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Rapid-convergent sliding mode proportional-integral technology with fuzzy gain scheduling for hydrogen energy applications

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ABSTRACT

This paper presents a rapid-convergent sliding mode proportional-integral (PI) technology with fuzzy gain scheduling for hydrogen energy applications. The rapid-convergent sliding mode control can provide insensitivity to system uncertainties and finite system-state convergence time to origin, however undesirable chattering behavior exists. The proposed technology utilizes the expansion of the plant model for designing the formation of a rapid-convergent sliding mode PI control and then the chatter is remarkably lessened. Moreover, a fuzzy gain scheduling assists in tuning the PI control parameters against uncertain disturbances. Simulations show that the presented hydrogen energy system leads to low distorted output-voltage under nonlinear load and fast transience under step-load change. Lab experiments obtained with a developed hydrogen energy system using a digital signal processing algorithm have been offered to demonstrate the performance improvement, especially in the presence of seriously nonlinear circumstance. In contrast with the proposed hydrogen energy system, the classic sliding mode-controlled hydrogen energy system has also been evaluated via both simulation and experiment.

Introduction

Hydrogen energy has received increasing attention, and been extensively applied in clean energy systems, such as solar hydrogen energy systems, wind hydrogen energy systems, geothermal hydrogen production systems and the like [1–10]. In above-mentioned systems, the overall performance is dependent upon the static inverter-filter arrangement, which is used to convert a DC voltage to a sinusoidal AC output. The requirements for a reliable hydrogen energy DC–AC inverter usually provides slight distorted output waveshape under nonlinear loading, fast transience under sudden change in loading and almost zero steady-state errors; these can be obtained by employing feedback control techniques. Early works on the inverter control can be found that include deadbeat control, repetitive control, and multi-loop control [11–13]. Nevertheless, hard implementation and complicated calculation occur. PI controller is widely used in industrial control systems due to its simple structure and ease of design; however, under high system uncertainties it cannot provide good control performance unless the model is modified [14–16]. The rapid-convergent sliding mode control is capable of making a control system robust with regards to system uncertainties and allows finite system-state convergence time to origin [17–19]. A number of rapid-convergent sliding mode control schemes have been developed for the inverters [20–23]. As previously remarked, though transience and

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steady-state response are improved, chatter exists. The chatter generates needless extremely nonlinear system dynamics, thus destroying transistor elements. Even the chatter occurring at rapid-convergent sliding mode controlled hydrogen energy system incurs a large amount of harmonic distortion. For the reduction of the chatter, this paper proposes the expansion of the plant model for the purpose of designing rapid-convergent sliding mode PI construction. The construction consists of lesser powered location and higher powered location. Within lesser powered location, a hydrogen energy DC–AC inverter will be unharmed to the controlled plant when the chatter exists. In contrast, the chatter occurring at higher powered location is unallowable due to probable injury of transistor elements, that is to say the chatter forbids appearing at rapid-convergent sliding mode output termination (plant input termination). More specifically, as illustrated in Figs. 1 and 2(a), the energy level can be found in the output termination of classic control technology; thus a lesser powered location can be regarded as energy level's input and a higher powered location stands for energy level's output. Once classic sliding mode control is employed to hydrogen energy DC–AC inverter, the unwanted chatter will be excited at higher powered location. For chatter reduction, the plant model with an expanded integrator can be redesigned into rapid-convergent sliding mode control. In Fig. 2(b), the expanded plant model includes an integrator, a prime plant and an energy level. Starting now, the chatter arises in integrator input termination, i.e., it lies in lesser powered location with the harmlessness. Therefore, there will be no chatter at higher powered location due to high operating frequency in rapid-convergent sliding mode output termination without delayed occurrence. Nevertheless, while a highly uncertain disturbance is applied, it is hard to determine proportional-integral parameters of the proposed technology, as a result, good hydrogen energy DC–AC inverter performance cannot be guaranteed. Fuzzy control belongs to the field of artificial intelligence [24–28] and has successfully been used in a wide variety of applications [29–31]; it also utilizes facts and rules to gain human knowledge in the controlled system well, such as solar energy systems, wind energy systems, and fuel cell energy systems [32–34]. For this reason proportional-integral parameters can adaptively be determined via fuzzy gain scheduling in the presence of highly uncertain disturbances. While a hydrogen energy DC–AC inverter via proposed technology is created, the system performance will be enhanced, such as lower total harmonic distortion (THD) with nonlinear circumstance and faster transience with step change in load. The organization of the paper is provided in the following: "Control technology design" Section illustrates presented hydrogen energy DC–AC inverter. "Simulation and experimental results" Section gives simulations and experiments. Conclusions represents as "Conclusions" Section.

Control technology design

Fig. 1 shows the hydrogen energy DC–AC inverter; it is composed of inductor-capacitor filter and load resistance. The hydrogen energy DC–AC inverter can generates an AC waveshape through the control of transistor switches to create

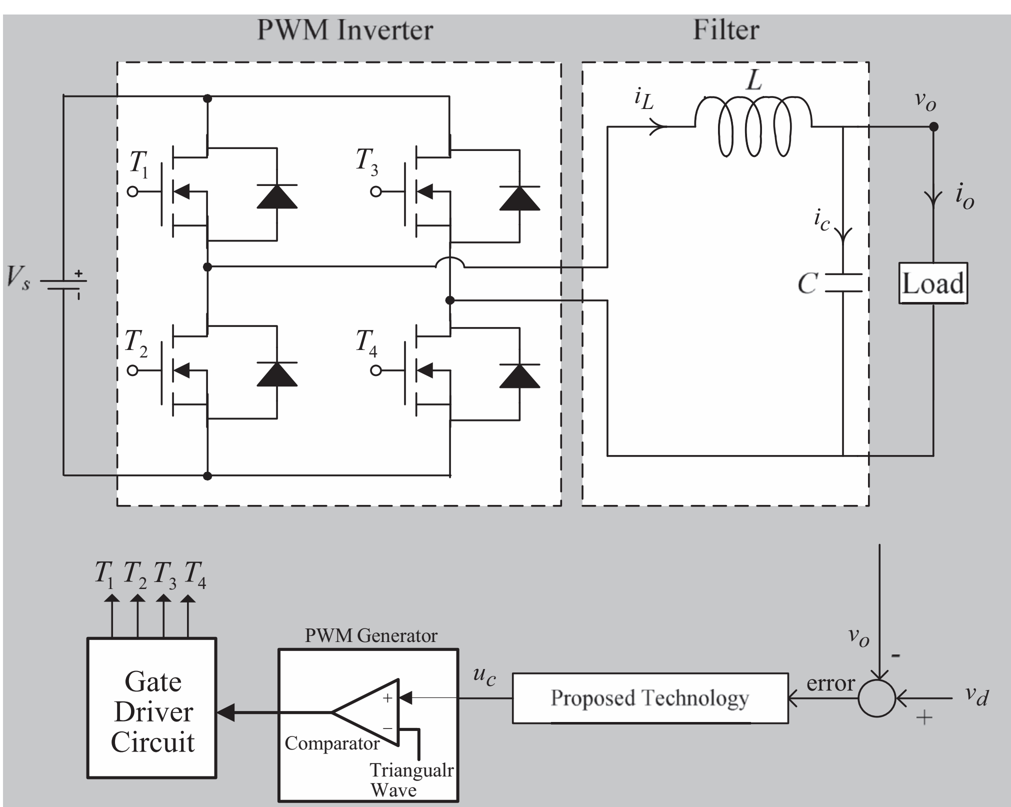

Fig. 1 – Circuitry of hydrogen energy DC–AC inverter.