students section

PERFORMANCE OF INDUCTION GENERATORS WITH LONG TRANSMISSION INFEEDS

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1. Introduction

Those hydro-power plants, having a generating capacity of 10 MW or less, were abandoned as growth of electricity demand in the world expanded rapidly leading to the construction of both large hydro and thermal generating stations. However by the early 1950s, with the increasing availability of fossil fuels and coal, thermal generation became preferred in countries where most electricity previously had been generated by hydro-power plants. Many small hydro-power plants were taken out of operation when expensive repairs were needed or when newer and larger plants were built which had lower operating cost. Several tea estates abandoned small hydro-power plants in Sri Lanka in the period 1955–75. In recent years, with the constant increase in price of fossil fuels, it has become essential to find an alternative source of energy and a reassessment of this practice has begun.

Many countries are still unable to provide the necessary minimum of electric power. The reasons are several, such as the inability to utilize their own resources, the necessary investigations which have not been done and of course the lack of large investment capital. Mountainous countries with adequate rainfall have sites for both large and small hydro-power stations. But most developing countries have neglected their small hydro potential concentrating instead on building large hydro stations in remote areas. This is partly due to the reason that as far as the national energy problems are concerned the contribution of small hydro potential is extremely small.

However, it has only recently been recognized that the more suitable small hydro-power plants should be installed wherever it is economically significant. Savings in the national fuel bill can be realized. Although small hydro-plants are susceptible to variation in stream fall and large capital cost, they require little maintenance and no fuel.

China has devoted much effort to develop small hydro plants. By 1979 it had a 5380 MW capacity in some 88,000 small hydro power stations which were in operation with a total installed capacity of 10 percent of China's total, the smallest was 5 KW and the largest 12 MW (Reference 1).

A recent paper (Reference 2) has reported that the total mini hydro potential available in Sri Lanka is of the order 95 MW at 395 GWH. A recent paper (Reference 3) puts the estimate at 75 MW.

Small hydro power plants can be classified into 3 categories, namely, small, mini and micro depending on whether their generating capacity is less than 10 MW, 1 MW, 0.1 MW respectively.

Again mini and micro projects can be classified into two categories. The run of the river plants at waterfall sites and storage plants at dam sites.

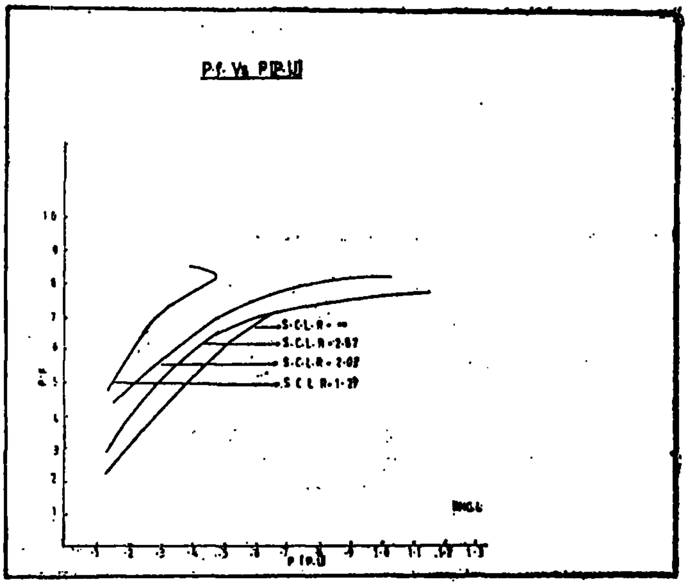
In Sri Lanka, in a recent study (Reference 2) the waterfall sites and the location of possible small schemes in the wet zone were investigated. Also proposed irrigation reservoirs and existing reservoirs where hydro potential is available were located in the dry zone. In this study 70 waterfall sites and 20 mini dams are located in the wet zone and in the dry zone, 30 proposed reservoirs and 30 existing irrigation reservoirs were located.

As far as mini and micro hydro power plants are concerned, there are certain advantages in the use of induction generators rather than synchronous generators. Induction generators do not have to be synchronized and they do not require a D.C. source for field excitation. Once started up for operation the machine can remain in operation even in a period of low waterflow as an induction motor running on no load. When water flow increases the machine automatically picks power as a generation. Clearly the set up is very simple and the machine is very easy to control sizes as low as 5 KW and of an unattended, type can be envisaged.

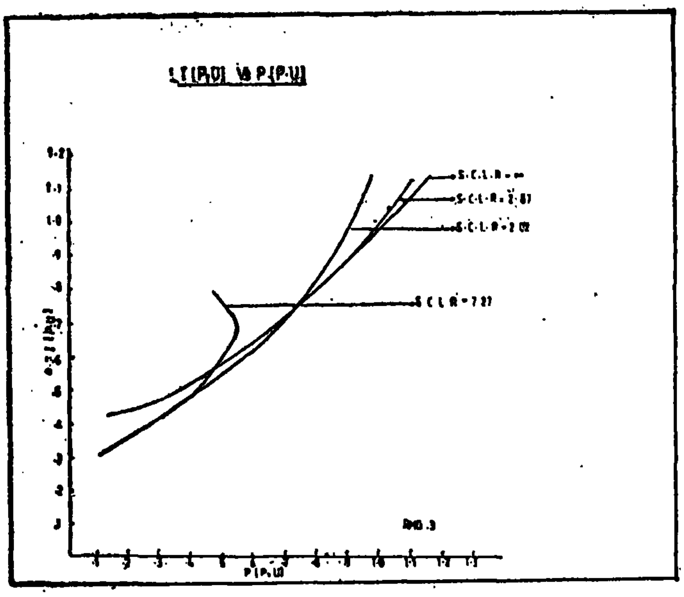
2. Subject Investigated

The study (Reference 2) also found that small waterfalls and small scale storage schemes are located in remote areas which are at a great distance from high tension lines (11/33/132 KV) of the present national grid in which case long transmission infeeds have to be employed. Since economics do not justify the construction of special high voltage lines to the site of micro generators it is necessary to employ existing or new low tension transmission infeeds to connect these plants to neighbouring substations.

Hence it is necessary to examine the behaviour of induction generators feeding a power system through long lines. The work reported in this paper was carried out to obtain the characteristics and operational limits of induction generators on long lines.



P. f Vs. P(P.U)



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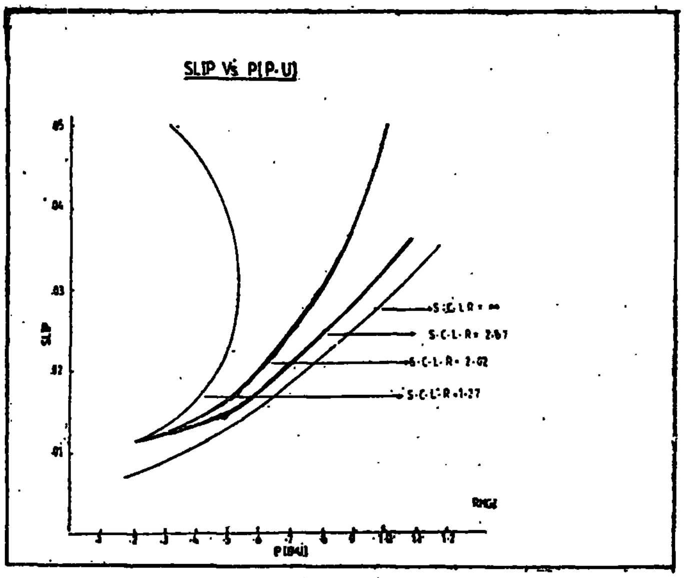

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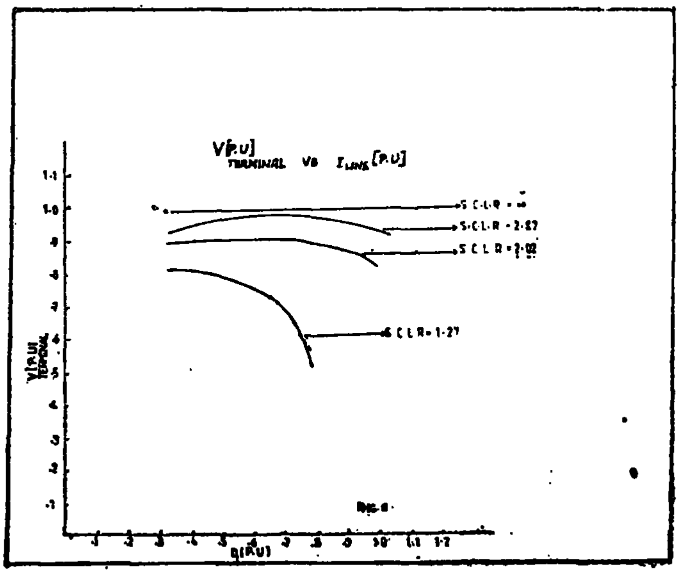

V (P.U) Terminal

3. Investigation Method

The method relied on was that of experimental investigation. The induction motor and transmission line were modelled in the laboratory and tests were performed over a wide range of loads.

Induction Motor Parameters

A 400 V, 3-phase 50 Hz 5KW induction motor was used in the generation mode. The machine has a wound rotor and changes of rotor resistance can be carried out if necessary.

Stator resistance/phase	= 2.34 ohms
Rotor resistance/phase (referred to stator)	= 2.67 ohms
Total (Stator and rotor) leakage reactance/phase (referred to stator)	= 19·3 ohms

Line Parameters

A 3-phase transmission line of R=X was modelled with laboratory components. The voltage of the receiving system was maintained constant at normal mains value.

The length of the line was measured in an equivalent "electrical" unit defined below as the Short Circuit Level ratio (S CLL ratio). This is the ratio of the system short circuit capacity at the far end of the line (i.e. generator end) to the generator rating

$$\text{S.C.L. ratio} = \frac{(V^2 / \sqrt{R^2 + X^2})}{G}$$

Where V = Nominal line KV
G = Rating of the machine in KVA
R = Series resistance of the line, ohms/phase
X = Series reactance of the line, ohms/phase

for a short line or zero length line the SCL ratio tends to infinity.

4. Results

It is clearly seen from the graphs that the operation of the machine becomes unstable as the S.C.L.R. decreases, that is when the infeed is very long. Operation with S.C.L.R. at 2.82 and higher is satisfactory. In the case of S.C.L.R. e= 1.27, the slip goes up very rapidly while power output and terminal voltage decresae, with power output. Therefore this operating condition is clearly unsatisfactory due to operational instability.

If an S.C.L.R. of 2.75 is taken as the cut off limit below which induction generator operation is not recommended it follows that the maximum permissible transmission line length is given by

$$L = \frac{2.75\, G\sqrt{r^2 + x^2}}{V^2}$$

Where r, x are line resistance and reactance in ohms/unit distance and the other symbols are as defined previously.

These results have been obtained with a standard wound rotor induction machine and for a transmission line of parameters R = X. These results can be rechecked for other line and machine R/X ratios. It is not likely that there will be a large difference in the results for limited variations of the R/X ratio.

Graph Scales

The per unit values used in scaling the graphs are as follows.

Power base	= G	= 5kVA
Voltage base	= V	= 4.25V line
Current base	= I	= 8.8A

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