DYNAMIC HYBRID REACTIVE POWER COMPENSATION (DHRPC) IN RADIAL DISTRIBUTION SYSTEM WITH WIND FARMS

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DYNAMIC HYBRID REACTIVE POWER COMPENSATION (DHRPC) IN RADIAL DISTRIBUTION SYSTEM WITH WIND FARMS

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A project report submitted in partial fulfilment of the
requirements for the award of the degree of
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To my family, especially my parents.....to my beloved wife and son "YAZAN" Finally to my first lecturer Prof.Mohammed Alsaeed

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ALAHMADI NAJI SALAH

ABSTRACT

As a renewable energy, wind power, most is anticipated to contributed a significant part of the generation in power systems in the future, but also bring new problems related to the integration of power quality, consisting mainly of voltage control and reactive power compensation. Wind power generally dose not contribute to voltage control in the system. Induction machines are mostly used as generators in wind power production based. Induction generators used in wind turbines and wind farms consume a large amount of reactive power. Next, since there is no voltage control of induction machines installed and draw reactive power from the power system, these machines are a source of of voltage fluctuations. Therefore, a combination of wind turbines for power networks, especially the poor distribution network is one of the major concerns of power system studies. Reactive power compensation and power quality in the poor distribution networks to connect the wind turbines are a big task for this thesis.This work was simulated using MATLAB / Simulink for a weak distribution network and the integration of wind power in the network. Without reactive power compensation of wind power in the network, the collapse of the system voltage and under voltage tripping of wind generators occur. For dynamic reactive power compensation, as STATCOM (Static Synchronous Compensator) and capacitors are used at the point of interconnection of wind farms and networks, the system absorbs the generated wind power while maintaining its voltage level. As a result the study shows that, reactive power compensation by STATCOM and capacitor banks make it possible the combination of wind farm in a weak distribution network.

ABSTRAK

Sebagai tenaga boleh diperbaharui yang mungkin, kuasa angin, kebanyakan dijangka akan menyumbang sebahagian penjanaan yang ketara dalam sistem kuasa pada masa akan datang, tetapi juga membawa masalah baru yang berkaitan integrasi berkualiti kuasa, yang terdiri terutamanya daripada pampasan kawalan voltan dan kuasa reaktif. Kuasa angin amnya tidak menyumbang kepada kawalan voltan dalam sistem. Mesin induksi kebanyakannya digunakan sebagai penjana dalam angin pengeluaran penjana kuasa based. Mesin induks yang digunakan dalam turbin angin dan ladang angin memakan sejumlah besar kuasa reaktif. Seterusnya, oleh kerana tidak ada kawalan voltan mesin induksi yang dipasang dan mengambil kuasa reaktif daripada sistem kuasa, mesin ini adalah sumber turun naik voltan. Oleh itu, gabungan turbin angin bagi rangkaian kuasa, terutamanya rangkaian agihan lemah merupskan salah satu daripada kebimbangan utama kajian sistem kuasa. Pampasan kuasa reaktif dan kualiti kuasa di rangkaian agihon lemah untuk menyambung turbin angin adalah satu tugas yang besar untuk thesis. Masalah ini dikaji dengan membuat simulasi menggunakan MATLAB / Simulink bagi rangkaian agihan yang lemah dan integrasi kuasa angin dalam rangkaian. Tanpa pampasan kuasa reaktif kuasa angin dalam rangkaian, kejatuhan voltan sistem dan di bawah voltan penyandungan penjana angin berlaku. Bagi pampasan kuasa reaktif yang dinamik, sebagai STATCOM (pemampas Synchronous Statik) dan kapasitor digunakan pada titik sambungtara ladang angin dan rangkaian, sistem menyerap kuasa angin yang dihasilkan pada masa yang sama akan mengekalkan tahap voltan. Hasilnya kajian menunjukkan bahawa, pampasan kuasa reaktif oleh STATCOM dan bank kapasitor membuat ia memungkinkan gabungan ladang angin dalam rangkaian pengedaran yang lemah diadakan.

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LIST OF ABBREVIATIONS

DHRPC	–	Dynamic Hybrid Reactive Power Compensation
DC	–	Direct Current
AC	–	Alternative Current
FACTS	–	Flexible AC Transmission System
STATCOM	–	Static Synchronous Compensator
SVR	–	Static Var Compensator
SSR	–	Subsynchronous Resonance
SSSC	–	Static Synchronous Series Compensator
TCR	–	Thyristor Controlled Reactor
UPFC	–	Unified Power Flow Controller
VSC	–	Voltage Source Converter
PWM	–	Pulse Width Modulation
IGCT	–	Integrated Gate Commutated Thyristor
IGBT	–	Insulated Gate Bipolar Transistor
HVDC	–	High Voltage Direct Current
GTO	–	Gate Turn-Off Thyristor
IEEE	–	Institute of Electrical and Electronics Engineers
IEC	–	International Electrotechnical Commission
HAWT	–	Horizontal Axis Wind Turbine
VAWT	–	Vertical Axis Wind Turbine
EHV	–	Extra High Voltage
UHV	–	Ultra High Voltage
VAr	–	Reactive Power

VA	–	Apparent Power
PF	–	Power Factor
K.E	–	Kinetic Energy
	–	

LIST OF SYMBOLS

v	–	speed
M	–	mass
ρ	–	density
A	–	Cross sectional area
m	–	meter
s	–	second
kw	–	kilo watt
HZ	–	hertz
MW	–	mega watt
	–	

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CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, the quality of the electricity supply has become more important than in the past. Over the recent years wind power generation is increasing around the world. Furthermore, wind power energy production is growing continuously because of the economical production and environmental impact as illustrated in Figure 1.1. That has posed a challenging to the power distribution networks and their effects are likely to be more widespread [1].

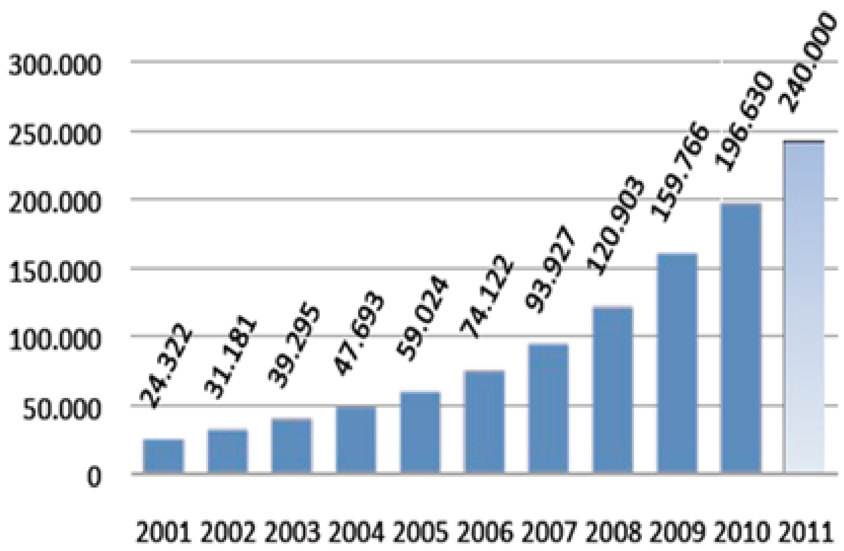

Figure 1.1: World total installed capacity [MW] against year

One of the problems with the connecting wind power turbine to distribution network is the huge reactive power consumed by generators. The Wind power turbines are seen as a consumer of reactive power because of the induction generator is used in wind power generation which cause power quality and voltage problems. Typically wind turbines may cause undesirable voltage on the distribution system due to of the varying nature of wind resources. When the wind speeds reach their maximum the induction machines will also reach the maximum value VAr consumption which causes the voltage to reach undesirable level. The main wind farm conversion system is built from wind turbines, squirrel cage induction generator, gearbox, transformer and reactive source which is a capacitor bank as illustrated in Figure 1.2. [2].

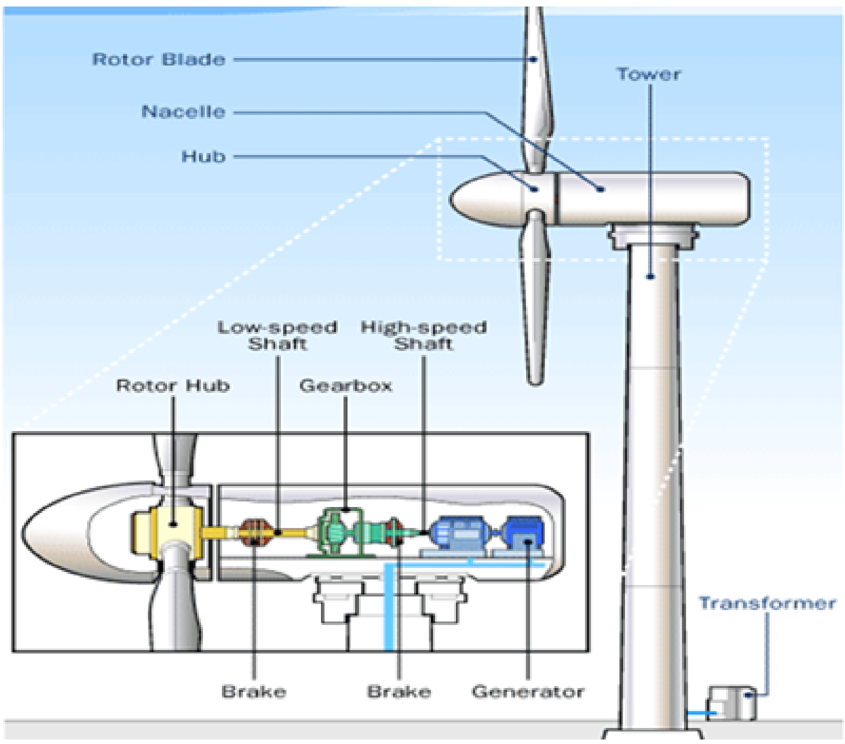

Figure 1.2: Schematic Diagram of Wind Turbine

On the other hand wind turbine components consist of blades, controller, gearbox, generator, nacelles, rotor and tower which is defined in Table 1.1. and illustrated in Figure 1.3 [3].

In addition the conventional squirrel cage induction generator draws reactive power which is undesirable behaviour for power system especially in the case of weak distribution system and large turbine. These types of generator causes slow down the voltage restoration after a voltage collapse which causes the rotor speed and voltage

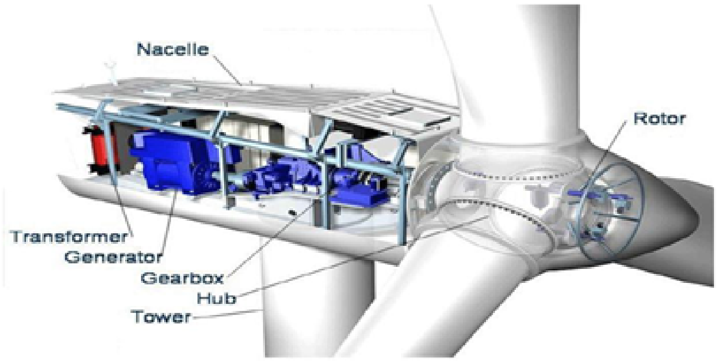

Figure 1.3: Schematic Diagram of Wind Turbine

Table 1.1: Wind Turbine components

Blades	Wind turbines usually have three blades. The blades are between 30-50 meters.
Controller	The controller is placed in the base of the wind turbines and in the nacelles.
Gearbox	Gearbox increases the rotational speed of the shaft. Some turbines do not have a gearbox and so they have direct drive generators.
Generators	Wind turbines typically use a single AC generator (induction) that converts the mechanical energy into electrical energy.
Nacelles	The main components such as the controller, gearbox, generator and shaft are called nacelles houses.
Rotor	The rotor involves both blades and the hub.
Tower	Usually build from tubular steel tower reaching light of 60-80 meters.

unstable. The reactive power will be consumed by the generator when the voltage restores. The generator continues to accelerate and absorb even big amount of reactive power when the voltage dose not return quickly. This eventually leads to increase in rotor speed and voltage instability. In order to overcome these types of instabilities, shunt capacitor is installed at the generator terminal to compensate its reactive power consumption [4].

In order to control the inherent voltage and stability resulting from the installation of wind turbines, the use of dynamic hybrid reactive power compensation (DHRPC) is necessary.There are two methods to minimize voltage problems caused by wind turbines connected to the grid, which are the internal and external solutions. The internal solution is by using devices placed inside the wind turbines to minimize the voltage problems. The external solution involves the use of devices outside the wind turbines to minimize the voltage problems [2].

A dynamic hybrid reactive power compensation (DHRPC) is used to minimize voltage problems as external solution.

On the other hand compensation of wind turbines can be classified into two types of events, steady state and transient. Voltage quality which involves voltage fluctuation, flicker and harmonic problems is the important thing to be considered from the first type. Voltage stability is the second type of event to be considered [2].

The devices are typically used to provide this compensation is shunt capacitors and FACTS devices.

1.2 Electric Power Systems

Electricity demand is the fastest growing energy demand worldwide. The rise in electricity use is related to the development of countries and surely it can be predicted to continue as the faster demand keeps increasing. Electric power system development worldwide is the world base on centralized generation stations. In these stations the voltage is stepped up to various levels (HV, EHV and UHV) to be then transmitted by the transmission system. The voltage after is then steeped down to be distributed by the radial distribution system to the load. Recently a number of influencing features combined to increase the interest in the use of small scale generation. The structure of electric power system is illustrated in Figure 1.4 [5, 6].

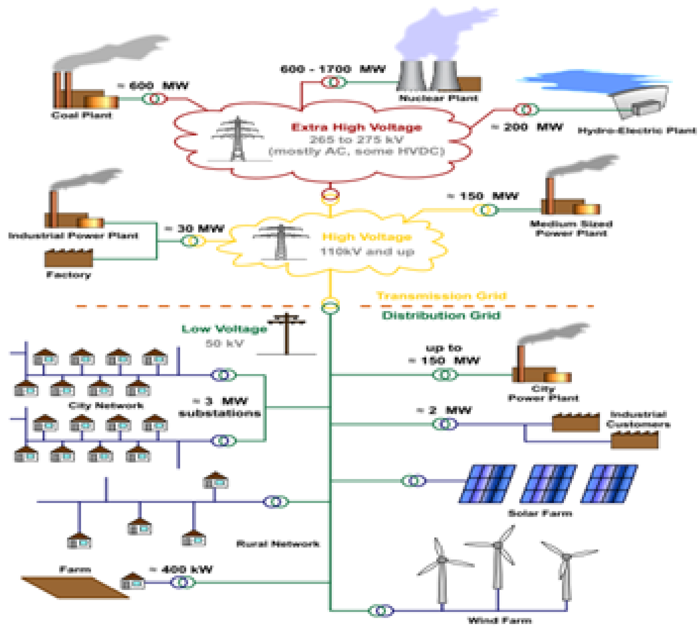

Figure 1.4: The Structure of Electric Power System

1.3 Traditional Concepts of Clectrical Power System

The large power plants producing electrical energy usually are located close to the primary energy sources and remote from the consumer canter. The distribution system which delivers electricity to the consumers are designed to operate radially .On the other hand before the power reaches the final user, it undergoes three stages as illustrated in Figure 1.5 [7].

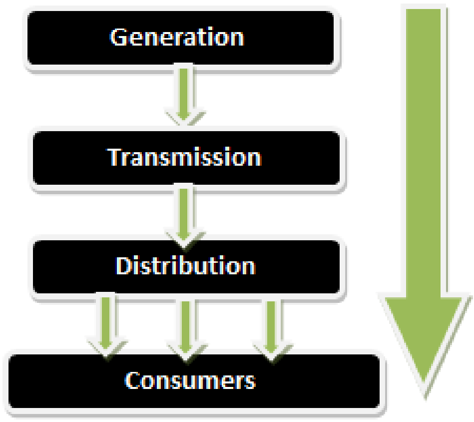

Figure 1.5: Traditional Conception of the Electrical Power System

1.4 New Concept of Electrical Power System

Nowadays, environmental issues, new energy policies, developed technology and the expansion of the electrical markets and the huge investment cost are encouraging innovations in the electricity generation sector. New technologies allow smaller sized plants (renewable sources) to generate the electricity via centralized generation or via renewable energy resources, especially wind power. In this concept the electricity will be produced closer to the consumer as illustrated in Figure 1.6 [7].

1.5 Distribution Network

Transmission and Distribution network system is used to transport energy from the distribution side to consumer side with less losses and minimum power quality problems as much as can. Normal configuration of the distribution system is in radial model. The radial distribution system is the opposite of a networked system and does not provide for other sources of power. The system is designed for power to flow in one-direction only as illustrated in Figure 1.7 [8, 9].

1.6 Power Quality Issues of Wind Farms

Network power quality is affected substantially from injection grid connected wind turbine. Some wind turbines cause system voltage dips. The startup of individual turbines is typically the problem. Some turbines are able to measure wind velocity and

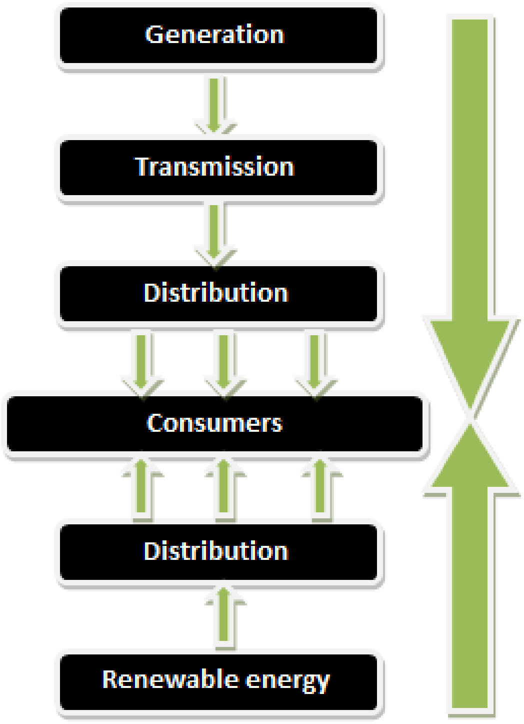

Figure 1.6: New Conception of the Electrical Power System

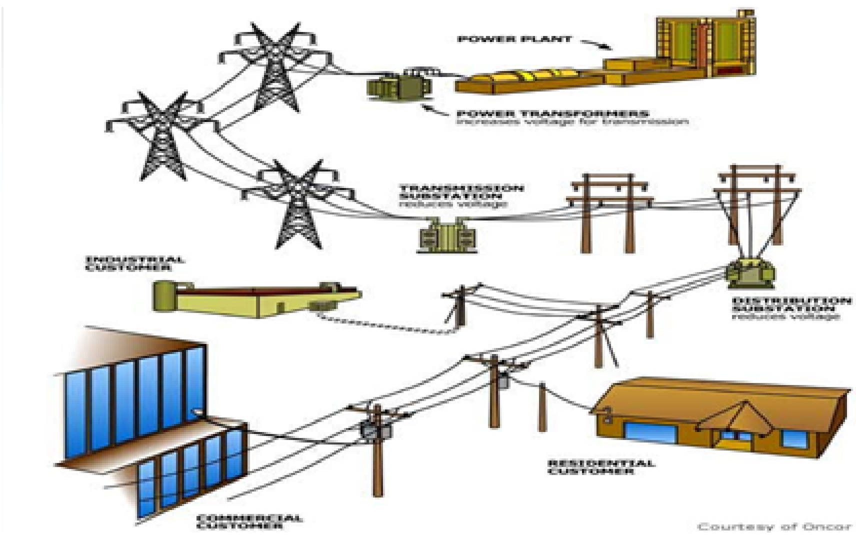

Figure 1.7: Radial Distribution System

do not start generating until the wind reaches a certain speed and a certain duration. By identifying the appropriate condition for the start up the wind turbines can draw huge reactive current which is similar to the starting current of induction machine. The starting current can be 2-3 times the rating of the machine and takes 10 second. The significant voltage dip on the system can be caused by this sudden current. In this case the interconnection requirements are applied by utilities that places limits on the depth, duration and frequency of voltage allowed at the point of common coupling. If the voltage dips may be caused by wind turbines are in excess of the interconnection requirements the utility will decide that the wind turbine be de-energized until the problem is solved [10].

1.7 Reactive Power

Reactive power is defined as the non working power caused by the magnetizing current, required to run & maintain the magnetism in the devices. Reactive power required by inductive loads (induction generators and motors) increases the amount of apparent power in the distribution system[11]. The increase in reactive and apparent power causes the decreasing of power factor.

1.8 Reactive Power (VAr) Compensation

VAr compensation is defined as the management of reactive power to develop the AC power system performance. The VAr compensation concept is to embrace a wide and diverse field of both system and customer problems, especially related to power quality issues, since most of power quality problems can be solved with an appropriate control of reactive power. In general, the problem of reactive power compensation is observed from two aspects: voltage support and load compensation. In general, voltage support is required to decrease voltage fluctuation at a given terminal of a transmission line. In load compensation the objectives are to raise the value of the system power factor, to balance the real power absorbed from the AC supply, compensate voltage regulation and to eliminate current harmonic components created by bulky and fluctuating nonlinear industrial loads. Therefore VAr compensation devices are used depending on the particular requirements of a specific application in power system as illustrated in Figure 1.8 [11, 12].

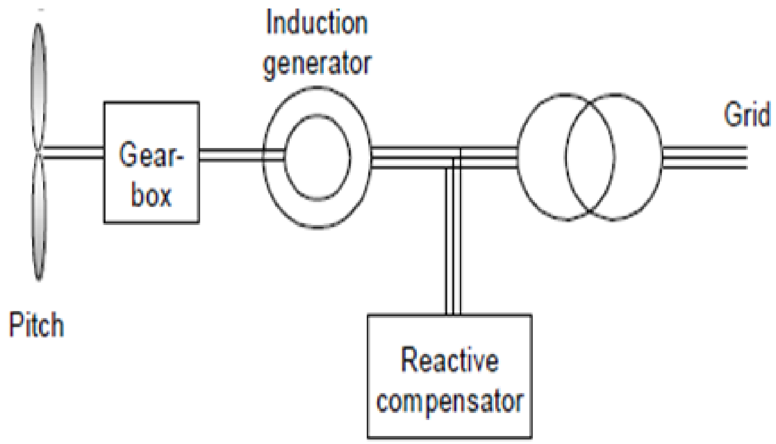

Figure 1.8: Reactive compensation with Wind Turbine

1.9 Problem Statement

Wind turbines consist of conventional squirrel cage induction generator which always consumes reactive power (VAr) that is undesirable for weak system especially in the case of large turbines. In general, this type of generator causes slow down the voltage restoration after a voltage collapse and this can cause the voltage and rotor speed instability. When the voltage restores, the generator will consume reactive power which causes blocking the voltage restoration. When the voltage does not go back quickly enough to the nominal value, the generator continues to consume also a big amount of reactive power. This process causes voltage and rotor speed instability if the wind turbines are connected to a weak system.

1.10 Objectives

The objectives are:

(1) To analyze the impact of Dynamic Hybrid Reactive Power Compensation (DHRPC) in a radial distribution system with wind farms within three different wind speed (low, medium and high).

(2) To study the characteristics of radial distribution system with wind turbines before and after introducing DHRPC

(3) To evaluate the effect of the compensation in power quality issues.

1.11 Scope

The general scope is to determine and analyze the impact of Dynamic Hybrid Reactive Power Compensation (DHRPC) in radial distribution system with Wind farms. The hybrid is considered as Shunt Capacitor and Static Synchronous Compensator (STATCOM).The network is represented in appendix A.

1.12 Thesis Outline

This thesis consists of 5 chapter. Chapter 2 presents an overview and revision of the previous work of integration between network system and wind farms. In addition it involves and shows the explanation of FACTS device types, wind turbine generators and power quality impact. Chapter 3 describes and shows the methodology deployed in this study used. The research method includes using an analytical approach to study and simulate three phase radial distribution system from MATLAB/SIMULINK simulation software is explained in this chapter.Chapter 4 , involves an analysis and a discussion of results which obtained from the simulation model of three-phase system using the Simpowersystem blackest software in MATLAB/Simulink.Chapter 5 , Conclusion of this research and future work were discussed based on the results.

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