Chapter 15
An Intelligent Motor–Pump System

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ABSTRACT

Process industries are energy intensive in nature and are one of the largest consumers of electrical energy that is commercially generated for utilization. Motor driven systems consume more than two-thirds of the total energy consumed by the industrial sector; among which, centrifugal pumps are the most widely used equipment mainly for the purpose of fluid transportation. The efficiency of pumping units is around 40 to 50%, hence they offer tremendous opportunities of not only improving the efficiency of the process, but also ensure effective energy utilisation and management. With the increasing use of power electronics equipment, power quality (PQ) has become a very serious issue of consideration. On account of the random switching of single-phase loads in addition to time varying operations of industrial loads, PQ problem of voltage variation and unbalance is inevitable across three-phase systems. Application of varying or unbalanced voltages across the three-phase motor terminals results in performance variations leading to inefficient operation. For the purpose of study, the performance of a motor-pump system can be separately analyzed from the motor and pump points of view. The motor efficiency may vary in a very narrow band; pump efficiency depends upon the system head and flow rate but the system efficiency is a combination of the two; hence, necessary to analyze separately. As centrifugal pumps are classified under variable torque-variable speed load category, variation on the input side has a significant effect on the output side. Therefore the system efficiency now becomes an important index for ensuring efficient energy utilisation and efficiency. The main objective of the chapter is to put forward a methodology to analyze the working performance of a three-phase induction motor driven centrifugal pump under conditions of voltage and load variations by, defining additional factors for correct interpretation about the nature and extent of voltage unbalance that can exist in a power system network; define induction motor derating factors for safe and efficient operation based on operational requirements and devise energy management strategies for efficient utilization of electrical energy by the motor-pump system considering the voltage and load conditions.

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INTRODUCTION

The industrial sector is the largest consumer of all the electrical energy that is commercially generated for utilization with process industries like fertilizer, cement, sugar, textile, aluminum, paper etc; being the major consumers (Palanichamy et al., 2001). With the conventional fuel supplies on the verge of becoming scarce and increasingly expensive, and initial investment for harnessing energy from renewable sources being too high; the concept of energy auditing and energy conservation / efficiency practices have gained significant importance. The process of energy management embodies engineering, design, applications, utilization, and to some extent the operation and maintenance of electric power systems to provide the optimal use of electrical energy (IEEE Std. 739-1995; Lee and Kenarangui, 2002). Energy audit programmes are inexpensive investments, as compared to the cost of energy utilization, and are an important tool in analyzing and controlling the demand-supply situation. On successful completion of energy audit, a list of number of energy conservation proposals can be prepared, which can then be prioritized for energy management.

As per IEEE Std. 1159-1995, power quality (PQ) refers to a wide variety of electromagnetic phenomena that characterize the voltage and current at a given time and at a given location on the power system (IEEE Std 1159-1995). As per International Electrotechnical Commission (IEC), “Electromagnetic compatibility is the ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment” (IEC 61000-1-1). Power quality disturbances are the result of various events that are internal and external to industrial utilities. Because of interconnection of grid network, internal PQ problems of one utility become external PQ problems for the other. With increasing stress towards improving energy efficiency, industrial utilities adopt energy saving technologies in the form of adjustable speed drives (ASDs), which are one of the main contributors towards PQ degradation. With the widespread use of non-linear loads, time varying single and three-phase loads, problem of controlling PQ is becoming a relevant issue (Aquila et al., 2004). The main concern of all industrial utilities is with regard to voltage and current quality. As voltage and current are closely related, deviation of any of them from the ideal may cause the other to deviate from the ideal case (Bollen, 2000). PQ variations are generally divided into four basic categories while the various kinds of disturbances that can possibly occur in a power system networks are impulsive transients, oscillatory transients, sag, swell, sustained interruption, undervoltages, overvoltages, voltage unbalance, dc offset, harmonics, interharmonics, notching, noise, voltage fluctuation, frequency fluctuations (IEEE Std 1159-1995; Dugan et al., 1996; Oliver et al., 2002). The sources that lead to PQ problems are quite complex in nature and sometimes difficult to detect; but most of the PQ problems are caused by factors that are beyond the control of the utilities; hence they can never be totally eliminated.

Motor driven systems consume about two-thirds of the total energy consumed by the industrial sector; among which, centrifugal pumps are the most commonly used equipment, and are the largest consumers of electrical energy (Mircevski et al., 1998). Pumping systems are the major energy consumers in the industrial sector while in many process plants; pumping systems are estimated to account for 40 to 60% of total plant energy consumption. With the efficiency of pumping units around 40 to 50%, they offer tremendous opportunities of not only improving the efficiency of the process, but also ensure effective energy utilisation and management.
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