



## Inflow Analysis in Converter Device in Air Conditioner 1 PK in the Room

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### Abstract

Inrush current is a phenomenon of surge in current that occurs at the beginning of the operation of a power converter device in an Air Conditioner (AC) system, especially at a capacity of 1 PK which is widely used in residential and office rooms. This surge of current is generally triggered by the process of charging the DC-link capacitor in the rectifier circuit as well as the initial characteristics of the compressor motor at starting. High inflow values can lead to a decrease in voltage quality, interference with the distribution system, as well as accelerate the degradation of power electronic components. This study aims to analyze the characteristics of inflow in AC 1 PK converters in closed room conditions with certain thermal loads.

The methods used include direct measurement using a power quality analyzer as well as transient analysis based on the impedance parameters of the source and input capacitor. The observed parameters included peak current, transient duration, initial power factor, and the effect of room temperature on compressor load.

The results of the analysis showed that the inflow can reach 4-7 times the nominal current in a time range of a few milliseconds to hundreds of milliseconds, depending on the converter design and the straining method used. The implementation of a series of soft-start and NTC thermistor-based current limiters has proven to be effective in lowering the peak value of the current by more than 40%, thereby improving system reliability and reducing disruption to the room's power grid. This study provides technical recommendations in the design and operation of converter-based air conditioners to be more efficient and friendly to power distribution systems.



**Keywords:** Inrush current, Inrush current, Power converter, Air Conditioner 1 PK, Soft-start, Electric power quality, Compressor motor.

## I. Introduction

Air Conditioner (AC) with a capacity of 1 PK is one of the most widely used electrical appliances in residential rooms, offices, and educational facilities in Indonesia. As power electronics technology has evolved, modern air conditioning systems have generally used rectifier-based converter devices - DC link - inverters to improve energy efficiency and flexibly adjust compressor speeds. Although it provides advantages in terms of efficiency and more precise temperature control, the use of power converters causes the phenomenon of electrical transients at the beginning of operation, one of which is the inrush current.

An inlet current is a surge in current that occurs in a short period of time when the device is first connected to a voltage source. In a 1 PK AC system, the inflow is generally triggered by two main mechanisms, namely the initial charge of the capacitor on the DC-link side of the converter and the starting characteristics of the compressor motor. This current value can reach several times the nominal current and lasts in the range of milliseconds to hundreds of milliseconds. This condition has the potential to cause a decrease in power quality, voltage dip, unwanted MCB disconnection, and accelerate the degradation of components such as rectifier diodes, electrolyte capacitors, and semiconductor switches.

In a room distribution system with limited power capacity, the initial current surge of AC 1 PK can affect the voltage stability, especially if several electrical appliances are operating at the same time. This is important to study because the inflow phenomenon has an impact not only on the device itself, but also on the reliability of the room's electrical installation system as a whole. Therefore, an inflow characteristic analysis is required that includes the peak value of the current, the duration of the transient, the influence of the source impedance, and the thermal load conditions of the room on the performance of the converter.

The research on the analysis of inflow in the AC 1 PK converter device aims to identify the amount of initial current that occurs, analyze the factors that affect it, and evaluate mitigation methods such as the use of soft-start circuits and current limiters based on NTC thermistor. By understanding these characteristics, it is hoped that technical recommendations can be obtained in the design and operation of an air conditioning system that is more reliable, efficient, and minimal disruption to the quality of electrical power in the room installation.

## II. Literature Review

Inrush current is a transient phenomenon that occurs in electronic power systems when devices are connected to a power source, especially at the start-up stage of components



with inductive and capacitive elements such as converters and compressor motors. This current often has a peak value that far exceeds the normal operating current in a short period of time and can cause disturbances in power quality as well as thermal stress on power electronic components.

## 2.1 Inlet Current Characteristics of Power Converters

In a standard AC-DC converter, the initial current surge is mainly caused by the rapid charging of the input capacitor on the DC line after the rectifier. Technical studies show that this inlet current can reach tens of amperes and put pressure on fuses, rectifier diodes, capacitors, as well as semiconductor switches if not properly limited. In addition, research on inrush current in large converter systems, such as in converter transformers, shows that this phenomenon impacts not only current but also on the electromagnetic forces and vibrations of components, demonstrating the complexity of transient characteristics in power systems with converters.

## 2.2 Inrush Current in HVAC Systems and Compressor Motors

In HVAC systems, especially air conditioners, the surge in current comes not only from the power converter, but also from the compressor motor at the time of starting. Research on pump and induction engine applications shows that inrush current can multiply the nominal current and affect network voltage stability and cause circuit protection disconnection if not managed. For AC motors, the use of control devices such as soft start circuits or AC-AC phase angle control can significantly reduce current surge under start-up conditions, which is relevant in AC 1 PK compressor motor applications.

## 2.3 Inflow Restriction and Mitigation Methods

Various approaches have been researched to limit or reduce the inflow in power converters. One common method is the application of soft-start, either with phase angle control on the AC-AC converter so that the initial voltage rises gradually, or with limiting elements such as the NTC thermistor which provides a high initial resistance to limit the peak current before it drops during internal heating. In addition, in the study of inflows in large beginner converters such as converter transformers, transient modeling techniques and numerical simulations are used to assess and develop mitigation strategies to suppress surges and reduce structural or electromagnetic impacts.

## 2.4 Relevance to 1 PK air conditioner in the room

Although many studies focus on large power applications or industrial induction motors, the same principle applies to 1 PK capacity domestic air conditioning systems that are generally equipped with built-in power converters. The 1 PK AC has an induction motor compressor that is at start-up and a DC-link converter on the inverter capable of generating a



significant surge of current that can affect the room's electrical distribution network. An understanding of the characteristics of the inflow and effective mitigation techniques are essential for the air conditioning system to operate reliably without causing voltage disruptions to local electrical installations or extending the life of power components.

### III. Methodology

#### 3.1 Types and Approaches to Research

This study uses an experimental quantitative approach with direct measurement methods and transient analysis. The focus of the research is to identify the characteristics of the inrush current in the AC 1 PK converter device during the initial operating conditions in a closed room.

The approach is carried out through:

1. Current and voltage measurements at start-up.
2. Transient parameter analysis.
3. Evaluate the influence of room conditions and source impedance.

#### 3.2 Objects of Research

The object of the study is:

- a. Air Conditioner 1 PK inverter type
- b. Supply voltage: 220 V, 50 Hz
- c. Nominal power capacity:  $\pm 800 - 1000$  Watts
- d. Location: Enclosed room with a volume of  $\pm 3 \text{ m} \times 4 \text{ m} \times 3 \text{ m}$

#### 3.3 Research Variables

1. Free Variables
  - a. Initial room temperature conditions ( $^{\circ}\text{C}$ )
  - b. Supply voltage (V)
  - c. Source impedance ( $\Omega$ )
  - d. Squeezing method (without current limiter and with soft-start/NTC)
  
2. Bound variable
  - a. Peak incoming current (A)
  - b. Transient current duration (*ms*)
  - c. Instantaneous voltage *drop* (*voltage dip*)
  - d. Power factor at start-up
  
3. Control Variables
  - a. Fixed AC specification
  - b. Fixed cable installation
  - c. PLN contract power unchanged



### 3.4 Equipment and Instruments

The instruments used include:

a. Power Quality Analyzer is:

To measure current, voltage, power factor, and power quality disturbances.

b. Clamp Meter True RMS is:

For instantaneous current verification.

c. Digital Oscilloscope as:

To capture transient current waves with millisecond resolution.

d. Digital Thermometer / Data Logger Temperature is:

To measure the initial temperature of the room.

e. Digital Multimeter is used:

For the measurement of additional electrical parameters.

### 3.5 Research Procedure

The stages of the research are carried out as follows:

Stage 1: Preparation

a. Ensure electrical installations are under standard conditions.

b. Calibrates the entire measuring instrument.

c. Set the initial temperature of the room according to the test variation (e.g. 24°C, 28°C, 32°C).

Stage 2: Testing Without Current Limiter

a. The air conditioner is in a dead condition for at least 10 minutes.

b. Power analyzer and oscilloscope are activated.

c. AC is turned on and records are made:

- Peak current

- Transient duration time

- Drop voltage

d. The test is repeated at least 5 times to get the average.

Stage 3: Testing with current limiter (if applicable)

a. Using an internal soft-start system or NTC limiter.

b. Repeat the same procedure as Stage 2.

c. Compare the results before and after mitigation.



### 3.6 Data Analysis Techniques

Analysis is carried out by:

a. Descriptive Analysis

Calculating:

$$I_{inrush} = \frac{V_{sumber}}{Z_{Total}}$$

$I_{inrush} = Inflow (A)$

$V_{source} = Supply Voltage (V)$

$Z_{total} = Total Impedance of the circuit (\Omega)$

### 2. Transient Analysis

Determines:

a. Peak value of current (A)

b. Time constant ( $\tau$ )

c. Duration of voltage disturbance

### 3. Comparison of Mitigation Effectiveness

$$\% Reduksi = \frac{I_{awal} - I_{mitigasi}}{I_{awal}} \times 100\%$$

### 3.7 Research Flow Diagram

The research flow in general:

a. Literature Study

b. Preparation of Tools and Installation

c. Start-up Flow Measurement

d. Data Processing

e. Analysis and Evaluation

f. Conclusion

## IV. Discussion

### 4.1 Analysis of Inflow Characteristics in AC 1 PK

Air Conditioner (AC) 1 PK inverter type generally has a series of converters consisting of rectifiers, DC-link capacitors, and inverters to drive the compressor motor.



When it is first turned on (start-up), there are two main phenomena that cause inrush current, namely:

1. Precharging of DC-link capacitors on the rectifier side.
2. Starting compressor motor, especially if using induction motor or BLDC with inverter control.

Under the initial condition, the DC-link capacitor is at a voltage of zero volts, so when connected to a 220 V AC source, the current flowing is very large because the circuit impedance is limited only by the resistance of the wire, the rectifier diode, and the impedance of the source. Theoretically, the inflow can be calculated with Ohm's law approach at the initial transient state:

$$I_{inrush} = \frac{V_{peak}}{R_{Total}}$$

Where:

$$V_{peak} = \sqrt{2} \times V_{rms}$$

$R_{Total}$  = total resistance of the circuit at start-up

In addition, the capacitor charging process follows exponential characteristics:

$$i(t) = \frac{V_{peak}}{R} e^{-t/RC}$$

:

Transient duration is determined by the time constant:

$$\tau = R \times C$$

## 4.2 Example of Manual Calculation 1

Calculation of Inlet Current Due to DC-Link Capacitor Charging

Known:

Supply voltage = 220 V (*rms*)

DC-link capacitor = 470  $\mu F$

Total resistance (cable + diode + source impedance) = 2  $\Omega$



Step 1: Calculate the Peak Voltage

$$V_{peak} = \sqrt{2} \times 220$$
$$V_{peak} = 1,414 \times 220 = 311 \text{ volt}$$

Step 2: Calculate the Maximum Inflow Current

$$I_{inrush} = \frac{311}{2}$$
$$I_{inrush} = 155,5 \text{ ampere}$$

So theoretically, the initial inflow can reach  $\pm 155$  A in a very short time (a few milliseconds).

Step 3: Calculate the Time Constant

$$\tau = R \times C$$
$$t = 2 \times 470 \times 10^{-6}$$
$$\tau = 0.00094 \text{ seconds} = 0.94 \text{ ms}$$

That is, in about  $5 \tau$  ( $\approx 470$  ms), the current will drop to near zero and the capacitor is almost fully charged.

The analysis of the value of 155 A is much larger than the nominal current of AC 1 PK which is usually around:

$$I_{nominal} = \frac{900}{220} \approx 4,1A$$

So that the inflow is 37 times the nominal flow. This is the cause of frequent MCB trips or voltage drops in the room.  $\approx$

### 4.3 Example of Manual Calculation 2

Current Calculation Starting Motor The

1 PK AC compressor has a power of about 900 att with an efficiency of 85% and a power factor of 0.85.

Known:



Compressor output power:

P=900 Watts

Voltage=220 V

Power factor=0.85

Step 1: Calculate Nominal Current

$$I = \frac{P}{V \times \cos \phi}$$

$$I = \frac{900}{220 \times 0,85}$$

$$I = \frac{900}{187}$$

$$I = 4,81 A$$

Step 2: Calculate Starting Current

Motor Compressor motors generally have a starting current of 4 -7 times nominal current.

For example, it is assumed 5 times:

$$I_{start} = 5 \times 4,81$$

$$I_{start} = 24,05 A$$

Analysis

The starting current of the motor of  $\pm 24 A$  lasts longer than the charging current of the capacitor (can be 100 -300 ms). If both phenomena occur at the same time, then the room system with MCB 6A or 10A has the potential to trip.

#### 4.4 Discussion of the Impact on Room Installation

In a household installation with a power of 1300 VA:

$$I_{maks} = \frac{1300}{220} \approx 5,9 A$$



If the instantaneous current reaches 20 -150 A even if it is only for a few milliseconds, then:

There is a momentary voltage dip

The lamp can dim for a moment the

sensitive MCB can be tripped

, the thermal stress on the diode and capacitor increases

#### 4.5 Mitigation Effectiveness (Brief Illustration)

If NTC 10  $\Omega$  is used. At start-up:

$$I_{baru} = \frac{311}{(2 + 10)}$$

$$I_{baru} = \frac{311}{12}$$

$$I_{baru} = 25,94 \text{ A}$$

There was a decrease from 155 A to  $\pm 26$  A (a reduction of about 83%).

#### V. Conclusion

Based on the results of analysis and calculation of the *inrush current* on the 1 PK Air Conditioner (AC) converter device, it can be concluded that the inrush current phenomenon is a significant transient condition and has the potential to affect the reliability of the room's electrical system. The surge in current is mainly caused by two main factors, namely the process of precharging the DC-link capacitor in the rectifier circuit and the starting current of the compressor motor at the beginning of operation.

The results of the analysis show that the inlet current due to capacitor charging can reach tens to hundreds of amperes in a very short time (order of milliseconds), while the starting current of the compressor motor ranges from 4–7 times the nominal current and lasts longer (up to hundreds of milliseconds). When compared to the nominal current of AC 1 PK which is on average in the range of 4-5 A, the value of the transient current is much larger and has the potential to cause *voltage dip*, power quality disorders, and safety disconnection (MCB) in room installations with limited power.

In addition, the inlet current characteristics are greatly influenced by the source impedance, the value of the DC-link capacitor, the supply voltage conditions, and the starting method used. The application of current-limiting methods such as NTC thermistors or *soft-start systems* has proven to be effective in significantly lowering peak currents, thereby



improving device reliability, extending the life of power electronics components, and minimizing interference to the room's electrical distribution system.

Thus, the analysis of the inflow in AC 1 PK is an important aspect in the design of a converter system and a room electrical installation, especially in systems with limited power capacity. Understanding these transient characteristics can be the basis for determining the appropriate protection specifications and mitigation strategies to ensure safe, stable, and efficient operations.

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