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An Innovative Technique for Smart Repair of Induction Motors

Bishal Silwal[1,*], Samyam Shrestha[1], Saugat Karki[1], and Bipin Nepal[1]
[1]Department of Electrical and Electronics Engineering, Kathmandu University, Nepal
[*]Correspondence: kshitij.shrestha@pcampus.edu.np
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***Abstract*—This paper introduces an innovative solution to tackle three-phase induction motor winding breakdown and repair issues through a three-step strategic approach. First, simulation-based models are used for the precise design of induction motors, especially the windings, providing a solid foundation for accurate winding repairs. This ensures innovative motor repair, enhancing key performance indicators of machines such as efficiency, power density, and power factor. Second, our proposal integrates health monitoring during the rewinding process, incorporating sensors at critical locations like windings and the core. Real-time temperature and vibration monitoring through an IoT-based platform enable proactive maintenance, preventing breakdowns and promoting overall motor health. Particularly relevant in Nepal, where traditional motor maintenance practices lack engineering solutions, this holistic model will revolutionize motor design, repair, and maintenance, offering a transformative solution for improved reliability in the industrial landscape.**

***Keywords*—Non-engineered, Pre-engineered, RC Buildings, Nepal Building Code (NBC), Seismic Retrofitting, OpenSees, Pushover Analysis, and Structural Vulnerability**

I. INTRODUCTION

INDUCTION motors are widely used in industries with around 90% of the industrial machineries in an industry using an induction motor as a prime mover [1]. It can be said that induction motors are the workhorse of industries. Its robustness in construction, high starting torque, efficiency and reliability makes it a favorable choice. Over 50% [2] of global electrical energy is consumed by industrial motors which is dominated by induction motors. However, these motors often face breakdowns due to factors like dynamic loads and environmental conditions, leading to both electrical and mechanical faults [1]. While some of the industries have their own in-house motor repair workshops or repair houses for the repair and maintenance of damaged motors, others are dependent on external local mechanical workshops. Although the repaired motor can operate and serve the need of the industries, it does not perform according to the nameplate efficiency, and as the repair is not technically validated, the service becomes temporary, leading to recurring breakdowns of such motors.

According to IEEE, more than 42% of the faults in induction motors are bearing-related faults. Similarly, about 28% of the faults are related to the stator winding whereas less than 10% are related to the faults in the rotor of the machine. 22% are categorized as other faults [3]. Fig. 1 shows the damage in the motor caused by bearing fault and stator winding fault. Once the motor breaks down, the typical next step of any industry is to have the motor repaired in the minimum possible turnaround time from the workshop. Due to the emphasis given on the minimum turnaround time, the actual factory specification of the motor is often overlooked during the repair. Very few literatures are found that discusses the proper repair or refurbishment procedures or strategies. Some of the initial literature that presents a discussion on this issue dates back to the 1980s. For example, [5] discusses the repair and restoration of large induction motors considering the turnaround time. The paper presents a procedure to estimate the time and the cost of repair and discusses the general steps for inspection and repair of motors. The paper also presents several factors that are vital for decision making during the repair process. The authors in [6] presents the refurbishment of an induction motor for an application where the input voltage is lower than the nominal voltage of the motor. The paper presents general calculations of the motor parameters for the changed voltage level and the results show that the motor can be refurbished to achieve the rated speed even after reduced input voltage, by changing the

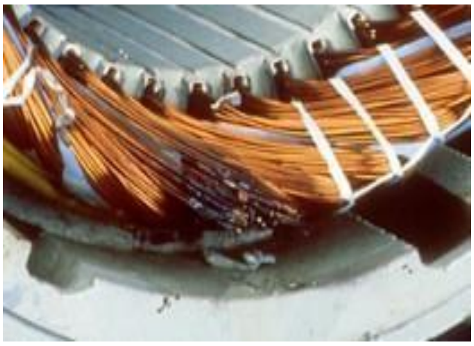

Fig. 1. Burnt winding due to stator winding fault [4].

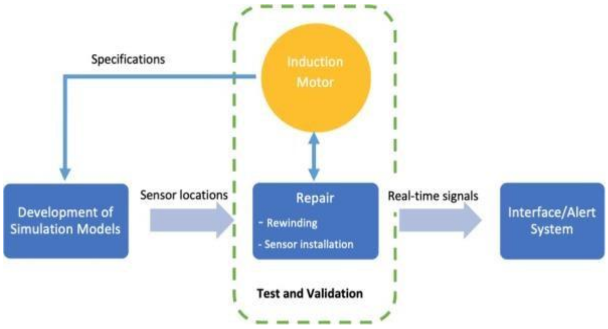

Fig. 2. Proposed repair methodology.

winding parameters. The author claims to have validated the calculated findings with tests.

It is generally assumed that a rewound motor is not as efficient as the original motor. This is, on one hand, due to the aforementioned emphasis on the turnaround time, and on the other hand, due to the inaccurate estimation methods after refurbishment. An algorithm to estimate the efficiency of the refurbished motor by the use of no-load tests has been presented in [7]. The author claims that the proposed procedure can be used in any electrical motor repair workshop and the efficiency can be calculated by over 99% accuracy.

In this paper, an innovative technique of rewinding an induction motor has been presented. This technique, when applied during the rewinding process of any motor that has a damaged winding will result in a motor with a performance better than or at least uprated compared to the original rating. In addition, the health of the winding is monitored in real-time. This will ensure the reliability of the repaired motor.

I. Proposed Winding Repair Technique

The idea of this paper is to come up with a smart and innovative repair technique for the winding of induction motor to solve the existing problems brough in by the conventional repair technique. For this purpose, a three-step technique has been proposed. The technique involves the development of simulation-based models for the design of induction motors, which will help to repair the motor windings based on the technically validated model.

The desired performance of the motor after refurbishment, for example, the efficiency or the power factor or the power density, etc. can be calculated from the model. Next, rewinding of the stator is performed based on the winding data and configuration obtained for the designed performance from the model. During the winding process, condition monitoring of the motor is enabled by installing multiple sensors during rewinding of the motor, which will help to prevent winding breakdown. When the motor is operational, the sensors are used to obtain the operating data of the motor in real-time, which is further used to assess the health of the motor, which is displayed in real-time through a user-friendly platform, incorporating graphs and figures for easy interpretation.

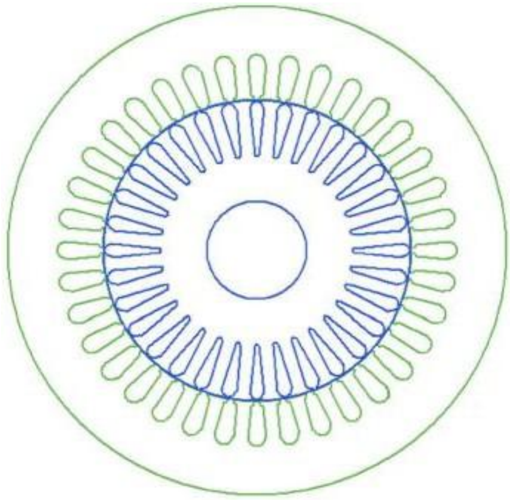

Fig. 3. Two-dimensional cross-section of the machine.

II. Implementation

The innovative winding repair technique proposed in this paper and described in Section II is implemented in a 7.5 kW induction motor, the winding of which was damaged. The parameters of the machine is shown in Table I. The machine has a distributed winding with 80 conductors in a slot and 3 slots per pole per phase.

A. Winding (Re)Design Using Simulation Model

A parametric model of an induction motor based on finite element method has been developed for this purpose. The model can be developed in any commercial or open-source finite element tool. In this study, Ansys Electronic Suite has been used. The model developed is a generic model and can be applied to any cage induction machine of all sizes. The model needs the motor dimensions, winding configurations and material properties as the input parameters. The model can be then simulated to obtain the desired performance of the machine. A two-dimensional cross-section of the machine is shown in Figure 3. The test machine had 78 conductors per slot originally. The number of turns was changed to find if any other number of turns resulted in the enhancement of one of the KPIs of the machine. The key performance indicators for different number of turns are shown in Table 2. Based on the result shown in the Table, the new number of turns was chosen to be 76.

TABLE I
Specifications of the Test-Machine

Parameter	Value
Number of poles	4
Connection	Delta
Rated Voltage [V]	420
Supply frequency [Hz]	50
Rated Current [A]	13.9
Rated Power [kW]	7.5
Rated Speed [rpm]	1440

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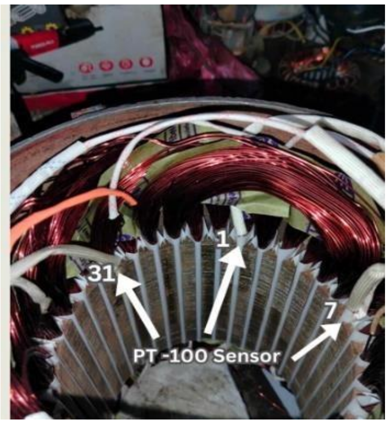

Fig. 4. Rewinding with PT-100 sensors installed in slot 1, slot 7 and slot 31.

maximum space for the conductors, allowing the required number to be inserted. During the winding process, PT-100 temperature sensors were installed in three-slots each with the coil of one of the three-phase windings. This is a key process in the rewinding process as the innovation in the repair technique proposed in this study is primarily due to installation of these sensors. These sensors were strategically placed to provide accurate and reliable data. Figure 3 shows a section of the end-winding of the repaired motor with the location of the temperature sensors.

B. Real-time Monitoring

The sensor data is then directed to a microcontroller, ESP-32. ESP-32 is chosen for its robustness in handling vibrations common in industrial settings. A key component is the microprocessor which gathers sensor data, processes that data, and sends it to a Wi-Fi module. This module transfers the data to another device with a Wi-Fi receiver. Through an application for mobile devices, one can monitor the motor health from this end. In this study, the sensor readings are remotely monitored using ThingSpeak platform, which is free for small non-commercial projects and includes a web service for collecting and storing sensor data. The interface is made in such a way that the temperature of the winding of all three- phases are displayed in real-time.

III. Machine performance evaluation

The test machine was refurbished using the technique described in the previous sections. The refurbished machine was tested under no-load conditions as such loads of such high rating was not available in the laboratory. The machine was supplied with rated voltage and the sensor data was observed in real-time through the IoT platform. Figure 5 shows the The no-load speed of the motor was measured by using a digital tachometer as shown in Figure 6. The speed was measured to be 1495.5 rpm. The three-phase current of the motor was measured by using three split-core transformer (SCT-013) type current sensors, which has a sensitivity of 30mA/Ampere. The sensors

Fig 5. Laboratory set-up to test the refurbished motor.

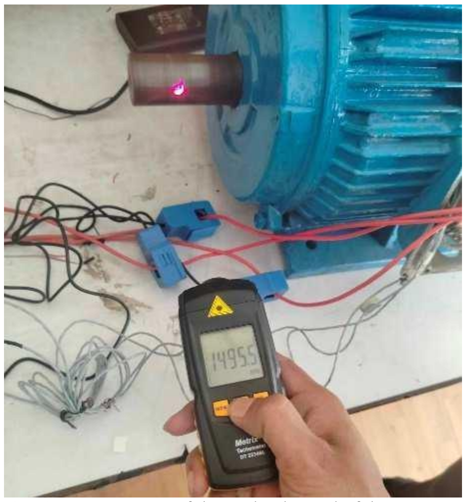

Fig. 6. Measurement of the no-load speed of the motor.

were calibrated before being deployed. The currents were measured in real-time. The laboratory test set-up measured currents were further filtered to remove the noise. Figure 7 shows the current of one of the phases before and after filtering. Figure 8 shows the waveform of the three-phase currents as displayed in real-time in the ThingSpeak platform.

The temperature of the three-phase windings is measured by the PT-100 temperature sensors installed inside the windings during the rewinding process. The measured temperature of phase A is shown in Figure 9. In Figure 9, it can be seen that the temperature of one of the phase windings is displayed in two graphs. The graph on the left shows the real-time temperature of the winding together with green, orange and red levels indicating the temperature level to be in the safe limit, critical range and very critical range, respectively. The value of the temperature displayed in Figure 9 (left) is in the normal range since the motor is being operated under no-load condition. The interface has been designed such that the indicator points green upto 80°C temperature, meaning safe operation range. Between 80°C to 120°C, the indicator points orange, indicating the need of a slight attention to the rise in temperature in the stator windings. Above 120°C, the indicator points red,

TABLE II
PERFORMANCE OF THE MACHINE WITH DIFFERENT WINDING CONFIGURATIONS

Winding Type	Parallel Branches	Conductors per slot	Efficiency (%)	Power Factor	Output Power(kW)
Whole coiled	1	50	83.87	0.9041	7.5006
Half coiled	1	50	82.85	0.9	7.5
Half coiled	1	55	77.276	0.869	7.5
Whole coiled	1	55	79.024	0.877	7.4996
Half coiled	2	58	79.91	0.36	7.4994
Whole coiled	2	58	80.28	0.351	7.4997
Whole coiled	2	68	92.65	0.67	7.5
Half coiled	2	68	92.1451	0.687	7.5
Half coiled	1	68	92.236	0.61	2.5
Half coiled	2	90	90.97	0.91	7.499
Whole coiled	1	90	93	0.91	1.4987
Half coiled	2	80	92	0.9	7.5
Whole coiled	2	80	92.92	0.90318	7.5
Whole coiled	2	84	92.353	0.9124	7.499
Whole coiled	2	76	93.3675	0.8816	7.49
Half coiled	2	76	93.107	0.882	7.5
Half coiled	2	72	93.086	0.812	7.499
Whole coiled	2	72	93.3.55	0.8055	7.499
Half coiled	2	83	92.21	0.91	7.499
Half coiled	2	85	91.89	0.91	7.499

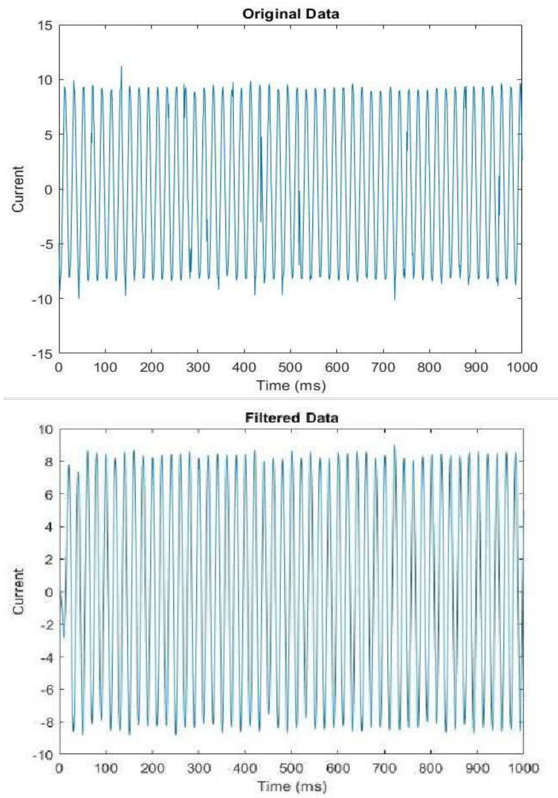

Fig. 7. Current in phase A before and after filtering.

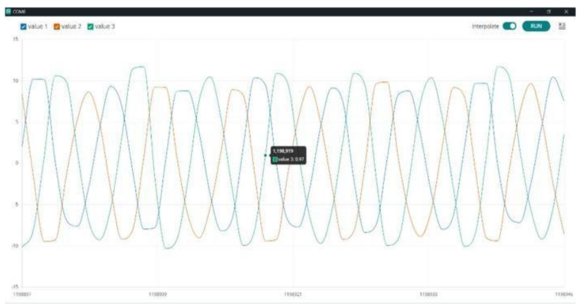

Fig. 8. Real-time display of the three-phase currents.

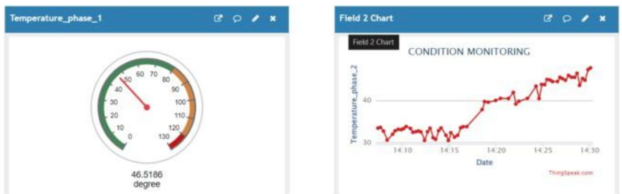

Fig. 9. Real-time display of the temperature in Phase A.

indicating critical range where the temperature of the winding is close to the insulation limit of the copper wires, as the insulation class of the test motor is Class B. The thresholds for the green, orange and red ranges can be changed for motors with different insulation Class. The right graph in Figure 9 shows the historical trend of the temperature which is also beneficial in assessing the health of the windings.

IV. Conclusion

A novel and innovative technique for the rewinding of damaged electrical machines has been proposed in this paper. The technique is based on the determination of the winding parameters of the machine based on a simulation model and then rewinding the machine with the parameters. Moreover, the rewinding process includes the deployment of sensors in crucial locations of the windings to monitor the health indicator, in this case the winding temperature, of the motor in real-time. An IoT based real-time data acquisition system is developed to monitor the sensor data in real-time. The proposed technique has been implemented in a 7.5 kW induction motor. Rewinding is performed on the motor by using the proposed technique and thereafter the performance of the motor is tested in the laboratory. The motor was run on no-load condition by supplying a rated voltage and the speed, current and temperature data were observed. The no-load speed of the original motor is 1500 rpm. The speed of the machine after rewinding was tested to be 1495.5 rpm, which is a deviation of a mere 0.3% and is reasonably accurate. This validates the effectiveness of the proposed technique.

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References

[1] Swapnil K. Gundewar, Prasad V. Kane, "Condition Monitoring and Fault Diagnosis of Induction Motor", JVET, 2020

[2] Paul Waide & Conrad U. Brunner, 2011. "Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems," IEA Energy Papers 2011/7, OECD Publishing.

[3] Thorsen, O. V., & Dalva, M. (1995). A survey of faults on induction motors in offshore oil industry, petrochemical industry, gas terminals, and oil refineries. IEEE Transactions on Industry Applications, 31(5), 1186–1196. doi:10.1109/28.464536

[4] Online Resource: https://easa.com/resources/failures-in-three-phase-stator-windings.

[5] Armintor, Kirk; Mills, Russell W.; Stiffler, Walter G. (1981). Repair, Restoration, and Revitalization of Large Induction Motors., IA-17(6), 0–586. doi:10.1109/tia.1981.4504008T.

[6] P.M, Enyong. "Refurbishment of a Three-Phase Induction Motor Reflecting Local Voltage Condition." *IOSR Journal of Electrical and Electronics Engineering* 8 (2013): 64-69.

[7] Al-Badri, Maher; Pillay, Pragasen; Angers, Pierre (2015). *A* Novel Algorithm for Estimating Refurbished Three-Phase Induction Motors Efficiency Using Only No-Load Tests. *IEEE Transactions on Energy Conversion, 30(2), 615–625.* doi:10.1109/tec.2014.2361258