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Integration of IoT, AI and Scada for Smart Drinking Water Treatment Plants

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***Abstract*— With urban populations growing at an fast rate and more infrastructure getting older, water treatment plants (WTPs) based on the traditional model are facing several problems including high energy consumption, late detection of faults, and a great dependence on human supervision, etc. To address these issues, the present research proposes a new concept in line with the times: the IoT, integrated SCADA. Using the water treatment plants in Katol and Akola as inspiration, the model integrates real, time sensing (monitoring flow pressure turbidity, and electrical parameters) on a single digital platform. Nowadays, what the changes could bring to the point that seem like the work of a magician. At first, people were relying heavily on reactive maintenance, but this has now been turned into preventive one leading to very few breakdowns and reduced repair costs. The employment of automated alerts and remote control was not only beneficial in reducing the response time but also helped in raising energy efficiency. Hence, this digital overhaul can be relied on to make the supply of water safer and cleaner thus enabling the facilities to comply with the environmental standards of the present day with a much higher degree of accuracy.**

***Index Terms*— IoT SCADA Water Treatment Plant, Smart Water, Automation.**

I. INTRODUCTION

Water treatment plants keep our tap water safe every day. Old systems rely a lot on people checking things and basic machines that don't talk to each other, which means delays in spotting problems, wasted energy, and lost work. Now, with IoT, small sensors linked to SCADA systems [1, 2] let us watch everything from one spot and collect live data. These days, industry has changed fast thanks to better automation, smart sensors, and smarter ways to handle data. How well equipment works matters a lot, unexpected breakdowns mean money goes out the window, risks to safety grow, and machines wear out faster. Old ways like fixing only when broken or doing routine checks don't cut it anymore in fast, 24/7 industries. That's why predictive maintenance [3,4] is gaining ground. It uses live sensor readings, history of how machines worked, and smart analysis to guess when something might fail. This helps stop problems before they start. It seems like this method is becoming more common because it helps keep things running smoothly. Failures in a way that they never cause the same failures again. Predictive maintenance (PdM) can detect the first signs of wear and tear so that maintenance can be planned when it is really necessary, resulting in a significant reduction of maintenance costs, downtime being cut down to the minimum, and increasing overall system availability.

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The integration of Industrial Internet of Things (IIoT), smart sensors, machine learning algorithms, and cloud, based platforms has turned predictive maintenance solutions into being not only more powerful but also more versatile across different sectors like power generation, oil and gas manufacturing transportation, and process automation. [4 5]

According to a researcher R. K. Mobley [4], there is a term in predictive maintenance which means the paradigm "Fix, it, when, it, breaks" to Know, before, it, breaks. Water treatment plants are essentially the silent heart of a city. Without any fuss, they keep on working day and night so that whenever anyone turns on a tap, the water is clean and safe. For a long time, the plants have been blending manual inspections with simple automation in their operations. If a pump made an unusual noise or a valve was stuck typically the technician would detect the problem during their next inspection round or sadly only after the equipment failure. Standard mode is very good in detection. Ultra is designed to be barely detected even by the most advanced detectors. In the Industrial Internet of Things (IIoT) narrative, it is like providing the factory with its own nervous system. By installing smart sensors on each pump, motor and filter, [6, 7] it is possible to find out the condition of the machinery at any time. The sensor information is then directed to a SCADA system (a control center), which not only measures the change and heat of the equipment but also the electrical usage. So, whereas a person only checks once a day, the system does it every fraction of a second.

Reasons Why Predictive Maintenance (PdM) is a Revolution Changing Game Besides this; we had preventive maintenance which was as if you were changing your light bulbs regularly even if they were working alright. It is always preferable to be ready than to be sorry. This approach identifies the "early warning signs" that are impossible for a human to notice through analytics and machine learning like the AI example given above. AI realizes that a slight variation in power and vibrations is indicative of changes or "symptoms" of the bearing might break in three weeks. Taking this data, driven path isn't just about cutting costs, its about saving time and freeing up staff. With predictive maintenance, we stop fixing things at midnight. Safety, wise, a leaking pipe under pressure shows up early so workers don't get in danger. Sustainability is high, efficient machines use less energy and last longer. This means the plant does less harm to the environment. In short, smart sensors and simple rules turn water treatment from guesswork into something steady and reliable. It seems like a big shift, but it is working well now. Plus, repairs happen before problems get bad. That's how things run smoothly today.

II. Design Methodology

A new setup aims to keep track of factory operations and power systems steadily, quickly, and without any delay. From all the devices on the machines and up to central data hubs, it links several levels of function. Sensors in the field feed into controllers that manage automation tasks as per the ladder logic written into the PLC also known as PLC Programming. These connect through secure industrial networks to larger control centers, which is also called as bus. Software used for supervision gathers live inputs alongside smart bridges that link to modern tools. Each piece works together so information flows smoothly from machine to screen. Components include measurement units, programmable logic boxes, remote stations, network paths, oversight programs, plus translation points for web, connected hardware [6 7]

Out in the fields, various sensors, both process and electrical, keep track of key operations nonstop and that too 24X 7. From pH sensors to devices that check turbidity in water, each one serves a specific purpose. Instead of relying on estimates, these tools measure things like chemical balance and how fast liquid moves through pipes. All the level sensors fitted on various tanks, constantly keeps giving the values of lever and that too 24 X 7. Power monitors connected directly into equipment, gives all the required data related to Power such, Voltage, Current, Power Factor, etc. Since every reading comes straight from live conditions, it becomes very easy to take decision fast and in close loop. No guesswork slips in when data flows without delay from sensor to control point. This raw information becomes the starting point for any review or follow, up action taken later.

Sensors transmit data to PLCs and RTUs. These act as the central control brains. PLCs are responsible for the immediate logical decisions, data verification, and quick checks at the spot. Performing such tasks locally helps to reduce time lags and ensures that things continue running even if signal failures occur or network failures happen. RTUs are meant to alter that spread, or help, letting remote sites send data efficiently to the control center. All data is going through industrial networks to the SCADA system. The SCADA display allows the operators to monitor the situation in real time via charts, alarms, and trend graphs. Operators monitoring the running plant, detecting any abnormalities and quickly solving issues. Alarm systems are a tool to help early detection of significant problems, which increases safety and reliability of the system.

Besides monitoring the system in real time, it also helps in storing and analyzing the historical data. The data that has been logged makes it possible to analyze trends over a long period, evaluate the performance, and identify recurring fault patterns. Gaining such historical insight is fundamental in planning preventive and predictive maintenance activities, minimizing the occurrence of unexpected equipment failures, and prolonging the life of the assets. Besides, the use of IoT gateways not only makes it possible to securely transmit data to higher, level analytics platforms but also supports advanced diagnostics and anticipated integration with machine learning, based predictive maintenance models. The design approach discussed here thoroughly covers various aspects of the automation activities of data acquisition, automation & control, and decision making. The features of collaboration of traditional automation systems and IoT based monitoring make the whole system more efficient. Hence, the design and the outcome of this project will definitely support industrial and utility, type applications in these modern era. Katol and Akola water treatment plants now run smoother. Thanks to the IoT, SCADA system. Operators see process and electrical data live, so they don't just guess or wait for routine checks. Issues show up early. Action can be taken right away. Problems don't get worse. It seems like things are working better now. Now, the system helps catch faults before they grow. Plus, daily runs feel more reliable.

Among the benefits brought about during operation, one of the most practical is the reduction in pump running hours. As pumps were only operated based on estimated demand and system conditions, longer periods of operation than necessary were common. Through continuous monitoring of flow, tank levels, and operating status, pump operation has become more demand, based and schedules have been flexibly adjusted. Consequently, this has reduced pump cycling and over, operation which also have their negative effects on energy consumption and pump/motor mechanical stress. As a result, equipment life will be significantly enhanced and maintenance frequency decreased.

Figure 1: Inline sensor installation at WTP

III. Results and Discussion

Another key enhancement is the rise in the power factor of the electrical system. Live power tracking through measuring instruments has assisted in highlighting the conditions of loading inefficiency and reactive power generation. Since these could be seen on the SCADA system, measures for correction, e. g. application of the right capacitor bank and load balancing, could be carried out in a more effective manner. The betterment of the power factor leads not only to the lowering of electrical losses but also to the escrow of penalties from the utility company, thereby economizing the operation system. Spotting high total harmonic distortion early turns out easier with this setup. Noticing harmonics from drives and similar devices usually takes constant watch, otherwise they slip through. Power analyzers built into the system showed odd THD spikes well ahead of trouble. Trends popped up clearly, making it possible to act before harm spread. Motors stayed cooler, cables wasted less energy, gear lasted longer because warnings came in time. About maintenance, historical trend data availability overcame several concerns like better planning and scheduling of maintenance activities. Plant engineers used to follow rigid time, based maintenance but with the help of trend data and alarm history they can assess the actual condition of equipment. This shift from time, based to condition, based maintenance has led to the reduction of emergency breakdowns and hence overall system reliability has been improved. Besides that, maintenance resources have also been used more efficiently since focus has been put on those pieces of

equipment that show actual signs of deterioration only. Taking operational quality as the focus, continually tracking the changes in water quality parameters such as pH, turbidity, and chlorine levels has been the major factor for the improvement of process consistency. If the values of the parameters fall outside the allowed limits, they are instantly shown in red on the SCADA screens, which lead the operators to the solution quickly [8].
Results from both the Katol and Akola WTPs [7] showcase that the combined IoT, SCADA method really enhances plant operations. Supplying operators with up, to, date details, boosting energy saving, and aiding preventive maintenance are ways through which the system even assists operators to switch from making reactive decisions to adopting a more regulated and well, informed operational approach.

Figure 2: SCADA-based monitoring and PLC architecture

Date	Time	Day	Voltage_RY_V	Voltage_YB_V	Voltage_BR_V	Current_R_A_Raw	Current_R_A_Pure	Active_Power_kW_Raw	Active_Power_kW_Pure	Power_Factor_Raw	Power_Factor_Pure	Current_THD_Raw	Current_THD_Pure	Voltage_THD_Raw	Voltage_THD_Pure
01-05-2025	00:00:00	Thursday	413.5731	413.9427	413.936	126.7929	300.4985	79.34335	192.6027	0.888657	0.826729	29.1027	36.40851	1.546745	1.993844
01-05-2025	01:00:00	Thursday	413.0122	413.0799	416.0346	127.5798	299.7545	80.24241	192.7948	0.90935	0.832243	30.44612	34.9083	1.523228	1.90202
01-05-2025	02:00:00	Thursday	413.5725	412.0383	415.6338	122.6137	294.676	81.53156	187.922	0.902478	0.839903	30.93176	37.53277	1.626819	2.035547
01-05-2025	03:00:00	Thursday	414.4811	411.974	414.0343	127.1308	291.8703	79.11788	190.1868	0.905802	0.816104	29.33808	33.20473	2.059689	2.333454
01-05-2025	04:00:00	Thursday	413.9349	414.0307	414.9836	124.9466	289.3347	78.51922	190.9075	0.896058	0.803158	28.37445	33.3245	1.630983	2.162552
01-05-2025	05:00:00	Thursday	415.449	413.1112	415.7338	127.4485	300.8985	79.59466	188.287	0.911212	0.811892	25.94686	33.17552	1.664274	2.266484
01-05-2025	06:00:00	Thursday	415.2281	412.4059	413.9049	123.9359	290.3702	79.98966	188.1097	0.903691	0.833672	28.06861	31.28574	1.831947	2.328673
01-05-2025	07:00:00	Thursday	412.7881	412.8534	414.1625	125.1799	296.2743	79.07714	187.2617	0.885311	0.817592	30.75021	37.33548	1.956086	2.26674
01-05-2025	08:00:00	Thursday	413.8263	412.9732	414.2715	123.7706	295.8252	81.71481	186.4121	0.89528	0.825574	26.59896	35.98079	2.010895	2.269422
01-05-2025	09:00:00	Thursday	413.6303	411.5626	415.4251	124.6295	298.8339	78.25753	189.0517	0.907635	0.826465	28.15805	38.14535	1.823949	1.994643
01-05-2025	10:00:00	Thursday	414.8682	413.3087	415.0512	123.9879	289.1661	81.22133	187.4176	0.902101	0.835862	29.07809	35.30048	1.745327	2.353462
01-05-2025	11:00:00	Thursday	415.0044	412.4803	415.4563	125.4178	289.5498	79.70203	193.4551	0.894882	0.800601	27.98336	33.48108	1.577729	2.112037
01-05-2025	12:00:00	Thursday	414.5619	413.6801	414.376	125.1391	293.2992	78.3823	193.4672	0.899687	0.800322	28.1307	34.70824	1.742763	2.163403
01-05-2025	13:00:00	Thursday	413.9098	413.5904	415.6425	127.1478	300.7757	79.51894	187.6623	0.907784	0.827463	26.3344	35.76704	1.995301	2.445269
01-05-2025	14:00:00	Thursday	415.0974	413.0169	415.8763	122.2845	291.848	81.23099	191.4732	0.900005	0.832411	30.29431	34.00818	1.564237	1.905347
01-05-2025	15:00:00	Thursday	413.1781	412.7612	416.0241	122.9001	289.9992	79.76823	193.0529	0.888781	0.835661	26.09827	33.24633	1.846131	2.392356
01-05-2025	16:00:00	Thursday	415.3404	411.8746	414.5757	127.6922	298.5857	81.37764	191.5276	0.909927	0.828312	30.73014	37.58766	1.576358	2.313282
01-05-2025	17:00:00	Thursday	414.9303	414.0888	414.8376	126.686	289.8246	81.48427	191.037	0.890897	0.810868	27.67507	35.92402	1.90802	2.192635
01-05-2025	18:00:00	Thursday	412.6849	412.0147	416.0165	127.2623	299.4832	78.28616	189.0395	0.900309	0.80277	29.71996	32.75235	1.641451	2.208968
01-05-2025	19:00:00	Thursday	413.3343	411.8234	414.1325	123.6302	294.863	78.30218	188.3301	0.891927	0.805822	25.61613	36.7661	1.7676	2.439559
01-05-2025	20:00:00	Thursday	415.3338	413.1717	413.7669	122.7645	295.8802	81.09012	190.4733	0.898031	0.811164	29.45962	32.95977	1.683957	2.437164
01-05-2025	21:00:00	Thursday	413.3709	414.4127	416.0082	126.2378	292.386	80.59243	193.0574	0.895084	0.80157	28.02306	36.03838	1.987673	2.090533
01-05-2025	22:00:00	Thursday	414.2659	412.1496	413.737	126.6572	298.6944	81.75691	188.1117	0.897958	0.830848	29.64332	32.01934	1.865044	1.945386
01-05-2025	23:00:00	Thursday	414.4875	412.6998	415.6466	124.1738	300.1831	78.72096	193.2718	0.893271	0.828137	30.10932	36.05232	1.810126	2.334286
02-05-2025	00:00:00	Friday	414.808	414.2702	414.8257	127.2341	289.4454	81.2817	188.3249	0.889271	0.803429	26.05239	35.92396	1.68391	2.237507
02-05-2025	01:00:00	Friday	412.9715	413.3414	414.8699	127.2017	296.5176	80.71829	191.449	0.893628	0.816108	26.82683	31.35542	1.863992	2.185537
02-05-2025	02:00:00	Friday	414.3316	413.0512	416.094	125.8384	298.119	81.67587	189.9427	0.895552	0.835857	27.61265	34.13662	1.890594	2.3345
02-05-2025	03:00:00	Friday	414.0229	411.9242	415.7136	127.29	290.3528	78.69541	189.082	0.890199	0.822792	30.37144	35.64228	1.876381	2.02077
02-05-2025	04:00:00	Friday	412.8944	414.2002	413.6554	126.3788	294.2615	81.03971	193.3101	0.90033	0.823484	29.84361	35.87683	1.782871	2.422371
02-05-2025	05:00:00	Friday	414.9941	411.5112	413.6975	122.854	295.923	81.19064	191.3889	0.885905	0.820341	27.67018	32.49314	1.521262	2.204403
02-05-2025	06:00:00	Friday	412.8001	413.9795	415.7896	123.8573	291.6817	80.57399	186.5079	0.913536	0.822824	27.47167	37.57752	2.09124	1.978692

Figure 03: Electrical Parameter Trend for Pump motor

Note: The above table shows the actual values taken with the help of IoT devices fitted on the main electrical feeders. The multifunctional meters connected to the main incomer with the help of CT/PT and then connecting such smart multifunctional meter to the SCADA, give

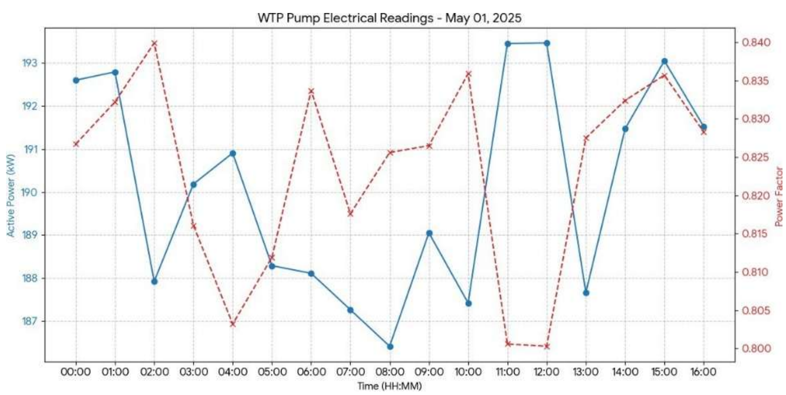

Figure 4: Graphical representation of Active Power and Power factor readings.

A. Quantifiable Output: [5]

Pump energy consumption reduced by 8–12%Improvement in power factor. Fault response time reduced by approximately 30% Early detection of electrical stress conditions avoided unplanned downtime.

IV. Conclusion

As per one of our researchers reports [2,3] mentioned below in the reference list S. Mumtaz and J. Rodriguez & M. Ahmed, M. A. Khan, and A. Al-Mamun. The integration of IoT and SCADA technologies greatly improves the efficiency and the reliability of water drinking treatment plants. The framework set forth increases the transparency of the system, decreases the number of non, revenue water, guarantees the adherence to regulations, and helps preventive maintenance by means of continuous monitoring and data analysis. Next research can be done on the security, the scale of the system, and the long, range cost, benefit analysis of smart water infrastructure.
The achievement of integrating IoT, based SCADA systems in the case of Katol and Akola Water Treatment Plants reveals the amazing potential of digital technologies for upgrading water infrastructure management.

Later studies suggest that conventional monitoring methods mainly reliant on manual supervision and periodic inspections are no longer adequate for satisfying the ever, increasing requirements of efficiency, reliability, and regulatory compliance of utilities in this modern era.

The proposed system of integrating real time sensors, PLC based control systems, energy meters, and centralised SCADA monitoring into one architecture [2] has greatly improved operational visibility and the capacity to make decisions. Continuous monitoring of process parameters, e. g., flow rate, turbidity, pH, and chlorine, has led to better water quality and quick response to the arising situation.

The new system has not only minimized manual work but has also lowered the risk of finding faults late. A key factor for this project was to integrate electrical measurements into the SCADA system. The measurement of voltage current power factor, and energy consumption at a very short interval enabled the identification of conditions at the very early stage of phase imbalance of the pump, overloading, and even mechanical wear & tear. Consequently, pump breakdowns have been fewer and therefore the lifespan of the pumps has been prolonged, and energy has been consumed more efficiently. The practice of performing maintenance after breakdown is a thing of the past. Now, the whole idea is maintenance based on the pump's condition and that's a major step forward. In fact, all these things have essentially demonstrated that the benefits include quick fault response and the enhanced energy efficiency of the pump, reduction of Operational downtime, increased data and reporting transparency, better maintenance planning and cost optimization, in addition to the data, driven insights coming from historical trend analysis that enable long, term infrastructure planning and capacity optimization. The design of this system is adaptable and can be implemented in other municipal Corporations as well as other industries.

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