Master thesis

Energy systems for transportation technologies

developed under direction of

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Acknowledgement

This master thesis is dedicated to my parents, Fernando and Isabel, whose always support me and made a great effort for me to obtain this engineering degree at Aveiro University.

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To my friends of Aveiro University, Diogo Gonçalves, Tiago Grilo and many more who helped me in during my five years of study there I am very grateful to them.

Abstract

The objective of the work developed in this master thesis is to implement in one system for the transport people in underdeveloped mountainous regions in Nepal. This is based on the idea of Asso. Prof. of Physics Lok Bahadur Baral from Tribhuvan University in Kathmandu (Nepal), who started to develop a gravitational potential energy for transportation. His work was conducted under supervision of Prof. Kartnig at the Department of Engineering Design for Transport and Conveying Systems at Vienna University of Technology in collaboration with Tribhuvan University.

This part of the project is to develop the power supply for the infrastructure created by David Guerrero in his bachelor thesis.

The infrastructure is already designed to receive one engine that will give the power necessary for this to be successfully accomplished. For the engine to work we have to have some energy supply in our system, that energy requirement will originate from a variation of renewable energy technologies.

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1. Introduction

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The purpose of this thesis is to design and develop the energy system for the infrastructure already developed by David Guerrero for a personal transport system that has the objective to aid the inhabitants of steep slopes in mountainous undeveloped countries. This project is considered a thesis and is under the guidance of Dipl.Ing. Dr.techn. Georg Kartnig, of Institute for Engineering Design and Logistics of the Vienna University of Technology, in collaboration with Tribhuvan University in Kathmandu in Nepal. The system was developed based on the main ideas of Asso. Prof. of Physics Lok Bahadur Baral.

The project was developed in parallel by David Guerrero, which complements this one and includes the constitution of all the design and features necessary for this project to be build up later.

1.1 Problem Approach

Underdeveloped countries are countries in which the generated resources are not enough to improve their socio-economic potential. This will result in a slower development than it should be. In this situation these countries have an array of issues in the society such as health care, clean water or food, and problems in the infrastructures such as inadequate housing and poor roads.

This infrastructure problem makes the development harder, so it means that this is a very important aspect to improve in order to increase the quality of life of the inhabitants.

The infrastructure present in Nepal is rudimentary and weak. The lack of accessibility has a strong impact in all aspects of their society. Furthermore this lack of accessibility is far greater if you have inhabitants located in the mountains like in Nepal. The poor quality of the infrastructure means it is difficult for the social services to work to help these inhabitants with a standard of living.

These inhabitants have to go to extreme efforts to reach their destinations and sometimes they have to transport their merchant up and down in those mountainous regions. This problem is a reality for those inhabitants because of the difficult relief in that part of the country.

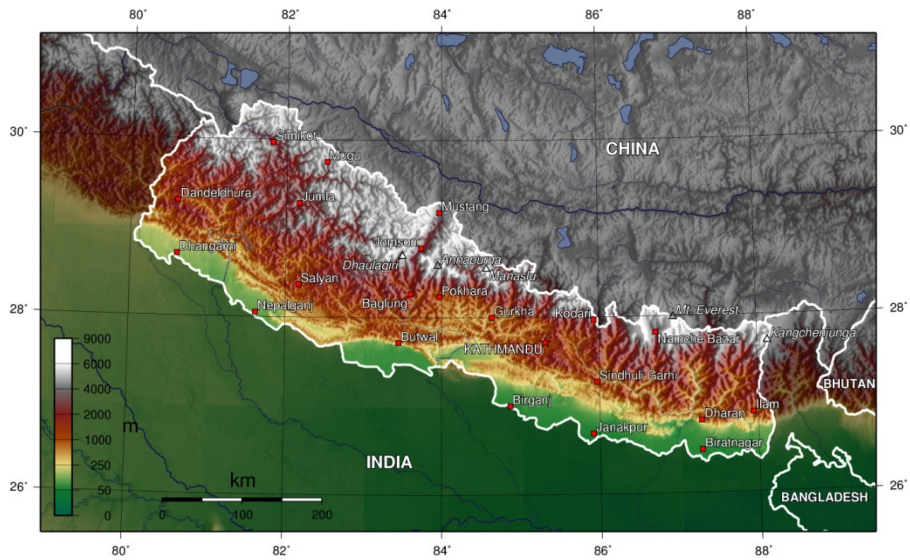

Figure 1: Topology of Nepal [20]

Nepal is a diverse landscape, ranging from the Terai plains in the south to the Himalayas in the north. This means the topology of Nepal can be less than 100 m above sea level in the Terai plains to more than 8000 m in the Himalayas.

With these significant differences of altitudes the Nepalese topology is divided in five ecological zones:

- Terai plains with an altitude less than 700m
- Siwalik with an altitude between 700m and 1500m
- Middle Mountains with an altitude between 1500m and 2700m
- High Mountains with an altitude between 2200m and 4000m
- High Himalaya with an altitude between 4000m and more than 8000m

In Nepal, with a population of around 29.3 million people, 48% is located in the Terai plains. This area is very important for the country, because here the Nepalese people have the major opportunity to use the space for agriculture; this area sustains about 76% of the population. This is possible because:

- the relief is not too steep;
- the presence of three important rivers: the Kosi, the Narayani, and the Karnali;
- the climate is hot and humid

Another important region of Nepal is Siwalik. Around 45% of the population lives in this region, but the proportion of the population in this area over the years is decreasing. This occurs because people have the necessity to move to better areas to improve their quality of life.

The population is located in the mountainous areas, however much like the Siwalik region, this figure is decreasing because of the difficult relief and poor resources.

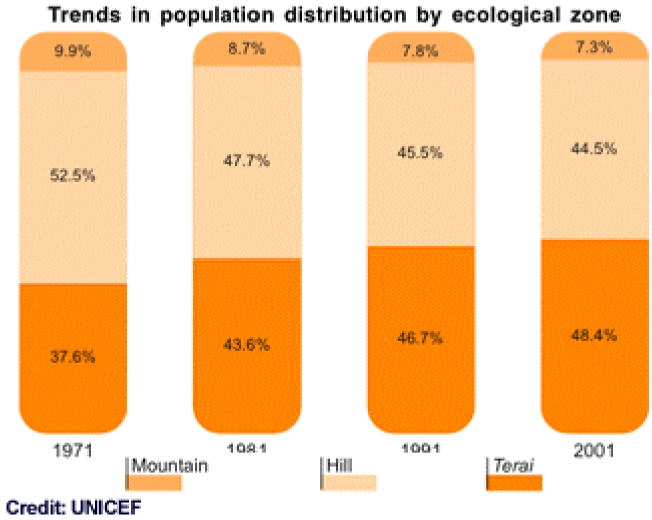

Figure 2: Population distribution by ecological zone

The other big problem in Nepal is the transport infrastructure. The country merely has approximately 17000 km of roads, where just 30% of them are paved. In the 30 million populations, only 43% of the population has access to the all-weather roads. This is due to the fact that more than two thirds of the country is mountainous, for that reason it is not reliable to build a proper road infrastructure in those areas. The existing roads are mainly located in the southern part of the country and some of them cannot be used all-year-round. The other type of transport is the railway network, however this is also underdeveloped.

Another means of transportation in Nepal is by air. This kind of transport is very important because it supports the connections between the mountainous areas and the other areas in the country. These connections help improve the development of the tourism and trade markets, however the major issue of air transportation is that it is not widely affordable for much of the population.

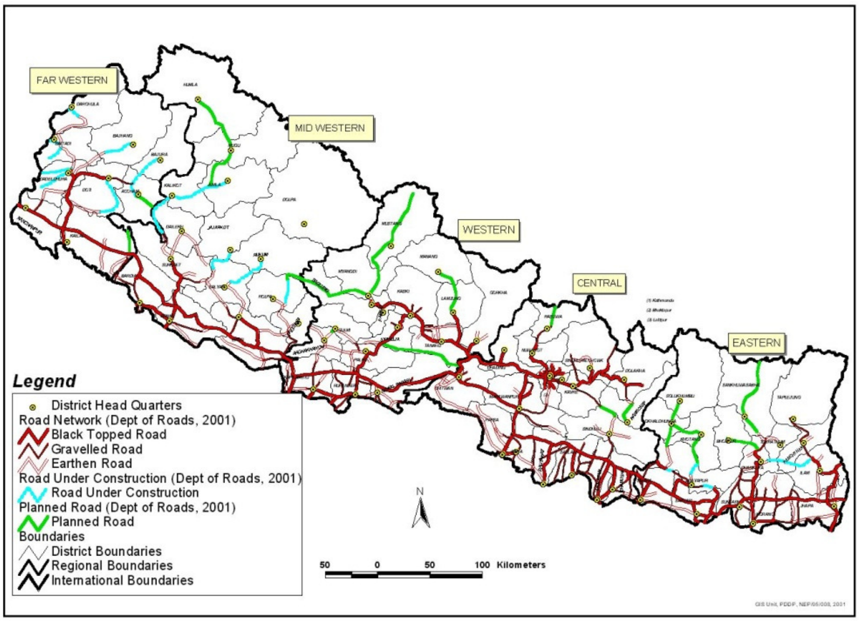

Figure 3: Nepal's road network [21]

All these infrastructural issues have a substantial impact in population's life, so they had to adopt new methods and solutions to improve their quality of life. These solutions are based and constructed in basic and rudimentary methods and often utilize animals as their source of power.

Figure 4: Rudimentary transport solutions in Nepal [7]

1.2 Objective

The objective is to design an engineering statement from the idea of Prof. Lok Bahadur Baral, integrating the CASWAT-G to help and improve life quality in hilly areas in Nepal.

In a previous study some aspects already were being developed for the system design.

Those aspects are:

- Design of the main and middle stations in the way to support all the system;
- Conception and dimensioning of the circulation cable;
- Conception of the connections between circulation cable and users;
- Safety for the users

In the part of the system development, we will improve the system with an addiction of an extra source of power, to solve the described problems before.

This extra source of power is a challenge because we are talking of remote areas in the mountains, and we don't have any power network in these locations. So the solutions have to be almost autonomous, just needing a few controls during certain periods. They also need to be simple construction and technology to be simple to solve some unexpected problems.

2. Energy in Nepal

Energy is a very important factor to develop and improve the quality of life in the countries.

An important natural resource of Nepal is water. This resource has the best potential for energy generation, but actually just 1% of energy consumption in Nepal comes from hydroelectric production. Other types of energy are imported from India, like the fossil fuels (oil and coal), as Nepal does not have any considerable deposits. The biggest supplies of energy are 'other types' of natural resources.

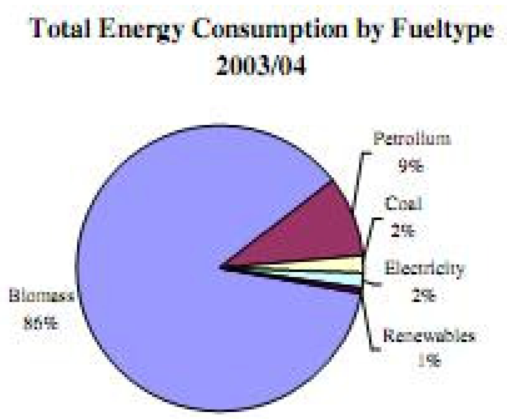

Figure 5: Energy sources in Nepal [2]

Nepal is the country in South Asia that uses the lowest amount of commercial energy, around 500 kWh per capita per year. The consumption of energy in Nepal in 2003/04 was 363 million GJ, and 90% of that energy was consumed by the residential sector, and just 1% was in the agriculture sector. The main share of the total energy consumed by Nepal is provided by biomass. This kind of energy represents 86% of energy, much more than the 9% of petroleum or 2% of electricity or even the 1% that comes from renewable energies.

The rural areas in Nepal consume around 288 million GJ from the total energy consumption. Biomass accounts 98% of that, while electricity just has a share of 0.1%, petroleum about 1.6% and 0.5% originate from a renewable energy. It is expected the consumption of energy will increase by around 1% to 4% in the next years, with a slight decrease in the biomass energy, and a consequent increase in the commercial and renewable energies.

The major energy consuming sectors in the country are the residential, industry, transport, commercial and agriculture. Results form 2002/03 show that 85% of the primary energy was consumed by the residential sector, followed by the transports, 4%, industry, 3%, commercial, 1%, and 1% in the agriculture. In the following years there is expected to be an increase in the industry and residential sector as well as some slight reductions in others.

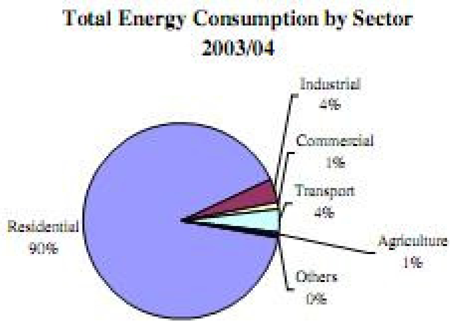

Figure 6: Energy Consumption by Sector in Nepal [2]

A study was made to explain the energy end use perspective in Nepal by Water and Energy Commission Secretariat (WECS). The results of this study were; in the residential and rural areas the biggest share in the primary consumption of energy is for cooling purposes, these accounts for 85% of the population. Also in the residential sector, other end-uses of energy is for heating of space, 8%, agro-processing, 3%, water boiling 2%, lighting and other uses.

The use of electricity in Nepal has an insignificant share. This can mean, in the next 25 years the expansion of these networks even for light can be impossible, because of the low speed of development. This represents a real problem, and deserves raised attention from the agencies located there to promote renewable energies.

2.1 Energy Resource Base in Nepal.

2.1.1 Biomass Energy

Biomass energy is the type of energy most used in Nepal. This is due to the lack of development in other types of energy production such as renewable, this affect is amplified further because of the weak economic situation of the country. The main form of biomass energy in Nepal is the fossil fuel wood, due to its abundance and easy sourcing.

The estimated sustainable annual yield of timber is approximately 25.8 million in Nepal, an average of 2.8 tons per hectare of forest. However, only 42% of the estimated sustainable supply is accessible.

Therefore in Nepal, due the increasing use of forest products, the forests themselves are becoming threatened. To control this situation the country needs to create annual restrictions for wood fuel, fodder or timber, and other products provide by the forests. Around 44000 of hectares are threatened annually, while just 4000 ha are reforested. The cause of this severe environmental problem is the increasing conversion of the forest areas into cultivation areas and the high growth of the population.

Despite the problem in the forests, the Nepalese population does continue to use the biomass energy from different sources such as crop residue and animal waste. These sources in 1994/95 were estimated to be 112 million tons. Annually the country has 4.8 million tons of animal waste potentially available for fuel. In 2002/03, about 78% of wood fuel was used for production of energy, 6% was provided from dung and 4% from agricultural residues. In the following years there is expected to be a reduction in the percentage of wood fuel to production of energy.

In 2005 it was reported that Nepal has 134570 biogas plants, which are divided amongst the 66 districts of the country. Due the quality control of the construction, installation and operation these plants have a big rate of success. With these plants, Nepal is capable of producing about 4.36 cubic meters per person day of biogas. A result of a subsequent study recognized that biogas production of 600000 plants can have some beneficial economic potential.

2.1.2 Hydropower

One of the important resources in Nepal, the hydropower potential is around 83000 MW but just 25% of it is potentially available for development. In this share just 1% of this potentiality is used. Nepal's total installed hydro-electric generation is 650 MW. This energy is provided to 880000 habitants through 1962km of distribution and transmission lines. This production represents 98% of the national grid and 99% of the supplied energy. Separately, some public and private sectors have their own power productions. These isolated supply systems are based in small hydroelectric plants existent in remote areas of the country.

The existing issue with hydroelectric networks in Nepal is the high cost of large hydro power plants, as well as power transmission line expansion in areas with difficult access, like mountainous areas.

2.1.3 Petroleum, Natural Gas, and Coal

Until now no substantial source of reliable energy adequate for commercial use has been found in Nepal. The petroleum is imported already refined, and ready to use. The main suppliers of these products are India and China.

Natural Gas like petroleum has not been found in Nepal in a considerable amount.

A further fossil fuel source is coal. This type of energy supply has been found in two economically viable deposit regions in Nepal, but is believed that there is an insignificant energy demand to validate their construction. They are located in Kathmandu and in Dang.

2.1.4 Renewable Energy in Nepal

In Nepal, all commercial energy sources are non-renewable with exception of hydropower which represents a small share in energy consumption, but the Tenth Five-Year Plan (2003-2007), aimed to bring the level of renewable energy used rurally to 12% , 5% more than the current share.

The energy governmental institutions in Nepal distinguish between two types of energy types: traditional and commercial energy. This is used to distinguish the sources as per their supply mechanism. The energy can be either bought on the commercial market, or it is generated in public sources without any monetary transactions occurring.

This acknowledgement also generates a lot of confusion, for example; solid biomass fuels are considered to be a renewable energy, however it was not included in the list of alternative and renewable energies. This means one of the most important sources in the Nepalese energy system was not included in the alternative energy development program.

The definitions in this program were; a new and renewable energy or alternative energy, to include only renewable energy based on new technologies, not the development of traditional energy generating technologies.

Despite these non-recognize biomass fuels, since the implementation of this program some alternative sources of energy were developed because of a development of new technologies. Actually we already had production of energy from alternative sources such as solar-thermal, solar power or wind power.

So in Nepal, the important types of energy production in the renewable energy sector are biogas, micro – hydropower, solar thermal, solar power and wind power. A national agency knows as Alternative Energy Promotion Center (AEPC) was established to coordinate and monitor all these new energy technologies.

In the solid biomass fuel sector, the current priority is to improve the heat efficiency of the wood burning cook stoves.

The main aim now in Nepal, is the improvement of the energy system with just new and renewable sources. For this, energy sources like micro – hydropower, solar – thermal, wind gas or biogas are being promoted.

Alternative Energy System	Number of installations	Total Capacity
Biogas (Capacities between 4 – 20 m^3)	134570	942000 m^3
Solar Photovoltaic Power (Mostly stand-alone systems)	44658	1661,3 kW
Micro – Hydropower	2065	14110 kW
Solar Thermal	30000	
Solar Water Heaters	2246	
Solar Cookers	400	
Wind Turbines	6	1900 Wp
Geo – Thermal	32	
Biomass Energy Improved Cooking Stoves (ICS) Biomass Briquettes	96086	

Table 1: Achievement in the alternative energy sub-sector in 2003 in Nepal [3]

In a way to improve the life quality of those populations without construction of new roads, cable car systems or railways, because is too expensive, it was proposed to build a simple system to help those people in their regular routine.

The idea came from Asso. Prof. of Physics Lok Bahadur Baral at Kathmandu University.

He proposed an alternative system using gravitational force called CASWAT-G.

The proposed system is a solution to the populations reduced mobility, helping them to carry their goods up and down in the mountainous regions, as well as for several other reasons. CASWAT-G is also eco-friendly, minimum effort requiring transport, and it is cheap. The system already has a prototype, which was tested and has had successful results. He also makes a theoretical brief study.

This proposal works in a very simple way, being similar to a ski resort lift. It consists of two main stations, one at the top of the hill and one at the bottom. It is a circulating cable, and uses simple components to connect the people to the circulating cable.

In the initial idea and in the prototype, the two main stations are constituted by two bull wheels, the structure to support the bull wheels, and a guiding component for the circulating cable. An additional intermediate station can be added if the relief of that area is to steep.

Theoretically the system works when we have two users, an ascending and descending one, both connected to the base point in the connection cable. In the theoretical study the descending user connected to the circulating cable, is transferring a force to the circulation cable. This force will move the circulating cable and start to pull the ascending user, in affect it is a way of walking up and down the hill, but with less effort.

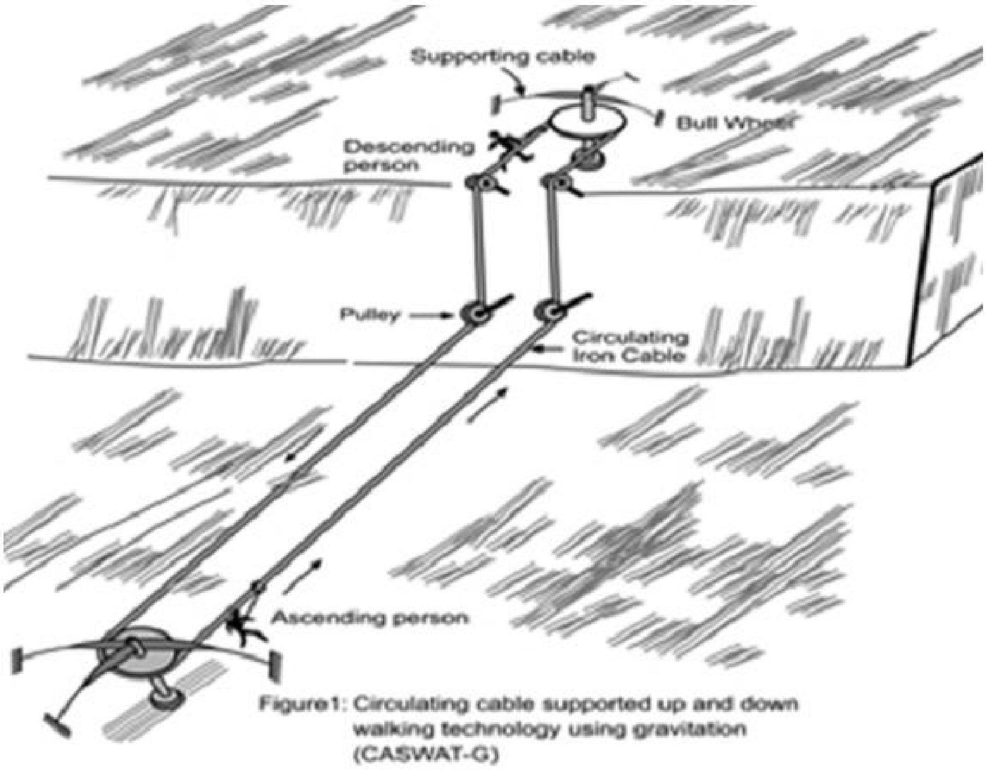

Figure 7: Basic CASWAT-G system layout [1]

In theory the system will work in practice without any problems, but first we have to consider a few aspects. These aspects can be common in the real usage and need to be considered, so that the system itself remains useful useless system.

A few of these aspects are:

- The system can only work if the ascending user has less weight than the descending user;
- Requiring a descending user ;
- The impossibility to control the system speed;
- The number of descending users has to be at least equal to the number of ascending users;
- The steepness of the slope influences the speed and force transferred in the system;

The conclusions of the theoretical study were; that the system will be ecological as we one does not need to cut trees or make any significant landscaping modifications to establish the construction. A further conclusion was that the system will develop and improve the quality of life for the communities located on the mountains.

3. Specification of the Task

At the start of a project, several different aspects of the task must be decided, specified and analyzed. This means a creation of a list of specifications. This list will contain the system requirements, objectives and conditions that have to be established to the design of the project.

These conditions will need different `requirements´ in order to be successful, but also some `desires´ that are not essential but can help to improve the end quality of the construction. The requirements are the part of the project that must be developed because they are the main constitution of the project and fundamental for a reliable system. On the other side, desires are the part of the project that can be developed only if they do not interfere with the main layout or do not interfere with the main requirements.

The system must be designed based on CASWAT-G. The basic layout will consist in:

- Lower station
- Upper station
- Cable circulation
- External power supply

The construction must be able to ascend a 100m slope, with a range of 40º to 60º. The maximum number of users of the system will be 20 (10 ascending, 10 descending), separated by 10 m. The speed of the system will be controlled by the engine and will be approximately 0.56 m per second. The circulating cable will be circulating at 1m over the ground. The speed of the system and the localization of the cable will provide a comfortable walk to the users.

The system also must have safety facilities to avoid accidents during the utilizations. The materials used in the construction should be inexpensive.

The installation must be possible in remote areas with difficult access, the tools required for construction as well as maintenance must also be suitable to those remote areas .

The target of this project is to be implemented in underdeveloped areas, so the budget has to be reduced to the minimum possible, so that it may be financed by an agency or NGO.

The maintenance has to be reduced to as basic a level as possible, because in remote areas the knowledge and resources required are not expected to be available.

The system also will include an extra power supply to lift the users when nobody is in the descending direction.

The design must be robust enough to resist hard weather conditions and other open air aggressions: rain, snow, cold temperatures, ultraviolet radiation, animals. It should also be flexible so that this system can be installed in different locations with different topography, weather conditions.

Specifications	Requirement	Desire
General Specifications		
Integrate CASWAT-G	X	
Distance between extreme stations up to 100m	X	
Slope: 40º-60º	X	
Minimum distance between users 10m	X	
Maximum number of users: 20	X	
Circulating cable speed: 2 km/h	X	
Distance between cable and ground: 1m approx.	X	
Flexible design to be installed in different locations	X	
Robust enough to resist open air aggressions	X	
Simple		X
Cheap		X
Connecting Cable		
Two possibilities: fixed at system and belonging to user equipment	X	
Connection safety lock	X	
Construction		
Simple to be carried out with little knowledge and basic tools	X	
Cheap		X
Maintenance		

Reduced to the minimum	X	
Possible with little knowledge		X
Possible with very limited resources		X
Energy		
Design adapted to work with an engine	X	
Storage of the energy released by a descending user		X

Table 2: Project specifications [7]

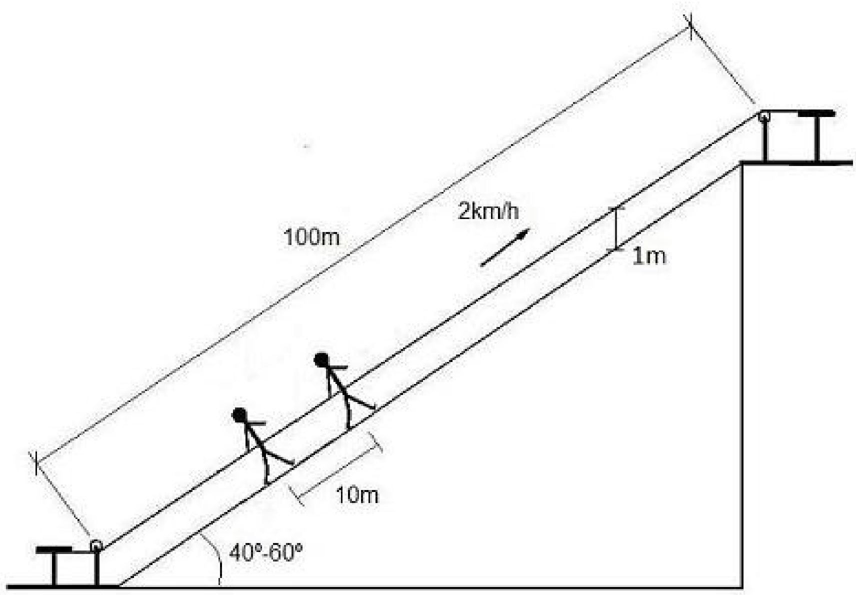

Figure 8: Layout of the system

4. Design Conception

The design conception of the system was based on the initial idea of Prof. Lok Bahadur Baral. The system is composed of a lower and upper station and if required an intermediate station, to make the transition between different inclinations.

The lower station is composed of:

- IPE Profiles
- C Profiles
- Bull Wheel
- Guiding Pulleys
- Counter weight

Similar to the lower station, the upper station has the same components apart from the bull wheel's car and the counter weight, which is replace with an electric engine. Another difference is; the upper station contains some specific components to avoid contact with the users against the upper bull wheel. The intermediate station is constituted only by guiding pulleys in the IPE profiles that work like supports.

In the construction of the design one of the aspects was the simplicity usage, a second was the use of cheap and easy to find components. For that reason the IPE and C profiles are with normalized measures and are almost all the same size. Also the wheels for the counter weight and the car are easy to find in any wheel manufacture.

On the other side we have the guiding pulley, the bull wheel and the bull wheel's car. The guiding pulleys do not have any special geometry, however finding the correct measurements can be difficult to source. In them, the bolts and the rolling bearings are the only standardized parts. The same is the case with the bull wheel's car. This component is one of a few that will be needed to build and is constituted by four different parts. These parts are the top and the bottom body of the car, in the sides we have the support for the wheels and on the back there is a connection with the counterweight with a cable. Another component is the bull wheel scaled in the standardized measures.

In the intermediate station the guiding pulleys are the same as the lower and upper station, like the IPE profile the only difference is the length of the profiles.

In the upper station with the inclusion of the electrical engine, other components have to be build. These components needing to be built include; the axle, devices for redirection of the user-machine connection, the platform for the engine or covers to prevent the entrance of the residues to the rolling bearings. Furthermore the bull wheel has to be built differently because of small differences between the both. The guiding pulleys will be the same for the lower station as will the rolling bearings.

The electrical engine used in the system is provided from an engine company and meets all the requirements of the system, as will be explained later in this work.

The system will have concrete foundations. The concrete foundations will include an iron mesh to provide more stability and to be easier to attach the connections with the IPE profiles that support the main components of the station. The concrete base will be similar on all different stations apart from the size, in addition in the lower station that will have a socket for the counterweight.

The counterweight system is used to provide pre-tension to the circulating cable to avoid any slippage. Without this component it will be a hard task to ensure the system works reliably in all conditions. It is constituted by a few parts including the counterweight, C profiles to drive the wheels, a guiding pulley to drive the cable, which is connected to the counterweight and the bull wheel's car in the lower station.

The entire system can only work properly with the inclusion of a circulating cable. This cable will be made by steel because is the cheap, it meets all the requirements and security coefficients, in addition the weight issue of the material used is not of high relevance. In the circulating cable we will have some components to attach the users to the system.

These components will provide the proper connection and will have safety devices to avoid all different kinds of accidents. Like many parts in this project these components are already existent in the normal market and for that reason it will be easier to find them and they will be relatively inexpensive, compared to having to produce new solutions.

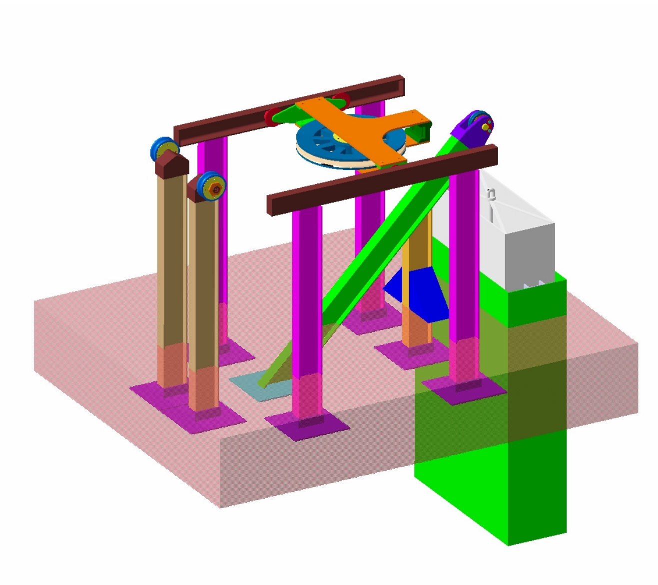

Figure 9: Lower station

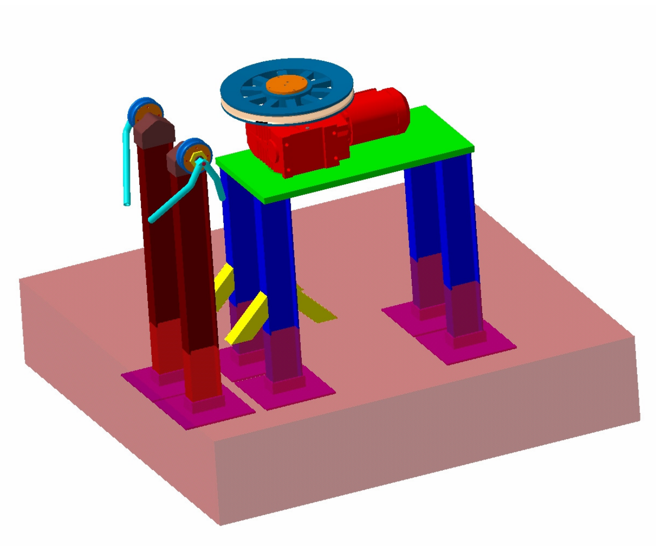

Figure 10: Upper station

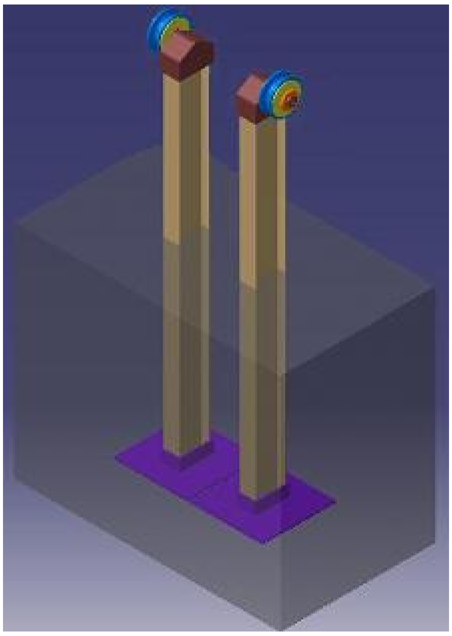

Figure 11: Intermediate station

4.1 Supporting beams

The supporting beams of the system are basically constituted by IPE profiles. These profiles were chosen because they are relativity cheap and easy to find, and have a big row of standardized measures that bring some advantages in our construction situation. To scale the profiles, it is necessary to have some information about the project, such as the length and loads that are to be applied.

The structural beams, in our case will suffer the effect of the forces in two directions, like the figure shows:

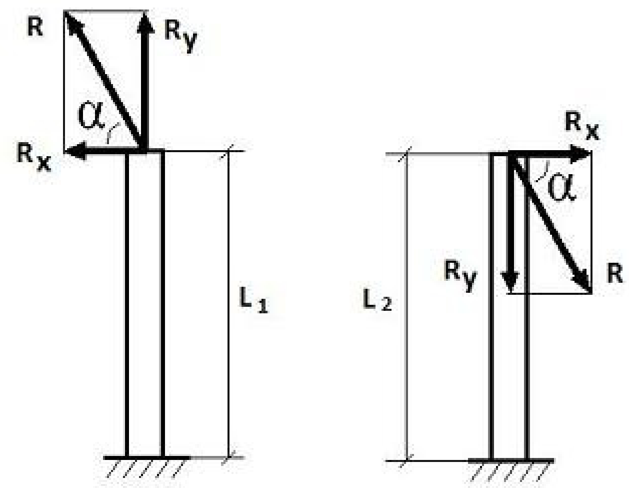

Figure 12: Representation of loads in guiding pulleys

To scale these components of the project, you must consider aspects like applied forces, generated moments, length, security coefficients and the quality of the steel. In our case we are using low yield strength steel because it is cheap and we believe that it is sufficient for our requirements.

The following assumptions will be used in order to precede with the calculations of the beams profiles:

Assumptions	
Steel yield strength	f_y = 255 MPa
Gravitational force	g = 9.81 m/s^2
Security Coefficient	S_o = 2
Applied Forces	R = 1179.4 kg R_x = 589.7 kg R_y = 1021.4 kg

Table 3: Assumptions for calculation of beam profiles

4.1.1 Lower Station

In the lower station the data values of the profiles are:

Beam	Length (mm)
Main supporting beam	960
Guiding pulley beam	1070
Counter-weight pulley beam	618

Table 4: Measurement data of the lower beams

So to proceed with the calculations of these beams we have to calculate the moment generated by the force, when applied on to the beams.

To calculate that moment we have to considerate their length.

So for the supporting beams we will have:

$$M = R_x \times g \times L$$

$$M = 589.7 \times 9.81 \times 960 \times 10^{-3}$$

$$M = 5553.6\ N.m$$

For the guiding pulley beams:

$$M = 589.7 \times 9.81 \times 1070 \times 10^{-3}$$

$$M = 6189.9\ N.m$$

For the counter weight beam, the calculations have a small difference because the applied force there is different due to the counterweight. The counterweight has a total weight of 1600 kg and because of that we need to calculate the applied force to that beam to proceed with the calculation of the profile.

The beam in the counterweight system is positioned with an inclination of 45º, like the figure 13 shows:

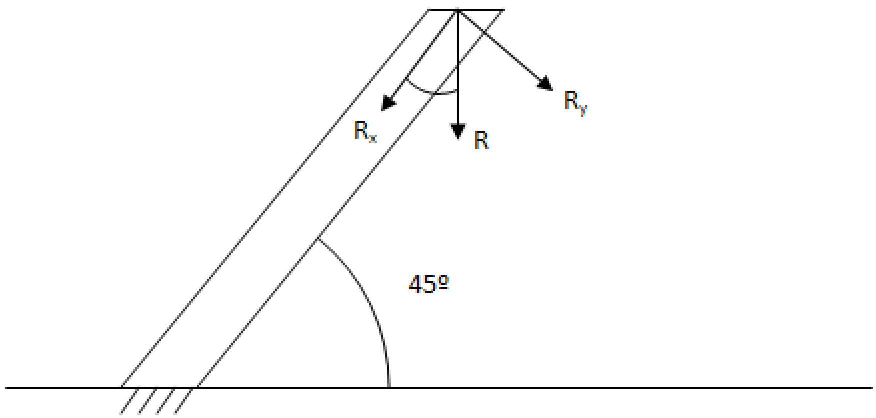

Figure 13: Scheme of loads in the counterweight beam

With

$$R = 1600kg$$

$$R_y = 1600 \times \sin 45º$$

$$R_y = 1361.5\ kg$$

With this applied force, we have the conditions needed to calculate the generated moment in the beam.

$$M = R_x \times g \times L$$

$$M = 1361.5 \times 9{,}81 \times 618 \times 10^{-3}$$

$$M = 8253.9\ N.m$$

Generated moments in the beams ($N.m^2$)	
Main supporting beam	5553,6
Guiding pulley beam	6189,9
Counter-weight pulley beam	8253,9

Table 5: Generated moments in the beams

The fundamental equation of bending consists of the tension related to the bending moment. That gives a linear distribution of tensions and the tensions have the maximum values in the extremes.

$$\sigma_x(y) = -\frac{M \times y}{I}$$

The maximum tension generated in these situations is provided by the bending modulus (W_z),

$$W = \frac{I}{|y_{max}|}$$

Where

$$\sigma_{x,max} = \frac{M}{W}$$

In the project because the bending forces are predominant, it is beneficial to choose IPE profiles with high values of the I_z and W_z.

With the obtained results, we can proceed with the calculation of the IPE profile that will be used in our project. In the lower station, the applied forces generate here will essentially be bending forces. To scale correctly the IPE profile we need to calculate the bending modulus (W). This calculation will provide the minimum bending modulus to make the correct choice of the IPE profile. In this calculation it also includes a security factor to guarantee a non-failure of the structure.

The formulas above can simplify the calculation of the bending modulus. The calculation will contain the maximum moment generated by the applied forces, the security coefficient already chosen for the project and the tensile strength of the beam's material.

$$W \geq \frac{S_o \times M_{max}}{f_y}$$

And with this formula the obtained results for the IPE profile of the beams are:

Supporting beams

$$W \geq \frac{2 \times 5553.6}{255}$$

$$W \geq 43.6\ cm^3$$

Guiding pulley beam

$$W \geq \frac{2 \times 6189.9}{255}$$

$$W \geq 48.5\ cm^3$$

Counter weight pulley

$$W \geq \frac{2 \times 8253.9}{255}$$

$$W \geq 64.7\ cm^3$$

The following table shows the results of a summary of the calculated bending modulus for the beams contained in the lower station. The results reveal that we have a bigger bending modulus in the counter weight beam due to the fact that the beams support the entire stress caused by the counter weight.

Bending modulus in the beams (cm^3)	
Supporting beams	43.6
Guiding pulley beams	48.5
Counter weight beam	64.7

Table 6: Bending modulus in the lower station beams

The following step in order to choose the right IPE profile is to compare the obtained bending modulus with the standard bending modulus provided by the beams manufacturers.

The choice of the IPE beam profile was the IPE 140. This profile was chosen because it has a bigger modulus [8], than the maximum calculated for the required beams. Also we could chose the IPE 120 [8], but this will just be used in the support and guiding pulley beams, and for that reason the IPE 140 shall be chosen, because it is the same profile for the whole project and the costs would not differ greatly.

Also the beams will have supporting features do avoid the vibration on them. With this will be improved the stability of the system. These supporting features also will be present in the upper station due to the presence of a motor.

4.1.2 Intermediate Station

In the intermediate station the calculations for the profile of the beams will be similar to the calculations of the lower station.

In these stations we have to consider different lengths for the beams because the lengths depend on the slope of the hill.

These beams, only in very particular situations, will reach stress values above the calculated stress for the lower station. We will illustrate this in the lower station explanation. We still have a good gap between the maximum calculated bending modulus and the standard bending modulus of the chosen IPE profile. That means the IPE 140 will be a valid choice for the beams, even if the lengths will be slightly larger.

4.1.3 Upper Station

In the upper station, with the inclusion of the electrical engine, the proposal design must be different. The engine will provide some height to the system and so for that reason the beams will have some design alterations in length but will be the same profile that we used in the lower station because the difference of height is not so relevant.

In this case the upper station will use four supporting beams, to support the engine and the bull wheel.

Beam	Length (mm)
Main supporting beam	634.5
Guiding pulley beam	940

Table 7: Measurement data of the upper beams

The length of the guiding pulley is slightly different to the lower station due to the position of the circulation cable.

Similarly to the calculations of the beams for the lower station, we precede with the calculation of the beams for the upper station.

So for the supporting beams we will have:

$$M = 589.7 \times 9.81 \times 634.5 \times 10^{-3}$$

$$M = 3670.6\ N.m$$

For the guiding pulley beam:

$$M = 589.7\ \times 9.81 \times 940\ \times 10^{-3}$$

$$M = 5437.9\ N.m$$

Analogously to the calculations of the bending modulus in the lower station, we proceed with the calculation of the maximum bending modulus in the beams in the upper station.

Supporting beams

$$W\ \geq \frac{2 \times\ 3670.6}{255}$$

$$W \geq 28.8\ cm^3$$

Guiding pulley beams

$$W \geq \frac{2 \times 5437.9}{255}$$

$$W \geq 42.7\ cm^3$$

The following table illustrates the results of the bending modulus for the upper station

Bending modulus in the beams (cm^3)	
Supporting beams	28.8
Guiding pulley beams	42.7

Table 8: Bending modulus in the upper station beams

The results are lower than the similar beams in the lower station due to the smaller length of the beams used in the upper station. Similarly to the lower station, the chosen IPE profiles are the IPE 140 that fulfills all the requirements of our project.

5. Power supplier of the system

According to the theoretical approach of Prof. Lok Bahadur Baral, the system provides the lifting behavior without any external source of power. This was verified in the development of our project. This is not possible and therefore the system we have developed includes an electrical motor in the upper station to provide the necessary power to the system to operate without any energy failures.

The motor will be connected by a shaft in to the upper bull wheel, and will provide the required speed to the system.

The energy necessary to operate the motor will be provided by renewable energies. The idea behind using renewable energies is that Nepal does not have any source of fossil fuel energy and if we were to take that option the overall cost of the system would be higher. Another reason is that Nepal has high potential in renewable energy production, especially concerning hydroelectric and solar energy.

This approach brings some ideas for power supply system with the available sources in Nepal. The chosen ideas were:

- Hydroelectricity
- Solar Energy
- Wind Power

5.1 Hydroelectricity

Hydroelectricity is one the major energy supplies in the world. In several developed countries around the world it is considered the most important source of energy, for example in Norway, Iceland or Canada, with the share of production above 50%.

A study from the International Energy Agency (IEA) shows this kind of energy production will grow on average 1.8% per annum between 2003 and 2030. "The hydropower capacity will expand from 2610 TWh (billion kilowatt-hours) in 2002 to 4248 TWh in 2030" [9].

This increase of capacity will occur more and more in developing countries like Nepal. The definition of hydropower capacity is the generation of electrical energy from the mechanical energy of water. This requires significant water availability for an efficient power delivery to the systems.

It is essential for hydropower that we have sufficient energy output availability in order to not limit energy levels for the entire system.

These systems use turbines to generate power. Turbines are rotary engines that produce energy due to the water flow and they are available in two types; reaction and impulse turbines. The reaction turbines are constituted by a swirl connected to a rotor that will produce the movement and energy with the water flow. Examples of this are the Kaplan, Francis or Tyson turbine. Unlike the reaction turbines, the impulse turbines do not need the swirl because they use a water jet that pushes the turbine curved blades and makes the turbine spin, generating energy in this way. Examples of that is the water wheel or Pelton turbine.

A hydroelectric system also includes storage systems, like reservoirs to save the excess water and to manage the hydroelectricity production with more efficiency. The problem of these storage systems is the considerable capital investment needed to create a reliable structure.

This option must be considered important for our project because of the big hydroelectric potential of Nepal. Two different ways to obtain energy from the hydroelectricity (with and without storage systems), have been developed.

5.1.1 Hydroelectricity with storage systems

This first approach to a solution for power supply systems to our project consists of a system that includes generation of electricity by water with two reservoirs. Unlike the reservoirs in the big hydroelectric systems, in our project the reservoirs will have simple construction, reduced size and a small cost. Apart from the reservoirs, the system also contains a turbine, a pipe connection and a pumping system to make it possible for the water to return to the beginning deposit. These components will create an artificial water flow in a close circuit.

The pumping system will be located in the lower part of the system, near the lower station and lower reservoir. Its role is to pump the water that comes down the hill to generate energy and can be supplied by a wind mill or photovoltaic solar panels.

This proposal means that we need to calculate the necessary power to of the turbine and the pump to create an efficient system.

To precede the calculations of the needed power we have to take into account some factors

Those factors are:

- Liquid properties (Water)
- Characteristics of the pipe
- Weight of the users
- Time of travel
- Characteristics of the turbine

So, for the first approach we need to know how much power is needed to transport the users in the critical situation.

Critical assumptions of the system	
Number of users	10
Weight of each user (kg)	90
Speed of the system (m/s)	0,56
Distance (m)	100
Slope inclination (º)	60

Table 9: Critical assumptions of the system

The critical situation will give the necessary information to calculate the right power needed for the system. That will provide the time of travelling and the total weight generated by the users.

The travelling time (T_L) of the users is a relation between the speed of the system (v) and the distance to travel (d), where the speed of the system is constant in every operation.

$$T_L = \frac{\mathrm{v}}{\mathrm{d}}$$

That gives a travelling time of

$$T_L \cong 180\ s$$

Before the calculation of the required power we have to calculate the component of distance that will represent the total height that the users will climb with the help of our system.

The figure 13 will represent the height that we have to consider for the calculation of the power.

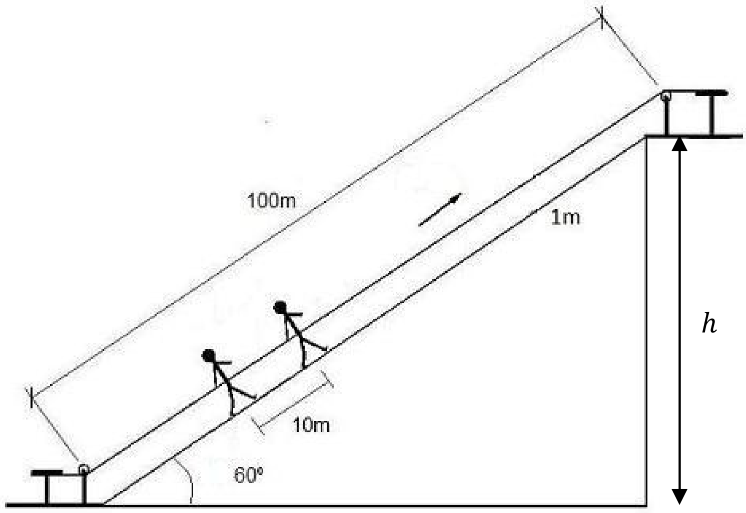

Figure 14: Scheme of the layout and correspondent height

In the an inclination of sixty degrees the correspondent height will be

$$h = d \times \sin(60º)$$

$$h \cong 87\ m$$

With the relation of the potential energy needed to transport the ten users and the travelling time.

$$P = \frac{E}{t} = \frac{m \times g \times h}{t}$$

This formula gives to us the required power in the critical situation.

$$P = 4267{,}4\ W$$

The power has to also relate to the characteristics of the chosen turbine. Actual turbines have mechanical efficiency greater than 90%. In our situation we consider an efficiency of 90%. For that the final power of the turbine will be

$$P_{real} = \frac{P}{\eta}$$

$$P_{real} = 4741{,}5\ W$$

Other information that the required power provides is the necessary flow rate that the system needs to have. The flow rate is related by factors such:

- Water density (ρ)
- Gravity (g)
- Head of water (h)
- Power of the turbine (P_{real})
- Efficiency of the turbine (η)

The head is important in the calculation of the flow rate because it is the difference in height between the inlet and outlet surfaces. We must take into account the kinetic energy of the flow.

$$Q = \frac{P_{real}}{\eta \times \rho \times g \times h}$$

$$Q = 6{,}17 \times 10^{-3} \frac{m^3}{s}$$

After the calculation of the flow rate, we can make an approximation of the pipes characteristics. The chosen pipes are made of PVC, because they are cheap and easy to find and replace. A disadvantage could be the UV degradation, but to solve this problem we can construct the pipe system underground.

To calculate the losses in the pipes we need to take into account the liquid properties, the diameter of the pipes and the speed of the liquid.

For that we assume the PVC pipe has a diameter of thirty centimeters and in relation to the flow rate we have conditions to calculate the speed of the liquid.

$$Q = v \times A$$

$$Q = \frac{v \times d^2 \times \pi}{4}$$

$$v = \frac{4 \times Q}{d^2 \times \pi}$$

$$v = 8{,}73 \times 10^{-2} \frac{m}{s}$$

The pipe losses are caused by the decrease in pressure inside of the pipe due to the resistance between the liquid and the pipe walls. So we need to verify the difference in energy between the entrance and the exit of the pipe to calculate the characteristics of the device to compensate this loss.

The losses in the pipe are initially related with the friction, length and diameter of the pipe, gravity and speed of the fluid.

$$h_l = 2\,f\,\frac{L \times v^2}{D \times g}$$

The friction coefficient (f) is important to know how much energy is lost during the flow. Dependent of the Reynolds number, this coefficient may or may not be affected by the roughness of the pipe. This occurs when we have a laminar flow, therefore we have to know firstly what type of flow we have in our system. In order to know the kind of flow in our situation we calculate the Reynolds number.

$$Re = \frac{\rho \times v \times D}{\mu}$$

In our situation the Reynolds number will be

$$Re = 2{,}62 \times 10^4$$

That means, in our situation the flow is turbulent, and for that we need to calculate the friction between the water and the wall pipes also in the turbulent state. The pipe will be considered as smooth because the Reynolds number is above 3000.

$$\frac{1}{\sqrt{f}} = 4 \times lo\,g\left(Re \times \sqrt{f}\right) - 0{,}4$$

$$f \cong 6{,}1 \times 10^{-3}$$

The result obtained for friction will replace the old value in the above equations of the pipe losses, and will have the linear losses in the pipes.

$$h_l = 3{,}2 \times 10^{-3}$$

This shows in our case that the losses in the pipes are insignificant because the water is flowing at a relatively low speed. Even with the inclusion of the valves and corners in the pipe system the value of the losses continues to be insignificant. Also we verify that the increase in diameter of the pipe can reduce these losses but in this case the reduction will be insignificant so our choice continues to be the thirty centimeter diameter because it is a cheaper solution.

These results of flow rate will be related to the size of the deposits located in both the stations, to ensure that we always have enough water to produce the necessary energy to lift a considerable number of users. So in our approach the reservoirs have a full capacity of thirty cubic meters. This value can ensure that the system can lift at least 250 users.

Due to the design of the system and the head of water value, in this approach, we must use a reaction turbine, more specifically a Francis turbine. In the other part of this close circuit, we include the pumping system. This system will be supplied with energy from an external power supply, already mentioned before. In this case we expect that we need more energy to pump the water uphill because we have a low rate of efficiency in the actual pumps compared to the turbines.

In order to calculate the pumping power, we assume that we need to pump the same amount of water that is coming downhill, so it means the same flow rate, the water properties, gravity and efficiency of the pump, have been taken into account.

$$P_{pump} = \frac{Q \times \rho \times g \times h}{\eta}$$

$$P_{pump} = 7527{,}1\ W$$

The highest value for the pump power is explained by the pumping of the same flow rate that is coming downhill. This already has efficiency associated which can further be explained by the low efficiency rate of the actual pumps (70%). The pumping system can be active by two different methods, mechanical and electrical.

In the mechanical method, the system will have a pumping wind mill that will provide the necessary power to pump the water. In this case we have a problem because we are dependent on wind speed, which averagely has a low value in Nepal. Also the meteorological conditions are important in this kind of system due the possibility of rain which helps in the replacement of the liquid level in the upper deposit. In this case we are not obliged to pump the same flow rate and in such a case this solution is more efficient. Advantages of this kind of approach are lower costs and easier maintenance than the electric solutions.

Another method is by electricity, this can be either by wind mill or photovoltaic panels. The problem with the wind mill, as has previously been explained, is that Nepal does not have significant wind speeds. The other solution, photovoltaic panels, can solve the problem but a higher capital investment is required. Also, both methods must include a generator that has a related efficiency, this further increases the investment in the overall system.

To provide this power to the pump, the auxiliary system has to produce more energy than is needed just for the lifting part of the system. This means it would be useful to have two systems. The second system works as an auxiliary system to produce more energy, to add to the energy produced by the main energy generator.

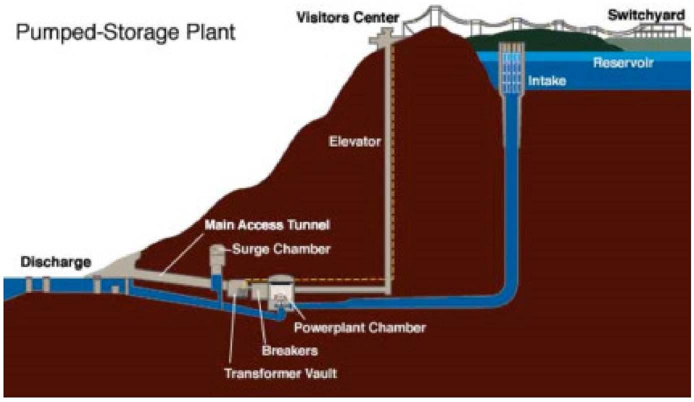

Figure 15: Wind – hydroelectric pumping system [23]

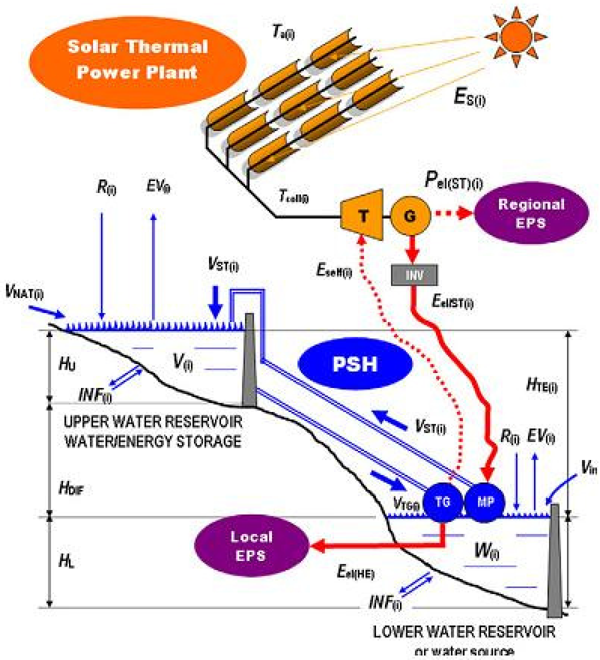

Figure 16: Photovoltaic – hydroelectric pumping system [13]

5.1.2 Hydroelectricity without storage system

To solve the issues that exist in the hydroelectricity production storage systems, we will now discuss the open water circuit system approach. That means the system will not require any reservoirs. This open water approach uses the turbine as its energy generator. The turbine is directly located on the water source like a river.

One proposal for the turbine will be the Tyson turbine. In the case of a river, this type of turbine is directly located in the middle of the river where the flow is fastest and has big advantages because we do not need to build any infrastructure, and the turbine could be moved very easily.

Analogous to the system explained above, the conditions will remain the same, so the previous calculations made for the engine power requirements also remain the same.

Figure 17: Hydroelectricity without storage system, Tyson turbine [24]

In comparison to the storage systems, the open water circuit solution will be cheaper because there is no pumping system. Depending on the type of turbine, it is possible that infrastructure will need to be built in order to place the turbine near the energy source.. This solution is dependent on the water sources, such as a river or waterfall. With the correct viability study of the water source the system can be reliable.

Additionally, a battery storage system can be implemented to provide some energy backup when the water sources are not capable of generating the required power. This feature brings more efficiency to the system but will also increase costs.

5.2 Solar Energy

The increase in environmental problems around the world in the last few years gives us another perspective of the world in the future. Environmental damage is caused by over utilization of fossil fuels and our increased energy consumption, which consequently increases the greenhouse gas effects. The worldwide fossil fuel resources decrease dramatically with this over consumption. This obliges the energy companies to search for different possibilities of energy generation.

The solution is renewable energy. These are clean, inexhaustible and environmentally friendly potential resources. Energy sources such as hydro, solar or wind power are increasingly utilized worldwide. Solar and wind power were deemed the more promising and with that were the ones who had more development.

The PV industry in the last 10 years becomes one of the most important energy suppliers in the world. The need to reduce the greenhouse gas effects was one of the main reasons for the improvement of production volume and technology. With this, the PV industry had an average growth of 25% since 1994 until today. In the same period of time the PV capacity increased from 500 MW to 92000 MW worldwide.

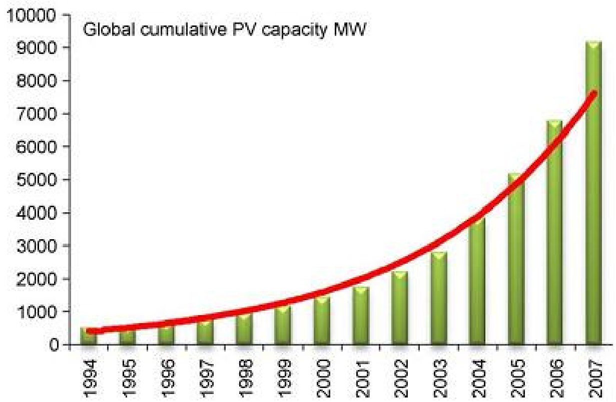

Figure 18: PV capacity between 1994 and 2007 [14]

The photovoltaic systems are where the solar energy is produced by the sunlight. These systems are constituted for

- Photovoltaic modules
- Trackers
- Inverters
- Mounting systems
- Batteries

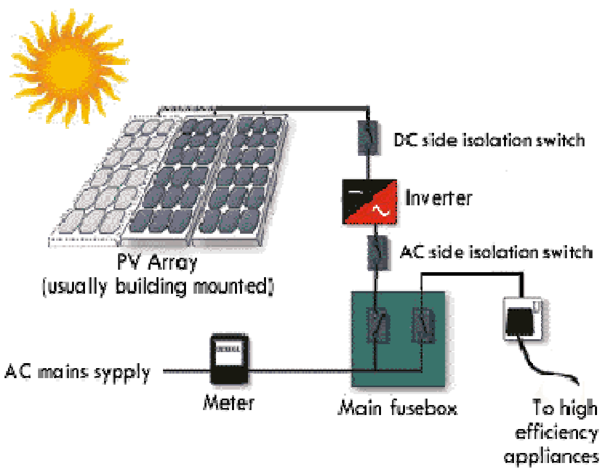

Figure 19: Photovoltaic System [25]

The photovoltaic modules are the most important component in this type of system. These are constituted by a group of low voltage cells generate energy with sunlight contact. Photovoltaic arrays are when we have a group of photovoltaic modules.

Trackers are used to control the tilts of the solar panels. They are used to tracking the brightest area or to aim the system directly at the sun in partly clouded times and are very effective in regions with large solar exposition. With this we guarantee that the sunlight that the panel receives is perpendicular and so therefore is more intense, making the system more efficient. They also increase the generation of energy on the sunrise and sunset times, producing in this way more useful power in more than one period each day. A disadvantage is in some weather conditions as cloudy or foggy, this system is not useful.

Another very important component in our case, are the inverters. The inverters are the connection between the energy produced in the photovoltaic modules and the energy that will be used, for example in a motor or lights.

The energy produced by the photovoltaic modules is in DC. In some cases we do not need to invert the energy because the system works with a DC grid. In our situation the motor used to supply the power has an AC connection, so for that we need to use the inverter to be able to use the energy produced.

The inverters can be denominated by micro-inverters or solar inverts. The difference is that the micro-inverters are used for single photovoltaic modules and the solar inverts for photovoltaic arrays and both are constituted by a DC and an AC side. On the DC side, the power generated by the photovoltaic arrays has to be optimized by checking the system voltage to find the maximum power point, using a maximum power point tracker.

The maximum power point tracker (MPPT), already included in the solar inverts, is the technique to find the maximum power point. This is needed because the interaction between the solar cells, solar irradiation and others factors produces a non-linear efficiency, I-V curves. The MPPT makes a sample of the output of the solar cells, and applies a resistance that will give the maximum power.

The AC part of the inverter is used to connect the system to an electric grid or a motor. In the AC part, the inverter has to supply the electricity with sinusoidal waves, synchronized with the grid frequency, and also uses limit of feed of voltage to the grid voltage. To implement this, an electric meter component in the main grid must be installed to ensure some security and control.

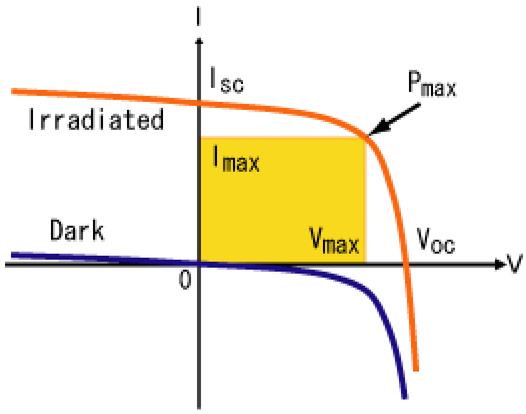

Figure 20: Maximum power point tracker (MPPT) [26]

The mounting system is one component of the solar energy production system. It will be mounted on the ground and provides either stability to the photovoltaic arrays, or movement if the tracking features are in place.

In addition to these components, this type of systems can include also a storage system, such as batteries. This feature is used for storage of excess energy produced in the system. This energy can later be used in the system itself, or for any feature that is connected to the system.

In our system the required power is 4.3 kW, this must be produced by the photovoltaic arrays. We have to take into account the efficiency of the inverter(s) and cables.

The next approach will show a solar energy production system that can be implemented in our system.

In order to achieve the required power for the system, it was verified that the system requires between 20 and 24 solar panels. This value was achieved by using the power output values of each solar panel. In the most advanced solar panels the power values are between 240W and 320W depending of the manufacturer. With this number of photovoltaic panels the system will expect a photovoltaic area of between 33 and 42m^2 and a power production between 5.6 kW and 6.4 kW.

To obtain the real values of the generated power, we need to consider the efficiencies of the inverters, cables, and photovoltaic panels. Once all these efficiencies have been considered, we will have slightly more than the required power for the system of 4.3kW. The appendix shows with more detailed information about systems that can be implemented in Nepal.

Another very important factor is the price. To build a system like the one described above would cost about 25 thousand Euros, without including the structural components and the motor.

One of the objectives of this project was to build a reliable, eco-friendly and reasonably cheap structure, taking into account the actual situation in Nepal. This approach can be a reliable and eco-friendly but the investment in the beginning is a big issue and needs special maintenance.

5.3 Wind Power

Like the other sorts of renewable energies, hydroelectric and solar, in the last few years the wind energy technology has developed immensely, now becoming a conventional energy system. Again, wind energy is used in order to reduce the greenhouse gas effects and energy security.

This technology development brings the possibility to increase the growth of developing countries such Nepal, because of the possibility to implement these kinds of systems in remote areas where other kinds of energy cannot be implemented.

One big advantage of the wind energy technology is that it can be a decentralized system. In less developed countries we can implement small energy systems that produce enough energy for the specific area. This is cheaper than building centralized power systems in remote areas. Also, the energy produced by these small energy systems in such countries is used more efficiently. “Cavallo and Grub [10] stress that one kWh of electricity provides ten times more services in India than it does in Indiana”

With such advantages the wind energy is becoming more usual in the rural areas in the developing countries, but as a consequence the rural areas have to improve the technical and economical conditions to be able to receive this kind of energy.

In Nepal, already in the past a wind power system of 20 kW (10 kW each) was implemented. The system worked for three months and then due a mechanical failure the blades and the towers broke. After this experiment, over the years small scale wind generators between 100 and 200 W have been implemented. In 2004, 19 of these wind power plants were implemented in various districts in Nepal. Also Nepal has a hybrid system, wind and hydro power, of 1.5 kW to supply the rescue hospital in the Himalayas, where the wind turbine is rated on 500 W.

So for that reason, nowadays the main goal is the high efficiency in energy production at the lowest cost. This means for optimization purposes tools must be so that the system can be evaluated in certain period of time.

To produce this kind of energy, a wind turbine system converts the mechanical energy obtained from the wind in the turbine into electrical energy through a generator.

Apart from the generator, the wind turbines are also constituted by blades, rotor, gearbox, wind analysis systems, low and high speed shafts, drives and a motor. The blades move due to wind forces, with this movement some energy is transferred to the rotor. The rotor is connected to a shaft that will provide the mechanical and rotational energy to the generator located on the other side of the shaft. In the generator, because of the electromagnetic properties, it will produce electrical voltage that will drive the electrical current to the power lines for distribution.

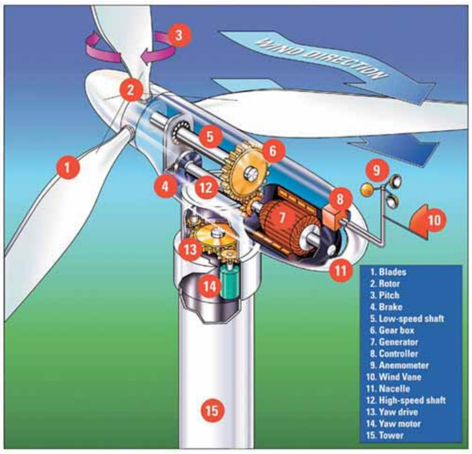

Figure 21: Wind mill components [22]

In the project, we will implement a wind power system consider a ‘small-scale’ wind power system, as it produces just 50 kW of electrical power. The implementation of this in Nepal’s rural areas can provide further development and better life conditions by giving the possibility to use electricity in the home, or lifting systems like we propose.

The problem of these kinds of systems is the production of energy can be highly variable, because of the weather conditions at different time scales. This results in the need to improve the efficiency of our system, introducing a battery system to store the generated energy that is not used, and can be used at a later time.

In our situation the wind in Nepal doesn’t have considerable speeds for a reasonable energy production, therefore the only possibility of installation of small wind power systems would be in the mountains.

To calculate the wind speed that is needed to produce the power required to the system it is necessary to have a relation between the area of the blades (A), air density (ρ), wind speed (V) and power coefficient of the turbines (C_p). With this relation the equation for the theoretical power is:

$$P = \frac{1}{2} \times \rho \times A \times V^3 \times C_P$$

A study made by Betz in 1919 [27], concludes that the rotor can only transmit 59% of the power, this value is considered as the turbine’s efficiency. Normally the turbines cannot reach that value of efficiency and are rated between 35 to 45%.

An advantage for these kinds of systems is that they do not require high maintenance costs, and due to the knowledge of small wind power plants which already exists in different districts of Nepal, we have the required technical conditions to implement a system like that.

5.4 Hybrid systems

The use of renewable energies to generate electrical energy can be obtained by different applications, where solar and wind energy is the most popular.

These kinds of energies have an issue that is the impossibility to provide continuous source of energy. In the solar case, this system has a low efficiency during the winter and no-sun periods, the same problem with wind energy generation because of the non-constant wind speed in a certain period.

To solve this kind of problems it is proposed to create a hybrid system, it means that there will be a combination of the two systems. This combination can be achieved not only with solar and wind energy, but another kinds of associations such hydro and solar energy. With this solution it is possible to balance the system to guarantee the continuous energy supply to the system, improving the efficiency. These kinds of systems may also include a battery storage system.

Nowadays the use of wind-photovoltaic hybrid systems is rising because of a decrease of turbine and photovoltaic panels and the increasing energy costs. Like other kind of energy production we have to optimize the system to achieve the best relation in efficiency and costs.

This type of proposal has already been discussed in our project in the hydroelectric chapter, such as the association of a hydroelectric system with a photovoltaic and wind energy production. In our situation the pumping system will need much more energy than the system to make the lift work, so for that reason it is not a useful solution. In a different perspective this kind of system can be used to supply only the motor. So, in this situation the photovoltaic or wind system can be used as a recovery system when the hydroelectric system does not have the possibility to generate the necessary power, or a photovoltaic-wind hybrid system can also be implemented.

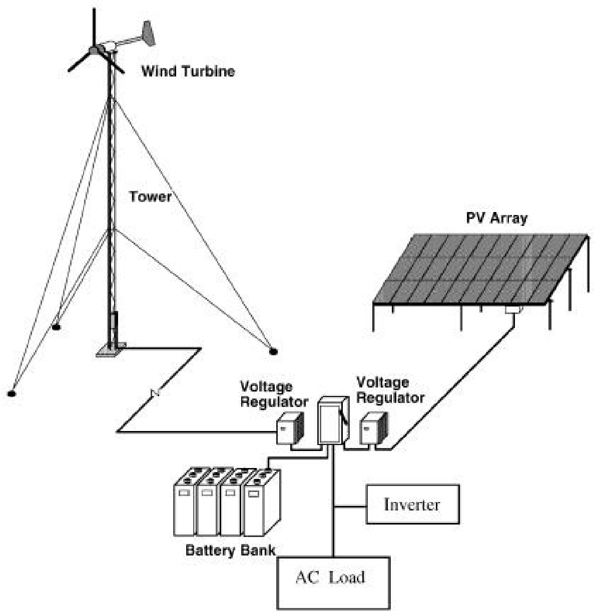

Figure 22: PV-Wind Hybrid Design [11]

5.5 Motor

This component of the project is very important because without it the entire system will be unable to operate. In our system there will be a three phase single speed AC motor.

To do a project planning of an AC motor, we have to follow some aspects to achieve a good result.

The planning is based on a group of aspects:

- Necessary information on the machine to be driven
- Calculation of the relevant application data
- Selection of the gear unit
- Selection of the factors of the system is dependent
- Motor selection
- Breaking resistor
- Options

The necessary information on the machine to be driven includes aspects such technical environmental data. This is important in order to see the real efficiency of the motor and to see if it works in a different environmental situation. Other aspects are the positioning setting range, speed setting range and the calculation of the travel cycle.

Another aspect is calculation of the relevant application data. These calculations will provide information such as power, torque or output speeds necessary for successful operation of the system.

The selection of the gear unit in the planning is based on the definition of the gear size, reduction ratios and unit types. These factors will provide an overview of the real size of the engine or the intended output speeds. Also there is the need to verify the gear unit utilization, which means if the torque generated by the entire system is below the maximum allowed torque by the gear unit.

The motor is a component dependent on other external factors such as positioning accuracy of the system, setting range or even control of the motor have to be taken into account in the planning.

After all the calculations and environmental studies, we are able to proceed with the motor selection. In this part of the planning we will take into account factors such as maximum torque, maximum speed, thermal loads, and selection of the correct encoder or motor accessories. Also, due to the low output speed intended in our project it is very important to limit the motor power according to the maximum allowed torque in the gear unit.

The breaking resistor is also important during planning because it will make the motor stop when the system is not being utilized. This resistor is based on calculations of regenerative power and the cycling duration factor (cdf).

Also in the planning we need to build an operation and communication interface, so that the motor recognizes when it has to work.

In the planning we also have to consider all the regulations to guarantee that the system will operate without any failures.

With all of these aspects we can calculate the characteristics of the ideal motor for our system.

The system was designed to cover a one hundred meter distance, with a gap of ten meters between the users. The weight of each user includes an extra load due to the goods and merchandise that they usually transport in Nepal. The low speed of the system will provide a regular walking speed and provide security features.

The regulations used in the planning of the AC motor give information about the performance, thermal characteristics, protection of the equipment, dimensions of the electrical equipment, cable interfaces or standardized dimensions and power ratings.

One of the important regulations, EN 60034-1, is responsible for the efficiency of the motor and thermal characteristics. Then the motor does not have any power reduction if is located within one thousand meters above the sea limit and not above forty degrees of ambient temperature.

This means, we must consider some power reduction in the motor due to the location in mountainous zones in Nepal, and a higher ambient temperature.

To calculate the power that we need in the system there is the need for a relation between the power of the engine in standard conditions (P_N) and temperature (f_T) and height factors (f_H).

$$P_{red} = P_N \times f_t \times f_h$$

So the assumptions to calculate the real output power of the motor are that it is located at 3000 meters and a 45ºC of ambient temperature and the reduced power will be the power needed for the system (P_{red}=4.3 kW)

To verify the relation between the power, the temperature and the height is manufacturer provides the corresponding catalog with graphs that show the relations for AC motors.

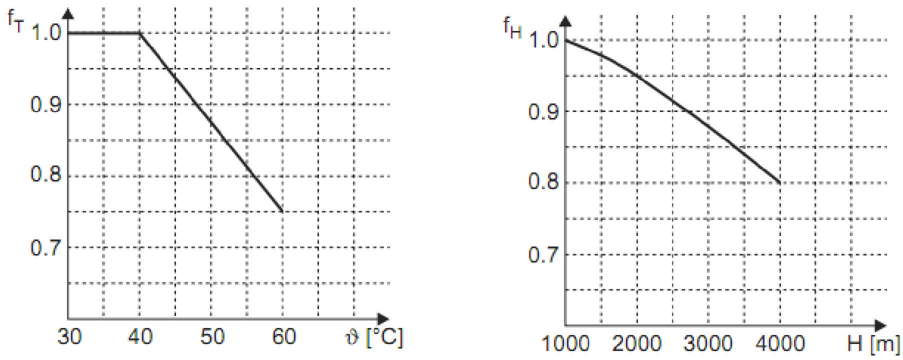

Figure 23: Power reduction dependent of ambient temperature and altitude [17]

These graphs show that for our assumptions we have to consider for the temperature f_T=0-93 and for the height f_H=0.87.

So with these values the power that is need will be:

$$P_N = 5.32\ kW$$

This power will be the value that our motor has to produce for the system to operate without any energy failure.

To select the motor we need to verify the torque of the motor and output speed.

The torque calculation is no more than the force generated in the critical situations: 10 users multiplied by the radius of the bull wheel.

$F = 8829\ N.m$

$r = 0.25\ m$

$$Torque = F\ \times r$$

$$Torque = 2207.3\ Nm$$

The intended speed on the circulating cable is 0.56 meters per second, and for that the motor has to ensure that it can operate at that speed. The speed provided for the motor will be in revolutions per minute (RPM). We need to know how many RPM's are required for the speed of the circulating cable. To do these calculations we also need the diameter of the bull wheel that in our system is 0.5 meters.

$$rpm = \frac{v\ \times 60}{\pi\ \times D_{bull\ wheel}}$$

$$rpm = 21.4\ rpm$$

After these calculations we proceed to the selection of the motor. The motor will be a three-phase AC motor, because it is cheaper and easier to transmit AC power.

The motor for the system will be provided by SEW-EURODRIVE. The type of motor will be a conic gear unit that will operate at constant speed and will connect with a shaft directly to the upper pulley. The selected model will provide a speed of 21 revolutions per minute that will increase the traveling time by two seconds. This reduction will not make any effect in the power generation system.

Figure 24: SEW-EURODRIVE Conic gear unit [17]

6. Evaluation of the system

After all the development and exposition of the solutions for the power supplier of the project, in this chapter we will evaluate all of the proposals in order to choose the right solution. That means all the proposals will be compared by different criteria to define which is the most reliable choice, taking into account the present situation of Nepal.

For this comparison the criteria must include factors like costs, implementation, maintenance, life time and operation. The costs will include the price of the components and implementation costs. The implementation is how the system will be built and the facilities needed to build that. The maintenance will include the period in which the system will be evaluated. We will consider the time that the components can be used without any replacement as the life-time of the components. The last criteria for evaluation of the system is the operation of the facility.

Considering the criteria by the order they were presented we will have:

A – Costs

B – Implementation

C – Maintenance

D – Life Time

E – Operation

To evaluate the proposals it is important to verify the relation between the chosen criteria. The relation will be performed by considering if the following criteria have any relation with each other (0), small relation (1) or major influence (2).

Comparative Criteria							
Criterion	A	B	C	D	E	Total	Importance
A – Costs	-	2	1	1	0	4	0.25
B – Implementation	2	-	1	0	1	4	0.25
C – Maintenance	0	1	-	2	0	3	0.19
D – Life Time	0	1	2	-	0	3	0.19
E – Operation	0	1	1	0	-	2	0.13

Table 10: Comparative Criteria

With the importance of the criterion now defined, we are able to see the relation between the criteria and the proposals. This relation will be evaluated from 0 to 10, with 10 the best grade in this evaluation. The proposals are defined from 1 to 5, and will consider by the order in which they were explained.

1 – Hydroelectricity with storage system

2 – Hydroelectricity without storage system

3 – Solar power

4 – Wind power

5 – Hybrid systems

Criterion	Importance	Proposals				
		1	2	3	4	5
		Value	Value	Value	Value	Value
A – Costs	0.25	4	7	4	5	3
B – Implementation	0.25	5	4	7	5	6
C – Maintenance	0.19	6	7	4	5	4
D – Life Time	0.19	5	5	7	7	7
E – Operation	0.13	5	7	5	5	5
Total = Σ Importance ∗values		4.99	5.94	5.49	5.43	4.99

Table 11: Evaluation of the system

The evaluation shows that the proposal 2, hydroelectricity without storage systems is the most reliable proposal to implement in our system. This option is the best ranked because of the lower price compared to the other proposals, also due to the lesser list of components, the low maintenance factor and the facility of operation. Apart from these advantages the system has a lack of implementation and the life time of the turbine is shorter than the photovoltaic panels, due to the cavitation pitting or fatigue cracking.

The evaluation also shows that the proposals three and four show very similar results. This shows that solar and wind power nowadays is very similar in application, efficiency and costs. The efficiency of this kind of system is affected by the weather conditions and has a bigger implementation cost compared to hydroelectricity.

The two proposals with the worst results are the hydroelectricity with storage system and the hybrid systems.

The hydroelectricity with storage system had a bad ranking like the hybrid systems, because one of the big issues is the inclusion of two systems to increase efficiency that increase the cost of the overall system. Despite the simplicity of hydroelectricity with a storage system, the implementation of this kind of system is very dependent of the location.

So, for the project the best solution for the power supplier system is the hydroelectricity without storage system because it is the most simple system, cheaper and with the right previous study about the river stream the kind of system will be efficient and reliable. One option of turbine to implement in this system would be the Tyson turbine. Also with this solution the country already has the technical conditions to solve the possible unexpected failures and the required maintenance due to the existence of micro-hydroelectric stations in the country.

7. Future of the system

The transportation in developing countries is a big issue due to the inexistent control of the authorities, the situation becomes even worse when we mention the poor areas in these countries. The lack of accessibility in transportation is a critical factor for the development of those areas and as a consequence increases the quality of life.

This presented system is simple, low budget and eco-friendly, as the author of the idea mentioned "Using a small straight trail inside the jungle avoids cutting trees and digging the land that makes this system eco-friendly. It uses gravitational force, so it is cheaper in operation costs than other systems. Using a small engine in case there is no descending person is still cheaper than other fuel operated transportation means. Its construction and installation is also cheaper over road construction".

The systems proposed can be implemented in those areas to increase the development due to the reduction of the effort that the people in the mountains areas must use in order to transport their goods. Normally the goods are carried up or downhill by dangerous small trails. This will reduce travelling time. In comparison to the present situation, and also with the facilities to transport a bigger volume of goods, this reduces the number of journeys required to carry goods. In the social context it can also be important because of the improvement the accesses to education or health.

As an economical perspective, it will generate only a small increase in trade conditions in those kinds of areas and because it is not a system to be used over long distances. Only with big infrastructures used as a complement to this kind of system, can it increase on a significant level the economical situation of those regions.

Also with these systems new routes of transportation can be created to allow access to the mountains, which until now were unused due the steep relief.

One system like this can be a reliable solution for the agencies already located in Nepal or even NGO, to improve the quality of life of the inhabitants in that areas.

As a conclusion from the project as the author refer "This is an eco-friendly, cheap and minimum effort requiring system that could bring revolution in the transportation field in hilly countries like Nepal".

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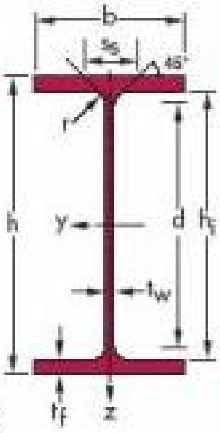
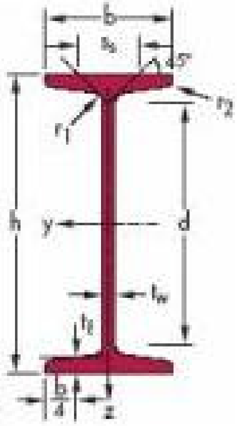
Appendix



IPE



IPN

Código	G (kg/m)	h (mm)	b (mm)	t_w (mm)	t_f (mm)	A (cm^2)	I_y (cm^4)	W_y (cm^3)	I_z (cm^4)	W_z (cm^3)
IPE 80	6.0	80	46	3.8	5.2	7.64	80.14	20.03	8.49	3.69
IPE 100	8.1	100	55	4.1	5.7	10.3	171.0	34.20	15.92	5.79
IPE 120	10.4	120	64	4.4	6.3	13.2	317.8	52.96	27.67	8.65
IPE 140	12.9	140	73	4.7	6.9	16.4	541.2	77.32	44.92	12.31
IPE 160	15.8	160	82	5.0	7.4	20.1	869.3	108.7	68.31	16.66
IPE 180	18.8	180	91	5.3	8.0	23.9	1317	146.3	100.9	22.16
IPE 200	22.4	200	100	5.6	8.5	28.5	1943	194.3	142.4	28.47
IPE 220	26.2	220	110	5.9	9.2	33.4	2772	252.0	204.9	37.25
IPE 240	30.7	240	120	6.2	9.8	39.1	3892	324.3	283.6	47.27
IPE 270	36.1	270	135	6.6	10.2	45.9	5790	428.9	419.9	62.20
IPE 300	42.2	300	150	7.1	10.7	53.8	8356	557.1	603.8	80.50
IPE 330	49.1	330	160	7.5	11.5	62.6	11770	713.1	788.1	98.52
IPE 360	57.1	360	170	8.0	12.7	72.7	16270	903.6	1043	122.8
IPE 400	66.3	400	180	8.6	13.5	84.5	23130	1156	1318	146.4
IPE 450	77.6	450	190	9.4	14.6	98.8	33740	1500	1676	176.4
IPE 500	90.7	500	200	10.2	16.0	116	48200	1928	2142	214.2
IPN 80	5.9	80	42	3.9	5.9	7.58	77.8	19.5	6.29	3.00
IPN 100	8.3	100	50	4.5	6.8	10.6	171	34.2	12.2	4.88
IPN 120	11.1	120	58	5.1	7.7	14.2	328	54.7	21.5	7.41
IPN 140	14.3	140	66	5.7	8.6	18.3	573	81.9	35.2	10.7
IPN 160	17.9	160	74	6.3	9.5	22.8	935	117	54.7	14.8
IPN 180	21.9	180	82	6.9	10.4	27.9	1450	161	81.3	19.8
IPN 200	26.2	200	90	7.5	11.3	33.4	2140	214	117	26.0
IPN 220	31.1	220	98	8.1	12.2	39.5	3060	278	162	33.1
IPN 240	36.2	240	106	8.7	13.1	46.1	4250	354	221	41.7
IPN 260	41.9	260	113	9.4	14.1	53.3	5740	442	288	51.0
IPN 280	47.9	280	119	10.1	15.2	61.0	7590	542	364	61.2
IPN 300	54.2	300	125	10.8	16.2	69.0	9800	653	451	72.2
IPN 320	61.0	320	131	11.5	17.3	77.7	12510	782	555	84.7
IPN 340	68.0	340	137	12.2	18.3	86.7	15700	923	674	98.4
IPN 360	76.1	360	143	13	19.5	97.0	19610	1090	818	114
IPN 380	84.0	380	149	13.7	20.5	107	24010	1260	975	131
IPN 400	92.4	400	155	14.4	21.6	118	29210	1460	1160	149
IPN 450	115	450	170	16.2	24.3	147	45850	2040	1730	203

Project name:	**New project**	**Location: India / Chandigarh**
Project number:		
Project file:	solar2.SDPR	Grid voltage: 1~230 V

System overview Part project 1

22 x Sharp NU-U240F1 (Generator1)

Azimuth angle: 0 °, Inclination: 30 °, Mounting type: Roof, PV Peak power: 5.28 kW

Inverters:

2 x SB 2500HF-30 (Inverter efficiency: 94.5 %)

Technical data

Total number of PV modules:	22	Energy usability factor:	100.0 %
		Performance ratio (ca.)*:	80.5 %
PV Peak power:	5.28 kWp	Spec. energy yield (ca.)*:	1512 kWh/kWp
Number of inverters:	2	Line losses (in % of PV energy):	---
Nominal AC power:	5.00 kW		
Annual energy yield (ca.)*:	7982.50 kWh	Unbalanced load:	5.00 kVA

Notes:

Version: 2.01.0.R

Signature

Evaluation of design

Project name: New project
Project number:
Project file: solar2.SDPR

Location: India / Chandigarh

Cell temperature:
Record Low Temperature: -10.00 °C
Average High Temperature: 50.00 °C
Record High Temperature: 70.00 °C

Part project 1

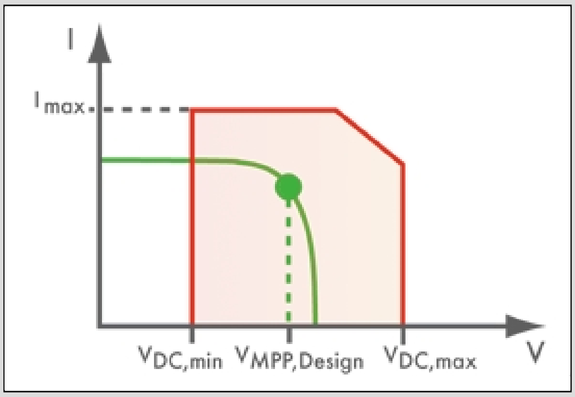
System overview

Inverter: 2 x SB 2500HF-30

PV-module:
A: (Generator1)
Sharp
NU-U240F1
Azimuth angle: 0 °, Inclination: 30 °
Mounting type: Roof

Technical data

PV Peak power:	5.28 kWp
Total number of PV modules:	22
Number of inverters:	2
Max. DC power:	2.60 kW
Max. AC power:	2.50 kW
Grid voltage:	230 V
Nominal power ratio:	98.0 % ✔
	Input A:
PV-array:	Generator1
Number of strings:	1
Number of PV modules (input):	11
Peak power (input):	2.64 kWp
Min. PV voltage:	266 V ✔
Typical PV voltage:	295 V ✔
Min. DC voltage (Grid voltage 230 V):	175 V
Max. PV voltage:	462 V ✔
Max. DC voltage (Inverter):	700 V
Max. current of PV array:	8.0 A ✔
Max. DC current:	15.0 A



PV/Inverter compatible
PV array and type of inverter are compatible. The nominal power ratio (max. DC power of the inverter divided by the peak power) is within the recommended range (80% - 120%).

Project name:	**New project**	**Location: India / Chandigarh**
Project number:		
Project file:	solar3.SDPR	Grid voltage: 1~230 V

System overview Part project 1

20 x Suntech STP280-24/Vd EU [08/2010] (Generator1)

Azimuth angle: 0 °, Inclination: 30 °, Mounting type: Roof, PV Peak power: 5.60 kW

Inverters:

2 x SB 3000TL-20 (Inverter efficiency: 95.8 %)

Technical data

Total number of PV modules:	20	Energy usability factor:	100.0 %
		Performance ratio (ca.)*:	83.1 %
PV Peak power:	5.60 kWp	Spec. energy yield (ca.)*:	1561 kWh/kWp
Number of inverters:	2	Line losses (in % of PV energy):	---
Nominal AC power:	6.00 kW		
Annual energy yield (ca.)*:	8739.40 kWh	Unbalanced load:	6.00 kVA

Notes:

Version: 2.01.0.R

Signature

Important: The yield values displayed are estimates. They are determined mathematically. SMA Solar Technology AG accepts no responsibility for the real yield value which can deviate from the yield values displayed here. Reasons for deviations are various outside conditions, such as soiling of the PV Modules or fluctuations in the efficiency of the PV modules.

Evaluation of design

Project name: New project
Project number:
Project file: solar3.SDPR

Part project 1

Location: India / Chandigarh

Cell temperature:
Record Low Temperature: -10.00 °C
Average High Temperature: 50.00 °C
Record High Temperature: 70.00 °C

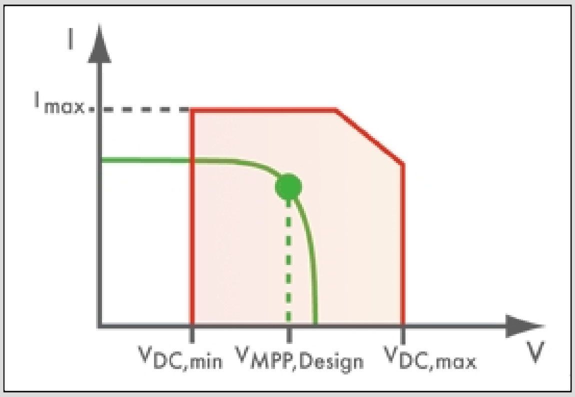
System overview

Inverter: 2 x SB 3000TL-20

PV-module:
A: (Generator1)
Suntech
STP280-24/Vd EU [08/2010]
Azimuth angle: 0 °, Inclination: 30 °
Mounting type: Roof

Technical data

PV Peak power:	5.60 kWp
Total number of PV modules:	20
Number of inverters:	2
Max. DC power:	3.20 kW
Max. AC power:	3.00 kW
Grid voltage:	230 V
Nominal power ratio:	114.0 % ✔
	Input A:
PV-array:	Generator1
Number of strings:	1
Number of PV modules (input):	10
Peak power (input):	2.80 kWp
Min. PV voltage:	283 V ✔
Typical PV voltage:	314 V ✔
Min. DC voltage (Grid voltage 230 V):	125 V
Max. PV voltage:	502 V ✔
Max. DC voltage (Inverter):	550 V
Max. current of PV array:	8.0 A ✔
Max. DC current:	17.0 A



PV/Inverter compatible
PV array and type of inverter are compatible. The nominal power ratio (max. DC power of the inverter divided by the peak power) is within the recommended range (80% - 120%).

Project name:	**New project**	**Location: India / Chandigarh**
Project number:		
Project file:	solar4.SDPR	Grid voltage: 1~230 V

System overview Part project 1

20 x Yingli Solar YL 280P-35b (Generator1)

Azimuth angle: 0 °, Inclination: 30 °, Mounting type: Roof, PV Peak power: 5.60 kW

Inverters:

2 x SB 3000TL-20 (Inverter efficiency: 95.8 %)

Technical data

Total number of PV modules:	20	Energy usability factor:	100.0 %
		Performance ratio (ca.)*:	81.9 %
PV Peak power:	5.60 kWp	Spec. energy yield (ca.)*:	1539 kWh/kWp
Number of inverters:	2	Line losses (in % of PV energy):	---
Nominal AC power:	6.00 kW		
Annual energy yield (ca.)*:	8620.70 kWh	Unbalanced load:	6.00 kVA

Notes:

Version: 2.01.0.R

Signature

Important: The yield values displayed are estimates. They are determined mathematically. SMA Solar Technology AG accepts no responsibility for the real yield value which can deviate from the yield values displayed here. Reasons for deviations are various outside conditions, such as soiling of the PV Modules or fluctuations in the efficiency of the PV modules.

Evaluation of design

Project name: New project
Project number:
Project file: solar4.SDPR

Location: India / Chandigarh

Cell temperature:
Record Low Temperature: -10.00 °C
Average High Temperature: 50.00 °C
Record High Temperature: 70.00 °C

Part project 1

System overview

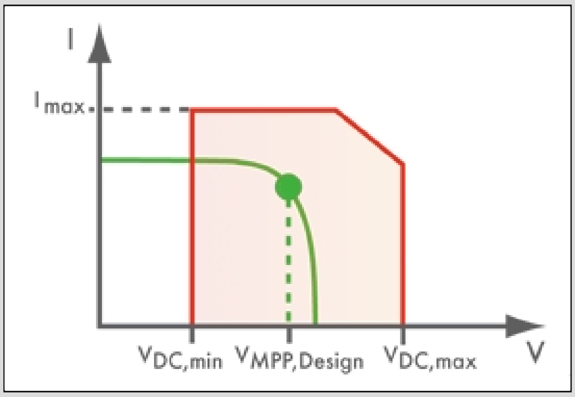
Inverter: 2 x SB 3000TL-20

PV-module:
A: (Generator1)
Yingli Solar
YL 280P-35b
Azimuth angle: 0 °, Inclination: 30 °
Mounting type: Roof

Technical data

PV Peak power:	5.60 kWp
Total number of PV modules:	20
Number of inverters:	2
Max. DC power:	3.20 kW
Max. AC power:	3.00 kW
Grid voltage:	230 V
Nominal power ratio:	114.0 % ✔

	Input A:
PV-array:	Generator1
Number of strings:	1
Number of PV modules (input):	10
Peak power (input):	2.80 kWp
Min. PV voltage:	280 V ✔
Typical PV voltage:	313 V ✔
Min. DC voltage (Grid voltage 230 V):	125 V
Max. PV voltage:	509 V ✔
Max. DC voltage (Inverter):	550 V
Max. current of PV array:	7.9 A ✔
Max. DC current:	17.0 A



PV/Inverter compatible
PV array and type of inverter are compatible. The nominal power ratio (max. DC power of the inverter divided by the peak power) is within the recommended range (80% - 120%).

Project name:	**New project**	**Location: India / Chandigarh**
Project number:		
Project file:	solar5.SDPR	Grid voltage: 1~230 V

System overview Part project 1

24 x CanadianSolar CS 6P-240 (Generator1)

Azimuth angle: 0 °, Inclination: 30 °, Mounting type: Roof, PV Peak power: 5.76 kW

Inverters:

2 x SB 3000TL-20 (Inverter efficiency: 95.8 %)

Technical data

Total number of PV modules:	24	Energy usability factor:	100.0 %
		Performance ratio (ca.)*:	82.0 %
PV Peak power:	5.76 kWp	Spec. energy yield (ca.)*:	1541 kWh/kWp
Number of inverters:	2	Line losses (in % of PV energy):	---
Nominal AC power:	6.00 kW		
Annual energy yield (ca.)*:	8873.60 kWh	Unbalanced load:	6.00 kVA

Notes:

Version: 2.01.0.R

Signature

Important: The yield values displayed are estimates. They are determined mathematically. SMA Solar Technology AG accepts no responsibility for the real yield value which can deviate from the yield values displayed here. Reasons for deviations are various outside conditions, such as soiling of the PV Modules or fluctuations in the efficiency of the PV modules.

Evaluation of design

Project name: New project
Project number:
Project file: solar5.SDPR

Location: India / Chandigarh

Cell temperature:
Record Low Temperature: -10.00 °C
Average High Temperature: 50.00 °C
Record High Temperature: 70.00 °C

Part project 1

System overview

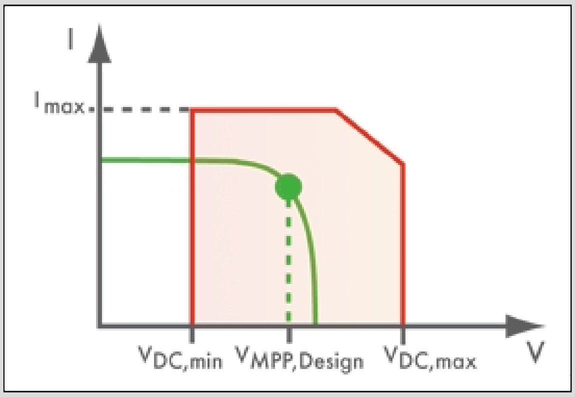
Inverter: 2 x SB 3000TL-20

PV-module:
A: (Generator1)
CanadianSolar
CS 6P-240
Azimuth angle: 0 °, Inclination: 30 °
Mounting type: Roof

Technical data

PV Peak power:	5.76 kWp
Total number of PV modules:	24
Number of inverters:	2
Max. DC power:	3.20 kW
Max. AC power:	3.00 kW
Grid voltage:	230 V
Nominal power ratio:	111.0 % ✔

	Input A:
PV-array:	Generator1
Number of strings:	1
Number of PV modules (input):	12
Peak power (input):	2.88 kWp
Min. PV voltage:	295 V ✔
Typical PV voltage:	326 V ✔
Min. DC voltage (Grid voltage 230 V):	125 V
Max. PV voltage:	499 V ✔
Max. DC voltage (Inverter):	550 V
Max. current of PV array:	7.9 A ✔
Max. DC current:	17.0 A



PV/Inverter compatible
PV array and type of inverter are compatible. The nominal power ratio (max. DC power of the inverter divided by the peak power) is within the recommended range (80% - 120%).

Project name:	**New project**	**Location: India / Chandigarh**
Project number:		
Project file:	solar6.SDPR	Grid voltage: 1~230 V

System overview Part project 1

20 x Sunpower SPR-300E-BLK-D (Generator1)

Azimuth angle: 0 °, Inclination: 30 °, Mounting type: Roof, PV Peak power: 6.00 kW

Inverters:

2 x SB 3000TL-20 (Inverter efficiency: 95.6 %)

Technical data

Total number of PV modules:	20	Energy usability factor:	100.0 %
		Performance ratio (ca.)*:	84.3 %
PV Peak power:	6.00 kWp	Spec. energy yield (ca.)*:	1584 kWh/kWp
Number of inverters:	2	Line losses (in % of PV energy):	---
Nominal AC power:	6.00 kW		
Annual energy yield (ca.)*:	9505.90 kWh	Unbalanced load:	6.00 kVA

Notes:

Version: 2.01.0.R

Signature

Important: The yield values displayed are estimates. They are determined mathematically. SMA Solar Technology AG accepts no responsibility for the real yield value which can deviate from the yield values displayed here. Reasons for deviations are various outside conditions, such as soiling of the PV Modules or fluctuations in the efficiency of the PV modules.

Evaluation of design

Project name: New project
Project number:
Project file: solar6.SDPR

Location: India / Chandigarh

Cell temperature:
Record Low Temperature: -10.00 °C
Average High Temperature: 50.00 °C
Record High Temperature: 70.00 °C

Part project 1

System overview

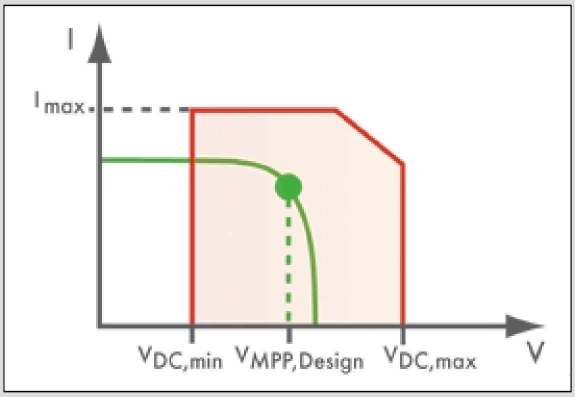
Inverter: 2 x SB 3000TL-20

PV-module:
A: (Generator1)
Sunpower
SPR-300E-BLK-D
Azimuth angle: 0 °, Inclination: 30 °
Mounting type: Roof

Technical data

PV Peak power:	6.00 kWp
Total number of PV modules:	20
Number of inverters:	2
Max. DC power:	3.20 kW
Max. AC power:	3.00 kW
Grid voltage:	230 V
Nominal power ratio:	107.0 % ✔

	Input A:
PV-array:	Generator1
Number of strings:	2
Number of PV modules (input):	5
Peak power (input):	3.00 kWp
Min. PV voltage:	234 V ✔
Typical PV voltage:	251 V ✔
Min. DC voltage (Grid voltage 230 V):	125 V
Max. PV voltage:	351 V ✔
Max. DC voltage (Inverter):	550 V
Max. current of PV array:	11.0 A ✔
Max. DC current:	17.0 A



PV/Inverter compatible
PV array and type of inverter are compatible. The nominal power ratio (max. DC power of the inverter divided by the peak power) is within the recommended range (80% - 120%).

Project name:	**New project**	**Location: India / Chandigarh**
Project number:		
Project file:	solar7.SDPR	Grid voltage: 1~230 V

System overview Part project 1

20 x Sunpower SPR-318E-WHT-D (Generator1)

Azimuth angle: 0 °, Inclination: 30 °, Mounting type: Roof, PV Peak power: 6.36 kW

Inverters:

2 x SB 3000TL-20 (Inverter efficiency: 95.7 %)

Technical data

Total number of PV modules:	20	Energy usability factor:	100.0 %
		Performance ratio (ca.)*:	84.3 %
PV Peak power:	6.36 kWp	Spec. energy yield (ca.)*:	1583 kWh/kWp
Number of inverters:	2	Line losses (in % of PV energy):	---
Nominal AC power:	6.00 kW		
Annual energy yield (ca.)*:	10070.90 kWh	Unbalanced load:	6.00 kVA

Notes:

Version: 2.01.0.R

Signature

Important: The yield values displayed are estimates. They are determined mathematically. SMA Solar Technology AG accepts no responsibility for the real yield value which can deviate from the yield values displayed here. Reasons for deviations are various outside conditions, such as soiling of the PV Modules or fluctuations in the efficiency of the PV modules.

Evaluation of design

Project name: New project
Project number:
Project file: solar7.SDPR

Location: India / Chandigarh

Cell temperature:
Record Low Temperature: -10.00 °C
Average High Temperature: 50.00 °C
Record High Temperature: 70.00 °C

Part project 1

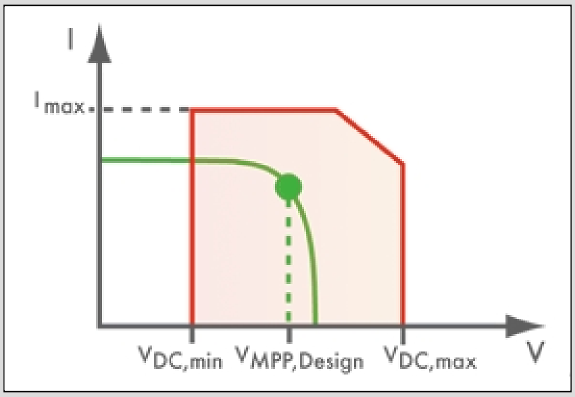
System overview

Inverter: 2 x SB 3000TL-20

PV-module:
A: (Generator1)
Sunpower
SPR-318E-WHT-D
Azimuth angle: 0 °, Inclination: 30 °
Mounting type: Roof

Technical data

PV Peak power:	6.36 kWp
Total number of PV modules:	20
Number of inverters:	2
Max. DC power:	3.20 kW
Max. AC power:	3.00 kW
Grid voltage:	230 V
Nominal power ratio:	101.0 % ✔
	Input A:
PV-array:	Generator1
Number of strings:	2
Number of PV modules (input):	5
Peak power (input):	3.18 kWp
Min. PV voltage:	234 V ✔
Typical PV voltage:	251 V ✔
Min. DC voltage (Grid voltage 230 V):	125 V
Max. PV voltage:	355 V ✔
Max. DC voltage (Inverter):	550 V
Max. current of PV array:	11.6 A ✔
Max. DC current:	17.0 A



PV/Inverter compatible
PV array and type of inverter are compatible. The nominal power ratio (max. DC power of the inverter divided by the peak power) is within the recommended range (80% - 120%).

Motor DATA-Sheet

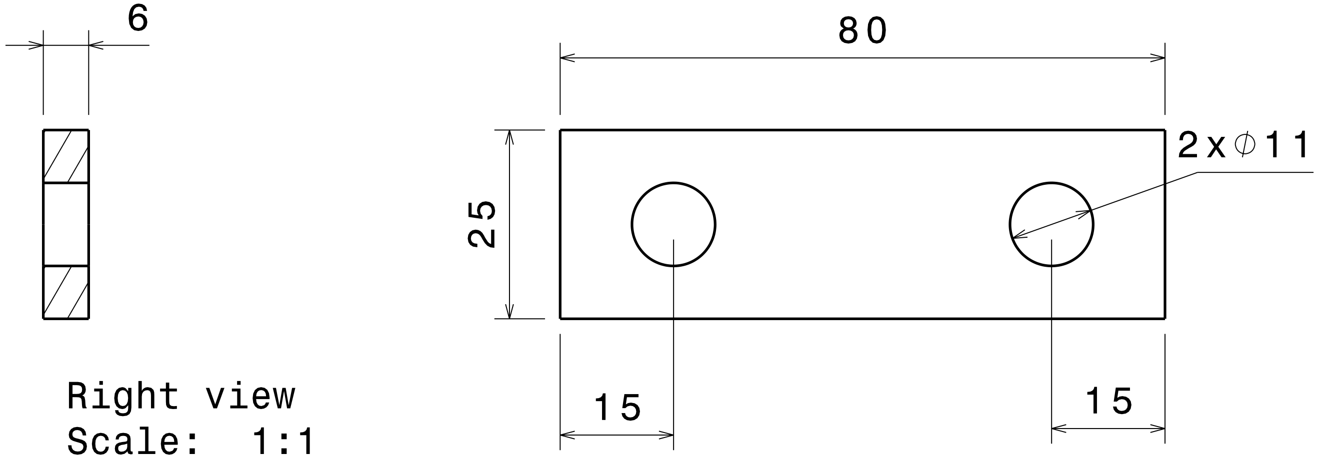
AC Gearmotor

SEW-EURODRIVE KAF87DRS132S4

Nominal motor speed [1/min]:	1445.00
Output speed [1/min]:	21.00
Transmission Ratio Average:	70.46
Output torque [Nm]:	2560.00
Service factor SEW-FB:	1.05
Entry mounting position:	M1A
Position of terminal box:	0
Entry Location of cable / connector:	3
Output shaft [mm]:	60
Maximum permissible radial load n = 1400[N]:	14100.00
Flange diameter [mm]:	350
Motor power [kW]:	5.50
Duration factor:	S1-100%
Motor voltage [V]:	230/400
Wiring diagram:	R13
Frequency [Hz]:	50
Rated current [A]:	19.2 / 11.1
Cos Phi:	0.82
Temperature class:	130 (B)
Protection class:	IP54
Design requires:	IEC
Net Weight [kg]:	141.00

Additional Features and Options:

Color: Bluish Gray 7031 (20070310)



Right view
Scale: 1:1

Front view
Scale: 1:1

Achshalter

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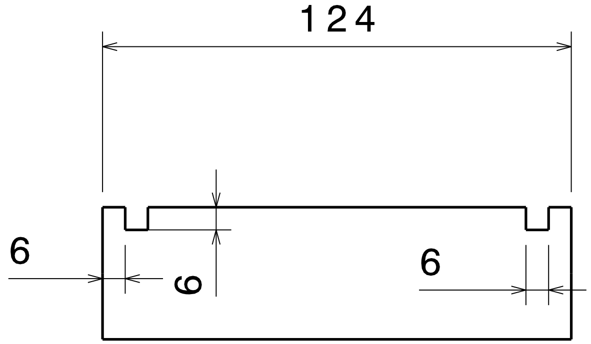

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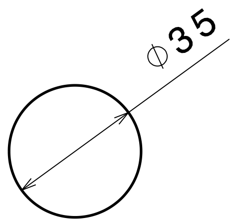

Front view
Scale: 1:2

Axle

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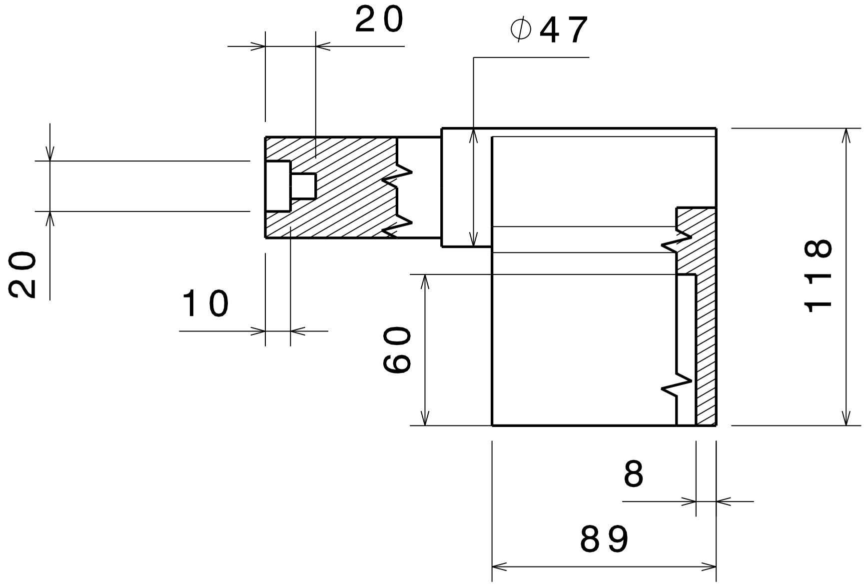

Right view
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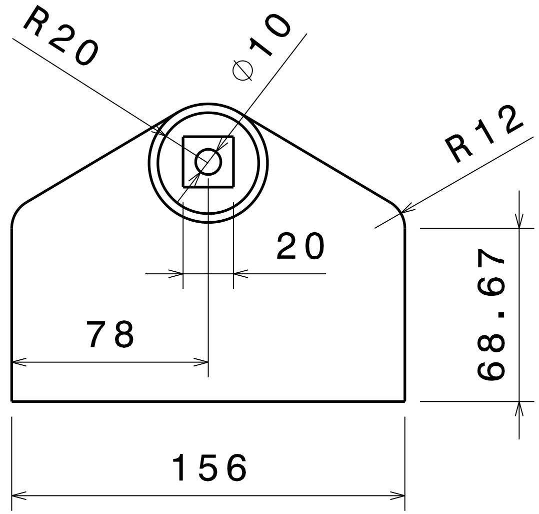

Front view
Scale: 1:3

Base

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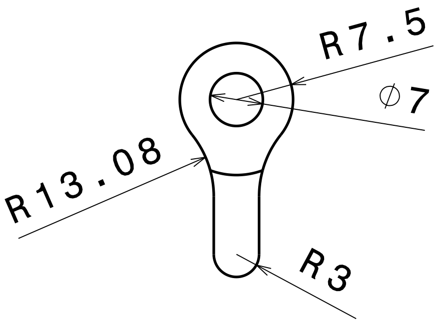

Right view
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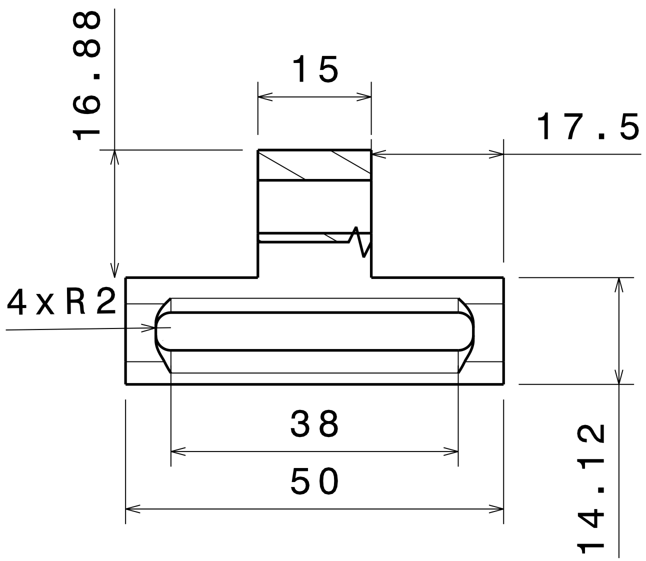

Front view
Scale: 1:1

Cable Attachment

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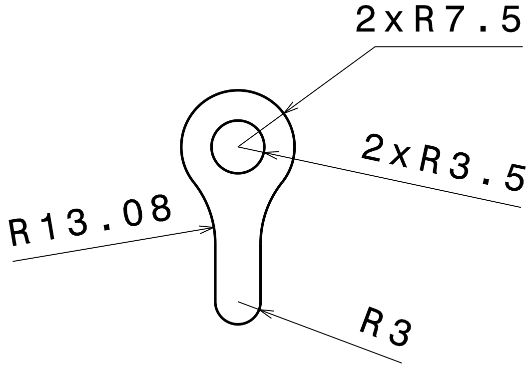

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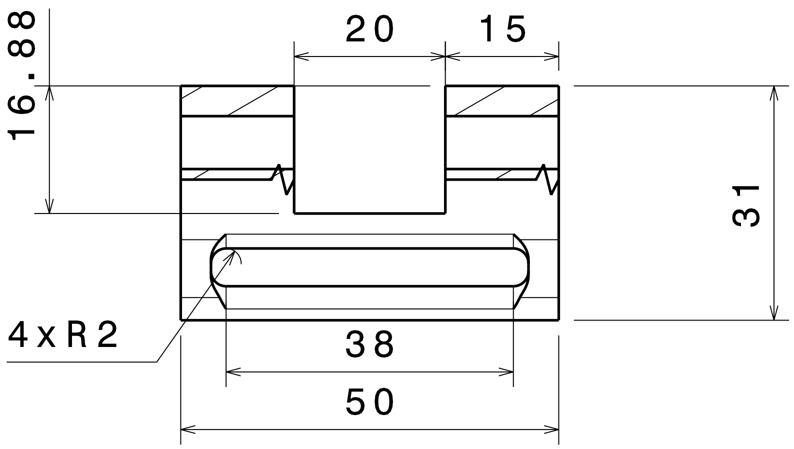

Front view
Scale: 1:1

Cable Attachment

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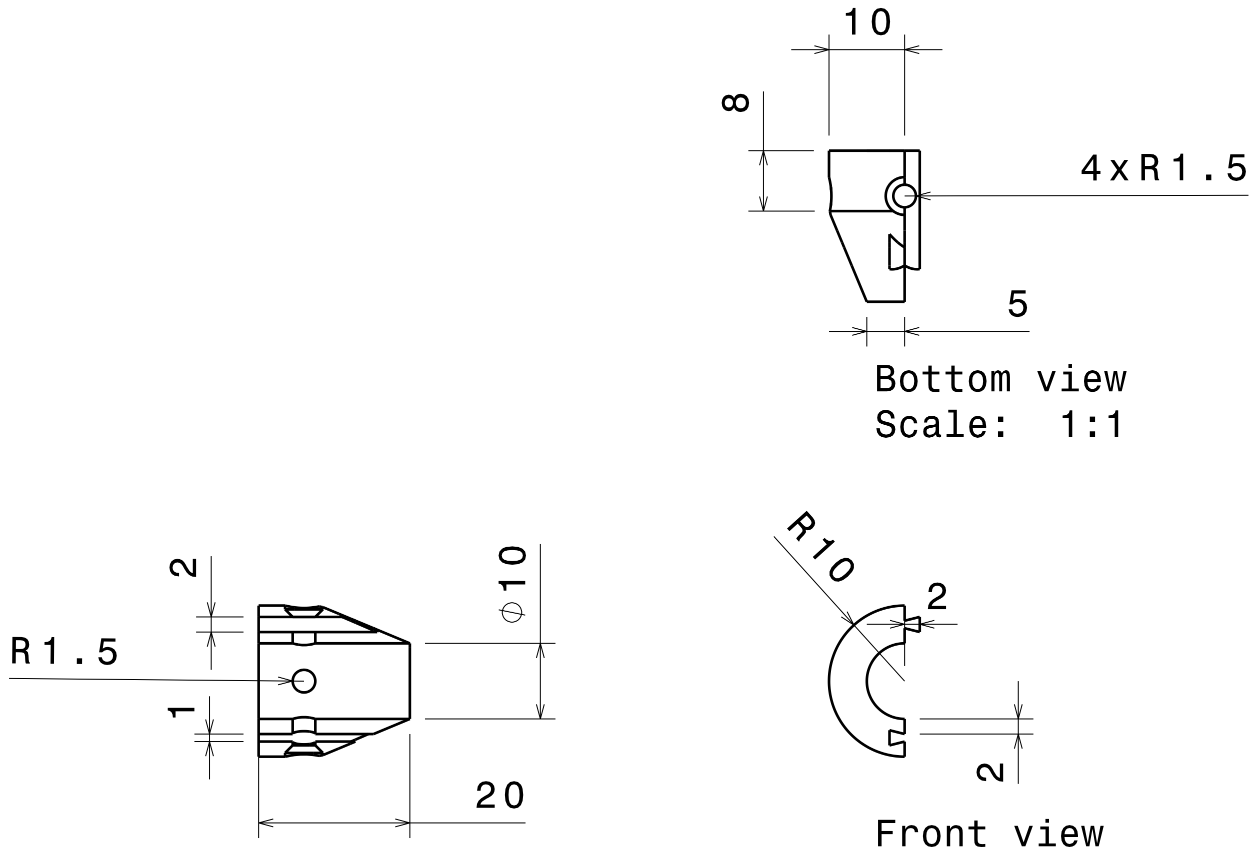

Bottom view
Scale: 1:1

Front view
Scale: 1:1

Right view
Scale: 1:1

Cable Connection

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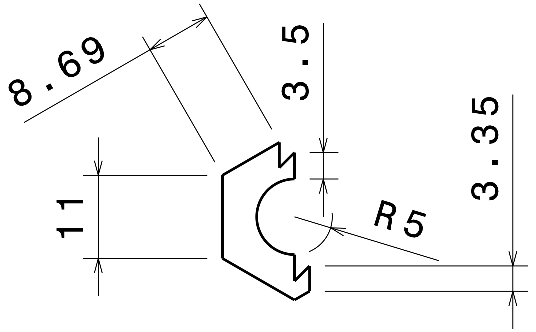
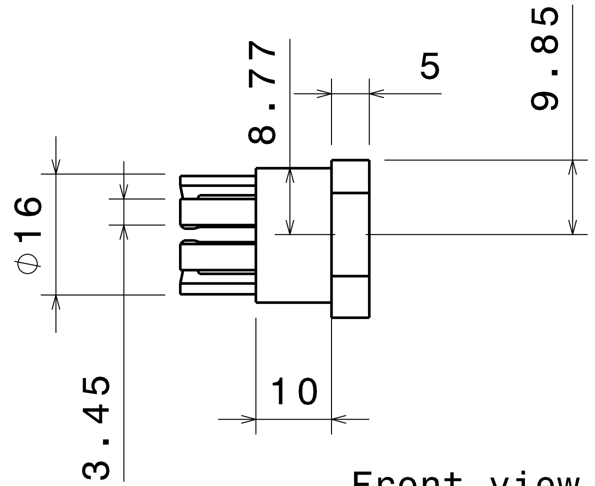
Luis Fartaria		SCALE 1:1	WEIGHT(kg) 0,00		SHEET 1/1



Right view
Scale: 1:1



Front view
Scale: 1:1

Cable Connection

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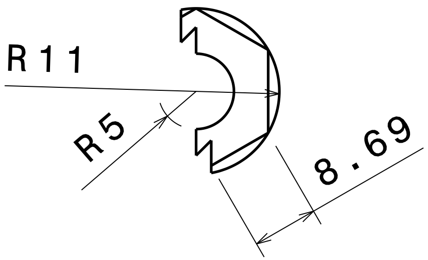
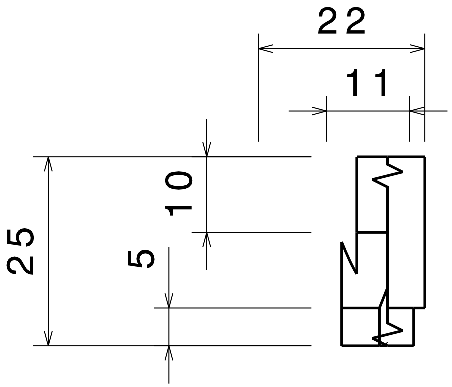


Bottom view
Scale: 1:1



Front view
Scale: 1:1

Cable Connection

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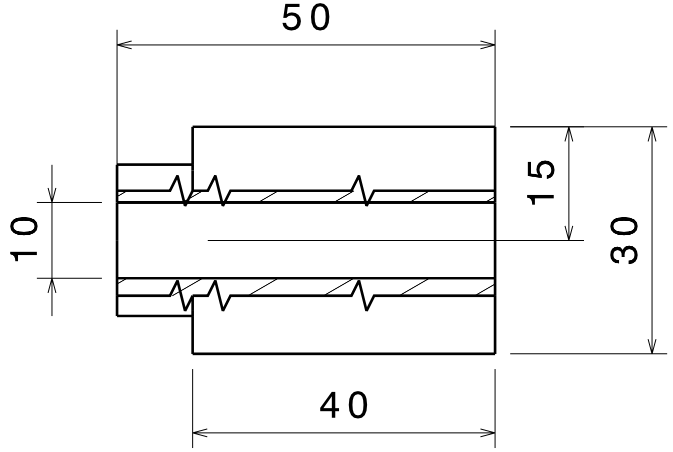
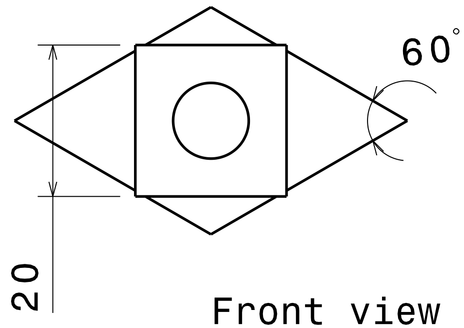


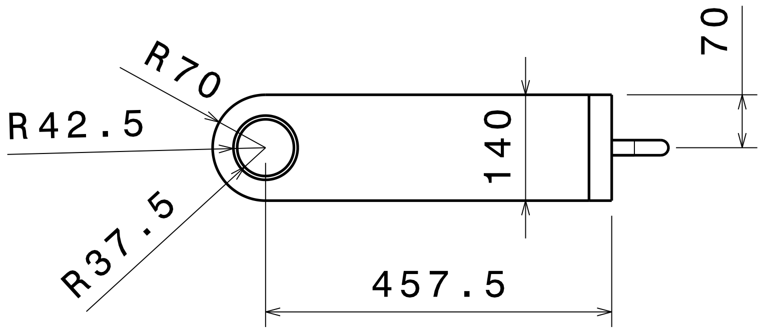
Right view
Scale: 1:1



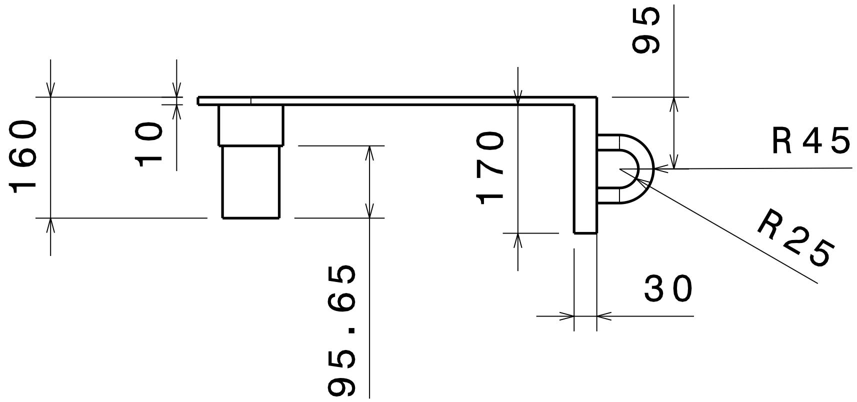
Front view
Scale: 1:1

Cable Guide Support

DRAWN BY Luis Fartaria
DATE 19-01-2011
SIZE A4
DRAWING NUMBER 9
REV X
SCALE 1:1
SHEET 1/1



Bottom view
Scale: 1:10



Front view
Scale: 1:10

Car Case Lower Part

DRAWN BY	DATE	SIZE	DRAWING NUMBER	REV
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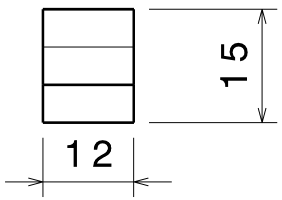
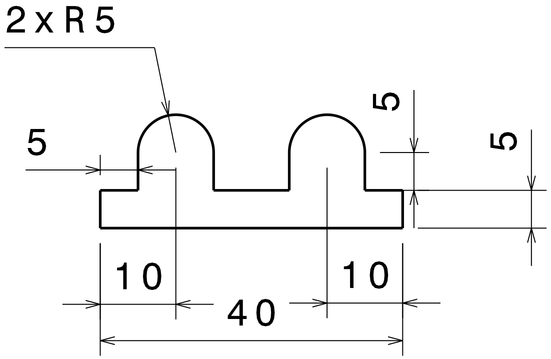
SCALE 1:1

SHEET 1/1



Right view
Scale: 1:1



Front view
Scale: 1:1

Cable Connection

DRAWN BY: Luis Fartaria	DATE: 19-01-2011	SIZE: A4	DRAWING NUMBER: 11	REV: X
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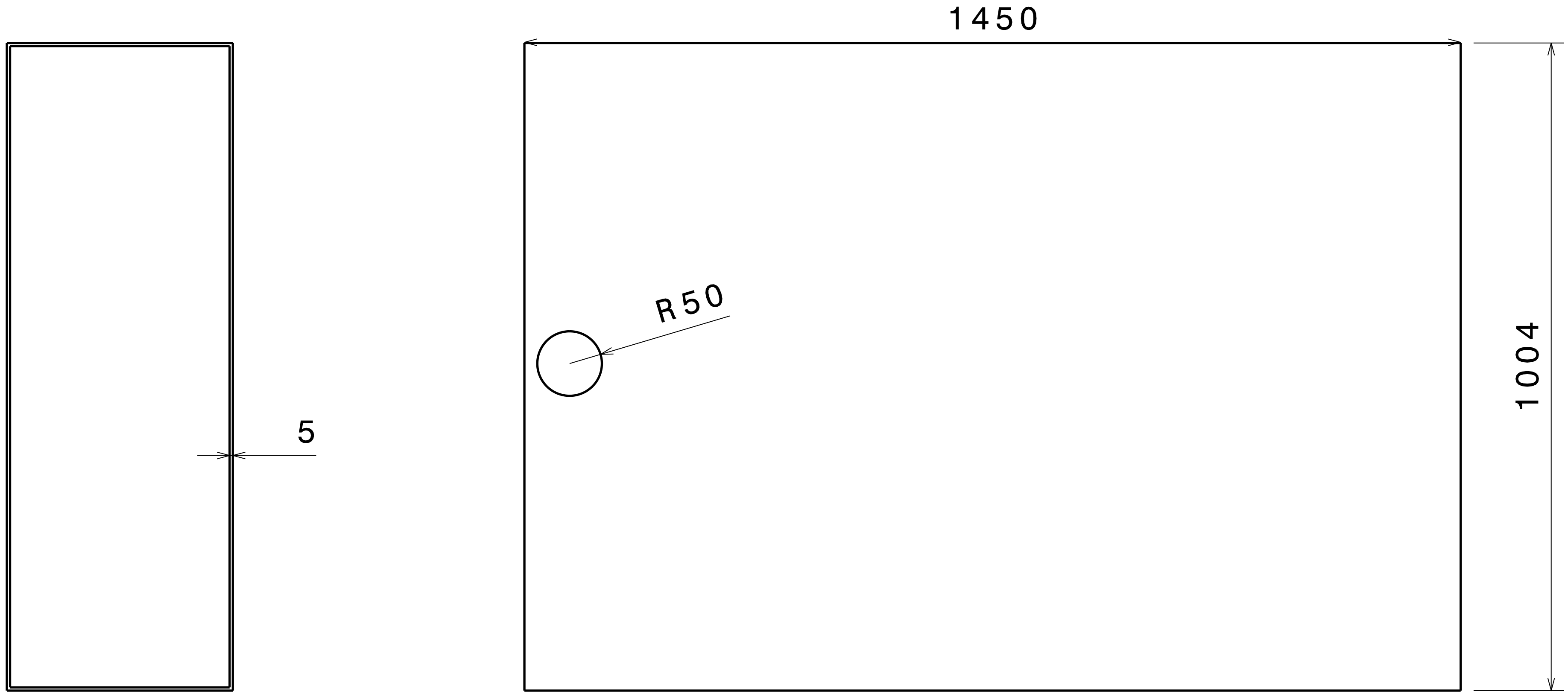

Right view
Scale: 1:10

Front view
Scale: 1:10

Counterweight Shell

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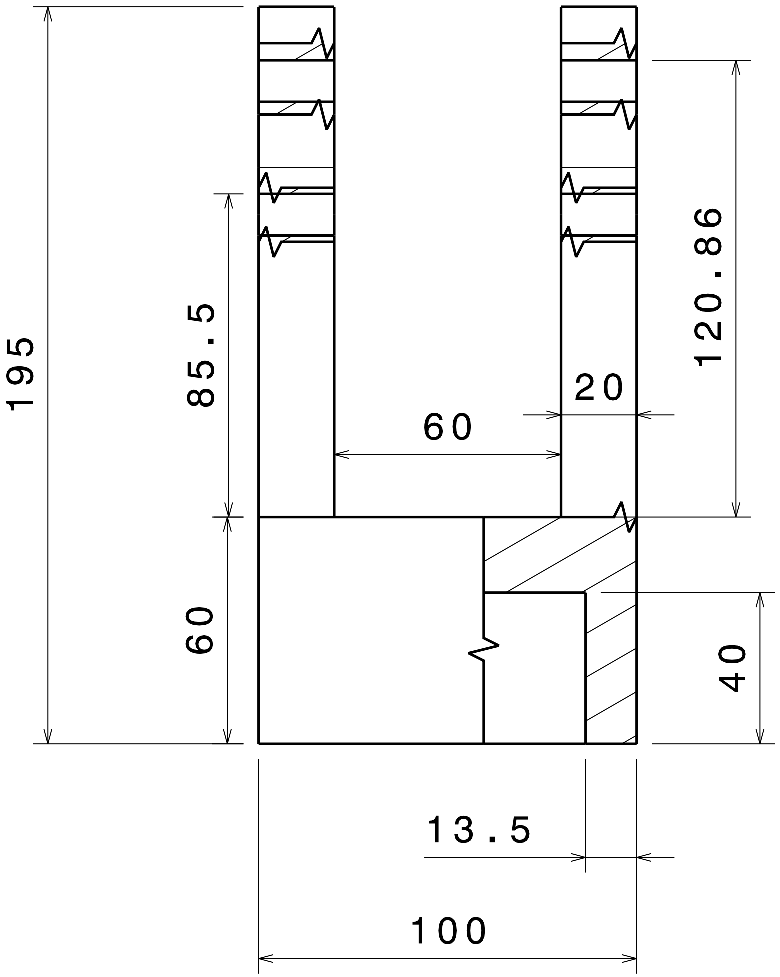
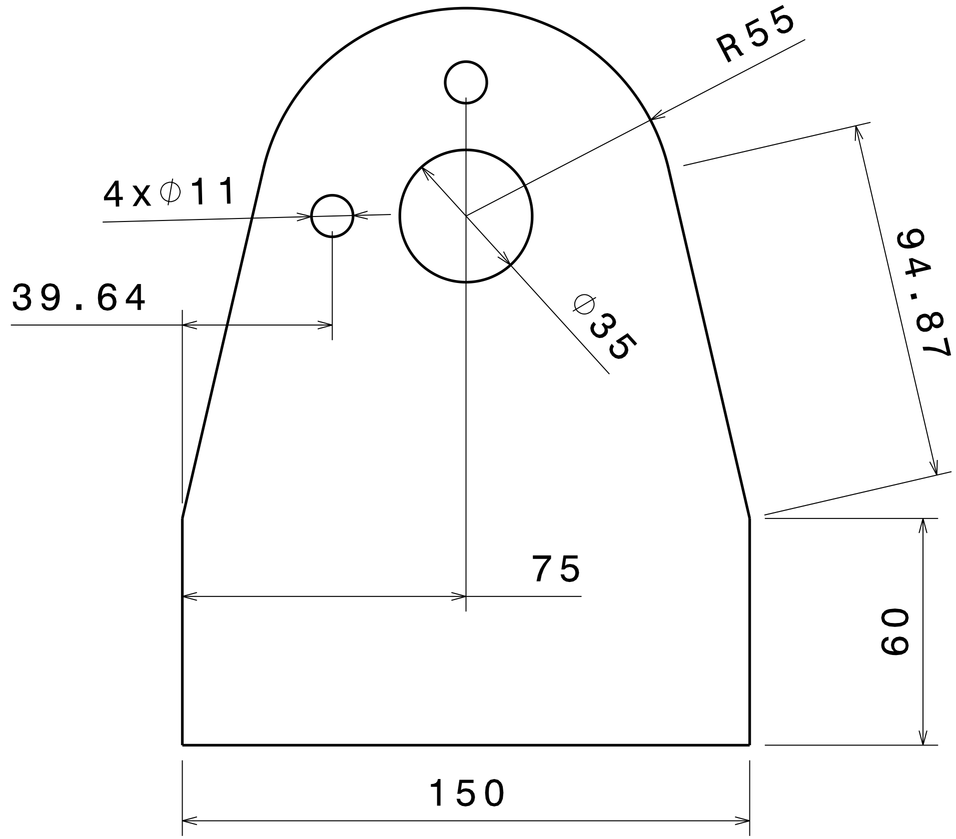


Right view
Scale:1:2



Front view
Scale: 1:2

Pulley Support

DRAWN BY	DATE	SIZE	DRAWING NUMBER	REV
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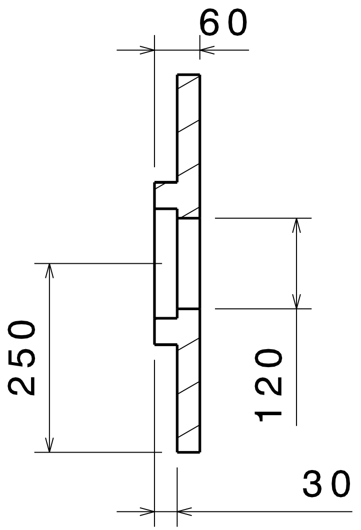

Right view
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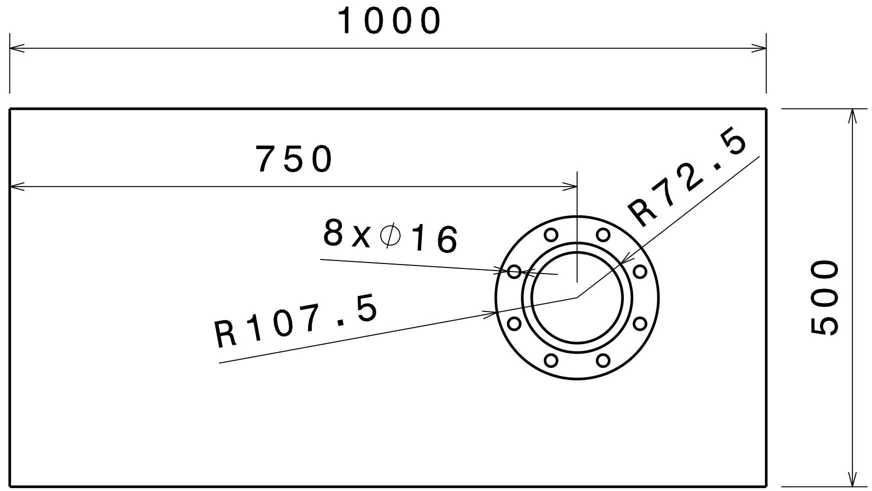

Front view
Scale: 1:10

Engine Support

DRAWN BY Luis Fartaria	DATE 19-01-2011	SIZE A4	DRAWING NUMBER 14	REV X
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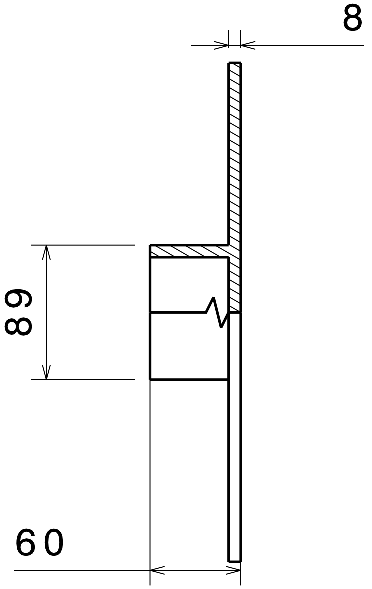
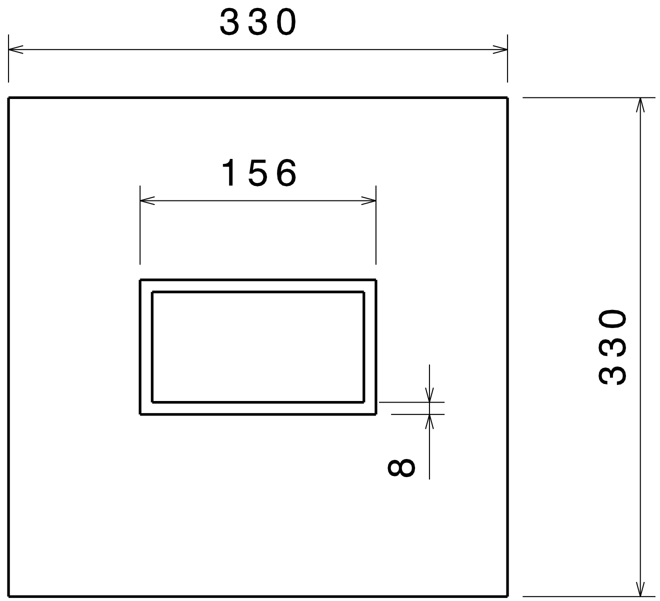


Right view
Scale: 1:5



Front view
Scale: 1:5

Fundation

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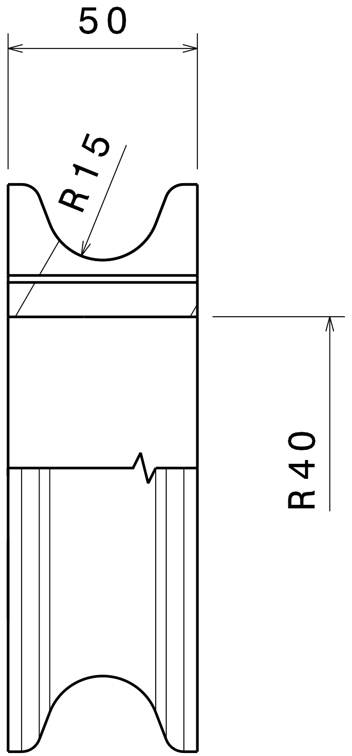
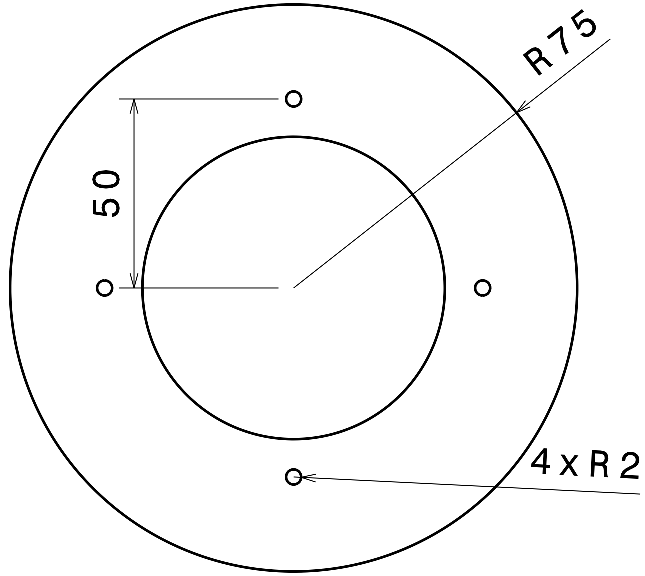


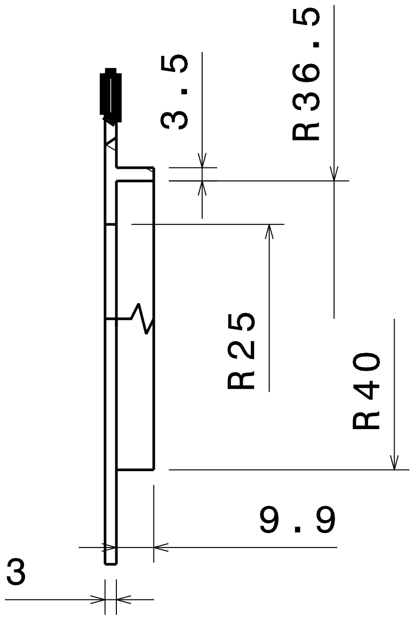
Right view
Scale: 1:2



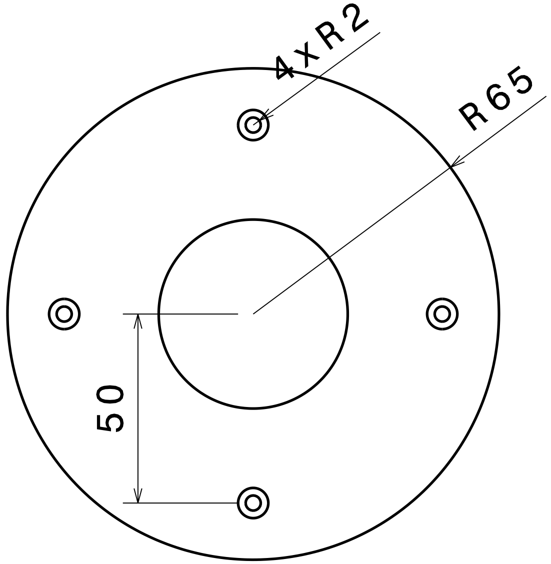
Front view
Scale: 1:2

Guiding Pulley

DRAWN BY Luis Fartaria	DATE 19-01-2011	SIZE A4	DRAWING NUMBER 16	REV X
		SCALE 1:2		SHEET 1/1



Right view
Scale: 1:2



Front view
Scale: 1:2

Guiding Pulley Cover

DRAWN BY	DATE	SIZE	DRAWING NUMBER	REV
Luis Fartaria	19-01-2011	A4	17	X
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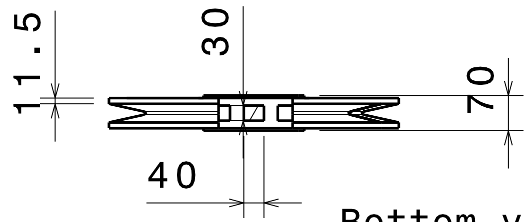
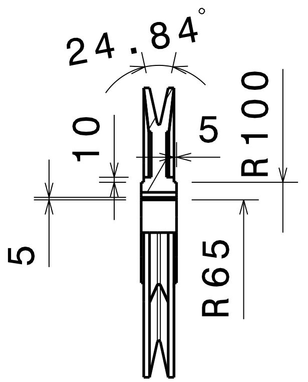
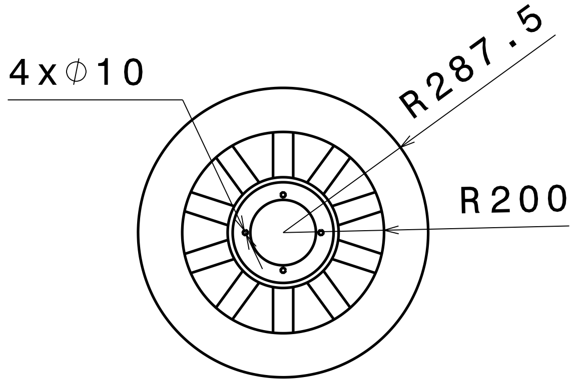


Bottom view
Scale: 1:15



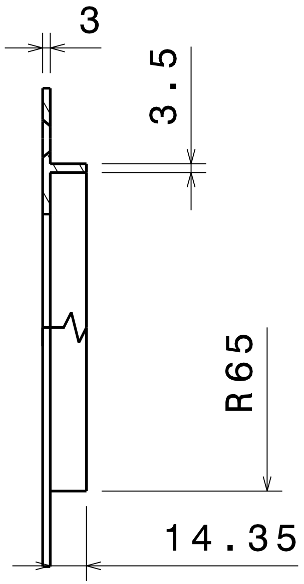
Right view
Scale: 1:15



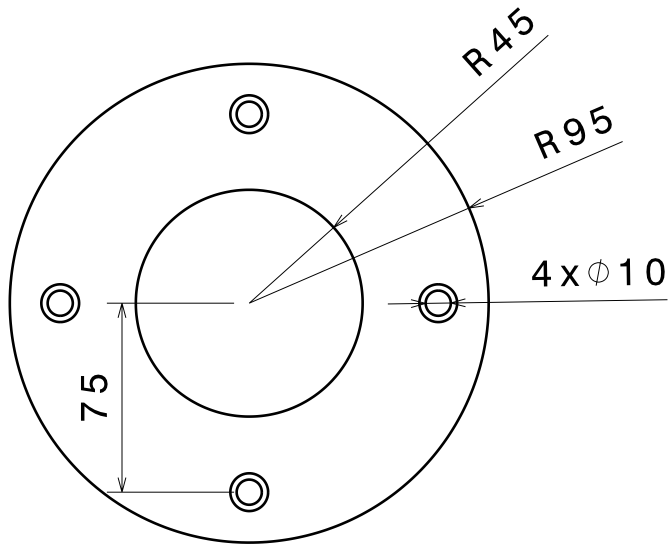
Front view
Scale: 1:15

Main Pulley

DRAWN BY	DATE	SIZE	DRAWING NUMBER	REV
Luis Fartaria	19-01-2011	A4	18	X
		SCALE 1:15		SHEET 1/1



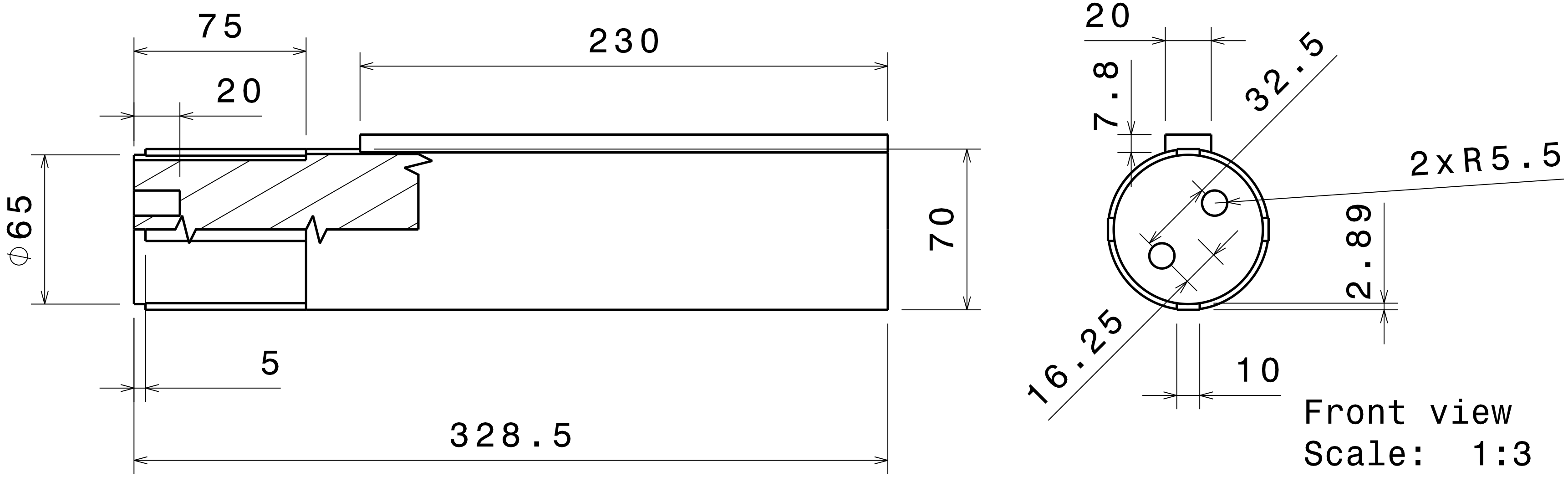
Right view
Scale: 1:3



Front view
Scale: 1:3

Main Pulley Cover

DRAWN BY	DATE	SIZE	DRAWING NUMBER	REV
Luis Fartaria	19-01-2011	A4	19	X
		SCALE 1:3		SHEET 1/1

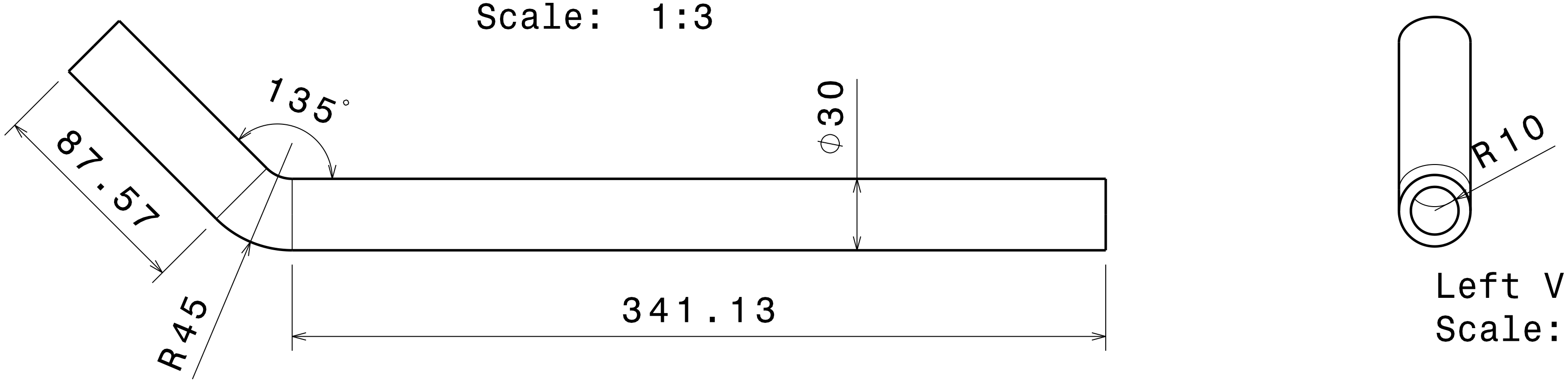


Right view
Scale: 1:3

Axle

DRAWN BY	DATE	SIZE	DRAWING NUMBER	REV
Luis Fartaria	06-02-2011	A4	20	
		SCALE 1:3		SHEET 1/1

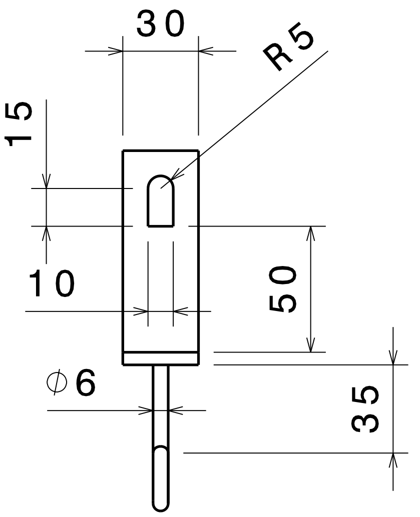
Front view
Scale: 1:3



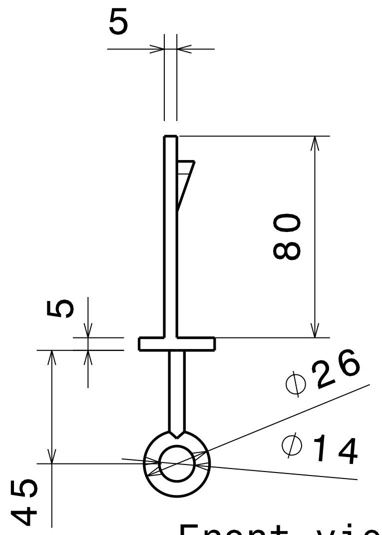
Left View
Scale: 1:3

Connection Cable Guide

DRAWN BY	DATE	SIZE	DRAWING NUMBER	REV
Luis Fartaria	19-01-2011	A4	21	X
		SCALE 1:3		SHEET 1/1



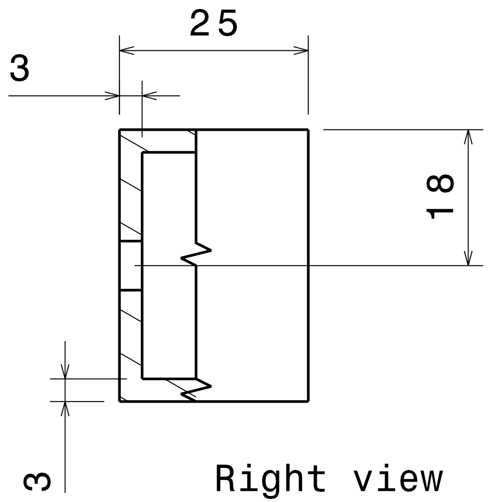
Right view
Scale: 1:3



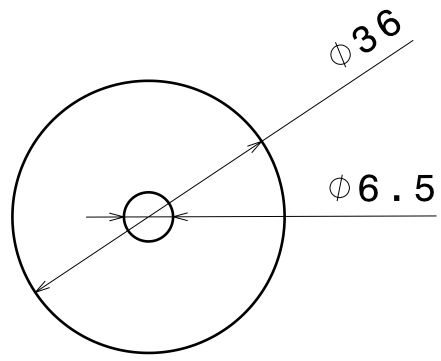
Front view
Scale: 1:3

Security System

DRAWN BY: Luis Fartaria	DATE: 19-01-2011	SIZE: A4	DRAWING NUMBER: 22	REV: X
		SCALE: 1:3		SHEET: 1/1



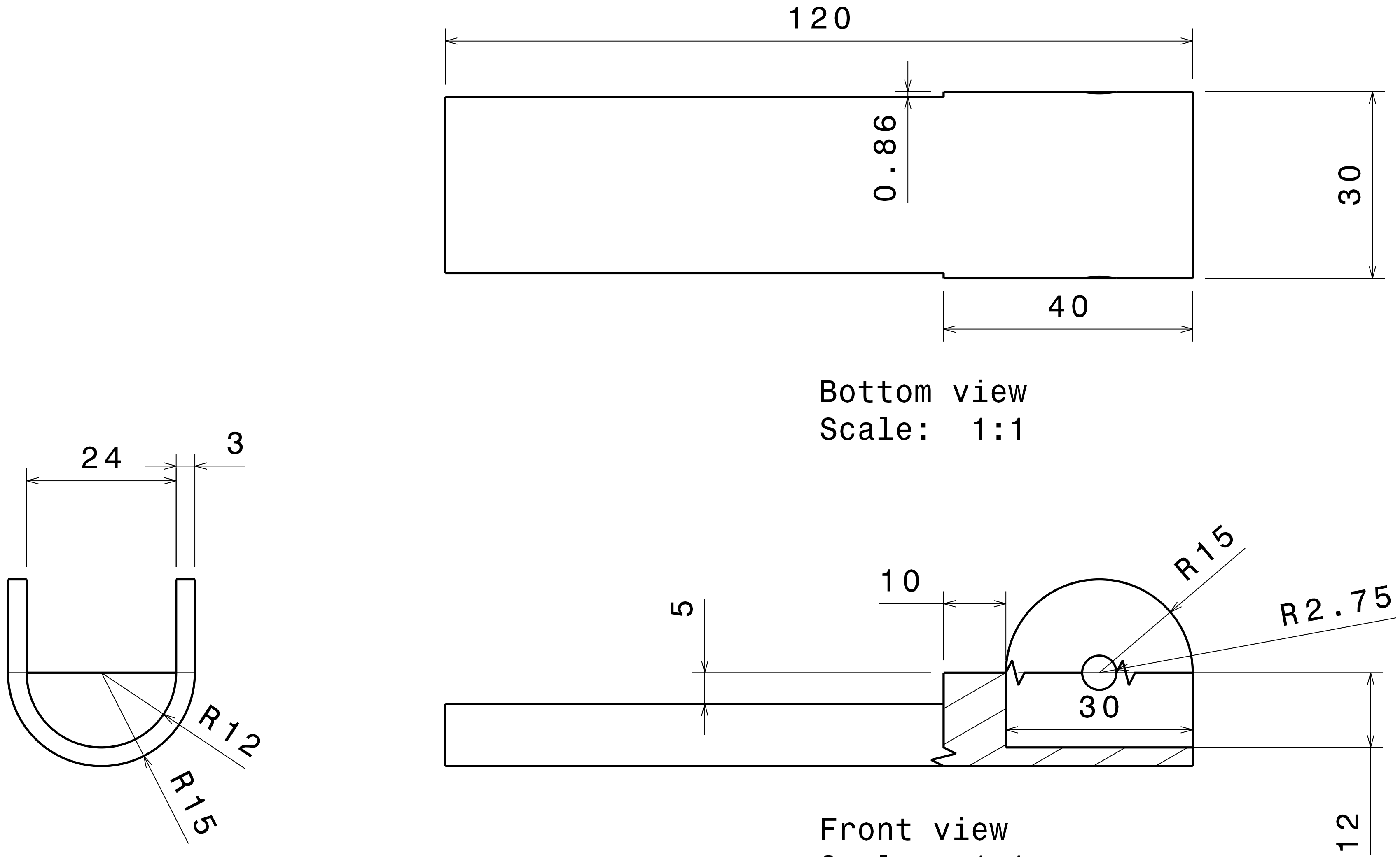
Right view
Scale: 1:1



Front view
Scale: 1:1

Security System Lock

DRAWN BY	DATE	SIZE	DRAWING NUMBER	REV
Luis Fartaria	19-01-2011	A4	23	X
		SCALE 1:1		SHEET 1/1



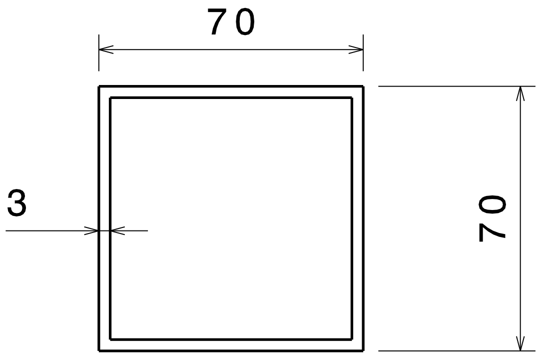
Bottom view
Scale: 1:1

Front view
Scale: 1:1

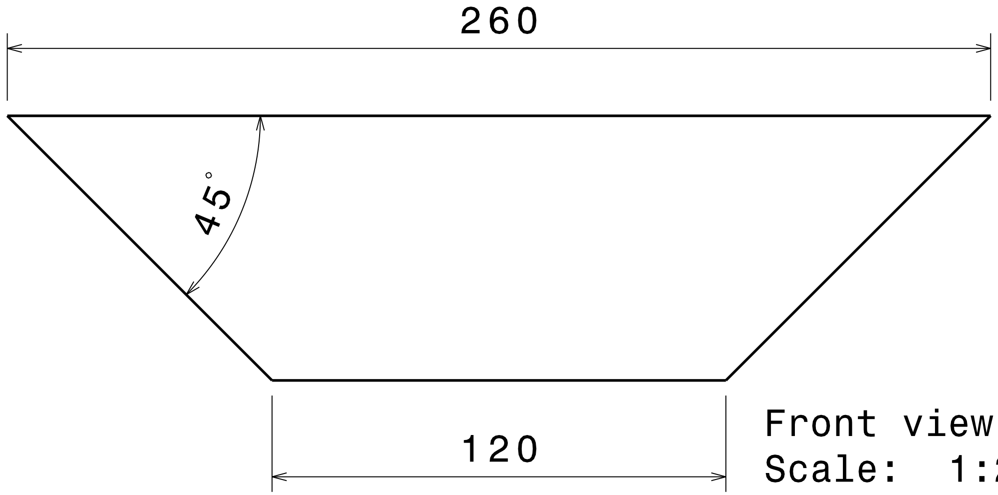
Right view
Scale: 1:1

Security system

DRAWN BY	DATE	SIZE	DRAWING NUMBER			REV
Luis Fartaria	29-06-2011	A4	24			X
		SCALE	1:1			SHEET 1/1



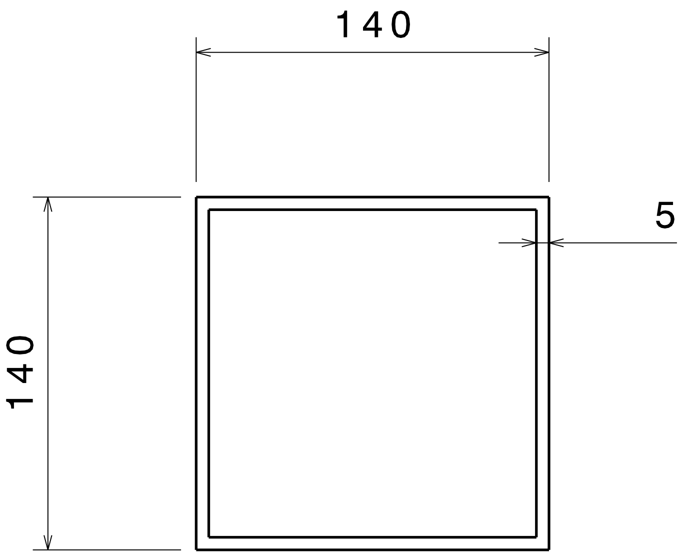
Right view
Scale: 1:2



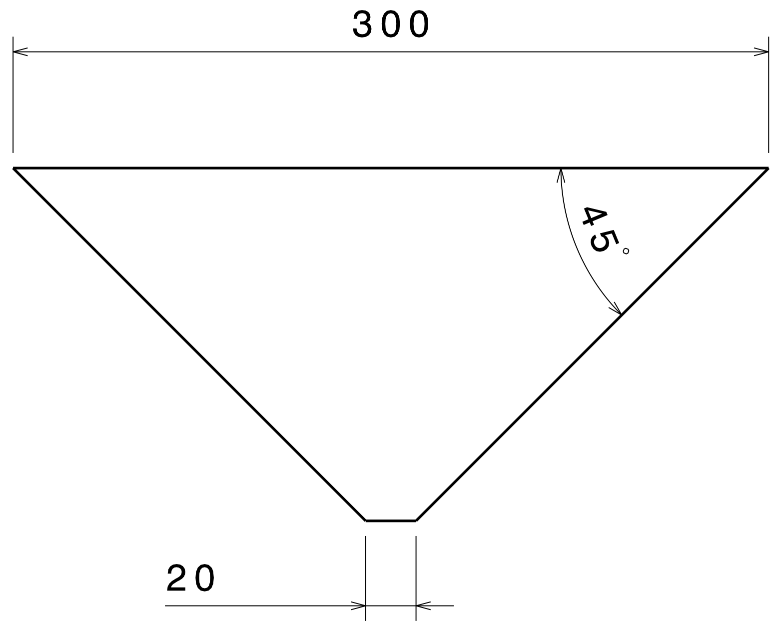
Front view
Scale: 1:2

Beam support

DRAWN BY	DATE	SIZE	DRAWING NUMBER	REV
Luis Fartaria	06-02-2011	A4	25	
		SCALE 1:2		SHEET 1/1



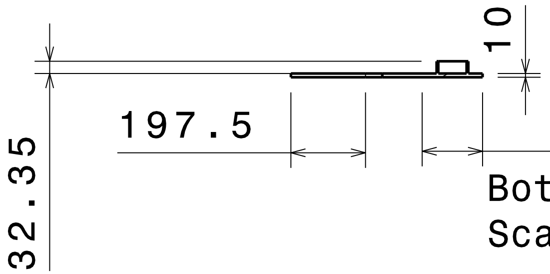
Right view
Scale: 1:3



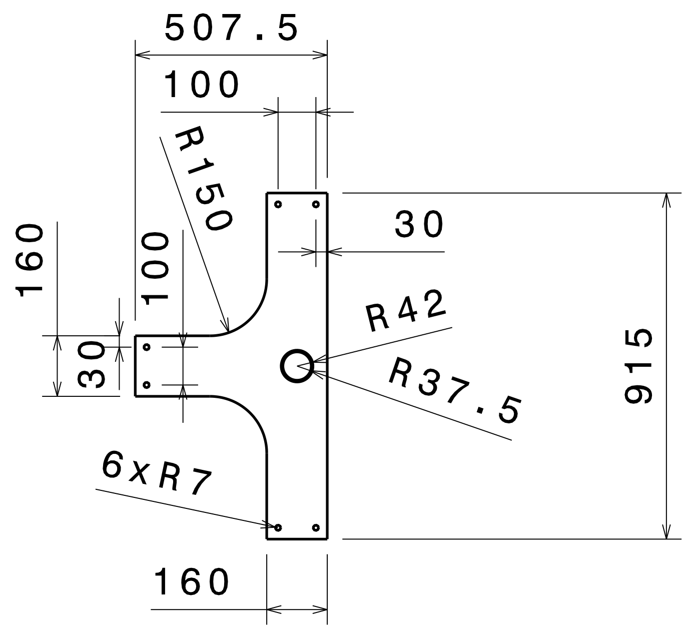
Front view
Scale: 1:3

Support Beam

DRAWN BY: Luis Fartaria
DATE: 06-02-2011
SIZE: A4
DRAWING NUMBER: 26
REV: X
SCALE: 1:3
SHEET: 1/1



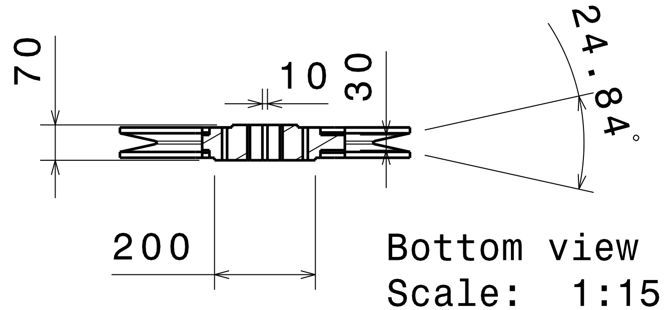
Bottom view
Scale: 1:20



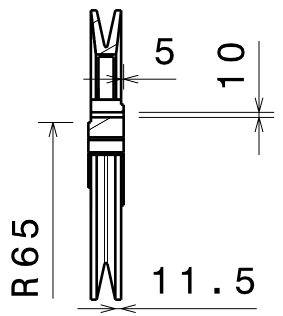
Front view
Scale: 1:20

Upper Car Part

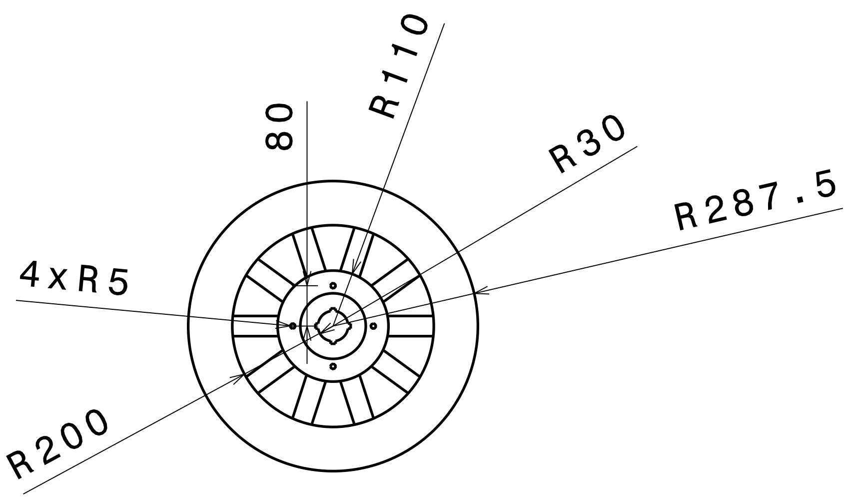
DRAWN BY	DATE	SIZE	DRAWING NUMBER	REV
Luis Fartaria	06-02-2011	A4	27	X
		SCALE 1:20		SHEET 1/1



Bottom view
Scale: 1:15



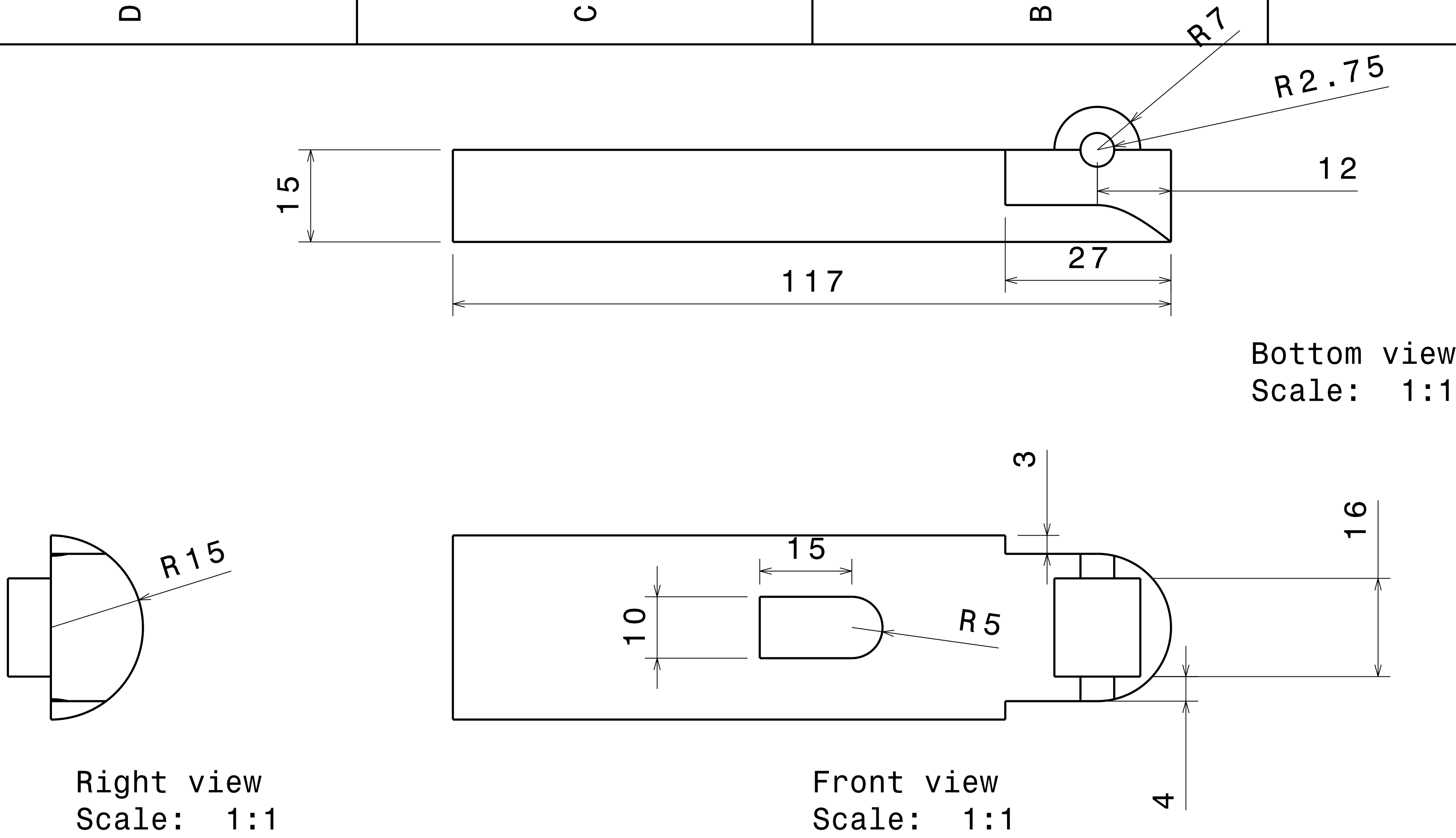
Right view
Scale: 1:15



Front view
Scale: 1:15

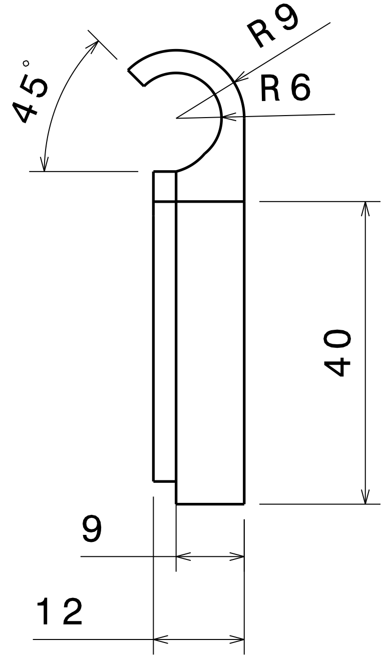
Upper Pulley

DRAWN BY	DATE	SIZE	DRAWING NUMBER	REV
Luis Fartaria	01-02-2011	A4	28	X
		SCALE 1:15		SHEET 1/1

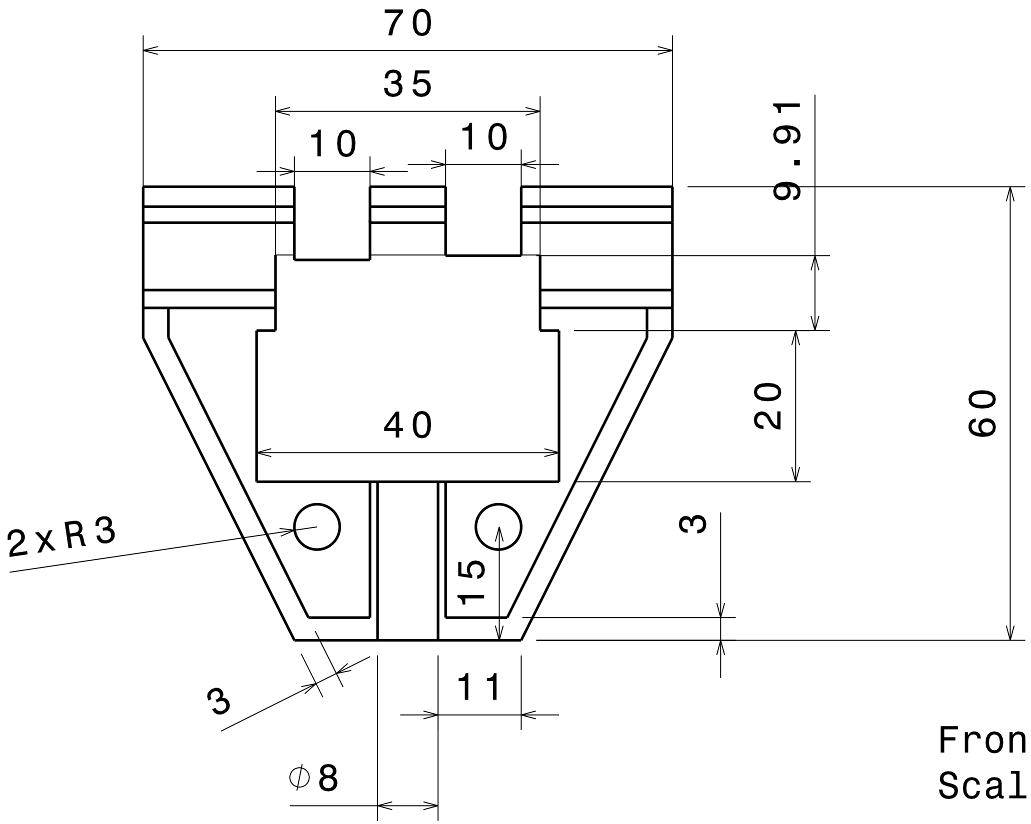


Security system

DRAWN BY	DATE	SIZE	DRAWING NUMBER	REV
Luis Fartaria	01-02-2011	A4	29	X
		SCALE 1:1		SHEET 1/1



Right view
Scale: 1:1



Front view
Scale: 1:1

Security System

DRAWN BY	DATE	SIZE	DRAWING NUMBER	REV
Luis Fartaria	01-02-2011	A4	30	X
		SCALE 1:1		SHEET 1/1