EFFICIENCY OF IPS AND ITS EFFECT ON BANGLADESH POWER SYSTEMS

An Independent Study

Submitted to the Department of Electrical and Electronic Engineering

of

BRAC University

by

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In Fulfillment of the

Requirements for the course

of

EEE491: Independent Study

August 2010

DECLARATION

I hereby declare that this thesis is based on the results found by myself. Materials of work found by other researcher are mentioned by reference. This Independent Study, neither in whole nor in part, has been previously submitted for any degree.

Signature of Supervisor	Signature of Author

ACKNOWLEDGMENTS

Special thanks to Keinosuke Fukunaga who taught me how to think of random data clearly when I was fortunate enough to be his research assistant, to Jack C. Ginther and the Magnavox Electronic Systems Company for supporting this work in ways too numerous to list, to Dr. Latifur Rahman.for accepting the difficult task of overseeing this work to completion, and to the members of my Advisory Committee Leah Jamieson, Michael Zoltowski and Dimitris Politis for taking time out of their busy schedules to consider this work.

ABSTRACT

Shortage of energy has always been a part of our life for many years in Bangladesh. Every year, the situation becomes more and more dire. In order to adjust with this, a some of us procured Instant Power Supply (IPS) to provide backup electricity at the time of load shading. The concept of an IPS is very simple; it stores energy in a battery when electricity is present in the main supply and during load shading hours, the energy stored in those batteries is supplied. However, some questions still remain. How effective are IPS? What percentage of the energy consumed to charge an IPS can we actually get back? To find the answers, I will be conducting a series of tests to determine the energy intake while charging the battery, determine the energy supplied while discharging the same battery and its effect on Bangladesh Power Systems.

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CHAPTER I

Introduction

1.1 An Overview

Electricity is vital for economic development, but only about 20 percent of the population has access to it (25 percent of urban population and 10 percent of rural). Other problems in the power sector include high system losses, delays in completion of new plants, low plant efficiencies, shortage of natural gas, erratic power supply, electricity theft, blackouts, etc. These factors contribute to Bangladesh's per capita electricity consumption being among the lowest in the world at about 110 kWh per person. We require new plants and fossil fuel the country can barely afford. The availability of gas is already in decline, and has been predicted to last until about 2011. To build new power plant is the best way to solve the crisis. However, to make a single midrange power station costs enormous sums of money. Money that we do not have. Although both government and private sector has risen up to the task, we cannot expect new plant any time soon.

Even then every year the energy demand is increasing by about 260MW [1] which is the size of a full size power plant. Hence we see that individuals, both in residential and commercial sector had to come up with their own solution and they did so by investing in generators and UPS/IPS equipment. With the decline of local and global fuel reserves, actions to save energy and maximize fuel utilization are long overdue for Bangladesh. As such there should be understanding and research among planners on the kind of effect using IPS has on efficient use of electricity and also its effect in Bangladesh power system.

1.2 Use of IPS in Bangladesh

Already the situation is so dire that IPS has become a common essential in most residential areas. Most mid class families in our capital has access to IPS to operate Tube lights and fans to enable their children to study environment and also to help selvage themselves form the hot and humid temperatures of our country.

Commercially, IPS is very common especially in if their equipment needs to run 24/7 without any interruption. As generators have starting delay, and UPS is so small scale as one UPS can provide 550VA on average for a short period of time, they opt to choose high capacity IPS. Banks, Mobile Base Station, large call centers Have large IPS backup for their computers and other equipment and also uses generators in most cases to provide backup for lighting and cooling.

Seeing this scope, a lot of industries has already started to meet the increasing demand for IPS. Rahimafroz and Navana Electronics are just two such companies who are widely known for their success in this area. There are a few other companies and also a lot of individual entrepreneurs who sell IPS in small scale by locally building them.

1.3 Possible draw backs of using IPS

There are certain areas. Main concern is the efficiency of the system. As we will see in the coming chapters, two major components of IPS are the transformer and a Si MOSFET based inverter. Both these have a rather low efficiency factor. Main form of loss is heat loss in both transformers and the MOSFET chips itself.

1.4 Research Objective

To try and combat the immense deficit in the ability to meet the demand of the country, we are now relying on IPS to backup out need for electricity. In this study, we will try to find some answers of determine the effect of IPS on our Power System. How effective are IPS? What percentage of the energy consumed to charge an IPS can we actually get back?

Therefore, to sum up, the objective of our paper here is:

- Determine the efficiency of IPS
- Cost benefit analysis of an community/locality and out Power Systems
- Look at alternate solution to better the results, if required.

CHAPTER II

IPS Construction

2.1 Operations

The operation of IPS is very straight forward. Figure 2.1 illustrates the operation of an IPS to its basics.

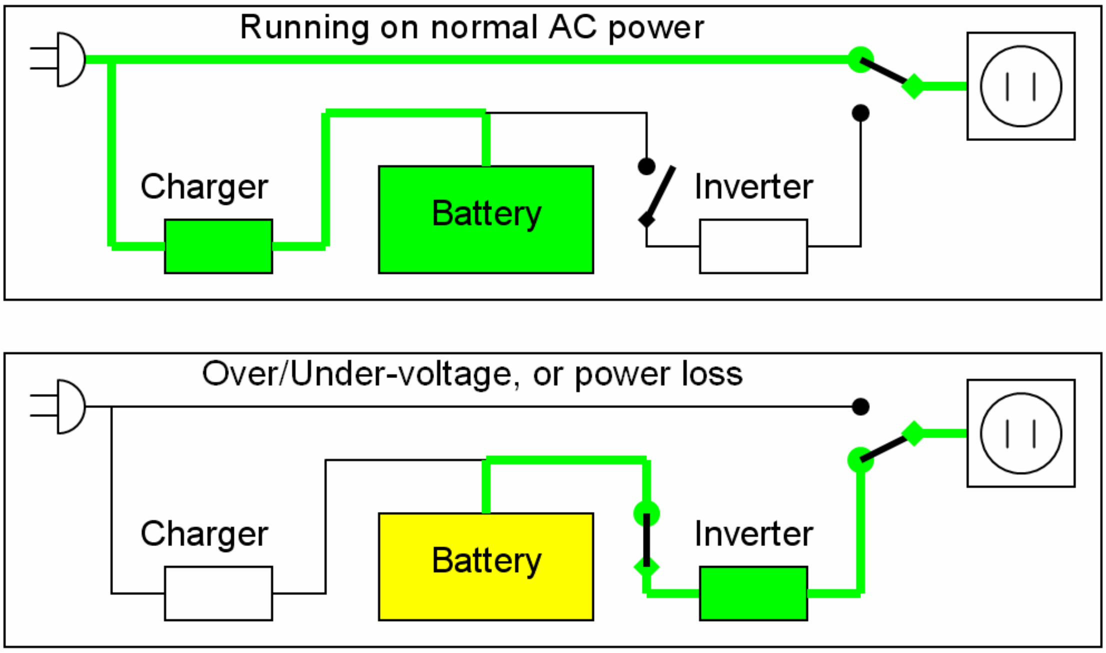

Fig.2.1 Operation of IPS

From the diagram, we can see that at the time when main electricity is present, our outlet is connected to the AC power source. The charger is connected to the main supply in parallel and is charging the battery if required.

At the time of power loss or over/under voltage, the out outlet is disconnected from the main AC line and is connected to the inverter which is connected to the battery, providing backup electricity as needed.

2.2 Components Breakdown

The main components present in an IPS are listed below in alphabetical order:

- Battery
- Charging Unit
- Control Unit
- Full Wave rectifier
- Low Voltage Detector
- MOSFET power Inverter
- Overload Detector
- Rectifier
- Transformer

Figure 2.2 shows us the flowchart of the operation of an IPS:

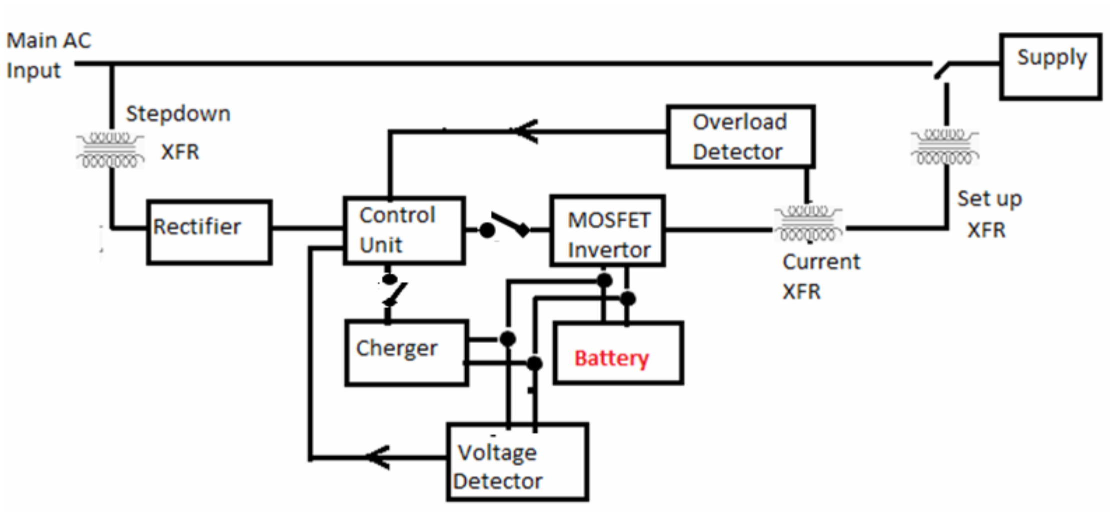

Fig.2.2 Flow diagram of an IPS

In figure 2.2, we can see that IPS is connected parallel to the main supply. Using a step-down transformer voltage to a lowered which is then rectified to DC. The Control Unit senses the presence of electricity in the main supply and determines if it needs to turn on the invertor or the charge. However, other factors are also included in the decision making. For example:

If the main power is available, and the voltage detector detects that battery is not at full capacity, it turns on the charger. That is, IF [(main AC=true); (Battery_Full = false)] THEN (turn on Charger)

If the main power is available, and the voltage detector detects that battery is at full capacity, it turns off the charger. That is, IF [(main AC=true); (Battery_Full = true)] THEN (turn off Charger)

If the main power is not available, and the voltage detector detects that battery is not at low capacity, and the overload Detector reads that power draw from inverter is not too high, it turns on the invertors; otherwise turning it off if any of the two conditions are true. IF [(main AC=False); (Battery_Low = false); (Overload = false)] THEN (turn on invertor).

Voltage detector, which is controlled by the CU, is connected to the battery. It detects the voltage level in the battery and sends the feedback accordingly based on which the CU knows whether to charge the battery or not.

In order to detect the power drawn by the load, an overload detected is placed using a current transformer in between the load and the inverter. This feedback is then sent to the CU.

2.3 IPS Schematics

The schematics diagram of an IPS is attached in Appendix A (pp. 21). It is a general form of standard IPS. However, it may not be followed to the letter when implementing the circuit in real life.

In there we can see that the electricity from main source is firstly passed through a set down Transformer, which is then rectified suing a Bridge Rectifier, whose output is feed to the Control Unit (CU). The CU is a comparator chip in this schematic with model ID: LM324N. The charging unit is also a LM324N chip which is connected to the CU. General purpose single operational amplifier is used as comparators to make the logic unit to determine low voltage and overload conditions.

A regulating pulse-width modulators (PWM) chip with ID: SG3524N is used to control the frequency at the output of the inverter. The PWM is connected to the inverter is composed of six MOSFETs which are connected in parallel in order to provide the high power to the system. The battery is connected these MOSFETs. The output from the MOSFET based inverter is then passed through a transformer in order to reach 220V and is supplied to the outlet.

CHAPTER III

Methodology & Test Setup

3.1 Methodology

In order to successful identify the efficiency factor of an IPS; we will be required to measure the energy it can supply to a load and then the energy it requires to recharge the battery to its fullest.

3.2 Required Experiments

In order to ensure that the experiment is reliable I will be conducting the experiment in two phases; one control test and one regular use test

3.2.1 Control Test: in this part of our test, I will first take a fully charged IPS. In order to ensure that the IPS is fully charged, we I will disconnect the IPS from all load and ensure that the IPS draws the minimum idle Wattage as per its specification.

After ensuring so, we will disconnect the IPS from its entire load and disconnect it from the main AC to ensure that there is no possibility of leakage charging/discharging. Upon ensuring so, we will connect the IPS to a fixed load via a Watt meter and will start discharging the battery for a fix period of time. From here we will know the energy supplied by the IPS using the following equation:

$$\text{Energy} = \text{Power} \times \text{Time in hour} \quad (1)$$

Following this, we will then disconnect the load and then connect the IPS to the main supply via the same Watt Meter and measure Watt with the time of recharge. I will continue taking reading till the IPS draws the minimum idle Wattage as per its specification. Using the Equation 1, we will calculate the energy consumed by the IPS while charging.

In order to find the efficiency, we can then use the following formula:

$$\text{Efficiency} = \text{Energy Supplied}/\text{Energy Consumed} * 100 \qquad (2)$$

Regular Use Test: in order to ensure that the control test results are also applicable in real life, I will be conducting a test while running the IPS with household equipment where external factors are controlling the load and the charging and discharging periods.

For this we will need to connect the IPS to the Main AC via a Watt meter and the output of the IPS connected to the usual loads via another Watt meter. The household members will be free to turn on/off any of the loads at will. At the beginning of the experiment, the IPS will be at full charge.

Readings will be taken just like in the first experiment. However, in order to find the charging wattage at any given time, the power being pulled by the loads at that time will have to be deducted.

3.3 Field Survey

In order to determine the number of families who have access to IPS, I will be conducting a field survey of around 1500 families. Survey will be conducted in Sector 4 of Uttara, Dhaka.

3.4 Apparatus required

The following apparatus will be required to conduct the required experiment I will be using the following apparatus:

1. Connecting Wire
2. Watt Meter
3. Energy Meter

4. 100W Filament Bulb x2
5. Rahimafroze Radian 550KVA

Note that I had to connect the two 100W bulbs in parallel to obtain a combined wattage of 200W.

Rahimafroze Radian 550KVA used for the experiment was chosen because this is the most popular version among their user, according to their salesperson, due to the pricing and 400W at 0.8 power factor and its ability to run three fans and three lights, which is sufficient for most middle class families.

The pictures of the internal circuitry of the IPS are presented in Appendix B.

3.5 Experiment setup

3.5.1 Control Test: This experiment starts off with a fully charged IPS. Figure 3.1 shows the connection setup to be used in this experiment while charging. Input in the IPS is feed directly from the AC Power Source through a Watt meter. Note that the output at this time is not connected to any load.

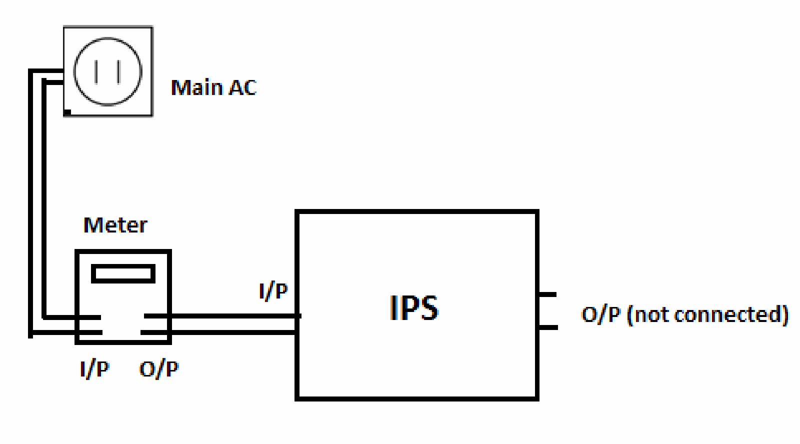

Fig.3.1 Experiment setup while charging the IPS

Figure 3.2 shows the connection setup to be used in this experiment while discharging. Here, the input in the IPS left open while the output is connected to two 100W filament bulb in parallel over a Watt meter.

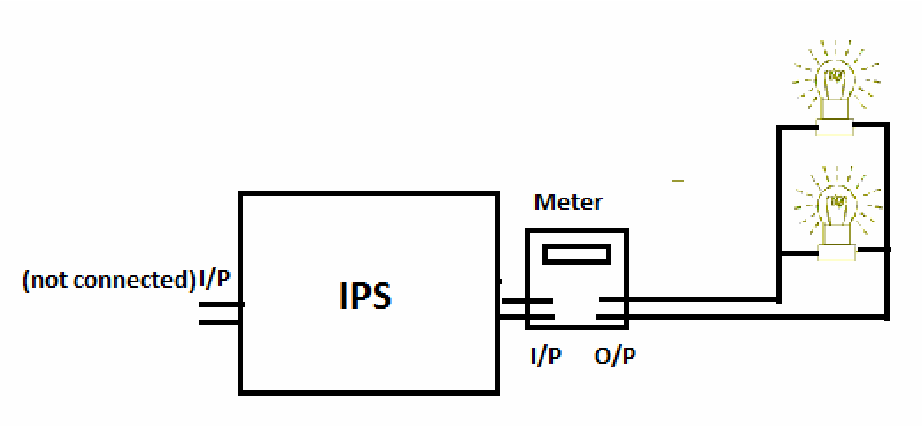

Fig.3.2 Experiment setup while discharging the IPS

3.5.2 Regular Use Test: Figure 6 shows the connection setup to be used in this experiment.

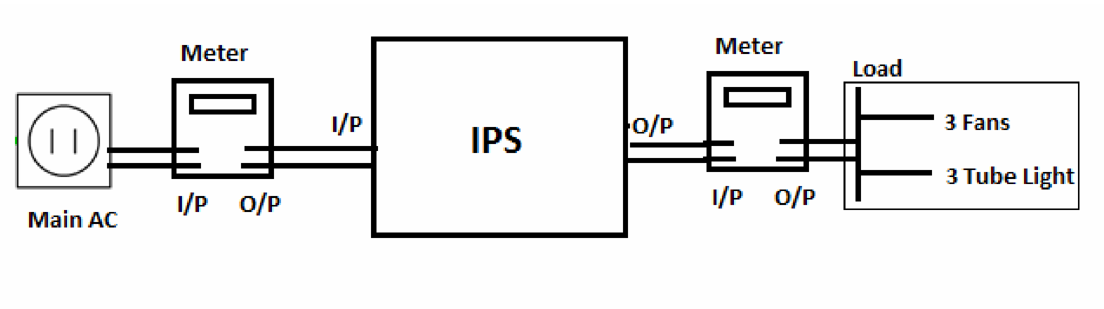

Fig.3.3 Experiment setup in regular use test

The setup for the regular usage test calls for the need of two Watt meter. However, as I could not procure two of these meters, I opted to use one Watt meter and one energy meter, which also provides us with the instantaneous power draw.

The output of the meter is connected to the normal load in a house hold; three ceiling fans and three lights. These loads are turned off/on as per requirement of the family.

CHAPTER IV

Test Results

4.1 Data Collection

Both these conducted as planned. Controlled test took about 450 minutes or 7.5 hours; while the Regular use test was conducted for 780 minutes, or 13 hours. During these time, reading were taken every 10 minutes for the controlled test, and for Regular Use test, readings were taken every 15 minutes. Please note that the data from the experiment is included in Appendix C (pp. 27).

4.2 Salient Features of the Data

From the reading we can see that we can easily identify if the IPS is in full charge by looking at the power consumption of the IPS, with no load connected. If the IPS sits idle, it only draws 15W. The maximum charging rate of the IPS is 160W when no load is connected or 145W to 150W when load is connected to it.

It can be noted that when the battery reaches optimal charge, the charging indicator on the IPS turns off. However, charging still proceeds at a low than the maximum charging rate. During this period, charging rate falls gradually over a period of about 2 hours.

4.3 Results of Control Test

Figure 4.1 shows us the Instantaneous Power Supplied at time T while discharging the IPS. It also plots the energy that was supplied from the beginning of the experiment till time T. Note that as time proceeds, the power supplied by the IPS falls slightly. It can be noted that temperature of the IPS at this time has risen significantly above the room temperature.

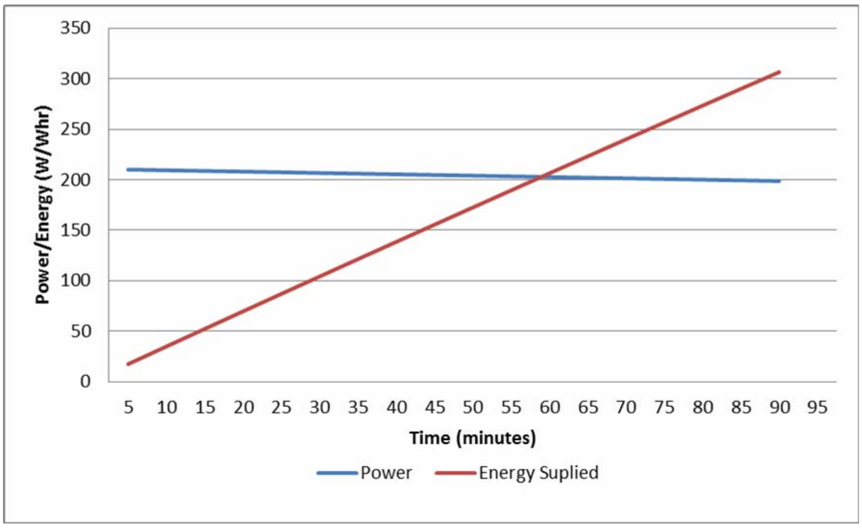

Fig.4.1 Power and Energy Supplied during Discharge

Figure 4.2 shows us the Instantaneous Power Supplied at time T while charging the IPS. It also plots the energy that was supplied from the beginning of the experiment till time T. Note that as time proceeds, the power supplied to the IPS is 160W which is the charging rate of the IPS. It can be noted that after 170 minutes, the charging rate or the power draw of the IPS starts to drop and then eventually settles at 15W, which is the idling wattage of the IPS.

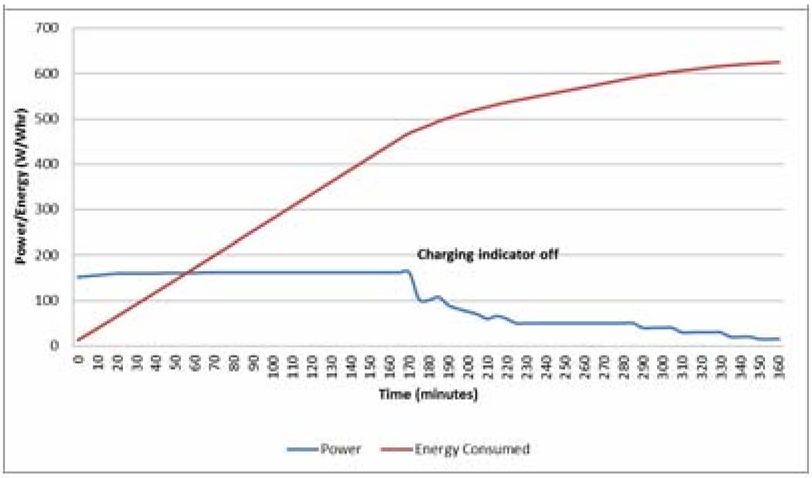

Fig.4.2 Power and Energy Supplied during charge

From the graphs, we can see that the IPS supplied a total of 323W while discharging through the 200W bulbs. However, while charging, we needed a total of 625W which indicates that the IPS has an efficiency of 51.68%

4.4 Results of Regular Use Test

Figure 4.3 shows us the Instantaneous Power at time T while discharging/charging the IPS. At starting time, we are experiencing load shading, so it starts to discharge. 60 minutes later, when electricity returns, it starts to charge. However, load shading starts again while system is charging at 145W (which is the charging rate when load is connected to IPS). The fact that charging rate has not decreased like in the Control Test indicates that the battery was not fully charged.

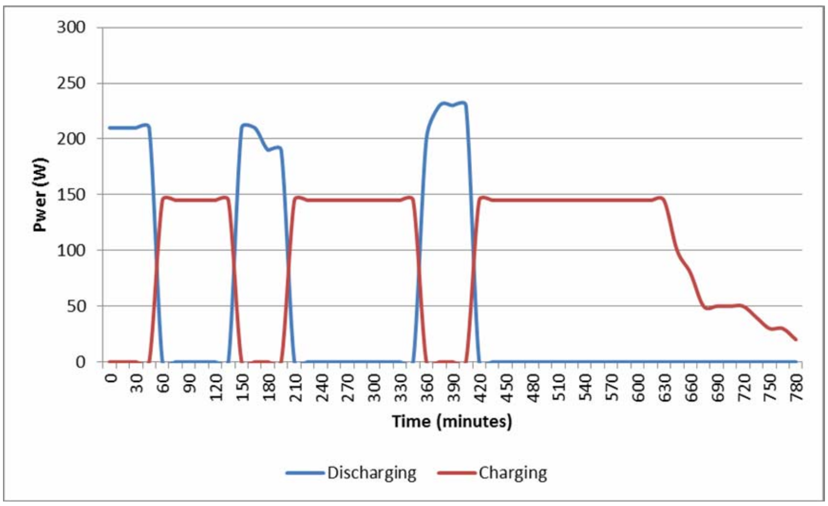

Fig.4.3 Power while charging/discharge IPS in Regular Use Test

Energy consumption during this time period of 780 minutes or 13 hours is plotted in Figure 4.4.

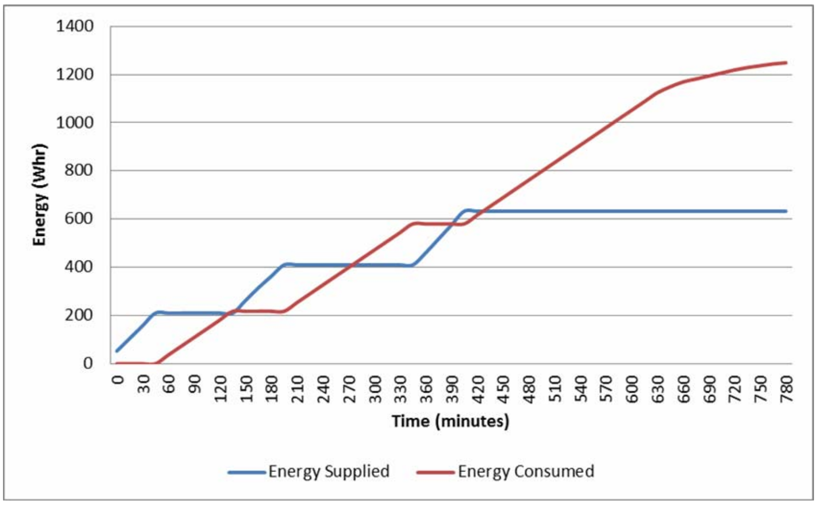

Fig.4.4 Energy while charging/discharge IPS in Regular Use Test

From the graphs, we can see that the IPS supplied a total of 632.5W while discharging. However, while charging, we needed a total of 1248.75W which indicates that the IPS has an efficiency of 50.65%

4.5 Field Survey Results

In order to identify the percentage of families who have access to IPS, I asked 1538 families if they had IPS and found that 978 of these families said yes. Meaning almost 63.59% of families in Uttara Sector 4 has access to IPS.

4.6 Analysis Findings

If we look at Regular Use test results, we will see that the duration of the test is 13 hours, starting from 5PM in the evening till 6Am in the morning. Since whenever the electricity is available, all the IPSs are charging at full load (145W) till 3:30AM in the morning. Meaning, out of the 1538 families that I surveyed, the 978 families who have IPS are adding 141KW load to our national grid right after electricity returns. At the same time, as the families are charging the battery, they wasted 602KWhr amount of energy during that tested 13 hour periods. However, this is only a very small population in this densely populated capital city. Table I shows us the effect of running IPS on load directly after electricity returns and the energy wasted if we have six hours of load shading every day.

TABLE IV.I
EFFECT ON BANGLADESH POWER SYSTEM

	Effect on	
No. of Families	**Load**	**Energy Wasted**
5,000	725KW	6.16 MWhr
10,000	1.7MW	12.32 MWhr
15,000	2.1MW	18.48 MWhr
20,000	2.9MW	24.64 MWhr
25,000	3.6MW	30.8 MWhr
50,000	7.25MW	61.6 MWhr
1,00,000	14.5MW	123.2 MWhr

CHAPTER IV

Conclusion & Recommendation

4.1 Recommendation

While conducting the experiments, it was noticed that there was a significant increase in the temperature of the device. The pictures of the internal circuitry of the IPS also show the use of large heat sink to support the six MOSFETs. Additionally, there is also a transformer working at high currents that creates considerable amount of loss. This indicates that there is a considerable energy loss, which again is confirmed by the poor efficiency that we deduced.

It is required of us to improve the efficiency of the IPS. I believe an easy way to do so is to replace the Si based MOSFET, whose efficiency is 80% [2], with Silicon-Carbide JFET whose efficiency is up to 98% [3]. Not only will it increase efficiency, but it will also enable the use of lower powered component in the IPS which will lower the cost of production of IPS. Additionally, SiC based JFET have higher thermal conductivity, higher operational temperature than Si based counterpart and at the same time has high speed and efficiency as well as superior capabilities in terms of modulator. [4]

4.2 Conclusion

Based on the findings in Table IV.I in Section 4.4, we can see that due to load efficiency of IPS, Bangladesh Power System has to pay a price. Although the amount of loss is not too steep, however, the price becomes steeper as soon as more and more families start using IPS and load shading becomes more frequent. As shown in the table a shows a loss of 123.2 MWhr for 1,00,000 families with IPS, is equivalent to one medium size power plant.

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[3] Hui Zhang Tolbert, L.M, *"Efficiency of SiC JFET-Based Inverters"*, Industrial Electronics and Applications, 2009. ICIEA 2009. 4th IEEE Conference, pp. 2056 – 2059, 25-27 May 2009.

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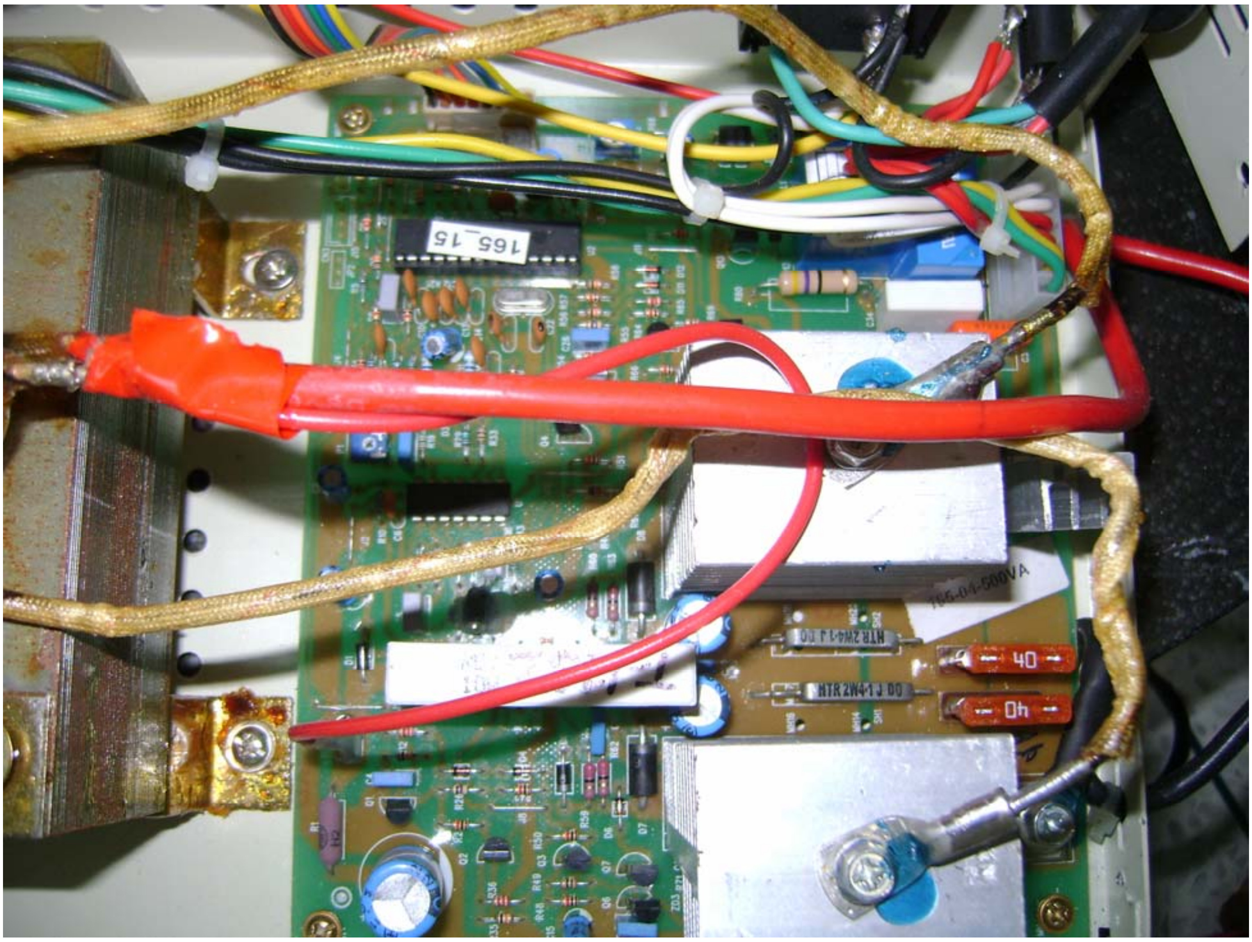
APPENENDICES

APENENDIX A
Schematics of IPS

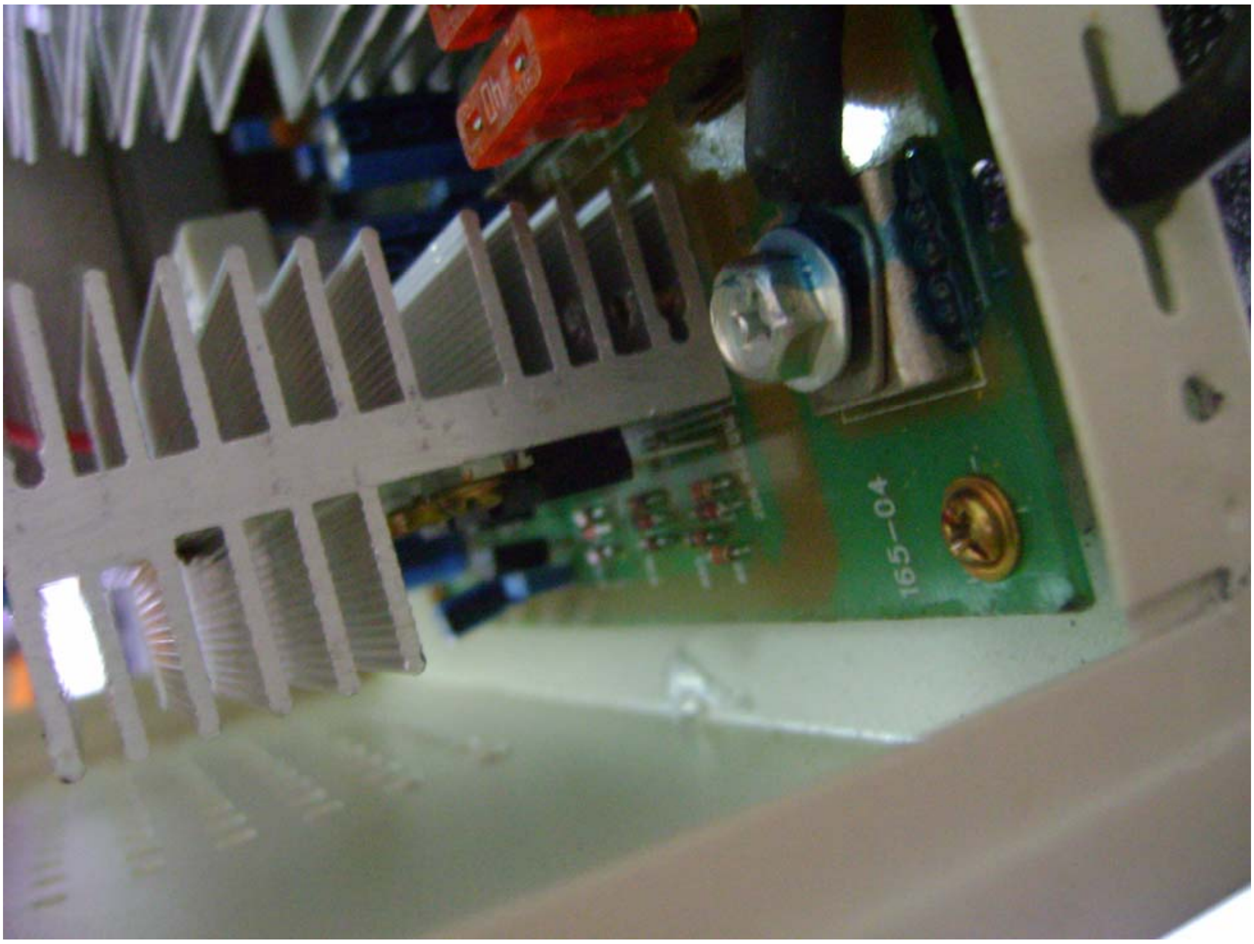
APENENDIX B

Internal Pictures of Rahimafroz Radian 550KV

Internal Circuitry of IPS



Internal Circuitry of IPS (zoomed in)



Heat Sink protecting the Power MOSFETS

APENENDIX C
Test Data