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TOTAL TRANSMISSION ENTROPY TO SUBSTITUTE MECHANICAL EFFICIENCY IN MULTIPLE FLOW SCHEMES

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Abstract
It is known that transmission localities are sources of power loss, depending on many factors, hence sources of uncertainty. Thus each transmission of power should not only be designated by a constant of efficiency but also by an expression of uncertainty, reflecting the probability of transmission. Furthermore, Shannon's expression of entropy has been used to quantify this so-called transmission uncertainty. The entropy of power transmission is given in an explicit entropic form that considers not only mechanical efficiencies, but also the uncertainty that comes along any transmission.

Keywords: Power Transmission, Entropy, Shannon's Entropy, Renyi's Entropy, Uncertainty.

INTRODUCTION

The power transmission is a complex phenomenon. The definition of the power "junction" by a constant of efficiency simplifies the computations and gives the designer an upper hand by allowing him to focus on more complicated matters. The downside to this simplification is that power transmission is a complicated matter itself. As any designer would agree, each of these portals is a source of uncertainty. Thus each transmission of power, or torque for that matter, should not only be designated by an efficiency but also by an expression of uncertainty. This statement of uncertainty would reflect the designers trust in the transmission.

To clear the issue further, one must understand that a constant of efficiency is nothing but an average value of previous experiments or a catalogue value of the manufacturer. This is to say that under all conditions, a certain percentage of power will always be transferred. But this is an oversimplification. Alongside this constant, a term of uncertainty also ought to be given. Considering the fact that power transmission is an interplay of many factors, from temperature to lubrication etc., transmission phenomenon is converted into a stochastic event. This stochasticity is expressed in entropy, which has deep roots in science, and can be expressed by information theory.

Entropy has been in use for decades in a wide range of areas. It has its origins back in the 19th century, dating back to Boltzmann. His formulation of entropy was meant to quantify the disorder that every physical system strives to maximize. A summary of the properties of entropy are given in [1,2,4].

In the following sections, reasons leading to entropy in a power transmission are stated. Then basic definitions of entropy and a comparison of formats are given. In later sections, formulations of optimization and interpretations are also provided.

Practically every connection in a mechanical system is a source of entropy. The ones with the highest entropy are probably the belt drives, clutch mechanisms, chain drives, etc.

ENTROPY AS A MEASURE OF UNCERTAINTY

Shannon in his seminal work in 1948 has described a formula of uncertainty. He devised a way to account for the uncertainty of any received message, say, in bits. The idea was to quantify the possibility of error due to channel noise. Information theory is naturally beyond the scope of this work.

A brief formulation of entropy is expressed below, [2]. The uncertainty by Shannon entropy was given by:

$$H=-\sum_{i=1}^{M} P_i \log_2 P_i \qquad (1)$$

where,
M : Number of symbols, P_i : Probability of a symbol appearing, H : Uncertainty.

Here, the base 2 logarithm refers to the two states of operation. The numbers of symbols are also limited to 2. These two symbols represent signal and no signal states. In this paper, they will mean "power pass" and "no pass" states. From now on, when a transmission is given by a constant of efficiency, this constant will be considered as the probability of power flow. Suppose that a unit has a probability of η (efficiency) to transmit power, that is just another way of saying that the power will be absorbed with a probability of $(1-\eta)$.

ENTROPY IN POWER TRANSMISSION

Logarithmic formulation of uncertainty penalizes low efficiencies further than simple algebric operations would do. The last part is especially important when the power has more than one route to flow. This is true of hybrid transmissions, where motion is split and partly transmitted through, say, over a planetary gear set and partly through a pulley-belt mechanism. Such a performance measure would fit well its niche in an application such as Ozdemir [3].

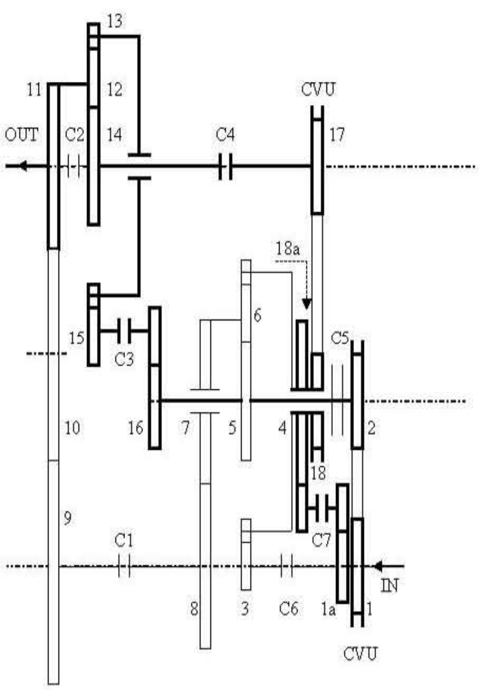

Fig. 1. A two-branch power split scenario, where C1..C7 : Clutches; CVU: Continuously Variable Units; 1, 2, 17, 18: Variable Pulleys; 3, 4..15, 16 : Gears, [3].

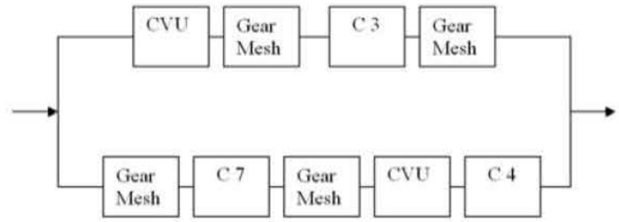

Fig. 2. Power flow diagram of Fig 1.

For a power line with power transmission localities, it would be proper to define a general "Total Transmission Entropy" (TTE);

$$TTE = -\sum_{k=1}^{B} \sum_{j=1}^{N} \sum_{i=1}^{2} P_i \log_2 P_i \tag{2}$$

where,

N : Total number of elements that can be assigned an efficiency of transmission on a single branch, B : Total number of branches that power is transmitted through, P_i : Transmitted power through a designated route.

TTE could be simplified with no loss of generality:

$$TTE = -\sum_{k=1}^{B} \sum_{i=1}^{N} P_i \log_2 P_i \tag{3}$$

where only "pass" state is considered, and every branch is given by the sum of the individual transmission entropies.

CONCLUSION

Power transfer is a highly stochastic and conditional property of the systems that perform this transmittal. Changing working conditions, imperfect manufacturing techniques, varying loads all affect the constant that distinguishes the locality. To summarize the characteristics of the entropic perspective on multiple flow schemes, the following may be stated:

1. Considers transmission as a probabilistic event.
2. Penalizes transmissions at low efficiency points more than basic algebra.
3. Gives an analytical expression to optimize for the power to flow.

The above statements would hopefully transform the way the power flow is comprehended. The authors hope that more emphasis might arise regarding the analysis of this complex yet interesting phenomenon.

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