Performance of Three Phase Induction Motoroperatingat voltage variations- A Review

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Abstract

It is the modest three- phase induction motors that have the greatest single customer of power with electrical motor- driven frameworks using more than 60% of aggregate power worldwide. The study demonstrates that these motors are the workhorses of the modern world's cutting edge, converting electrical energy into mechanical energy. This review study relates to monitoring the effectiveness of a three- phase squirrel cage induction motor working under voltage variations. Based on the observations of this study various models are discussed by various authors. Here's a quick rundown of these models.

Keywords

Induction Motor, Efficiency, Unbalance Voltage, Power quality

1. Introduction

M. S. Erlicki et al. presented a model of the poly-phase asynchronousmotor based on optimization techniques. The aim of optimization was to achievecost savings**[1]. R. Ramarathnam et al.** Compared five different unconstrained minimization approaches using both direct and indirect search techniques. The direct search strategy has been discovered to be the best and most appropriate technique found in rotating electrical machines**[2]. N.N.Fultonet al.** described a method of minimizing the material cost in a small poly phase ACIM by optimizing (1) turns per coil (2) wire diameter and (3) stack length**[3].K. Hasuike et al.** presented a study to improve the efficiency of poly-phase asynchronous motors operating at low voltages. In this article twenty-five, input elements arediscussed which are directly related to efficiency improvement **[4]. David C. Montgomery** analyzed the efficiency and operating cost of apoly-phase asynchronousmotor that had been rewound two to three times over its lifetime and compared the results to a new motor **[5]**.**According to N.H. Fetih et al**., the annual price of a polyphase IM is estimated by adding the annual cost of material depreciation, the annual cost of energetic power loss, and the annual electricity cost required to supply such a power loss**[6]. L. Sridhar et al.** presented a model for the design of a three-phase induction motor that operates under various field circumstances for irritation. A novel motor design is compared to the standard one, and the key differences are explored in detail**[7].Min-Kyu Kim et al.** presented a research article by considering the primary dimensions of the induction motor as variables factors and alternate dimensions that have little impact on the target work as constant factor. A model is set up for efficiency improvement based on the above- said conditions **[8].DavarMirabbasi et al.** pointed out that the unbalanced voltages in the motors may bring troubles like more copper losses, over voltage and mechanical oscillations .The performance of motor is

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calculated based on the above said conditions [9**].Jawad Faizin et al**. published a paper based on the optimized design of a poly-phase squirrel cage IM and compared the results of this model to a conventional motor, taking into account three objective functions: efficiency, cost, and a combination of both. The Hooke Jeeves search technique is used in this article for optimization purposes **[10].**The results of unbalanced voltages in the presence of over-and below-rated voltages were also presented by **P. Pillay et al.** Differences in unbalancing voltage standards are also discussed in Ref.**[11].**In a research study, **Annette Von Jouanne et al**. highlighted a few sources of voltage unbalance and explained its consequences for the electricity network **[12]**. **A. Ansari et al.** additionally displayed a research article showing the impacts of unequal voltages ranging from 3.05% to 3.94% **[13].Mehmet Cunkas et al.** Mehmet Cunkas and colleagues proposed an optimum planning method for replacing a poly-phase IM using GA as an optimal tool. The optimally designed motor is compared to the existing one, and it is found that the advanced model is more efficient than the existing one **[14]**.**Jawad Faiz et al.** concluded that the unbalanced voltages builds up more heat losses in the motors, which reduces its efficiency and life span also. In comparison to motors operating under balanced voltages, the performance of unbalanced voltage motors can be improved significantly by making alternate arrangements **[15]**.**Pragasen Pillay et al**. proposed a model for calculating IM losses at a specific temperature and as temperature changes over the time. The insulation material life of the motor is evaluated by using an electrical model and thermal ageing formulae**[16]**.**M Sharma et al**. published a paper on the stator design of a poly-phase squirrel cage IM that claims to function well across a wide range of supply voltages (both below and above the rated voltages), even without the usage of automatic protection. **[17] P. Giridhar Kini et al.** find out that variation of voltages and variations in load, both factors are essential to check its performance **[18]**.**S.S. Sivaraju et al**. modified the design of a three-phase squirrel cage induction motor to improve its optimized output power under variable load applications by minimizing its total losses**[19].C. Thanga Raj et al.** optimized a 7.5 KW poly-phase IM for textile spinning load, and the result so obtained was compared to that of a typical industrial motor **[20].A.Raghuram et al.** also provided an optimized induction motor design using a reduced genetic set of technique, and completed the findings with the aim of maximizing efficiency **[21].Krishna Moorthy et al.** published a research paper on applying Genetic Algorithms to create an optimal three-phase squirrel cage induction motor by considering cost minimization as an objective function. Eleven parameters with a major impact on the motor's performance are identified**[22]**.According to **Ramandip Singh et al**. a rewound motor consumes 1.5 to 3 times more energy than a brand new motor. Its future power factor review is also being studied **[23]**.**Deepa Vincent et al.** added a windows programming technique for the design of a poly-phase induction motor**[24].W. AbithaMemala et al.** also investigated how to determine turn to turn fault in a poly-phase IM winding under no load conditions **[25].Govindasamy. K. Sathishkumar et al.** developed a finite element technique for the design of a three-phase, five-horsepower squirrel cage induction motor. To determine efficiency and torque, both simulation and experimental findings are evaluated **[26]**. Meanwhile, **Vladimir Sousa Santos et al**. used the BFA approach to determine the efficiency and other features of a 1.5 kwpoly-phase IM. **TiberiuRusu and Saini Raj Kumaret al.;TiberiuRusu et al.** studied the performance and design modification of poly-phase IM, when these motors are to be operated under the variations of voltages**[27, 28, 29, 30], [94, 95, 96, 97, 98]**.

2. Models based on unbalanced voltages

Various authors explore various models for unbalanced voltages and efficiency enhancement. Here's a quick rundown of these models.

The efficiency of a three-phase squirrel cage induction motor operating at unbalanced voltages was calculated by **Williams et al.[31].** According to **Gafford WC et al.** unbalanced voltages causes a significant temperature rise and shorten the life of motors **[32**]. **Berndt NL et al**. also found that motors that operate on unbalanced voltages have a lower performance. **Woll. RF1 et al**. on the other hand gave a brief overview of the impact of unbalanced voltages and their negative impact on motor protection. **Cummings et al.** proposed a method for protecting against these effects. The authors also mention that a large number of induction motor pump sets are operating under the rated voltage in agricultural countries like India. Only by lowering the losses can the capability of these motors be increased[33-35].**Kersting WH and Gillbert AJ.et al**. concluded that the presence of unbalanced voltage at the motor terminals increases rotor losses more as compared to stator losses. [36- 37]. **Wallace A et al**. found that the motors which are operating at unbalanced voltage had 2% lower efficiency as compared to balanced voltage motors [38].The insulation failure of induction motors operating under unbalanced voltages was studied by **Fermandez XML et al.** [39].The overall losses of the motor can be calculated tentatively by assuming its losses equal to its rated losses and considering its current comparable to its rated current, according to **Jalilian A et al.** [40]. The overall losses of the motor can be calculated tentatively by assuming its losses equal to its rated losses and considering its current comparable to its rated current, according to **Jalilian A et al.** [41**]. J. Faiz et al.** investigated the capacity of induction motors driven by unbalanced voltages, such as over-or under voltages.A motor's life was evaluated both for continuous operation at a constant temperature and also for changes in temperature over time [42].**P. Pillay et al.** studied the effect of unbalanced supply voltage on motor drives.The rotor current of wound type motor was measured by positive and negative voltage sequences in various unbalance parameters by an experimental study. [43]. Reactive power management, according to Hugo Morais et al., is a critical task in large power distribution networks. In this study, the equipment and methods for power compensation are explored. Reactive power management can be maintained by providing transmission and distribution systems to the facilities [44].**Makbul Anwari et al**. wrote an article about unbalanced voltages and the effects of positive sequence voltage on the temperature rise of induction motors. According to the authors, this voltage must be taken into account while calculating precise findings. [45] **A. M. S. Mendes et al.**concluded that both voltage and load variations should be taken into account when calculating efficiency [46].**According to E. C. Quispe, et al**. Pointed out that none of the current techniques discovered are capable to give the exact data of the negative impact of unbalanced voltage. Further, different precision to evaluate the level of unbalance voltages have been talked about additionally [47]. **Allan A. et al.** presented a model which was based on voltage unbalanced and harmonic distortion. To calculate the overall performance, both factors (voltage unbalanced and harmonic distortion) are added together [48].

3. Models based on optimum design and efficiency improvement

Different models for optimum design and efficiency improvement of three-phase induction motors are discussed by many authors. The brief research findings of these models are as below.

According to Goodwin **GL et al.,** there is a growing interest in the perfect design of poly-phase IM motors to lower the overall operating costs [49].**According toRamarathnam et al**., direct research is the best way to measure the performance of rotating electrical machines [50]. **Fetih NH et al.** carried out work on the optimized design of a poly-phase IM by minimizing the annual operating cost of the motors [51].**Appelbaum J et al.** concluded that the best optimum design of the motor depends upon two factors. One is a variable and the second one is a constant factor [52]. **Fci R et al.** worked on efficiency, power factor, and cost of material in a view of optimization process [53**]. Li C, et al.** worked on Hooke-Jeeve’s research techniques to find out the optimized efficiency [54]. **Faiz J. et al.,** on the other hand, worked on Hooke-Jeeves techniques [55], While **Vier GF et al.** use GA to determine the best induction motor design [56].**Jawad Faiz et al.** also investigated the best design for a poly-phase SC IM, and the findings were compared to those of a conventional motor with a similar rating [57]. **MR. Fevzi et al.** worked on three optimum techniques for the design of stator slots, and the results were compared to the information provided by the current manufacturer. The findings revealed a significant improvement in motor efficiency as well as a reduction in manufacturing costs [58]. With the use of software, **Jae-Woo Kim et al.** optimized the design of stator slots in three-phase induction motors. The acquired software findings are compared to the experimental model [59].To optimize the design of an induction motor, a proposed technique, using a Radial Basis Function approach is applied. **Thomas Bellarmine et al.** [60]. **Yon-Do Chun et al**. gave a multi- target optimized strategy based on GA calculation [61]. **RadhaThangaraj et al**. also presented GA and PSO optimization approaches for the design of a poly-phase IM and a spinning mill. The results are in agreement with the universal drive motor. By employing more advanced methodologies, the authors were able to achieve superior results [62].Meanwhile, **V.P. Sakthivel et al.** published a study that by applying an organically stirred approach known as "bacterial foraging" advanced calculation to improve the design of a three-phase induction motor for energy conservation. In comparison to other evolutionary algorithms, the BF analysis can be used as a global analyzer to provide acceptable solutions [63]. **S. S. Sivaraju et al.** apply GA-based optimization techniques to improve a 7.5-kW, 4-pole SCIM. They developed a software approach and verified the results with an experimental model [64**]. R.L.J. Sprangers et al.** introduces an Expert System (ES) for investigation and design streamlining of three phase- induction motor [65]. **PratyushPrasanna Das et al.** worked on an optimized design of polyphase induction- motor with the aid of Artificial Bee Colony Algorithm [66].

4. Models based on power quality

In manufacturing systems, electric power frameworks have turned out to be contaminated with undesirable variations in the voltage & current flag. Power quality issues are more because of the expanding demand for inductive power. The three phase system is exposed to unbalanced loads. The short portrayal of models in light of power quality is talked about in the accompanying references.

According to **I. Hunter et al.,** power quality issues are frequently caused by the ever-increasing number of disturbances that develop in interconnected power grids, which comprise vast amounts of electricity resources, transmission lines, transformers, and inductive loads. Furthermore, such systems are subject to adverse disturbances such as lightning strikes. **[67].** Power quality issues, such as harmonics and low power factor, were highlighted by **MS. Kandil et al.** In order to optimize these aspects in the power system, the authors proposed a modified processes [68]**.** Advanced applications of neural networks and fuzzy logic in the power system were addressed by **M.Kezunovic and Wael R. et al.** This study provides an overview of optimal models for power control quality, incorporating fuzzy logic, neural systems, and GA. **[69,-70].** Voltage dips and harmonic distortion are discussed in details by **M.H.J. Bollen [71].T. Lin et al.** published a study based on real-time measurements.It plays a very important role to measure protection and fault location under abnormal conditions **[72]**. Modern solutions for resolving power quality issues were emphasized by **M. H. J. Bollen et al. [73, 74].Augusto S. Cerqueira et al.** proposed a methodology for classifying power quality disturbances based on real-time data **[75].Mansour Ojaghi et al.** also observed that the working of induction motors due to voltage wiggles may be studied by using simulation models **[76].** Meanwhile, **Mahesh Illindala et al**., submitted a research article based on frequency/sequence selective channels. For three phase space vectors, the circuits use band pass and band stop filters. Validation of simulation and experimental results carried out **[77].Morteza Ghaseminezhad et al**. investigated the functioning behavior of three phase induction motors under voltage fluctuations. Power factor and efficiency are theoretically and practically validated. A voltage restorer (DVR) is used in conjunction with a PWN controller to improve power quality. This combination was found to be appropriate for low-voltage load **[78]. Amir Hameed Abed and Vicky T. et al.** investigate the impact of power quality on three-phase induction motors using "Fast Fourier Transform analysis" (FFTA). MATLAB is used to obtain the results [79-80].

5. Models based on voltage fluctuations& three phase induction motors

Polyphone induction motors, which are used in industries and agriculture, are subjected to a wide range of voltage fluctuations. Different experts have studied the characteristics of these motors when they are operating under voltage swings. The following is a brief summary of various model.

Aleksandar M. Stankovic and Timur Aydin et al. presented a simulation model based on unbalanced voltage faults using a three-phase synchronous generator connected to an infinite-bus-bar transmission line. It has been found that models based on dynamic phasors provide realistic transient features. C.A.G. Medeiro and Gucci et al. investigate the behavior of equipment in the presence of voltage fluctuations by taking into account various load conditions. Induction motors are affected by voltage fluctuations and low voltage in terms of speed fluctuations, noise, and mechanical stress. The purpose of this study was to use an experimental approach to examine these impacts. **[81, 82, 83, 84].G.Bhuvaneswari et al.** also studied that the active filters can reduce the starting current and unnecessary torque in the large rating of induction motors. This can be an effective tool where a large number of polyphase motors are working in industries which are being run by soft starters. **[85].N. Eghtedarpour et al.** investigated a method for locating the flicker source in the distribution system using an Artificial Neural Network [86]. **Krause, Gnacin ski, and Marcin Peplin ski et al.**concluded that the efficiency, stator & rotor losses of three phase asynchronous motors can be calculated under the influence of fluctuating voltages**,** while the effect of voltage sub harmonic, current, and temperature rise can be studied on the cage of a polyphase asynchronous motor (**[87, 88]).** S. Tennakoon and Ta. Yang, et al. also looked into the impact of voltage dips on the machine's overall performance. In the case of voltage disturbance analysis, traditional methods are led by dynamic phasor models **[89, 90].**

Ke Lia et al. presented aresearch article on the performance of bearing less induction motors by using magnetic wedges in semi-closed slots. Air gap reluctance can be reduced by this process, which reduces losses and hence efficiency can be increased **[91]. Amir Nikbakhsh et al.** concluded that measurement of rotor temperature by direct method with the help of thermal sensors is costly. The authors proposed some suitable methods, like parameter estimation methods, thermal model-based estimation methods, and hybrid methods. Advantages and draw backs of previous methods with the new ones are compared. It is a good way to start the day **[92]. Emad Jamila et al.** presented a research article on power quality improvement in the power grid. Three different systems were developed to improve the effectiveness of the STATCOM to improve the voltage regulation and stability **[93].**

6. Conclusion

In a developing country like India the demand of power is still more as compared to its supply. It is vital to conserve electricity because of the herbal resources that offer power and are being depleted faster than they can be regenerated. Up to some extent we can save the power by reducing the losses and improving the design of these motors, which are mostly playing its part in industries and farming under the variations of voltages. Different models based on three phase induction are presented in the literature. Models based on unbalance voltages, power quality, GA and PSO techniques are studied in details.

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