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The new Wind Power Pioneers and the Emergence of the Modern Wind Industry

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During the years from 1975 to 1979 an unique and unconventional development process created the concept for a new generation of Danish wind turbines.

Wind power was nearly forgotten or considered as a far distant piece of history, when the first "oil crisis" hit Denmark and the rest of the world in 1973-74. With more than a decade with an abundance of cheap oil Denmark had created a society with a high energy consumption and a high degree (92%) of dependency of oil, all of which was imported.

The answer for this crisis was energy diversification. For the political system and the electrical power producers the short term solution was a rapid change from oil to coal in the big central power stations - and the long term plan was to supplement with nuclear power.The young and growing renewable energy movement pointed out wind, solar and biomass as the only realistic energy options of the future. This led to a political battle lasting more than ten years, before the nuclear plans was ultimately cancelled by the Danish parliament in 1985.

For the renewables the handicap in this battle was obvious. While nuclear power was heavily supported by national and international research laboratories and big industry, the renewable energy solutions relied fully on the power of people through their motivation, engagement, creativity and confidence in a transition from the conventional energy forms.

After the 1974 oil crisis, the Danish industrial FLS-group - in 1940-44 producers of the "Aeromotors" - considered to re-enter the wind turbine market. The visionary engineer and architect Jean Fischer made drafts of a number of Darrieus-type turbines. One of them was on the cover of the estimated magazine "Science" in July 1975. But in November same year, FLS cancelled the project. Instead new Danish wind pioneers started from scratch - often using automobile-parts from the scrap dealer. (photo right)

Re-inventing wind energy

Nevertheless, during this political battle. Denmark soon got a unique position within wind energy and was for many years the leading wind power country. No single invention, institute, company or person can be pointed

Erecting a 30 kW Riisager wind turbine at Bovbjerg on the Danish North Sea coast 1978. The tail fan yaw mechanism is the same as used on the older Danish windmills. (Private photo, Asbjørn Bjerre)

The 30 kW wind turbine from Bovbjerg can be seen today at the Danish Museum of Electricity. (Photo: Benny Christensen, DVS) **Riisager's two first 22 kW turbines are now at the Folkecenter for Renewable Energy.**

at as the key of understanding for this industrial breakthrough. From 1975 and for the following 15 years no single patent or property right either blocked for the innovative process in a new industry with many thousands employed, putting Denmark in a leading world position. All new knowledge and experience was shared and generously made available for anyone that might find a practical use of it whether it was home-builders, SMEs (Small and Medium-sized Enterprises) or regular industrial companies: This is in deep contrast to conventional theory of successful industrial innovation.

At that time the most basic renewable energy technologies were non-existing. At best some pictures and reports from previous wind energy époques could be found but all practical, concrete solutions had to be re-invented using contemporary materials and applications. The big scale state-financed wind power projects launched in USA and Denmark were not of much help; they resulted in pilot wind turbines that were extremely expensive and not intended for manufacturing. In fact many early experiments with wind power used parts from car-breakers or scrap-dealers.

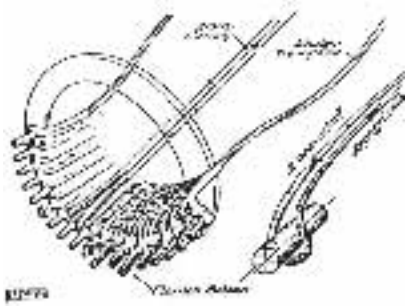
The wind power pioneer Chr. Riisager

Among the early wind power pioneers, Christian Riisager (1930-2008) was especially important for the later development. Where many others wanted to use the wind power for heat production in order to replace the expensive oil, Riisager had from the very start the concept and ambition, that his wind turbine should produce electricity and be coupled to the public AC-grid. In 1975 he built a small wind turbine with a 7 kW asynchronous generator in his garden, connected it, without permission, to the grid and made the electric meter in his house run backwards. This experiment helped to force the utilities to make formal rules for the sale of electricity from private wind turbines to the public grid.

Together with a local blacksmith two robust grid-connected wind turbines with 22 kW generators were built and delivered to private consumers in 1976. Riisager was a carpenter by profession and his wind turbines had

Among the heat-producinig wind turbines, the "SJ-Windpower" was popular, combining traditional windmill technology with modern materials. And the users avoided problems with coupling to the public grid. (Photo: Flemming Hagensen, DVS)

wooden blades. They were inspired by the work of Johannes Juul in the 1960s. During the following years Riisager had cooperation with several industrial companies and some of them started their own production of wind turbines after his concept. These "Riisager clones" were the first small steps towards a new Danish wind turbine industry, but due to the design they could not benefit from the emerging industry of compatible components from the new specialized sub-suppliers.



Ulrich Hütters unique design of the blade root. With the glass-fiber strands running around the bolts (or bolt holes) the crucial problem of combining blade and hub was solved.

The Tvind wind turbine and a new blade technology.

The next step forward was made around a wind turbine at another scale. In May 1975 the Tvind Schools in western Jutland started, with their own means, building of one of the biggest wind turbines in the world. It was finished in 1978 and it is still running 30 years later - an achievement, which in December 2008 was awarded with the *European Solar Prize*.

Both the big 2000 kW Tvind wind turbine and the smaller turbine built by the school were of great technical and symbolic importance for the development of wind power in Denmark. The Tvind people were innovative and courageous, which inspired many others to work with wind power.

Most decisive for the Danish wind turbine industry was the choice of concept for the 27 m, cantilevered (self supporting), glass-fiber reinforced blades of the big Tvind windmill. Tvind's founder and prime mover *Amdi Petersen* insisted on the use of the concept developed and tested in practice on wind turbines and helicopters by professor Ulrich Hütter from DLR, *"Deutsche Luft- und Raumfahrt Institut"* at the Technical University in Stuttgart, Germany. His blade technology was characterized by the way in which the blades were fastened around the hub bolts at the blade roots with glass-fiber strands.

The small "PTG-turbine" built by the Tvind schools in 1978 used the same blade construction as the big wind turbine. Its design was a starting point for a new Danish blade concept. (Photo: Erik Grove-Nielsen)

Tvind was assisted with the calculations by experts from Risoe and Denmark's Technical University, but the leading national laboratories preferred blade concepts quite different from Tvind's. These were to be found in two versions on the "official" test turbines at Nibe, erected by the utilities in 1979. None of these constructions paved the way for a "winning" blade concept that would become industrial mature. It was Tvind who in 1976 introduced the blade technology of the future. It became industrial standard and the core technology in the decisive breakthrough for Danish windmill producers in the following years .

The first 27 m blade for the big Tvind wind turbine was finished in February 1977. (Photo: Tvindkraft)

With a 54 m rotor diameter, the Tvind wind turbine from 1978 was for quite many years the Worlds largest in active service. The red and white livery was applied around its 25 years birthday and is designed by the Danish architect, Jan Utzon, son and partner of the late Jørn Utzon, who created the Sidney Opera House. (Photo: Nordic Folkecenter for Renewable Energy)

The Tvind blade technology commercialized

Tvind did not aim for industrial production but allowed private builders to have a blade technology available for copying. A group of wind pioneers in 1977 made a blade mould by copying a 4,5 m Tvind blade, but gave up the project and soon after the mould was bought by Erik Grove-Nielsen, Økær at Viborg, and he commercialised the Tvind blades. He was the first independent blade- supplier. At a simple stroke this made it much easier to bring a wind turbine to the market.

The first set of Økær blades was delivered at the end of 1977 to mechanic Svend Adolfsen in Knudstrup at Viborg, who had built an 11 kW wind turbine with a truck rear axle - a downwind turbine with active yawing. It survived a long life as the Kuriant, the Bosted and the Genvind wind turbines. But the 4.5 m blade had three important shortcomings: It had no air brakes, it ran too fast and was too noisy.

In Thy, at north-western Jutland, a group within NIVE (North-western Jutland Institute for Renewable Energy) consisting of a few engineers, blacksmiths, teachers from the technical school and interested users had decided to design a 22 kW windmill from scratch: A modern upwind wind turbine with an asynchronous generator, a Fenner gear, electrical yawing and locally developed control system.

Most of the parts could be produced locally - except for the blades. As the 4.5 m blade was refused, Økær with an order from NIVE on five sets of blades was ready to develop a less noisy 5 m blade with specifications similar to those on the Gedser windmill from 1958, but scaled down. In

The "Kuriant" wind turbine (originally "Adolfsen") was first to get the new "system certification" from Risø in August 1979 and it was in the following years a close competitor to the Riisager turbines. With its downwind placed rotor (like the Tvind turbines) it was different from most other Danish wind turbines.

Left: The first set of 5 m Økær blades was delivered in May 1978 and used on the NIVE wind turbine.
Right: Revolving tip brakes after the principles used by J. Juul on his Gedser wind turbine of 1958 were introduced on the latest versions of the Økær 5 m blades after several breakdowns in 1978. (Photos: Erik Grove-Nielsen)

May 1978 the first set of 5 m blades vere delivered and later that year they were was supplied with revolving tip brakes. This blade soon became standard on several types of wind turbines. Once more the inspiration came from Juul's Gedser turbine.

The cooperation between the Danish Blacksmiths Organization and the Folkecenter resulted in a detailed "construction handbook" enabling local blacksmiths to start wind turbine production. (Photos: Nordic Folkecenter for Renewable Energy)

The SMEs joins the efforts

Fortunately, early on The *Danish Blacksmiths Association (DS)*, representing 2,000 small and medium-size enterprises showed serious interest in the potential of these emerging energy solutions which could be manufactured by their members and generate new job opportunities.

Their vision was the unlimited and free access to the best professional construction know-how with the SMEs as the primary actors. Many years earlier DS had made standard drawings and calculations available for their members and had, since the 1950s, implemented non-profit technology transfer for agricultural equipment as direct support to local production. So why do not also do the same with wind turbines - the products of the future? However, the technological concept of the new products had to be defined first and subsequently designed, developed, engineered and tested before they were of any value for the SMEs. They could manufacture sell and maintain the equipment, they had the professional skills and were flexible, but they did not have their own engineers and other resources to invest in new product development.

A close cooperations was established with the group from NIVE, forming a foundation for the later "Folkecenter for Renewable Energy". To satisfy their needs, the structural break-up of a wind turbine into a number of main components was the innovation, which would, in the following years, give Denmark a decisive comparative advantage with regard to wind turbine manufacturing. It was far more manageable and cheaper to buy compatible components than to develop and produce all the parts. This is an important point to understand, that by applying the component concept, some years later, around 1984, 20-30 small enterprises could deliver the state-of-the-art wind technology for the flourishing US market. This is also why a Danish "Blacksmith Wind Turbine" often got a better reputation than products from several big international companies, trying to enter the promising wind turbine market.

The importance of this kind of alliance with the SMEs became obvious, when the nuclear energy option was cancelled in 1985. This paved the way for the renewable energies and local combined heat and power production as a promising industrial sector. When the SME's organization entered this sector it was rather for industrial political reasons than for energy political concerns. Early on, they got important influence on the political process,

preparing the structural and economical framework for decentralized solutions that by 2001 delivered 45 % of the electric power in Denmark.

The safety guidelines

Until 1978 the new generation of wind turbine builders thought it was possible to construct safe, mechanical brakes, which in all predictable circumstances would be able to prevent the windmill from runaway damage. But several serious breakdowns with the 5-m Økær blades in 1978 seriously put the brakes on the agenda. The Organisation for Renewable Energy (OVE) arranged half-yearly "wind gatherings", and in one of these the OVE *Committee for Windmill Security* was formed. No official authorities were represented in this self-established committee. It soon identified the decisive principles which were published in a security leaflet in 1979. As the most important principle, the wind turbine should have at least two mutually independent braking systems, of which at least one should be based on aerodynamic forces and released centrifugally. Blade and turbine producers soon modified the technology to comply with OVE's security principles. The *Danish Wind Turbine Owner's Association*, established in 1978, actively advised their members against buying turbines without air brakes. Later the rules were largely adopted as norm by Risoe in their system certification, and they contributed to ensuring the good reputation of Danish wind turbines as safe and reliable.

The 22 kW HVK-10 from the blacksmith Karl Erik Jørgensen in Herborg was the starting point for the Vestas wind turbine production. (Photos: Benny Christensen and Flemming Hagensen, DVS)

The "Danish concept" defined

This part of the history is then nearly complete. By 1979 Denmark already had an independent supply chain of blades and several other sub-suppliers of specialized components, that were able to deliver to all the future wind turbine producers . They soon seized the opportunity. The Herborg wind turbine became an important training ground for future wind turbine manufacturers with Vestas as a direct result. In November 1978 the first three 5 m Økær blades available with air brakes were delivered for the 22 kW wind turbine, built by the innovative blacksmith Karl Erik Jørgensen, at Herborg, Jutland. It was designed by a young student, Henrik Stiesdal - now director of technology at Siemens Wind Power. One year later the production rights for the HVK wind turbine were sold to Vestas in Lem.

When the later well known Danish brands like many other smaller manufacturers of wind turbines entered the market by the end of the decade, the technological development of the extremely successful Danish concept was more or less accomplished. Along the road a multitude of innovative principles had been tried and demonstrated: One, two, three or four blades, advanced multi-blade turbines, blades from wood, aluminum or steel, turbine with vertical axis and many other concepts. But the new industrial standard for reliable and affordable wind turbines was the concept with horizontal axis, three fiberglass reinforced blades up-wind, grid connected asynchronous generator, independent brake systems and automatic operation. Thirty years later the fast growing world-wide wind industry is basically using the concept developed in Denmark from 1975 to 1979.