

## Development of an Improve Power Factor Corrector Trainer Set

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### Abstract

The main goal of this study is to find out how common power factor correction (PFC) method works. Using the APFC trainer located at Makmal Peralatan dan Pengujian Univesity Tun Hussein Onn Kampus Pagoh, the experiment looks at different types of loads, such as resistive, inductive, and capacitive loads with different value. After that, the test results are compared to theoretical calculations to see how good the trainer is at adjusting power factor correctly. The study tries to find out if changing the value on the capacitive load can help get the desired power factor under different load conditions. The research results help to understand how APFC (Automatic Power Factor Correction) systems can be used in real life to improve the efficiency of power factors in electrical systems. The study shows that the APFC trainer can change the power factor for different loads, which is very close to what theoretical calculations predicted would happen. By changing the APFC trainer's and RLC load parameters in a planned way, the desired power factor is always reached in the experimental setup. The results show that APFC systems can work in real life, which is useful information for understanding how they can make electrical networks more efficient and improve the quality of power. This study shows how important it is to use APFC technology to improve power factor management.

## 1. Introduction

The power factor is a way to measure how much reactive power is in an electrical system. The energy in electricity that isn't being used for anything useful is called reactive power. Reactive power is made when electrical current and induction fur work together. A bad power factor happens when there are a lot of motors in an electric system. This means that there are more losses in the wires and transformers. A capacitor could be added to improve the power factor. [1]

The main goal of this study is to improve the quality of power in electrical systems. To do this, this study will look at some common Power Factor Correction (PFC) methods and use an Automatic Power Factor Correction (APFC) trainer to test different loads (resistive, inductive, and capacitive) and compare the results. The objective is to study if changing the capacitive load value can achieve the desired power factor in different situations. This would show that APFC systems can manage power factor well in real-life situations, which would result in higher energy efficiency and lower operating costs.

Maintaining a power factor close to one to improve power quality and lower costs is one way that power factor improvement has been looked into in the past. Other ways include using capacitor banks for voltage

stability and system capacity, and using automated systems with microcontrollers for energy monitoring and power factor correction. These studies show how important and useful APFC technology is for making electrical systems more efficient. Table 1 shows the summary of the comparison of previous projects that are related to the objectives of this project.

**Table 1** Comparison of the previous project

Title of project	Summary
Case Study on Improvement of Power Factor of an Industrial Load [2]	Improved power factor improves quality, reduces losses, and lowers costs; used simulations to model and size capacitor banks.
Analysis of Power Factor Over Correction in a Distribution Feeder [3]	Capacitor banks improve voltage stability, power factor, and capacity; switched based on load.
Automated Power Factor Correction and Energy Monitoring System [4]	APFC unit monitors and improves power factor using open-source library for accurate calculations.
Long Term Effect of Power Factor Correction on the Industrial Load: A Case Study [5]	Optimal capacitor locations and sizes improve power factor, proving efficiency and economic benefits.
Microcontroller based Automatic Power Factor Correction System for Power Quality Improvement [6]	Maintains high power factor by adding capacitors; uses sensor and Arduino microcontroller.

## 2. Hardware and Methods

The methods required to carry out the project are divided into two parts: Practical and Theoretical.

### 2.1 Hardware

The hardware needed for practical testing are:

- Automatic Power Factor Correction Trainer
- Resistive Loading Unit
- Inductive Loading Unit
- Capacitive Loading Unit
- LCR Meter
- Clamp Meter

On the other hand, the theoretical equations needed are:

- Power Factor

$$\text{Power Factor} = \frac{\text{Real Power (W)}}{\text{Apparent Power (VA)}} \quad (1)$$

$$\text{Apparent Power (VA)} = \sqrt{W^2 + VAR^2} \quad (2)$$

- Active Power

$$P = \sqrt{3}(415)(I)\cos\theta \quad (8)$$

- Reactive Power for Capacitor and Inductor

$$3 \times \frac{415^2}{3} \times 2\pi fC \quad (9)$$

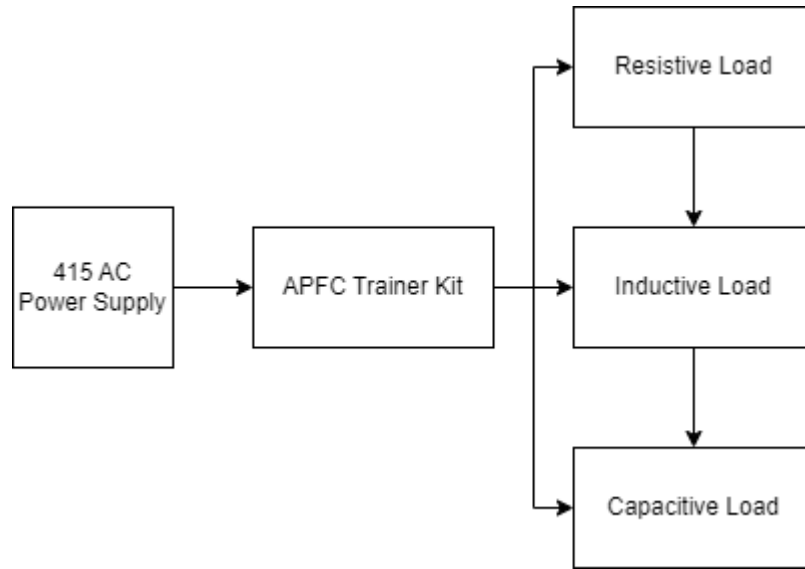
$$3 \times \frac{415^2}{3} \times \frac{1}{2\pi fL} \quad (10)$$

- Required Var

$$Q_C = P \times (\tan\theta_1 - \tan\theta_2) \quad (11)$$

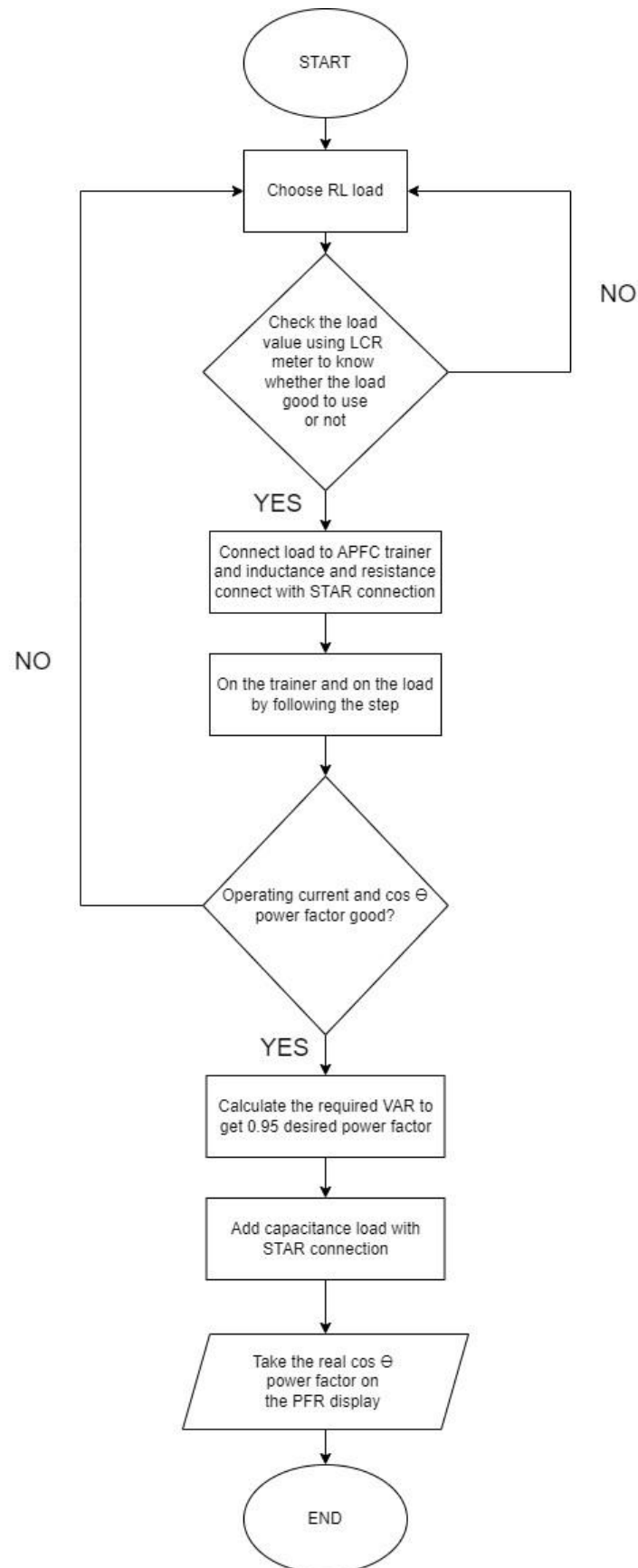
## 2.2 Methods

Methods in carrying out projects include system block diagrams, project flowcharts, and hardware circuit design. Figure 1 shows a setup in which an APFC trainer kit is connected to a 415 V AC power source. The APFC trainer kit then powers an RLC (Resistor, Inductor, and Capacitor) load unit and the load unit is connected in STAR each other. By changing the RLC load, the APFC trainer kit is used to find the power factor. The APFC trainer kit consistently increases the power factor in response to changes in the load's characteristics, while the RLC load unit acts like a real load by using resistive, inductive, and capacitive elements. This setup is often used for training and education purposes to show the basic ideas and real-world applications of power factor correction in electrical systems.

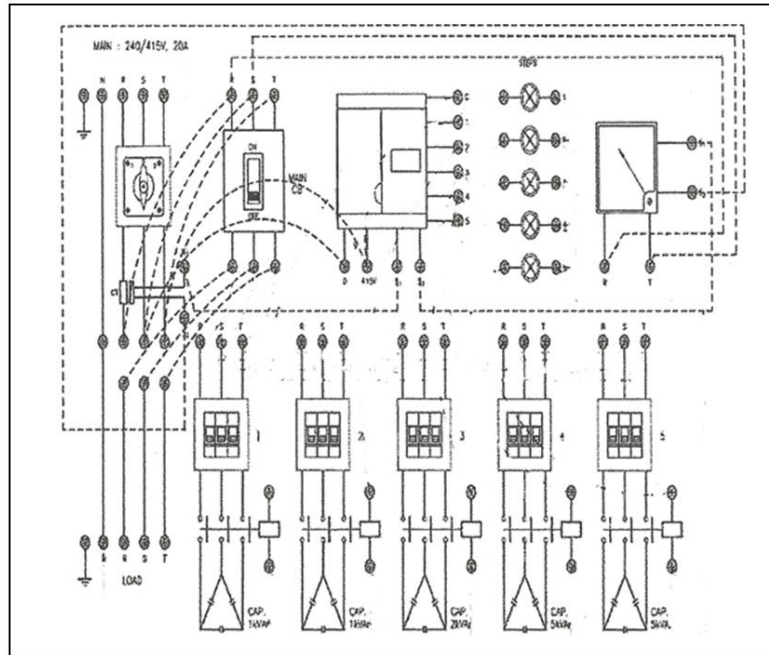


**Fig 1** Block Diagram of system

The provided flowchart figure 2 illustrates the procedure for establishing and fine-tuning a automatic power factor correction (APFC) system using an RL (resistor-inductor) load. The process begins by choosing an RL load and conducting a test using LCR meter to verify its functionality. Upon successful completion of the test, connect the load to an APFC trainer, inductive and resistive are link with STAR connection. Proceed by according to the instructions provided on the trainer in order to get measurements of current and  $\cos \theta$  (a metric indicating power factor) from the APFC display. If the measurements are unsatisfactory, the procedure entails determining the necessary capacitance to modify the power factor to the target level of 0.95. After completing the computation, the capacitive load is added via a STAR connection. Ultimately, the actual cosine  $\theta$  power factor is once again measured on the APFC trainer display to verify the modifications, and the procedure concludes whenever the target power factor is attained.

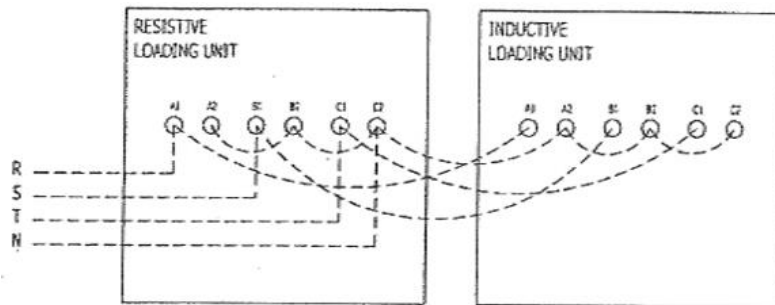
**Fig 2** Flowchar of the project

To conduct this testing, adhere to the connection scheme shown in figure 3 and by using connecting leads. Subsequently, the selector switch must be set to mode 2, using the power supply from the 5-pin socket.



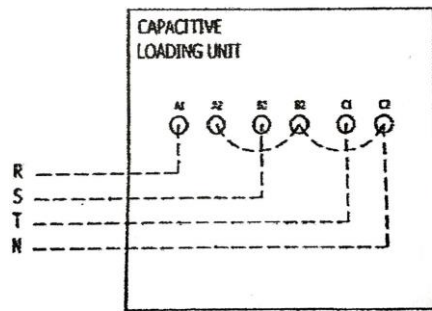
**Fig 3** Schematic circuit connection

For connections to loading units, resistive and inductive loading units should be connected in a star configuration as shown in figures 3.9. Before choosing to use this loading unit, a continuity test has been carried out first.



**Fig 4** Schematic STAR connection for resistor and inductor loading unit

After complete collect the data for operating current ( $I$ ) and power factor ( $\cos \theta$ ) and complete calculate the desired (VAR), add the capacitive loading unit with STAR connection as shown in figure 3.10 below.



**Figure 5:** Capacitive loading unit with STAR configuration

### 3. Result and Discussion

#### 3.1 Theory Power Factor before Correction Value

Table 1 shows determination of power factor requires the calculation of both real power and reactive power. The calculation for real power and reactive power is determined by using the theoretical value for each incremental change in the inductor and resistor. This calculation goes through 4 conditions which are variable step of inductor and fixed 2, 3, 5 and 7 step resistors. Fixed step resistor is where the number of steps on the resistor does not change until step 8 step inductor. The value for each inductor is 760mH and resistor 240 $\Omega$ .

**Table 1** Theory value of variable step of inductor and fixed 2,3,4 and 7 steps of resistor

Step L:R	Power Factor ( $\cos \Theta$ )
1:2	0.89
2:2	0.71
3:2	0.55
4:2	0.45
5:2	0.37
6:2	0.32
7:2	0.27
8:2	0.24
1:3	0.95
2:3	0.83
3:3	0.71
4:3	0.6
5:3	0.51
6:3	0.45
7:3	0.39
8:3	0.35
1:5	0.95
1:5	0.83
2:5	0.71
3:5	0.6
4:5	0.51
5:5	0.45
6:5	0.39
7:5	0.35
8:5	0.95
1:7	0.99
2:7	0.96
3:7	0.92
4:7	0.87
5:7	0.82
6:7	0.76
7:7	0.71
8:7	0.66

### 3.2 Operating Power Factor before and after Correction Value

Power factor operating value is the value from the APFC trainer that is connected to the resistor and inductor load unit with a STAR connection on both load units as shown in figure 6. Real power factor value is the result of the desired VAR calculation needed to reach the desired power factor of 0.95. For the desired VAR value is used to determine the number of steps required to achieve the desired power factor and for the capacitor load connection is also connected as a STAR connection on the resistor and inductor load. There are 5 sets that need to be tested.

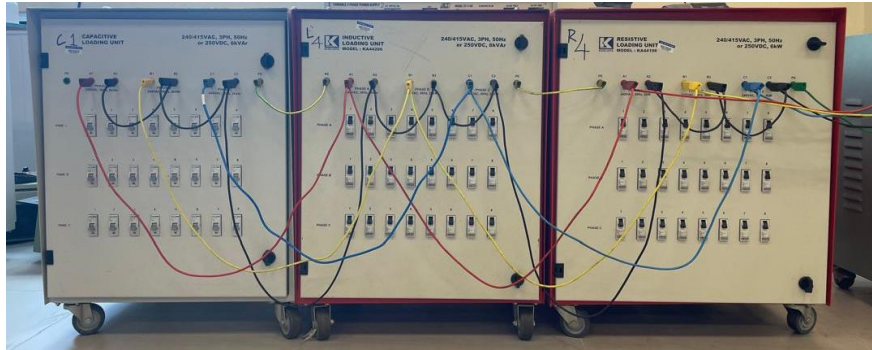


Fig 6 Set 1 with STAR connection

Table 2 Operating value of variable step of inductor and fixed 2,3,4 and 7 steps of resistor

Step L:R	Operating Current(A)	Operating Cos $\theta$ (pf) before correction	Power W	Required Step for Capacitor	Operating Cos $\theta$ (pf) after correction
1:2	2.14	0.92	1415.2	1	1
2:2	2.71	0.77	1499.9	1	0.95
3:2	3.43	0.63	1553.3	2	0.96
4:2	4.22	0.54	1638	3	0.98
5:2	5.07	0.45	1639.9	4	0.98
6:2	5.93	0.43	1832.9	5	1
7:2	6.81	0.38	1860.1	6	1
8:2	7.71	0.34	1884.3	6	0.95
1:3	3.07	0.96	2118.5	-	-
2:3	3.51	0.86	2169.8	1	0.98
3:3	4.1	0.75	2210.3	2	0.98
4:3	4.81	0.68	2351.1	3	0.98
5:3	5.58	0.59	2366.4	3	0.96
6:3	6.38	0.55	2522.3	4	0.95
7:3	7.21	0.49	2539.5	5	0.96
8:3	8.06	0.45	2607.1	6	0.98
1:5	4.94	0.98	3479.9	-	-
2:5	5.26	0.94	3554	1	0.99
3:5	5.7	0.89	3646.5	1	0.95
4:5	6.25	0.82	3683.9	2	0.95
5:5	6.86	0.76	3747.5	3	0.98
6:5	7.54	0.71	3848	4	0.98
7:5	8.27	0.66	3923.4	5	0.99
8:5	9.02	0.61	3955	5	0.96

1:7	6.82	0.99	4853.2	-	-
2:7	7.07	0.97	4929.5	-	-
3:7	7.42	0.94	5013.5	1	0.98
4:7	7.87	0.89	5034.7	2	0.98
5:7	8.39	0.86	5186.4	2	0.95
6:7	8.96	0.81	5216.8	3	0.96
7:7	9.59	0.76	5238.9	4	0.96
8:7	10.28	0.72	5320.3	5	0.98

As shown in Table 2, this time the test will focus on sets 1 of combinations of the three types of loads with different unit numbers. Set 1's test results were good, and they were very close to the theoretical value. This is because as the size of the inductor increases, the current increases and the power factor value decreases. For the required VAR part, it also shows how many steps are needed by capacitor load 4 to get to the power factor value there is. Then, after the set number of steps, the real power factor reached the goal value of 0.95, which is the same as the new power factor count. The other set will be put through the same tests.

### 3.3 Comparison

These readings for the operating power factor show that the APFC trainer and load unit are working well, based on the tests done on the five sets of load units above. This is because the operating value of the power factor goes down for each set as the inductor load goes up by one step. At the start of the operating current, the reading will be based on the step value for the resistor, since each resistor has a current value of 1A. In addition, the comparison will be done by using the operating value for power factor with the same ratio between resistor and inductor. After that, the value for the operating power factor will also be compared with the theoretical power factor count.

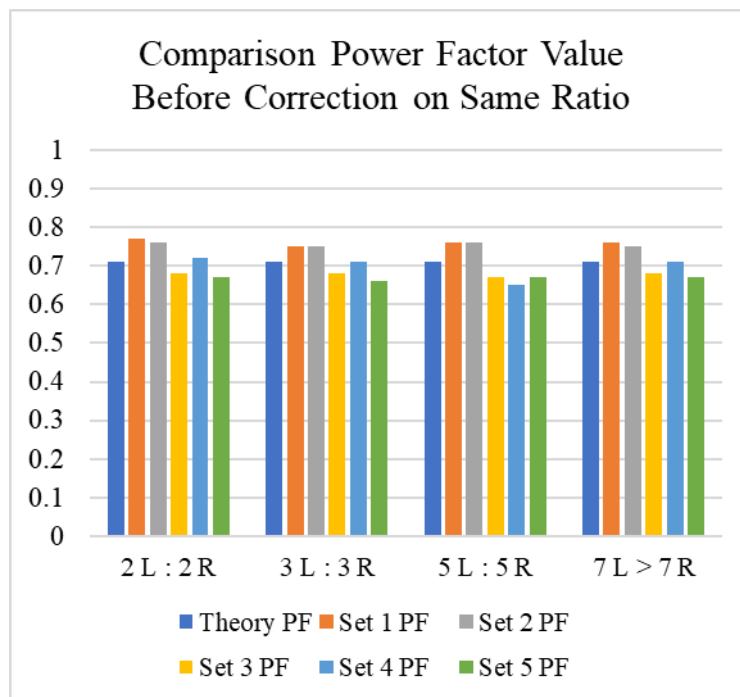


Fig 7 Comparison power factor value on same ratio

The graph in figure 7 illustrates a comparison of power factor (PF) values for different sets with the same ratio. The x-axis is labelled with specific ratios: "2 L : 2 R," "3 L : 3 R," "5 L : 5 R," and "7 L : 7 R" which mean number of step inductor and resistor. Each set of bars represents the power factor values for these ratios across multiple datasets. This indicates that the data for both theory and experiment in each set show a nearly identical value, with a margin of error of approximately ±0.7. Hence, this data serves as evidence that the APFC trainer

and each individual unit for resistors and inductors are functioning properly and can be used for educational purposes.

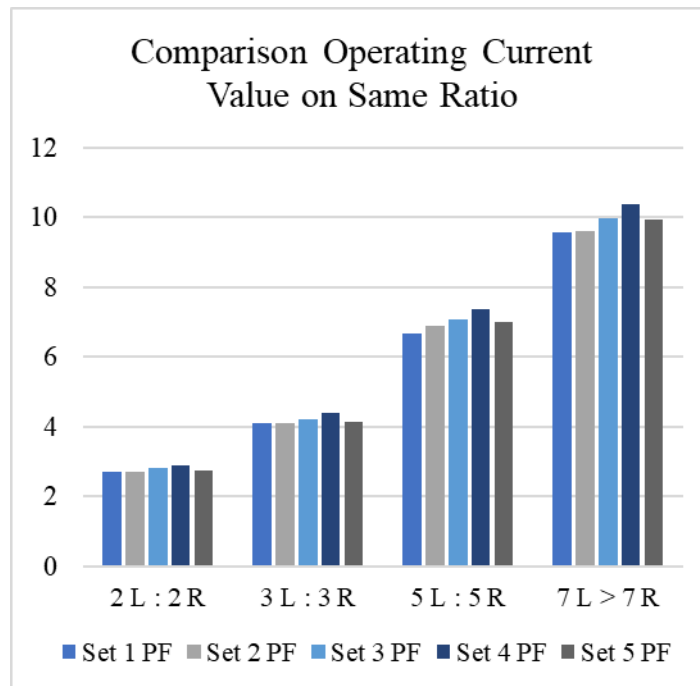


Fig 8 Comparison operating current value on same ratio

Figure 4.7 shows how operating current values change for five different sets, with conditions ranging from “2 L : 2 R” to “7 L : 7 R” and “3 L : 3 R.” The current values rise steadily across all sets as the L > R conditions get stronger. The value start at about 2.5 A for the 2 L : 2 R condition and reach about 10 A for the 7 L : 7 R condition. The values for each set in the same condition are very close to each other, which means that the sets don't perform very differently when they're in the same working conditions. Higher L > R conditions are matched by higher current values, as seen in this trend. This behavior was seen in all sets.

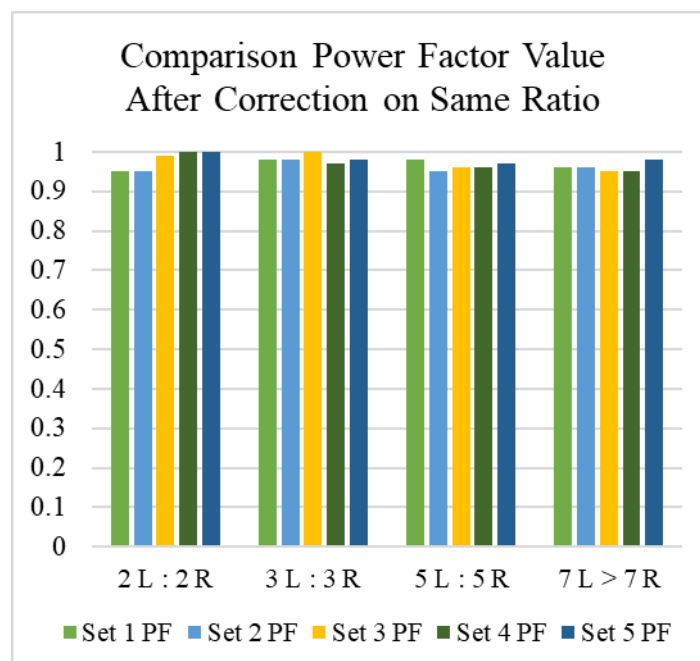


Fig 9 Comparison Power Factor Value After Correction on Same Ratio

Figure 9 shows a comparison of power factor values after correction. This experiment shows that the desired power factor value is successfully achieved which is 0.95 and also shows that the capacitive load works well.

#### 4. Conclusion

In conclusion, there is a strong link between the theoretical calculations and the results of the tests that were done with different types of loads and the Automatic Power Factor Correction (APFC) trainer. The APFC trainer was able to set the power factor to the right level for all types of loads, which supported the ideas behind power factor correction. The test results showed that the APFC system is good to use, by adjusting the number of steps on capacitive loads because the power factor got closer to 1. This proves the theory that correcting for capacitance can effectively lower the lag power factor caused by inductive loads.

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#### Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

#### Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Muhammad Izzuddin Bin Asan1, Rasida Binti Norjali2; **data collection:** Muhammad Izzuddin Bin Asan1; **analysis and interpretation of results:** Muhammad Izzuddin Bin Asan1, Rasida Binti Norjali2; **draft manuscript preparation:** Muhammad Izzuddin Bin Asan1, Rasida Binti Norjali2. All authors reviewed the results and approved the final version of the manuscript.

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