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IOT BASED REMOTE MONITORING SYSTEM (RMS) FOR SOLAR WATER PUMPING SYSTEM

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***Abstract*—A solar pump, remote monitoring system allows you to monitor and control solar-powered pumps from a remote site location. System design and application of an open-source-based Supervisory Control and Data Acquisition (SCADA) system for solar pumping system are put forth in this paper. To implement this Internet of Things for solar pumps, various hardware components (sensors, communication modules), and software platforms (cloud platforms, data analysis tools) are required. Implementing Internet of Things (IoT) technology for solar pumps involves connecting the pumps to the Internet to enable remote monitoring, control, and data analysis. It's also significant to study the cost, compatibility, and support of the chosen components and platforms. The aim of this learning is to create a sophisticated and comprehensive SCADA design that takes the support of open-source software platform to assess the world's most pertinent problem -water scarcity. In this system, the entire data is and can be stored and evaluated from a remote location, which ensures the data is safe and secure and lets the consumer make decisions based on the composed and compiled data. Amongst the key components of this system are the water level sensors, the GSM kit, and the web-based data analytics software. The various software options available for solar pumps, and remote monitoring systems (RMS) are – SCADA Systems, IoT Platforms, Energy Management Solutions, and custom-made solutions. This technology is often used in agricultural irrigation projects and water supply applications to optimize water pump efficiency and reduce maintenance costs. IoT SCADA systems, the fourth-generation systems infrastructural cost are reduced by implementing IoT through cloud computing. Maintaining as well as integrating these systems is easy compared with others. Currently, this model can be groundbreaking for the solar pump industry for its private sector and government sector tendered projects. The developed model performance is better than the few existing, limited models and the experimental results are validated.**

***Index Terms*—Solar, RMS, SCADA, IoT, Agriculture, Sensors, Pumps**

I. INTRODUCTION

Solar Pumping System also known as a solar water pumping system, is a technology that utilizes solar energy to power pumps for water or other fluids. These systems are commonly used in areas where grid electricity is unavailable or unreliable, and where there's a need for water supply for irrigation, livestock, domestic use, or other applications.

Solar Pump Layout:

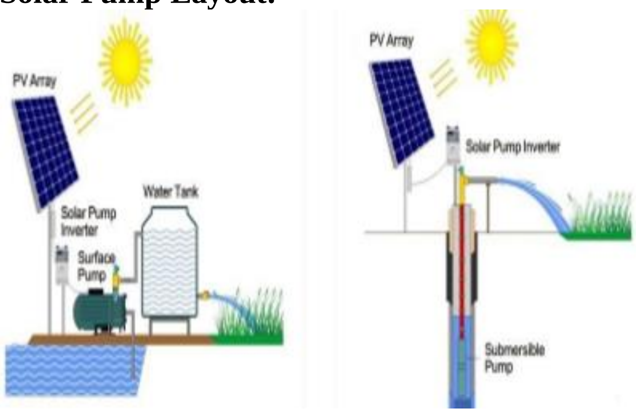

Fig1: Solar Pumping System Layout

Functioning of Solar Pump: When the solar energy sun rays fall on the PV panels, the solar PV panel converts the solar rays into electrical energy with the use and help of Silicon wafers fixed in the PV panels. Then the DC power runs the electrical motor to operate the solar motor system using AC cables.

Components of Solar Pumping System

- Solar Pump Set- DC or AC as per MNRE defined models
- Solar PV Panels/Modules
- Solar Pump Controller (VFD based or PCB based)
- Modules Mounting Structure
- AC Cables,DC Cables,MC4 connectors and earthling kit

Overview of research work: Developing IoT (Internet of Things) technology for solar pumps involves connecting the pumps to the internet to enable remote monitoring, control, and data analysis. Here's an overview of how IoT can be used for solar pumps:

1. Sensors and Data Collection: Install sensors on the solar pumps to gather data such as solar panel output ,water levels, pump status, temperature, and more. These sensors will continuously collect data and transmit it to a central platform.
2. Communication: Use communication technologies such as Wi-Fi, cellular (3G/4G/5G), LoRa, or satellite to send the collected data to the cloud or a central server.
3. Cloud Platform: Data received from the sensors is stored and processed in a cloud-based platform. This platform can be provided by IoT service providers like AWS IoT, Google Cloud IoT, Microsoft Azure IoT, or custom-built solutions.
4. Data Processing and Analysis: Once the data is in the cloud, you can perform real-time analysis, generate insights, and identify trends. This helps in optimizing pump performance and energy usage.
5. Remote Monitoring and Control: Access a user- friendly dashboard or mobile app to monitor the real-time status of the solar pump system. You can remotely turn the pump on or off, adjust settings, and receive alerts or notifications for anomalies.
6. Energy Efficiency: IoT can help optimize energy consumption by analyzing energy production, consumption patterns, and suggesting ways to improve efficiency.
7. Predictive Maintenance: By analyzing sensor data, you can predict when maintenance is needed, reducing downtime and avoiding costly repairs.
8. Data Security: Implement proper security measures to protect the data transmitted between the pumps and the cloud to ensure the system's integrity.
9. Integration: IoT platforms often allow integration with other systems, databases, or applications for more comprehensive data utilization.
10. Scalability: IoT solutions can scale to handle multiple pumps across various locations, making them suitable for large-scale agricultural or industrial applications.

II. RELATED WORK

Earlier, GSM enabled 2G technology based SMS application wise solar pumping system was in exercise until 2019- 2020.An SMS-based solar pump system is a variation of a solar pumping system that incorporates the use of SMS (Short Message Service) or text messaging to remotely control and monitor the operation of the solar pump. This technology is particularly useful in remote or rural areas where internet connectivity might be limited, but cellular networks are available.

Revolution happened on the advent of 4G GSM based modules,4G SIM cards, open source website platforms and hence the IoT based RMS for solar pumping system was initiated.

SCADA: SCADA stands for "Supervisory Control and Data Acquisition." It is a system of hardware and software components used for monitoring and controlling industrial processes, infrastructure, and facilities in real-time. SCADA systems are commonly employed in a wide range of industries such as manufacturing, energy, water and wastewater management, transportation, and more.

RTU: An RTU can gather data from various sensors and meters installed in and around the solar pump system. These sensors could measure parameters such as solar panel output, water level in the storage tank, pump speed, voltage, current, and more. The RTU processes this data and sends it to a central monitoring system. Based on the collected data and predetermined logic, the RTU can control the operation of the solar pump. For instance, it could start or stop the pump based on the water level in the storage tank or the amount of sunlight available for solar power generation. RTUs often come with remote access capabilities, allowing operators and maintenance personnel to monitor and control the solar pump system from a centralized location. This can help in quickly diagnosing issues, optimizing performance, and making necessary adjustments. The RTU can log historical data, which is useful for analyzing system performance over time, identifying trends, and making improvements to efficiency.

PLC: PLCs can automate the control of solar pump systems based on conditions such as water levels, solar panel output, and time of day. This ensures efficient utilization of solar power and optimal pumping operations.

Solar PV Panels: Solar panels are made up of solar cells that convert sunlight into direct current (DC) electricity through the photovoltaic effect. These panels are typically made from silicon-based semiconductor materials. When sunlight strikes the solar cells, it excites electrons in the material, generating an electric current.

RMS: A Solar Pump Remote Monitoring System (RMS) is a sophisticated technological solution that integrates solar- powered water pumping systems with remote monitoring and control capabilities. It combines solar energy utilization, sensor technology, data communication, and web-based interfaces to enable efficient management of water resources, especially in remote or off-grid areas.

III. OBJECTIVES

This paper is presenting a complete Remote Monitoring System for Solar Pumps using a Cortex M0 microcontroller is an objective of this paper and this objective involves various hardware components and software modules. In this paper provide a high-level overview of what components and functionalities you might include in the system, along with some sample code for reference. The objective of designing a Supervisory Control and Data Acquisition (SCADA)system for a solar pumping system is to provide efficient and centralized control and monitoring capabilities for the entire solar pumping system.

IV. METHODOLOGY

A) IoT Design (SCADA based) RMS

A solar pump remote monitoring system allows you to monitor and control solar-powered pumps from a distance. This is done with the help of SCADA based GSM enabled kit in the solar pump controller. Designing an IoT system, particularly one based on SCADA (Supervisory Control and Data Acquisition) principles, involves integrating various components to create a robust and efficient Remote Monitoring and Control System (RMS). Here's a step-by-step guide to help you design an IoT system with SCADA-based RMS:

Define Requirements: Clearly outline the goals and objectives of your RMS. What do you want to monitor and control remotely? What are the critical parameters? This step helps you understand the scope of the project.

Select Hardware: Choose the appropriate sensors, actuators, and communication devices for your application. Ensure they're compatible with your chosen communication protocol (e.g., Modbus, OPCUA) and capable of sending and receiving data reliably.

Communication Infrastructure: Establish a robust communication network for data transmission. This might involve selecting the right wireless technology (e.g., Wi-Fi, cellular, LoRa) or wired communication (Ethernet) based on your application's requirements and coverage area.

Data Acquisition and Processing: Set up the data acquisition system to collect information from sensors. This could involve analog-to-digital converters (ADCs) for analog sensors and digital

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interfaces for digital sensors. Process the raw data to ensure accuracy and consistency.
SCADA System Setup: Choose a suitable SCADA software platform for your RMS. This software will provide the interface for remote monitoring and control. It should support your chosen communication protocol and allow for data visualization, alarms, and historical data storage.
Data Storage and Management: Set up a database to store collected data for historical analysis. This data can provide insights into long-term trends and anomalies.
User Interface: Design a user-friendly interface for operators and administrators to monitor and control the system remotely. Ensure the interface is intuitive and provides real-time information about the monitored parameters.
Alarms and Notifications: Implement an alarm system that alerts operators when parameters exceed predefined thresholds. This can be through visual alerts on the user interface, email notifications, or text messages.
Security: Implement robust security measures to protect your IoT system from unauthorized access and cyber threats. This includes encryption, user authentication, firewalls, and regular security updates.
Remote Control: Enable the capability to remotely control actuators based on the information received from the sensors. This might involve setting up rules and logic within the SCADA system to automate certain actions.

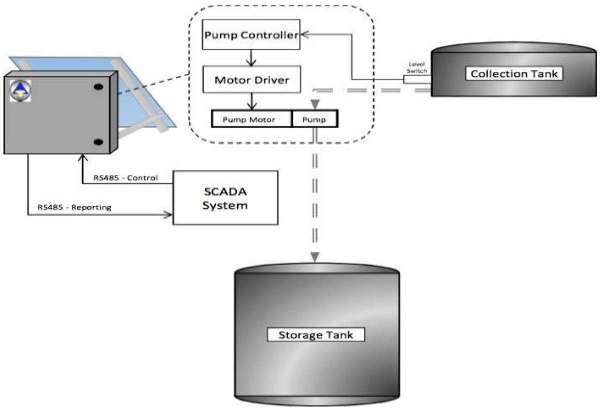

Fig2: Schematic of SCADA based RMS enabled Solar Water Pumping System

A) Algorithm for SCADA based RMS system

SCADA systems use algorithms to manage data, automate processes, and ensure efficient operation. Here are some key algorithms used in SCADA systems for solar pump applications Control Algorithms: PID: Proportional-Integral-Derivative (PID) controllers are usually used in SCADA systems to control pump speed and maintain desired water flow rates. These algorithms calculate control signals based on the difference between the desired set point and the actual pump performance. Optimization Algorithms: Energy Optimization: Algorithms can optimize the energy usage of solar pumps by adjusting pump speed based on solar panel efficiency and available solar energy. These algorithms help balance water demand with available solar power, maximizing energy savings. Water Demand Forecasting: SCADA systems can incorporate algorithms that predict water demand based on historical data and external factors such as weather forecasts. This helps the system adjust pump operations preemptively. Predictive Maintenance Algorithms: Anomaly Detection: Machine learning algorithms can be used to detect anomalies in sensor data, such as unexpected changes in pump performance or energy consumption. These anomalies could indicate impending failures or maintenance needs.
Failure Prediction: By analyzing historical data and patterns, predictive algorithms can estimate when specific components of the solar pump system might fail. This enables proactive maintenance planning.
Data Filtering and Smoothing Algorithms:
Moving Averages: Algorithms like moving averages can be applied to sensor data to smooth out fluctuations and noise, providing a clearer picture of the system's performance over time.

Communication and Data Exchange Algorithms:
Data Aggregation: SCADA systems often collect data from multiple sensors across various locations. Algorithms are used to aggregate and organize this data, ensuring efficient communication and reducing network congestion.
Data Compression: Algorithms can compress data before transmission to reduce bandwidth usage while maintaining essential information.
Security Algorithms: Encryption and Authentication: SCADA systems use encryption algorithms to secure data transmission and ensure that only authorized personnel can access the system. Authentication algorithms verify the identity of users and devices.
Alarm and Event Handling Algorithms: Threshold-based Alarms: Algorithms can be programmed to trigger alarms and notifications when certain thresholds are exceeded. For example, if pump speed drops below a certain level, an alarm could be generated.
Remote Monitoring and Visualization Algorithms:
Data Visualization: Algorithms create graphical representations of data collected from sensors, providing operators with a visual understanding of the system's status in real-time.
Data Analytics Algorithms: Trend Analysis: Algorithms analyze historical data to identify trends and patterns, helping operators make informed decisions about system adjustments and optimizations.
B) System Flow Chart

```
Start
|
| ---------- Monitor Solar Panel Output
|            |
|            |--- Sufficient Solar Power?
|           |    |
|             |      |----Yes -- >Run Pump Directly using Solar
Power
|            |    |
|            |    |----No -- >Check Mains Supply
|                 |
|                 |--- Is Battery SoC High Enough?
|                      |
|                         |----Yes -- >Run Pump using Battery
Power
|                      |
|                        |----No --->Run Pump in Hybrid Mode
(Solar+ Mains)
|
| ---------- Monitor Water Demand
|            |
|            |--- Is Water Demand High?
|                 |
|                 |---- Yes-- >Increase Pump Speed
|                 |
|                 |---- No-- >Maintain Pump Speed
|
| ---------- Monitor System Health
|            |
|            |--- Any Fault Detected?
|                 |
```

```
|                |----Yes--->Raise Alarm and Take Corrective
Action
|                |
|                |---- No-- >Continue Normal Operation
|
| ---------- Data Logging and Reporting
|            |
|            |--- Log Operational Data
|
|            |--- Generate Reports
|
| ---------- Remote Monitoring and Control
|
| -------------- Is Remote Control Needed?
|
|----Yes---->Allow Remote Adjustment of Pump Parameters
|
|---- No --------------- >Continue Regular Monitoring

End
```

C) Development-Design Specifications for the SCADA System

Parameters	Specifications
Supply Voltage	DC 24V/500mA
Reverse Polarity Protection	Yes
MCU	Atmel ARM CortexM0+32bit
GSM/GPRS	Quad Band850/900/1800/1900MHz GPRS Mobile Station Class B Push type Mega SIM slot
Storage	Micro SD card(SDHC)(Optional) Supportupto4GBfor 5year data Logging
USB Interface	InbuiltMicroUSB2.0 To read power data &other parameters on a laptop
RS-485Interface	Support Standard Modbus protocol To read/write parameters of pump controller
Display	LCD 16X2 Character Alphanumeric To Display Power & other parameters
Digital/Analog input	2digital input (programmable) 1 digital output (On/Off pump Remotely) 2Analog input(4-20mAforFlow Sensor)
LED indication	Power On/Off Status Fault Connectivity
Ambient Temperature	0°C to 60°C
Display Parameters	Flow In LPM, Water output per Day, Energy, Generated Power, Solar PV voltage, Current, Frequency, Motor current & voltage, Error code, GSM Signal Strength, Total UP time

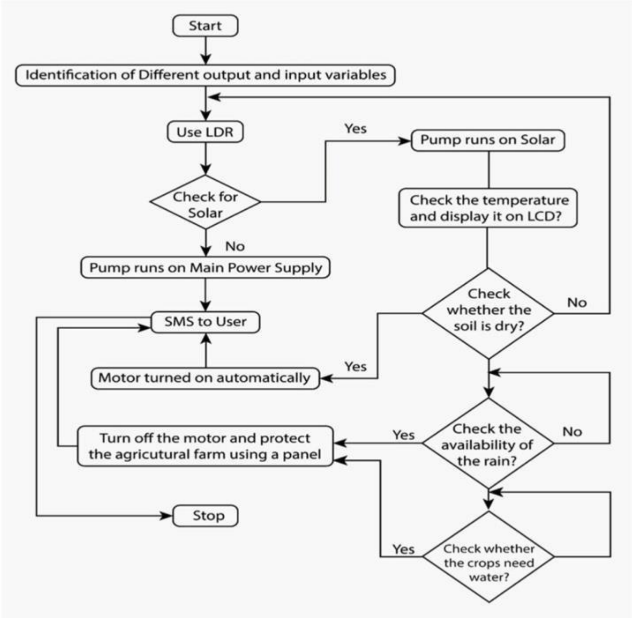

Figure3 Operational Flowchart

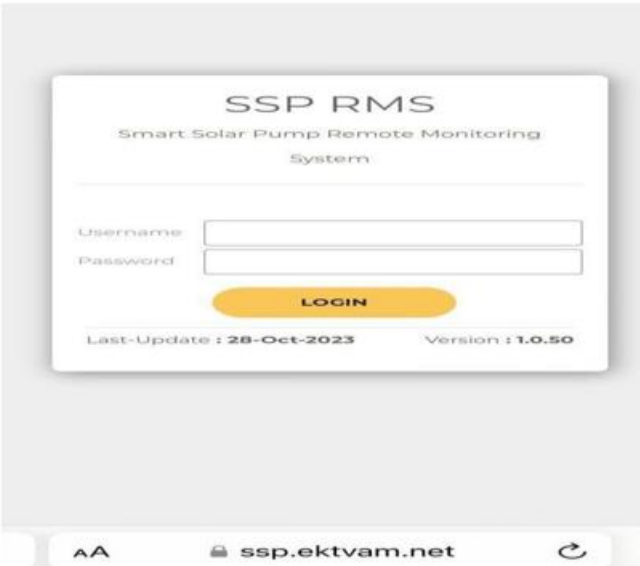

Figure 4 Website Server

IV. DISCUSSION

A remote monitoring system for solar pumps is an important component of solar pumping installations. It enables users to remotely track and manage the performance of their solar pumps and associated equipment. Such systems provide real- time data, help with troubleshooting, and ensure the overall efficiency and reliability of the system. The key aspects related to solar pump remote monitoring systems are: Data Collection: Remote monitoring systems collect data from various sensors and components of the solar pumping system. This can include information about solar panel output, pump status, water flow rates, battery charge levels, and environmental conditions. Real-time Monitoring: Users can access real-time data on the performance of the solar pump system from anywhere with an internet connection. This allows for quick responses to issues and helps prevent system failures. Alerts and Notifications: Monitoring systems can be configured to send alerts and notifications in case of system faults, low battery levels, or other critical issues. Users can receive these alerts via email, SMS, or through a dedicated app. Energy Management: Monitoring systems help users understand how efficiently their solar pump system is utilizing energy. This data can lead to better energy management and optimization of system performance. Historical Data: Data logging and historical data analysis provide insights into long- term system performance and allow for the identification of trends and areas for improvement. Remote Control: Some monitoring systems also offer the ability to remotely control the pump system. Users can start, stop, or adjust the pump operation as needed, which can be particularly useful for agricultural irrigation. Energy and Cost Savings: By identifying and addressing inefficiencies or system issues promptly, remote monitoring. Compatibility: Ensure that the remote monitoring system is compatible with the specific components and controllers used in the solar pump] setup. It should be adaptable to different pump models and configurations. User-Friendly Interface: An easy-to-use interface is important for users to navigate and understand the data provided by the monitoring system. It should be accessible on various devices. Cost-Benefit Analysis: Consider the cost of implementing a remote monitoring system compared to the benefits it provides. It's essential to assess the return on investment in terms of improved efficiency and reduced operational costs. Implementing a remote monitoring system for solar pumps can significantly enhance the performance, reliability, and longevity of your solar pump system, making it a worthwhile investment, especially in remote or off-grid locations where timely maintenance and troubleshooting can be challenging.

V. RESULT

				Report Name:	All Devices				
		Created By:							
		State:	N/A	District:	N/A				
		Block:	N/A	Village:	N/A				
Device-ID	IMEI	Motor HP	PV Voltage(V)	PV Current(A)	Motor Frequency (Hz)	Motor Run-Hours(Hrs)	LPM (Litre)	Today Energy(kWh)	Fault
114122120351	864180052611444	3 HP	333.3	0.9	47.5	7	20	25.7	0
114122120047	864180052613499	3 HP	339.6	1.1	42.1	6.5	18	35.8	0
114122120096	864180052652695	3 HP	315.1	1	45.2	4.5	17	0	0

Table1:3 HP Motor Data

				Report Name:	All Devices				
		Created By:							
		State:	N/A	District:	N/A				
		Block:	N/A	Village:	N/A				
Device-ID	IMEI	Motor HP	PV Voltage(V)	PV Current(A)	Motor Frequency (Hz)	Motor Run-Hours(Hrs)	LPM (Litre)	Today Energy(kWh)	Fault
1412212035	864180052611444	5 HP	551	0.9	41	7.15	25	25.7	0
1412212004	864180052613499	5 HP	565	1.05	42.1	5.5	28	35.8	0
1412212009	864180052652695	5 HP	540.2	1	45	5	26	31.8	0

Table2: 5HP Motor Data

				Report Name:	All Devices				
		Created By:							
		State:	N/A	District:	N/A				
		Block:	N/A	Village:	N/A				
Device-ID	IMEI	Motor HP	PV Voltage(V)	PV Current(A)	Motor Frequency (Hz)	Motor Run-Hours(Hrs)	LPM (Litre)	Today Energy(kWh)	Fault
114122120351	864180052611445	7.5 HP	551	0.9	40.5	7	45	45.8	0
114122120047	864180052613500	7.5 HP	565	1.05	43.5	6.5	42	40.5	0
114122120096	864180052652699	7.5 HP	540.2	1	44.5	5.5	46	41.5	0

Table3: 7.5HP Motor Data

				Report Name:	All Devices					
		Created By:								
		State:	N/A	District:	N/A					
		Block:	N/A	Village:	N/A					
Device-ID	IMEI	Motor HP	PV Voltage(V)	PV Current(A)	Motor Frequency (Hz)	Motor Run-Hours(Hrs)	LPM (Litre)	Today Energy(kWh)	Fault	
114122120351	864180052611445	10 HP	550	0.9	40.3	6	65	45.8	0	
114122120047	864180052613500	10 HP	545	1.05	41.2	5.5	68	40.5	0	
114122120096	864180052652699	10 HP	565	1	41.9	6.5	75	41.5	0	

Table4:10HP Motor Data

VI. CONCLUSION

In this paper, the design of a cost-effective and game changing SCADA system for a solar water pumping system was presented. It consisted of a GSM kit, 3G module, and sensors for voltage, current, and sunlight and website server. This server provides the system with a secure and complete monitoring and controlling GUI place where the user can connect from anywhere through the internet and monitor and control a remote solar water pumping system. In conclusion, the implementation of a solar pump Remote Monitoring System (RMS) presents a significant advancement in the field of sustainable water management and agricultural practices. The primary goal of this project was to enhance the efficiency, reliability, and maintenance of solar-powered water pumping systems used for irrigation and other agricultural activities. Through the deployment of cutting-edge IoT (Internet of Things) technology, we successfully established a comprehensive RMS that allows real-time monitoring and control of solar pumps across remote locations. The system's integrated sensors facilitated the collection of critical data such as water flow rates, pump performance and solar panel efficiency. This data was transmitted to a centralized dashboard accessible via web servers and mobile interfaces, enabling users to make informed decisions regarding pump operation and maintenance scheduling. The results of this project demonstrated several key benefits. Firstly, the RMS empowered farmers and water resource managers with actionable insights into pump performance, leading to optimized water usage and increased crop yield. Secondly, the early detection of anomalies and faults allowed for timely maintenance interventions, reducing downtime and minimizing repair costs. Moreover, the integration of renewable energy sources like solar power showcased a commitment to environmental sustainability. In summary, the solar pump RMS project showcased the transformative potential of IoT technology in the realm of agriculture and water management. By merging renewable energy utilization with remote monitoring capabilities, the system addresses challenges related to water scarcity, energy efficiency, and agricultural productivity. As we move forward, the insights gained from this project will contribute to the ongoing evolution of smart farming practices and the broader adoption of IoT solutions for sustainable energy development

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