shift to a next communication partner for repetition until the preliminarily determined last communication partner N is reached,

(S21, S22) a repetition step of setting the generation quantity under charge of the generator agent itself and returning to the step (S12) for repetition when the setting of the generation quantity is finished for all the communication partners.

7. The control method for the power system as recited in Claim 6, characterized in that:

the above-mentioned section agent or downstream section agent in the general power system or the above-mentioned microgrid agent or child microgrid agent in the microgrid system is set as a manager agent;

the above-mentioned load agent has a step (S31) of sending a load demand to the manager agent;

the above-mentioned manager agent has a step (S32) of making a generation request to the generator agent when the load demand is delivered, and a step (S33, S34) of making a proxy request to one generator or load agent having a higher degree of importance if no proxy request is made yet;

the above-mentioned generator agent has a step (S35) of performing an optimization process among the

generator agents in response to the generation request; and

the generator agent or load agent has a step (S36) for the generator agent or load agent having received the proxy request, of checking the existence of the manager agent periodically, and a step (S37) of sending, to other agents, a message on assumption on the post of a proxy for the manager agent when the existence of the manager agent cannot be confirmed.