THE SIGNIFICANCE AND EVALUATION OF ALTERNATIVE POWER SOURCES FOR TELECOMMUNICATION SYSTEMS

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ABSTRACT

During the latest 5 - 10 years of time as a result of the energy crises in the early 70:ies great interest has been focused on the development of alternative power sources all over the world. Both large scale alternative power systems and small scale systems for powering telecommunications equipment have been developed, tested and put into operation.

The interest for small scale systems is not only initiated from the general energy point of view but mainly from the pronounced need and interest to develop rural communications in a broader sense. This includes powering single radiochannel systems, navigation aids and other industrial communications systems at remote sites and offshore.

The attraction of alternative power is the reduction of investment and operation cost in comparison to older technical systems. The paper summarizes todays trends and technical experiences from testing and operation, and give an evaluation of the market development significant for telecommunications. Some aspects and comments on the influence of the use of new inventions and technologies on the historical development in general and in the field of telecommunications in particular are also given.

INTRODUCTION

In the years of energy crises, during the early seventies, a great interest focused on the development of alternative power sources all over the world. Now after more than 10 years of development and testing, some results of this work can be summarized.

It has been combined with great difficulties, both technical and economical to prove large scale alternative power systems competitive. A great number of prototypes for both wind and solar power has been built, of which only a few have become commercial.
In California on the American Westcoast a kind of commercial alternative power production has been established thanks to great tax reductions and favourable wind conditions. Especially the windfarms of the Altamont Pass (fig. 1) have become famous (7).
They consist of large number of windgenerators in the range of 100 kW - 300 kW. There are both horisontal axis and vertical axis machines in these windfarms.

In the field of powering telecommunications equipment however an other situation of competition is to be found. Especially at remote sites for radiolinks etc, the conventional mains connection is not feasible because of the high cost for the pole line to reach the site. Also the

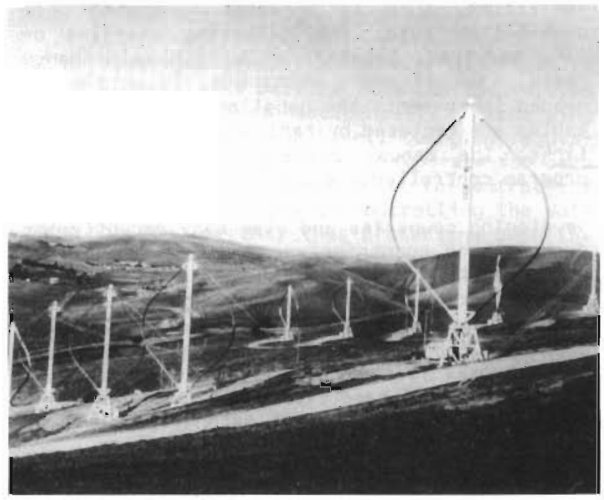


Figure 1. The windfarms of the Altamont pass.

power consumption is fairly low ranging from just a few watts to some hundreds of watts which today can be produced on site with photovoltaics or windgenerators to a lower investment cost than the pole line at distances from 3-5 km.

In earlier years continously running diesels often were selected at such sites. However, high operation costs in connection with these systems has made the alternative power sources more competitive.
For powering of rural telephony alternative power sources have a great potential.

RURAL TELEPHONY

Good telecommunications in rural areas (5) are a prerequisite for the expansion of trade and industry outside urban regions. They also improve the possibilities of providing social services for the people in these areas. Extension of the telephone network in rural areas is a profitable investment from the point of view of national economy. This view is often opposed by more short-term business economy arguments, for example that the investment cost per subscriber is high and the income low. In many cases these arguments are correct, but they do not apply for the overall profitability over a long period of time.

The situation in rural networks is different in industrialized and developing countries.

In industrialized countries automatization has usually been completed. Today such countries have relatively well branched telephone networks consisting of small terminal exchanges of the step-by-step or crossbar type. The transmission media are mainly open wire and pair cable on pole lines. Small carrier systems with 12, 24 or 60 channels on pair cable or radio relay links can occur, but low frequency circuits over loaded pairs are the most common form of transmission.

Alterations in these networks often mean replacing old equipment. The main reason for replacement is the need for improved transmission quality, others are that existing exchanges cannot handle new telephone facilities, such as services initiated from push-button sets, toll-ticketing charging or data services, together with high maintenance costs, lack of spare parts etc. To obtain the needed improvments the usual open wire and pair cables are replaced by radio relay links and PCM links. The manual exchanges are changed to program controlled electronic exchanges.

Developing countries and also many recently industrialized countries are faced with the task of automatizing the manual network and extending the network to new places where telephone services have not previously been available. In these countries the exploitation of new technology in the networks is therefore not tied to existing equipment to the same extent. It is then possible to skip a generation of technological development and let the new technology govern.

Power supplies for rural communications range from the usual mains connected DC power supply with rectifiers, lead-acid batteries and standby diesel-driven generators to the innovative alternative power sources such as single or hybrid systems with wind-driven and photovoltaic generators together with fuel consuming generators (FCG).

The ability to generate alternative power on site is a prerequisite for the extension of a rural communication system, where mains power is not available. At these sites the cost of power supply will be a predominant factor in the cost of providing the telecom service. Power supply cost has long been the limiting factor preventing the penetration of the much needed services to rural communities. The new alternative power sources have made it possible to plan and extend the rural network transmission lines in new and more cost effective routes as mains connection or costly access roads are no more prerequisite, maybe reducing the total number of sites needed in a transmission line. This contributes to reduced costs and improves the penetration of telecom to rural communities.

With the high rate of change in the development of telecommunications facilities it is much conceivable that the rural telecommunications network may be required to carry high quality voice and different data communication facilities. This development towards digital transmission causes an increase in the power consumption in comparison with the old passive transmission and exchange technology.

As the investment cost for the alternative power supply systems is high, and at the same time the power demands tend to increase, it is of vital importance to closely watch the ultimate power demands in the design of a power supply for rural communications. It needs to match the requirements of todays communications system as well as those for the future.
In the design of a power supply system for rural telecommunication the system-cost requires a most critical examination. A result of such an examination leads to the conclusion that the most promising method to counteract increasing power cost due to digitalization is to use the concept of hybrid systems in the design of alternative power for telecommunications.

A PRESENTATION OF THE REVISED CCITT HANDBOOK ON PRIMARY SOURCES OF ENERGY (3)

The committe that revised the CCITT handbook, GAS 4 expressed its mandate as the following:

"To study the characteristics, availability and economics of all primary sources of energy which could be applied to the problem of supplying power to telecommunication installations in areas where it is not practical to obtain supplies from an electricity distribution network".

"To produce as a result of this study guidance material on such of the sources and systems which are found to be practical and available. Such material to deal in detail with the technical characteristics and economic factors."

The handbook covers all to telecommunications relevant power sources of today. It has been written with an open minded attitude to future developments, considering that the handbook most probably should bridge a period of about 20 years.
The table of content below, gives the complete list of the power sources which have been considered practical and available of the GAS 4.

Chapter 2 and 3 of the handbook covers the characteristics of the different power sources and their single systems. Chapter 4 is a new chapter and describes combined or hybrid systems. This will especially be commented below as it may be considered the most important chapter of the handbook. The most important paragraph of chapter 4.1 concerns the battery (4.1.4.). This paragraph is quoted below:

4.1.4 FEATURES COMMON TO ALL HYBRID SYSTEMS

4.1.4.1 The battery and its control system

The processing and control equipment of a hybrid power system must perform the following functions to assure safe, efficient and reliable operation and low maintenance:

- monitor the state of charge of the station battery in order to start up the fuel consuming generator only when necessary to limit its running hours and reduce maintenance.
- protect the battery from overcharging and thus reduce water consumption.
- protect the battery against deep discharge
- protect the system against overvoltage.

The storage battery state is monitored by a threshold electronic device which delivers four categories of information:

- battery partially discharged (before the automatic start up of the FCG)
- battery discharged near a preset minimum
- battery recharged to near full capacity (say 90%)
- battery fully charged

Because at low rates it is difficult to monitor accurately the state of partial discharge of the battery, suitable devices and control systems should be provided. These control devices are activated when certain thresholds are reached and they are established in conjunction with the supplier of the battery. Figure 2 illustrates

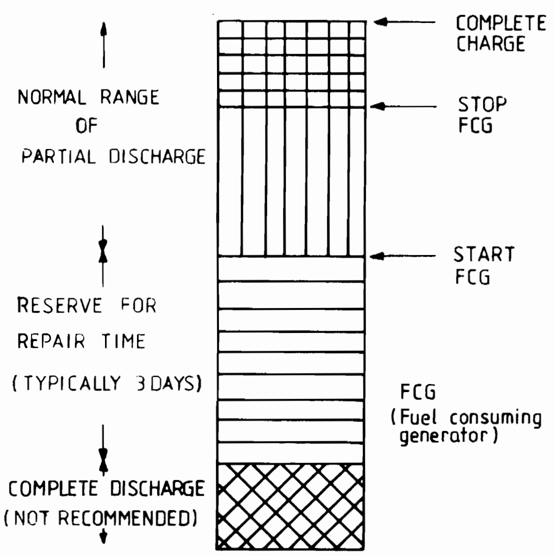


Figure 2. Battery functions.

the way in which battery capacity is allocated for different functions.

The operating company should establish the threshold at which the fuel consuming generator is automatically started. In order to limit the number of starts and to limit running costs, it must be started only when necessary.

If necessary, a circuit breaker or other device can disconnect the battery from the load system to prevent it from accidentally discharging beyond a preset minimum level. Charging regulators in the system are usually separate for each energy source. The main task is to control the charging of the battery by controlling the voltage and the current, thus protecting both the battery and the energy source. The regulators can, in certain cases, be controlled from a common device.

Information and alarm devices are needed to provide:

- fully charged battery information
- startup failure of the FCG
- battery discharged information
- alarms and information concerning the fuel converter, related primarily to its start-up capability (state of start-up auxiliares) and to prolonged operation (fuel, oil levels etc...).(End of quotation)

Comment

The station-battery is a very important part of any photovoltaic and wind power system and as a comment to the above paragraphs I would like to discuss the discharge characteristics of a lead acid cell fig. 3.

In all power systems with photovoltaic and or wind generators a big station-battery is included and its discharge will be low indeed at times. The reason is that during periods of insufficient solar and wind conditions the battery will supply the short fall to the load. During these periods the discharge current is low and the voltage discharge curve flat. A lower discharge rate than the indicated 240 h would be predominant. The battery can in worst cases be discharged nearly up to twice its nominal 10 hours capacity repeatedly, maybe without detection. This would increase the ageing process and shorten the battery life. The conclusion is that a threshold electronic device, which can accurately monitor the battery state of partial discharge for delivering start up information and alarms on the battery is urgently needed in a hybrid power system. This device must have an Ah-counting facility-detection. Voltage detection alone would be insufficient. The Ah-counting facility would most probably be built in micro processor-technique.

In paragraphs 4.2 and 4.3 the wind and photovoltaic generators are combined with fuel consuming generators respectively. In 4.4. both the wind and photovoltaic generators together are combined with a fuel consuming generator. This system have interesting inherent characteristics which

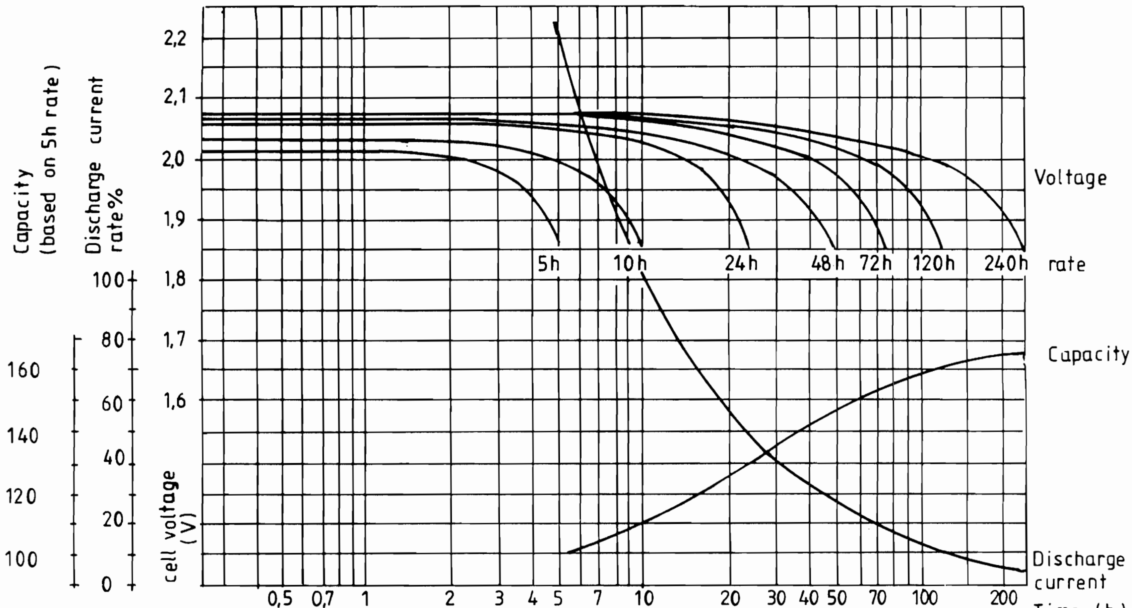


Figure 3. Discharge characteristics of a lead acid cell

are summarized below.

By combining solar, wind and diesel generators their specific advantages combine in a for power production prosperous way. They have a complementary nature in short and long term perspective. This complementary nature increases the continuity of supply compared with a non-combined system and smoothes out the variations in the power supply from the separate sources. Another typical characteristic for solar and wind hybrid systems that can be utilized is that the tilt of the solar modules can be chosen to optimize for the summer period or for the season when the wind resource is low. This increases the total energy production per module and reduces the required number of solar modules.

With a startup-reliable fuel consuming generator in the system the need for precise meterological sizing data is reduced. The safety margins in installed peak power capacity normally required to cover for extreme weather variations can be reduced in the solar and windpower plants.

When all these prosperous factors are added the battery capacity may be chosen smaller as the safety and continuity of supply has been increased. For loads higher than 300 W, especially in temperated areas of the world, combined power systems are probably the most cost effective systems.

By the use of computerized sizing a tight dimensioning would be possible. It would be recommended to check the sizing on site with a datalogger for approximately one year of operation.

EXPERIENCES OF OPERATION

Photovoltaic power

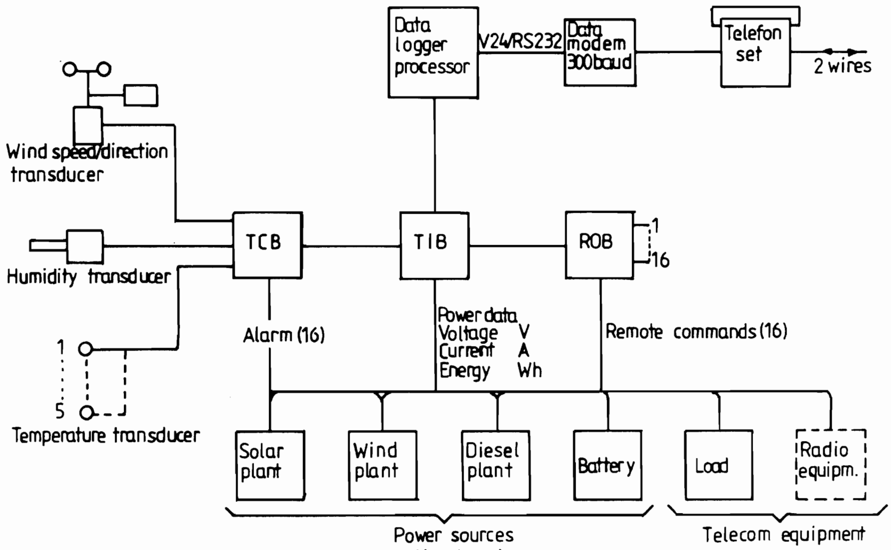
Photovoltaic power systems have generally shown excellent results in operation, but there have been difficulties in sizing and in performance due to local site variations in solar radiation, which might well differ a lot from the data used in the sizing.

According to Canadian experiences (2) the following problems can be quoted. In the sizing of the arrays the manufacturer had not sufficiently considered the extreme deviation from average radiation that occurs in a 5-7 year cycle. As a result the charge of the batteries were found poor, and complete failures during 2 winters occured. The reason for this was not solely an insufficiently sized solar array but also problems with the batteries. In the Canadian case the batteries were stored in cold housing with the lowest temperatures between -5°C -30°C. These low temperatures also occured during the lowest solar radiation-period. The problem that contributed the most to the failures was that the cold batteries started gasing early during charge and in consequence had a low charge acceptance. When they during the winter occasionally had opportunities to be recharged the current only produced gas. The reason for the gasing was proposed to be the stratification of the acid in the cells. As a result the lifetime of the batteries was radically reduced, because of an too early sulphate build up. The Canadians propose a 4-6 hours boost charge with a portable generator in the winter to solve the problem.

In addition to the Canadian experiences Ericsson has had a similar experience directly related to stratification. During the extremely hard winter this year -85 the batteries in one of our prototype systems froze on top. This was clearly a result of the stratification, as the acid specific gravity on top of the cells was very low.

From the Australian Telecom (4) there has been reported similar experiences. They report the importance of experience and engineering judgement combined with computer sizing of systems. The later can only give rough ideas, that never can take into account the local circumstances. The stations are often spread over large areas with many different local conditions. There are problems in knowing, if the desired 50 % minimum battery state of charge is obtained in reality, as it is difficult to

The "Erigen" Data logger



TCB = Transducer connection board
TIB = Transducer interface board
ROB = Relay output board

Figure 4. System block diagram Erigen Data logger

monitor the performance. The reason for this difficulty, is that the stations are remote and not too often visited. It is not satisfactory only to note, that the system is still on the air. The battery charge could as well be near zero in the winter and as a result, it will not return to a fully charged state in the summer. This would result in a faster battery ageing and a system failure in the following year.

The system performance is susceptible to array size, and a 10 % change in solar array capacity or radiation can mean the difference between a fully charged and half-charged battery. A solution of this problem could be a long term monitoring and if necessary resizing of the system. One feasible correction of a not properly dimensioned system could be to increase the size of the solar array, which is simple due to the high modualarity of solar panels.

Costly oversizing need to be pratised to secure for the above mentioned risks and to cover for the 5-7 years extreme solar radiation minimas. There seems to be two options to use in order to secure safe operation. One is to individually monitor the systems performances for a long period and to correct the dimensioning afterwards. The other is to introduce a fuel consuming generator thus forming a hybrid system.

An example of the first mentioned option is the Erigen datalogger developed by Ericsson (fig.4) which is especially designed to monitor solar wind and diesel hybrid systems. It registers and processes information of the power system performances.
The energy produced and consumed is registered in kWh. Battery voltage and battery capacity state of charge is continously monitored. Dieselgenerator running hours and numbers of startups are registered. Transducers for environmental data such as outdoor and indoor temperatures, windspeed, wind direction and relative humidity can be connected.

The datalogger can also be equipped to execute remote commands such as different start, stop and resets and supervise other equipment.

The second option can be illustrated by the Erigen Mini-diesel which is a very small and simple highly reliable dieselgenerator with DC output and unique safe start-up system. It is especially designed for solar and wind plants and can be installed in a practical container with integrated fueltank.

Windpower

Reports on windgenerators are mainly focused on the reliablility problem of the windgenerator itself and the difficulties with its long term good functioning.
Telecom Australia (1) has a long experience of windgenerators in their network. They have some 50 machines in operation. The problems they have had are much related to the need for continuous maintenance to keep them in operation. The windgenerators are located at remote sites, often with rough climate conditions, and seldom visited. The windgenerators need to be serviced up on the top of the mast in all weather conditions i.e. in the actual weather for the service visit. This means that at difficult locations the service routines are often neglected by the personnel in bad weather and the windgenerators usually fail due to bad upkeep.

Other causes of failures are corrosion, fatigue, overspeed protection mechanism failures, and failures during storms and extreme gusts. Lightning strikes have also caused complete destructions.
In addition to these problems there are difficulties in sizing windsystems due to lack of winddata which locally varies strongly. In the end this strikes back on the battery with the same problems resulting as in solar systems.

Well aware of the problem of executing routine service on top of masts under extreme weather conditions, Ericsson designed a new type of wind turbine, which has a minimum need of maintenance. The turbine has also a built in lightning protection. The generator windings are located beneath the rotating "lightning rod" which is the turbine axis itself. As it is a vertical axis design, it is not at all sensitive to extreme gusts and quickly changing wind directions, which take hard on the horisontal axis designs at the tail and at the overspeed protection mechanism.
The SAAB-Ericsson VA 3 turbine is designed to produce energy in the harshest of climate conditions with a minimum of maintenance during a long period of time.

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Ericsson have delivered over 60 photovoltaic power systems including combined systems with mini dieselgenerators. Wind-solar-diesel-systems have been delivered to 3 places in Sweden and Norway.

The Berakupen (fig.5) in Norway is the toughest. It is the Norwegian Telecoms test site for telecom alternative energy. The climate conditions are extreme with heavy icing and tremendously strong winds. The site is operated in trial mode.The two other systems are delivered to the Swedish Coast Guard to power a lighthouse offshore and to the Swedish Railways to power the train-radio-telephone-system along a railway line in northern Sweden.

COST AND GENERAL TRENDS

The alternative power sources have created great hopes to make possible a significant cost reduction for the powering of rural telecom equipment. This issue is rather complex and not easy to unravel straight away.

To begin with, it is quite clear that for smaller loads such as single radiochannel system or other low capacity systems these hopes have been fulfilled to 100 percent. The older power systems for the supply of low capacity telecom equipments such as unrechargeable batteries of different types or different fuelconsuming devices have great disadvantages with pollution, fuel and transportation costs. In comparison with those the photovoltaic power supply is the ideal and without discussion the most economic in the respect of investment and operation costs.

For higher loads however the economy in a system becomes more complex. Many other factors than the capital or investment cost such as reliability, maintenance and installation cost, building requirements, access road cost, fuel cost, training etc. have to be considered. The previous experience within telecom administrations of power plant cost, is that it has been considerably less than the communications equipment cost, especially when the major part so far has been mains AC connected where also operation costs has been low. The relative investment cost for an

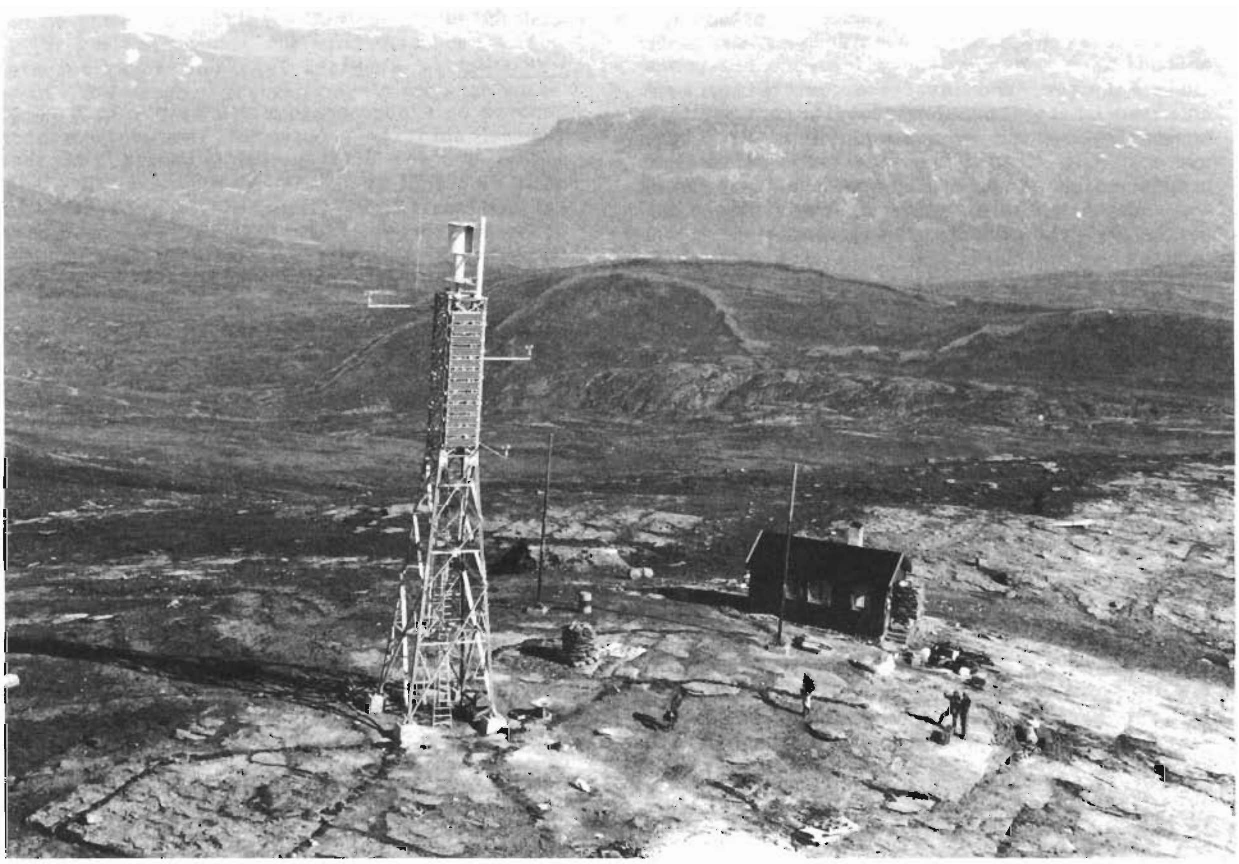

Figure 5. Berakupen. The Norwegian Telecoms test site.

alternative power supply system is considerably higher than people in the administrations have experienced for power supply earlier. This causes problems of acceptance and approval from the economists in the administrations, as often only investment or capital costs has been compared earlier. Such a comparison is not true and fair to alternative power supply systems. The new systems advantages towards the older stand alone ones are inherent in the other factors mentioned above. The cost advantage of these are difficult to measure and prove.

A more true and complete comparison between the old and new power supply technology is to compare the net present value over a 10 to 20 years period. It is obvious that the final overall acceptance of the alternative power for telecommunication will be given when this comparison has been verified in practice. To prove this takes a long time but as the number of installations increases and the alternative technique matures the prove of superiority will come. In administrations with a high degree of experience of stand alone power systems this acceptance has already come.

It seems that the market development of rural telecommunications is fairly slow. The major problem seems to be that rural telecom economically is a marginal business for the administrations.

The development of rural telecom is dependent on political decisions, based on social equality reasons, as the economical potential for a business short term calculus is not at hand. One reason is for example equality between the urban and rural communities in public service level. The result is a shortage of investment money as the administrations like other companies need to invest their money where the pay-off is the fastest. An other complication is the numerous debt crisis in the developing countries which also leads to low activities. The true situation is that the slow development of rural telecommunications has not allowed for a rise in activities in the field of alternative power supply.

Although if there has been a low activity in the market for alternative power supply for telecommunications there has been a technical development of interest. The trend is strong towards hybrid and combined systems. The reason is probably to find in a trend of increased power needs due to the digitalization of the networks. This has created new facilities and telecom services, which also are to be destinated to the rural communities.

THE HISTORY OF INNOVATION

The work with the innovative photovoltaic and wind power sources have made me curious of how much new innovations have influenced the historical development. Also the process by which innovation and change comes about is of great interest. To illustrate just a little of this interesting subject I would like to present some examples and general conclusions from the book "Connections" by James Burke (6) which tells a lot of the history of innovations.

The outcome of the battle of Hastings 1066 may serve as an example of what influence an actual innovation has had. The invention used by the conquerors was the stirrup (fig. 6). It made possible for the first time in history the use of cavalry. The Normans had invented a new fighting technique as they could use the lance and sword riding a hourse standing up in the stirrups. This gave the cavalryman a long radius of action, a great striking-power and good balance.

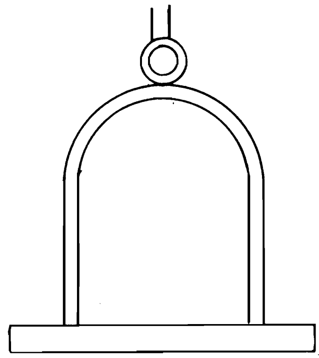

Figure 6. A stirrup the invention of 1066

The Saxons, who had a conservative battle ethic, would never have ridden a horse into battle as it would have been to come to the field already prepared for flight. Both the Saxons and the Normans knew about the stirrup. The Normans used its full potential, won the victory and changed the history.

An analog device to the stirrup relevant to telecommunication of today would be the micro processor.

The process by which innovation and change comes about has recurring patterns which are the following;

- An innovation is the result of deliberate attempts to develop it.
- The attempt to find one thing leads to the discovery of another.
- The ease with which information can be spread is critical to the rate of innovation and change.
- An innovation is almost always a new combination of already known facts and functions.

As an example I will explain the invention of the telephone made by Alexander Graham Bell.
The telephone is the synthesis of the different works of five persons Scott, Faraday, Oersted, Sturegon and Helmholtz.

- Scott had shown that a membrane vibrated and that a stick attached to the membrane was moved by the membrane.
- Faraday showed that a moving magnet could produce an electric current.
- Oersted showed that an electric current had a magnetic field around it.
- Sturegon wound the wire around a core and made an electromagnet.
- Helmholtz used an electromagnet to set a membrane to vibrate and to produce sound.

What Alexander Graham Bell did was to put everybody else's work together in a brilliant synthesis to invent the sound reproducing machine- the telephone.

In a similar way the combination of several of the power sources, the solarpower, the windpower, the dieselpower and the storage battery with modern microprocessor technique has created new possibilities for safe and independent powering of rural telecommunication.

CONCLUSIONS

As a summary of the significance of alternative power sources for telecommunications equipment a recapitulation of an historic event of adjacent art might conclude what social and industrial developments could result from the impact of alternative power.

This event is attached to a munks order of the catholic church, the Cistercians. They originated from another order namely the Benedictines, whose main rule was the edict "laborare est orare" to work is to pray.
Benedict also laid the foundation for self-sufficiency, as he wanted his munks to produce their own food and other indispensable commodities needed to survive. The Benedicts where successful but soon they morally declined. As a reaction to the decadence in the order like many other times in history, a "protestant" left with his fellow revolutionaries to set up a rival order in a poor and marshy part of the Burgundian forest known as Cîteaux, after which they later called themselves Cistercians. Thanks to their true observation of the original rule of St Benedict and vital additions, it developed to be the most advanced technological community in Europe during the early Middle Ages. The Cistercians had a strict rule to found their new abbeys far away from "civilisation" of moral reasons. They also should be self-sufficient. This made survival more difficult, but had the effect of training the munks to become masters of making marginal land productive. In doing this they developed and used all kinds of technology available at that time. They built their houses whenever possible with the local water supply running through the center of the site to provide water for hygiene and to power the waterwheel, the medieval equivalent of the modern power-station of which they also became masters.

They organized and administrated foundries fulling mills, corn mills, water-powered workshop, for toolmaking and wooltreating, with forges, oil mills and wine presses.

The monasteries engaged a lot of people in their business, who where not munks and whom they educated and instructed on irrigation, in mill use and upkeep, husbandary, land clearance, crop rotation, administration and management of finance. In this way the experience which the Cistercians had built up spread quickly to the benefit of the whole community.

What history tells us is that it is highly feasible to develop the rural communities which often are poor and neglected with the means of education and technology.
One technology needed is the rural telephony, in which alternative power sources are of major significance.

The people who work with the alternative power sources for telecom are working in the marginal land of telephony and the geography with a harsh terrain and hard weather conditions (fig. 7). In a modern perspective they highly contribute to the development or the rural community in a similar manner as the Cistercians did.

Figure 7. The El Negrito repeater in Tucuman Argentine 4000 m above see level was built by Ericsson in 1984. All equipment were carried up to the top by men and mules.

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