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Analysis of the dynamic response improvement of a turbocharged diesel engine driven alternating current generating set

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Abstract

Reliability of electric supply systems is among the most required necessities of modern society. Turbocharged diesel engine driven alternating current generating sets are often used to prevent electric black outs and/or as prime electric energy suppliers. It is well known that turbocharged diesel engines suffer from an inadequate response to a sudden load increase, this being a consequence of the nature of the energy exchange between the engine and the turbocharger. The dynamic response of turbocharged diesel engines could be improved by electric assisting systems, either by direct energy supply with an integrated starter–generator–booster (ISG) mounted on the engine flywheel, or by an indirect energy supply with an electrically assisted turbocharger. An experimentally verified zero dimensional computer simulation method was used for the analysis of both types of electrical assistance. The paper offers an analysis of the interaction between a turbocharged diesel engine and different electric assisting systems, as well as the requirements for the supporting electric motors that could improve the dynamic response of a diesel engine while driving an AC generating set. When performance class compliance is a concern, it is evident that an integrated starter–generator–booster outperforms an electrically assisted turbocharger for the investigated generating set. However, the electric energy consumption and frequency recovery times are smaller when an electrically assisted turbocharger is applied.

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1. Introduction

A diesel engine is a reliable and cost effective power source with high power density, suitable for driving electric generators. The development of diesel engines leads to a compact design and high specific power. The increase of specific power or brake mean effective pressure (bmep) of a diesel engine is generally the consequence of turbocharging and subsequent charge cooling of the working medium. Turbocharged diesel engines attain stationary values of bmep with a delay during the sudden load increase phase due to the low starting boost pressure. Advanced turbocharged diesel engines are generally equipped with a boost pressure controlled fuel limiting system (LDA). The purpose of the LDA is to assure complete combustion during engine transient operation, thereby reducing exhaust gas emissions, predominantly that of black soot. Thus, the LDA is indispensable for meeting strict environmental regulations. This and simultaneous improvement of the baseline engine's dynamic response are made possible by application of supporting electric assisting systems.

The idea of the electrically assisted turbocharger has already been presented in Refs. [1–6], whereas the concept of an electrically driven compressor followed by an ordinary turbocharger was introduced in Ref. [7]. Numerical simulations in Refs. [1,2,7] based on the neural nets MATLAB SIMULINK software presented in Refs. [1,3] are limited to the presentation of one realistic engine loading case with corresponding electrical assistance. However, a deeper understanding of the interaction between the turbocharged engine and the electric assisting systems was not possible due to the large time scale dependence of the interaction. Improvement of the dynamic response of a turbocharged diesel engine by electric assisting systems is influenced by the applied load, engine speed change and, mostly, by the duration of the transient operation when an electrically assisted turbocharger is considered.

Dynamic response improvement of the turbocharged diesel engine by electric assisting systems when propelling a truck was investigated by the first author in Refs. [8,9]. Typical operational times of electric assisting systems for vehicle application last several seconds. An electrically assisted turbocharger is, therefore, superior to an ISG, since it offers a better ratio of engine dynamics improvement to electric energy consumption, as well as greater potential for engine dynamics improvement since the ISG power potential hardly competes with that of additional fueling due to the higher engine boost pressure.

Numerical simulations of a turbocharged diesel engine driving an AC generating set are presented in this paper. Driving an AC generating set sets higher demands on an instantaneous engine power increase in comparison with vehicle propulsion under dynamic conditions where the operational times are longer and engine speed changes are substantial. Evaluation of the dynamic response improvement of the turbocharged diesel engine by electric assisting systems for various sudden load increases was, therefore, performed. Along with the simulations of the engine with an electrically assisted turbocharger, engine simulations with an integrated starter–generator–booster (ISG) mounted on the engine flywheel were also performed. A variety of electric assisting systems combined with the operation of the engine under various loading conditions