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AN IMPROVED SIMULATED LOAD FREQUENCY CONTROL SYSTEM USING DEMAND SIDE CONTROLLABLE LOAD FOR SMART METERS

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ABSTRACT

The current perspective of power system control has changed as network technology has developed and renewable energy has emerged as a significant source. Smart meters will be essential to electricity networks in the future. Demand will have a big influence on system stability if there is a power outage. Traditionally, generating units are in charge of reestablishing system frequency following an unexpected power outage. This approach increases emissions of the greenhouse gas carbon dioxide and is time-consuming and expensive. The technology is more stable since conventional generators cannot keep up with the demands of a smart metre. The first and most important task is to comprehend how these new technologies operate. A Matlab/Simulink model for a load frequency control system with demand-side control via the smart meter is presented in this work. The load frequency control system can be improved by using demand-side control, according to the simulation.
Keywords—controllable loads; demand-side; Great Britin; load frequency control; smart meters

INTRODUCTION

A centralized power grid has long been in charge of managing the electricity produced by large central power facilities. Technologies for renewable energy now present new challenges. Power instability may result from the unexpected loss of renewable energy sources [1]. Fortunately, current advancements in computing and communication technologies can offer trustworthy and affordable solutions that aid in raising the reliability of the power system. Future energy systems must be open and decentralized [2]. The load frequency management in a centralized power control system is one of the primary problems [3]. As a result, the power infrastructure needs to be flexible enough to meet shifting customer demands. The cost of this generated power at peak demand will rise as a result of dynamic pricing. Renewable energy penetration is also expected to rise in the near future [1]. As a result, the control system for the electrical grid will be under increased stress. Load control is an important consideration in the generation-demand game, according to the authors in [4].Load frequency control has been an old challenge in centralized power systems for decades [5]. Load frequency control has three primary objectives: 1) to maintain a constant frequency, 2) to distribute the load among the generators, and 3) to regulate the time at which the tie-lines interchange. There has been a centralized implementation of automatic generation control (AGC) and load frequency control (LFC) ever since the integrated power system began [7]. The AGC uses the frequency deviation to detect changes in load demand when determining the load frequency. The AGC signals are transmitted via a specific communication channel in the AGC. Alternative communication channels, such as telephone lines, are used in the event of a failure of the primary

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communication channel [8]. As the number of supplementary services grows, so does the requirement for a duplex and dispersed communication link. The Area Control Error (ACE) and Generator Control Error (GCE) signals are distributed throughout the various areas of the classical power system in order to ensure that the frequency stays within the allowed range. The generated power can be increased or decreased by using the ACE or the GCE. Smart metres could be utilised to switch controllable loads in an emergency [9]. Smart metering's introduction has the potential to improve the efficiency and dependability of the power grid while also lowering emissions of greenhouse gases. It's estimated that the UK will have installed some 20 million smart metres by 2020. New energy metres, known as "smart metres," are used to track and record data about how people use energy [10]. For both customers and operators, access to this information is provided. We'll be able to monitor the electrical grid at all times thanks to smart metres. The load characteristics are also included in this section. Customers will have access to dynamic pricing information via smart metres, allowing them to reduce peak demand and achieve load shaving. In the event of a power outage, the smart metres can also be utilised to disconnect the loads. The importance of smart metres in regulating load frequency has been emphasised by a number of authors. A model of the smart metre as a load controller is presented in this paper using Matlab/Simulink. A demand-side control load frequency model for the United Kingdom's (GB) power system is used to begin the article. A few examples of controlled loads are then given. We must comprehend the impact on system performance 978- 1-5090-6751-0/13/$31.00 2017 IEEE frequency control system performance through the use of modelling. Model of load frequency control system with adjustable loads and communication delays is shown here. [Show more...] Computer simulation is used to verify the loads controllers' functionality.Load frequency regulation aims to achieve the following objectives:2) Distribute the load between the generator and the fans to keep the frequency constant.the generators, and 3) control the tie-line changeover scheduleAutomatic Generation Control (AGC) and the Load Implementation of Frequency Control (LFC) the interconnected system has had a centralised administration since its inception[7] Power supply system The AGC is responsible for achieving the load frequency.It makes advantage of the difference in frequency deviation to monitor the loading requirements. specialised communication channels exist in the AGC.The AGC signals are transmitted using this method. In the event of an error,in addition to the specialized communication channel, there are also alternative forms of communication. voice communications over telephone lines are the most commonly employed method.The number of supplementary services has expanded as a result of this.a need for dispersed and duplex communication[8] becomes more noticeable Power was distributed in a more traditional way inthe classical power structure. To ensure that the frequency will be within the acceptable range. Error Limit (EL) and the Area Control Error Distribution of Generator Control Error signals (GCE) communication between the various places networks. employ the ACE and the GCE in order to raise or raise reduce the amount of power generated. According to the proposal, in the future emergency Switching the electricity supply will be done by the smart metres. Loads that can be controlled. This technology is known as "smart metres."can improve the efficiency, reliability, and security of electric power systems.CO2 emissions are reduced. For instance, the United Kingdom intends to By the year 2020, you should have installed 20 million smart metres. The term "smart metres" refers to energy is being measured in a new way by modern equipment. The data [10]. These details are at the disposal of anyone who desires them.operators and customers. Real-time data will be provided by smart metres.The electricity system's current time. In addition, this covers the data about the nature of the load As a result of smart metres, The continuous information that customers need a pricing strategy that can assist reduce peak demand and achieve efficiency Load reduction. Smart metres can also be utilised for the following purposes: In the event of an emergency, remove all electrical connections. According to a number of authors,analysis of load frequency and the role played by smart metres control. Models for Matlab/Simulink are presented in this study.the smart metre acting as a load regulator. The document has a section dedicated to describing how often the loads are applied control from the consumer side, where the United Kingdom (UK) has the most influence As a case study, the system is used. the loads that can be controlled a few words are used to characterise them. In order to get the best results, it's crucial to use a modelling programme. understanding the load's response to various parameters control system efficiency in reaction to many criteria, such as load frequency. Prototype of load frequency control system with adjustable loads and communication delays is shown here. [Show more...] Computer simulation is used to verify the loads controllers' functionality.

METHODOLOGY

Load Frequency With Demand-Side Control

Figure 1 depicts the frequency response of the UK grid.50–0.5 Hz [9] and [11] are permissible frequencies in the United Kingdom. The frequency must fall in the range of 50 to 0.2 Hz for normal operation. Within 1 min, the frequency shall not fall below 49.2 Hz if the maximum load loss of 1320 MW happens. Fossil fuel generators are responsible for this task. The highest generation loss in the national grid scenario "Gone Green" is 1800 MW [11]. The generators in a traditional LFC system reactto variations in frequency. The generators are slow when compared to the loads. The load can be turned off in a matter of seconds. To make matters more complicated, the manageable loads are dispersed over the grid. Renewable sources will make up a large portion of the world's electricity supply in the future. The variable nature of renewable energy sources allows for rapid response times.

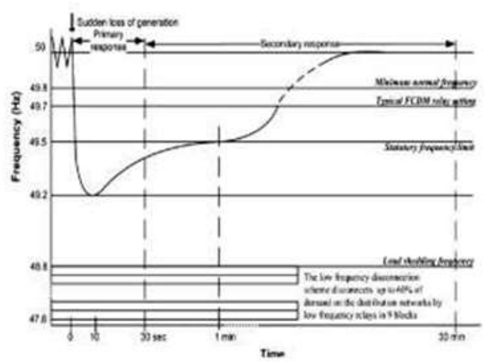

Fig. 1. Frequency response in the UK grid

The reliability of the electricity grid becomes a concern at such a high level of renewable energyconsumption. When the frequency goes below a specific threshold, load shedding is enabled in the typical LFC system. Load shedding decouples theentire region, resulting in customer unhappiness. Controllable loads can provide better performances where the loss is only partly noticeable and in many cases it is completely unnoticeable.

The Controllable Loads

Controllable loads include household equipment suchas refrigerators, air conditioners, in-line heaters, cooktops, and computers. As a result of theirprojected future use as regulated loads, energystorage, V2G, and heat storage systems, among others, Centralized, centralized, or decentralized control strategies can all be used for load control[13]. To compete with established power system control, the created control should always be developed [14]. The LFC must also be responsiveand quasi through load control [14] in order to be effective. Controllable and non-controllable loads aretwo types of electrical loads. For peak shaving, voltage stability, and frequency balancing, adjustable loads can be used. The three categories of controlled loads are Type I, Type II, and Type III. Vehicle-to- grid (V2G), energy storage and cogeneration (CHP) units are under Type II, whilst microgrids and virtualized power plants go under Type III. Using the smart metre, the frequency of the load can be measured and controlled, as shown in [9]. As stated in [9], the weights are broken down into five categories. In Fig. 2, an example of a standard power system with variable loads is illustrated.

Fig. 2. Smart meter with controllable load

For the purposes of Table I, the important operations and features of the loads are grouped together. Fig. 3 depicts the process flow diagram for the load frequency control technique as it pertains to the controlled loads. The load is detached from the system if the frequency falls under the switch-off frequency (FOFF) for a certain load category. For a period of time, the load is disengaged, which is known as the Off Time (TOFF). This is followed by a check to see if there's an increase in frequency above what's considered the switch on frequency (FON). The observation period begins here (TM).During the same time, if the frequency isn't recovered, the load should be kept detached for a period known as the delay period (TD). Loads with a lower priority are disconnected and rejoined after a random time delay (TR) [9]. Figure 4 depicts the controllable load's graph.

TABLE I. THE TYPES OF THE LOADS AND THEIR PRIORITIES

Load Type	Appliances	Priority
Type I	Electric space, water heaters, refrigerators, and freezers	Lowest
Type II	Washing machines and tumble dryers	↓
Type III	Cooking appliances	↓
Type IV	Inline heaters	↓
Type V	Lighting loads	Highest

Fig. 5. The Simulink implementation of the load controller

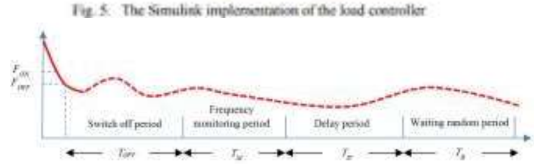

Fig. 4. The load controller timing diagram

Listed in Table II are the switching frequencies and load control timings. Fig. 3's technique in Matlab/Simulink is used in the modelling. Controllable load and mask are both presented in Fig.5.

TABLE II. LOAD CONTROL TIMING AND SWITCHING FREQUENCIES

	F_{OFF}, Hz	F_{ON}, Hz	T_{OFF}, (s)	T_M, (s)	T_D, (s)	T_R, (s)	T_T,
Type I	49.7	49.8	30	150	90	30	5 min
Type II	49.5	49.7	30	90	60	30	3.5 min
Type III	49.3	49.5	30	30	30	30	2 min
Type IV	49.0	NA	10	0	0	5	15 (s)
Type V	48.9	NA	2	0	0	2	4 (s)

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The Model Of The Load Frequency ControlSystem With Controllable Load

Figure 6 shows the simplified LFC system concept for the United Kingdom with controllable loads. There is a 0.2-second governor time constant (Tg), two-second lead-lag compensator time constants (T1 and T2), a governor droop control gain (Req), a three-second turbine time constant (Tt), and a one- second damping constant (D) for each of these variables. Heq is the corresponding inertia of the Great Britain power system (9 seconds)

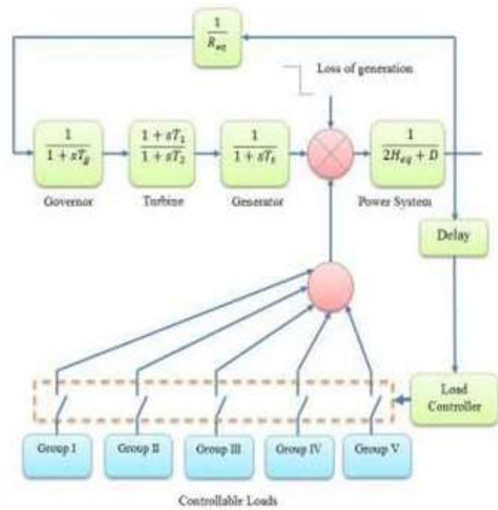

Fig. 6. The simplified GB power system model with controllable load

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RESULTS & DISCUSSION

Figure 7 depicts the Simulink implementation of the GB power system with configurable loads. If you lose all of your energy, you'll lose 1.32GW of it. Since wind energy penetration is likely to rise in the future, the loss of a generating unit might reach 1.8 GW [9]. The GB power system's corresponding inertia now stands at 9 s, although this is predicted to drop to 3 s as wind power generation rises. As can be seen in Fig. 8, the frequency response changes with loss generation and inertia. The very worst situation is a loss of 2.5 GW of production. There could be a wide-ranging load-shedding response, specifically if the wind turbines are to blame for the loss of generating of 2.5 GW, as depicted in Figure 8. It is carried out in order to verify the operation of the load controllers. Frequency response with 2.5 GW loss of generation and 3 s corresponding inertia shown in Fig. 9. They are the non-critical loads, and they are the first to be disconnected because of their frequent switch-offs. Increased loads are removed as the frequency decreases. It's imperative that the inlineheaters and lights are the last things to be wired up. Loads are rejoined in accordance with their switch-onfrequency following the chosen blocking duration, as seen in Figure 10. In terms of blocking time, lighting and in-line heaters are the most efficient. Types I, II, and III wait between 2 and 5 minutes to re-establish aconnection.

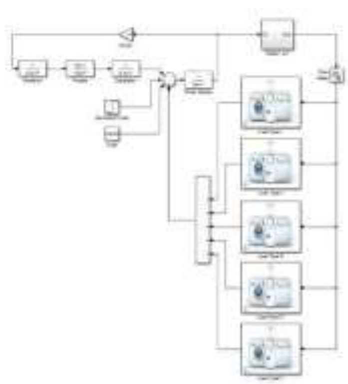

Fig. 7. The Simulink implementation of the load frequency control with controllable loads

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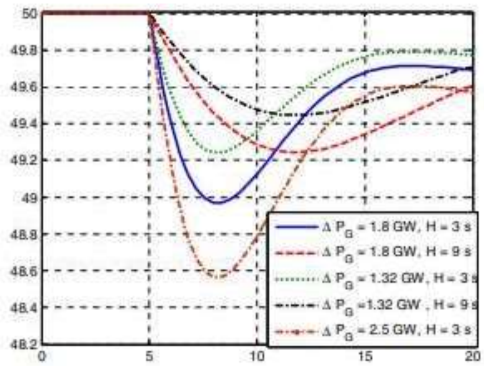

Fig. 8. The frequency response with different inertia and generation loss

It is possible to rejoin the loads automatically shouldthe frequency rise while they are being monitored.

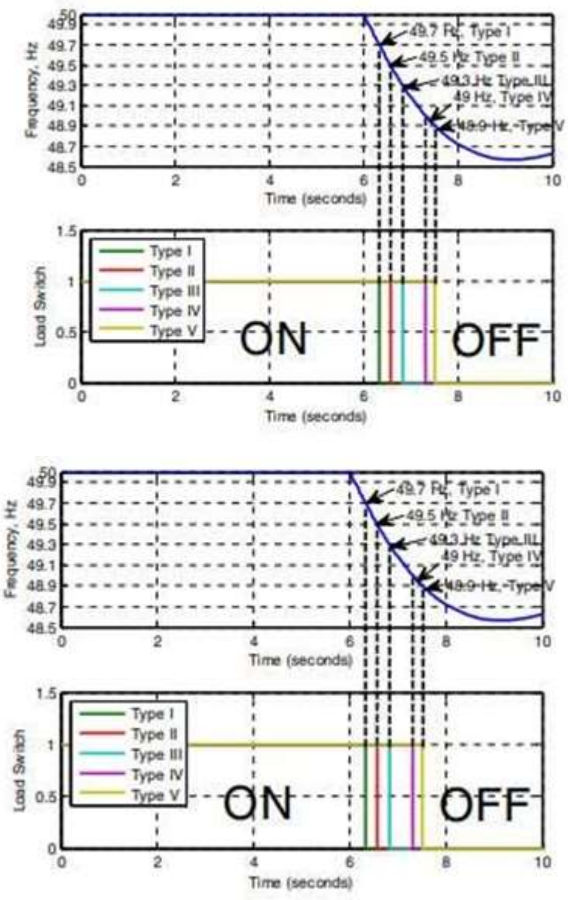

Fig. 9. The load during the disconnection

this can help the load frequency control system workbetter in an urgent situation. Figure 11 depicts the frequency control system for loads either with or without controllable loads. Increased frequency response and decreased unjust wide-range load shedding were made possible because to the regulated loads.

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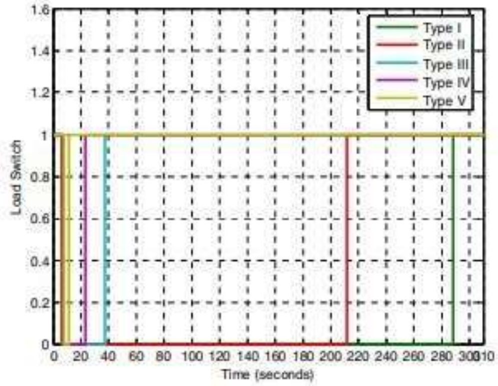

Fig. 10. The load during the reconnection

Figure 12 depicts the modifiable loads. Load types I, II, and III were disconnected as aresult of the loss of generation. Because the frequency is still greater than the switch-off frequency of Type IV and V, they do not disconnect from the network. Realistically, however, when the frequency decreases, the remaining generators attempt to maintain a stable frequency by using the secondary control. Load frequency control system with controllable loadis depicted in Fig. 13. The PI controller, with gains ofKp=0.01 and Ki=0.05, is used for secondary control. Fig. 14 depicts the frequency response with secondary load frequency control and controllable load.

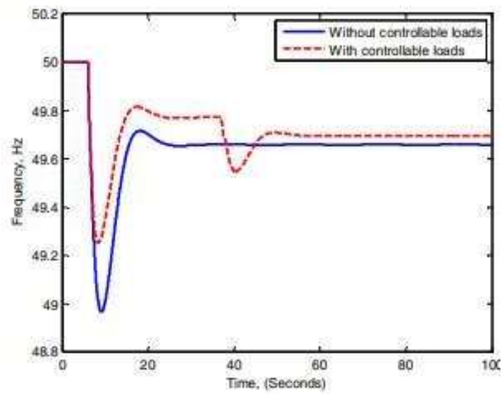

Fig. 11. The frequency response with and without controllable load

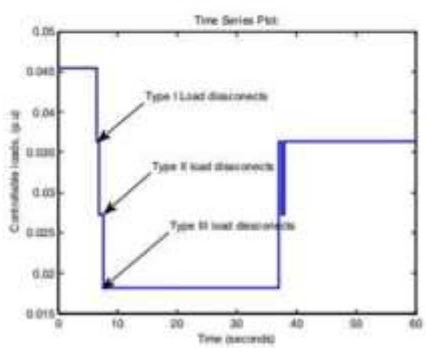

Fig. 12. The blocked loads

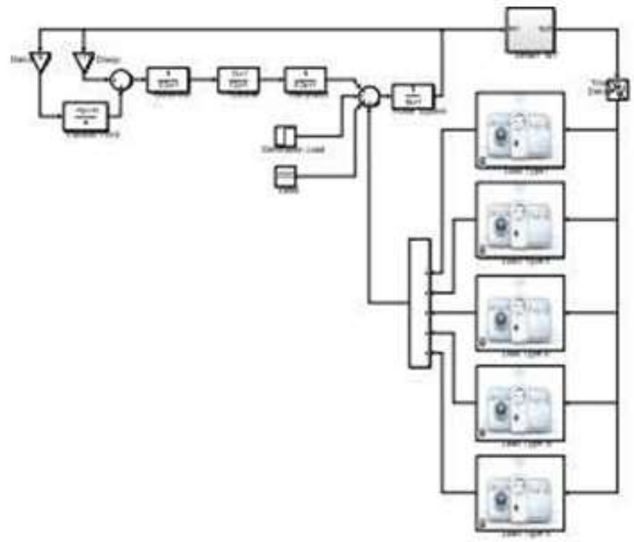

Fig. 13. The load frequency control system with controllable load

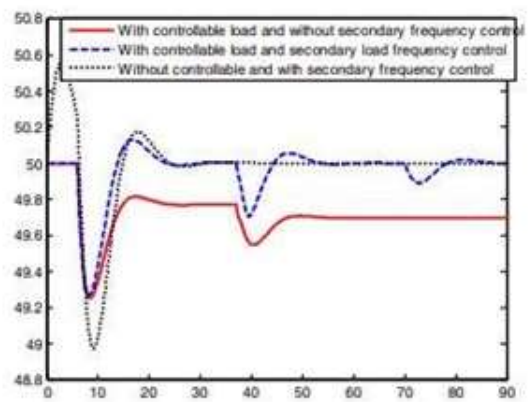

Fig. 14. The frequency response with secondary control and controllable loads

Load frequency control systems with adjustable loads perform better, as seen by Fig. 14. The frequency stays within the acceptable range, however it is deflected from 50 Hz.Because the secondary control takes longer to recover the frequency, the frequency drops to roughly 49 Hz when just secondary control is used. In addition, more gasoline will be consumed, resulting in higher CO2 emissions. System instability can occur when control signals are transmitted across a communication network [16]. The LFC system with controlled loads can be treated as a networked control system by incorporating the wireless time delay into the system model [17]. In this instance, it is necessary to compute the system's maximum delay bound [18]. The amount of failures in a wireless network can be rather large, and the controller should be designed to take this into mind [19]. The dynamic model of the controllable loads should be taken into consideration for future research. If the controllable loads are not switched off at the same time for a certain load type, further enhancement should be made to the current algorithm.

CONCLUSIONS

There is a very high expectation of substantial generation loss due to the increased penetration of renewable energy, particularly wind energy. Smartmetres can play a significant role in regulating demand. The smart metre and load frequency control system modelling are discussed in this study. A simulink model for the frequency of the load with an adjustable load is shown. There are 5 types of controlled loads, each with its own unique set of features. The load frequency control system can benefit considerably from the use of controlled loads, according to simulations. They can prevent unfair load shedding by acting quicker generators than are controllable.

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