Installation Guide
Pico Hydropower

Type: TB-PH-111-0

Head: 5-8 m
Power: 100-200 W per unit
Yearly power generation: 1750 kWh

`

Version 1.1 (April 2011)
Rik Voerman
www.triplebenefit.nl
support@triplebenefit.nl

Table of contents

1. Introduction

With the TB-PH—111-0 hydropower kit you can easily install a very small (*pico*) hydropower unit at low costs. Installing the pico hydropower (PHP) kit can be cheap and… very exciting! You can have a lot of fun with the system if you have all-year round water supply at temperatures above 0° Celsius. Naturally, there might be other solutions if you need electric power. A solar pV system for example might be cheaper to purchase and to maintain. Check this option if enough sunlight is available all year round.

Before you start installing the kit, read the other sections of this chapter first!

1.1 Background

It was summer 2008 when Stichting Veldwerk asked me to help them build a prototype hydropower in Nepal using a car alternator. When I started the work my enthusiasm grew. During the project I realized how difficult it is to arrange proper materials and make them fit under remote and harsh conditions. Nevertheless the concept of the generator was sublime: the runner directly mounted onto the shaft implied no other moving parts than de alternator shaft itself and a children home of 100 persons could be supplied with sufficient energy by only one single generator. When looking around in the streets i saw plenty potential hydropower alternators at a time: the ubiquitous Suzuki Marutis carrying a suitable alternator just were everywhere! When during installation a huge monsoon washed the entire penstock pipe away because it had not been properly fixed yet, the costs of the entire project raised. But altogether this solution could have been cheap, and even cheaper when all parts had been adjusted to each other and selectively obtained from efficient western-world suppliers. I decided to redesign parts of the concept, and to provide this as a universal kit to local users. Because the alternator and battery can be bought locally, the electrical system and the alternator casing can be small and light and easily shipped around the world.

1.2 Kit description

The kit is not the only thing you need. The alternator, the battery and the piping will require a substantial part of your budget. Not to mention the effort you have to make to build water pressure from your river or creek. Take this into account before you start.

1.2.1 Content of the kit

The kit consists of the following:

- Water resistant casing with fixture holes and rotating labyrinth seal, suitable for most car-alternator types
- Nozzle- and runner set to turn water pressure into rotating power
- M6 imbus bolt and thick washer to fix the runner onto the alternator shaft
- Three M8 bolts including nut and washer to mount the alternator
- Control panel with switches, charge current and voltage meter and a 12V connector
- Wires between the control panel and the generator (standard: 3,5 m)
- Wires between control panel and battery (standard: 0,8 m)
- Three screws to fix the cover onto the kit
- 5 spare tie-rips
- This document

1.2.2 Additional needed equipment

Locally you should buy the following to make the system work:

- A car alternator. Almost any car alternator can be used, but the design was developed with a Suzuki Alto 800 (Maruti). See the appendix if you consider to use a different alternator type.
- A general 12V car battery with power storage of around 100 Ah
- The penstock pipe, typically 2,5" up to 200 mm diameter (see the chapter 'Generating water pressure from running water' which pipe diameter and length to choose)
- A filter or grid to prevent that dirt or stones flow into the water inlet
- Stone & concrete to build the forebay and to fix the penstock pipe
- Fitting to the 2,5" threaded pipe connection

In order to give the control panel including battery a dry place you might want to build a small housing for it as well.

1.2.3 Needed tools

You will need at least the following to install the PHP:

- Cross screw driver
- Hex screw driver, size 5
- Wrenches 10 and 13
- Drill 5 mm, Tap set M6
- Multimeter
- Concrete for fixation of supports to the world
- Additional tools for installation of the penstock pipe

1.2.4 Options to the kit

The PHP kit can be expanded with the following options:

- Extra long wire between control panel and generator of 6m (standard: 3,5 m)
- Diodes for installation of multiple parallel power sources
- Buzzer instead of control lamp
- Adjustable field control
- 230 V inverter to transport electrical energy over longer distances
- 230 V relais to switch hydro and grid power in areas where grid power is frequently switched off (in combination with 230V inverter only)

1.3 Considerations before installation

1.3.1 Do I have enough water power?

Water power is obtained from an amount of water (*flow*), coming from a certain height (*head*) from a hill with a certain *slope*.

Head
The PHP is suitable for a total height difference (*head*) between 5 and 8 meter as long as no sharp bends are needed. If you have more head available, just make sure that the kit is not exposed to a higher pressure than 0,8 bar. This can be done by either installing the kit at a higher location, making the forebay lower, release water pressure just before the kit by making an outlet valve or installing a blocking timber in the nozzle.

If you have less than 5 m head, water pressure may be too low to overcome the electric field forces in the alternator. Naturally this depends not only on the runner configuration but also on the characteristics of the alternator used.

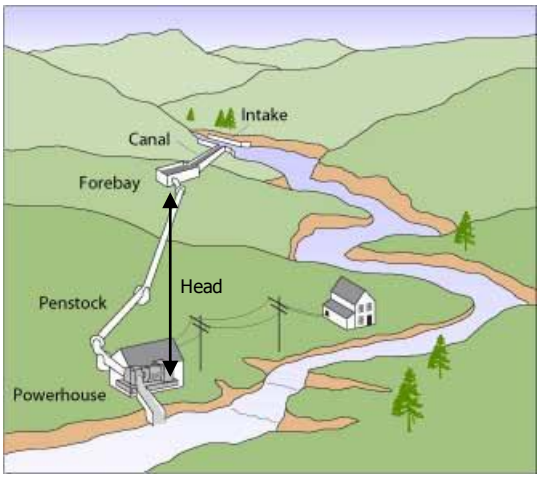
An overview of typical power output and water consumption is listed below.

Head (m)	Optimum speed, (rpm)	Flow (l/s)	Power (W)	Annual max. power production (kWh)
5	1210	6.8	100	875
6	1330	7.4	130	1130
7	1430	8.0	165	1450
8	1530	8.6	200	1750

Note that the maximum power is limited by the runner construction. It might get damaged due to fatigue at higher pressures. It takes several weeks of full time service before fatigue becomes evident. Although even the smaller alternators can produce at least 400 W when loaded to their max, the control panel was not constructed to handle much higher power output.

Flow

Generally, excess water flows along the *forebay*. Note that also a small water supply can be sufficient, but if not much water is flowing through your river, you might need to check the flow first (at least 6.8 l/s).



Slope

Ideally water flows through the penstock pipe vertically. This is however not necessary and a longer pipe starting more upstream in the river is a suitable solution for this hydropower type. Naturally costs increase when longer pipes are needed, and therefore consider what pipe length is allowed by your budget. If you have plenty pipe, do not worry about a total pipe length of 150 m or more, as long as the diameter is large enough.

1.3.2 How much electrical power do I need?

Installed power

Generally, power consumption is not constant during the day. Light is often used during the evening hours only and refrigerators and heaters are not operating at full power continuously. The totally installed power is therefore an indication of the maximum power consumption when all devices are operating simultaneously. Since the battery can deliver additional power during these peaks, the maximum power peak may be several times higher than the power produced by the alternator. Typically, make sure that the maximum power consumption is around 1000 W when a single alternator is operated.

Consumed power

The total consumed power during a daily cycle of 24 hours can be calculated by multiplying the used power per unit time. For instance, if 2 lamps of 50W are both used during two hours, the total power consumption during the day is 50 x 2 x 2 / 1000 = 0,2 kWh daily, or 73 kWh yearly.

Electrical power transportation

The generated electric power should be stored in a battery, close to the alternator. The standard kit comes with a cable of 0,8 m between control panel and battery. Make sure that the control panel and the battery can be placed close enough to the alternator, or vice versa (standard cable length is 4,5 m). From the battery 12 V power cannot be transported too far, since the resistance of cables will result in power losses.

If generated power is very spare, one would want to limit the power loss when transported by waires. Theb table below shows that very thick (and expensive) wires are needed, when power loss is accepted up to 10% at different wire lengths.

Distance between battery and user (m)	Wire cross section mm2
2	2,5
5	3
10	5

Required copper wire cross section to limit power loss to 10%, at 12 V, 120 W.

If the total distance from battery to user is larger than 20 m, consider the use of a higher voltage (e.g. 230V) by using an inverter. It is also possible to refill empty batteries at the PHP and transport batteries over a longer distance, or even sell loaded batteries to local customers.

1.3.3 Maintenance

The PHP kit requires all-year-round guidance. Obstructions like leaves may flow into the system (or onto the inlet) at any time and there might be water-sided or electrical complications. Make sure that skilled or trained users are nearby all year round in order to keep the PHP in operation.

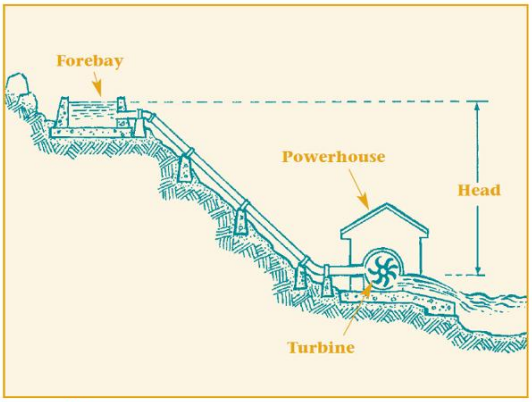
2. Building water pressure

In this chapter the construction of the water supply is discussed.

2.1 General configuration of the water system

The general construction for a hydropower consists of:

- The *forebay*, containing the water inlet or start of the penstock pipe. The function of the forebay is to let the flowing water stream calmly and let the containing sand sediment
- The *penstock pipe*, leading towards the *generator*
- The total height difference between water surface of the forebay and the turbine is called *head*.



2.1.1 Head measurement

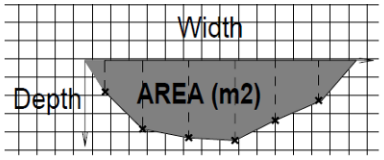
The total head should be 5 to 8 m for the PHP, that can be determined with a:

- Water filled tube
- Altimeter
- Laser
- Abney level
- A pressure gauge at the end of the tube

2.1.2 Flow measurement

If there is little flow, you might want to measure it first, since more than 6,8 l/s is required. The flow can be measured in different ways:

- With a large bucket (at least 20 l), determining the time it takes to fill it
- Float method: determine the time it takes to let a leave flow over a certain distance with a fixed cross section and determine the area of this cross section. The cross section can be estimated by drawing the water depth on squared paper. Calculate the flow speed: area * speed * 0,75



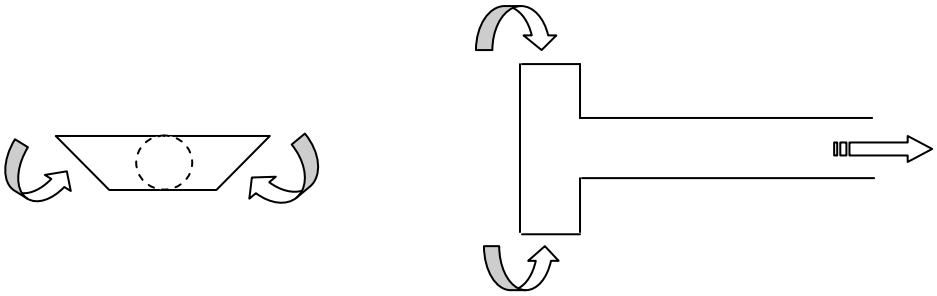
2.2 Constructing the water inlet

The water inlet can be constructed in many different ways. Think carefully what is the optimum for your situation.

- The forebay can be constructed in-river (by making a small dam) or beside the creek
- If the forebay is constructed beside the creek, the connection with the creek can be immediate, or by digging a small channel from the creek toward the forebay. Make a concrete lining in this channel
- If a small canal is constructed, you can separate large dirt and wood with a coarse grid
- In the forebay, choose the water inlet of the tube:
    - Not too low, if you expect a lot of sedimentation like sand
    - Not too high / too close to the water surface, to prevent a vortex drawing air and leaves from the water surface

- Note that the heigt of the water surface determines the head and hence the effective power, and not the height of the water inlet

- If you expect heavy flows, e.g. during monsoon, make sure that the dam and the rest of the construction can stand the forces
- For maintenance purposes, make sure that the forebay or the water inlet can be disconnected from the water supply. A sandbag in the channel can be a simple solution
- Make a strong grid on the water inlet. Coarseness of the grid should be max. 3 mm to prevent that stones can enter and obstruct the runner
- The grid of thicker pipes might need to be reinforced with additional rods, as indicated in the picture
- Leaves and plastic could obstruct the water inlet. The effect of this can be reduced by using a T-shaped inlet with the grid facing downward, as indicated below.



2.3 Head losses

The *effective head* can be calculated by subtracting all head losses from the total head. Head losses occur due to friction in the tube and at the location of junctions. When head losses are significant, you could compensate for this by installing a longer penstock pipe with more head.

2.3.1 Head losses due to friction

Assuming that the inner side of the tube is smooth, friction forces still cause head losses. In the figures below head losses are illustrated as a function of *inner* pipe diameter for a flow of 8 l/s and 16 l/s (when two PHP's are installed). In the graphs head losses of pipelengths from 10 – 200 m are plotted. The required pipe length depends mainly on the slope at which it can be installed.

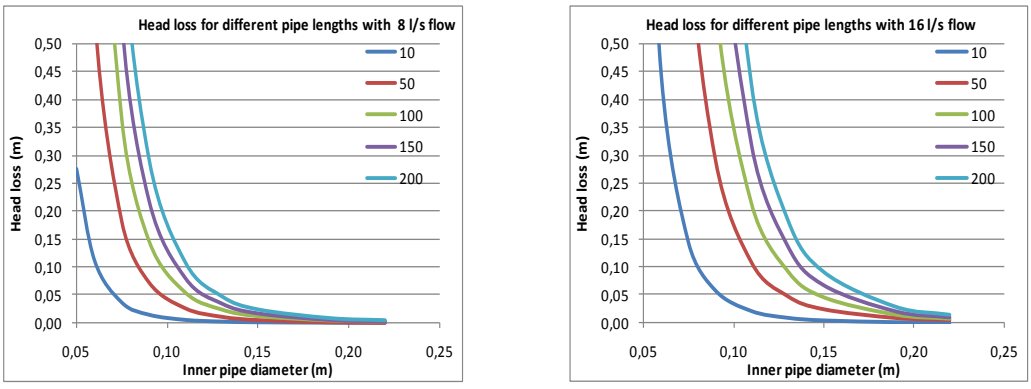


Figure: Head losses for pipe lengths up to 200 m, for one and for two PHP's (8 and 16 l/s).

2.3.2 Static and dynamic pressure

If you install the penstock pipe over a long distance with small slope, you need to use a thicker pipe to keep friction losses low. Water flow inside the pipe becomes then lower as well. The pressure just

before the nozzle can be considered as 'hydrostatic' and is roughly 0,1 * h bar, where h is the total head.
However, when water would flow at higher speed in a thinner pipe, additional hydrodynamic pressure results in additional power. The highest speed would be with a pipe of 2,5" installed vertically. The additional dynamic pressure would be a head gain of approximately 0,3 m in that case. In other words: when a short almost vertical pipe is installed, a thicker pipe would result in a maximum loss of dynamic pressure with an amount of 0,3 m head.

2.3.3 Head losses due to obstructions

Additional head losses are caused by obstructions in the pipe like bends or thickness changes. Examples of such head losses are summarized below.

	Inner pipe diameter (m)			
Obstruction	**0.07**	**0.15**	**0.20**	**0.25**
45°, sharp	0.0551	0.0026	0.0008	0.0003
90°, sharp	0.2535	0.0120	0.0038	0.0016
Narrowing before nozzle	0.0110	0.0005	0.0002	0.0001
T coupling inlet	0.0661	0.0031	0.0010	0.0004

Head losses in m for different obstructions at a flow of 8 l/s for different pipe diameters.

The table shows that sharp bends of small pipes results in significant losses. Make sure that no sharp bends are needed or compensate for this with additional head.

2.4 Installing the penstock pipe

2.4.1 Pipe diameter

Generally the price of pipes increases substantially with increasing diameter. You should select the thinnest pipe to keep costs low, but a thicker pipe to minimize head loss. The diameter you choose depends on the amount of PHP's to be installed, pipe length, pipe availability, your budget and your wish to gain maximum power.

Use the graphs from the previous section to choose the best pipe diameter for your situation.

2.4.2 Pipe properties and installation

Pipe material can be anything like Polyethylene, PVC or steel. Generally Polyethylene is the cheapest option of these, but take into consideration that junctions can be problematic because gluing is not possible. A sustainable pipe material could possibly be bamboo.

- Fire hoses with diameter up to 3 inch are generally available. This can be a good option for short penstock pipes
- Water pressure rises up to 0,8 bar just before the generator when the head is 8 m. Make sure that the pipe or hose and also the junctions can stand this pressure
- Take into consideration that pipe length may vary considerably due to thermal expansion in any case, but particularly when the pipe is made from PVC or PE or no water is flowing in the pipe and the sun is heating it. Junctions can therefore be loaded significantly if the construction does not compensate for this
- Preferably the inner surface of the pipe should be smooth. A rough inner surface of the pipe will cause power losses. These losses will be less when you choose a larger diameter
- When installing the pipe, fix it well. Remember that the pipe will gain additional weight when it is filled with water (up to 31 kg for a pipe with inner diameter of 20 cm) so that it is well supported. Heavy rainfall or monsoon will also act large forces on the pipe when it can be flooded, possibly with impact of transported stones or any dirt.

3. Building the power generator

The PHP kit can be completed by mounting the alternator. This chapter describes the selection of a proper alternator and battery, and how to assemble the kit.

3.1 Selection of the alternator

The kit was designed for alternators that come with the Suzuki Alto 800 (in Nepal this car type is called Maruti). This type of alternator has a built-in regulator and can easily be installed.

Nevertheless another alternator type can be used. When choosing another alternator type take care of the following:

- Maximum height: 180 mm (almost all alternators do)
- Maximum outer diameter of the alternator casing: 200 mm (almost all alternators do)
- Direction of rotation should be clockwise (almost all alternators do); Often the proper direction of rotation can be seen from the fan: When running in the right direction, the blades will push the air outwards and the fan will work efficiently. Sometimes there is an arrow on the fan indicating the direction of rotation
- Make sure the alternator comes with a regulator (many types have them built-in)
- The control panel of the PHP kit was made for 12 V (or actually 14.4V). The kit is not suitable for 24V alternator types
- Electric connections of alternators can be confusing. In the appendix an overview of commonly used alternator connections can be found
- Pulley type: many types have the pulley consisting of two halves. The PHP kit was designed for this type of pulleys but other pulley types can also be installed.

3.2 Selection of the battery

For energy storage use a normal Pb car battery of 12V. Car batteries are available in many different capacities, usually expressed in Ah. For a battery of 12V, 1 Ah equals 12Wh. The capacity of a typical battery is 50 Ah. So prices may be the lowest for this type. But consider the following to make sure that you have the specifications that suit your situation best.

Generally power consumption changes during the day. The required battery capacity is then determined by both *Peak power consumption* and the *Total power consumption*. Calculate both using the table below.

Appliance	Hours per day	Power (W)	Daily (kWh)
Lamp 1	3	5	15
Lamp 2	2	10	20
		Peak power	**Total power**
Total		**15**	**35**

An overview of power consumption of frequently used devices is listed in the appendix.

3.2.1 Peak power consumption

Determine the peak power consumption by summing the total installed power of lamps and other electrical appliances.

Since power is generated continuously, you might not need to store energy when peak power consumption is not more than the generated power. In that case you still need to install a small battery of typically 5-10 Ah.

3.2.2 Total power consumption

The total power consumption per day can be determined by summing the amount of power of each device, multiplied by the duration of use. The total power consumption should not exceed the generated power by the alternator. If the power consumption is larger during a few hours, the battery is needed for buffering. When you expect to use 200 W during three hours and the PHP generates 100 W, you need to draw 600Wh from the battery. In that case the battery capacity should be at least 50 Ah.

3.3 Assembling the alternator into the casing

3.3.1 Prepare the shaft of the alternator

In order to mount the runner onto the shaft, an RVS bolt is used. Prepare the shaft in the following way:

1. Place the alternator on a stable place with proper perpendicular support
2. Put a cloth around the alternator to prevent that chips can fall into it
3. Drill a hole of 5,0 mm diameter, 20 mm deep
4. Tap 6 mm thread into the hole with a proper tap set, using a bit of oil. The best tool is a three-piece tap set
5. File off the shaft (if necessary including the nut) so that it does not stick out of the pulley. Be sure that the pulley is kept undamaged!
6. Unscrew the bolt off the shaft and remove the pulley (is it V-shaped, consisting of two shells?

3.3.2 Mount the alternator

1. Take out the frame from the casing
2. If two holes on the frame-circle do not match with the alternator holes, drill new ones so that the alternator shaft is still in the centre of this circle
3. Mount the alternator onto the frame with two bolts
4. Make sure the bottom plate is properly screwed onto the casing. If the alternator has a split pulley, keep the bottom shell of the pulley on the shaft. If the alternator has a pulley in one piece, place the throw-off ring (or 'inner ring') onto the shaft. Note: the inner diameter of this ring possibly needs to be increased
5. Place the alternator in the casing and fix the screws smoothly
6. Do the same with the upper fixture plate of the alternator

3.3.3 Adjust the labyrinth (two-shell V-shaped pulleys)

If the alternator has a split pulley:

- Place the throw-off ring onto the shaft

- Screw the circular 'first sheet' onto the separation sheet with the distance ring in between
- Place the other shell of the pulley onto the shaft
- Place the original nut onto the shaft and fix it tightly; do not use the original spring washer
- Fix the alternator frame in the casing such that the there is no metal-metal contact between the rotating and fixed parts. This can be checked by rotating the shaft.

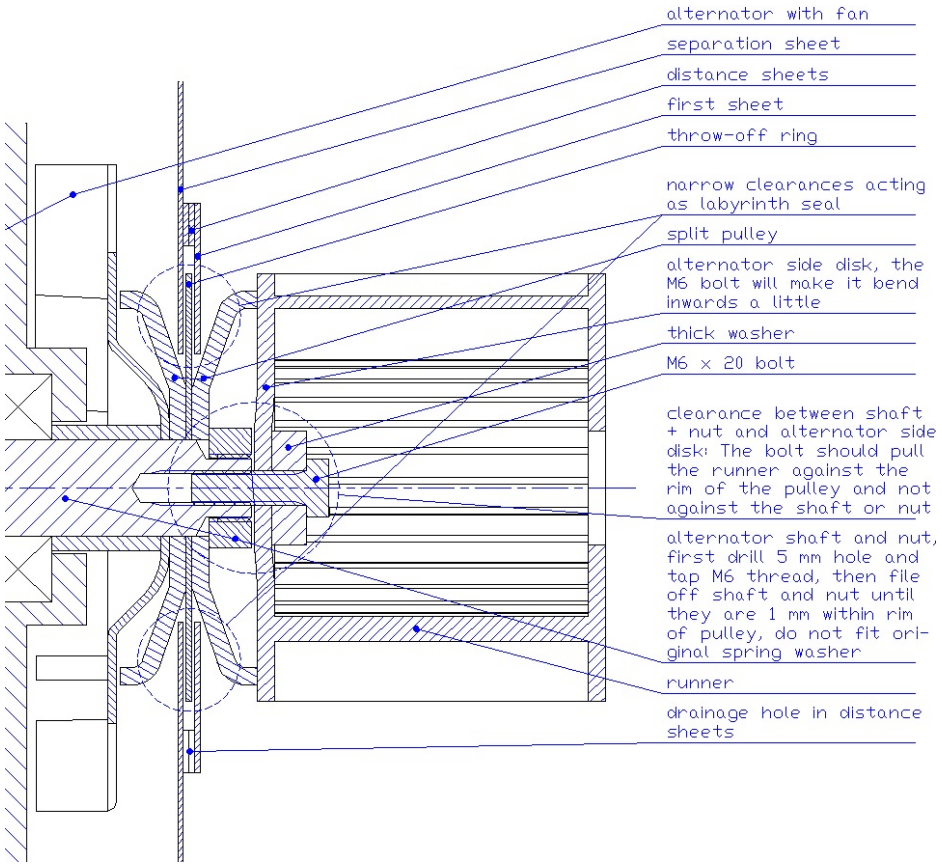
3.3.4 Adjust the labyrinth (other pulley types)

If the alternator has a pulley in one piece:

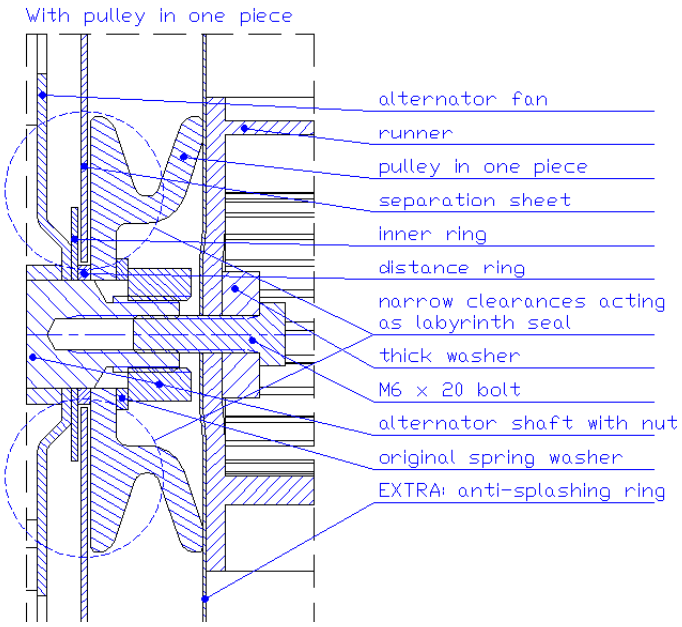
- In some cases the circular 'first sheet' and the distance ring can be screwn at the inner side of the separation sheet, before mounting the alternator frame into the casing. In that case the trow-off ring should be place loosely in between.
- Put the pulley in place
- Place the original nut onto the shaft and fix it tightly; do not use the original spring washer
- Fix the alternator frame in the casing such that the there is no metal-metal contact between the rotating and fixed parts. This can be checked by rotating the shaft

3.3.5 Mount the runner and nozzle

Mount the runner onto the shaft, using the M6 bolt and the thick washer. A cross-section of the total shaft assembly is drawn below.



A cross-section of an alternator with pulley in one piece is drawn at the right here.



Screw the runner onto the shaft tightly using the M6 imbus bolt and the thick washer. Check the alignment of the runner by rotating the shaft. File off the runner to make it turn smoothly.

The nozzle can now be mounted with the three bolts. Adjust the nozzle so that it just not touches the runner when the runner is rotated.

3.3.6 Fixation to the world

When the penstock pipe is stiff (e.g. steel) and is fixed well, the PHP can hang freely attached to the pipe connection by the nozzle. When a weak tube like a fire hose is used, the PHP casing must be fixed to a solid foundation out of rock or concrete. Drill 8 mm holes at the proper positions in the casing to bolt the PHP onto fixation points. Remember that the thermal expansion of all pipe materials can result in significant displacements. These displacements will generate large forces when the PHP is not fixed in the right way.

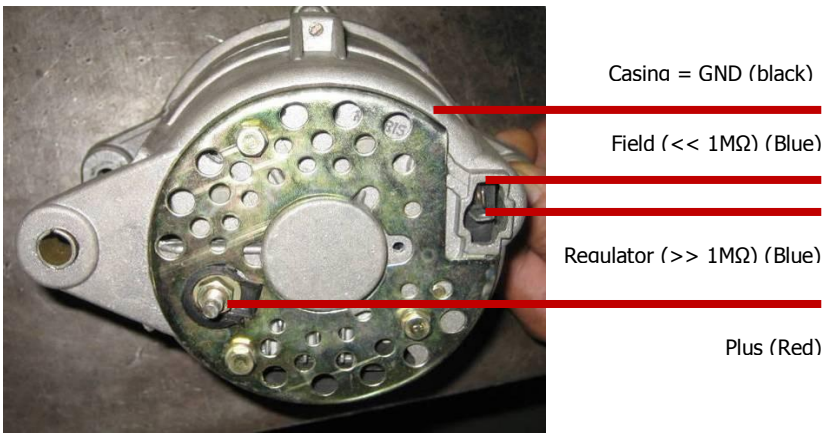
4. Installing the power generator

4.1 Connecting the wires

Below two types of commonly used alternators are instructed. (For proper wiring of different alternator types, see the appendix).

4.1.1 Alternator with Field and Regulator connections

- Ground post (thick black wire): typically the casing. Connect this wire at a screw that is mounted onto the casing.
- Positive terminal (thick red wire): typically the isolated 6 mm bolt on the casing. An in-wire fuse is mounted to protect the alternator against unintended short-cuts.
- Field Ignition (Blue): used to give initial current to the field coil
- Regulator (yellow/green): This regulator connection is used to measure the battery voltage
- Since there is no Lamp connection, leave the brown wire unused. The control lamp is not used.



Example alternator with Field and Regulator connections

4.1.2 Alternator with L and IG connections

Another frequently used alternator type has Ignition and Lamp connections:

- The Ground and Positive terminal are connected in the same way;
- Ignition (Blue): used for starting the alternator
- Control lamp (Brown): in most regulator types the control lamp is connected between this wire and the IG connection
- (yellow/green wire): Since there is no Regulator connection, do not use this wire. Cut the wire inside the control panel to exclude mistakes.

4.2 Connecting the user side

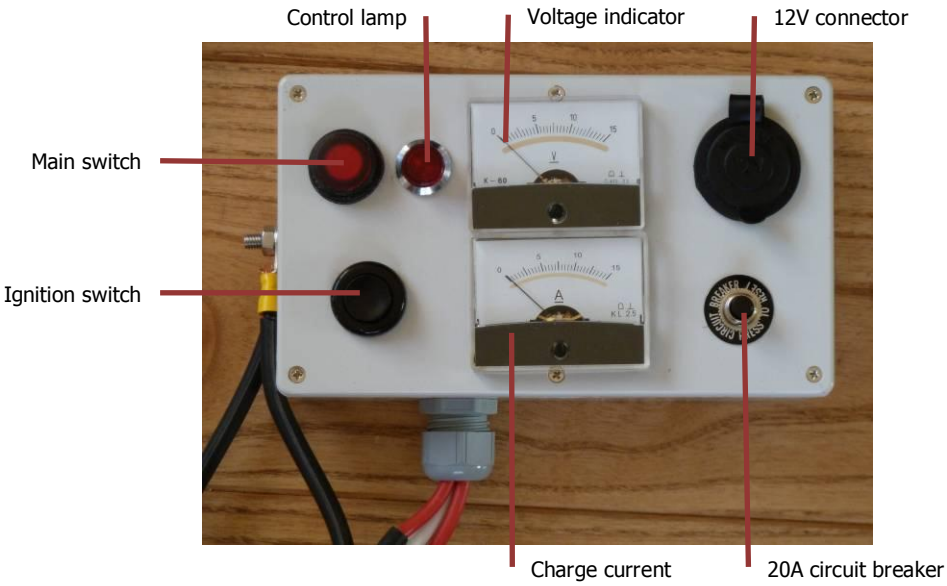
At the 12V connection on the control panel, 12V power can be tapped. If you want to connect devices directly to the battery, connect the Ground and positive wire to the respective battery poles. Make sure that a fuse is installed in the positive wire, to prevent damage in case of power overload.

4.3 Installing the Control Panel

4.3.1 Description of the Control Panel

Install the control panel and the battery on a dry place, preferably inside a building. Make sure that the main switch is turned off. Connect the wires to the battery (red on the plus pole). The voltage indicator should now indicate the voltage of the battery.

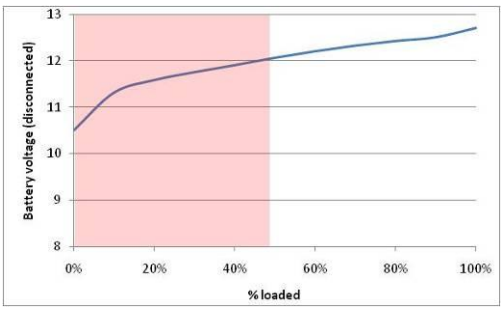
Below the functions of the control panel are listed.



- Main switch: to switch on or off the PHP
- Control lamp: lights up when the system is not charging (only if the alternator has a Lamp connection). The lamp can be replaced by a buzzer.
- Ignition switch: to start loading when the alternator is turning
- Voltage indicator: indicates the voltage over the battery clamps, also when the alternator is switched off
- Charge current: indicates the current that is flowing from the alternator to the battery
- Circuit breaker: switches off when current between alternator and battery exceeds 20 A.

4.3.2 Battery characteristics

The battery is required to start the alternator to generate power. So, no battery voltage means no start of loading. When the main switch is turned off, the voltage of the battery can indicate the percentage that it is loaded, as visualized in the graph.



If the battery has a voltage below 10 V before charging, it is completely empty. Prevent a standard automotive battery to get completely discharged, since this will shorten battery life considerably

During operation the voltage and current depend on the state of charge.

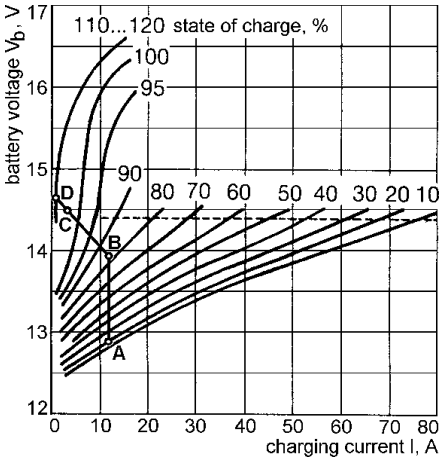
- When the voltage has risen above 14.5 V and the current has dropped below 4 A, the battery can be considered fully charged. When the voltage rises further, the battery is being overcharged

- A worn-out battery will accept only a very small charging current

Assuming that the electrical power is 165 W and that the voltage is 14 V, the normal charging current is 11.8 A in this figure. The charging characteristic is represented by the lines connecting the points A, B, C and D:

A. Starting point for charging the battery at the maximum possible current
B. Voltage regulator starts reducing field current
C. Fully charged
D. Absolute end point of charging

This graph depends of the ambient temperature. At a higher temperature, a battery will accept a higher charging current; all lines will then shift to the left.



4.4 Starting up and usage

To start up the PHP:

1. Check whether the voltage indicator indicates a voltage larger than 11 Volt
2. Let water flow through the penstock pipe
3. Turn on the system with the main switch
4. Start the alternator by pressing the Ignition switch for one second; the sound of the alternator changes due to the change of load
5. Check the charging current of the charge current indicator.

Switch off the main switch of the control panel if the PHP is not running at full speed! If not, the field current will draw power from the battery and may get overheated.

5. Appendix

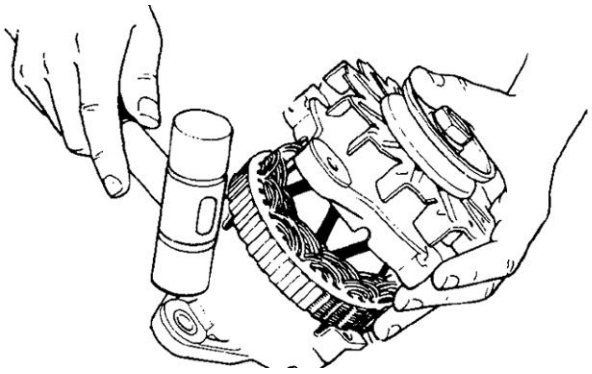
5.1 Maintenance

5.1.1 Alternator life

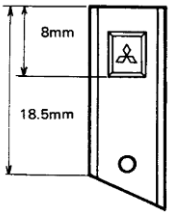
Compared to the amount of rotations in a general car, the expected alternator life will be approximately three years. Although the alternator may last much longer because it is operating at low and constant load, it is possible that brushes will wear out within that period.

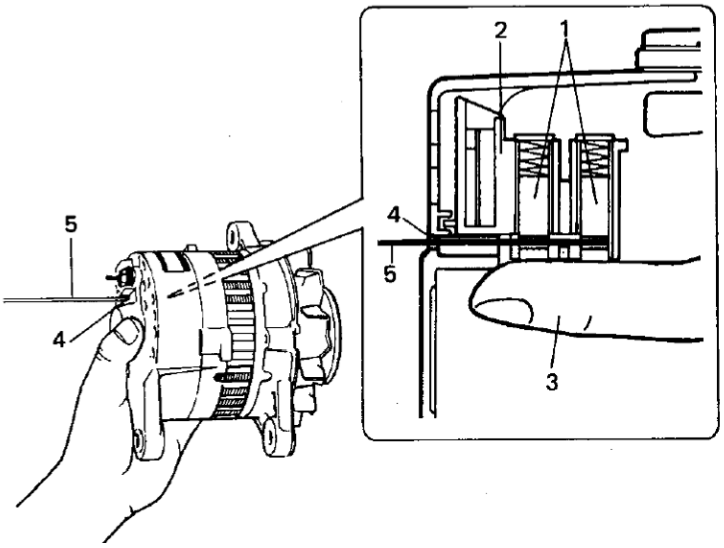
5.1.2 Replacing the brushes of a Maruti alternator

When brushes are worn out and the alternator still seems to be in good shape, the brushes can be replaced as follows:



- Unscrew the three screws at the back of the rotor casing
- Carefully hammer the rotor casing from the front cover (use a plastic hammer)
- Protect the rotor and clamp it carefully in a bench-screw
- Unscrew the pulley nut
- Unscrew the three screws of the DC-AC bridge and the nut of the isolation-connection
- Unsolder the wire between stator and brush holder and remove it
- If the brushes have shortened more than 8 mm (the logo is not visible anymore), remove the entire unit
- Assemble the alternator in reverse order





1. Brushes
2. Brush casing
3. Press brushes into alternator
4. Fixture opening for brushes
5. Metal wire

5.1.3 Inspection of the filter system

The filters (upstream grid and the tube inlet) should be inspected visually on a daily basis and cleaned if dirt is present. Make sure that leaves or plastic is not obstructing the water inlet.

The tube inlet should be free of sand, so especially in the monsoon period remove sand from the creek bed or forebay bottom frequently.

5.1.4 Inspection of the battery

Check the condition of the battery every four weeks. The 'water' level of each of the 6 cells should be well above the metal plates. If this is not the case, add *distilled* water only. If the battery voltage is lower than 11 V, it should be reloaded or it is broken.

5.2 Troubleshooting

5.2.1 Troubleshooting startup (Ignition)

1. Too much torque during ignition: If the alternator is blocked when pressing the Ignition button, the ignition current should be lower. This can be attained by adding a 10W resistance of up to 22 Ohm parallel to the others
2. The alternator has difficulty to ignite (Maruti wiring): In the Maruti wiring the control lamp is placed in series with ignition. At low rations speeds the current flowing through the lamp may be insufficient. Place a 10W resistance of 22 Ohm in parallel to the lamp.
3. In both cases an adjustable resistance (high power; 60W!) can be delivered separately.

5.2.2 Troubleshooting lack of water power

If water power is reducing while there is sufficient water available, make sure the pipe is totally clean at the inside, with the following procedure:

1. Switch off the alternator with the main switch
2. Flush the river dam, so that no water enters the tube anymore;
3. Dismantle the end piece of the penstock pipe
4. If there is any dirt inside the pipe, remove it manually
5. Flush the pipe by letting water into it at the dam side
6. Flush the river dam again, so that no water enters the pipe
7. Restore the end pieces and secure it tightly
8. Let the water into the tube at the dam side
9. Switch on the alternator with the main switch and iginite.

5.2.3 Troubleshooting lack of electrical power

If no or little electrical power is available, check in the following sequence:

1. Check if the alternator is running properly
2. Check the loading Voltage and Current with the indicators:
    - If the loading current is high, power is consumed somewhere in the circuit. Turn off the alternator with the main switch and disconnect the battery. If the voltage is lower than 11V and the internal resistance of the battery is extremely low, the battery might be worn-out and needs to be replaced.
    - If there is no current and no voltage, check the circuit breaker (press to reset), the in-wire fuse at the alternator and the alternator itself.

- Check the condition of the wire to the power station

5.3 Technical specifications

Casing diameter:	23 cm
Casing height:	24 cm
Wire between generator and control panel	3,5 m, 6 m^2
Wire between control panel and battery	0,8 m, 6 m^2
Weight of the kit (casing, cable and control panel):	6 kg (without alternator)
Runner / Turbine type:	Cross flow (Banki-Michell)
Recommended head:	5 - 8 m
Expected power output:	100 – 200 W
Yearly power output at full service	800 – 1750 kWh

5.4 Electrical power

5.4.1 Alternator connections

Unfortunately manufacturers use different ways of connecting the alternator. In the table below connections of different alternator brands are listed. Note that these alternators are built in many different car brands.

Description	GND	+V12	Field		Charge warning Lamp
Connect to wire					
Recognise by	Screw directly on engine				
Alternators with separate regulator					
Hitachi	E	A	F	N	
Bosch	D-	B+	DF		D+
Nippon-Denso	E	B+	F	N	
Mitsubishi	E	B+	F	N	
Ducellier and Paris-rhone	-		+	EXC	
Fiat	earth	30	67	85	

	GND	Charge warning Lamp		Field		+V12	Field ignition	Regulator
							Resistance < 1 kOhm	Resistance > 1 MOhm
Separate regulators								
Hitachi	E	L	.	F	N	A	IG	
Bosch	D-	D+		DF				
Nippon-Denso	E	L	.	F	N	B	IG	
Mitsubishi	E		IG	F				
Ducellier and Paris-rhone	.		+	EXC				
Fiat	earth		15	67				

The poles of the alternator in the coloured cells should be connected to the same letter of the regulator
If connection codes are printed under one another in one column, they are completely interchangeable

Alternators with built-in regulator														
Mutisubishi	.	.										.		.
Mitsubishi (a.o. Suzuki)	.	B			L								IG	
Bosch	D-	B+		D+										

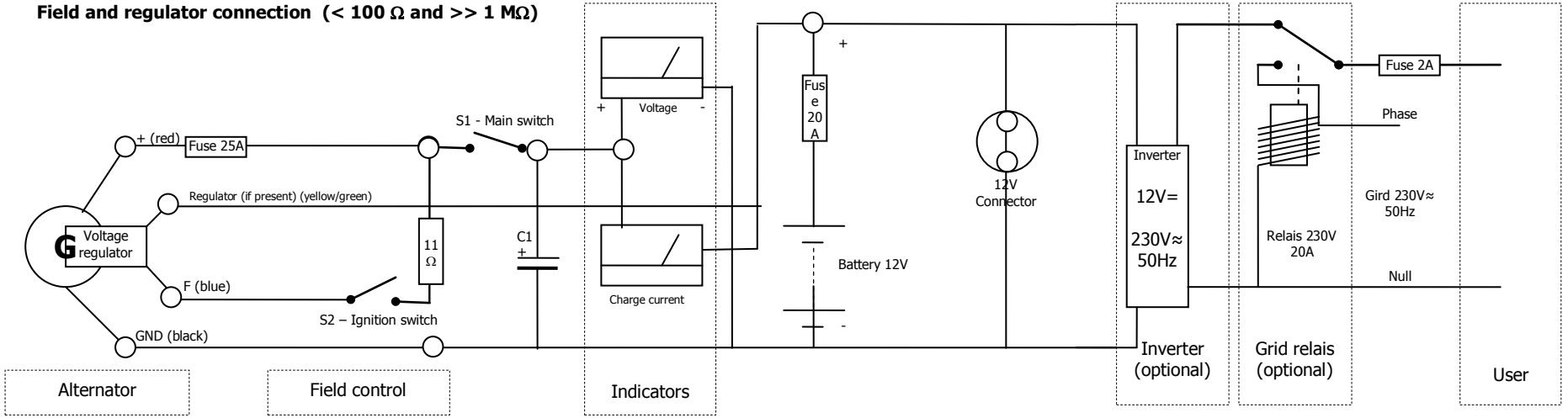
- The 'F' and 'E' connection can be found by checking with a tester between which contact there is a diode, and the polarity of this diode. But this won't work with all regulators since some might have a resistor instead.
- Bosch type alternators with built-in regulators regulate the Ground of the supplied energy to the rotor. Almost all other brands and Bosch alternators with external regulator regulate the PLUS of the supplied voltage to the rotor
- There are multiple wiring possibilities for the charge warning lamp of alternators. Try to find out what is the proper wiring for your alternator. If not sure, you might rather leave the lamp unused.

5.4.2 Electric circuit

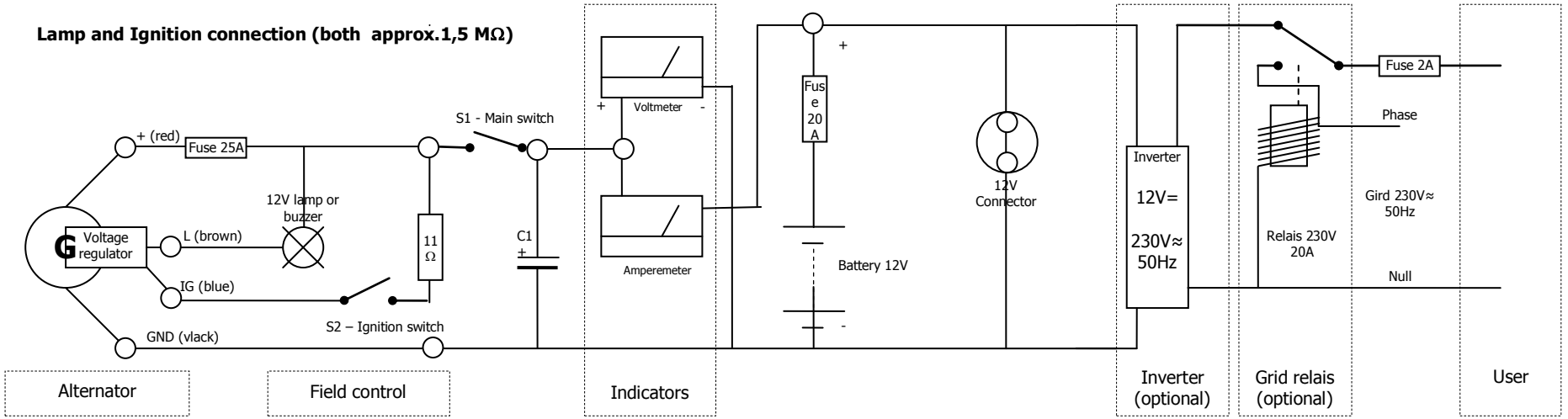
Below the electric circuit for the standard control panel is drawn, including components for extensions.

Electric Circuit of the Control Panel

Field and regulator connection (< 100 Ω and >> 1 MΩ)



Lamp and Ignition connection (both approx.1,5 MΩ)



5.4.3 Power consumption of devices

The table below lists examples of devices that are commercially available and can be connected to the PHP. The typical power consumption value can be used to calculate the installed and peak power consumption.

	Power consumption at 12 V (A)	Power consumption at 230 V (A)
LED lamp 4 white LEDs 18000 mcd	0.03 (est)	0.012
LED lamp DP-124921-1, 3W 45 LEDs, white		0.013
LED lamp E27LB100, 1.8 W Warm white		0.0078
1 W IL R1W, 22 LEDs, (Interlight)	0.0043 (est.)	
PL lamp 18W (Myna)		0.136
PL lamp 5W		0.038 (est.)
Smoke detector		0,080
TV (12V: 37 cm 35W)	3	
TV 65W		0,28
Sewing machine		
Small deskfan	0,35	
Electric fence (schrikdraad)	0,25	
Immersion heater 120W	10	0.5
Refrigerator 40 l, 105W*	8.75	
Big refrigerator 100W; 0,7kWh/day*		0,13
Laptop power supply (Toshiba SP1600)*		0.6
Loading device PDA / mobile phone / camera*		0.120

* These devices do not draw the indicated power continuously, but intermittently.

5.5 Other options to the kit

5.5.1 Grid relais to switch to grid when power is available

If grid power is cut on a daily basis, you might want to switch to the grid when power is available. An optional relais can be installed for this that can only be used when an inverter is installed. When grid power is available, all hydropower is then used to load the battery. When the grid power is cut, the relais switches to the hydropower.

5.5.2 Parallel alternators

If you have sufficient water supply, you might be interested in generating more power by installing an additional alternator in parallel. Advantages are that:

- You can use one single water inlet and penstock pipe for multiple alternators
- If one alternator needs maintenance, power is still generated by the other power source

The following adjustments should be taken into consideration:

1. If one penstock pipe is used for multiple alternators, make sure that head losses will not hinder the required power output (i.e. choose the proper pipe diameter)
2. The systems can **NOT** be connected to one single battery without modification. If you wish to do so, an additional power-diode needs to be installed between the battery and each power source.

5.5.3 Floating PHP to improve head

When the water level in the river can change substantially during the seasons and the total head is critical, you might consider to make the PHP floating. For example, if you need to construct the PHP 1 m above general water level and the total head is 6 m, you lose almost all head that is needed to generate electrical power.

If the alternator would be floating according to the drawings below, the head loss can be reduced to a minimum amount and the equipment is protected against floods.

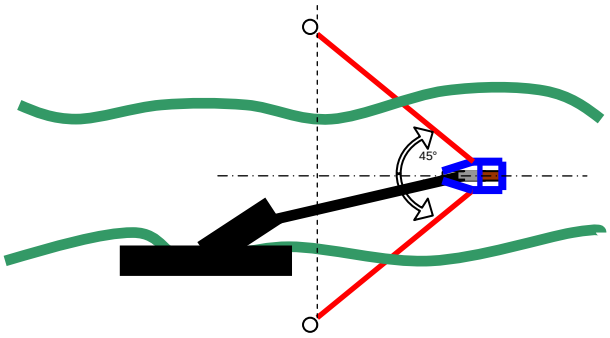


Figure: View from abouve

- Use two closed floating pillars of 200 mm diameter and 2,2 m in length
- Fill them with empty mineral water bottles and/or polyurethane foam
- The blue frame should connect the pillars firmly, and should have mounting holes to fixate the PHP
- Two junction holes to connect the red ropes should be mounted on the sides of the floating unit
- The two red ropes should make an angle of 45° with the river-bank to prevent horizontal oscillation
- Maximum length of the flexible tube should be 3m
- The bottom of the runner should be approximately 15 cm above the water level

Make sure the river bed under the PHP is flat, so that it stands horizontally when there is little or no water.