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Control and devices for the feed-in of renewable energy generating systems into the distribution network

Feeding the renewable energy back into the distribution network causes serious difficulties for the system operators due to the changeable nature of weather conditions. Despite the rapid development of energy storage technologies, no solution has yet been developed for storing the generated surplus energy. In Germany, the production is controlled in order to ensure the balance of the power grid. This article presents the devices implementing this control.

Feeding the renewable energy such as wind and solar energy back to the distribution network is a major difficulty for system operators, because production is completely exposed to the changeable nature of weather conditions. The rapid spreading of household sized small power plants requires that a specific means of intervention be available to restrict in a few seconds the geographically and quantitatively distributed energy production.

The functions of smart metering could make it a suitable solution, as both metering the feed-in and switching on/off remotely are available, but its communication method does not ensure fast and mass access.

The solution for the problem of having a high number of and sporadically located household sized small power plants is a long-wave radio ripple control receiver, while the smaller group of high output power plants will be monitored and remote controlled by the “younger brothers” of the two-way communication enabled RTUs (Remote Terminal Units), generally used in the industry at high and medium voltage transformer substations.

OVERVIEW OF RIPPLE CONTROL

Audio frequency ripple control systems are used all over the world, including Hungary. These are mainly employed for switching on/off of controlled power consumers with storage heaters; furthermore, they are used by operators to switch public lighting on/off. The controlling communication between the ripple control transmitter of the medium voltage substation and the ripple control receiver of the consumer is maintained through audio frequency signals superimposed on the distribution network cables. The control of storage heater devices serves mainly to resolve load management problems of the service provider, i.e. to make peak shaving and to increase the load during low consumption periods. For this controllability, the consumer receives much lower tariffs in exchange. Around 2006 Hungarian power suppliers of E.ON started to introduce long-wave radio ripple control technology that had already been in use in Germany for some time.

This system is inherently used for the same purposes as the audio frequency ripple control systems, but it is much more flexible and can have a variety of uses.

The Hungarian transmitter station located at Lakihegy transmits the control signals at a 135.5 kHz frequency band. This transmitter station also broadcasts frequency-modulated current time signals in every 11 seconds. In general, these signals can also be used for time synchronisation purposes.

Germany has two transmitter stations, located in Burg (139 kHz) and Mainflingen (129.1 kHz) to provide 200 Bd one-way communication in a cover range of 500 km for each station. (See Figure 1)

Figure 1 *- Ripple control transmitters*

The operation of the transmitters and the broadcast of the signals are performed by the German EFR GmbH and its subsidiary for all three transmitters (source: http://www.efr.de/en/efr-system/).

In comparison to the audio frequency ripple control systems, this system is more flexible, because it allows the long-wave ripple control receivers to be grouped within the coverage area based on different scenarios regardless of the cable topology and the receivers can be accessed even with unique addresses in about 2-3 seconds. System operators can use the EFR terminals to directly send the required signals according to the required timing scheme.

These features enable the system to control and restrict the feed-in of a large number of renewable energy production units into the grid.

COMMUNICATION PROTOCOLS

The different manufacturers use two types of standardised one-way data transfer protocol at the 200 Bd long-wave communication channel. One of them is DIN 43861-401 Typ A, popularly referred to as Versacom, while the other one is DIN 43861-402 Typ B, popularly referred to as Semagyr Top. Both of them were developed based on the protocols used for audio frequency ripple control systems.

Semagyr Top has evolved into a DIN standard from being a manufacturer’s protocol of Landys&Gyr. The foundations of this protocol were created before the era organised in bytes, for pulse-based audio frequency ripple control systems used on analogue circuits. The transformation of this standard for the long-wave radio ripple control technology has maintained these old features, i.e. the information units do not have to fall on byte borders, but could have one half in one byte and the other in the other. However, this is still a highly usable and flexible protocol with several features to offer. Its addressing scheme is primarily tailored for the receiver units and the clusters created from these units. The data transmission commands of the protocol do not directly trigger the switching of relays. Instead, they initiate smaller applications and algorithms that may (but not necessarily) include the switching of specific physical relays.

Versacom is a standard formulated by a group of manufacturers, also primarily for the purpose of audio frequency ripple control systems.

As compared with Semagyr Top, the Versacom protocol is simpler, easier to understand, but offers less features and flexibility. In terms of its addressing scheme, it focuses on relays and relay groups instead of devices. In general, the Versacom data transmission commands are related to the switching of individual relays.

The German and Hungarian organisations of E.ON use the Semagyr Top protocol.

LONG-WAVE RECEIVERS

Radio ripple control receivers are produced by several European manufacturers such as the Swiss Landis&Gyr, the German Langmatz, the Austrian Elster and the Hungarian Prolan Process Control Co. Ltd.

The introduction of radio ripple control technology in Hungary has prompted Prolan Ltd. to develop its own long-wave radio ripple control receiver (RRCR) product family with the following three variants:

- RRCR - 230 with three relays, used mainly in Hungary
- RRCR - 260 with six relays, used mainly in Germany
- RRCR - 330 designed especially for street lighting control

The receivers can be operated by both of the two protocols mentioned above. The protocol to be installed into a specific receiver can be selected on the production line.

The common features of the receivers include that they use the same protocols and embedded software; they differ only in terms of appearance, the number of relays used and their area of application.

Each receiver is equipped with a motor-driven self-adjusting antenna that will find the direction of the optimal signal strength when the receiver is installed or if any (even temporary) interference occurs.

The RRCR-260 six-relay receiver, the largest unit of the product family shown in Figure 2, is used in Germany by electricity operators to control storage heater devices and tariff changes. This unit can also be equipped with an external radio to manage feed-in of renewable energy.

The RRCR-230 three-relay receiver is typically used by Eastern European E.ON firms (in Hungary, the Czech Republic and Slovakia) for the control of storage heaters, as well as tariff control.

The RRCR-330 three-relay receiver was designed specifically for street lighting control. The receiver's elongated casing with rounded edges ensures easy mounting into street light poles' interior, if necessary, but typically they are installed in the transformer house of the specific service area.

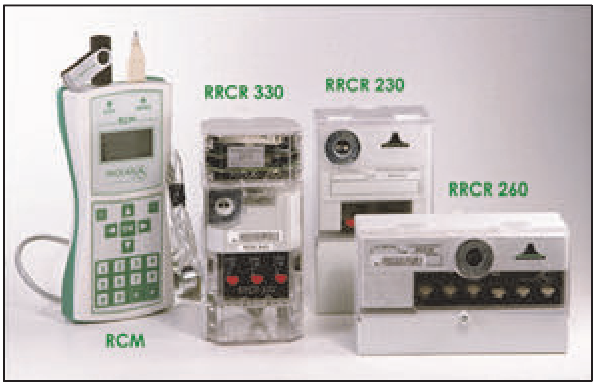

Figure 2 *- RRCR product family*

Another important feature of this receiver is the detachable radio unit that can be moved away from the receiver. This may help mounting the radio part in a better location for better transmission conditions if shielding or interference is a concern.

In addition to the LW one-way radio signals, the receivers can also communicate via two-way local infrared connection. The users may connect their laptop computer to the receiver, which can be a difficult solution in the field, but they can also use the dedicated RCM testing unit instead, seen on the photo. The RCM test unit is a robust device, developed for electricians, and has a simple menu system. It supports on-site configuration, testing, reading out log files, as well as the measurement of long-wave field strength and also the graphic representation of the results, each of which can largely support finding the best mounting location for the external radio unit.

CONTROLLING THE FEED-IN OF ENERGY GENERATED BY SOLAR CELL SYSTEMS

The number of household sized solar systems is so low in Hungary that controlling the feed-in of these systems into the grid does not constitute a serious problem for system operators.

In Germany, however, the number of these small power plants is well over 300,000 now, and their deployed nominal output has reached 33 GW which means significant tasks for system operators.[1]

These issues are regulated by the German Renewable Energy Act (Erneuerbare-Energien-Gesetz, EEG). The Act only applied to solar cell systems with output power above 100 kW until the end of 2011. According to an amendment of the Act, effective from 2012, even systems with an output power below 100 kW must have a centralised solution to manage their performance and feed their energy back into the grid. An exception to this regulation may be the case when the operator of a specific solar system agrees to feed back not more than 70% of the energy generated by that system. In that case, no mandatory deployment of a centralised management system is required.

The Act also stipulates that in addition to the newly installed systems, remote control must also be implemented retrospectively until 2014 for those systems that were deployed earlier with an output power between 30 kW and 100 kW.

Figure 3 *- Radio ripple control, Power Reducer Box and inverters (under installation)*

[1] For further information on the current status of the German solar energy production and the relevant archive data, see the http://www.sma.de/unternehmen/pv-leistung-in-deutschland.html home page.

To comply with the EEG Act, E.ON's German companies selected for their purposes the RRCR-260 model without an internal radio, equipped with an external radio unit and an 8-meter long cable. This cable is long enough to install the radio unit detached from the inverter to find the optimal long-wave signal range.

Typically four of the six receiver relays are used to set the 0%, 30%, 60% or 100% grid feed-in load. Instead of connecting the relays directly to the inverter, a Power Reducer Box is installed between the two sides to convert the relay contacts into the manufacturer-specific communication code of the inverters. Today the communication interfaces used by the different inverter manufacturers are not standardised and this is the reason why the Power Reducer Box is included in the system configuration. Not only will it increase the complexity of the system configuration, but it also leads to significantly higher system costs.

The unification and standardisation issues related to communication protocols are addressed by the SUNSPEC Alliance (www.sunspec.org), formed by manufacturers of solar energy systems. The mission of this alliance is to develop an open interface standard that enables the compatibility of IT systems built on various existing standards.
This interface standard would enable the development of radio ripple control devices that can be connected directly to the inverter via the open, standardised interface without having to include expensive relays and a Power Reducer Box in the configuration of the system.

Figure 4 *- Packaging, receiver unit, and external radio unit with accessories*

When E.ON places an order for RRCR units, they are shipped directly to the operators of the solar power systems. The receivers are deli-vered in a packaging with accessories included as shown in Figure 4.

E.ON uses these devices not only to control the feed-in of energy generated by solar systems, but also to manage the feed-in of wind, water and biomass power, based on the same principles and solutions.

POWER PLANTS EXCEEDING THE SIZE OF HOUSEHOLD INSTALLATIONS

The power plants that are larger than household installations but are still considered to be small power plants are controlled by the "small variants" of the RTUs (Remote Terminal Units), generally used in high and medium voltage transformer substations in the industry. Small variant means only a lower number of input and output ports, but in terms of other functionalities or communication and EMC requirements, these smaller units provide the same features as their larger counterparts installed in the distribution and carrier network transformer substations.

Prolan Ltd. has designed the ProField-FWA-6 unit especially for the remote monitoring and control of small power plants, as part of its ProField RTU product family, which is installed in large numbers at transformer substations (See Figure 5).

ProField-FWA-6 is a modular unit that may include up to 6 input and output cards and offers LAN, USB and RS232 output ports for physical communication. It can be optionally equipped with a GSM modem to enable wireless GPRS communication and can also be applied with VHF radio as a supplement.

As for communication protocols, it includes the industry standard IEC60870-5-104, -101 and IEC61850 protocols.

Figure 5 *- ProField-FWA-6 RTU*

Modules of the device

- TM0F8 power supply unit including charging of its uninterrupted battery backup
- MF186 CPU and communication module with embedded Linux system and web server
- DI415CI 16-channel galvanically isolated digital input
- VR516CI 16-channel galvanically isolated relay output
- AH040C 8-channel galvanically isolated analogue input

The I/O configurations listed here cannot be regarded as a comprehensive list, because such a list is subject to the technological features intended to be measured, monitored and controlled by the system operator. As many as 50-60 I/O ports can be included.

Digital inputs

- Statuses of the power transmission line's 20 kV disconnector and ground switch
- Statuses of 20 kV disconnect switch and ground switch at the transformer substation junction
- Status of the 0.4 kV mains supply disconnector
- Alarm signals
- Feedback on grid feeding load reduction
- A few DC side and telemechanical diagnostic signals

Digital outputs and controls

- 20 kV supply circuit breaker switch-off
- Permission for switching on the 20 kV supply circuit breaker
- Initiating and cancelling the reduction of grid feeding load
- Deleting of error signals and diagnostic signals

Analogue measurements

- Voltage and current measurements for all 3 phases of the 20 kV supply
- Zero-point voltage measurement
- Diagnostic measurements for the telemechanical system's own power supply

By using the ProField-FWA-6 device, the system operator of the distribution network receives feedback on the 20 kV status of the small power plant, its current and voltage values, on the basis of which the current output power of the plant can be calculated. The system operator can initiate a grid feeding load reduction request and if necessary (due to maintenance or operational failure) the small power plant can be disconnected from the distribution network by switching off the 20 kV circuit breaker. When the circuit breaker needs to be switched on again, the system operator can only issue a switch-on request command, but is unable to directly reconnect the power plant. For safety considerations, the reconnection can only be carried out locally at the power plant.

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