DESIG OF HYBRID INVERTER WITH SOLAR POWER BATTERY CHARGING

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Abstract: The daily uses of electricity is increasing rapidly which results in frequents power cut offs. The disruption in supply of power may cause great problems in important places like hospital, industries, etc. The proposed Hybrid inverter system can play a vital role in solving those problems. In this project, solar and grid power, are chosen as two power sources and automatic switching system to select the power source to supply uninterrupted power to the load is designed. Also, solar energy and wind which is abundantly available in earth's surface which makes the availability of energy source easy.

Battery charger circuit is designed to charge the battery from solar or grid and supply power to the load whenever required. The switching algorithm connects the load to solar or battery during peak time and connects it to grid during off peak time. The switching algorithm is designed to supply uninterrupted power to the load by connecting it to available source when any one of the source failure occurs. Hybrid Solar Inverter utilizes three inputs AC mains, wind energy and solar energy to charge battery. The DC current generated from solar panels is used to charge the battery and if solar panels stops generating current then battery is charged by AC mains. Usually, the load operates on main supply but if there is no presence of AC mains then Inverter uses the power from battery to operate the loads.

The designed system is tested in MATLAB simulation software. The designed system is economically feasible and efficient in supplying uninterrupted power to the load.

Keywords: Renewable energy, Hybrid inverter, Multi-Port, Battery Energy Storage, Solar power.

1. Introduction

Commercial grid power supply fluctuations largely depend on the peak power demand load. This challenge is further compounded by the fact that most generation plants are located far away from the cities, and the losses that occur during the transmission increase due to the distance factor [1, 2]. The capacity in the supply lines become often insufficient during peak time. The problem is not only raised by the transmission failures during peak times, but also by generation capacity shortages. In order to help alleviate such fluctuations as well as insufficiency of generated power, suppliers use local power generators in some countries during peak periods but most of these generators are costly oil or gas-fired plants. This has a ripple effect where the price of electricity gets increased considerably for big consumers.

The reduction in using grid electricity during peak time benefits both sides: consumers and suppliers on consumer side, the price will be reduced and on suppliers side there will not be any constraints due to the transmission of electricity during this peak time. As a result, any method that can be used to reduce total dependence on grid power during peak period is highly welcome. Despite many alternative measures taken by the electricity suppliers to reduce the peak time energy demand, it remains a problem due to the reality of the need for electrical power supply during peak time.

This leads us to the need of alternative energy to be combined with the mains by using the time - based power source selection. The alternative energy source should be preferably renewable (in this study, we selected Solar energy). In South Africa, thermal energy is popular for supplying power to the grid. The use of biomass, nuclear, solar, wind, and wave power generations are the other ways to generate electricity. The benefit of renewable energy systems was realized at an international renewable energy conference in Bonn, June 2004 - a follow-up to the 2001 world summit on sustainable energy development held in Johannesburg. The major factors motivating the use of renewable energy were economic reasons, energy security and climatic change mitigation. The adoption of solar energy is from two major advantages, in particular:

a) Availability; as South Africa is listed as having areas of the highest solar irradiation levels in the world.
b) Indefinitely renewable.

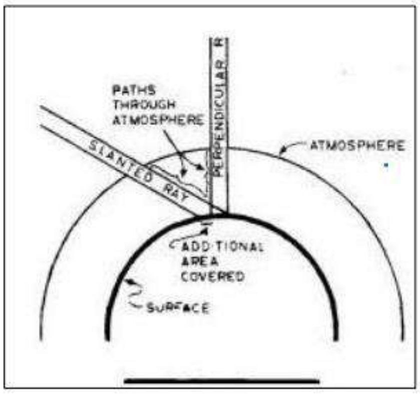
The important aspect of using photovoltaic (PV) system is estimating the system output. The power produced by a PV system is proportional to the sunlight striking the solar array surface, which is not regular due to weather condition and the time of the day. This also leads to the factors that contribute to the variation effects in the output of a solar power system. They are important in giving the end user with realistic expectations of overall system output and economic benefits under unstable weather conditions over time. Also, the mounting and installation of PV system is an important aspect in meeting the peak power demand.

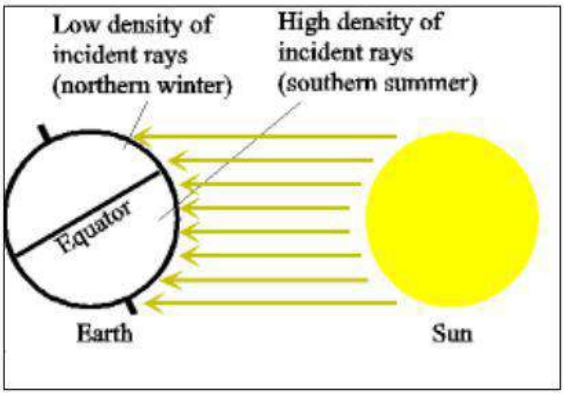
Different methods developed to solve the problem of peak power demand are:

a) Turn off unnecessary load during peak time: this is the traditional and very elemental method used by the consumers and/or suppliers but sometimes finds difficulties in selecting which unnecessary load to be turned off as compared to another.
b) Monitoring usage: this is a method used by predicting the demand of the next period of time where the alarm of the maximum demand is set for the operator to take action, but this intervention of the human being in such instantaneous operations have been found inadequate.

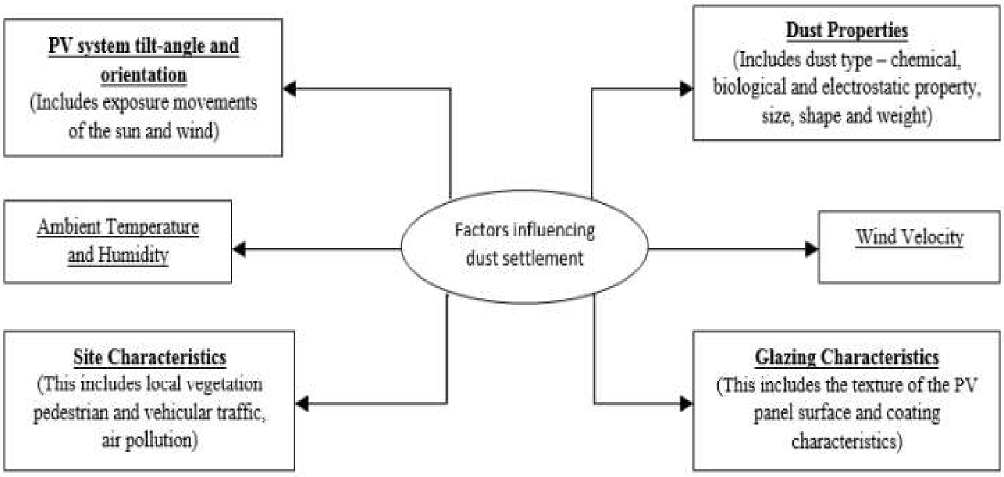
2. LITERATURE REVIEW

The energy from the sun reaches the earth in the form of light originating from the core of the sun through radiation phenomenon in which the nuclear activity generates radiation and reaches the surface of the earth in the form of massless photons. Different photons carry different wavelengths of light, some of these photons carry infrared and ultra-violet lights which are nonvisible lights whilst others carry visible white light. Overtime, these photons will come out from the core of the sun. The time for pushing out from the core to the surface of the sun can reach one million of year, and once they reach the surface, they rush through space at speed of 1.09 billion km/hr, that to say an average of 8 minutes and 20 seconds to travel from the Sun to the Earth. Photons on their journey from the sun to the earth are absorbed or deflected by colliding with other particles which will absorb radiation generating heat. This also explains the reason why a sunny day in winter is colder than a sunny day in summer. Our main challenge is developing technologies which will help in conversion process. Energy obtained from the Sun is in two patterns; heat and light, leading to the two main divisions of solar power system. These are solar thermal systems which capture heat to warm up water, and/or the solar PV systems which convert sunlight into electricity used to various activities. Direct current (DC) is generated when PV modules are exposed to direct sunlight. The generated electricity from PV system may serve for dual purpose: On-Grid and Off-Grid solar PV systems.





The panel cleaning robot is needed to maximize solar panels exposure, by keeping on cleaning them from the dust or any other impurity after a certain period of time for its optimum performance. On PV solar panel, the dust settles due to the following factors



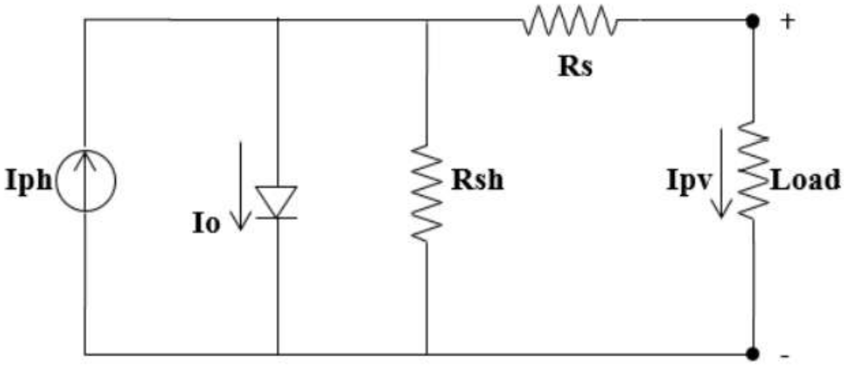
3. SOLAR AND MAINS SYSTEM TECHNOLOGY

The word "photovoltaic" means "Capable of producing a voltage, usually through photoemission when exposed to radiant energy" and this energy is from the sun, mostly called "Sol" by astronomers [75]. Even more, the term "photovoltaic" itself, basically means "light-electricity"; a device that converts light into electricity, etymologically: "photo + voltaic" the word-forming two elements:

a) Photo, which originates from Greek, "light" or "photographic" or "photoelectric" or in other words: "to shine".
b) Voltaic, designating electricity produced by chemical action, formed in memory of Italian physicist Alessandro Volta (1745-1827), who perfected a chemical process used in electrical batteries.

For this kind of solar system, the "greenhouse effect" technology is used. The "greenhouse effect," is simply the ability of a reflective surface to transmit short wave radiation and reflect long wave radiation. In the solar water heater, the greenhouse (also called "glasshouse"), the radiation from the sun is absorbed inside the glass box of the solar water heater and re-radiated inside in all directions. The heat is kept inside due to the solar radiation wavelength which is in a form of shortwave capable to refract the glass then the reflection from inside of the glass box is emitted in the form of long wave which does not easily refract back from the glass cover. Concisely, solar water heating collectors capture and retain heat from the sun and transfer this heat to a liquid (usually water). Solar

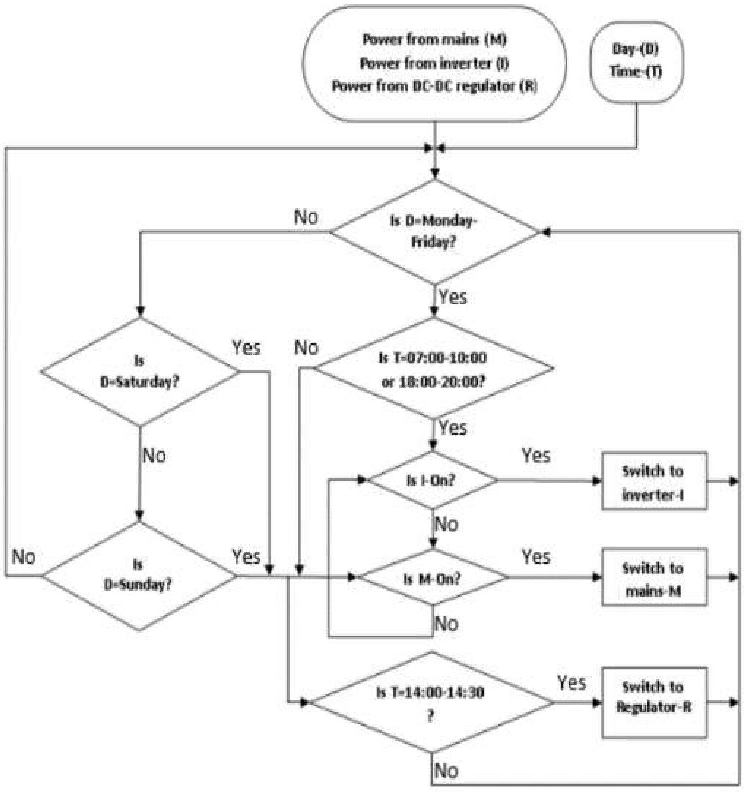
PV technology is not new. The photons from the sun light with different wavelengths of energy particles hit a photovoltaic cell with the possibility of reflecting aside, cut through or getting absorbed into. The energy absorbed from photons is transferred to the electrons of the cell atoms. This energy will cause the electrons to escape from the orbit associated with the atoms and become part of a current in an electrical circuit. The current is then generated by the flow of electrons. When metal contacts are placed on both sides of the photovoltaic cell, the generated current can be extracted for external use. However, the electrical properties of a cell will not allow it to generate sufficient energy to make a standard voltage electric device work: 12, 24 or 48 volts. Hence, the cells have to be interconnected, encapsulated and mounted on a framework structure, to make up the photovoltaic module. A solar cell can be modelled as a diode circuit as shown in Figure



The current source Iph represents the cell photocurrent. Rsh and $Rs$are the intrinsic shunt and series resistances of the cell, respectively. Usually, the value of Rsh is very large and Rs is very small, hence they may be neglected to simplify the analysis. PV cells are grouped in larger units called PV modules which are further interconnected in a parallel-series configuration to form PV arrays.

The amount of solar irradiation measurements used is for the GHI – Global Horizontal Irradiance besides the DNI (Direct Normal Irradiation) and the DHI (Diffused Horizontal Irradiation). The DNI is referred as the amount of solar radiation coming directly from the sun to the perpendicular unit area; it is considered as the irradiance without any disturbance or ideal irradiance for which its quantity measurement is done to maximize the amount of solar received by a surface annually. The DHI is in turn the illumination or amount of radiation received on the surface of the earth through the clouds after being scattered by the molecules and particles. In this thesis, the calculations are done based on the GHI recordings which is the combination of DNI and DHI as shown in Figure 3-2 and they are named as "three components of solar irradiation" measured with Pyranometer.

The automatic power source selector of the hybrid system is designed using Proteus Virtual System Modelling simulator. The flow code software is used to write the algorithm which also enables the user to download the program into a microcontroller and also user friendly. The design automatically selects solar panel power from battery to supply 1kW load during peak power demand period and during mains power shut off period. The selection between solar and mains power is automatic the system does automatically check the availability of the sources to switch between solar and mains during peak and off-peak times. During night when the mains shut off, battery is utilized to power the load. The program is user friendly and can be changed any time according to the requirement. Also, for emergency needs, manual switching is provided to change the source. The program is written based on the peak time's electricity demand.



The designed system can work continuously and the monitoring is done on second to second basis depending on the frequency of the used microcontroller. In this simulation we have used ATMEGA 3290P with its CPU (Central Processing Unit) frequency of 16MHz.

4. SUB-SYSTEM DESIGN AND MODELLING

In this chapter, the modelling of converters used in solar system have been discussed. The automatic cleaning system used to increase the efficiency of the solar panels has been designed. The solar panels are periodically and automatically cleaned by the programmed microcontroller. The maximum power point tracker has been designed for optimizing the possible power from photovoltaic modules since the solar irradiance, the panel resistance and the temperature produce non-linear output efficiency and observed to have a complex relationship when analysed by different techniques; we have analysed this relationship from the I-V curve. The power flows in the following way as also shown on the block diagram, Figure 4-1. The solar panel receives power from the sun and the solar panel is connected to the Maximum Power Point Tracker (MPPT), a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver the maximum available power. Additional power harvested from the modules is then made available as increased battery charge current [37]. MPPT can be used in conjunction with a mechanical tracking system, but the two systems are completely different. In this study the mechanical MPPT system has not been tackled. The power harvested from the PV panel and MPPT is then stored in the battery bank and converted through the DC-DC boost converter and through DC-AC inverter then fed to the AC load during the peak time demand. The switching of this solar energy to the load is done automatically by means of the time-based programmed microcontroller as switch. Alternatively, the load is supplied by the power from the AC mains of the grid during the Off-Peak time according to ESKOM's data source [105] by means of the same automated switch. The panel cleaning robot is directly fed from the solar power after being converted through the DCDC converter for getting the linear output power. The cleaning cycle is also automatically done by the same programmed microcontroller and the program is set according to the panel dirt settlement rate of the area. Besides the common AC load, the system is designed to supply also the DC load and this supply is directly from the battery bank All automatic switches are combined (or installed in parallel) with a manual switch for the user to take action any time manually. In addition to this, the LCD screen displays any activity done instantaneously.

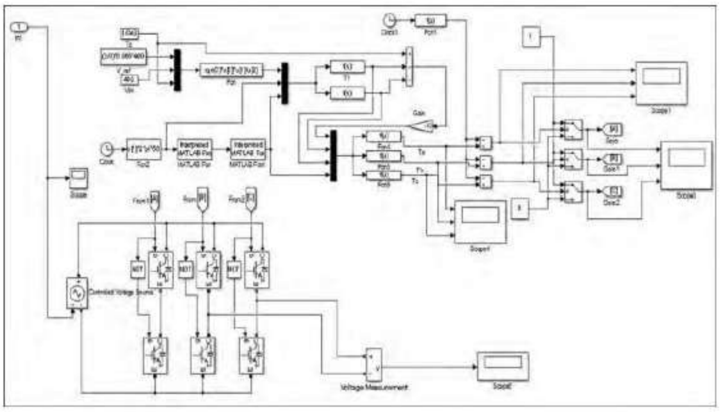
Voltage Vectors	Switch Vectors			Line to neutral voltage			Line to line voltage		
	a	b	c	V_{an}	V_{bn}	V_{cn}	V_{ab}	V_{bc}	V_{ca}
V_0	0	0	0	0	0	0	0	0	0
V_1	1	0	0	02-Mar	-0.33333	-0.33333	1	0	-1
V_2	1	1	0	01-Mar	01-Mar	-0.66667	0	1	-1
V_3	0	1	0	-0.33333	02-Mar	-0.33333	-1	1	0
V_4	0	1	1	-0.66667	01-Mar	01-Mar	-1	0	1
V_5	0	0	1	-0.33333	-0.33333	02-Mar	0	-1	1
V_6	1	0	1	01-Mar	-0.66667	01-Mar	1	-1	0
V_7	1	1	1	0	0	0	0	0	0

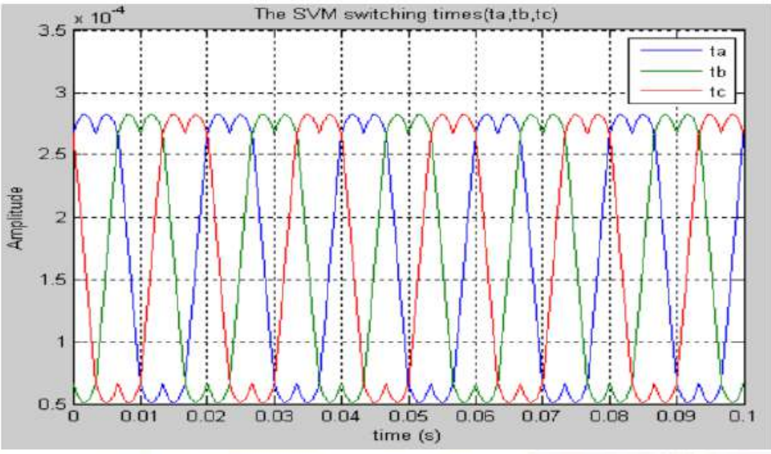
The three upper switches can operate in eight possible combinations: once the states of the upper switches are known, the "on" and "off" states of the lower switches opposite to the upper ones are easily determined. The results of the equations, the eight switching vectors, the output line-to neutral voltage and the output line-to-line voltages in terms of DC-link Vdc.

5. SIMULATION RESULTS AND DISCUSSION

The study, design and implementation of the hybrid system leads to the solution of the fluctuations in commercial grid originated from the peak time power demand. The results of the simulations obtained in this study are used as a prototype to guide the implementation of the system in the University of KwaZulu-Natal, Howard College. The system considerably reduces the electricity cost; the savings and the costs for the design of the current hybrid system were calculated from rates indicated on the Ethekwini Municipality website; (http://www.durban.gov.za). The cost of electricity during peak time was about R2/kWh for domestic customers who consumed more than 1 000kWh a month [78]. In this study, only 5kWh essential loads to be supplied by solar panels during peak time were selected. The 5kWh load connected to the mains for five hours per day, five days a week cost around R200 a month. This was the amount calculated for supplying load only during peak power demand time; mains outings were not included. To implement the system would be R20 000; paid back after about eight years. In other words, this system saves R20 000 in eight years. The asset of the study does not only go to the reduction of electricity price but it opens out to the environmental conservation of the nature. As said, the use of non-renewable energy sources have got quite number of drawbacks. However, with their current availability but limited with time, the hybrid of non-renewable and renewable energy technology is one way found comfortable. The present project shows the sustainability of hybrid solar and mains system since the cost of solar system is gradually decreasing on the global market. The SVM scheme drives the inverter gating signals from the sampled amplitudes of the reference phase voltages. The real implementation of inverter proceeds according to the MATLAB SIMULINK simulation model presented. The input voltage and current of the inverter is 220V, 3A which is the output of the DC-DC boost converter. The inverter output signal is practically a square wave which explains the origin of losses calculated earlier, although these losses are so small. Another simulation of the same inverter is done in Proteus using the programmed AVR microcontroller with the same parameters (input voltage and current values) and the simulation results show a good performance with pure sine wave yielding less power losses. However, the simulation of DC-DC boost converter connected to the inverter.

This block receives two inputs, voltage and current. It multiplies them and gets power at that particular time, while the previous power is stored by the memory element. The powers are then subtracted accordingly to check which power is greater to find the maximum power and the switch is switched accordingly as to increase or decrease the duty cycle in accordance to comparing the voltages also. For better understanding, the P&O algorithm is explained. In the simulation block, the PWM varies with temperature and constant irradiation.





(a) (b) (c)

6. CONCLUSIONS AND RECOMMENDATION FOR FUTURE STUDIES

The reduction of fluctuations on the commercial grid during the peak power demand by adopting the use of renewable energy sources in combination with the power from the mains improves the power transmission stability. In this research work, a hybrid solar and mains automatic selection scheme based on off or peak times demand between solar energy and mains, coupled with an automatic solar panel cleaning system has been designed.

Peak time power demand causes fluctuations in the electrical network from the generation, transmission and distribution sections of the power grid. This instability globally causes problems of insufficiency in electricity access in remote areas. This subject has therefore elicited a lot of interest from many researchers that explore different ways on how to satisfy the load demand.

The system developed here shows that the hybrid solar and mains system meets the power demand during the peak time. The MPPT system is simulated using MATLAB-Simulink; a real-time simulator and model testing platform for many physical systems. The MPPT algorithm determines the duty cycle of the boost converter according to the power output from the solar panel. It also tracks the panel along the maximum point in the I-V characteristic. The regulated solar output charges the battery bank. The boost converter boosts up the input voltage to the required level. Furthermore, the microcontroller determines the duty cycle of the boost converter according to the MPPT algorithm. The automatic selection of power sources for supplying 1kW of power during peak power demand period to a coffee shop is demonstrated using Proteus virtual visualization software.

The system is demonstrated to optimally meet this demand according the results obtained. In our design, there is also provision for automatic choice of the power source in case of mains or solar system failure. The design also includes a panel cleaning robot operated by a dc motor supplied by solar panel, and works on a cleaning schedule that is programmed in the microcontroller. The cleaning operation process is also displayed on the LCD display as it is done for other activities.

The designed system is economically feasible and considerably reduces the load connected to the grid during peak time, the window of opportunity to increase the electricity access programs in under developing countries and the positive impact to the global warming reduction issues. Though the initial cost is high, it would be a good alternate to full time engagement of the mains, if subsidy is provided by government.

The clock time for the whole program is the embedded one of the microcontroller. This has the disadvantage of not getting easily adjusted by the user. If the time gets wrong for example instead of running at the corresponding time it happens to run one hour lead or lag due to the failure of the microcontroller battery or any other reason, it will operate according to that wrong time, until the clock adjustment is done by the programmer. The future work may improve this by making the program to run by the external clock which can even be adjusted by any user not a programmer. The power source selection to the load may be done with respect to the load power demand in addition to the peak time power demand.

The combination of automatic panel cleaning robot periodically programmed as designed in this research with the remotely controlled panel cleaning robot [107] may result in better achievement. Also, the dirt sensibility program on solar panels may be added so that the cleaning process may automatically be done at any time when the panel gets dirty.

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