Enabling voltage dip ride-throughs of large electric driven gas compressors

Andrea Cortinovis a,⁎, Mehmet Mercangöz a, Thomas Besselmann a, Arne-Marius Ditlefsen b, Tor Olav Stava c, Sture Van de moortel d, Erling Lunde e

a ABB Switzerland Ltd., Corporate Research Center, 5405 Baden Dättwil, Switzerland
b ABB AS Norway, Industrial Automation, Oil and Gas, Ole Devilvisei 10, 0601 Oslo, Norway
c GASSCO AS, Process and Safety Technology, Kopervik, Norway
d ABB Switzerland Ltd., Medium Voltage Drives, 5300 Turgi, Switzerland
e Statoil ASA, Research & Technology, Trondheim, Norway

ARTICLE INFO

Article history:
Received 14 March 2017
Received in revised form 8 December 2017
Accepted 22 December 2017
Available online xxx

Keywords:
Gas compressor modeling
Electric driven gas compressors
Surge protection
Voltage dip ride-through
Under-voltage protection

ABSTRACT

This article is concerned with the impact of voltage or power dips on large electric driven gas compressors (EDC) in typical oil and gas applications. EDCs are sensitive to voltage dips affecting the operation of the gas compression process through the complete or partial loss of motor torque. These events result in unpredictable shutdowns and plant trips typically leading to large economic losses in production. The loss of motor torque often puts the process at risk of surge conditions resulting in unstable operating conditions and possibly also in severe damage of the centrifugal compressors and their surrounding equipment. The critical nature of this problem and the fast dynamics involved, pose challenging requirements for the control and safety systems of the gas compressor and the variable-speed drive system. The main aim of the present paper is to present a model-based protection algorithm to safely decide if the EDC can ride-through or needs to be shutdown during voltage dips. This is done by dynamically computing the time to surge using online information from the process, from the electrical system and a process model to predict the behavior of the compression system. The time to surge value is then compared to a safety limit in order to reach a ride-through or shut-down decision. The approach is tested in simulation and after the deployment on an industrial sized compressor, two recorded voltage dips from the field are presented and discussed.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

Centrifugal gas compressors are often considered of key-importance in industrial oil and gas applications such as gas lifting, gas processing and pipeline transport [1]. Unscheduled trips and unmet demand requirements typically lead to large economic losses, which underline the fact that these machines are most of the time mission critical. In order to cope with these issues, high availability and dedicated control and safety systems are strict requirements for gas compression applications [2].

Ensuring controllability and safety during the operation of centrifugal gas compressors is not always straightforward, mainly because of the inherent constraints of the gas compression process, such as minimum speed, maximum speed, maximum power limit, choke limit and surge limit. Most of these constraints can be handled relatively easily with simple control logic, but maintaining the surge limit or avoiding surge conditions pose significant challenges [3]. Due to unpredictable disturbances, it can happen that the network resistance becomes larger than the pressure gradient generated by the compressor and this leads to unstable operating conditions referred to as compressor surge conditions. These unstable conditions lead to fluctuations of pressures and flow, higher vibrations levels, overheating and potential mechanical damage to the compressor components but also to the surrounding equipment. Dedicated anti-surge control systems use so called recycle valves or blow-off valves to reduce the system resistance and to ensure forward compressor flow [4].

⁎ Corresponding author.
E-mail addresses: andrea.cortinovis@ch.abb.com (A. Cortinovis), mehmet.mercangoez@ch.abb.com (M. Mercangöz), thomas.besselmann@ch.abb.com (T. Besselmann), arne-marius.ditlefsen@no.abb.com (A.-M. Ditlefsen), toros@gassco.no (T.O. Stava), sture.vandemoortel@ch.abb.com (S.V. de moortel), elunde@statoil.com (E. Lunde).

https://doi.org/10.1016/j.jprocont.2017.12.007
0959-1524/© 2017 Elsevier Ltd. All rights reserved.

In the last decade clear trends from fixed-speed applications to variable-speed drives, as well as from conventional gas turbine driven compressors to electric driven gas compressors (EDCs) were observed. These trends are expected to gain more momentum in the future, mainly because of increased efficiencies, reduced maintenance and operational costs [5,6]. Moreover, new legislations on CO$_2$ emissions are expected to encourage the utilization of EDCs or even ban the installation of new gas turbine driven gas compressors in certain areas. Finally, electrical driven machines are the only viable option for sub-sea applications [7].

In addition to their advantages, EDCs also bring along new challenges to the operation of dynamic gas compressors. Whereas the loss of fuel injection in gas turbines affects the driving torque only in the range of seconds, the sudden loss of electric power in EDCs is more problematic because the loss of motor torque takes place in the range of milliseconds. Voltage or power dips usually occur in remote places where grid conditions are already weak and are mainly caused by transmission grid faults, e.g. due to lightning strikes or iced overhead power lines touching each other in winter [8]. Since most compressor stations are located in remote places, these electrical disturbances have a direct influence on their operation. It is industrial state-of-the-art that the electric drive control system initiates a so-called zero-torque ride through in the case of a voltage dip, resulting in a temporary loss of motor torque [9]. The loss of motor torque pushes the compression system towards surge conditions and this effect is more pronounced if the motor torque vanishes fast as is the case in EDCs. As the torque reduces during a voltage dip, the speed of the shaft is decreasing when the impeller of the compressor is still in pressurized conditions. At some point, the impeller cannot maintain the pressure gradient across the machine anymore and local back-flow will occur causing the onset of surge. If the speed continues to fall, the compression system will be pushed into surge conditions and a shutdown needs to be initiated. This is especially problematic, when the anti-surge valves are slow or the recycle piping design is sub-optimal. Some aspects influencing the operating of gas compressors in presence of voltage dips can be found in Bakken et al. [10].

The specific EDC treated in this article comprises as electric drive a synchronous motor fed by a load commutated inverter (LCI). The loss of motor torque being the primary problem, it should be prevented or at least mitigated. For this purpose the existing control system of the LCI was replaced by a model predictive control (MPC) solution [11–13]. Among other benefits, MPC-controlled LCIs have the ability to provide partial motor torque during voltage dips, thus mitigating the voltage dip problematic for the EDC. Since only a negligible amount of energy is stored in the electric drive, the level of partial torque provided to the compressor is dependent on the amount of residual voltage during the voltage dip. Thus, depending on the depth of the voltage dip, the divergence of the compressor into surge can either be prevented or at least be delayed by applying partial torque, leaving more time for the grid voltage to return or for protective measures to be taken. However, as was shown in Besselmann et al. [14], if the compressor protection system does not take the available partial torque into account, the EDC might be tripped nevertheless and a possibly unnecessary shutdown takes place.

This paper presents a model-based protection scheme based on the concept of the time to surge (T2S) and is based on Cortinovis et al. [15]. The time to surge is defined as the time elapsed from the current operating point to the crossing of the surge line given a prediction horizon and some assumption on the motor torque. The proposed method numerically integrates the process model in order to estimate the process state trajectories. From these trajectories, the time to surge is computed identifying where the surge line is crossed. This is repeated in a receding horizon fashion in order to update the T2S value in real-time.

While this paper is based on Cortinovis et al. [15], it does not only cover simulation results, but shows the successful implementation on an industrial site. The main new contributions are twofold: (i) more details are provided regarding the industrial implementation; and (ii) two field cases are presented, which show that the proposed procedure also works in practice. One field case covers a successful ride-through, and the other one a successful shutdown of the plant.

Using the online computed time to surge and comparing it continuously against a safety margin, it is possible to assess if the EDC is able to ride-through the voltage dip or if a trip sequence needs to be initiated. Moreover, this information might also be used to directly manipulate safety valves, such as the hot recycle or the cold recycle valves. This new approach is first tested in a simulation environment and then implemented as a protection logic on an industrial-sized EDC system. Field results covering two voltage dip occurrences are presented and discussed in detail.

The considered setup of an industrial sized EDC is depicted in Fig. 1. The overall system is composed of (i) the electrical system, (ii) the mechanical system and the (iii) gas compression process. The synchronous motor is fed through an input transformer, line and machine converters and is excited by the excitation system. The motor is connected to the gas compressor through a gear box dividing the shaft into a low speed motor shaft and a high speed
دریافت فوری
متن کامل مقاله

امکان دانلود نسخه تمام متن مقالات انگلیسی
امکان دانلود نسخه ترجمه شده مقالات
پذیرش سفارش ترجمه تخصصی
امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
امکان دانلود رایگان ۲ صفحه اول هر مقاله
امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
دانلود فوری مقاله پس از پرداخت آنلاین
پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات