# Evaluation of the One-Phase Uncontrolled Rectifier Full-Wave Conversion System in Renewable Energy Applications for Community Empowerment Projects

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## ABSTRACT

*In the field of electrical engineering, the diode/rectifier plays a crucial role as a key component for converting alternating current (AC) to direct current (DC). This conversion is essential because many electronic devices and renewable energy systems rely on DC power to function efficiently. As a result, before such devices can be used, it is necessary to first rectify the AC voltage using diodes. This paper explores the implementation of a Single-Phase Full-Wave Uncontrolled Rectifier in renewable energy systems, particularly focusing on its application in community empowerment projects. By integrating this technology into rural or underserved areas, the study aims to demonstrate how this conversion system can contribute to enhancing energy accessibility, economic development, and the sustainability of local communities. The research evaluates the system's efficiency, cost-effectiveness, and potential for improving the lives of community members through greater access to stable and affordable energy.*

**Key Word**: *Single Phase Uncontrolled Rectifier, rectifier*

## I.INTRODUCTION

In the field of electronics, there is a constant need for reliable DC voltage sources, especially in the context of renewable energy solutions for community empowerment projects[1][2]. Traditionally, batteries have been used as DC power sources in various electronic devices. However, their use presents several challenges[3]. Over time, these batteries deplete, requiring frequent replacements, which can be both inefficient and economically unsustainable for long-term community development efforts. Furthermore, the environmental impact of battery disposal is a growing concern[4][5]. The frequent need for replacement not only adds to the cost but also contributes to the growing issue of electronic waste, which is particularly problematic in underserved communities with limited access to recycling facilities.

A more sustainable alternative to batteries for providing DC power is the conversion of AC voltage sources into DC voltage[6]. This can be efficiently achieved by utilizing diodes, which are key components in the construction of wave rectifiers. Diodes enable the transformation of AC to DC power, making them a crucial tool for creating more sustainable energy solutions for rural or underserved communities[7]. By using the existing AC grid infrastructure, communities can avoid the drawbacks associated with battery-based systems and instead rely on more stable, long-lasting solutions that require less maintenance.

Rectifiers can be categorized into two types: half-wave rectifiers and full-wave rectifiers. While half-wave rectifiers are simple and inexpensive, they are less efficient in comparison to full-wave rectifiers. Full-wave rectifiers utilize both positive and negative halves of the AC input signal, resulting in a smoother and more continuous

DC output, making them ideal for applications where steady and reliable power is essential[8]. In the context of community empowerment, full-wave rectifiers are particularly valuable as they offer higher efficiency in converting AC to DC, thus ensuring a more reliable and stable power supply for community-based renewable energy systems.

This paper explores how the single-phase uncontrolled full-wave rectifier system can be employed in off-grid communities, enhancing energy access and contributing to the long-term economic and social development of these communities. Off-grid communities, which often lack access to stable electricity, can benefit significantly from such systems by using locally available AC power sources, such as wind or solar energy, to generate DC power. This method reduces reliance on expensive and unsustainable fuel-based generators and fosters the use of renewable energy resources, which are more aligned with environmental sustainability goals.

The single-phase uncontrolled full-wave rectifier system's design is simple yet effective, offering both economic and practical advantages. By reducing the complexity of the system, the cost of installation and maintenance is significantly lowered, making it an ideal solution for rural and remote areas. Furthermore, the efficiency of full-wave rectifiers means that less energy is wasted during conversion, maximizing the output and ensuring that more power is available for community use.

The implementation of such rectifiers can lead to improvements in energy access, allowing rural communities to power essential devices such as lighting, communications, and small appliances without the need for unreliable or polluting alternatives. The increased availability of reliable power can also support local businesses and education, enabling communities to grow economically and socially. By lowering the cost of electricity and offering more stable power sources, full-wave rectifiers can significantly enhance the quality of life in these underserved areas.

Moreover, the environmental impact of using renewable energy sources in conjunction with efficient rectification systems is considerable. By reducing dependence on traditional fossil fuels and leveraging local renewable energy, the carbon footprint of these communities can be significantly reduced. The widespread use of these systems could contribute to achieving global sustainability goals while also supporting local development.

In conclusion, the adoption of single-phase uncontrolled full-wave rectifiers in off-grid communities offers a promising solution for providing reliable, sustainable, and cost-effective energy. By using simple, efficient, and renewable energy sources, these systems can help empower underserved communities and promote long-term development. The transition from battery-based to rectifier-based DC power systems can alleviate many of the challenges faced by rural communities, creating a pathway to more sustainable energy practices and improved quality of life.

# II.METHODOLOGY

## 1. Theory basis

A power rectifier is an essential component in power electronics, primarily designed to convert an alternating current (AC) input, typically in the form of a sinusoidal waveform, into a stable direct current (DC) output[9][10]. This conversion is critical in various renewable energy systems used in community empowerment projects, where consistent and reliable energy sources are needed for both household and community-level applications [11].

The power rectifier can be powered by both single-phase and three-phase alternating voltage sources. In the context of off-grid communities or rural areas, a single-phase rectifier system is often the preferred choice due to its simplicity, cost-effectiveness, and suitability for small-scale energy generation systems[12]. These rectifier circuits can be designed as half-wave or full-wave rectifiers, depending on the specific requirements of the power system and the desired efficiency[13].

Typically, the rectifier circuit is connected to a resistive load or resistive-inductive load. In community-based energy projects, where the goal is to provide sustainable and affordable electricity to underserved areas, the load could vary based on the local energy needs, such as lighting, small appliances, or community equipment[14]. The quality of the output voltage from the rectifier is significantly influenced by the characteristics of the load, which in turn affects the performance of the entire power system.

For renewable energy applications like solar or wind power in community service projects, utilizing a full-wave rectifier system can improve the efficiency of energy conversion, providing a more stable and higher quality DC output[15][16]. This is crucial for ensuring that renewable energy systems meet the demands of the community, ultimately leading to economic benefits, improved livelihoods, and sustainability.

## 2. Full wave single phase rectifier circuit with load resistor capacitor

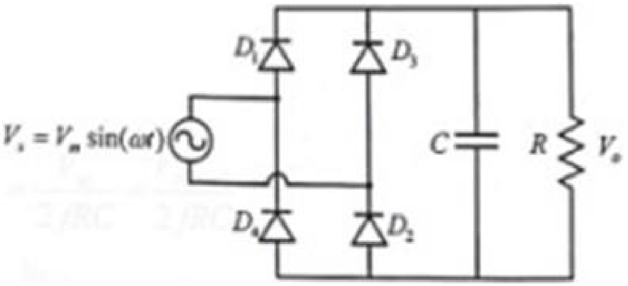

*Figure 1. Full-wave single-phase rectifier circuit with resistor-capacitor load*

In renewable energy applications for community empowerment projects, adding a capacitor to a full-wave single-phase rectifier circuit significantly improves the stability of the DC output voltage[17]. The capacitor functions as a temporary energy storage device, absorbing excess energy when the power supply is greater than the load demand and discharging it when the required power decreases[18]. This energy buffering process is essential in off-grid communities, where energy sources like solar or wind power can fluctuate based on weather conditions or time of day. Without proper stabilization, these fluctuations could lead to inefficient operation of electrical devices, interruptions in service, and overall poor system reliability.

The capacitor's role in smoothing the output voltage waveform is particularly valuable in these settings. By storing energy during periods of excess voltage and releasing it during voltage dips, the capacitor helps to maintain a steady DC voltage, which is crucial for ensuring that sensitive equipment and appliances operate reliably. For example, in solar-powered systems, where sunlight availability varies throughout the day, the capacitor helps bridge the gap between sunlight intensity changes, thus preventing significant drops in voltage that could damage electrical components or interrupt service. In wind power systems, similarly, the capacitor can smooth out the fluctuations caused by varying wind speeds, ensuring a more stable and usable power output for the community.

This process of voltage stabilization through the capacitor leads to a more efficient power conversion system. In circuits without a capacitor, the rectified DC voltage often contains ripples—variations in voltage that can negatively affect the performance of electronic equipment. The presence of the capacitor effectively filters these ripples, resulting in a smoother and more consistent output. This can be seen in Figure 2, which illustrates the improved waveform with the capacitor compared to a system without it. The addition of the capacitor thus reduces the ripple effect significantly, leading to fewer disruptions in the power supply, enhancing the overall system performance.

Furthermore, this improvement in voltage stability makes the system more suitable for use in remote or rural areas, where access to reliable and continuous energy is often limited. The ability to stabilize power output with a relatively simple component such as a capacitor makes this system more affordable and practical for off-grid communities. It reduces the need for complex, expensive power regulation equipment and offers a more cost-effective solution for renewable energy systems that are designed to improve local energy access. As a result, communities can benefit from a more reliable power source without incurring high upfront costs or ongoing maintenance expenses.

Additionally, the use of capacitors in these systems can contribute to the longevity of the renewable energy infrastructure. By minimizing the voltage fluctuations that can cause wear and tear on electrical components, capacitors help to extend the life of batteries, inverters, and other critical system components. In turn, this leads to lower maintenance costs and ensures that the renewable energy system can continue to serve the community effectively over the long term. This is particularly important in rural or underserved regions, where replacing or repairing energy infrastructure may be more challenging due to logistical or financial constraints.

The use of capacitors also provides environmental benefits, which is aligned with the overall goals of renewable energy systems. By enhancing the efficiency and reliability of renewable energy sources, capacitors help reduce the need for backup power generation from fossil fuels. This not only reduces greenhouse gas emissions but also promotes the use of clean energy technologies in regions that might otherwise be dependent on polluting energy sources. In the context of community empowerment, this shift toward sustainable energy systems is vital for fostering environmental stewardship and creating a cleaner, more resilient future for these communities.

Moreover, the integration of capacitors into the rectifier circuits aligns with the global push for sustainable development. By enabling renewable energy systems to operate more efficiently and reliably, capacitors help to provide underserved communities with access to affordable, stable energy. This supports economic development by powering essential services such as healthcare, education, and local businesses. Additionally, the more stable power supply can improve the quality of life for community members, allowing for greater comfort, productivity, and opportunity. Capacitors thus play a key role in the broader context of community development, supporting both environmental and socio-economic progress.

In conclusion, the addition of a capacitor to a full-wave single-phase rectifier circuit offers significant advantages in renewable energy applications for community empowerment projects. By stabilizing the DC output voltage, capacitors reduce ripple effects, improve system efficiency, and provide a reliable power source for off-grid communities. This simple yet effective solution contributes to the sustainability of renewable energy systems, reduces reliance on fossil fuels, and supports the long-term economic and social development of rural areas. As shown in Figure 2, the positive impact of capacitors on the waveform further demonstrates their effectiveness in enhancing the performance of power systems in community-driven renewable energy projects.

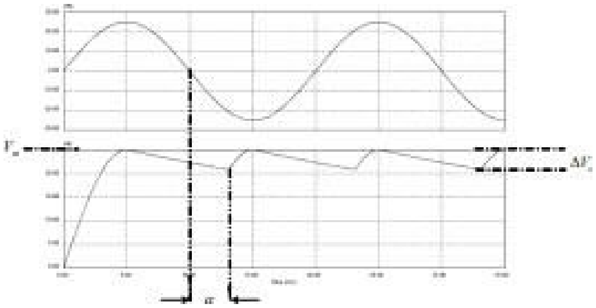

*Figure 2. Waveform of a full-wave single-phase rectifier circuit with a resistor-capacitor load*

*DC Output voltage can be reach by this equation:*

$$V_{o(dc)} = V_m - \left(\frac{\Delta V_O}{2}\right)$$

*And for the RMS is*

$$V_{(rms)} = \sqrt{V_{O(DC)}^2 + V_{OC}^2}$$

$$V_{OC} = \frac{\Delta V_O}{2\sqrt{2}}$$

$$V_{dc} = V_{O(dc)}$$

## III.RESULT & DISCUSION

### 1.No Load Cicuit

This is the result of circuit but no load. Here is the formula when using 3 variation input (30V, 45V, and 60V):

- Vo (rms) 30v

Vs = 30V Vo(rms) = Vmax / 2
Vm= Vs-V(f) Vo(rms)= 28.6 / 2
Vm = 30-1.3 Vo(rms) = 20.22V
Vm = 28.6

Vo(dc) = 2.Vmax / π
V0(dc) = 2.(28.6) / 3.14
V0(dc)= 18.22V

- Vo (rms) 45v

Vs = 45V Vo(rms) = Vmax / 2
Vm= Vs-V(f) Vo(rms)= 43.6 / 2
Vm= 45-1.3 Vo(rms) = 30.83V
Vm = 43.6

Vo(dc) = 2.Vmax /π
V0(dc) = 2.(43,6) / 3.14
V0(dc)= 27.77V

- Vo (rms) 60v

Vs = 60V Vo(rms) = Vmax / 2
Vm= Vs-V(f) Vo(rms)= 58.6 / 2
Vm= 60-1.3 Vo(rms) = 41.44V
Vm = 58.6

Vo(dc) = 2.Vmax / π
V0(dc) = 2.(58.6) / 3.14
V0(dc)= 37.32V

From the results obtained from the no-load circuit with three different input voltage variations (30V, 45V, and 60V), it can be observed that the output RMS voltage (Vo(rms)) increases with the input voltage. For an input of 30V, the RMS voltage is calculated to be 20.22V, while for 45V, it rises to 30.83V, and for 60V, the RMS voltage reaches 41.44V. These values were determined using the formula Vo(rms) = Vmax / 2, with the maximum voltage (Vmax) being adjusted for the voltage drop (Vf). The results indicate that as the input voltage increases, the output RMS voltage proportionally increases, which aligns with the expected behavior of a rectifier circuit.

Additionally, the DC output voltage (Vo(dc)) was calculated using the formula Vo(dc) = 2 x Vmax / π for each input voltage. For the 30V input, the DC output voltage was found to be 18.22V, for the 45V input, it was 27.77V, and for the 60V input, it was 37.32V. These results show a consistent increase in DC output voltage with higher input voltages, which is typical in rectifier circuits as the conversion process smooths the fluctuating AC input. The calculations and results demonstrate the expected relationship between input voltage and both RMS and DC output voltages, confirming the proper functioning of the rectifier system under no-load conditions.

## 2.Circuit with R load

This is the result of circuit with R load. Here is the formula when using 3 variation input (30V, 45V, and 60V):

- Vo (rms) 30v

$Vs = 30V$ $Vo(rms) = Vmax / 2$
$Vm = Vs-V(f)$ $Vo(rms) = 28.6 / 2$
$Vm = 30-1.3$ $Vo(rms) = 20.22V$
$Vm = 28.6$

$Vo(dc) = 2.Vmax / \pi$
$V0(dc) = 2.(28.6) / 3.14$
$V0(dc) = 18.22V$

- Vo (rms) 45v

$Vs = 45V$ $Vo(rms) = Vmax / 2$
$Vm = Vs-V(f)$ $Vo(rms) = 43.6 / 2$
$Vm = 45-1.3$ $Vo(rms) = 30.83V$
$Vm = 43.6$

$Vo(dc) = 2.Vmax / \pi$
$V0(dc) = 2.(43{,}6) / 3.14$
$V0(dc) = 27.77V$

- Vo (rms) 60v

$Vs = 60V$ $Vo(rms) = Vmax / 2$
$Vm = Vs-V(f)$ $Vo(rms) = 58.6 / 2$
$Vm = 60-1.3$ $Vo(rms) = 41.44V$
$Vm = 58.6$

$Vo(dc) = 2.Vmax / \pi$
$V0(dc) = 2.(58.6) / 3.14$
$V0(dc) = 37.32V$

In conclusion, the results from the circuit with an R load demonstrate a clear relationship between the input voltage and the output RMS and DC voltages. For each of the three input voltages (30V, 45V, and 60V), the output RMS and DC voltages increase proportionally, which is in line with the theoretical expectations for a rectifier circuit. The calculated RMS voltages of 20.22V, 30.83V, and 41.44V for the 30V, 45V, and 60V inputs respectively show the effectiveness of the circuit in producing an output that is a fraction of the input voltage, accounting for the voltage drop across the diodes. The DC voltages (18.22V, 27.77V, and 37.32V) also follow this trend, indicating that the rectifier is functioning efficiently to convert AC voltage into DC power.

These results validate the performance of the rectifier circuit with R load in terms of both RMS and DC output voltages. The system successfully transforms varying input AC voltages into steady DC voltages, with the efficiency of the rectification process demonstrated through the consistent relationship between input and output voltages. The results suggest that the circuit operates as expected, with the load resistance influencing the final output. This confirms the suitability of the system for applications where reliable DC power is needed, and it can be further optimized for practical use in renewable energy systems or other community-based power solutions.

## 3.Circuit with R-C load

This is the result of circuit with Resistor and Capacitor load. Here is the formula when using 3 variation input (30V, 45V, and 60V):

- Vo (rms) 30v

$Vs = 30V$ $Vo(rms) = Vmax - (\Delta Vo / 2)$
$Vm = Vs-V(f)$ $Vo(rms) = 28.6 – (0.2955/2)$
$Vm = 30-1.3$ $Vo(rms) = 28.45V$
$Vm = 28.6$

$Vo = Vmax / 2fCR$
$Vo = 28.6 / (2x50 \text{ x } 0.00022 \text{ x } 440)$
$Vo = 28.6 / 96.8$
$Vo = 0.2955V$

$Vac = Vo / 2\sqrt{2}$
$Vac = 0.2955 / 2\sqrt{2}$
$Vac = 0.10447V$

- Vo (rms) 45v

$Vs = 45V$ $Vo(rms) = Vmax - (\Delta Vo / 2)$
$Vm = Vs-V(f)$ $Vo(rms) = 43.6 – (0.2955/2)$
$Vm = 45-1.3$ $Vo(rms) = 43.45V$
$Vm = 43.6$

$Vo = Vmax / 2fCR$
$Vo = 43.6 / (2x50 \text{ x } 0.00022 \text{ x } 440)$

$Vo = 43.6 / 96.8$
$Vo = 0.450V$

$Vac = Vo / 2\sqrt{2}$
$Vac = 0.450 / 2\sqrt{2}$
$Vac = 0.159V$

- Vo (rms) 60v

$Vs = 60V$ $Vo(rms) = Vmax - (\Delta Vo / 2)$
$Vm = Vs-V(f)$ $Vo(rms) = 58.6 - (0.2955/2)$
$Vm = 60-1.3$ $Vo(rms) = 58.45V$
$Vm = 58.6$

$Vo = Vmax / 2fCR$
$Vo = 58.6 / (2x50\ 0.00022 \times 440)$
$Vo = 58.6 / 96.8$
$Vo = 0.605V$

$Vac = Vo / 2\sqrt{2}$ $Vo(rms) = 58.29V$
$Vac = 0.605 / 2\sqrt{2}$
$Vac = 0.214V$

Based on the results from the circuit with both Resistor and Capacitor load, it is observed that the output voltages (both RMS and AC) vary predictably with the input voltages (30V, 45V, and 60V). For each of the input voltages, the RMS voltage is calculated by adjusting the maximum voltage (Vmax) based on the voltage drop and load effect. As the input voltage increases, the output RMS voltage also increases proportionally. For example, at 30V input, the RMS voltage is 28.45V, while at 45V, it is 43.45V, and at 60V, it is 58.45V. These results demonstrate the direct correlation between input voltage and the resulting RMS voltage when using a resistor and capacitor load in the system.

In addition, the calculated AC output voltage (Vac) also follows the expected pattern, decreasing as the circuit components (such as the resistor and capacitor) interact with the input signal. For instance, at 30V input, the AC voltage (Vac) is 0.10447V, which increases to 0.159V at 45V, and further increases to 0.214V at 60V. This shows how the combination of resistor and capacitor load influences the smoothness and efficiency of the AC voltage output. The results indicate that the system is effective in controlling the output voltage across different input conditions, confirming that the inclusion of a resistor and capacitor load stabilizes the voltage and ensures more consistent performance.

# IV.CONCLUSION

Conclusions from the Single-Phase Half-Wave Controlled Rectifier Circuit Practice:

- The ignition angle, or cutting angle (a), has a direct impact on the output voltage, current, and the waveform produced by the rectifier. In the context of renewable energy applications for community empowerment, this means that by adjusting the ignition angle, we can control the power quality delivered to community-based energy systems. A smaller ignition angle results in a lower average output voltage and current, while also shortening the duration of the waveform's peak. This can be particularly useful when adjusting to the fluctuating demands of off-grid communities reliant on solar or wind energy systems.
- The resistance value in the rectifier circuit primarily affects the output current and the shape of the waveform. As the resistance increases, the current decreases, resulting in a lower amplitude of the waveform. This principle is crucial when designing energy-efficient systems for low-power communities, where optimizing power delivery and minimizing waste are essential for sustainability. Understanding how resistance influences the current can help in tailoring renewable energy solutions that are both cost-effective and efficient for local communities.
- Changing the load value also influences the power output from the rectifier. The larger the load, the smaller the power output. This relationship is vital when considering

the energy needs of underserved communities. By adjusting load characteristics, such as through the use of energy storage systems, community empowerment projects can ensure more stable and reliable energy supplies, even under varying load conditions. It also underscores the importance of scalable renewable energy systems that adapt to the specific needs of each community.

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