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Implementation of an Overheat Monitoring and Protection System for Community Empowerment Programs Using Thermocouples

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Abstract: *Induction motors, which operate continuously, such as those used in power plant cooling systems, are at risk of failure that can result in significant losses, such as power outages when the turbine halts due to overheating. Therefore, it is crucial to have a system that monitors the temperature of the induction motor to detect potential overheating and facilitate maintenance. This study aims to design and test a temperature monitoring system for induction motors using thermocouple sensors connected to an LCD display. The methodology begins by identifying issues related to motors running non-stop, followed by a review of relevant literature and system design. Once the system was built, testing was conducted by heating the probe and measuring the temperature with a thermometer to compare the readings with those from the thermocouple sensor. The test results showed that the system accurately displayed the temperature on the LCD, with an error margin that was calculated to evaluate the sensor's accuracy. Based on these results, it can be concluded that the temperature monitoring system functions well and can be used as a reliable overheat detection system for induction motors. This system is expected to simplify maintenance processes and reduce the risk of motor damage caused by overheating. Additionally, the integration of this technology in community-based power plant initiatives could enhance the sustainability and safety of rural energy projects, ensuring a more reliable power supply for community empowerment programs.*

Keyword: *Monitoring, Overheat, Thermocouple*

Introduction

Electric motors are devices that convert electrical energy into mechanical energy. The induction motor is a type of electric motor that operates based on the principle of electromagnetic induction[1]. Unlike other motors, induction motors do not receive an external voltage directly to their rotor. Instead, the current in the stator induces voltage through the air gap in the rotor windings, generating rotor current and a magnetic field, which causes the motor to rotate [17]. Induction motors are widely used in various industrial applications where mechanical work is required, including driving large blowers for furnace combustion, operating conveyors for material handling, and powering water pumps for cooling systems.

Induction motors play a vital role in powering many industrial processes, converting electrical energy into mechanical power to drive equipment like large-scale fans, pumps, and conveyors[2][3]. Although these motors are generally reliable, they can face operational challenges that may lead to severe damage, especially in continuous operations. For instance, motors in critical infrastructure, such as power plants or rural development projects, may experience overheating due to prolonged use or improper load management[4]. Overheating is a major concern because it can result in total motor failure, which could lead to costly repairs, operational downtime, and even power outages that disrupt community empowerment initiatives [12].

Temperature is a crucial indicator of a system's heat intensity. High temperatures indicate that an object has accumulated a significant amount of heat, while low temperatures suggest a minimal heat content. This concept is fundamental in understanding the behavior of induction motors[5][6]. When motors run for extended periods, their internal temperature can rise, which, if unchecked, may lead to overheating [7]. Overheating, or overheat, is a condition where a motor exceeds its safe operating temperature, often leading to equipment failure. The primary causes of overheating include excessive load, inadequate cooling, or an imbalance between the motor's capacity and the load it is required to carry.

Overheating in induction motors can be triggered by various factors, including an overload that demands more power than the motor is designed to handle[8]. This can cause the motor's temperature to rise to unsafe levels, affecting its efficiency and longevity. Regular monitoring of the motor's temperature is crucial to prevent overheating and ensure the system's reliability. In industrial and community empowerment contexts, such as rural energy systems or small-scale manufacturing, preventing motor damage through effective temperature management is critical for maintaining continuous operation and reducing downtime.

To mitigate the risks of overheating, temperature monitoring of induction motors is essential throughout their operation, from startup to shutdown[10]. One effective solution for this is using temperature sensors such as LM35, which are capable of providing real-time temperature data to monitor and prevent overheating. The implementation of such monitoring systems, particularly in community-based programs, ensures that vital infrastructure operates efficiently and without interruption, thereby supporting the sustainability and success of community empowerment initiatives [9].

Literature Study

The research aims to monitor vibrations and temperature increases caused by induction motors, which are critical in various community-driven projects, such as rural electrification and small-scale manufacturing. Vibration and temperature fluctuations in induction motors are monitored regularly, from before the motor starts operation until it is turned off [9]. This ongoing monitoring ensures that the motors used in community empowerment initiatives, which are often vital for local infrastructure, operate efficiently without risking damage due to overheating or mechanical failures.

As industries advance, the integration of automatic control systems has led to the development of devices that monitor various electrical equipment. In sectors like oil and gas, where motors play a crucial role in the transfer of fluids such as fuel oil between tanks, it is essential to monitor key parameters like temperature and vibration. These parameters can directly affect the safety and reliability of the equipment, which in turn impacts the success of community-driven projects that rely on such equipment. Real-time monitoring systems are thus necessary to ensure optimal performance and to prevent failures that could disrupt local operations [7].

A thermocouple is a sensor that generates a voltage difference due to temperature variations between two different metals at their junction[12]. One metal serves as a reference, while the other acts as the temperature sensor [18]. Thermocouples are widely used in monitoring systems because of their accuracy, reliability, and ability to operate in various temperature ranges, making them suitable for monitoring temperature changes in induction motors used in community empowerment applications.

Temperature is a critical indicator in research and applications requiring stable conditions, particularly when assessing the performance of induction motors [14]. Regular temperature measurements are essential to track temperature variations over time. These measurements can be stored and visualized in the form of graphs, which help monitor the motor's condition and predict potential issues before they escalate. One of the most effective sensors for this task is the type-K thermocouple, known for its precision and versatility in various monitoring systems [15].

The objective of this study is to compare the accuracy of temperature measurement using the resistance method and the K-type thermocouple method for monitoring the rise in motor winding temperatures. Accurate monitoring is essential for community-based initiatives, where overheating could lead to equipment failure, interrupting critical services [16].

The continuous monitoring of power plant systems, such as the temperature of the stator, rotor, and bearings of generator motors, is crucial for ensuring uninterrupted service. This requires operators to work in shifts to back each other up. Without constant monitoring of these parameters, the likelihood of system failures or operational downtimes increases, which can have a significant impact on community infrastructure, especially in rural or underserved areas where power is essential for daily activities [13].

In the monitoring process, data recording media that can capture data continuously from system startup to shutdown is also necessary. This makes maintenance of induction motors more manageable, particularly in remote areas where immediate access to technicians may not always be available.

A data logger is an electronic device used to record data from sensors and instruments. It is typically small in size, battery-powered, portable, and equipped with a microprocessor and internal memory to store data[17]. One of the key benefits of using data loggers is their ability to automatically collect data over long periods, such as 24 hours. Once activated, the data logger can be left to record and monitor system performance continuously, which is especially useful for community empowerment projects that require constant monitoring of equipment to ensure reliability [11].

The data logger system used in this research is built around an Arduino Nano module, serving as the controller, and an SD card for data storage. The stored measurement data can be displayed in real-time, thanks to the inclusion of an RTC (Real-Time Clock) and an LCD screen to show sensor voltage and current readings each second. The designed data logger is crucial for storing measurement results, and its real-time display and storage features make it an invaluable tool for community-based monitoring and maintenance initiatives [14]

Methodology

This research employs a systematic and comprehensive approach that begins with the identification of core issues related to continuously operating induction motors, particularly in environments where overheating could lead to significant operational failures[18]. The initial phase focuses on diagnosing the primary problem—motor overheating due to extended use without proper temperature monitoring—and understanding its potential impact on performance and safety. Following this, an extensive review of relevant literature is conducted, focusing on existing methods of motor temperature monitoring, failure prevention, and system protection. This literature review provides valuable insights and serves as the foundation for conceptualizing and designing a tailored monitoring system that can effectively address the identified issues.

Once the conceptual design is completed, the system is constructed with careful attention to its functionality and integration. The device is then subjected to rigorous testing under various conditions to assess its performance, reliability, and accuracy. The testing phase ensures that the monitoring system works as intended, providing real-time temperature readings and alerts for potential overheating.

Additionally, this study is grounded in internationally recognized standards for the protection of induction motors, which ensures that the developed monitoring system complies with global safety and operational guidelines[19]. By adhering to these standards, the system not only offers a practical solution for preventing motor failure but also aligns with best practices in industrial safety and efficiency. This research emphasizes the dual importance of providing effective, community-driven solutions while maintaining compliance with established norms, ensuring that the system is both reliable and applicable to a wide range of real-world applications, particularly in community-based and industrial settings[20].

Table 1. Insulation Class standart

Class Insulation	Temperature
A	105°C
B	130°C
F	155°C
H	180°C

As shown in the table above, the protection standards for motors, according to the National Electrical Manufacturers Association (NEMA), are classified based on their insulation class. Each insulation class has a specific temperature limit, designed to protect the motor from damage caused by excessive heat. Class A has a safe temperature limit of up to 105°C, Class B up to 130°C, Class F up to 155°C, and Class H has the highest safe temperature limit of 180°C. These standards are internationally recognized and serve as a reference for the design and manufacture of electric motors. Therefore, every electric motor produced will specify its insulation class, providing crucial information regarding the motor's ability to withstand certain operational temperatures without damaging its insulation and internal components. By including the insulation class, manufacturers ensure that the motors meet safety and performance requirements in accordance with applicable global standards.

RTD Temperature vs. Resistance Table

For American Curve, Alpha = .00392 — 1° Celsius Increments

°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms
-100	59.57	-38	84.80	24	109.51	86	133.75	148	157.53	210	180.86	272	203.74	334	226.17	396	248.16
-99	59.98	-37	85.20	25	109.90	87	134.14	149	157.91	211	181.23	273	204.11	335	226.53	397	248.51
-98	60.39	-36	85.60	26	110.30	88	134.52	150	158.29	212	181.61	274	204.47	336	226.89	398	248.86
-97	60.80	-35	86.01	27	110.69	89	134.91	151	158.67	213	181.98	275	204.84	337	227.25	399	249.21
-96	61.21	-34	86.41	28	111.09	90	135.30	152	159.05	214	182.35	276	205.20	338	227.61	400	249.56
-95	61.63	-33	86.81	29	111.48	91	135.68	153	159.43	215	182.72	277	205.57	339	227.96	401	249.91
-94	62.04	-32	87.21	30	111.88	92	136.07	154	159.81	216	183.09	278	205.93	340	228.32	402	250.26
-93	62.45	-31	87.61	31	112.27	93	136.46	155	160.19	217	183.47	279	206.30	341	228.68	403	250.61
-92	62.86	-30	88.01	32	112.66	94	136.84	156	160.57	218	183.84	280	206.66	342	229.04	404	250.96
-91	63.27	-29	88.42	33	113.06	95	137.23	157	160.95	219	184.21	281	207.02	343	229.39	405	251.31
-90	63.68	-28	88.82	34	113.45	96	137.62	158	161.33	220	184.58	282	207.39	344	229.75	406	251.66
-89	64.09	-27	89.22	35	113.84	97	138.00	159	161.70	221	184.95	283	207.75	345	230.11	407	252.01
-88	64.50	-26	89.62	36	114.24	98	138.39	160	162.08	222	185.32	284	208.12	346	230.46	408	252.36
-87	64.91	-25	90.02	37	114.63	99	138.77	161	162.46	223	185.70	285	208.48	347	230.82	409	252.71
-86	65.32	-24	90.42	38	115.02	100	139.16	162	162.84	224	186.07	286	208.85	348	231.18	410	253.06
-85	65.73	-23	90.82	39	115.42	101	139.55	163	163.22	225	186.44	287	209.21	349	231.53	411	253.41
-84	66.14	-22	91.22	40	115.81	102	139.93	164	163.60	226	186.81	288	209.57	350	231.89	412	253.76
-83	66.55	-21	91.62	41	116.20	103	140.32	165	163.97	227	187.18	289	209.94	351	232.25	413	254.11
-82	66.96	-20	92.02	42	116.59	104	140.70	166	164.35	228	187.55	290	210.30	352	232.60	414	254.46
-81	67.36	-19	92.42	43	116.99	105	141.09	167	164.73	229	187.92	291	210.66	353	232.96	415	254.80
-80	67.77	-18	92.82	44	117.38	106	141.47	168	165.11	230	188.29	292	211.03	354	233.31	416	255.15
-79	68.18	-17	93.22	45	117.77	107	141.86	169	165.48	231	188.66	293	211.39	355	233.67	417	255.50
-78	68.59	-16	93.62	46	118.16	108	142.24	170	165.86	232	189.03	294	211.75	356	234.03	418	255.85
-77	69.00	-15	94.02	47	118.56	109	142.63	171	166.24	233	189.40	295	212.11	357	234.38	419	256.20
-76	69.41	-14	94.42	48	118.95	110	143.01	172	166.62	234	189.77	296	212.48	358	234.74	420	256.55
-75	69.81	-13	94.82	49	119.34	111	143.39	173	166.99	235	190.14	297	212.84	359	235.09	421	256.89
-74	70.22	-12	95.22	50	119.73	112	143.78	174	167.37	236	190.51	298	213.20	360	235.45	422	257.24
-73	70.63	-11	95.62	51	120.12	113	144.16	175	167.75	237	190.88	299	213.56	361	235.80	423	257.59
-72	71.04	-10	96.02	52	120.51	114	144.55	176	168.12	238	191.25	300	213.93	362	236.16	424	257.94
-71	71.44	-9	96.42	53	120.91	115	144.93	177	168.50	239	191.62	301	214.29	363	236.51	425	258.29
-70	71.85	-8	96.81	54	121.30	116	145.31	178	168.88	240	191.99	302	214.65	364	236.87	426	258.63
-69	72.26	-7	97.21	55	121.69	117	145.70	179	169.25	241	192.36	303	215.01	365	237.22	427	258.98
-68	72.66	-6	97.61	56	122.08	118	146.08	180	169.63	242	192.73	304	215.37	366	237.58	428	259.33
-67	73.07	-5	98.01	57	122.47	119	146.47	181	170.00	243	193.09	305	215.74	367	237.93	429	259.67
-66	73.48	-4	98.41	58	122.86	120	146.85	182	170.38	244	193.46	306	216.10	368	238.28	430	260.02
-65	73.88	-3	98.81	59	123.25	121	147.23	183	170.76	245	193.83	307	216.46	369	238.64	431	260.37
-64	74.29	-2	99.20	60	123.64	122	147.61	184	171.13	246	194.20	308	216.82	370	238.99	432	260.72
-63	74.70	-1	99.60	61	124.03	123	148.00	185	171.51	247	194.57	309	217.18	371	239.35	433	261.06
-62	75.10	0	100.00	62	124.42	124	148.38	186	171.88	248	194.94	310	217.54	372	239.70	434	261.41
-61	75.51	1	100.40	63	124.81	125	148.76	187	172.26	249	195.31	311	217.90	373	240.05	435	261.75
-60	75.91	2	100.80	64	125.20	126	149.15	188	172.63	250	195.67	312	218.26	374	240.41	436	262.10
-59	76.32	3	101.19	65	125.59	127	149.53	189	173.01	251	196.04	313	218.63	375	240.76	437	262.45
-58	76.72	4	101.59	66	125.98	128	149.91	190	173.38	252	196.41	314	218.99	376	241.11	438	262.79
-57	77.13	5	101.99	67	126.37	129	150.29	191	173.76	253	196.78	315	219.35	377	241.47	439	263.14
-56	77.53	6	102.38	68	126.76	130	150.67	192	174.13	254	197.14	316	219.71	378	241.82	440	263.49
-55	77.94	7	102.78	69	127.15	131	151.06	193	174.51	255	197.51	317	220.07	379	242.17	441	263.83
-54	78.34	8	103.18	70	127.54	132	151.44	194	174.88	256	197.88	318	220.43	380	242.53	442	264.18
-53	78.75	9	103.57	71	127.93	133	151.82	195	175.26	257	198.25	319	220.79	381	242.88	443	264.52
-52	79.15	10	103.97	72	128.32	134	152.20	196	175.63	258	198.61	320	221.15	382	243.23	444	264.87
-51	79.56	11	104.37	73	128.71	135	152.58	197	176.01	259	198.98	321	221.51	383	243.58	445	265.21
-50	79.96	12	104.76	74	129.09	136	152.96	198	176.38	260	199.35	322	221.87	384	243.94	446	265.56
-49	80.36	13	105.16	75	129.48	137	153.35	199	176.75	261	199.71	323	222.23	385	244.29	447	265.90
-48	80.77	14	105.56	76	129.87	138	153.73	200	177.13	262	200.08	324	222.59	386	244.64	448	266.25
-47	81.17	15	105.95	77	130.26	139	154.11	201	177.50	263	200.45	325	222.94	387	244.99	449	266.59
-46	81.58	16	106.35	78	130.65	140	154.49	202	177.88	264	200.81	326	223.30	388	245.35	450	266.94
-45	81.98	17	106.74	79	131.04	141	154.87	203	178.25	265	201.18	327	223.66	389	245.70	451	267.28
-44	82.38	18	107.14	80	131.42	142	155.25	204	178.62	266	201.55	328	224.02	390	246.05	452	267.63
-43	82.79	19	107.53	81	131.81	143	155.63	205	179.00	267	201.91	329	224.38	391	246.40	453	267.97
-42	83.19	20	107.93	82	132.20	144	156.01	206	179.37	268	202.28	330	224.74	392	246.75	454	268.31
-41	83.59	21	108.32	83	132.59	145	156.39	207	179.74	269	202.64	331	225.10	393	247.10	455	268.66
-40	83.99	22	108.72	84	132.98	146	156.77	208	180.12	270	203.01	332	225.46	394	247.46	456	269.00
-39	84.40	23	109.11	85	133.36	147	157.15	209	180.49	271	203.38	333	225.81	395	247.81	457	269.35

Figure 2. RTD Resistanc Table

Results

Once the concept of the device was determined, the research progressed to the creation of the physical device designed to monitor the temperature of the induction motor. The developed system is equipped with a temperature sensor connected to a 16x2 LCD display to show real-time temperature readings. The device was tested by comparing the data displayed on the LCD with the temperature measurements taken using a thermometer as a reference tool. This comparison between the two devices provides insight into the accuracy of the developed system. By evaluating the measurement results, it is possible to assess the extent to which the temperature sensor used can produce valid and accurate data. The following table presents the test results conducted in this study. It includes the temperature data recorded by the sensor, along with a comparison to the temperature values obtained using the thermometer, allowing for the evaluation of the consistency and reliability of the device created.

Table 2. Result comparasion

No	Thermometer	Research tool
1	25	23
2	35	32
3	45	42
4	55	53
5	70	67
6	75	73

This table shows the temperatures measured by the thermometer in the first column, while the second column displays the corresponding readings from the research tool. As observed, the readings from the research tool are slightly lower than those from the thermometer, indicating a small error in measurement. The difference between the two sets of readings helps assess the accuracy of the research tool. In general, the tool's measurements are close to the values obtained with the thermometer, demonstrating that the research tool provides reliable temperature data, though minor adjustments may be needed for perfect calibration.

Discussions

Based on the tests conducted, the system functions according to the initial concept. The sensor's ability to read temperature works as expected, as evidenced by the temperature readings displayed on the 16x2 LCD. However, when evaluating the sensor's performance through the provided table, it becomes apparent that the accuracy level is slightly lower than desired.

Previous research using the LM35 sensor [17] showed higher accuracy with lower error margins. However, the LM35 sensor's ability to read temperature is not suitable for measuring the higher heat levels generated by electrical motors, as it is not designed to handle the elevated temperatures that induction motors typically produce.

Additionally, the temperature sensor used in this study, a thermocouple, shows slightly lower sensitivity compared to other sensors. This is due to a minor delay in measurement, as the metal sheath at the sensor's tip hinders the heat transfer, causing a slower response time. Despite this, the thermocouple remains a viable option for temperature monitoring in this application, offering sufficient performance for community-focused projects where cost-efficiency and robustness are key.

Conclusion

From the results of the prototype development process, which includes concept design, component procurement, programming, assembly, and testing, it can be concluded that the prototype functions as intended based on the initial concept. The use of thermocouple sensors is preferred due to their higher temperature measurement range. However, a limitation arises from the metal sheath, which slightly reduces the speed of temperature reading. Despite this, the values displayed on the LCD are consistent with the measured values, and no significant issues have been encountered that would affect the overall functionality of the system.

This prototype can be effectively implemented in community empowerment programs, offering an affordable and reliable solution for monitoring temperature in induction motors, thus contributing to improved maintenance practices and reducing the risk of motor damage due to overheating.

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