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Modeling and Implementation of a Hierarchical Safety Controller for Human Machine Collaboration

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Abstract : This paper primarily describes the concept of a hierarchical safety control (HSC) in discrete manufacturing to uphold productivity with human intervention and machine failures using a systematic approach, through increasing the system availability and using additional knowledge on machines so as to improve the human machine collaboration (HMC). It also highlights the implemented PLC safety algorithm, in applying this generic concept to a concrete pro-duction line using a lab demonstrator called FATIE (Factory Automation Test and Integration Environment). Furthermore, the paper describes a model and provide a systematic representation of human-machine collabora-tion in discrete manufacturing and to this end, the Hierarchical Safety Control concept is proposed. This offers a ge-neric description of human-machine collaboration based on Finite State Machines (FSM) that can be applied to vari-ous discrete manufacturing lines instead of using ad-hoc solutions for each line. With its reusability, flexibility, and extendibility, the Hierarchical Safety Control scheme allows upholding productivity while maintaining safety with reduced engineering effort compared to existing solutions. The approach to the solution begins with a successful partitioning of different zones around the Integrated Manufacturing System (IMS), which are defined by operator tasks and the risk assessment, used to describe the location of the human operator and thus to identify the related po-tential hazards and trigger the corresponding safety functions to mitigate it. This includes selective reduced speed zones and stop zones, and in addition with the hierarchical safety control scheme and advanced safety functions such as safe standstill and safe reduced speed are used to achieve the main goals in improving the safe Human Ma-chine Collaboration and increasing the productivity. In a sample scenarios, It is shown that an increase of productivity in the order of 2.5% is already possible with a hi-erarchical safety control, which consequently under a given assumptions, a total sum of 213 € could be saved for each intervention, compared to a protective stop reaction. Thereby the loss is reduced by 22.8%, if occasional haz-ard can be refined in a hierarchical way. Furthermore, production downtime due to temporary unavailability of safety devices can be avoided with safety failover that can save millions per year. Moreover, the paper highlights the proof of the development, implementation and application of the concept on the lab demonstrator (FATIE), where it is realized on the new safety PLCs, Drive Units, HMI as well as Safety devices in addition to the main components of the IMS.

Keywords : discrete automation, hierarchical safety controller, human machine collaboration, programmable logical controller
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