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# Energy Saving Implementation in Hydraulic Press Using Industrial Internet of Things (IIoT)

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**Abstract:** With the growing cost of electrical energy, the necessity of energy-saving implementation in industries based on energy audits has become a major focus area. Energy audit results indicate energy-saving potential in an application and require the physical presence of the auditor's team for monitoring and analyzing the energy consumption data. The use of Industrial Internet of Things (IIoT) for remote data monitoring and analysis is growing and new industrial applications based on IIoT are being developed and used by various industrial sectors. Possibilities of a mixed method of physical and remote energy audit using IIoT in industrial applications and its advantages as proposed in this research work needs to be explored. Existing hydraulic press machines running with direct online starter (DOL) can be run with variable speed drive (VSD) for energy saving but this requires an extensive energy audit. Key electrical and operational parameters of the hydraulic pump motor were monitored and analyzed remotely using IIoT in this research work by operating the hydraulic press with DOL and VSD motor control methods one by one. The input power factor of the hydraulic pump motor showed an improvement from 0.79 in DOL control to 0.9 in VSD control at different motor loads. The hydraulic pump motor starting current showed a reduction of 84% with VSD control. The hydraulic pump motor's continuous current was reduced by 40% and 65% during the loading and unloading cycle, respectively, with VSD control. Electrical consumption was reduced by 24% as a result of operating the hydraulic pump motor at 35 Hz with VSD control without impacting the performance of the hydraulic press. These results indicated more efficient control by changing to VSD control in comparison with DOL control. A combination of physical and remote energy audits as performed in this research work using the proposed IIoT framework can be utilized for implementing energy saving in hydraulic presses thus motivating industries to adopt available more energy-efficient technologies at a faster pace.

**Keywords:** energy audit; energy saving; energy efficiency; hydraulic press; Industrial Internet of Things (IIoT); sustainability; variable speed drive



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## 1. Introduction

Manufacturing relies heavily on hydraulic forming technology [1]. Numerous types of presses have been created since Bramah created the hydraulic press in 1795 for a wide range of uses [2]. Hydraulic presses are frequently used in a variety of forming operations in industrial applications because of their advantages of having a high power-to-mass ratio, high rigidity, and high load capability [1]. Although hydraulic systems are frequently utilized in engineering machinery, their high energy consumption and low energy efficiency restrict their growth and utilization [3]. The low energy efficiency of the motor and the high energy consumption brought on by the pump unloading are significant issues for hydraulic presses [1]. The energy efficiency of hydraulic presses is often relatively low, ranging from 6 to 40% [4]. As a result, it is critical to increase the energy efficiency of a hydraulic press when it is in use, given the growing environmental challenges and issues related to high energy consumption in industries [5–8].

More than 280 billion kWh will be utilized annually if the average power requirement of one of these presses is 40 kWh [9], which is like Spain's annual energy consumption [9]. More than 57.1 billion kWh would be saved annually if 20% of energy usage were cut, which could reduce carbon emissions by 47.62 million tons [10], or the amount of $CO_2$ absorbed annually by 5.83 million hectares of the forest [10]. Energy efficiency promotion and energy savings for manufacturing systems and equipment are currently receiving more attention [3]. Given the loss of resources and energy, climate change and carbon emissions are currently major problems [11]. Therefore, more work needs to be done to increase energy efficiency and adopt green energy technologies, especially for industries with high energy consumption rates [12].

In the past, numerous devices have been utilized in hydraulic power systems to increase energy efficiency, including bypass valves, hydraulic accumulators, multi-pump systems, and variable displacement pumps [13,14]. However, there are many disadvantages to valve-controlled hydraulic systems, including significant energy and pressure loss [15]. Recent studies on the energy efficiency of hydraulic presses have mainly concentrated on energy matching and energy recovery. When it comes to energy recovery, an energy regeneration system is used to recover and store in an accumulator the kinetic energy or gravity potential energy of the hydraulic press slider that will be released during the subsequent operation [16–20]. To match the loads and improve efficiency, the operational parameters of the hydraulic press are examined and improved using data envelopment theory [21].

In hydraulic systems, a three-phase asynchronous motor is frequently employed to transform electrical energy into mechanical energy [3]. An electric motor powers a hydraulic pump in hydraulic systems, which pressurizes a fluid [22]. To operate hydraulic pistons, motors, and other machinery, this pressurized fluid is used. Even when the machine is not in use, the hydraulic pump continues to function to maintain pressure and response time [22]. This mode of operation is referred to as "idle" mode [22]. Pumping hydraulic fluid through a bypass loop while the engine is running uses energy to overcome friction and maintain pressure [22]. Different forms of variable-speed motors, including servo motors and variable-speed motors, are used to drive actuators directly without the necessity of intermediate variable valves in a variable control system [23–25]. Motors and pumps are used to change the required pressure, flow, and direction of the working liquid to address the issue of mismatched control and lower energy usage [26–28]. The energy efficiency of machines can also be increased by changing their processing speed [29–31].

An apparatus that controls the speed and rotational force, or output torque, of electromechanical equipment, is known as a variable speed drive (VSD) [32]. VSD applications have gained popularity recently due to the promise of significant energy savings [33]. Most of the industrial machinery powered by hydraulic systems is often operated largely in partial operating conditions. The hydraulic power systems based on VSD have a greater potential for energy savings in these conditions. The electric motor, the power converter, and the control system make up the majority of electric VSD systems. The load is connected to the electric motor either directly or indirectly using gears. By properly controlling power semiconductor switches, the power converter regulates the flow of power to the motor from an AC (Alternating Current) source, as shown in Figure 1. The basic block diagram of a VSD, as shown in Figure 1, depicts its working to control the speed of an AC induction motor. Three-phase or single-phase AC input power supply to the VSD is rectified to direct current (D.C) supply by a full wave diode bridge rectifier (converter) stored in the D.C bus capacitors. The inverter section provides variable voltage and variable frequency ratio to the three-phase AC inductor motor based on the actual requirement of the process.

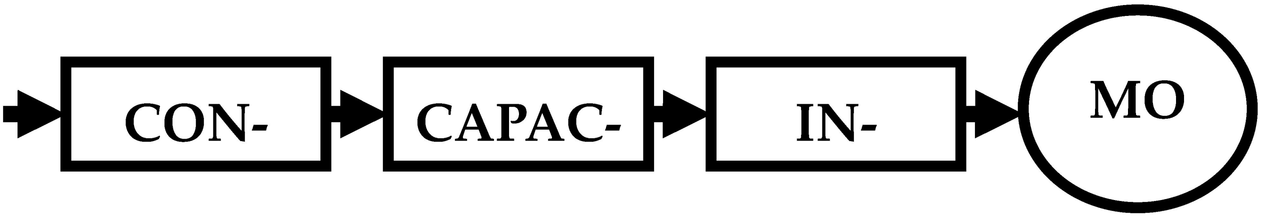


**Figure 1.** Basic block diagram of a VSD.

Energy savings and increased productivity are the benefits of using VSDs in equipment like pumps, fans, and compressors [32]. By enabling motors to operate at the ideal speed for every load scenario, VSD improves energy consumption patterns [32]. In the case of pump applications, the general hydraulic parameters of the pump, such as pressure, flow rate, power, and speed, vary with the change in rotational speed of the electric motor since the speed of the motor is controlled by the supply voltage using a VSD. The following equations from the hydraulic affinity laws can be used to describe how to speed fluctuations affect the pump characteristic [34]:

Law I—flow rate and air flow rate Q are proportional to the motor rotational speed (N):

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2} \tag{1}$$

Law II—The head and the static pressure H vary in proportion to the square of the motor rotational speed (N):

$$\frac{H_1}{H_2} = \left(\frac{N_1}{N_2}\right)^2 \tag{2}$$

Law III—The shaft power P varies in proportion to the cube of the motor rotational speed (N):

$$\frac{P_1}{P_2} = \left(\frac{N_1}{N_2}\right)^3 \tag{3}$$

VSDs are a crucial component of automation and aid in process optimization and cutting down on investment expenses, energy utilization, energy expenditures, and greenhouse gas (GHG) emissions [35]. Since motor systems consume more than 60% of the electrical power used by industry, there is a good potential for energy savings with shifting to VSD control [36]. The significance of further investigation into this issue is increased by this critical circumstance [37,38]. However, to use this VSD approach in the actual industrial area, it is important to calculate the amount of energy saved by considering both the varied operating conditions and the actual cycle parameters of the machine applications [39]. A more crucial step is to do an economic study to demonstrate the viability of this kind of VSD application [39]. Another strategy to achieve energy savings is integrated optimization of processing parameters and scheduling [40–43].

To determine the scope of energy saving using VSD in any application, it is important to conduct a comprehensive and detailed energy audit of the equipment. The purpose of an energy audit is to offer the organization important recommendations regarding its energy usage and efficiency potential [44]. According to Woo and Moore, the energy audit process includes (i) a fundamental or first survey of units, (ii) information gathering, and (iii) data analytics and conclusion from the interpretation of the acquired data for the enhanced procedures [45]. Data from monitoring and energy usage statistics are used to conduct energy audits [46]. Energy monitoring at various levels is now possible because of faster and more precise energy and power measurement technologies [47]. An energy audit is a time-consuming process as it involves a collection of critical data related to the process and energy consumption over a long period. Beyond this, energy audits demand a good amount of financial investment, which often becomes impractical, especially for micro, small, and medium enterprises (MSMEs) due to the lack of financial budget. Hence, there is an urgent need to design innovative solutions to achieve a significant reduction in the overall cost of conducting energy audits so that more and more industries adopt the latest available technologies to implement energy saving. This will result in the reduction of greenhouse gas (GHG) emissions in a highly significant manner.

Internet of Things (IoT) is a term that is currently most used in the industrial sphere due to the expanding use of digitalization in industries. IoT has now been extended to the industrial sector, referred to as Industry 4.0 or IIoT, for greater productivity, control, and fulfillment of high-energy demands. This has a significant positive impact on the sustainability, efficiency, requirements, and safety of society [48]. Utilizing the IIoT and the required technology advancements can improve working conditions, reduce risks to people and the environment, and conserve resources [49]. The IIoT's implications for sustainable development are now the subject of a few scientific projects and studies. Still, the connections between digitalization and sustainability have recently drawn more attention [50–53]. IIoT has great scope in bringing out major changes in the industrial world with its growing implementation across various applications. In this research work, a mixed method based on IIoT is used to conduct an energy audit of hydraulic presses for the collection of critical data, both physically and remotely, to prepare a feasibility report based on which the end user decides to implement energy [54] saving using VSD in place of the DOL starter [55]. The methodology section describes various components of a hydraulic press and the method used in this research paper. Analysis of the observed parameters has been done in the results and discussions section, which compares the electrical energy consumption pattern between DOL and VSD control. The conclusion section includes our main observations based on this research work and mentions the future scope of the research work.

## 2. Materials and Methods

In the automotive industry, hydraulic presses are used in different applications, including gasket manufacturing. Gaskets of different shapes and sizes are manufactured with the help of hydraulic press machines. In the automotive industry, multiple hydraulic press machines are generally used, which are operated in different shifts for longer durations per day and focus on implementing energy-saving measures [56,57]. Hydraulic pressure in these machines is generated with the help of a hydraulic pump which operates at its rated speed. Different components of a typical hydraulic pump system are shown in Figure 2. Hydraulic pressure is converted into a sufficient mechanical force through hydraulic cylinders used to operate the press as per the required pressure [58]. A pressure relief valve, as shown in Figure 2, operates based on a pre-configured pressure value to return the hydraulic fluid into the hydraulic tank once the press operation has been performed. This operation runs in sequence and is known as the loading and unloading cycle [59]. Loading means press operation is executed and during this time the hydraulic pump motor draws maximum current or electrical power. With VSD control as per the possibilities in the hydraulic press, the hydraulic pump motor can be operated at a reduced speed as compared to the DOL starter and saves electrical energy as per the affinity law, as discussed in the introduction section. Unloading in the hydraulic press application means that press operation has been executed; during this time hydraulic pump motor is said to be operating in idle mode, drawing less current than at loading time. With VSD control, electrical energy saving becomes possible if the hydraulic pump motor rotational speed is set to a minimum value based on the energy audit recommendations and the actual process requirements. Loading and unloading cycle time varies based on the design of the hydraulic press. The higher the unloading time, the higher the electrical energy-saving potential in hydraulic press application by shifting from DOL to VSD control. In the case of the DOL control, it is not possible to change the rotational speed of the hydraulic pump motor; it operates at its rated speed during both loading and unloading time, consuming higher electrical energy compared to the VSD starter.

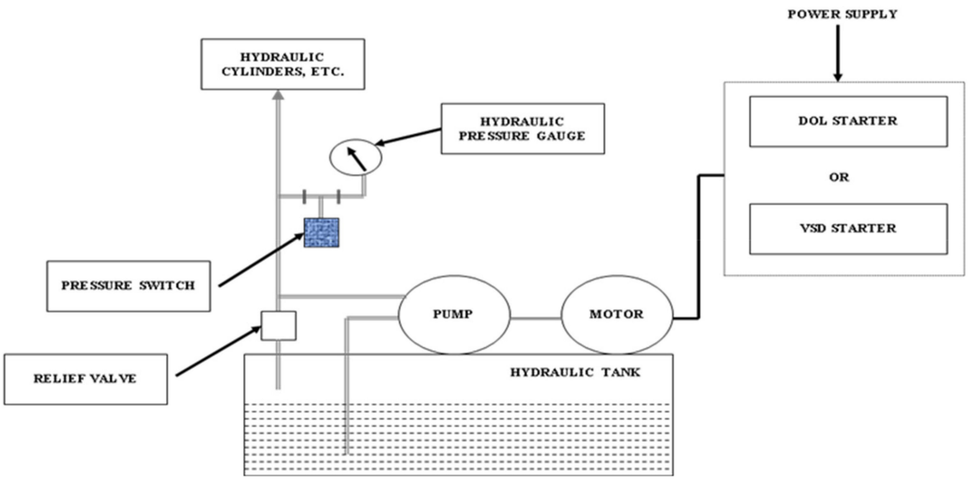


**Figure 2.** Basic components of a hydraulic pump system.

In the tested system, the hydraulic pump motor was operated with a DOL starter with a loading time of 1.5 s and an unloading time of 0.5 s. This means that for every press or stroke [60], the hydraulic press pump motor was idle for 0.5 s and continued running at its rated speed with a DOL starter. This provided an opportunity to study the electrical energy-saving potential (based on the affinity law–power consumption varies cubically with the rotational speed of the pump motor) in this hydraulic press by shifting from DOL to VSD control and modifying the operating speed of the hydraulic pump motor with VSD as per actual process requirement.

Technical specifications of the tested hydraulic pump motor are provided in Table 1. During the loading time, the hydraulic pump pressure gauge reading was monitored to be 16.54 MPa.

**Table 1.** Technical specifications of hydraulic pump motor.

| Parameter | Rated Specification |
|---|---|
| Power | 7.5 kW |
| Volts | 415 V |
| Current | 14 A |
| Frequency | 50 Hz |
| RPM | 1450 |
| Poles | 4 |
| Insulation class | B |
| Make | SEING |

The energy audit was conducted to estimate the energy-saving potential of this hydraulic press by changing the hydraulic pump motor control from existing DOL to VSD control. Utilizing the IIoT framework, conducted energy audit was based on 02 different methods—(i).

Physical energy audit, and (ii). Remote energy audit [61,62]. Physical energy audit, which was done by visiting the manufacturing unit, consisted of the following steps—

- Collection of important data related to the existing mode of operation (DOL starter), which included hydraulic pump motor starting current, continuous current during the loading and unloading cycle, input supply voltage, input power factor, hydraulic pump pressure, and the number of press strokes, etc.
- Design of IIoT-based remote monitoring and data analysis system for conducting energy audits remotely. This system was composed of—(i). Power meter, (ii). Human Machine Interface (HMI), (iii). Networking hardware for enabling remote access of HMI, (iv). VSD and (v). The remote monitoring station is shown in Figure 3. The power meter and VSD were connected to the HMI over the RS-485 communication protocol for the interchange of important data digitally. Networking hardware connected HMI with the remote monitoring station over a high-speed ethernet communication network utilizing a virtual private network (VPN).

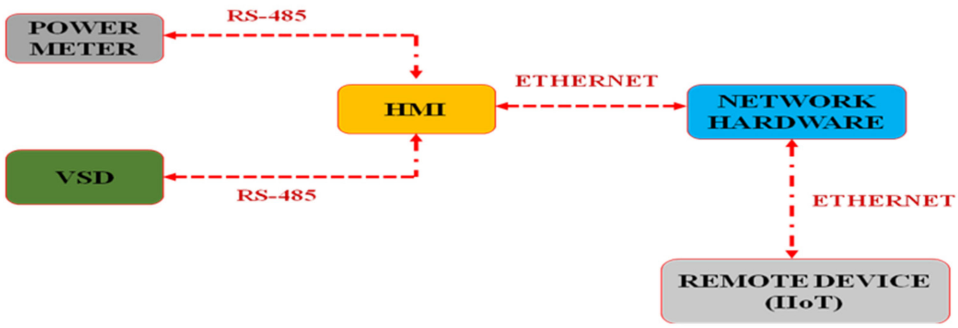


**Figure 3.** Architecture of the IIoT-based remote monitoring system.

- Installation of IIoT-based remote monitoring and data analysis system for a remote energy audit with both DOL and VSD control methods one by one.

Remote energy audit, which was done by accessing HMI data remotely with a VPN using an IIoT framework, consisted of the following steps—

- Data recorded in HMI during the DOL mode of operation was accessed remotely, monitoring and data analysis [63].
- System related to VSD and data recorded in HMI with the VSD mode of operation were accessed remotely for monitoring and data analysis [64]. Technical specifications of VSD used for the hydraulic pump motor in this study are shown in Table 2.

**Table 2.** Technical specifications of hydraulic pump motor VSD.

| Parameter | Rated Specification |
|---|---|
| Power | 7.5 kW |
| Input Volts | 3 Phase, 380–480 V |
| Input Frequency | 50, 60 Hz |
| Output Current | 16.5 A |
| Overload capability | 120% of rated current for 1 min. |
| Model Code | FRN7.5F1S-4A |
| Make | Fuji Electric |

- A detailed energy-saving audit report was prepared based on data collected remotely using IIoT.

An energy audit report was prepared remotely by the team of energy auditors and provided to the end user for implementation of energy-saving measures in the hydraulic press based on the energy audit conducted using a mixed approach of physical and remote energy audit utilizing IIoT technology [65,66].

## 3. Results and Discussions

In the physical energy audit, it was found that the design pressure (31.4 MPa) of the tested hydraulic press was higher than the required pressure (16.54 MPa). In the existing DOL starter, it was impossible to regulate motor speed and reduce design pressure to the required pressure value. Due to this, the hydraulic pump motor ran continuously at its rated speed during loading and unloading time. The hydraulic press system was then connected to the IIoT-based remote monitoring system and critical parameters for studying electrical consumption patterns as stored in HMI. Recorded parameters included input power consumption (kWh), input power factor, and the number of press strokes. These parameters were stored in HMI for one shift of operation of the hydraulic press, starting at 07:00 A.M. and ending at 05:30 P.M.; as has been tabulated in Table 3. As observed electrical energy consumption varied linearly with the number of press strokes, as shown in Figure 4. The input power factor with DOL control was observed to be 0.79. For a total number of 12,672 strokes with DOL control in one shift of hydraulic press operation, the total amount of electrical energy consumption was observed to be 31.1 kWh.

**Table 3.** Data collection was accomplished using an IIoT-based monitoring system with DOL control.

| Time | Power Meter Reading (kWh) | Press Strokes Count | kWh Consumed | Input Power Factor |
|---|---|---|---|---|
| 07:00 a.m. | 217.1 | 0 | 0 | 0.79 |
| 08:00 a.m. | 220.2 | 1045 | 3.1 | 0.79 |
| 09:00 a.m. | 222.8 | 2080 | 5.7 | 0.79 |
| 10:00 a.m. | 226.2 | 3565 | 9.1 | 0.79 |
| 11:00 a.m. | 229.5 | 4912 | 12.4 | 0.79 |
| 12:00 p.m. | 232.4 | 6301 | 15.3 | 0.79 |
| 01:00 p.m. | 235.4 | 7427 | 18.3 | 0.79 |
| 02:00 p.m. | 237 | 8000 | 19.9 | 0.79 |
| 03:00 p.m. | 239.7 | 9320 | 22.6 | 0.79 |
| 04:00 p.m. | 242.6 | 10,570 | 25.5 | 0.79 |
| 05:00 p.m. | 246.2 | 11,920 | 29.1 | 0.79 |
| 05:30 p.m. | 248.2 | 12,672 | 31.1 | 0.79 |

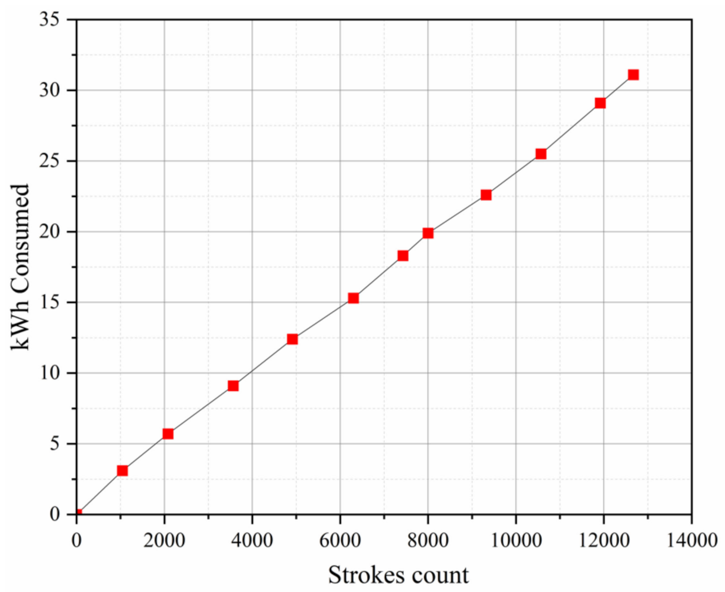


**Figure 4.** Electrical energy consumption variation with press stroke counts with DOL control.

To study the impact of replacing the existing DOL control with VSD control, the existing DOL starter was replaced with VSD, and the IIoT-based remote monitoring system was connected to collect critical parameters as stored in HMI. With VSD control, the operating speed of the hydraulic pump motor was regulated to find the optimum required pressure value without impacting the hydraulic press machine operation and the quality of the pressed material (gasket). This was done with close monitoring of its impacts on the hydraulic press machine's operation and in discussions with the machine operator to record any abnormalities. It was observed that speed variation of the hydraulic pump motor with VSD control resulted in a beneficial change in electrical energy consumption compared to DOL control. The hydraulic pump motor was then operated at 45 Hz, 40 Hz, and 35 Hz with a different number of press strokes as per the production requirement in that shift. Input electrical consumption and input power factor were stored in HMI for monitoring and data analysis remotely using IIoT. Variations in input electrical energy consumption and input power factor at different VSD output frequencies are tabulated in Table 4.

**Table 4.** Data collection was accomplished with an IIoT-based monitoring system with VSD control.

| Time | VSD Output Frequency (Hz) | Press Strokes Count | kWh Consumed | Input Power Factor |
|---|---|---|---|---|
| 07:00 a.m.–05:30 p.m. | 45 | 12,993 | 29.7 | 0.9 |
| | 40 | 12,852 | 23.1 | 0.9 |
| | 40 | 12,401 | 22.7 | 0.9 |
| | 35 | 13,190 | 23.5 | 0.9 |
| | 35 | 11,256 | 20.5 | 0.9 |
| | 35 | 10,696 | 17.1 | 0.9 |

As per recorded data, the input power factor with VSD control improved from 0.79 to 0.9 compared to the DOL control. Input electrical energy consumption varied with the operating speed of the hydraulic pump motor, as shown in Figure 5.

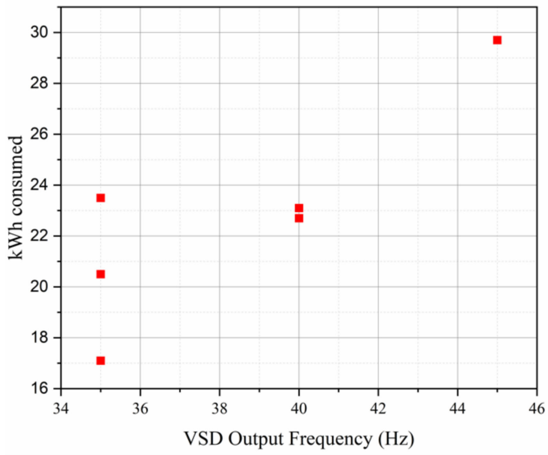


**Figure 5.** Electrical energy consumption variation with hydraulic pump motor speed in VSD control.

It was observed that if the operating speed of the hydraulic pump motor was reduced to below 35 Hz, the required hydraulic pump pressure dropped, causing improper press operations hence, it was decided to set the operating speed of the hydraulic press pump motor to 35 Hz. As shown in Figures 6 and 7, in comparison to a DOL control, variations in the electrical consumption of the hydraulic pump motor with VSD control were not linear with the press strokes count.

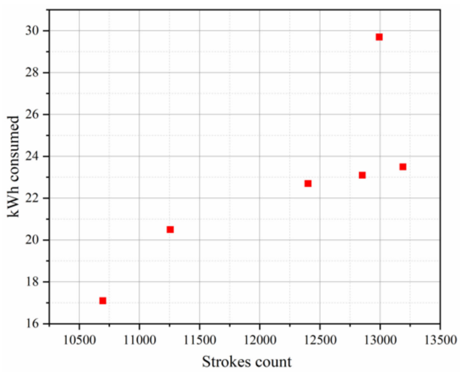


**Figure 6.** Electrical energy consumption variation with press strokes in VSD control.

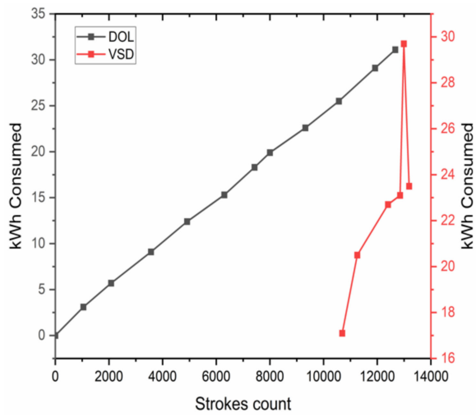


**Figure 7.** Electrical energy consumption variation with press stroke counts in DOL and VSD control.

With a total of 13,190 strokes in one shift of equal duration as in the case of DOL control, VSD control resulted in a reduction in input electrical consumption of the hydraulic press pump motor from 31.1 kWh in the DOL control to 23.5 kWh. With 518 extra press strokes, the electrical energy saving potential in this hydraulic press application due to shifting from DOL control to VSD control at 35 Hz operating speed was observed to be 24%. With a better input power factor and a 24% reduction in electrical energy consumption, VSD control in hydraulic press application proved to be a less energy-intensive than DOL control. The benefits of VSD control in comparison with DOL control in hydraulic press application as per the observations made in this research work are as tabulated in Table 5.

**Table 5.** Comparison of DOL and VSD control as per the proposed research work for the hydraulic press.

| S.No. | Hydraulic Pump Motor Control Method | | VSD Benefits in Hydraulic Press |
|---|---|---|---|
| | DOL | VSD | |
| 1 | Input power factor of the hydraulic pump motor was monitored to be 0.79 at different loads. | Input power factor of hydraulic pump motor was monitored to be 0.9 at all the tested motor loads. | Improvement of input power factor from 0.79 to 0.9 in comparison with DOL control method. Input power factor remained 0.9 in VSD control at all the tested motor loads. |
| 2 | Motor starting current was monitored to be 112 Amps. | Motor starting current was monitored to be 18 Amps. | 84% reduction in motor starting current. This reduced the electrical and mechanical stress on the motor due to smooth motor start as was possible with VSD control. |
| 3 | For every press cycle, motor loading time was monitored to be 1.5 s. Motor continuous current during loading time was monitored to be 27–28.5 Amps. | Motor continuous current during loading time was monitored to be 16–17 Amps. | 40% reduction in motor continuous current during loading time with VSD control. |
| 4 | For every press cycle, motor unloading time was monitored to be 0.5 s. Motor continuous current during unloading time was monitored to be 9.5–10.5 Amps. | Motor continuous current during unloading time was monitored to be 3–3.59 Amps. | 65% reduction in motor continuous current during unloading time with VSD control. |
| 5 | Motor speed regulation was not possible. Motor operated at its rated speed even during unloading time. | Motor tested at variable operational speeds—45 Hz, 40 Hz, and 35 Hz. Speed of operation was fixed at 35 Hz after careful observations. | Speed regulation with VSD control enabled the running of the motor as per operated conditions reducing the speed of the motor from 50 Hz in the DOL control to 35 Hz with VSD control. |
| 6 | Linear variation of electrical energy consumption with different press strokes was observed. | Electrical energy consumption varied non-linearly with change in speed of operation. Hydraulic press was operated at 45 Hz, 40 Hz, and 35 Hz with a different number of press strokes. | With speed regulation functionality in VSD control, electrical energy consumption was reduced significantly at lower speeds in comparison with DOL control where the speed of operation was fixed at 50 Hz. |
| 7 | For 12,672 press strokes by hydraulic press, electrical energy consumption was monitored to be 31.1 kWh. | For 13,190 press strokes by hydraulic press, the electrical energy consumed was monitored to be 23.5 kWh. | Energy saving of 24% with 518 additional strokes in VSD control at 35 Hz in comparison to DOL control without impacting hydraulic press machine operation and quality of the end product (gasket). |

A brief comparison of a physical energy audit with a remote energy audit (to be done utilizing IIoT as demonstrated in this research paper) is represented in Table 6 below.

**Table 6.** Comparison of a physical energy audit with remote energy audit method.

| S.No. | Energy Audit Method | |
|---|---|---|
| | **Physical Energy Audit** | **Remote Energy Audit** |
| 1 | Requires audit team to be physically present at audit site. | No physical presence of the audit team is needed as data collection, monitoring, and analysis can be done remotely using IIoT. |
| 2 | Less flexible as audit team, as well as plant site team, are required to be physically present at audit site. Energy audit takes more time due to the unavailability of audit team for the physical visit as they may be engaged in other urgent works. | More flexible as audit team can access the audit data at any time remotely as per their availabilities. Audit team needs to connect with the site system over IIoT to access the audit-related key data. |
| 3 | Cost is high as physical visit may require multiple travels and stays at audit site. | Cost is low as no travel and stays are required. Data monitoring and analysis can be done using IIoT. |
| 4 | Does not require IIoT connectivity and infrastructure at audit site. | Requires reliable IIoT connectivity and strong infrastructure all the time during audit period. |
| 5 | In some cases, physical audit does not result in actual implementation of energy-saving recommendations due to longer duration of total energy audit. | Remote energy audit has potential tomore positively influence the end user regarding implementation of energy-saving recommendations at a faster pace as audit results can be generated at a faster pace compared to physical energy audit. |

IIoT-enabled remote monitoring and data analysis, as proposed in this research work, took less time to prepare the energy audit report, which can influence end users in the implementation of energy-saving measures at their manufacturing facility within a short period.

## 4. Conclusions

In this study, a mixed method of performing an energy audit of a hydraulic press using IIoT showed improvements in input power factor from 0.79 to 0.9, an 84% reduction in motor starting current, a 40% reduction during the loading cycle, a 65% reduction during the unloading cycle, and a 24% reduction in electrical consumption with 518 extra press strokes by changing hydraulic pump motor. Energy-saving implementation using this proposed mixed method of a physical energy audit and remote data monitoring and analysis has a high potential to influence industrial units' decisions to adopt more energy-efficient hydraulic press technologies at a faster rate. After a careful study of the existing processes and available infrastructure required for the use of IIoT in energy-saving studies, this mixed approach of conducting energy audits with the help of IIoT frameworks can be extended to other applications in the plant. The future scope of this research work could include investigating the effect of VSD control on the temperature rise of hydraulic press pump motors at various operating speeds, as well as the actual financial implications of using IIoT for remote energy audits.

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