Residential Energy Audit

Name **: Rohan Rajesh Kalbag** Roll **: 20d170033**
Course**:** *EN 110* **-** *Fundamentals of Energy Engineering*
Spring Semester 2020 - Indian Institute of Technology Bombay
Course Instructor **- Prof. S.B Kedare**

Electricity Bill Terminology and Analysis - for the month Apr 2021

/ ELECTRICITY BILL
GSTN No: 29AACCB1412G1Z5
O/o.AEE(Ele.) E0-NAGAWARA

Account Details

/RR No A1306	MS9EH22113
/Acc Id	8236088803
/ M.R Code	14010982

Personal Details
/Name and Address
ROOPA RAJESH KALBAG AND RAJESH GANESH KALBAG,#A-1306 ARGE HELIOS APTS KOTHANUR BA

Connection Details

/Tariff	1LT2A1-N
/Sanc Load	7KW+0HP

Billing Details

/Bill Period	01/04/2021 - 01/05/2021
/Rdng. Date	01/05/2021
/Bill No	421565215010568

Consumption Detail

/Pres. Rdg.	9458
/Prev. Rdg.	9187
/Constant	
/Consumption(Units)	271
/Average	
/Recorded MD	1KW
/Power Factor	0.9
/Connected Load	1.5KW

/Fixed Charges (Unit, Rate, Amount)

1 KW	70	70.00
6 KW	80	480.00

/Energy Charges (Unit, Rate, Amount)

30	4	120.00
70	5.45	381.50
100	7	700.00
71	8.05	571.55

/FAC Charges (Unit, Rate, Amt)

271	0	0.00

Additional Charges

/ Rebate	0.00
/PF Penalty	0.00
/Ex.Load/MD Penalty	0.00
/Interest	0.00
/Others	0.00
/Tax	159.57
/Bill Amt	2482.62
/Arrears	0.00
/Credits & Adjustment	0.00
/GOK Subsidy	0.00

/Net Amt Due	₹ 2483.00
/Due Date	15/05/2021

Call 1912/Contact Subdivision

Account Details - Specific to the consumer.
Revenue Register (RR) unique number used to identify the consumer.
M.R code - used to identify the meter of consumer

Tariff Category - billable amount category, determine the rate structure applicable to the bill.
Sanctioned load - mutually agreed maximum power load. For 3BHK apartments in Bangalore, it is 7kW

Billing Period - The time period for which the electricity bill was calculated.

Prev Rdg. - Previous month-end reading in kWh
Pres Rdg. - Present month-end reading in kWh
Constant - No of revolutions of meter/kWh (N/A for digital meter)
Consumption = (Pres - Prev)Rdg. - Net energy consumption for this month.
Recorded MD (Maximum Demand) - Total recorded maximum load for the house. If it exceeds **sanctioned load** then penalties will be levied.
Power Factor - The value of **cos theta** where theta is the phase angle between the actual power and apparent power. Generally lies b/w **0.8 - 1**.
Connected Load - The net-connected load (As in the cumulative power of all the connected loads). It should be less than Sanc load.
Fixed Charges - The fixed charges that must be paid every month irrespective of unit consumption. It depends on the **sanctioned load**. It has a rate (₹/ kW) varying for ranges of sanctioned load.
Energy Charges - The charges that must be paid for the amount of energy used which is measure in units (kWh). It has a rate (₹/ kWh) varying with cumulative energy used.
FAC (Fuel Adjustment Charge) - is the amount that electricity companies apply on bills based on the varying price of fuel or Coal. Due to sudden demand and supply inflation.

PF penalty - Penalty amount charged if the power factor cos phi goes below a certain threshold.
MD penalty - Penalty charged if the maximum demand of the house exceeds the sanctioned load

Performing an Energy Audit for the month of Apr 2021

Some Assumptions Made

1) The power consumption of various devices follows a digital nature, i.e remains either 0(when off) or a constant P (while in use).
2) Refrigerator follows the energy consumption as per BEE compliance rating. Since its compressor is a device that is not permanently running when turned on.
3) Electronic devices (like laptops, TV, washing machine) use half of their rated maximum power in general use.
4) The other non routinely used appliances like radio, mobile chargers, bathroom lights are termed miscellaneous and are not directly considered in the audit.

Some routinely used devices and their daily usage routine for the month of Apr 2021

1. **Lenovo Legion Y740 Laptop -** Used nearly a full day for online classes. Goes through on average 4 charging cycles per day of nearly 2hrs each. The average power rating of charger = 100W (max power rating = 200W)
   Average daily consumption = (0.1)*2*4 = **0.8kWh**

2. **Hp XPS Laptop** - Used nearly a full day for work. Goes through on average 4 charging cycles of nearly 2 hrs each. The average power rating of charger = 75W (max power rating = 150W)
   Average daily consumption = (0.15)*2*4 = **0.6kWh**

3. **Acer Aspire P3 Laptop** - Used nearly a full day for online classes. Goes through on average 4 charging cycles of nearly 2 hrs each. The average power rating of charger = 75W (max power rating = 150W)
   Average daily consumption = (0.15)*2*4 = **0.6kWh**

4. **55' Panasonic Viera Plasma TV** - on average 4 hrs per day. (2 hrs from 8 am - 12 pm and 2 hrs from 9 - 12 pm) The average rated power of this device = 350W.
   Average daily consumption = (0.35)*4 = **1.4kWh**

5. **LG GL -368YSQ4 (2012) Refrigerator** - kept on 24 hours a day. Annual consumption according to BEE rating is 410. Assuming this is still applicable to the appliance. The daily average consumption 410/365 = **1.1 kWh**

6. **LG 6 kg front load washing machine** - Rated power consumption = 1700 kW (But in a given usage time only half of the time it consumes 1700kW (while spin and wash)). Hence assuming average power to 850kW. Daily 30 min preset 3:00 - 3:30 pm. The daily average consumption = (0.85)0.5 = **0.425 kWh**

7. **Table Fan** - On from 8 am to 12 pm and 3 pm to 8 pm on average. Average usage time = 9hrs. The power rating of the fan 50W. The daily average consumption = 9(0.05) = **0.45 kWh**

8. **Ceiling Fan** - 3 ceiling fans used for three rooms from 10pm - 6am on medium speed and 1 ceiling fans from 8am - 11pm and 12pm - 5pm for study rooms while attending online classes. Medium speed power rating 50W. Average daily power consumption = 3(0.05)(8) + (0.05)8 = 4(0.05)8 = **1.6 kWh**

9. **Lighting** - 1 - 18W LED bulb used in the study room for 7pm - 12am on average. 5* 3W LED bulbs used in the living-dining room for 7pm - 10pm on average daily. Daily average consumption = (0.018)(5) + (0.015)3 = **0.135 kWh**.

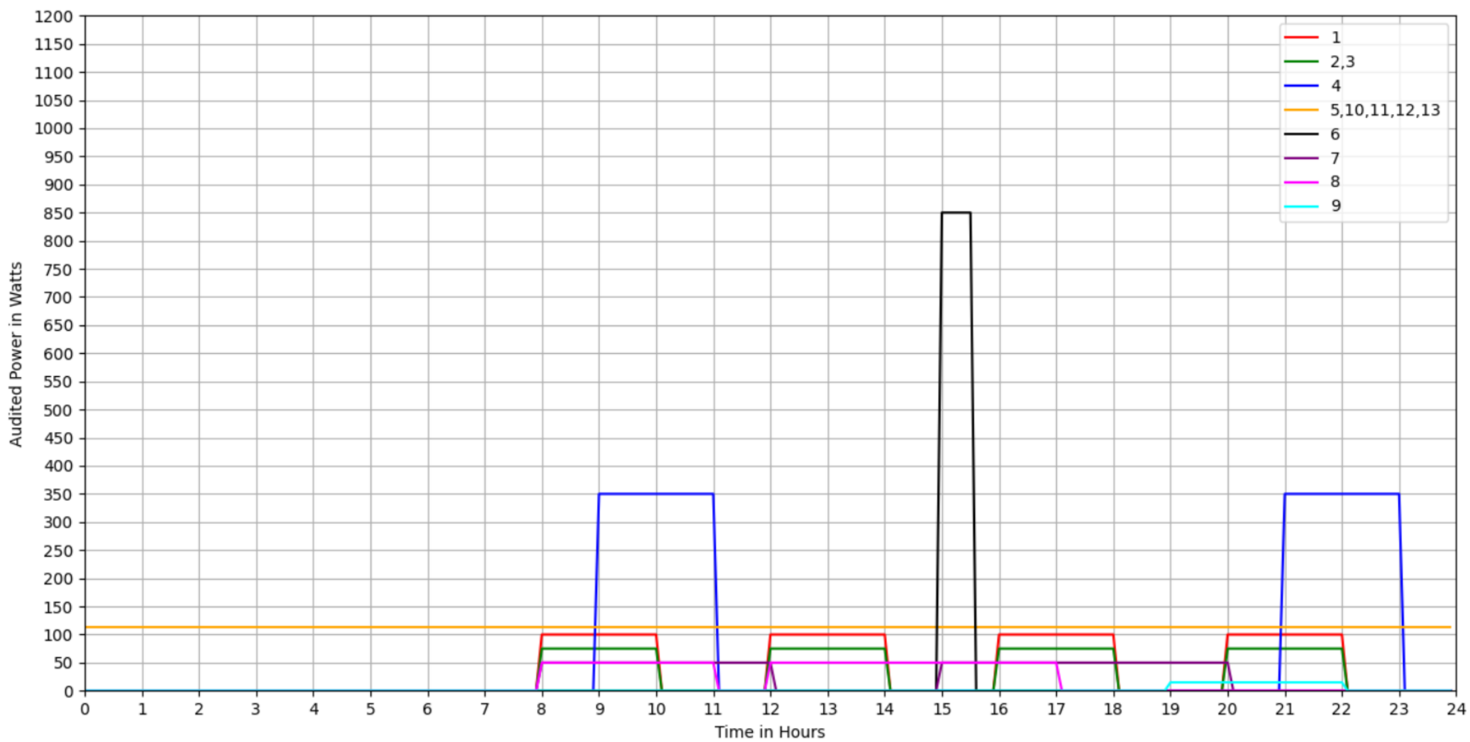
10. **Aquarium Pump** - switched on for 24 hours, 30W. The average daily consumption is thus equal to 24(0.03) = **0.72kWh**
11. **Tp-link Archer wifi router** - switched on for 24 hours, 5W. The average daily consumption is = 24(0.005) = **0.12kWh**
12. **Asiapower UPS backup** - switched on for 24 hours. Generally on standby mode due to infrequent power cuts. Standby wattage = 30W. The average daily consumption is thus equal to 24(0.03) = **0.72kWh**

13. **IoT devices** (**8 Wipro smart bulbs and Amazon Alexa Echo Dot** used for room and balcony lighting) - switched on for 24 hours, but generally in standby mode and switched on rarely. The standby wattage of bulbs is 0.15W and the wattage of the echo dot is 3W. The average daily consumption is (8(0.15)+3)W(24h) = **0.1kWh**

From the above data, the **net routine consumption** per day is = 0.8 + 0.6 + 0.6 + 1.4 + 1.1 + 0.425 + 0.45 + 1.6 + 0.135 + 0.72 + 0.12 + 0.72 + 0.1 = **8.77 kWh/day**
The corresponding **audited monthly consumption** is = 30(8.77kWh) = **263.1 kWh**

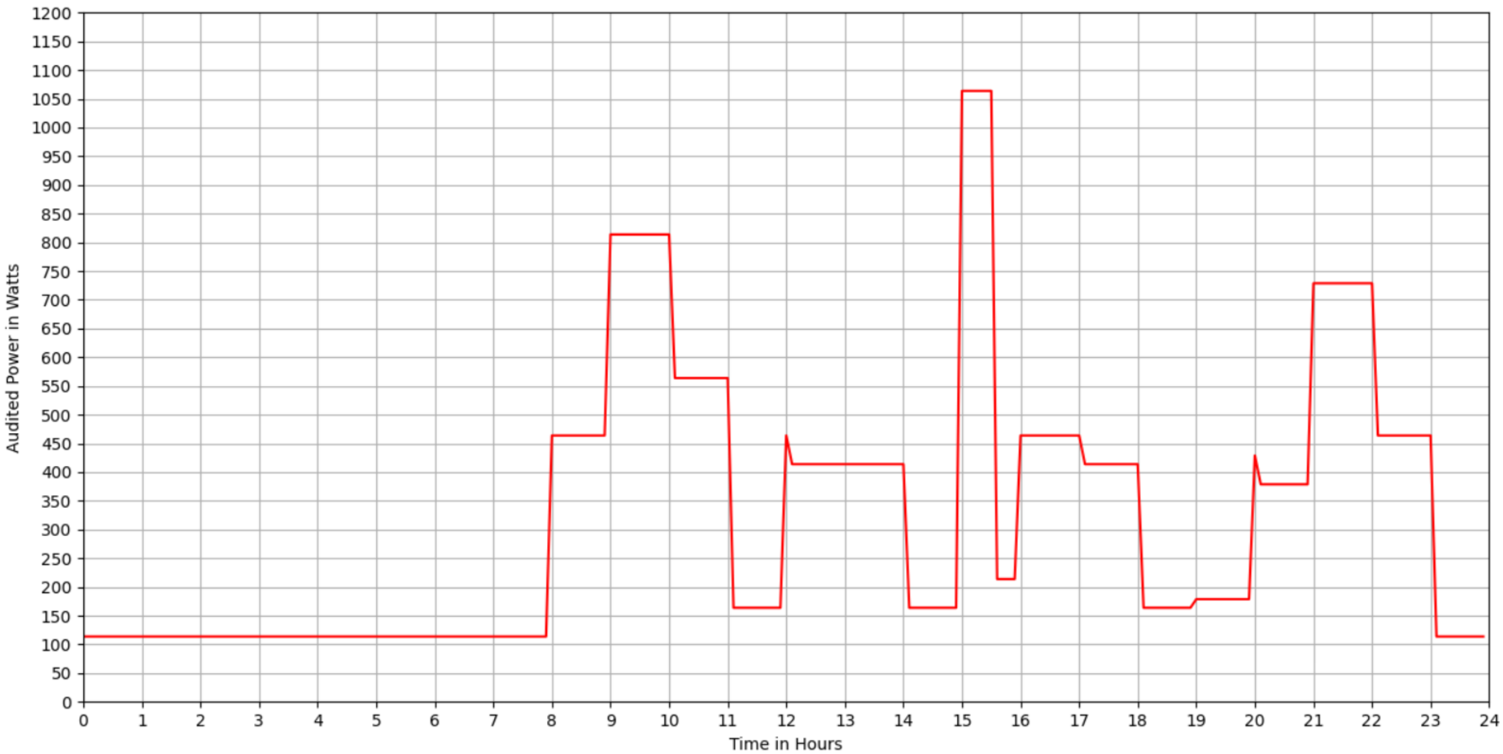
Power vs Time Plot

Graph 1:
A plot was made using matplotlib.pyplot library in python with the constant power digital curves of above 13 appliances. The power plotted vs 0 - 24 h time of individual devices is shown below. Labelling each of the 13 appliances with different colour codes as shown in the legend



Graph 1: Plot of Power vs Time of individual devices plotted using python wrt to the above assumptions

Graph 2:
Another plot was made using matplotlib.pyplot library in python with the sum $f_1 + f_2 + f_3 .... f_{13}$ of all the above constant power digital curves $f_1, f_2 .... f_{13}$ of above 13 appliances. This gave an approximate net power vs time graph considering all the devices together



Graph 2: Plot of net Power vs Time of all devices plotted using python wrt to the above assumptions

Conclusions Drawn

1) The calculated monthly audited consumption is 263.1 kWh. Whereas the billed value is 271 kWh. There is a deviation of 8kWh. Which is nearly 0.26kWh/day which could be due to the usage of untracked miscellaneous devices (non routinely used).

2) The major consumers of electricity are the ceiling fans, the 3 laptops charging and discharge cycles which have increased due to increased online presence due to online classes and online work, followed by the TV and Refridgerator. The major load is the washing machine with ~850kW power, so we must be careful not to use it for longer times than usual. And try to avoid using it twice and pool all clothes in one batch

3) From the overall Power vs Time plot, we see that there are 5 power peaks during the day. With the maximum peak when the washing machine is in use. The maximum load overall is of the order of 1kW which is tallying with the MD(Maximum Demand) in the electricity bill.

The code and plots can be found here
https://github.com/rohankalbag/Residential-and-Industrial-Energy-Audit/blob/main/Residential%20Audit.ipynb

Industrial Energy Audit

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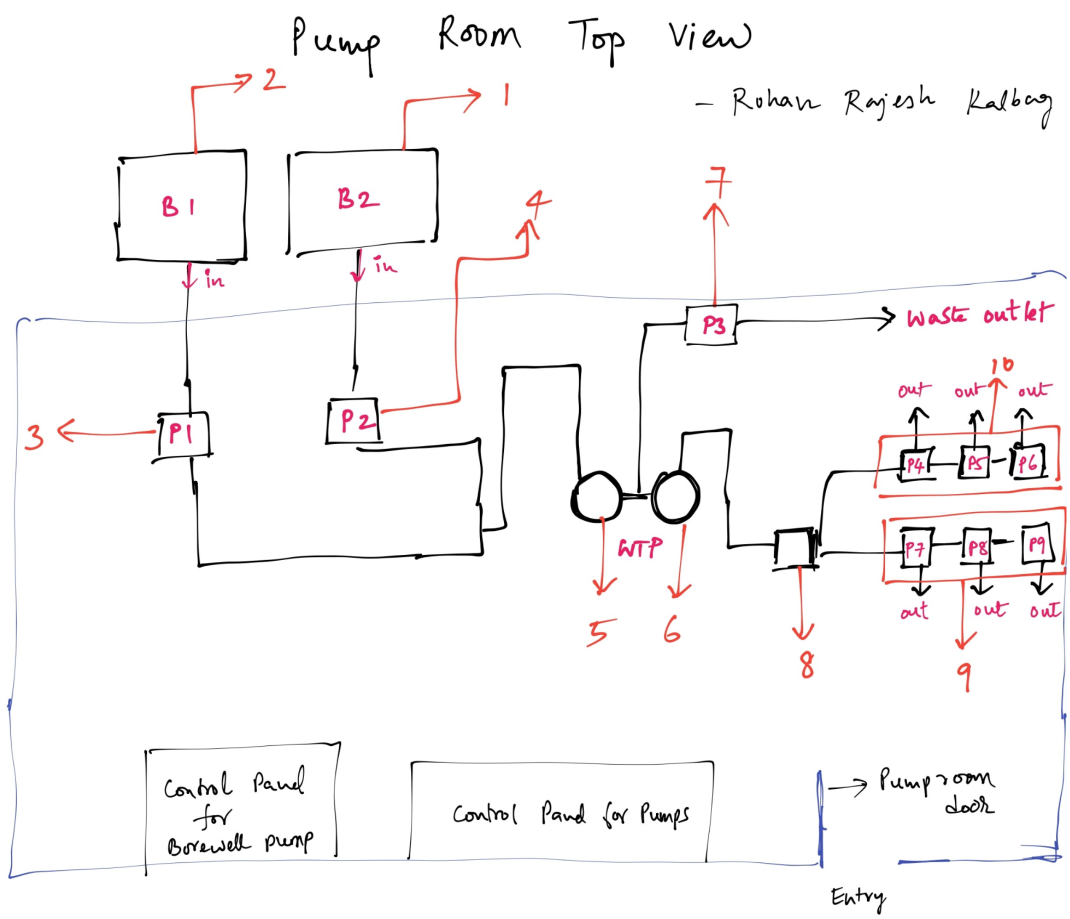
I visited the water pumping unit/pump room of my apartment that supplies water for 150 flats in a 13 storied building. **Arge Helios Apartment** in **Bangalore, Karnataka** on **13th May 2021**.

The Setup Schematic



Labelling

1 - Borewell 1 - Common Building Underwater Borewell
2 - Borewell 2 - Common Building Underwater Borewell
3 - Pump 1 - To pump water from Borewell 1 to the WTP
4 - Pump 2 - To pump water from Borewell 2 to the WTP
5 - Sand Filter of Water Treatment Plant

6 - Carbon Filter of Water Treatment Plant
7 - Pump 3 to remove wastewater produced by the WTP filter to the ground floor
8 - Pressure Tank
9 - Three pumps Pump 7, Pump 8, Pump 9 that pumps water from 8th floor to 13th floor
10 - Three pumps Pump 4, Pump 5, Pump 6 that pumps water from the ground floor to the 8th floor.

Photographs of the Setup and Equipment.

Fig 1.1 Fig 1.2

Fig 1.1 - Control Panel and Level Checker for Borewells 1 and 2
Fig 1.2 - Pumps 1 and 2 that connect Borewells to Water Treatment Plants and their ON and OFF switches (labelled 3 and 4)

Fig 1.3 Fig 1.4

Fig 1.3 - Water Treatment Plant containing Sand and Carbon Filtration Tanks also the small Pump 3 can be seen on the right (labelled 5 and 6).

Fig 1.4 - Pressure tank (labelled as 8). It regulates water pressure and enhances the life of the pumps. **It is used to change the water flow rate.**

Fig 1.5

Fig 1.6

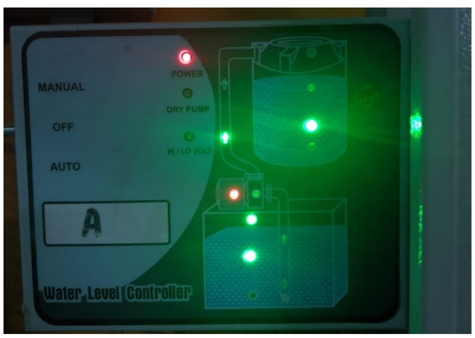


Fig 1.7

Fig 1.5 and 1.6 - Pump 3 can be seen here. The green pipe is the outlet from the filter that drops wastewater into the ditch shown below. The pump then pumps the wastewater up to the ground floor.

Fig 1.7 - Water Level Controller on the control panel for the main pumps.

Fig 1.8

Fig 1.9

Fig 1.8 and 1.9 - Pumps 4,5,6 pumps from the basement to the ground floor to the 7th floor. Pumps 7,8,9 pump from the basement to 8th floor to 13th floor.

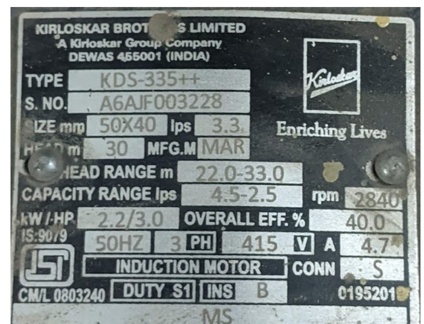
The Functions of the Pump Room

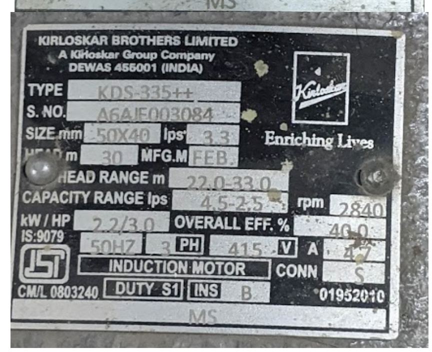
The pump room has a system of 9 pumps to supply water from the underground water sump (borewell) 100ft (~30m) to nearly 150 flats in a 13 storied building. The water is also filtered using a water treatment plant and then the waste generated in the filter is pumped back up to water the plants in common areas. It also has a pressure tank to regulate water pressure.

Specifications of the Pumps

Pump 1 and Pump 2 - From Borewell to WTP (~30m)

Make - Kirloskar KDS - 355++
Rated Power = 2.2kW = 3HP
Efficiency = 0.4
Head range = 22 - 33m
rpm = 2840
Flow rate range = 2.5 - 4.5 litres/sec





Pump 3 - From WTP to ground floor (~15m)

Make - Kirloskar Chhotu
Rated Power = 0.5 HP = 0.37 kW
rpm = 2700
Head range = 6 -24m
Flow rate range = 6 - 33 litres/min
Efficiency - Not known (firm claims high efficiency) so assuming it to be nearly 0.8.

Pump 4, Pump 5, Pump 6 - For Basement to Ground Floor - 7th Floor (~3.5m*(7+1(groundfloor)+1(basement)) = (~31.5m)

Make - **CRI MVS - 8/08**
Rated Power = 4HP ~3kW
Motor efficiency = 83% = 0.83
cos phi = power factor = 0.92
rpm = 2900
Set flow rate = $9m^3/h$
Corresponding head = 70m

ELECTRICAL DATA (3Ph, 380V, 50Hz)

Motor (kW)	Motor (HP)	Rated Current in Amps	Motor Eff. %	PF (cosø)
0.37	0.5	0.9	70	0.86
0.55	0.75	1.4	70	0.89
0.75	1	1.86	72	0.90
1.1	1.5	2.52	73	0.91
1.5	2	3.50	77	0.91
2.2	3	5	83	0.91
3	4	6.4	83.2	0.92
4	5.5	8.2	84.5	0.92
5.5	7.5	11.2	86.0	0.92

Pump 7, Pump 8, Pump 9 - For Basement to 8th Floor - 13th Floor (~3.5m*(13+1+1)) = (~52.5m)

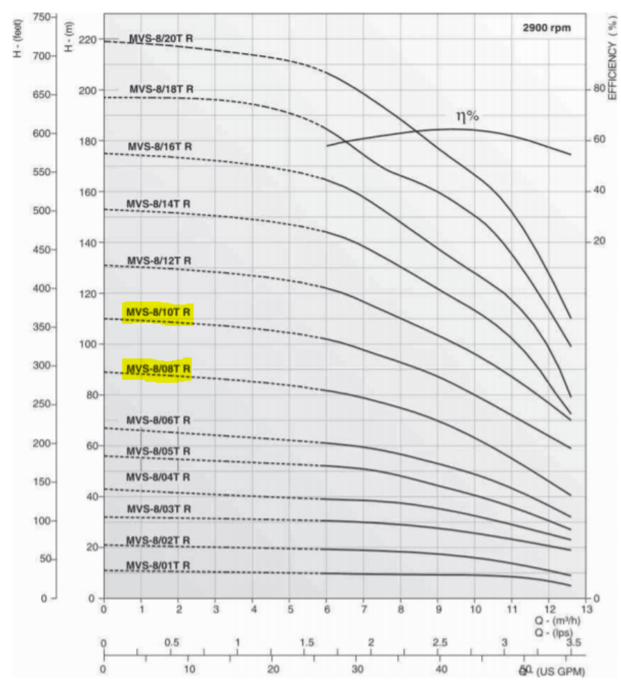
Make - **CRI MVS - 8/10**
Rated Power = 5.5HP ~ 4kW
Motor efficiency = 85% = 0.85
rpm = 2900
cos phi = power factor = 0.92
Set flow rate = $9m^3/h$
Corresponding head = 87.5m

MV-8

C.R.I. PUMPS

NOMINAL FLOW : $8m^3/h$

PERFORMANCE CURVES



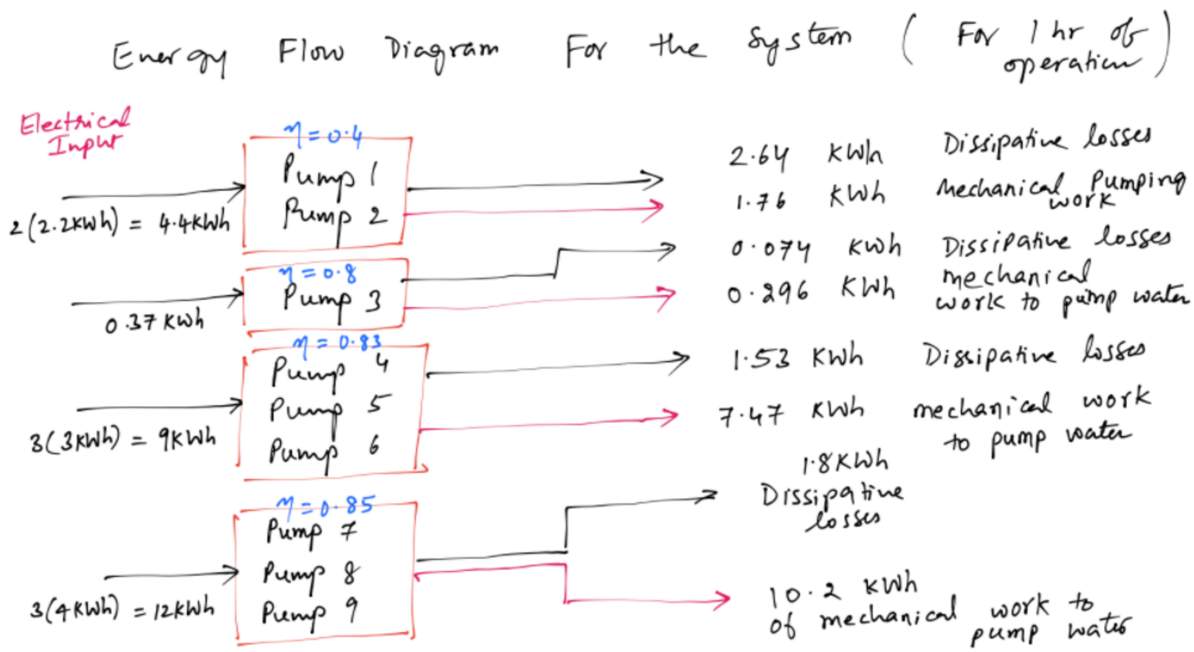
PERFORMANCE TABLE

PIPE SIZE : DN 40

PUMP MODEL	MOTOR POWER kW	MOTOR POWER HP	DISCHARGE lps	0	1.66	1.94	2.22	2.5	2.77	3.05	3.47
			m³/h	0	6	7	8	9	10	11	12.5
MVS-8/01	0.37	0.50	TOTAL MANOMETRIC HEAD IN METRES	11	10	9.7	9.5	9.5	9	8	5
MVS-8/02	0.75	1.0		21	19.5	19	18	17.5	16	14	9.5
MVS-8/03	1.1	1.5		32	30.5	30	29	27.5	25.5	23	19
MVS-8/04	1.5	2.0		43	39	38.5	37.5	35	32.5	29	23
MVS-8/05	2.2	3.0		56	42	51	48	44.5	40	35.5	27.5
MVS-8/06	2.2	3.0		67	61	59.5	57	52.5	48.5	43	32.5
MVS-8/08	3.0	4.0		89	82	79	75	70	63	55	40.5
MVS-8/10	4.0	5.5		110	102	97.5	92.5	87.5	80	72.5	59.5
MVS-8/12	4.0	5.5		130	122	117	110	103	96	87.5	70
MVS-8/14	5.5	7.5		152	144	138	130	122	112.5	102.5	72.5
MVS-8/16	5.5	7.5		175	165	157.5	147.5	137.5	127.5	117.5	79
MVS-8/18	7.5	10		197	185	175	166	160	150	135	99.5
MVS-8/20	7.5	10		219	207	198	188	177.5	167	152	110

Energy Flow Diagram for the System

Assumption Made - The pumps follow the ratings and performance parameters as per the plates and curves and do not deviate from them.



$$\text{Overall Efficiency of system} = \frac{\text{Energy used for mechanical work}}{\text{Total Electrical Energy used}}$$

$$= \frac{19.726}{25.77} = 0.765 \times 100 = \underline{76.5\%}$$

Conclusions Drawn

The overall efficiency of the pumping system is nearly **76.5%**. Additionally, I observed that pumps 1,2,3 have **their heads set nearly to the required height** to move the water, I believe this is because **the pipings here are vertically straight and have no bends**. However, pumps 4-9 have **heads nearly two times the required height**. I believe this is because the pumps 4-9 need to work even in high water demand scenarios and also to account for the **pressure losses from bends in pipes on every floor** and **PVC pipe frictional losses in pressure**. Also, I observed that pumps 1 and 2 have very low efficiency (0.4) which leads to more dissipative losses than mechanical work. I believe pumps 1 and 2 should be upgraded to more efficient ones as because of the large losses, new efficient pumps should have a short payback period.