INTEGRATION OF LARGE PHOTOVOLTAIC POWER PLANTS TO DISTRIBUTION NETWORKS

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ABSTRACT

The growth in dependence on petrol and other fossil fuels, the increase in their import and the increasing power producing running costs, cause that our society has become more vulnerable. Exploitation of renewable energy sources (RES), when considering generating of electricity, can help to reduce this dependence, at least to some extent. The European Union has established a mandatory (strictly obligatory) aim of 20 % ratio of the renewable energy sources in the production of electricity until 2020. Particularly, the Czech Republic has agreed on 13 %. This creates a way to general implementation of the renewable energy sources into energy policies and on the EU market.

PVPPs, as a representative of RES, are significantly supported in the Czech Republic which is the reason for their huge expansion, for instance in contrast to wind power energy which is backgrounded. In regard to this, PVPPs of enormous output (tens of MW) are installed in the Czech Republic. They are connected by long cable lines into distribution and transmission system. The act of connecting of such sources brings about specific problems. Namely, the huge capacitive power of cables which must be individually compensated as the regulation capabilities of reactive power inverters are restricted and vary according to their loading. Huge charging currents and temporary overvoltage of cables represent the next problem here.

This paper deals with the analysis of these transient phenomena demonstrated on the example of connection of 2×26 MW PVPP into 110 kV distribution system through AC medium voltage cables 17 km and 24 km long. The simulation calculations analyze features during the switching on of the cables and they discuss several possibilities of the distribution of the shunt reactor. Further, the problems considering the voltage regulation of the 110 kV level are described.
The paper is concerned with the usage of a device of the FACT (STATCOM) type.

INTRODUCTION

The following paper deals with issues considering the power output of a photovoltaic power plant of 52 MW into distribution network of 110 kV. It is a newly built up currently the biggest photovoltaic power plant in the Czech Republic in operation. Its power runs out through long cable lines of 35 kV from two localities which are 23 km and 17 km far away from the connection point to the distribution network (transformation 35kV/110kV), see Fig. 1. Both localities are connected via two long cable lines, A1 240 mm^2. The paper is analyzing the rates of reactive power and options how to regulate reactive power when operating a PVPP. The regulation options of reactive power are differ from a classical source with synchronous generator. In addition, the paper displays results taken from the simulation of temporary procedure when switching cables on. The temporary procedure is important with regard to the lengths of cables.

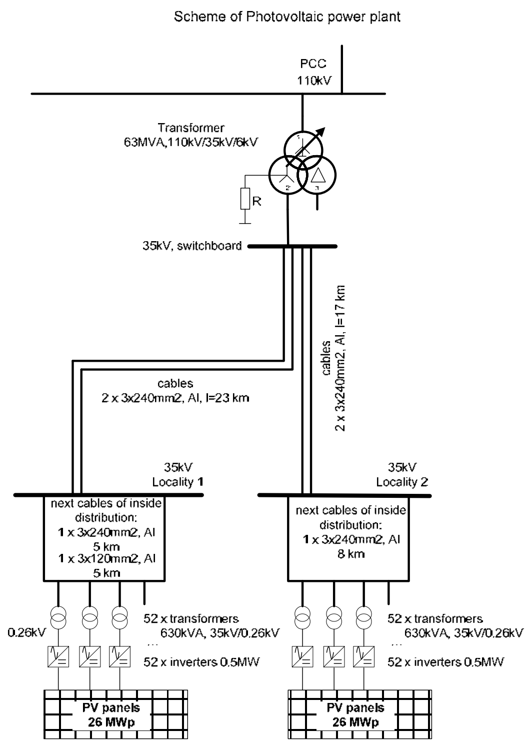

Fig.1 Photovoltaic Power Plant Scheme

REACTIVE POWER RATES IN PVPP NETWORK

When there is no load, the PVPP network has the capacitive character determined by long cable lines which for the cable network between transformation station 35kV/110kV and locality 1 represents reactive power Q = 2.82 MVAr and the cable network between transformation station 35kV/110kV and locality 2 represents reactive power Q = 3.815 MVAr. Within both localities cable lines of internal networks are partly considered (Q = 0.7 MVAr for locality 1 and Q = 0.62 MVAr for locality 2). Inductive power is here determined by transformers working no load which for the transformer 63 MVA 110/35kV represents Q = 95 kVAr and for 104 transformers 630 kVA 35kV/0.26kV in individual fields represents Q = 655 kVAr. If the mentioned hypothesis is taken into account, it is essential provide inductive reactive power Q = 7.2 MVAr for a full decompensation.

The reactive power can be provided via decompensation coils (shunts) or a compensation device on the basis of FACTS (SVC, STATCOM). When providing active power by photovoltaic cells (i.e. converters are automatically synchronized), it is possible to exploit regulation of power factor of individual voltage converters. However, the main disadvantage is small absolute regulation range of the reactive power when providing only a small amount of active power and decrease in active power at the expense of reactive power.

When increasing the amount of active power, the resulting reactive character of the PVPP is changing. The following consequences are the increase in reactive losses in transformers and a slight decrease in capacitive character of cables (determined by cable natural power). As the provided amount of active power into the network is increasing, the capacitive character of the system is decreasing and simultaneously, the regulation abilities of the PVPP voltage converters increase. The system reactive character is thus versatile in dependence on the change in active power provided. Since the active power is changing according to light during the day, there is also a change in the resulting reactive power. Fig. 2 shows dependence of the resulting reactive power on the amount of the active power provided by PVPP and possible regulation area of voltage converters until power factor PF = 0.95. The chosen display of diagram axes in Fig. 2 is present, as it corresponds to the displays of operational diagrams of classical generators. Fig. 3 shows results network reactive power and reactive character of individual elements.

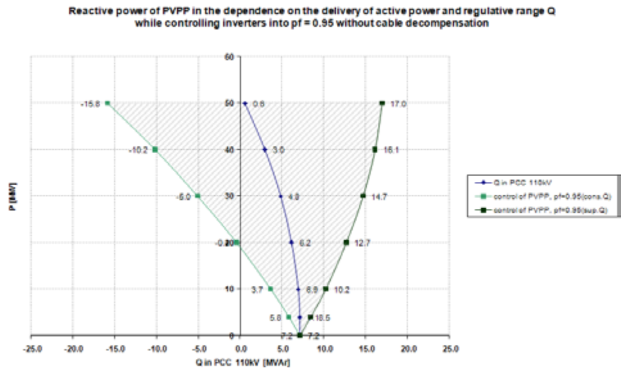

Fig.2 Reactive power of PVPP in the dependence on the delivery of active power and regulative range Q while controlling inverters into pf = 0.95

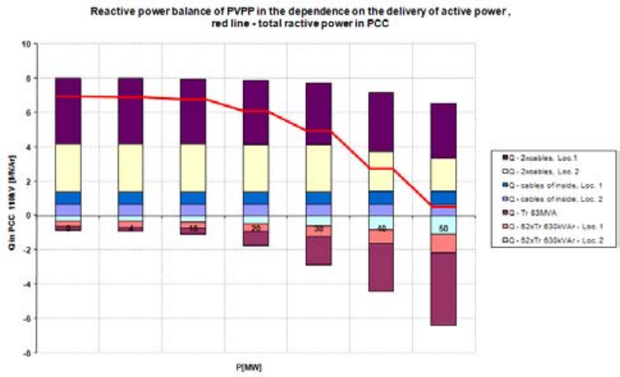

Fig.3 Reactive power balance of PVPP in the dependence on the delivery of active power

REACTIVE POWER REGULATION (VOLTAGE REGULATION) IN PCC (POINT OF COMMON COUPLING)

In the framework of grid code (in the Czech Republic), requirements for delivery and regulation of reactive power are defined considering distributed generation (distributive network 110 kV, 35 kV, 22 kV). There are three options of reactive power regulation in PCC:

- On the desired level of voltage in PCC.
- On the desired reactive power in PCC.
- On the desired power factor in PCC.

If the changing character of reactive power is taken into consideration, it is necessary to have in the PVPP system a dynamic regulation element of reactive power which represents a significant difference from classical production with a synchronous generator which through the change in amount of excitation enables an alternation of reactive power in relatively extensive range set by its operational diagram. As dynamic regulation elements of reactive power in the case of PVPP it can be used:

- Smoothly tunable coils, coils with tap changers
- Regulation of power factor of voltage converters
- Device on the FACTS base (SVC or STATCOM)

The mentioned PVPP uses for reactive power regulation combination solid-state coils together with exploitation of regulative abilities of voltage converters.
Disadvantage of this solution is the demand on the control system with regard to numerous voltage converters and coils. Moreover, it leads to decrease in delivery of active power caused by voltage converters when regulating power factor and low regulation range of voltage converters when the delivery of active power is zero or minimal.

EXPLOITATION OF FACTS

Next option is the exploitation of devices on the FACTS base (SVC, STATCOM), see Fig. 4. This solution has an advantage in the smooth control of the reactive power delivery with constant regulation range (here +- 10 MVAr) with no regard to active power delivered. Simultaneously, it is possible to implement the algorithm of power control in the spot of desired voltage level together the regulation possibility of tap changer of transformer 110kV/35kV. Fig. 5 shows regulation area of reactive power of such solution. The usage of solid-state coil in the system (e.g. placed in tertiary winding of transformer 110kV/35kV) enables transposition of the whole area to the center.

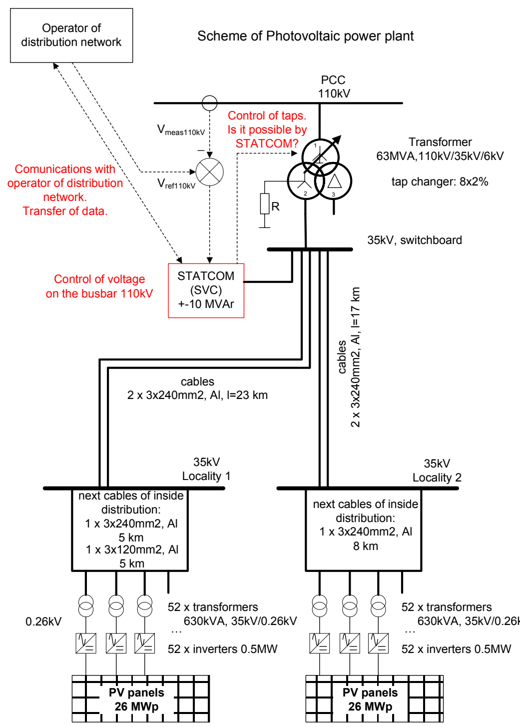

Fig.4 Scheme of Photovoltaic power plant with using STATCOM

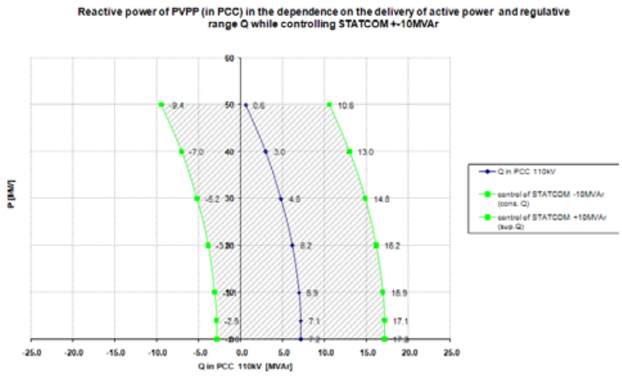

Fig. 5 Reactive power of PVPP (in PCC) in the dependence on the delivery of active power and regulative range Q while controlling STATCOM +-10MVAr

TRANSIENT PHENOMENON DURING SWITCH ON OF PVPP CABLE NETWORK.

During the switch on of long cable lines, there is a transient phenomenon which characterizes overload and overvoltage on both cable ends.
Figures 6, 7 and 8 show the waveforms of the current and voltage from simulation when two no-load 23 km long cables are switching.

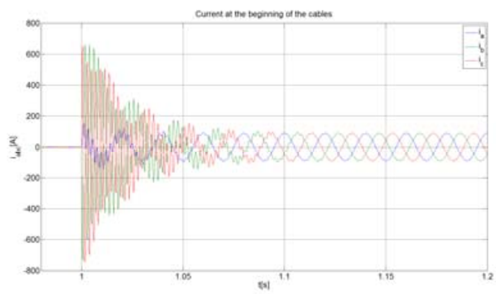

Fig. 6 Current at the beginning of the cables

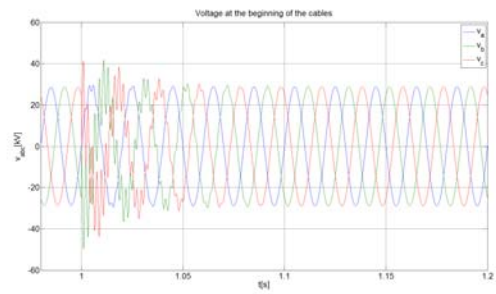

Fig. 7 Voltage at the beginning of the cables

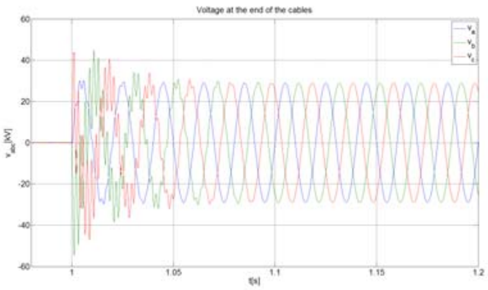

Fig. 8 Voltage at the end of the cables

CONCLUSION

This paper deals with possibilities of reactive power regulation of PVPP power sources which are currently booming. The possibilities for PVPP reactive power regulation of are significantly different from a classical power source with synchronous generator. This paper stresses pros and cons of some solutions of reactive power regulation. Moreover, the paper displays results of the simulation of transient phenomena when switching on of long cable lines which output power of PVPP fields into distribution network.

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