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主 論 文 の 要 旨

論文題目 Feedback Control of Multiple Machines using Narrowband Power Line Communication（狭帯域電力線通信を用いた複数機器フィードバック制御）

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論 文 内 容 の 要 旨

Up to now the field of communications for control has not been thoroughly explored. Classic control theory generally does not take into account what happens in the communication channel linking the main components of the control system, the controller and the plant. Between these two elements lies a communication channel in which disturbances such as noise and interference can occur. These disturbances may corrupt the information being exchanged between the controller and the plant, thus impairing the capacity to effectively control the plant.

In physical terms, the communication channels joining the controller and the plant may be a set of dedicated cables, which is the most common case, or wireless channels, among others. Recently there is a growing interest in wireless for control because of its ease of implementation and scalability and its relative low cost. However, due to the unreliable nature of wireless channels, this technology has not become so widespread in critical control applications. Another alternative which is the one explored throughout this work is that of existing power transmission cables inside buildings and all over the public electric grid. Unlike dedicated cabling, power lines are already installed for electric transmission purposes, so this presents a cost-effective alternative and one which may offer improved reliability, especially when compared to wireless channels. Transmission of information along with power signals is an old technology dating from the beginning of the 20th century.

Power line communications (PLC) can be divided into two main categories, broadband power line communications and narrowband power line communications. Broadband PLC makes use of a wider portion of the electromagnetic spectrum than narrowband PLC, thus higher transmission speeds are possible. However, broadband PLC has a potential to interfere with other communication systems and its short range of communication limits it to indoor use.

Narrowband PLC on the other hand, uses a thinner portion of the electromagnetic spec-

trum; therefore data transmission may be rather slow. However, narrowband PLC also has a lower potential for interference with other systems and its longer propagation range makes it more suitable for outdoor use than broadband PLC.

Aside from the spectrum usage and interference considerations, PLC possesses another remarkable feature and that is the somewhat deterministic nature of its noise and attenuation. Taking this fact into consideration, communication schemes of predictive nature may be applied to improve the overall performance of a PLC system. In this work such a feature is taken into consideration in order to improve the delivery of control commands to and from the plant.

In a feedback control system, specifically, there exists a so called feedback loop between the controller and the plant. Under ideal conditions, the commands sent from the controller to the plant and the state information transmitted from the plant to the controller are considered to be undisturbed and uncorrupted by the channel, therefore error detection and correction techniques typically considered in communication theory are disregarded. In real world conditions, however, disturbances occurring in the feedback loop and in the plant itself may corrupt the control commands and deteriorate the overall performance of the system. From the viewpoint of control theory, improvements in the controller to consider disturbances in the system may help improve the performance, however these measures may not suffice and the need to consider communication theory techniques may be necessary for optimization. This work makes use of a simple control system and intends to perform optimizations from the viewpoint of communications theory by observing the necessities of the plant.

In the first part of this work, the basic structure of a feedback control system is explained together with the inclusion of the communication channel connecting the controller and the plant. The type of controller and plant chosen for this work are also explained here. In chapter three, the basic features of PLC are explained. Noise and attenuation in PLC present dominant cyclic features. In this work these features are thought of as good and bad alternating channel conditions to transmit information, or in other words periodic low and high noise instants respectively. In the fourth chapter, the way in which the noise and attenuation in PLC affect the effectiveness of control and a way to evaluate the quality of control are explained. The evaluation methods used throughout this work are mainly to rate the stability and accuracy of the control system to assure an overall control quality.

In chapter five the application of a predictive control scheme is shown to be effective in the improvement of the control quality when conditions in the communication channel are bad. However, a floor in the performance of the system shows that further improvements in control quality must be done from the control theory viewpoint, by applying a more advanced controller for example. Later in chapter six the introduction of more plants (multiple machines) to the system poses the issue of multiple access to the communication medium. A simple periodic reorganization of the order in which plants are served in the time domain, proves to be effective in assuring the same control quality to all machines. However, this fair access does not necessarily provide good control quality to all machines. As shown in chapter five, an improvement from the viewpoint of control theory may be necessary to improve the overall control quality.

Concluding this work, it was observed how the cyclic features of PLC affect control quality and how these features can be used to improve the quality of control. However, it was noticed that further improvements may be achieved from the control theory point of view to mitigate the effects of disturbance in the plant. In the case of multiple machines, it was shown that both the control and the channel present cyclic features, therefore a cyclic time access scheme was effective.