FIELD EXPERIENCE WITH CONNECTING THE DISPERSIVE SOURCES TO MV POWER LINES IN THE CZECH REPUBLIC

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ABSTRACT

This study of connecting the dispersive source to the MV power line kept the Operation Standards of Distribution Systems. The project of the electric part solves an electric connection, a switching station and electric protections. The electric protection system must be a selective one, with engine protections. Primary tests are recommended for testing the electric protections, including the simulation of AR function in MV power lines.

INTRODUCTION

After the study of connecting the dispersive source to MV power lines has been finished and the zoning and planning decision and the building permit have been obtained, it is possible to start with designing the building and the electric parts of the dispersive source. A technical solution is the matter of the electric part. Service and commissioning conditions will be included too. The protective system on MV side, in the break point, must satisfy the conditions of the selective setting with the protections of MV power lines. New possibilities of the power regulation can be used for an optimal utilization of the wind-power plants, e.g. the regulation to a mean power value in the interval of 15 min.

STUDY ON CONNECTING THE DISPERSIVE SOURCE /WIND-POWER PLANTS - WPP/

In principle we have followed the Operation Standards of Distribution Systems, Attachment No. 4 [1] at the study preparation. On conditions of the Czech power industry the operational power diagram – active power P – idle power Q of the engine – is not used yet. This diagram also includes new possibilities of the idle power control and so the voltage conservation in the delivery point within the framework of the limits according to the engine diagrams P-Q. The generator must be able to supply the rated active power at intervals of the power factors cos fi = 0,85 ind. to cos fi = 0,95 cap. /generator operation under the underexcited conditions/, at allowed voltage range on the generator terminals ±5% and at the frequency intervals 48,5 to 50,5 Hz“.
If the engine P-Q diagram is used, there is a possibility to realize WPP without any additional costs. 2 to 4 engines of specific outputs 1,5 MW possibly 2 MW can be connected to the existing MV power line /consisting of the parts AlFe 110, 70, 50 mm2/ that is supplied from the switching station 110/22 kV /the transformer output is usually 40 MVA or 25 MVA/ with the set minimum 3-phase short-circuit power on 110 kV side /usually higher than 800 MVA/. If only the electrical power with the power factor 1 has to be supplied /neutral power factor/, another solution must be found, e.g. to change the parameters of the block transformers 22/0,69 kV, to replace the existing AlFe cables with bigger cross-sections. To improve the calculations, we set the home consumption of the power plants and the setting of the branch line of the block transformers. The utilization of WPP is expectable in tens of percents. In practice they do not operate with rated powers. Also this fact should be considered at the calculations of WPP connections.

DESIGNING OF THE ELECTRIC PART OF DISPERSIVE SOURCES, FIRST OF ALL WPP [2].

The technical report is the body of the project and includes following items:
- Background for solving the project,
- Technical solution,
- Commissioning and operating conditions,
- Requirements for the designed equipment realization.

Background for solving the project is given by the scope of the designed equipment, by regulations and standards, by basic technical data, by marking.

Scope of the designed equipment

In case of wind-power parks the project solves an electric connection, a switching station and electric protections.

The matter of the project is a kiosk-type concrete switching station that includes:

Switchboard 22 kV, LV distribution boards, DC switchboard with a rectifier and a battery, commercial measurement distribution boards, operator’s measurement distribution boards, internal connecting line of the transformer station, lighting of the transformer station, internal earthing system including test terminals, circumferential earthing of the wind-power plant including the kiosk-type switching station, cable line 22 kV between the kiosk-type switching station and the support point of MV power line from the respective switching station 110/22 kV, possible replacement of the existing MV power line support point with a new one.

The design documentation has been prepared in correspondence with regulations and ČSN standards, as well as with catalogues that have been valid at that time.
WPP power factor compensation, e.g. Vestas' generators, is a part of the delivery of the power plant itself. Asynchronous generators that are used for WPPs consist of stators and „double" rotors with rings. They are supplied from the system through the rectifiers /IGBT technology is used/. The voltage and frequency are hold constant, independently on the rotor revolutions. The frequency inverter is switched in the rotor circuit that superimposed the voltage at an adjustable frequency of the rotor winding. An optimal way of the idle power compensation can be determined at the commissioning.

Commercial measurement – the produced, possibly taken-off, power is measured in MV switchboard – in its measuring field. Calibrated current and voltage transformers measure it with the accuracy classes according to CZ standards. A-type measurement is used (continuous power measurement with a remote data transfer). The current and voltage measuring transformers are parts of the delivery of 22 kV switchboard. The distribution system operator will deliver and installed the commercial measuring set. The set will be installed in the commercial measurement distribution board that is a part of the project.

Operator's measurement - the operator's measurement distribution board makes possible following links between MV switchboard and a power-dispatching centre of the competent distribution plant:
Remote control of the switch,
Bistable signalling of the conditions of switching elements,
Signalling of switching-off the switch by the protections,
Current (3 I - 3 x 5 A) and voltage (3 U - 3 x 100/√3 V) measurement.
A programmable multi-converter for the measurement of electric values with three analogue outlets for the measurement in four-wire three-phase mains with a non-uniform load is a part of the delivery of the operator's measurement distribution board.

ELECTRIC PROTECTIONS ON MV SIDE

Electric protections on MV side in the break point are listed in the Single-line diagram of the equipment and of the protection setting, that is a part of the Project of the electric part. MV switchboard is recommended to be equipped with following electric protections (individual functions are specified according to ANSI/IEEE):

27 - undervoltage three-phase protection
59 - overvoltage three-phase protection
81.1 - underfrequency protection
81.2 - overfrequency protection
47 - amplitude change
78 - vector protection

Excepting 47 and 78, all functions can be time-delayed.

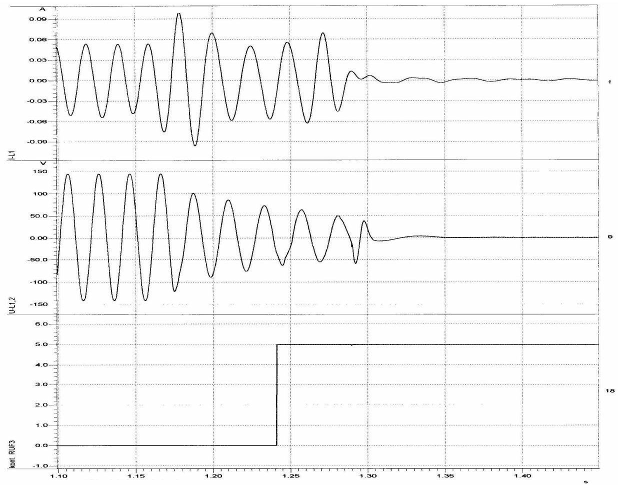
With respect to the setting of the electric protections of the engine we submit *a design of the selective setting of the electric protections* of the engine and of the electric protections in MV break point [3]:
Overfrequency protection - with respect to the setting of the electric protections of the engine - 110 %, time delay 60 s, 113,5% - time delay 200 ms. For the setting of the overfrequency protection in the break point the values of approx. 115 % Un and 300 ms are recommended.
Underfrequency protection – the values of 85 % Un, 600 ms, 70 % Un 120 ms are recommended for the setting of the underfrequency protection in the break point.

Overfrequency protection of the engine – the setting 51 Hz, 0,2 s can be kept. For the setting of the overfrequency protection in the break point we choose the values of 51 Hz, 0,3.

Underfrequency protection at the engine – the setting 47 Hz, 0,2 s is too low. Te manufacturer of the engine is recommended to set for the "Czech version" - in line with the requirement of our power industry – the values of approx. 49 Hz, 0,2 s. Then it is possible to satisfy the condition of the selective setting of the protection in the break point on MV side at the setting 49 Hz, 0,3 s.

Under so designed setting the WPP selective switching-off conditions would be satisfied, first of all the electric protections of the engine on LV side would operate and the supply of the WPP home consumption would be kept.

For WPP the vector protection [4] is applied. This is a snap-acting protection that operates at a power line voltage loss and also in the power line at the AR function. Positive field experience has been gained with this protection. In principle *primary tests with the simulation of AR function* [*3*] are recommended for its setting. For an example of the vector protection operation at the forced AR simulation – see Picture 1.



Picture 1 - Forced AR, the detail of current and voltage history, of the operation of the vector protection

Following current functions have been used:
- 51 – short-circuit protection with a time-delay I>,
- 49 – overload with a time-delay It>,
- 64 – ground-fault current protection I_0,

In MV switching station of WPP, there should be overcurrent protections with a primary current setting and with a time delay that provides their selective operations with respect to the existing setting of the overcurrent protections at the beginning of MV power line. A short-circuit fault in the respective MV line must be always disconnected before the overcurrent protection at the beginning of the line starts to operate, i.e. WPP will not start with an isle operation /CZ power industry requirement/.

COMMISSIONING AND OPERATING CONDITIONS

Background of the commissioning

- The equipment must conform to the design documentation; the transformer station must be equipped with a safety device and protective aids,
- Complex testing,
- Starting check according to ČSN standards,
- Trained personnel with sufficient qualification according to appropriate ČSN standards and edicts.

WIND-POWER PARK REGULATION

At connecting the wind-power plants to MV power lines the maximum output must be determined. With respect to the stated wind conditions, this maximum output will be very rarely utilized /approx. 2 % a year/. That is why the question of better utilization of installed outputs of WPPs is discussed more often. One of the progressive methods is the wind-power park remote control /monitoring/ by a regulation software. There is a possibility of an optimum regulation of the whole wind-power park and the output loss level can be as low as possible. There are two options – a regulation for an instantaneous power /by the power distributor set power of the wind-power park can be never exceeded/ or a regulation, e.g. for a quarter-hour average /mean/ value that cannot be exceeded. The above-mentioned is expectable in the new-installed WPPs.

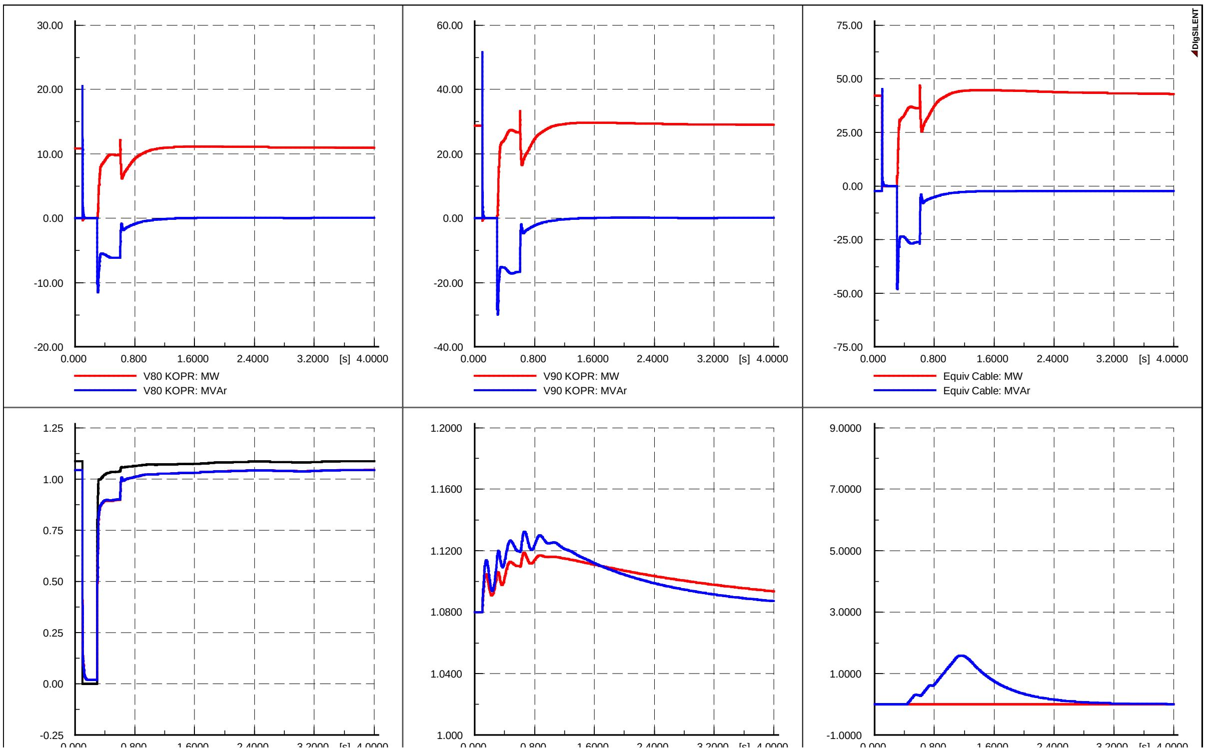
DYNAMIC BEHAVIOUR OF WIND-POWER PLANTS

At dynamic calculations of the behaviour of WPPs in the WP park Kopřivná to the power line 110 kV a new product of the company VESTAS has been tested - VestasGridSupport *AGO2 – Advanced Grid Option 2 [5]*. With this product WPPs can tolerate voltage drops at power line faults for short periods. At such faults WPP is a source of a capacitive short-circuit current, WPP operation is stable, a power-line stability is not disturbed. WPP supplies the power line after clearing the fault. For an example of the history of electric and mechanic quantities of WPP in WP Park Kopřivná at the 3-phase short circuit with the operating period 200 ms and with the module AGO2 – see Picture 2.

Important is the judgement of WP Park's Kopřivná behaviour at the set regulation of VESTAS engines with AGO2 regulation. This regulation enables short-time tolerance of voltage drops, e.g. 0,2 Un for the time of approx. 0,5 s. *Based on such an analysis it is in principle recommended to equip VESTAS engines with AGO2 modules - Advanced Grid Option **2.***

FIELD EXPERIENCE

Field experience with connecting 850 kW and 2 MW VESTAS engines in the Czech Republic is very good. The results of long-time measurements of the power quality, of the content of higher harmonics, of the voltage fluctuation and of the flicker correspond with the calculated analyses in the Connection study and with the results of the measurements that have been mentioned in the individual engines' certificates. The experience with setting the basic angles of the generators 2 x 1,5 MW REpower /13° was set, i.e. the power factor 0,974 cap./ in the underexcited area is very positive too. The voltage changes in the connecting point are lower than at the neutral power factor. Another WPP 2MW Vestas could be connected to the same MV power line.



Picture 2 – History of electric and mechanic quantities of WP / V80,V90/ in WP park Kopřivná at the development of the 3-phase metal short-circuit, period tk=200 ms, in DP Hanušovice 110 kV, *WP with regulation AGO2 - WP park Kopřivná holds the operation*

CONCLUSION

At the determination of an optimum number of WPPs for the connection to MV power lines it is recommended to utilize the power P-Q engine diagram and to limit the maximum active power.

The technical solution of the design of the electric part of the dispersive sources consists of the project of the electric connection, of the switching station and of the electric protections. It includes also the project of commercial and operator's measurements.

The selective setting of the electric protections has been designed for the break point and for the engine manufacturer.

At checking the vector protection function the simulation of the forced AR in the appropriate MV power line is recommended. There have been mentioned new possibilities of WPPs' regulation and of the control of WPPs' dynamic behaviour – AGO2 product of VESTAS.

LITERATURE

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