Chapter

Introductory Chapter: Emerging Electric Machines - Advances, Perspectives and Applications

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1. Introduction

With increasing attention on modern energy conversion (EC) systems, electrical machinery (EM) has been given more and more attention to developing new topologies and innovative drives to realize the increasing advantages of current industrial needs. Direct current (DC) machines, induction machines (IMs), and synchronous machines (SMs) were conventional most commonly used EMs in the industry in the past. Still, IMs, mainly the squirrel-cage IM (SCIM) types, are the most widely used EMs because they provide many advantages like effortless simple control, easy but efficient repair, high efficiency, and low cost and sizes [1].

EMs' energy consumption in the industry is 40% plus of the total generated energy worldwide [2]; thus, improving the machines' design and efficiency, even the conventional types, can considerably save energy. However, new EMs and their drives are industrialized with many extra features to meet the recent application areas, for example, electric vehicles (EVs), electric ships (ESs), aircraft machines, robotics, wind power generation, automated propulsion systems, and others [3].

These machines have to cope with numerous new applications under uncertain operating conditions, e.g. fixed or variable speed, uncertain loads (fixed or variable loads), and alteration of the supply voltage (whether constant or variable supply) [1].

2. Emerging Electric Machines

Several factors affect EC systems' efficiency, motor-system efficiency, and the system's performance (from the perspective of power quality (PQ), energy efficiency, or reliability). For instance, all stakeholders should pay much attention to harmonic distortion problems associated with the variable frequency drives (VFDs), power electronic-based equipment, and nonlinear loads [4], oversizing of equipment distribution losses and power factor of the motors [5], variation of the loading conditions and load management practice (matching between motors and loads at any loading level), maintenance practices (for electrical, electronic and mechanical parts alike, and transmission system issues [6].

Despite the importance of these critical factors, they are often disregarded in practice. Considering these factors can significantly improve efficiency and enhance the motor systems' power quality and reliability performance.

In [3], the conventional brushed-type EMs is categorized as:

i. Series or shunt delf-excited DC machines,

ii. Separately-excited DC (field or permanent-magnet (PM), and

iii. Synchronous or induction (wound-rotor and double-fed types).

Also, the brushless EMs can be categorized as:

i. Synchronous (wound-rotor type),

ii. Induction (squirrel-cage type),

iii. Brushless PM, and

iv. Advanced magnetless machines.

The traditional brushless PM can have more than one machine – surface (SPM), inserted, and double-salient, so-called IPM, and DCPM, respectively. However, there are a lot of new PM machines, which have different flux distribution than the traditional brushless PM machines [3], such as hybrid-excited, memory, vernier, double-stator, double-rotor, magnetic-geared, linear, axial, and transverse PM machines.

The advanced magnetless machines can also have many types associated with the DC field excitation, such as the switched reluctance (SR), vernier reluctance (VR), and flux switching and reversal machines.

Figure 1 illustrates the various control strategies for EMs [7]. The control strategies can be applied with both types of machines (traditional and emerging machines). Besides, they can be adopted to be suitable for both types. The control strategies include:

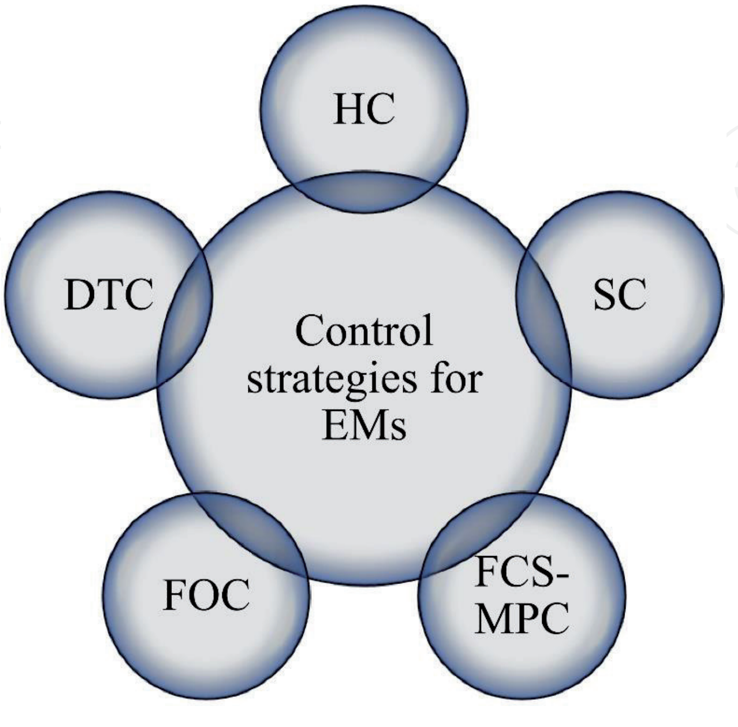

Figure 1.
Control strategies for EMs.

i. Model predictive control associated with the finite-control set (FCS-MPC),

ii. Control using field-orientation (FOC),

iii. Direct torque-based control (DTC),

iv. Sensorless-based control (SC), and

v. Hybrid control techniques (HC).

The corresponding merits that these emerging EMs can fulfill with these various control strategies are shown in **Figure 2** [3, 8]. These merits allow them to efficiently and effectively operate with different emerging applications such as robotics and EVs.

From the application point of view, conventional EMs are usually dedicated to industrial applications, power generation, renewable energy generation, conversion, and domestic home appliances usage. However, emerging EMs are by default dedicated to new high-performance, innovative applications and intelligent devices besides their potential to be used in conventional applications. This is because of the weakness issues of traditional EMs, such as their need for regularly scheduled maintenance, complicated control and narrow speed range (particularly in alternating current (AC) machines), the complexity of operation and management in high-speed operation, low efficiency, and low capability to be overloaded.

On the other side, the emerging EMs also have some weakness issues because of their exceptional design and necessary control. The difficulty of manufacture and the high cost are examples of these demerits.

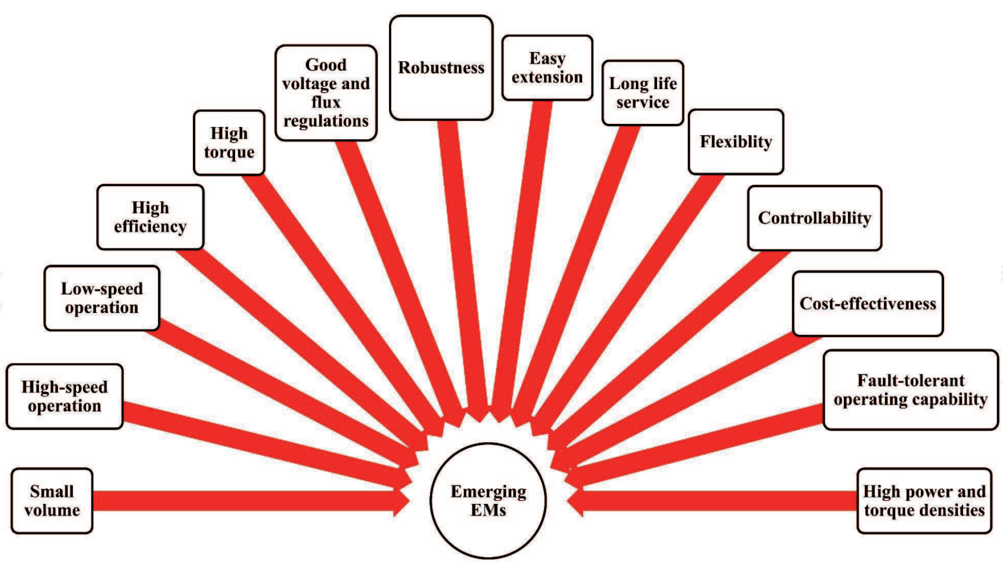

Figure 2.
Features and merits of emerging EMs.

Abbreviations

AC	Alternating current
DC	Direct current
DCPM	Double-salient PM

DTC	Direct torque-based control
EC	Energy conversion
EM	Electrical machinery
ESs	Electric ships
EVs	Electric vehicles
FCS-MPC	Finite-control set model predictive control
FOC	Field-orientation-based control
IMs	Induction machines
IPM	Inserted PM
HC	Hybrid control
PM	Permanent-magnet
PQ	Power quality
SC	Sensorless-based control
SCIM	Squirrel-cage IM
SG	Synchronous generator
SMs	Synchronous machines
SPM	Surface PM
SR	Switched reluctance
VFDs	Variable frequency drives
VR	Vernier reluctance

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