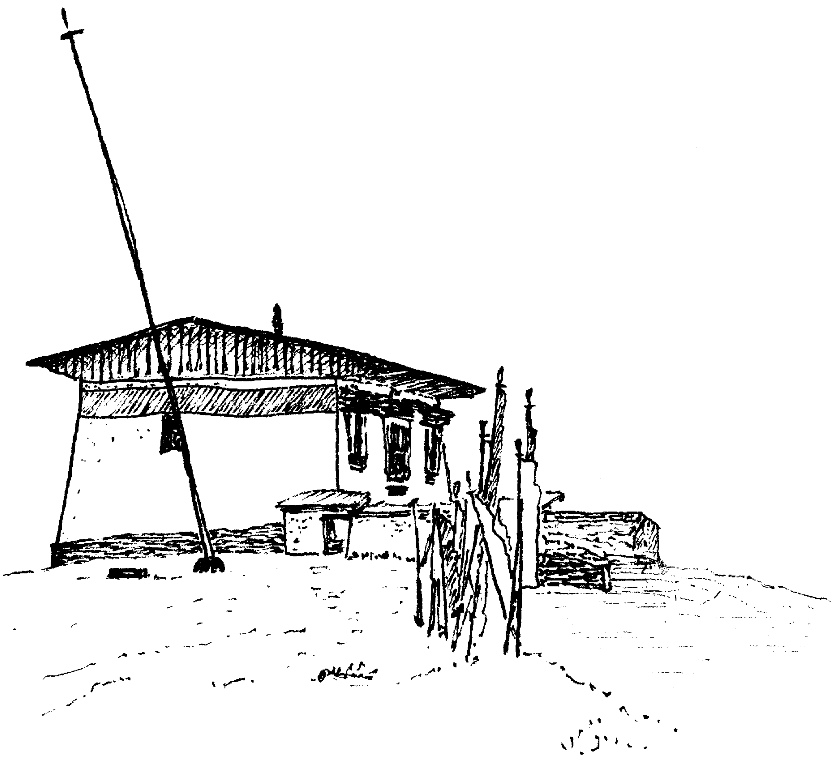
Final Checking of the Electrical Installations at the Teacher Training Center, Paro, Bhutan

Design Checking of the Electrical Installations at the RNR - Research Center, Jakar, Bhutan

26.9.1999 - 29.10.1999



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1 Terms of Reference

1.1 Terms of reference for TTC Paro

1. Checking of installation (overall, spot check of details)

1.1	Academic area	SB 1-4, Library and Administration building, School building
		SB 5, Sport / Staff house D
1.2	Residential area	Senior staff houses A/ 3B (4 buildings)
		Dining hall/ Kitchen (3 buildings)
		2 Hostel and Staff houses near Hostels
		Staff houses at village (2 buildings)

2. Checking of maximum load and voltage fluctuations
3. Comments on the possibility to extend the system
4. Advises on operation and maintenance of the electrical installation (O + M documentation)
5. Comments on the “toolkit” for engineers and supervisors (checklist electrical installation).

Remarks:

The transformer-station will be completed by RGOB in June/ beginning of July 1999. Connection of completed buildings by the contractors by July/ August. Final check of installation in August/ September 1999 (visual inspection, operation check and measurements).

Checklists are developed for material check, installation of distribution systems and final check/ measurements.

1.2 Terms of reference for RNR-RC Jakar

1.2.1 General

The RNR-RC Jakar (total building area ca. 30% of total NRTI) is being built on the opposite valley side of the Bumthang Hospital. There will be mainly three parts

- Office complex with 3 three-story buildings and 1 two-story buildings (Administration, Professional Building, Meeting/ Library, Laboratory building).
- Staff housing complex (6 buildings)
- Dormitory for guest and people attending a training.

The Department of Power, due to a general shortage of power from the Hydel in Chumey, agreed to supply a maximum of 10 kVA to the RNR-RC for the time being. A 20 kVA Diesel generator has been imported recently from Germany.

In the first phase, the Administration and the Professional Building are under construction. The construction has been started in December 1998 and the electrical installation (conduit installation) will be started by August 1999.

At a later stage, the Information/ Meeting Building, the Laboratory Building, the Dormitory Building and five to six staff houses are planned.

The installation of the first two buildings is done with two separate supplies (one only main supply and one main supply/ generator supply. The generator supply will be used initially as long as not more power is available. At a later stage when more power will be available, the entire installation will be combined into one system.

The generator is already used for construction works and the substation will be ready by middle of July 1999. A generator house will be built by August/ September 1999.

1.2.2 Detailed tasks for RNR-RC Jakar

- Checking of installation as far as done (sub-station, generator, feeder pillar, installation as far as done at the time of the consultancy in the phase 1 buildings)
- Checking of design of electrical layout and installation of the Professional and Administrative Building
- Checking of overall load calculation
- Checking of main distribution and sub distribution (Generator and Main)
- Checking of design and layout of Meeting Hall and laboratory building (building phase 2)
- Advise on maintenance of the Diesel generator
- Advise on facilities (in-built) to be provided for communication, computer installation and networking

1.2.3 Equipment which will be required

All equipments will be provided by TTC Paro and RNR-RC Jakar.

2 Program

Sun 26.09.99	flight to Delhi	1
Mon 27.09.99	flight to Paro, delay, arrival 17.30	1
Tue 28.09.99	TTC, meeting, short inspection of all houses	1
Wed 29.09.99	TTC, checking distribution panels and wiring, work on block-diagram	1
Thu 30.09.99	TTC, checking distribution panels and wiring	1
Fri 01.10.99	TTC, checking distribution panels and wiring	1
Sat 02.10.99	weekend	
Sun 03.10.99	weekend	
Mon 04.10.99	TTC, checking distribution panels and wiring, work on action plan	1
Tue 05.10.99	TTC, work on action plan, meeting	1
Wed 06.10.99	off	
Thu 07.10.99	off	
Fri 08.10.99	off	
Sat 09.10.99	weekend	
Sun 10.10.99	weekend	
Mon 11.10.99	Travel to Bumthang, visit at site RNR-RC	1
Tue 12.10.99	checking of drawings, load calculation	1
Wed 13.10.99	checking of drawings, load calculation	1
Thu 14.10.99	checking of drawings, load calculation, measuring of voltage fluctuations	1
Fri 15.10.99	travel to Thimphu	1
Sat 16.10.99	weekend (meeting with fb, Pema)	
Sun 17.10.99	weekend	
Mon 18.10.99	checking of drawings, load calculation	1
Tue 19.10.99	checking of drawings, load calculation	1
Wed 20.10.99	summarising, meeting with fb, Pema	1
Thu 21.10.99	travel to Paro, review of changes	1
Fri 22.10.99	checking distribution panels and wiring	1
Sat 23.10.99	weekend	
Sun 24.10.99	weekend	
Mon 25.10.99	preparation for instruction	1
Tue 26.10.99	preparation for instruction, instruction	1
Wed 27.10.99	checking distribution panels and wiring, reporting to Werner Christen	1
Thu 28.10.99	flight to Delhi	1
Fri 29.10.99	flight to Zürich	0.5
Sat 30.10.99	weekend	
Sun 31.10.99	weekend	
Mon 01.11.99	writing report	1

Total		23.5

3 Summary

3.1 General

This report is mainly a composition of the documents worked out at the site or at construction office. This time I tried more to describe not only my work and the found shortcomings but also the distribution system itself. It seems very important to me to give an overview documentation of the electrical system (final at TTC as well as draft at RNR-RC) where the structure of distribution is visible and can be followed.

Compared to my stay five years ago not much has changed in regard of electrical wiring and distribution. Still the quality of the wiring and the panels depend strongly on the skills of the labours carrying out the work. Some new brands came up with good quality materials like MDS and HAVELS, but material has to be mounted and connected proper and has to be chosen according to the function needed, otherwise the best material is useless.

3.2 TTC

During the first part of my stay at TTC, I concentrated on checking the main distribution system, from the main distribution panel to the sub-distribution panels. The wiring I checked with spot-checks.

All findings of these checks were entered in a action plan which is attached in the annex (see 10.1). These shortcomings together with recommendations for improvement were discussed in a meeting with W. Christen and the site supervisors.

During my absence work has been started already on this plan. When I came back for the second part of my stay I supervised this ongoing work and concentrated in the documentation for maintenance. A training among the site-supervisors was held (see 10.9). The last buildings where the wiring was just finished at that time were checked in detail.

Finally a meeting was held to brief W. Christen about all points of my contracts work.

3.3 RNR-RC

The design of the electrical distribution system which was designed in detail by Pema based on instructions of Fritz Baumgartner. It was foreseen to have a complete separate installation for the generator supply from the generator to the outlet. This structure was changed into an installation system for both grid supply and generator supply.

During the first part at the site office I concentrated on the checking of the layout and the load calculation. All findings were gathered in notes (see 10.3) which were discussed first time shortly after coming back from Bumthang and a second time after revision and completion before I left for Paro.

4 TTC – Distribution System

4.1 Description

The distribution system has slightly been modified compared to the design in my report from 1994, i.e. some houses are connected by overhead-line.

The structure can be seen from the block diagram (see 4.6)

4.2 Transformer Station

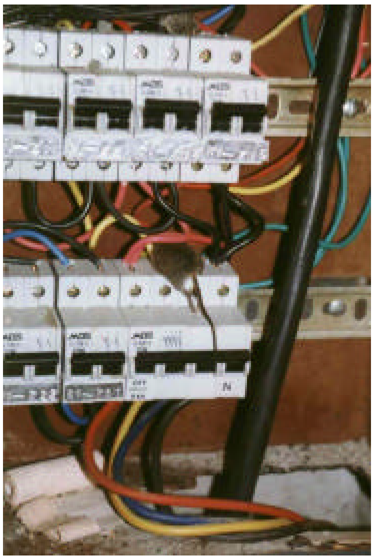
The new transformer has a capacity of 1000 kVA which is much more than proposed in the report from 1994. The standard of switch gear is very high, not to compare with what has been installed up to now. It seems that the old transformer station will be removed later. With this size of transformer future connection of additional load will not be a problem but in case of damage two smaller units are still better than one single unit.

4.3 Main Distribution Panel

The main distribution is manufactured according to my proposal. Isolators will be replaced with MCCB's.

4.4 Sub Distribution Panel

All the sub-distribution panels and the main-sub-distribution panels have been checked. Manufacturing and arrangement of the appliances is ok but different "standards" according to the contractor are visible.



right side:

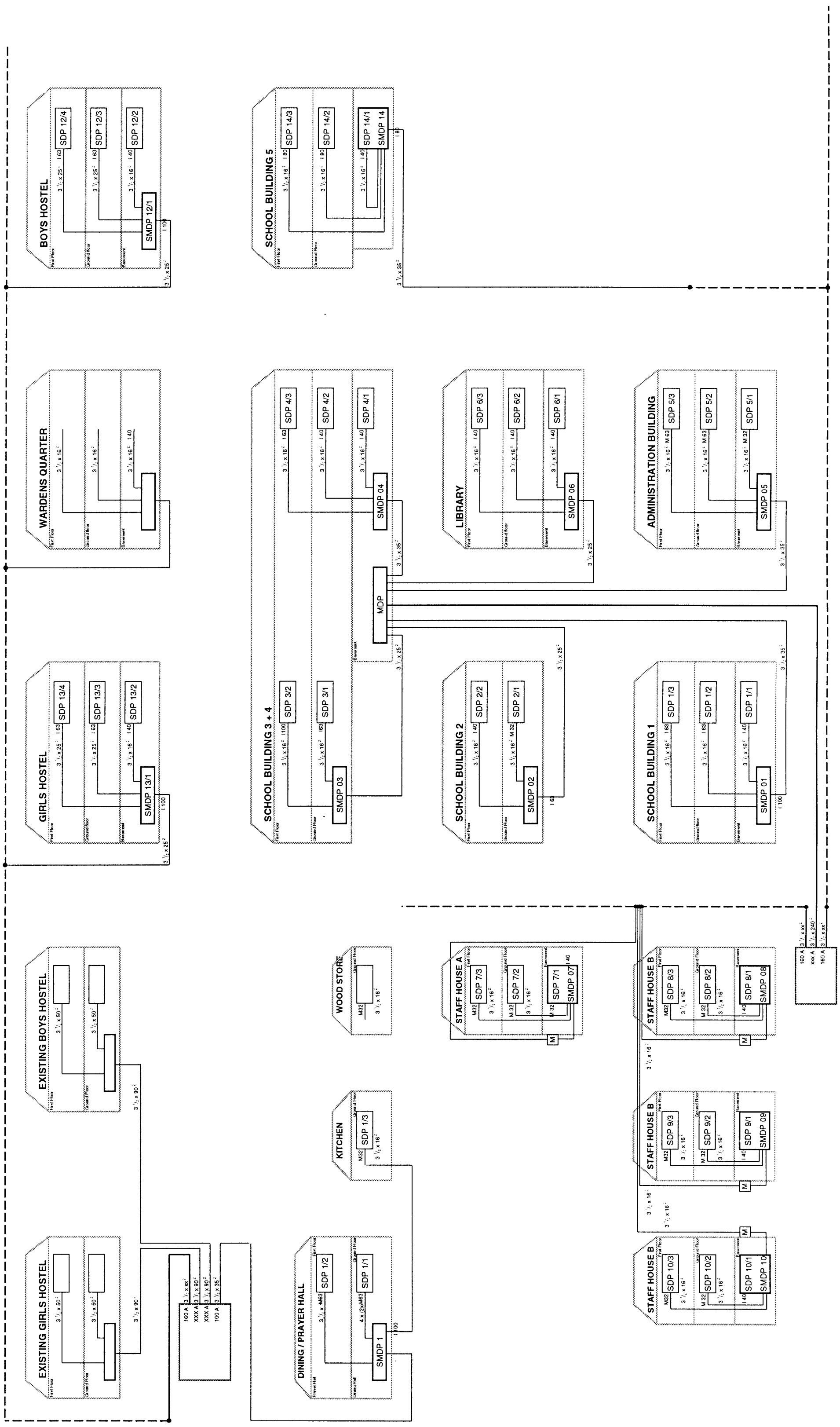
sub-distribution panel with two habitants

(could not profit for long time from this nice accommodation, which is used as first aid box as well)

4.5 Staff Houses (Type A and B)

The distribution system has been taken over from the academic buildings with a separate panel in each floor even though the principle was given in the block diagram and a sample was shown (see last report 8.5). Also the three phase system is applied. All in all it's overdone. A Distribution system similar to the one at NRTI staff houses would be much more appropriate.

4.6 Block Diagram



5 TTC – Load Calculation

5.1 TTC – Load Calculation

The load of the whole project was calculated by Mr. Chetri based on the revised layouts and checked by myself. Since there is still no experience (load measurement) from similar projects like NRTI it is difficult to make a reliable prediction. Still the values from my last report are more or less valid.

5.2 TTC – Load Measurement

At the time of checking only little power was drawn. Therefore it is not possible to compare the load calculation with these measuring values. Mr. Chetri is instructed to measure frequently at different times the current and to collect these values in a list. A XL-file which will show a graph according to the progress of the load was handed over already.

From these values only statements can be made relating the accuracy of the predictions.

5.3 TTC – Future Expansion

Since the capacity of the transformer is much larger than the recommendations which included already additional load to cover uncertainty and unforeseen connections this transformer station can bear nearly any size of extension of the project. Buildings near to the academic complex can be connected to the main connection at the main distribution panel (connected to the bulk-meter), buildings more away from the academic complex can be connected to the L.T. overhead-line at any point but need separate metering.

6 TTC - Voltage Fluctuations

The voltage at Paro valley is still very unstable but can not be influenced by the customer, for instance with high quality installations. Therefore the only thing is to endure it and to protect susceptible appliances with voltage stabilisers.

The different reasons for such fluctuations are given in the appendix in detail (see 10.4).

During my stay on 22.10.99 it happened even that the voltage in 2 phases was as low as approximately 120 Volts. Such cases are caused by problems at the high voltage supply (1 phase off) and can not be avoided. Even stabilisers can not correct such a bad supply and can get damaged itself. The only recommendation: to switch off all appliances and call the Department of Power to do the repair work.

It can be said that the level in general is high due to the close distance of the transformer station. D.o.P. could lower the voltage at the transformer outlet on request, but this does not protect from fluctuations.

7 RNR-RC – Distribution System

7.1 Description

Similar to TTC Paro the 'academic' buildings will be supplied by underground cables, controlled from one main distribution panel and measured with a single bulk meter. The building more distant to the transformer station will be supplied with L.T. overhead-lines.

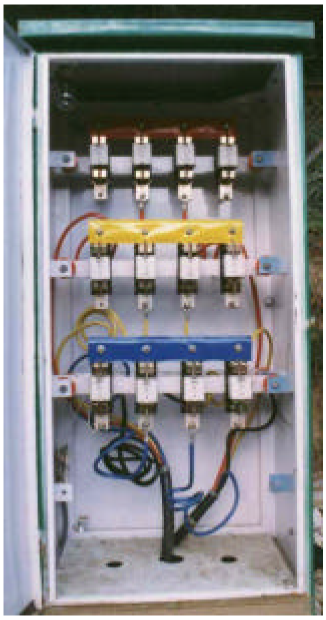
The structure can be seen from the block diagram (see 7.4)

7.2 Power Supply

As mentioned already in the terms of reference (see 1.2.1) the D.o.P can not supply the power requested for the whole project now. Therefore and to bridge power interruptions a generator is installed during construction an will be connected to the project distribution system later.

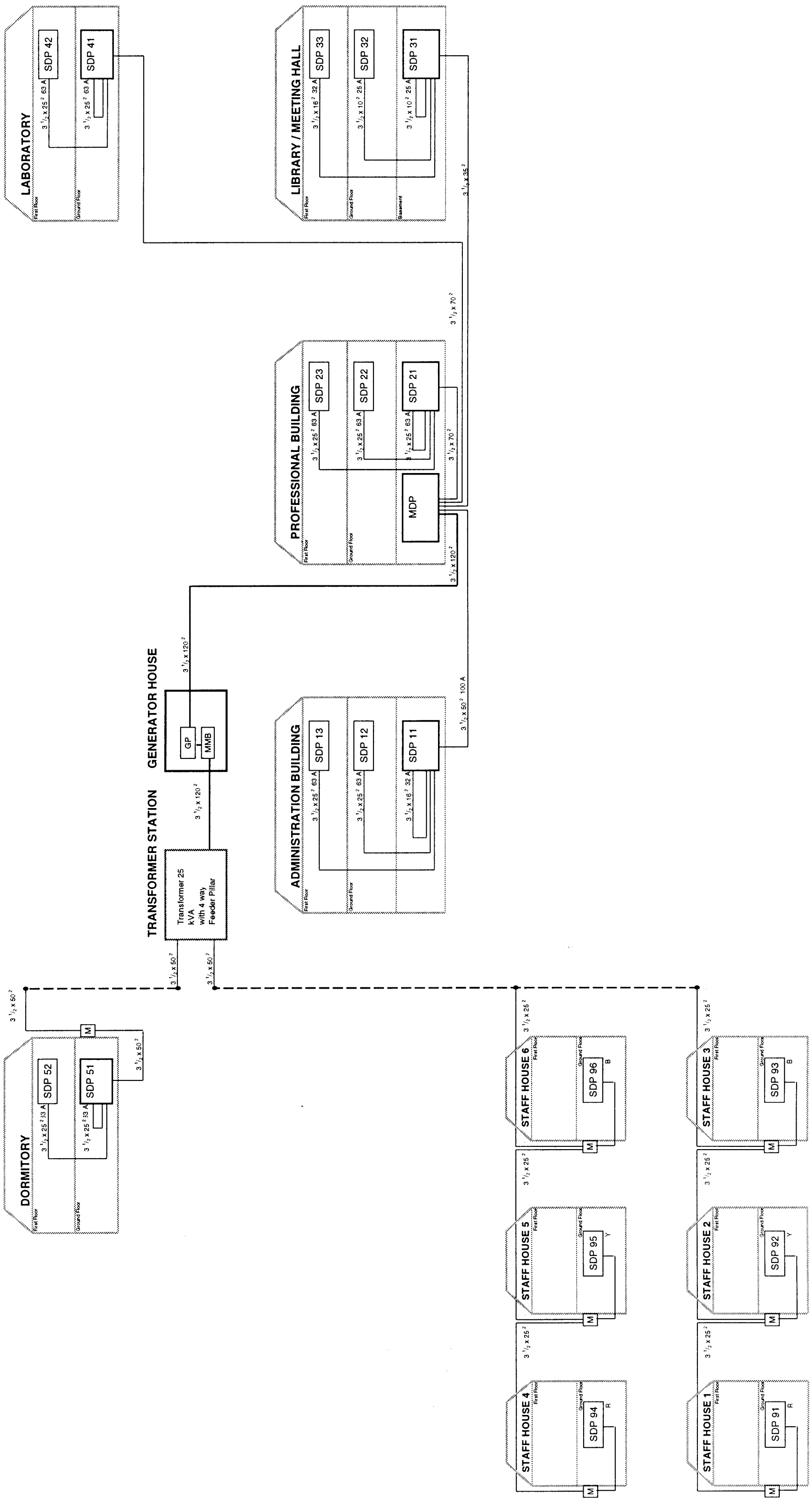
7.3 Transformer Station

The transformer station is now equipped with a 25 kVA transformer even though D.o.P. allows only 10 kVA to be used from the grid. To distribute this load a 4-way-pillar is installed containing already fuses of 400 A (good for approx. 260 kVA). These fuses can not protect the transformer and must be replaced.



4-way pillar with 400 A fuses

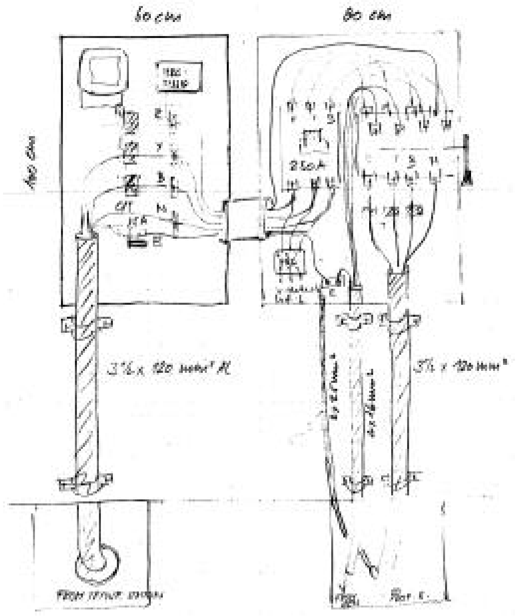
7.4 Block Diagram



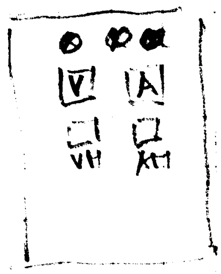
7.5 Generator House

At the generator house close to the transformer station the bulk meter with the change-over switch (line / generator) will be installed. As long as D.o.P. can supply only little load, instead of the bulk meter with current transformers a normal 3 phase meter for direct connection can be installed and instead of the 250 A MCCB a 32 A MCB can be installed.

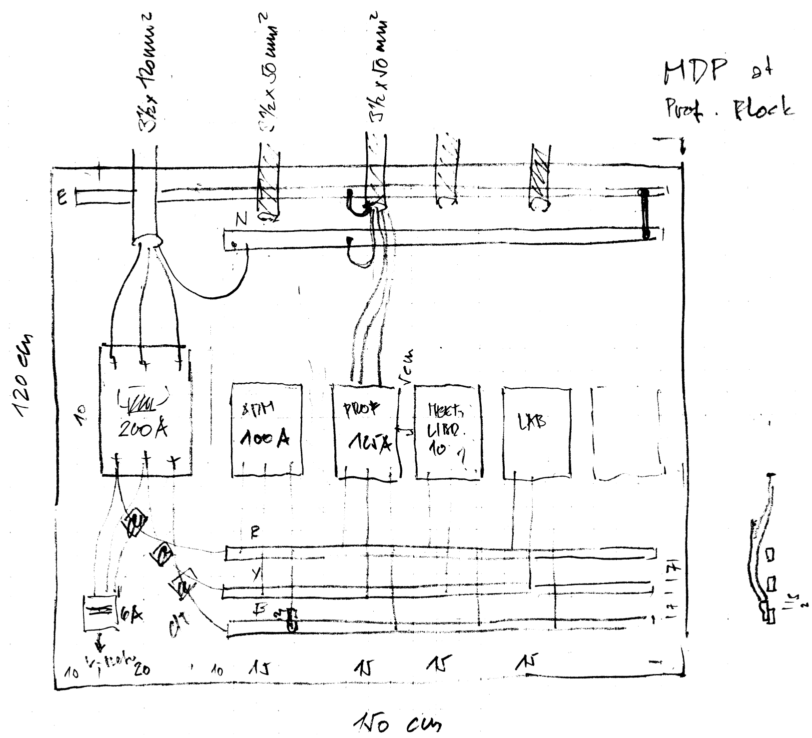
Panels for meter box and change-over switch without door



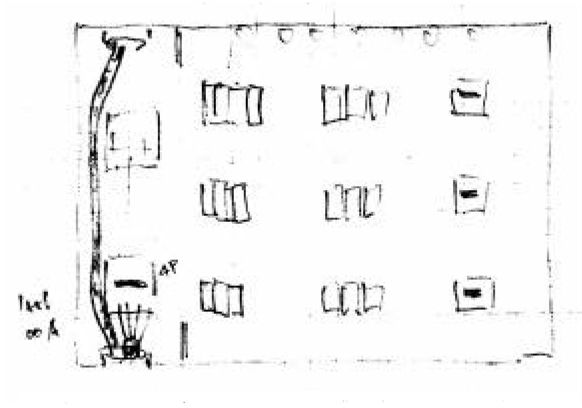
Door of panel for change-over switch with meters and indicator lights



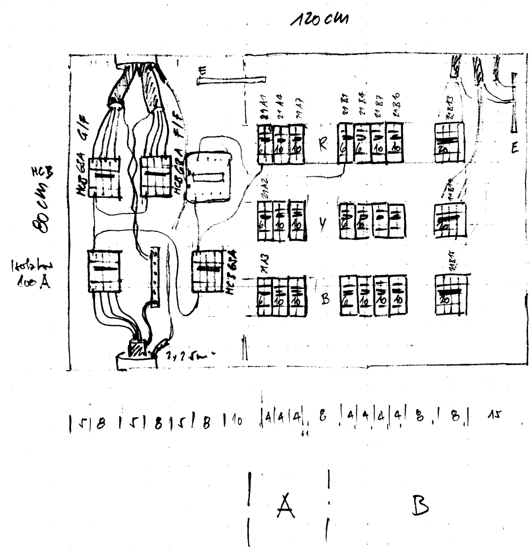
7.6 Main Distribution Panel



7.7 Sub Distribution Panels



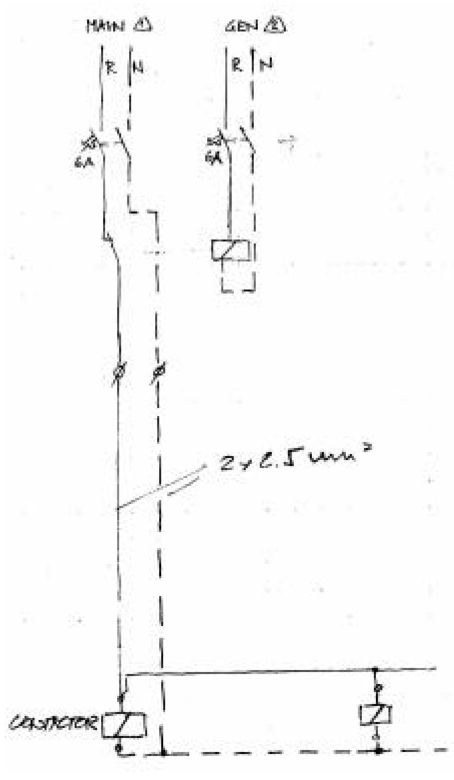
Ground Floor



Basement

7.8 Control circuit

Control circuit for the contactors which will disconnect in every sub distribution panel a part of the load in case of generator supply only.



8 RNR-RC – Load Calculation

8.1 RNR-RC – Load Calculation

Because there is still no experience about load consumption of similar institution (like NRTI) much time has been spent to calculate the load.

Uncertainty exists regarding agriculture machines and appliances. At the present location of RNR-RC - office we found only few seed dryers. These are for 1-phase connection and are not high powered.

Load Calculation

Abstract		Load	t-factor	Mains	Generator
ADMINISTRATION BLOCK	calculated	40'741 VA	0.80	32'593 VA	5'563 W
PROFESSIONAL BLOCK	calculated	102'377 VA	0.80	81'901 VA	21'920 W
MEETING HALL	estimated	8'000 VA	0.90	7'200 VA	
LABORATORY	estimated	20'000 VA	0.90	18'000 VA	0 W
Total load		**171'117 VA**	***0.82***	**139'694 VA**	**27'483 W**
Average current per phase				**194.3 A**	
min. cross section area (load)				**120 sq mm**	
suggested cable type	**200 A**	143'756 VA		**120 sq mm**	

8.2 RNR-RC – Future Expansion

Regarding the connections, additional buildings close to the institutional buildings can be connected to the main distribution panel. More distant buildings can be connected through extended L.T. overhead-lines.

9 RNR-RC - Voltage Fluctuations

It is not possible to make any predictions for voltage fluctuations on the bases of measurements during my stay because all wiring from transformer station to the construction site were temporary.

During my stay, we (fb, ste) tried to record the voltage during night time with a measuring instrument and a laptop. But due to a interruption of power supply the measuring failed (irony of fate). fb will do it later.

It was questioned to install a large, centralised stabiliser or UPS. The following reasons show the advantage of small units.

- If damaged or under repair all appliances are nor save
- It seems the better solution to have for all critical appliances a stabiliser or UPS of the appropriate size.

10 Appendix

10.1 TTC - Action Plan

General remarks

Object	Description	Action	Remarks
Access	Access to rooms and / or Panels not given due to missing keys Panels in Staff Houses not locked	Registration system, board for keys Lock required?	
Rats and mice	Mice inside the panels (three found dead) Entering the Panels by gaps in the inlet-slots and through the channels	Closing all holes Slots in the panels to be closed with Bakelite sheets remaining holes at the cable inlet to be filled with glass wool	Closing the channels also between the floors and under the roof obstruct the easy access to the building for hygienic reasons
Material of bus bars	In some panels it looks like brass	-	for future improvement control
MCCB, MCB, Isolators	Function of apparatus not clear	Partly to be changed	
Labeling system	Some numbers are not according to the system The numbers are not unique	Checking of all numbers again, Labels to be replaced if wrong -	 for future improvement introduction of system with unique numbers
Dirt	Dirt inside the panels (pieces of insulation, stones, dust, excrements of mice, food), dirt is attracting the mice	cleaning	
Earth system	Shield of the cable armor (steel) at the incoming cable not connected In some Panels the case is not connected with the Earth	- Connection from Earth to screw at case	For future improvement connecting all Earth together lowers the Earth-restance
Connection of E- and N-wiring	Twisted and fixed under one single terminal	-	For future improvement connecting E- and N-wires with terminals
Documentation	Missing a block diagram	Revision of drawings "as it is"	
Bakelite cover	Size and openings too accurate, problems to remove them	See particular remarks	For future improvement Little more gap
Crimping of cable shoes	common pliers used instead of the proper crimping tool	-	for future improvement use of proper tools

Particular remarks

Object	Description	Action	Remarks
Main Fuse/Switch Unit at MDP (School Building 4)	Connection at main switch not insulated, cable shoes coming out of box Wires inserted like fuses instead of cartridges	Adding a covering box at in- and outlet inserting cartridges	 For future improvement MCCB installed instead of Fuse/Switch Unit
MDP (School Building 4)	Isolators (6 pcs. of 100 A) instead of MCCB's or MCB's Door lock inside of the door causes problems if key is lost N-line presses towards a sharp edge at the panel opening connection of V- and A- meter not yet completed	Changing to 3 pcs. MCCB 80 A 3 pcs. MCB 63 A - PVC-Support	 for future improvement provision for Padlock

		to be completed	
SMDP 01 (School Building 1)	Blue wires pressing on bars E-screw loose	Improving of the bends Tighten the screw	done 30.9.99, ste
SDP 1/1	Isolator 40 A at entrance point	Change to MCB 32 A	
SDP 1/2	Isolator 63 A at entrance point	Change to MCB 32 A	
SDP 1/3	Isolator 63 A at entrance point	Change to MCB 32 A	
SMDP 02 (School Building 2)	Insulation scratch at R-wire leading to bar Slot in panel at top to be closed No connection from Earth to the case	Taping Bakelite sheet from inside connection from Earth to screw at case	
SDP 2/1	Slot in panel at top to be closed	Bakelite sheet from inside	
SDP 2/2	Isolator 40 A at entrance point	Change to MCB 32 A	
SMDP 03 (School Building 3)	Open gaps	To be closed with Bakelite sheet	
SDP 3/1	Isolator 63 A at entrance point All N-wires (5) connected to the Isolator terminal	Change to MCB 32 A -	For future improvement connecting E- and N-wires with terminals
SDP 3/2	Isolator 40 A at entrance point	Change to MCB 32 A	
SDP 4/1	Isolator 40 A at entrance point	Change to MCB 32 A	
SDP 4/2	Isolator 40 A at entrance point	Change to MCB 32 A	
SDP 4/3	Isolator 63 A at entrance point Incoming cable not fixed with clamps inside channel	Change to MCB 32 A Fixing with clamp	
SMDP 05 (Administration B.)	R-wires from bar pressing towards the Y-bar mouse inside the Panel	better bending, keeping sufficient air inbetween Cleaning!	
SDP 5/2	MCB 63 A at entrance point E-screw at incoming cable (shield) loose	Change to MCB 32 A Tighten the screw	done 30.9.99, ste
SDP 5/3	MCB 63 A at entrance point E-screw at incoming cable (shield) loose	Change to MCB 32 A Tighten the screw	done 30.9.99, ste
SMDP 06 (Library)	Y-wire from Isolator loose in the cable shoe at bar Screws have bad heads (slots not deep enough)	proper crimping changing the screws	
SDP 6/1	Isolator 40 A at entrance point Bakelite cover can not be removed	Change to MCB 32 A Cutting little bit smaller	
SMDP 07 + SDP 7/1 (Staff House type A)	Isolator 40 A at entrance point MCB 32 A at entrance of SDP Naked life-parts accessible R-wire from bar leading to ground and first floor completely burnt due to loose connection	Change to MCB 32 A Change to Isolator 40 A and shift towards the partition of SMDP Covering with Bakelite sheet new crimping and fixing at bar, taping	
SDP 7/2	Naked life-parts accessible	Covering with Bakelite sheet	

SDP 7/3	Naked life-parts accessible	Covering with Bakelite sheet	
SMDP 08 + SDP 8/1 (Staff House type B)	Isolator 40 A at entrance point MCB 32 A at entrance of SDP Naked life-parts accessible Earth-fault from switched line (bulb at basement), drawing approx. 4 A	Change to MCB 32 A Change to Isolator 40 A and shift towards the partition of SMDP Covering with Bakelite sheet Remove of the Earth-fault	wire not accessible
SDP 8/2	Naked life-parts accessible Cable not fixed with clamps inside the channel	Covering with Bakelite sheet to be fixed with clamps	
SDP 8/3	Naked life-parts accessible	Covering with Bakelite sheet	
SMDP 12/1 (Boys Hostel)	Isolator 100 A at entrance point System-Number according to documentation No. 13 (due to single Layout-plan)	Change to MCCB 160 A Changing the numbers in the documentation	
SDP 12/2	Isolator 40 A at entrance point	Change to MCB 32 A	
SDP 12/3	Isolator 63 A at entrance point no Bakelite cover, can not be inserted due to wiring	Change to MCB 63 A -	all MCBs are fingerproof
SDP 12/4	Isolator 63 A at entrance point no Bakelite cover, can not be inserted due to wiring	Change to MCB 63 A -	all MCBs are fingerproof
SMDP 13/1 and SDP (Girls Hostel)	similar to Boys Hostel System-Number according to documentation No. 12 (due to single Layout-plan)	Changing the numbers in the documentation	
SMDP 14 (School Building 5)	Isolator 80 A at entrance point	Change to MCCB 80 A	
SDP 14/1	Isolator 40 A at entrance point	Change to MCB 32 A	
SDP 14/2	Isolator 80 A at entrance point	Change to MCB 32 A	
SDP 14/3	Isolator 80 A at entrance point	Change to MCB 32 A	
SMDP 01 (Dining Hall)	provision for V- and A- meter Bulb-Lights as line indicators on the channel	removing the wooden provision for V- and A- meter changing with colored indicator lights, fused with MCB 6 A	
SDP 1/3 (Kitchen)	cable outlet to wood store not fused properly	connection through MCB 16 A	

10.2 TTC - Open Tasks

Following tasks have been discussed with Mr. Chetri and should be done:

- work according to action plan
- rechecking of the wiring (with self-manufactured test-box, see 10.10)
- measuring of the load
- improvement of the earth resistance (see 10.8)

10.3 RNR-RC - Notes discussed with fb and Pema

10.3.1 Connection to the Grid

It seems useless to relay on a proper and safe feeding point from D.o.P.

Conclusion:

- All installations under responsibility of D.o.P. shall be done according to their standard.
- Each cable coming from a feeder pillar or from a L.T. overhead line shall be fused with the proper rating at the entrance point
- Arrangements for the meters (box, location) shall be discussed on the proposals given in the report as early as possible

10.3.2 Structure of distribution system for generator supply

For the load points supplied by generator in case the main supply is not available no separate distribution structure is installed (as designed before). The same distribution structure will be used for main supply as well as for generator supply. But in case of generator supply part of the load will be switched off at the SDPs on each floor by a contactor.

Definition:

- Priority A means always supplied, by main supply or generator (earlier called G)
- Priority B means supplied only when main supply is available (earlier called M)

The arrangement of MCB's in the Panels shall always be in the same way, for instance A left, B right.

10.3.3 Layout of Panels

The Layouts of the panels must be shown in scale, at least approximately. Only on this base the contractor can be made responsible in case the arrangement of the apparatus and the spacing in-between them is not proper.

The sequence of RYB shall always be from the top to the bottom respectively from the left to the right (even though more line crossings result in the diagram).

10.3.4 Numbering

Numbers shall be given to each panel and circuit in such a way that every circuit can be identified by this number. Such a number has to be unique throughout the whole project.

This number shall appear in all documents (wiring layout, layout of panels, maintenance reports) as well as on the devices itself (MCB's, switches, sockets).

Proposal for Numbering and Naming of Distribution Panels

Short Name	Building	Floor	Contents
FP (Feeder Pillar)	Transformer Station	-	HRC-Fuses
MMB (Main Meter Box)	Generator House	-	Changeover-Switch
GP (Generator Panel)	Generator House	-	Bulk consumption meter
MDP (Main Distribution Panel)	Professional Block	Basement	Main Distribution for the Buildings of institutional buildings
SDP 11	Academic Block	Basement	Main distribution for the building and distribution for the related floor
SDP 12	Academic Block	Ground Floor	Distribution for the related floor
SDP 13	Academic Block	First Floor	Distribution for the related floor
SDP 21	Professional Block	Basement	Main distribution for the building and distribution for the related floor
SDP 22	Professional Block	Ground Floor	Distribution for the related floor
SDP 23	Professional Block	First Floor	Distribution for the related floor
SDP 31	Meeting Hall	Basement	Main distribution for the building and distribution for the related floor
SDP 32	Meeting Hall	Ground Floor	Distribution for the related floor
SDP 33	Meeting Hall	First Floor	Distribution for the related floor
SDP 41	Laboratory	Basement	Main distribution for the building and distribution for the related floor
SDP 42	Laboratory	Ground Floor	Distribution for the related floor
SDP 43	Laboratory	First Floor	Distribution for the related floor
SDP 51	Dormitory		
SDP 91	Staff House 1	Basement	Distribution for the whole house
SDP 92	Staff House 2	Basement	Distribution for the whole house
SDP 93	Staff House 3	Basement	Distribution for the whole house
SDP 94	Staff House 4	Basement	Distribution for the whole house
SDP 95	Staff House 5	Basement	Distribution for the whole house
SDP 96	Staff House 6	Basement	Distribution for the whole house

10.3.5 Number of Poles of Switch Gear

According to the common local standard where always all poles including Neutral wire are disconnected 2 pole MCB's will be put in for single phase circuits and 4 pole MCB's for 3 phase circuits. This has the following additional advantages:

- The Neutral wires of each circuit can be proper connected at the MCB's outlet terminal and therefore are assigned to the related circuit. Otherwise they will be all bundled at a Neutral terminals or even worse, twisted at a single terminal
- Heating up of Panels is reduced. MCB's will get warm because of the thermorelay. Placing of one Neutral without thermorelay in-between the MCB's is minimizing the heating up due to narrow clustered MCB's.

10.3.6 Fuse rating of power sockets

10.3.6.1 16 A power sockets, single phase

Even though the nominal current for these sockets is 15 A it is not advisable to use them at this maximum (approx. 3600 W). Earlier tests have resulted in burnt out sockets while charged with such a load.

Since heaters are not allowed at all during the first phase power sockets are fused with 10 A, allowing approx. 2300 W.

The wiring is carried out in 2.5 mm2 (or 3/20 SWG) which carries 16 A, i.e. MCB's can be changed in a later phase when the grid supply is sufficient and heaters are allowed.

10.3.6.2 *32 A power sockets, three phase*

Appliances with more than 3600 Watts need to be supplied in 3 phase. There are also other reasons to supply in 3 phase like use of 3 phase motors. Up to now no 3 phase appliances are in use at RNR, but provision is made.

To connect 3 phase appliances to the wiring following devices are possible:

32 A socket, Indian standard, 4 conductors (RYB = 3 Pin, E = metal case), carrying

10.3.7 Centralised Stabiliser or UPS

Not foreseen

10.3.8 Earth System

All buildings connected among each other with the armour of the supply cables

Connection to irons of reinforced concrete

Connection to the lighting protection system

Connection to water supply pipes

Connection between Neutral an Earth at MDP (and each entry point of a building)

10.3.9 Lighting protection system

Connection of roof (corrugated sheets) to the Earth

Lighting arresters ?

10.3.10 Earth leakage protection

10.3.11 Various

- Instead of TP (three pole) write 3P, or 3PN if with Neutral or 3PNE if With Neutral and Earth
- Instead of SP (three pole) write 1P, or 1PN if with Neutral or 1PNE if With Neutral and Earth
- Smaller or other symbols for switch or bulb holder
- Show 5 A sockets in the layout drawings of the light circuits and assign the circuit clearly

10.4 Remarks on Voltage Fluctuations

As stated already in earlier reports voltage fluctuation is a serious problem causing damages but can be influenced hardly by the customers.

10.4.1 Voltage Measuring

The voltage in a distribution system can be measured in-between phase-lines (R-Y, Y-B, B-R) or in-between a phase-line and the neutral-line (R-N, Y-N, B-N). The voltage in-between phase-lines (also called voltage line to line or three phase voltage) is theoretically always 1.732 times larger then the voltage measured between phase-line and neutral-line (also called voltage line to neutral or single phase voltage).

Single Phase $V_{\text{Line-Neutral}}$	Three Phase $V_{\text{Line-Line}}$
220 V	380 V
230 V	400 V
240 V	415 V

10.4.2 Nominal Voltage and Tolerances

Whereas in Switzerland and some other European countries the nominal voltage earlier was 220 / 380 V and has been increased to 230 / 400 V according to the standard of the International Electrical Committee (IEC), in the Indian standard the voltage is not uniform. Some nameplates of single-phase appliance show a value of 240 V but some warning signs show values up to 440 Volts. Observations of newer appliances and transformer stations show that the standard of IEC is introduced.

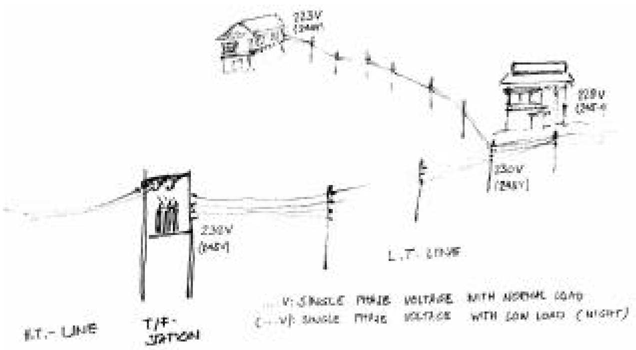
For the future the nominal voltage can be taken as **230 V** for single phase and 400 V for three phase but there are still some transformers in use with other transforming ratios.

Usual tolerances are +/- 10 %. The therefore acceptable voltage range is given in the table beside. Within these tolerances, even if they seem high, nothing should happen to appliances.

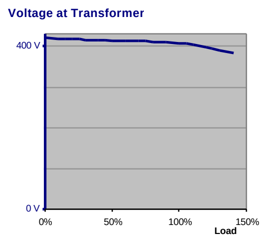
nominal Value	- 10%	+ 10%
230 V	207 V	253 V
400 V	360 V	440 V

10.4.3 Voltage drop and “normal” fluctuations

Due to the voltage drop along a distribution system the voltage decreases from feeding point towards the consumer. And because the voltage drop itself is depending on the load (drawn at any point of this distribution system) changes can not be avoided.



Also transformers do not have a stabile voltage. They are designed for use with nominal load and do supply at this load a voltage slightly higher than the nominal voltage of the grid to compensate certain voltage drop on the distribution system. So at night time, when only a few bulbs are switched on, the voltage reaches extremely high values also at consumers far away from the transformer station because of minimum voltage drop (transformer voltage offloaded 245 / 420 V). All the above mentioned



occurrences can cause disturbance but do not lead to voltages far out of any tolerances and should not lead to damages.

At the transformer the value of the low tension can be adjusted stepwise. This would help to lower the voltage at night time, but leads on the other hand to a lower voltage at customers far away. To improve the situation, more transformer stations should be built to have shorter and more equal distances to the customers.

10.4.4 Heavy Voltage Fluctuations

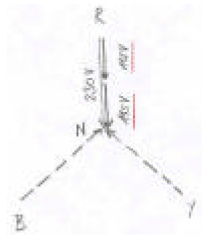
Sometimes it happens that the voltage collapses (to values of 50 % or less) or even worse, getting high and higher. These cases are always caused by problems in the distribution system.

Cause 1: Short Circuit

Somewhere in the grid a short circuit draws a high current but does not blow the fuse. At the short circuit point, the voltage becomes zero, and on the way towards this point accordingly (any voltage between 0 ...200 V instead 230 V)

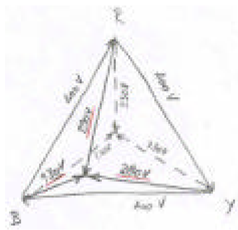
Cause 2: One Fuse blown on High Tension

If one fuse is blown at high tension line, the two remaining lines are working like a single phase system and the voltage is shared equally to two phases (voltage approx. 115 V instead 230 V).



Cause 3: Interruption of Neutral

The line-voltages of the three phase system can be seen as a regular triangle and the single-phase-voltages as a star with its centre point in the centre of the triangle. If there is no Neutral connection, this point can be anywhere within this triangle and pulling the single-phase-voltages like rubber-bands (voltage between 0 ...400 V instead 230 V).



10.4.5 Risks

The life of bulbs is shorten approximately by the half if the applied voltage is 10 % higher than nominal voltage.

Tube lights do not start anymore if voltage is lower than 190 V. Because the starter tries always to start the tube (and starter) gets damaged. The iron core of the choke has more losses with higher voltage and tends to burn out like any magnetic circuit (motors).

10.4.6 Remedial Actions

For critical appliances like computer equipment stabilisers are recommended. In case of heavy voltage fluctuations it is even recommended to switch of the main-switch of the supply and to inform D.o.P.

10.5 Connection to the Grid

Still the quality and standards of D.o.P. are not really reliable. May be communication between D.o.P. and the construction office is difficult. Few samples:

After many requests for supply of the RNR-RC Jakar D.o.P. agreed to supply at best 10 kVA. The transformer installed has a capacity of 25 kVA (nominal current at secondary side 35 A) and is fused with 400 A! This transformer is not protected against overload at all!

At TTC staff houses meters could not be installed inside the house like at NRTI because of free access for meter reading. At the time of this information all provisions have been made to install the meter in the distribution panel (pipe laying, space for meter in panel). Extra work and adaptation are necessary now.

At TTC, request was placed for a transformer of 250 kVA with possibility to extend with an other 250 kVA unit. Finally a 1000 kVA transformer is installed. That's fine from point of load capacity but the short circuit current is now 32 kA instead of 8 kA.

Conclusions:

- The principle of connection with the related topics (size of wiring, fusing, place of meter, access to meter) should be discussed early with D.o.P.
- The design should include a protection system at the entrance point to have in any case a secure system, regardless the execution of D.o.P.

10.6 Remarks on short circuit current and breaking capacity of switch gear

Regarding the short circuit current two values must be considered.

Minimum: The short circuit current should be at least that high to blow a fuse in useful time.

Maximum: The switch-gear should withstand such a high current and should be able to open the circuit in case of a short circuit.

That means, close to transformer stations (specially with large transformers) the breaking capacity of the switch-gear must be high (MCCB, HRC-fuses), whereas at the end of the distribution system after long cables and wiring MCB are sufficient.

Samples:	Transformer Size:	25 kVA	Short Circuit Current:	720 A
	Transformer Size:	1000 kVA	Short Circuit Current:	29000 A

10.7 Remarks on voltage drop on distribution cables

Cross section area of cables and wires are defined according to rules and regulations in such a way, that usual lengths up to approx. 100 m do not lead to significant voltage losses.

10.8 Connection between Neutral and Earth

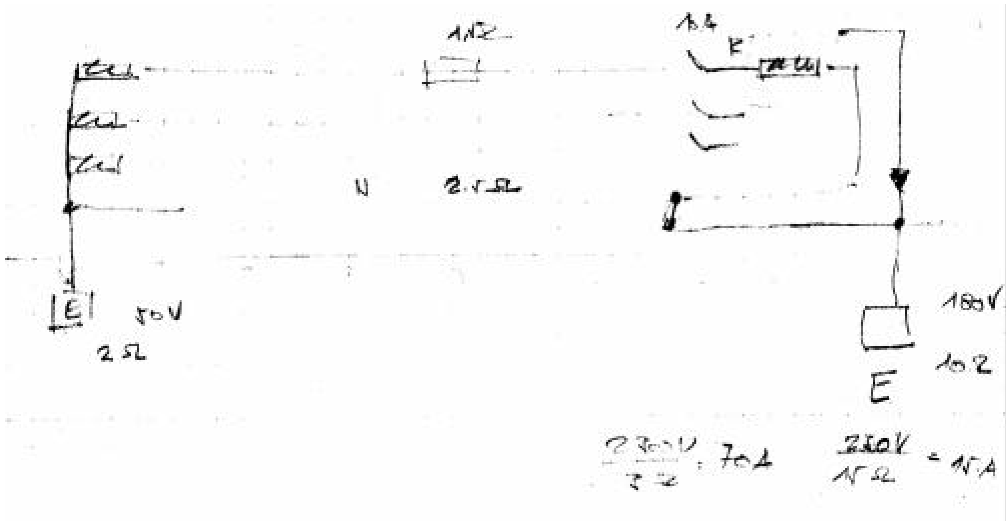
The protection system applied according to Indian standard is **TT** (Earth Protection). If the earth is bad, i.e. has a high resistance, the current in case of an earth leakage will be only a few Amps an will not be sufficient to blow the fuse.

In Europe usually the **TN** protection system is applied where a connection is made between Earth an Neutral. This leads to a much lower earth resistance, hence the current is much higher and the fuse is blow immediately.

It is not advisable to mix up these systems but in such close institutions like NRTI or TTC it will have only advantages if such a link is made between Earth and Neutral.

This link should be made only at one single point (at Main Distribution Panel). Before inserting, the voltage must be measured (max. 1-2 volts) and current flowing over this link should be observed later on.

In the following sample, only 15 A will flow with system **TT**, what is not enough to blow a 16 A fuse. But 70 A will flow if system **TN** is applied.



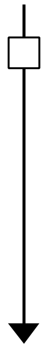
10.9 TTC - Instruction

How to Distribute Electricity

rule # 1

always protect a line at the starting point with a properly rated protective device

Conductors (wires, cables, bars, coils) are heated due to the **current** flowing in them. (flow of electrons)

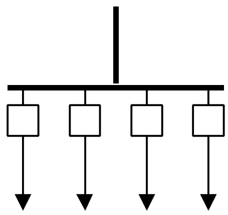


Current A	Aluminium solid mm^2	Copper solid / (str) mm^2	Copper stranded Nos / SWG
6	1.5	1	-
10	2.5	1.5	3 / 22
16	4	2.5	3 / 20
20	6	4	7 / 22
25	10	6	7 / 20
32	16	10	7 / 20
40	16	10	-
63	25	(16)	-
80	35	(25)	-
100	50	(35)	-
125	70	(50)	-
160	95	(70)	-
200	120	(95)	-

Sample: a copper wire 3 / 22 SWG must not be fused higher than 10 A

rule # 2

wherever the cross-section area of the line is reduced protecting devices have to be put in

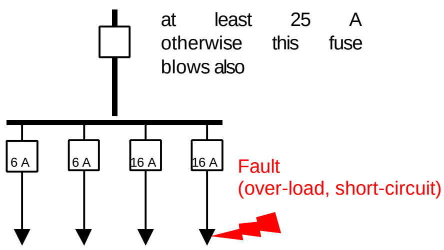


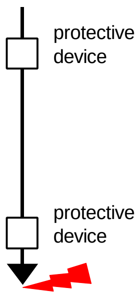
protective devices rated according to rule # 1

rule # 3

protective devices should switch off only the faulty part

to ensure this: choose protective devises by a factor 1.6 smaller (bigger) than the last one in sequence





do not put protective devices of the same rate into the same line (both will blow)

if you reduce the rate of the second one, you reduce the load capacity of the conductor unnecessarily

practical application

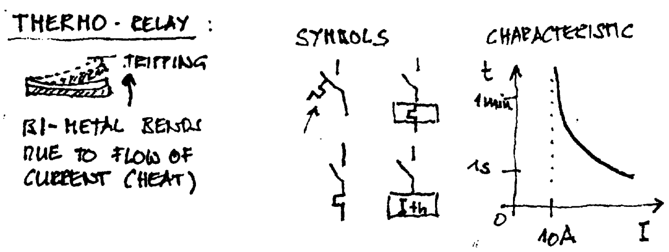
Protective Devices

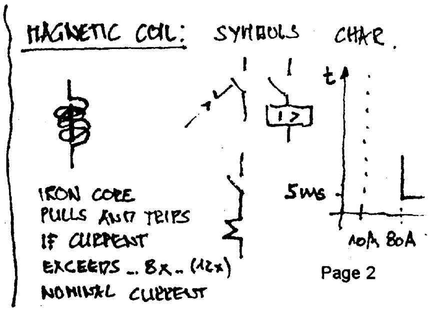
Name	Description / Size	Symbols	Breaking Capacity	Remarks
Kit-Kat fuses	Ceramic Holder with replaceable fuse wire from 6 A to 160 A ...	16A	unknown, approx. up to 5 kA	ok for simple wiring **if well maintained**
HRC-Fuses 400A HRC-Switch/Fuse – Unit	Ceramic cartridges filled with sand with holders from 6 to 630 A Fuse-Holder combined with a switch	HRC 63A HRC 63A	up to 100 kA	very safe as long as not manipulated replacement expensive
MCB Miniature Circuit Breaker	Tripping device with thermorelay (overload) and magnetic coil (short circuit) from 6 A to 63 A 1P, 1PN ... 3PN	L N 16A	6 kA ... 10 kA	no replacement needed while tripping
MCCB Molded Case Circuit Breaker	Tripping device with thermorelay (overload) and magnetic coil (short circuit) from 40 A to 1600 A ... 3P, 3PN	R Y B 160A	15 kA to 40 kA ... THERMORELAY MAG. COIL	for main switches near transformer stations and main panels where short circuit current is high expensive

Switches, Isolators (non-protective device)

Some of those devices look like MCB's but do not have any automatic breaking device in!

Name	Description / Size	Symbols	Breaking Capacity	Remarks
2 pole Gang-Switch usually combined with Kit-Kat fuse L N 4 pole Gang-Switch	Switch made with iron clamp from 16 to 63 A ...	L N L N WITH KIT-KAT		ok for simple wiring **if well maintained**
Isolator	Looking like MCB, some in black case from 40 to 100 A ...	R Y B N		at entrance point of panels

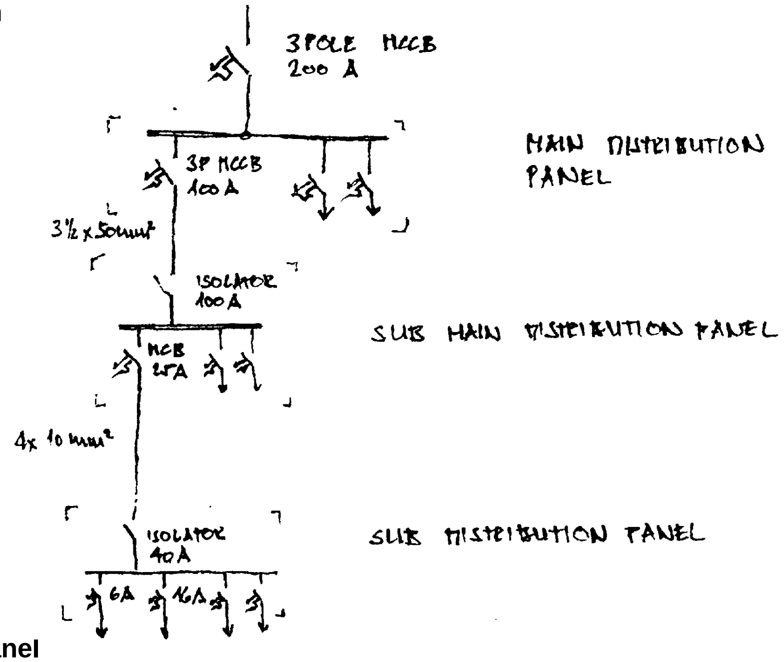




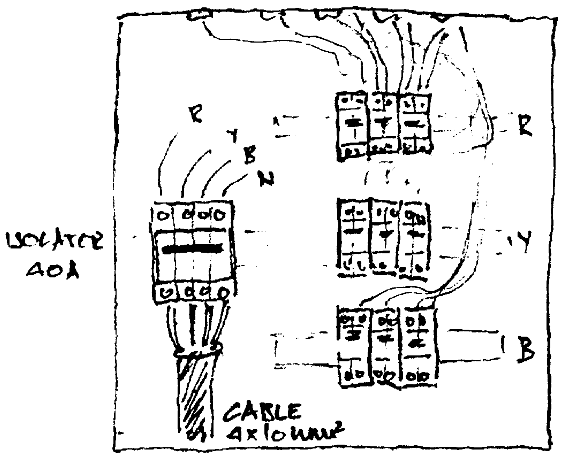
TTC / 27.10.99, Ste

Page 2

Sample of Distribution System



Sample of Sub-Distribution-Panel



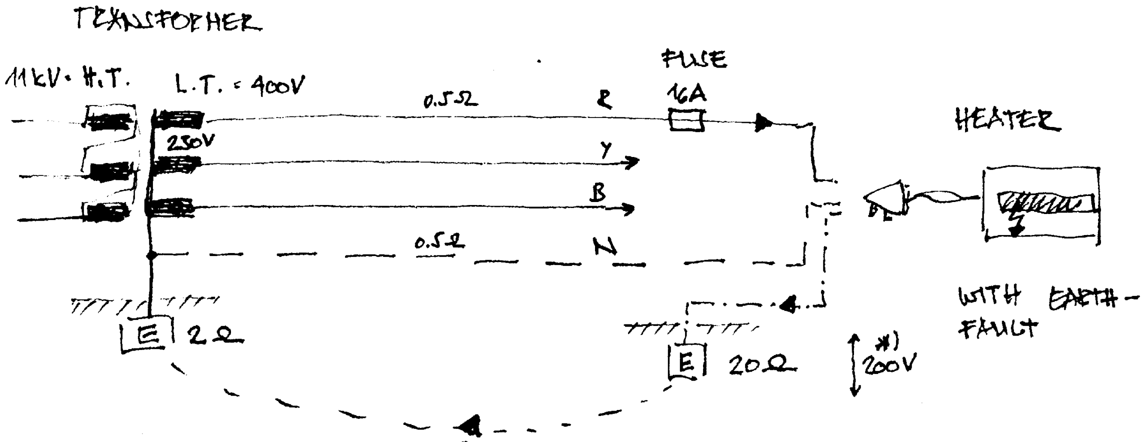
Rules and Regulations

The above given ratings are according to the ISI (Indian Standard Institute). To security in buildings constructed by Helvetas following decisions were

- No Kit-Kat-fuses are used, also HRC-fuses are
- cross-section area of wiring 1 step bigger than the common
- 15 A power sockets are fused with 10 A
- 2 pole MCB's are used for single phase circuits (to disconnect completely and to Neutral-
- 4 pole Isolators are used to disconnect the Sub-Distribution-Panels at there completel

The Bhutanese regulations are demanding steel pipes for conduit wiring (surface an Since this is can cause serious security problems (isolation of wires scratched at sha pulling) conduit wiring is done with PVC- or PE-

protection through Earth



LEAKAGE CURRENT $= \frac{\text{VOLTAGE}}{\text{RESISTANCE}} = \frac{230V}{23\Omega} = 10A$

$\boxed{\text{THE FUSE WILL NOT TRIP !!!}}$

→ KEEP RESISTANCE OF EARTH AS LOW AS POSSIBLE !

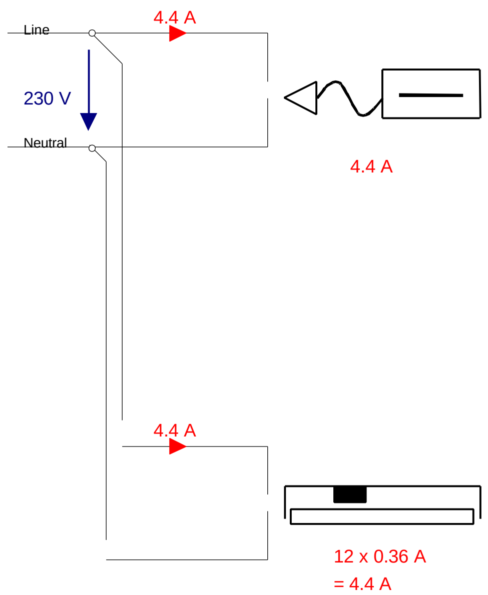
∴ → DO NOT REDUCE SIZE OF EARTH · WIRE

*) VOLTAGE DROP ACROSS EARTH = 200 V
AS LONG AS THE LEAKAGE·CURRENT IS FLOWING

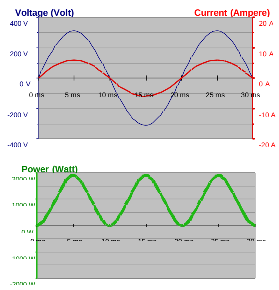
→ ALL PARTS CONNECTED TO EARTH ARE
ON 200V !

Introduction to Single Phase System

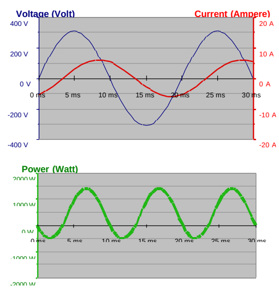
Apparent Power = Voltage x Current



Heater 1000 W
Apparent Power =
230 V x 4.4 A = 1000 VA
Powerfactor =
1000 W / 1000 VA = 1



12 Tubelights 40 W each
Apparent Power =
230 V x 4.4 A = 1000 VA
Powerfactor =
480 W / 1000 VA = 0.48



Total		
Power:	1000 W (Heater) + 480 W (Tubelights)	= 1480 W
Apparent Power:	1000 VA (Heater) + 1000 VA (Tubelights)	= 2000 VA
Power Factor:	1480 W / 2000 VA	= 0.74

Any conductor (cable, wire) is heated due to flow of **current**

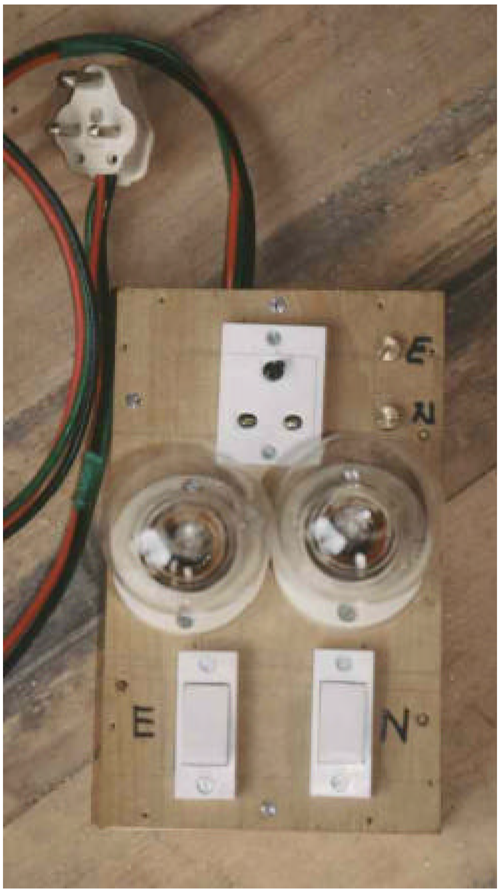
Introduction to Three Phase System

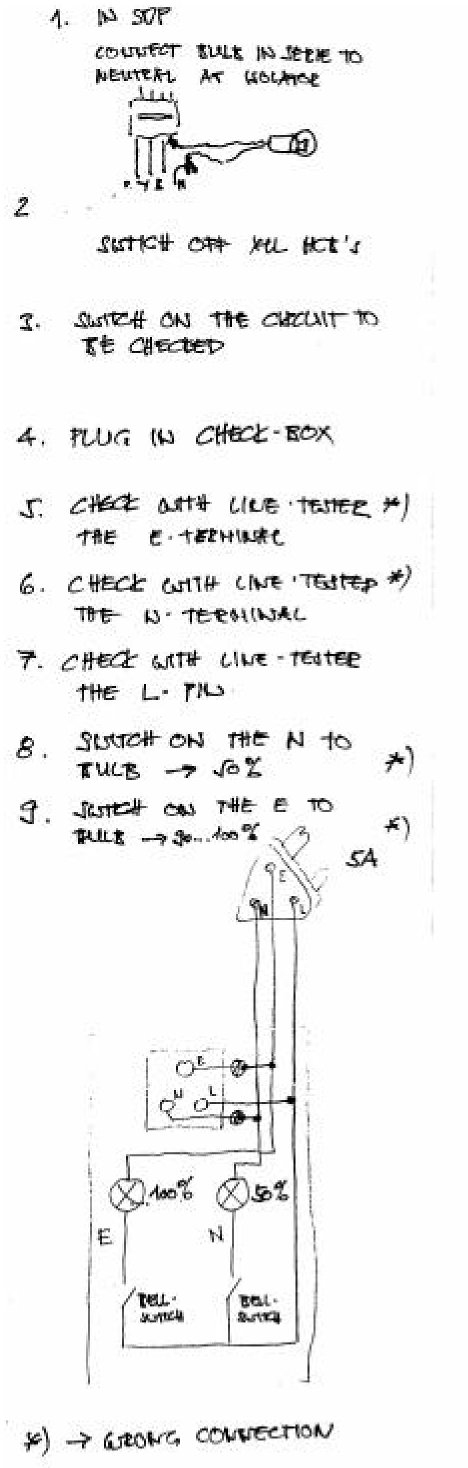
The voltage in a 3 phase distribution system can be measured in-between phase-lines (R-Y, Y-B, B-R) or in-between a phase-line and the neutral-line (R-N, Y-N, B-N). The voltage in-between phase-lines (also called voltage line to line or three phase voltage) is theoretically always 1.732 times larger then the voltage measured between phase-line and neutral-line (also called voltage line to neutral or single phase voltage).

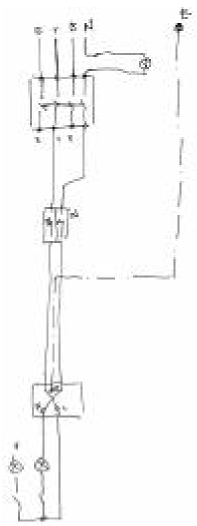
Single Phase V_{Line}	Three Phase $V_{Line-Line}$
220 V	380 V
230 V	400 V
240 V	415 V

10.10 Checking of Wiring

With usual testing equipment it is not possible to check proper connection of neutral and earth. Therefore manufacturing of a test box as shown in the following picture and diagram is recommended. The checking procedure is also given:



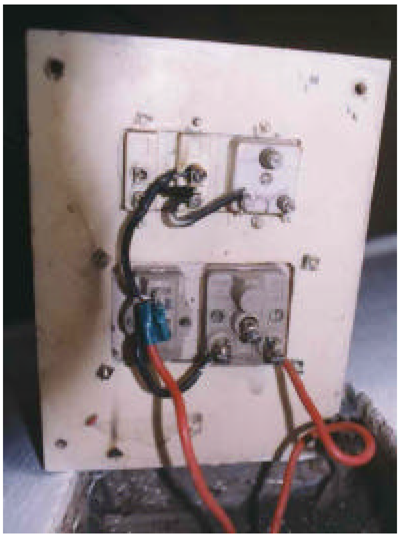




10.11 Some Samples - Usual Standard

10.11.1 Outlets at any Office

Because the upper socket was not working even switches have been changed to all possible combinations of positions, and at the lower one the protection shutter did not open, I got curious and checked it from the backside:

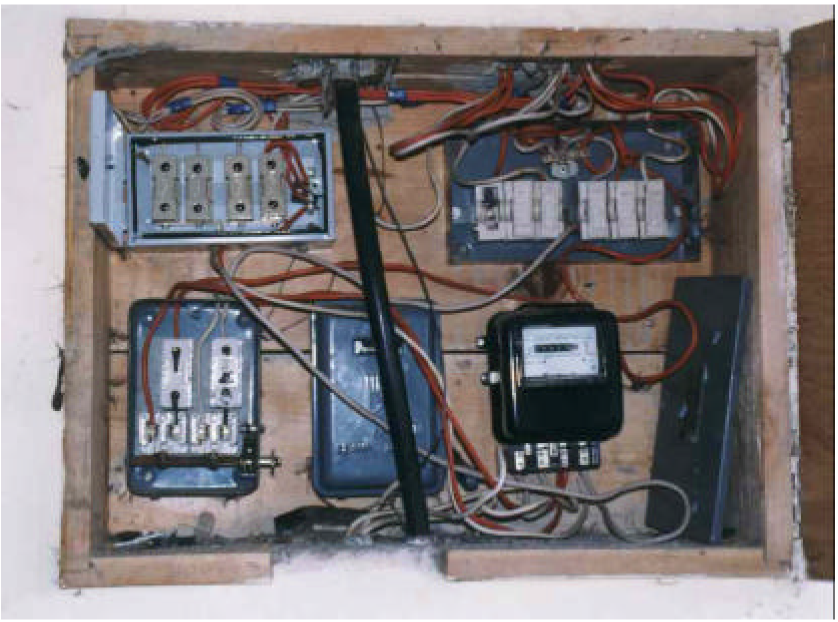


No line wire connected to the upper socket makes it very safe but useless!

No earth protection wire connected makes it dangerous!!!

(Office is known to the author)

10.11.2 Distribution Panel at any Office



10.11.3 Cable Tree

View from my hotels window

Because the cable coming from the left side was to short to reach the connection box with terminals at the pole, wires are twisted outside.

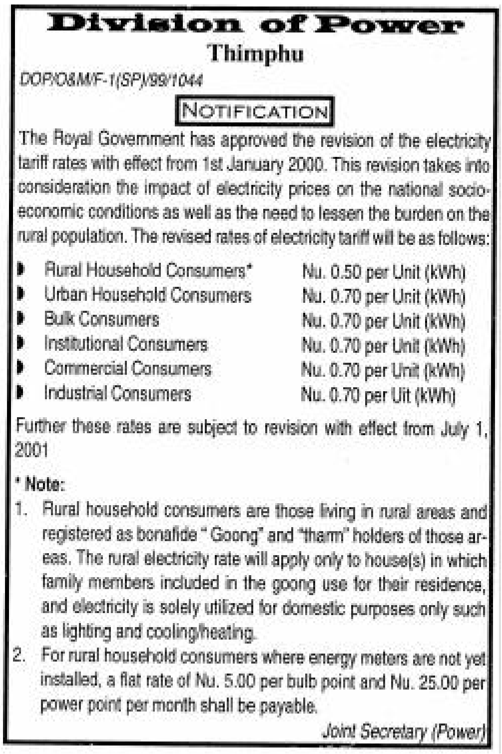
10.12 Prices of Electricity

1994:

1kWh = 0.4 Nu x1 sFr / 22 Nu = sFr. -.018 /kWh

The rates will increase beginning of 2000 for urban Household Consumers:

1kWh = 0.7 Nu x1 sFr / 28 Nu = sFr. -.025 /kWh



Division of Power

Thimphu

DOP/O&M/F-1(SP)/99/1044

NOTIFICATION

The Royal Government has approved the revision of the electricity tariff rates with effect from 1st January 2000. This revision takes into consideration the impact of electricity prices on the national socio-economic conditions as well as the need to lessen the burden on the rural population. The revised rates of electricity tariff will be as follows:

Rural Household Consumers*	Nu. 0.50 per Unit (kWh)
Urban Household Consumers	Nu. 0.70 per Unit (kWh)
Bulk Consumers	Nu. 0.70 per Unit (kWh)
Institutional Consumers	Nu. 0.70 per Unit (kWh)
Commercial Consumers	Nu. 0.70 per Unit (kWh)
Industrial Consumers	Nu. 0.70 per Uit (kWh)

Further these rates are subject to revision with effect from July 1, 2001

*** Note:**

1. Rural household consumers are those living in rural areas and registered as bonafide " Goong" and "tharm" holders of those areas. The rural electricity rate will apply only to house(s) in which family members included in the goong use for their residence, and electricity is solely utilized for domestic purposes only such as lighting and cooling/heating.
2. For rural household consumers where energy meters are not yet installed, a flat rate of Nu. 5.00 per bulb point and Nu. 25.00 per power point per month shall be payable.

Joint Secretary (Power)