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Reducing Power Losses Using Optimal Accommodation and Smart Operation of Renewable Distributed Generation

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ABSTRACT: The penetration of distributed generation and wind power in particular is expected to increase significantly over the coming years, and a huge shift in control, operation and planning of distribution networks is going to be necessary if this generation is to be connected in a cost effective manner. Traditionally, distribution networks have been operated as passive networks with uni-directional power flows and were designed through deterministic (load flow) studies considering the critical cases so that distribution networks could operate with a minimum amount of control. With the connection of increasing amounts of distributed generation, these networks are becoming active and with power flowing in the two directions, hence requiring more intelligent forms of management. Increasing connection of intermittent distributed generation, such as wind power, to distribution networks requires new control strategies to provide greater flexibility and use of existing network assets. Active network management (ANM) will play a major role in this and will help in facilitating connection of new generation without the need for traditional reinforcements. A multi-period AC optimal power flow (OPF)-based technique for evaluating the maximum capacity of new intermittent distributed generation able to be connected to a distribution network when ANM control strategies are in place. The ANM schemes embedded into the OPF include coordinated voltage control, adaptive power factor, energy curtailment and demand side management

KEYWORDS: Load Flow, Optimal power Flow, Maximizing Demand, Minimising Losses.

I. INTRODUCTION

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II. GENERAL

Distributed generation is an electric power source connected directly to the distribution network or on the customer site of the meter. The penetration of distributed generation and wind power in particular is expected to increase significantly over the coming years, and a huge shift in control, operation and planning of distribution networks is going to be necessary if this generation is to be connected in a cost effective manner. Traditionally, distribution networks have been operated as passive networks with uni-directional power flows and were designed through deterministic (load flow) studies considering the critical cases so that distribution networks could operate with a minimum amount of control. With the connection of increasing amounts of distributed generation, these networks are becoming active and with power flowing in the two directions, hence requiring more intelligent forms of management.

III. DISTRIBUTED GENERATION

Distributed generation (DG) refers to power generation at the point of consumption, generating power on-site, rather than centrally and according to the CIGRE Working Group definition, which characterizes dispersed generation as:

- Not centrally planned

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- Today not centrally dispatched
- Usually connected to the distribution network
- Smaller than 50 or 100 MW

Not centrally planned or dispatched means that major influences such as unit commitment or reactive power generation are out of control of the system operator.

IV. MAXIMIZING THE DG CAPACITY

The passive distribution network operating philosophy tends to limit the amount of EWG that can be connected into the distribution network demonstrates the benefits of alternative active network controls such as generation curtailment, reactive power absorption and coordinated OLTC (on-load-tap-control), for voltage regulation within an existing distribution network. It was shown that by implementing active network management, the increase in installed capacity of EWG (Embedded wind generation) which can be connected to the existing distribution networks can be increased considerably , as shown in the examples, especially that using coordinated OLTC control). Advanced optimal power flow (OPF) was developed to investigate the potential benefits and cost of the proposed controls. The optimal accommodation and operation of DG plants to minimize losses has attracted the interest of the research community in the last 15 years. The studies found in the literature can be classified into two approaches: minimization of power losses and minimization of energy losses.

V. MINIMISATION OF POWER LOSSES

The "optimal" accommodation and sizing of DG units where the time-varying characteristics of demand are neglected is very likely to lead to sub-optimal results presents a simple four-bus test feeder with a total peak demand of 7.5 MW. A 1.01 p.u target voltage at the grid supply point (GSP) secondary bus bar is assumed. In order to investigate the impact of DG on losses three cases are evaluated:

1. Maximum Demand—a "power only" snapshot at fixed maximum DG output and fixed maximum demand.
2. Variable Demand—an energy analysis at fixed maximum DG output and an annual load curve.
3. Variable Demand and DG—an energy analysis where DG output is driven by wind power data and demand.

VI. MINIMISATION OF ENERGY LOSSES

Optimal power flow is widely accepted and mainly used to solve the economic dispatch problem. It can be adapted for different objectives and constraints with, e.g., an OPF-like (reduced gradient) method applied to a (power) loss minimization problem. A similar formulation with the objective of maximizing DG capacity has also been adopted. However, in these OPF-based approaches, only peak demand and passive operation of the network were considered. The basic multi-period AC OPF formulation minimizes the total energy losses of the network over a time horizon comprising periods, Using the elements of the OPF.

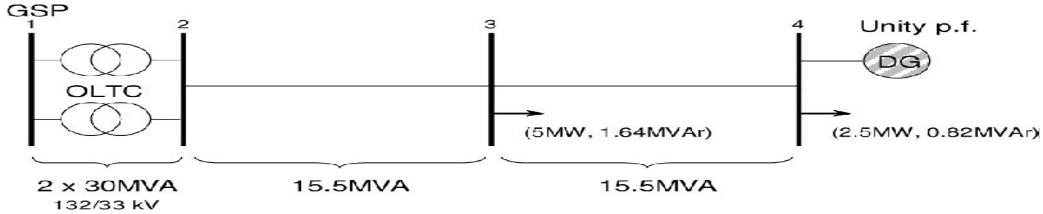

Fig. 1 One-line diagram for the four-bus test feeder at maximum load.

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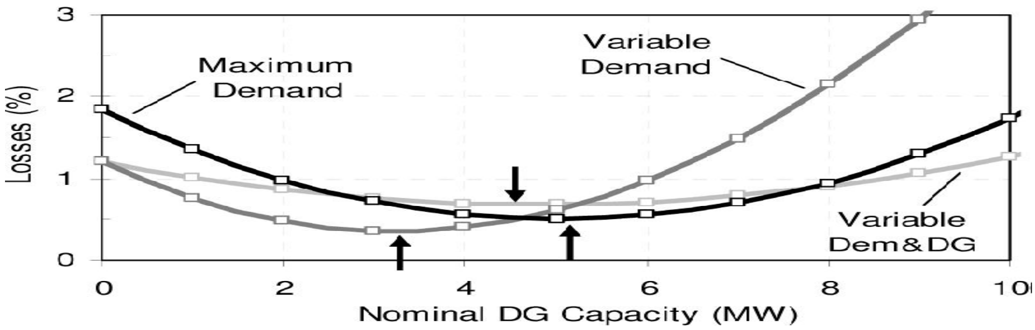

Fig. 2 Percentage power losses (peak demand) and annual energy losses relative to the delivered power and energy

VII. POWER LOSSES VS ENERGY LOSSES

The objective function of this loss analysis-focused AC OPF is the minimization of the total energy (line) losses over a given time horizon. The multi periodicity, in terms of demand/generation. Combinations, is achieved by providing each combination, with a different set of power flow variables with a unique, inter-period set of generation capacity variables is used throughout the analysis.

VIII. FORMULATING THE ENERGY LOSS PROBLEM USING A MULTIPERIOD AC OPTIMAL POWER FLOW

Dynamic control of the substation transformer tap changer (OLTC) may allow more DG capacity to be connected by selecting the OLTC secondary voltage to allow maximum export from DG while ensuring upper and lower voltages are respected. In each period, the OLTC secondary voltage is treated as a variable (not fixed) parameter, varying within the statutory range. The OLTC model follows standard OPF practice in allowing the “best” tap setting to be chosen. This differs from the strict voltage constraints applied in power flow and in the OLTC OPF models used. In effect, the OPF’s choice is mimicking the decision process of the coordination system in selecting the voltage that delivers most benefit. The desired voltages at the node buses can be kept within acceptable limits by either directly controlling the voltage or by controlling the reactive power flow. The equipment normally used for the voltage and reactive power control are on-load tap-changer (OLTC) transformers, switched shunt capacitors and steps voltage regulator. An on-load tap changer transformer (OLTC), is a transformer with automatically adjustable taps, typically with steps of 1-3 %. And discrete valued control, capable of regulating the voltage of the secondary side of a transformer at one point in the network, is usually available in the distribution system for this purpose. While a step voltage regulator is an autotransformer with automatically adjustable taps, which is usually installed when the feeder is too long especially when voltage regulation with OLTC and shunt capacitors is not sufficient to keep the voltage within acceptable limits. Voltage and reactive power control involves proper coordination among the available voltage and reactive power control equipment. The use of coordinated voltage control with on-load tap changers enables the connection of an increased DG capacity by actively changing the OLTC transformer setting and maintaining the voltages of a distribution network within defined limits. The word coordination comes from choosing the proper tap setting of both the OLTC and the voltage regulator during each period. For a complex network configuration, the OLTC transformer and voltage regulator tap settings can be determined by optimization techniques but as mentioned before, for simplicity, the taps will have continuous values and not discrete values to avoid changing the model from non-linear model to a mixed non-linear model which has much higher complexity.

IX. IADAPTIVE POWER CONTROL

Many DG technologies can operate at a range of power factors. It is envisaged that DG can provide a scheme in which the power angle of each generator is dispatched for each period within a given range. Wind turbines especially those equipped with power electronic controllers should be able to provide necessary reactive power support to the grid and this reactive power needed could be centrally dispatched by Distribution Network Operators (DNO’s), in other words the power factor of the wind turbines could be controlled so that the wind energy penetration level is maximized. The proposed control scheme requires wind turbines to generate reactive power during load peak hours and low generation and to absorb reactive power during load off-peak hours and high generation. So in practice DG will be required to operate within a certain range of power factor.

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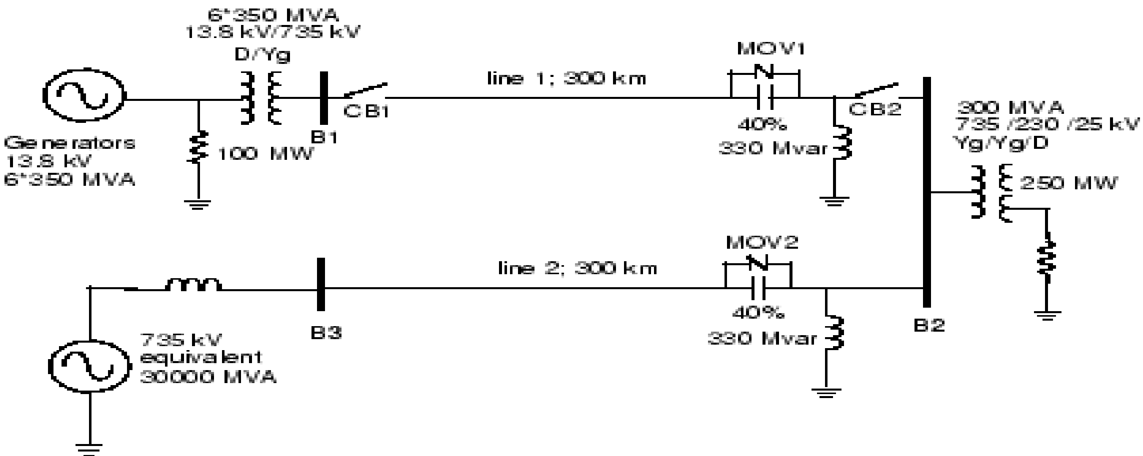
X. ENERGY CURTAILMENT

The main idea behind the generation curtailment is that a power producer may find it economically convenient to be cut off in some circumstances if the power producer can install bigger power generator and sell energy most of the time This active power generation curtailment is a type of control that may be effective when the generator is connected to a weak network, with a high R/X ratio. It is profitable to curtail some of the active power output of the wind generator for a limited period to allow connection of larger capacity and to avoid network reinforcement. Generation wind curtailment is likely to be required during times when minimum demand coincides with high output, such as summer nights in Sweden. The active power generation curtailment is a local voltage control scheme, which controls the voltage by constraining the active power of the DG to limit the voltage rise, and it is very useful because it allows a larger plant capacity to be connected .So in order to alleviate the over-voltage problem and the thermal network limits which restrict the DG capacity especially at minimum demand, it may be necessary to curtail a certain amount of wind energy injected into the network . Although the wind energy output is reduced, The Wind Turbine developer may still gain more profits due to the possibility of installing more wind turbines. In the proposed method the wind energy may be curtailed during certain periods in order to alleviate any voltage or thermal constraint violation. For example, for a specific period, there are different possible combinations of load demand and wind power. Wind energy is curtailed at the combination of minimum demand and maximum wind power. Power curtailment is formulated here by adding a negative generation (or positive demand) variable at the same location of each DG unit, solely affecting the constraints related to active and reactive nodal power balance.

XI. PROPOSED METHOD

To study low frequency electromechanical oscillations in large interconnected power systems. Despite its small size, it mimics very closely the behaviour of typical systems in actual operation.



The single-line diagram shown here represents a three-phase, 60 Hz, 735 kV power system transmitting power from a power plant consisting of six 350 MVA generators to an equivalent system through a 600 km transmission line. The transmission line is split into two 300 km lines connected between buses B1, B2, and B3.To increase the transmission capacity, each line is series compensated by capacitors representing 40% of the line reactance. Both lines are also shunt compensated by a 330 MVAr shunt reactance. The shunt and series compensation equipment is located at the B2 substation where a 300 MVA-735/230 kV transformer feeds a 230 kV-250 MW load. Each series compensation bank is protected by metal-oxide varistors (MOV1 and MOV2). The two circuit breakers of line 1 are shown as CB1 and CB2

XII. CONCLUSION

The minimization of energy losses is and will be an important focus for DNOs in liberalized electricity markets. The growing interest in (renewable) generation connected at distribution levels represents an opportunity that, if harnessed correctly (through optimal accommodation or through incentives/ economic signals), could help reduce energy losses. As demonstrated in this paper, the practice of minimizing power losses by examining only a single (peak) load condition is unlikely to lead to an overall optimal energy reduction. In addition, the sole objective of minimizing energy losses tends to compromise the potential renewable generation capacity that could be connected to distribution networks. Instead, a trade-off must be found where, in a regulatory framework in which excessive losses are penalized, the net benefit between low-carbon energy and losses is maximized. The multi period AC OPF-based technique has demonstrated that optimal accommodation combined with adequate power factor settings for the DG units can harvest significant benefits in terms of loss reduction. This less technically complex solution could easily be implemented in most distribution networks provided that potential commercial and regulatory barriers are alleviated through the use of incentives. Further gains can be achieved by the use of Smart Grid-based control schemes (coordinated voltage control and adaptive power factor control), although the economics of energy losses alone might not justify the required infrastructure.

After this work, the following conclusions can be made:

1. Passive distribution network operating philosophy tends to limit the amount of EWG that can be connected into the distribution network.
2. By strategically adopting ANM schemes, very high penetration levels of new variable generation capacity can be reached when compared to the widely used passive operation of distribution networks.
3. The Multi-period AC OPF-based technique was able to explore the maximum wind energy that can be delivered through network with different active management option and thus can be used to asses' network operators during system planning processes.
4. Generation curtailment main purpose is to allow the connection of DG capacity beyond distribution network limit which tends to raise the energy losses and thus when the objective is the minimization of the energy losses, the energy curtailment control scheme is not considered.
5. The Multi-period AC OPF-based technique has demonstrated that optimal CVC combined with adequate power factor setting for the DG unit can lead to significant benefits in terms of loss reduction.
6. It has been found that with ANM schemes, the average voltage deviation can be reduced.
7. By increasing the level of the load power that can be curtailed, more DG capacity can be achieved.

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